Factors Affecting the Accommodation of Thermal Movement in Halter Based Aluminium Standing Seam Systems

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September 2014

MSc Façade Engineering

Word Count: 21959

Declaration

I hereby declare that the following dissertation '*Factors Affecting the Accommodation of Thermal Movement in Halter Based Aluminium Standing Seam Systems*' is the outcome of my own personal work and research except where mentioned and referenced within the text. A list of references has been included.

David Cottrell
September 2014

Abstract

Halter based aluminium standing seam systems have been used successfully as part of the building envelope on projects the world over, however there are a growing number of instances were failure has occurred due to the restriction of thermal movement in particular where long length sheets are used. The understanding of how the system works in accommodating and controlling thermal movement and the various factors which can affect it is of importance to prevent failures occurring. Unfortunately there is little detailed information available in the public domain which this dissertation attempts to address.

The amount of thermal movement to be accommodated is often underestimated especially with uncoated aluminium which can attain much higher surface temperatures than previously envisaged. The material stresses and resultant forces are shown to be very large and can cause failure to welds at penetration details and fasteners in perimeter flashings if movement is restricted.

As standing seam sheets attempt to move over the heads of the halters restriction is encountered which generates an in-plane force which can result in halters and substructures to overturn if this force is not accounted for in detail design. This will lead to penetration of the seams and potential sheet detachment. The in-plane force is determined by testing and its magnitude is influenced by the degree of misalignment of the halters. This form of testing is now compulsory for BBA approval but results of the testing are very rarely published by system manufacturers.

A variety of problems are looked at in detail from purely aesthetic issues where halters are visible through the seam to where the sheets are penetrated or are being abraded away. It is seen that the permanent remedial action is replacement of the sheets and in many cases the full roof. Factors causing these problems are shown to occur during manufacturing, in detail design, out of tolerance support steelwork and through poor installation on site. Often poor installation is attributed to insufficient training.

The role of the manufacturer is examined to ascertain what information and assistance is provided to the stakeholders to ensure that their systems are successfully designed and installed. The dissertation concludes with a set of recommendations for a proposed MCRMA Technical Bulletin on this subject.

Acknowledgements

I would like to thank Alan Keiller my supervisor for this dissertation together with the other MSc Façade Engineering academic staff; Dr Steve Lo, Dr Stephen Ledbetter and David Metcalfe. The journey has been a wonderful experience and one that has been thoroughly enjoyed. It has been a pleasure meeting with my fellow students both full and part time and I now know what those that have gone through the dissertation process have experienced and what is waiting for those who will be taking this path in the coming years. For the latter enjoy the experience and good luck for the future.

I would like to thank my former employers Kalzip Ltd for the opportunity to take this course in particular Dr Jürgen Neuwald. For all friends and colleagues past and present at Kalzip I wish you all the best for the future.

A would also like to thank all the people who have contributed information and completed questionnaires to make this all possible. In no particular order thank you to: Kevin Turton, Allan Ineson, Trevor Downs, Clive Atkinson, Lindsey Ellis. David Hicks, Keith Bradley, Bob Troughton, Barry Jackson, Mike Otlet, Paul Clayton, Nigel Bishop, Karlfriedrich Fick, Joanne Booth, Rakesh Proag, Carlton Jones, Brian Morris, David Lowe, Andrew Dunn, Nick Selves, Keith Roberts, David Roy, Steve Darlington, Andreas Schmelzer and Tom Stultiens. Hopefully I haven't missed anyone but if I have a big thank you anyway.

A moment of reflection now. A loving tribute to my sadly missed late wife Faith, who encouraged me to take up this opportunity and started this journey with me but sadly lost her long and hard fought battle with cancer between my first and second year of the course. "*If I should fall behind wait for me"* FD22X.

A big thank you for all the support and good wishes to my children Ste, Sam and Becky, hopefully you will see a lot more of me in the near future. To friends Bob and Maralyn, that's one "D" down, now for the other two. To Paul, from one "semi-retired student pensioner" to another, good luck with completing your dissertation.

Last but by no means least, all my love and thanks to my partner Hazel who has supported me and encouraged me over the last few months. It's at an end, now we can start to enjoy life again!!!

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Abbreviations

APL	Architectural Profiles Ltd
ARS	Abrasion Resistant System, polyamide modified polyurethane paint system
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
ASTM	American Society for Testing and Materials
BBA	British Board of Agrément
BCSA	British Constructional Steelwork Association
BRE	Building Research Establishment
BS	British Standard
BSI	British Standards Institute
CIBSE	Chartered Institution of Building Services Engineers
CIB	CIB (Conseil International du Bâtiment) – International council for research in buildings and construction
CITB	Construction Industry Training Board
CSCS	Construction Skills Certification Scheme
CT	Computerised tomography
CUAP	Common Understanding of Assessment Procedure
CWCT	Centre for Window and Cladding technology
DIBt	Deutsches Institut für Bautechnik
EN	European Standard
EOTA	European Organisation for Technical Assessment
ETA	European Technical Approval
FMEA	Failure mode and effects analysis
GDA	Gesamtverband der AluminiumIndustrie (Aluminium Industry Federation)
HAZ	Heat affected zone
ISO	International Organization for Standardisation
LEED	Leadership in Energy and Environmental Design
MCRMA	Metal Cladding and Roofing Manufacturers’ Association
MOB	Method of Building
NBS	National Building Specification
NFRC	National Federation of Roofing Contractors
NPD	No performance declared
NSSS	National Structural Steelwork Specification
PIR	Polyisocyanurate
PSA	Property Services Agency
PV	Photovoltaic

PVDF	Polyvinylidene Fluoride, also known as PVF_2
QMS	Quality management system
RPN	Risk priority number
RCI	Roofing, Cladding & Insulation
RIBA	Royal Institute of British Architects
SCI	Steel Construction Institute
SRI	Solar Reflective Index
SVP	Soil and vent pipe

Nomenclature

F_{fp} = Fixed point force applied at a standing seam halter (N/halter)
L = Length of standing seam sheet (m)
b = Width of the standing seam sheet (m)
g = Self weight of the standing seam sheet (N/m^2)
S = Snow or imposed load (kN/m^2)
a = Roof pitch (°)
T = Temperature (K)
ΔT = Uniform change in temperature (K)
e = Change in length (m)
e_{exp} = Change in length due to expansion (m)
e_{con} = Change in length due to contraction
α = Coefficient of thermal expansion (10^{-6}K^{-1})
L = Length (m)
f = Stress (N/mm^2)
f_{exp} = Stress due to expansion (N/mm^2)
f_{con} = Stress due to contraction
E = Modulus of elasticity (N/mm^2)
F = Force (N)
F_{exp} = Force due to expansion (N)
F_{con} = Force due to contraction (N)
A = Cross sectional area (mm^2)
F_{ip} = In-plane force applied at a standing seam halter (N/halter)
M = Moment (Nm)
T_n = Tension in fastener (N)

Equations

$F_{fp} = L \times b \times (g * Sin\ a + S \times Sin\ a \times Cos\ a)$ Equation 3.1

$e = \alpha L \Delta T$ Equation 4.1

$f = \alpha E \Delta T$ Equation 4.2

$F = fA$ Equation 4.3

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1. Introduction

1.1 Introduction and Aim

Halter based aluminium standing seam systems have been used successfully as part of the building envelope on projects the world over, however there are a growing number of instances were failure has occurred due to the restriction of thermal movement within the system in particular where long length sheets are used. David Hicks an independent roofing and cladding consultant claims that 77% of all failed building envelopes that his company has inspected in the two years to September 2011 involved aluminium standing seam systems (Hicks, 2011).

The understanding of how thermal movement is accommodated and the various factors which can affect it is of prime importance if the design and installation of this type of system is to be successfully incorporated into the building envelope.

The broad aim of the dissertation is to help reduce the instances of failure in halter based aluminium standing seam systems through a greater understanding of factors affecting the accommodation of thermal movement. If this lack of awareness and knowledge is not addressed then failures will continue to occur which ultimately could result in a loss of confidence in the use of this type of system irrespective of the number of successful installations.

Figure 1.1 shows a typical failure of aluminium standing seam system where the halter has penetrated the standing seam sheet.

Figure 1.1: Typical failure of standing seam system

1.2 Drivers

1.2.1 Industry Experiences

As well as personal experience of this type of failure, discussions with a number of industry professionals have shown that the extent of the problem is fairly wide spread although specific information is difficult to find as it is invariably of a confidential nature; ("…*this is very much a live issue*…", discussion with Keith Roberts May 2014). The industry professionals predominantly work within the metal roofing and cladding industry, most in a consultancy capacity, and who are or have been involved in investigating failures of standing seam systems on projects.

It was generally perceived that many problems are due to poor quality installation which could be as a result of lack of suitable training. It is also perceived that there is lack of knowledge within the construction industry of this type of problem and its causes and in particular a lack of knowledge of some of the system manufacturers themselves.

1.2.2 Limited Information in Public Domain

There is very little information and guidance on the potential problems of standing seam systems available in the public domain; (…"*we have been unable to find any information of this type of problem in our searches*…", discussion with Mike Otlet May 2014).

Outside of individual manufacturers' promotional and technical literature what little industry documentation there is is generally of a generic nature or only gives "rule of thumb" guidance. Typical examples are:

- Metal Cladding and Roofing Manufacturers' Association (MCRMA): Technical paper No. 3 – Secret fix roofing design guide
    - Gives design guidance on all types of secret fix system including amount of thermal movement, support tolerances and installations.
- The Steel Construction Institute (SCI) publication P346 – Best practice for the specification and installation of metal cladding and secondary steelwork
    - Includes advice on support steelwork tolerances for different types of metal roofing and cladding including standing seam systems.

Discussion with Carlton Jones, Secretary of MCRMA, indicated that Technical Paper 3 is deemed to be out of date and in need of an overhaul. This document was originally published in 1992 with a minor revision in 1999.

1.2.3 Lack of Clarity of Thermal Movement Tests

There is a lack of clarity as to the type of testing for thermal movement of standing seam systems, the extent that it is carried out by system manufacturers and their use in product approvals and certifications.

An article by CERAM published in Roofing, Cladding & Insulation (RCI) discusses the problem of testing for thermal expansion of aluminium standing seam roofs and that there is no standard test to simulate it and states that "*no one yet has enough understanding of thermal behaviour in standing seam roofs under current climatic conditions*" (CERAM, 2010).

British Board of Agrément (BBA) have a thermal expansion test specification as part of their assessment process. Most of the aluminium standing seam systems manufactured in UK have BBA approval. Testing for thermal movement does not appear to be a compulsory part of the approval process as some but not all of the systems have been tested.

As a route to CE marking of standing seam systems a European Technical Approval (ETA) can be developed to the guidelines in Common Understanding of Assessment Procedure (CUAP) 03.02/6 – Roof and Wall Systems with Hidden Fastenings DIBt, 2010). This CUAP includes a sliding test which is virtually the same as the BBA test specification. Unfortunately the sliding test is only optional in the CUAP.

1.3 Current Practice

1.3.1 Halter Based Aluminium Standing Seam Systems

A self-supporting standing seam system consists of a metal, predominantly aluminium, roofing and cladding roll-formed profile with virtually no through fixings. It can also be known as a secret fix system. Standing seam sheets are often manufactured on construction sites using portable roll-formers and can be in very long lengths e.g. over 150 m long. The standing seam sheets which act as the weathering layer of the system are connected to the supporting structure or sub-structure with “T” shape connections known as halters and then mechanically seamed into position. The halters being set-out and fixed to the support structure or sub-structure prior to the installation of the sheets. The halters can also be used as a spacer for the incorporation of insulation into the system.

Figure 1.2: Halter as part of a standing seam system (Kalzip Ltd, 2010)

The shape of the head of the halter and the standing seam prevent the sheet from detaching under wind suction forces but allow it to expand and contract longitudinally due to changes in temperature. Figure 1.2 shows an example of an extruded aluminium halter as part of an insulated standing seam system.

Standing seam systems have been used successfully as part of the building envelope on projects the world over with halter based aluminium systems predominant in Europe, Middle East and Asia Pacific. Similar systems utilising the same type of profile but utilising a hook clip connection are more predominant in America. The 2013 market size in Great Britain for aluminium standing seam systems was approximately 1.232 million m^2 (Construction Markets, 2014).

Due to the capability of manufacturing very long length sheets on site this system is often used on large non-domestic constructions such as airports and stadia, and in the leisure, industrial, retail, commercial, education, health and custodial sectors.

The systems are used for both roofs and walls and as a result of recent advances in roll forming technology three dimensional standing seam sheets can be manufactured for use as a geometrically complex building envelope. Figures 1.3 and 1.4 show examples of projects where this form of standing seam sheeting has been used.

Figure 1.3 Southern Cross Station, Melbourne, Australia (Kalzip)

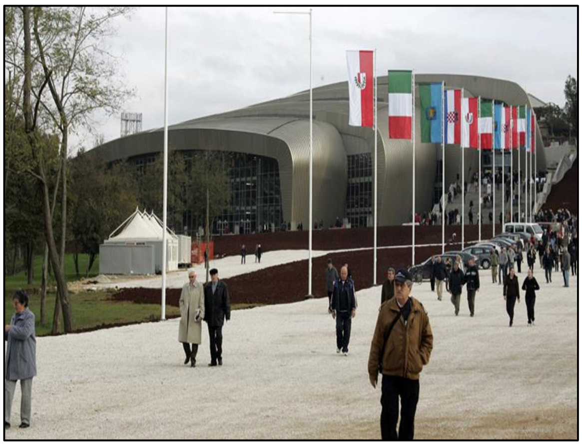

Figure 1.4 Žatika Sports Hall, Poreĉ, Croatia (Kalzip)

Standing seam systems are also increasingly being used as a weathering layer and support for other forms of façade materials such as rainscreen panels, perforated panels, tiles etc. These façade materials are supported on rails fixed to devices which are clamped to the seams of the standing seam sheet without penetrating the sheet itself. Figures 1.5 and 1.6 show examples of projects where this form of construction has been used.

Figure 1.5 Rimex stainless steel panels, Welsh Millennium Centre, Cardiff (Kalzip)

Figure 1.6 Tiles, China Central Academy of Fine Arts, Beijing, China (Kalzip)

1.3.2 Typical Thermal Movement Problems

Typical problems that can result from the restriction or lack of accommodation of thermal movement in halter based standing seam systems are:

- Appearance/aesthetics
    - Halters are visible through seams (figure 1.7).
- Excessive noise
    - Clicking noises can be heard as the standing seam moves over the halter.
- Weathertightness
    - In-plane force from the standing seam sheet can cause the halter to overturn and penetrate the standing seam sheet (figure 1.8).
    - Welded details can split due to excessive stress from thermal movement. Welding reduces the material strength of the aluminium at the position close to the weld itself which is known as the heat affected zone (HAZ).
- Structural
    - Halters and/or fasteners shear or disconnect from the structure/sub-structure increasing the risk of sheets detaching under wind suction loads.
    - Structure, sub-structure or substrate collapses. Figure 1.9 shows a failure where a substrate of a polyisocyanurate (PIR) foam insulation board suffered from localised compression at the position of the halter.
- Thinning material
    - Movement over the halter can erode the aluminium standing seam sheet dramatically reducing the service and design life of the building envelope.

Figure 1.7 Halters visible through seams

Figure 1.8 Halters penetrating seams

Figure 1.9 Collapse of PIR substrate

1.3.3 Typical Factors Affecting Performance

There are a multitude of factors which can affect the thermal movement performance of a halter based aluminium standing system some of which are given below.

- Manufacture
    - If the seam is too tight this can restrict the thermal movement of the sheet over the halter. If the seam is too loose then thermal movement is accommodated but the risk of detachment from the halter under wind suction loads is increased.
- Support Structure
    - Support structure tolerances for standing seam systems are more critical than is standard for other types of cladding in terms of both level and rotation.
    - Standing seam systems do not offer any lateral restraint to the support structure or sub-structure leading to a risk of rotation or overturning if not adequately designed for.
- Detail design
    - No fixed point, multiple fixed points and/or structurally inadequate fixed points
    - In-plane force not taken into account in design of fasteners, sub-structure and/or substrate leading to collapse.
    - Amount of potential movement underestimated or not taken into account at perimeters and penetration details.
- Installation
    - Structure tolerances not checked for suitability
    - Halters not set out correctly to system manufacturer’s recommended installation tolerances e.g. below cover width, out of alignment, skewed on plan etc.,
    - Sheets not fully engaged over halters prior to closing seam
    - Seaming/zipping machine has not been maintained or is designed for another manufacturer’s system
- Additional components clamped to seams
    - When installing other components such as rainscreens, snow guards, solar PV panels etc. using clamps their positioning must not be too close to or directly over the halter position as this may lead to restriction of thermal movement of the standing seam sheet.

1.3.4 Key Deficiencies and Issues to be Resolved

Awareness and knowledge amongst all the key stakeholders (architects, structural engineers, principal contractors, steelwork contractors, specialist sub-contractors, detail designers, and test and approval bodies) in the construction process as to the existence of these forms of failure and their causes appears to be very low. This could also be said of some of the system manufacturers themselves as most systems of this type in the UK are copies of other manufacturers' systems.

Currently there is very little information available on this subject and what little there is very generic and not specific to the type of system in question. Especially critical is an understanding of the support tolerance requirements for this type of system which are much tighter than standard steel work tolerances.

When this form of failure is identified it is invariably put down to poor installation or lack of supervision during the installation process. As the installation is deemed to be at fault the failure would not necessarily be covered by the manufacturer's system guarantee and blame subsequently falls on to the specialist sub-contractor. This can lead to protracted contractual arguments or potential litigation especially where the specialist sub-contractor has gone into liquidation.

Remedial action to the identified problem maybe temporary such as patching penetrated seams with tape or by welding until a more permanent solution is found. This may involve a modification of details (e.g. to allow more movement around a soaker to a penetration), partial removal and replacement of sheets and halters through to a full replacement of the standing seam system. Permanent solutions can become very costly and will invariably impact on the operation and activity within a building.

If this lack of awareness and knowledge across the stakeholders is not addressed then similar failures will continue to occur along with the subsequent contractual arguments and litigation.

From a metal roof and cladding industry perspective continued instances of failure may result in a loss of confidence in the use of this type of system irrespective of the number of successful installations that have been completed worldwide.

1.4 Proposed Solution and Contribution to Knowledge

This dissertation seeks to collate the existing disparate knowledge in to a single document in order to raise awareness of the type of problems experienced by failing to accommodate thermal movement in halter based aluminium standing seam systems, the factors causing them and how they can be alleviated. This will be researched with desk base study, interviews and questionnaires with industry professionals (consultants) and other relevant parties. The research will attempt to identify the extent of this type of failure within the UK market and to establish if there are particular trends e.g. building type, construction type, sheet length etc.

Discussions and questionnaires with system manufacturers will look to ascertain what information is provided on testing, approvals and certification; design information; production tolerances; support and installation tolerances and installation and how this information or advice is disseminated to relevant stakeholders such as the design team, specialist sub-contractors and installation teams. Information on what alternative methods there are available which could assist in alleviating the problems will also be an element of this research.

The outcome and the contribution to knowledge will be the development of a set of recommendations and guidance based on the research findings. It is intended that this will form the basis of a new MCRMA Technical Bulletin which will provide an update and partial replacement to the current MCRMA Technical Paper 3 – Secret Fix Roofing Design Guide.

Although emanating from the manufacturers who are members of the MCRMA their Technical Bulletins and Technical Papers are aimed at all stakeholders within the construction industry who have interest in metal roofing and cladding. These would include, but are not limited to: architects, structural engineers, façade engineers, principal contractors, steelwork contractors, specialist sub-contractors, detail designers and installation teams.

1.5 Scope, Limitations and Boundaries

The scope of this research dissertation will be thermal movement failures in halter based aluminium self-supporting standing seam systems in the UK. The main stakeholders that will form part of the research will be manufacturers and consultants. Other stakeholders within the design and construction process will however benefit from the output. It will also be of use in other geographical locations and with other metals.

Figure 1.10 shows an overview of the configurations of standing seam systems. The area within the red line is a boundary of the specific standing seam configuration within the scope of this dissertation.

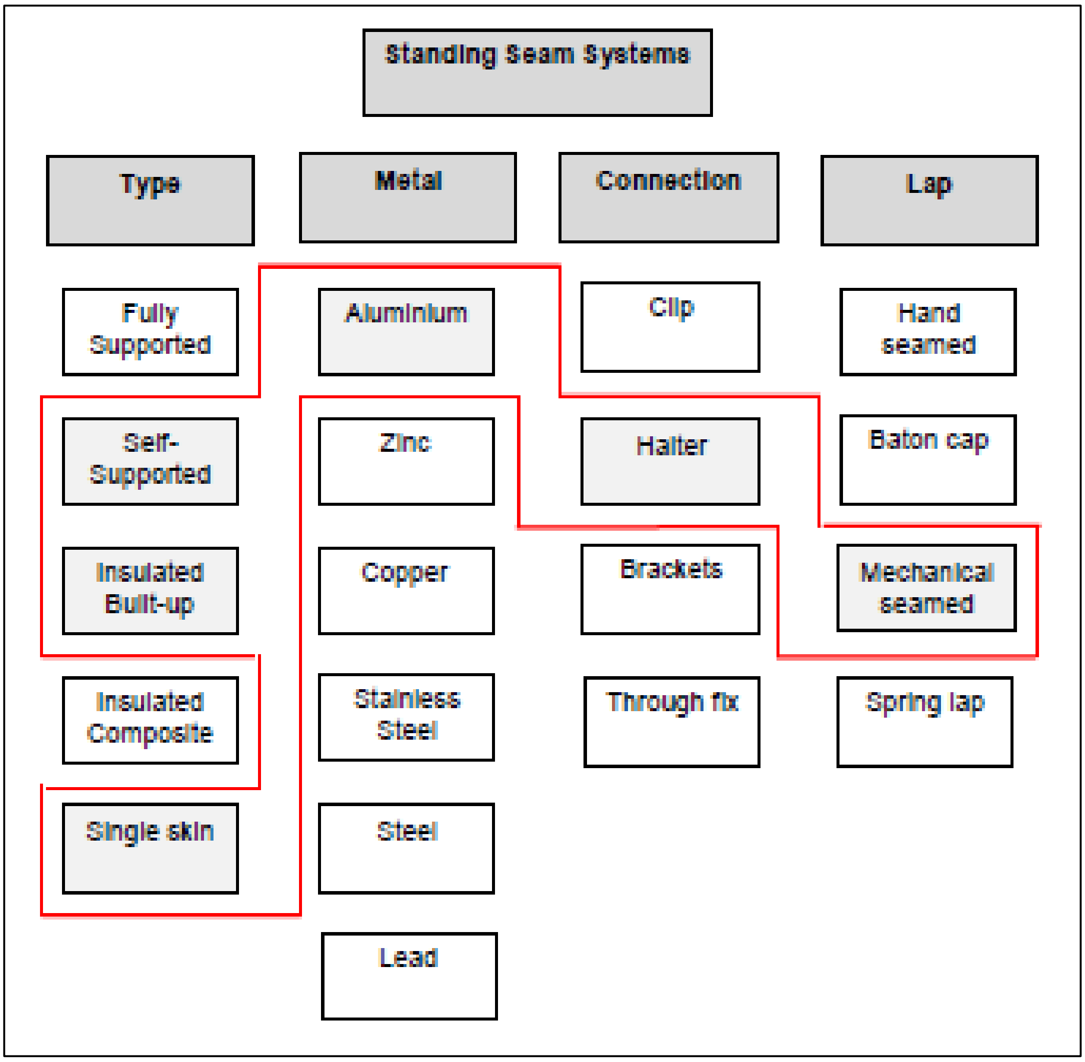

Figure 1.10: Standing seam configurations and boundary highlighting scope of dissertation

1.6 Objectives and Research Methodology

Table 1.1 outlines the objectives of the dissertation together with a brief description, shows the research methods that are adopted to meet the objectives and indicates which chapters they are included.

Objectives		Description	Research Method	Chapter
1	Review available literature	Identify and comment on the extent of relevant literature on the subject:	Desk based study of industry publications, trade literature and third party approvals	2. Literature review 3. Halter based standing seam systems 4. Thermal movement and stress
2	Determine how standing seam systems accommodate thermal movement	Identify the configuration of standing seam systems in the UK and describe how thermal movement is accommodated and controlled in halter based standing seam systems	Desk based study	3. Halter based standing seam systems
3	Determine the amount of potential thermal movement and stress to be accommodated	Expand on current industry "rule of thumb" advice into project specific advice taking into account type of alloy, finish of material, potential extremes of surface temperature, production and installation temperatures etc.	Desk based study Dialogue with coating and material specialists	4. Thermal movement and stress
4	Define in-plane forces in standing seam systems	Describe how in-plane forces can be determined by testing and how results are used in detail design Describe how testing is used in approvals and certification	Desk based study Dialogue with Testing body and Approval body	5. In-plane force

Objectives		Description	Research Method	Chapter
5	Define the issues that need to be resolved	Expand on the type of problems and factors that cause failures looking to identify extent of and any trends (e.g. type of building, length of sheet, type of construction etc.) and gauge the opinion of industry professionals	Dialogue with industry professionals (consultants) Questionnaire	6. Current knowledge of thermal movement problems 7. Problems associated with thermal movement 8. Factors affecting performance
6	Examine the role of the Manufacturer	Identify relevant information available from manufacturers and ascertain how this information is disseminated to specifiers, detail designers and installers	Dialogue with UK manufacturers Questionnaire Desk based study of trade literature	9. System manufacturers
7	Identify alternative methods to assist the accommodation of thermal movement	Identify other materials, components, methods etc. available to assist with thermal movement accommodation in order to alleviate problems		
8	Propose key recommendations and guidance	Propose recommendations for development of MCRMA Technical Bulletin on thermal movement of standing seam systems	Desk based study taking account feedback from dialogue with stakeholders and questionnaires	10 Conclusions and recommendations

Table 1.1 Objectives and Research Methodology

2. Literature Review

2.1 Introduction

One of the drivers for undertaking this research dissertation is that there is little information and guidance available in the public domain regarding problems relating to thermal movement in standing seam systems and more importantly how to alleviate them. Information is generally available on the need to allow for thermal movement but it is of a very generic basis. Other associated aspects can also be found in various pieces of literature such as support tolerances, installation tolerances, fixed points and lateral restraint to support steelwork.

The majority of the information is contained within system manufacturers' technical literature and various trade body and association documents. Table 2.1 gives a list of the documents to be reviewed in this chapter. As the information contained within the system manufacturers' technical literature and third party approvals is of a similar nature they will generally be treated as a body of work rather than as individual items.

Author	**Title**	**Aspect covered**
Industry Documents		
MCRMA	Technical paper No.3 secret fix roofing design guide	Long length sheets. thermal movement, fixed points, lateral restraint, support and installation tolerances
GDA	Thermal elongation in trapezoidal and corrugated aluminium sheeting for sheet thicknesses from 1.0 to 1.5 mm	Thermal movement, thermal forces generated
Heywood M D (SCI)	Publication P346 - Best practice for the specification and installation of metal cladding and secondary steelwork	Lateral restraint, support tolerances

Author	Title	Aspect covered
System manufacturers' technical literature and third party approvals		
APL	Zip Seam installation instructions	Thermal movement, thermal forces generated, in-plane friction forces, fixed points, lateral restraint, support tolerances, installation tolerances
Ash & Lacy	Ashzip installation guide	
BEMO UK	BEMO installation manual	
Bradclad	Prozip roofing system technical manual	
Euro Clad	Technical specifications Euroseam standing seam roofing systems	
Kalzip	Kalzip systems product information and specification	
	Kalzip systems products and applications	
	Kalzip thermal movement information – German (English language) and UK websites	
RigiSystems	Ziplok design and installation guide	
SpeedDeck	Speedzip zip-up standing seam roofing systems	
BBA	06/4301 - Ashzip standing seam roof systems	Thermal movement, thermal movement tests, fixed points, installation tolerances, lateral restraint
	13/5036 – Bemo secret fix roof systems	
	04/4151 – Euro Clad Euroseam roof systems	
	98/3481 – Kalzip liner roof system (product sheet 1) and Kalzip deck roof system (product sheet 2	
	96/3262 – Speedzip double-skin roof systems	
	99/3605 – Ziplok standing seam roof systems	
	09/4666 – Alumasc secret fix roof system – Armaseam (obsolete)	

Table 2.1: List of documents in literature review and summary of aspects covered

2.2 Industry documents

2.2.1 MCRMA Technical Paper 3 – Secret fix roofing design guide

This design guide written in 1992 with a minor revision in 1999 is currently classified as being under review. It covers a wide variety of secret or concealed fix systems, many of which are unavailable in the UK market today, as well as the halter based aluminium standing seam systems.

Due to the wide variety of systems covered design advice is of a generic nature. The design guide adopts a "basic requirements" approach rather than a detailed design one and covers long length sheets, thermal movement, fixed points, lateral restraint and installation and support tolerances. It also touches briefly on flashings but this is covered in greater detail in MCRMA Technical Paper 11 – Metal fabrications: Design, detailing and installation guide.

Both steel and aluminium are covered in the section on thermal movement with colour of coating broken down into light or dark. Typical temperature ranges are given together with overall movement range and movement about ambient which is taken as being +5°C. Table 2.2 gives a summary of the thermal movement table for aluminium in this document.

Material	Colour of coating	Typical temperature range °C	Overall movement mm/m	Movement about ambient mm/m
Aluminium	Light (including mill)	-10 to +50	1.38	-0.345, + 1.035
	Dark	-10 to +70	1.84	-0.345, + 1.495

Notes

1. Typical roof temperature may be exceeded in exceptional circumstances
2. Ambient sheet temperature at installation assumed to be +5°C. If the sheeting is installed during very cold weather the temperature range should be decreased to -2°C (sic). **NB** This should be -20°C.
3. Coefficient of expansion, Aluminium = 23 – 24 x 10^{-6}

Table 2.2: Summary of thermal movement table for aluminium taken from MCRMA Technical Paper 3 (MCRMA, 1999)

The positive movement about ambient temperature indicated in table 2.2 of approximately 1 mm/m for light (and mill) finished aluminium and approximately 1.5 mm/m has somewhat been adopted in the UK for aluminium and can be seen quoted in other literature in particular those produced by UK standing seam manufacturers.

Uncoated, or mill finish, aluminium is categorised as a light colour in this document. Information in other literature e.g. Roofs and roofing performance, diagnosis, maintenance, repair and the avoidance of defects 3rd edition (Harrison et al, 2009) and studies that have been undertaken, indicate that the surface temperatures reached by uncoated aluminium can be as high as or even surpass that of dark coloured aluminium. This will be discussed in greater detail in chapter 4.

Technical paper 3 gives typical examples of support and installation tolerances for clip and halter systems (figure 2.1) and indicates that they are only for guidance only and that specific tolerance information should be sought from the manufacturer as they maybe more demanding than those indicated.

The document is lacking in any mention of in-plane or friction forces, how they could be determined by testing and how the results can be used in project design calculations.

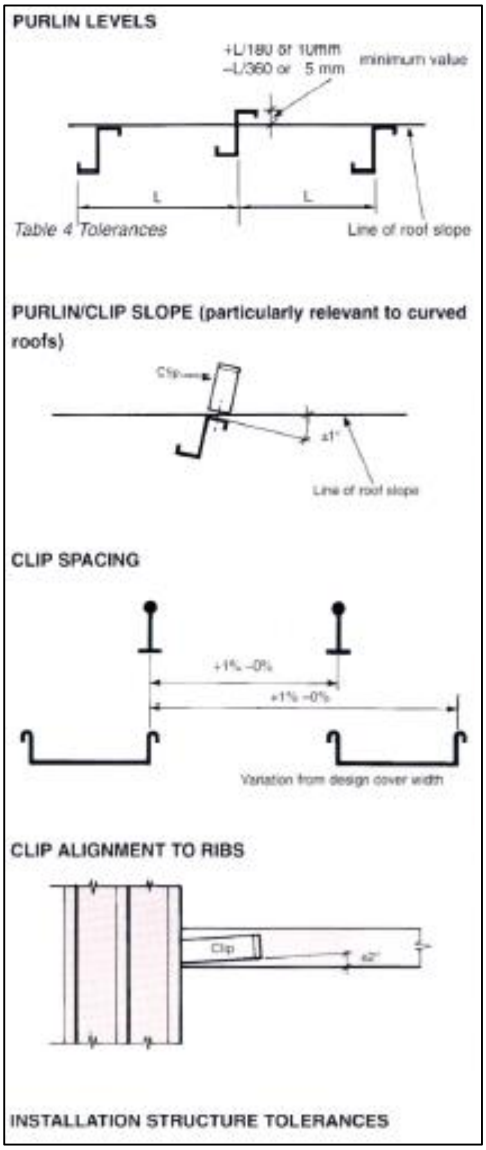

Figure 2.1: Tolerance guidance in MCRMA Technical Paper 3 (MCRMA, 1999)

Although giving a good indication of the basic requirements that should be taken into account with regard to accommodation of thermal movement in secret fix systems; future revisions of the document would benefit from going into greater detail of the calculation procedures for determining such things as: thermal movement allowance at details, forces at fixed points, stress in material and resultant forces generated by sheeting due to restriction of movement in sheets and resistance to in-plane forces all of which are necessary to carry out a detail design of a secret fix or standing seam system.

2.2.2 GDA - Thermal elongation in trapezoidal and corrugated aluminium sheeting for sheet thicknesses from 1.0 to 1.5 mm

This document produced by the German Aluminium Industry Federation does not cover standing seam or secret fix systems but trapezoidal and corrugated (sinusoidal) sheeting which is directly fixed to the support. It is however a useful document as it includes guidance and worked examples for calculating elongation and forces due to thermal movement.

It demonstrates that the thermal movement forces can be very large and includes examples where this will impact on the weather tightness of the aluminium sheeting as it will produce elongated holes at the fixing positions potentially leading to water leakage of the roofing or cladding.

Although not directly related to the detail design of aluminium standing seam systems the calculation examples are easy to follow and would be of use in calculating extremes of thermal expansion and contraction and their resultant forces if fully restrained. The advice on fixings through aluminium would also be useful in the detail design of peripheral aluminium flashings.

2.2.3 Martin Heywood – SCI P346 – Best practice for the specification and installation of metal cladding and secondary steelwork

The aim of this publication is to give guidance on the specification and installation of the three main forms of profiled metal cladding systems, built up trapezoidal systems, composite (insulated sandwich panels) and standing seams (as per figure 3.5) currently used in the UK in conjunction with lightweight cold-formed steel support purlins and wall-rails. Constructions using deep profiled structural decking fixed transverse direct to primary support rafters (as per figure 3.6) are outside the scope of the document. This document refers back to MCRMA Technical Paper 3 for further information on standing seam systems.

This document reinforces the fact that standing seam systems cannot provide lateral restraint or be used where stressed skin action is required unless this is provided by the use of a suitably robust liner sheet directly fixed to the purlins (figure 3.5). The advice on liner sheet suitability is the same that is included in MCRMA Technical Paper 3 but provides a greater amount of information as to the determination of the lateral restraint capability of the liner sheet with reference to clause 10.1.1 of Eurocode 3 (EN 113-1-3).

The need to check the stability of bracket and bar spacer systems (figure 3.7) is raised as being important as the externally applied loads are transmitted through this member into the purlins. Although not specifically mentioned this should also include the in-plane forces produced by thermal movement of the sheets.

There is a section on erection tolerances raising the point that there is currently little available guidance in the UK for erection tolerances of secondary steel members (purlins and wall-rails) but the need for accurate tolerances is crucial to obtain the required performance requirements of the installed roofing or cladding system. Brief reference is made to the 5th edition of the National Structural Steelwork Specification (NSSS) stating that secondary steelwork is not covered by it but the section on "tolerances on attachments" gives information on the tolerances for the positioning of support cleats attached to the primary steelwork members.

The position of the purlin mid-point of the span is discussed indicating that the maximum allowable deviation 'y' for the top flange level from a datum point (figure 2.2) will be dependent on the type of cladding used and that information should be obtained from the system manufacturer. The point that standing seam systems are sensitive to rotation of the purlin/wall-rail is also included again stating that manufacturer's recommendations should be obtained.

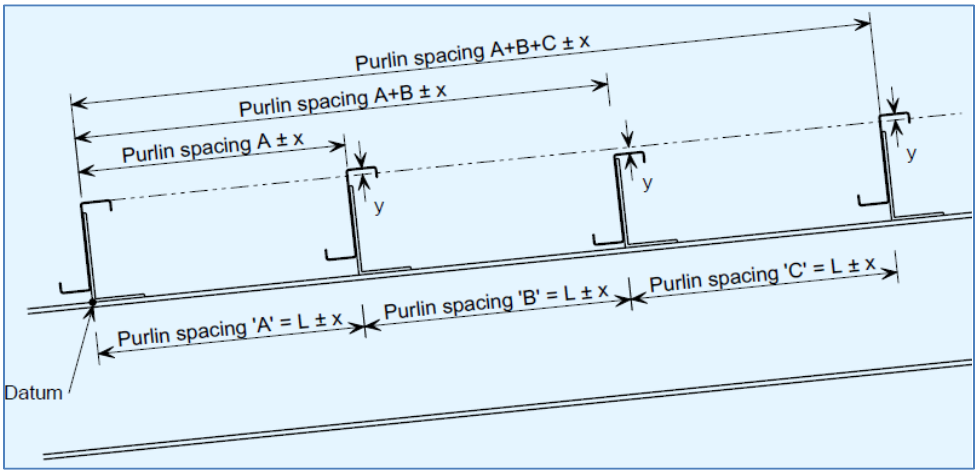

Figure 2.2: Limits on purlin position (Heywood, 2006)

2.3 System manufacturers’ technical literature and third party approvals

2.3.1 System manufacturers’ technical literature

Information and advice on the accommodation and control of thermal movement contained within standing seam system manufacturers’ publically available technical literature is very much of a general nature. Most of the literature covers the amount of thermal movement to be accommodated. All the literature provide information on fixed-point types and support and installation tolerances whilst a few mention the need to provide lateral restraint to the support structure. An overview of the subjects covered in manufacturers technical literature is given in table 2.3.

Only the Prozip roofing system technical manual from Bradclad Ltd provides detailed information on the in-plane forces generated by restraint of thermal movement and also gives tested values together with a design procedure on how to accommodate them.

In a similar manner to MCRMA Technical Paper 3, manufacturers generally adopt a “rule-of-thumb” approach to the amount of thermal elongation to be accommodated using approximately 1 mm/m for light (including mill finish) coloured aluminium and approximately 1.5 mm/m for dark coloured aluminium . The APL literature gives advice that aluminium expansion can be as much as 2 mm/m. There is however contradictory advice in the Kalzip literature and website information. In the UK versions “rule-of-thumb” thermal elongation for uncoated mill or stucco embossed finish material is given as 1 mm/m as per other manufacturers with an approximate temperature of 40° to 50° being attained. In the German versions 1.5 mm/m elongation is given for this material with a temperature of 70° to 80° being attained. As mentioned earlier this later advice is more in keeping with other literature.

The Kalzip literature is the only literature that includes any limit to the effective length (i.e. the length from a fixed point) of the standing seam sheet that should be utilised. This limit is conditional and applies to extruded aluminium haters. The literature recommends that above this effective length plastic halters should be used. Again there is contradictory advice in the various pieces of literature. The German version gives the limit as 20 m whilst the UK version gives the limit as 40 m.

The Architectural Profiles Ltd (APL) installation instructions is the only literature that indicates that the halters can be set out as the sheeting is installed as well as being set out prior to installation of sheeting. This is due to the base of the halter being asymmetric rather than symmetrical as is the case with the other systems.

Apart from some of the information given in the Prozip literature most of the information is of a very basic nature but generally requests the reader to contact their technical departments for further information and advice.

2.3.2 Third party approvals

Of the current eight systems manufactured in the UK six of them have BBA certificates. The Proclad roofing system from Bradclad Ltd., which does not currently have a BBA certificate, was formerly known as Armaseam manufactured by Alumasc Exterior Building Products Ltd., the BBA certificate of which is now obsolete. Table 2.1 gives a list of BBA certificates for standing seam systems. There appears to be very little consistency with the content relating to thermal movement contained within the various British Board of Agrément (BBA) certificates for aluminium standing seam systems.

The main area of concern is the undertaking of thermal movement tests. It would appear that testing is not compulsory. The intention of the thermal movement test is “to determine the load applied to the support structure when the roof is installed to the maximum out of alignment tolerances specified by the manufacturer” (BBA, 2014). The results of the testing being used in calculations “to verify the adequacy of the support structure to resist in plane forces due to thermal movement” (BBA, 2014).

Some certificates indicate that testing has been carried out and state that the system can accommodate thermal movement if installed to the manufacturer’s instructions. A number of other certificates do not include such statements. Even were they are included no further advice is given as to the results from the tests or guidance of their use in detail design calculations. As indicated in section 2.4.1 most manufacturers also do not publically publish thermal movement test results. There has been one exception to this in the now obsolete Armaseam BBA certificate. An overview of the subjects covered in manufacturers’ BBA Certificates is given in table 2.4.

System Manufacturer	Thermal Movement Allowance	Thermal Movement Forces Generated	In-plane force test results	In-plane force design	Fixed point types	Fixed point design	Lateral restraint	Support tolerances	Installation tolerances
APL	Yes				Yes			Yes	Yes
Ash & Lacy	Yes				Yes			Yes	Yes
BEMO					Yes			Yes	Yes
Bradclad	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes
Euro Clad	Yes				Yes	Yes	Yes	Yes	Yes
Kalzip	Yes				Yes			Yes	Yes
RigiSystems	Yes				Yes			Yes	Yes
SpeedDeck					Yes			Yes	Yes

Table 2.3: Overview of subjects relating to thermal movement accommodation and control in manufacturers' technical literature

Manufacturer	System	Thermal Movement Statement	Thermal Movement Tested	In-plane force test results	In-plane force design	Fixed point types	Fixed point design	Lateral restraint	Support & Installation tolerances
Ash & Lacy	Ashzip	Yes	Yes						
BEMO UK	BEMO								
Euro Clad	Euroseam	Yes	Yes			Yes		Yes	
Kalzip	Kalzip	Yes	Yes[1]			Yes			
RigiSystems	Ziplok								
SpeedDeck	SpeedZip					Yes			Yes
Alumasc[2]	Armaseam[2]	Yes	Yes	Yes	Yes	Yes	Yes		

Notes

1. Thermal movement tests have been carried out but it is not noted in the BBA certificate
2. The BBA certificate for this system is now obsolete

Table 2.4: Overview of subjects relating to thermal movement accommodation and control in manufacturers' BBA certificates

3. Halter Based Aluminium Standing Seam Systems

3.1 Introduction

The standing seam systems which are the subject of this research dissertation consist of self-supporting profiled sheets manufactured from aluminium coils and produced by a roll-forming process. The sheets are supported on "T" shaped halters predominantly manufactured from extruded aluminium although recently other materials have been adopted such as injection moulded plastic, pultruded fibre reinforced resin and formed stainless steel.

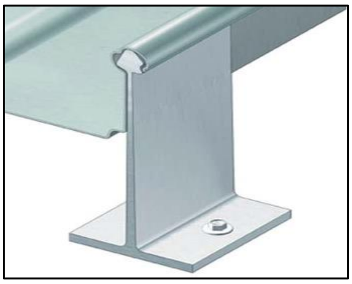

Figure 3.1: Standing seam sheet installed over halter (Ash and Lacy, 2012)

Figure 3.2: Zipping machine (Ash and Lacy, 2012)

The halters are fixed direct to the support steelwork, e.g. purlins or wall-rails, or to a sub-structure incorporated within the depth of the system. The standing seam sheets are installed over the head of the halters (figure 3.1) and are mechanically seamed together with a seaming machine (figure 3.2). The process is known as "zipping" and the mechanical seaming machine is commonly referred to as a "zipping" machine. In the UK there are currently eight manufacturers who produce halter based aluminium standing seam systems. A brief history and development of halter based standing seam systems can be found in appendix D.

There are other types of standing seam system available the world over which have different forms of lap joint, different fixing methods and which may be manufactured from other metals as aluminium. These different standing seam types will be referenced where appropriate.

Research conducted for the MCRMA shows that in 2013 the UK market for profiled metal (steel and aluminium) was 14,788,000 m^2 of which 1,507,000 m^2 (10.2%) was standing seam systems. Other forms of profiled metal are trapezoidal sheet and insulated composite panels. The aluminium standing seam system market stood at 1,232,000 m^2 which is 81.1% of the standing seam market and 8.3% of the overall profiled metal market (data from Construction Markets, 2014). A more detail overview of the UK market can be found in appendix E.

This chapter will give an overview of the type of roof and cladding system configurations that halter based aluminium standing seam systems are used in and provide a description of how thermal movement is controlled and accommodated. A comparison with a similar standing seam system which utilises a sliding clip instead of a halter will also be given.

3.2 Current system configurations

The standing seam sheets manufactured from aluminium typically have a cover-width of between 250 and 600 mm and a seam height of between 50 mm and 75 mm with a thickness of 0.9, 1.0 and 1.2 mm. The sheets are supplied either uncoated with a stucco-embossed finish or colour coated with PVDF, ARS or polyester paint finishes.

By reference to UK manufacturers' product literature and BBA certificates (BBA, various years) the most common standing seam variation in the UK has a 400 mm cover-width and 65 mm seam height (figure 3.3) manufactured from 0.9 mm uncoated aluminium alloy with a stucco-embossed finish.

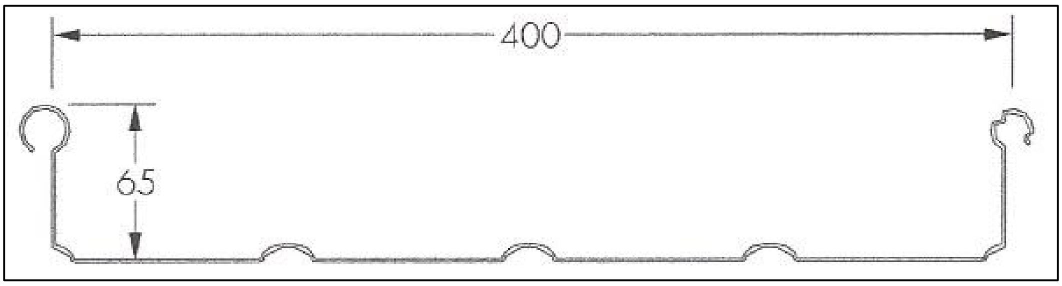

Figure 3.3: Common dimensions of standing seam sheet (BBA, 2007)

As the standing seam sheets have virtually no exposed fixings and can be supplied in extremely long continuous lengths they can be laid to very low pitches. Typically the minimum pitch is 1.5° as per the system BBA certificates (BBA, various years) although they are often used on barrel vault roofs where the majority of the roof is below that pitch and will be flat at the apex.

Standing seam systems can be used in both un-insulated single skin and insulated double skin constructions.

Single skin constructions are predominantly used in refurbishment, e.g. re-cladding existing pitched roofs or over-roofing existing flat-roofs (flat-to-pitch roof conversion) or are applied over a substrate such as plywood, timber boarding etc. They can also be used in unheated buildings where there is no requirement for insulation such as stadia and warehouses. The structural support for the system will generally be purlins spanning between rafters to which the halters will be fixed to directly (figure 3.4).

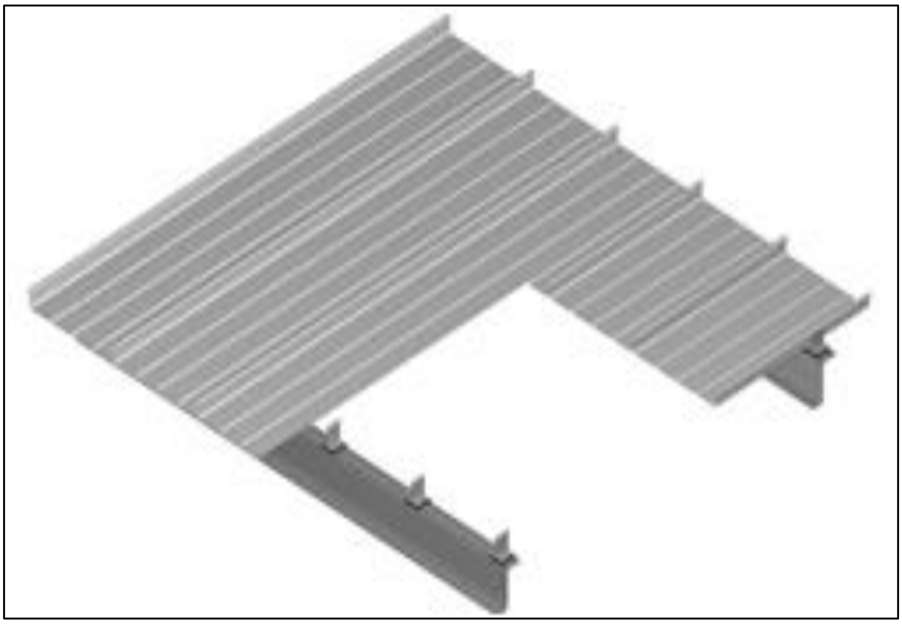

Figure 3.4: Standing seam system in a single skin application (Kalzip)

Insulated double skin constructions are primarily used for new build, although they can be used for refurbishment usually where the existing roofing system has been completely removed. Although the support for the standing seam system can take many forms it will generally be either purlin or rafter based.

The former has the outer standing seam sheet and the internal liner sheet laid in the same direction across the roof purlins (figure 3.5). Typical purlin centres would be approximately 1.0 to 2.4 m. This type of construction can be known as a liner or purlin system.

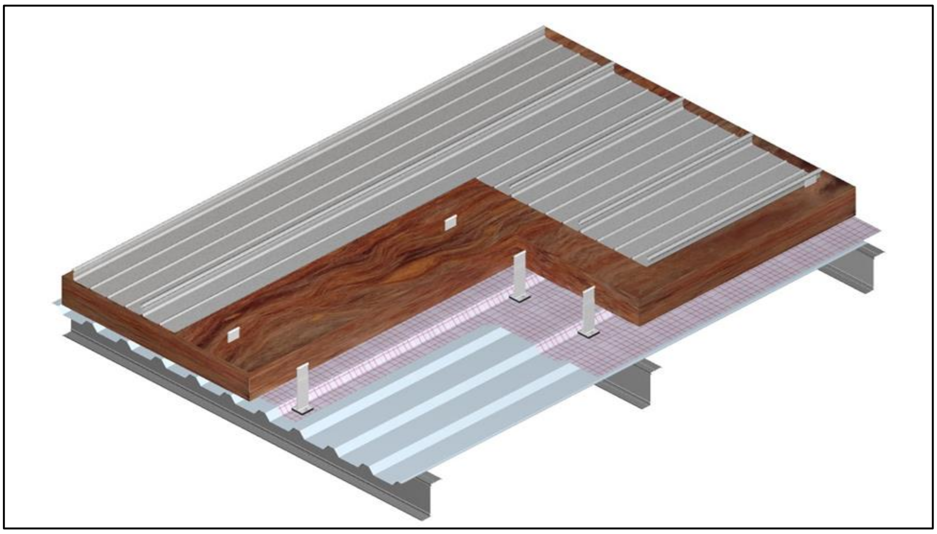

Figure 3.5: Standing seam system in a double skin liner/purlin roof application (Kalzip)

The other common method has the outer standing seam sheet running transverse to an inner structural deck sheet which spans between the primary support rafters (figure 3.6). Typical rafter centres would be approximately 3 to 10 m. This type of roof construction can be known as a deck or rafter roof system.

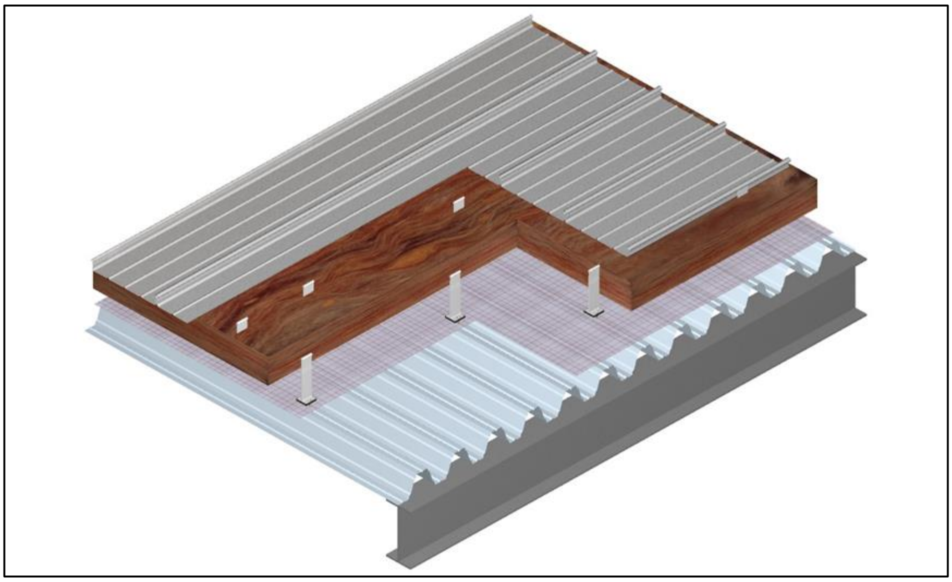

Figure 3.6: Standing seam system in a double skin deck/rafter roof application (Kalzip)

The cavity for the insulation between the outer standing seam sheet and the inner liner/decking sheet can be created by a tall halter or with a halter fixed to a sub-structure. Maximum cavity depth for a halter is approximately 200 mm. For roof system depths greater than this the halter can be used with a bracket and bar/rail system (figure 3.7), or on a top-hat profiled sub-purlin (figure 3.8). A plastic barrier pad is usually installed on the base of the halter where it is manufactured from extruded aluminium in order to help reduce thermal bridging through the halter.

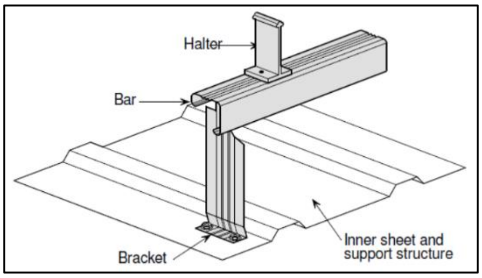

Figure 3.7: Halter with bracket and bar spacer kit (BM Trada Certification, 2011)

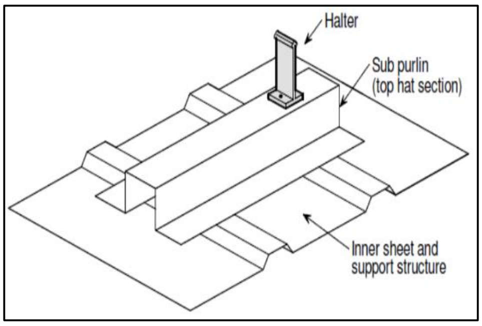

Figure 3.8: Halter with top-hat profiled sub-purlin (BM Trada Certification, 2011)

Aluminium standing seam systems are also being used in other forms of application providing a support and weathering layer for extensive green roof systems (figure 3.9) and other façade materials such as rainscreen panels, flat panels, perforated panels, tiles etc. (figure 3.10).

Figure 3.9: Extensive green roof system on aluminium standing seam system (Ash and Lacy, 2013)

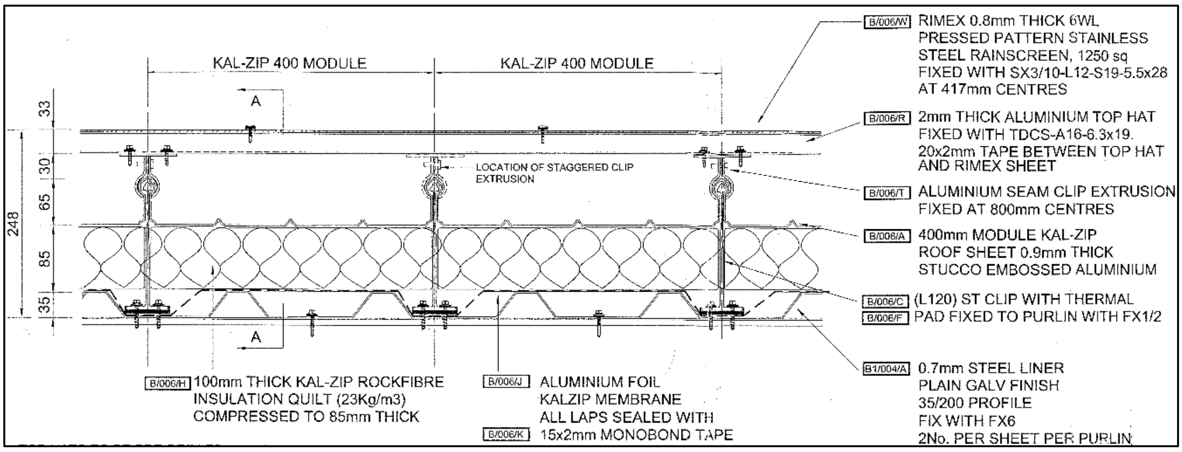

Figure 3.10: Rimex stainless steel rainscreen panels fixed to supporting structure connected to aluminium standing seam system (Kelsey, 2002)

3.3 Thermal movement accommodation and control

3.3.1 Thermal movement accommodation

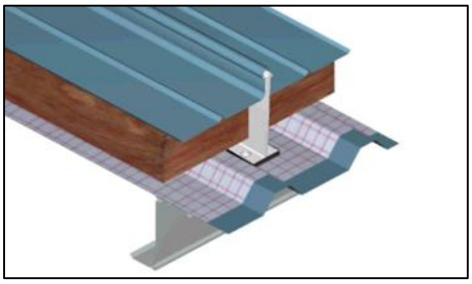

Figure 3.11: Standing seam sheets on haler (Kalzip)

Standing seam sheets are designed to accommodate thermal movement by moving over the heads of concealed halters. The shape of the head of the halter and the standing seam sheet prevent the sheet from detaching under wind suction forces but allow it to expand and contract longitudinally due to changes in temperature. These halters also provide support to resist imposed loads such as snow, access etc. and can also act as a spacer to incorporate insulation where it is required (figure 3.11).

It is common practice to set-out and install the halters prior to installation of the standing seam sheets (figure 3.12) therefore adherence to the system manufacturers' halter setting-out tolerances is critical.

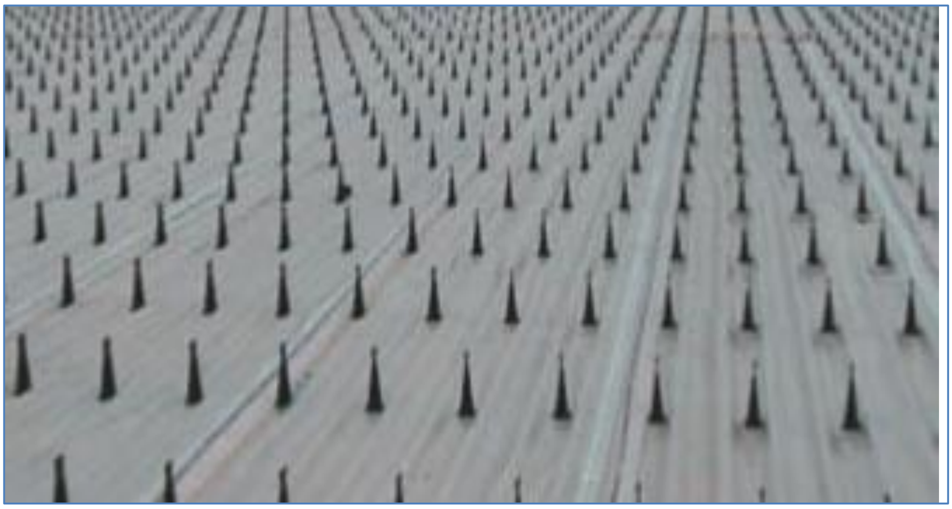

Figure 3. 12: Halters set-out on roof prior to installation of standing seam sheets (Kalzip Ltd, 2010)

To achieve the full thermal movement of the standing seam sheet as calculated there is an assumption that there is no restraint to restrict it from moving. In reality this does not happen as there will nearly always be some form of restraint in place caused by such instances as friction between the head of the halter and the sheet, erection misalignment of supporting steelwork, design of steelwork frame (e.g. pre-cambered rafters), misalignment in installation of halters and insufficient movement allowance at details (e.g. at end conditions, abutments and penetrations) to name but a few.

Of these potential restrictions, the friction between the head of the standing seam sheet and the halter is a fundamental part of how the system works and is mainly under the control of the system manufacturer in terms of product design and the tolerances to which it is manufactured to. The installation of the halters can also influence its magnitude.

Other potential restrictions are generally outside the direct control of the manufacturer but can be influenced in their occurrence through advice and training to the relevant parties who undertake the specification, detail design and installation work.

Figure 3.13 shows a visualisation of the friction force, also known as in-plane force due to thermal movement of standing seam acting on the head of the halter.

The in-plane or friction force acting on the head of the halter creates a “lever-arm” effect trying to overturn the halter. This overturning is resisted by the rigidity of the support and the resistance of the fasteners from the support.

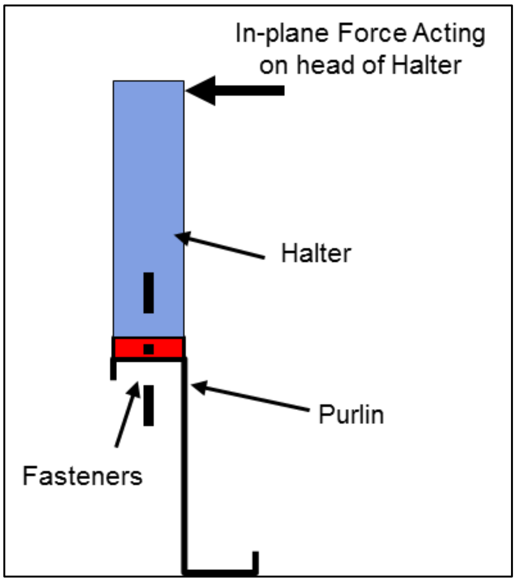

Figure 3.13: Visualisation of in-plane/friction force acting on head of halter (Kalzip Ltd, 2011)

The magnitude of this in-plane force can be determined by testing with the results being used in detail design calculations to determine the fastener and support/sub-support requirements to resist the force. The tests will usually be carried out with the halters misaligned to the system manufacturer’s published setting out tolerances.

3.3.2 Lateral restraint to supports

As standing seam sheets are not directly fixed to the structure, e.g. Z-sections purlins and wall rails, they will not provide any lateral restraint to assist in preventing failure of the support through lateral-torsional buckling especially with cold formed steel sections. This will also be the case where a sub-structure is utilised e.g. bracket and rail/bar system

In an insulated double skin application (figure 3.5) a non-perforated profiled liner sheet should provide lateral restraint if manufactured from minimum 0.4 mm steel or 0.7 mm aluminium (MCRMA, 1999 and Heywood,2006) but the manufacturer's guidance should be sought (MCRMA, 1999).

In a single skin standing seam application (figure 3.4) and where the internal liner does not provide suitable lateral restraint then it is necessary that this is taken into account in the design of the support structure or sub-structure. Generally purlin and wall rail manufacturers assume that lateral restraint is provided by cladding panels or sheets (Heywood, 2006) in instances where it is not then permanent lateral restraint must be provided by other means e.g. lateral support angles (Metsec, 2011).

3.3.3 Fixed points

To control thermal movement and avoid creep of the standing seam sheet down-slope a fixed point is introduced into the system. The fixed point acts as both an anchor to transfer the axial loads on the sheet to the structure and a datum point in order to determine the direction and amount of thermal movement of the sheet.

Although fixed points are usually installed at the ridge position, thus allowing thermal movement to take place at the eaves position there are instances where it may be suitable to install them at the eaves position (e.g. if there is a tight radius or crank at the eaves) or within the slope (e.g. if there are banks of penetrations or the steelwork rafters have been pre-cambered to a central support). In instances where there are very long length roof slopes the fixed point can be positioned mid-slope in order to reduce the effective length of the standing seam sheet and thus the amount of thermal movement to be accommodated.

There should only be one fixed-point introduced into each standing sheet length with all connected standing seam sheets being detailed to move in the same direction. If there is more than one fixed point this will restrict the accommodation of thermal movement leading to the potential of failure.

There are a number ways of forming a fixed point in a standing seam sheet but the two most common methods are shown in figure 3.14. The left hand image shows a fixed point being formed by installing a rivet through the small roll of the standing seam sheet into the head of the halter. When the large roll is zipped into position the rivet will be concealed. The right hand image shows a nut and bolt arrangement fixed through the upstands of adjoining sheets and the halter. This method of forming a fixed point is generally exposed but maybe concealed behind the ridge closure and flashings if positioned at the ridge position of the sheet.

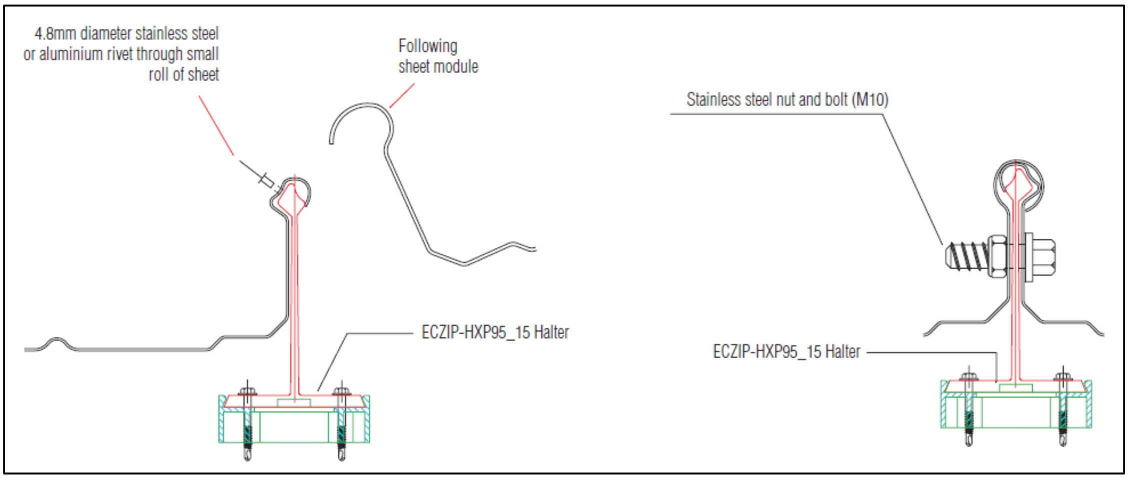

Figure 3.14: Common methods of creating fixed point in standing seam systems (Euro Clad, 2006)

The type of fixed point that is adopted is determined by the axial or fixed point force acting in the plane of the roof that it needs to resist which is based upon the intensity of snow loading, roof pitch and length, width and weight of the standing seam sheets

The force acting at the fixed point in the plane of the roof can be calculated from the following equation:

$$F_{fp} = L \times b \times (g * \sin a + S \times \sin a \times \cos a) \qquad (3.1)$$

Where:

F_{fp} = Fixed point force applied at a halter (kN/halter)

L = Length of standing seam sheet (m)

b = Width of the standing seam sheet (m)

g = Self weight of the standing seam sheet (kN/m^2)

S = Snow or imposed load (kN/m^2)

a = Roof pitch (°)

It is imperative that the forces generated at the fixed point position must be able to be safely transferred to and resisted by other elements of the construction, e.g. halter fasteners, sub-structure etc., and the structure i.e. sufficient restraint must be provided to prevent the purlin/support at the fixed point position from overturning.

3.3.4 Comparison between halter and clip based systems

The halter based systems described above are predominant in Europe, Middle East and Asia Pacific. Similar systems with the same type of profile but utilising a sliding hook clip connection (figure 3.14) are predominant in America.

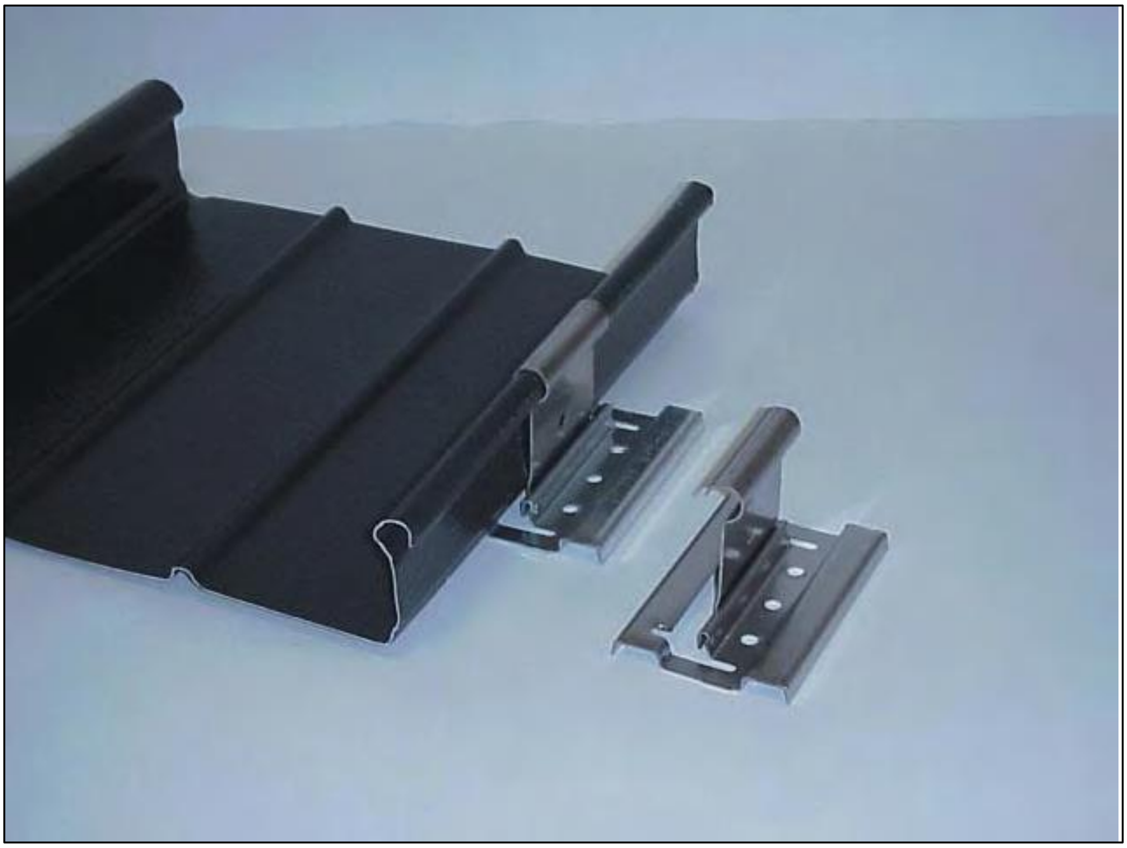

Figure 3.14: Standing seam system with sliding hook clip (Merchant & Evans, 2009)

A sliding hook clip is a two-piece pressed metal, usually stainless steel, clip which has an upstand hook tab which is retained but allowed to slide within the base of the clip. The base of the clip is fixed through its leading edge into the support or sub-support once the hook tab has been installed over the small roll of the sheet. The large roll of the following sheet is zipped over the small roll locking the hook tab in position.

In halter based systems thermal movement is accommodated by the sheet moving over the head of the halter. Theoretically the amount of movement and accordingly the sheet length that can be accommodated is unlimited. The halters are set-out and installed prior to the installation of the standing seam sheets. Therefore it is imperative that their setting out is to the manufacturer's published tolerances or better to prevent thermal movement being restricted. There is a potential for failure of the system if the in-plane force between the sheet and halter is too great.

In sliding hook clip based systems thermal movement is accommodated by the hook tab of the clip sliding within the base of the clip. The amount of movement and accordingly the sheet length is therefore limited by the movement capacity between the hook tab and the base of the clip. If the hook tab is positioned centrally within the base of the clip then typically between ±1" (≈25 mm) to 1.5" (≈38 mm) movement could be accommodated, a "maximum uninterrupted roof width of about 200 ft. (≈61 m) beyond which stepped expansion joints are needed" is recommended (Newman, 2004). As the sliding hook clips are set out by the sheets there is virtually no risk of misalignment. There is no in-plane or friction force between the sheet and the clip but potential failures due to restriction of thermal movement can arise if the hook tab is not positioned centrally in the clip base during installation or if the sheet length and corresponding amount of thermal movement is too much for the capacity of the clip.

4. Thermal Movement and Stress

4.1 Introduction

The amount of expansion and contraction likely to occur in a length of a standing seam sheet and its subsequent stress needs to be calculated in order that it can be accounted for in the design process. Typical examples being: dimensional allowance at details; stress impact on welded joints and fasteners in flashings etc.

As seen in the literature review as a rule of thumb, thermal movement for aluminium is generally taken as ± 1 mm per 1 m length of sheet. For dark coloured sheets this is increased to ± 1.5 mm per 1 m length of sheet. Although this rule of thumb is usually adequate for some conditions there is often the necessity to calculate the amount of thermal movement in greater detail, for example in more extreme climates and especially when long length standing seam sheets are used. There is also some debate as to the surface temperature attained by uncoated mill or stucco embossed finish aluminium.

The overall thermal movement and stress are calculated by using the coefficient of thermal expansion of a material and taking into account the maximum and minimum temperatures that the surface attains. The potential installation temperature range would also be needed to determine the maximum expansion and contraction of the sheet.

4.2 Coefficient of Thermal Expansion

Metal	**α ($10^{-6}K^{-1}$)**
Aluminium	23 - 24
Copper	16
Lead	30
Steel	12
Stainless steel	16.5
Zinc	22

Table 4.1: Coefficient of thermal expansion (α) of various metals

The coefficient of thermal expansion (α) of various metals commonly used for roofing and cladding is shown in table 4.1. As can be seen aluminium has one of the highest coefficients amongst these metals and is approximately twice that of steel. The exact coefficient of thermal expansion for aluminium will vary slightly for different alloys for example EN AW 3005 = 23.1 x $10^{-6}K^{-1}$, EN AW 3004 = 23.3 x $10^{-6}K^{-1}$ and EN AW 5052 = 23.7 x $10^{-6}K^{-1}$ to name but a few of the alloys designated as being suitable for self-supporting roofing sheets (BSI, 2008).

A uniform temperature rise (ΔT) in the metal will cause an expansion of:

$$e = \alpha L \Delta T \qquad (4.1)$$

Where:

e = change in length
α = coefficient of thermal expansion
L = Length

If the material is fully restrained against this expansion the stress (f) in the material will be:

$$f = \alpha E \Delta T \qquad (4.2)$$

Where:

E = Modulus of Elasticity (for aluminium, E_{alum} = 70,000 N/mm^2)

Using equation (4.2) for aluminium the stress in the material if fully restrained against expansion or contraction would be between: f = 1.61T N/mm^2 and f = 1.68T N/mm^2 for coefficients of thermal expansion of 23 x $10^{-6}K^{-1}$ and 24 x $10^{-6}K^{-1}$ respectively.

4.3 Surface Temperature

In extremes of direct sunlight surface temperatures of materials can be much higher than the air temperature due to solar overheating. Solar energy, which is conventionally divided into short wave and long wavebands, falls on to a surface causing its temperature to rise above air temperature. Some of this absorbed heat is re-radiated from the surface but this is only in the long waveband.

Light coated surfaces have high thermal reflectance and will absorb less solar energy. They also have high thermal emittance at long wavebands so will re-radiate energy from the surface. This combination of high reflectance and high emittance is best for reducing solar gain and keeping the surface temperature relatively cool.

Dark coated surfaces on the other hand although having high emittance values have relatively low reflectance values so will invariably attain much higher surface temperatures in direct sunlight than light coated surfaces.

Bright uncoated metal sheet finishes, e.g. uncoated mill or stucco-embossed finish aluminium though having high reflectance values unfortunately have low thermal emittance and therefore can experience significant solar heating and attain relatively high surface temperatures not too dissimilar to dark coated material. This is contrary to what is included in some of the literature covered in chapter 2 e.g. MCRMA Technical Paper 3 and some system manufacturers' technical literature which indicate uncoated material attaining temperatures similar to light coloured coated material.

Calculation methods can be used to predict temperatures that the surface of the building envelope can achieve in direct sunlight. One such method is determining the sol-air temperature which is the "hypothetical outdoor temperature that would give the same heat flows in the absence of radiation" this being similar to what would be expected the surface of an insulated panel if no heat was conducted to the structure or space behind it (Harrison et al, 2009). Methodology for determining the sol-air temperature can be found in CIBSE Guide A (CIBSE, 2007) and the ASHRAE handbook of fundamentals (ASHRAE, 2009).

Figure 4.1 gives calculated extreme surface temperatures for various materials and finishes for air temperatures of 30°C, calculated to the methodology in CISE Guide A (Harrison et al, 2009).

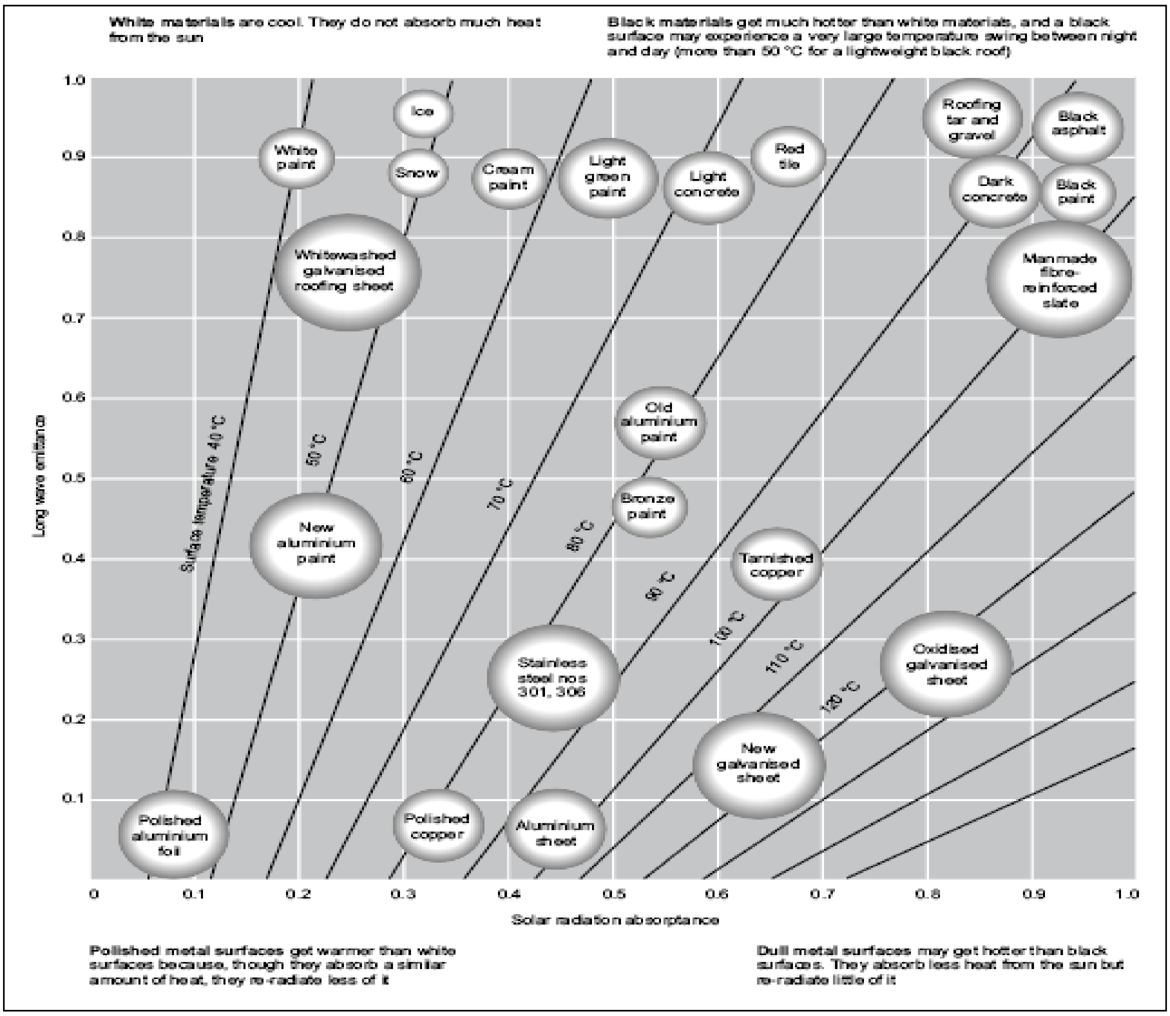

Figure 4.1 Calculated extreme metal surface temperatures for air temperatures of 30°C (Harrison et al, 2009)

Figure 4.1 shows the hypothetical surface temperature that aluminium sheet could reach in direct sunlight and an ambient air temperature of 30°C as being between 100 and 100°C this being similar to black paint.

With the advent of the Leadership in Energy and Environmental Design (LEED) environmental rating and certification scheme having a greater influence in environmental design of buildings globally the availability of solar absorption and thermal emittance data of specific materials, finishes and colours is becoming more widely available. Paint manufacturers and coating specialists have undertaken tests in order to provide information to enable designers and specifiers to obtain scheme credits for the heat island effect of a roof where the use of materials and finishes with a high solar reflective index (SRI) is encouraged (USGBC, 2011).

In communication with coating specialist Euramax Ltd and industry professionals in Germany, Karlfreidrich Fick (independent roofing and cladding consultant) and Andreas Schmelzer (Novelis Europe), information has been obtained regarding solar reflectance, thermal emittance and SRI test values and details of a study regarding maximum temperature attained by various colours and finishes of aluminium respectively. Table 4.2 shows a summary of this information for a selection of colours and finishes common with roofing and cladding products.

Colour / Material	**RAL Code**	**Solar Reflectance**	**Thermal Emittance**	**SRI value**	**Max. Temp (°C)**
Pure white	9010	0.777	0.85	95	55
Cream	9001	0.732	0.86	89	57
Light ivory	1015	0.629	0.85	75	60
Grey white	9002	0.615	0.82	72	62
Metallic Silver	9006	0.616	0.67	67	62
Light grey	7035	0.512	0.85	58	64
Light green	6027	0.515	0.87	60	69
Pigeon blue	5014	0.283	0.86	28	74
Stucco embossed[1]	-	0.79/0.52	0.06/0.30	76/35	78
Slate grey	7015	0.119	0.85	6	78

Note

1. Two sets of values are given for stucco embossed aluminium the first of which is for new material, the second is for oxidised (weathered) material

Table 4.2: Solar Reflectance, Thermal Emittance and SRI values and Maximum Temperatures Attained in Direct Sunlight for Various Coated and Un-coated Aluminium Surfaces

Solar reflectance was determined in accordance with ASTM E903, thermal emittance was determined in accordance with ASTM C1371 and the resultant SRI values calculation in accordance with ASTM E1980.

The German study was based on an air temperature of 30°C and a geographic latitude of 50°. The geographic latitude having an impact on the insolation (solar radiation energy) received on a surface. As a point of reference, Bracknell used in CIBSE Guide A for solar and weather data for the “London area” location is at a latitude of 51° (CIBSE, 2007).

It can be seen from these tested values and the higher the SRI value the lower the surface temperature will be although this is not the case with uncoated material (mill or stucco embossed) due to its low thermal emittance.

In reality the temperatures would be expected to be lower than this as the surface is cooled down by natural air flow as wind blows over the surface. The temperature would also be dependent upon the angle of incidence to the sun with horizontal surfaces (i.e. flat roofs) attaining higher surface temperatures than vertical surfaces (i.e. walls). The SRI calculation method in ASTM E-1980 takes into account wind speed and the cooling effect it can have on a surface through a convection coefficient for low, medium and high wind speeds. The SRI values in table 4.2 utilise a convection coefficient of 12 $Wm^{-2}K^{-1}$ for a medium wind speed. The convection coefficients for low and high wind speeds are 5 $Wm^{-2}K^{-1}$ and 30 $Wm^{-2}K^{-1}$ respectively. Using the low wind speed convection coefficient would have the effect of lowering the SRI value and increasing the predicted surface temperature and vice-versa when the high wind speed convection coefficient is adopted.

The extreme minimum temperature attained by a surface will also need to be determined. The opposite of solar overheating is cooling by night sky radiation. On very clear night sky conditions surface temperatures can be as much as 8°C lower than air temperature due to the surface still radiating at long wavebands to the upper atmosphere whilst not benefiting from any solar gain. On cloudy nights the temperature drop will be less and if fog is present surface temperatures should be almost that of the surrounding air temperature (Harrison et al, 2009).

The real life effects of direct sunlight and night sky radiation on metal roof surfaces can be seen in figures 4.2 to 4.5 which give a series of graphs of monitored surface and ambient air temperatures of a stucco embossed finish aluminium halter based standing seam roof located in the South of England. There are two areas of roof: one exposed to direct sunlight; the other is sheltered in a manner which is not too dissimilar to that shown in figures 1.5, 1.6 and 3.10 where the standing seam roof is used as a support for a rainscreen system.

Figure 4.2 is the exposed roof area monitored over a summer month (June 2014). This shows that the surface temperature during the daylight hours can be more than double the ambient air temperature. During 20th June the surface attained a temperature of 51°C against a peak ambient air temperature of 24°C. The effects of night sky radiation can also be seen where the surface temperature drops below that of ambient air temperature. Late on 29th June the surface temperature was recorded as being 5°C lower than the ambient air temperature.

Figure 4.3 is for the same exposed roof area but monitored over a winter month (January 2014). Although the temperatures are much lower the surface temperature can still be approximately double that of the ambient air temperature. Again the effects of night sky radiation can be seen with a drop in surface temperature of 6°C below that of ambient air temperature being recorded midnight 11-12th January.

Figure 4.4 is for the sheltered roof area monitored over a summer month (June 2013). This shows that the surface temperature deviates very little from the ambient air temperature as the surface is not exposed to direct sunlight. However the ambient air temperature recorded is much higher than the ambient air would be expected to be, peaking at 48°C during 19th June rather than the expected mid 20's °C. This could be accounted for by the air in the void between the standing seam system and the rainscreen being heated from the direct sunlight acting on the metal rainscreen.

Figure 4.5 is for the same sheltered roof area monitored over a winter month (January 2014). Except for a few spikes early in the month the surface temperature deviates very little from the ambient air temperature. As the surface is sheltered there is no night sky radiation effect taking place. By reference to figure 4.3 for the same monitored month the ambient air temperature for the sheltered roof does not generally increase except on the few occasions early in the month where the ambient air temperature is a few degrees warmer than the recorded ambient air temperature for the exposed roof. Again it would be expected that the airspace has been heated by the direct sunlight acting on the metal rainscreen.

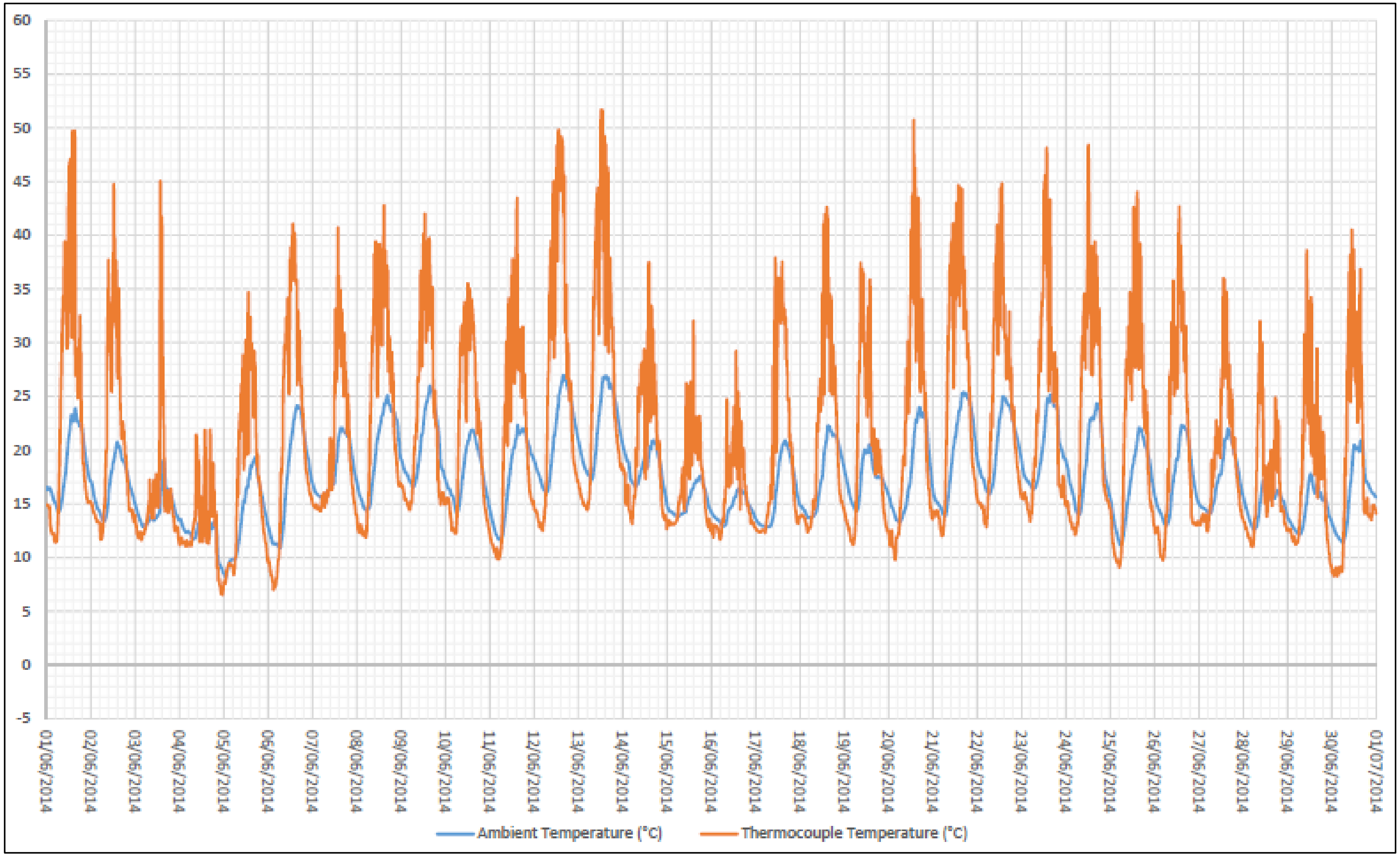

Figure 4.2: Record of ambient air temperature and surface temperature for exposed roof in South of England for June 2014 (Atkins)

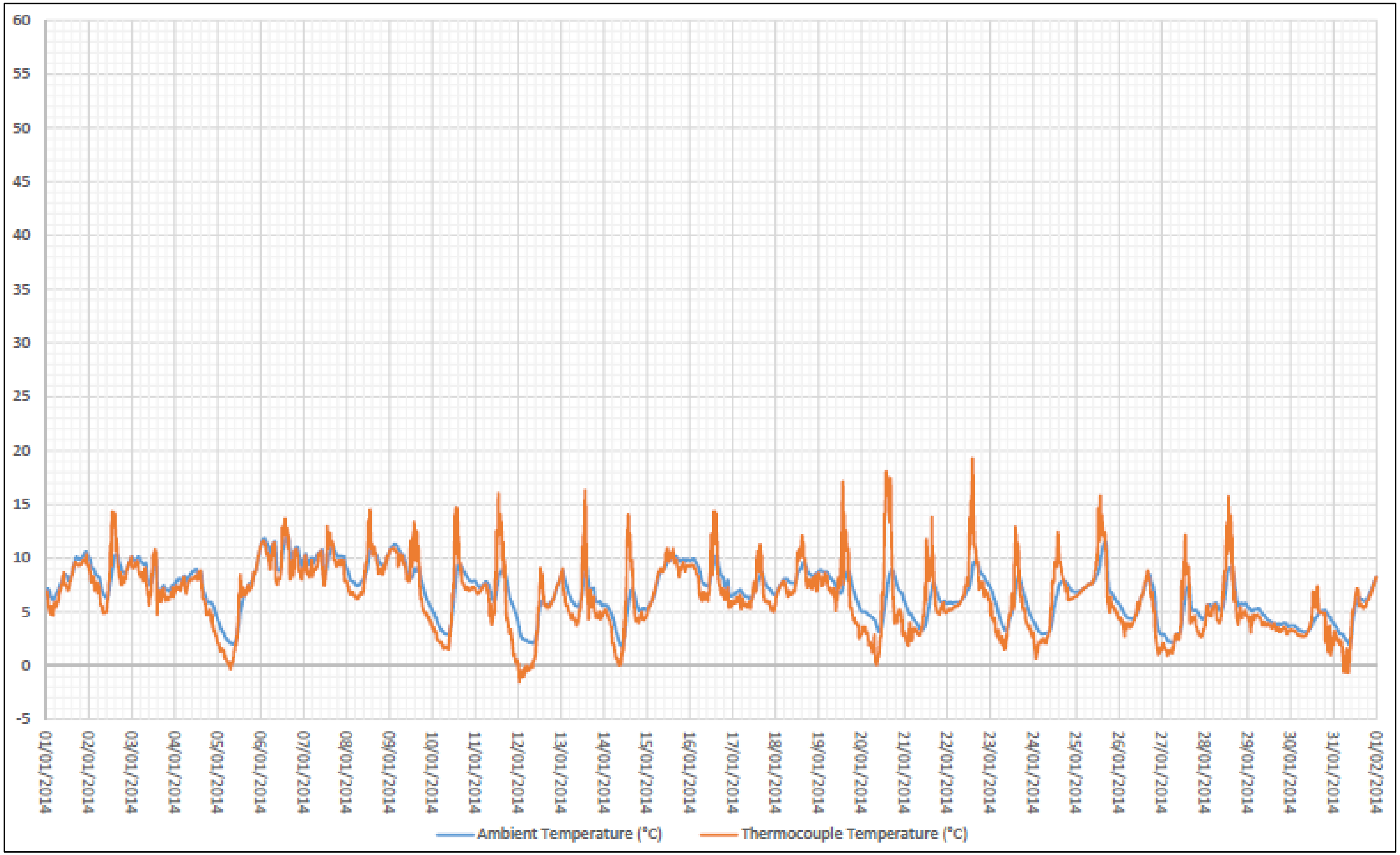

Figure 4.3: Record of ambient air temperature and surface temperature for exposed roof in South of England for January 2014 (Atkins)

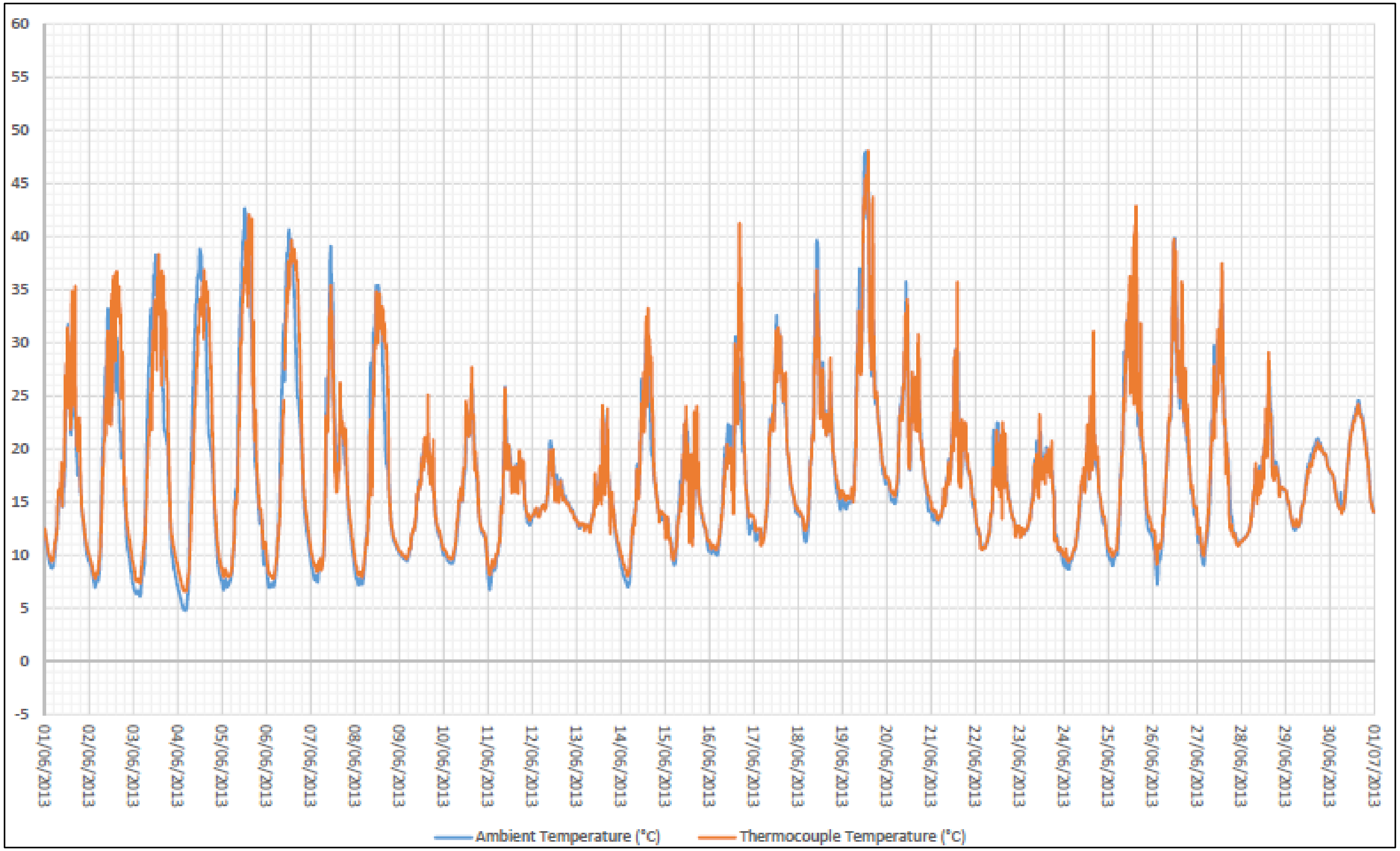

Figure 4.4: Record of ambient air temperature and surface temperature for sheltered roof in South of England for June 2014 (Atkins)

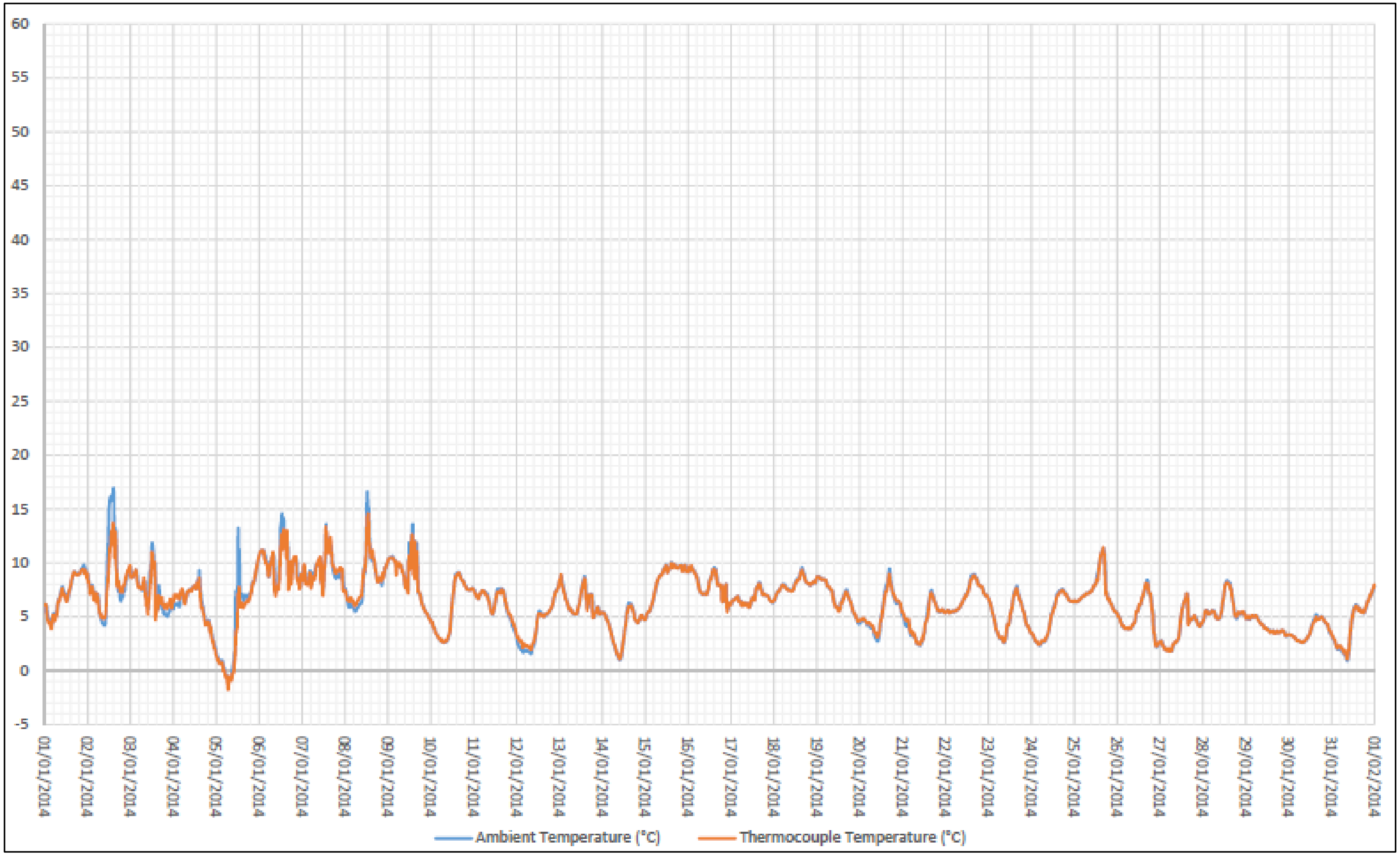

Figure 4.4: Record of ambient air temperature and surface temperature for sheltered roof in South of England for January 2014 (Atkins)

4.4 Thermal Movement and Stress Calculation

When looking to determine the amount of thermal movement that needs to be accommodated and its subsequent stress we have to take into the extremes of temperature range that the standing seam system and its associated flashings and penetration details may encounter over its service life.

The following example is based on extreme material surface temperatures for uncoated stucco embossed aluminium (alloy EN AW 3004) of -28°C to +78°C. The minimum surface temperature of -28°C has been determined from the recommendation in MCRMA Technical Paper 3 to utilise -20°C together with a -8°C allowance for drop in temperature due to night sky radiation (Harrison et al, 2009). The maximum surface temperature of +78°C has been taken from table 4.2.

It is assumed that the aluminium sheets will be installed at an ambient air temperature within the range of -5°C to +25°C.

The maximum rate of thermal expansion and contraction (i.e. '*x'* mm/m) utilising equation (4.1) will need to be calculated.

The maximum rate of expansion will need to be taken from the minimum temperature envisaged for installation whilst the maximum rate of contraction will be taken from the maximum installation temperature. To determine the rate, L is taken as 1 m.

Overall rate of thermal movement:

$e = \alpha L \Delta T$

$e = 23.3\text{x}10^{-6} \text{ x } 1 \text{ x } (78 – [-28])$

$e = 0.00247 \text{ m}$ $\qquad$ $e = 2.47 \text{ mm}$

Overall rate of thermal movement: 2.47 mm/m

Maximum rate of expansion:

$e_{exp} = \alpha L \Delta T$

$e_{exp} = 23.3\text{x}10^{-6} \text{ x } 1 \text{ x } (78 – [-5])$

$e_{exp} = 0.00193 \text{ m}$ $\qquad$ $e = 1.93 \text{ mm}$

Maximum rate of expansion: 1.93 mm/m

Maximum rate of contraction:

$e_{con} = \alpha L \Delta T$

$e_{con} = 23.3x10^{-6}$ x 1 x (-28 – [+25])

$e_{con} = - 0.00123\ m$ $e = - 1.23\ mm$

Overall rate of thermal movement: 1.23 mm/m

By calculation it can be seen that the ‘rule of thumb’ guidance of ± 1 mm per 1 m length of aluminium sheet that can be found in industry literature can be an underestimate when the specific finish and extremities of conditions are taken into account. The calculation example shows that the amount could be much closer to +2 mm/1 m length of aluminium sheet. This is in keeping with the advice in the APL literature covered in section 2.4.1.

The stress in an aluminium standing seam sheet or flashing if it is restrained from expanding or contracting can also be calculated utilising equation (4.2).

Maximum expansion stress in restrained aluminium standing seam sheet or flashing:

$f_{exp} = \alpha E_{alum} \Delta T$

$f_{exp} = 23.3 \times 10^{-6} \times 70{,}000 \times (78 – [-5])$

$f_{exp} = 135.373\ N/mm^2$

Maximum contraction stress in restrained aluminium standing seam sheet or flashing:

$f_{con} = \alpha E_{alum} \Delta T$

$f_{con} = 23.3 \times 10^{-6} \times 70{,}000 \times (-28 – [+25])$

$f_{con} = 86.443\ N/mm^2$

The maximum expansion and contraction forces (F) in a standing seam sheet or flashing would be determined from the following equation:

$$F=fA \tag{4.3}$$

Where:

A = cross section area (mm^2)

The approximate cross sectional area (A) of a typical 0.9 mm standing seam sheet with a coverwidth of 400 mm and a seam height of 65 mm as per figure 3.3 is 0.9 mm x 578 mm = 520.2 mm^2.

Maximum expansion force in restrained 0.9 mm aluminium standing seam sheet:

$F_{exp} = f_{exp}A$

$F_{exp} = 135.373 \times 520.2$

$F_{exp} = 70{,}421\ N$ $F_{exp} = 70.4\ kN$

Maximum contraction force in restrained 0.9 mm aluminium standing seam sheet:

$F_{con} = f_{con}A$

$F_{con} = 73.395 \times 520.2$

$F_{con} = 38{,}180\ N$ $F_{con} = 38.2\ kN$

By calculation it can be seen that the thermal expansion and contraction forces can be very large which can result in considerable damage being caused to roofing and cladding components (e.g. sheeting, halters, fasteners etc.), welded joints (e.g. end laps, soakers etc.) and supporting substructure if thermal movement of the standing seam sheet or flashing is restrained.

In response to the consultants' questionnaire respondent 7 provided information on a project that emphasises this point; "*Verge trims 32m long fixed both sides to butt straps and to roof sheets and rigid to block wall, verge was stronger than block wall and took some blocks out*".

5. In-plane Force

5.1 Introduction

It is discussed in section 3.3.1 that there is an in-plane force which acts on the head of the halter when the standing seam sheet moves under thermal movement. Figure 3.13 shows a visualisation of this. The in-plane force may not be of the level that is calculated in the previous chapter where the sheet is fully restrained but there will be some restraint present as the sheet moves over the halter. This needs to be taken into account in the detail design of the fasteners and substructure in order that this force is resisted.

The in-plane force is determined by testing and it can be shown that the magnitude of the force is very much dependent upon the alignment or misalignment of the halters. From the test results a set of tolerances for the support and installation of halters can be developed. The test results are also used to provide information for the value of in-plane force to be adopted in the detail design.

The purpose of these tolerances and design guidance is to offer advice to specifiers, detail designers and installers as to the correct utilisation and installation of the standing seam system and help reduce the occurrence of problems through thermal movement due to poor design and installation.

Unfortunately there is very little information on in-plane forces that is readily available and as the literature review shows only one manufacturer publishes this information in their technical literature. Other manufacturers who have undertaken this type of testing may also provide this information on request, as part of their training courses for designers or just use the results internally.

Examples of what little available information there is on in-plane force tests and how the results are used in detail design is discussed in this chapter together with a brief overview on the use of in-plane force testing in approvals and certification.

5.2 Results of in-Plane force testing

The first known in-plane force tests on a halter based aluminium standing seam system were carried out in 1987 at the research institute for steel, timber and masonry (Versuchsanstalt für Stahl, Holz und Steine) at Karlsruhe University in Germany for Kaiser Aluminium Europe Inc. The tests looked at the forces generated versus the amount of movement for a number of halter tolerance variations and sheet installation formats (straight and curved). Two standing seam sheets were zipped together to create a complete seam over a halter mounted on a rigid frame. The test was carried out by pushing the zipped standing seam sheets with a hydraulic plunger over the halter. The applied force was measured with an electric load cell and the movement of the sheet over the halter was measured with a displacement transducer. Figures, 5.1 (straight sheets, perfect alignment (0°)), 5.2 (curved sheets to 12.5 m radius, perfect alignment (0°)), 5.3 (straight sheets, misaligned (1°)) and 5.4 (straight sheets, misaligned (3.1°)) show load-displacement graphs for the tested variations.

The figures show that if the halters are installed with perfect alignment (0°) there is only a small in-plane force which is fairly constant. The magnitude of the force increases when the sheet is curved but it is still fairly low and remains constant. For tests where the halters are installed misaligned there is a dramatic increase in the magnitude of the force. The force also has an erratic behaviour. The more misaligned the higher forces are experienced at lower movement distances.

This erratic behaviour with force peaks may also explain the phenomena of the “clicking” noise sometimes heard on roofs of this type due to thermal movement. The standing seam sheet tries to expand and builds up an internal force until it reaches such magnitude to allow it to move over the head of the halters.

Over the years the standing seam system utilised in the aforementioned tests had undergone a number of modifications to the shape of the halter with it becoming symmetrical around its centre line allowing it to be installed in either direction rather than the original asymmetric shape which could only be installed in one direction. A plastic version of the halter was also introduced.

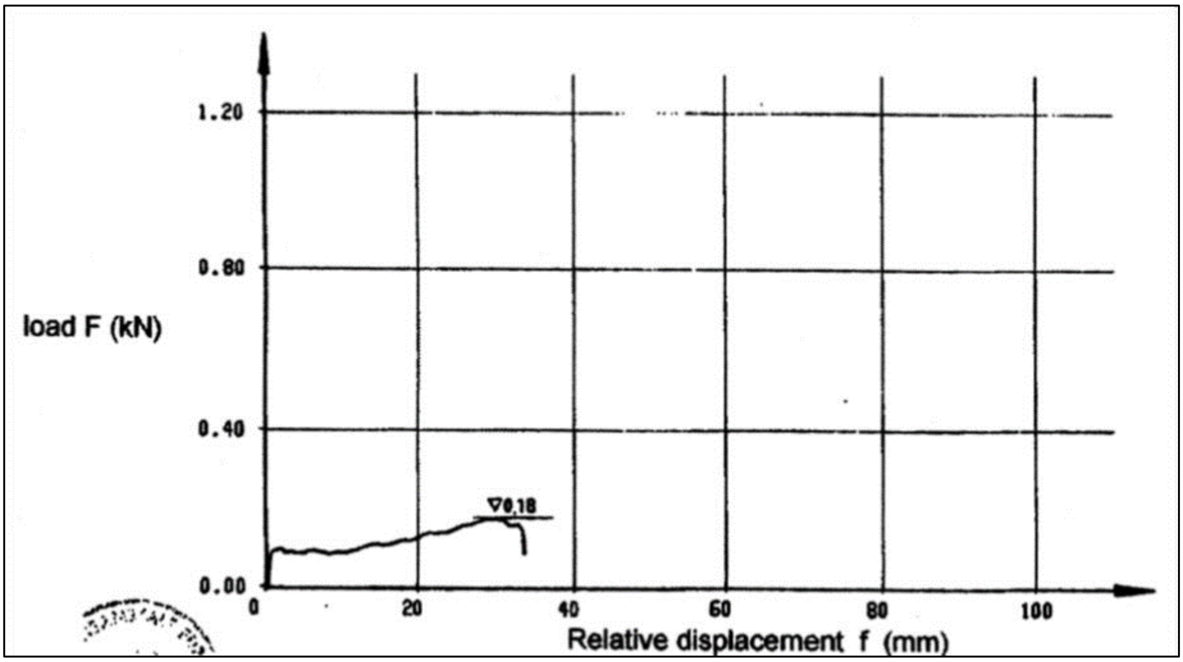

Figure 5.1: Results of in-plane force test for straight standing seam sheets with halters perfectly aligned (0°) (Versuchsanstalt für Stahl, Holz und Steine, 1987)

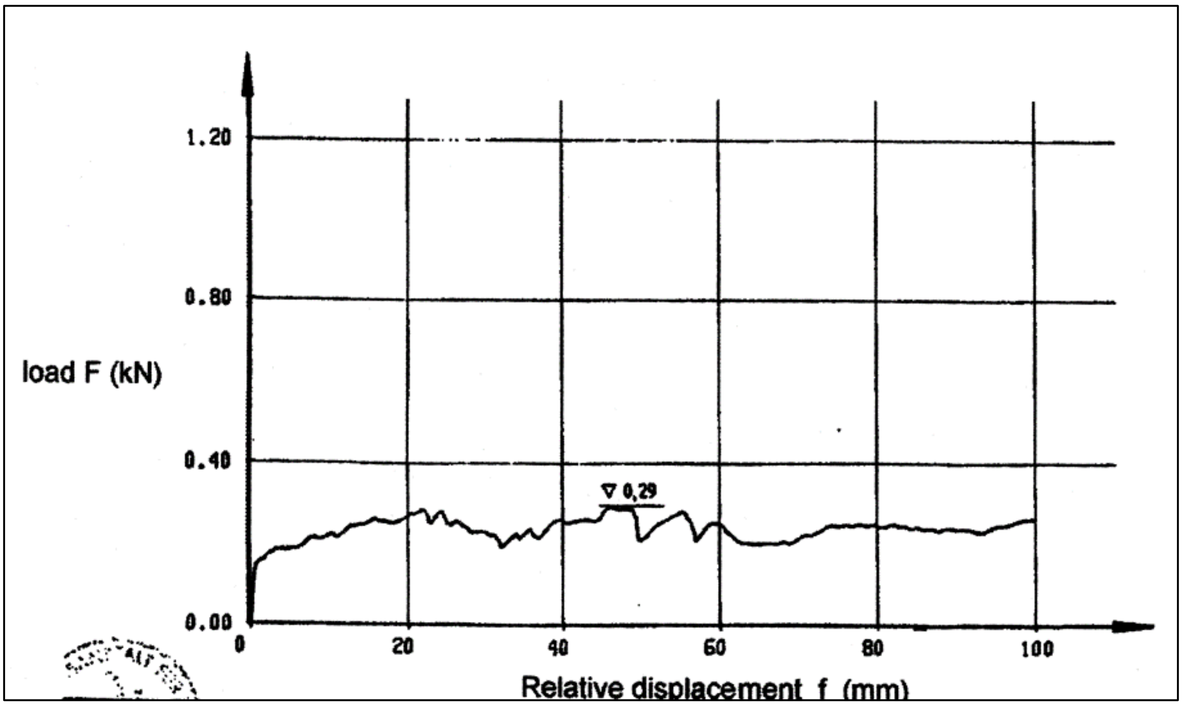

Figure 5.2: Results of in-plane force test for sheets curved to a 12.5 m radius with halters perfectly aligned (0°) (Versuchsanstalt für Stahl, Holz und Steine, 1987)

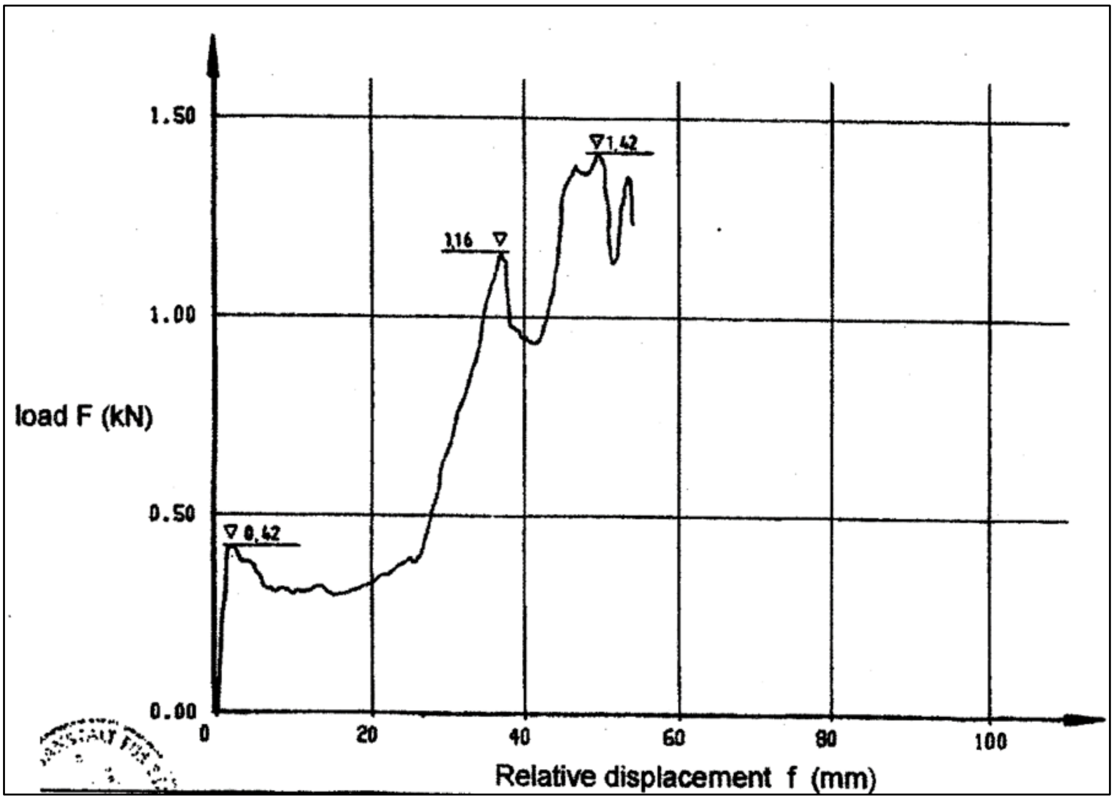

Figure 5.3: Results of in-plane force test for straight standing seam sheets with halters misaligned (1°) (Versuchsanstalt für Stahl, Holz und Steine, 1987)

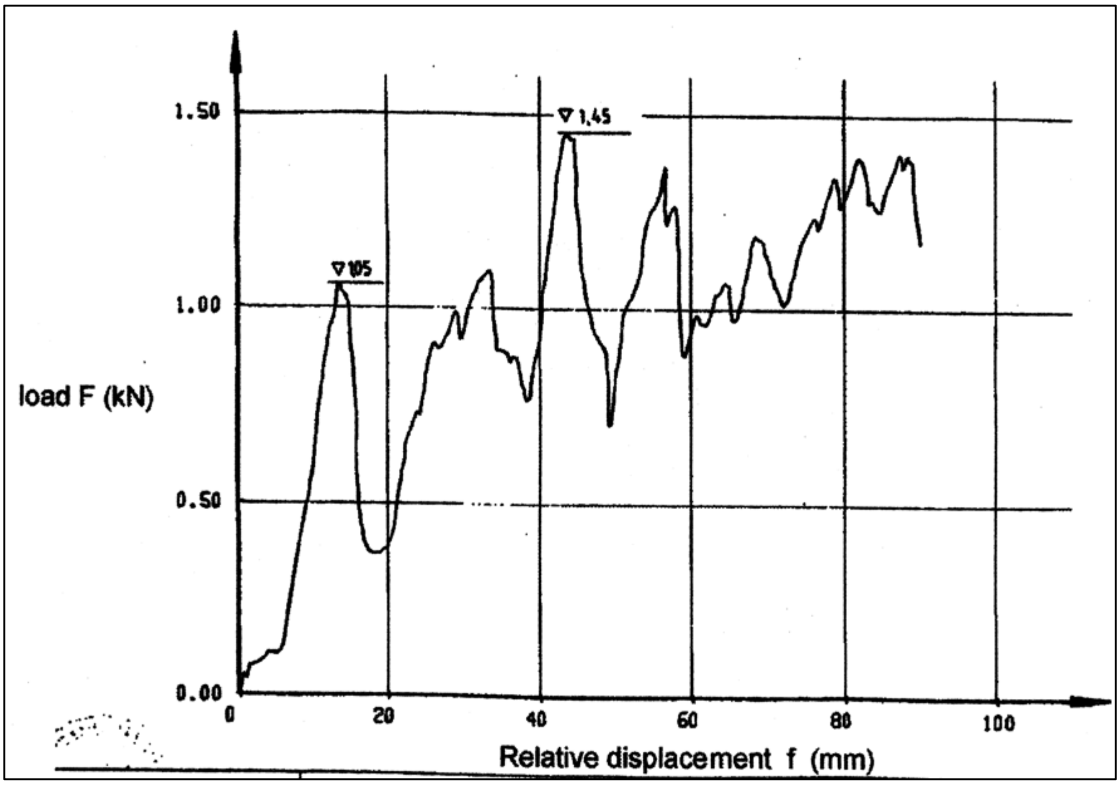

Figure 5.4 Results of in-plane force test for straight standing seam sheets with halters misaligned (1°) (Versuchsanstalt für Stahl, Holz und Steine, 1987)

Further in-plane force tests were carried out utilising both extruded aluminium halters and plastic halters with 0.9 and 1.2 mm thick aluminium standing seam sheets utilising different misalignment of halters. An alternative zipping regime (e.g. zipping 0.9 mm sheets with zipper roll-sets designed for thicker 1.2 mm sheets) was also tested to see if “loosening” the zipped seam would have any impact on reducing the in-plane force when using extruded aluminium halters. The test set-up was near identical to the previous test set-up with the exception that the zipped seam was installed on two halters in-line spaced 400 mm apart.

Figure 5.5 shows the results of in-plane force tests of the aluminium standing seam sheets with extruded aluminium halters. It is shown that the standing seam sheets with extruded aluminium halters at 1° misalignment have a similar in-plane force as observed in the earlier Karlsruhe tests, approximately 1.0 to 1.5 kN. When extruded aluminium halters misaligned at 3° the recorded in-plane force was significantly increased to approximately 4.5 kN with 0.9 mm sheets and 5.0 kN with1.2mm. What is interesting from these test results is that by “loosening” the zipped seam by zipping a 0.9 mm sheet with 1.2 mm rollers when the halters were 3° misaligned the recorded in-plane force was similar to those set out at a misalignment of 1° or less.

When the tests were carried out on standing seam sheets with plastic halters (figure 5.6) the peak in-plane force was recorded at 0.2 kN at 3° misalignment and approximately 0.02 kN at 1° misalignment or when set out correctly. These values are significantly lower than those recorded with extruded aluminium halters misaligned.

A number of points can be taken from observing this latter series of tests. Plastic halters can accommodate thermal movement much more easily than extruded aluminium halters with relatively little in-plane force which can also help reduce the potential of the “clicking” noise sometimes heard. Support and installation tolerances, are less critical with plastic halters as they are able to accommodate a greater level of contractor/installer error than extruded aluminium halters.

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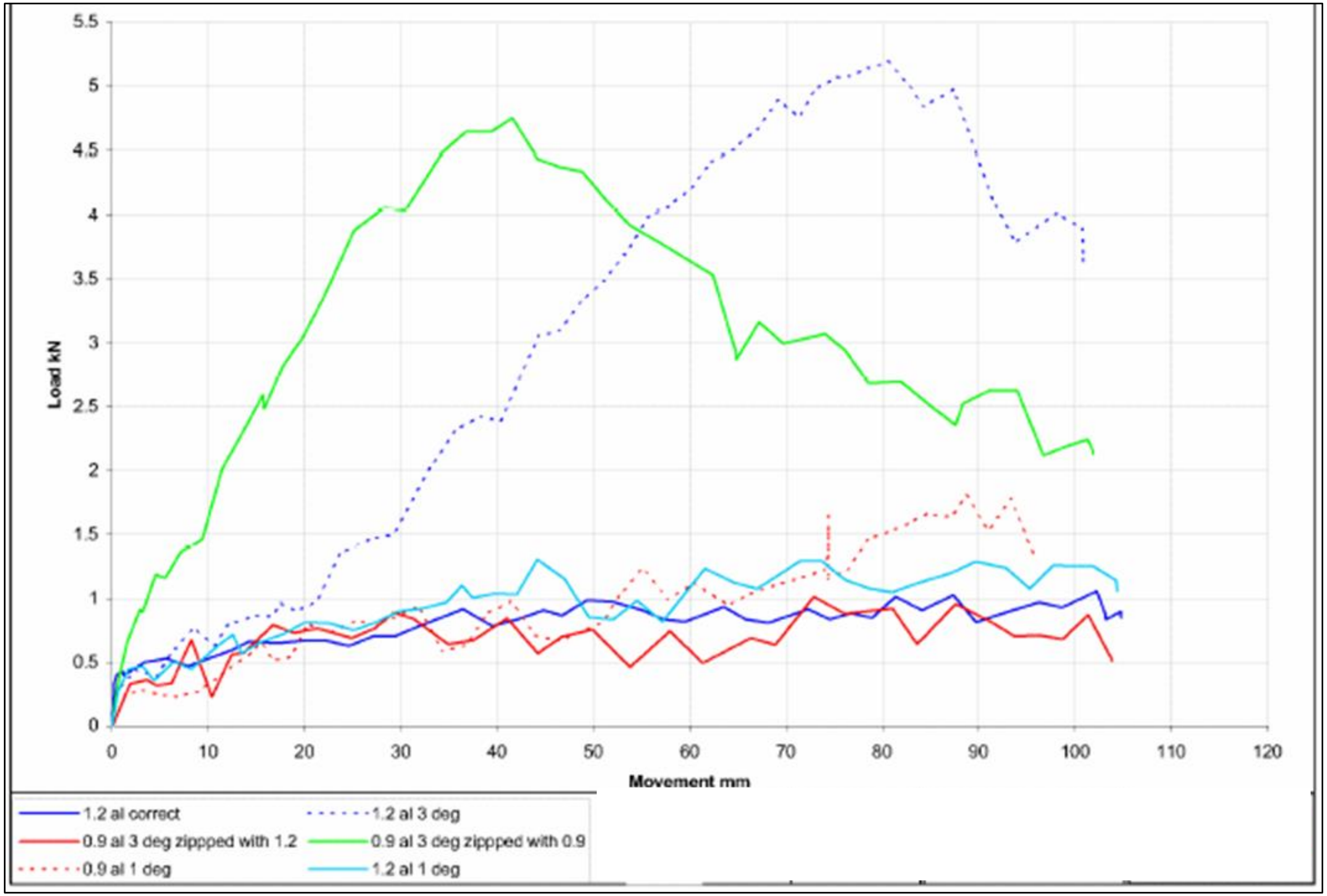


Figure 5.5: Results of in-plane force tests on aluminium standing seam sheets with extruded aluminium halters (Kalzip Ltd, 2011)

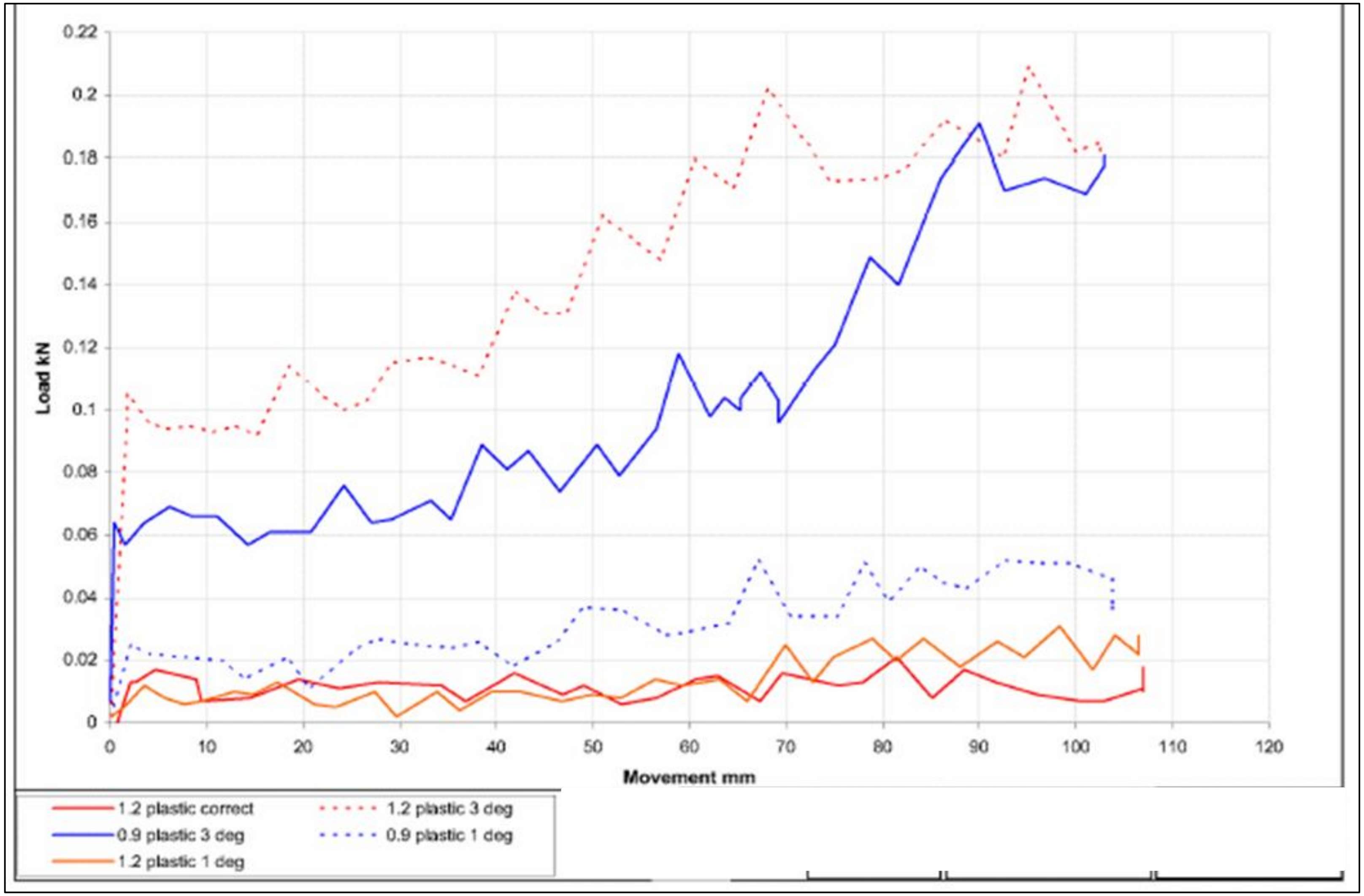


Figure 5.6 Results of in-plane force tests on aluminium standing seam sheets with plastic halters (Kalzip Ltd, 2011)

5.3 Designing for In-plane forces

The in-plane force (F_{ip}) acting on the head of the halter creates a “lever-arm” effect trying to overturn the halter. This overturning is resisted by the rigidity of the support and the resistance of the fasteners from the support. A moment (M) can be taken around the front edge of the halter to determine the tensile resistance (T_1) requirement of the fastener connection. The taller the halter the larger the moment will be and the subsequent fastener resistance requirement. The resistance of the fasteners is influenced by:

- Type, strength and thickness of support
- Tensile and pull-out strength of fasteners
- Number of fasteners

The same design process is adopted to determine tensile resistance (T_2) of the fasteners of the substructure support for the halters e.g. top-hat profile sub-purlins, bracket and bar spacer systems etc. It is of extreme importance that the halter and structure that they are fixed to are as rigid and stable as possible.

Figure 5.7 shows a visualisation of this with relative dimensions indicated, L_1, $L_2 \ldots L_n$.

The in-plane force to be used in determining the resistance requirement of the fastener connection would be dependent upon the specific standing seam system and this information should be sought from the system manufacturer.

Tables 5.1 and 5.2 show in-plane force information from two system manufacturers. The format of the information will normally reflect the system configurations tested.

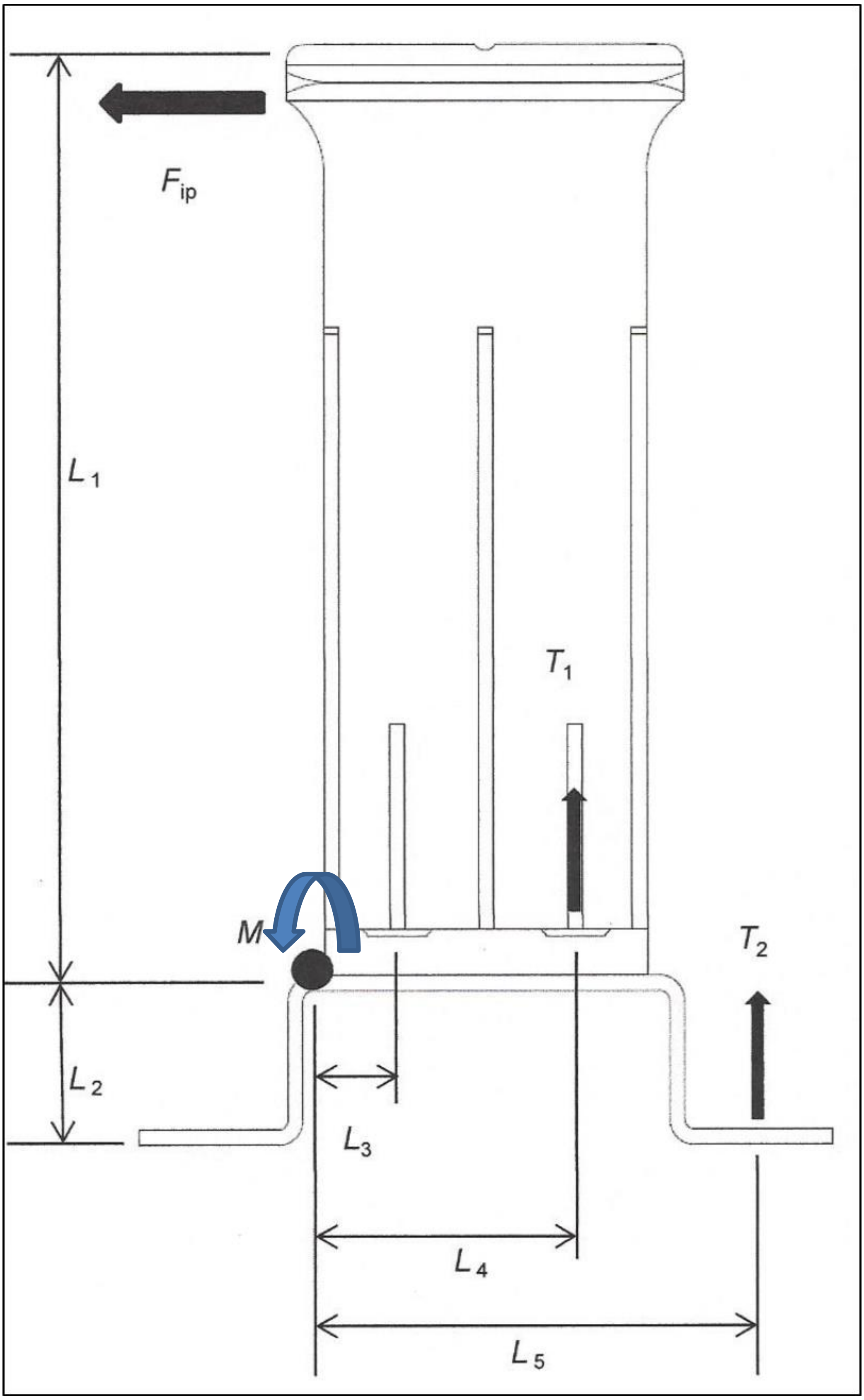


Figure 5.7: Visualisation of in-plane force acting on halter and tensile force required from halter and support fasteners (Kalzip Ltd, 2011)

Test Condition	**Mill finish (painted) F_{ip} (N/halter)**	**Stucco embossed finish F_{ip} (N/halter)**	**Design usage**
Halters in perfect alignment	22	29	Do not use
Halter 3 mm out of alignment	129	229	Typical installation values
Halters on 1° tilt (=1800 mm radius curved sheet)	663	643	For use on smooth curved roofs and single skin roofs
Halters on 3° tilt	1670	1731	For use on crimp curved roofs

Table 5.1: Example of in-plane force (F_{ip}) values (data from Bradclad Ltd, 2009)

<table>
<tr><th colspan="4">Extruded aluminium halters</th></tr>
<tr><th rowspan="2">Amount of thermal movement (mm)</th><th colspan="2">Straight sheets</th><th>Curved sheets (radius ≤ 60 m)</th></tr>
<tr><th colspan="2">F_{ip} (N/halter)</th><th>F_{ip} (N/halter)</th></tr>
<tr><td>< 25</td><td colspan="2">420</td><td>530</td></tr>
<tr><td>25 to < 40</td><td colspan="2">1160</td><td>1.270</td></tr>
<tr><td>≥ 40</td><td colspan="3">Use plastic halters</td></tr>
<tr><th colspan="4">Plastic halters</th></tr>
<tr><th colspan="2">Amount of thermal movement (mm)</th><th colspan="2">F_{ip} (N/halter)</th></tr>
<tr><td colspan="2">< 20</td><td colspan="2">200</td></tr>
<tr><td colspan="2">20 to < 45</td><td colspan="2">350</td></tr>
<tr><td colspan="2">45 to < 80</td><td colspan="2">400</td></tr>
<tr><td colspan="2">≥ 40</td><td colspan="2">450</td></tr>
<tr><td colspan="4">Note
1. Halters and support to system support and installation tolerances</td></tr>
</table>

Table 5.2: Example of in-plane force (F_{ip}) values (data from Kalzip Ltd, 2011)

5.4 In plane force testing in approvals and certification

There has been a lack of clarity as to the type of testing to simulate thermal movement in standing seam systems, the extent that it is carried out by system manufacturers and their use in product approvals and certifications.

Over the years there have been variations of tests that have evolved from the original tests undertaken at Karlsruhe University, including combinations of the following:

- Increased number of supports
- Increased number of halters
- Increased number of sheets and zipped seams
- Load application by pulling (tension force) as well as pushing (compression force)
- Increased number of cycles of loading

An article by CERAM (now Lucideon) published in Roofing, Cladding & Insulation (RCI) discusses the problem of testing for thermal expansion of aluminium standing seam roofs and that there is no standard test to simulate it and states that "no one yet has enough understanding of thermal behaviour in standing seam roofs under current climatic conditions" (CERAM, 2010).

The article also questioned whether mechanical means testing was replicating reality and undertook a trial test by cooling (to 5°C) and then heating with radiant heaters (to 125°C) the standing seam sheets of an insulated construction in a 12 m long test rig. The roof sheets were monitored and found to have expanded by 6 mm, much less than would be predicted by theoretical means. When the sheets were restrained from expanding and the force measured the results were found to be higher than what would have been measured by mechanical means for 6 mm of movement. Again the findings were deemed to be inconclusive as to whether this method would be better at simulating thermal movement than mechanical test methods and that further research would be necessary.

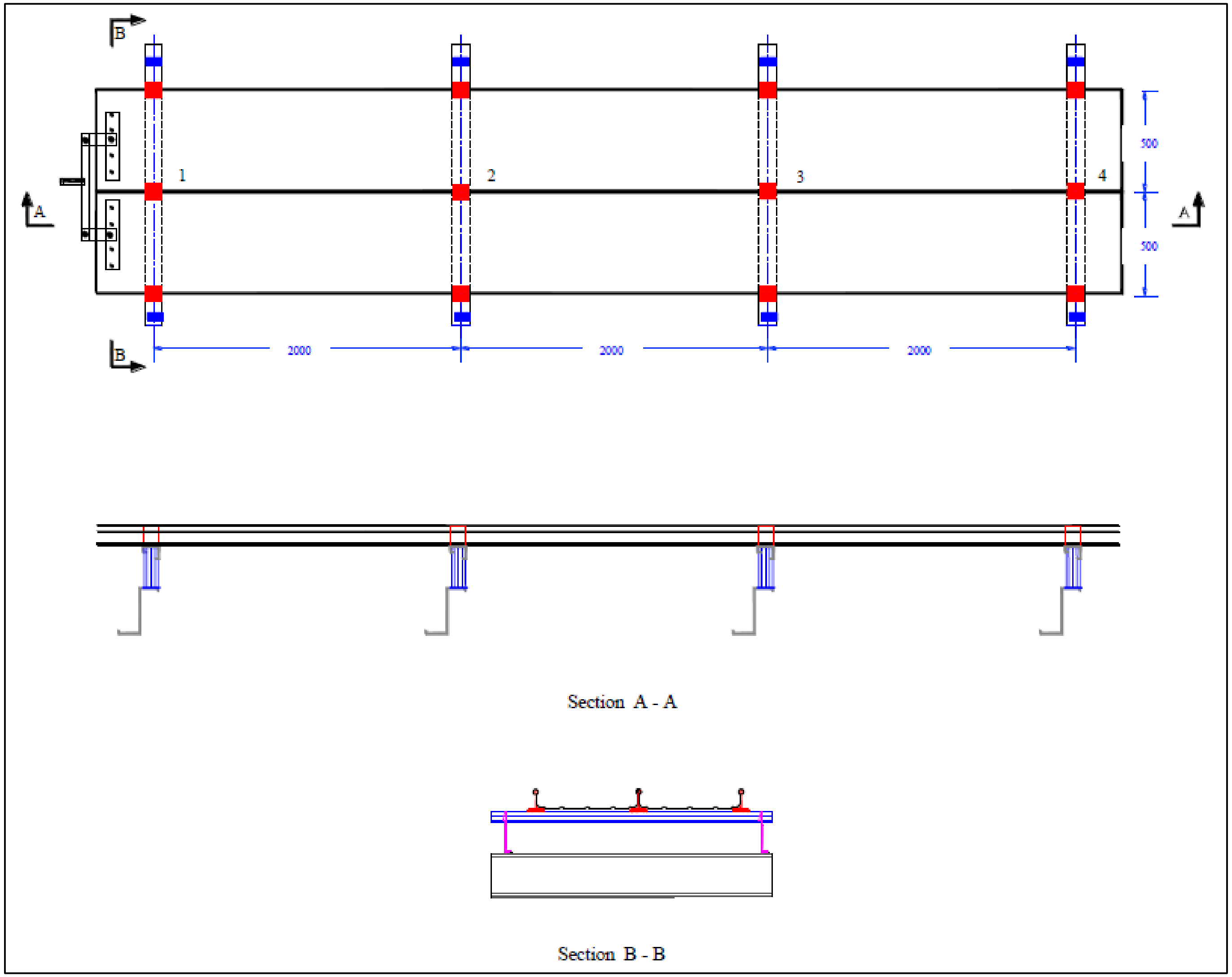
As seen in the literature review most of the system manufacturers' have their systems approved by BBA but that there is very little consistency with the level of information contained within the certificates regarding thermal movement and it would appear that testing for thermal movement is not compulsory.

As part of this research discussions have taken place with BBA who have now confirmed that testing for thermal movement accommodation in halter based standing seam systems is now compulsory and will apply to all new approval applicants as well as those seeking re-approval. BBA have also confirmed that they will also be looking to standardise information in the near future.

The BBA have an updated thermal expansion test specification as part of their assessment process which is "intended to determine the load applied to the support structure when the roof is installed to the maximum out of alignment tolerances specified by the manufacturer". The results of the testing being used in calculations "to verify the adequacy of the support structure to resist in plane forces due to thermal-movement" (BBA, 2014). Figure 5.8 shows a plan view and sectional elevations of the test set-up.

As a route to CE marking of standing seam systems an ETA can be developed to the guidelines in CUAP 03.02/6 – Roof and Wall Systems with Hidden Fastenings (DIBt, 2010). This CUAP includes a sliding test which is virtually the same as an earlier version of the BBA thermal expansion test specification, fatigue test specification version 3 (BBA, 2005) with the same purpose of the results to be used in design calculations. Unfortunately the sliding test is only optional in the CUAP allowing a 'no performance declared' (NPD) statement to be made for this product characteristic.

To date only one UK manufacturer of standing seam systems have claimed to CE mark their systems to this CUAP but have not undertaken the optional sliding test. Other manufacturers preferring to CE mark only the standing seam sheet to the harmonised European Standard BS EN 14782: 2006: Self-supporting metal sheet for roofing, external cladding and internal lining – Product specification and requirements (BSI, 2006). Halters can also be CE marked as a product independent of the standing seam sheets to the method in CUAP 04.01/12 – Spacer kits for built-up metal roof and wall cladding (BM Trada certification, 2011).



Fiigure 5.8: Plan view and sectional elevations of thermal movement test rig (BBA, 2014)

6. Current Knowledge of Thermal Movement Problems

6.1 Introduction

This part of the research attempts to gauge the opinion of professionals and examine the extent of failures within the UK market of standing seam systems which have resulted from a restriction of thermal movement and to establish if there are any specific trends either with the construction form (e.g. building type, construction type, geometry, sheet length etc.) or with associated human factors (e.g. design, installation, training etc.).

A questionnaire was issued to a group of professionals who are predominantly working within the metal roofing and cladding industry, most in a consultancy capacity, and who are or have been involved in investigating failures of standing seam systems on projects.

The questionnaire is broken down into the following sections:

- Section 1 – Personal Information
- Section 2 – Experiences
    - This is broken down to two parts and lists a series of “typical problems” and “typical factors affecting performance” associated with halter based standing seam systems.
    - The respondents are asked to indicate which “problem” or “factor” they have identified on projects and also add any further ones that they have experienced.
    - For each “problem” or “factor” identified the respondent is asked to evaluate it from a risk perspective on a scale of 1-5 for its severity (S), its frequency of occurrence (O) and the likelihood of early detection (D) of the identified “problem” or “factor”.
    - The results of this section will be reported on in chapter 7 – problems associated with thermal movement and chapter 8 – factors affecting performance.
- Section 3 – Opinions
    - A number of statements were given to which the respondent were asked for their opinion as their level of agreement or disagreement.
    - A Likert scale was adopted with the options: *strongly agree, agree, neither agree nor disagree, disagree* and *strongly disagree*.

  - The respondents were also invited to add their own comments where they felt it necessary to illustrate their response.
  - The results of this section will be reported on in this chapter.
- Section 4 – Project specific information
  - Respondents were invited to provide some basic information on projects were they had encountered problems due to the restriction of thermal movement.
  - The results of this section will be reported on in this chapter.
- Section 5 – Additional comments
  - Respondents were invited to add any additional comments, they will be used throughout this dissertation where appropriate.

The questionnaire was issued to eleven people all of whom responded. As is common with reporting on failures information can be commercially sensitive and may be the subject of litigation (Roberts, 2010). A number of the respondents provided information confidentially and requested that this information and their comments were not directly attributed to themselves. In reporting on the findings of this questionnaire no names have been disclosed and respondents have been referred to as respondent 1, respondent 2 etc. Respondents names have been attributed to additional comments were permission has been provided

Copies of the returned questionnaires have been included in the appendix but any confidential information has been redacted. Other information provided confidentially such as photographs, drawings and reports will be used only for illustrative purposes and will not be referenced.

6.2 Consultants’ questionnaire: Section 3 – Opinions

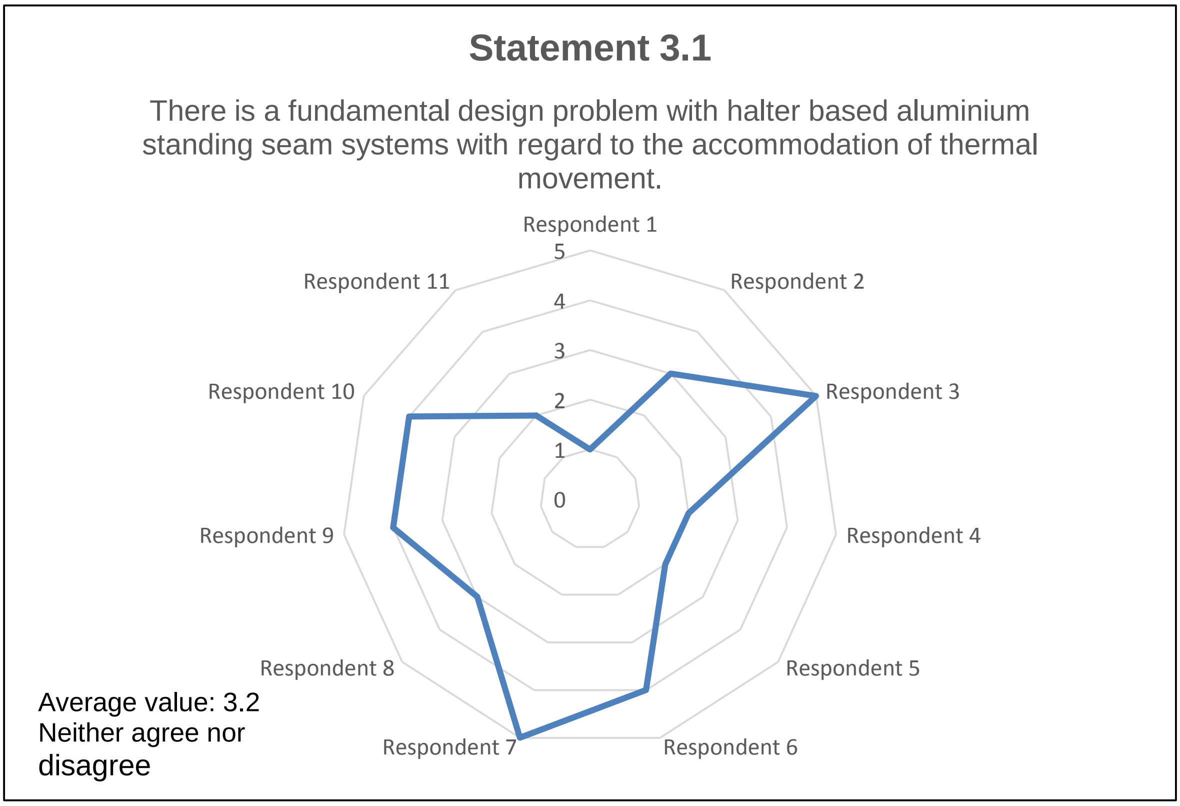
The results of the questionnaire have been amalgamated and are presented as radar graphs for each of the statements, figures 6.1 to 6.12. Table 6.1 shows the axis values adopted for the aforementioned Likert scale options.

Axis value	Likert scale option
1	Strongly disagree
2	Disagree
3	Neither agree nor disagree
4	Agree
5	Strongly agree

Table 6.1: Axis values for Likert scale options

For each statement the average value and opinion is given together with a brief summary of the result. Respondents’ comments are also given to illustrate the statement.

6.2.1 Statement 3.1



Average value: 3.2
Neither agree nor disagree

Figure 6.1: Radar graph of statement 3.1

The results show that opinions vary across the two extremes of strong agreement to strong disagreement with the average opinion being neither agreement nor disagreement.

It should be noted however that there is a similarity in the comments whether their opinion was one of agreement and disagreement with the tendency being that there is not a design problem with the system but that the problems are due to a lack of understanding of how the system works and how that knowledge can be applied at the detail design and construction phases of a project.

Respondent 1 who strongly disagreed with the statement commented *"…would certainly not agree that it's a fundamental design problem. It's a system with restrictions and limitations which need to be designed accordingly*". Respondent 3 who strongly agreed with the statement commented similarly: "*there is nothing fundamentally wrong with the systems but designers need to be aware of their limitations*". Respondent 11 who disagreed with the statement added "the *typical issues have developed largely from lack of quality and care during construction, setting out of halters, planning of interface detailing and rectification of issues rather than specific design or product problems*".

6.2.2 Statement 3.2

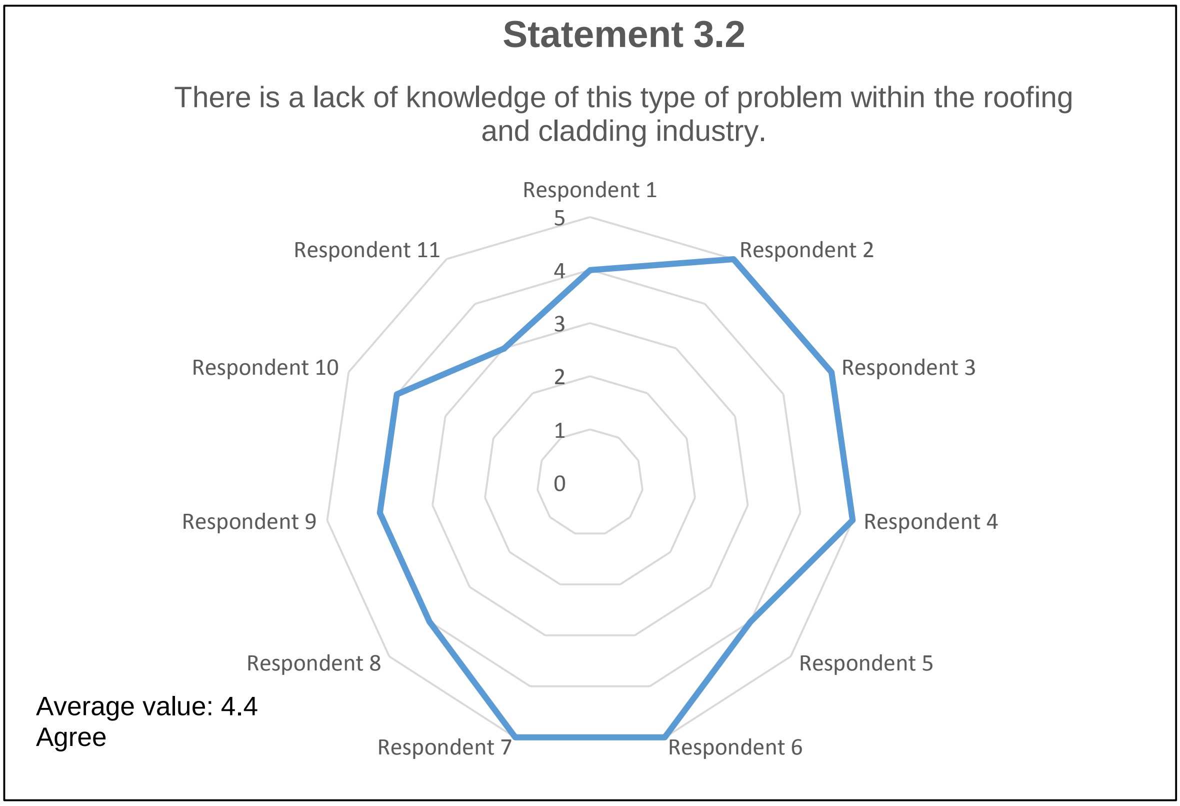


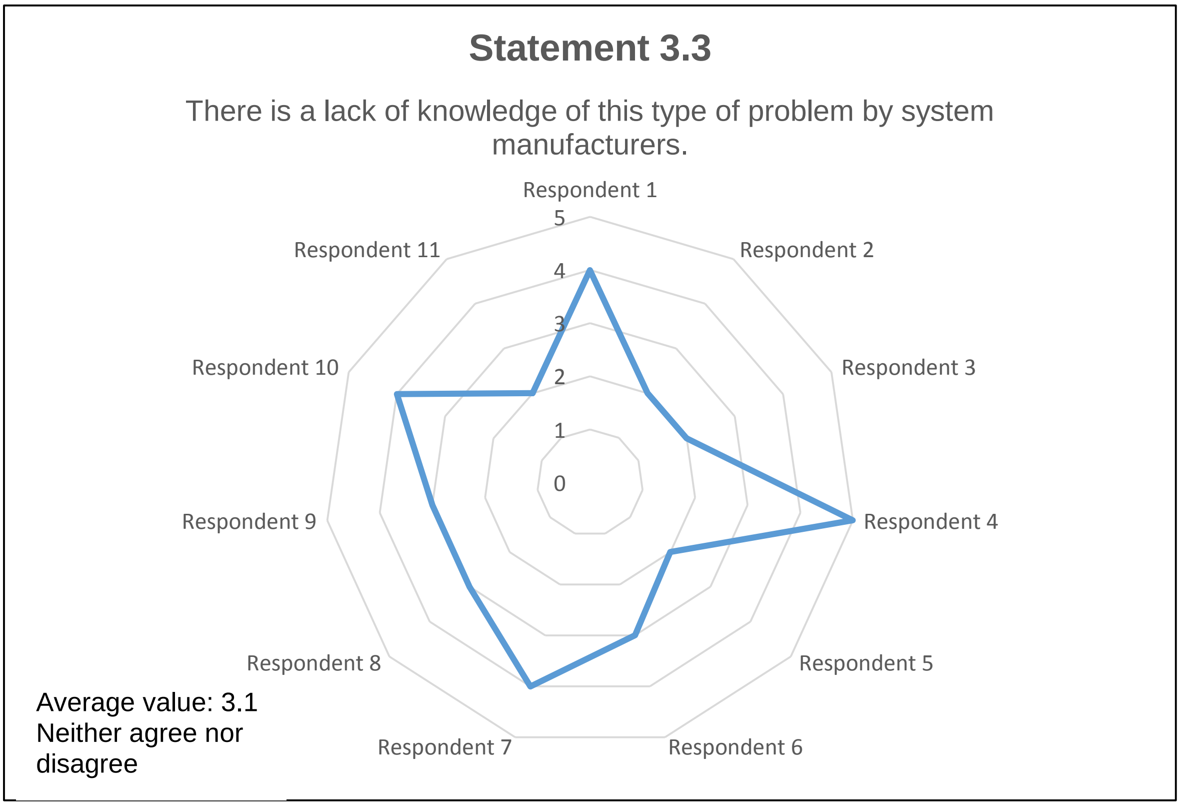
Figure 6.2: Radar graph of statement 3.2

The results show that there was an agreement with this statement with five respondents strongly agreeing and five agreeing and only one neither agreeing nor disagreeing.

Similar to comments to statement 3.1 knowledge in the areas of contractor detail design and site installation appears to be lacking. Respondent 6 commented that "*this lack of knowledge/training extends to both the roofing contractors design team and especially where the site operatives are concerned*" with respondent 7 commenting "*roofers doing detail design often have little understanding of the problem at the perimeter of the roof*". Respondent 8 commented that the lack of knowledge is more problematic "*…where aluminium sheets are used in long lengths*".

More worrying is the comment from respondent 1 which seems to imply that even where there is knowledge of the issues it is ignored: "*there is a large element of non-understanding and for the few that do understand it tends to be ignored*".

6.2.3 Statement 3.3



Average value: 3.1
Neither agree nor disagree

Figure 6.3: Radar graph of statement 3.3

The results show that there is neither agreement nor disagreement with this statement with a rough split between those who agree and those who disagree.

There is a trend amongst the comments from the respondents that potential problems due to thermal movement are generally known by the majority of the system manufacturers but there is a reluctance to let this knowledge be known. Respondent 2 commented *"I believe suppliers are aware, but most do not care – they just want to sell the product*" and respondent 3 similarly commented "*the system manufacturers know they have problems but either keep going certain it will 'work itself out' or they are not prepared to investigate for fear of collapse of the reputation of the product – after all – why point out the shortfalls of something you are selling*".

There are indications that some system manufacturers are acting on this knowledge and improving the way their system performs under thermal movement. Respondent 11 commented "*restrictions to thermal movement have been investigated and products such as thermohalters are now widely in use with the aim of improving the ability of standing seam systems to accommodate thermal movements*".

6.2.4 Statement 3.4

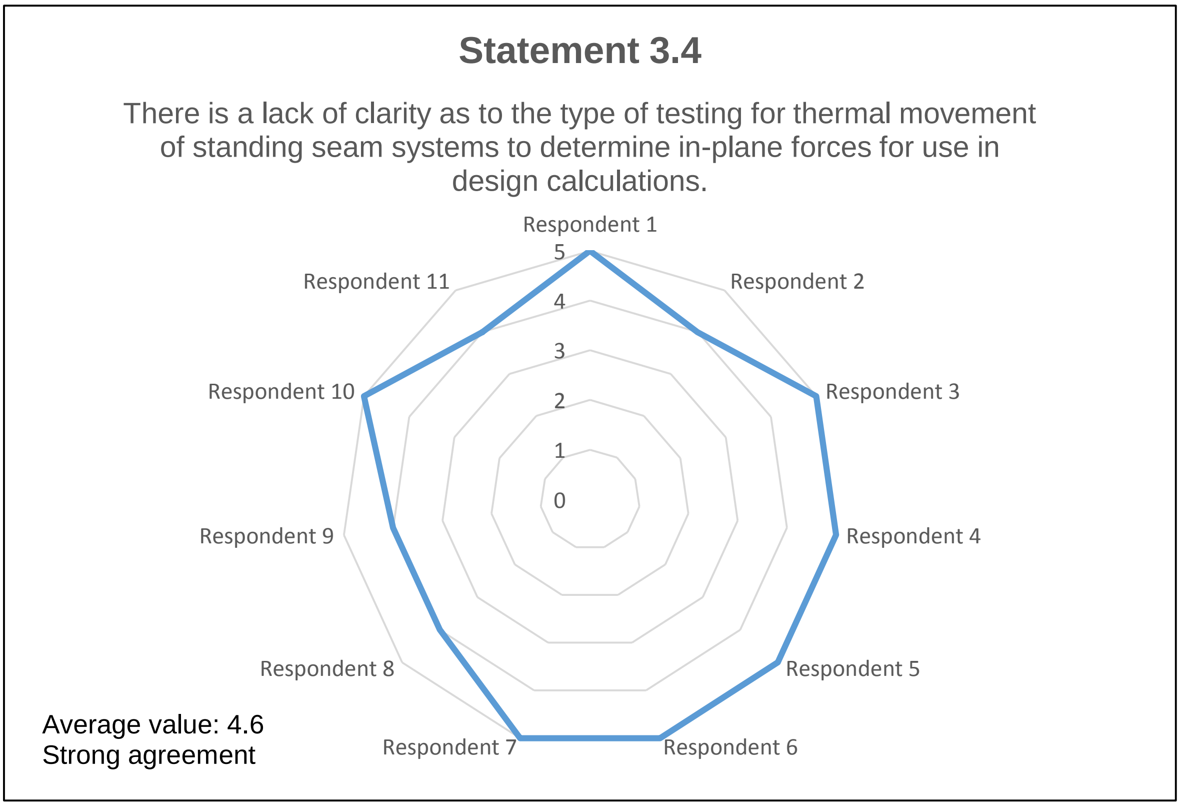


Figure 6.4: Radar graph of statement 3.4

The results show that overall there is a strong agreement with this statement with only ‘strongly agree’ or ‘agree’ opinions being recorded.

Although the respondents were aware that testing to determine in-plane forces has been carried out by system manufacturers with respondent 11 commenting “*information is available but has not been publicised*”, there was a general agreement amongst those who commented as to the lack of a recognised or standard test and the need to have one in place. Respondent 4 commented that “*there appears to be no agreed testing regime for thermal movement to determine ‘in-plane’ forces*”. This was further expanded upon by respondent 1 who commented “*there are no recognised tests. Laboratory devised tests (mechanical type) do not represent the problem accurately and larger scale tests are impractical. Monitoring of actual installations would be preferred*”. Respondent 3 commented in a similar vein in that “*there are no codified tests or indeed design standard authority on this form of construction. The CWCT has developed robust documents that are used as industry standards – it would be useful if roof construction systems had similar guidance.*”

6.2.5 Statement 3.5

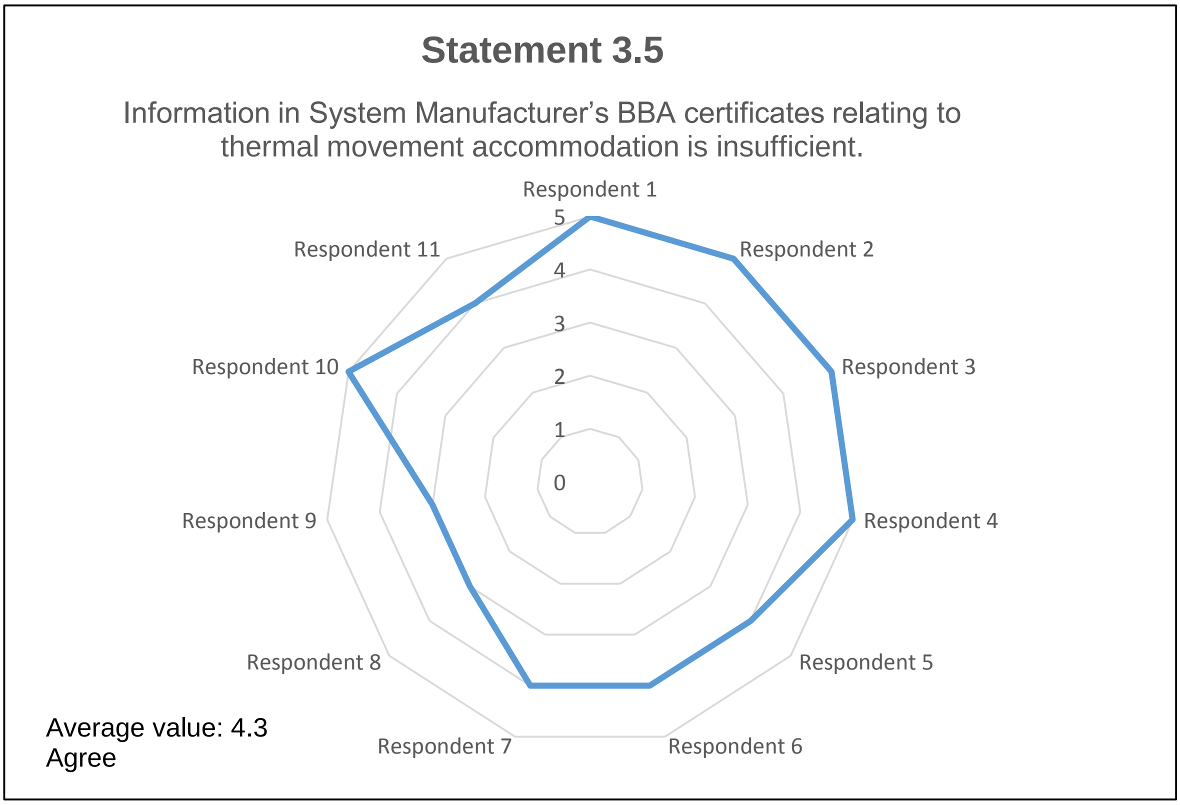


Figure 6.5: Radar graph of statement 3.5

The respondents agreed with the statement that the information contained in BBA certificates is insufficient with only two neither agreeing nor disagreeing. As was shown in table 2.4 there is a lack of consistency in the information contained within the certificates with a number of certificates having no information at all. Respondent 1 who strongly agreed with the statement commenting that the information is "*insufficient, non-existent or toned down*" and respondent 11 commenting that "*more publicised information is required*".

One possible cause of this was put down to information being copied by manufacturers who introduced systems based on other systems available in the market. Respondent 3 commenting *"…this is as such because the original lead design source never published this information and the products that have effectively copied this original data have failed to progress information*" and respondent 6 commenting in a similar manner that there is a "*tendency for new manufacturers to follow the BBA format of the 'original' aluminium standing seam manufacturers…*".

6.2.6 Statement 3.6

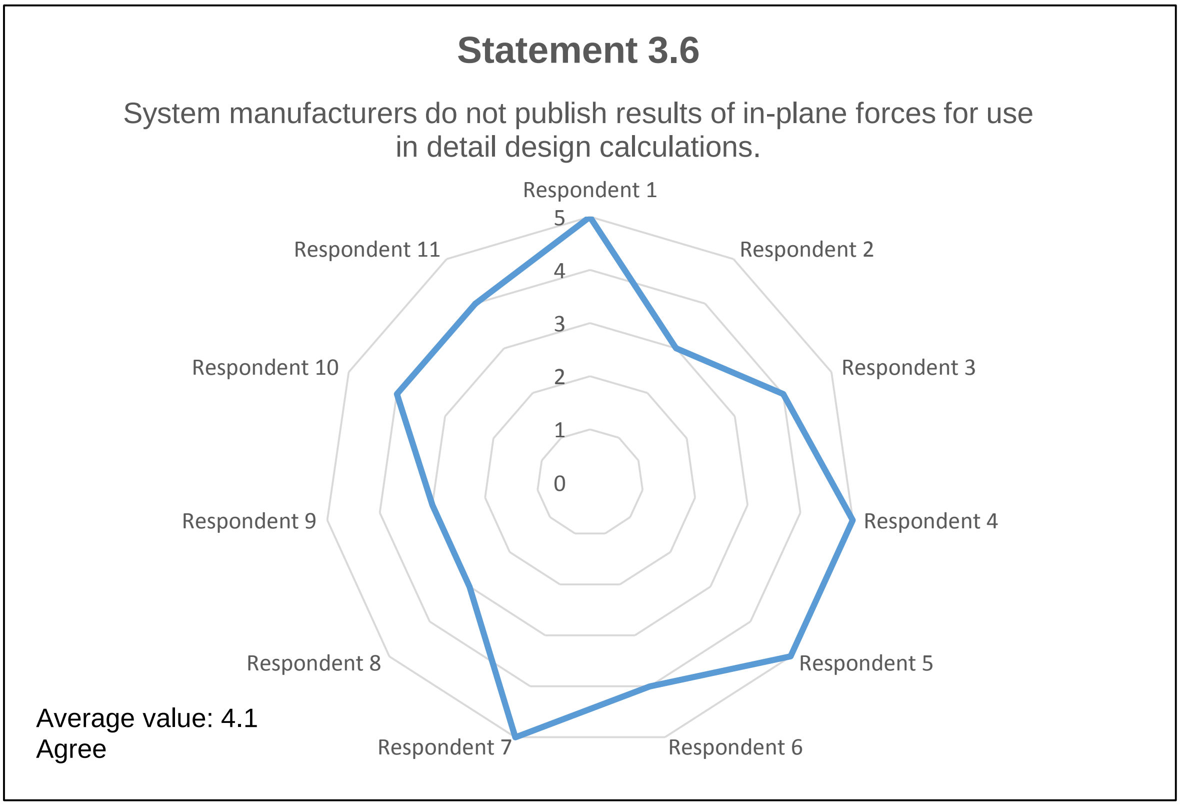


Figure 6.6: Radar graph of statement 3.6

The respondents agreed with the statement with only three neither agreeing nor disagreeing.

Respondent 1 commented that "*only one manufacturer known of that does*" and respondent 2 commented "*some do, but not most*" whilst respondent 11 has "*not seen any data to date*". This is a similar finding as discussed in the literature review of manufacturers' technical literature and shown in table 2.3 that only one system manufacturer has published in-plane force test results.

As shown in table 2.4 a number of the system manufacturers have undertaken thermal movement tests on their systems as part of their BBA approval process but most have not published the in-plane force results from these tests. The BBA certificates of other manufacturers do not indicate that thermal movement tests have been carried out to date. It may be the case that testing has not been carried out on some systems as respondent 7 comments that "*one major profiling competitor to … is either unable or refuses to disclose information, probably unable*".

6.2.7 Statement 3.7

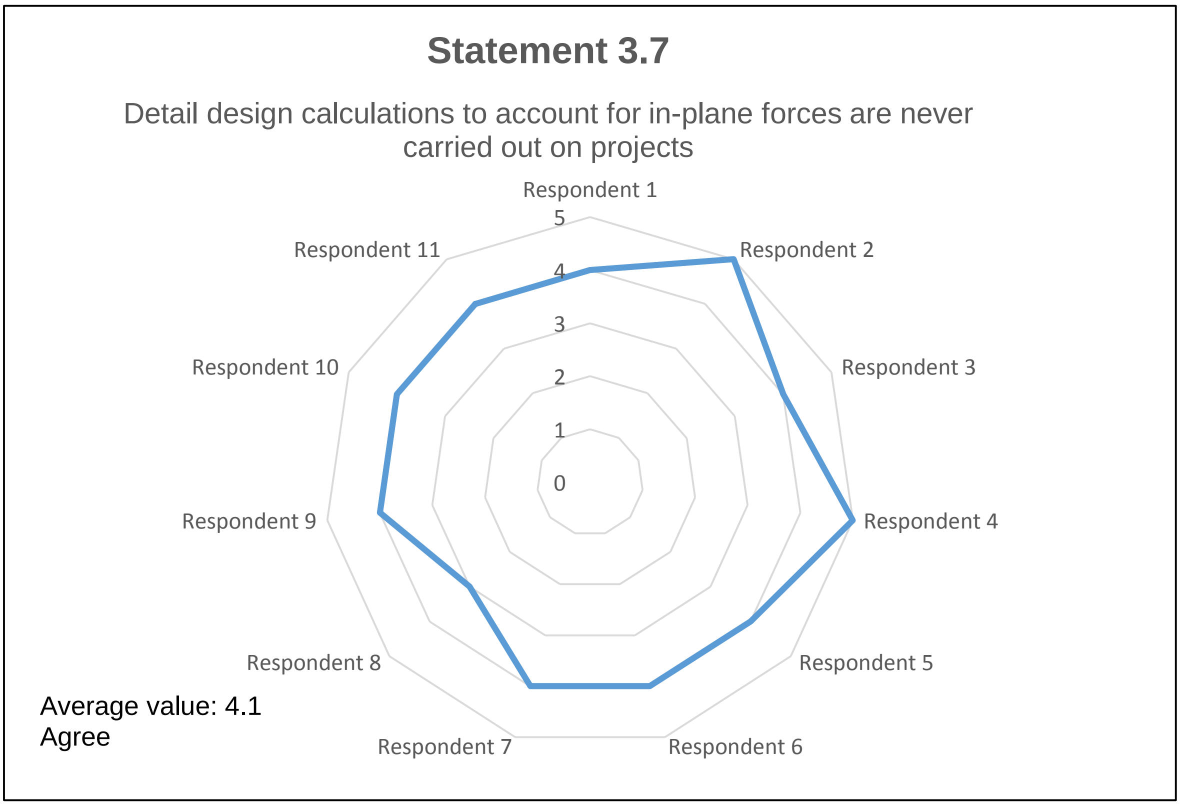


Figure 6.7: Radar graph of statement 3.7

The respondents agreed with the statement with only one neither agreeing nor disagreeing.

Some of the comments highlight that this may be down to a lack of awareness by all of the stakeholders in the specification and detail design phases of a project of the need to request or provide in-plane force design calculations. Respondent 1 commented "*very rarely seen as very rarely asked for as very rarely identified as a requirement*" and respondent 7 adding "*unless someone asks and even then results are not always made available*".

6.2.8 Statement 3.8

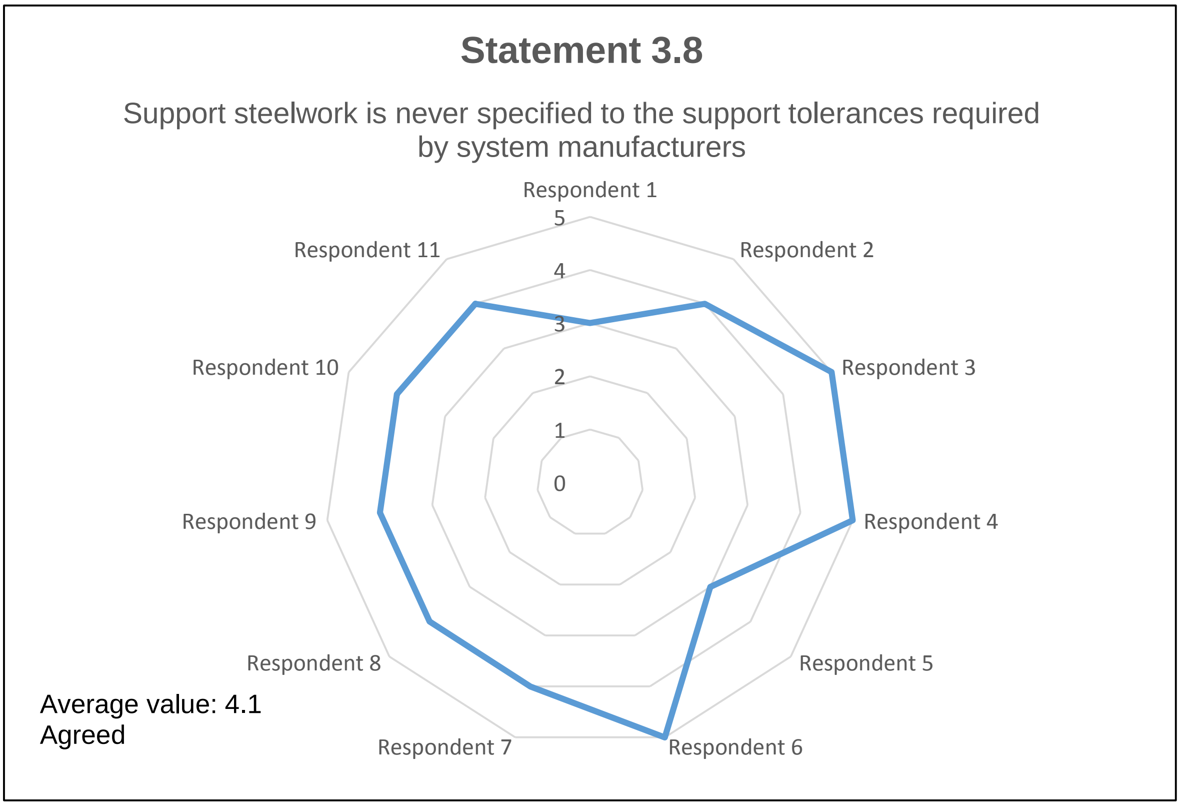


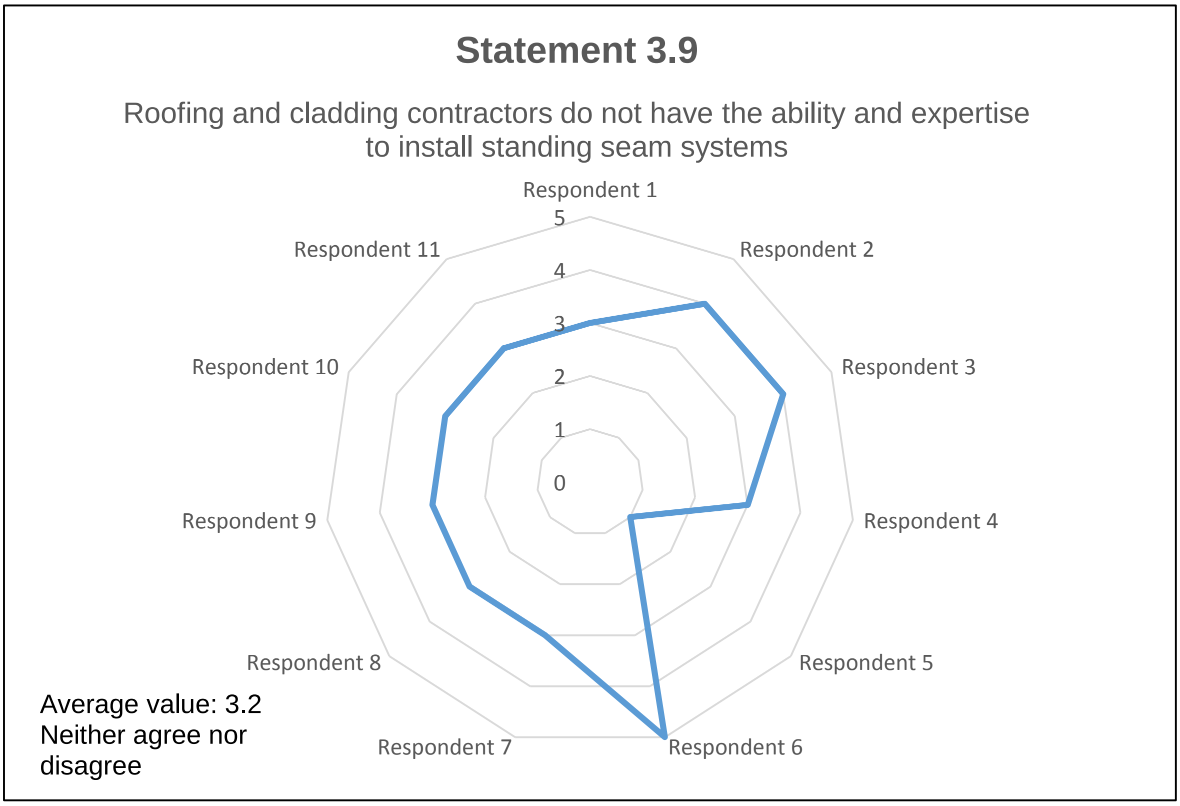
Figure 6.8: Radar graph of statement 3.8

There is agreement to this statement with only two respondents offering neither agreement nor disagreement.

Respondent 1 comments that "*some is some isn't. Tend to get the 'black book' consulted which is only relevant for primary steelwork*". The 'black book' referred to is the National Structural Steelwork Specification (NSSS) referred to in section 2.2.3.

Respondent 3 raises the point that the tolerance requirements for the system and their difference to steelwork tolerances is known and that the responsibility for adjustment should be carried out at the construction stage in his comment "*there is a significant disparity between tolerances for steelwork and tolerances for most types of cladding. As this is clearly understood by all parties I believe it is the responsibility of the contractor to make tolerance adjustment provision*". This opinion is echoed by respondent 11 who commented *"…if this is not specified early on in the project, the roofing installer should be aware and accommodate these differences in their halter connection detailing*".

6.2.9 Statement 3.9



Average value: 3.2
Neither agree nor
disagree

Figure 6.9: Radar graph of statement 3.9

There was neither agreement of disagreement with this statement with seven respondents offering this opinion. One respondent strongly agreeing and another strongly disagreeing.

The result can be summed up in the comments regarding the range of abilities of roofing and cladding contractors with respondent 4 commenting that ”*some have been very good*”, respondent 1 commenting “*very wide range of skills encountered*” and respondent 10 commenting “*significant variation in performance. The lack of in house technical support/design office can be handicap*”.

There were a number that were in agreement or strong agreement with the statement; respondent 2 stating that in his experience of the roofs he has inspected “*…77% of roofing failures appear to be standing seam …*”: respondent 3 adding “*but they should have*”; and respondent 6 commenting that this lack of ability and expertise could be due to the labour used “*roofing contractors tend to employ sub-contract labour rather than employ directly. Therefore the training, experience and qualifications of these operatives is questionable*”

The theme of training is also raised. Respondent 7 commented that installers “*need more specific product training*” and respondent 8 adding that “*this depends on each company’s willingness to train their installation teams and have qualified supervision on site at all times during installation*”. The question of training standards was raised by respondent 11: “*Experienced installers have the ability – but we are not aware of adequate training standards*”.

6.2.10 Statement 3.10

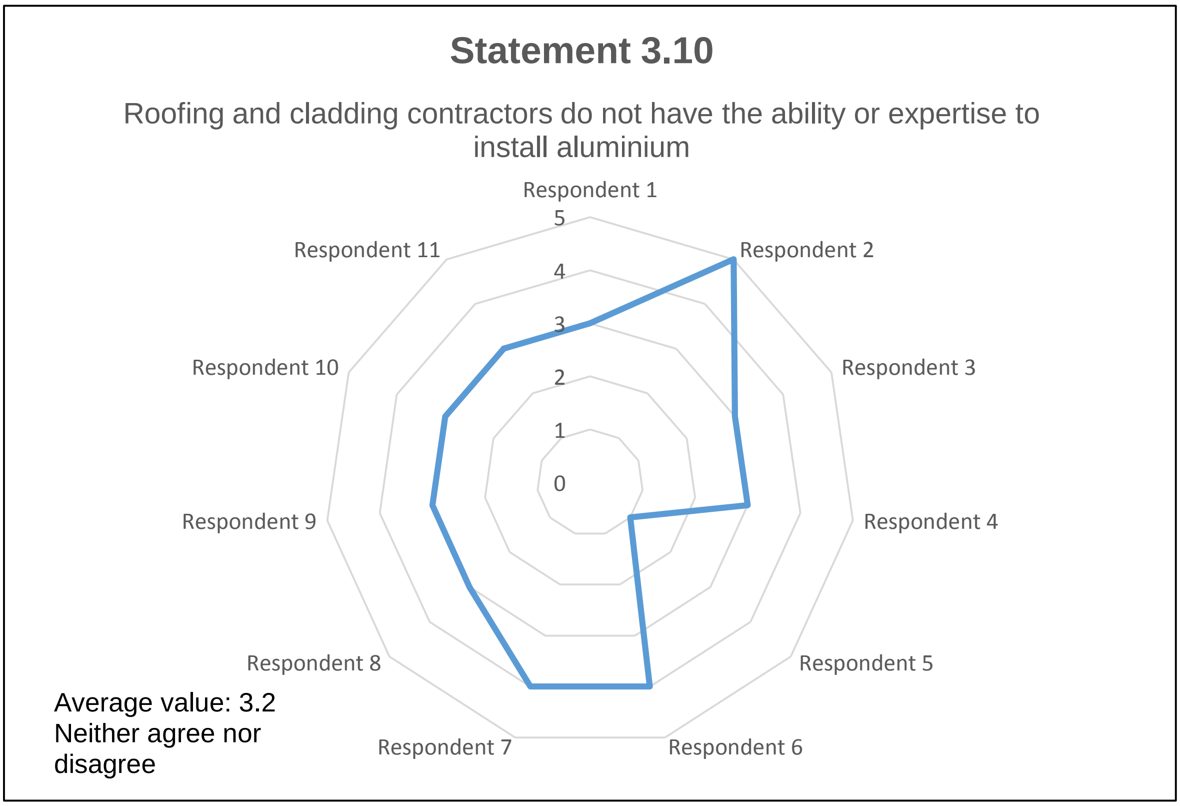


Figure 6.10: Radar graph of statement 3.10

The results were very similar to the previous statement in that overall there was neither agreement nor disagreement.

A number referred back to their comments to statement 3.9 with respondent 7 adding that “*more frequently get it wrong*”. Respondent 6 suggested “*that all roofing contractors are licenced to install their systems and operatives undergo recognised training (i.e. similar to CSCS testing)*” picking up on the need for adequate training standards raised by respondent 11 in statement 3.9.

6.2.11 Statement 3.11

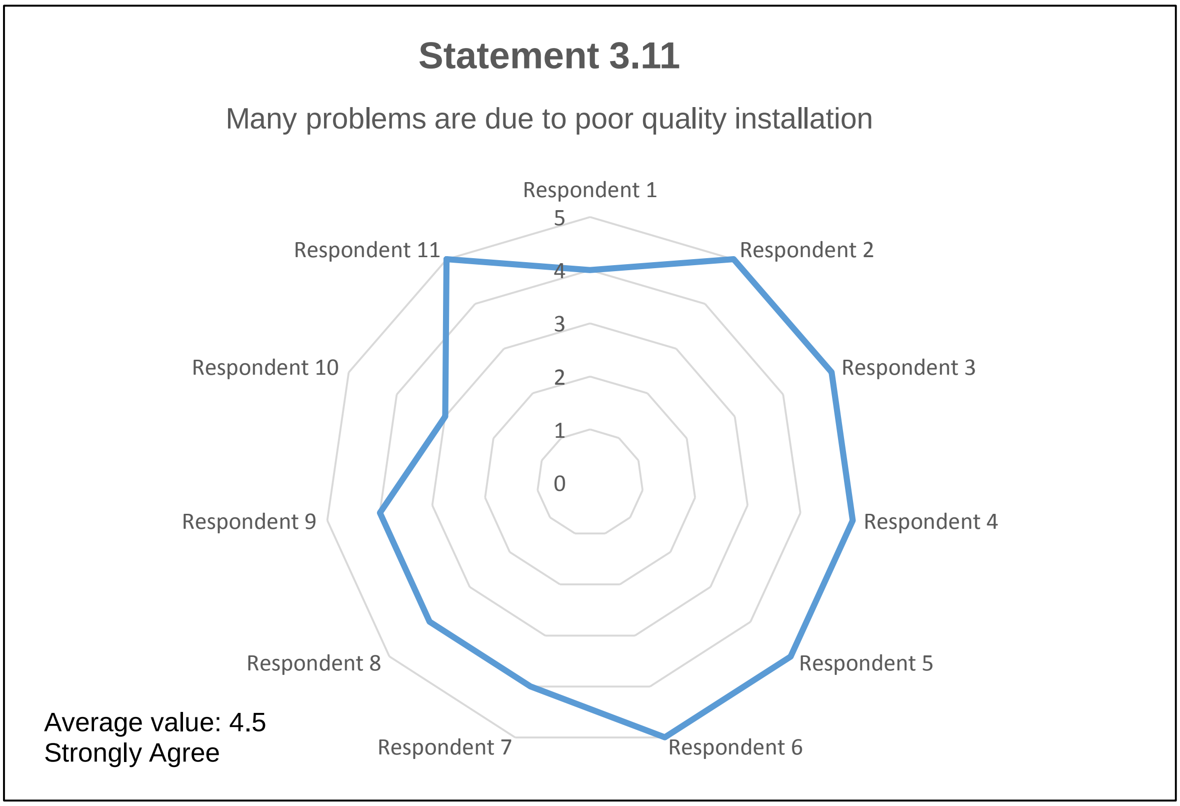


Figure 6.11: Radar graph of statement 3.11

There was strong agreement with this statement with 10 of the respondents either agreeing or strongly agreeing. This overview can be summed up by the comment from respondent 11: "*The majority of problems seen to date have been caused by poor quality installation*".

The theme of training raised in comments to other statements is touched on again; respondent 6 blaming "*lack of training and quality of workmanship of operative*" and respondent 8 commenting 8 that "*training in all aspects of installation of sheets and flashing is key to good installations as well as having qualified supervision overseeing installations*".

Comments from other respondents have put forward potential factors that could contribute to the occurrence of problems due to poor installation. Respondent 3 raises the issue that due to the way that the system is constructed deviation from the manufacturer's recommendations could be costly: "*The system is a site assembled product and so is critical that on site practices are in accordance with manufacturer's recommendations and practices. Any changes to speed the process or costs may prove costly at a later date*". Respondent 4 raised the issue that some practices have changed increasing the potential of problems occurring on site: “*In the last four years many contractors have stopped generating shop details. The fixing regime is left to operatives which is very bad practice*”.

6.2.12 Statement 3.12

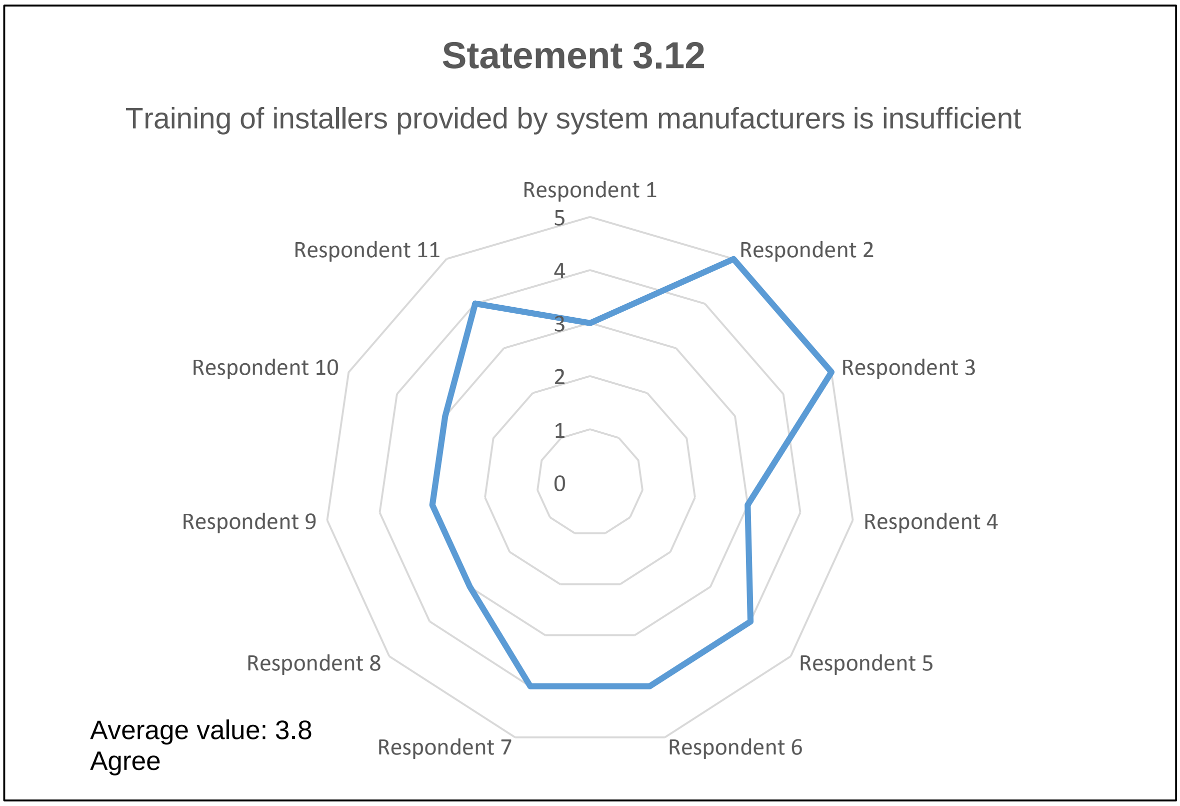


Figure 6.12: Radar graph of statement 3.12

Overall there was agreement with the statement although there were five respondents who expressed neither agreement nor disagreement.

There were a number who implied that the sufficiency of training depended upon the system manufacturer providing it. Respondent 1 commenting that training sufficiency was “*mixed*” whilst respondents 2 and 11 commented “*with exception of one supplier*” and “(one company) *appears to be the most proactive*” respectively. Respondent 8 extended his comments to include site inspections: “*some manufacturers have comprehensive training courses followed on by site inspections of actual site installations; other manufacturers pay lip service to this necessity*”.

Although training courses are provided by system manufacturers respondent 6 reiterated comments given in response to statements 3.9 and 3.10 of the need for more standardised or certified training: “*as mentioned previously a sort of certified competency needs to be introduced*”. Respondent 3 raised the point that project specific training for all relevant parties may be beneficial with his comment “*an initial start-up training meeting with all and any subsequent fixers is highly recommended*”.

The issue of the number of trained installers on a project was raised by respondent 7 together with an observation regard to the retention of the training received: “*results depend on how the roofer remembers the training and how many of the gang are trained*”.

6.3 Consultants’ questionnaire: Section 4 – Project specific information

Respondents were invited to provide information on projects that they had been involved with in investigating problems or failures relating to restricted thermal movement of halter based aluminium standing seam roof systems. The respondents provided twenty six examples of projects where problems had been encountered. Some reported on the same project and there were a further three projects involving aluminium composite standing seam systems which are outside the scope of this research dissertation. In total there were twenty individual projects on which information was provided.

Due to the confidential nature of some of the information provided, a number of the projects are subject to ongoing investigation and litigation or potential litigation, only very basic information will be included in this summary of this section of the consultants’ questionnaire.

Table 6.2 shows the type of project specific information requested together with typical examples of types of response.

<table>
<tr><th colspan="4">Section 4 – Project Specific Information</th></tr>
<tr><td colspan="2">Building type</td><td colspan="2"><i>e.g. Industrial, retail, stadium, arena, school, office etc.</i></td></tr>
<tr><td>Year built</td><td></td><td>Year problem found</td><td></td></tr>
<tr><td colspan="2">Support type</td><td colspan="2"><i>e.g. purlin, structural deck, timber deck etc.</i></td></tr>
<tr><td colspan="2">Construction</td><td colspan="2"><i>e.g. single skin, insulation double skin</i></td></tr>
<tr><td colspan="2">Halter type</td><td colspan="2"><i>e.g. material, full height, short etc.</i></td></tr>
<tr><td colspan="2">Substructure</td><td colspan="2"><i>e.g. bracket and rail, top-hat, zed etc.</i></td></tr>
<tr><td colspan="2">Sheet length</td><td colspan="2"></td></tr>
<tr><td colspan="2">Sheet geometry</td><td colspan="2"><i>e.g. straight, curved, tapered, tapered & curved, wave-form, complex</i></td></tr>
<tr><td colspan="2">Fixed point position</td><td colspan="2"><i>e.g. ridge, eaves, mid-slope</i></td></tr>
<tr><td colspan="2">Identified problem/s</td><td colspan="2"></td></tr>
<tr><td colspan="2">Potential cause/s</td><td colspan="2"></td></tr>
<tr><td colspan="2">Recommended remedial action</td><td colspan="2"></td></tr>
</table>

Table 6.2: Project specific information requested

Table 6.3 provides a summary of the responses for the building type and construction details. In some categories information was not provided or was not known. Little information on ‘year built’ or ‘year problem found’ was provided so this has been excluded from the summary.

Information Category	Response	Occurrence
Building Type	Industrial	4
	Education	4
	Arena	1
	Office	2
	Data processing	1
	Airport	1
	Military	1
	Domestic	1
	Stadium	1
	Distribution centre	1
	Leisure complex	1
	Retail	1
	Conference centre	1
Support Type	Purlin	11
	Structural decking	5
	Timber	1
	Information not provided	3
Construction	Single skin	2
	Insulated double skin	15
	Information not provided	3
Halter – material	Aluminium	20
Halter – height	Short	5
	Full height	10
	Mixed	2
	Information not provided	3
Substructure	Direct to purlin	3
	Direct to structural deck	1
	Direct to timber deck	1
	Bearer plate on rigid insulation	1
	Bar and bracket	4
	Top-hat profile	5
	Zed profile	2
	Information not provided	3

Information Category	Response	Occurrence
Sheet length	< 20 m	1
	≥ 20, < 40 m	3
	≥ 40, < 60 m	3
	≥ 60, < 80 m	3
	≥ 80, < 100 m	2
	> 100 m	1
	Information not provided	7
Sheet geometry	Straight	5
	Straight, naturally curved on site	8
	Wave-form	3
	Mixed	1
	Information not provided	3
Fixed point position	Ridge	4
	Apex of barrel vault	4
	Mid-slope	2
	Various positions	3
	None	1
	Not discovered	1
	Information not provided	5

Table 6.3: Summary of responses of building types and construction details

All the projects on which problems were identified had extruded aluminium alloy halters and that the majority of standing seam sheets were of a length greater than 20 m hence the amount of thermal movement was fairly substantial. Other than these observations it is very difficult to ascertain if there is any additional trends within the summary of information that could contribute to the instances of thermal movement problems. The mix of the system construction and support type are similar to what would be experienced in the UK market in that most buildings will be insulated rather than single skin and that the use of cold rolled steel purlins is the most common form of support.

What the summary does indicate is that problems and failures relating to restriction of thermal movement can occur in all types of buildings and with all types of construction but that there is a tendency for potential failure where long length standing seam sheets are used with extruded aluminium alloy halters.

Table 6.4 provides a summary of the responses for identified problems, potential causes and proposed or actual remedial action on the twenty individual projects on which information was provided by the respondents. On some of the projects multiple problem were identified as well as potential causes. Similar types of problem or cause have been grouped together.

Identified Problem	**Occurrence**
Standing seam sheets penetrated by halters	12
Standing seam sheets buckling	4
Standing seam sheets detaching from halters	3
Sheet erosion	1
Excessive noise on roof	1
Halter failure (overturning, shearing, bending etc.)	5
Fastener failure (shearing, pulling or backing out etc.)	7
Substructure rotation or failure	5
Detail failure (flashings, welds etc.)	5
Potential Causes	**Occurrence**
Misalignment of halters	8
Inadequate, multiple or no fixed point	4
Inadequate substructure	3
Inadequate fasteners	4
Insufficient allowance for thermal movement	7
Poor detailing	2
Standing seam sheets not zipped	1
Inadequate knowledge of system or material	2
Proposed or actual remedial action	**Occurrence**
Full replacement of roof sheets/system	9
Patch or partial replacement of roof sheets	3
Replace aluminium halters with plastic halters	1
Replace fasteners	1
Replace substructure	1
Reposition halters	3
Redesign details to accommodate thermal movement	4
Action pending or investigations ongoing	5

Table 6.4: Summary of identified problems, potential causes and proposed or actual remedial action

The above summary shows that the most reported problem encountered is where the halter penetrates the standing seam sheet. These will invariably be in tandem with failure of the halter itself, the fasteners that fix the halters and/or failure of the substructure that the halters are fixed to, these could also be in conjunction with buckling of the sheets as well. The severest problem reported is one were the standing seam sheet detaches from the secret fix halter which can cause serious damage and potential loss of life through flying debris under high wind suction loads.

Potential causes for these reported problems could emanate at both the installation and detail design phase of the roofing and cladding package. Misaligned halters, multiple fixed points and failure to zip sheets are predominately due to poor installation and on-site supervision. Inadequate fasteners and substructure and to a certain extent multiple fixed points could be attributed to poor detail design. The fasteners and substructure need to be designed to accommodate the potential in-plane forces that would act on the halter under thermal movement of the standing seam sheet. Some of this could be attributed to inadequate knowledge of the standing seam system or aluminium itself as reported in two instances.

Failure of details has also been reported as a common problem. This could be splitting of welds at penetrations and laps or problems with perimeter flashings such as failure of fasteners, buckling etc. These problems will usually be caused by poor detailing and insufficient allowance for thermal movement at the detail design phase.

The most worrying aspect is the amount of projects on which the roof sheets and/or system has had to be fully replaced. This has been reported to have occurred on nine of the fifteen projects on which remedial action has occurred. In other instances partial sheet replacement or patching up of roof sheets, realignment of halters, replacement of fasteners and substructure and redesign of details to accommodate thermal movement have been utilised. In one instance the replacement of aluminium halters with plastic halters was adopted as part of the remedial action on a project.

7. Problems Associated with Thermal Movement

7.1 Introduction

The respondents to the consultants’ questionnaire were presented with a number of potential thermal movement problems and asked to indicate which they have identified on projects (question 2.1 of section 2 – experiences) and also to add any further ones that they have experienced. Although a number of respondents indicated other problems some were deemed not to be related to thermal movement issues so have not been taken account. Others were deemed to be of a similar nature to the presented problems so were included in the summary under the one that was closest. All the responses can be seen in the appendix.

For each problem identified the respondent is asked to evaluate it from a risk perspective on a scale of 1-5 for its severity (S), its frequency of occurrence (O) and the likelihood of early detection (D). The rating values are shown in table 7.1.

Rating	Severity (S)	Occurrence (O)	Detection (D)
1	No noticeable effect	Never	Very high
2	Low (e.g. appearance)	Very occasionally	High
3	Medium (e.g. functional failure – weathertightness)	Occasionally	Medium
4	High (e.g. reduced service life)	Frequently	Low
5	Very high (e.g. potential safety failure)	Very frequently	Zero

Table 7.1: Rating values for risk analysis

This type of risk analysis is similar to a failure mode(s) and effects analysis (FMEA) which looks at predicting all potential failures and the modes of failure of a system or component, the effects that the failure will have on its function and what the potential measures that can be taken to prevent it from happening. In terms of failure, it may not necessarily be a catastrophic failure but could be a consequence of not meeting a customer’s functional requirements (Fox, 1993). For standing seam system the extremes of failure could be the life-threatening detachment of the sheet or flashings under high wind suction forces to the aesthetic concern of halters being visible through the seams. In both instances the functional requirements of the system, safety and aesthetics, have not been met but their importance is of a different magnitude.

It is not the intention of undertaking a full FMEA as part of this research as this would ideally need to involve many other stakeholders in the process. However it is felt that there is value in seeking the opinions of the industry professionals who have been involved in investigating these form of problems as to what they see as being the highest risk and the ease or difficulty of which it can be detected before the problem can lead to failure.

Table 7.2 gives a summary of the responses. For each problem the average of the severity (S), occurrence (O) and detection (D) rating is given. An ‘S x O x D’ summary rating is also given which could be used to indicate the ranking of the problem and the prioritisation that would be given in order to carry out actions to alleviate it. In FMEA terms this is known as the risk priority number (RPN). A high RPN will indicate problems which have a major impact whilst a low RPN may not be of too much concern. If there is a score of 4 to 5 in the severity (S) column then this will indicate that there is a potentially dangerous safety problem that would need to be addressed and priority to be resolved. In the summary the problems with the three highest RPN values are indicated by coloured cells. The highest RPN is coloured red, the second highest is coloured orange and the third highest is coloured yellow. **NB** the S, O and D average ratings in the summary are shown rounded up with the RPN being the product of the actual values rather than the rounded up values.

The problem that is of most concern is “halters shearing or disconnecting” (RPN = 43.1) followed by “fasteners shearing or disconnecting” (RPN = 37.3) and “material wear/abrasion of seam” (RPN = 37.1). The first two of these also had the highest severity rating of 4.6 and 4.5 respectively indicating that there is a concern that the problem could lead to a safety failure such that standing seam sheets could become detached in high winds and cause injury through flying debris. The other would be more of a concern to the service life of the system.

Other problems that were deemed to have a high severity (S) rating that could lead to a safety failure were “collapse /over-turning of structure”, “collapse/over-turning of sub-structure” and “failure of fasteners in flashings”. Again all of these could lead to detachment of standing seam sheets and flashings with the risk of flying debris.

The problem that was identified the most was halters being visible through seams followed by halters penetrating through the seam.

Section 2 Experiences	**Problem Identified**		**Risk**			
2.1 Typical problem			**Rating**			**RPN (S x O x D)**
	No.	**%**	**S**	**O**	**D**	
Halters visible through seams	11	100	3.4	3.7	3	36.6
Excessive “clicking” noise	7	64	2	3.5	1.8	12.8
Halters penetrating through seam	10	91	3.8	2.6	3.4	33.4
Halters shearing or disconnecting	5	45	4.6	2.4	3.9	**43.1**
Fasteners shearing or disconnecting	9	82	4.5	2.3	3.7	**37.3**
Material wear/abrasion of seam	9	82	3.6	2.9	3.6	**37.1**
Collapse/over-turning of structure	3	27	4	2.3	2.7	24.9
Collapse/over-turning of sub-structure	5	45	4	2	2.5	20
Collapse of substrate (e.g. insulation board)	4	36	3.3	2.3	4.7	36.3
Failure of fixed point	7	64	3.7	2.5	3.7	33.6
Multiple fixed points	8	73	2.6	2.1	2.4	13.4
Movement restricted by components clamped to seams	7	64	3.5	3	2.7	28
Splitting/cracking of welds	7	64	3.5	3.2	2.2	24
Buckling of standing seam sheet	7	64	2.3	2.3	2.5	13.6
Buckling of flashing	8	73	3.4	3.6	1.9	22.7
Failure of fasteners in flashings	8	73	4.3	3.7	2.1	34.1

Table 7.2: Summary of responses to consultant’ questionnaire, section 2 – experiences: 2.1 typical problems

Some of these problems are looked at in greater detail in section 7.2. It can also be shown that a number of the problems are inter-related and may increase in severity during the life of a building as it experiences different cycles of climatic conditions.

7.2 Examples of typical problems

7.2.1 Halters visible through seams

Terms used for where the halters are visible through the seam of the standing seam sheet are “halter shadowing” or “halter rash”. This problem can have a number of different forms and degrees of severity.

The lowest level of severity and one which is not much of an issue is where the position of the halters is only just discernible and can be identified from certain angles and in certain light conditions. No deformation of the seam upstand can be seen or felt. The appearance is usually uniform throughout the roof or wall and is very difficult to photograph but could be of an aesthetic concern especially if occurring in a wall application.

More severe is where the halter has deformed the upstand of the seam and its outline can be both seen and felt. This usually occurs in a non-uniform manner across the roof/wall. An example of this are shown in figures 1.7. The worst severity is where the head of halter has not been fully engaged in the seam and can deform both the seam upstand and the lower part of the seam roll (figure 7.1).

Figure 7.1 Halter deforming seam and lower part of seam roll

In the most severe instances the aluminium sheet can be split when zipping occurs (figure 7.2). The occurrence of these is usually isolated instances.

Figure 7.2: Halter splitting standing seam sheet after zipping

There can be a number of causes for halter shadowing:

- Halters set out at negative tolerances or misaligned
- Structure or sub-structure being out of tolerance

- Standing seam profile manufactured out of tolerance
    - Both shape and seam roll dimensions
- Zipping machine and roll sets used incorrectly or not designed for a particular gauge of material.

7.2.2 Halters overturning and penetrating seams

Halters can penetrate the seam if they overturn (figure 1.8). One of the most important aspects of halter based systems is that the halter must be connected as rigidly as possible. In-plane forces due to thermal movement will push against the halter and will cause it to overturn if it does not have a solid connection. As we have seen earlier the magnitude of the in-plane force within the system is very much dependent upon the alignment of the halters and the support.

Preventing the halter from overturning relies on the fasteners and the element that they are fixed to (structure, substructure) and/or fixed through (substrate) being able to resist the in-plane forces that will occur.

Figure 7.3 shows an example of where the standing seam sheet has been penetrated by the halter over-turning. This was caused by incorrect installation of fasteners causing the threads of the fasteners to strip when being installed. The fastener acted like a dowel connection allowing the halter to rotate when subjected to the in-plane forces with the system.

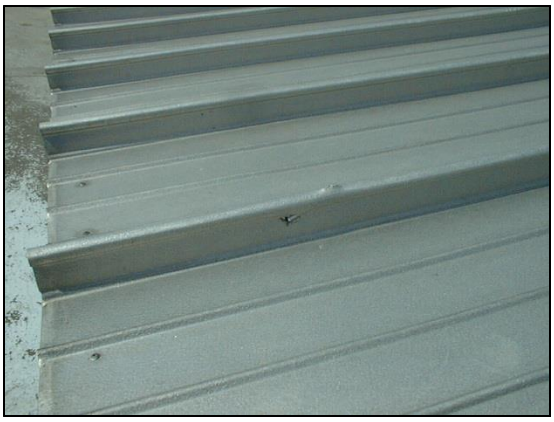


Figure 7.3: Over-turning of halter due to failure of fastener

Figure 7.4 Over-turning of halter due to overturning of sub-structure

Figure 7.4 shows an example where a bracket and bar sub-structure has over-turned leading to the over-turning of the halter. There is a need to check the stability of bracket and bar spacer systems as the externally applied loads are transmitted through this member into the purlins (Heywood, 2006 and Kachichian and Dunai, 2011).

Figure 7.5: Over-*turning of halter due to collapse of substrate*

Figure 7.5 shows an example of a substrate collapsing. The halter was installed on a PIR board in conjunction with a bearer plate. The fasteners for the halter were fixed through the bearer plate and PIR board into a steel decking profile. As the whole support and connection mechanism wasn't able to resist the in-plane forces acting on the halter the PIR board collapsed causing the halter to rotate and penetrate the seams, see figure 7.6.

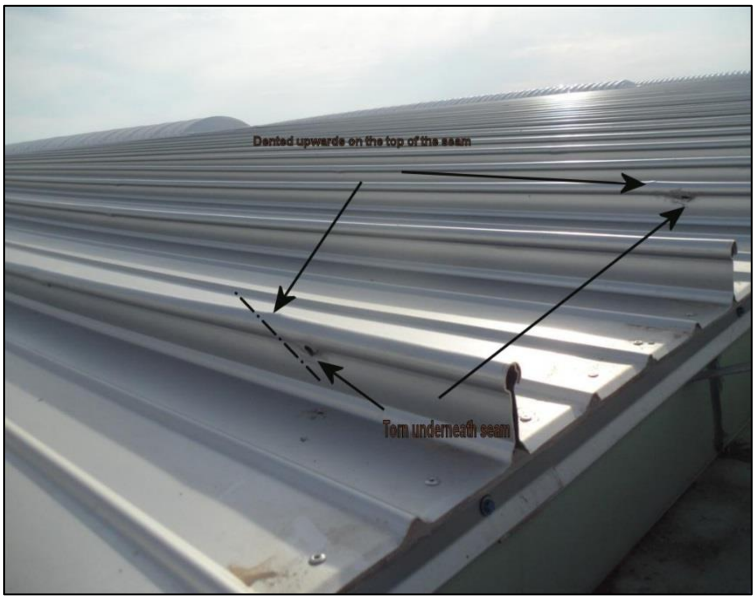


Figure 7.6: Over-turning of halter on PIR substrate leading to seam penetration

The requirement of a rigid connection for the halters was also commented upon by respondent 10: "*There is a common lack of recognition of the need for the base of the halter to have a firm base and not allow any base rotation that would cause the seam to lock*".

7.2.3 Material wear/abrasion of seams

Even if the halter is rigidly installed problems can still occur. The halter is produced from extruded aluminium which is a lot stronger and harder than the aluminium used to produce the standing seam sheet. If the halters are installed below system coverwidth tolerances or the standing sheet is manufactured outside of the production tolerances then the sheet can become too tight on the halters causing the halter to abrade the seam of the standing seam sheet as it tries to move under thermal movement (figure 7.7). This can lead to a thinning and eventually wearing through of the aluminium.

Figure 7.7: Abrasion on underside of seam

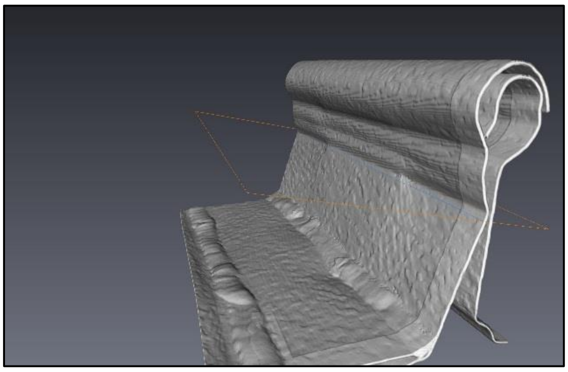


Figure 7.8: Image from CT scan of seam

This can have a serious impact on the reduction in service life of the system leading to premature failure whether through holes or splits appearing thereby reducing its weathering capability or by reducing its load bearing capacity. Figure 7.8 shows an image from a CT scan of an abraded seam. Figure 7.9 shows a section through the CT scan and thicknesses of material are shown at various positions of the seam. The standing seam sheet was produced from aluminium with a nominal thickness of 1.2 mm. The CT scan shows that the sheet has been abraded by the halter reducing its thickness to as low as 0.43 mm in places.

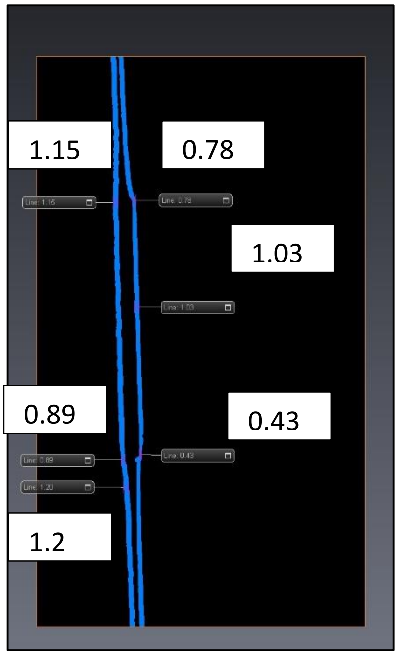


Figure 7.9: Section through CT scan

7.2.4 Failure of fixed points

The fixed point acts as both an anchor to transfer the axial loads, resulting from self-weight of sheet, snow loads etc., acting on the sheet to the structure and a datum point in order to determine the direction and amount of thermal movement of the sheet. The designed fixed point also needs to be the strongest point of the roof and must also be able to resist thermal movement in-plane forces that could occur in the system if another fixed point is inadvertently introduced. This could be due to excessive misalignment of halters, out of tolerance structure, poor detailing at penetrations etc.


Figure 7.10: Failure of fixed point


Figure 7.11: Top-hat sub-purlin fastener elongating hole in liner sheet under thermal movement at fixed-point position

Figure 7.10 shows a failure at a fixed point position where the halter has overturned. This was because of an inadequate fastener connection to the sub-purlin support at this position. Figure 7.11 shows the sub-purlin fastener elongating a hole in the liner sheet under thermal movement as the connection mechanism was unable to resist the in-plane forces that were present in the system.

7.2.5 Splitting/cracking of welds

Welding is carried out quite often on aluminium standing seam systems especially when used on a low pitched roofs i.e. ≤ 3°. Below this pitch system manufacturers require that all penetrations (e.g. soil and vent pipes (SVPs), roof hatches, roof lights etc.) and sheet laps are welded.

When aluminium is welded, unlike with steel, the area around the weld, the HAZ is much weaker than the parent metal.

As was seen in the example calculations in section 4.4 thermal expansion and contraction forces can be very large which can result in considerable damage being caused if thermal movement is restrained.

Figure 7.12: Splitting of weld in aluminium

Figure 7.13: Valley gutter detail welded into standing seam roof

Figure 7.12 shows an aluminium weld that has split. This occurred at the detail were a valley gutter was formed in a standing seam roof by welding the ends of the sheets onto the gutter which itself was formed from standing seam sheets (figure 7.13). The length of valley gutter was restrained from moving due to it being connected to the sheet ends with no movement allowance made in its length. As thermal movement tried to take place the expansion and contraction forces in the valley gutter caused the detail to fail at its weakest point which is the HAZ.

When considering welding of details in aluminium a good maxim to take into account is raised by Kissell and Ferry, 1995, that with aluminium welding “less is more”.

8. Factors Affecting Thermal Movement Performance

8.1 Introduction

The respondents to the consultants' questionnaire were presented with a number of typical factors that can affect thermal movement and asked to indicate which they have identified on projects (question 2.2 of section 2 – experiences). For each factor identified the respondent is asked to evaluate it from a risk perspective on a scale of 1-5 for its severity (S), its frequency of occurrence (O) and the likelihood of early detection (D).

Table 8.1 gives a summary of the responses and adopting the same process as that described in chapter 7 an FMEA type risk analysis was also conducted.

In the opinion of the industry professionals the factor that is of most concern is "in-plane force not taken into account in design calculation" (RPN = 48.8) followed by "inadequate number or type of fasteners specified" (RPN = 44.5) and "halters not set out to system tolerances" (RPN = 42.1). Most of the examples of problems given in section 7.2 of the previous chapter can arise from these factors.

All of these had a severity rating between 4 and 5 indicating that this could lead to a safety failure. There were a number of other factors which had high severity ratings such as "inadequate fasteners in flashings", "sheets not fully engaged over halters prior to zipping" and "insubstantial sub-structure" or substrate specified" which were rated highest.

Some of these factors are looked at in greater detail in section 8.2. The examples are broken down as per the various stages in table 8.1 i.e. manufacture, support structure, detail design and installation.

Section 2 Experiences		Factor Identified		Risk			
2.2 Typical factors affecting performance				**Rating**			**RPN (S x O x D)**
		No.	**%**	**S**	**O**	**D**	
Manuf.	Sheet cover width out of production tolerance	9	82	3.4	2.5	3.5	29.5
	Seam too tight	8	73	3.4	2.4	3.1	26.2
	Seam too loose	6	55	4	2.4	3.4	32.6
Structure	Not to System tolerance requirements	8	73	3.6	3.3	3	35.2
	Inadequate lateral restraint	2	18	3	4	3	36
Detail design	No, inadequate or multiple “fixed points” to sheets	10	91	4.1	3	2.6	31.5
	In-plane force not taken into account in design calculations	5	45	4	3.8	3.3	**48.8**
	Amount of movement underestimated or ignored	9	82	3.9	3.4	2.9	37.6
	Insufficient movement allowance at details	9	82	3.8	3.8	2.6	36.9
	Inadequate number or type of fasteners specified	10	91	4.3	2.9	3.6	**44.5**
	Insubstantial sub-structure or substrate specified	8	73	4.3	3	3	38.6
	Geometry of building not taken into account	8	73	3.7	2.6	2.7	25.9
Install’n	Structure not checked for suitability	10	91	4.1	3	3.1	38.4
	Halters not set out correctly to System tolerances	9	82	4.2	3.5	2.9	**42.1**
	Halters installed on compressible material	4	36	4	2.7	3	32
	Sheets not fully engaged over halters prior to zipping	9	82	4.3	2.6	3	33.5
	Incorrect zipper roll sets used for thickness of material	8	73	3.9	2.7	3.1	32.9
	Zipping machine not maintained or designed for another System	7	64	3.8	3.2	2.7	32.4
	Insufficient movement allowance in flashings	9	82	4.1	3.8	2.5	38.7
	Inadequate fasteners in flashings	9	82	4.6	4.1	2.2	41.6
	Additional components clamped directly over or close to halters	9	82	3.6	3.1	2.8	31.2

Table 8.1: Summary of responses to consultant’ questionnaire, section 2 – experiences: 2.2 typical factors affecting performance

8.2 Examples of typical factors

8.2.1 Manufacture

There is a complex interaction between the head of the halter and the seam of the standing seam sheets to enable thermal movement accommodation and wind uplift resistance to occur to their optimum performance as per the system design and the production tolerances required are generally very tight in these crucial areas.

The engineered design of extrusion dies enables the aluminium halters to be manufactured to very tight tolerances and to a consistent quality. However the performance of the system can be affected during the manufacturing process of the standing seam sheets and the adherence to production tolerances is critical. If the seam is too tight this can restrict the thermal movement of the sheet over the halter. If the seam is too loose then thermal movement is accommodated but the risk of detachment from the halter under wind suction loads is increased.

The width of the manufactured standing seam is also critical. Measured at the widest point of the bottom flange it should typically be 5 mm or more below the system coverwidth. As an example for a 400 mm system nominal coverwidth (figure 3.3) it should be no more than 395 mm.

If the sheets are manufactured too wide then binding on the halters can occur and the halter becomes visible through the seam (figure 8.1). This can also lead to the potential failure effect that the sheet becomes punctured by the halter and potentially the roof leaks or the sheet can erode through constant rubbing on the halter reducing the effective service life of the system. An example of this is given in section 7.2.3.

Figure 8.1: Standing seam sheets binding on halters

8.2.2 Support structure

Structural support tolerance requirements for standing seam systems are much tighter than those in the NSSS 5th edition. Tolerance requirements include for both level and rotation of supports. If this is not taken into in the steelwork specification early on in the design process then there is a risk that potential problems can occur when the standing seam system is installed. As they are not self-levelling they will follow the steelwork shape. At best this can give an unsightly appearance and at worst can lead to the formation of unwanted fixed-points with the sheets locking up at that position. Figure 8.2 shows an example of a standing seam system installed on out of tolerance steelwork.

Figure 8.2: Standing seam system installed on out of tolerance steelwork

The question of where the responsibility for rectifying this should lie is open to debate. As was seen in section 6.2.8 some respondents commented that this should lie with the roofing contractor.

What is critical though is this factor should be rectified prior to installation of the standing seam system. This could be by means of a secondary support section being installed on the steelwork (figure 8.3)

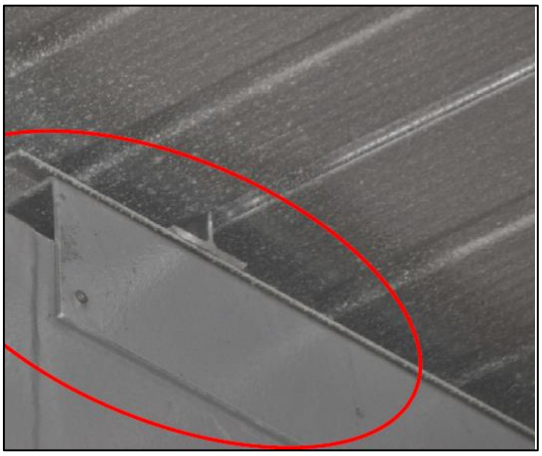


Figure 8.3: Secondary support section installed to rectify out of tolerance steelwork

in order to a support surface which is at the correct level and angle.

Respondent 11 raises this point in his additional comments: “*Sign off of the base/supporting structure is critical – the relationship between the primary steelwork tolerances and tolerances for the cladding need to be addressed and variations between the two appropriately rectified*.”

8.2.3 Detail design

Three of the key aspects that need to be accounted for in the detail design process for a standing seam roofing or cladding project to ensure that the accommodation of thermal movement is not restricted are: in-plane force calculations; fixed-point design and position; and potential thermal movement allowance at details and penetrations. The effects of undertaking these design aspects can be seen clearly with the typical problems shown in chapter 7.

In-plane force design calculations not being carried out on projects had the highest RPN rating from the respondents. As seen previously this could be down to both lack of awareness by the detail design team or that the necessary information is not available from the system manufacturer. As respondent 1 commented *“the mystery needs to be revealed regarding ‘in-plane’ forces in standing seam roof systems by testing, case studies, research and good communication*”.

With fixed point design most problems are due to the forces not being sufficiently able to be transferred to the structure rather than one not being included. All manufacturers provide details of how the fixed point can be created in the standing seam sheet but very few raise the issue of the requirement for the load transfer to the structure.

Problems with the dimensional allowance for thermal movement at details or perimeters could be down to conflicting information as to what needs to be accommodated. Other problems can occur due to poor planning and the over-reliance that details will be sorted out on site potentially giving rise to the example as shown in figure 8.4.

Figure 8.4: Poor site detail for SVP penetration (Hicks, 2013)

8.2.4 Installation

Installing halters to the correct system dimension and tolerances is critical to the successful installation of a standing seam system. Incorrect setting out and misaligned halters, as figure 8.5, can lead to issues such as that shown in figure 8.6 with halters becoming deformed or ultimately shearing.

Figure 8.5: Misalignment of halters

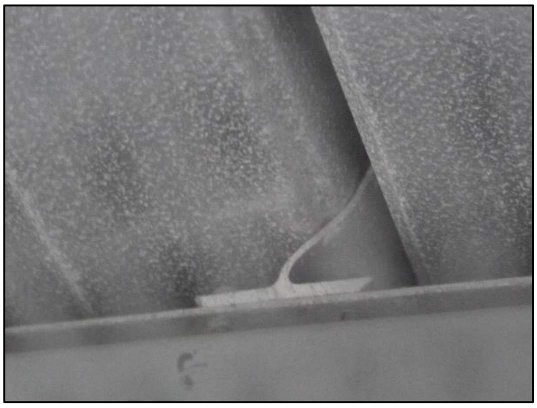


Figure 8.6: Deformed halter

It is common practice when setting-out halters in a double-skin insulated roof system (figure 3.5) to use the side of the trapezoidal rib of the liner sheet as a form of template, (figure 8.7) when it has a compatible pitch to that of the standing seam sheet.

Figure 8.7: Halters set out from side of rib of compatible liner sheet

Care should be taken when adopting this method to ensure the coverwidth and pitch of the liner sheet is within the tolerances requirements of the standing seam sheet. The production tolerances of the liner sheet are much looser than that of the standing seam sheet. The tolerance on the pitch of the ribs is ±2 mm and the coverwidth ±5 mm (BSI, 2008).

Care also needs to be taken with pre-assembly of halters on support rails etc.to ensure the correct halter set-out is adopted and that when installed on site they are all in correct alignment.

All manufacturers state that standing seam sheets should be zipped together as work progresses in order that the full load capacity of the seam is achieved. It is vital that they are fully installed on the halters and that the large roll is correctly installed over the small roll prior to zipping the sheets together. Figures 7.1 and 7.2 show examples of problems resulting from the sheets not being fully engaged on the halters.

Figure 8.8 shows an example of where zipping has been carried out without fully engaging the large roll over the small roll. In this example the right side of the seam has been pushed down causing a height difference to occur between the two sides of the seam. This has caused the sheet to become in contact with the top of the base of the halter with the result that the sheet has abraded at this position and holes have been formed causing water leakage. The photograph shows a patch welded onto the sheet as a means of temporarily rectifying the problem.

The zipping process has also deformed the large roll of the seam causing it to also deform the small roll and push against the halter. This can also lead to problems shown in section 7.2.3 and figures 7.7 to 7.9.

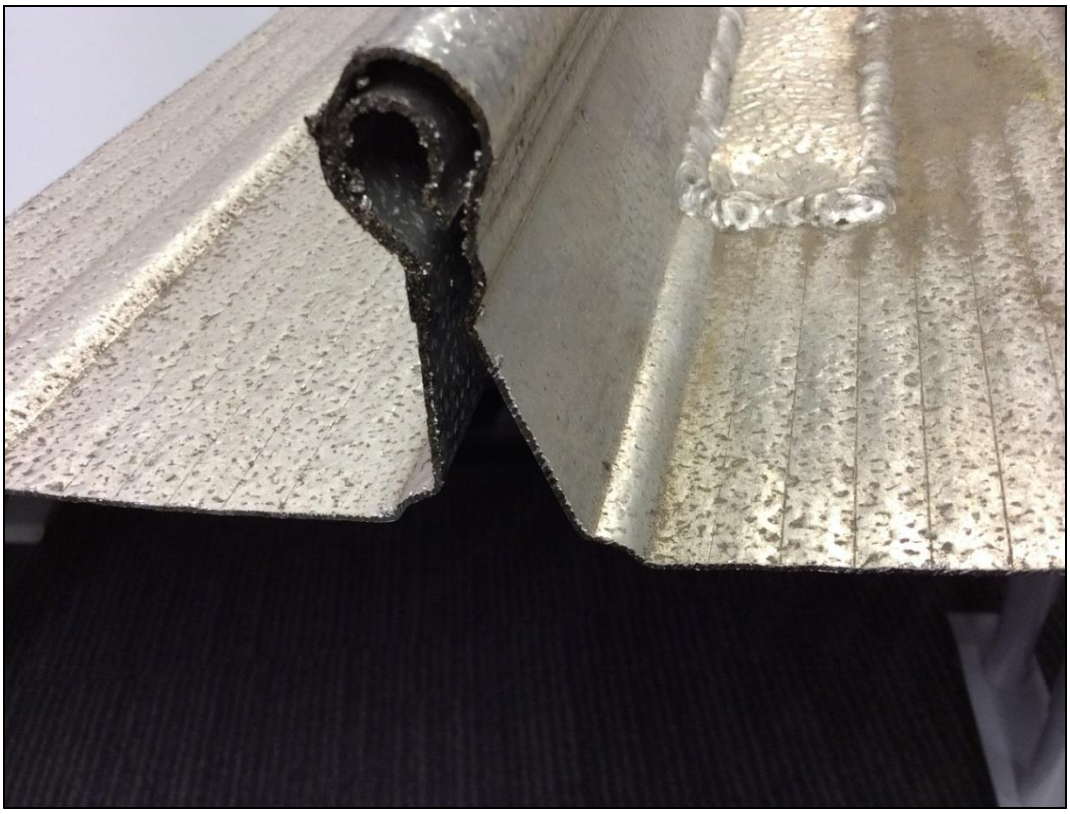


Figure 8.8: Large roll of seam not fully engaged over small roll prior to zipping

Increasingly additional items such as photovoltaic (PV) panels are being installed on standing seam roofs using clamping mechanisms (figure 8.9) in a similar manner to when rainscreen systems are installed (figures 1.5, 1.6 and 3.10). If the clamps are installed too close to the halter position then thermal movement can be restrained as

Brian Morris of BEMO in responding to the manufacturers' questionnaire commented "*3rd party products attached using seam clamps, need careful consideration i.e. PV panels with clamps near halter positions*". Some of these clamping devises use grub screws which can indent and deform the aluminium of the standing seam sheet seam potentially clamping them against a halter (figure 8.10).

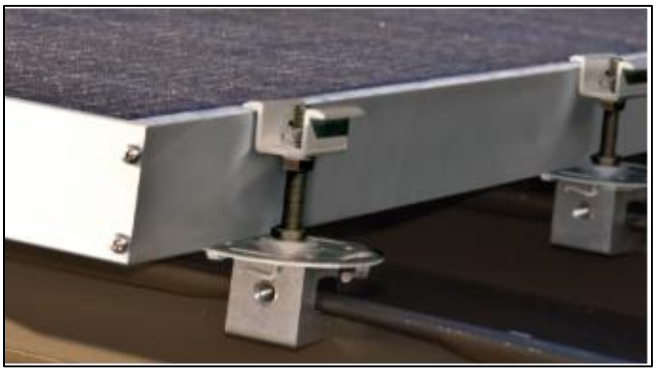


Figure 8.9: PV panel clamped to standing seam roof (Kalzip Ltd, 2012a)

Figure 8.10: Damage to Standing seam sheet from seam clamp (Kalzip Ltd, 2012a)

Systems manufacturers often have requirements for a minimum distance that seam clamps should be positioned from a halter (figure 8.11).

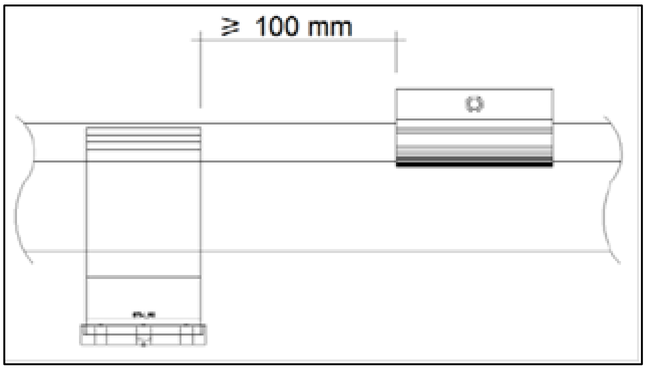


Figure 8.11: Minimum distance requirements for seam clamp from halter (Kalzip Ltd, 2012a)

9. Standing Seam System Manufacturers

9.1 Introduction

This part of the research attempts to ascertain what information is provided on testing, approvals and certification; design information; production tolerances; support and installation tolerances and installation and how this information or advice is disseminated to relevant parties of the design and construction teams. Information on the use of alternative methodologies which could assist in alleviating the problems within the system was also an element of this part of the research.

Although information can be provided whether or not it is used is open to conjecture as Keith Bradley commented: "*We can publish many thousands of words of technical advice and support, test data and so on. This might provide the manufacturer with cover and protection in the event of a failure. However, unless the advice is read, understood and incorporated into the design and installation of the roof, failures – and the arguments about how and by whom - will continue. We still meet with architects and designers who seem to have forgotten that aluminium expands when it gets warmer - and too many installers who need to appreciate the importance of what they do and how they do it.*"

The questionnaire consists of seven sections as follows. In sections 2 to 6 a number of questions were asked with the respondents invited to indicate those responses which are applicable to their company and/or standing seam system.

- Section 1 – Personal Information
- Section 2 – Testing, approvals and certification
- Section 3 – Design information
- Section 4 – Production tolerances
- Section 5 – Support and installation tolerances
- Section 6 – Installation
- Section 7 – Additional comments

The questionnaire was issued to the eight UK manufacturers of standing seam systems, seven of whom responded; copies are in the appendix. The recipients were senior technical or managerial personnel. Summaries of sections 2 to 6 are given in tables 9.1 to 9.6 together with a brief overview of the responses.

9.2 Manufacturers' questionnaire – summary

9.2.1 Section 2 – Testing, approvals and certification

In-plane force testing has been undertaken by six of the respondents, the majority of which is part of the process for BBA approval. Testing has also been carried out by five of the respondents for other purposes. Testing has been carried out with halters fixed direct to purlins and/or to bracket and rail systems. Testing has been undertaken with halters perfectly aligned or misaligned to their published installation tolerances. Only half have tested to halter misalignment beyond this.

No testing has been carried to enable CE marking via the route in CUAP 03.02/16. Only one manufacturer has claimed CE marking via this route but in-plane force testing is only an optional test. All those who have CE marked have done so via BS EN 14782 which only looks at the sheet as a product rather than the system as a whole. The same applies to the CE marking of halters to CUAP 04.01/12, halters are treated as a product rather than a system. Both do not include an in-plane force test. Two of the respondents have not CE marked their standing seam sheets or halters.

9.2.2 Section 3 – Design Information

All manufacturers publish a technical or design manual/guide with the majority publishing this on their web-site. All but one manufacturer offers design training.

The worrying aspect is how few publish the results of their in-plane force testing. As per the literature review only one manufacturer publishes this information in their literature with another manufacturer claiming that they only release the information on request. The other manufacturers who have tested their products will only use the results internally.

The majority of respondents provide 'rule of thumb' advice relating to the amount of thermal movement typical to that in table 2.2 with only one respondent claiming that they can provide more specific colour/finish information e.g. as per table 4.2. Three of the respondents publish information or a design methodology on how to determine thermal expansion based on specific project information whilst one undertakes this service utilising a computer design tool or software.

Two of the respondents whose companies provide project specific information provided additional comments on the subject of thermal movement that emphasise its importance. Paul Clayton, Euro Clad Ltd commented that *“most common issue is detailing and consideration of movement against welded joints*”, whilst Steve Darlington, Ash and Lacy Ltd, commented that “*the same factors govern expansion of perimeter flashings. Failure to detail and allow for expansion can lead to problems with perimeter component failure*”.

Only one manufacturer publishes information on how to determine material stresses and resultant forces within their literature. Two other manufacturers will issue this on request whilst the majority do not provide this information.

Five of the respondents say they advise on the limit to the effective length of their standing seam sheet that should be used, although this advice does not appear in their published literature. One respondent indicates that the effective length advised is conditional upon the use of alternative methods to be adopted. In this case this is included in published literature were the use of plastic halters are advised above a certain sheet length.

9.2.3 Section 4 – Production Tolerances

Five respondents have an audited quality management system (QMS) to ISO 9001. They are all members of the MCRMA for which this is a requirement of their membership charter. Four of these companies together with one other also have a QMS which is audited by BBA as part of their approval. One respondent does not operate a formalised QMS.

The dimensional accuracy is checked by all as part of their manufacturing processes with four of them having slightly different production tolerances when manufacturing is carried out on site. These slight differences relate only to length of sheet.

Only three provide their customers with a means of checking the dimensional accuracy of the standing seam sheet with only one providing a template of the correct shape.

9.2.4 Section 5 – Support and installation tolerances

All respondents provide information on support and installation tolerances with four of them requiring different tolerances when curved sheets are used. Only one includes tolerances in their sales literature and another one has information available on their web-site. All include this information in their technical or installation manuals with some including it in both.

The majority of manufacturers base their tolerances on recommendations in industry literature, i.e. MCRMA Technical Paper 3. This is often backed up with their own practical testing.

9.2.5 Section 6 – Installation

All publish an installation manual which is available on request and in two cases via their web-site. They all offer installation training but only one has theirs accredited by a third party e.g. construction industry training board (CITB).

All provide information on how to set out halters to the required system tolerances either within their installation literature or as part of their training. Five provide installers with templates to assist with setting out of halters. Figures 9.1 and 9.2 show examples.

Figure 9.1: Halter setting-out template (Ash and Lacy Ltd)

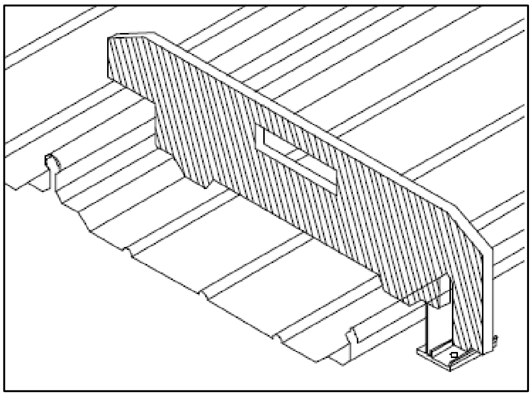


Figure 9.2: Timber module gauge (Architectural Profiles Ltd)

Information on how to install perimeter flashings and penetrations is also provided in literature and/or as part of their installation course.

All will carry out site inspections during installation with six offering this service after installation. Site inspections would generally be on request and maybe a requirement if a guarantee is offered on a project. The majority of people undertaking site inspections are technical personnel with three companies having dedicated site personnel.

Section 2 – Testing, Approvals and Certification		Response	Summary	
Question			**No.**	**%**
2.1	Do you have a BBA (British Board of Agrément) or other third-party approval for your standing seam system?	Yes	5	71
		No	2	29
2.2	Is your standing seam system CE marked either as individual products or as a system (i.e. both standing seam sheet and halter together)?	Yes, standing seam sheet as a product to BS EN 14782:2006	5	71
		Yes, halters as a product to CUAP 04.01/12	2	29
		Yes, standing seam and halters as a system to CUAP 03.02/16	1	14
		No	2	29
2.3	Has in-plane force testing been carried out on your standing seam system?	Yes, as part of the BBA (or other) approval process	4	47
		Yes, as part of CE marking to CUAP 03.02/16	0	0
		Yes, independent of approvals and certification	5	71
		No	1	14
2.4	Was in-plane force testing carried out to different degrees of alignment of halter?	Perfectly aligned	5	71
		Misaligned to published system tolerances	6	86
		Misaligned beyond published system tolerances	3	43
		Not applicable	1	14
2.5	Was in-plane force testing carried out with halters installed to different forms of structure or sub-structure?	Halter fixed direct to purlin	5	71
		Halter fixed to structural decking profile	0	0
		Halter fixed to bracket and rail system	4	57
		Halter fixed to other type of structure/sub-structure	0	0
		Not applicable	1	14

Table 9.1: Summary of responses to manufacturers' questionnaire – section 2 – testing, approvals and certification

Section 3 – Design Information		Response	Summary	
Question			**No.**	**%**
3.1	Do you publish a technical or design manual/guide for your standing seam system?	Yes, readily available e.g. on web-site	5	71
		Yes, available on request	2	29
		No	0	0
3.2	Do you provide design training on your standing seam system to specialist roofing and cladding contractors and/or detail designers?	Yes	6	86
		No	1	14
3.3	If you have undertaken in-plane force testing on your standing seam system how do you utilise or disseminate the results for use in design calculations?	Results readily available e.g. in Company literature or web-site	1	14
		Results available on request	1	14
		Results only available to key contacts, customers etc.	0	0
		Results only used internally	4	57
		Results not used	0	0
		Not applicable	1	14
3.4	What form of information or advice do you provide on how to determine the amount of thermal movement to be accommodated for use in detail design?	“Rule of thumb” for material, e.g. 1 mm per 1 m of sheet length	0	0
		“Rule of thumb” taking into account generic material, finish and/or colour (e.g. 1.5 mm per 1 mm of sheet length for dark coloured sheets)	5	71
		“Rule of thumb” taking into account specific material, surface finish and colour (e.g. 1.7 mm per 1 mm of sheet length for PVDF coated aluminium sheets to RAL 7016 – Anthracite Grey)	1	14
		Information or design methodology to determine extremes of thermal expansion and contraction based on specific project conditions	3	43
		Computer design tool/software to determine extremes of thermal expansion and contraction based on specific project conditions	1	14
		Other	0	0
		None	0	0

Section 3 – Design Information		**Response**	**Summary**	
Question			**No.**	**%**
3.5	Do you provide information or advice on how to determine the amount of stress within a standing seam sheet and its resultant force if thermal movement of the sheet is fully restrained?	Yes, published within Company literature or web-site	1	14
		Yes, on request	2	29
		No	4	57
3.6	Do you advise on a limit to effective length (i.e. length of sheet from fixed point) of standing seam sheet to be used or advise on the need for alternative methods to be adopted to limit the level of in-plane force within the system	Yes	5	71
		Yes, conditional on alternative method being adopted	1	14
		No	1	14
3.7	Where conditions are applied to the limit of the effective length of the standing seam sheet, what alternative methods do you recommend to reduce the level of in-plane force within the system?	Secret gutter or step lap detail.	2	29
		Increased number of fasteners in base of halter.	3	43
		Longer aluminium halters.	2	29
		Halters of an alternative material, e.g. plastic.	1	14
		Sliding halters/clips	0	0
		Halters installed into a sliding rail running perpendicular or diagonal to direction of sheeting.	0	0
		Halters installed on a more robust sub-structure.	1	14
		Other	1	14
		Not applicable	1	14

Table 9.2: Summary of responses to manufacturers' questionnaire – section 3 – design information

Section 4 – Production Tolerances		**Response**	**Summary**	
Question			**No.**	**%**
4.1	Is your system manufactured under an independently accredited and audited quality management system e.g. to ISO 9001?	Yes, to ISO 9001	5	71
		Yes, as part of ongoing BBA (or other) approval	5	71
		No	1	14
4.2	Do you check the dimensional accuracy of the standing seam sheet as part of your manufacturing processes?	Yes	7	100
		No	0	0
4.3	Do your manufacturing tolerances differ for site production as opposed to factory production of standing seam sheets?	Yes, major differences in tolerances	0	0
		Yes, but only differ slightly (e.g. length)	4	57
		No	3	43
4.4	Do you provide customers with a means of checking the dimensional accuracy of the shape of the standing seam sheet?	Yes, production drawing	2	29
		Yes, template of correct shape	1	14
		Yes, other means	0	0
		No	4	57

Table 9.3: Summary of responses to manufacturers' questionnaire – section 4 – production tolerances

Section 5 – Support and Installation Tolerances		Response	Summary	
Question			**No.**	**%**
5.1	Do you have support tolerance requirements (e.g. purlin level, rotation etc.) and installation tolerance for your standing seam system?	Yes, both support and installation tolerances	7	100
		Yes, support tolerances only	0	0
		Yes, installation tolerances only	0	0
		No	0	0
5.2	Do you have different support and/or installation tolerance requirements when curved standing seam sheets are utilised?	Yes, both support and installation tolerances are different	4	57
		Yes, support tolerances only are different	0	0
		Yes, installation tolerances only are different	0	0
		No, same as for straight standing seam sheets	3	43
		Not applicable	0	0
5.3	How are your support and/or installation tolerances disseminated?	Published in sales literature	1	14
		Published in technical or design manual/guide	4	57
		Published in installation manual/guide	4	57
		Issued as part of installation training	5	71
		Available on web-site	1	14
		Available on request	4	57
		Not applicable	0	0
5.4	How were the support and/or installation tolerances derived?	By practical testing	4	57
		By desk-top study	1	14
		By reference to industry recommendations	6	86
		By other method	0	0
		Not applicable	0	0

Table 9.4: Summary of responses to manufacturers' questionnaire – section 5 – support and installation tolerances

Section 6 – Installation		**Response**	**Summary**	
Question			**No.**	**%**
6.1	Do you publish an installation manual/guide for your standing seam system?	Yes, readily available e.g. on web-site	2	29
		Yes, available on request	6	86
		No	0	0
6.2	Do you provide installation training on your standing seam system to installers?	Yes	7	100
		No	0	0
6.3	If yes, are your training courses accredited by a third party e.g. CITB, NFRC etc.?	Yes	1	14
		No	6	86
		Not applicable	0	0
6.4	Do you provide installers with information or advice on how to set out halters to system tolerances?	Yes, readily available e.g. in Company literature or web-site	4	57
		Yes, as part of installation training	4	57
		Yes, available on request	4	57
		No	0	0
6.5	Do you provide installers with any aids to assist in setting out halters, e.g. templates?	Yes	5	71
		No	2	29
6.6	Do you provide installers with information or advice on how to install perimeter flashings and penetrations?	Yes, readily available e.g. in Company literature or web-site	5	71
		Yes, as part of installation training	5	71
		Yes, available on request	1	14
		No	0	0
6.7	Do you carry out site inspections either during or after installation?	Yes, during installation	7	100
		Yes, after installation	6	86
		No	0	0
6.8	If yes, who carries out your site inspections	Dedicated site personnel	3	43
		Technical personnel	6	86
		Sales personnel	2	29
		Other	0	0
		Not applicable	0	0

Table 9.5: Summary of responses to manufacturers' questionnaire – section 6 – installation

9.3 Alternative methods to assist the accommodation of thermal movement

9.3.1 Mid-slope position of fixed point

The most common method adopted is to position the fixed point mid-slope. This reduces the effective length of the roof sheet and thus the amount of thermal movement that needs to be to be accommodated. Thermal movement will also need to be accommodated in the ridge detail as well as at the eaves position. Axial forces resulting from snow and self-weight for full slope still need to be taken into account though in the design of the fixed point and its connection to the structure.

9.3.2 Secret gutter or step lap detail

Introducing secret gutters or step laps can allow for shorter length sheets to be used thus reducing the amount of thermal movement to be accommodated. Figure 9.3 shows a typical example of a step lap detail. This form of detail would require careful planning at an early stage of a project to allow steelwork support to be positioned correctly.

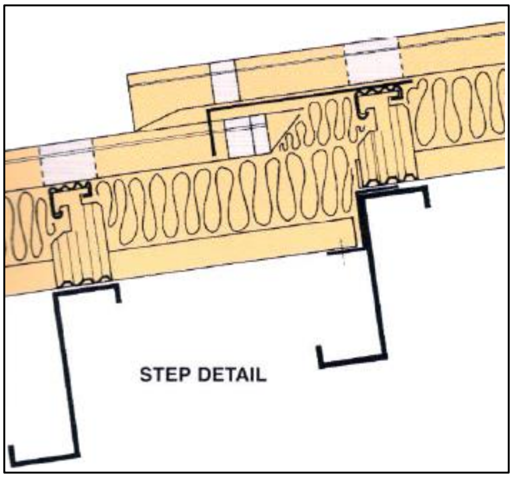


Figure 9.3: Typical step lap detail (MCRMA, 1999)

9.3.3 Increased number of fasteners in base of halter

It is common practice to install two fasteners in the base of the halter. These should ideally be positioned diagonally on opposite sides of the base (figure 9.4). This helps to stabilise the halter much better than if two fasteners are installed on the centre line of the base which it is possible to do with some halters (figure 9.5).

Installing additional fasteners in the base can increase the resistance to over-turning of the halter due to in-plane forces. Some standard halters will allow up to six fasteners to be installed (figure 9.5).

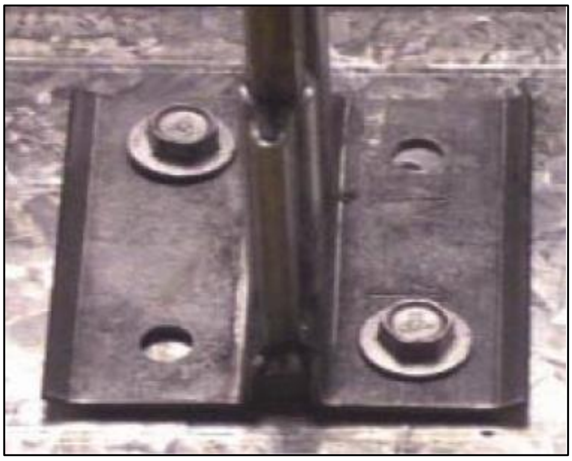


Figure 9.4: Two fasteners positioned diagonally in base of halter (Ash and Lacy Ltd)

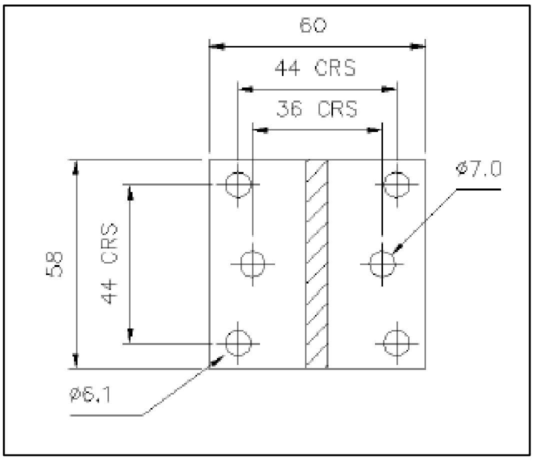


Figure 9.5: Halter base with six holes for fasteners (Kalzip Ltd, 2012b)

9.3.4 Longer halters

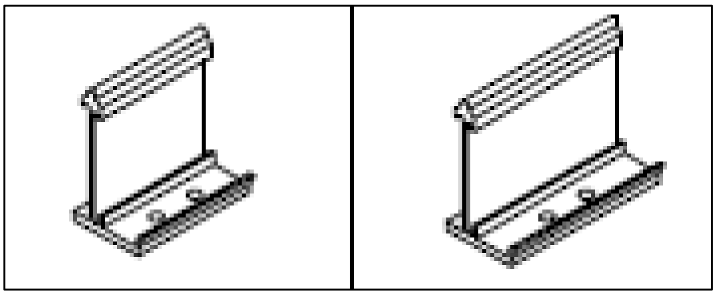


Figure 9.6: Standard length and long length halters (Architectural Profiles Ltd)

Aluminium halters are manufactured from lengths of extruded aluminium. They can theoretically be cut down to different lengths other than just the standard which is approximately 60 mm. Some manufacturers have longer halters in their range of standard components. Figure 9.6 shows a standard halter with a longer one.

The use of longer length halters can reduce the over-turning moment of the halter due to in-plane forces because of its increased base length. Some have additional holes so an increased number of fasteners may also be used.

9.3.5 Halters of an alternative material

Halters of alternative materials were initially developed to reduce the amount of thermal bridging that took place through an aluminium halter in order to meet the ever increasing demands of energy efficiency of buildings and the building envelope that was required in building regulations. Typical examples of alternative materials include injection moulded plastic, pultruded glass fibre reinforced resin and formed stainless steel. Their use was found to also have the benefit of dramatically reducing the in-plane force which is present in the standing seam system. Figures 9.7 and 9.8 show some typical examples.

Figure 9.7: Steel reinforced injection moulded plastic halters (Kalzip GmbH, 2011)

Figure 9.8: Pultruded glass fibre reinforced resin halters (BEMO Systems GmbH, 2012a)

9.3.6 Sliding Halters/Clips

As discussed in section 3.3.4 the use of sliding halters or clips eliminate any in-plane forces between the sheet and the halter/clip as accommodation of thermal movement is taken up within the hater/clip itself. Problems due to thermal movement can still occur if the halter/hook tab is not positioned centrally in the halter/clip base during installation or if the sheet length and corresponding amount of thermal movement is too much for the capacity of the halter/clip. Figure 9.9 and 9.10 show examples of a sliding halter and a sliding clip respectively.

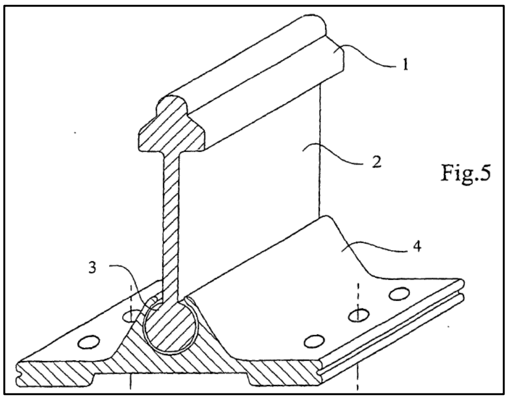


Figure 9.9: Sliding halter design (Gehlhaar et al, 2003)

Figure 9.10: Sliding clip (BEMO Systems GmbH, 2012a)

9.3.7 Halters in sliding rails

Halters can be installed in a sliding rail which runs perpendicular (in a liner/purlin roof, figure 3.5) or diagonally (in a deck/rafter roof, figure 3.6) to the direction of the standing seam sheeting (figure 9.11).

This improves the alignment of the halters as the sheets will set-out their final position rather than them being set out at pre-determined centres. This will reduce the in-plane force acting on the head of the halters as they are better aligned.

Figure 9.11: Halter installed in sliding rail (Kalzip GmbH, 2011)

9.3.8 Robust substructure

The robustness of a substructure may need to be improved in order to increase the resistance of the halter over-turning under in-plane forces. Typical examples of failures are discussed in section 7.2.2. Bracket and bar/rail spacer systems are commonly used (figure 3.7) with brackets typically positioned at 1.0 m centres.

Greater robustness be achieved by decreasing the centres of the brackets. Other options would be to introduce a more substantial bracket (figure 9.12) or to utilise a top-hat profile sub-purlin (figure 3.8).

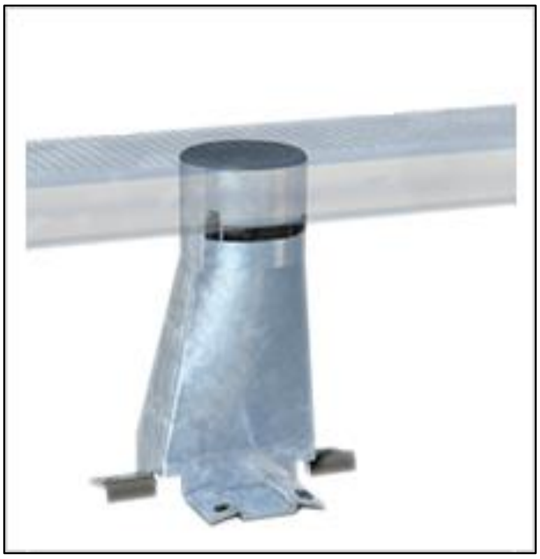


Figure 9.12: Robust bracket to spacer system (Euro Clad Ltd)

10. Conclusions and Recommendations

10.1 Conclusions

The broad aim of this research dissertation is to help reduce the instances of failure in halter based aluminium standing seam systems through a greater understanding of factors affecting the accommodation of thermal movement. It seeks to collate the existing disparate knowledge in to a single document in order to raise awareness of the type of problems experienced, the factors causing them and how they can be alleviated. The outcome and the contribution to knowledge will be the development of a set of recommendations based on the research findings which will form the basis of a new MCRMA Technical Bulletin.

The success of the research dissertation could be measured in terms of how the objectives have been met. This is reviewed as follows.

10.1.1 Objective 1: Review available literature

The literature review shows that there is very little detailed information on this subject and what there is very generic. Industry publications ‘give rule-of-thumb’ advice and ask the reader to contact the system manufacturer. Some of the information particular surface temperatures of uncoated material is out of date. Manufacturers’ technical and installation literature give information on fixed points and support and installation tolerances but provide very little design information on how to determine the forces that the system will need to accommodate. There is little consistency in the content of the systems’ BBA approvals relating to thermal movement and in two instances there is none at all.

10.1.2 Objective 2: Determine how standing seam systems accommodate thermal movement

Before problems can be investigated and potential factors identified as to their cause the way the system is supposed to work must first be understood. Chapter 3 provides an overview of the system configurations currently and describes how thermal movement is accommodated and controlled and how they interact with the structure. A comparison is also made with a clip based system.

10.1.3 Objective 3: Determine the amount of thermal movement and stress to be accommodated

Chapter 4 provides detailed methodologies on how to determine the theoretical amount of thermal movement that needs to be accommodated based on project specifics together with stresses in the material and the resultant forces if the system is restrained from moving. The surface temperatures that materials can achieve is looked at in detail from both a theoretical point of view and an example of a roof being monitored. It is shown that the surface temperature attained can be much higher that ‘rule of thumb’ guidance in the literature especially for uncoated aluminium. Examples are given showing that material stresses and forces can be very large if movement is restricted and needs to be taken into account in the detail design of a project.

10.1.4 Objective 4: Define in-plane forces in standing seam systems

The in-plane force is specific to a system and can be determined by testing and its magnitude is dependent on the degree of misalignment of the halters which should be set-out to the system recommended tolerances. Plastic clips are shown to accommodate movement more easily than extruded aluminium halters with very little in-plane force present in the system even when installed out of tolerance. How the in-plane force can be used in detail design is also explained and how it is of extreme importance that the halter and the structure that they are fixed to are as rigid and as stable as possible.

There is a lack of a standard form of testing but BBA have a test specification and confirm that this is now compulsory as part of their approval process. A similar test specification is included in a CUAP to enable CE marking but the test is only optional and no UK manufacturer has undertaken it.

10.1.5 Objective 5: Define the problems that need to be resolved

Chapter 6 summarised opinions and specific project failures. On average none of the statements given were disagreed or strongly disagreed with. There was strong agreement with the statements relating to lack of clarity with in-plane force testing and that most problems are caused by poor installation. The need for installers to be better trained was a common theme that was occurring in response to a number of statements. The summary of project failures shows that the most reported problem is where the halter penetrates the standing seam sheet. Potential causes included misaligned halters and poor design of fasteners and sub-structure. Problems and failures can occur in all types of buildings and with all types of construction but that there is a tendency where long length are used with extruded aluminium halters. The most worrying aspect is the amount of projects on which the roof had to be fully replaced.

Chapter 7 summarised typical problems. An FMEA type risk analysis was conducted on the responses from the industry professionals. The problem that is of most concern is ‘halters shearing or disconnecting’ followed by ‘fasteners shearing or disconnecting’ and ‘material wear/abrasion of seam’. Some of the problems were looked at in greater detail and it was shown that they can be inter-related and increase in severity over the life of the building.

Chapter 8 summarised factors affecting performance. A similar FMEA type risk analysis was conducted which showed that the factor that is of most concern is ‘in-plane force not taken into account in design calculation’ followed by ‘inadequate number or type of fasteners specified’ and ‘halters not set out to system tolerances’ Most of the examples of problems shown in chapter 7 can arise from these factors.

10.1.6 Objective 6: Examine the role of the manufacturer

Chapter 9 summarised responses from the system manufacturers. All have technical or installation literature, publish support and installation tolerances and provide installation training. All but one has carried out in-plane force testing but only one publishes the results. Five claim to put a limit on the length of a sheet that should be used but this is not included in their literature. The dimensional accuracy of the sheet is checked by all but only three provide their customers with a means of checking it themselves and only one provides a template of the sheet profile. Information is available to installers on how to set out halters with five providing templates to assist in this task.

10.1.7 Objective 7: Identify alternative methods to assist the accommodation of thermal movement

Section 9.2 discusses some alternative methods and provides information on the factors that are being resolved. Positioning the fixed point mid slope or including a step detail will reduce the effective sheet length and amount of movement. Plastic halters will reduce the magnitude of the in-plane force. Sliding halters eliminate the in-plane force. Increased number of fasteners, longer halters and a robust substructure can increase the resistance to halters rotating. Halters in sliding rails can improve the alignment of halters.

10.1.8 Objective 8: Propose key recommendations and guidance

This will be discussed in the next section.

10.2 Recommendations for MCRMA Technical Bulletin

The recommendations for the content of the proposed MCRMA Technical Bulletin "Thermal movement of halter based standing seam systems" are as follows:

- Description of how this type of system accommodates thermal movement (based on the information in section 3.5)
  - Thermal movement accommodation
  - In-plane forces
  - Lateral restraint to supports
  - Fixed points
    - Type
    - Position
- Determination of thermal movement and stresses (based on information in chapter 4)
  - Amend basic 'rule of thumb' advice regarding higher surface temperature of uncoated aluminium
  - Overview of stresses in material and resultant forces in sheets and flashings if thermal movement is restrained
- Detail design
  - Designing for in-plane forces (method from section 5.3)
    - Fastener design
    - Substructure design
      - Bar and bracket systems
      - Top-hat profile sub-purlins
  - Fixed-point design (method from section 3.3.3)
    - Transfer of fixed point forces to structure/sub-structure
  - Detail design to accommodate thermal movement and stresses (method from section 4.4)
    - Penetrations
    - Flashings
    - Welded details
  - Worked examples of above
  - Designing for additional components clamped to seams (information from section 8.2.4)
  - Alternative methods to assist thermal movement accommodation (information from section 9.3)

- Support Tolerances
    - Utilise existing tolerances emphasising need to contact system manufacturer for specific tolerance requirements
    - Reference to SCI P346 and NSSS (information from section 2.3.3)
    - Check steelwork accuracy before installation
- Installation (information from sections 8.2 and 9.2.5)
    - Need for trained installers in specific system
    - Halter set-out tolerances
        - Utilise existing tolerances emphasising need to contact system manufacturer for specific tolerance requirements
    - Setting out halters (information from section 8.2.4)
        - Use of templates
        - Use of liner sheets
        - Pre-assembly of halters
    - Standing seam profile dimensions
        - Checking dimensional accuracy
    - Zipping
        - Full engagement of seam over halter and large seam over small seam
        - Correct zipping machine for system
    - Position of clamping devices in relation to halter
    - Flashings and penetrations
        - Fixing and movement at joints of flashings
        - Welded details

In order for the guidance in the proposal to be successfully followed it is imperative that MCRMA members who manufacture this type of system, of which there are five, publish the results of in-plane testing on their specific systems.

It would also be beneficial if the members also provided their customers with a means of checking the dimensional accuracy of the standing seam profile ideally in the form of a template.

10.3 Recommendations for further research

Potential opportunities for further research arising from this research dissertation are as follows:

- Economic and legal cost of failure
    - It has been shown that in many cases where failures have been encountered the permanent solution has been to fully replace the roof system. This will have a cost throughout the supply chain from owner/user to manufacturer as failure could be due to many causes and blame cannot easily be apportioned. This can lead to protracted contractual arguments and ultimately litigation.
- In-plane force testing
    - In-plane force testing has evolved over the years but there is no definitive test standard. Whether a mechanical form of testing is the best method to simulate thermal movement or other methods such as radiant heat would be best suited is open to question. Actual monitoring of live installations may also be of benefit in defining any future standard test method.
- Thermal movement failure of composite standing seam systems
    - A number of respondents to the consultants' questionnaire commented that they have experienced thermal movement problems with insulated composite/sandwich standing seam systems on projects they had investigated.
- Detachment failure of halter based standing seam systems
    - It was reported by a number of respondents to the consultants' questionnaire that thermal movement problems can be a contributory factor to standing seam sheets detaching from halters. There are other factors that could lead to this form of failure which would merit further research.

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Appendix

Appendix A – List of Contributors

The following is a list of people who contributed to this research dissertation.

Consultants’ questionnaire

Clive Atkinson, Technical Director – Façade Engineering, Mott Macdonald

Trevor Downs, Consultant, Trevor Downs FIoR Consultant

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Mike Otlet, Technical Director, Atkins

Keith Roberts, Director, Roberts Consulting

David Roy, Director, Roofconsult Ltd

Nick Selves, Director, RSK Building Sciences

Bob Troughton, Director, WRT Consultants

Kevin Turton, Design/Site Services/Training Manager, Kalzip Ltd

Manufacturers’ Questionnaire

Keith Bradley, Owner, Bradclad Ltd

Paul Clayton, Group Technical Manager, Euro Clad Ltd

Steve Darlington, Technical Manager, Ash and Lacy Ltd

Andrew Dunn, Managing Director, Architectural Profiles Ltd

David Lowe, Head of Technical, SpeedDeck Ltd (Omnis Industries)

Brian Morris, Technical Manager, BEMO UK

Kevin Turton, Design/Site Services/Training Manager, Kalzip Ltd

Surface Temperature of Aluminium

Nigel Bishop, Area Sales Manager Architectural Products – UK, Euramax Coated Products Ltd

Lindsey Ellis, Senior Structural Engineer, Atkins

Karlfriedrich Fick, Consultant and officially recognised expert witness for steel and aluminium

Mike Otlet, Technical Director, Atkins

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Ton Stultiens, Technical Support Engineer, Euramax Coated Products BV

In-plane Force

Joanne Booth, Manager Structures Group, Lucideon

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MCRMA (Metal Cladding and Roofing Manufacturers’ Association)

Carlton Jones, Secretary, MCRMA

Appendix B – Consultants' Questionnaire

Research Dissertation Questionnaire – Consultants

I am currently undertaking a research dissertation as part of my Master of Science in Façade Engineering at University of Bath, entitled "*factors affecting the accommodation of thermal movement in halter based aluminium standing seam systems"*.

The Problem: Standing seam systems have been used successfully as part of the building envelope on projects the world over, however there appears to be a growing number of instances were failure has occurred due to the restriction of thermal movement within the system. The understanding of how thermal movement is accommodated and the various factors which can affect it is of prime importance if the design and installation of this type of system is to be successfully incorporated into the building envelope

Proposed Solution: This dissertation seeks to collate the existing disparate knowledge in to a single document in order to raise awareness of the type of problems experienced by failing to accommodate thermal movement in halter based aluminium standing seam systems, the factors causing them and how they can be alleviated. The outcome will be the development of a set of recommendations and design guidance based on the research findings. It is intended that this will form the basis a new MCRMA Technical Bulletin which will provide an update and partial replacement to the current MCRMA Technical Paper 3 – Secret Fix Roofing Design Guide.

Part of the research will attempt to examine the extent of these type of failures within the UK market and to identify any specific trends either with the construction form (e.g. building type, construction type, geometry, sheet length etc.) or with associated human factors (e.g. design, installation, training etc.).

It would greatly appreciated if you could help contribute to this research by taking a few minutes to complete the following questionnaire. Please be assured that any information given will be treated in confidence and will not be used for non-study purposes.

Questionnaire – Consultants

Section 1 – Personal Information	
Name:	
Company:	
Position:	
Would you be willing to be contacted to discuss your responses (yes/no)?	
Would you be willing for any comments to be attributed to yourself (yes/no)?	

Section 2 - Experiences

2.1 **Typical Problems**

The following is a list of typical thermal movement problems that can be experienced with halter based aluminium standing seam systems. Please indicate (with an X) those that you have identified on projects.

From a risk perspective, could you also please rate on a scale of 1 – 5 what you consider to be: the severity (S), the occurrence (O) and the likelihood of early detection (D), of the identified problem.

Please use the following rating values:

Severity (S)	***Occurrence (O)***	***Detection (D)***
1 – No noticeable effect	1 – Never	1 – Very high
2 – Low (e.g. appearance)	2 – Very occasionally	2 – High
3 – Medium (e.g. functional failure – weathertightness)	3 – Occasionally	3 – Medium
4 – High (e.g. reduced service life)	4 – Frequently	4 – Low
5 – Very high (e.g. potential safety failure)	5 – Very frequently	5 - Zero

Typical Problem		***Identified***	***S***	***O***	***D***
Halters visible through seams					
Excessive “clicking” noise					
Halters penetrating through seam					
Halters shearing or disconnecting					
Fasteners shearing or disconnecting					
Material wear/abrasion of seam					
Collapse/over-turning of structure					
Collapse/over-turning of sub-structure					
Collapse of substrate (e.g. insulation board)					
Failure of fixed point					
Multiple fixed points					
Movement restricted by components clamped to seams					
Splitting/cracking of welds					
Buckling of standing seam sheet					
Buckling of flashing					
Failure of fasteners in flashings					
Other (please state)					

2.2

Typical Factors Affecting Performance

The following lists typical factors that can affect thermal movement and may lead to some of the aforementioned problems experienced with halter based aluminium standing seam systems. Please indicate (with an X) those that you have identified on projects.

From a risk perspective, could you also please rate on a scale of 1 – 5, what you consider to be: the severity (S), the occurrence (O) and the likelihood of early detection (D) of the identified factor.

Please use the following rating values:

Severity (S)	***Occurrence (O)***	***Detection (D)***
1 – No noticeable effect	1 – Never	1 – Very high
2 – Low (e.g. appearance)	2 – Very occasionally	2 – High
3 – Medium (e.g. functional failure – weathertightness)	3 – Occasionally	3 – Medium
4 – High (e.g. reduced service life)	4 – Frequently	4 – Low
5 – Very high (e.g. potential safety failure)	5 – Very frequently	5 - Zero

Typical Factors Affecting Performance		***Identified***	***S***	***O***	***D***
Manufacture	Sheet cover width out of production tolerance				
	Seam too tight				
	Seam too loose				
Structure	Not to System tolerance requirements				
	Inadequate lateral restraint				
Detail design	No, inadequate or multiple “fixed points” to sheets				
	In-plane force not taken into account in design calculations				
	Amount of movement underestimated or ignored				
	Insufficient movement allowance at details				
	Inadequate number or type of fasteners specified				
	Insubstantial sub-structure or substrate specified				
	Geometry of building not taken into account				
Installation	Structure not checked for suitability				
	Halters not set out correctly to System tolerances				
	Halters installed on compressible material				
	Sheets not fully engaged over halters prior to zipping				
	Incorrect zipper roll sets used for thickness of material				
	Zipping machine not maintained or designed for another System				

		Insufficient movement allowance in flashings				
		Inadequate fasteners in flashings				
		Additional components clamped directly over or close to halters				
	Other (please state)					

Section 3 – Opinions

Using the responses: *strongly agree*, *agree*, *neither agree nor disagree*, *disagree*, *strongly disagree*, please indicate (with an X) what is your opinion of the following statements. Please add additional comments where you feel it is necessary to illustrate your response.

		Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
3.1	There is a fundamental design problem with halter based aluminium standing seam systems with regard to the accommodation of thermal movement					
	Response					
	Additional Comments					
3.2	There is a lack of knowledge of this type of problem within the roofing and cladding industry					
	Response					
	Additional Comments					
3.3	There is a lack of knowledge of this type of problem by system manufacturers					
	Response					
	Additional Comments					
3.4	There is a lack of clarity as to the type of testing for thermal movement of standing seam systems to determine in-plane forces for use in design calculations					
	Response					
	Additional Comments					
3.5	Information in System Manufacturer’s BBA certificates relating to thermal movement accommodation is insufficient					
	Response					
	Additional Comments					

Section 3 – Opinions

Using the responses: *strongly agree*, *agree*, *neither agree nor disagree*, *disagree*, *strongly disagree*, please indicate (with an X) what is your opinion of the following statements. Please add additional comments where you feel it is necessary to illustrate your response.

		Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
3.6	System manufacturers do not publish results of in-plane forces for use in detail design calculations					
	Response					
	Additional Comments					
3.7	Detail design calculations to account for in-plane forces are never carried out on projects					
	Response					
	Additional Comments					
3.8	Support steelwork is never specified to the support tolerances required by system manufacturers					
	Response					
	Additional Comments					
3.9	Roofing and cladding contractors do not have the ability and expertise to install standing seam systems					
	Response					
	Additional Comments					
3.10	Roofing and cladding contractors do not have the ability or expertise to install aluminium					
	Response					
	Additional Comments					
3.11	Many problems are due to poor quality installation					
	Response					
	Additional Comments					
3.12	Training of installers provided by system manufacturers is insufficient					
	Response					
	Additional Comments					

Section 4 – Project Specific Information

Please provide some basic information of projects where you have encountered problems due to the restriction of thermal movement in halter based aluminium standing seam systems.

Project 1			
Building type		*e.g. Industrial, retail, stadium, arena, school, office etc.*	
Year built		Year problem found	
Support type		*e.g. purlin, structural deck, timber deck etc.*	
Construction		*e.g. single skin, insulation double skin*	
Halter type		*e.g. material, full height, short etc.*	
Substructure		*e.g. bracket and rail, top-hat, zed etc.*	
Sheet length			
Sheet geometry		*e.g. straight, curved, tapered, tapered & curved, wave-form, complex*	
Fixed point position		*e.g. ridge, eaves, mid-slope*	
Identified problem/s			
Potential cause/s			
Recommended remedial action			
Project 2			
Building type		*e.g. Industrial, retail, stadium, arena, school, office etc.*	
Year built		Year problem found	
Support type		*e.g. purlin, structural deck, timber deck etc.*	
Construction		*e.g. single skin, insulation double skin*	
Halter type		*e.g. material, full height, short etc.*	
Substructure		*e.g. bracket and rail, top-hat, zed etc.*	
Sheet length			
Sheet geometry		*e.g. straight, curved, tapered, tapered & curved, wave-form, complex*	
Fixed point position		*e.g. ridge, eaves, mid-slope*	
Identified problem/s			
Potential cause/s			
Recommended remedial action			
Project 3			
Building type		*e.g. Industrial, retail, stadium, arena, school, office etc.*	
Year built		Year problem found	
Support type		*e.g. purlin, structural deck, timber deck etc.*	
Construction		*e.g. single skin, insulation double skin*	
Halter type		*e.g. material, full height, short etc.*	
Substructure		*e.g. bracket and rail, top-hat, zed etc.*	
Sheet length			
Sheet geometry		*e.g. straight, curved, tapered, tapered & curved, wave-form, complex*	
Fixed point position		*e.g. ridge, eaves, mid-slope*	
Identified problem/s			
Potential cause/s			
Recommended remedial action			

Section 5 – Additional Comments Please add any additional comments which you feel would add to this research dissertation and help reduce the instances of failure in halter based aluminium standing seam systems through a greater understanding of factors affecting the accommodation of thermal movement.

Thank you for taking the time to complete this questionnaire. Your input will be compiled with other respondents and reported upon within the research dissertation. If you are interested in the outcome of this research dissertation then I would be pleased to forward a copy to you.

Best Regards

David A Cottrell

Appendix B.1 – Respondent 1

Section 1 – Personal Information	
Name:	[redacted]
Company:	[redacted]
Position:	[redacted]
Would you be willing to be contacted to discuss your responses (yes/no)?	Yes
Would you be willing for any comments to be attributed to yourself (yes/no)?	Yes

Section 2 - Experiences

2.1 **Typical Problems**

The following is a list of typical thermal movement problems that can be experienced with halter based aluminium standing seam systems. Please indicate (with an X) those that you have identified on projects.

From a risk perspective, could you also please rate on a scale of 1 – 5 what you consider to be: the severity (S), the occurrence (O) and the likelihood of early detection (D), of the identified problem.

Please use the following rating values:

Severity (S)	***Occurrence (O)***	***Detection (D)***
1 – No noticeable effect	1 – Never	1 – Very high
2 – Slight owner/user annoyance	2 – Very occasionally	2 – High
3 – Some owner/user annoyance	3 – Occasionally	3 – Medium
4 – High degree of owner/user dissatisfaction	4 – Frequently	4 – Low
5 – Potential safety problem	5 – Very frequently	5 - Zero

Typical Problem	***Identified***	***S***	***O***	***D***
Halters visible through seams	X	5	3	5
Excessive “clicking” noise				
Halters penetrating through seam	X	5	3	5
Halters shearing or disconnecting				
Fasteners shearing or disconnecting	X	5	3	5
Material wear/abrasion of seam	X	5	3	5
Collapse/over-turning of structure	X	5	3	4
Collapse/over-turning of sub-structure				
Collapse of substrate (e.g. insulation board)	X	5	2	5
Failure of fixed point				
Multiple fixed points				
Movement restricted by components clamped to seams				
Splitting/cracking of welds	X	4	3	2
Buckling of standing seam sheet				
Buckling of flashing				
Failure of fasteners in flashings				
Other (please state)				

2.2

Typical Factors Affecting Performance

The following lists typical factors that can affect thermal movement and may lead to some of the aforementioned problems experienced with halter based aluminium standing seam systems. Please indicate (with an X) those that you have identified on projects.

From a risk perspective, could you also please rate on a scale of 1 – 5, what you consider to be: the severity (S), the occurrence (O) and the likelihood of early detection (D) of the identified factor.

Please use the following rating values:

Severity (S)	***Occurrence (O)***	***Detection (D)***
1 – No noticeable effect	1 – Never	1 – Very high
2 – Slight owner/user annoyance	2 – Very occasionally	2 – High
3 – Some owner/user annoyance	3 – Occasionally	3 – Medium
4 – High degree of owner/user dissatisfaction	4 – Frequently	4 – Low
5 – Potential safety problem	5 – Very frequently	5 – Zero

Typical Factors Affecting Performance		***Identified***	***S***	***O***	***D***
Manufacture	Sheet cover width out of production tolerance				
	Seam too tight				
	Seam too loose				
Structure	Not to System tolerance requirements				
	Inadequate lateral restraint				
Detail design	No, inadequate or multiple “fixed points” to sheets				
	In-plane force not taken into account in design calculations	X	5	5	4
	Amount of movement underestimated or ignored	X	5	5	4
	Insufficient movement allowance at details				
	Inadequate number or type of fasteners specified	X	5	3	4
	Insubstantial sub-structure or substrate specified	X	5	3	3
	Geometry of building not taken into account				
Installation	Structure not checked for suitability	X	5	3	3
	Halters not set out correctly to System tolerances				
	Halters installed on compressible material	X	5	3	3
	Sheets not fully engaged over halters prior to zipping				
	Incorrect zipper roll sets used for thickness of material				
	Zipping machine not maintained or designed for another System				

		Insufficient movement allowance in flashings				
		Inadequate fasteners in flashings				
		Additional components clamped directly over or close to halters				
	Other (please state)					

Section 3 – Opinions

Using the responses: *strongly agree*, *agree*, *neither agree nor disagree*, *disagree*, *strongly disagree*, please indicate (with an X) what is your opinion of the following statements. Please add additional comments where you feel it is necessary to illustrate your response.

		Strongly Agree	Agree	Neither agree nor disagree	Disagree	Strongly Disagree
3.1	There is a fundamental design problem with halter based aluminium standing seam systems with regard to thermal movement					
	Response					X
	Additional Comments	Maybe a fundamental design requirement to accommodate thermal movement, would certainly not agree that its a fundamental design problem. It’s a system with restrictions and limitations which need to be designed accordingly.				
3.2	There is a lack of knowledge of this type of problem within the roofing and cladding industry					
	Response		X			
	Additional Comments	There is a large element of non understanding and for the few that do understand it tends to be ignored.				
3.3	There is a lack of knowledge of this type of problem by system manufacturers					
	Response		X			
	Additional Comments	There are high levels of understanding by some manufacturers and a good appreciation by others. Aluminium standing seam manufacturers tend to be more knowledgeable....but not all.				
3.4	There is a lack of clarity as to the type of testing for thermal movement of standing seam systems to determine in-plane forces for use in design calculations					
	Response	X				
	Additional Comments	There are no recognised tests. Laboratory devised tests (mechanical type) do not represent the problem accurately and larger scale tests are impractical. Monitoring of actual installations would be preferred.				
3.5	Information in System Manufacturer’s BBA certificates relating to thermal movement accommodation is insufficient					

Section 3 – Opinions

Using the responses: *strongly agree*, *agree*, *neither agree nor disagree*, *disagree*, *strongly disagree*, please indicate (with an X) what is your opinion of the following statements. Please add additional comments where you feel it is necessary to illustrate your response.

		Strongly Agree	Agree	Neither agree nor disagree	Disagree	Strongly Disagree
	Response	X				
	Additional Comments	Insufficient or nonexistent/toned down				
3.6	System manufacturers do not publish results of in-plane forces for use in detail design calculations					
	Response	X				
	Additional Comments	Only one manufacturer known of that does				
3.7	Detail design calculations to account for in-plane forces are never carried out on projects					
	Response		X			
	Additional Comments	Very rarely seen as very rarely asked for as very rarely identified as a requirement.				
3.8	Support steelwork is never specified to the support tolerances required by system manufacturers					
	Response			X		
	Additional Comments	Some is and some isn’t. Tend to get the ‘black book’ consulted which is only really relevant for primary steelwork.				
3.9	Roofing and cladding contractors do not have the ability and expertise to install standing seam systems					
	Response			X		
	Additional Comments	Very wide range of skill levels encountered				
3.10	Roofing and cladding contractors do not have the ability or expertise to install aluminium					
	Response			X		
	Additional Comments	As above				
3.11	Many problems are due to poor quality installation					
	Response		X			
	Additional Comments	Unfortunately yes				

Section 3 – Opinions

Using the responses: *strongly agree*, *agree*, *neither agree nor disagree*, *disagree*, *strongly disagree*, please indicate (with an X) what is your opinion of the following statements. Please add additional comments where you feel it is necessary to illustrate your response.

		Strongly Agree	Agree	Neither agree nor disagree	Disagree	Strongly Disagree
3.12	Training of installers provided by system manufacturers is insufficient					
	Response			X		
	Additional Comments	Mixed				

Section 4 – Project Specific Information

Please provide some basic information of projects where you have encountered problems due to the restriction of thermal movement in halter based aluminium standing seam systems.

Project 1			
Building type		*Industrial*	
Year built	*2002?*	Year problem found	*2004?*
Support type		*Structural decking*	
Construction		*Rigid insulation*	
Halter type		*Short, aluminium on 'bearer plates'*	
Substructure		*Bearer plates through fixed into thin decking material*	
Sheet length		*82m*	
Sheet geometry		*Symmetrical 'barrel vault'*	
Fixed point position		*Apex*	
Identified problem/s		Seam splitting, halter/fastener failure, roof leaks	
Potential cause/s		Weak substructure, sub-structure trapezoidal profile not consistent with halter CTRS. Weak bearer plates. Incorrect fastener. Rigid insulation not rigid enough.	
Recommended remedial action		Replace with larger/stringer bearer plates and swap aluminium clips for plastic clips.	

Section 5 – Additional Comments

Please add any additional comments which you feel would add to this research dissertation and help reduce the instances of failure in halter based aluminium standing seam systems through a greater understanding of factors affecting the accommodation of thermal movement.

I agree that further research should be carried out regarding thermal expansion, there is also a need to raise the awareness of the potential long term issues with an inadequately design standing seam roof system (especially if the outer sheet is manufactured from aluminium).

Positive steps would include the document you refer to for the MCRMA in addition to a suitable test methodology and standardised data reporting format for use by all manufacturers.

The mystery needs to be revealed regarding ‘in-plane’ forces in standing seam roof systems by testing, case studies, research and good communication.

Appendix B.2 – Respondent 2

Section 1 – Personal Information	
Name:	[redacted]
Company:	[redacted]
Position:	[redacted]
Would you be willing to be contacted to discuss your responses (yes/no)?	yes
Would you be willing for any comments to be attributed to yourself (yes/no)?	yes

Section 2 - Experiences

2.1 **Typical Problems**
The following is a list of typical thermal movement problems that can be experienced with halter based aluminium standing seam systems. Please indicate (with an X) those that you have identified on projects.

From a risk perspective, could you also please rate on a scale of 1 – 5 what you consider to be: the severity (S), the occurrence (O) and the likelihood of early detection (D), of the identified problem.

Please use the following rating values:

Severity (S)	***Occurrence (O)***	***Detection (D)***
1 – No noticeable effect	1 – Never	1 – Very high
2 – Low (e.g. appearance)	2 – Very occasionally	2 – High
3 – Medium (e.g. functional failure – weathertightness)	3 – Occasionally	3 – Medium
4 – High (e.g. reduced service life)	4 – Frequently	4 – Low
5 – Very high (e.g. potential safety failure)	5 – Very frequently	5 - Zero

Typical Problem		***Identified***	***S***	***O***	***D***
Halters visible through seams		x	4	3	2
Excessive "clicking" noise					
Halters penetrating through seam					
Halters shearing or disconnecting					
Fasteners shearing or disconnecting		x	5	2	3
Material wear/abrasion of seam		x	2	2	2
Collapse/over-turning of structure					
Collapse/over-turning of sub-structure					
Collapse of substrate (e.g. insulation board)					
Failure of fixed point					
Multiple fixed points		x			
Movement restricted by components clamped to seams					
Splitting/cracking of welds					
Buckling of standing seam sheet					
Buckling of flashing					
Failure of fasteners in flashings					
Other (please state)					

2.2 Typical Factors Affecting Performance

The following lists typical factors that can affect thermal movement and may lead to some of the aforementioned problems experienced with halter based aluminium standing seam systems. Please indicate (with an X) those that you have identified on projects.

From a risk perspective, could you also please rate on a scale of 1 – 5, what you consider to be: the severity (S), the occurrence (O) and the likelihood of early detection (D) of the identified factor.

Please use the following rating values:

Severity (S)	***Occurrence (O)***	***Detection (D)***
1 – No noticeable effect	1 – Never	1 – Very high
2 – Low (e.g. appearance)	2 – Very occasionally	2 – High
3 – Medium (e.g. functional failure – weathertightness)	3 – Occasionally	3 – Medium
4 – High (e.g. reduced service life)	4 – Frequently	4 – Low
5 – Very high (e.g. potential safety failure)	5 – Very frequently	5 - Zero

Typical Factors Affecting Performance		***Identified***	***S***	***O***	***D***
Manufacture	Sheet cover width out of production tolerance	X	5	3	3
	Seam too tight	x	5	2	4
	Seam too loose	x	5	3	2
Structure	Not to System tolerance requirements	x	4	2	4
	Inadequate lateral restraint				
Detail design	No, inadequate or multiple “fixed points” to sheets	x	5	3	4
	In-plane force not taken into account in design calculations				
	Amount of movement underestimated or ignored	x	4	5	3
	Insufficient movement allowance at details	x	5	5	2
	Inadequate number or type of fasteners specified	x	5	5	4
	Insubstantial sub-structure or substrate specified	x	5	5	4
	Geometry of building not taken into account	x	5	2	5
Installation	Structure not checked for suitability	x	5	2	5
	Halters not set out correctly to System tolerances	x	5	3	5
	Halters installed on compressible material				
	Sheets not fully engaged over halters prior to zipping	x	5	3	5
	Incorrect zipper roll sets used for thickness of material	x	4	4	3
	Zipping machine not maintained or designed for another System	x	4	4	2

		Insufficient movement allowance in flashings	x	5	5	2
		Inadequate fasteners in flashings	x	5	5	1
		Additional components clamped directly over or close to halters	x	4	5	1
	Other (please state)					
		Lack of barrier tape / direct connection to other metals	x	5	5	1
		Carbon steel screws used	x	5	5	2

Section 3 – Opinions

Using the responses: *strongly agree*, *agree*, *neither agree nor disagree*, *disagree*, *strongly disagree*, please indicate (with an X) what is your opinion of the following statements. Please add additional comments where you feel it is necessary to illustrate your response.

		Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
3.1	There is a fundamental design problem with halter based aluminium standing seam systems with regard to the accommodation of thermal movement					
	Response			X		
	Additional Comments					
3.2	There is a lack of knowledge of this type of problem within the roofing and cladding industry					
	Response	X				
	Additional Comments					
3.3	There is a lack of knowledge of this type of problem by system manufacturers					
	Response				X	
	Additional Comments	I believe suppliers are aware, but most do not care – they just want to sell the product				
3.4	There is a lack of clarity as to the type of testing for thermal movement of standing seam systems to determine in-plane forces for use in design calculations					
	Response		X			
	Additional Comments					
3.5	Information in System Manufacturer's BBA certificates relating to thermal movement accommodation is insufficient					
	Response	X				

Section 3 – Opinions

Using the responses: *strongly agree*, *agree*, *neither agree nor disagree*, *disagree*, *strongly disagree*, please indicate (with an X) what is your opinion of the following statements. Please add additional comments where you feel it is necessary to illustrate your response.

		Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
	Additional Comments					
3.6	System manufacturers do not publish results of in-plane forces for use in detail design calculations					
	Response			X		
	Additional Comments	Some do, but not most				
3.7	Detail design calculations to account for in-plane forces are never carried out on projects					
	Response	X				
	Additional Comments					
3.8	Support steelwork is never specified to the support tolerances required by system manufacturers					
	Response		X			
	Additional Comments					
3.9	Roofing and cladding contractors do not have the ability and expertise to install standing seam systems					
	Response		X			
	Additional Comments	As 77% of roofing failures appear to be standing seam, then I have to agree				
3.10	Roofing and cladding contractors do not have the ability or expertise to install aluminium					
	Response	X				
	Additional Comments					
3.11	Many problems are due to poor quality installation					
	Response	X				
	Additional Comments					
3.12	Training of installers provided by system manufacturers is insufficient					
	Response	X				

Section 3 – Opinions

Using the responses: *strongly agree*, *agree*, *neither agree nor disagree*, *disagree*, *strongly disagree*, please indicate (with an X) what is your opinion of the following statements. Please add additional comments where you feel it is necessary to illustrate your response.

		Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
	Additional Comments	With exception of one supplier				

Section 4 – Project Specific Information

Please provide some basic information of projects where you have encountered problems due to the restriction of thermal movement in halter based aluminium standing seam systems.

Project 1			
Building type		*school*	
Year built		Year problem found	
Support type		*purlin,*	
Construction		*double skin*	
Halter type		*full height,*	
Substructure		*zed*	
Sheet length		*Various*	
Sheet geometry		*straight,*	
Fixed point position		*ridge*	
Identified problem/s		Alignment incorrect, sheets buckled, wrong fixings used	
Potential cause/s		Lack of knowledge by contractor on how to detail and install aluminium	
Recommended remedial action		Strip and re sheet with standard trapezoidal roof	
Project 2			
Building type		*arena,*	
Year built		Year problem found	
Support type		*purlin*	
Construction		*double skin*	
Halter type		*Mixed*	
Substructure		*bracket and rail, zed .*	
Sheet length			
Sheet geometry		*Generally straight, with some curved, & , wave-form*	
Fixed point position		*Various*	
Identified problem/s		Roof detached in wind	
Potential cause/s		(due in court – can not comment)	
Recommended remedial action		Redesign and replace	
Project 3			
Building type		*office.*	
Year built		Year problem found	
Support type		*timber deck .*	
Construction		*single skin,*	

Halter type	*full height,.*
Substructure	*To timber ply deck only.*
Sheet length	
Sheet geometry	*Straight with hips and hipped valleys*
Fixed point position	*Possibly none at all ?*
Identified problem/s	Sheets bucking and fixed with carbon screws (some through pan into timber noggins – and in coastal environment (< 200m from sea)
Potential cause/s	Lack of contractor knowledge
Recommended remedial action	Strip and re-roof with standard construction

Section 5 – Additional Comments

Please add any additional comments which you feel would add to this research dissertation and help reduce the instances of failure in halter based aluminium standing seam systems through a greater understanding of factors affecting the accommodation of thermal movement.

Please also see articles on my website.

Appendix B.3 – Respondent 3

Section 1 – Personal Information	
Name:	[redacted]
Company:	[redacted]
Position:	[redacted]
Would you be willing to be contacted to discuss your responses (yes/no)?	Yes
Would you be willing for any comments to be attributed to yourself (yes/no)?	discuss

Section 2 - Experiences

2.1 **Typical Problems**

The following is a list of typical thermal movement problems that can be experienced with halter based aluminium standing seam systems. Please indicate (with an X) those that you have identified on projects.

From a risk perspective, could you also please rate on a scale of 1 – 5 what you consider to be: the severity (S), the occurrence (O) and the likelihood of early detection (D), of the identified problem.

Please use the following rating values:

Severity (S)	***Occurrence (O)***	***Detection (D)***
1 – No noticeable effect	1 – Never	1 – Very high
2 – Low (e.g. appearance)	2 – Very occasionally	2 – High
3 – Medium (e.g. functional failure – weathertightness)	3 – Occasionally	3 – Medium
4 – High (e.g. reduced service life)	4 – Frequently	4 – Low
5 – Very high (e.g. potential safety failure)	5 – Very frequently	5 - Zero

Typical Problem		***Identified***	***S***	***O***	***D***
Halters visible through seams		X	4	4	3
Excessive “clicking” noise		X	3	3	1
Halters penetrating through seam		X	4	3	4
Halters shearing or disconnecting		X	5	3	4
Fasteners shearing or disconnecting		X	5	3	4
Material wear/abrasion of seam		X	4	4	3
Collapse/over-turning of structure			5	2	5
Collapse/over-turning of sub-structure		X	5	2	4
Collapse of substrate (e.g. insulation board)			4	1	4
Failure of fixed point		X	3	3	4
Multiple fixed points		X	3	3	3
Movement restricted by components clamped to seams		X	3	4	3
Splitting/cracking of welds			3	2	4
Buckling of standing seam sheet		X	2	2	4
Buckling of flashing		X	2	2	3
Failure of fasteners in flashings		X	3	3	4
Other (please state)	Failure of seam dams	X	3	3	4

2.2 **Typical Factors Affecting Performance**

The following lists typical factors that can affect thermal movement and may lead to some of the aforementioned problems experienced with halter based aluminium standing seam systems. Please indicate (with an X) those that you have identified on projects.

From a risk perspective, could you also please rate on a scale of 1 – 5, what you consider to be: the severity (S), the occurrence (O) and the likelihood of early detection (D) of the identified factor.

Please use the following rating values:

Severity (S)	***Occurrence (O)***	***Detection (D)***
1 – No noticeable effect	1 – Never	1 – Very high
2 – Low (e.g. appearance)	2 – Very occasionally	2 – High
3 – Medium (e.g. functional failure – weathertightness)	3 – Occasionally	3 – Medium
4 – High (e.g. reduced service life)	4 – Frequently	4 – Low
5 – Very high (e.g. potential safety failure)	5 – Very frequently	5 - Zero

Typical Factors Affecting Performance		***Identified***	***S***	***O***	***D***
Manufacture	Sheet cover width out of production tolerance	X	4	4	4
	Seam too tight	X	4	3	4
	Seam too loose		3	1	5
Structure	Not to System tolerance requirements	X	3	2	4
	Inadequate lateral restraint		5	1	5
Detail design	No, inadequate or multiple “fixed points” to sheets	X	4	4	3
	In-plane force not taken into account in design calculations		3	1	5
	Amount of movement underestimated or ignored	X	5	3	3
	Insufficient movement allowance at details	X	4	4	3
	Inadequate number or type of fasteners specified	X	5	3	3
	Insubstantial sub-structure or substrate specified	X	5	4	3
	Geometry of building not taken into account	X	5	4	2
Installation	Structure not checked for suitability	X	4	3	3
	Halters not set out correctly to System tolerances	X	5	4	2
	Halters installed on compressible material		3	3	3
	Sheets not fully engaged over halters prior to zipping	X	5	3	3
	Incorrect zipper roll sets used for thickness of material		4	2	4
	Zipping machine not maintained or designed for another System	X	3	2	4

		Insufficient movement allowance in flashings	X	4	3	3
		Inadequate fasteners in flashings	X	5	4	4
		Additional components clamped directly over or close to halters	X	4	4	4
	Other (please state)					

Section 3 – Opinions

Using the responses: *strongly agree*, *agree*, *neither agree nor disagree*, *disagree*, *strongly disagree*, please indicate (with an X) what is your opinion of the following statements. Please add additional comments where you feel it is necessary to illustrate your response.

		Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
3.1	There is a fundamental design problem with halter based aluminium standing seam systems with regard to the accommodation of thermal movement					
	Response	X				
	Additional Comments	There is nothing fundamentally wrong with these systems but designers need to be made aware of their limitations.				
3.2	There is a lack of knowledge of this type of problem within the roofing and cladding industry					
	Response	X				
	Additional Comments	The industry itself is aware of the issues I am certain – they are just suppressing it so that it does not affect sales.				
3.3	There is a lack of knowledge of this type of problem by system manufacturers					
	Response				X	
	Additional Comments	The system manufacturers know they have problems but either keep going certain it will ‘work itself out’ or they are not prepared to fully investigate for fear of collapse of the reputation of their product – after all – why point out the shortfalls of something you are selling.				
3.4	There is a lack of clarity as to the type of testing for thermal movement of standing seam systems to determine in-plane forces for use in design calculations					
	Response	X				
	Additional Comments	There are no codified tests or indeed design and standards authority on this form of construction. The CWCT has developed robust documents that are used as industry standards – it would be useful if roof construction systems had similar guidance.				
3.5	Information in System Manufacturer’s BBA certificates relating to thermal movement accommodation is insufficient					
	Response	X				

Section 3 – Opinions

Using the responses: *strongly agree*, *agree*, *neither agree nor disagree*, *disagree*, *strongly disagree*, please indicate (with an X) what is your opinion of the following statements. Please add additional comments where you feel it is necessary to illustrate your response.

		Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
	Additional Comments	Agreed – this is as much because the original lead design source never published this information and the products that have effectively copied this original data has failed to progress information.				
3.6	System manufacturers do not publish results of in-plane forces for use in detail design calculations					
	Response		X			
	Additional Comments					
3.7	Detail design calculations to account for in-plane forces are never carried out on projects					
	Response		X			
	Additional Comments					
3.8	Support steelwork is never specified to the support tolerances required by system manufacturers					
	Response	X				
	Additional Comments	There is a significant disparity between tolerances for steelwork and tolerances for most types of cladding systems. As this is clearly understood by all parties I believe it is the responsibility of the contractor to make tolerance adjustment provision.				
3.9	Roofing and cladding contractors do not have the ability and expertise to install standing seam systems					
	Response		X			
	Additional Comments	But they should have!!				
3.10	Roofing and cladding contractors do not have the ability or expertise to install aluminium					
	Response			X		
	Additional Comments	Not sure if I understand what you are asking here – aluminium coping systems?				
3.11	Many problems are due to poor quality installation					
	Response	X				
	Additional Comments	The system is a site assembled product and so is critical that on site practices are in accordance with the manufacturers recommendations and practices. Any				

Section 3 – Opinions

Using the responses: *strongly agree*, *agree*, *neither agree nor disagree*, *disagree*, *strongly disagree*, please indicate (with an X) what is your opinion of the following statements. Please add additional comments where you feel it is necessary to illustrate your response.

		Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
		changes to speed the process or costs may prove costly at a later date.				
3.12	Training of installers provided by system manufacturers is insufficient					
	Response	X				
	Additional Comments	This appears to be the case – an initial start up training meeting with all and any subsequent fixers is highly recommended.				

Section 4 – Project Specific Information

Please provide some basic information of projects where you have encountered problems due to the restriction of thermal movement in halter based aluminium standing seam systems.

Project 1			
Building type		*Computer Process Building*	
Year built	*2002*	*Year problem found*	*2002*
Support type		*Sinusoidal structural deck*	
Construction		*Double skin with membranes and insulation*	
Halter type		*Aluminium regular height with plastic isolated foot*	
Substructure		*Purlins and primary steel*	
Sheet length		*Maximum 12m*	
Sheet geometry		*Squared with valley joints*	
Fixed point position		*Ridge*	
Identified problem/s		*Water leakage at gutter, splitting valley welds*	
Potential cause/s		*Poor detailing*	
Recommended remedial action		*Strip out and re-roof*	
Project 2			
Building type		*Stadium*	
Year built	*2006*	*Year problem found*	*2011*
Support type		*Primary steel and purlins*	
Construction		*Single skin*	
Halter type		*Aluminium fixed at standard height*	
Substructure		*Aluminium top hat*	
Sheet length		*Maximum 30m*	
Sheet geometry		*Straight to slight curved*	
Fixed point position		*Varies*	
Identified problem/s		*Sheet erosion, poor movement, bent halters, fractured halters, water leaks, poor interfaces, etc*	
Potential cause/s		*Poor construction and system choice – system used in 'innovative' fashion*	
Recommended remedial action		*TBA - ongoing*	

Project 3			
Building type		*e.g. Industrial, retail, stadium, arena, school, office etc.*	
Year built		Year problem found	
Support type		*e.g. purlin, structural deck, timber deck etc.*	
Construction		*e.g. single skin, insulation double skin*	
Halter type		*e.g. material, full height, short etc.*	
Substructure		*e.g. bracket and rail, top-hat, zed etc.*	
Sheet length			
Sheet geometry		*e.g. straight, curved, tapered, tapered & curved, wave-form, complex*	
Fixed point position		*e.g. ridge, eaves, mid-slope*	
Identified problem/s			
Potential cause/s			
Recommended remedial action			

Section 5 – Additional Comments Please add any additional comments which you feel would add to this research dissertation and help reduce the instances of failure in halter based aluminium standing seam systems through a greater understanding of factors affecting the accommodation of thermal movement.
This is a problem that is likely to upset the industry and will generate a lot of resistance against any proposed changes.

Appendix B.4 – Respondent 4

Section 1 – Personal Information	
Name:	[redacted]
Company:	[redacted]
Position:	[redacted]
Would you be willing to be contacted to discuss your responses (yes/no)?	yes
Would you be willing for any comments to be attributed to yourself (yes/no)?	yes

Section 2 - Experiences

2.1

Typical Problems
The following is a list of typical thermal movement problems that can be experienced with halter based aluminium standing seam systems. Please indicate (with an X) those that you have identified on projects.

From a risk perspective, could you also please rate on a scale of 1 – 5 what you consider to be: the severity (S), the occurrence (O) and the likelihood of early detection (D), of the identified problem.

Please use the following rating values:

Severity (S)	***Occurrence (O)***	***Detection (D)***
1 – No noticeable effect	1 – Never	1 – Very high
2 – Low (e.g. appearance)	2 – Very occasionally	2 – High
3 – Medium (e.g. functional failure – weathertightness)	3 – Occasionally	3 – Medium
4 – High (e.g. reduced service life)	4 – Frequently	4 – Low
5 – Very high (e.g. potential safety failure)	5 – Very frequently	5 - Zero

Typical Problem	***Identified***	***S***	***O***	***D***
Halters visible through seams	X	3.5	4	2
Excessive “clicking” noise	X	2	4	2
Halters penetrating through seam	X	2	2	2
Halters shearing or disconnecting		5	1	3
Fasteners shearing or disconnecting	X	5	1	3
Material wear/abrasion of seam	X	5	2	3
Collapse/over-turning of structure	X	5	2	1
Collapse/over-turning of sub-structure	X	4	2	1
Collapse of substrate (e.g. insulation board)		4	1	4
Failure of fixed point	X	4	2	3
Multiple fixed points	X	3	2	2
Movement restricted by components clamped to seams	X	4	2	2
Splitting/cracking of welds	X	4	3	2
Buckling of standing seam sheet		3	2	2
Buckling of flashing	X	4	5	1
Failure of fasteners in flashings	X	4	4	2
Big problem with [redacted]	X	4	3	3

	Other (please state)	[redacted] Thermal Movement				

Would2.2

Typical Factors Affecting Performance
The following lists typical factors that can affect thermal movement and may lead to some of the aforementioned problems experienced with halter based aluminium standing seam systems. Please indicate (with an X) those that you have identified on projects.

From a risk perspective, could you also please rate on a scale of 1 – 5, what you consider to be: the severity (S), the occurrence (O) and the likelihood of early detection (D) of the identified factor.

Please use the following rating values:

Severity (S)	***Occurrence (O)***	***Detection (D)***
1 – No noticeable effect	1 – Never	1 – Very high
2 – Low (e.g. appearance)	2 – Very occasionally	2 – High
3 – Medium (e.g. functional failure – weathertightness)	3 – Occasionally	3 – Medium
4 – High (e.g. reduced service life)	4 – Frequently	4 – Low
5 – Very high (e.g. potential safety failure)	5 – Very frequently	5 - Zero

Typical Factors Affecting Performance		***Identified***	***S***	***O***	***D***
Manufacture	Sheet cover width out of production tolerance *Yes, would not zip*	X	4	2	1
	Seam too tight	X	4	2	1
	Seam too loose				
Structure	Not to System tolerance requirements				
	Inadequate lateral restraint				
Detail design	No, inadequate or multiple “fixed points” to sheets	X	4	3	3
	In-plane force not taken into account in design calculations	X	4	3	2
	Amount of movement underestimated or ignored	X	4	3	2
	Insufficient movement allowance at details	X	4	3	2
	Inadequate number or type of fasteners specified	X	3	3	4
	Insubstantial sub-structure or substrate specified	X	4	2	4
	Geometry of building not taken into account	X	4	2	1
Installation	Structure not checked for suitability	X	4	2	1
	Halters not set out correctly to System tolerances	X	4	4	1
	Halters installed on compressible material		4	1	2
	Sheets not fully engaged over halters prior to zipping	X	4	2	3

		Incorrect zipper roll sets used for thickness of material	X	4	2	2
		Zipping machine not maintained or designed for another System	X	3	3	3
		Insufficient movement allowance in flashings	X	4	5	1
		Inadequate fasteners in flashings	X	4	5	1
		Additional components clamped directly over or close to halters	X	4	2	3
	Other (please state)					

Section 3 – Opinions

Using the responses: *strongly agree*, *agree*, *neither agree nor disagree*, *disagree*, *strongly disagree*, please indicate (with an X) what is your opinion of the following statements. Please add additional comments where you feel it is necessary to illustrate your response.

		Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
3.1	There is a fundamental design problem with halter based aluminium standing seam systems with regard to the accommodation of thermal movement					
	Response				Disagree	
	Additional Comments	If engineered correctly OK No problem on massive projects such as [redacted] Project Engineered in house and correctly supervised at site. No problems whatsoever				
3.2	There is a lack of knowledge of this type of problem within the roofing and cladding industry					
	Response	Yes				
	Additional Comments	Major lack of knowledge about standing seam Fixed points and thermal expansion Contractors are tending to ignore thermal expansion				
3.3	There is a lack of knowledge of this type of problem by system manufacturers					
	Response	Yes				
	Additional Comments	Good knowledge at [redacted], [redacted]. Big errors made by [redacted]. Some well-known suppliers have little knowledge of expansion and fixed points. [redacted]				

Section 3 – Opinions

Using the responses: *strongly agree*, *agree*, *neither agree nor disagree*, *disagree*, *strongly disagree*, please indicate (with an X) what is your opinion of the following statements. Please add additional comments where you feel it is necessary to illustrate your response.

		Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
3.4	There is a lack of clarity as to the type of testing for thermal movement of standing seam systems to determine in-plane forces for use in design calculations					
	Response	Yes				
	Additional Comments	[redacted], [redacted] and [redacted] have all had tests carried out in relation to in-plane forces. [redacted] when interviewed had no knowledge of in plane forces and lock up.				
3.5	Information in System Manufacturer's BBA certificates relating to thermal movement accommodation is insufficient					
	Response	Yes				
	Additional Comments					
3.6	System manufacturers do not publish results of in-plane forces for use in detail design calculations					
	Response	Yes				
	Additional Comments					
3.7	Detail design calculations to account for in-plane forces are never carried out on projects					
	Response	Yes				
	Additional Comments	Some difficulty as setting out has an impact on in plane force. [redacted] has Always used the [redacted] graphs and research. Careful approach required for tall halters.				
3.8	Support steelwork is never specified to the support tolerances required by system manufacturers					
	Response	Yes				
	Additional Comments	The removal of tie rods can be an issue for clip stability				
3.9	Roofing and cladding contractors do not have the ability and expertise to install standing seam systems					
	Response			Yes		
	Additional Comments	Some have been very good. Example [redacted]. Some have been poor including the [redacted] Contractor who installed the 300 x 65 and [redacted].				

Section 3 – Opinions

Using the responses: *strongly agree*, *agree*, *neither agree nor disagree*, *disagree*, *strongly disagree*, please indicate (with an X) what is your opinion of the following statements. Please add additional comments where you feel it is necessary to illustrate your response.

		Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
3.10	Roofing and cladding contractors do not have the ability or expertise to install aluminium					
	Response					
	Additional Comments					
3.11	Many problems are due to poor quality installation					
	Response	Yes				
	Additional Comments	In the last four years many contractors have stopped generating shop details. The fixing regime is left to operatives which is very bad practice.				
3.12	Training of installers provided by system manufacturers is insufficient					
	Response					
	Additional Comments	BBA has a poor knowledge of standing seam and the movement issues. [redacted] has a Agrement Certificate for [redacted] This fails at very modest slope lengths due to expansion.				

Section 5 – Additional Comments

Please add any additional comments which you feel would add to this research dissertation and help reduce the instances of failure in halter based aluminium standing seam systems through a greater understanding of factors affecting the accommodation of thermal movement.

Private

We are short on dates but note the following.

[redacted]

We have recently inspected two projects where there are unwanted fixed points and expansion problems. Results in leakage at end laps. [redacted] do not understand thermal movement and the issue of fixed points. [redacted]. Problem occurs with aluminium standing seam foamed panels in slopes. Circa 25m + The system was designed by [redacted] and has never worked. There was cracking of sheets at [redacted] due to collision with upstands leakage of end laps at [redacted]

[redacted]

Blow off failure due to poor installation of fasteners clip rotation tolerance combined with high wind loads and expansion. Clip fixation damaged and high winds did the rest.

[redacted] sheets buckling, clips telegraphed through sheet very poor appearance. Likely to leak by now.

[redacted] **- metal zinc not alu.**
Bar and bracket support. Rotation of clips, lockup, buckling of sheets, holes in sheet.

[redacted] **Project Domestic Dwellings** [redacted]
Unwanted fixed points, sheets not seamed and not safe due to contractor ignorance and error. Likely to blow off when inspected by [redacted].

I am of the opinion that there is a major latent defect problem with [redacted] or [redacted] copies. These problems do not always show up until there is a major storm.

There is a [redacted] system with 85m barrel vaulted slope at [redacted]
The default fixed point must be the crown so the bar and bracket system must accommodate 42m of movement each side of the crown and the clips will rotate and be levered out of the seam, clip failure (bar & bracket) or fastener pull out.

Was a live airfield for jets when inspected by [redacted].

David let me have a copy when complete.

Appendix B.5 – Respondent 5

Section 1 – Personal Information	
Name:	[redacted]
Company:	[redacted]
Position:	[redacted]
Would you be willing to be contacted to discuss your responses (yes/no)?	y
Would you be willing for any comments to be attributed to yourself (yes/no)?	y

Section 2 – Experiences

2.1 **Typical Problems**

The following is a list of typical thermal movement problems that can be experienced with halter based aluminium standing seam systems. Please indicate (with an X) those that you have identified on projects.

From a risk perspective, could you also please rate on a scale of 1 – 5 what you consider to be: the severity (S), the occurrence (O) and the likelihood of early detection (D), of the identified problem.

Please use the following rating values:

Severity (S)	***Occurrence (O)***	***Detection (D)***
1 – No noticeable effect	1 – Never	1 – Very high
2 – Low (e.g. appearance)	2 – Very occasionally	2 – High
3 – Medium (e.g. functional failure – weathertightness)	3 – Occasionally	3 – Medium
4 – High (e.g. reduced service life)	4 – Frequently	4 – Low
5 – Very high (e.g. potential safety failure)	5 – Very frequently	5 - Zero

Typical Problem		***Identified***	***S***	***O***	***D***
Halters visible through seams		X	2	4	2
Excessive “clicking” noise		X	1	5	2
Halters penetrating through seam		X	3	2	5
Halters shearing or disconnecting		X	5	2	4
Fasteners shearing or disconnecting					
Material wear/abrasion of seam					
Collapse/over-turning of structure					
Collapse/over-turning of sub-structure					
Collapse of substrate (e.g. insulation board)		X	3	3	5
Failure of fixed point		X	4	2	5
Multiple fixed points		X	4	4	2
Movement restricted by components clamped to seams					
Splitting/cracking of welds		X	3	3	2
Buckling of standing seam sheet		X	3	4	2
Buckling of flashing		X	3	4	2
Failure of fasteners in flashings		X	5	4	1
Other (please state)					

2.2

Typical Factors Affecting Performance

The following lists typical factors that can affect thermal movement and may lead to some of the aforementioned problems experienced with halter based aluminium standing seam systems. Please indicate (with an X) those that you have identified on projects.

From a risk perspective, could you also please rate on a scale of 1 – 5, what you consider to be: the severity (S), the occurrence (O) and the likelihood of early detection (D) of the identified factor.

Please use the following rating values:

Severity (S)	***Occurrence (O)***	***Detection (D)***
1 – No noticeable effect	1 – Never	1 – Very high
2 – Low (e.g. appearance)	2 – Very occasionally	2 – High
3 – Medium (e.g. functional failure – weathertightness)	3 – Occasionally	3 – Medium
4 – High (e.g. reduced service life)	4 – Frequently	4 – Low
5 – Very high (e.g. potential safety failure)	5 – Very frequently	5 - Zero

Typical Factors Affecting Performance		***Identified***	***S***	***O***	***D***
Manufacture	Sheet cover width out of production tolerance	X	4	2	3
	Seam too tight	X	3	2	2
	Seam too loose				
Structure	Not to System tolerance requirements	X	4	4	1
	Inadequate lateral restraint				
Detail design	No, inadequate or multiple “fixed points” to sheets	X	5	3	2
	In-plane force not taken into account in design calculations				
	Amount of movement underestimated or ignored	X	4	4	2
	Insufficient movement allowance at details	X	4	4	2
	Inadequate number or type of fasteners specified	X	5	3	2
	Insubstantial sub-structure or substrate specified	X	5	2	2
	Geometry of building not taken into account				
Installation	Structure not checked for suitability	X	4	3	3
	Halters not set out correctly to System tolerances	X	4	4	2
	Halters installed on compressible material				
	Sheets not fully engaged over halters prior to zipping	X	5	3	2
	Incorrect zipper roll sets used for thickness of material	X	5	2	3
	Zipping machine not maintained or designed for another System	X	5	4	2

		Insufficient movement allowance in flashings	X	4	3	3
		Inadequate fasteners in flashings	X	5	4	2
		Additional components clamped directly over or close to halters	X	3	2	2
	Other (please state)					

Section 3 – Opinions

Using the responses: *strongly agree*, *agree*, *neither agree nor disagree*, *disagree*, *strongly disagree*, please indicate (with an X) what is your opinion of the following statements. Please add additional comments where you feel it is necessary to illustrate your response.

		Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
3.1	There is a fundamental design problem with halter based aluminium standing seam systems with regard to the accommodation of thermal movement					
	Response				X	
	Additional Comments					
3.2	There is a lack of knowledge of this type of problem within the roofing and cladding industry					
	Response		X			
	Additional Comments					
3.3	There is a lack of knowledge of this type of problem by system manufacturers					
	Response				X	
	Additional Comments					
3.4	There is a lack of clarity as to the type of testing for thermal movement of standing seam systems to determine in-plane forces for use in design calculations					
	Response	X				
	Additional Comments					
3.5	Information in System Manufacturer's BBA certificates relating to thermal movement accommodation is insufficient					
	Response		X			
	Additional Comments					

Section 3 – Opinions

Using the responses: *strongly agree*, *agree*, *neither agree nor disagree*, *disagree*, *strongly disagree*, please indicate (with an X) what is your opinion of the following statements. Please add additional comments where you feel it is necessary to illustrate your response.

		Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
3.6	System manufacturers do not publish results of in-plane forces for use in detail design calculations					
	Response	X				
	Additional Comments					
3.7	Detail design calculations to account for in-plane forces are never carried out on projects					
	Response		X			
	Additional Comments					
3.8	Support steelwork is never specified to the support tolerances required by system manufacturers					
	Response			X		
	Additional Comments					
3.9	Roofing and cladding contractors do not have the ability and expertise to install standing seam systems					
	Response					X
	Additional Comments					
3.10	Roofing and cladding contractors do not have the ability or expertise to install aluminium					
	Response					X
	Additional Comments					
3.11	Many problems are due to poor quality installation					
	Response	X				
	Additional Comments					
3.12	Training of installers provided by system manufacturers is insufficient					
	Response		X			
	Additional Comments					

Section 4 – Project Specific Information

Please provide some basic information of projects where you have encountered problems due to the restriction of thermal movement in halter based aluminium standing seam systems.

Project 1 **CONFIDENTIAL**			
Building type		[redacted]	
Year built		Year problem found	[redacted]
Support type		[redacted]	
Construction		[redacted]	
Halter type		[redacted]	
Substructure		[redacted]	
Sheet length		[redacted]	
Sheet geometry		[redacted]	
Fixed point position		[redacted]	
Identified problem/s		[redacted], [redacted] [redacted], [redacted] [redacted]	
Potential cause/s		[redacted]	
Recommended remedial action		[redacted]	
Project 2			
Building type		*Industrial*	
Year built	*1995*	Year problem found	*2011*
Support type		*Purlin*	
Construction		*Built up*	
Halter type		*Full height into liner*	
Substructure		*Fixed through liner into purlin*	
Sheet length		*50m overall but with riveted endlap*	
Sheet geometry		*straight*	
Fixed point position		*Mid point adjacent to endlap*	
Identified problem/s		Halters shearing through sheets in places	
Potential cause/s		Halter positioning	
Recommended remedial action		Replace roof or patch	
Project 3			
Building type		*Leisure Complex*	
Year built	*2012*	Year problem found	*2014*
Support type		*Glulam beams*	
Construction		*Double Skin structural deck*	
Halter type		*Full height*	
Substructure		*Top hat*	
Sheet length		*60m*	
Sheet geometry		*waveform*	
Fixed point position		*e.g. ridge, eaves, mid-slope*	
Identified problem/s		Welds splitting at rooflights	
Potential cause/s		Lack of movement	
Recommended remedial action		Allow movement at interface	

Section 5 – Additional Comments

Please add any additional comments which you feel would add to this research dissertation and help reduce the instances of failure in halter based aluminium standing seam systems through a greater understanding of factors affecting the accommodation of thermal movement.

Whilst there are design issues labour needs better training

Large aluminium flashing should be weathered below and better movement provision provided. Sealants are unable to cope with the movement

There have been many examples of flashings blowing off

Appendix B.6 – Respondent 6

Section 1 – Personal Information	
Name:	[redacted]
Company:	[redacted]
Position:	[redacted]
Would you be willing to be contacted to discuss your responses (yes/no)?	***Yes***
Would you be willing for any comments to be attributed to yourself (yes/no)?	***Yes***

Section 2 - Experiences

2.1 **Typical Problems**

The following is a list of typical thermal movement problems that can be experienced with halter based aluminium standing seam systems. Please indicate (with an X) those that you have identified on projects.

From a risk perspective, could you also please rate on a scale of 1 – 5 what you consider to be: the severity (S), the occurrence (O) and the likelihood of early detection (D), of the identified problem.

Please use the following rating values:

Severity (S)	***Occurrence (O)***	***Detection (D)***
1 – No noticeable effect	1 – Never	1 – Very high
2 – Low (e.g. appearance)	2 – Very occasionally	2 – High
3 – Medium (e.g. functional failure – weathertightness)	3 – Occasionally	3 – Medium
4 – High (e.g. reduced service life)	4 – Frequently	4 – Low
5 – Very high (e.g. potential safety failure)	5 – Very frequently	5 - Zero

Typical Problem	***Identified***	***S***	***O***	***D***
Halters visible through seams ***(`Shadowing`)***	***X***	***4***	***4***	***3***
Excessive “clicking” noise	***X***	***3***	***4***	***3***
Halters penetrating through seam	***X***	***5***	***3***	***3***
Halters shearing or disconnecting	***X***	***3***	***3***	***4***
Fasteners shearing or disconnecting	***X***	***2***	***2***	***3***
Material wear/abrasion of seam	***X***	***3***	***2***	***3***
Collapse/over-turning of structure	***X***	***2***	***2***	***3***
Collapse/over-turning of sub-structure	***X***	***2***	***2***	***3***
Collapse of substrate (e.g. insulation board)	***X***	***2***	***2***	***4***
Failure of fixed point	***X***	***3***	***3***	***4***
Multiple fixed points	***X***	***2***	***2***	***3***
Movement restricted by components clamped to seams	***X***	***3***	***3***	***3***
Splitting/cracking of welds	***X***	***3***	***3***	***3***
Buckling of standing seam sheet	***X***	***2***	***2***	***3***
Buckling of flashing	***X***	***3***	***4***	***2***
Failure of fasteners in flashings	***X***	***4***	***5***	***2***
Other (please state)				

2.2

Typical Factors Affecting Performance

The following lists typical factors that can affect thermal movement and may lead to some of the aforementioned problems experienced with halter based aluminium standing seam systems. Please indicate (with an X) those that you have identified on projects.

From a risk perspective, could you also please rate on a scale of 1 – 5, what you consider to be: the severity (S), the occurrence (O) and the likelihood of early detection (D) of the identified factor.

Please use the following rating values:

Severity (S)	***Occurrence (O)***	***Detection (D)***
1 – No noticeable effect	1 – Never	1 – Very high
2 – Low (e.g. appearance)	2 – Very occasionally	2 – High
3 – Medium (e.g. functional failure – weathertightness)	3 – Occasionally	3 – Medium
4 – High (e.g. reduced service life)	4 – Frequently	4 – Low
5 – Very high (e.g. potential safety failure)	5 – Very frequently	5 - Zero

Typical Factors Affecting Performance		***Identified***	***S***	***O***	***D***
Manufacture	Sheet cover width out of production tolerance	***X***	***2***	***2***	***4***
	Seam too tight	***X***	***2***	***2***	***4***
	Seam too loose	***X***	***2***	***2***	***4***
Structure	Not to System tolerance requirements	***X***	***3***	***5***	***2***
	Inadequate lateral restraint	***X***	***3***	***4***	***3***
Detail design	No, inadequate or multiple “fixed points” to sheets	***X***	***4***	***3***	***3***
	In-plane force not taken into account in design calculations	***X***	***3***	***3***	***3***
	Amount of movement underestimated or ignored	***X***	***3***	***3***	***3***
	Insufficient movement allowance at details	***X***	***3***	***3***	***3***
	Inadequate number or type of fasteners specified	***X***	***2***	***2***	***4***
	Insubstantial sub-structure or substrate specified	***X***	***2***	***3***	***3***
	Geometry of building not taken into account	***X***	***3***	***3***	***3***
Installation	Structure not checked for suitability	***X***	***3***	***4***	***3***
	Halters not set out correctly to System tolerances	***X***	***4***	***3***	***3***
	Halters installed on compressible material	***X***	***2***	***3***	***3***
	Sheets not fully engaged over halters prior to zipping	***X***	***3***	***3***	***3***
	Incorrect zipper roll sets used for thickness of material	***X***	***3***	***3***	***4***
	Zipping machine not maintained or designed for another System	***X***	***4***	***4***	***2***

		Insufficient movement allowance in flashings	***X***	***5***	***4***	***1***
		Inadequate fasteners in flashings	***X***	***3***	***4***	***2***
		Additional components clamped directly over or close to halters	***X***	***2***	***3***	***3***
	Other (please state)					

Section 3 – Opinions

Using the responses: _strongly agree_, _agree_, _neither agree nor disagree_, _disagree_, _strongly disagree_, please indicate (with an X) what is your opinion of the following statements. Please add additional comments where you feel it is necessary to illustrate your response.

		Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
3.1	There is a fundamental design problem with halter based aluminium standing seam systems with regard to the accommodation of thermal movement					
	Response		***X***			
	Additional Comments	***Designers having a full appreciation of the fundamental principles of aluminium standing seam systems especially the tight tolerances required for any type of substructure (i.e. steelwork, timber etc.).***				
3.2	There is a lack of knowledge of this type of problem within the roofing and cladding industry					
	Response	***X***				
	Additional Comments	***This lack of knowledge/training extends to both the roofing contractors design team and especially where the site operatives are concerned – very often sub-contract labour sourced.***				
3.3	There is a lack of knowledge of this type of problem by system manufacturers					
	Response			***X***		
	Additional Comments	***Any manufacturer of the aluminium standing seam system should have full knowledge of the basic principles of the system and offer all `back up` from a technical point of view with appropriate data.***				
3.4	There is a lack of clarity as to the type of testing for thermal movement of standing seam systems to determine in-plane forces for use in design calculations					
	Response	***X***				
	Additional Comments	***There appears to be no agreed testing regime for thermal movement to determine `in-plane` forces.***				
3.5	Information in System Manufacturer's BBA certificates relating to thermal movement accommodation is insufficient					
	Response		***X***			

Section 3 – Opinions

Using the responses: *strongly agree*, *agree*, *neither agree nor disagree*, *disagree*, *strongly disagree*, please indicate (with an X) what is your opinion of the following statements. Please add additional comments where you feel it is necessary to illustrate your response.

		Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
	Additional Comments	***Tendency for new manufacturers to follow the BBA format of the `original` aluminium standing seam manufacturers and copy their Technical Data sheets for `in-plane` forces.***				
3.6	System manufacturers do not publish results of in-plane forces for use in detail design calculations					
	Response		***X***			
	Additional Comments					
3.7	Detail design calculations to account for in-plane forces are never carried out on projects					
	Response		***X***			
	Additional Comments					
3.8	Support steelwork is never specified to the support tolerances required by system manufacturers					
	Response	***X***				
	Additional Comments					
3.9	Roofing and cladding contractors do not have the ability and expertise to install standing seam systems					
	Response	***X***				
	Additional Comments	***Roofing contractors tend to employ sub-contract labour rather than employ directly. Therefore the training, experience and qualification of these operatives is questionable.***				
3.10	Roofing and cladding contractors do not have the ability or expertise to install aluminium					
	Response		***X***			
	Additional Comments	***Suggestion that all roofing contractors are licenced to install their system and operatives undergo a recognised training (i.e. similar to CSCS testing).***				
3.11	Many problems are due to poor quality installation					
	Response	***X***				

Section 3 – Opinions Using the responses: *strongly agree*, *agree*, *neither agree nor disagree*, *disagree*, *strongly disagree*, please indicate (with an X) what is your opinion of the following statements. Please add additional comments where you feel it is necessary to illustrate your response.						
		Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
	Additional Comments	***Lack of training a quality of workmanship of operative***				
3.12	Training of installers provided by system manufacturers is insufficient					
	Response		***X***			
	Additional Comments	***As mentioned previously a form of certified competency needs to be introduced.***				

Section 4 – Project Specific Information Please provide some basic information of projects where you have encountered problems due to the restriction of thermal movement in halter based aluminium standing seam systems.	
Project 1	
Building type	***Distribution Centre***
Year built	***2012***
Support type	***Galv. zed purlins on rafters***
Construction	***Insulation double skin***
Halter type	***Full height***.
Substructure	***Zed rail***
Sheet length	***60metres +***
Sheet geometry	***Natural curved***
Fixed point position	***Ridge***
Identified problem/s	***Penetration of seam walls and roll***
Potential cause/s	***Rotation due to thermal movement and misaligned halter clips***
Recommended remedial action	***Replacement***

Section 5 – Additional Comments Please add any additional comments which you feel would add to this research dissertation and help reduce the instances of failure in halter based aluminium standing seam systems through a greater understanding of factors affecting the accommodation of thermal movement.
It is extremely difficult (if neigh impossible) to simulate natural thermal movement in a laboratory on the aluminium standing seam system due to the numerous factors that will have a serious effect on its theoretical design performance. One does not know how natural heating of the sheet profile is dissipated through the profile of the sheet (i.e. seam and pan). Personal experience found that failures are not generally attributed to one particular condition but possibly to a combination of conditions as highlighted in the questionnaire above.

Appendix B.7 – Respondent 7

Section 1 – Personal Information	
Name:	[redacted]
Company:	[redacted]
Position:	[redacted]
Would you be willing to be contacted to discuss your responses (yes/no)?	yes
Would you be willing for any comments to be attributed to yourself (yes/no)?	yes

Section 2 - Experiences

2.1 **Typical Problems**

The following is a list of typical thermal movement problems that can be experienced with halter based aluminium standing seam systems. Please indicate (with an X) those that you have identified on projects.

From a risk perspective, could you also please rate on a scale of 1 – 5 what you consider to be: the severity (S), the occurrence (O) and the likelihood of early detection (D), of the identified problem.

Please use the following rating values:

Severity (S)	***Occurrence (O)***	***Detection (D)***
1 – No noticeable effect	1 – Never	1 – Very high
2 – Low (e.g. appearance)	2 – Very occasionally	2 – High
3 – Medium (e.g. functional failure – weathertightness)	3 – Occasionally	3 – Medium
4 – High (e.g. reduced service life)	4 – Frequently	4 – Low
5 – Very high (e.g. potential safety failure)	5 – Very frequently	5 - Zero

Typical Problem	***Identified***	***S***	***O***	***D***
Halters visible through seams	X	3	3	4
Excessive “clicking” noise	X	2	2	1
Halters penetrating through seam	X	3	3	4
Halters shearing or disconnecting				
Fasteners shearing or disconnecting	X	4	2	3
Material wear/abrasion of seam	X	2	3	4
Collapse/over-turning of structure			1	
Collapse/over-turning of sub-structure			1	
Collapse of substrate (e.g. insulation board)			1	
Failure of fixed point	X	4	2	3
Multiple fixed points	X	4	2	4
Movement restricted by components clamped to seams	X	4	3	2
Splitting/cracking of welds	X	4	3	2
Buckling of standing seam sheet	X	3	3	4
Buckling of flashing	X	3	3	2
Failure of fasteners in flashings	X	4	3	2
Other (please state) Failure of fasteners in flashings to rigid wall e.g. block	X	5	3	2

2.2 **Typical Factors Affecting Performance**

The following lists typical factors that can affect thermal movement and may lead to some of the aforementioned problems experienced with halter based aluminium standing seam systems. Please indicate (with an X) those that you have identified on projects.

From a risk perspective, could you also please rate on a scale of 1 – 5, what you consider to be: the severity (S), the occurrence (O) and the likelihood of early detection (D) of the identified factor.

Please use the following rating values:

Severity (S)	***Occurrence (O)***	***Detection (D)***
1 – No noticeable effect	1 – Never	1 – Very high
2 – Low (e.g. appearance)	2 – Very occasionally	2 – High
3 – Medium (e.g. functional failure – weathertightness)	3 – Occasionally	3 – Medium
4 – High (e.g. reduced service life)	4 – Frequently	4 – Low
5 – Very high (e.g. potential safety failure)	5 – Very frequently	5 - Zero

Typical Factors Affecting Performance		***Identified***	***S***	***O***	***D***
Manufacture	Sheet cover width out of production tolerance	X	2	3	4
	Seam too tight			1	
	Seam too loose	X	4	2	4
Structure	Not to System tolerance requirements	X	3	3	4
	Inadequate lateral restraint			1	
Detail design	No, inadequate or multiple “fixed points” to sheets	X	3	3	2
	In-plane force not taken into account in design calculations	X	4	4	4
	Amount of movement underestimated or ignored	X	3	2	3
	Insufficient movement allowance at details	X	3	2	3
	Inadequate number or type of fasteners specified	X	4	2	4
	Insubstantial sub-structure or substrate specified	x	4	2	2
	Geometry of building not taken into account	X	2	2	3
Installation	Structure not checked for suitability	X	4	2	4
	Halters not set out correctly to System tolerances	X	4	3	3
	Halters installed on compressible material			1	
	Sheets not fully engaged over halters prior to zipping	X	4	2	3
	Incorrect zipper roll sets used for thickness of material	X	4	2	3
	Zipping machine not maintained or designed for another System			1	

		Insufficient movement allowance in flashings	X	4	3	3
		Inadequate fasteners in flashings	X	4	3	3
		Additional components clamped directly over or close to halters	X	4	4	3
	Other (please state)					

Section 3 – Opinions

Using the responses: *strongly agree*, *agree*, *neither agree nor disagree*, *disagree*, *strongly disagree*, please indicate (with an X) what is your opinion of the following statements. Please add additional comments where you feel it is necessary to illustrate your response.

		Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
3.1	There is a fundamental design problem with halter based aluminium standing seam systems with regard to the accommodation of thermal movement					
	Response	x				
	Additional Comments	On curved, hips and other angled intersections.				
3.2	There is a lack of knowledge of this type of problem within the roofing and cladding industry					
	Response	x				
	Additional Comments	Roofers doing detail design often have little understanding of the problem at the perimeter of the roof.				
3.3	There is a lack of knowledge of this type of problem by system manufacturers					
	Response		x			
	Additional Comments	Some profilers seem to have very little technical back-up.				
3.4	There is a lack of clarity as to the type of testing for thermal movement of standing seam systems to determine in-plane forces for use in design calculations					
	Response	x				
	Additional Comments	One major profiling competitor to [redacted] is either unable or refuses to disclose information, probably “unable”.				
3.5	Information in System Manufacturer’s BBA certificates relating to thermal movement accommodation is insufficient					
	Response		x			
	Additional Comments	Expansion per m is too simplistic without additional information on how and where to allow for the movement e.g. on long slopes the space required in theory for the gutter end of the roof sheets to move.				

Section 3 – Opinions

Using the responses: *strongly agree*, *agree*, *neither agree nor disagree*, *disagree*, *strongly disagree*, please indicate (with an X) what is your opinion of the following statements. Please add additional comments where you feel it is necessary to illustrate your response.

		Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
3.6	System manufacturers do not publish results of in-plane forces for use in detail design calculations					
	Response	x				
	Additional Comments	See 3.4 above				
3.7	Detail design calculations to account for in-plane forces are never carried out on projects					
	Response		x			
	Additional Comments	Unless someone asks and even then results are not always made available.				
3.8	Support steelwork is never specified to the support tolerances required by system manufacturers					
	Response		x			
	Additional Comments	Where it is the purlin for fixed point is often altered but this rarely occurs on projects.				
3.9	Roofing and cladding contractors do not have the ability and expertise to install standing seam systems					
	Response			x		
	Additional Comments	Need more specific product training.				
3.10	Roofing and cladding contractors do not have the ability or expertise to install aluminium					
	Response		x			
	Additional Comments	As 3.9 but more frequently get it wrong.				
3.11	Many problems are due to poor quality installation					
	Response		x			
	Additional Comments					
3.12	Training of installers provided by system manufacturers is insufficient					
	Response		x			
	Additional Comments	Results depend on how the roofer remembers the training and how many of the gang are trained.				

Section 4 – Project Specific Information

Please provide some basic information of projects where you have encountered problems due to the restriction of thermal movement in halter based aluminium standing seam systems.

Project 1

Building type	*University roof in Ireland using zinc rolled on-site by aluminium standing seam profiler. Long S shape curves in single length.*
Year built	
Year problem found	*2009*
Support type	*e.g. purlin, structural deck, timber deck etc. structural deck*
Construction	*e.g. single skin, insulation double skin insulated double skin*
Halter type	*e.g. short*
Substructure	*e.g. top hat + bracket and rail,.*
Sheet length	
Sheet geometry	*e.g. wave-form, complex S shape*
Fixed point position	*e.g. various or none varied along roof*
Identified problem/s	Zinc sheets torn, halters penetrated roof, halter screws backed out, welds failed
Potential cause/s	Movement in opposing directions, no adequate fixed points and no gaps for thermal movement.
Recommended remedial action	Roof was replaced.

Project 2

Building type	*school*
Year built	
Year problem found	
Support type	*structural deck,.*
Construction	*insulation double skin*
Halter type	*short etc.*
Substructure	*, top-hat,*
Sheet length	*Approx 20m*
Sheet geometry	*shallow wave-form,*
Fixed point position	*Not discovered*
Identified problem/s	Noise – clicking as sheet caught and then slipped on halters, halters starting to show through standing seam.
Potential cause/s	Thermal movement
Recommended remedial action	Confirm where fixed point should be and check if any installed, possible break barrel vault from rest of S shape. Don't know what if any solution was adopted, budget would not pay for much work so may be still in use as-built.

Project 3

Building type	*University*
Year built	
Year problem found	*2009*
Support type	*e.g. purlin,*
Construction	*insulation aluminium standing seam panels*
Halter type	*e.g. material, full height,*
Substructure	*e.g. na.*
Sheet length	*32m*
Sheet geometry	*e.g. straight,*

Fixed point position	*e.g. ridge,*
Identified problem/s	Weld failures around numerous roof penetrations which acted as secondary fixed points, leaks through joints including welded panel end-laps. Verge trims 32m long fixed both sides to butt straps and to roof sheets and rigid to block wall, verge was stronger than block wall and took some blocks out.
Potential cause/s	No design for thermal movement.
Recommended remedial action	All roof penetration welds cut to allow movement, sealed over with local flexible membrane. Verge re-designed and 100% replaced.

Section 5 – Additional Comments

Please add any additional comments which you feel would add to this research dissertation and help reduce the instances of failure in halter based aluminium standing seam systems through a greater understanding of factors affecting the accommodation of thermal movement.

Aluminium perimeter flashings including ridge and verge may have profilers designed thermal movement between roof sheets and trim but are fixed to both sides of butt straps and often to rigid walls with no clearance holes at fasteners including curtain walling, steel faced cladding and as above various types of block work etc.

Tolerances on halter set out especially when a whole roof is set out before the site rolled sheets are supplied and these roofs are often curved requiring a difference in set out tolerance.

Getting halters at right angles to spacer bars with in MCRMA tolerance.
Getting spacer bars or purlins to achieve MCRMA tolerances at top of halter assembly.

Getting two screws of the correct type in the correct holes for halter and more when required, nobody reads the fixing instructions.

Appendix B.8 – Respondent 8

Section 1 – Personal Information	
Name:	[redacted]
Company:	[redacted]
Position:	[redacted]
Would you be willing to be contacted to discuss your responses (yes/no)?	yes
Would you be willing for any comments to be attributed to yourself (yes/no)?	yes

Section 2 - Experiences

2.1 **Typical Problems**

The following is a list of typical thermal movement problems that can be experienced with halter based aluminium standing seam systems. Please indicate (with an X) those that you have identified on projects.

From a risk perspective, could you also please rate on a scale of 1 – 5 what you consider to be: the severity (S), the occurrence (O) and the likelihood of early detection (D), of the identified problem.

Please use the following rating values:

Severity (S)	***Occurrence (O)***	***Detection (D)***
1 – No noticeable effect	1 – Never	1 – Very high
2 – Low (e.g. appearance)	2 – Very occasionally	2 – High
3 – Medium (e.g. functional failure – weathertightness)	3 – Occasionally	3 – Medium
4 – High (e.g. reduced service life)	4 – Frequently	4 – Low
5 – Very high (e.g. potential safety failure)	5 – Very frequently	5 - Zero

Typical Problem	***Identified***	***S***	***O***	***D***
Halters visible through seams	X	2	4	3
Excessive “clicking” noise	X	1	3	2
Halters penetrating through seam	X	3	2	3
Halters shearing or disconnecting	X	5	2	3
Fasteners shearing or disconnecting	X	5	2	4
Material wear/abrasion of seam	X	3	2	4
Collapse/over-turning of structure				
Collapse/over-turning of sub-structure	X	5	2	2
Collapse of substrate (e.g. insulation board)				
Failure of fixed point	X	4	3	3
Multiple fixed points				
Movement restricted by components clamped to seams	X	3	2	3
Splitting/cracking of welds	X	3	4	2
Buckling of standing seam sheet	X	4	3	2
Buckling of flashing	X	4	4	1
Failure of fasteners in flashings	X	5	4	1
Other (please state)				

2.2

Typical Factors Affecting Performance

The following lists typical factors that can affect thermal movement and may lead to some of the aforementioned problems experienced with halter based aluminium standing seam systems. Please indicate (with an X) those that you have identified on projects.

From a risk perspective, could you also please rate on a scale of 1 – 5, what you consider to be: the severity (S), the occurrence (O) and the likelihood of early detection (D) of the identified factor.

Please use the following rating values:

Severity (S)	***Occurrence (O)***	***Detection (D)***
1 – No noticeable effect	1 – Never	1 – Very high
2 – Low (e.g. appearance)	2 – Very occasionally	2 – High
3 – Medium (e.g. functional failure – weathertightness)	3 – Occasionally	3 – Medium
4 – High (e.g. reduced service life)	4 – Frequently	4 – Low
5 – Very high (e.g. potential safety failure)	5 – Very frequently	5 - Zero

Typical Factors Affecting Performance		***Identified***	***S***	***O***	***D***
Manufacture	Sheet cover width out of production tolerance	x	2	2	4
	Seam too tight	x	2	2	3
	Seam too loose	x	4	3	3
Structure	Not to System tolerance requirements	x	4	4	2
	Inadequate lateral restraint				
Detail design	No, inadequate or multiple “fixed points” to sheets	x	4	2	3
	In-plane force not taken into account in design calculations				
	Amount of movement underestimated or ignored	x	3	2	3
	Insufficient movement allowance at details	x	4	4	2
	Inadequate number or type of fasteners specified	x	5	2	3
	Insubstantial sub-structure or substrate specified				
	Geometry of building not taken into account				
Installation	Structure not checked for suitability	x	4	4	2
	Halters not set out correctly to System tolerances	x	3	2	3
	Halters installed on compressible material	x	5	2	3
	Sheets not fully engaged over halters prior to zipping	x	4	3	2
	Incorrect zipper roll sets used for thickness of material	x	3	2	3
	Zipping machine not maintained or designed for another System	x	4	2	3

		Insufficient movement allowance in flashings	x	4	3	3
		Inadequate fasteners in flashings	x	5	3	2
		Additional components clamped directly over or close to halters	x	5	3	2
	Other (please state)					

Section 3 – Opinions

Using the responses: *strongly agree*, *agree*, *neither agree nor disagree*, *disagree*, *strongly disagree*, please indicate (with an X) what is your opinion of the following statements. Please add additional comments where you feel it is necessary to illustrate your response.

		Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
3.1	There is a fundamental design problem with halter based aluminium standing seam systems with regard to the accommodation of thermal movement					
	Response			x		
	Additional Comments					
3.2	There is a lack of knowledge of this type of problem within the roofing and cladding industry					
	Response		x			
	Additional Comments	Especially where Aluminium sheets are used in longer lengths				
3.3	There is a lack of knowledge of this type of problem by system manufacturers					
	Response			x		
	Additional Comments					
3.4	There is a lack of clarity as to the type of testing for thermal movement of standing seam systems to determine in-plane forces for use in design calculations					
	Response		x			
	Additional Comments					
3.5	Information in System Manufacturer's BBA certificates relating to thermal movement accommodation is insufficient					
	Response			x		
	Additional Comments	The information in the certification could be clearer				

Section 3 – Opinions

Using the responses: *strongly agree*, *agree*, *neither agree nor disagree*, *disagree*, *strongly disagree*, please indicate (with an X) what is your opinion of the following statements. Please add additional comments where you feel it is necessary to illustrate your response.

		Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
3.6	System manufacturers do not publish results of in-plane forces for use in detail design calculations					
	Response			x		
	Additional Comments					
3.7	Detail design calculations to account for in-plane forces are never carried out on projects					
	Response			x		
	Additional Comments					
3.8	Support steelwork is never specified to the support tolerances required by system manufacturers					
	Response		x			
	Additional Comments					
3.9	Roofing and cladding contractors do not have the ability and expertise to install standing seam systems					
	Response			x		
	Additional Comments	This depends on each company’s willingness to train their installation teams and have qualified supervision on site at all times during installation				
3.10	Roofing and cladding contractors do not have the ability or expertise to install aluminium					
	Response			x		
	Additional Comments	This depends on each company’s willingness to train their both their design and installation teams and have qualified supervision on site at all times during installation				
3.11	Many problems are due to poor quality installation					
	Response		x			
	Additional Comments	Training in all aspects of Installation of sheets and flashing is key to good installations as well as having qualified supervision overseeing installations				
3.12	Training of installers provided by system manufacturers is insufficient					
	Response			x		
	Additional Comments	Some manufacturers have comprehensive training courses followed on by site inspections of actual site installations; other manufacturers pay lip service to this necessity.				

Section 4 – Project Specific Information

Please provide some basic information of projects where you have encountered problems due to the restriction of thermal movement in halter based aluminium standing seam systems.

Project 1			
Building type		Retail	
Year built		Year problem found	
Support type		Purlin	
Construction		Double Skin	
Halter type		Aluminium - Full Height	
Substructure		Clip direct to purlin	
Sheet length		70m	
Sheet geometry		Naturally Curved	
Fixed point position		Mid-slope	
Identified problem/s		Standing seam wavering, eaves clips failed	
Potential cause/s		Not sufficient allowance for movement to occur, eaves clips with wrong type of fastener	
Recommended remedial action		Undo affected sheets and realign, refasten the clips in affected areas.	
Project 2			
Building type		Conference Centre	
Year built		Year problem found	
Support type		Structural Deck	
Construction		Double Skin	
Halter type		Aluminium - Full Height	
Substructure		Top-Hat	
Sheet length		60m	
Sheet geometry		Naturally Curved	
Fixed point position		Mid Position	
Identified problem/s		Clip coming through seams, clip failure at Ridge	
Potential cause/s		Insufficient allowance for movement to occur around welded ridge detail, clips fastened on one side only	
Recommended remedial action		Undo seams and re-fix clips correctly, make allowance for movement in the ridge detail	
Project 3			
Building type		Industrial Warehouse	
Year built		Year problem found	
Support type		Purlin.	
Construction		Double Skin	
Halter type		Aluminium - Full Height	
Substructure		Top-Hat	
Sheet length		100m	
Sheet geometry		Naturally Curved	
Fixed point position		Mid-Slope	
Identified problem/s		Clips coming through the standing seams	
Potential cause/s		Incorrect alignment of clips and Insufficient movement allowed to occur	
Recommended remedial action		Undo seams and reset the clip alignment	

Section 5 – Additional Comments

Please add any additional comments which you feel would add to this research dissertation and help reduce the instances of failure in halter based aluminium standing seam systems through a greater understanding of factors affecting the accommodation of thermal movement.

Utilise trained men on all aspects of installation from fitting to supervising the project.

Emphasise the need for thermal allowance to occur along the sheet length, especially in design stages.

On longer lengths consider the use of plastic clips rather than aluminium.

Appendix B.9 – Respondent 9

Section 1 – Personal Information	
Name:	[redacted]
Company:	[redacted]
Position:	[redacted]
Would you be willing to be contacted to discuss your responses (yes/no)?	Yes
Would you be willing for any comments to be attributed to yourself (yes/no)?	No

Section 2 - Experiences

2.1 **Typical Problems**

The following is a list of typical thermal movement problems that can be experienced with halter based aluminium standing seam systems. Please indicate (with an X) those that you have identified on projects.

From a risk perspective, could you also please rate on a scale of 1 – 5 what you consider to be: the severity (S), the occurrence (O) and the likelihood of early detection (D), of the identified problem.

Please use the following rating values:

Severity (S)	***Occurrence (O)***	***Detection (D)***
1 – No noticeable effect	1 – Never	1 – Very high
2 – Low (e.g. appearance)	2 – Very occasionally	2 – High
3 – Medium (e.g. functional failure – weathertightness)	3 – Occasionally	3 – Medium
4 – High (e.g. reduced service life)	4 – Frequently	4 – Low
5 – Very high (e.g. potential safety failure)	5 – Very frequently	5 - Zero

Typical Problem		***Identified***	***S***	***O***	***D***
Halters visible through seams		x	2	3	3
Excessive “clicking” noise					
Halters penetrating through seam		x	4	2	2
Halters shearing or disconnecting					
Fasteners shearing or disconnecting					
Material wear/abrasion of seam					
Collapse/over-turning of structure					
Collapse/over-turning of sub-structure					
Collapse of substrate (e.g. insulation board)					
Failure of fixed point					
Multiple fixed points					
Movement restricted by components clamped to seams					
Splitting/cracking of welds					
Buckling of standing seam sheet					
Buckling of flashing					
Failure of fasteners in flashings					
Other (please state)					

2.2 **Typical Factors Affecting Performance**

The following lists typical factors that can affect thermal movement and may lead to some of the aforementioned problems experienced with halter based aluminium standing seam systems. Please indicate (with an X) those that you have identified on projects.

From a risk perspective, could you also please rate on a scale of 1 – 5, what you consider to be: the severity (S), the occurrence (O) and the likelihood of early detection (D) of the identified factor.

Please use the following rating values:

Severity (S)	***Occurrence (O)***	***Detection (D)***
1 – No noticeable effect	1 – Never	1 – Very high
2 – Low (e.g. appearance)	2 – Very occasionally	2 – High
3 – Medium (e.g. functional failure – weathertightness)	3 – Occasionally	3 – Medium
4 – High (e.g. reduced service life)	4 – Frequently	4 – Low
5 – Very high (e.g. potential safety failure)	5 – Very frequently	5 - Zero

Typical Factors Affecting Performance		***Identified***	***S***	***O***	***D***
Manufacture	Sheet cover width out of production tolerance				
	Seam too tight				
	Seam too loose				
Structure	Not to System tolerance requirements				
	Inadequate lateral restraint				
Detail design	No, inadequate or multiple “fixed points” to sheets	x	3	2	1
	In-plane force not taken into account in design calculations				
	Amount of movement underestimated or ignored				
	Insufficient movement allowance at details				
	Inadequate number or type of fasteners specified				
	Insubstantial sub-structure or substrate specified				
	Geometry of building not taken into account	x	3	2	1
Installation	Structure not checked for suitability				
	Halters not set out correctly to System tolerances				
	Halters installed on compressible material				
	Sheets not fully engaged over halters prior to zipping				
	Incorrect zipper roll sets used for thickness of material				
	Zipping machine not maintained or designed for another System				

		Insufficient movement allowance in flashings				
		Inadequate fasteners in flashings				
		Additional components clamped directly over or close to halters				
	Other (please state)					

Section 3 – Opinions

Using the responses: *strongly agree*, *agree*, *neither agree nor disagree*, *disagree*, *strongly disagree*, please indicate (with an X) what is your opinion of the following statements. Please add additional comments where you feel it is necessary to illustrate your response.

		Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
3.1	There is a fundamental design problem with halter based aluminium standing seam systems with regard to the accommodation of thermal movement					
	Response		x			
	Additional Comments					
3.2	There is a lack of knowledge of this type of problem within the roofing and cladding industry					
	Response		x			
	Additional Comments					
3.3	There is a lack of knowledge of this type of problem by system manufacturers					
	Response			x		
	Additional Comments					
3.4	There is a lack of clarity as to the type of testing for thermal movement of standing seam systems to determine in-plane forces for use in design calculations					
	Response		x			
	Additional Comments					
3.5	Information in System Manufacturer's BBA certificates relating to thermal movement accommodation is insufficient					
	Response			x		
	Additional Comments					

Section 3 – Opinions

Using the responses: *strongly agree*, *agree*, *neither agree nor disagree*, *disagree*, *strongly disagree*, please indicate (with an X) what is your opinion of the following statements. Please add additional comments where you feel it is necessary to illustrate your response.

		Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
3.6	System manufacturers do not publish results of in-plane forces for use in detail design calculations					
	Response			x		
	Additional Comments					
3.7	Detail design calculations to account for in-plane forces are never carried out on projects					
	Response		x			
	Additional Comments					
3.8	Support steelwork is never specified to the support tolerances required by system manufacturers					
	Response		x			
	Additional Comments					
3.9	Roofing and cladding contractors do not have the ability and expertise to install standing seam systems					
	Response			x		
	Additional Comments					
3.10	Roofing and cladding contractors do not have the ability or expertise to install aluminium					
	Response			x		
	Additional Comments					
3.11	Many problems are due to poor quality installation					
	Response		x			
	Additional Comments					
3.12	Training of installers provided by system manufacturers is insufficient					
	Response			x		
	Additional Comments					

Section 4 – Project Specific Information

Please provide some basic information of projects where you have encountered problems due to the restriction of thermal movement in halter based aluminium standing seam systems.

<table>
<tr><th colspan="4">Project 3</th></tr>
<tr><td colspan="2">Building type</td><td colspan="2">Office</td></tr>
<tr><td>Year built</td><td></td><td>Year problem found</td><td></td></tr>
<tr><td colspan="2">Support type</td><td colspan="2">purlin</td></tr>
<tr><td colspan="2">Construction</td><td colspan="2">insulation double skin</td></tr>
<tr><td colspan="2">Halter type</td><td colspan="2">, full height, short etc.</td></tr>
<tr><td colspan="2">Substructure</td><td colspan="2">e.g. bracket and rail, top-hat, zed etc.</td></tr>
<tr><td colspan="2">Sheet length</td><td colspan="2"></td></tr>
<tr><td colspan="2">Sheet geometry</td><td colspan="2">straight,</td></tr>
<tr><td colspan="2">Fixed point position</td><td colspan="2">ridge</td></tr>
<tr><td colspan="2">Identified problem/s</td><td colspan="2">Halters penetrating through seam</td></tr>
<tr><td colspan="2">Potential cause/s</td><td colspan="2">multiple “fixed points” to sheets</td></tr>
<tr><td colspan="2">Recommended remedial action</td><td colspan="2">Replace sheets</td></tr>
</table>

Section 5 – Additional Comments

Please add any additional comments which you feel would add to this research dissertation and help reduce the instances of failure in halter based aluminium standing seam systems through a greater understanding of factors affecting the accommodation of thermal movement.

Appendix B.10 – Respondent 10

Section 1 – Personal Information

Name:	[redacted]
Company:	[redacted]
Position:	[redacted]
Would you be willing to be contacted to discuss your responses (yes/no)?	yes
Would you be willing for any comments to be attributed to yourself (yes/no)?	yes

Section 2 - Experiences

2.1 **Typical Problems**

The following is a list of typical thermal movement problems that can be experienced with halter based aluminium standing seam systems. Please indicate (with an X) those that you have identified on projects.

From a risk perspective, could you also please rate on a scale of 1 – 5 what you consider to be: the severity (S), the occurrence (O) and the likelihood of early detection (D), of the identified problem.

Please use the following rating values:

Severity (S)	***Occurrence (O)***	***Detection (D)***
1 – No noticeable effect	1 – Never	1 – Very high
2 – Low (e.g. appearance)	2 – Very occasionally	2 – High
3 – Medium (e.g. functional failure – weathertightness)	3 – Occasionally	3 – Medium
4 – High (e.g. reduced service life)	4 – Frequently	4 – Low
5 – Very high (e.g. potential safety failure)	5 – Very frequently	5 - Zero

Typical Problem		***Identified***	***S***	***O***	***D***
Halters visible through seams		X			
Excessive “clicking” noise		X			
Halters penetrating through seam		X			
Halters shearing or disconnecting					
Fasteners shearing or disconnecting		X			
Material wear/abrasion of seam		X			
Collapse/over-turning of structure					
Collapse/over-turning of sub-structure		X			
Collapse of substrate (e.g. insulation board)		X			
Failure of fixed point		X			
Multiple fixed points		X			
Movement restricted by components clamped to seams		X			
Splitting/cracking of welds		X			
Buckling of standing seam sheet		X			
Buckling of flashing		X			
Failure of fasteners in flashings		X			
Other (please state)	Push masonry top course sideways	X			

2.2 **Typical Factors Affecting Performance**

The following lists typical factors that can affect thermal movement and may lead to some of the aforementioned problems experienced with halter based aluminium standing seam systems. Please indicate (with an X) those that you have identified on projects.

From a risk perspective, could you also please rate on a scale of 1 – 5, what you consider to be: the severity (S), the occurrence (O) and the likelihood of early detection (D) of the identified factor.

Please use the following rating values:

Severity (S)	***Occurrence (O)***	***Detection (D)***
1 – No noticeable effect	1 – Never	1 – Very high
2 – Low (e.g. appearance)	2 – Very occasionally	2 – High
3 – Medium (e.g. functional failure – weathertightness)	3 – Occasionally	3 – Medium
4 – High (e.g. reduced service life)	4 – Frequently	4 – Low
5 – Very high (e.g. potential safety failure)	5 – Very frequently	5 - Zero

Typical Factors Affecting Performance		***Identified***	***S***	***O***	***D***
Manufacture	Sheet cover width out of production tolerance	X			
	Seam too tight	X			
	Seam too loose	X			
Structure	Not to System tolerance requirements	X			
	Inadequate lateral restraint	X			
Detail design	No, inadequate or multiple “fixed points” to sheets	X			
	In-plane force not taken into account in design calculations	X			
	Amount of movement underestimated or ignored	X			
	Insufficient movement allowance at details	X			
	Inadequate number or type of fasteners specified	X			
	Insubstantial sub-structure or substrate specified	X			
	Geometry of building not taken into account	X			
Installation	Structure not checked for suitability	X			
	Halters not set out correctly to System tolerances	X			
	Halters installed on compressible material	X			
	Sheets not fully engaged over halters prior to zipping	X			
	Incorrect zipper roll sets used for thickness of material	X			
	Zipping machine not maintained or designed for another System	X			

		Insufficient movement allowance in flashings	X			
		Inadequate fasteners in flashings	X	5	5	1
		Additional components clamped directly over or close to halters	X			
	Other (please state)					

Section 3 – Opinions

Using the responses: *strongly agree*, *agree*, *neither agree nor disagree*, *disagree*, *strongly disagree*, please indicate (with an X) what is your opinion of the following statements. Please add additional comments where you feel it is necessary to illustrate your response.

		Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
3.1	There is a fundamental design problem with halter based aluminium standing seam systems with regard to the accommodation of thermal movement					
	Response		X			
	Additional Comments	[redacted] panels do have fundamental design problems, reflected by the withdrawal of the BBA Certificate in [redacted]				
3.2	There is a lack of knowledge of this type of problem within the roofing and cladding industry					
	Response		X			
	Additional Comments					
3.3	There is a lack of knowledge of this type of problem by system manufacturers					
	Response		X			
	Additional Comments					
3.4	There is a lack of clarity as to the type of testing for thermal movement of standing seam systems to determine in-plane forces for use in design calculations					
	Response	X				
	Additional Comments					
3.5	Information in System Manufacturer's BBA certificates relating to thermal movement accommodation is insufficient					
	Response	X				

Section 3 – Opinions

Using the responses: *strongly agree*, *agree*, *neither agree nor disagree*, *disagree*, *strongly disagree*, please indicate (with an X) what is your opinion of the following statements. Please add additional comments where you feel it is necessary to illustrate your response.

		Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
	Additional Comments					
3.6	System manufacturers do not publish results of in-plane forces for use in detail design calculations					
	Response		X			
	Additional Comments					
3.7	Detail design calculations to account for in-plane forces are never carried out on projects					
	Response		X			
	Additional Comments					
3.8	Support steelwork is never specified to the support tolerances required by system manufacturers					
	Response		X			
	Additional Comments					
3.9	Roofing and cladding contractors do not have the ability and expertise to install standing seam systems					
	Response			X		
	Additional Comments	Significant variation in performance. The lack of in house technical support / design office can be handicap				
3.10	Roofing and cladding contractors do not have the ability or expertise to install aluminium					
	Response			X		
	Additional Comments					
3.11	Many problems are due to poor quality installation					
	Response			X		
	Additional Comments					
3.12	Training of installers provided by system manufacturers is insufficient					
	Response		X			

Section 3 – Opinions

Using the responses: *strongly agree*, *agree*, *neither agree nor disagree*, *disagree*, *strongly disagree*, please indicate (with an X) what is your opinion of the following statements. Please add additional comments where you feel it is necessary to illustrate your response.

		Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
	Additional Comments					

Section 4 – Project Specific Information

Please provide some basic information of projects where you have encountered problems due to the restriction of thermal movement in halter based aluminium standing seam systems.

Project 1			
Building type		College	
Year built	2008	Year problem found	2008
Support type		Purlin	
Construction		Composite panel	
Halter type		Proprietary halter, built into seam, fixed through lower panel, preventing sliding movement	
Substructure			
Sheet length		up to 30m long. 30mm of movement actually measured over 12 months. Also transverse thermal movement measured of 1mm / m	
Sheet geometry		Rectangular roofs, with many rooflight openings	
Fixed point position		ridge	
Identified problem/s		Water leakage	
Potential cause/s		Lack of provision for thermal movement	
Recommended remedial action		Form movement joints, with debonded reinforced liquid coatings to make weathertight, although unsatisfactory appearance and durability	

Section 5 – Additional Comments

Please add any additional comments which you feel would add to this research dissertation and help reduce the instances of failure in halter based aluminium standing seam systems through a greater understanding of factors affecting the accommodation of thermal movement.

There is a common lack of recognition of the need for the base of the halter to have a firm base and not allow any base rotation, that would cause the seam to lock

The performance of [redacted] standing seam / composite panels is a matter of serious concern. I am off early in the morning to investigate another one where there was no provision for thermal movement on an aluminium roof 36m long, with roof leaks reported for 6 years and multiple liquid coating repairs that have failed.

Appendix B.11 – Respondent 11

Section 1 – Personal Information	
Name:	[redacted]
Company:	[redacted]
Position:	[redacted]
Would you be willing to be contacted to discuss your responses (yes/no)?	Yes
Would you be willing for any comments to be attributed to yourself (yes/no)?	No

Section 2 - Experiences

2.1 **Typical Problems**

The following is a list of typical thermal movement problems that can be experienced with halter based aluminium standing seam systems. Please indicate (with an X) those that you have identified on projects.

From a risk perspective, could you also please rate on a scale of 1 – 5 what you consider to be: the severity (S), the occurrence (O) and the likelihood of early detection (D), of the identified problem.

Please use the following rating values:

Severity (S)	***Occurrence (O)***	***Detection (D)***
1 – No noticeable effect	1 – Never	1 – Very high
2 – Low (e.g. appearance)	2 – Very occasionally	2 – High
3 – Medium (e.g. functional failure – weathertightness)	3 – Occasionally	3 – Medium
4 – High (e.g. reduced service life)	4 – Frequently	4 – Low
5 – Very high (e.g. potential safety failure)	5 – Very frequently	5 - Zero

Typical Problem		***Identified***	***S***	***O***	***D***
Halters visible through seams		X	4	5	2-3
Excessive “clicking” noise					
Halters penetrating through seam		X	5	3-4	2-3
Halters shearing or disconnecting		X	5	2	4-5
Fasteners shearing or disconnecting		X	5	3	4-5
Material wear/abrasion of seam		X	5	5	4-5
Collapse/over-turning of structure					
Collapse/over-turning of sub-structure					
Collapse of substrate (e.g. insulation board)					
Failure of fixed point					
Multiple fixed points		X	2	2	3
Movement restricted by components clamped to seams		X	4	4	3
Splitting/cracking of welds					
Buckling of standing seam sheet					
Buckling of flashing		X	5	3	2
Failure of fasteners in flashings		X	5	3	3
Other (please state)	Poor Halter Alignment	X	4	5	4-5
	Bent/Damaged Halters	X	4	4	3

2.2 **Typical Factors Affecting Performance**

The following lists typical factors that can affect thermal movement and may lead to some of the aforementioned problems experienced with halter based aluminium standing seam systems. Please indicate (with an X) those that you have identified on projects.

From a risk perspective, could you also please rate on a scale of 1 – 5, what you consider to be: the severity (S), the occurrence (O) and the likelihood of early detection (D) of the identified factor.

Please use the following rating values:

Severity (S)	***Occurrence (O)***	***Detection (D)***
1 – No noticeable effect	1 – Never	1 – Very high
2 – Low (e.g. appearance)	2 – Very occasionally	2 – High
3 – Medium (e.g. functional failure – weathertightness)	3 – Occasionally	3 – Medium
4 – High (e.g. reduced service life)	4 – Frequently	4 – Low
5 – Very high (e.g. potential safety failure)	5 – Very frequently	5 - Zero

Typical Factors Affecting Performance		***Identified***	***S***	***O***	***D***
Manufacture	Sheet cover width out of production tolerance	X	4	2	5
	Seam too tight	X	4	4	4
	Seam too loose	X	5	2	4
Structure	Not to System tolerance requirements	X	4	3	4
	Inadequate lateral restraint				
Detail design	No, inadequate or multiple “fixed points” to sheets	X	5	4	2
	In-plane force not taken into account in design calculations				
	Amount of movement underestimated or ignored				
	Insufficient movement allowance at details	X	3	5	4
	Inadequate number or type of fasteners specified	X	5	3	4
	Insubstantial sub-structure or substrate specified				
	Geometry of building not taken into account	X	4	3	4
Installation	Structure not checked for suitability	X	4	4	4
	Halters not set out correctly to System tolerances	X	4-5	5	4
	Halters installed on compressible material				
	Sheets not fully engaged over halters prior to zipping	X	4	2	3
	Incorrect zipper roll sets used for thickness of material	X	4	4	4
	Zipping machine not maintained or designed for another System				

		Insufficient movement allowance in flashings	X	3	4	4
		Inadequate fasteners in flashings	X	5	4	4
		Additional components clamped directly over or close to halters	X	3	2	4
	Other (please state)					

Section 3 – Opinions

Using the responses: *strongly agree*, *agree*, *neither agree nor disagree*, *disagree*, *strongly disagree*, please indicate (with an X) what is your opinion of the following statements. Please add additional comments where you feel it is necessary to illustrate your response.

		Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
3.1	There is a fundamental design problem with halter based aluminium standing seam systems with regard to the accommodation of thermal movement					
	Response				X	
	Additional Comments	The typical issues have developed largely from lack of quality and care during construction, setting out of halters, planning of interface detailing and rectification of issues, rather than specific system design or product problems.				
3.2	There is a lack of knowledge of this type of problem within the roofing and cladding industry					
	Response					
	Additional Comments	Industry suppliers know there is a problem, but this is not widely known				
3.3	There is a lack of knowledge of this type of problem by system manufacturers					
	Response				X	
	Additional Comments	Restrictions to thermal movements have been investigated and products such as thermohalters are now widely in use with the aim of improving the ability of standing seam systems to accommodate thermal movements.				
3.4	There is a lack of clarity as to the type of testing for thermal movement of standing seam systems to determine in-plane forces for use in design calculations					
	Response		X			
	Additional Comments	Information is available but has not been publicised				
3.5	Information in System Manufacturer's BBA certificates relating to thermal movement accommodation is insufficient					
	Response		X			

Section 3 – Opinions

Using the responses: *strongly agree*, *agree*, *neither agree nor disagree*, *disagree*, *strongly disagree*, please indicate (with an X) what is your opinion of the following statements. Please add additional comments where you feel it is necessary to illustrate your response.

		Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
	Additional Comments	More publicised information is required				
3.6	System manufacturers do not publish results of in-plane forces for use in detail design calculations					
	Response		X			
	Additional Comments	Have not seen any data to date				
3.7	Detail design calculations to account for in-plane forces are never carried out on projects					
	Response		X			
	Additional Comments					
3.8	Support steelwork is never specified to the support tolerances required by system manufacturers					
	Response		X			
	Additional Comments	However, if this is not specified early on in the project, the roofing installer should be aware and accommodate for these differences in their halter connection detailing				
3.9	Roofing and cladding contractors do not have the ability and expertise to install standing seam systems					
	Response			X		
	Additional Comments	Experienced installers have the ability – but we are not aware of adequate training standards				
3.10	Roofing and cladding contractors do not have the ability or expertise to install aluminium					
	Response			X		
	Additional Comments					
3.11	Many problems are due to poor quality installation					
	Response	X				
	Additional Comments	The majority of problems seen to date have been caused by poor quality installation				

Section 3 – Opinions

Using the responses: *strongly agree*, *agree*, *neither agree nor disagree*, *disagree*, *strongly disagree*, please indicate (with an X) what is your opinion of the following statements. Please add additional comments where you feel it is necessary to illustrate your response.

		Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
3.12	Training of installers provided by system manufacturers is insufficient					
	Response		X			
	Additional Comments	[redacted] appear to be the most pro-active				

Section 4 – Project Specific Information

Please provide some basic information of projects where you have encountered problems due to the restriction of thermal movement in halter based aluminium standing seam systems.

Project 1 – Confidential therefore Non Disclosed.

Building type			
Year built		Year problem found	
Support type			
Construction			
Halter type			
Substructure			
Sheet length			
Sheet geometry			
Fixed point position			
Identified problem/s			
Potential cause/s			
Recommended remedial action			

Section 5 – Additional Comments

Please add any additional comments which you feel would add to this research dissertation and help reduce the instances of failure in halter based aluminium standing seam systems through a greater understanding of factors affecting the accommodation of thermal movement.

Bent and badly spaced halters contribute to the majority of issues. Poor construction quality is a major factor having seen around 80% of halters surveyed be misaligned and we would question whether installers appreciate the importance of correct alignment.

Sign off of the base/supporting structure is critical – the relationship between the primary steelwork tolerances and tolerances for the cladding need to be addressed and variations between the two appropriately rectified.
Unconventional construction methodology can lead to alignment issues and therefore needs careful planning, control and site management.
Can you realistically prefabricate halters before you install? Installation methodology is as critical as the setting out tolerances.

Appendix C – Manufacturers' Questionnaire

Research Dissertation Questionnaire – Manufacturers

I am currently undertaking a research dissertation as part of my Master of Science in Façade Engineering at University of Bath, entitled "*factors affecting the accommodation of thermal movement in halter based aluminium standing seam systems"*.

The Problem: Standing seam systems have been used successfully as part of the building envelope on projects the world over, however there appears to be a growing number of instances were failure has occurred due to the restriction of thermal movement within the system. The understanding of how thermal movement is accommodated and the various factors which can affect it is of prime importance if the design and installation of this type of system is to be successfully incorporated into the building envelope

Proposed Solution: This dissertation seeks to collate the existing disparate knowledge in to a single document in order to raise awareness of the type of problems experienced by failing to accommodate thermal movement in halter based aluminium standing seam systems, the factors causing them and how they can be alleviated. The outcome will be the development of a set of recommendations and design guidance based on the research findings. It is intended that this will form the basis a new MCRMA Technical Bulletin which will provide an update and partial replacement to the current MCRMA Technical Paper 3 – Secret Fix Roofing Design Guide.

Part of the research will attempt to ascertain what information is provided on production tolerances, testing and approvals and recommended support and installation tolerances and how this information or advice is disseminated to relevant stakeholders such as the design team, specialist sub-contractors and installation teams. Information on the use of alternative methodologies, materials and components which could assist in alleviating the problems will also be an element of this research.

It would greatly appreciated if you could help contribute to this research by taking a few minutes to complete the following questionnaire. Please be assured that any information given will be treated in confidence and will not be used for non-study purposes.

Questionnaire – Manufacturers

Section 1 – Personal Information		
F bName:		
Company:		
Position:		
Would you be willing to be contacted to discuss your responses (yes/no)?		
Would you be willing for any comments to be attributed to yourself (yes/no)?		

Section 2 - Testing, approvals and certification Please indicate (with an X) all responses to the questions which are applicable. Please add additional comments where you feel it would be beneficial to expand on your responses.		
2.1	Do you have a BBA (British Board of Agrément) or other third-party approval for your standing seam system?	
	Yes	
	No	
2.2	Is your standing seam system CE marked either as individual products or as a system (i.e. both standing seam sheet and halter together)?	
	Yes, standing seam sheet as a product to BS EN 14782:2006 – *Self-supporting metal sheet for roofing, external cladding and internal lining – Product specification and requirements*	
	Yes, halters as a product to CUAP 04.01/12 – *Spacer kits for built-up metal roof and wall cladding*	
	Yes, standing seam and halters as a system to CUAP 03.02/16 – *Roof and wall systems with hidden fastenings*	
	No	
2.3	Has in-plane force testing been carried out on your standing seam system? **NB** *In-plane force testing may also be known as friction resistance testing, sliding testing, simulated thermal movement testing etc.*	
	Yes, as part of the BBA (or other) approval process	
	Yes, as part of CE marking to CUAP 03.02/16	
	Yes, independent of approvals and certification	
	No	
2.4	Was in-plane force testing carried out to different degrees of alignment of halter?	
	Perfectly aligned	
	Misaligned to published system tolerances	
	Misaligned beyond published system tolerances	
	Not applicable	
2.5	Was in-plane force testing carried out with halters installed to different forms of structure or sub-structure?	
	Halter fixed direct to purlin	
	Halter fixed to structural decking profile	
	Halter fixed to bracket and rail system	
	Halter fixed to other type of structure/sub-structure	
	Not applicable	
Additional comments		

Section 3 – Design Information Please indicate (with an X) all responses to the questions which are applicable. Please add additional comments where you feel it would be beneficial to expand on your responses.		
3.1	Do you publish a technical or design manual/guide for your standing seam system?	
	Yes, readily available e.g. on web-site	
	Yes, available on request	
	No	
3.2	Do you provide design training on your standing seam system to specialist roofing and cladding contractors and/or detail designers?	
	Yes	
	No	
3.3	If you have undertaken in-plane force testing on your standing seam system how do you utilise or disseminate the results for use in design calculations?	
	Results readily available e.g. in Company literature or web-site	
	Results available on request	
	Results only available to key contacts, customers etc.	
	Results only used internally	
	Results not used	
	Not applicable	
3.4	What form of information or advice do you provide on how to determine the amount of thermal movement to be accommodated for use in detail design?	
	“Rule of thumb” for material (e.g. 1 mm per 1 m of sheet length)	
	“Rule of thumb” taking into account generic material, finish and/or colour (e.g. 1.5 mm per 1 mm of sheet length for dark coloured sheets)	
	“Rule of thumb” taking into account specific material, surface finish and colour (e.g. 1.7 mm per 1 mm of sheet length for PVDF coated aluminium sheets to RAL 7016 – Anthracite Grey)	
	Information or design methodology to determine extremes of thermal expansion and contraction based on specific project conditions	
	Computer design tool/software to determine extremes of thermal expansion and contraction based on specific project conditions	
	Other	
	None	
3.5	Do you provide information or advice on how to determine the amount of stress within a standing seam sheet and its resultant force if thermal movement of the sheet is fully restrained?	
	Yes, published within Company literature or web-site	
	Yes, on request	
	No	
3.6	Do you advise on a limit to effective length (i.e. length of sheet from fixed point) of standing seam sheet to be used or advise on the need for alternative methods to be adopted to limit the level of in-plane force within the system (e.g. different halter materials, different halter types etc.)?	
	Yes	
	Yes, conditional on alternative method being adopted	
	No	

3.7	Where conditions are applied to the limit of the effective length of the standing seam sheet, what alternative methods do you recommend to reduce the level of in-plane force within the system? *Typical reasons for adopting an alternative methodology are indicated in italics.*	
	Secret gutter or step lap detail. *Shorter effective length of sheet*	
	Increased number of fasteners in base of halter. *Increases resistance to over-turning moment of halter*	
	Longer aluminium halters. *Reduces over-turning moment of halter*	
	Halters of an alternative material, e.g. plastic. *Reduces friction between sheet and halter*	
	Sliding halters/clips. *Thermal movement is taken up within halter/clip itself*	
	Halters installed into a sliding rail running perpendicular or diagonal to direction of sheeting. *Improves alignment of halters*	
	Halters installed on a more robust sub-structure. *Increases resistance to over-turning moment of halter*	
	Other (please state in additional comments below)	
	Not applicable	
Additional comments		

Section 4 – Production tolerances Please indicate (with an X) all responses to the questions which are applicable. Please add additional comments where you feel it would be beneficial to expand on your responses.		
4.1	Is your system manufactured under an independently accredited and audited quality management system e.g. to ISO 9001?	
	Yes, to ISO 9001	
	Yes, as part of ongoing BBA (or other) approval	
	No	
4.2	Do you check the dimensional accuracy of the standing seam sheet as part of your manufacturing processes?	
	Yes	
	No	
4.3	Do your manufacturing tolerances differ for site production as opposed to factory production of standing seam sheets?	
	Yes, major differences in tolerances	
	Yes, but only differ slightly (e.g. length)	
	No	
4.4	Do you provide customers with a means of checking the dimensional accuracy of the shape of the standing seam sheet?	
	Yes, production drawing	
	Yes, template of correct shape	
	Yes, other means	
	No	
Additional comments		

Section 5 – Support and installation tolerances

Please indicate (with an X) all responses to the questions which are applicable. Please add additional comments where you feel it would be beneficial to expand on your responses.

5.1	Do you have support tolerance requirements (e.g. purlin level, rotation etc.) and installation tolerance for your standing seam system?	
	Yes, both support and installation tolerances	
	Yes, support tolerances only	
	Yes, installation tolerances only	
	No	
5.2	Do you have different support and/or installation tolerance requirements when curved standing seam sheets are utilised?	
	Yes, both support and installation tolerances are different	
	Yes, support tolerances only are different	
	Yes, installation tolerances only are different	
	No, same as for straight standing seam sheets	
	Not applicable	
5.3	How are your support and/or installation tolerances disseminated?	
	Published in sales literature	
	Published in technical or design manual/guide	
	Published in installation manual/guide	
	Issued as part of installation training	
	Available on web-site	
	Available on request	
	Not applicable	
5.4	How were the support and/or installation tolerances derived?	
	By practical testing	
	By desk-top study	
	By reference to industry recommendations (e.g. MCRMA Technical Paper 3 – Secret fix roofing design guide etc.)	
	By other method	
	Not applicable	
Additional comments		

Section 6 – Installation

Please indicate (with an X) all responses to the questions which are applicable. Please add additional comments where you feel it would be beneficial to expand on your responses.

6.1	Do you publish an installation manual/guide for your standing seam system?	
	Yes, readily available e.g. on web-site	
	Yes, available on request	
	No	
6.2	Do you provide installation training on your standing seam system to installers?	
	Yes	
	No	
6.3	If yes, are your training courses accredited by a third party e.g. CITB, NFRC etc.?	
	Yes	
	No	
	Not applicable	
6.4	Do you provide installers with information or advice on how to set out halters to system tolerances?	
	Yes, readily available e.g. in Company literature or web-site	
	Yes, as part of installation training	
	Yes, available on request	
	No	
6.5	Do you provide installers with any aids to assist in setting out halters, e.g. templates?	
	Yes	
	No	
6.6	Do you provide installers with information or advice on how to install perimeter flashings and penetrations?	
	Yes, readily available e.g. in Company literature or web-site	
	Yes, as part of installation training	
	Yes, available on request	
	No	
6.7	Do you carry out site inspections either during or after installation?	
	Yes, during installation	
	Yes, after installation	
	No	
6.8	If yes, who carries out your site inspections	
	Dedicated site personnel	
	Technical personnel	
	Sales personnel	
	Other	
	Not applicable	

Additional comments

Section 7 – Additional Comments Please add any additional comments which you feel would add to this research dissertation and help reduce the instances of failure in halter based aluminium standing seam systems through a greater understanding of factors affecting the accommodation of thermal movement.

Thank you for taking the time to complete this questionnaire. Your input will be compiled with other respondents and reported upon within the research dissertation. If you are interested in the outcome of this research dissertation then I would be pleased to forward a copy to you.

Best Regards

David A Cottrell

Appendix C.1 – Kalzip Ltd

Section 1 – Personal Information		
Name:	Kevin Turton	
Company:	Kalzip Ltd.	
Position:	Design/Site/Training Manager	
Would you be willing to be contacted to discuss your responses (yes/no)?		Yes
Would you be willing for any comments to be attributed to yourself (yes/no)?		

Section 2 - Testing, approvals and certification

Please indicate (with an X) all responses to the questions which are applicable. Please add additional comments where you feel it would be beneficial to expand on your responses.

2.1	Do you have a BBA (British Board of Agrément) or other third-party approval for your standing seam system?	
	Yes	X
	No	
2.2	Is your standing seam system CE marked either as individual products or as a system (i.e. both standing seam sheet and halter together)?	
	Yes, standing seam sheet as a product to BS EN 14782:2006 – *Self-supporting metal sheet for roofing, external cladding and internal lining – Product specification and requirements*	X
	Yes, halters as a product to CUAP 04.01/12 – *Spacer kits for built-up metal roof and wall cladding*	
	Yes, standing seam and halters as a system to CUAP 03.02/16 – *Roof and wall systems with hidden fastenings*	
	No	
2.3	Has in-plane force testing been carried out on your standing seam system? **NB** *In-plane force testing may also be known as friction resistance testing, sliding testing, simulated thermal movement testing etc.*	
	Yes, as part of the BBA (or other) approval process	X
	Yes, as part of CE marking to CUAP 03.02/16	
	Yes, independent of approvals and certification	X
	No	
2.4	Was in-plane force testing carried out to different degrees of alignment of halter?	
	Perfectly aligned	X
	Misaligned to published system tolerances	X
	Misaligned beyond published system tolerances	X
	Not applicable	
2.5	Was in-plane force testing carried out with halters installed to different forms of structure or sub-structure?	
	Halter fixed direct to purlin	X
	Halter fixed to structural decking profile	
	Halter fixed to bracket and rail system	
	Halter fixed to other type of structure/sub-structure	
	Not applicable	
Additional comments		

Section 3 – Design Information Please indicate (with an X) all responses to the questions which are applicable. Please add additional comments where you feel it would be beneficial to expand on your responses.		
3.1	Do you publish a technical or design manual/guide for your standing seam system?	
	Yes, readily available e.g. on web-site	X
	Yes, available on request	
	No	
3.2	Do you provide design training on your standing seam system to specialist roofing and cladding contractors and/or detail designers?	
	Yes	X
	No	
3.3	If you have undertaken in-plane force testing on your standing seam system how do you utilise or disseminate the results for use in design calculations?	
	Results readily available e.g. in Company literature or web-site	
	Results available on request	
	Results only available to key contacts, customers etc.	
	Results only used internally	X
	Results not used	
	Not applicable	
3.4	What form of information or advice do you provide on how to determine the amount of thermal movement to be accommodated for use in detail design?	
	"Rule of thumb" for material (e.g. 1 mm per 1 m of sheet length)	
	"Rule of thumb" taking into account generic material, finish and/or colour (e.g. 1.5 mm per 1 mm of sheet length for dark coloured sheets)	X
	"Rule of thumb" taking into account specific material, surface finish and colour (e.g. 1.7 mm per 1 mm of sheet length for PVDF coated aluminium sheets to RAL 7016 – Anthracite Grey)	
	Information or design methodology to determine extremes of thermal expansion and contraction based on specific project conditions	
	Computer design tool/software to determine extremes of thermal expansion and contraction based on specific project conditions	
	Other	
	None	
3.5	Do you provide information or advice on how to determine the amount of stress within a standing seam sheet and its resultant force if thermal movement of the sheet is fully restrained?	
	Yes, published within Company literature or web-site	
	Yes, on request	
	No	X
3.6	Do you advise on a limit to effective length (i.e. length of sheet from fixed point) of standing seam sheet to be used or advise on the need for alternative methods to be adopted to limit the level of in-plane force within the system (e.g. different halter materials, different halter types etc.)?	
	Yes	
	Yes, conditional on alternative method being adopted	X
	No	
3.7	Where conditions are applied to the limit of the effective length of the standing seam sheet, what alternative methods do you recommend to reduce the level of	

	in-plane force within the system? *Typical reasons for adopting an alternative methodology are indicated in italics.*	
	Secret gutter or step lap detail. *Shorter effective length of sheet*	
	Increased number of fasteners in base of halter. *Increases resistance to over-turning moment of halter*	X
	Longer aluminium halters. *Reduces over-turning moment of halter*	
	Halters of an alternative material, e.g. plastic. *Reduces friction between sheet and halter*	X
	Sliding halters/clips. *Thermal movement is taken up within halter/clip itself*	
	Halters installed into a sliding rail running perpendicular or diagonal to direction of sheeting. *Improves alignment of halters*	
	Halters installed on a more robust sub-structure. *Increases resistance to over-turning moment of halter*	
	Other (please state in additional comments below)	
	Not applicable	
Additional comments		

Section 4 – Production tolerances Please indicate (with an X) all responses to the questions which are applicable. Please add additional comments where you feel it would be beneficial to expand on your responses.		
4.1	Is your system manufactured under an independently accredited and audited quality management system e.g. to ISO 9001?	
	Yes, to ISO 9001	X
	Yes, as part of ongoing BBA (or other) approval	X
	No	
4.2	Do you check the dimensional accuracy of the standing seam sheet as part of your manufacturing processes?	
	Yes	X
	No	
4.3	Do your manufacturing tolerances differ for site production as opposed to factory production of standing seam sheets?	
	Yes, major differences in tolerances	
	Yes, but only differ slightly (e.g. length)	X
	No	
4.4	Do you provide customers with a means of checking the dimensional accuracy of the shape of the standing seam sheet?	
	Yes, production drawing	
	Yes, template of correct shape	
	Yes, other means	
	No	X
Additional comments		

Section 5 – Support and installation tolerances

Please indicate (with an X) all responses to the questions which are applicable. Please add additional comments where you feel it would be beneficial to expand on your responses.

5.1	Do you have support tolerance requirements (e.g. purlin level, rotation etc.) and installation tolerance for your standing seam system?	
	Yes, both support and installation tolerances	X
	Yes, support tolerances only	
	Yes, installation tolerances only	
	No	
5.2	Do you have different support and/or installation tolerance requirements when curved standing seam sheets are utilised?	
	Yes, both support and installation tolerances are different	
	Yes, support tolerances only are different	
	Yes, installation tolerances only are different	
	No, same as for straight standing seam sheets	X
	Not applicable	
5.3	How are your support and/or installation tolerances disseminated?	
	Published in sales literature	X
	Published in technical or design manual/guide	
	Published in installation manual/guide	X
	Issued as part of installation training	
	Available on web-site	
	Available on request	X
	Not applicable	
5.4	How were the support and/or installation tolerances derived?	
	By practical testing	X
	By desk-top study	
	By reference to industry recommendations (e.g. MCRMA Technical Paper 3 – Secret fix roofing design guide etc.)	X
	By other method	
	Not applicable	
Additional comments		

Section 6 – Installation

Please indicate (with an X) all responses to the questions which are applicable. Please add additional comments where you feel it would be beneficial to expand on your responses.

6.1	Do you publish an installation manual/guide for your standing seam system?	
	Yes, readily available e.g. on web-site	
	Yes, available on request	X
	No	
6.2	Do you provide installation training on your standing seam system to installers?	
	Yes	X
	No	

6.3	If yes, are your training courses accredited by a third party e.g. CITB, NFRC etc.?	
	Yes	X
	No	
	Not applicable	
6.4	Do you provide installers with information or advice on how to set out halters to system tolerances?	
	Yes, readily available e.g. in Company literature or web-site	X
	Yes, as part of installation training	X
	Yes, available on request	
	No	
6.5	Do you provide installers with any aids to assist in setting out halters, e.g. templates?	
	Yes	
	No	X
6.6	Do you provide installers with information or advice on how to install perimeter flashings and penetrations?	
	Yes, readily available e.g. in Company literature or web-site	
	Yes, as part of installation training	X
	Yes, available on request	
	No	
6.7	Do you carry out site inspections either during or after installation?	
	Yes, during installation	X
	Yes, after installation	X
	No	
6.8	If yes, who carries out your site inspections	
	Dedicated site personnel	X
	Technical personnel	X
	Sales personnel	X
	Other	
	Not applicable	
Additional comments		

Section 7 – Additional Comments

Please add any additional comments which you feel would add to this research dissertation and help reduce the instances of failure in halter based aluminium standing seam systems through a greater understanding of factors affecting the accommodation of thermal movement.

Appendix C.2 – SpeedDeck Ltd

Section 1 – Personal Information	
Name:	David Lowe
Company:	SpeedDeck Ltd (Omnis Industries)
Position:	Head of Technical
Would you be willing to be contacted to discuss your responses (yes/no)?	Yes
Would you be willing for any comments to be attributed to yourself (yes/no)?	Yes

Section 2 - Testing, approvals and certification
Please indicate (with an X) all responses to the questions which are applicable. Please add additional comments where you feel it would be beneficial to expand on your responses.

2.1	Do you have a BBA (British Board of Agrément) or other third-party approval for your standing seam system?	
	Yes	X
	No	
2.2	Is your standing seam system CE marked either as individual products or as a system (i.e. both standing seam sheet and halter together)?	
	Yes, standing seam sheet as a product to BS EN 14782:2006 – *Self-supporting metal sheet for roofing, external cladding and internal lining – Product specification and requirements*	X
	Yes, halters as a product to CUAP 04.01/12 – *Spacer kits for built-up metal roof and wall cladding*	
	Yes, standing seam and halters as a system to CUAP 03.02/16 – *Roof and wall systems with hidden fastenings*	
	No	
2.3	Has in-plane force testing been carried out on your standing seam system? **NB** *In-plane force testing may also be known as friction resistance testing, sliding testing, simulated thermal movement testing etc.*	
	Yes, as part of the BBA (or other) approval process	
	Yes, as part of CE marking to CUAP 03.02/16	
	Yes, independent of approvals and certification	X speedddeck profile
	No	
2.4	Was in-plane force testing carried out to different degrees of alignment of halter?	
	Perfectly aligned	X speedddeck profile
	Misaligned to published system tolerances	
	Misaligned beyond published system tolerances	
	Not applicable	
2.5	Was in-plane force testing carried out with halters installed to different forms of structure or sub-structure?	
	Halter fixed direct to purlin	
	Halter fixed to structural decking profile	
	Halter fixed to bracket and rail system	X speedddeck profile

	Halter fixed to other type of structure/sub-structure	
	Not applicable	
Additional comments		

Section 3 – Design Information Please indicate (with an X) all responses to the questions which are applicable. Please add additional comments where you feel it would be beneficial to expand on your responses.		
3.1	Do you publish a technical or design manual/guide for your standing seam system?	
	Yes, readily available e.g. on web-site	X
	Yes, available on request	
	No	
3.2	Do you provide design training on your standing seam system to specialist roofing and cladding contractors and/or detail designers?	
	Yes	
	No	X
3.3	If you have undertaken in-plane force testing on your standing seam system how do you utilise or disseminate the results for use in design calculations?	
	Results readily available e.g. in Company literature or web-site	
	Results available on request	
	Results only available to key contacts, customers etc.	
	Results only used internally	
	Results not used	X
	Not applicable	
3.4	What form of information or advice do you provide on how to determine the amount of thermal movement to be accommodated for use in detail design?	
	“Rule of thumb” for material (e.g. 1 mm per 1 m of sheet length)	
	“Rule of thumb” taking into account generic material, finish and/or colour (e.g. 1.5 mm per 1 mm of sheet length for dark coloured sheets)	X
	“Rule of thumb” taking into account specific material, surface finish and colour (e.g. 1.7 mm per 1 mm of sheet length for PVDF coated aluminium sheets to RAL 7016 – Anthracite Grey)	
	Information or design methodology to determine extremes of thermal expansion and contraction based on specific project conditions	
	Computer design tool/software to determine extremes of thermal expansion and contraction based on specific project conditions	
	Other	
	None	
3.5	Do you provide information or advice on how to determine the amount of stress within a standing seam sheet and its resultant force if thermal movement of the sheet is fully restrained?	
	Yes, published within Company literature or web-site	
	Yes, on request	
	No	X
3.6	Do you advise on a limit to effective length (i.e. length of sheet from fixed point) of standing seam sheet to be used or advise on the need for alternative	

	methods to be adopted to limit the level of in-plane force within the system (e.g. different halter materials, different halter types etc.)?	
	Yes	
	Yes, conditional on alternative method being adopted	
	No	X
3.7	Where conditions are applied to the limit of the effective length of the standing seam sheet, what alternative methods do you recommend to reduce the level of in-plane force within the system? *Typical reasons for adopting an alternative methodology are indicated in italics.*	
	Secret gutter or step lap detail. *Shorter effective length of sheet*	
	Increased number of fasteners in base of halter. *Increases resistance to over-turning moment of halter*	
	Longer aluminium halters. *Reduces over-turning moment of halter*	
	Halters of an alternative material, e.g. plastic. *Reduces friction between sheet and halter*	
	Sliding halters/clips. *Thermal movement is taken up within halter/clip itself*	
	Halters installed into a sliding rail running perpendicular or diagonal to direction of sheeting. *Improves alignment of halters*	
	Halters installed on a more robust sub-structure. *Increases resistance to over-turning moment of halter*	
	Other (please state in additional comments below)	
	Not applicable	X
Additional comments		

Section 4 – Production tolerances Please indicate (with an X) all responses to the questions which are applicable. Please add additional comments where you feel it would be beneficial to expand on your responses.		
4.1	Is your system manufactured under an independently accredited and audited quality management system e.g. to ISO 9001?	
	Yes, to ISO 9001	X
	Yes, as part of ongoing BBA (or other) approval	
	No	
4.2	Do you check the dimensional accuracy of the standing seam sheet as part of your manufacturing processes?	
	Yes	X
	No	
4.3	Do your manufacturing tolerances differ for site production as opposed to factory production of standing seam sheets?	
	Yes, major differences in tolerances	
	Yes, but only differ slightly (e.g. length)	X
	No	
4.4	Do you provide customers with a means of checking the dimensional accuracy of the shape of the standing seam sheet?	
	Yes, production drawing	
	Yes, template of correct shape	
	Yes, other means	

	No	X
Additional comments		

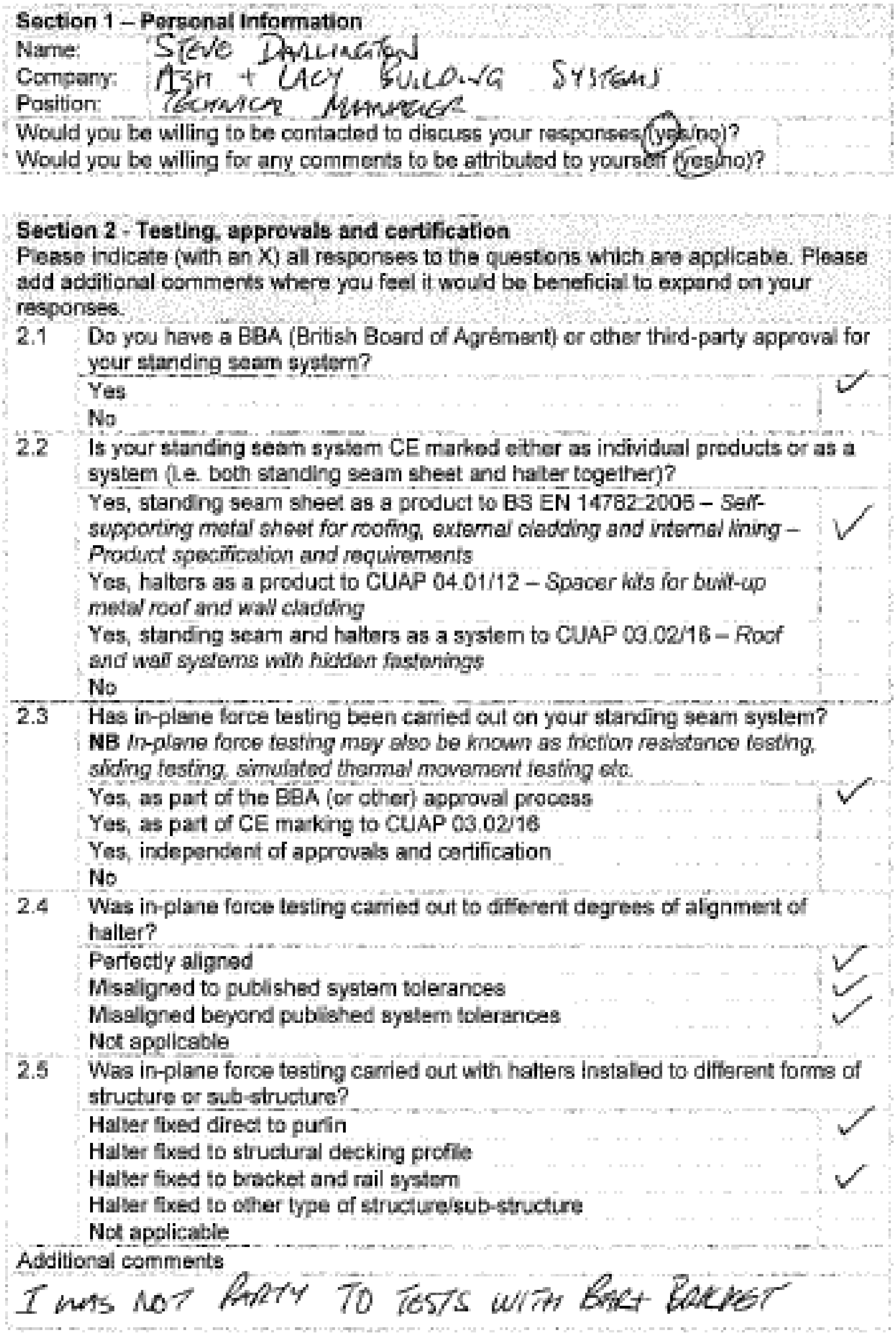
Section 5 – Support and installation tolerances Please indicate (with an X) all responses to the questions which are applicable. Please add additional comments where you feel it would be beneficial to expand on your responses.		
5.1	Do you have support tolerance requirements (e.g. purlin level, rotation etc.) and installation tolerance for your standing seam system?	
	Yes, both support and installation tolerances	X
	Yes, support tolerances only	
	Yes, installation tolerances only	
	No	
5.2	Do you have different support and/or installation tolerance requirements when curved standing seam sheets are utilised?	
	Yes, both support and installation tolerances are different	
	Yes, support tolerances only are different	
	Yes, installation tolerances only are different	
	No, same as for straight standing seam sheets	X
	Not applicable	
5.3	How are your support and/or installation tolerances disseminated?	
	Published in sales literature	
	Published in technical or design manual/guide	X
	Published in installation manual/guide	
	Issued as part of installation training	
	Available on web-site	
	Available on request	
	Not applicable	
5.4	How were the support and/or installation tolerances derived?	
	By practical testing	
	By desk-top study	
	By reference to industry recommendations (e.g. MCRMA Technical Paper 3 – Secret fix roofing design guide etc.)	X
	By other method	
	Not applicable	
Additional comments		
Section 6 – Installation Please indicate (with an X) all responses to the questions which are applicable. Please add additional comments where you feel it would be beneficial to expand on your responses.		
6.1	Do you publish an installation manual/guide for your standing seam system?	
	Yes, readily available e.g. on web-site	X
	Yes, available on request	
	No	

6.2	Do you provide installation training on your standing seam system to installers?	
	Yes	X
	No	
6.3	If yes, are your training courses accredited by a third party e.g. CITB, NFRC etc.?	
	Yes	
	No	
	Not applicable	X
6.4	Do you provide installers with information or advice on how to set out halters to system tolerances?	
	Yes, readily available e.g. in Company literature or web-site	
	Yes, as part of installation training	
	Yes, available on request	X
	No	
6.5	Do you provide installers with any aids to assist in setting out halters, e.g. templates?	
	Yes	X
	No	
6.6	Do you provide installers with information or advice on how to install perimeter flashings and penetrations?	
	Yes, readily available e.g. in Company literature or web-site	X
	Yes, as part of installation training	
	Yes, available on request	
	No	
6.7	Do you carry out site inspections either during or after installation?	
	Yes, during installation	X if Protector warranty chosen
	Yes, after installation	X
	No	
6.8	If yes, who carries out your site inspections	
	Dedicated site personnel	X
	Technical personnel	
	Sales personnel	
	Other	
	Not applicable	
Additional comments		

Section 7 – Additional Comments

Please add any additional comments which you feel would add to this research dissertation and help reduce the instances of failure in halter based aluminium standing seam systems through a greater understanding of factors affecting the accommodation of thermal movement.

Appendix C.3 – Ash and Lacy Ltd



Section 1 – Personal Information

Name: STEVE DARLINGTON
Company: ASH + LACY BUILDING SYSTEMS
Position: TECHNICAL MANAGER

Would you be willing to be contacted to discuss your responses [✓ yes]/no)?
Would you be willing for any comments to be attributed to yourself ([✓ yes]/no)?

Section 2 - Testing, approvals and certification

Please indicate (with an X) all responses to the questions which are applicable. Please add additional comments where you feel it would be beneficial to expand on your responses.

2.1	Do you have a BBA (British Board of Agrément) or other third-party approval for your standing seam system?	
	Yes	✓
	No	
2.2	Is your standing seam system CE marked either as individual products or as a system (i.e. both standing seam sheet and halter together)?	
	Yes, standing seam sheet as a product to BS EN 14782:2006 – *Self-supporting metal sheet for roofing, external cladding and internal lining – Product specification and requirements*	✓
	Yes, halters as a product to CUAP 04.01/12 – *Spacer kits for built-up metal roof and wall cladding*	
	Yes, standing seam and halters as a system to CUAP 03.02/16 – *Roof and wall systems with hidden fastenings*	
	No	
2.3	Has in-plane force testing been carried out on your standing seam system? **NB** *In-plane force testing may also be known as friction resistance testing, sliding testing, simulated thermal movement testing etc.*	
	Yes, as part of the BBA (or other) approval process	✓
	Yes, as part of CE marking to CUAP 03.02/16	
	Yes, independent of approvals and certification	
	No	
2.4	Was in-plane force testing carried out to different degrees of alignment of halter?	
	Perfectly aligned	✓
	Misaligned to published system tolerances	✓
	Misaligned beyond published system tolerances	✓
	Not applicable	
2.5	Was in-plane force testing carried out with halters installed to different forms of structure or sub-structure?	
	Halter fixed direct to purlin	✓
	Halter fixed to structural decking profile	
	Halter fixed to bracket and rail system	✓
	Halter fixed to other type of structure/sub-structure	
	Not applicable	

Additional comments

I WAS NOT PARTY TO TESTS WITH BACK BRACKET

Section 3 – Design Information

Please indicate (with an X) all responses to the questions which are applicable. Please add additional comments where you feel it would be beneficial to expand on your responses.

3.1	Do you publish a technical or design manual/guide for your standing seam system?	
	Yes, readily available e.g. on web-site	✓
	Yes, available on request	
	No	
3.2	Do you provide design training on your standing seam system to specialist roofing and cladding contractors and/or detail designers?	
	Yes	✓
	No	
3.3	If you have undertaken in-plane force testing on your standing seam system how do you utilise or disseminate the results for use in design calculations?	
	Results readily available e.g. in Company literature or web-site	
	Results available on request	
	Results only available to key contacts, customers etc.	
	Results only used internally	✓
	Results not used	
	Not applicable	
3.4	What form of information or advice do you provide on how to determine the amount of thermal movement to be accommodated for use in detail design?	
	"Rule of thumb" for material (e.g. 1 mm per 1 m of sheet length)	
	"Rule of thumb" taking into account generic material, finish and/or colour (e.g. 1.5 mm per 1 mm of sheet length for dark coloured sheets)	X
	"Rule of thumb" taking into account specific material, surface finish and colour (e.g. 1.7 mm per 1 mm of sheet length for PVDF coated aluminium sheets to RAL 7016 – Anthracite Grey)	
	Information or design methodology to determine extremes of thermal expansion and contraction based on specific project conditions	X
	Computer design tool/software to determine extremes of thermal expansion and contraction based on specific project conditions	
	Other	
	None	
3.5	Do you provide information or advice on how to determine the amount of stress within a standing seam sheet and its resultant force if thermal movement of the sheet is fully restrained?	
	Yes, published within Company literature or web-site	
	Yes, on request If You Mean Relative To Fixed Point	X
	No	
3.6	Do you advise on a limit to effective length (i.e. length of sheet from fixed point) of standing seam sheet to be used or advise on the need for alternative methods to be adopted to limit the level of in-plane force within the system (e.g. different halter materials, different halter types etc.)?	
	Yes	✓
	Yes, conditional on alternative method being adopted	
	No	
3.7	Where conditions are applied to the limit of the effective length of the standing	

Depends upon
Project Specifics
Usually work
to Rule of
Thumb for
sheets upto
say 30m.

	seam sheet, what alternative methods do you recommend to reduce the level of in-plane force within the system? *Typical reasons for adopting an alternative methodology are indicated in italics.*	
	Secret gutter or step lap detail. *Shorter effective length of sheet*	X
	Increased number of fasteners in base of halter. *Increases resistance to over-turning moment of halter*	X
	Longer aluminium halters. *Reduces over-turning moment of halter*	X
	Halters of an alternative material, e.g. plastic. *Reduces friction between sheet and halter*	
	Sliding halters/clips. *Thermal movement is taken up within halter/clip itself*	
	Halters installed into a sliding rail running perpendicular or diagonal to direction of sheeting. *Improves alignment of halters*	
	Halters installed on a more robust sub-structure. *Increases resistance to over-turning moment of halter*	
	Other (please state in additional comments below)	
	Not applicable	

Additional comments

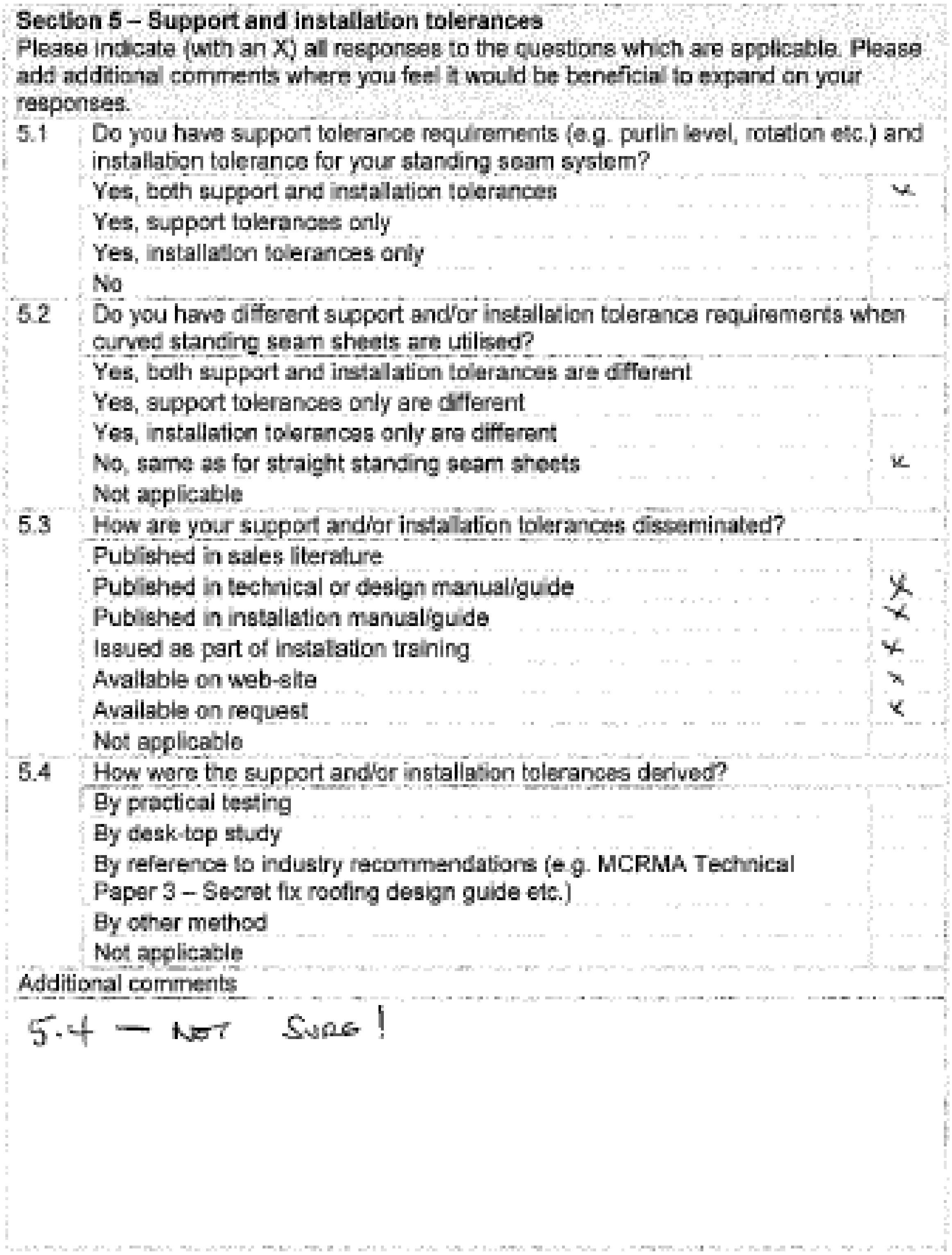
IT DEPENDS UPON SHAPE TYPE AS WE PRODUCE TWO SHAPE SYSTEMS

Section 4 – Production tolerances

Please indicate (with an X) all responses to the questions which are applicable. Please add additional comments where you feel it would be beneficial to expand on your responses.

4.1	Is your system manufactured under an independently accredited and audited quality management system e.g. to ISO 9001?	
	Yes, to ISO 9001	X
	Yes, as part of ongoing BBA (or other) approval	X
	No	
4.2	Do you check the dimensional accuracy of the standing seam sheet as part of your manufacturing processes?	
	Yes	X
	No	
4.3	Do your manufacturing tolerances differ for site production as opposed to factory production of standing seam sheets?	
	Yes, major differences in tolerances	
	Yes, but only differ slightly (e.g. length) ONLY IN LENGTH	X
	No	
4.4	Do you provide customers with a means of checking the dimensional accuracy of the shape of the standing seam sheet?	
	Yes, production drawing	
	Yes, template of correct shape	
	Yes, other means	
	No	X

Additional comments



Section 5 – Support and installation tolerances

Please indicate (with an X) all responses to the questions which are applicable. Please add additional comments where you feel it would be beneficial to expand on your responses.

5.1	Do you have support tolerance requirements (e.g. purlin level, rotation etc.) and installation tolerance for your standing seam system?	
	Yes, both support and installation tolerances	X
	Yes, support tolerances only	
	Yes, installation tolerances only	
	No	
5.2	Do you have different support and/or installation tolerance requirements when curved standing seam sheets are utilised?	
	Yes, both support and installation tolerances are different	
	Yes, support tolerances only are different	
	Yes, installation tolerances only are different	
	No, same as for straight standing seam sheets	X
	Not applicable	
5.3	How are your support and/or installation tolerances disseminated?	
	Published in sales literature	
	Published in technical or design manual/guide	X
	Published in installation manual/guide	X
	Issued as part of installation training	X
	Available on web-site	X
	Available on request	X
	Not applicable	
5.4	How were the support and/or installation tolerances derived?	
	By practical testing	
	By desk-top study	
	By reference to industry recommendations (e.g. MCRMA Technical Paper 3 – Secret fix roofing design guide etc.)	
	By other method	
	Not applicable	

Additional comments

5.4 — NOT SURE!

Section 6 – Installation

Please indicate (with an X) all responses to the questions which are applicable. Please add additional comments where you feel it would be beneficial to expand on your responses.

6.1	Do you publish an installation manual/guide for your standing seam system?	
	Yes, readily available e.g. on web-site	X
	Yes, available on request	
	No	
6.2	Do you provide installation training on your standing seam system to installers?	
	Yes	X
	No	
6.3	If yes, are your training courses accredited by a third party e.g. CITB, NFRC etc.?	
	Yes	
	No	X
	Not applicable	
6.4	Do you provide installers with information or advice on how to set out halters to system tolerances?	
	Yes, readily available e.g. in Company literature or web-site	X
	Yes, as part of installation training	X
	Yes, available on request	X
	No	
6.5	Do you provide installers with any aids to assist in setting out halters, e.g. templates?	
	Yes	X
	No	
6.6	Do you provide installers with information or advice on how to install perimeter flashings and penetrations?	
	Yes, readily available e.g. in Company literature or web-site	X
	Yes, as part of installation training	X
	Yes, available on request	
	No	
6.7	Do you carry out site inspections either during or after installation?	
	Yes, during installation	X
	Yes, after installation	X
	No	
6.8	If yes, who carries out your site inspections	
	Dedicated site personnel	
	Technical personnel	X
	Sales personnel	
	Other	X
	Not applicable	

Additional comments

6.7 – UPON REQUEST OR SOMETIMES VIA THIRD PARTY SUCH AS AWM.

Section 7 – Additional Comments

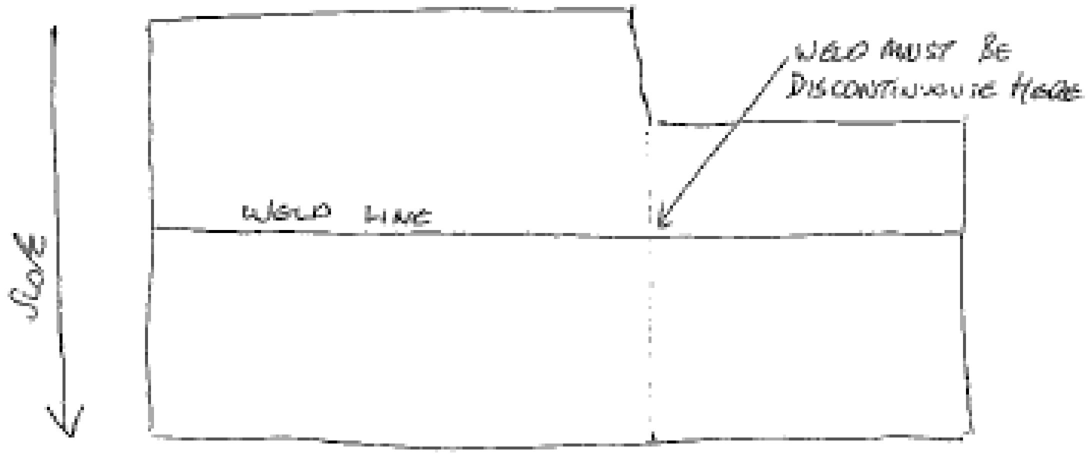
Please add any additional comments which you feel would add to this research dissertation and help reduce the instances of failure in halter based aluminium standing seam systems through a greater understanding of factors affecting the accommodation of thermal movement.

- THE SAME FACTORS GOVERN EXPANSION OF PERIMETER FLASHINGS. FAILURE TO DETAIL AND ALLOW FOR EXPANSION CAN LEAD TO PROBLEMS WITH PERIMETER COMPONENT FAILURE.
- WHERE A WELDED JOINT IS USED ACROSS THE WIDTH OF A ROOF, IF SHEET LENGTHS DIFFER ALONG THAT WIDTH DUE TO THE PLAN SHAPE, THE WELDS MUST BE DISCONTINUOUS. SEE SKETCH BELOW.

Thank you for taking the time to complete this questionnaire. Your input will be compiled with other respondents and reported upon within the research dissertation. If you are interested in the outcome of this research dissertation then I would be pleased to forward a copy to you.

Best Regards

David A Cottrell



Appendix C.4 – Bradclad Ltd

Section 1 – Personal Information	
Name:	Keith Bradley
Company:	Bradclad Limited
Position:	Owner
Would you be willing to be contacted to discuss your responses (yes/no)?	yes
Would you be willing for any comments to be attributed to yourself (yes/no)?	yes

Section 2 - Testing, approvals and certification

Please indicate (with an X) all responses to the questions which are applicable. Please add additional comments where you feel it would be beneficial to expand on your responses.

2.1	Do you have a BBA (British Board of Agrément) or other third-party approval for your standing seam system?	
	Yes	
	No	x
2.2	Is your standing seam system CE marked either as individual products or as a system (i.e. both standing seam sheet and halter together)?	
	Yes, standing seam sheet as a product to BS EN 14782:2006 – *Self-supporting metal sheet for roofing, external cladding and internal lining – Product specification and requirements*	
	Yes, halters as a product to CUAP 04.01/12 – *Spacer kits for built-up metal roof and wall cladding*	
	Yes, standing seam and halters as a system to CUAP 03.02/16 – *Roof and wall systems with hidden fastenings*	
	No	x
2.3	Has in-plane force testing been carried out on your standing seam system? **NB** *In-plane force testing may also be known as friction resistance testing, sliding testing, simulated thermal movement testing etc.*	
	Yes, as part of the BBA (or other) approval process	
	Yes, as part of CE marking to CUAP 03.02/16	
	Yes, independent of approvals and certification	x
	No	
2.4	Was in-plane force testing carried out to different degrees of alignment of halter?	
	Perfectly aligned	x
	Misaligned to published system tolerances	x
	Misaligned beyond published system tolerances	x
	Not applicable	
2.5	Was in-plane force testing carried out with halters installed to different forms of structure or sub-structure?	
	Halter fixed direct to purlin	x
	Halter fixed to structural decking profile	
	Halter fixed to bracket and rail system	
	Halter fixed to other type of structure/sub-structure	
	Not applicable	
Additional comments		

Section 3 – Design Information Please indicate (with an X) all responses to the questions which are applicable. Please add additional comments where you feel it would be beneficial to expand on your responses.		
3.1	Do you publish a technical or design manual/guide for your standing seam system?	
	Yes, readily available e.g. on web-site	x
	Yes, available on request	
	No	
3.2	Do you provide design training on your standing seam system to specialist roofing and cladding contractors and/or detail designers?	
	Yes	x
	No	
3.3	If you have undertaken in-plane force testing on your standing seam system how do you utilise or disseminate the results for use in design calculations?	
	Results readily available e.g. in Company literature or web-site	x
	Results available on request	
	Results only available to key contacts, customers etc.	
	Results only used internally	
	Results not used	
	Not applicable	
3.4	What form of information or advice do you provide on how to determine the amount of thermal movement to be accommodated for use in detail design?	
	“Rule of thumb” for material (e.g. 1 mm per 1 m of sheet length)	
	“Rule of thumb” taking into account generic material, finish and/or colour (e.g. 1.5 mm per 1 mm of sheet length for dark coloured sheets)	
	“Rule of thumb” taking into account specific material, surface finish and colour (e.g. 1.7 mm per 1 mm of sheet length for PVDF coated aluminium sheets to RAL 7016 – Anthracite Grey)	
	Information or design methodology to determine extremes of thermal expansion and contraction based on specific project conditions	x
	Computer design tool/software to determine extremes of thermal expansion and contraction based on specific project conditions	
	Other	
	None	
3.5	Do you provide information or advice on how to determine the amount of stress within a standing seam sheet and its resultant force if thermal movement of the sheet is fully restrained?	
	Yes, published within Company literature or web-site	x
	Yes, on request	
	No	
3.6	Do you advise on a limit to effective length (i.e. length of sheet from fixed point) of standing seam sheet to be used or advise on the need for alternative methods to be adopted to limit the level of in-plane force within the system (e.g. different halter materials, different halter types etc.)?	
	Yes	x
	Yes, conditional on alternative method being adopted	
	No	

3.7	Where conditions are applied to the limit of the effective length of the standing seam sheet, what alternative methods do you recommend to reduce the level of in-plane force within the system? *Typical reasons for adopting an alternative methodology are indicated in italics.*	
	Secret gutter or step lap detail. *Shorter effective length of sheet*	x
	Increased number of fasteners in base of halter. *Increases resistance to over-turning moment of halter*	
	Longer aluminium halters. *Reduces over-turning moment of halter*	
	Halters of an alternative material, e.g. plastic. *Reduces friction between sheet and halter*	x
	Sliding halters/clips. *Thermal movement is taken up within halter/clip itself*	
	Halters installed into a sliding rail running perpendicular or diagonal to direction of sheeting. *Improves alignment of halters*	
	Halters installed on a more robust sub-structure. *Increases resistance to over-turning moment of halter*	x
	Other (please state in additional comments below)	
	Not applicable	
Additional comments		

Section 4 – Production tolerances Please indicate (with an X) all responses to the questions which are applicable. Please add additional comments where you feel it would be beneficial to expand on your responses.		
4.1	Is your system manufactured under an independently accredited and audited quality management system e.g. to ISO 9001?	
	Yes, to ISO 9001	
	Yes, as part of ongoing BBA (or other) approval	
	No	x
4.2	Do you check the dimensional accuracy of the standing seam sheet as part of your manufacturing processes?	
	Yes	x
	No	
4.3	Do your manufacturing tolerances differ for site production as opposed to factory production of standing seam sheets?	
	Yes, major differences in tolerances	
	Yes, but only differ slightly (e.g. length)	
	No	x
4.4	Do you provide customers with a means of checking the dimensional accuracy of the shape of the standing seam sheet?	
	Yes, production drawing	
	Yes, template of correct shape	
	Yes, other means	
	No	x
Additional comments		

Section 5 – Support and installation tolerances
Please indicate (with an X) all responses to the questions which are applicable. Please add additional comments where you feel it would be beneficial to expand on your responses.

5.1	Do you have support tolerance requirements (e.g. purlin level, rotation etc.) and installation tolerance for your standing seam system?	
	Yes, both support and installation tolerances	x
	Yes, support tolerances only	
	Yes, installation tolerances only	
	No	
5.2	Do you have different support and/or installation tolerance requirements when curved standing seam sheets are utilised?	
	Yes, both support and installation tolerances are different	x
	Yes, support tolerances only are different	
	Yes, installation tolerances only are different	
	No, same as for straight standing seam sheets	
	Not applicable	
5.3	How are your support and/or installation tolerances disseminated?	
	Published in sales literature	
	Published in technical or design manual/guide	x
	Published in installation manual/guide	
	Issued as part of installation training	x
	Available on web-site	
	Available on request	
	Not applicable	
5.4	How were the support and/or installation tolerances derived?	
	By practical testing	x
	By desk-top study	
	By reference to industry recommendations (e.g. MCRMA Technical Paper 3 – Secret fix roofing design guide etc.)	x
	By other method	
	Not applicable	
Additional comments		

Section 6 – Installation
Please indicate (with an X) all responses to the questions which are applicable. Please add additional comments where you feel it would be beneficial to expand on your responses.

6.1	Do you publish an installation manual/guide for your standing seam system?	
	Yes, readily available e.g. on web-site	
	Yes, available on request	x
	No	
6.2	Do you provide installation training on your standing seam system to installers?	
	Yes	x
	No	

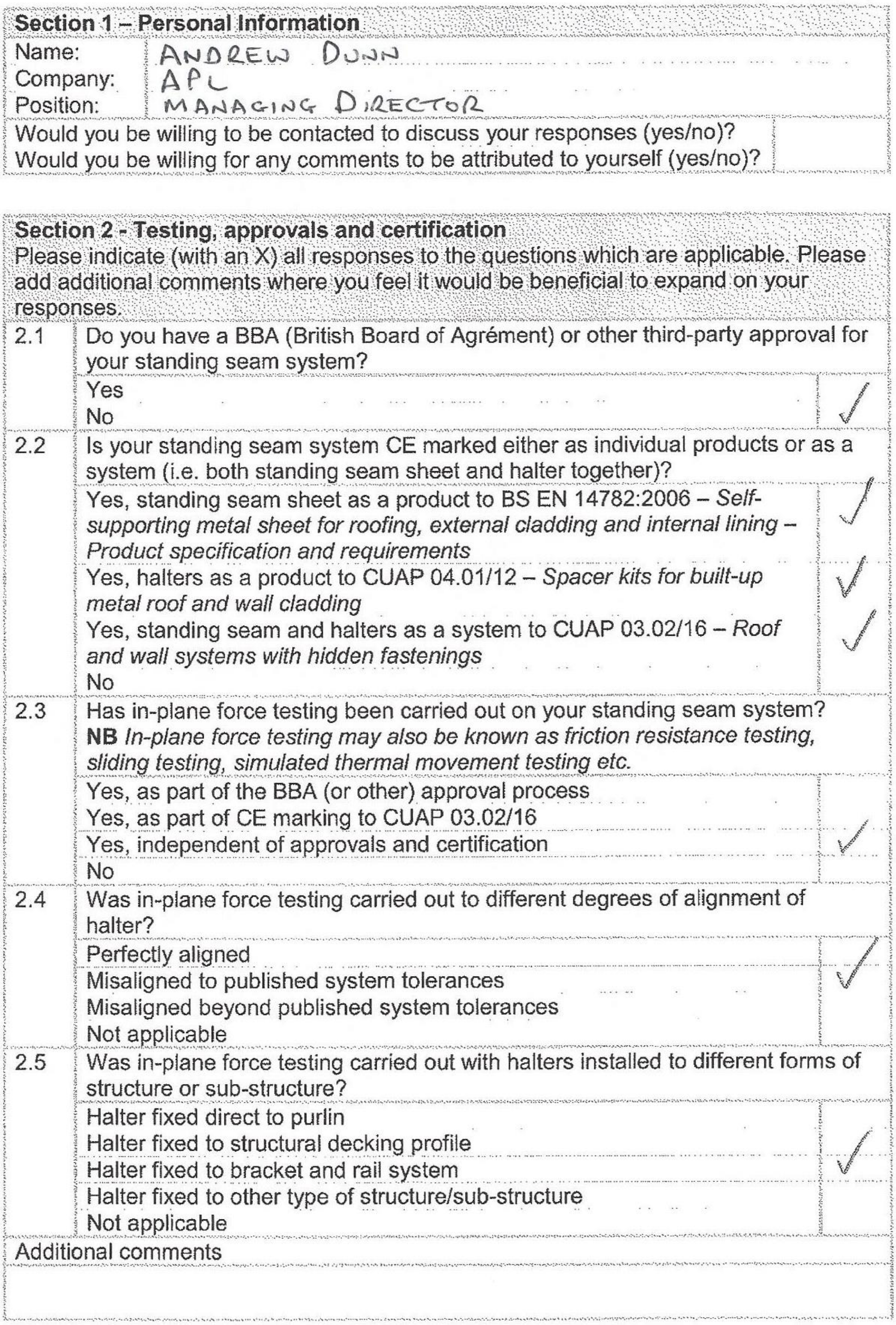
6.3	If yes, are your training courses accredited by a third party e.g. CITB, NFRC etc.?	
	Yes	
	No	x
	Not applicable	
6.4	Do you provide installers with information or advice on how to set out halters to system tolerances?	
	Yes, readily available e.g. in Company literature or web-site	x
	Yes, as part of installation training	
	Yes, available on request	
	No	
6.5	Do you provide installers with any aids to assist in setting out halters, e.g. templates?	
	Yes	x
	No	
6.6	Do you provide installers with information or advice on how to install perimeter flashings and penetrations?	
	Yes, readily available e.g. in Company literature or web-site	x
	Yes, as part of installation training	
	Yes, available on request	
	No	
6.7	Do you carry out site inspections either during or after installation?	
	Yes, during installation	x
	Yes, after installation	x
	No	
6.8	If yes, who carries out your site inspections	
	Dedicated site personnel	
	Technical personnel	x
	Sales personnel	
	Other	
	Not applicable	
Additional comments		

Section 7 – Additional Comments

Please add any additional comments which you feel would add to this research dissertation and help reduce the instances of failure in halter based aluminium standing seam systems through a greater understanding of factors affecting the accommodation of thermal movement.

We can publish many thousands of words of technical advice and support, test data and so on. This might provide the manufacturer with cover and protection in the event of a failure. However, unless the advice is read, understood and incorporated into the design and installation of the roof, failures – and the arguments about how and by whom - will continue. We still meet with architects and designers who seem to have forgotten that aluminium expands when it gets warmer - and too many installers who need to appreciate the importance of what they do and how they do it.

Appendix C.5 – Architectural Profiles Ltd



Section 1 – Personal Information

Name: ANDREW DUNN
Company: APL
Position: MANAGING DIRECTOR

Would you be willing to be contacted to discuss your responses (yes/no)?	
Would you be willing for any comments to be attributed to yourself (yes/no)?	

Section 2 - Testing, approvals and certification
Please indicate (with an X) all responses to the questions which are applicable. Please add additional comments where you feel it would be beneficial to expand on your responses.

2.1	Do you have a BBA (British Board of Agrément) or other third-party approval for your standing seam system?	
	Yes	
	No	✓
2.2	Is your standing seam system CE marked either as individual products or as a system (i.e. both standing seam sheet and halter together)?	
	Yes, standing seam sheet as a product to BS EN 14782:2006 – *Self-supporting metal sheet for roofing, external cladding and internal lining – Product specification and requirements*	✓
	Yes, halters as a product to CUAP 04.01/12 – *Spacer kits for built-up metal roof and wall cladding*	✓
	Yes, standing seam and halters as a system to CUAP 03.02/16 – *Roof and wall systems with hidden fastenings*	✓
	No	
2.3	Has in-plane force testing been carried out on your standing seam system? **NB** *In-plane force testing may also be known as friction resistance testing, sliding testing, simulated thermal movement testing etc.*	
	Yes, as part of the BBA (or other) approval process	
	Yes, as part of CE marking to CUAP 03.02/16	
	Yes, independent of approvals and certification	✓
	No	
2.4	Was in-plane force testing carried out to different degrees of alignment of halter?	
	Perfectly aligned	
	Misaligned to published system tolerances	✓
	Misaligned beyond published system tolerances	
	Not applicable	
2.5	Was in-plane force testing carried out with halters installed to different forms of structure or sub-structure?	
	Halter fixed direct to purlin	
	Halter fixed to structural decking profile	
	Halter fixed to bracket and rail system	✓
	Halter fixed to other type of structure/sub-structure	
	Not applicable	

Additional comments

Section 3 – Design Information

Please indicate (with an X) all responses to the questions which are applicable. Please add additional comments where you feel it would be beneficial to expand on your responses.

3.1	Do you publish a technical or design manual/guide for your standing seam system?	
	Yes, readily available e.g. on web-site	
	Yes, available on request	✓
	No	
3.2	Do you provide design training on your standing seam system to specialist roofing and cladding contractors and/or detail designers?	
	Yes	✓
	No	
3.3	If you have undertaken in-plane force testing on your standing seam system how do you utilise or disseminate the results for use in design calculations?	
	Results readily available e.g. in Company literature or web-site	
	Results available on request	
	Results only available to key contacts, customers etc.	
	Results only used internally	✓
	Results not used	
	Not applicable	
3.4	What form of information or advice do you provide on how to determine the amount of thermal movement to be accommodated for use in detail design?	
	"Rule of thumb" for material (e.g. 1 mm per 1 m of sheet length)	
	"Rule of thumb" taking into account generic material, finish and/or colour (e.g. 1.5 mm per 1 mm of sheet length for dark coloured sheets)	✓
	"Rule of thumb" taking into account specific material, surface finish and colour (e.g. 1.7 mm per 1 mm of sheet length for PVDF coated aluminium sheets to RAL 7016 – Anthracite Grey)	
	Information or design methodology to determine extremes of thermal expansion and contraction based on specific project conditions	
	Computer design tool/software to determine extremes of thermal expansion and contraction based on specific project conditions	
	Other	
	None	
3.5	Do you provide information or advice on how to determine the amount of stress within a standing seam sheet and its resultant force if thermal movement of the sheet is fully restrained?	
	Yes, published within Company literature or web-site	
	Yes, on request	
	No	✓
3.6	Do you advise on a limit to effective length (i.e. length of sheet from fixed point) of standing seam sheet to be used or advise on the need for alternative methods to be adopted to limit the level of in-plane force within the system (e.g. different halter materials, different halter types etc.)?	
	Yes	✓
	Yes, conditional on alternative method being adopted	
	No	

3.7	Where conditions are applied to the limit of the effective length of the standing seam sheet, what alternative methods do you recommend to reduce the level of in-plane force within the system? *Typical reasons for adopting an alternative methodology are indicated in italics.*	
	Secret gutter or step lap detail. *Shorter effective length of sheet*	
	Increased number of fasteners in base of halter. *Increases resistance to over-turning moment of halter*	
	Longer aluminium halters. *Reduces over-turning moment of halter*	✓
	Halters of an alternative material, e.g. plastic. *Reduces friction between sheet and halter*	
	Sliding halters/clips. *Thermal movement is taken up within halter/clip itself*	
	Halters installed into a sliding rail running perpendicular or diagonal to direction of sheeting. *Improves alignment of halters*	
	Halters installed on a more robust sub-structure. *Increases resistance to over-turning moment of halter*	✓
	Other (please state in additional comments below)	
	Not applicable	

Additional comments

SPECIAL EAVES HALTERS ALSO AVAILABLE

Section 4 – Production tolerances

Please indicate (with an X) all responses to the questions which are applicable. Please add additional comments where you feel it would be beneficial to expand on your responses.

4.1	Is your system manufactured under an independently accredited and audited quality management system e.g. to ISO 9001?	
	Yes, to ISO 9001	✓
	Yes, as part of ongoing BBA (or other) approval	
	No	
4.2	Do you check the dimensional accuracy of the standing seam sheet as part of your manufacturing processes?	
	Yes	✓
	No	
4.3	Do your manufacturing tolerances differ for site production as opposed to factory production of standing seam sheets?	
	Yes, major differences in tolerances	
	Yes, but only differ slightly (e.g. length)	✓
	No	
4.4	Do you provide customers with a means of checking the dimensional accuracy of the shape of the standing seam sheet?	
	Yes, production drawing	
	Yes, template of correct shape	✓
	Yes, other means	
	No	

Additional comments

Section 5 – Support and installation tolerances
Please indicate (with an X) all responses to the questions which are applicable. Please add additional comments where you feel it would be beneficial to expand on your responses.

5.1	Do you have support tolerance requirements (e.g. purlin level, rotation etc.) and installation tolerance for your standing seam system?	
	Yes, both support and installation tolerances	✓
	Yes, support tolerances only	✓
	Yes, installation tolerances only	
	No	
5.2	Do you have different support and/or installation tolerance requirements when curved standing seam sheets are utilised?	
	Yes, both support and installation tolerances are different	✓
	Yes, support tolerances only are different	
	Yes, installation tolerances only are different	
	No, same as for straight standing seam sheets	
	Not applicable	
5.3	How are your support and/or installation tolerances disseminated?	
	Published in sales literature	
	Published in technical or design manual/guide	
	Published in installation manual/guide	✓
	Issued as part of installation training	✓
	Available on web-site	
	Available on request	
	Not applicable	
5.4	How were the support and/or installation tolerances derived?	
	By practical testing	✓
	By desk-top study	
	By reference to industry recommendations (e.g. MCRMA Technical Paper 3 – Secret fix roofing design guide etc.)	
	By other method	
	Not applicable	

Additional comments

Section 6 – Installation Please indicate (with an X) all responses to the questions which are applicable. Please add additional comments where you feel it would be beneficial to expand on your responses.		
6.1	Do you publish an installation manual/guide for your standing seam system?	
	Yes, readily available e.g. on web-site	
	Yes, available on request	✓
	No	
6.2	Do you provide installation training on your standing seam system to installers?	
	Yes	✓
	No	
6.3	If yes, are your training courses accredited by a third party e.g. CITB, NFRC etc.?	
	Yes	
	No	✓
	Not applicable	
6.4	Do you provide installers with information or advice on how to set out halters to system tolerances?	
	Yes, readily available e.g. in Company literature or web-site	
	Yes, as part of installation training	✓
	Yes, available on request	✓
	No	
6.5	Do you provide installers with any aids to assist in setting out halters, e.g. templates?	
	Yes	✓
	No	
6.6	Do you provide installers with information or advice on how to install perimeter flashings and penetrations?	
	Yes, readily available e.g. in Company literature or web-site	
	Yes, as part of installation training	✓
	Yes, available on request	
	No	
6.7	Do you carry out site inspections either during or after installation?	
	Yes, during installation	✓
	Yes, after installation	
	No	
6.8	If yes, who carries out your site inspections	
	Dedicated site personnel	
	Technical personnel	✓
	Sales personnel	
	Other	
	Not applicable	
Additional comments		

Appendix C.6 – Euro Clad Ltd

Section 1 – Personal Information	
Name:	Paul Clayton
Company:	Euro Clad Ltd
Position:	Group Technical Manager
Would you be willing to be contacted to discuss your responses (yes/no)?	yes
Would you be willing for any comments to be attributed to yourself (yes/no)?	yes

Section 2 - Testing, approvals and certification Please indicate (with an X) all responses to the questions which are applicable. Please add additional comments where you feel it would be beneficial to expand on your responses.		
2.1	Do you have a BBA (British Board of Agrément) or other third-party approval for your standing seam system?	
	Yes	yes
	No	
2.2	Is your standing seam system CE marked either as individual products or as a system (i.e. both standing seam sheet and halter together)?	
	Yes, standing seam sheet as a product to BS EN 14782:2006 – *Self-supporting metal sheet for roofing, external cladding and internal lining – Product specification and requirements*	yes
	Yes, halters as a product to CUAP 04.01/12 – *Spacer kits for built-up metal roof and wall cladding*	yes
	Yes, standing seam and halters as a system to CUAP 03.02/16 – *Roof and wall systems with hidden fastenings*	
	No	
2.3	Has in-plane force testing been carried out on your standing seam system? **NB** *In-plane force testing may also be known as friction resistance testing, sliding testing, simulated thermal movement testing etc.*	
	Yes, as part of the BBA (or other) approval process	yes
	Yes, as part of CE marking to CUAP 03.02/16	
	Yes, independent of approvals and certification	yes
	No	
2.4	Was in-plane force testing carried out to different degrees of alignment of halter?	
	Perfectly aligned	yes
	Misaligned to published system tolerances	yes
	Misaligned beyond published system tolerances	
	Not applicable	
2.5	Was in-plane force testing carried out with halters installed to different forms of structure or sub-structure?	
	Halter fixed direct to purlin	yes
	Halter fixed to structural decking profile	
	Halter fixed to bracket and rail system	yes
	Halter fixed to other type of structure/sub-structure	
	Not applicable	
Additional comments		

Section 3 – Design Information

Please indicate (with an X) all responses to the questions which are applicable. Please add additional comments where you feel it would be beneficial to expand on your responses.

3.1	Do you publish a technical or design manual/guide for your standing seam system?	
	Yes, readily available e.g. on web-site	yes
	Yes, available on request	
	No	
3.2	Do you provide design training on your standing seam system to specialist roofing and cladding contractors and/or detail designers?	
	Yes	Yes*
	No	
3.3	If you have undertaken in-plane force testing on your standing seam system how do you utilise or disseminate the results for use in design calculations?	
	Results readily available e.g. in Company literature or web-site	
	Results available on request	
	Results only available to key contacts, customers etc.	
	Results only used internally	yes
	Results not used	
	Not applicable	
3.4	What form of information or advice do you provide on how to determine the amount of thermal movement to be accommodated for use in detail design?	
	“Rule of thumb” for material (e.g. 1 mm per 1 m of sheet length)	
	“Rule of thumb” taking into account generic material, finish and/or colour (e.g. 1.5 mm per 1 mm of sheet length for dark coloured sheets)	yes
	“Rule of thumb” taking into account specific material, surface finish and colour (e.g. 1.7 mm per 1 mm of sheet length for PVDF coated aluminium sheets to RAL 7016 – Anthracite Grey)	
	Information or design methodology to determine extremes of thermal expansion and contraction based on specific project conditions	yes
	Computer design tool/software to determine extremes of thermal expansion and contraction based on specific project conditions	
	Other	
	None	
3.5	Do you provide information or advice on how to determine the amount of stress within a standing seam sheet and its resultant force if thermal movement of the sheet is fully restrained?	
	Yes, published within Company literature or web-site	
	Yes, on request	yes
	No	
3.6	Do you advise on a limit to effective length (i.e. length of sheet from fixed point) of standing seam sheet to be used or advise on the need for alternative methods to be adopted to limit the level of in-plane force within the system (e.g. different halter materials, different halter types etc.)?	
	Yes	yes
	Yes, conditional on alternative method being adopted	
	No	
3.7	Where conditions are applied to the limit of the effective length of the standing seam sheet, what alternative methods do you recommend to reduce the level of	

	in-plane force within the system? *Typical reasons for adopting an alternative methodology are indicated in italics.*	
	Secret gutter or step lap detail. *Shorter effective length of sheet*	yes
	Increased number of fasteners in base of halter. *Increases resistance to over-turning moment of halter*	
	Longer aluminium halters. *Reduces over-turning moment of halter*	
	Halters of an alternative material, e.g. plastic. *Reduces friction between sheet and halter*	
	Sliding halters/clips. *Thermal movement is taken up within halter/clip itself*	
	Halters installed into a sliding rail running perpendicular or diagonal to direction of sheeting. *Improves alignment of halters*	
	Halters installed on a more robust sub-structure. *Increases resistance to over-turning moment of halter*	
	Other (please state in additional comments below)	
	Not applicable	
Additional comments		
*Design training on request		

Section 4 – Production tolerances Please indicate (with an X) all responses to the questions which are applicable. Please add additional comments where you feel it would be beneficial to expand on your responses.		
4.1	Is your system manufactured under an independently accredited and audited quality management system e.g. to ISO 9001?	
	Yes, to ISO 9001	yes
	Yes, as part of ongoing BBA (or other) approval	yes
	No	
4.2	Do you check the dimensional accuracy of the standing seam sheet as part of your manufacturing processes?	
	Yes	yes
	No	
4.3	Do your manufacturing tolerances differ for site production as opposed to factory production of standing seam sheets?	
	Yes, major differences in tolerances	
	Yes, but only differ slightly (e.g. length)	
	No	no
4.4	Do you provide customers with a means of checking the dimensional accuracy of the shape of the standing seam sheet?	
	Yes, production drawing	yes
	Yes, template of correct shape	
	Yes, other means	
	No	
Additional comments		

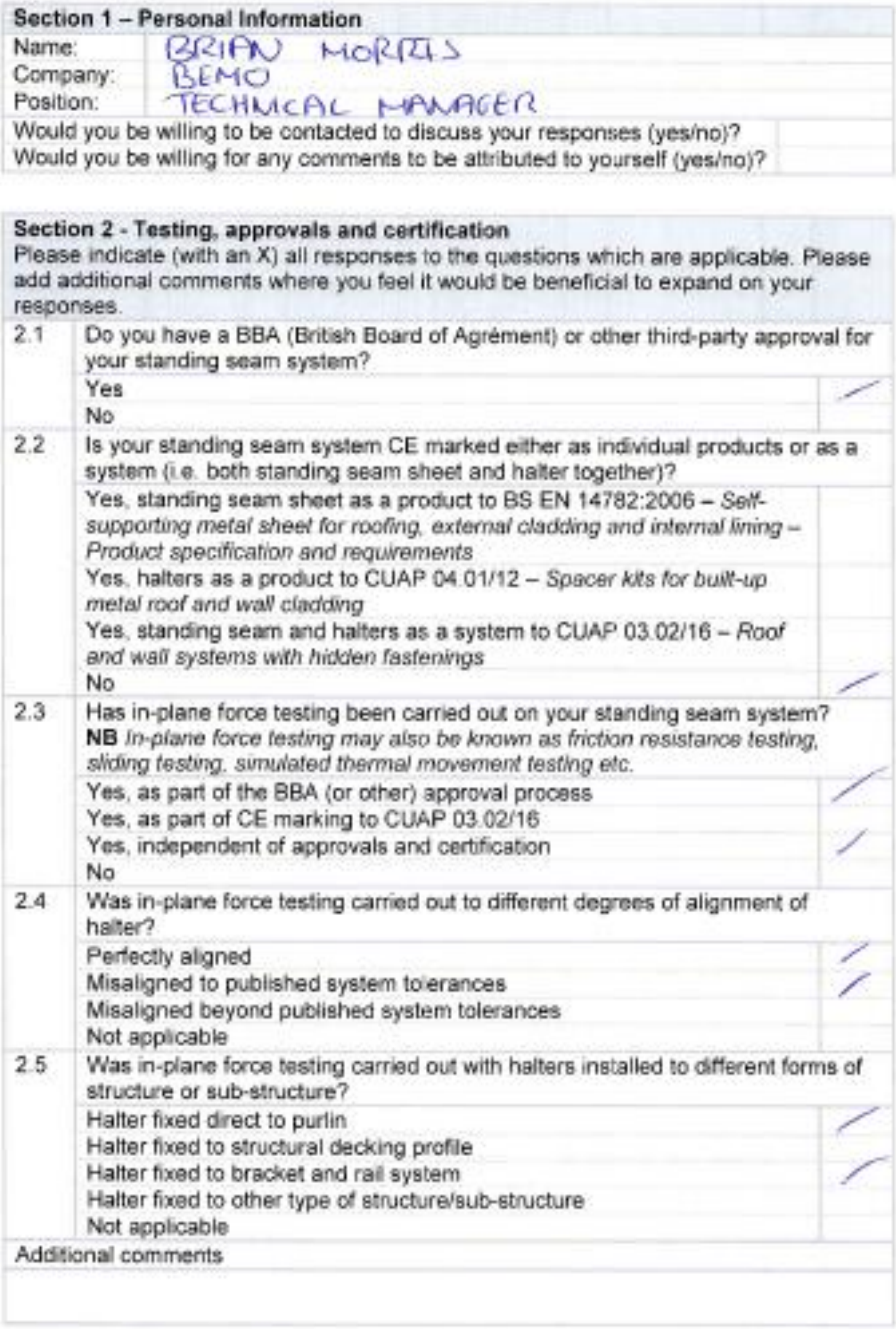
Section 5 – Support and installation tolerances Please indicate (with an X) all responses to the questions which are applicable. Please add additional comments where you feel it would be beneficial to expand on your responses.		
5.1	Do you have support tolerance requirements (e.g. purlin level, rotation etc.) and installation tolerance for your standing seam system?	
	Yes, both support and installation tolerances	yes
	Yes, support tolerances only	
	Yes, installation tolerances only	
	No	
5.2	Do you have different support and/or installation tolerance requirements when curved standing seam sheets are utilised?	
	Yes, both support and installation tolerances are different	yes
	Yes, support tolerances only are different	
	Yes, installation tolerances only are different	
	No, same as for straight standing seam sheets	
	Not applicable	
5.3	How are your support and/or installation tolerances disseminated?	
	Published in sales literature	
	Published in technical or design manual/guide	yes
	Published in installation manual/guide	
	Issued as part of installation training	yes
	Available on web-site	
	Available on request	yes
	Not applicable	
5.4	How were the support and/or installation tolerances derived?	
	By practical testing	yes
	By desk-top study	yes
	By reference to industry recommendations (e.g. MCRMA Technical Paper 3 – Secret fix roofing design guide etc.)	yes
	By other method	
	Not applicable	
Additional comments		

Section 6 – Installation Please indicate (with an X) all responses to the questions which are applicable. Please add additional comments where you feel it would be beneficial to expand on your responses.		
6.1	Do you publish an installation manual/guide for your standing seam system?	
	Yes, readily available e.g. on web-site	yes
	Yes, available on request	yes
	No	
6.2	Do you provide installation training on your standing seam system to installers?	
	Yes	yes
	No	

6.3	If yes, are your training courses accredited by a third party e.g. CITB, NFRC etc.?	
	Yes	
	No	no
	Not applicable	
6.4	Do you provide installers with information or advice on how to set out halters to system tolerances?	
	Yes, readily available e.g. in Company literature or web-site	yes
	Yes, as part of installation training	yes
	Yes, available on request	yes
	No	
6.5	Do you provide installers with any aids to assist in setting out halters, e.g. templates?	
	Yes	yes
	No	
6.6	Do you provide installers with information or advice on how to install perimeter flashings and penetrations?	
	Yes, readily available e.g. in Company literature or web-site	yes
	Yes, as part of installation training	yes
	Yes, available on request	
	No	
6.7	Do you carry out site inspections either during or after installation?	
	Yes, during installation	yes
	Yes, after installation	yes
	No	
6.8	If yes, who carries out your site inspections	
	Dedicated site personnel	yes
	Technical personnel	yes
	Sales personnel	yes
	Other	
	Not applicable	
Additional comments		

Section 7 – Additional Comments Please add any additional comments which you feel would add to this research dissertation and help reduce the instances of failure in halter based aluminium standing seam systems through a greater understanding of factors affecting the accommodation of thermal movement.
Most common issue is detailing and consideration of movement against welded details. For example inclusion details for weathering where multiple fixed points are created or where multiple welds have been included which would be susceptible to damage.

Appendix C.7 – BEMO UK



Section 1 – Personal Information	
Name:	BRIAN MORRIS
Company:	BEMO
Position:	TECHNICAL MANAGER
Would you be willing to be contacted to discuss your responses (yes/no)?	
Would you be willing for any comments to be attributed to yourself (yes/no)?	

Section 2 - Testing, approvals and certification

Please indicate (with an X) all responses to the questions which are applicable. Please add additional comments where you feel it would be beneficial to expand on your responses.

2.1	Do you have a BBA (British Board of Agrément) or other third-party approval for your standing seam system?	
	Yes	✓
	No	
2.2	Is your standing seam system CE marked either as individual products or as a system (i.e. both standing seam sheet and halter together)?	
	Yes, standing seam sheet as a product to BS EN 14782:2006 – *Self-supporting metal sheet for roofing, external cladding and internal lining – Product specification and requirements*	
	Yes, halters as a product to CUAP 04.01/12 – *Spacer kits for built-up metal roof and wall cladding*	
	Yes, standing seam and halters as a system to CUAP 03.02/16 – *Roof and wall systems with hidden fastenings*	
	No	✓
2.3	Has in-plane force testing been carried out on your standing seam system? **NB** *In-plane force testing may also be known as friction resistance testing, sliding testing, simulated thermal movement testing etc.*	
	Yes, as part of the BBA (or other) approval process	✓
	Yes, as part of CE marking to CUAP 03.02/16	
	Yes, independent of approvals and certification	✓
	No	
2.4	Was in-plane force testing carried out to different degrees of alignment of halter?	
	Perfectly aligned	✓
	Misaligned to published system tolerances	✓
	Misaligned beyond published system tolerances	
	Not applicable	
2.5	Was in-plane force testing carried out with halters installed to different forms of structure or sub-structure?	
	Halter fixed direct to purlin	✓
	Halter fixed to structural decking profile	
	Halter fixed to bracket and rail system	✓
	Halter fixed to other type of structure/sub-structure	
	Not applicable	
Additional comments		

Section 3 – Design Information

Please indicate (with an X) all responses to the questions which are applicable. Please add additional comments where you feel it would be beneficial to expand on your responses.

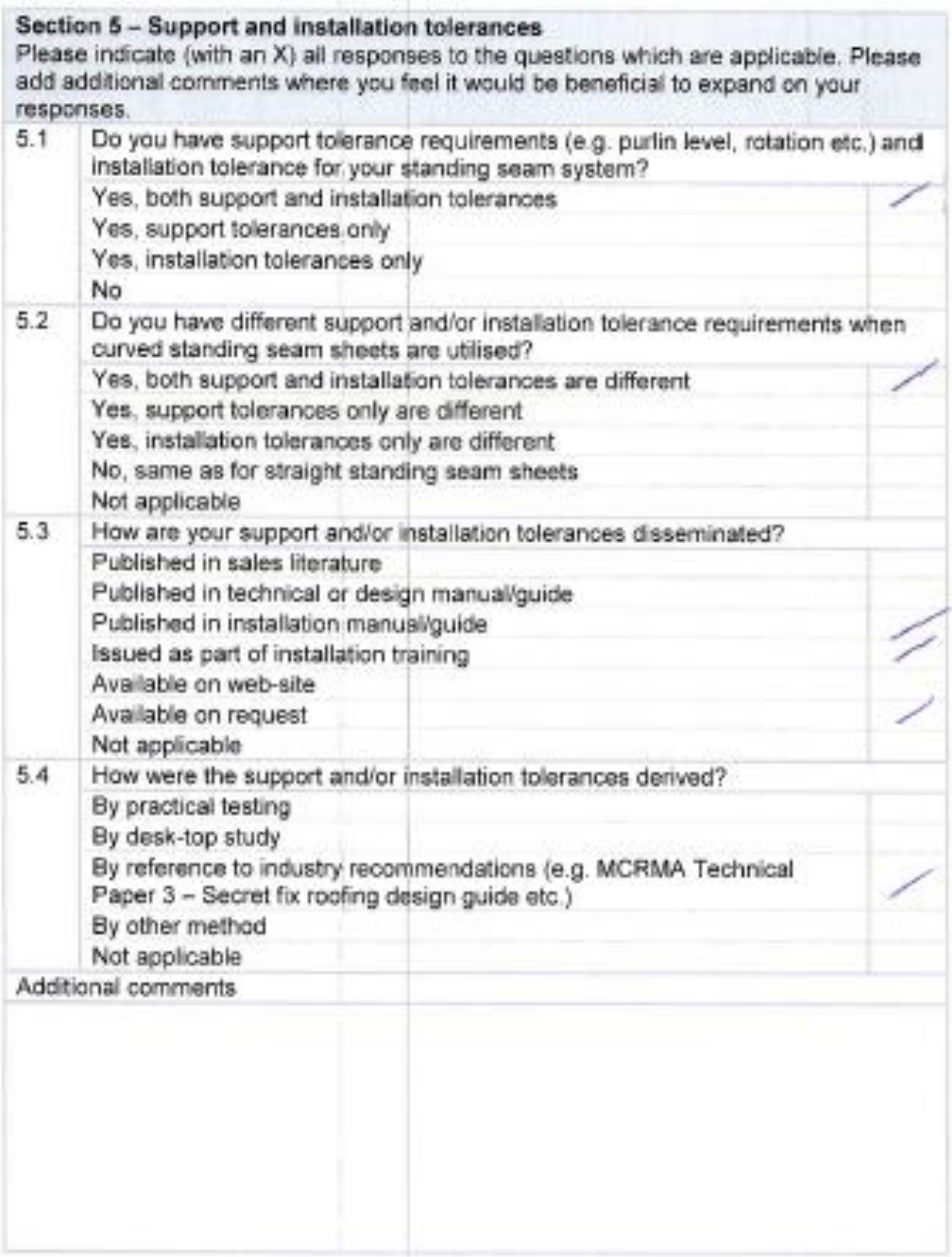
3.1	Do you publish a technical or design manual/guide for your standing seam system?	
	Yes, readily available e.g. on web-site	
	Yes, available on request	✓
	No	
3.2	Do you provide design training on your standing seam system to specialist roofing and cladding contractors and/or detail designers?	
	Yes	✓
	No	
3.3	If you have undertaken in-plane force testing on your standing seam system how do you utilise or disseminate the results for use in design calculations?	
	Results readily available e.g. in Company literature or web-site	
	Results available on request	✓
	Results only available to key contacts, customers etc.	
	Results only used internally	
	Results not used	
	Not applicable	
3.4	What form of information or advice do you provide on how to determine the amount of thermal movement to be accommodated for use in detail design?	
	"Rule of thumb" for material (e.g. 1 mm per 1 m of sheet length)	
	"Rule of thumb" taking into account generic material, finish and/or colour (e.g. 1.5 mm per 1 mm of sheet length for dark coloured sheets)	
	"Rule of thumb" taking into account specific material, surface finish and colour (e.g. 1.7 mm per 1 mm of sheet length for PVDF coated aluminium sheets to RAL 7016 – Anthracite Grey)	✓
	Information or design methodology to determine extremes of thermal expansion and contraction based on specific project conditions	
	Computer design tool/software to determine extremes of thermal expansion and contraction based on specific project conditions	✓
	Other	
	None	
3.5	Do you provide information or advice on how to determine the amount of stress within a standing seam sheet and its resultant force if thermal movement of the sheet is fully restrained?	
	Yes, published within Company literature or web-site	
	Yes, on request	✓
	No	
3.6	Do you advise on a limit to effective length (i.e. length of sheet from fixed point) of standing seam sheet to be used or advise on the need for alternative methods to be adopted to limit the level of in-plane force within the system (e.g. different halter materials, different halter types etc.)?	
	Yes	✓
	Yes, conditional on alternative method being adopted	
	No	
3.7	Where conditions are applied to the limit of the effective length of the standing	

	seam sheet, what alternative methods do you recommend to reduce the level of in-plane force within the system? *Typical reasons for adopting an alternative methodology are indicated in italics.*	
	Secret gutter or step lap detail. *Shorter effective length of sheet*	
	Increased number of fasteners in base of halter. *Increases resistance to over-turning moment of halter*	✓
	Longer aluminium halters. *Reduces over-turning moment of halter*	
	Halters of an alternative material, e.g. plastic. *Reduces friction between sheet and halter*	
	Sliding halters/clips. *Thermal movement is taken up within halter/clip itself*	
	Halters installed into a sliding rail running perpendicular or diagonal to direction of sheeting. *Improves alignment of halters*	
	Halters installed on a more robust sub-structure. *Increases resistance to over-turning moment of halter*	
	Other (please state in additional comments below)	✓
	Not applicable	
Additional comments		
Revised fixed point location, ie. centre of sheet		

Section 4 – Production tolerances

Please indicate (with an X) all responses to the questions which are applicable. Please add additional comments where you feel it would be beneficial to expand on your responses.

4.1	Is your system manufactured under an independently accredited and audited quality management system e.g. to ISO 9001?	
	Yes, to ISO 9001	
	Yes, as part of ongoing BBA (or other) approval	✓
	No	
4.2	Do you check the dimensional accuracy of the standing seam sheet as part of your manufacturing processes?	
	Yes	✓
	No	
4.3	Do your manufacturing tolerances differ for site production as opposed to factory production of standing seam sheets?	
	Yes, major differences in tolerances	
	Yes, but only differ slightly (e.g. length)	
	No	✓
4.4	Do you provide customers with a means of checking the dimensional accuracy of the shape of the standing seam sheet?	
	Yes, production drawing	✓
	Yes, template of correct shape	
	Yes, other means	
	No	
Additional comments		

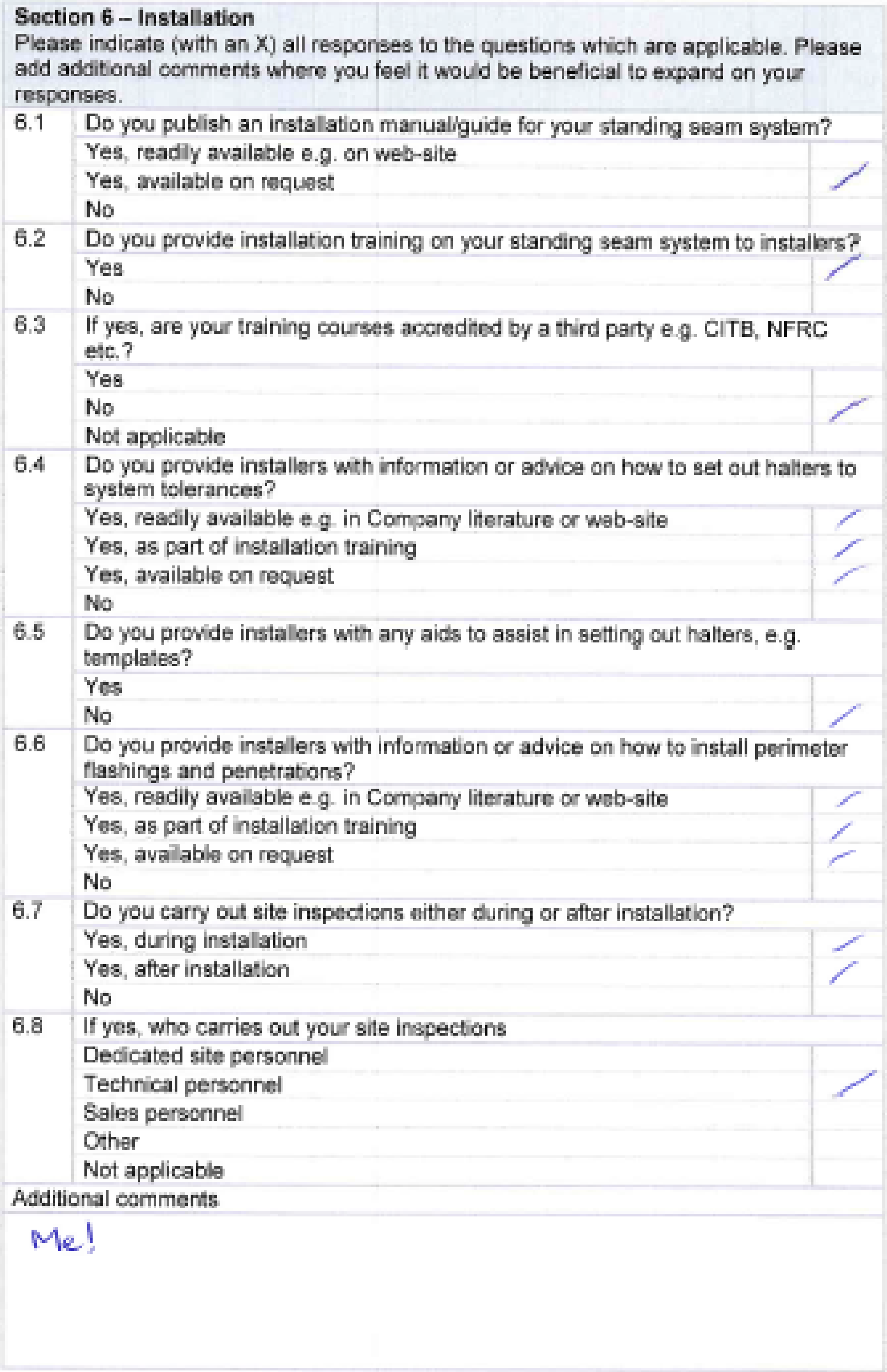


Section 5 – Support and installation tolerances

Please indicate (with an X) all responses to the questions which are applicable. Please add additional comments where you feel it would be beneficial to expand on your responses.

5.1	Do you have support tolerance requirements (e.g. purlin level, rotation etc.) and installation tolerance for your standing seam system?	
	Yes, both support and installation tolerances	✓
	Yes, support tolerances only	
	Yes, installation tolerances only	
	No	
5.2	Do you have different support and/or installation tolerance requirements when curved standing seam sheets are utilised?	
	Yes, both support and installation tolerances are different	✓
	Yes, support tolerances only are different	
	Yes, installation tolerances only are different	
	No, same as for straight standing seam sheets	
	Not applicable	
5.3	How are your support and/or installation tolerances disseminated?	
	Published in sales literature	
	Published in technical or design manual/guide	
	Published in installation manual/guide	✓
	Issued as part of installation training	✓
	Available on web-site	
	Available on request	✓
	Not applicable	
5.4	How were the support and/or installation tolerances derived?	
	By practical testing	
	By desk-top study	
	By reference to industry recommendations (e.g. MCRMA Technical Paper 3 – Secret fix roofing design guide etc.)	✓
	By other method	
	Not applicable	

Additional comments



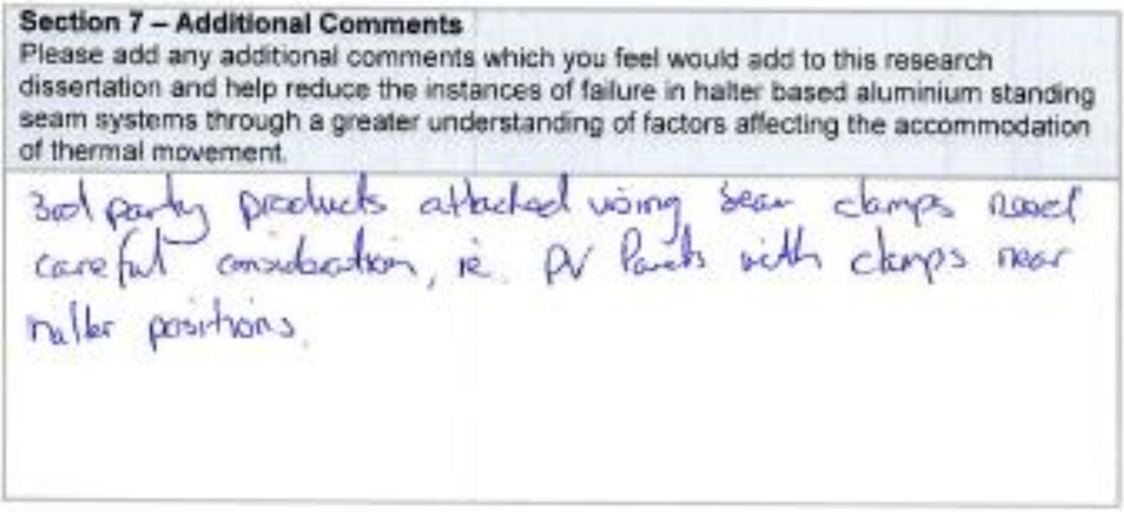
Section 6 – Installation

Please indicate (with an X) all responses to the questions which are applicable. Please add additional comments where you feel it would be beneficial to expand on your responses.

6.1	Do you publish an installation manual/guide for your standing seam system?	
	Yes, readily available e.g. on web-site	
	Yes, available on request	✓
	No	
6.2	Do you provide installation training on your standing seam system to installers?	
	Yes	✓
	No	
6.3	If yes, are your training courses accredited by a third party e.g. CITB, NFRC etc.?	
	Yes	
	No	✓
	Not applicable	
6.4	Do you provide installers with information or advice on how to set out halters to system tolerances?	
	Yes, readily available e.g. in Company literature or web-site	✓
	Yes, as part of installation training	✓
	Yes, available on request	✓
	No	
6.5	Do you provide installers with any aids to assist in setting out halters, e.g. templates?	
	Yes	
	No	✓
6.6	Do you provide installers with information or advice on how to install perimeter flashings and penetrations?	
	Yes, readily available e.g. in Company literature or web-site	✓
	Yes, as part of installation training	✓
	Yes, available on request	✓
	No	
6.7	Do you carry out site inspections either during or after installation?	
	Yes, during installation	✓
	Yes, after installation	✓
	No	
6.8	If yes, who carries out your site inspections	
	Dedicated site personnel	
	Technical personnel	✓
	Sales personnel	
	Other	
	Not applicable	

Additional comments

Me!



Section 7 – Additional Comments

Please add any additional comments which you feel would add to this research dissertation and help reduce the instances of failure in halter based aluminium standing seam systems through a greater understanding of factors affecting the accommodation of thermal movement.

3rd party products attached using seam clamps need careful consideration, ie. PV Panels with clamps near halter positions.

Appendix D – Brief history and development of halter based standing seam systems

Metal roofs have been used for many centuries and can be seen on many old public buildings such as cathedrals and churches. The materials used were malleable, such as lead and copper, so that they could be hand-worked to form joints and perimeter details. As these materials had little structural strength they were used in a fully-supported condition over a continuous support, often timber boards.

The practice of fully-supported metal roofing is still prevalent today although the choice of metals is much wider. BS 6229: 2003 (BSI, 2003) lists zinc, stainless steel, aluminium as well as the more traditional lead and copper as suitable metals for fully-supported flat roofs. These metals are also used for pitched roofs. Different forms of jointing detail can be used although the most common are roll-cap and standing seam joints (Harrison et al, 2009), figures D.1 and D.2 respectively.

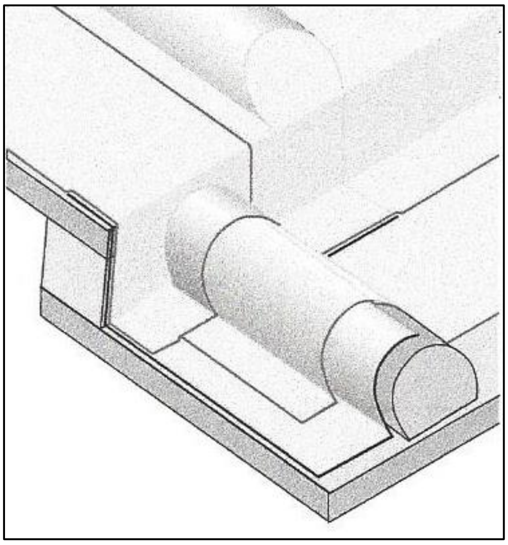


Figure D.1: Roll cap joint (Harrison et al, 2009)

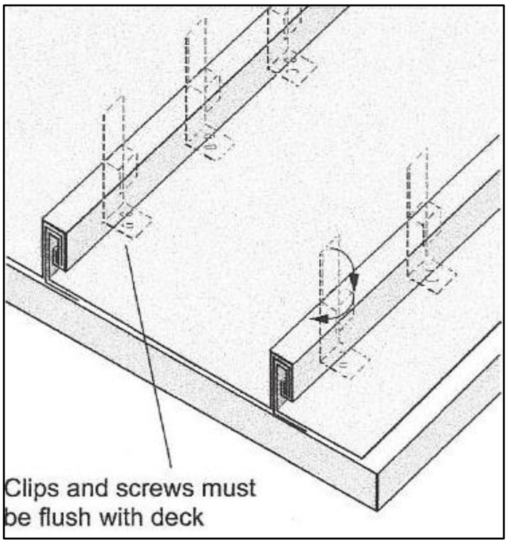


Figure D.2: Standing seam joint (Harrison et al, 2009)

The origins of the current form of self-supporting standing seam systems could be said to lie with two significant developments patented in USA (Cottrell, 2007). The first of which was an improvement in the way that standing seam joints were formed and was patented in 1889 by Longley Lewis Sagendorph. The patent, No. 417,947, included a tubular headed anchor-cleat around "which the overlapping flanges of the sheets are compressed and locked by means of a suitable tool, as tongs" (Sagendorph, 1889a). The patent claimed that the forming of the standing seam in this manner "will permit of ample expansion and contraction" (Sagendorph, 1889a). Figure D.3 shows the illustrations from Sagendorph's patent No.417, 948.

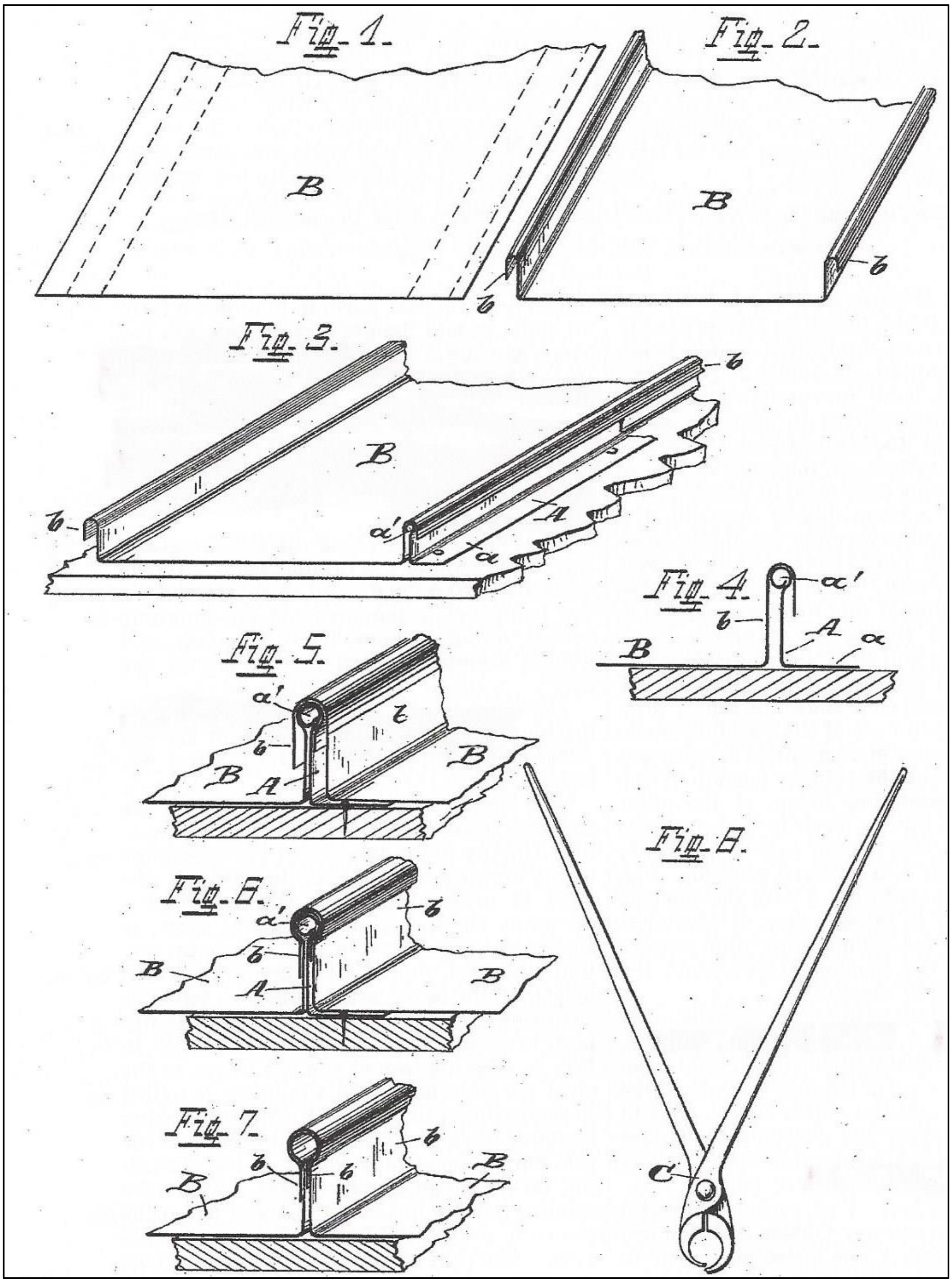


Figure D.3: Illustrations from patent No. 417, 948 (Sagendorph, 1889a)

The roofing tongs were also patented at the same time by Sagendorph, patent No. 417,948. Similar tongs are still used today to close the seam prior to using the seaming /zipping machine.

The second significant development was patented (No. 3,312,028) in 1967 by Patrick L Schroyer of Kaiser Aluminum & Chemical Corporation. The development claimed to provide “a large amount of self-supporting capacity for ordinary roof loads and spans”, an “improved means for arresting capillary travel of moisture between the mating services” and a “blind connector …to securely hold the panels down”; with the seams being formed by a power operated “rolling tool” (Schroyer, 1967). Figure D.4 shows the illustrations from PL Schroyer’s patent No. 3,312,028.

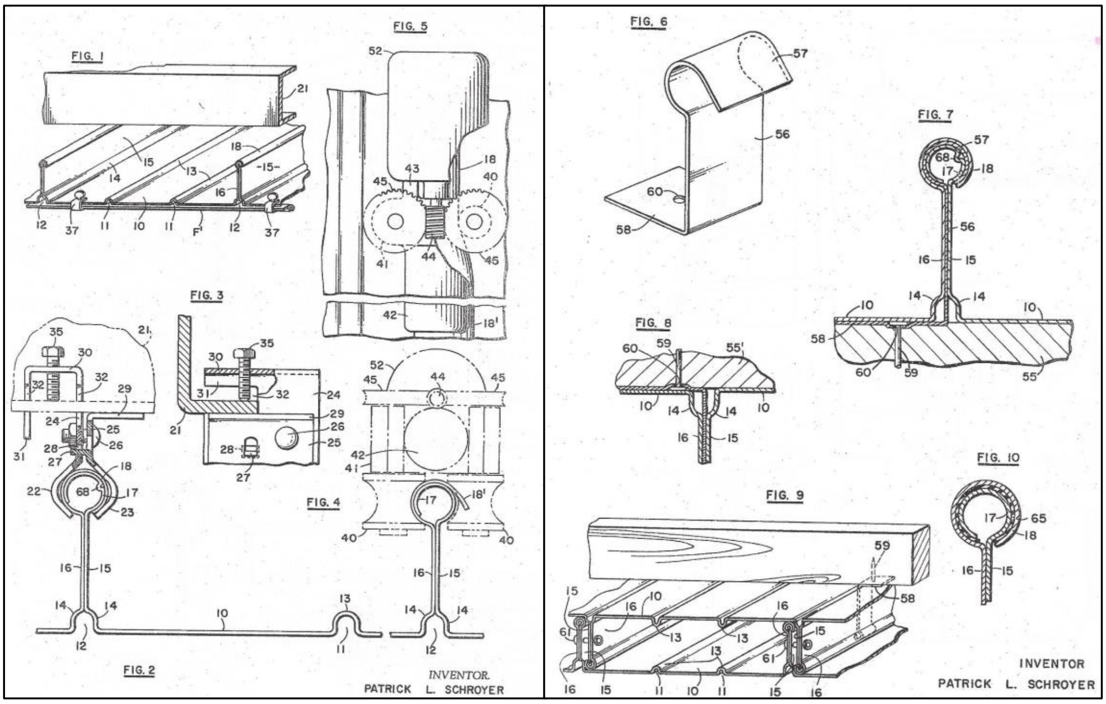


Figure D.4: Illustrations from patent No. 3,312,028 (Schroyer, 1967)

Developments in subsequent years initially focused on the development of connections for the standing seam sheets either in the form of clips or halters.

A clip is a connection where the hooked head of the clip is installed over the small seam of the standing seam sheet with its base fixed to the support in order to hold down the sheet under wind suction forces. The clip is subsequently locked into position as the large seam of the sheet is seamed over the small seam. A simple form of this type of clip is shown in figure D.4. Other variations include two-piece “sliding” clips which allow thermal movement to take place within the clip itself, see figure D.5.

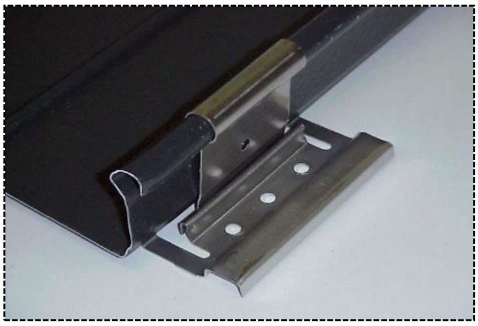


Figure D.5: Sliding Hook Clip

A halter is a connection where both the small and large seams of the standing seam sheets are installed over the bulbous head of the halter and locked into position on subsequent seaming of the sheets. Thermal movement is accommodated by the sheet moving over the head of the halter. Figure D.6 shows an early version of an extruded aluminium halter patented in Germany.

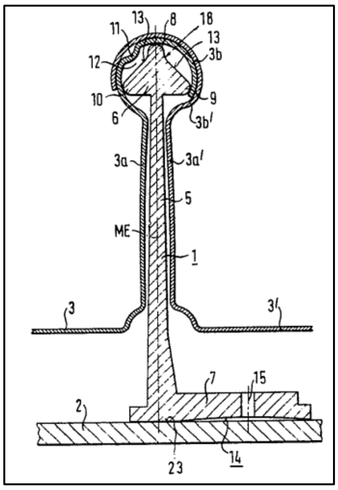


Figure D.6: Extruded aluminium halter (Gehlhaar, 1987)

Developments in machine technology have seen roll-forming equipment becoming much smaller, lighter and portable leading to the capability of standing seam sheets being able to be produced in extremely long lengths e.g. over 150 m, directly on construction sites.

Advances in roll-forming technology have also made it possible for standing seam sheets to be produced in a variety of different shape formats such as straight, curves, tapers, curved-tapers, wave-form and three-dimensional free-form allowing standing seam systems to be used as part of the building envelope on many forms of building from the simple to the geometrically complex (figure D.7).

Figure D.7: Standing seam system used on geometrically complex building envelope (BEMO Systems GmbH, 2012b)

Appendix E – UK Market for standing seam systems

In November 1987 the Property Services Agency (PSA), part of the Department of the Environment, published MOB 01-709 – Technical Guidance Roofing Systems – Profiled Steel and Aluminium (Concealed Fixed Low Pitched) as part of their Method of Building (MOB) series of publications. The intention of the guide was “to give designers and specifiers a background to concealed systems available currently in the UK”.

The guide gave the number of concealed fix systems available in the UK at the time as eighteen, many of which originated in the USA and Australia (PSA, 1987). It classified concealed fix systems into four main types by their method of jointing the sheets together and their fixing to the structure with many sub-variations. The first three being described as standing seam systems.

- Welted or mechanically seamed
- Interlocking over-lap
- Spring clip over-lap
- Non-standing seam concealed joints

Over the years the UK market consolidated itself into two dominant forms of standing seam joint: the spring-snap over-lap and the mechanically seamed or zipped joint. The spring-snap over-lap standing seam fixed with either a clip, bracket or fixed through its concealed leading edge is predominately manufactured from steel whilst the mechanically seamed standing seam is predominantly manufactured from aluminium. Figure E.1 shows a spring-snap over-lap joint in conjunction with fixing brackets.

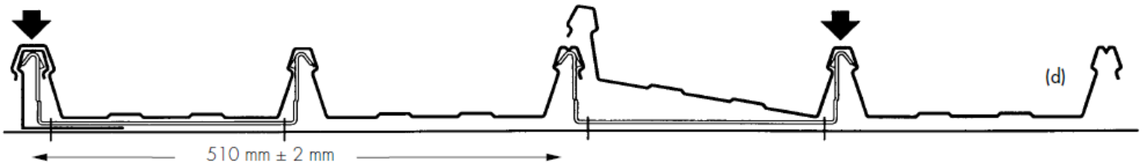


Figure E.1: Steel Standing seam system with spring-snap over-lap joint with fixing brackets (BBA, 2008)

In the early 1990’s the recently formed MCRMA commissioned Construction Markets Ltd. to produce figures for the profiled metal (steel and aluminium) roofing and cladding market in the UK. Market figures have since been reported on an annual basis.

Figures E.2, E.3 and E.4 show the UK market in area (m^2) for profiled metal (steel and aluminium) systems, profiled metal standing seam systems and profiled aluminium respectively over the period 1992 to 2013. The figures show only the area of external profiled metal sheeting and do not include profiled metal used for internal lining purposes.

With reference to figure E.2; in 1992 the market for profiled metal roofing and cladding totalled approximately 16,822,000 m^2 of which 2,032,000 m^2 (12.1%) was standing seam systems. In 2013 the market for profiled metal was 14,788,000 m^2 of which 1,507,000 m^2 (10.2%) was standing seam systems.

Figure E.3 shows the split in metal for standing seam systems over the same period. In 1992 the predominant material for standing seam systems was steel with aluminium only accounting for 721,000 m^2 (35.5%). Aluminium standing seam systems only accounted for 4.3% of the overall profiled metal market. The dominant metal for standing seam systems became aluminium by 1996. In 2013 the aluminium standing seam system market stood at 1,232,000 m^2 which is 81.1% of the standing seam market and 8.3% of the overall profiled metal market.

A similar rise in the use of aluminium standing seam system can be observed when compared to other types of aluminium system, see figure E.4. In 1992 standing seam systems only accounted for 28.6% of the overall aluminium systems market. By 2013 this figure has risen to 68.6%.

In summary: over the period 1992 to 2013 aluminium has become the dominant choice for standing seam systems (28.6% to 81.1%); standing seam is now the dominant form of system used in profiled aluminium (28.6 % to 68.6%) and aluminium standing seam systems have virtually doubled their percentage share of the overall profiled metal market (4.3% to 8.3%).

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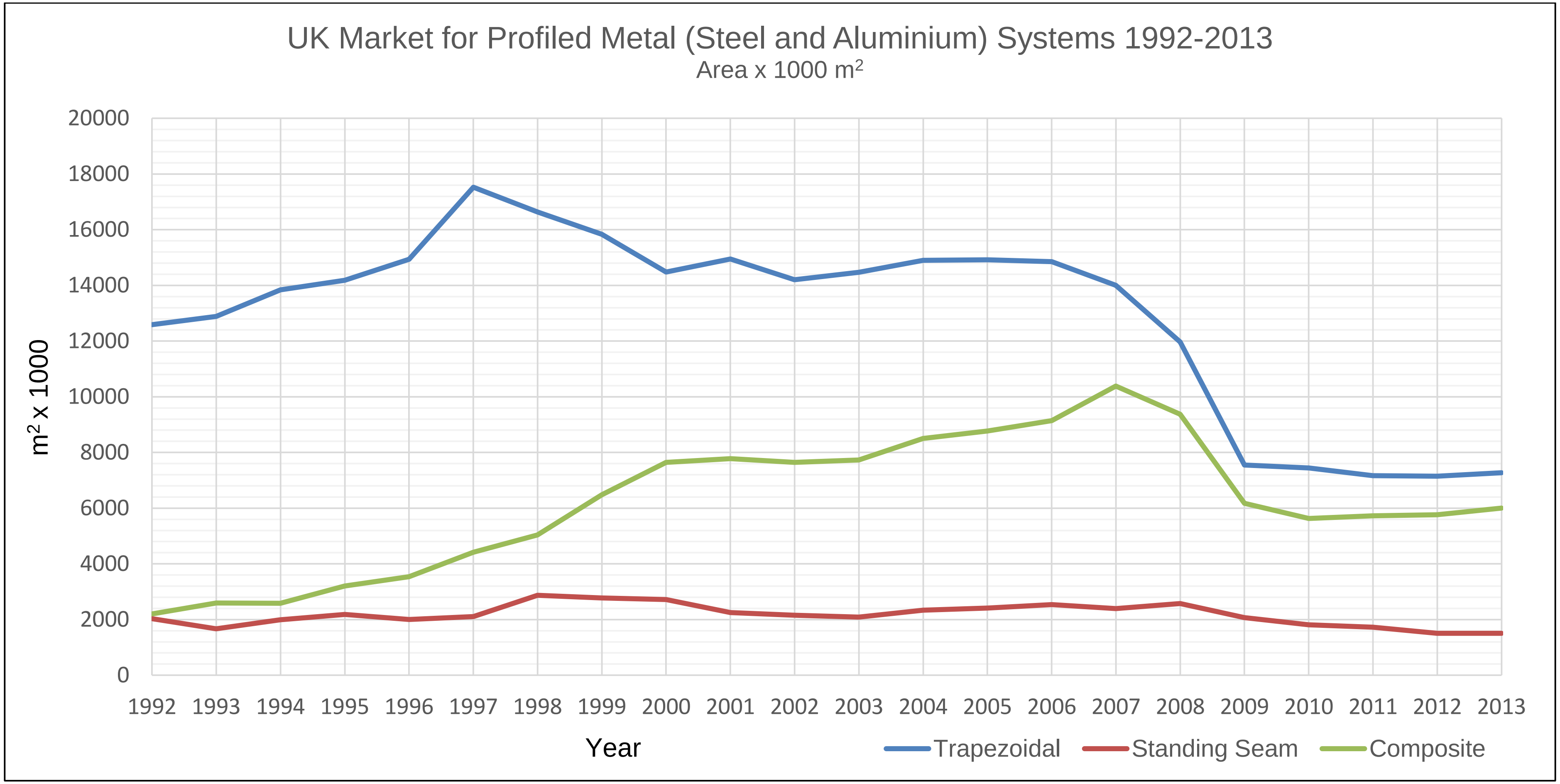

Figure E.2: UK market for profiled metal (steel and aluminium) systems over the period 1992-2013 (data taken from Construction Markets, 2014)

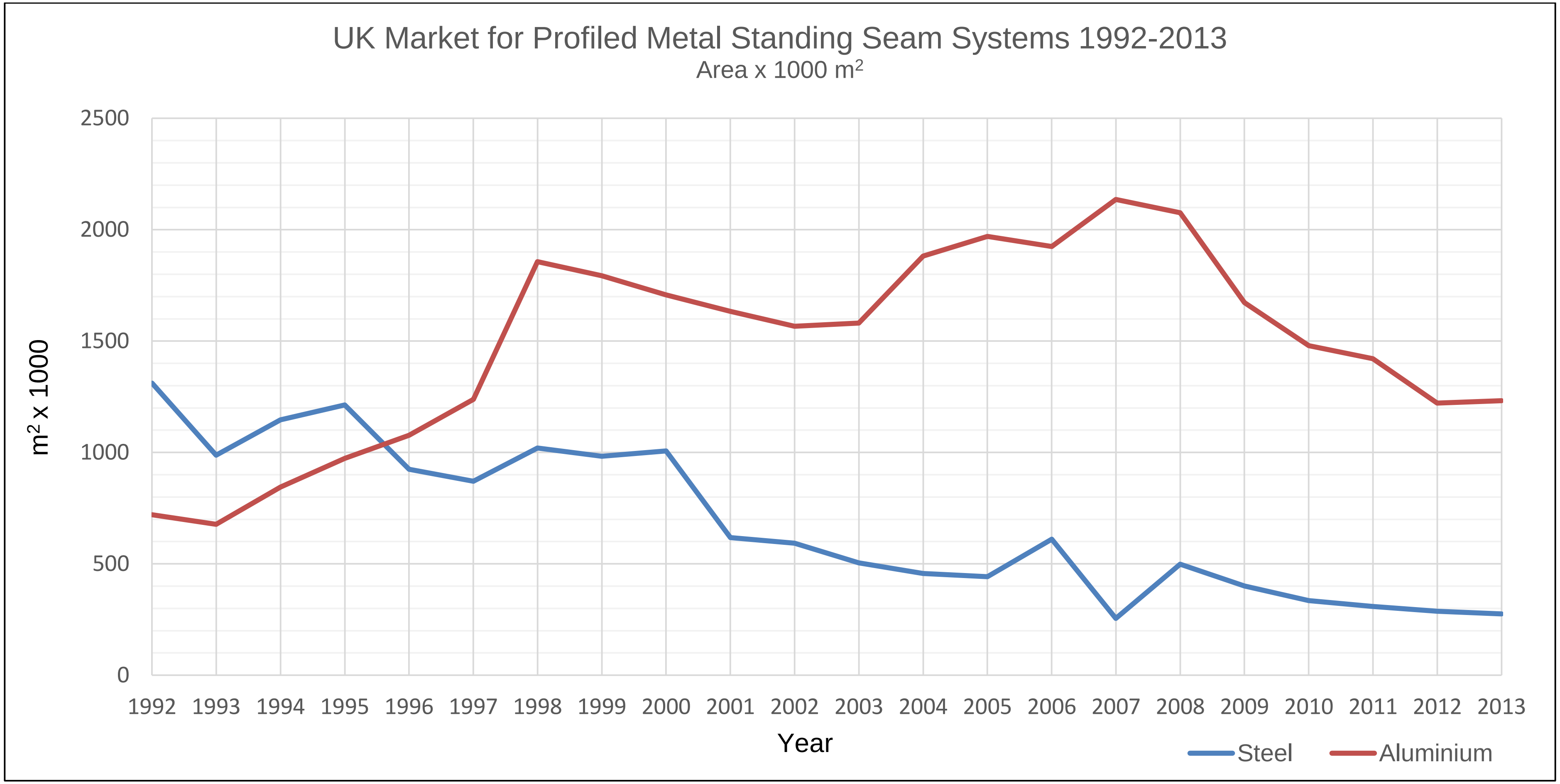

Figure E.3: UK market for profiled metal (steel and aluminium) standing seam systems over the period 1992-2013 (data taken from Construction Markets, 2014)

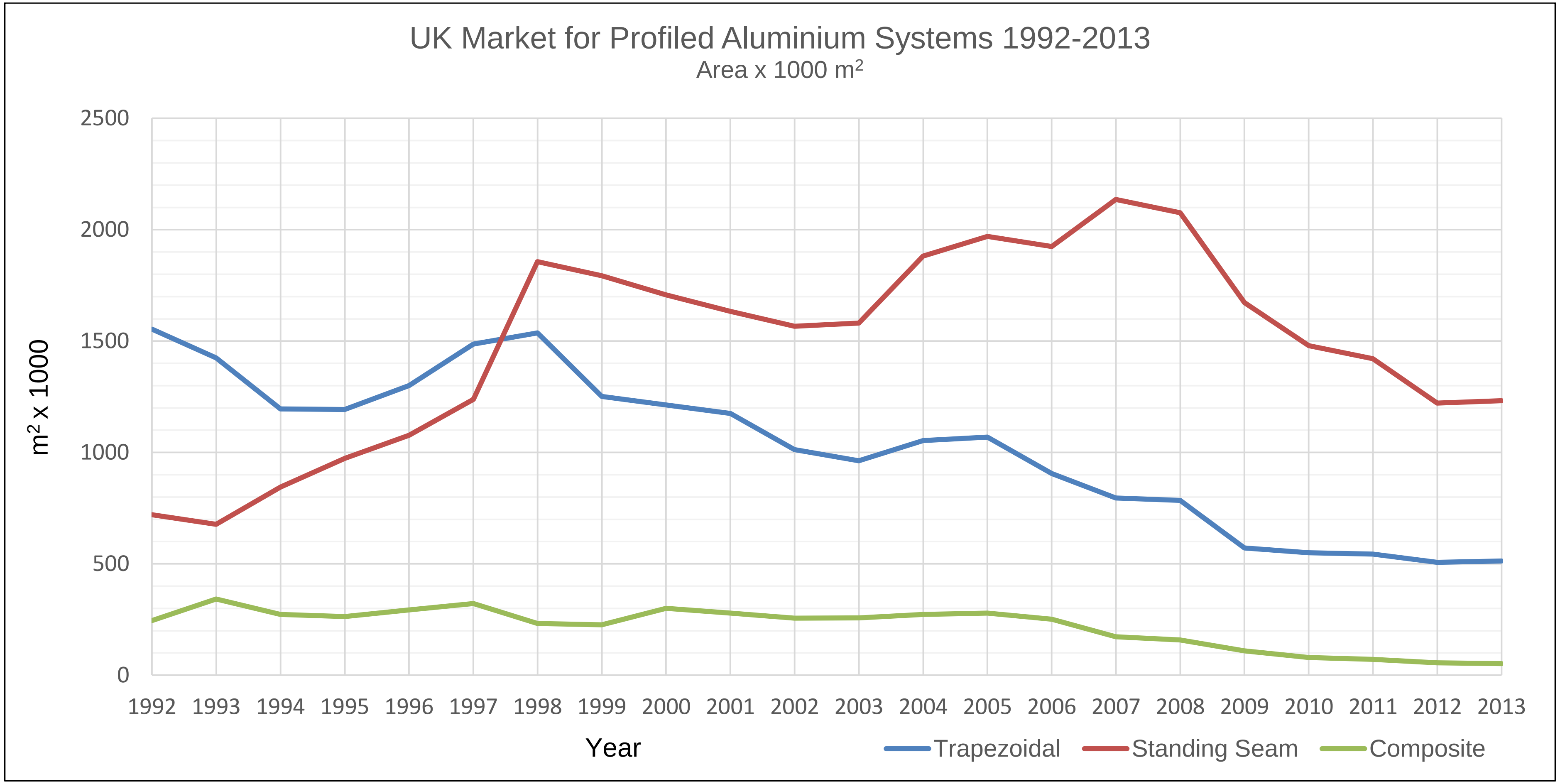

Figure E.4: UK market for profiled aluminium systems over the period 1992-2013 (data taken from Construction Markets, 2014)