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Code of practice for the use of profiled sheet for roof and wall cladding on buildings

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Summary of pages

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Foreword

Publishing information

This British Standard is published by BSI Standards Limited, under licence from The British Standards Institution, and came into effect on 30th April 2016. It was prepared by Subcommittee B/542/6, *Corrugated sheeting materials*, under the authority of Technical Committee B/542, *Roofing and cladding products for discontinuous laying*. A list of organizations represented on this Subcommittee can be obtained on request to its secretary.

Supersession

This British Standard supersedes BS 5427-1:1996, which is withdrawn.

Information about this document

This is a full revision of the standard. It takes into account recent changes and developments in materials, components, cladding systems and design practice, such as sheeting profiles, surface coatings, fixing systems, thermal insulation, the use of liners, and alleviation of condensation.

Use of this document

As a code of practice, this British Standard takes the form of guidance and recommendations. It should not be quoted as if it were a specification and particular care should be taken to ensure that claims of compliance are not misleading.

Any user claiming compliance with this British Standard is expected to be able to justify any course of action that deviates from its recommendations.

It has been assumed in the preparation of this British Standard that the execution of its provisions will be entrusted to appropriately qualified and experienced people, for whose use it has been produced.

Presentational conventions

The provisions of this standard are presented in roman (i.e. upright) type. Its recommendations are expressed in sentences in which the principal auxiliary verb is "should".

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

Contractual and legal considerations

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

1 Scope

This British Standard gives recommendations for the design and construction of external cladding assemblies for roofs and walls of buildings in the UK, using longitudinally profiled sheeting as the external surface, including standing seam. It is not applicable to profiled sheeting used as a supporting substrate, decking, structural liner trays, fully supported profiled sheets, structural composite formations of profiled metal sheeting and concrete, small element cladding or exceptional applications, such as buildings for cold storage.

The principal profiled sheeting materials covered by this British Standard are steel, aluminium, fibre cement, bitumen fibre and plastics, including insulated sandwich panel assemblies of profiled sheeting, thermal insulation and linings.

In addition to referencing performance recommendations, materials and components identified by other British Standards, advice on other materials and components which are in common use but not covered by other British Standards is also given.

This British Standard is intended for use by designers, manufacturers and installers of the roofing products.

This British Standard excludes profiled sheets used for structural purposes.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

Standards publications

BS 476-3, *Fire tests on building materials and structures – Part 3: Classification and method of test for external fire exposure to roofs*

BS 476-6, *Fire tests on building materials and structures – Part 6: Method of test for fire propagation for products*

BS 476-7, *Fire tests on building materials and structures – Part 7: Method of test to determine the classification of the surface spread of flame of products*

BS 476-20, *Fire tests on building materials and structures – Part 20: Method for determination of the fire resistance of elements of construction (general principles)*

BS 476-21, *Fire tests on building materials and structures – Part 21: Methods for determination of the fire resistance of loadbearing elements of construction*

BS 476-22, *Fire tests on building materials and structures – Part 22: Methods for determination of the fire resistance of non-loadbearing elements of construction*

BS 476-23, *Fire tests on building materials and structures – Part 23: Methods for determination of the contribution of components to the fire resistance of a structure*

BS 5250, *Code of practice for control of condensation in buildings*

BS 5516-1, *Patent glazing and sloping glazing for buildings – Part 1: Code of practice for design and installation of sloping and vertical patent glazing*

BS 6100-0, *Building and civil engineering – Vocabulary – Part 0: Introduction and index*

BS 6229, *Flat roofs with continuously supported coverings – Code of practice*

BS 8219, *Installation of sheet roof and wall coverings – Profiled fibre cement – Code of practice*

BS 8490, *Guide to siphonic roof drainage systems*

BS 8530, *Traditional-style half round, beaded half round, Victorian ogee and moulded ogee aluminium rainwater systems – Specification*

BS EN 494, *Fibre-cement profiled sheets and fittings – Product specification and test methods*

BS EN 506, *Roofing products of metal sheet – Specification for self-supporting products of copper or zinc sheet*

BS EN 508-1, *Roofing and cladding products from metal sheet – Specification for self-supporting of steel, aluminium or stainless steel sheet – Part 1: Steel*

BS EN 508-2, *Roofing products from metal sheet – Specification for self supporting products of steel, aluminium or stainless steel sheet – Part 2: Aluminium*

BS EN 508-3, *Roofing products from metal sheet – Specification for self supporting products of steel, aluminium or stainless steel sheet – Part 3: Stainless steel*

BS EN 534, *Corrugated bitumen sheets – Product specification and test methods*

BS EN 544, *Bitumen shingles with mineral and/or synthetic reinforcements – Product specification and test methods*

BS EN 612, *Eaves gutters with bead stiffened fronts and rainwater pipes with seamed joints made of metal sheet*

BS EN 795, *Personal fall protection equipment – Anchor devices*

BS EN 1013, *Light transmitting single skin profiled plastics sheets for internal and external roofs, walls and ceilings – Requirements and test methods*

BS EN 1991-1-1, *Eurocode 1: Actions on structures – Part 1-1: General actions – Densities, self-weight, imposed loads for buildings*

BS EN 1991-1-3, *Eurocode 1 – Actions on structures – Part 1-3: General actions – Snow loads*

BS EN 1991-1-4, *Eurocode 1: Actions on structures – Part 1-4: General actions – Wind actions*

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

BS EN 10147, *Continuously hot-dip zinc coated structural steels strip and sheet – Technical delivery conditions*

BS EN 12056-3, *Gravity drainage systems inside buildings – Part 3: Roof drainage, layout and calculation*

BS EN 12865:2001, *Hygrothermal performance of building components and building elements – Determination of the resistance of external wall systems to driving rain under pulsating air pressure*

BS EN 13162, *Thermal insulation products for buildings – Factory made mineral wool (MW) products – Specification*

BS EN 13165, *Thermal insulation products for buildings – Factory made rigid polyurethane foam (PU) products – Specification*

BS EN 13501-1, *Fire classification of construction products and building elements – Part 1: Classification using test data from reaction to fire tests*

BS EN 13501-2, *Fire classification of construction products and building elements – Part 2: Classification using data from fire resistance tests, excluding ventilation services*

BS EN 14509, *Self-supporting double skin metal faced insulating panels – Factory made products – Specifications*

BS EN 14782, *Self-supporting metal sheet for roofing, external cladding and internal lining – Product specification and requirements*

BS EN 62305-3, *Protection against lightning – Part 3: Physical damage to structures and life hazard*

BS EN ISO 6946, *Building components and building elements – Thermal resistance and thermal transmittance – Calculation method (ISO 6946:2007)*

BS EN ISO 10211, *Thermal bridges in building construction – Heat flows and surface temperatures – Detailed calculations (ISO 10211:2007)*

BS EN ISO 11600, *Building construction – Jointing products – Classification and requirements for sealants*

BS EN ISO 12944-2:1998, *Paints and varnishes – Corrosion protection of steel structures by protective paint systems – Part 2: Classification of environments*

BS EN ISO 13788, *Hygrothermal performance of building components and building elements – Internal surface temperature to avoid critical surface humidity and interstitial condensation – Calculation methods (ISO 13788:2012)*

PD CEN/TS 16415, *Personal fall protection equipment – Anchor devices – Recommendations for anchor devices for use by more than one person simultaneously*

Other publications

[N1]THE ADVISORY COMMITTEE FOR ROOFSAFETY. ACR[M]001 – Test for non-fragility of profiled sheeted and large element roofing assemblies. Fourth edition. London, 2011.

3 Terms and definitions

For the purposes of this British Standard, the terms and definitions given in BS 6100-0 and the following apply.

NOTE Geometrical definitions of profiles are illustrated in Figure 1.

Figure 1 **Geometrical definitions of profiles**

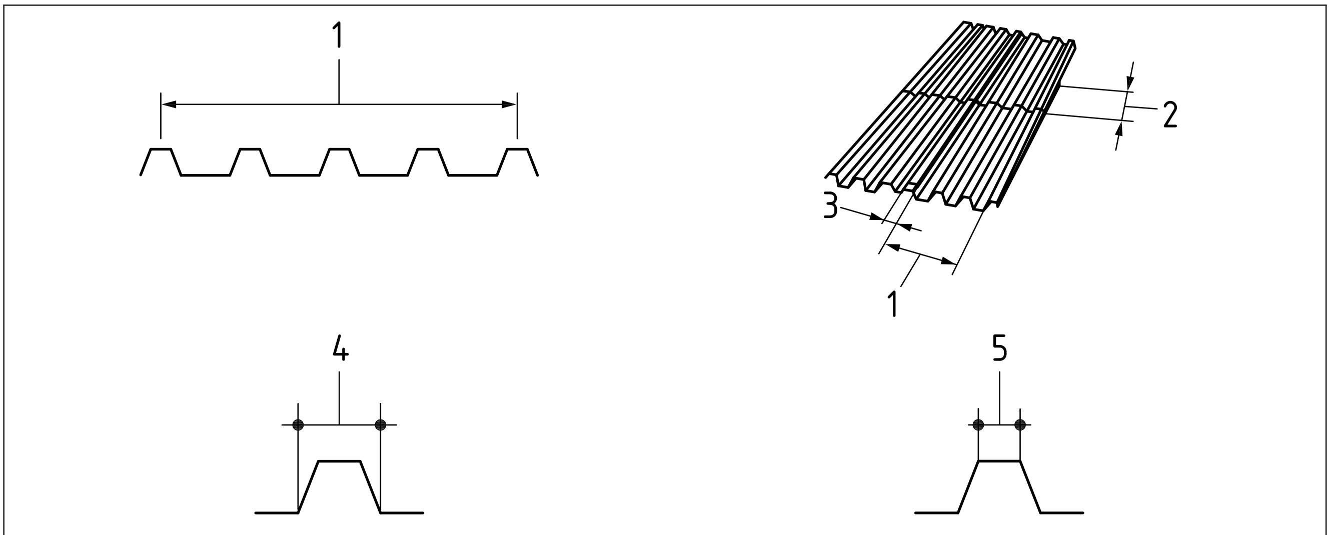
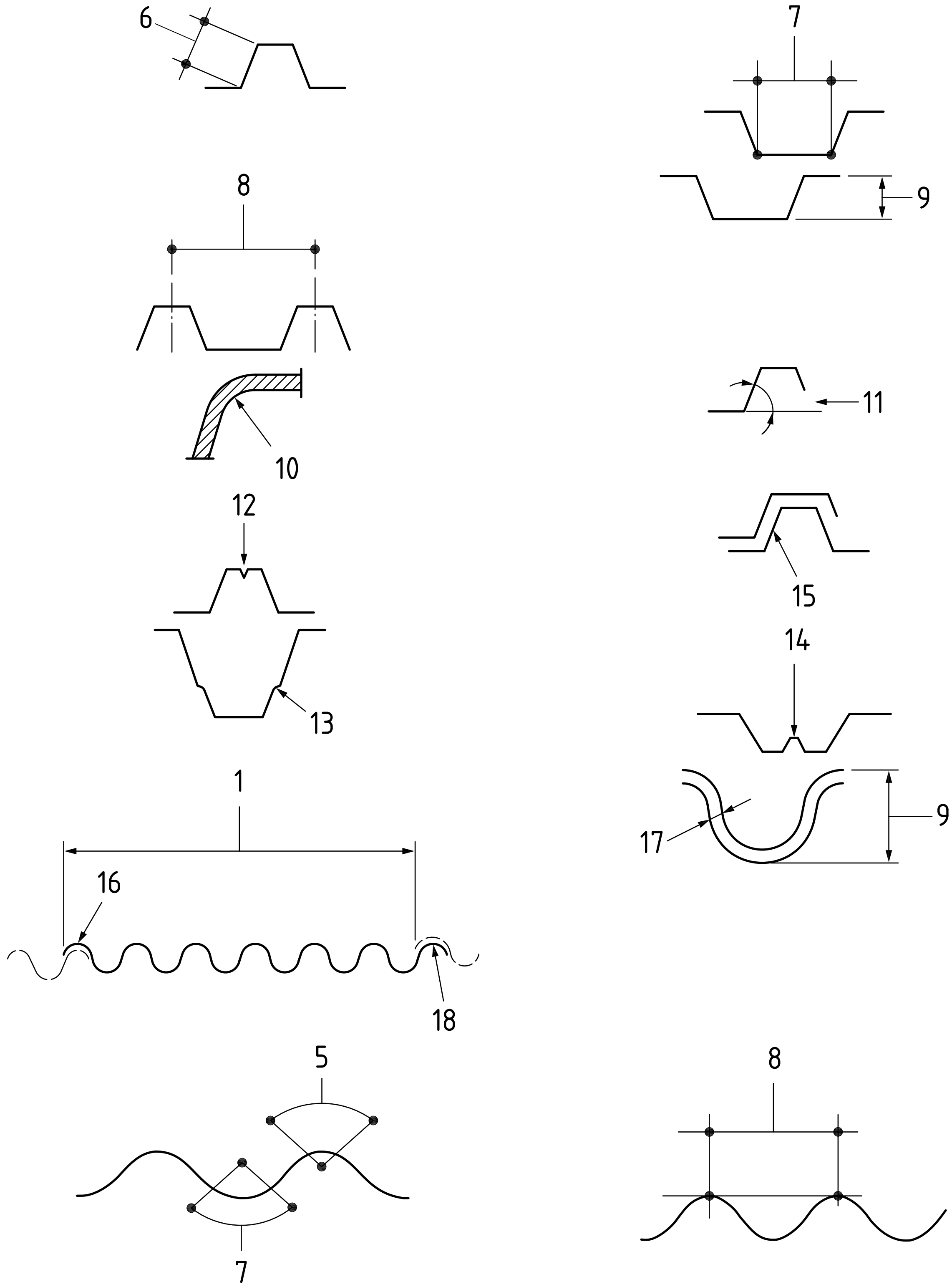


Figure 1 **Geometrical definitions of profiles**



Key

1	Cover width	10	Bend radius
2	Endlap	11	Web angle
3	Sidelap	12	Crown stiffener
4	Rib	13	Web stiffener
5	Crown	14	Valley stiffener
6	Web	15	Supported side lap rib

Figure 1 **Geometrical definitions of profiles**

7	Trough or valley	16	Overlap
8	Pitch	17	Thickness for fibre cement
9	Depth	18	Underlap

3.1 airtightness
resistance to passage of air through a building envelope

3.2 bonded panel
panel that consists of a flat or longitudinally profiled sheeting bonded to rigid insulation

NOTE For example polyisocyanurate (PIR) or mineral fibre.

3.3 cladding assembly
roof or wall covering system which can be a site assembly of liner, spacer and profiled sheeting elements together with insulation and vapour control layers, an insulated sandwich panel, composite panel or a bonded panel

3.4 dew point
temperature at which air becomes saturated with water vapour

3.5 fastener
connecting device for a fixing

3.6 fibre cement
cement reinforced with natural or man-made fibres

NOTE Where significant differences are evident between the different fibres used to reinforce the cement matrix these are detailed in this British Standard.

3.7 fixing
system of connection between two or more profiled sheets or between profiled sheets or accessories and a supporting structure

3.8 in-plane rooflight
translucent or transparent profiled sheet to match the surrounding profile and installed in the same plane as the surrounding profiled sheet that admits daylight into the building

3.9 insulated sandwich panel
self-supporting panel that consists of two parallel flat or profiled sheets separated by factory-filled insulation adhering to the profiled sheets

NOTE Also known as insulated composite panels.

3.10 non-rigid fastener
connecting device for fixings that, by the nature of their design, can permit thermal or other movement to take place between the connecting materials

NOTE Typical fasteners are hook bolts and bolts with elastomeric sleeves. Self-drilling and self-tapping screws can also be used where clearance holes or slots in the sheeting, together with purpose designed washers, allow movement.

3.11 out-of-plane rooflight
translucent or transparent product installed onto kerbs or upstands above the plane of the surrounding roof that admits daylight into the building

NOTE These products include dome, barrel vault, pyramid or flat glazing systems.

3.12 primary fastener
connecting device for a fixing that secures flat or profiled sheeting or lining to the supporting structure

NOTE The supporting structure could be the structural frame, sheeting rail or purlin, and any spacer system.

3.13 profiled sheeting
self-supporting sheeting, longitudinally formed with regularly spaced shapes of corrugated or trapezoidal cross-sections

NOTE This includes substantially flat sheeting with side lapping profiles, which can support load over a span.

3.14 rigid fastener
connecting device for a fixing that rigidly connects materials together

NOTE These are typified by self-drilling and self-tapping screws where any movement is accommodated by the connecting materials themselves, i.e. roof sheet and/or spacer or structure. No allowance for movement is required in the connection itself.

3.15 secondary fastener
connecting device for a fixing that secures the laps of profiled sheets to each other but not to the supporting structure and can be used to attach flashings and accessories

3.16 vapour control layer
material with water vapour resistance in excess of 200 MN·s/g

3.17 weathertightness
resistance of profiled sheet and walls to the penetration of precipitation and dynamic wind loads to the inside of the building

3.18 design life
DEPRECATED: intended service life; expected service life

service life intended by the designer

NOTE As stated by the designer to the client to support specification decisions.

[SOURCE: BS ISO 15686-1:2011, **3.3**]

3.19 service life
period of time after installation during which a facility or its component parts meet or exceed the performance requirements

[SOURCE: Adapted from DD ISO/TS 15686-9:2008, **3.4**]

3.20 secret fix system
self-supporting metal profiled with virtually no through fixings

NOTE Variously expressed as concealed fixing, standing seam, clip fix raised seam.

4 Design

4.1 General

The design of profiled sheet cladding systems for roofs and walls should include careful consideration of, but not limited to, the following factors:

a) weathertightness (Clause **6**);

b) strength and rigidity (see **7.2**);

c) safety and non-fragility (see **7.3**);

d) control of condensation (see **7.4**);

e) thermal performance (see **5.7** and **7.5**);

f) air permeability (see **7.5**);

g) sound insulation (see **7.6**);

h) fire resistance and fire precautions (see **7.7**);

i) daylighting (see **7.8**);

j) appearance (see **7.9**);

k) durability (see **7.9**);

l) lightning protection (see **7.11**);

m) external attachments (see **5.11**, **5.12**, **5.13** and **5.14**);

n) maintenance, remedial work and renewal (Clause **8**); and

o) all relevant harmonized standards quoted in this British Standard.

At the design stage the principal designer should define the methodology for erecting and fitting the cladding system on the building during construction.

Roof constructions should be capable of withstanding being walked upon without damage or failure. Roof constructions should also be designed to be classed as non-fragile (see **7.3**).

*NOTE 1 Walkability and non-fragility are completely separate issues. See **7.3**, Note 4.*

NOTE 2 A roof assembly, if tested to ACR[M]001 [N1] and supported by Annex C from ACR[CP]001:2014 [1] can be regarded as a method of preventing a person from falling through the fully and finally fixed assembly. It does not necessarily indicate whether walking on the roof would damage the roofing product.

NOTE 3 Walkable refers to an assembly that when walked upon normally neither fails nor shows signs of physical damage.

*NOTE 4 Attention is drawn to the Construction (Design and Management) Regulations 2015 [2] (see **7.3**).*

NOTE 5 Minimum performance requirements for weathertightness, structural stability, air leakage thermal insulation, fire precautions and durability are laid down in the relevant Building Regulations for England [3], Northern Ireland [4] ,Scotland [5], and Wales [6]. More detailed performance criteria and other recommendations are discussed in this British Standard.

In addition to satisfying the employer's specification, the design should involve choosing from many alternative combinations of materials and systems for the profiled sheeting, surface finishes, thermal insulation, condensation control layers and linings, to best suit the technical and aesthetic requirements of the client.

Cladding products and systems should satisfy the relevant performance requirements and recommendations by reference to BS EN ISO 6946 and BS EN ISO 10211, or established methods of predictive calculations, including thermal performance and thermal bridging.

NOTE 6 Any subsequent painting, sealing or insulation could considerably change the intended performance of the roofing or wall system.

4.2 Weatherproofing properties of profiled sheeting

In selecting profiled sheeting for its weatherproofing properties, the following criteria should be satisfied.

a) The sheeting should have proven waterproofing performance.

b) The profile should have capacity to drain the run-off at the relevant roof slope and length from maximum rainfall without immersing the crown.

c) The profile should be satisfactorily side-lapped, and, where appropriate end lapped/jointed and sealed with sealant to form joints of watertightness.

d) The profile should allow fixings to be made to secure the sheeting against dead, imposed and wind loads.

Water permeability of a complete profiled roof system should be tested in accordance with the recommendations given in Annex F.

NOTE 1 Recommendations for the strength and stiffness of profiled sheeting are given in Annex C.

NOTE 2 Profiles for roofs are generally suitable for walls but the reverse might not be true due to the greater drainage capacity required for roof sheeting.

5 Components

5.1 Profiled sheeting

*COMMENTARY ON **5.1***

Profiled roofing and cladding systems are widely specified and used across a range of domestic and non-domestic buildings including agricultural, industrial and commercial, warehouses, education and leisure, healthcare, transport and infrastructure.

5.1.1 General

The profiled sheeting, the materials from which it is made and its use, should conform to the relevant British Standards as listed in Table 1.

NOTE 1 Profiled sheeting is available in copper, coated steel, stainless steel, aluminium, zinc, fibre cement, and various plastics, in addition to the profiles covered by the British Standards listed in Table 1. There are many other proprietary profiles and sheeting systems in common use, including standing seam or concealed-fixed cladding systems with wide troughs and narrow upstands for seamed, snap-on or sprung-fixed side lapping.

NOTE 2 All profiled roof sheeting is designated as fragile by Management of Health and Safety at Work Regulations 1999 [7] and Health and Safety at Work, etc. Act 1974 [8] unless fully installed in accordance with a method as tested by a competent person for determination of non-fragility in accordance with ACR[M]001 [N1]. Guidance on health and safety regulations is given in HSG 33 [9].

NOTE 3 The maximum length of profiled sheeting available depends on the method of manufacture and the convenience of handling, transport and erection. Long lengths laid continuously over several supports reduce the number of end laps and risk of rain penetration.

NOTE 4 For further guidance on standing seam metal sheets for fully supported applications see BS EN 14783 and the relevant metal product standards.

Table 1 **Harmonized European self-supporting profiled sheet standards**

Profiled sheet	Product material	Product standard (if different from harmonized standard)	Harmonized standard
Bitumen fibre	—	—	BS EN 544
Fibre cement		—	BS EN 494
Insulated sandwich panels	—	—	BS EN 14509
Metal	Aluminium	BS EN 508-2	BS EN 14782
	Copper and zinc	BS EN 506	—
	Steel	BS EN 508-1	—
	Stainless steel	BS EN 508-3	—
Translucent rooflights	Glass reinforced plastic, polycarbonate	—	BS EN 1013

5.1.2 Data on structural properties of profiled sheeting

The following properties of profiled sheeting or panels should be available where applicable for referencing during the design process:

- profile type and code, including profile dimensions, material thickness, with sketches of the cross-section;
- cover width;
- mass per unit area;
- moment of inertia per metre width at a specified stress;
- effective cross-sectional area per metre width;
- moment of resistance per metre width for both directions of loading;
- yield stress or 0.2% proof stress of material;
- modulus of elasticity of the material; and
- load-span tables stating the basis of the design.

Published load/span tables should be expressed as safe working loads, including:

- maximum allowable permanent loads and imposed roof loads or undrifted snow loads with specified deflection limits and maximum allowable concentrated imposed load;
- maximum allowable wind uplift loads, and where appropriate, the maximum allowable uplift limited by fixings or concealed attachment devices (e.g. clips, halters etc.) with specified deflection limits;
- maximum concentrated load or maximum span to meet concentrated load in **C.5.4.3**;
- maximum allowable bending moment due to permanent load and drifted snow load; and
- maximum allowable bending moment due to permanent and exceptional snow load.

The maximum allowable loads should distinguish between values for single spans and equal or unequal continuous spans, with specified deflection limits.

NOTE For profiled metal sheets this British Standard does not cover products intended for use in constructions of Class III (in accordance with Eurocode BS EN 1993-1-3), and products intended for use in constructions of Classes I and II (in accordance with Eurocode BS EN 1993-1-3) intended to contribute to the global or partial stability of the building structure by providing racking resistance. Profiled sheets are available for these applications for example over-laid with concrete but in those applications more stringent structural properties are required in accordance with the Eurocodes.

Data on the impact resistance of wall sheeting for specified categories of public access should also be specified. Where the impact resistance relies on the composite action of the sheeting and substrate, details of the composite construction should be recorded.

5.1.3 Minimum roof pitch

The supporting structure should be designed at a pitch of 1.5° more than the minimum pitch specified by the client for the sheeting, to allow for tolerances and onsite variations, unless justified by more detailed structural analysis of the main frame and secondary steelwork to account for deflections/settlement.

To allow free drainage off the roof, the minimum finished roof pitch in all cases should be greater than or equal to 1° (2.5° design pitch).

Where through fixed trapezoidal profiled sheeting/sandwich panels are to be used roofs should be designed for a finished pitch of at least 4° (5.5° design pitch).

For very low pitch roofs of less than 4° (less than 5.5° design pitch), including the apex of a curved roof which approaches flat, endlaps should be avoided and secret fixed types of profiled sheeting or sandwich panels with raised side laps in continuous lengths should be used.

*NOTE 1 Proprietary secret fixed roofing systems with properly engineered endlaps can be purchased where all aspects of performance have been proven by independent testing. The guidance for minimum recommended pitch of endlaps in these proprietary systems is outside the scope of **5.1.3**.*

*NOTE 2 Complete proprietary roofing systems of both profiled sheeting, spacers, insulation, sealants and fasteners or sandwich panels with sealants and fasteners are available and can be purchased where all aspects of performance have been proven by independent testing. The guidance for minimum recommended pitch for these proprietary systems is outside the scope of **5.1.3**.*

Manufacturers should be consulted about the design and performance of the roof if the intended use of their proprietary systems is outside the scope of **5.1.3**.

NOTE 3 Workmanship and quality of installation of roof systems becomes more critical as roof pitch decreases. The risk of leaks occurring as a result of small variations from system manufacturers recommendations (including specification and relevant position of fasteners and sealants and steelwork tolerances) increases as roof pitch decreases.

When specified, designed and installed all details and tolerances should be agreed between the system manufacturer, steelwork contractor and roofing contractor before installation.

NOTE 4 See SCI P346 [10] and MCRMA GD24 [11] together with MCRMA GD20 [12].

5.2 Built-up metal

5.2.1 General

Built-up metal based roofing and cladding systems are constructed on-site from a series of component parts and should provide a weatherproof structural envelope to the building. The built-up metal envelope should also perform an aesthetic function and an environmental function to separate the building's internal and external atmospheres. The component parts used in the construction and assembly of such systems should be specified to ensure individual elements are functionally compatible with other associated components within the assembly. However, some elements might not be interchangeable and therefore the specifier should ensure that individual elements meet with the manufacturer's or system supplier's recommendations.

NOTE Layered built-up metal roofing and cladding systems offer many different design options. The specification of individual component parts (i.e. profile shape and material, insulation type, thermal performance, acoustic performance, construction detail and assembly) enables the specifier to tailor the system or assembly to meet the specification design parameters.

The performance should be tailored for the application by the specifier or building designer in consultation with the supplier and manufacturer.

5.2.2 Function

*COMMENTARY ON **5.2.2***

The primary function of a built-up roofing and cladding system is to provide a weather proof and thermal barrier to keep the weather out of the building and the internal environment in.

To meet the primary function the outer sheet of a built-up metal system should be effectively sealed at both side and end laps to ensure weathertightness from the outside.

NOTE 1 Effective seal may be achieved for example by use of sealants or from the inherent nature of the profile or by welding.

NOTE 2 Other functions can include meeting specified performance levels for air leakage, thermal, fire and acoustic performance, etc.

The liner sheet should be sealed to minimize air-permeability and perform as a vapour seal to minimize the risk of condensation within the construction (see **7.4.1**).

NOTE 3 This can be achieved by sealing end and side laps or by use of a separate sealed vapour control membrane.

Where the liner is perforated a separate sealed vapour control membrane should be used. The liner sheets (and any vapour control membrane) should be sealed around the roof perimeter and all penetrations and roof lights.

In addition to the primary function of the built-up metal system the construction should be capable of providing structural capacity to support both dead and imposed design loads, which it might be subjected to during its functional life (see **7.2**).

For buildings which are unheated such as agricultural storage sheds, some animal housing, certain warehouses and buildings where the internal processes generate excessive amounts of heat, the built-up system might take the form of a single skin construction; this type of construction should provide a structurally sound weather shield.

5.2.3 Fire

Where sandwich panels with different levels of fire resistance are specified the manufacturer's recommendations should be followed.

NOTE Fire performance might be specified to meet the relevant Building Regulations [3], [4], [5] and [6] and/or specifiers or insurers requirements.

5.2.4 Insulation

For buildings, built-up metal roof and cladding systems should include thermal insulation material of a type, quality and thickness to ensure adequate thermal performance.

NOTE 1 Minimum standards for thermal insulation are laid down in the relevant Building Regulations for England, Northern Ireland, Scotland, and Wales [3] ,[4] [5] and [6].

The insulation should be installed between the inner lining and external profiled sheet in accordance with the manufacturer's recommendations.

*NOTE 2 Installed thermal insulation might also provide an acoustic benefit to limit noise attenuation between the inside and outside of a building (see **7.6**).*

Where specific acoustic insulation is needed, additional layers of acoustic material should be included in the construction to provide the necessary performance (see **7.6**). Manufacturers should be consulted for specific advice and recommendations. Where additional layers of insulation need to be added to improve inherent acoustic performance it might be necessary to install the acoustic layer over a perforated liner; in this case a separate vapour control layer should be included on the warm side of the thermal insulation and in a position to ensure moisture from within the construction does not create a risk of condensation (see **7.4**).

Condensation risk analysis, in accordance with **7.4.1**, should be undertaken to ensure insulation layers are not subjected to the ingress of moisture and the temperature of surface layers are above the local dew point temperature.

5.2.5 Profile types

*COMMENTARY ON **5.2.5***

Built-up metal roof and wall constructions provide the opportunity to specify, within limits, the shape, form, structural strength and aesthetics of both the internal liner and the external profile. External profiles are available in a wide range of profile shapes which provide both an aesthetic and functional weather layer. External profiles are produced for both roof and wall applications.

Profiles with narrow ribs and wide troughs should be chosen for roof applications that enable the profile to shed rainwater. Wall profiles are produced with both wide and narrow external ribs and should be specified to meet structural and aesthetic needs.

External profiles are mostly manufactured in a factory but in some cases the roof profiles are manufactured on-site and close to the building for final installation; the latter should be used as the preferred method of manufacture for standing seam or concealed fix profiles, which are designed to minimize end laps for roofing applications.

NOTE Minimizing end laps increases individual sheet length and therefore the ease of transport and delivery might be an influencing or limiting factor. The cross-sectional shape of the manufactured profile or the method of attachment to the sub-structure usually defines the name of the profile. Profiles include:

- *sinusoidal;*
- *trapezoidal;*

- *secret fix (including standing seam); and*
- *bespoke.*

5.2.6 Performance

The structural performance of built-up metal roofing and cladding systems and its component parts should be determined and assessed in accordance with the recommendations contained in the following clauses:

- **7.2.6** and Table 9 and Table 10 for structure;
- **5.2.10.2** for metal liners;
- **5.8.1** for bracket and bar spacer kits;
- **7.2.7** for stressed skin;
- **7.2.8** for restraint to purlin; and
- **7.3** for safety and non-fragility.

5.2.7 Materials

Substrate material used to form the external profiles and the internal lining used in the assembly of built-up metal roofing and cladding systems should conform to the relevant British Standards in Table 1.

NOTE The substrate material used can be steel, aluminium, stainless steel and other metals such as copper or zinc.

5.2.8 Coatings

*NOTE 1 Depending upon the environmental application and aesthetic demands the substrate material (see **5.2.7**) can be uncoated or coated with either a metal sacrificial coating plus an organic coating for both the top surface and the underside surface.*

The durability of the surface organic coatings should be determined in accordance with **7.9** and the relevant British Standard listed in Table 12. The performance should be assessed in accordance with the manufacturer's declared values.

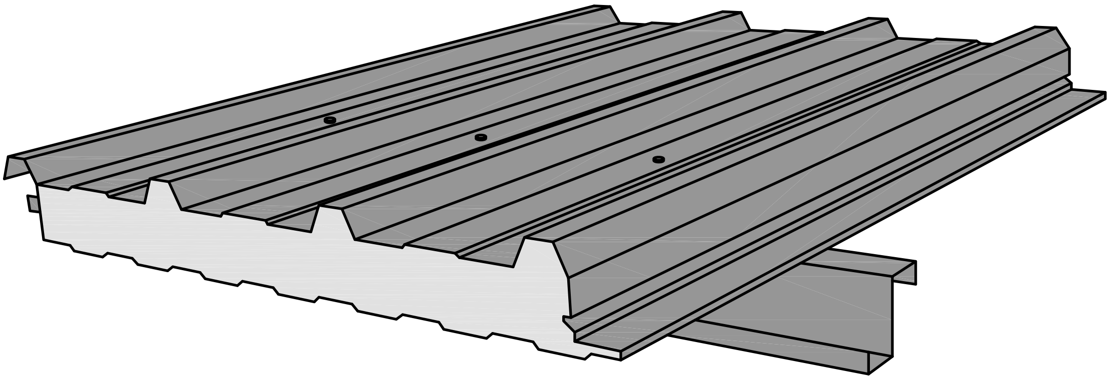
*NOTE 2 Further information is available in **7.9**, Table 12 and Annex A on the durability of coated metal profiles when subject to various exposure conditions.*

5.2.9 Position of thermal insulation in cladding

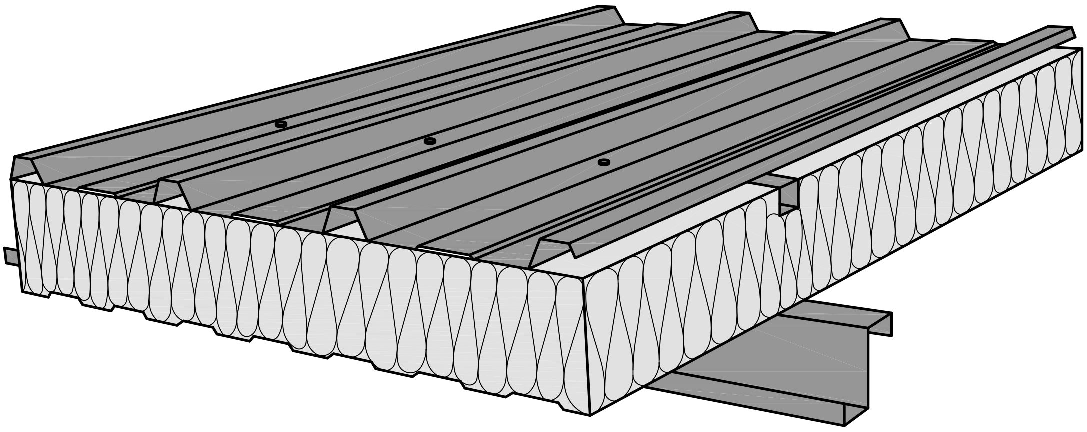
Roofs and walls should be classified into different types of design for thermal insulation and condensation control, according to the position in which the thermal insulation layer is placed, as shown in Figure 2.

NOTE Warm roofs or warm walls, in which the principal thermal insulation layer is placed immediately inside the outer profiled sheeting, result in the supporting structure and any voids being at a temperature close to that of the interior of the building. The condensation risk plane is also at the outer face of the insulation.

Figure 2 **Schematic showing cross section of popular roofing and cladding systems**



a) Factory made composite panel



b) Double skin system with bracket and bar spacer

NOTE Figure reproduced by kind permission of the MCRMA.

5.2.10 Liner sheets

5.2.10.1 General

The structural stability of the liner system should have sufficient strength and stiffness to support its own weight, the dead weight of the insulation, the vapour control layer and other attachments.

Liners should be able to resist internal pressures from both wind suction and positive pressure in accordance with BS EN 1991-1-4 including appropriate allowance for any dominant opening. Where liners need to provide temporary cover to the building during construction before the cladding installation is completed, they should be able to resist wind loads of the appropriate return period in accordance with BS EN 1991-1-4, and any other construction loads.

Where the client requires a specific limit on air permeability, a sealed lining system should usually form either part of or the complete air barrier. An air barrier should extend over the whole of the element into which it is incorporated and should be integrated with and sealed to adjoining elements, such as junctions, penetrations and glazing systems, and any air barrier in those elements.

Where a manufacturer offers roofing and cladding systems as systems that meet the relevant Building Regulations[3], [4], [5] and [6] minimum requirements, evidence that the systems are fit for their intended purpose should be recorded.

5.2.10.2 Metal liners

*COMMENTARY ON **5.2.10.2***

Metal liners are available in the form of pre-coated profiled sheets of steel or aluminium, or in the form of liner trays that incorporate an integral spacer or structural element. Metal liners are usually used in conjunction with rigid foam or mineral fibre insulation. When used with sealed joints, metal liners can act as a vapour control layer and air barrier.

The purlin manufacturer should provide details of their minimum requirements for the provision of restraint to the supporting purlins, (see SCI P346 [10]).

Lighter weight metal sheets or shallower profiles cannot usually provide significant restraint to purlins; the designer should specify the cladding system accordingly where it is expected that purlin restraint is to be provided partially or fully by the cladding system.

NOTE Perforated metal liners might be used to reduce the volume of internally reflected sound. However, when perforated liners are included in the design they might not provide lateral restraint.

The liner manufacturer should provide details of their minimum fastener requirements for non-fragility (see **7.3**).

5.2.10.3 Walkable and/or non-fragile liners

*COMMENTARY ON **5.2.10.3***

Walking on roofs during the construction phase or to carry out maintenance poses a risk of falling and imparting an impact load on the roof.

NOTE 1 There are benefits to using liner systems which are non-fragile (but not necessarily walkable) as they allow safety nets to be removed at an earlier stage during construction. In addition during refurbishment work they might avoid the need for safety nets if the outer sheet is removed.

NOTE 2 There are benefits to using liner systems which are walkable (but not necessarily non-fragile) as they can provide a working platform during construction.

Liner systems which are non-fragile and/or walkable are not essential but should be used wherever practicable.

*NOTE 3 Walkability and non-fragility are completely separate issues. See **7.3**, Note 4.*

5.2.10.4 Rigid board liners

Rigid board liners of plasterboard and faced insulation have been superseded in most applications by self-supporting profiled liner sheets; where edge support for board type liners is required the board manufacturer's advice should be sought.

NOTE Liner systems based on panels of gypsum plasterboard or rigid insulation materials are available with galvanized T-bar supports and fixing straps.

The joints between the board and supporting T-bars, and gaps that occur where the lining is penetrated, e.g. at rooflights or ventilators, should be sealed in accordance with the manufacturer's instructions to prevent risk of condensation by reducing the entry of humid air into the roof cavity from inside the building.

5.3 Sandwich panels

*COMMENTARY ON **5.3***

Sandwich panels are building products consisting of two metal faces positioned on either side of a core that is a thermally insulating material and firmly bonded to both metal faces so that the three components act as a composite when under load. The most common insulating materials are polyisocyanurate (PIR) or alternatively mineral fibre (see Table 3).

Sandwich panels are available with a wide range of profiles, side joints, exposed fixings, concealed fixings, secret fixings and varying aesthetic appearance options for roof and wall cladding applications.

Trapezoidal or sinusoidal profiled through fixed sandwich panels, with over-lapping side joints and over-lapping end laps, can be installed on walls in horizontal and vertical applications.

Secret fix panels, with concealed fixings, with a male/female type interlocking joint, with heavy louvre profile, half round, lightly profiled or un-profiled (flat) external facings, are available for aesthetic options, and can be installed on walls in horizontal and vertical applications.

For aesthetic reasons, sandwich panel cover widths can be available with varying sizes for secret fix type panels with a male/female type joint designed to also conceal the primary fixings.

5.3.1 General

Sandwich panels when fixed to spaced structural supports should be capable of supporting – by virtue of their materials and shape – their own weight and all applied loadings (e.g. snow and wind) and also be capable of transmitting these loadings to the supports.

5.3.2 Function

*COMMENTARY ON **5.3.2***

The primary function of a composite sandwich panel roofing and cladding system is to provide a weather proof and thermal barrier to keep the weather out of the building and the internal environment in.

To meet the primary function the sandwich panel system should be effectively sealed at both side and end laps to ensure weathertightness from the outside.

NOTE 1 Effective seal may be achieved for example by use of sealants or from the inherent nature of the profile.

NOTE 2 Other functions can include meeting specified performance levels for air leakage, thermal, fire and acoustic performance, etc.

5.3.3 Fire

Where sandwich panels with different levels of fire resistance are specified the manufacturer's recommendations should be followed.

NOTE Fire performance might be specified to meet the relevant Building Regulations [3], [4], [5] and [6] and/or specifiers or insurers requirements

5.3.4 Roof applications

*COMMENTARY ON **5.3.4***

Trapezoidal or sinusoidal profiled through fixed sandwich panels with over-lapping side joints and over-lapping end laps can be installed for roof slopes down to 4° after deflection.

Pantile effect stamped/profiled through fixed sandwich panels with over-lapping side joints and over-lapping end laps can be installed for roof slopes down to 12° after deflection.

Recommendations for minimum pitch should be carried out in accordance with **5.1.3**.

5.3.5 Performance

The deflection under a uniformly distributed load of sandwich panels in single, double and multi-span conditions should be determined by calculation and/or testing in accordance with BS EN 14509, and should be confirmed together with load/span tables by the manufacturer.

*NOTE 1 See **7.2.6** and Table 9 and Table 10 for maximum permissible deflection for sandwich panels under distributed loads.*

Panels with through fixings either with an exposed or a concealed appearance, or with attachments via a bracket or halter, concealed within the panel side joint, can provide restraint to the top flange of the roof purlin, and should be in accordance with the manufacturer's recommendations.

*NOTE 2 See also **7.2.8** for restraint to purlin.*

Sandwich panels should also conform to **7.3** for safety and non-fragility.

5.3.6 Facing materials

The facing materials used in the manufacture of sandwich panels should be in accordance with BS EN 14509.

5.3.7 Coatings

Surface coatings should be in accordance with **5.2.8**.

5.3.8 Fixings and fasteners

Special designs of dual-threaded fastener should be used with sandwich panels for the primary locations, with an appropriate lower thread for fixing into the support member and a second larger diameter high-thread under the fastener head; the high-thread is to support the outer skin of the sandwich panel when combined with a bonded washer that contributes to long term weathertightness.

High-thread sandwich panel type fixings are generally not needed for secret fix wall applications, and the need for their use should be confirmed by the manufacturer.

Fasteners for sandwich panels should be selected according to the panel manufacturer's recommendations to suit the specific system and application.

*NOTE Further information can be found in **5.9**.*

5.4 Rooflights

5.4.1 General

Rooflights save energy by allowing electric lights to be turned off; electric lighting systems should always be automatically controlled to realize the full potential benefits of available daylight (see **7.8**).

NOTE 1 For many larger buildings (including most buildings with profiled sheeted roofs) windows are ineffective for much of the interior of the building, and rooflights are the only practical method of admitting sufficient daylight.

NOTE 2 Rooflights in well-designed buildings give a good spread of natural light and when used in conjunction with automatic lighting controls offer a dramatic reduction in a building's total energy consumption and in the associated CO_2 emissions. A naturally lit interior reduces building operating costs and provides a more pleasant environment than artificial lighting which can help people feel better and work more efficiently.

5.4.2 Rooflight layout and area

Rooflight layout and area should be designed to provide the best internal illumination levels, ensure ease of installation, reliability of weathertightness and safe roof access. The distribution of daylight within a building should also ensure that there are no dark areas and no direct solar glare; use of diffusing rather than transparent rooflights is recommended for this reason.

The rooflight area should be sufficient to minimize the use of the electric lighting system for as many hours per annum as possible, saving energy, operating costs and minimizing CO_2 emissions to conform to relevant Building Regulations [3], [4], [5] and [6].

NOTE 1 The Simplified Building Energy Model (SBEM) used for conformance to the relevant Building Regulations [3], [4], [5] and [6] incorporates a 12% rooflight area in the toplit notional building. For a typical large span building clad with profiled sheeting the total CO_2 emissions can increase dramatically if the rooflight area is reduced significantly below this notional level, and can be reduced if the rooflight area is increased above this value in many but not all circumstances. Generally for larger buildings a rooflight area of 12% to 15% of the floor area is optimal.Full details are provided in NARM ADL2A and ADL2B [13].

NOTE 2 The best layout of in-plane rooflights in profiled sheeted roofs is often runs of rooflight from near the ridge to near the eaves, with opaque sheeting on either side. Special consideration is needed if rooflights are positioned within 1.5 m of ridge or eaves to ensure safe roof access and positioning of fall protection systems, resistance to accidental mechanical damage, satisfactory fixing of accessories such as ridge flashings and resistance to localized zones of high wind/snow load.

Factory assembled in-plane rooflights should generally not be installed in runs across the roof, with large numbers of rooflights adjacent to one another, as this would give a risk of cover width tolerances accumulating, making it difficult to fit the rooflights correctly

5.4.3 Thermal insulation of rooflights

Rooflights in heated buildings should always be specified to achieve a *U* value of at least 2.2 W/m²K or better; there should be a minimum of triple-skin rooflights, which should always be specified by the manufacturer and fitted to reduce heat loss and minimize condensation.

NOTE Attention is drawn to the relevant Building Regulations [3], [4], [5] and [6].

The *U* value should be calculated or tested to take into account any framing or glazing bars. Manufacturers should be able to quote rooflight *U* values, and it should be reported and made clear whether quoted values are in the vertical or horizontal plane.

For out-of-plane rooflights this limiting value should be based on the developed area of the rooflight (U_d value) rather than the area of the rooflight aperture (see [14] for full details).

Patent glazing should be designed and detailed in accordance with BS 5516-1.

5.4.4 In-plane rooflight

In-plane rooflights (light transmitting sheets replacing one or more opaque profiled sheets in the roof) are generally suitable for use at finished roof pitches in accordance with the guidance on minimum pitch for through fix sheets given in **5.1.3**; at lower pitches, out-of-plane rooflights should generally be used (see **5.4.5**).

NOTE 1 Lighter weight in-plane rooflights are more flexible allowing them to deflect under loading to a greater extent without being damaged than those made from metal or fibre cement. This flexibility increases the reliance on good workmanship and the risk of poor workmanship causing problems at low pitch.

Heavier weight in-plane rooflights are available which are more rigid, offering improved compression of sealants and less deflection around fixings, ensuring there is no greater risk of poor workmanship resulting in any problems than there is with surrounding opaque sheets, and should be considered for use at low pitch.

The maximum deflection of the rooflights should meet the following criteria:

a) At the design stage of wind suction loading, the deflection should be limited to $L/30$ (L = span) and be not greater than 50 mm to prevent fixing holes becoming oval, which could result in failure due to pullover or localized cracking.

b) When subject to imposed snow loads, deflection should not exceed $L/30$ (L = span) and be not greater than 50 mm to avoid the disruption of sealants at end laps.

The deflection of the rooflights under self-load should not be so great that it creates a negative pitch, as this results in ponding, which leaves dirt deposits after drying which are unsightly and impair light transmission.

NOTE 2 Risk of ponding is affected by profile, pitch and rooflight specification, but is only likely at very low pitch, and is more likely on single span sheets which deflect further than multispan sheets.

Out-of-plane rooflights eliminate risk of this problem and should be considered for very low pitch applications

Site-assembled in-plane rooflights, consisting of an external sheet conforming to the roof sheet profile and a separate inner liner sheet conforming to the lining sheet profile, with a separate light transmitting insulating core, should generally be used with built-up profiled sheeting roofs (as detailed in **5.2**).

For site-assembled rooflights used in conjunction with sealed metal lining systems, the translucent liner should form an integral part of the vapour sealed liners, and therefore end laps and side laps should be sealed.

NOTE 3 Closures can be used between the sheet skins around the perimeter of the rooflights to prevent the ingress of insulation materials between the translucent panels.

Although in-plane plastic rooflights are available to match most metal and fibre cement sheet profiles, the availability of such rooflights conforming to BS EN 1013 should be confirmed with the manufacturer before specifying.

Factory-assembled in-plane rooflights consisting of an external sheet conforming to the profile of the composite panel, with a flat or profiled liner forming a box with an integral light transmitting insulating core should generally be used with profiled composite panel roofs (as detailed in **5.3**).

*NOTE 4 The correct selection of site-assembled or factory-assembled rooflights is dictated by the roof construction: incorrect selection (e.g. use of factory-assembled rooflights in a built up roof, or site assembled rooflights in a composite panel roof) can increase risk of condensation in both the rooflight and surrounding roof (see **7.4.5.3**).*

Although factory-assembled triple-skin units are more rigid than single-skin sheets, the manufacturer's recommended purlin centres should not be exceeded as any excessive deflection could strain or weaken bonding joints.

Factory assembled in-plane rooflights should generally not be installed in runs across the roof, with large numbers of rooflights adjacent to one another (see **5.4.2**).

*NOTE 5 Purlin extension plates might be necessary at end lap positions in composite panel systems, including at end laps between composite panels and factory assembled rooflights (see **6.1**)*

Manufacturers should provide evidence of satisfactory performance with regard to manufacturing tolerances, proper nesting of end laps and side laps with appropriate metal or fibre cement sheeting, weathertightness, strength, light transmission, thermal insulation, solar heat input, condensation risk, fire rating and method of fixing.

NOTE 6 The deflection of rooflight liners with shallow depths that need to match the metal liner can determine purlin centres.

*NOTE 7 The type and method of fasteners used to secure in-plane rooflights might be different to the surrounding opaque sheet. In particular, larger washers – typically 29 mm in diameter – and/or saddle washers might be needed (see **5.9.7**). Also, special sidelap fasteners might also be needed where a rooflight is the underlapping material (see **6.4.3**).*

The method of installation of in-plane rooflights might be different to the surrounding opaque sheet (see [15] and **6.4** for guidance); detailed installation recommendations should always be sought from the manufacturer of the specific rooflight used, and should be followed.

NOTE 8 See BS EN 1013 for material and performance requirements in regards to corrugated sheets for translucent and transparent profiled rooflight sheets.

5.4.5 Out-of-plane rooflight

*COMMENTARY ON **5.4.5***

Out-of plane rooflights (bespoke designs to fit onto separate kerbs or upstands above the plane of the roof, such as barrel vault or dome rooflights) are available for use on any very low pitch, flat or curved roofs, or special applications (such as running along the ridge of a roof).

Detail of out-of-plane rooflights can vary from one manufacturer to another, and many systems and applications are bespoke; the relevant manufacturer should be consulted and their installation recommendations followed.

NOTE See BS EN 1873, BS EN 14963 and [16] for material and performance requirements for out-of-plane rooflights.

5.4.6 Rooflight materials and surface protection

*COMMENTARY ON **5.4.6***

In-plane and out-of-plane rooflights are both available in a number of alternative glazing materials, typically glass reinforced polyester (GRP) or polycarbonate. Some out-of-plane rooflights are also available in glass.

Plastics rooflights are classified as either thermosetting or thermoplastic. Thermosetting plastics, such as GRP, pass through a chemical action during manufacture and become permanently set. Polycarbonate are typical thermoplastics which soften when heated and can be remoulded into different shapes after manufacture.

All offer good properties as rooflight glazing materials when correctly applied, but each has different properties, affecting their suitability for specific applications. Detailed information on the different properties of these materials and their suitability for different rooflight applications is given in [17].

Guidance on expected durability is given in Table 15.

All plastic rooflights should be protected with an ultra-violet (UV) absorbing surface coating (see **7.9.4.2**).

Rooflight materials should be compatible with surrounding materials; polycarbonate should be isolated from plastisol coated sheets and should not be allowed into contact with some specific sealant materials (see **7.10**).

Thermal movement of rooflight materials can be greater than the surrounding opaque sheeting or the structure, and measures to accommodate this movement should be taken, particularly if long sheet lengths are specified (see **6.4** and **7.2**).

To prevent damage during and after installation, the handling, drilling and fixing of polycarbonate in-plane rooflights should be carefully managed and the manufacturer's written instructions should be adhered to.

5.4.7 Condensation in rooflights

*COMMENTARY ON **5.4.7***

Rooflights are often not as well insulated as surrounding opaque roofing, so can be at a greater risk of condensation in certain circumstances; if condensation does occur, it is visible so can cause an aesthetic problem.

Particular care should be taken to alleviate the risk of condensation in rooflights (see **7.4.5.3**).

Where high internal humidities increase condensation problems, confirmation of the suitability of rooflights should be obtained from the manufacturer.

5.4.8 Structural performance of rooflights

Rooflights should be specified to resist relevant wind and snow loads (see **7.2**); correctly specified and fixed, they can generally resist loads as high as the surrounding opaque roof without a problem, although rooflights are significantly more flexible than surrounding sheet and should not be considered as part of a stressed skin construction (see **7.2.7**).

Rooflights or plastics sheet liners cannot usually provide lateral restraint to the supporting purlins or rails; they should only be used as such where confirmation is given by the designer that it is safe to do so.

Rooflights should be specified to ensure an assembly of the roof, including rooflights, achieves the same non-fragility classification as the roof without rooflights, otherwise the non-fragility classification of the entire roof is reduced (see **7.2.1** and **7.3**).

5.4.9 Solar gain

Solar gain is often a benefit, countering any additional heat loss due to poorer insulation of the rooflight compared to surrounding opaque sheeting, but care should be taken to avoid direct solar glare, or excessive solar gain which could lead to solar overheating. Care should always be taken if the rooflight area exceeds 18% to 20% of the roof or where there are particularly high process gains.

5.4.10 Fire

NOTE Rooflights are generally available in a range of fire ratings to British or European standard to meet the various requirements of relevant Building Regulations [3], [4], [5] and [6], for both inner and outer skins of roof and wall.

The necessary fire ratings should be specified (see also **7.7**).

5.5 Fibre cement

5.5.1 Profiled fibre cement sheets for roofing applications should have sufficient profile depth to achieve the intended span length when tested in accordance with the method in BS EN 494; shallower profiles are only suitable for wall cladding.

5.5.2 On heated buildings, the fibre cement sheets should be installed over insulation which can be either self-supporting boards or laid on a supporting liner sheet, as recommended by the sheet and insulation manufacturers.

5.5.3 Roof sheets should have sufficient depth of profile to drain rain to the gutters without risk of leaks through side laps.

NOTE Roof sheets are available with integral fibre mesh to reduce the risk of collapse under impact loads.

5.5.4 The maximum permitted load and deflection should be determined in accordance with BS 8219 and be published by the sheet manufacturer. Fibre cement sheets should not be relied on to provide any bracing of supporting purlins or sheeting rails.

NOTE No calculation method exists for predicting the resistance to deflection of profiled fibre cement sheets with uniform or point loading.

5.5.5 Coatings on fibre cement sheets should be in accordance with **7.9.4.3**.

5.5.6 Foam spray or retrospective coatings should only be applied with the agreement of the manufacturer.

NOTE Fibre cement sheets and their associated factory-applied coatings are vapour permeable, allowing the relatively free transfer of excessive moisture. Any subsequent coating or foam spray application that partially or fully seals the sheeting on one side only after installation of the roof, could be detrimental to this important characteristic and ultimately to the performance of the roof covering.

5.5.7 Fibre cement sheets should be fixed through clearance holes to allow for moisture movement of the material. A clearance of 2 mm greater than the fastener diameter should be allowed, unless installing proprietary self-drilling screws intended for fixing fibre cement with a self-cutting clearance are used.

5.5.8 The four way lap corners of fibre cement sheets should be cut to form mitred corners as recommended by the sheet manufacturer and guides to good practice (see [18]). Butyl strip sealants should be installed in the side- and end laps as required for the intended exposure conditions in accordance with BS 8219.

5.5.9 Flashings for fibre cement roof and walls are available in matching materials, and unlike other profiled materials the building envelope should be designed to use the factory-made standard range of flashing components (see [18]) and not to rely on bespoke shapes and sizes (see **5.11**).

5.6 Bitumen fibre

5.6.1 For roofing applications, corrugated bitumen sheets should be category R in accordance with BS EN 534 unless otherwise stated as suitable for use in the relevant climatic conditions in the sheet manufacturer's installation guide.

NOTE Category R or category S sheets can be used on wall cladding.

5.6.2 On heated buildings the corrugated bitumen sheets should be installed over insulation, which should be either self-supporting boards or laid on a supporting liner sheet as recommended in the sheet manufacturer's installation guide.

NOTE The use of corrugated bitumen sheets as an underlay to slate or tile roofs is not covered in this British Standard.

5.6.3 Category R corrugated sheets manufactured in accordance with BS EN 534 should have larger tested values than for category S for bending strength, impact performance and tear strength before and after freeze/thaw cycling.

5.6.4 The maximum permitted load and deflection should be determined by testing and published by the sheet manufacturer in accordance with BS EN 534.

NOTE 1 Bitumen sheets do not provide any bracing of supporting purlins or sheeting rails.

NOTE 2 No calculation method exists for predicting the resistance to deflection of corrugated bitumen sheets with uniform or point loading.

5.6.5 Bitumen sheets should not be installed in contact with materials that deteriorate due to chemical reactions with bitumen; for example, some plasticized polymer membranes.

NOTE Guidance on the expected durability of bitumen sheets is given in Table 15. Durability can be improved by the factory application of a coating to reflect solar UV radiation. Coloured coatings can be factory-applied for aesthetic reasons.

5.6.6 Fasteners should be installed to allow for thermal movement as recommended by the sheet manufacturer's installation guide. The fasteners should have weather sealing washers and should only be of a type recommended in the sheet manufacturer's installation guide.

5.6.7 Unless recommended otherwise by the sheet manufacturer's installation guide for the intended application, the end laps of sheets, when unsealed, should be 200 mm long and side laps should be either one or two corrugations, normally unsealed.

5.7 Thermal insulation and moisture vapour control

5.7.1 Thermal insulation materials

*COMMENTARY ON **5.7.1***

The principal factors affecting the choice of insulating materials are:

a) thermal resistance and required thickness;

b) vapour diffusion resistance;

c) strength and rigidity for use in conjunction with particular cladding systems;

d) chemical compatibility with associated cladding and fixing materials;

e) durability in service including condensation risks and exposure to extreme service temperature range;

f) thermal and moisture movement;

g) sound insulation value;

h) effect on fire performance of the cladding assembly; and

i) ease of handling, fixing and installation.

The thermal resistance of profiled sheeting is small and makes an insignificant contribution to the total insulation value of the cladding system.

Suitable insulating materials for profiled roof and wall cladding systems include foamed plastics and mineral wool or glass fibre in a variety of rigid, semi-rigid and flexible forms; their typical thermal properties should be obtained from BS 5250. The thermal resistance of insulating materials generally reduces with increased moisture content and care should be taken when selecting the thermal resistance value appropriate to the equilibrium or service moisture content of the insulant during design. In addition, the thermal resistance of most types of foamed plastics reduces with age and similar care should be taken in selecting the appropriate long term value.

Foam spray or retrospective coatings should only be applied with the agreement of the manufacturer in accordance with **5.5.6**.

Insulating material should be secured in place against downward slippage and gapping in steep roofs and walls, and wind dislodgement in ventilated cavities, to avoid local reductions of thermal insulation values in the roof or wall cladding system.

Thermal insulation materials should conform to the appropriate British Standards listed in Table 2.

Table 2 **Common insulating materials for use with profiled sheeting**

Insulating product	**Other common name**	**Harmonized Standard**
Mineral fibre	Fibres of glass, rock or slag	BS EN 13162
Rigid polyurethane foams	PUR and PIR foams	BS EN 13165
Polyisocyanurate foams	PUR and PIR foams	–

5.7.2 Thermal transmittance

For a multi-layer cladding, the thermal transmittance *U* should be calculated in accordance with BS EN ISO 6946.

For sandwich panels the thermal transmittance *U* should be calculated in accordance with BS EN 14509.

Thermal transmittance *U* value of systems should be calculated including regular repeating thermal bridging by metal or other good conductors of the insulation layers, which includes fixings through insulated sandwich panels and spacers in built-up systems.

NOTE 1 BS EN ISO 10211 provides a calculation method using finite element analysis for calculating these effects where these effects are not covered by the method in BS EN ISO 6946.

NOTE 2 Guidance on assessing the effects of thermal bridging at junctions and around openings in the external elements of buildings and how to assess their overall heat loss is given in [19] using numerical analysis to the method of BS EN ISO 10211.

NOTE 3 BS 5250 gives data on the thermal resistance of air spaces and thermal conductivity of various cladding and insulating materials which can be applied to the thermal design of cladding.

NOTE 4 Attention is drawn to the relevant Building Regulations [3], [4], [5] and [6] and consideration of thermal comfort, conditions of use of the building and control of condensation.

5.8 Spacers

5.8.1 General

*COMMENTARY ON **5.8.1***

Spacer kits are used within built-up insulated roof and wall cladding systems to provide a cavity of a specified depth. The cavity is occupied by thermal insulation material and might also accommodate acoustic insulation. The spacer kit provides for the mechanical fastening of the external weather sheet and the transfer of imposed loads (including wind and snow loads) to the supporting structure.

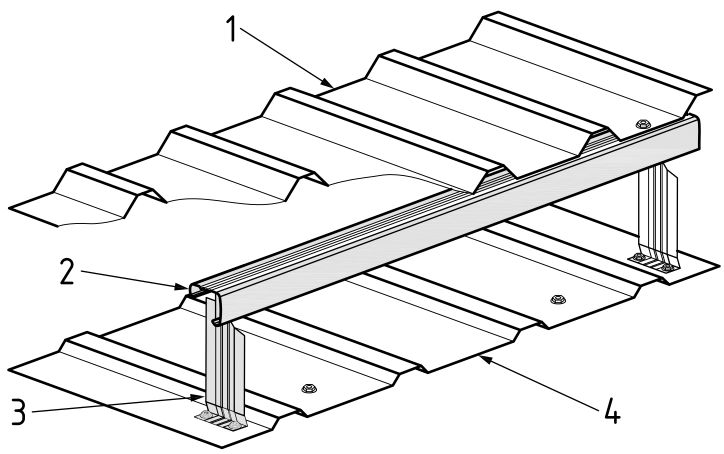
Various forms of spacer kit are available, but in all cases, their primary function is to hold the liner and outer sheets of the cladding system at a specified distance apart in order to create a void for the insulation material. Spacer kits are manufactured from a range of materials. A typical kit includes one or more of the following components: light gauge metallic brackets, bars, halters, sub-purlins and fasteners, and non-metallic components such as plastic blocks, knuckles and pads.

Spacer kits can generally be categorized as either bar and bracket or halter systems, as shown in Figure 3, although other types also exist.

Spacer kits can be used to fulfil the following functions:

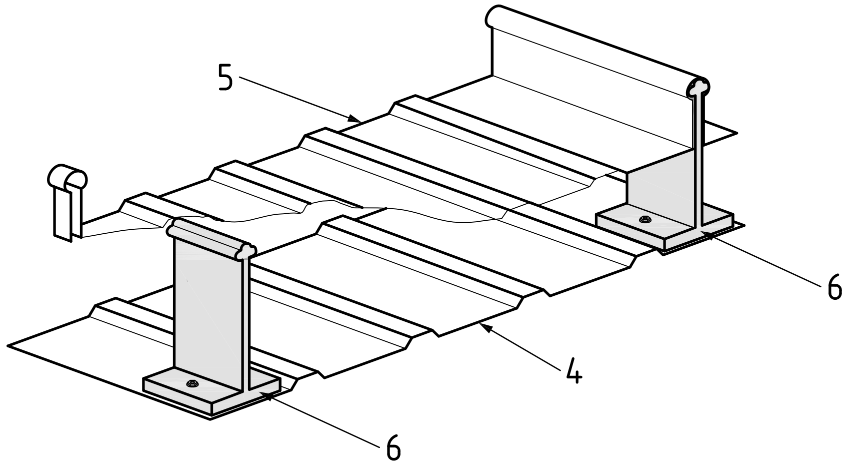
- *connect the outer profiled cladding (weather) sheet to the supporting building structure underneath;*
- *provide a predefined cavity depth between the outer cladding sheet and the inner liner to accommodate the manufacturer's required thickness(s) of insulation. The cavity depth might also be needed to accommodate other materials in addition to thermal insulation, e.g. acoustic layers;*
- *transfer forces acting on the outer cladding sheet to the supporting building structure without excessive deformation or instability; and*
- *minimize thermal bridging to provide an effective thermal barrier between the outer sheet and the internal surface of the envelope.*

Figure 3 **Bar and bracket and halter spacer kits**



a) Bar and bracket spacer kit

Figure 3 **Bar and bracket and halter spacer kits**



b) Halter spacer kit

Key

1	Outer weather sheet	4	Inner sheet support and structure
2	Bar	5	Outer weather sheet (standing seam)
3	Bracket	6	Halter

Spacer systems form repeating thermal bridges which should be included when calculating the thermal performance of cladding.

Spacers are located in the cladding system in a position exposed to interstitial condensation risk; spacers and associated fasteners should therefore be moisture and corrosion resistant, and components should be made of compatible materials.

Timber spacers should not be used with metal and polycarbonate profiles. Where used with fibre cement and/or bitumen fibre, timber spacers should be preservative-treated and dried before installation to avoid excessive shrinkage in service. Preservative treatment to timber spacers should be compatible with the sheet and associated materials (see also **7.10** for recommendations on the compatibility of materials).

5.8.2 Spacer performance

The performance of spacer assemblies should be tested or calculated in accordance with Annex E and for information on safety factors in accordance with Annex C.

NOTE 1 Users of this British Standard are advised to refer to accreditation certificates and manufacturers' technical data relevant to the conditions of use in the UK.

NOTE 2 The local environment in the cavity is usually non-corrosive for normal building applications, since the components of the spacer kit are protected from the external environment by the weather sheet and from the inner environment of the building by the liner. A vapour barrier may be included within the envelope if appropriate for the site conditions and building use.

Where corrosive conditions are expected in the cavity around the spacer, spacer and fastener materials should be selected that are resistant to the corrosion for the intended life of the building envelope.

Spacer rails should provide a support flange of adequate width, thickness and tensile strength to accommodate the designated fixings and provide a stable bearing surface to the underside of the weathering sheet. The bearing surface should provide support to the underside of the weather sheet sufficient to avoid local deformation of the weather sheet across the spacer rail under the design positive (downward) loading conditions. The rail should be sufficiently wide to accommodate the alignment of weather sheet fasteners.

In practice, a minimum bearing width of 40 mm is satisfactory for use with steel sheeting, although this should be increased to 50 mm when used with some aluminium materials.

The thickness and material grade of spacer rails should be sufficient to safely resist the pull-out action of the weather sheet fastener under negative wind loading conditions.

NOTE 3 The pull-out resistance is directly related to the tensile strength of the rail material and its thickness.

Advice on performance should be obtained from the supplier of the fastener or rail components.

NOTE 4 A minimum thickness of 1.5 mm is satisfactory for steel of Z22 quality, conforming to BS EN 10147, and a minimum thickness of 2 mm is satisfactory for aluminium with a minimum 0.2% proof stress of 180 N/mm².

NOTE 5 Various forms of spacer kit are available and are described in AnnexDand Figure 3.

5.9 Fixings and fasteners

5.9.1 General

Primary and secondary fixings should be selected and positioned so that they can secure the cladding system against dead, imposed and wind loads in service, maintain watertightness, are durable for the service life of the cladding and, in certain types, accommodate some thermal movement of the cladding.

The design load of the fixings should not be less than:

a) the characteristic strength derived from **C.5.6.3**, Annex E (**E.6**), with safety factors in accordance with those in Annex C; and

b) level of deformation at which there would be a risk of leakage.

NOTE 1 The strength of fixings can be determined by the method of test and acceptance levels as specified in Annex E.

NOTE 2 The strength of a fixing is influenced by the combined behaviour under load of the fastener, washer and connected materials, and not merely by the strength of the fastener alone.

In the case of fasteners of the self-tapping or self-drilling type the thickness and strength of the material in which the screw thread is formed should be suitable for the particular fastener and be in accordance with the fastener manufacturer's recommendations for use under practical site conditions.

NOTE 3 Fastener manufacturers define the range of types, thicknesses and material strengths that each of their selfdrillers is suitable for and also, for selftappers, the required predrill hole diameter.

For a given fastener size and type applied to flexible sheeting (e.g. metal or plastics), the strength of crown fixings is usually less than trough fixings, due to limited buckling resistance of the profiled sheeting under uplift load; large washers or saddle washers of adequate size and stiffness or sheet to support fasteners should be used to improve the strength of such fixings if required.

Exposed fixings should remain watertight under all maximum and various loading conditions. Therefore the sealing washers should be of adequate diameter, thickness, softness and strength to accommodate these loading conditions and, additionally, where thermal movement is a potential condition, they should maintain a seal over any oversize holes or potential localized slotting or distortions.

NOTE 4 Fixings on the sheeting can affect the external appearances of the building.

The size, shape, colour, numbers and positioning of cladding fasteners and washers in relation to the type of profiled sheeting might significantly affect the performance and external overall appearance of the building, particularly walls and steeply pitched roofs, and should be included in the design.

To avoid unsightly inward dimpling of flexible sheeting around fasteners, firm backing support to the sheeting at the fixing positions should be provided.

5.9.2 Fasteners

*COMMENTARY ON **5.9.2***

Proprietary fasteners have been developed, particularly self-drilling screws, rivets, washers and colour heads, to meet the fixing requirements of single layer and multi-layer cladding systems incorporating components which might include a combination of thermal and acoustic insulation, condensation and air control layers, spacing systems and internal linings.

When correctly installed, self-tapping screws and self-drilling screws should have hardness to form threads and, in the case of self-drilling screws, drill through the material and thicknesses of the profiled sheeting and structural element to be connected without stripping the threads in the fasteners or connected element.

Fastener and cladding manufacturers should be consulted on the choice of fasteners for the cladding design and the suitability of fasteners should be evaluated by examining the available performance data.

NOTE 1 In general, fasteners cannot be replaced during the life of the building as part of any routine maintenance.

NOTE 2 Examples of fasteners are illustrated in Figure 4. Annex E gives methods for determining the strength of fasteners and fixings.

The fastener material should be able to resist corrosion for a period comparable to the functional life of the sheeting, including any over-painting in the intended environment of use.

NOTE 3 Fasteners are available in a range of materials including coated carbon steel, various grades of stainless steel and aluminium.

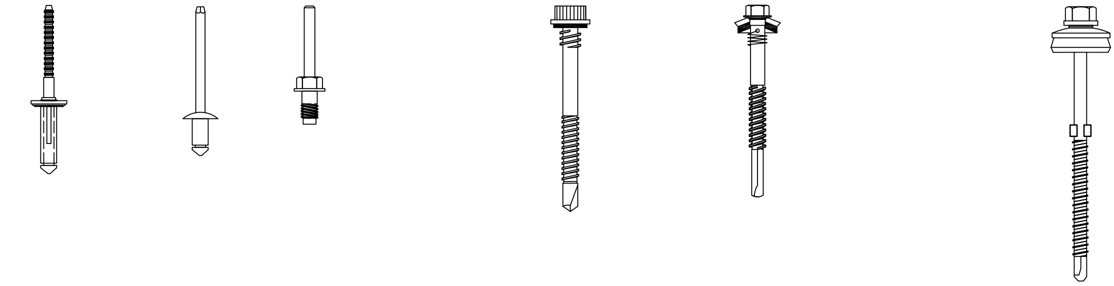
NOTE 4 BS EN ISO 6988 specifies a method of test on the appearance of rust after exposure to an alternating atmosphere containing sulfur dioxide, and BS EN ISO 9227 for an atmosphere combining salt spray. These are used for evaluating the corrosion resistance of fasteners.

Figure 4 **Examples of fasteners**

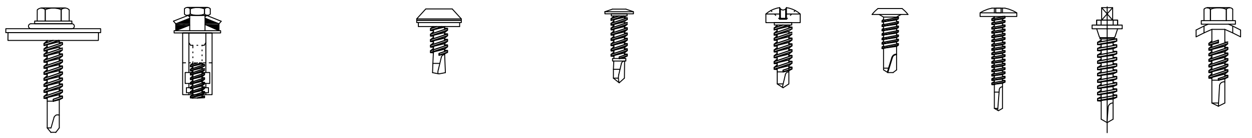
a) Self-drilling fasteners for metal sheet to steel/aluminium substructure

b) Self-tapping fasteners for metal sheet to steel/aluminium/timber/concrete substructure

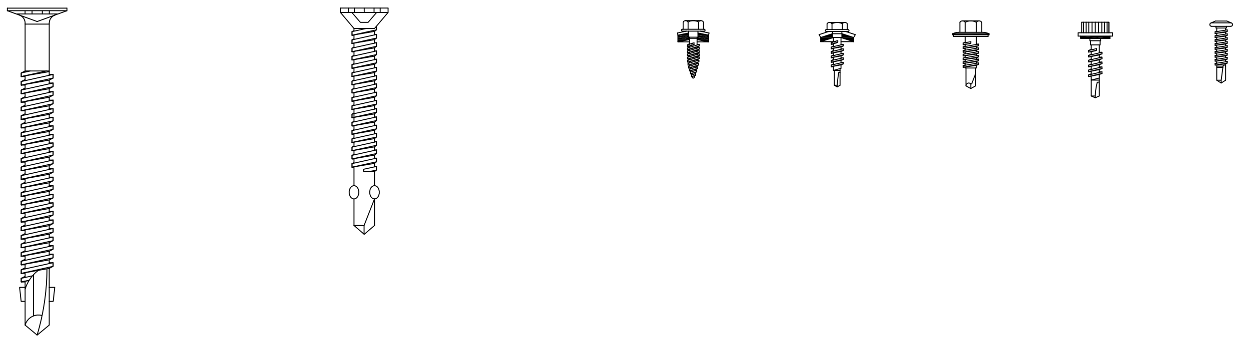
Figure 4 **Examples of fasteners**



c) Rivet fasteners d) Fasteners for insulated panels e) Fastener for fibre cement roofing



f) Fasteners for rooflights g) Fasteners for specialist application – clipfix, standing seams, rainscreen, etc.



h) Fasteners for timber to steel i) Fasteners for stitching of sidelaps and flashings

5.9.3 Primary fixings

Primary fixings should be positioned along and secured to the lines of purlins, sheeting rails or spacers. End laps in profiled sheeting should be arranged to occur over purlin, sheeting rail or spacer lines and secured by the same primary fixings.

NOTE 1 Along the purlin, sheeting rail or spacer lines, extra primary fasteners might be needed to maintain a tight end lap, resist the wind suction loads on the cladding and fasteners in accordance with the profiled sheeting manufacturer's instructions, and avoid vibration of the sheeting.

NOTE 2 Fasteners for primary fixings can be fixed through the crowns or troughs, provided the fasteners and seals are suitable for the purpose and their installed appearance is acceptable. Crown fixings are subjected to less rainwater but, because of their longer lengths, they are at a greater risk of not being inserted perpendicularly to the crown, which can adversely affect the effectiveness of the seal. There is also a greater risk of the profile being distorted in the event of the fastener being overtightened. Crown fixings might not provide sufficient compression of sealants at end laps.

Fibre cement sinusoidal sheeting should always be crown-fixed on roofs.

NOTE 3 Primary fasteners are divided into two types:

a) rigid fasteners; and

b) non-rigid fasteners.

Primary fixings should have sufficient strength to resist the design imposed loads, imposed loads and wind loads, and maintain weathertightness and also resist lateral loads where the cladding system is intended to provide lateral restraint to the substructure.

NOTE 4 In addition, they might be required to accommodate some thermal movement in the direction of the profiles (and transversely in the case of inflexible sheets). This can be achieved by oversize fixing holes or by elastic displacement of purlins and spacers. Particular care is needed to accommodate the thermal movement of thermoplastic rooflights which need oversized fixing holes, and to ensure fasteners remain watertight at extremes of thermal movement.

The rooflight manufacturer should be consulted to ascertain their specific recommendations for which primary fixings to use.

The watertightness of fixings with fasteners penetrating the sheeting should remain effective when the sheeting is subjected to the maximum inward imposed loads and wind loads.

*NOTE 5 For insulated panels fasteners would normally be dual threaded, in accordance with **5.3.8**.*

For built up roof systems the insulation quilt should be underneath the spacer bar. Some firewall systems may require the insulation to be compressed over the spacer bar. Reference should be made to the manufacturer's firewall certificate.

NOTE 6 Under such loads, the sheeting and any insulating substrate compress and tend to loosen the seal in the fastener as a result, increasing the risk of water penetration. It is therefore important to ensure that the sheeting, substrate and fastener, including sealing washer, provides adequate performance under these conditions. Additional security might be obtained by the use of fasteners which secure the sheeting against inward movement as well as against outward loads.

5.9.4 Secondary fixings

Secondary fixings should maintain a tight lap and seal and transfer concentrated load to adjacent sheets. Also, the secondary fasteners should be long enough to clamp all materials and compress the sealant.

NOTE Purpose-designed stitching/clamping fasteners for sidelaps and flashings are available. Their design includes special drillpoints, threadforms and washers that reduce the risk to the installer of overdriving. These provide an alternative to rivets.

Where required, fasteners for secondary fixings, or stitch fasteners, should be positioned at side laps on the crown for roof cladding and in the trough or crown for wall cladding, depending on the profile and according to the profiled sheeting manufacturer's recommendations. The fastener and method of installation should accommodate and compress a seal in the lap joint where a seal is used.

The spacing of stitch fasteners where required depends on the thickness and profile of the sheeting and the presence or otherwise of a sealant in the joint, but should generally be not more than 450 mm apart. For firewall systems reference should be made to the manufacturer's firewall certificate.

For aluminium sheeting proprietary self-drilling screws or rivets designed for the purpose and sheet thickness, the manufacturer's recommendations should be followed.

For plastic sheets the manufacturer's advice should be followed regarding the suitability of fasteners, in accordance with **5.9.2**.

5.9.5 Installation of fasteners

The effectiveness of fasteners is dependent on correct installation and the following should be considered.

- Where self-drillers are used, and to ensure a suitable threaded hole is forrmed through the sheet and structure, the correct selection of fastener in terms of drillpoint range and thread type should be based on the manufacturer's data.
- Where self-tappers are used, predrilled holes should be drilled (not punched) with drills of the correct diameter and hardness, perpendicular to the surface of the sheeting. Swarf should be removed from the roof before tightening the fastener, unless the drill bit is designed to remove the swarf during drilling.
- Self-tapping or self-drilling screws and rivets should be of the correct length and hardness and be suitable for the type and thickness of materials to be connected.
- Where screw guns are used, the fastener manufacturer's recommendations for speed and tightness should be followed. Screw guns should be fitted with depth sensitive devices.

Where aluminium of thickness below 2 mm and steel of thickness below 1.5 mm is used for spacers or primary support members, the grades and tensile strengths should be shown by testing fastener pull-out strength, in accordance with Annex E, to conform to the intended design loads.

NOTE Where no test results are available higher safety factors or special fasteners might be required unless suitable guidance is available from the fastener manufacturers.

5.9.6 Materials for fasteners

*COMMENTARY ON **5.9.6***

Fasteners are available in a range of materials to resist the corrosive internal and external environments in which they are used. These environments are classified in BS EN ISO 12944-2. Typical materials include coated carbon steel, various grades of stainless steel and also aluminium.

The choice of fastener material should be made based on the corrosive environment (if any) and the required service life for the building envelope.

Fasteners should be manufactured with materials that have the strength to resist without failure or excessive deformation the loads imposed on them and the connected elements during installation and service.

Carbon steel fasteners should be provided with a protective zinc based coating of adequate thickness to prevent corrosion in the design environment.

NOTE 1 Zinc can be supplemented by an organic coating.

NOTE 2 Fasteners are also available in aluminium and stainless steel.

Conditions of bimetallic corrosion should be avoided; this is done by selecting a fastener material that is more noble than the material it is fastening into or through. For example, it is for this reason that austenitic stainless fasteners (or aluminium fasteners) should be used when fastening into/through aluminium and stainless sheeting and substrates. Carbon steel fasteners should not be used in conjunction with aluminium or stainless materials.

NOTE 3 Stainless steel compositions are defined in BS EN ISO 3506 and BS EN 10088-2. The appropriate grades of fasteners for profiled sheet for roof and wall cladding are typically 1.4301, 1.4401 and 1.4547. Table 3 contains cross references to the equivalent popular names.

Table 3 **Typical chemical composition of austenitic stainless steel fasteners (based on BS EN 10088-2, BS EN ISO 3506-1 and BS EN ISO 3506-4)**

Popular name	Grade name number	BS EN name	BS EN number	Chemical composition of key elements by% by mass max		
				Chromium (Cr)	Molybdenum (Mo)	Nickel (Ni)
304 standard chromium nickel austenitic	A2	X5CrNi18-10	1.4301	17.5–19.5	0	8.0–10.5
316 molybdenum chromium nickel austenitic	A4	X5CrNiMo17-12-2	1.4401	16.5–18.5	2.0–2.5	10.0–13.0
High alloy molybdenum austenitic	A5	X1CrNiMoCuN20-18-7	1.4547	19.5–20.5	6.0–7.0	17.5–18.5
		X1NiCrMoCuN25-20-7	1.4529	19.0–21.0	6.0–7.0	24.0–26.0

For aesthetic reasons, coloured heads of fasteners should be colour matched to the profiled sheeting. The colour matched material should be durable for the intended life of the profiled sheeting and be factory-applied (e.g. nylon moulding or powder coating).

5.9.7 Washers

The type, size and stiffness of washers, in relation to the type of fastener, are of critical importance in achieving a weathertight seal and an airtight seal where required; their design and specification should provide a firm uniform seal without damage to the washer, fastener or sheeting, but should not significantly impede rain run-off, particularly in valley fixings.

For crown fixings of corrugated sheeting, shaped crown washers should be used as these provide a greater bearing area and increased resistance to pullover under outward loads.

NOTE 1 Saddle washers can be used with crown fixings on trapezoidal and sinusodial profiled sheeting, particularly for aluminium or plastic sheeting, to increase the fixing strength by providing a larger bearing area for the fastener and increase the uplift resistance of the sheeting. Where used these need to have adequate stiffness to develop the required bearing area under load.

Washers should incorporate a seal that is bonded/vulcanized to a metal washer (made of galvanized steel, austenitic stainless or aluminium) of suitable thickness and diameter to provide an even and acceptable level of sealing pressure when correctly installed.

NOTE 2 Compressible gasket or sealing washers are available in elastomeric and plastics materials, as separate components for site assembly or as integral parts of the fastener. Ethylene propylene diene monomer (EPDM) is the preferred sealing material and is available in different thicknesses and hardnesses appropriate to the particular fixing application, as stipulated by the profiler and fastener manufacturer.

When in service, the materials used should be durable, provide sealing pressure and be resistant to climatic conditions. The washer material should be compatible with the fastener and the sheet.

5.10 Sealants and profile fillers

5.10.1 Sealants

Where sealants are to be provided, an airtight and/or weathertight barrier should be installed at end laps and side laps, penetrations, junctions, and at the joints between profiled sheeting and its accessories. The durability of the sealant should be considered, taking into account the design life of the cladding system and the importance of the sealant within it as, in general, sealants cannot be replaced during the life of the building as part of any routine maintenance.

Where sealants are used they should be:

- non-corrosive to the joined components;
- gap filling;
- remain permanently flexible within the design temperature range over the predicted life;
- capable of being compressed under load;
- adhesive;
- capable of accommodating movement at laps and movement joints;
- water resistant;
- chemically compatible with the sheet or coating;
- UV-resistant where exposed to UV light; and
- applied to a surface that is clean, dry and free from frost, grease and loose materials.

NOTE BS 6093 gives recommendations and guidance for the design of joints and jointing in building construction. NFRC technical bulletin No. 36 [20] gives a method of assessing sealant performance for roofing applications. Guidance for side lap and end lap sealing of profiled metal sheets, sandwich panels excluding proprietary concealed fixed systems is given in NFRC technical bulletin 44 [21]. Guidance is given in MCRMA GD19 [15] for sealing end laps of inplane rooflights and profiled metal.

5.10.2 Profile fillers

Profiled fillers should be used at all intersections to close the inter-profile cavities to exclude rain, snow, wind-driven debris and birds (although not intended to provide a primary water seal). They should be inserted between the profiled sheet and an appropriate flashing. For example, at ridge and hip positions they should be inserted above the sheet between the sheet and a ridge/hip flashing to fill the troughs; at eaves and valley positions they should be inserted below the sheet, and between the sheet and an eaves/valley flashing to fill the crowns.

Fillers should be set back by no less than 80 mm from the edge of the upper sheet/flashing to discourage attention from birds (gulls can be particularly destructive), whilst the lower sheet/flashing should extend at least 100 mm upslope from the filler to trap any minor leaks. When closures are fitted between ridge capping and sheeting the ends should be butt jointed over profiled crowns to minimize the entry of wind-blown rain. Fillers should usually be sealed to the sheet using a proprietary sealant (whilst taking care not to block any intentional ventilation or drainage paths).

Profiled fillers are available in a range of materials, including polyethylene and ethylene propylene diene monomer (EPDM) blends; filler materials should always be closed cell materials, with very low water absorption rates.

Ridge/eaves fillers should be flexible and soft to ensure they conform to the exact shape of the cavity, and do not distort flashings or lightweight profiled sheet (particularly liner panels), which means they are not suitable for providing support or carrying loads. Alternative materials should be used where support is required (e.g. where profile fillers act as spacers or provide support for crown fixings).

Fillers should be durable for an appropriate period for the project (typically 25 years). Filler materials should also have high resistance to UV attack.

NOTE 1 In built-up roofs it is often a benefit to provide passive ventilation to minimize the risk of interstitial condensation, which can be achieved by the use of ventilated fillers at ridge and eaves, and to specify ventilated fillers to ensure that passage of any condensate to the gutter is not impeded.

A variety of ventilated filler types (e.g. mesh inserts, tops off or notched) are available for different applications; any ventilation gaps should be limited in size to prevent ingress of debris and minimize potential nuisance from flying insects.

Profiled fillers are available cut to an angle and are recommended for use at hip and valley positions; the angle of cut depends on both the angle on plan and roof pitch, and should be clearly communicated.

NOTE 2 The length of an angle cut filler varies depending on the angle of cut. Acute angles can result in excessive lengths and fillers might have to be made in a number of pieces, or at very high angles (over 60°). It is often preferable to fit individual blocks into each trough rather than a continuous filler.

NOTE 3 Fire-resistant profiled fillers are also available for use where a cavity barrier is required. However, these are completely different materials and are not interchangeable with ridge/eaves fillers.

5.11 Flashings

*COMMENTARY ON **5.11***

*Flashings for profiled sheet roof and wall cladding are available either in the same material as the sheets or other compatible materials. Except where noted in **5.11**, the size and shape of flashings can be standard or designed for the particular building. Some sheet materials impose limitations on fabrication techniques making alternative materials the preferred choice.*

*Flashings for profiled metal and metal-faced insulated panels are made in similar shapes with limitations as described in **5.11**.*

*For recommendations on roof penetrations see **5.13**.*

5.11.1 Aluminium

All aluminium sheets and flashings should be designed to allow for thermal movement (see **7.1.2.6**).

NOTE Uncoated aluminium can be welded in the factory or on-site to provide complex shapes.

5.11.2 Coated Steel

*COMMENTARY ON **5.11.2***

No allowance for thermal expansion is normally needed for steel sheets and flashings unless recommended by the manufacturer for long lengths.

Steel used for profiled sheets and flashings on industrial and commercial buildings should have a metallic coating and a functional and decorative applied coating.

Steel used for profiled sheets and flashings on agricultural and similar buidlings should have a durable metallic coating as a minimum.

NOTE These materials cannot be welded.

5.12 Gutters and rainwater goods

*COMMENTARY ON **5.12***

The arrangement of pitch directions depends on the roof area, the presence of any expansion joints in the building, the roof shape, and drainage capacity and position of gutters and outlets (see BS EN 12056-3 for roof drainage calculations). Draining to perimeters is generally less liable to blockage than draining to internal outlets. Where there is a parapet, special care might be necessary to avoid blockage of drain outlets due to build-up of debris or of ice and snow.

5.12.1 Gutters

*COMMENTARY ON **5.12.1***

Recommendations for the design of gutters and rainwater pipes are given in BS EN 12056 and for siphonic systems in BS 8490. A suitable rainfall rate for design purposes is given in BS EN 12056 for eaves gutters, where overflow is unlikely to occur inside a building. For valley and boundary wall gutters, where overflow could occur inside the building, a higher rate is more appropriate.

5.12.1.1 Eaves gutters

The appearance of gutters and downpipes in relation to the cladding and building should be considered at the design stage.

Eaves gutters should be secured to the substructure or incorporated as part of the cladding system and the method of attachment should resist wind uplift, snow loads/drifts and maintenance loads.

NOTE For further information see [22], in particular, the snow loading section.

5.12.1.2 Valley and boundary wall gutters

NOTE Valley and boundary wall gutters are usually designed and made to suit the individual building details.

Valley and boundary wall gutters should have a minimum top width of 500 mm where they are designed to take maintenance foot traffic. They should also be capable of supporting the imposed concentrated load for water, snow and foot traffic (see **C.5.3**); they may be self-supporting as a single profiled element or supported from structural framing and gutter straps.

Valley and boundary wall gutters should be insulated to reduce the risk of underside condensation, maintain thermal insulation (see **5.7**) and avoid excessive build-up of snow and ice (see **5.12.3**).

They should also be detailed enough to avoid overflow of water into the building in the event of blockage where possible by providing overflow weirs through the stop-ends of the guttering to the outside of the building.

Where gutters are intended to be used as access or walkways during or after construction they should be confirmed by the designer/manufacturer as non-fragile to ACR[M]001 [N1].

5.12.1.3 Continuous curved eaves without guttering

*COMMENTARY ON **5.12.1.3***

Where the eaves of the building are formed from curved profiled sheeting matching the profile of the roof and wall sheeting without the use of intervening gutter, most of the run-off from both the roof and wall cladding is collected in the wall cladding profiles and discharged at the bottom of the wall.

In heavy rainfall and wind-driven rain, a significant proportion of the run-off from the roof can overshoot the eaves and land on the apron at some distance away from the wall; aprons should provide drainage capacity and erosion resistance and avoid harmful splash-back.

5.12.2 Rainwater goods

Rainwater goods should be in accordance with Table 4.

Table 4 **Standards for rainwater goods**

Gutter type	Product material	Product standard (if different from harmonized standard)	Harmonized standard
Eaves gutters with bead stiffened fronts	Made from metal sheet	–	BS EN 612
Steel and aluminium rainwater systems – specification.	Steel and aluminium formed sheet gutters	–	–
Half round, beaded half round, Victorian ogee and moulded ogee	Aluminium	BS 8530	–
Siphonic drainage	–	BS 8490	–
Gravity drainage system	–	–	–

NOTE 1 Although BS 569 covers asbestos cement rainwater goods, the composition of the material no longer includes asbestos fibres is generally fibre cement. However, to facilitate compatibility, gutter profiles, accessories and downpipes are manufactured to the dimensions specified in BS 569.

NOTE 2 Parapet and valley gutters are usually purpose-made to suit the building on which they are installed. Gutters of these types are commonly made from pre-galvanized steel in accordance with BS EN 10346, post-galvanized steel in accordance with BS EN ISO 1461 or aluminium. Additional site or factory applied protection should be specified to protect the galvanized coating on the steel or the aluminium substrate from corrosion, provide additional durability and extend their useful life. Guidance is given in MGMA information sheet 05,[23].

NOTE 3 Parapet and valley gutters are usually purpose-made to suit the building on which they are installed and can be made of flexible membranes factory-bonded to steel or aluminum substrate. The membrane forms the waterproof layer and can be heated, welded or bonded at the joints. Guidance is given in MGMA information sheet 07 [24].

5.12.3 Insulation of gutters

All gutters within the building envelope (i.e. valley and boundary wall gutters) should be insulated to minimize the risk of condensation and maintain thermal insulation values. However, to reduce the risk of blockage and overflow from snow and ice deposits, gutters should be less well insulated than the cladding system to allow some heat from the building to induce melting of snow and ice. This increased local thermal transmittance should be taken into account when calculating the overall insulation value of the building.

5.13 Roof and wall penetrations

5.13.1 General

*COMMENTARY ON **5.13.1***

Some roof penetrations can be considered as types of flashings made from similar materials to the roof sheets.

Any penetration which needs a hole greater than one third of the width of the profiled sheet should have structural trimmers fitted to provide support unless the sheet manufacturer provides alternative recommendations.

Where the penetration forms an upstand to which another component (e.g. an extract fan) is fitted the minimum upstand height above the roof surface should be 150 mm. Where pipes or cables penetrate a roof or wall they should be sealed and inclined upward to drain water away from the seal.

When a roof penetration extends across the valley of the roof sheet profile, provision for drainage around the obstruction should be made; in aluminium this can be achieved with a welded design including a gutter channel across the upslope side of the penetration and in steel sheets a similar layout can be formed in GRP or similar rigid materials (which can be applied in-situ to seal to the roof).

Warm or hot penetrations should be protected with insulation where they pass through the roof system.

The roof system vapour control and air barrier should be sealed to all roof penetrations.

Penetrations through secret fix roof systems designed to accommodate thermal movement by sliding over clips or halters should incorporate spaces to allow for that movement as the penetration is a fixed component.

5.13.2 Photovoltaic panels

*COMMENTARY ON **5.13.2***

Photovoltaic (PV) panels impose static loads on the supporting roof system and dynamic loads from wind and snow especially if they are not laid parallel to the roof sheets.

A structural engineer should check that the building structure is suitable to accept the imposed loads. If fitted to a portal frame building the structural checks should include any asymmetric loading caused by the panels. The load from the PV panel should be transmitted back to the structural frame along the recommended load path agreed with the roof systems supplier. When fitted to secret fix profiled sheets which are designed to slide over clips or halters to accommodate thermal movement, the panel fasteners should not restrict the sliding motion.

The suitability and compatibility for the proposed method of installing a PV system above or onto a roof system should be confirmed by the roof system supplier.

PV panels laid parallel or at a shallow angle to roof sheets create a micro-climate which can reduce the durability of the roof sheets; the profile manufacturer should be consulted before installation.

Care should be taken to ensure that grids supporting PV panels do not cause bi-metallic corrosion with metal roofs by installing a separating layer that is durable for the intended life of the assembly.

All cables penetrating the roof or wall should conform to **5.13.1** on weathering of penetration.

5.13.3 Solar water heat panels

Solar water heat panels should be considered as similar to PV panels (see **5.13.2**) in respect of loading, supporting frames and any micro-climate.

The inlet and outlet pipes for solar water heat panels should be insulated through the roof system using weatherproof roof sheet penetrations that rise at least 150 mm above the roof surface. The pipes should be sealed to the vapour control layer in the roof.

5.13.4 Smoke vents

The upstands to smoke vents should be insulated with a vapour control layer on the warm side of the insulation which should be sealed to the vapour control layer in the roof system.

NOTE Attention is drawn to the relevant Building Regulations [3], [4], [5] and [6] in reference to opening louvres or flaps of smoke vents.

5.13.5 Access hatch

A vapour control layer on the warm side of insulation of the access hatch upstand should be sealed to the vapour control layer in the roof system. The upstand should have a height no less than 150 mm above the roof surface to minimize the risk of rain ingress.

The hatch cover should be insulated to reduce the risk of condensation forming and dripping into the occupied space.

NOTE Attention is drawn to the relevant Building Regulations[3], [4], [5] and [6] in reference to the upstand and other parts of an access hatch.

Access hatches should have a secure latching mechanism and be able to withstand wind forces if open during stormy conditions. Precaution should be taken to ensure access hatches are not opened during stormy conditions.

5.14 Safety systems

*COMMENTARY ON **5.14***

For further detailed guidance see ACR[CP]007 [25] and ACR[M]002 [26].

5.14.1 General

If access is required for the inspection or maintenance of roof and wall cladding, then provision should be made for safe access at the design stage.

5.14.2 Hierarchy of safety

The designer of the roof, also referred to as designer or duty holder should:

- avoid working at height where they can;
- use all measures possible to prevent a worker getting into a fall situation, via a collective means, such as hand railing or parapet wall of a height no less than 1.1 m and by individual means, such as a work positioning horizontal life line system and using personal protective equipment (PPE) as part of a safety system designed in accordance with BS EN 795; and
- use work equipment or other measures which have been designed in accordance with BS EN 795, where the risk of a fall cannot be eliminated.

Where a fall cannot be totally eliminated an arrest system should be designed. When installed, an arrest system should optimize the distance from the hazard and minimize consequences in the event of a fall from height.

5.14.3 Restraint system (no risk of a fall)

NOTE 1 BS EN 795 states that all restraint systems be designed more rigorously, so that in the event of any misuse the system can still perform an arresting role.

NOTE 2 Typical shock absorbing/arresting lanyards range from 1.2 m to 2 m in length.

So that a horizontal life line can perform in 'restraint' it should be positioned in such a way that a user with a system-specific lanyard length cannot reach the hazard; for example, a 2 m lanyard should be used on a line placed 2.3 m from the roof edge. The length and type of PPE should be recorded in the operation manual along with details of the access point onto the system.

5.14.4 Arrest system (potential risk of a fall)

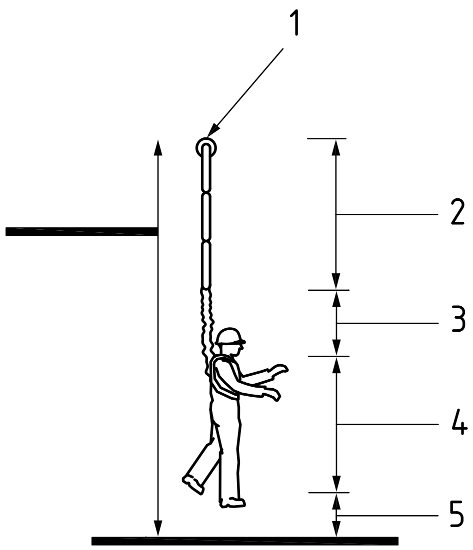
Care should be taken to ensure that any arrest system installed on a building can fulfil its mandatory arresting requirements. Many aspects of the building construction, its size, location and even the intended use should all be considered before a suitable system is designed.

NOTE 1 A building's height, roof construction, rooflights and proximity to other buildings and the surrounding features all play their part in this decision making process.

NOTE 2 Many arrest systems require more specialised PPE and considerably more training – arrest systems are not ideal for basic/novice users. In all scenarios, it is considered best practice to design a system to restraint.

NOTE 3 Arrest systems might only be effective for buildings above a certain height (see Figure 5) and in some circumstances restraint systems might be a better solution.

Figure 5 **Minimum heights for arrest systems**



Key

1	Anchorage point on roof	4	Man's height (1.8 m)
2	Lanyard length (2 m)	5	Safety margin (1 m)
3	Shock absorber deployed length (1.75 m)		

A working calculations package should be available from the supplier which provides information on system performance, post spacings and line deflection.

NOTE 4 The roof anchor posts that support a horizontal life line system are generally fixed/secured to the outer sheet/skin of the roof. Dependent upon the manufacturer these methods can feature large structural sized 7.9 mm minimum diameter structural rivet or hexagon head self-drilling screws. Screws are generally quicker to install, although usually greater in number, whereas rivets are significantly stronger, offering enhanced fixing security as the trend to reduce roof sheets thicknesses continues.

Fragile roof sheets such as a roof constructed from an outer skin made from bitumen fibre sheeting does not support reliable engagement of mechanical fasteners and is too fragile to take the kind of loadings generated from a person's fall; such roofs normally feature a life line system secured onto traditional bespoke (rigid) fabricated roof anchor posts and should incorporate shock absorbing components.

Due to the many varied types of modern roof constructions and sheet combinations standard 10 m post spacings cannot be relied upon and specialist advice should be sought for each individual roof construction/build-up/size.

NOTE 5 Each different type of roof construction tends to produce its own unique performance results when subjected to a horizontal life line fall simulation.

Test results should be requested on the appropriate safety system and roof assembly prior to system specification because of the variations in manufacturers' products and to accommodate the retrofit sector of the market.

NOTE 6 Line end and corner locations can produce load figures from as little as 5.5 kN. However, some systems can go beyond 15 kN (approximately 1.5 tons).

The system should be strong enough not to deform during installation or by accident. Also, when it deploys it should not damage or deform the roof skin.

To guarantee the longest possible life from a system, all components should be made from stainless steel, the highest grade practical, normally A2 or A4, or other material which has been proved to be equally suitable.

NOTE 7 Some manufacturers' products are produced using other non-ferrous materials. Responsible material selection helps maximize the service life of the system, and by avoiding a dissimilar metal/electrolytic/bi-metal reaction ensures that the individual components resist corrosion for a long service life.

5.14.5 Horizontal safety lines

When installing a horizontal safety line, the client should select a system that is accepted by the sheet manufacturer and conforms to current industry standards, and has been tested in accordance with PD CEN/TS 16415 and BS EN 795.

Before using any safety equipment it should be checked that the horizontal safety line has been tested in accordance with PD CEN/TS 16415 and BS EN 795 and that any safety line is fitted with a tag on which at least the following information is clearly visible:

a) date of installation;

b) next inspection due date;

c) number of persons the system is designed for;

d) lanyard length;

e) any special PPE requirements; and

f) contact numbers for manufacturer/installer.

6 Installation and weathertightness – laps and seals

*COMMENTARY ON CLAUSE **6***

Laps in profiled sheeting are locations where rain and wind can penetrate the cladding. Their detailed design and construction are therefore critical to weathertightness.

6.1 Design detailing

Care should be taken in the design of the cladding system details to ensure continuity of watertightness, vapour control and airtightness, thermal insulation and compatibility with the structure and dissimilar elements, particularly at vertical and horizontal changes of direction, abutments, junctions and around doors, windows and external attachments.

NOTE 1 Good detailing reduces premature deterioration of the cladding system.

Site cut edges of coated steel profiled sheeting should be kept to a minimum for durability.

NOTE 2 Edge corrosion is inhibited by the sacrificial action or barrier protection of the metallic coating on the steel. The onset of edge corrosion can be delayed by the application of additional edge protection or by bending the edge down at eaves to improve drainage.

The metal manufacturers' recommendations should be followed for the appropriate type of edge protection required with regard to the roof pitch and local environment.

Roof end laps should be weather sealed.

NOTE 3 Unsealed end laps are unlikely to provide adequate weathertightness in UK climatic conditions.

The length of sealed laps should be kept short to avoid opening out under deflection of the sheeting, but should accommodate the seal and primary fastener, and provide bearing length on the spacer, purlin or sheeting rail. The dimension from primary fastener to the end of the outer sheet should be not less than 50 mm.

NOTE 4 Purlin extension plates or wider purlin top flange sections might be necessary at end lap positions in composite panel systems, taking into consideration site tolerances and alignment of laps and non-fragility requirements.

Where proprietary systems have special lapping arrangements, the manufacturer's recommendations should be followed.

Laps should be as tight fitting as possible, and where necessary closed up by seals and lap stitching. This is particularly important when lapping profiled sheets of the same nominal profile but of different thicknesses, such as when combining metal sheeting with plastic rooflight sheeting; in such cases the end and side laps should always be sealed.

Sealed laps provide a barrier to both water and air, but should not be used to resist a hydrostatic head of water. Sealants should be placed at a suitable edge distance within the lap to protect them from exposure to sunlight as recommended by the manufacturer and verified by measurement during installation.

Seals should be applied to the under-lapping sheet before the laps are made and not edge-sealed afterwards. For all laps and seals of profiled sheet products the manufacturer's instructions should be followed.

See Table 5 and Table 6 for recommendations that should be followed for the end lap sealing of profiled metal, rooflights and sandwich panels, based on MCRMA GD19 [15].

For long sheets, thermal movement and the possible need for movement joints should be considered (see **7.1**).

Where expansion of the profile is accommodated by floating (sliding) end laps, an increased overlap might be necessary and the manufacturer's recommendations should be followed.

NOTE 5 Floating end laps might be necessary with aluminium roofing (see MCRMA GD19 [15]).

Table 5 **Size, shape and position of sealant(s) for typical 150 mm roof end lap details (built up systems) A)**

Built up systems	Size, shape and position of sealant(s)
Profiled metal to metal combinations	Two lines of sealant (central or asymmetric primary fixing position) with a single run of 6 mm × 5 mm or 6 mm Ø bead sealant positioned 10 mm to 15 mm from each end of the lap.
Profiled metal to GRP rooflight combinations	Two lines of sealant (asymmetric primary fixing position) with a single run of 6 mm × 5 mm or 6 mm Ø bead sealant positioned 10 mm to 15 mm either side of the primary fixing.
	Or, three lines of sealant (central primary fixing position) with a single run of 6 mm × 5 mm or 6 mm or 8 mm Ø bead sealant positioned 10 mm to 15 mm from each end of the lap with an 18 mm × 4 mm or 22 mm × 5 mm U-section positioned beneath the line of the primary fixing. B)

A) The information in this Table is generic. For any specific project, manufacturer's recommendations should be followed.

B) Where a seal is needed at the bottom of the lap to keep out dirt and trapped water, a bead of premium quality neutral cure silicone sealant positioned approximately 15 mm from the bottom of the lap should be used. The silicone sealant should conform to classification ISO 11600- F-25 LM of BS EN ISO 11600 and adhesion to the substrates involved verified.

NOTE The information provided in this Table has been reproduced by kind permission of the MCRMA.

Table 6 **Size, shape and position of sealant(s) for typical 150 mm roof end lap details (sandwich systems) A)**

Sandwich systems	Size, shape and position of sealant(s)
Sandwich panel to panel combinations	Three lines of sealant (asymmetric primary fixing position) with a single run of 6 mm × 5 mm or 6 mm Ø bead sealant positioned approximately 10 mm to 15 mm either side of the primary fixing with a third seal positioned 15mm from the bottom of the lap.
Sandwich panel to factory-assembled GRP rooflight combinations	Two lines of sealant (asymmetric primary fixing position) with a single run of 6 mm × 5 mm or 6 mm Ø bead sealant positioned approximately 10 mm to 15 mm either side of the primary fixing. B)

A) The information in this Table is generic. For any specific project, manufacturer's recommendations should be followed.

B) Where a seal is needed at the bottom of the lap to keep out dirt and trapped water, a bead of premium quality neutral cure silicone sealant positioned approximately 15 mm from the bottom of the lap should be used. The silicone sealant should conform to classification ISO 11600- F-25 LM of BS EN ISO 11600 and adhesion to the substrates involved verified.

NOTE The information provided in this Table has been reproduced with kind permission of the MCRMA.

6.2 Profiled metal and sandwich panels

6.2.1 General

Recommendations for minimum pitch should be carried out in accordance with **5.1.3** and in accordance with **5.4** for rooflights.

6.2.2 External roof side laps

Roof side laps should be weather sealed and stitched at centres no greater than 450 mm unless this goes against the manufacturer's recommendations.

Seals should be placed sufficiently close to the fixing line to ensure correct compression of the sealant. The roof side laps should provide support during fixing and sealing and for foot traffic when installed; the profile shown in Figure 6 is an example of how this can be achieved.

NOTE There might be a need to air seal side laps in certain circumstances including with single skin non air permeable profiled sheeting or insulated composite panels.

Figure 6 **Supported roof side lap**

a) Profiled sheet

b) Sandwich insulated panel

Key

1 Side lap stitcher

2 Side lap sealant

6.2.3 Junction of side lap and end lap seals

Particular care should be taken to ensure that there is no leak path at three-way and four-way laps. The end lap sealant and side lap sealant should meet, providing a continuous seal between every layer of profiled sheeting. The manufacturer's recommendations should be followed.

6.2.4 Internal roof liner

Impermeable metal or rooflight liner sheets often form part of the air and vapour control layers; for this use the side laps and end laps should be sealed in accordance with the profile manufacturer's recommendations.

Liner sheets should be regarded as fragile unless the liner system has been successfully tested to ACR[M] 001. Where a liner system has been successfully tested, the manufacturer's recommendations for the relative position of sealants (if included in the test), sheet laps and fasteners (which should typically be at least 50mm from the end of the sheet) should be followed to maintain non-fragile performance, otherwise the liner should be regarded as fragile (see also **7.3**).

NOTE Where liner assemblies are used as a roof over other works before the insulation and weather sheets are installed, it is necessary to fully seal the liner side and end laps creating a weatherproof product.

6.2.5 External wall end and side laps

NOTE 1 End laps and side laps in external wall sheets are generally unsealed. Side stitching might be required to maintain closeness of fit.

Profiled sheet wall end laps should be not less than 100 mm in length when unsealed to reduce the risk of wind driven rain ingress. Where profiled sheets are fixed horizontally, the end laps should be sealed and not less than 50 mm in length.

In special conditions, such as in coastal environments, the manufacturer's recommendations should be followed.

For sandwich panels, the panel side laps and end laps should be sealed to provide an air barrier as part of the overall air leakage requirement of the building.

NOTE 2 This applies to both horizontally and vertically laid sandwich panels.

Fire wall side laps and end laps should be fixed and sealed in accordance with the manufacturer's fire test report.

*NOTE 3 Additional requirements may apply to wall constructions used for fire protection. See **7.7**.*

6.3 Fibre cement sheeting

6.3.1 End laps and side laps

The profile of fibre cement corrugated sheets should ensure good nesting of end and side laps which minimizes the possibility of water ingress by capillary action. However, for roofs of normal (sheltered) exposure at the lowest recommended roof pitches (5° to 15°) both end and side laps should be sealed and, in certain circumstances, a double line of sealant in the end laps should be applied. For roofs of medium pitch (over 15° up to 22°) the end laps should be sealed or, alternatively, the end laps should be increased from the standard 150 mm length to 300 mm length to eliminate the need for sealing. The profiled sheet manufacturer's recommendations should be followed for size and sealing methods.

When forming the end laps there should be a projection of 100 mm below the fixing accessory in 150 mm end laps and from 225 mm to 250 mm in the case of 300 mm end laps.

Sealant should be not less than 6 mm in diameter and not greater than 10 mm in diameter at the end of rooflights depending on profile (refer to manufacturer). Sealant should be butyl or polyisobutylene based or of a similar material which has a rubbery, tacky characteristic and adheres to both surfaces in end laps and side laps. In side laps the sealant should be positioned on the crown of the underlapping corrugation and intersect with the end lap sealant on the high-point of the mitre outside the fastener.

Sealants used for rooflights fitted to fibre cement sheets should not be acidic as this attacks the cement matrix.

6.3.2 Wall end and side laps

End and side laps in vertical cladding should not be sealed for fibre cement sheets.

6.4 Rooflight laps

6.4.1 General

*COMMENTARY ON **6.4.1***

The mechanical properties of plastics rooflights are different from those of metal and fibre cement. They have greater flexibility and different values for fastener pull-over failure. The critical conditions for design purpose are those imposed by wind suction.

The profiles of plastics rooflights might not be such an exact match as metal-to-metal profiles and additional care is needed in the selection of suitable sealants.

Non-fragility of rooflights should be tested as an assembly within the surrounding roof, in accordance with ACR[M]001 [N1]. Where a system including rooflights has been successfully tested, the rooflight manufacturer's recommendations for the relative position of sealants (if included in the test), sheet laps and fasteners should be followed to maintain non-fragile performance, otherwise the rooflight should be regarded as fragile. The number and position of fasteners is critical; typically at least five fasteners should be used per metre width on each purlin, and fasteners should be no less than 50 mm from the end of the rooflight sheet (see also **7.3**).

Use of poppy red fasteners to secure rooflights should be considered to highlight the position of rooflights on the roof, to reduce risk of inadvertent foot traffic

As the thermal movement of plastic rooflights is greater than that of steel, rooflights used in conjunction with metal roofs and fixed over three or more purlins should be progressively secured from one end to prevent possible thermal deflections. Rooflights should not be fixed by first securing the ends and then inserting intermediate fasteners.

Fasteners should restrain rooflights when subjected to wind gust loadings, determined in accordance with BS EN 1991-1-4. Fasteners should generally be fitted with larger washers of no less than 29 mm diameter to meet these loadings.

To prevent damming of the rainwater flow on roofs when such fasteners are located in the bottom flat of narrow troughs of trapezoidal profiles, the diameter of such washers should be no less than 10 mm less than the width of the troughs; wide trough profiles might require more than one fastener in each trough. When fixing through the crowns of rooflights greater than 20 mm deep, saddle washers should be used with rigid shaped supports located between the rooflights and supporting members to take the pressure required by the saddle washer, without distorting the rooflight profile.

Factory-assembled insulating rooflights, which match insulated sandwich panels, incorporate internal supports at each purlin position; full support should be provided for these internal supports (by the purlin or extension plate) and fasteners should pass through these internal supports, with washers located entirely over these internal supports. Fasteners should not be overtightened (or cause any significant deflection of the internal supports) but should ensure the washers are fully sealed. Soft (typically 40 shore) hardness washers should be used to ensure this can be easily achieved.

Primary fixings should not be located within 50 mm of the ends of rooflights.

Where polycarbonate rooflights are installed with rigid fixings in sheet lengths up to 2 m, the diameter of the hole should be 3 mm greater than that of the fastener to allow for movement. On sheets greater than 2 m, the clearance hole should be increased by 1 mm for each additional metre length unless the rooflight manufacturer confirms otherwise.

Where flexible fasteners such as synthetic rubber shanked bolts are installed, there should be no additional allowance.

Rooflights in fibre cement sheeting should be installed in accordance with BS 8219:2001+A1:2013 **6.8**, together with the manufacturer's recommendations.

6.4.2 External rooflight end laps

All end laps between rooflights and adjacent opaque sheeting should be sealed with a pale coloured sealant, typically 6 mm by 5 mm, as shown in MCRMA GD19 [15]. At least two beads should be used at end laps, located equally spaced above and below the line of main sheet fasteners, approximately 10 mm to 15 mm from the fastener line. If the tail of the lap is also to be sealed, a gun-applied silicone sealant should be used.

Specification for fixing rooflights should be in accordance with manufacturer's instructions as pull-over performance varies for different materials and products.

6.4.3 External rooflight side laps

Single skin or site-assembled rooflight sheets should lap over adjacent opaque sheets on both sides wherever possible, allowing for the use of standard stitching screws. Where rooflight sheets lap under adjacent metal sheets, or at rooflight to rooflight sidelaps, expanding rubber bolt fasteners should be used. Alternatively, a metal support section (the same height as the profile) can be fitted longitudinally beneath the underlapping sheet along the sidelap, allowing standard stitching screws to be used.

Factory-assembled rooflights lap under adjacent insulated sandwich panels on one side, and should be specified and supplied with an integral metal strip on the underlap side to allow for the use of standard stitching screws.

Side laps should be sealed with a single bead of pale coloured sealant located on the crown, outside the line of the fixings.

Side laps should be stitched at centres not greater than 400 mm (reduced to 300 mm on exposed sites).

When stitching polycarbonate, allowance should be made for thermal movement by providing clearance round the fixing holes or using a flexible fastener.

6.4.4 Rooflight liner end laps

End laps between rooflight liners and adjacent opaque sheeting should be sealed with a single bead of sealant within the lap, along the line of fixings.

A continuous line of sealant is critical and should be installed to achieve airtightness and prevent ingress of dust or moisture.

6.4.5 Rooflight liner side laps

Rooflight liners should lap over adjacent opaque liners on both sides wherever possible.

Side laps should be sealed with a 50 mm wide film backed butyl tape applied over the lap on both sides.

7 Building physics

7.1 Temperature and thermal movement

7.1.1 General

*COMMENTARY ON CLAUSE **7.1.1***

The following is a guide to the temperature changes that can be expected in the UK.

- *Annual: the annual range of external air temperature is generally about 30 °C; it is rarely more than 50 °C and the maximum recorded temperature range is 55 °C.*
- *Daily: the daily 24 h range of air temperature is greatest in the summer and is generally about 15 °C; it is rarely more than 20 °C and the maximum recorded temperature range is 24 °C.*
- *Sheeting surface: the temperature of the sheeting surface depends, in addition to the air temperature and radiation from the sun and other heat sources, upon cooling due to night sky radiation heat loss, the thermal capacity of the sheeting, thermal insulation of the substrate, the colour and reflectivity of the surfaces, the indoor temperature and the cooling effect of convected air.*

Table 7 gives a guide to the maximum temperature ranges in the summer during a 24 h period; these temperature ranges are greater than those for the remainder of the year and should be used when considering the effects of thermal movement.

7.1.2 Thermal movement

7.1.2.1 General

If the cladding is constructed in the warmer seasons of the year, the provision for thermal movement may be based on the maximum summer temperature change given in Table 7; exceptionally, if the cladding is installed during extreme winter low temperatures, the temperature range for this purpose should be increased by 10 °C.

NOTE Thermal movement might not fully occur because of the restraint which can be imposed by fixings and supports. In this case, the restraint induces a longitudinal force in the direction of movement in the sheeting, the fixings and the supports. If the restraint is complete, i.e. allowing no movement of the sheeting, the restraining force induced is equal to the product of the cross-sectional area, the modulus of elasticity of the sheeting material, the coefficient of expansion and the temperature range involved. In practice, partial freedom to thermal movement always exists due to sheet flexibility and/or oversize holes, deformation in bearing against holed fixings in the sheeting and angular rotation of supports, such as spacer bars and elements, and crown fixings. Table 7 gives a guide to sheet thermal movements and recommended fixings.

Table 7 **Accommodation of thermal movement along sheets**

Material	Maximum 24 h surface temperature change °C	Coefficient of linear expansion per °C	Approximate maximum 24 h unrestrained change in length per metre of sheet mm	Recommendations to accommodate thermal movement along the sheet [A)]
Aluminium light-coloured	50	24×10^{-6}	1.0	End lap movement joints at 11 m (max.) centres for through fix profile sheet
Aluminium mill finish or dark-coloured	70	24×10^{-6}	1.3	End lap movement joints at 8 m (max.) centres for through fix profile sheet [B)]

Table 7 **Accommodation of thermal movement along sheets**

Material	Maximum 24 h surface temperature change °C	Coefficient of linear expansion per °C	Approximate maximum 24 h unrestrained change in length per metre of sheet mm	Recommendations to accommodate thermal movement along the sheet A)
Steel (hot-dip zinc-coated or aluminium-zinc-coated, or (light-coloured)	45	12×10^{-6}	0.4	No special requirement
Steel (dark coloured)	70	12×10^{-6}	0.7	—
Stainless steels	50–70	10×10^{-6} ferritic 18×10^{-6} austenitic	0.7 0.9	No special requirement
Fibre cement	40	8×10^{-6}	0.3	Non-rigid fixings
GRP rooflights	40	22×10^{-6}	1.0	No special (sheet very flexible)
UPVC rooflights	40	60×10^{-6}	2.4	Oversize fixing holes required
Polycarbonate rooflights	40	67×10^{-6}	2.7	Oversize fixing holes required
Bitumen fibre	40	100×10^{-6}	—	Provision should be made for thermal movement

A) For sandwich panels information is provided in BS EN 14509.
B) For proprietary systems to accommodate thermal movement reference should be made to the manufacturer.

7.1.2.2 Flexible sheets

Flexible sheets characterized by a high coefficient of expansion, such as aluminium, should have special provision in fixings for thermal movement in accordance with Table 7.

In addition to thermal movement, profiled sheets, especially on roofs, might be damaged by surface temperatures outside the ranges shown in Table 7; if surface temperatures are anticipated outside the safe range shown in Table 8 the designer should contact the profile manufacturer for advice.

Table 8 **Temperature limitations**

Sheet material	Safe temperature range °C	Comments
Aluminium	–80 to 100	Above 100 °C gradual loss of strength. No embrittlement or other adverse effects (at low temperatures).
Hot-dip zinc-coated steel	–50 to 200	

Table 8 **Temperature limitations**

Sheet material		Safe temperature range °C	Comments
Stainless steel		–200 to 650	Some loss of strength occurs above 300 °C but softening is only significant above 600 °C. No embrittlement or other adverse effects at low temperatures.
Hot-dip aluminium 55% zinc 45% coated steel		–50 to 300	Good heat reflectivity. For use at higher temperatures consult manufacturer.
Organic coated steel or aluminium	Acrylics and alkyds	–50 to 100	Above safe range coating discolours and deteriorates. Below safe range coating becomes susceptible to mechanical damage.
	PVC organisol solution	–50 to 60	
	vinyl		
	PVC plastisol		
	PU polyurethanes	–50 to 80	
	Fluorides PVF, PVF2,	–50 to 100	
	PVF2 acrylic		
Fibre cement		–25 to 80	
Plastic rooflights	GRP	–25 to 80	Above 70 °C discolouration can occur.
	UPVC	0 to 60	When fitted over dark coloured sheets, where solar radiation can cause surface temperatures to exceed 60 °C, degradation and distortion occurs.
	Polycarbonate	–35 to 80	Provision should be made for thermal movement.
Bitumen fibre		–40 to 100	Above 80 °C gradual loss of strength. Below -35 °C becomes brittle.

7.1.2.3 Rigid sheets

In the case of rigid sheets, typified by materials such as fibre cement, thermal movement should be accommodated by oversize holes or non-rigid fixings in the length of the sheet. Thermal movement across the sheets should be accommodated by the provision of a movement joint where building length is greater than 45 m, and an additional movement joint for each subsequent 30 m.

7.1.2.4 Insulated sandwich panels, bonded panels and thick sheeting of low thermal conductivity

Differential temperature and thermal movement between the outer and inner faces of the panel or sheeting causes panels to bow and should be allowed for in the design of the panel, the number, type and location of fixings, and the strength and stiffness of the supporting members such as purlins and spacer bars; differential temperatures can be reduced by the use of lighter colours on the external face.

Use of different metals for the faces can increase the bowing, for example, aluminium outer and steel liner; the maximum sheet lengths should be limited to avoid excessive thermal stress at panel ends, particularly when panels are end lapped without movement joints. Panel manufacturer's recommendations should be followed.

7.1.2.5 Effect of temperature on sheeting and surface coatings

To avoid buckling due to thermal expansion of inflexible metal, flashings should not bridge movement joints in the sheeting. Where dark coloured sheeting is used for roofs, the additional heat gain should be considered at the design stage.

NOTE The temperature ranges within which various sheeting materials can safely be used are given in Table 8, with comments on the effect of temperatures outside of the safe range on the strength, durability and colour of profiled sheeting and their coatings.

7.1.2.6 Allowance for thermal movement in roofing systems

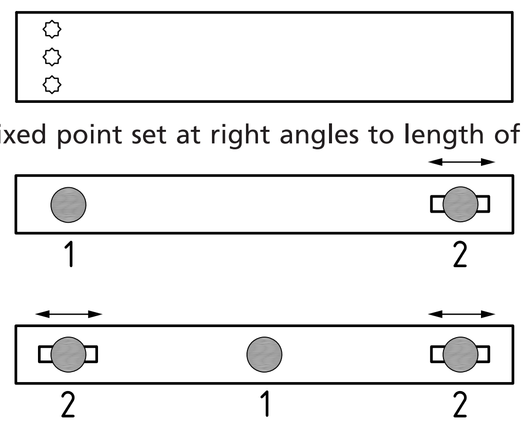
Where different materials are in contact or connected to each other provisions should be made to accommodate differential thermal movement. Where roof coverings are designed to move to allow for thermal movement, for example, standing seam roofs, nothing should prevent this by rigidly fixing to both the system and other elements; for example, flashings, rooflight upstands and penetrations.

NOTE 1 Steel flashings thickness equal to or less than 0.7 mm might be fixed to steel sheets and structures without allowance for thermal movement. They can be joined by over lapping or fixed to butt straps at least 100 mm in width on walls and 150 mm on roofs. MCRMA Technical Paper No 11 [27] provides typical details.

Special details are essential for aluminium flashings which should be designed with allowance for thermal movement (see MCRMA Technical Paper No.11 [27] section 6 for further guidance). Over laps should not be used and laps should only be fixed to one side of a butt strap. Large aluminium flashings greater than 2 mm thickness and not greater than 3 m in length should allow for movement to avoid shearing the fasteners; this can be achieved by a rigid fixing at the centre of the flashing length and slotted holes towards both ends to allow 1 mm/m to 1.5 mm/m of movement for light and dark colours respectively.

NOTE 2 Figure 7 includes fixed point and floating point fastener positions for rigid aluminium flashings.

Figure 7 **Examples of fixed point and floating point fastener positions for rigid aluminium flashings**



a) Three fasteners forming a fixed point set at right angles to length of flashing

b) Examples of a fixed point and a floating point for thick aluminium flashings

Figure 7 **Examples of fixed point and floating point fastener positions for rigid aluminium flashings**

Key

1 Fixed points (two or more fasteners forming a fixed point set at right angles to a length of flashing with the other end free to move)

2 Floating points

7.2 Structural loads, spans and strength

7.2.1 Permanent and variable loads

Imposed roof loads should be calculated in accordance with BS EN 1991-1-1, snow loads in accordance with BS EN 1991-1-3 and wind loads in accordance with BS EN 1991-1-4. Separate loads should be calculated for the sheeting and other supporting elements such as purlins, spacer bars, liners and gutters. Profiled sheeting for roofs is normally designed for use with no access to the roof other than for cleaning and maintenance; where the roof is designed for regular access, special walkways should be provided for the purpose.

Information from the manufacturer should be acquired about whether or not the concentrated loads specified in the appropriate product standard (see Table 1) can be achieved. Advice should also be sought from the manufacturer about the appropriate precautions that should be taken when accessing the roof for maintenance and cleaning.

NOTE 1 Roofs are specified and installed to be non-fragile to ACR[M]001 [N1], with performance proven by testing.

Rooflight non-fragility should be tested as part of the complete roof assembly in accordance with ACR[M]001 [N1] and should be specified to match the non-fragility classification of the surrounding roof, to ensure the non-fragility classification of the whole roof is maintained (see also **7.3**).

NOTE 2 NARM NTD 03 [28] gives guidance on recommended minimum weights for GRP in-plane rooflights for various different applications, non-fragility classifications and expected periods of non-fragility, including rooflights which can be expected to remain non-fragile for 25 years. Rooflight manufacturers have information on other rooflight types.

The roof cladding should not be overloaded or damaged to the extent that permanent deflection or other damage is visible.

NOTE 3 This is particularly important when working with concentrated loads.

Where critical, load spreading protective measures should be taken.

NOTE 4 Depending upon the location, the variable load due to snow specified in BS EN 1991-1-3 can be greater than the imposed roof load specified in BS EN 1991-1-1.

For checking the ultimate strength of cladding sheets under normal conditions, undrifted and drifted snow loads should be treated as alternatives. Exceptional snow loads caused by wind-drift should be treated like accidental loads

Where sheets extend over two or more spans, normal imposed snow loads should be applied on all spans but should also be applied on a single span only, to determine the worst condition when considering strength. When considering deflection or exceptional snow loads due to drifting, the load should be applied to all spans.

7.2.2 Wind loads

Wind loads for roofs and walls appropriate to the location, exposure, roof height, building shape and size should be calculated in accordance with BS EN 1991-1-4.

Where sheets extend over two or more spans, the wind load should be applied uniformly.

7.2.3 Impact loads on wall cladding

Wall claddings should be designed to resist impact loads, in accordance with Annex B, according to the appropriate category of public access to the outside of the building. Such loads should not be taken simultaneously with wind loads.

7.2.4 Vibration

Buildings subject to dynamic loads, such as from gantry cranes or other sources associated with their use, can induce vibration and chatter in lightweight cladding and linings; the use of resilient packings and seals in laps and connections should be considered to minimize these risks. Fixings should be resistant to loosening by vibration. In these situations, advice from competent structural engineers should be followed.

7.2.5 Strength

For each project, the complete roofing/cladding system should be calculated and designed so that all components can safely accommodate the most unfavourable combination of permanent load, imposed roof load or snow load, wind load and impact load that each element within the system is likely to be subjected to.

Where no product standard listed in Table 9 gives a method to determine strength and stiffness of profiled sheeting the method in Annex C should be used.

7.2.6 Deflections under load

The deflection under uniformly distributed load of profiled sheeting in single, double and multi-span applications should be determined by calculation and/or testing, and declared by the profile manufacturer.

For roof sheeting, the most unfavourable combinations of permanent load and imposed roof load or snow load , should be used. For wall cladding, wind loads only should be used, but impact loads should be considered separately (see Annex B).

NOTE A list of the appropriate product standards which include methods of determining strength and rigidity are given in Table 9.

Table 9 **Methods of determining strength and rigidity**

Profiled sheet material	Standard for method of calculation	Standard for method of test	Method of test to be used until revised product standard includes calculation or test
Bitumen fibre	Not available	BS EN 534	–
Fibre cement	Not available	BS EN 494	–
Insulated sandwich panels	BS EN 14509	BS EN 14509	–
Profiled metal sheet:			
Aluminium	BS EN 1999-1-4	BS EN 14782 for concentrated load for all listed materials	–
Copper	Not available		BS EN 14782
Steel	BS EN 1993-1-3		–
Stainless steel	BS EN 1993-1-3		–
Zinc	Not available		BS EN 14782

Where the appropriate product standard does not include a method of calculation or test, the strength and rigidity should be declared by the manufacturer using the method in BS EN 14782.

Information should be obtained from the manufacturer about the quoted deflections, which should identify the method of test or calculation used to determine the performance values.

Construction loads should not be included in the serviceability loads.

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

When checking the deflections the most adverse realistic combination and arrangement of serviceability loads should be assumed. Wind loading should normally be assumed to be uniform on all spans of multi-span sheeting.

The deflection limits for various types of sheeting in Table 10 should be used as guidance. Circumstances could arise where greater or lesser values are more appropriate; for fibre cement sheets, the deflection should not exceed *L*/120 (*L* = span) under any load conditions.

If the deflection under permanent load and uniformly distributed imposed roof load or undrifted snow load is within acceptable limits, deflections under the concentrated imposed load or exceptional snow drift loads, as specified in BS EN 1991-1-3, should not be checked. It should be ensured that localized deflection under concentrated loads does not cause damage to substrate materials, particularly for profiles with wide troughs.

To check the deflection for the purpose of avoiding reverse falls in low pitch roofs, only the dead load should be taken.

Table 10 **Normal maximum permissible deflection for profiled sheeting and sandwich panels under distributed loads**

	Load condition	**Permissible deflection as a multiple of span**	
		Roof cladding	**Wall cladding**
Built up sheets	Permanent	*L*/500	–
	Permanent load plus imposed roof load or undrifted snow load	*L*/200	–
	Permanent and wind	*L*/90	–
	Wind	–	*L*/120
Sandwich panels	Permanent load plus imposed roof load or undrifted snow load	*L*/200	–
	Permanent and wind	*L*/150	–
	Wind	–	*L*/100
Rooflights	Permanent and wind load	See **6.4.1**	–

7.2.7 Stressed skin construction

*COMMENTARY ON **7.2.7***

Profiled metal sheeting designed and constructed to act as in-plane bracing of the roof and/or walls to provide lateral stability as part of the building structure against wind and other horizontal loads is known as stressed skin construction.

Design methods for stressed skin construction are specified in BS EN 1993-1-3; such methods are applicable to particular combinations of sheeting and supporting elements and their connections, and should not be extrapolated to other combinations.

As the profiled sheeting forms part of the structural frame, the coordination of design and the division of responsibility between the profiled sheet supplier and the structural frame designer should be clearly established.

The following aspects should be taken into account in stressed skin design.

a) The material and profile of the sheeting should be suitable in regards to strength, stiffness and durability for stressed skin structural resistance, in addition to its structural resistance to other normal sheeting loads.

b) Secret fixed profiled sheeting systems which rely only on sliding frictional connections between sheeting and purlins or spacer bars should not be relied upon to develop stressed skin action.

c) The shear or bearing loads on the fasteners through the fastener holes in the sheeting due to stressed skin action should not cause excessive elongation of the holes to impair weathertightness.

d) The unclad or partially clad building should be stable under horizontal loads during construction or repair.

e) The supporting elements such as purlins, spacer bars and their fixings should be capable of transmitting the shear forces without excessive displacement or distortion.

f) Rooflights and other roof penetrations should not be considered as part of a stressed skin.

The designer should not assume any structural interaction of a steel frame covered with fibre cement or bitumen fibre sheeting.

7.2.8 Restraint to purlins

Designers of roofs, including the structural steel frame, where applicable, should ensure that the steel frame and its purlins and side rails are restrained in the vertical, horizontal and rotational plain to minimize movement and avoid deflection or twisting under design or loads.

NOTE 1 Attention is drawn to the MCRMA Guidance document on serviceability states and deflection criteria [11].

The unclad or partially clad building should be stable under horizontal loads during construction or repair.

The cladding system and purlins/side rails interact and the structural engineer should consider all components to ensure restraint is provided by the interaction between components: purlins, sheeting, spacers, liners and fasteners.

NOTE 2 Rooflights do not provide any restraint to purlins.

NOTE 3 See SCI P346:2006 [10] for further information.

Any unsupported projection beyond a support should not exceed the manufacturer's recommendations.

7.3 Safety and non-fragility

Roofs should be designed with safety in mind, by ensuring they are safe, both during the construction phase and during use of the building (and subsequent demolition).

NOTE 1 The designer, as well as contractors during construction and the building owner, have specific responsibilities for safety. Attention is drawn to the Work at Height Regulations 2005 [29] and the Construction (Design and Management) Regulations [2] in respect of the specific responsibilities for the designer and others in the construction chain. Guidance is also given in HSG 33 [9].

The following hierarchy for risk analysis should be followed.

a) Where possible, access to the roof should be avoided.

b) Where work at height cannot be avoided, work equipment should be used and measures put in place to prevent risk of falls (e.g. non-fragile roof assemblies, roof parapets).

c) Where risk of falls cannot be avoided, work equipment should be used and measures put in place to prevent risk of injury (e.g. safety harnesses).

NOTE 2 Passive measures (including non-fragile roofs and parapets) are preferred to active measures (such as safety harnesses which require specific measures by an operator).

NOTE 3 Advice is available from the Advisory Committee for Roofsafety (ACR) website (www.roofworkadvice.info [last accessed 18 April 2016]) and in their publications:

- *the "Red Book" ACR[M]001 [N1];*
- *the "Orange Book" ACR[CP]001:2014 [1];*
- *the "Green Book" ACR[CP]002 [30].*

Whenever roof access is likely at any time throughout the life of the building and wherever it is practicable, the roof should be designed to be non-fragile, with appropriate edge protection (e.g. a parapet) with a safe method of access (e.g. internal staircases and an access hatch).

Wherever it is not practicable to provide all of these measures or long term non-fragility cannot be ensured, then use of additional safety systems (e.g. safety lines) should be provided.

Whenever regular roof access is likely, particularly by people not skilled in roofwork (e.g. if an air conditioning plant is positioned on a roof which requires visiting by service engineers) then additional measures such as dedicated walkways and safety barriers should be provided to minimize risk and minimize the likelihood of damage to the roof.

Non-fragility is defined in the ACR[M]001 *"Red Book"* [N1] and is property of a whole roof assembly, not individual components; a non-fragile classification should apply to the whole roof including any accessories such as rooflights. The non-fragility of any particular roof assembly should never be assumed. Evidence should be made available (usually from a roof system supplier) based on sufficient repeatable test data of the specific assembly being used to ensure the results are always valid.

The manufacturer's installation recommendations should be followed in detail; e.g., small changes such as the number of fasteners, or distance of fasteners from the end of a sheet are critical, and any deviation can affect the non-fragile performance of an assembly.

NOTE 4 Walkability is not a clearly defined term and does not mean the same thing as non-fragility, so it is not related directly to safety: some roofs might be non-fragile (so safe) but damaged by foot traffic or a falling person (necessitating repair) whilst others might be undamaged by foot traffic but could fail under the impact of a falling person (so fragile).

7.4 Control of condensation

7.4.1 General

Excessive and prolonged interstitial condensation can cause serious damage to the cladding, insulation, fixings, linings and supporting structure; controlling the risk of condensation to within safe limits should be in accordance with BS 5250 and take into consideration the type of cladding and indoor and outdoor climates.

The side laps and end laps of impermeable metal or rooflight liner sheets should be sealed to provide a vapour control layer.

NOTE 1 Alternatively, a separate flexible vapour control membrane with sealed joints can be used on the warm side of the thermal insulation to provide vapour control in built-up systems.

The performance of the vapour control layer should be confirmed by a condensation risk analysis. To allow for effects of night sky radiation condensation risk calculations for roofs should be made using a minimum temperature of -5°C.

NOTE 2 With perforated metal liners and acoustic insulation a flexible vapour control membrane can be used in between the acoustic insulation and thermal insulation, provided that no more than one third of the total thermal resistance is on the warm side of the membrane.

Where there are high levels of internal humidity such as in swimming pools, paper mills, laundries and commercial kitchens there should be additional internal vapour seals at all junctions and penetrations.

All penetrations, junctions and abutments through the vapour control layer (except for fasteners) should be sealed to the vapour control layer.

A sealed vapour control layer of rigid liner or flexible membrane may be used as part of the air barrier (air control layer); any air control layer should extend over the whole of the element into which it is incorporated and should be integrated with and sealed to adjoining elements, such as junctions, penetrations and glazing systems, and any air control layer in those elements.

For high-humidity applications, the performance of the internal materials and surface coatings should be specified to resist degradation from both the internal environment and any chemicals which might be in the internal atmosphere.

7.4.2 Position of thermal insulation in cladding

*COMMENTARY ON **7.4.2***

Roofs and walls can be classified into the following types according to the position in which the thermal insulation layer is placed.

Warm roof or warm wall is where the principal thermal insulation layer is placed immediately inside the outer profiled sheeting, resulting in the supporting structure and any voids being at a temperature close to that of the interior of the building. The condensation risk plane is also at the outer face of the insulation. The amount of maximum condensation likely to be deposited in a notional winter period may be estimated by the method of calculation specified in BS 5250 and BS 6229 to ensure that it is not excessive as to cause damage to the insulation or significantly impair the thermal insulation resistance value. Profiled sheeting underlaid with insulation which completely fills the profiles of the cladding sheet, such as a composite panel, is an example of a warm roof type.

Profiled sheeting laid over insulation, rigid or semi-rigid, or compressed flexible insulation minimizing air spaces between the outer face of the insulation and the crowns of the profiled sheet, is typical of site assembled systems with a profiled outer sheet. Methods of alleviating the harmful effects of interstitial condensation for this form of construction are given in ***7.4.5.2****.*

The cold roof or cold wall is where the principal thermal insulation layer is placed at or immediately inside the internal lining, resulting in the external profiled sheeting being substantially colder (in winter) than the interior of the building. The plane of interstitial condensation risk is within the void and at the internal face of the outer sheet.

Hybrid roof or wall, which combines the characteristics of warm roofs and cold roofs. Profiled sheeting underlaid with insulation, rigid or semi-rigid, or compressed flexible insulation minimizing air spaces between the outer face of the insulation and the crowns of the profiled sheet, is an example of a hybrid roof type. Methods of alleviating the harmful effects of interstitial condensation for this form of construction are given in ***7.4.5.2****. This type of construction generally applies to site assembled systems.*

Unless special precautions are taken it is impracticable to expect airtight construction.

For cold roofs, to alleviate condensation, the void between the insulation and external profiled sheeting should be through-ventilated to the outside air and a vapour control layer included in the construction where necessary.

This form of cold roof construction should be used with caution particularly with low-pitched roofing with long slope lengths, where ventilation through the air space could be negligible or non-existent. Condensation risk calculations in accordance with BS 5250 and BS 6229 should be used to access the risk.

NOTE 1 Attention is drawn to the need for fire stopping of large voids between the profiled sheeting or lining of combustible material, which is sometimes required by building control officers.

NOTE 2 This British Standard does not apply to inverted roofs or walls, where the thermal insulation is placed outside the roof or wall cladding.

Profiled sheets are generally considered to have low thermal mass and therefore the thermal bridging by spacers and fasteners of the thermal insulation layer(s) should be included in any calculation of U-value and condensation risk.

NOTE 3 The method of calculating U-values given in BS EN ISO 6946 does not apply to metal sheeting systems.

For insulated metal sheeting systems the method of finite element analysis by computer programmes compliant with BS EN ISO 10211 should be used.

NOTE 4 The method given in BS EN ISO 10211 allows the calculation of the cladding system U-value including repeating thermal bridging with a linear heat loss coefficient y value W/mK and surface temperature factor f_{min}. The linear heat loss coefficient y value is a prediction of the additional heat loss through junctions and thermal bridges where condensation is likely to occur. The f_{min} factor is used for assessing localised risk of condensation in BS 5250 at the thermal bridges.

NOTE 5 Guidance on the calculation and use of surface temperature factor f_{min} and linear heat loss coefficient y value is published jointly by EPIC and MCRMA [31] for built-up metal and sandwich panel systems.

7.4.3 Moisture vapour control

COMMENTARY ON ***7.4.3***

A vapour control layer can consist of one or more membranes such as plastics, bitumen, and aluminium foil. The most commonly used materials have a vapour resistance in excess of 200 MN/g, but their effective resistance is reduced by imperfect joints or accidental perforation.

Vapour control layers should be durable against water vapour and resistant to perforation. Where the cladding layers are air-permeable, the vapour control layer and its fixings should be resistant to wind pressure.

NOTE Suitable metallic and plastic profiled liners installed with sealed joints, penetrations and junctions can act as a vapour control layer.

Vapour leakage through unsealed joints or perforations reduces significantly the effective vapour resistance of vapour control layers and should be taken into account, in accordance with BS 5250 and BS 6229.

7.4.4 Air resistance

*COMMENTARY ON **7.4.4***

Air movement transports any moisture vapour present through gaps in profiled sheeting. Individual profiled sheets of the materials listed in Table 1 are not air permeable at normal pressures found in buildings. Individual profiled sheets are airtight when tested at 50 Pa. However, to achieve a required whole building envelope air permeability value it is usually necessary to air seal the side laps and end laps of profiled sheets.

To reduce the risk of condensation, the side laps and end laps, penetrations and junctions should be sealed as part of vapour control measures (see BS 5250).

7.4.5 Interstitial condensation

*COMMENTARY ON **7.4.5***

Moisture generated by building occupants or use develops a higher water vapour pressure than the outdoor air during cold weather, causing the water vapour to permeate outwards into the cladding. As the water becomes colder towards the outer layers of the cladding system, the temperature can fall to or below dew point. When this occurs within the cladding layers, interstitial condensation results.

Conversely, an inward flow of vapour might occur in warm weather or in an air-conditioned building when the outdoor vapour pressure is greater than the indoor vapour pressure.

7.4.5.1 General

Insulating material which would degrade under prolonged wetting should not be used as there is a risk of condensation occurring within the cladding layers due to differences in humidity and temperature differences between the internal and external environments.

NOTE 1 Condensation can adversely affect the internal surface coating on metal sheeting.

NOTE 2 Careful attention to creating an effective air/vapour control layer largely eliminates the problem.

For internal conditions which are excessively humid, hydrostatically controlled mechanical ventilation should be used. In internally pressurized buildings, seals should be provided wherever possible in the cladding or lining which can sustain internal pressure, and minimize the transfer of moisture through air leaks in the cladding system. Roof voids should not be used as plenums for air conditioning or mechanical ventilation unless specially designed for this purpose.

NOTE 3 Local condensation on the back of the sheeting is usually intermittent and non-cumulative because its low thermal mass responds quickly to ambient temperature changes: condensate re-evaporation closely follows a rise in temperature.

NOTE 4 Where there is a void between the profiled sheeting and the insulation, local condensation for short periods in low outdoor temperatures on the internal face of the profile sheeting in the void is unavoidable. This occurs because the profiled sheeting, particularly when of thin or highly conductive material, responds rapidly to sudden changes of outdoor temperature. The temperature in the sheeting can fall to or below dew point, causing the water vapour in the void to condense as water.

7.4.5.2 Alleviating condensation

The harmful effects of local and interstitial condensation should be alleviated by one of the following methods.

a) Where the insulation is likely to be affected by the local condensate, a breather membrane on top of the insulation might need to be included; fixings and supports through the affected layers should be corrosion resistant. The liner or vapour control layer should discharge condensate externally.

   Breather membranes suitable for this application in profiled metal roofing should have a water vapour permeability of ≤0.6 MN·s/g (see BS 5250). They should not be left exposed to the weather because they are held in place by the external roof profile. These breather membranes should be durable in service for the life of the roofing system.

NOTE 1 Reliance is placed on the vapour control layer or liner tray to control the occurrence of interstitial condensation from the internal environment, and to drain away the local condensate in the roofing or cladding system. The local condensate could percolate through the insulation, which can suffer a temporary reduction in thermal resistance.

b) Ventilation openings should also be resistant to ingress of rain, birds and large insects and not prone to blockage by dust or debris (see **5.10.2**).

NOTE 2 The voids are vented to the outside air at both ends of the sheeting through profile fillers incorporating venting openings.

Method a) should only be used for dry conditions of occupancy. For humid conditions of occupancy, method b), should be adopted in addition to method a). Where the voids in profiled sheeting are completely filled by insulation, such as in insulated sandwich panels with a vapour impermeable undersheet (e.g. metal), local condensation cannot in principle occur; however, in practice, small voids still occur at side laps and end laps where vapour leakage would occur and local condensation could develop, so insulated sandwich panel systems should be capable of being sealed to prevent moist air entering the joints between panels.

NOTE 3 Fibre cement sheeting has the ability to absorb moisture and dissipate it in more favourable conditions or to transmit the vapour to the ventilated roof cavity. This can have a significant effect on reducing the occurrence of condensation.

7.4.5.3 Alleviating condensation in rooflights

*COMMENTARY ON **7.4.5.3***

Thermal transmittance of rooflights is generally greater than surrounding opaque sheeting, potentially giving greater risk of condensation.

Condensation is not normally expected in most building environments, but care should be taken in particularly humid environments, and additional precautions (including specification of better insulated rooflights, ventilation of rooflight cavities, or localized ventilation to control humidity in the immediate vicinity of rooflights) might be necessary.

In a hybrid roof comprising profiled sheeting built up on-site, with through-ventilation of the void between the insulation and the external profiled sheeting, where in-plane rooflights are used they should also comprise profiled sheeting built up on-site. The rooflight liner panels should be sealed to the adjacent opaque liners (or separate vapour control layer if used). The rooflight cavity should not be blocked at the head or tail of the rooflight, in order to maintain the ridge to eaves ventilation path allowing the ventilation flow to also ventilate the rooflight cavity, and to maintain drainage passage for any condensate to eaves.

Factory-assembled in plane rooflights should not be used in this construction as they block the ventilation path in the roof, and cannot be effectively sealed against surrounding profiled liner panels.

NOTE 1 This increases the risk of air from inside the building entering the roof around the rooflight, thus increasing risk of condensation in the roof; also, the drainage path for any condensate upslope of the rooflight would be blocked, so it would drain as far as the rooflight then drip into the building.

In a warm roof constructed from insulated sandwich panels, factory-assembled rooflights should be used to ensure air from inside the building cannot enter the rooflight cavity, which cannot be ventilated.

NOTE 2 In exceptional applications where condensation risk is particularly high, ventilation of the cavity might be necessary, which is usually achievable by specification of out-of-plane rooflights that are often available, incorporating natural or mechanical ventilation

Care should be taken to ensure upstands are fully insulated and do not introduce any thermal bridge.

7.4.5.4 Indoor moisture conditions

*COMMENTARY ON **7.4.5.4***

Moisture and high temperature, which in combination generate water vapour pressure, vary with the density of occupation and the moisture generating processes in the use of the building. Data on indoor climates for various building uses are given in BS 5250 and BS 6229.

Heating appliances which burn paraffin, natural gas, butane and propane release large amounts of water in the products of combustion and the flue gases should be vented to the outside of the building, otherwise they should not be used.

Extra ventilation should be provided during construction and, where possible, for not less than six months after completion of new buildings to dry out the large amounts of trapped water introduced by the wet trades.

7.5 Limitation of energy use by control of air leakage and effective thermal insulation

NOTE 1 Air leakage limits are set for all types of building with the requirement to test the completed building envelope included in some building codes.

When tested the air leakage rate should be measured by the method given in ATTMA, "*Measuring air permeability of buildings envelopes*", TSL1 [32] and TSL2 [33] or BS EN 13829.

The side laps and end laps of impermeable metal or rooflight liner sheets should be sealed to provide an air barrier; alternatively, a separate flexible membrane with sealed joints can be used on the warm side of the thermal insulation to provide an air barrier in built-up systems.

*NOTE 2 For information about the control of condensation see **7.4**.*

NOTE 3 The amount of maximum condensation likely to be deposited in a notional winter period can be estimated by the method of calculation specified in BS 5250 and BS 6229 to ensure that it is not excessive as to cause damage to the insulation or significantly impair the thermal insulation resistance value; however, the condensation amounts calculated using this method, which are based on vapour diffusion only, might not be enough to fully assess the situation because additional water vapour could be carried into the cladding system by wind forces and convection due to air leakage through side laps and end laps.

NOTE 4 Unless special precautions are taken it is impracticable to expect airtight construction. Profiled sheeting underlaid with insulation which completely fills the profiles of the cladding sheet, such as a composite panel, is an example of a warm roof type.

NOTE 5 Having a cold wall, in which the principal thermal insulation layer is placed at or immediately inside the internal lining, results in the external profiled sheeting being substantially colder in winter than the interior of the building.

With cold wall construction the plane of interstitial condensation risk is within the void and at the internal face of the outer sheet; to alleviate such condensation, the void between the insulation and external profiled sheeting should be through-ventilated to the outside air and a vapour control layer included in the construction where necessary.

7.6 Acoustics

*COMMENTARY ON **7.6***

Roof and wall cladding systems and assemblies can provide a functional acoustic barrier between the buildings inner and outer environments. The barrier can dampen sound transmission from outside to inside, inside to outside and also reverberated sound within the building. The intensity of sound depends on pressure levels which are measured in decibels (dB). The human ear responds to sound intensity which also depends on the pitch. Pitch frequency is expressed in hertz (Hz).

The performance of the acoustic barrier is dependent upon many different parameters including weight of the component parts, stiffness of the assembly, connections across or within the assembly, flanking sound transmission at junctions and sound absorption coefficients for materials within the construction.

Table 11 provides examples of sound pressure levels in relation to hearing threshold and pain threshold (in dB).

Table 11 **Examples of sound pressure levels in relation to hearing thresholds and pain thresholds**

Source / observing situation	Typical sound pressure level (dB SPL) dB
Hearing threshold	0
Leaves fluttering	20
Whispering in an ear	30
Normal speech	60
Cars/vehicles for a close observer	60 - 100
Airplane taking-off	120

Metal roof and wall cladding assemblies fine tune the acoustic performance of the construction and the manufacturer or system supplier should be consulted to establish how the make-up of the assembly can be engineered or adapted to improve performance or uprated with the inclusion of additional layers to achieve improved performance.

Reverberating sound waves within the building can be dampened with the substitution of the standard liner with a perforated metal liner system and the inclusion of a dense acoustic layer immediately above the perforated liner; this solution should incorporate a separate vapour check on the warm side of the insulation between the dense layer and the lower density quilt insulation to minimize the risk of interstitial condensation (see **7.4.5**). In addition a condensation risk analysis should be calculated in accordance with BS 5250.

7.7 Fire precautions

Profiled sheeting should be specified with appropriate fire performance classification in accordance with BS 476-3, BS 476-6, BS 476-7, BS 476-20, BS 476-21, BS 476-22, BS 476-23, BS EN13501-1 and BS EN 13501-2.

NOTE 1 Minimum requirements are determined by the relevant Building Regulations [3], [4], [5] and [6] and might be higher as required by insurers, specifiers or others.

7.8 Artificial lighting systems

The operation of artificial lighting systems should always be automatically controlled, using daylight sensors, in conjunction (where appropriate) with additional sensors such as timers and/or motion sensors. This maximizes the benefit of utilizing available natural daylight and minimizes energy use and associated CO_2 emissions.

Emergency lighting systems should also be provided.

NOTE 1 Provision of good levels of daylight, in conjunction with automatic control of lighting systems, ensures artificial lighting systems are only used when required to minimize energy use. This can save a large proportion of the overall energy use of the building.

*NOTE 2 For many larger buildings (including most buildings with profiled sheeted roofs) windows are ineffective for much of the interior of the building, and rooflights are the only practical method of admitting sufficient daylight. Use of rooflights to provide good natural lighting levels inside the building saves energy, and also creates a more pleasant internal environment which can help people feel better and work more efficiently. For recommended rooflight area see **5.4.2**.*

7.9 Durability and coatings

*COMMENTARY ON **7.9***

Durability of the roofing and cladding includes sheeting and all associated components, including fasteners, sealants, rooflights, rainwater goods, safety systems, etc. all of which need to be considered in relation to the internal and external environmental conditions.

7.9.1 Durability

Surface coatings should be used on some types of profiled materials to provide durability and aesthetic finish.

*NOTE 1 Further information on surface coatings is given in **7.9.4**.*

The required life of sheeting should be related to the design life of some of the building or the building as a whole (see BS 7543), but need not necessarily be the same.

*NOTE 2 The definitions of UK micro climates used in this British Standard which are to be considered when assessing the expected durability, are based on Annex A of BS 7543 (see **7.9.2**).*

NOTE 3 Atmospheric environments are classified in BS EN ISO 12944-2, and split into six atmospheric-corrosivity categories for metals. See Table A.1 of this British Standard.

NOTE 4 Test methods for the durability of coatings on some materials are not available. As guidance the methods listed in Table 12 apply.

NOTE 5 Most of these properties can be measured by methods of test given in the appropriate parts of BS EN 13523 and BS EN 10169. Guidance cannot be given on the acceptable levels of performance of these properties in different exposure conditions. However, such test results can provide a basis of comparison between different coatings and substrate.

Table 12 **Test methods for the durability of coatings**

Property	**Test method**
Nominal organic coating thickness	BS EN 13523-1
Specular gloss 60°	BS EN 13523-1
Non matt colours	BS EN 13523-1
Matt colours	BS EN 13523-2
Scratch resistance	BS EN 13523-12
Abrasion resistance	–
Taber 250 rev 1 kg	BS EN13523-16
Flexibility	–
Min bend radius	BS EN 13523-7
Reverse impact	BS EN 13523-5
Abrasion cross hatch	BS EN 13523-6
Pencil hardness	BS EN 13523-4
Max continuous operating temperature	–
Corrosion resistance	–
Salt spray	BS EN 13523-8
Humidity	BS EN 13523-26
Corrosion resistance category	BS EN 10169
UV resistance category	BS EN 10169
Internal environment classification	BS EN 10169

NOTE 6 The durability of profiled sheeting is a measure of the ability of the material, and its finishes and fixings to retain satisfactory appearance and performance in various conditions of exposure over a certain period. Deterioration can occur on both faces of the sheeting and can be more pronounced at fixings, laps, edges and abrupt changes in profile.

7.9.2 External environments

Different precautions should be taken for each of the following environments.

a) Coastal environments.

In coastal environments there is likely to be a detrimental effect on durability and special precautions might be necessary; advice should be taken from the manufacturer.

NOTE 1 Coasts are usually milder in temperature than inland regions during the winter, and cooler in the summer. Windward shores tend to be of similar temperature to the sea, but leeward shores will vary more – they tend to be prone to showers during spring and summer, unlike windward shores where the tendency for showers is greater during autumn and winter. Sea fogs or mists might also linger within several miles of coasts. Particular consideration should be given to wind-blown salt atmosphere and how far inland this will impact the design specification.

NOTE 2 Coastal environments can extend inland, depending on the lie of the land and the prevailing wind. Where offshore wind predominates and the land rises steeply, this environment is limited to a narrow belt several hundred metres wide. In the worst coastal environments, erosive attack on organic coatings is considerable, with the UV attack being aggravated by windborne particles.

Product manufactures use different definitions of “coastal” or “marine environments”, the user should check the quoted definition when considering the expected durability.

b) Inland environments.

*NOTE 3 This environment covers areas away from the coast and remote from polluted industrial environments. Corrosive attack is governed mostly by humidity and rainfall, but is normally less than in either of the environments described in **7.9.2** a) and **7.9.2** c).*

NOTE 4 Erosive attack on organic coatings in this environment is usually less than in coastal environments.

c) Polluted environments.

NOTE 5 The principal effect is corrosion due to sulfur dioxide attack. Conditions of high humidity and specific chemical pollution (e.g. acid chloride conditions) can drastically increase corrosion of some materials.

NOTE 6 Deposition of grime on the surface and the effect of contamination on colour might be considerable.

d) High UV environments.

Exposure to high UV may cause premature degradation of coatings and materials, and aesthetic appearance; materials suppliers should be consulted for their site-specific recommendations.

7.9.3 Internal environments

7.9.3.1 Internal humidity classes

NOTE Internal humidity classes are defined in BS 5250:2011 and shown in Table 13.

Table 13 **Internal humidity classes: building types and limiting relative humidities** [A)]

Humidity class	**Building type**	**Relative humidity at internal temperature**		
		15 °C	**20 °C**	**25 °C**
1	Storage areas	<50	<35	<25
2	Offices, shops	50–65	35–50	25–35
3	Dwellings with low occupancy	65–80	50–60	35–45
4	Dwellings with high occupancy, sports halls, kitchens, canteens, buildings heated with unflued gas heaters	80–95	60–70	45–55
5	Special buildings, e.g. laundry, brewery, swimming pool.	>95	>70	>55

[A)] The values in Table 13 apply to an external temperature of 0 °C.

The design of the structure and cladding should ensure that over the coldest month the average relative humidity at internal surfaces does not exceed 80%, the limit for mould growth.

The risk of degradation of materials should be assessed in terms of the maximum level of condensate which might occur.

To determine the risk of condensation occurring within or on the roof and wall cladding, a condensation risk calculation should be carried out in accordance with the method in BS EN ISO 13788, using the internal humidity classes from Table 13.

With light weight cladding systems of low thermal mass such as most insulated sheeting and composite panels the condensation risk calculation should be carried out with an external air temperature of -5C to allow for the effects of night sky radiation which cools the external surface below the minimum air temperature.

If that assessment indicates condensation is likely to occur, then the designer should assess the likelihood of it causing damage to the materials used and if necessary modify the design. Organic materials should not be exposed to harmful and prolonged condensation.

Typically, humidity class 1, class 2 and class 3 are unlikely to require any design modification; however, for humidity class 4 and class 5, design modifications are likely and the systems supplier should be consulted.

The recommendations for vapour control and air resistance laid out in Clause **7** should be followed for all buildings regardless of humidity class.

7.9.3.2 Pollutants in internal environments

*COMMENTARY ON **7.9.3.2***

Wherever corrosive and potentially detrimental chemicals are present, these may have a significant effect on the durability of materials; general classifications are defined in accordance with BS EN ISO 12944-2:1998, Table 1.

Wherever the corrosive category is higher than C1 or C2 (very low or low) (see Table A.1), the detail of the pollutant should be established and technical advice sought from the manufacturer.

7.9.3.3 Damp and polluted internal environments

Advice from the manufacturer should always be sought wherever moisture from damp environments is combined with chemical pollutants as this accelerates any corrosive effect.

NOTE Typical examples are where a combination of humidity and pollution could cause a dilute chemical solution to condense on or between surfaces, or where dust collects in a damp environment.

The design should ensure that any condensate drains, and that damp dust cannot collect on the structure or cladding.

The effect of high concentrations of chemical fumes are likely to be of much greater consequence than in an external environment, and a coating on the internal face that is resistant to chemical attack shoud be used.

A long life protective system or material should be used where components are inaccessible for inspection and maintenance after installation.

7.9.3.4 Hot internal conditions

NOTE Hot internal conditions can be found in buildings such as brickworks, chemicals factories and bakeries.

The manufacturer of the roof sheeting should be consulted if internal temperatures are likely to exceed 50 °C.

7.9.4 Surface coatings

*COMMENTARY ON **7.9.4***

Metal profiled sheeting is usually protected with an organic coating applied before profiling, on one or both faces to the same or different specification, to provide additional durability and/or choice of colour. Aluminium and fibre cement sheeting do not require coating for primary surface protection and may be used in their natural state. In some environments hot dip zinc and 55% aluminium-zinc alloy coatings of the appropriate thickness can also provide adequate durability without additional organic coating.

The durability of a particular plastics coating or paint of given thickness can be significantly affected by its surface colour. Light colours reflect thermal radiation more efficiently, resulting in lower surface temperatures in summer and higher surface temperatures in winter, which reduces degradation of the coating and extends its durability.

7.9.4.1 Surface coatings for profiled metal sheeting

Performance of surface coatings should be assessed based on the manufacturer's declared values.

In accordance with BS EN 14782 for profiled metal sheeting, the profile manufacturer should state the type, thickness and grade of metal and, if appropriate, type and thickness (or mass) and/or category of any coating(s) to enable users to select suitable products. The user when selecting suitable products should consider which types may be expected to provide the required durability of the product having regard to the expected environment and/or exposure conditions and feasibility of maintenance.

NOTE 1 For profiled sheets in accordance with BS EN 14782 and composite panels in accordance with BS EN 14509 the grades of steel and nominal metallic coating masses are provided in BS EN 508-1 for steel and grades of aluminium in BS EN 508-2.

NOTE 2 Most of these properties can be measured by methods of test given in the appropriate parts of BS EN 13523 and BS EN 10169. Guidance cannot be given on the acceptable levels of performance of these properties in different exposure conditions. However, such test results provide a basis of comparison between different coatings and substrate.

7.9.4.2 Surface coatings for profiled rooflights

Profiled GRP rooflights should be protected with a UV-absorbing surface film on one or both faces, to minimize long term discoloration or loss of light transmission. Presence and adhesion of surface films and resistance to discoloration should be assessed based on the manufacturer's values declared in accordance with BS EN 1013.

Profiled polycarbonate rooflights should be protected with a co-extruded UV-absorbing layer, to prevent loss of structural strength and minimize long term discoloration or loss of light transmission. Resistance to discoloration should be assessed based on the manufacturer's values declared in accordance with BS EN 1013.

Abrasion can damage rooflight surface protection, and polycarbonate is not suitable for use in certain chemical environments; suitability of any profiled rooflight for use wherever there is any unusual internal or external environment should be in accordance with manufacturers' recommendations.

NOTE Guidance on expected durability is given in Table 12.

7.9.4.3 Surface coatings of profiled fibre cement

Fibre cement sheets may be supplied with factory-applied coloured coatings for aesthetic reasons; however, these coatings are likely to have less durability than the substrate and should not be used to extend the functional life of the sheets.

7.10 Compatibility of materials

*COMMENTARY ON **7.10***

Contact between certain dissimilar metals in the presence of moisture acting as an electrolyte induces a flow of electrical current between the two metals, resulting in the potential for a progressive loss of metal in the anodic baser metal, the extent of which is dependent on the surface area ratios.

Bimetallic corrosion can occur at junctions between profiled sheets and accessories of incompatible metals; if the use of incompatible materials cannot be avoided, they should be separated from each other by non-conducting non-metallic isolators, e.g. seals and grommets in fixing systems or coating with compatible or inert materials.

NOTE 1 Galvanized steel in the presence of moisture and at a temperature above about 70 °C suffers inverse corrosion, in which the steel corrodes and the zinc is protected. This can occur in end laps of low pitch roofs with dark coloured sheeting.

Inverse corrosion should be prevented by providing an improved backing coat, painting the lap on-site or by using light-coloured sheeting.

NOTE 2 Rain water discharging from roofs which have moss, lichen or algae growing on them is likely to be acidic and attack metallic cladding, gutters, soakers and flashings. Run-off from copper or lead surfaces can attack cast iron, galvanized steel or aluminium.

Copper or lead surfaces on roofs and on the inside of gutters should be painted over as they are likely to be damaged by acid rain.

Polycarbonate rooflights should be isolated from plastisol coated sheets, and PVC tape should not be used. Compatibility with other materials should be checked with the manufacturer.

NOTE 3 Polycarbonate rooflights can be attacked by some chemicals, including plasticisers in flexible PVC tape, and plastisol coated steel.

Timber treated with certain types of preservative, particularly of copper-chrome-arsenic formulation, can cause corrosion of zinc, carbon steel and aluminium in contact with it, and can attack polycarbonate rooflights; such combinations should be avoided, particularly for embedded fasteners such as nails, wood screws and bolts.

For advice on the corrosion risk of metal fasteners in contact with preservative treated timber the fastener manufacture's advice for the particular type of metal and any coating should be followed.

Where there is a risk that the moisture content of the timber exceeds 20% (mass of moisture/oven dried mass of timber), or if the timber is likely to become wet and a long service life is required, fixings of austenitic stainless steel should be used (see Table 4).

Table 14 and Table 15 provide further detail and some recommendations that should be followed on various exposure conditions on the durability of profiled sheeting materials.

Table 14 **The effect of various exposure conditions on the durability of profiled metal sheeting materials** *(1 of 3)*

Detrimental action	**Aluminium, plain (mill finish) and stucco embossed**	**Aluminium, organic coated**	**Hot-dip zinc coated steel**	**Hot-dip aluminium 55% zinc, 45% coated steel**	**Organic-coated steel**	**Stainless steel** [A)]
1. Rain sleet, snow and hail	Gradual change to dull metallic grey in rural areas, dark grey in industrial areas.	Weathering varies with the type of coating.	Good resistance, corrodes slowly; sacrificial action provides protection at cut edges and damaged areas.	Good resistance, corrodes slowly; sacrificial action provides protection at cut edges and damaged areas.	Weathering varies considerably according to the type of coating.	The initial finish is maintained indefinitely in most areas where austenitic steel grades are used. Can be beneficial in washing off airborne pollutants.
2. External attack by polluted and coastal atmospheres	Freely exposed surfaces as for "rain sheet, etc." Sheltered areas become darker and might suffer only superficial attack.	Weathering varies with the type of coating and environment.	Life considerably reduced. Apply suitable organic coating. If pollution is not too severe, uncoated sheets might be used. Acidic atmospheres cause severe corrosion.	Longer life than hot-dip zinc coated of same thickness If pollution is not too severe, uncoated sheet may be used. Acidic atmospheres cause severe corrosion.	Weathering varies considerably according to the type of coating.	Slight rusting and pitting can occur. However, washing or cleaning prevents this. Molybdenum bearing austenitic steel grades maintain their bright initial condition indefinitely.
3. Ultraviolet radiation	No effect.	Some colour change and chalking depending on the type of coating.	No effect.	No effect.	Some colour change and chalking depending on the type of coating.	No effect.
4. Condensation	Only a problem when the local environment contains corrosive influences, e.g. combustion products. Generally paint coating the affected area gives adequate protection.	Normally no effect.	Usually satisfactory in severe damp atmospheres. Sheets should be painted. The manufacturer should be consulted for suitable paints.	Usually satisfactory in severe damp conditions. Should be painted. Consult manufacturer for suitable paints	Moisture resistance varies.	Negligible effect.
5. Temperature range	See Table 7 and Table 8.	See Table 7 and Table 8.	See Table 7 and Table 8.	See Table 7 and Table 8.	See Table 7 and Table 8.	See Table 7 and Table 8.

Table 14 **The effect of various exposure conditions on the durability of profiled metal sheeting materials** (*2 of 3*)

Detrimental action	**Aluminium, plain (mill finish) and stucco embossed**	**Aluminium, organic coated**	**Hot-dip zinc coated steel**	**Hot-dip aluminium 55% zinc, 45% coated steel**	**Organic-coated steel**	**Stainless steel** A)
6. Use of cleaning agents	Mild, neutral dilute detergents and soft brush. Wash down with clear water. Avoid strong alkaline and acidic cleaners.	See plain aluminium.	See plain aluminium.	See plain aluminium.	See plain aluminium.	Use detergent.
7. Chemical attack	Certain chemicals attack aluminium under specific conditions. Design to avoid deposits remaining on sheeting and to ensure ventilation and/or protection on inside surfaces.	Avoid cement or plaster splashes during erection.	Run-off acidic environment and alkaline causes corrosion.	Acidic environment and alkaline cause corrosion.	The manufacturer should be consulted about the performance of any particular coating type.	Resistant to attack by any chemical reagents. Dirt and salt deposits might cause some localized pitting if left in situ for long periods under wet conditions. The use of bleaches, etc., silver cleaners, and acids such as sulfuric and hydrochloric should be avoided.
8. Scratches or minor abrasions	Scratched metal is not less durable than unscratched metal.	Resistance to abrasion depends on coating (see Annex E).	Good resistance. Sacrificial action of zinc can protect against minor scratching.	Good resistance. Sacrificial action of zinc can protect against minor scratching.	Thick coat provides very good protection from scratches and abrasion. Embossed pattern conceals scratches and minor blemishes but can trap dirt. Smooth or satin finish does not conceal scratches or minor blemishes.	No detrimental effect to base material, but could spoil a coloured passive film.

Table 14 **The effect of various exposure conditions on the durability of profiled metal sheeting materials** (*3 of 3*)

Detrimental action	**Aluminium, plain (mill finish) and stucco embossed**	**Aluminium, organic coated**	**Hot-dip zinc coated steel**	**Hot-dip aluminium 55% zinc, 45% coated steel**	**Organic-coated steel**	**Stainless steel** [A]
9. Attack by bird droppings, rodents, insects, soil, etc.	Generally no more than staining. Avoid the formation of wet poultices. Cinders and ash might be aggressive.	See plain aluminium.	See plain aluminium.	See plain aluminium.	The manufacturer shoud be consulted about the performance of any particular coating type.	Can cause slight corrosion if not removed.
10. Cause and effect on some other material properties related to durability	Resists coastal atmospheres well but special consideration should be given when used in highly polluted atmospheres. Bright surfaces soon dull. The manufacturer should be consulted for guidance on durability.	Factory-applied coatings might fade with exposure but the coating is aesthetic and maintenance is only necessary for appearance. Paint finishes can help to minimize the early growth of lichen and mosses.	Bright surface soon dulls. Should be painted in polluted atmospheres. Various masses of zinc coating are available to BS EN 10147; coating life varies accordingly.	Two phase structure. Initially preferential corrosion of the minor zinc rich phase. Thereafter slow corrosion of the rich phase in which the formation of aluminium oxide/ hydroxide provides barrier protection.	Some colours of factory-applied coatings might fade with exposure. The manufacturer should be consulted about the functional life of selected coatings and colour.	The manufacturer should be consulted about the grade of steel to be used. The grade is normally chosen to last the life of the building.

[A] The grade and surface finish of stainless steel needs careful consideration to avoid problems relevant to the external environment.

Table 15 **The effect of various exposure conditions on the durability of profiled non-metallic sheeting materials** (*1 of 3*)

Detrimental action	Fibre cement	Glass-reinforced polyester (GRP)	Polycarbonate	Bitumen fibre
1. Rain sleet, etc.	Moisture combined with dirt on surface encourages algae growth.	Water resistance is generally good and can be improved by surface treatment (e.g. by applying polyester film or gelcoat).	Prolonged contact with water (e.g. trapped between seals at laps) can cause cracking and loss of strength, especially if trapped water is heated by the sun.	Unaffected but pollution slowly affects colours.
2. External attack by polluted and coastal atmospheres	With age surface slightly softens with solution of cement. This exposes fibres, which encourages dirt retention and mass and algae growth. Painted surface is affected more slowly.	Generally good resistance to coastal and mild chemical atmospheres. Contact with sea water and sand can accelerate erosion of surface protection layer, improved by specialist surface protection; e.g. PVF film. See (7) for aggressive chemical atmospheres, or where pollutants might condense on rooflights in liquid or solid form.	Contact with sea water and sand at the coast can erode the surface, causing loss of gloss and surface haze. Susceptible to severe attack by certain chemicals and materials, especially when under stress. Should only be used in any polluted or coastal atmosphere with specific approval from the manufacturer.	Resistance of some bitumens to coastal atmospheres can be poor.
3. Ultraviolet radiation	No effect.	Structural strength of GRP is unaffected by UV radiation. UV radiation causes yellowing of unprotected GRP, particularly of fire retardant grades. Appropriate surface protection (e.g. UV-absorbing polyester film) minimizes yellowing.	UV radiation causes significant reduction in strength and discoloration of unprotected polycarbonate. A UV-absorbing co-extruded surface protection layer should be used, and offers good resistance to any UV degradation, providing it is not damaged.	Can be affected by UV radiation.
4. Condensation	Acidic condensation eventually softens the surface.	Unaffected by short term exposure. Permanent contact with high levels condensation can cause slight discoloration. See 7. if condensation might be contaminated with chemicals.	Unaffected by short term exposure. Prolonged contact can cause crazing and loss of strength, especially if heated by the sun. See 7 if condensation might be contaminated with chemicals.	Excessive and continuing dampness can affect fibres.

Table 15 **The effect of various exposure conditions on the durability of profiled non-metallic sheeting materials** (*2 of 3*)

Detrimental action	**Fibre cement**	**Glass-reinforced polyester (GRP)**	**Polycarbonate**	**Bitumen fibre**
5. Temperature range	See Table 7 and Table 8	See Table 7 and Table 8.	See Table 7 and Table 8.	See Table 7 and Table 8
6. Suitable cleansing agents	Lichen and moss can be brushed and washed off with an antifungicidal solution applied to neutralize growths.	Clean with copious quantities of warm water and mild dilute detergent, using a soft cloth or soft bristled brush. Use of abrasives, chemicals, pressure washers, hard brushes, scouring pads or sharp tools can affect long term durability and should be avoided.	Clean with copious quantities of warm water and mild dilute detergent using a soft cloth. Any use of abrasives, chemicals, pressure washers, hard brushes, scouring pads, sharp tools or anything which might cause damage to the surface protection layer should be avoided.	Avoid petroleum based cleaning agents.
7. Chemical attack	Acid fumes attack the surface The manufacturer should be consulted.	Generally excellent resistance to most pollutants and chemical atmospheres, better than most metals (and usually outperforming surrounding sheeting, fixings and the surrounding structure). Chemical resistance further improved by specialist surface protection (e.g. PVF film). However, suitability for use in any aggressive chemical atmosphere (particularly if GRP sheets are in long term contact with chemicals in solid or liquid state, including condensate) should be confirmed with manufacturer.	Highly susceptible to attack by specific chemicals especially when under stress (including plasticisers found in plastisol coated steel or PVC tape, and some solvents and adhesives). Suitability for use in any polluted or chemical atmosphere should be confirmed with manufacturer.	Very resistant to chemical attack, except by petroleum products and hydrocarbons.
8. Abrasion	Scratches do not greatly mar appearance but exposed fibre encourages dirt retention.	Susceptible to scratches, but these do not greatly mar appearance. Surface protection films can be damaged by severe abrasion, which can ultimately lead to localized long term yellowing.	Susceptible to abrasion causing noticeable increase in haze. Co-extruded surface protection can be damaged by severe abrasion, leading to discoloration and loss of strength.	Abraded material no less durable than unabraded surface.

Table 15 **The effect of various exposure conditions on the durability of profiled non-metallic sheeting materials** (*3 of 3*)

Detrimental action	**Fibre cement**	**Glass-reinforced polyester (GRP)**	**Polycarbonate**	**Bitumen fibre**
9. Attack by bird droppings, rodents, insects, soil, etc.	Rodent resistant. Acidic water attacks the surface.	Little effect. Algae might cause staining.	Generally little effect. Suitability should be confirmed with the manufacturer. Algae might cause staining.	Little effect. May cause staining if not cleaned.
10. Cause and effect on some other material properties related to durability	Age lowers impact resistance but increases transverse strength. Resists all coastal and most polluted atmospheres well. Where extreme pollution is strongly acidic, the manufacturer should be consulted. Factory-applied coatings might fade with exposure but the coating is aesthetic and maintenance is only necessary for appearance. Paint finishes can help minimize the early growth of lichen and mosses. The manufacturer should be consulted for guidance on durability.	Durability varies considerably between good and poor quality sheets. Long term, there is no significant loss of structural strength of good quality sheets with UV-absorbing surface protection, although some yellowing is likely. Surface erosion occurs on unprotected or poor quality sheets, resulting in thinning and corresponding loss of strength, with significantly more yellowing.	Provision should be made to allow for thermal movement, and direct contact with plastisol coated steel should be avoided. Good quality co-extruded surface protection shoud be used, which offers excellent long term performance in ideal conditions. Unprotected sheets are not suitable for external applications. Damage to surface protection, or incorrect application conditions are likely to result in loss of structural strength and discoloration.	Some actions of nature, in particular sunlight, may reduce effective life. Durability depends on type of bitumen and the organic coating, if any. Sheets have low strength and require frequent supports.

7.11 Lightning and electrical charges

7.11.1 Protection against lightning

*COMMENTARY ON CLAUSE **7.11.1***

The incidence of buildings in the UK struck by lightning is very low and special protection is generally not provided for typical low-rise buildings.

Lightning protection systems should be provided for buildings of exceptional risk, such as those which:

a) have inherent explosive risk;

b) accommodate large numbers of people;

c) accommodate essential public services;

d) are very tall or isolated; and

e) are situated in a lightning prevalent area.

Other buildings that should be protected include those that are of historic or cultural importance.

The recommendations given in BS EN 62305-3 on assessing the risk of lightning strike, the consequential effects and the design of protection systems should be followed.

7.11.2 Protection against induced electrical charges

Internal and external metal cladding enclosing electrical equipment should be earthed to dissipate induced electrical charges and reduce the risk to personnel who might touch the sheeting.

NOTE This is usually met by the fixing between sheeting and steel frame, but special provision might be required where the sheets are insulated from the supports or where a non-metallic building frame is used.

In order to prevent aluminium coming into contact with steel frames, aluminium earthing straps should be used.

8 Inspection and maintenance

8.1 General

The roof should be visually inspected regularly by the client at defined intervals, which should be at least once per year, and after severe storms.

NOTE Lack of maintenance accelerates deterioration.

Where practicable, roofs should be inspected avoiding the need to walk on the roof. Any existing roof should be treated as fragile, unless evidence is available to the contrary. Appropriate safe methods of working should be undertaken.

The checklist given in Table 16, although not exhaustive, should be used as a guide to the recommended minimum level of inspection.

The roof should be designed to minimize the need for inspection and maintenance on the completed roof structure. There should be safe access and a safe place of work for any inspection and maintenance that is required.

Table 16 **Checklist inspection of profiled sheet roofs**

Item	Action A)
Establish a safe method of work	Check that the roof is non-fragile. B) Check that the safety equipment is tested in accordance BS EN 795 (including safety lines) (see **5.14**).
Leaks, inspect from inside for location	Repair as soon as possible and do not leave until annual maintenance.
Damage or decay	Repair or replace as necessary.
Accumulated debris, e.g. trapped leaves or pine needles	Clean away.
Gutters and drain pipes clean, and free draining	Clean out.
Gutter joints defective sealant or loose bolts	Repair.
Loose ridge or other flashings	Repair.
Missing foam fillers or evidence of damage by birds	Replace.
Staining caused by ponding or water	Seek advice from a roofing specialist.
Discoloured areas of the surface coating	Inspect the surface coating and attend to any peeling, corrosion or other evident deterioration, as necessary.
Discoloured areas around fume extract ducts should be closely inspected	Re-coat without delay where attack of the coating has occurred.
Dirty rooflights	Clean to maintain light transmission.
Evidence of access to the roof e.g. for maintenance of ventilators	Touch-up any scratches in coating.
Missing/faded colour caps from fasteners	Replace.
Missing fasteners	Investigate and replace.
Corroded or degraded fasteners (including sealing element)	Seek advice on replacement.
Loose fasteners, e.g. where the washer is not in contact with the sheet	Tighten only fasteners that are loose. Investigate the cause.
Sealants visible on roof surface	Seek advice on replacement and suitability of the sealant.

A) Where any defects are discovered, these should be reported to the client. Some of these items might be covered by a product/system guarantee, which should be pursued via the contractual chain.

B) See ACR[M]001 "Red Book" [N1], ACR[CP]001:2014 "Orange Book" [1] for further guidance on non-fragile roofs (Recommended practice for work on profile sheeted roof) and ACR[CP]002 (Guidance Note for Safe Working on Fragile Roofs, otherwise known as the "Green Book" [30]).

8.2 Maintenance of profiled sheeting

Maintenance should be carried out when the original protective system would otherwise break down and provide inadequate protection to the substrate, or when the appearance, including that of the protective or decorative system, becomes unacceptable.

In some environments it might be preferable to coat the cut edges of sheets; the manufacturers' recommendations should be obtained.

8.3 Indications of the need for maintenance

Most coated metals have an organic layer which might be pigmented, which age as it weathers and eventually start to chalk, crack, erode away, or flake; where one or more of these changes occurs over a large percentage of the coated profile sheet it should be considered as an indicator of the need for maintenance recoating.

8.4 Paint and conversion coatings

*COMMENTARY ON **8.4***

The breakdown of the protective or decorative paint film, in order of increasing seriousness, takes the form of chalking, cracking and blistering. If left without maintenance at this last stage, breakthrough of rust or corrosion products and/or flaking of the paint could occur and, in the case of decorative coatings, the appearance might be unacceptable. For the purposes of BS 5427, schemes including paints are considered to have reached the end of their expected life when maintenance painting has to be undertaken to prevent this further breakdown or to maintain appearance. However, some treatments may be provided for initial appearance (e.g. conversion coating on aluminium sheeting to reduce glare); in this case, deterioration in time of the surface to substantially that of the weathered untreated substrate might be acceptable without further maintenance, when the durability of the substrate applies. The coating on fibre cement and asbestos cement sheeting is only aesthetic and gradual erosion of this coating does not result in the life expectancy of the material being reduced.

If any of the defects in the commentary to **8.4** are present, advice about remedial action should be obtained from the manufacturer and followed.

8.5 Plain aluminium

*COMMENTARY ON **8.5***

Plain mill finish, including stucco embossed aluminium, is normally expected to last the design life of the building without maintenance. In certain exceptional conditions pitting and/or the formation of a loose deposit, particularly on the internal surface, can occur (see Table 9). Evidence of this normally appears shortly after commissioning.

If pitting or the formation of a loose deposit is observed, advice about remedial action should be obtained from the manufacturer and followed.

8.6 Anodized aluminium

Generally, anodized aluminium does not require maintenance but in polluted environments in areas not washed by rain should be washed regularly.

8.7 Metallic coated steel

NOTE The breakdown of these coatings is usually indicated by extensive rust or growth of rust spots.

Some zinc coatings produced by hot-dip galvanizing or sherardizing develop a brown coloration from the iron-zinc alloy layer but continue to provide satisfactory protection to the steel; if any of these defects are observed, advice about remedial action should be obtained from the manufacturer and followed.

8.8 Fibre cement

The surface might erode from weathering; where the fibre cement is colour-coated and has lost its coating through weathering, it should be maintained.

8.9 Stainless steel

Generally stainless steel does not require maintenance other than for aesthetics, but in adverse environments areas not washed by rain should be washed regularly.

8.10 Translucent sheets

Translucent sheets should be periodically cleaned to maintain light transmission.

8.11 GRP

The surface should incorporate a UV-absorbing protective film to minimize discolouration or surface erosion. The surface should be cleaned with warm water and detergent, and with a soft bristle brush or cloth at appropriate intervals. Old rooflights which have been discoloured severely or where the surface has eroded to expose glass fibres should be replaced.

8.12 PVC and polycarbonate

Polycarbonate rooflights incorporate a UV-absorbing surface layer, which should not be damaged, to avoid loss of structural strength.

PVC and polycarbonate should be wetted to soften dirt then wiped with a soft sponge and mild detergent, and rinsed.

Annex A (normative) Corrosion protection

The corrosivity categories in Table A.1 should be used for assessing the expected durability of profiles.

NOTE These categories are in accordance with BS EN ISO 12944-2 with examples of typical environments in UK climate.

Table A.1 **Corrosion categories for assessing the expected durability of profiles**

Corrosion category	Examples of typical environments in a temperate climate typical Result	
	Exterior	**Interior**
C1 very low	–	Heated buildings with clean atmospheres,e.g. offices, shops, schools, hotels.
C2 low	Atmospheres with low level of pollution. Mostly rural areas.	Unheated buildings where condensation can occur e.g. depots, sports halls.
C3 medium	Urban and industrial atmospheres, moderate sulfur dioxide pollution. Coastal area with low salinity.	Production rooms with high humidity and some air pollution, e.g. food-processing plants, laundries, breweries, dairies.
C4 high	Industrial areas and coastal areas with moderate salinity.	Chemical plants, swimming pools, coastal ships and boatyards.
C5-I very high (industrial)	Industrial areas with high humidity and aggressive atmosphere.	Buildings or areas with almost permanent condensation and with high pollution.
C5-M Very high (marine)	Coastal and offshore areas with high salinity.	Buildings or areas with almost permanent condensation and with high pollution.

Annex B (normative) Impact test for wall cladding

B.1 General

The visible surfaces of vertical enclosures should be capable of withstanding applied or transferred impacts that occur during normal use without sustaining damage which is not easily repairable and without deterioration of its performance. There should be no visually unacceptable indentation marks resulting from such impacts.

The risk of hazard to occupants or to people outside the building due to the more severe but infrequent accidental impacts should be minimized.

B.2 Performance category

*COMMENTARY ON **B.2***

The vulnerability of a wall surface to impacts varies considerably according to location, both location on an individual building and of the building itself. Larger and more frequent impacts tend to occur on vertical surfaces adjacent to public areas as compared with privately used areas.

For those with access to a vertical surface, the degree of incentive to exercise care is also an important factor in determining the likely impact loads; this provides a wide spectrum of use but for practical purposes four categories should be considered for vertical surfaces up to 1.5 m above pedestrian level (see category A to category D in Table B.1).

NOTE Above this level the vulnerability to damage is reduced, giving two possible further categories (see category E and category F in Table B.1).

These categories should be used to aid the designer in selecting suitable vertical enclosure components.

In addition special consideration should be given to walls adjacent to areas used by vehicular traffic. The use of guardrails is often appropriate in this situation.

B.3 Impact resistance

Minimum test impact values for opaque wall components as described in Table B.1 should be as suggested in Table B.2 and Table B.3; windows and other translucent areas are not suitable to testing with this method.

NOTE 1 The intention is for the wall to provide resistance to all of the impacts shown for the relevant category.

NOTE 2 Wall surfaces might have a lower resistance than those values indicated in Table B.2 if they are easily replaceable or repaired (e.g. slates and tiles).

Table B.1 **Categories associated with impacts on surfaces of the vertical enclosure to buildings**

<table>
<tr><th>Category</th><th>Description</th><th colspan="2">Examples</th></tr>
<tr><td>A</td><td>Readily accessible to public and others with little incentive to exercise care. Prone to vandalism and abnormally rough use.</td><td>External walls of housing and public buildings in vandal prone areas.</td><td rowspan="4">Zone of wall up to 1.5 m above pedestrian floor level</td></tr>
<tr><td>B</td><td>Readily accessible to public and others with little incentive to exercise care. Chances of accident occurring and of misuse.</td><td>Walls adjacent to pedestrian thoroughfares or playing fields when not in category A.</td></tr>
<tr><td>C</td><td>Accessible primarily to those with some incentive to exercise care. Some chance of accident occurring and of misuse.</td><td>Walls adjacent to private open gardens. Back walls of balconies.</td></tr>
<tr><td>D</td><td>Only accessible, but not near a common route, to those with high incentive to exercise care. Small chance of accident occurring or of misuse.</td><td>Walls adjacent to small fenced decorative garden with no through paths.</td></tr>
<tr><td>E</td><td>Above zone of normal impacts from people but liable to impacts from thrown or kicked objects.</td><td colspan="2">1.5 m to 6 m above pedestrian or floor level at location categories A and B.</td></tr>
<tr><td>F</td><td>Above zone of normal impacts from people and not liable to impacts from thrown or kicked objects.</td><td colspan="2">Wall surfaces at higher positions than those defined in category E.</td></tr>
</table>

Table B.2 **Test impacts for retention of performance of exterior wall surfaces**

Wall category (see Table B.1)	Test impact energy for impactor shown		
	H1	H2	S1
	Nm	Nm	Nm
A	(see Note 1)	–	–
B	–	10	120
C	6	–	120
D	(see Note 2)	–	–
E	6	–	–
F	3	–	–

NOTE 1 No test impact values are given for category A walls. In each case the type and severity of vandalism needs to be carefully assessed and appropriate impact values determined.

NOTE 2 With category D walls the risk of impact is minimal and impact test values are therefore not appropriate.

The wall, when subjected to the impacts in Table B.2, should not have a reduced performance.

The results of the test should be defined as follows:

a) brittle materials: failure or no damage; and

b) other materials: damage to surface finish, indentation, or no damage.

Where the damage is a dent, the depth of the dent should be quantified although the criterion for failure may be an aesthetic one only. The depth of indentation which should be inspected visually depends on the characteristics of the material, its finish and location.

B.4 Method of test for impact resistance of opaque wall components

B.4.1 Apparatus

Hard and soft body impactors should be as described in Table B.3.

Table B.3 **Impactors for test purposes**

Reference	Type	Description	Diameter mm	Approximate mass kg
H1	Hard body	Steel ball	50	0.5
H2			62.5	1.0
S1	Soft body	Canvas spherical/conical bag filled with 3 mm diameter glass spheres A)	400	50

A) Shape of spherical/conical bag: 

B.4.2 Procedure

B.4.2.1 General

The sample walling to be tested should be fixed in its final position in the building or, if the fixing arrangement is likely to vary with each use of the product, the component should be fixed on all edges to a rigid frame. For the hard body tests, where the influence of the test impact is concentrated on a local area only, the method of fixing should provide rigid support beyond the area of influence.

The vertical distance in (in m), *H*, through which an impactor has to freely fall to achieve a given test impact energy value should be determined from the following equation:

$$H + \frac{e}{9.8m} \tag{B.1}$$

where:

e is the test impact energy (in Nm).

m is the mass of the impactor (in kg).

B.4.2.2 Hard body impact tests

Hard body tests should be performed by supporting the specimen horizontally and allowing the impactor to drop vertically onto it. A number of repeat tests should be done so that account might be taken of the varying impact resistance that might occur over the surface of the panel.

B.4.2.3 Soft body impact tests

The soft body impactor, suspended on a cord at least 3 m long, should be allowed to swing in a pendulum movement until it hits the specimen normal to its face. The test should be performed to determine the strength of the weakest part of the specimen; this might entail several tests at different locations.

Annex C (normative) Determination of strength and stiffness of profiled sheeting

*COMMENTARY ON ANNEX **C***

For an explanation of limit state design see BS EN 1993-1-3. For information on testing of light gauge profiled steel sheeting and BS EN 1999-1-4 for information on testing of light gauge profiled aluminium sheeting.

Limit state design is defined as that state of a structure at which it becomes unfit for the use for which it was designed. Design is carried out by considering the limit state at which something becomes unfit for its intended purpose and applying appropriate partial load (γ_f) and material (γ_m) factors.

Generally two limit states are considered:

a) ultimate limit state (partial load and material factors are applied);

1) strength;

2) stability against overturning and swaying;

3) fatigue fracture;

4) brittle fracture.

b) Serviceability limit state (no partial load and material factors are applied);

1) deflection;

2) thermal effects;

3) vibration;

4) repairable damage due to fatigue;

5) corrosion and durability.

Profiled sheeting on roof or walls becomes unfit for the use for which it is intended when the sheets with any seals allow rain or other adverse external environmental conditions to penetrate the building envelope as a result of deflection or movement. The serviceability limit state load would be expected to be less than the ultimate limit state when permanent damage occurs to the profiled sheeting. The following tests allow for measurement of both load limits.

C.1 General

Where no product standard listed in Table 1 gives a method to determine strength and stiffness of profiled sheeting the following method should be used.

C.2 Test spans

For a concentrated load the test on the maximum intended span should be carried out. For uniformly distributed loads the test on the minimum and maximum intended spans should be carried out.

The double span and single span simply supported conditions should be tested. The design strength and stiffness appropriate to the support conditions should be derived from such test results.

The derived strength and stiffness from the two-span test results should be applied to other support conditions; alternatively, derive the strength and stiffness of continuous equal or unequal spans directly by test.

The span should be measured, defined by the distance between centre lines of supports, to an accuracy of ±3 mm.

C.3 Direction of load

Tests should be carried out with load in both directions perpendicular to the plane of the sheeting, to derive the sheeting's strength and stiffness against reversible wind loading and, in the case of roof applications, dead and imposed loads. This should be carried out either by two separate directions of load for the tests, or by reversing the faces of the sheeting. The support conditions in practice are usually different for the opposite load directions and should be taken into account in the testing arrangement.

For sheeting or sandwich panels of asymmetric cross-section, the particular face of the sheeting relative to the direction of loading for the tests and load span tables should be identified.

C.4 Test sheets

The sheets should be tested in at least single widths as supplied. For sheets of different materials intended to be side-lapped together in use, and where advantage is to be taken of their structural interaction (such as translucent sheeting between metal or asbestos cement sheeting), the test specimen should consist of three sheet widths side-lapped, with the outer sheets being of the stronger or stiffer material.

NOTE When testing profiles which spread under load to suppress the lateral spreading of the profiled sheet, not less than two transverse ties equally spaced between supports in the span or at a spacing of not less than 20 times the profile depth, and connected to the end troughs of the sheeting before load testing may be fitted.

For sheeting material subject to weakening by moisture, the test sheets should be conditioned by immersion in water for 24 h at a temperature of between 10 °C to 20 °C before testing. The sheets should be tested at service temperatures most unfavourable to their strength and stiffness, where relevant; where such test conditions are impractical, apply increased safety factors beyond those recommended in design for sheeting known to have strength reducing characteristics at extreme temperatures.

C.5 Application of test loads

C.5.1 General

Separate loading tests should be carried out for uniformly distributed and concentrated loads; the concentrated load test need not be considered where the sheeting is classified as a fragile material which requires the use of crawl boards for access to maintenance.

C.5.2 Uniformly distributed loads

Uniformly distributed loads should be applied by dead weight, pressure bags or vacuum chamber.

C.5.3 Concentrated loads

For the concentrated load test, the load at the most unfavourable position in the span, on a crown of the profiled sheet at or nearest to the centre of the width of the sheeting should be applied.

NOTE A method of test is given in BS EN 14782 for profiled metal.

For materials where BS EN 14782 is not applicable the load should be applied through a rigid loading plate and an 18 mm thick plywood packing 125 mm long by the full width of the crown should be applied. Where the crown is curved or splayed, the packing should be shaped to the crown profile with a width of 15 mm.

C.5.4 Test procedure

C.5.4.1 Stiffness

The load should be applied in not less than five approximately equal increments to 1.25 times the expected design load, and the maximum deflection at the narrowest crown or trough of the profile, to the nearest 0.5 mm at each load increment should be recorded. The last increment of load should be sustained until no further increase in deflection occurs. If the deflection continues to increase after 30 min, the stiffness test should be abandoned and repeated with a new test sheet tested to a lesser maximum load. The final deflection at maximum load should be recorded, then the load released without shock; the residual deflection should be recorded.

C.5.4.2 Strength

After completing the stiffness test, the load should be re-applied in similar increments and deflections recorded, until failure occurs. The maximum load at failure should be recorded. In the report of the test, the mode of failure, e.g. local buckling, crushing, tensile fracture of the compression or tension flanges or web, failure in the fixings should be stated.

C.5.4.3 Concentrated load

The test should be carried out in two stages. For stage one (aesthetic acceptability test), the concentrated load of 0.9 kN should be gradually applied (not dropped) and sustained for 30 s. The load should be then be removed and observations recorded. For stage two (point load strength test), stage one should be repeated but with an applied load of 1.26 kN (0.9 kN × partial load factor for wind 1.4).

C.5.5 Number of tests

At least four tests for each loading and span condition should be carried out. In the case of concentrated load, only the maximum intended spans should be tested.

C.5.6 Interpretation of test results

*COMMENTARY ON **C.5.6***

The flexural rigidity test is generally a measure of the serviceability limit state, whereas the ultimate resistance test corresponds to the ultimate limit state load.

C.5.6.1 Derivation of flexural ridigity *EI*

The effective flexural rigidity *EI* of the profiled sheeting should be derived from the results of the uniformly distributed load test by the equation:

$$EI = (k_1)(W_d)\frac{L^3}{D} \tag{C.1}$$

in kNm²

where:

k_1 is a coefficient depending on support continuity and load distribution, and equal to 0.013 for a simply supported span with uniformly distributed load.

NOTE *Values of k_1 for continuous spans can be derived by elastic analysis.*

W_d is the total load on the span (in kN).

L^3 is the span (in m).

D is the maximum deflection in the span (in m).

C.5.6.2 Derivation of ultimate moment of resistance

The ultimate moment of resistance M_u should be derived from the equation:

$$M_u = (k_2)(W_u) \tag{C.2}$$

in kNm

where:

k_2 is a coefficient depending on support continuity and load distribution, and equal to 0.125 for a simply supported span with uniformly distributed load.

NOTE *Values of k_2 for continuous spans can be derived by elastic analysis.*

W_u is the total load on the span at failure (in kN).

C.5.6.3 Derivation of characteristic strength

The characteristic value of strength V_{ch} (which could be the moment of resistance, of sheeting or strength of fasteners) should be derived from the equation:

$$V_{ch} = V_m - (k_v)S(V) \tag{C.3}$$

where:

V_m is the mean value from the number of tests.

k_v is to be taken from the following Table, where η is the number of test results

S is the standard deviation of the population of test results.

η	4	5	6	8	10	20	30	∞
k_v	2.63	2.33	2.18	2.00	1.92	1.76	1.73	1.64

C.5.6.4 Partial safety factors for limit state design

Appropriate partial safety factors should be applied for materials and loads when using the characteristic value for design.

A simplified limit state equation should be used as follows:

$$W \times \gamma_f \leq \frac{V_{ch}}{\gamma_m} \tag{C.4}$$

where:

W is load

V_{ch} is characteristic performance value

γ_f is partial load factor

γ_m is partial material factor

NOTE 1 This can also be written as:

$$W \times \gamma_f \times \gamma_m \leq V_{ch} \tag{C.5}$$

NOTE 2 In accordance with ***C.5.6.3*** *the following partial load and material factors can be adopted:*

Values of partial load factors (γ_f) applied to loads should be:

a) Dead loads:
   1) 1.35;
   2) when resting wind uplift.
b) Wind loads:
   1) 1.5
c) Imposed (e.g. snow loads):
   1) 1.5;
   2) 1.05 for exceptional snow drift load.

Values of partial material factors (γ_m)should be:

- Steel: 1.0;
- Aluminium: 1.1.

NOTE 3 No partial load and material factors are utilized for the serviceability limit state when considering deflection.

C.5.6.5 Acceptance criteria for resistance to concentrated load

C.5.6.5.1 Stage 1 – aesthetic acceptability test

Deformations should be observed and the resistance to concentrated load should be considered satisfactory if there are no permanent deformations.

NOTE A permanent deformation is defined as a local change in geometry so great as to reduce the strength and stiffness of the sheet or to impair its ability to keep out the weather or to reduce its aesthetic value as a roof sheet (i.e. to render it unsightly when viewed from a distance of greater than 3 m).

C.5.6.5.2 Stage 2 – point load strength test

Some denting, buckling or permanent deformation is permitted but it should be tested so that the sheet can sustain the load for a minimum of 30 s without collapse or penetration.

Annex D (informative) Types of spacer kits and halters

D.1 General

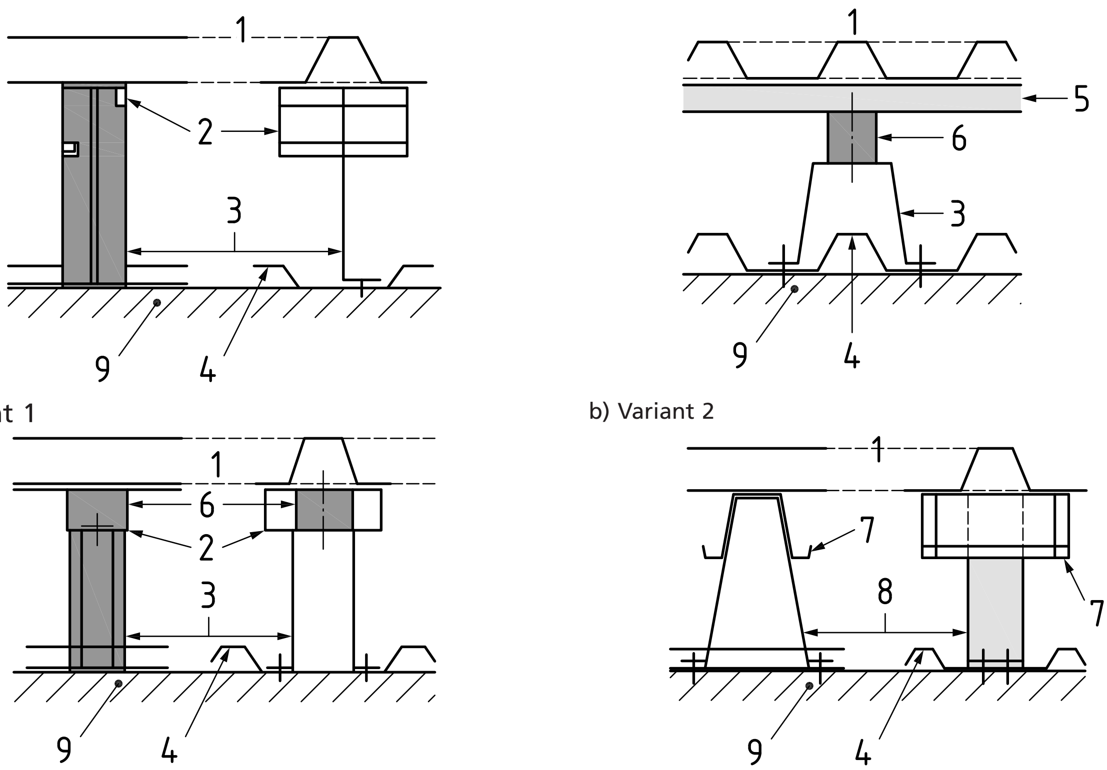
Spacer kits comprising bars and brackets are most commonly made of light gauge galvanised steel. Various steel bracket cross sections are used for which L shapes, stools and hollow closed section brackets are common. Examples of commercially available bar and bracket spacer kits are shown in Figure D.1 and Figure 3a.

A range of bracket heights is available, allowing the depth of the void between the liner and outer cladding sheet to be varied to suit the thickness of insulation. Bars are available in a variety of cross-sections but they are typically of a shape that allows interlocking of the bracket and bar in some form. Bars span between brackets, which are generally 1 m apart, but this span might be reduced or increased depending on the structural support centres and the loading conditions.

Where wall cladding is specified to have the outer weather sheet laid horizontally, the spacer kit has to be tied vertically, usually spanning between horizontal structural sheeting rails, which tend to be at centres greater than 1 m – typically 1.5 m to 2 m. Spacer kits specifically designed for this application are available, usually based on a bar and bracket system.

To provide a thermal break within the building envelope, a thermal or insulating pad may be included beneath the bracket. In other cases, the thermal break is provided at the bar to bracket connection.

Figure D.1 **Bar and bracket spacer kit variants**



a) Variant 1

b) Variant 2

c) Variant 3

d) Variant 4

Key

1	Outer cladding	6	Plastic block
2	Steel bar	7	Metal bar (top hat)
3	Steel bracket	8	Metal bracket
4	Inner sheet	9	Structural purlin
5	Steel zed bar		

Although the most common bar and bracket kits are made of galvanized light gauge steel, these kits can be made from aluminium.

D.2 Halter based spacing kits for standing seam cladding

Halter spacer kits comprise individual brackets, known as halters, onto which the weather sheet is directly attached (i.e. they do not include bars). The halters are specifically used in conjunction with standing seam weather sheets, which are mechanically seamed over the top of the halter, as shown in Figure 3b. The base of the halter is fastened to the supporting structure or to a separate spacer kit or sub-purlin.

The halters are typically manufactured either from aluminium alloy or from a reinforced plastic material. Metallic halters are generally placed on an insulating thermal pad to provide the necessary thermal break; this is not be done for plastic halters as the thermal break is an integral part of the halter.

In its simplest form, a halter based spacer kit comprises only halters (see Figure 3b). When used alone in this way, the maximum depth of the void is limited by the maximum height of the halter.

Where void depths greater than those achievable by the halter alone are required, additional spacer components need to be included within the kit.

NOTE 1 This might consist of a light gauge steel or aluminium top hat section, commonly termed a sub-purlin.

The flanges of the subpurlin are fastened directly to the walkable liner or via top hat spacers if fixed into the purlins.

NOTE 2 A bar and bracker spacer kit may also be used to support a halter.

The bracket of the spacer kit is fastened directy to the supporting structure below, while the halter is fastened to the top surface of the bar.

NOTE 3 Top hat sub-purlins might also be used where there is a requirement for an additional acoustic layer.

Various other halter-based hybrid spacer systems are available in addition to the above examples.

D.3 Ancillary components for spacers

Spacer kits can include a number of ancillary components providing additional in-plane stability to the spacer kit, e.g. cleats and/or bracing, including the following:

a) additional metal sections, e.g. top hat sub-purlins, which provide a platform onto which the spacer kit may be attached. Sub-purlins are commonly used to provide a flat surface for the base of the bracket/block (or pad) and/or additional depth for thermal and acoustic insulation;

b) heavy duty metal brackets specifically for use during the construction process. These may be used to provide safe storage areas on the roof for packs of cladding sheets; and

c) fasteners.

D.4 Other forms of spacer kit

*COMMENTARY ON **D.4***

*In addition to the bar and bracket and halter systems described in **D.1**, other forms of spacer system might be used; for example, for deeper voids or for supporting heavier loads.These secondary structural spacers are often factory-formed top hat sections in galvanised steel or aluminium.*

The dimensions and metal thickness of the other forms of spacer kit should be verified by structural calculations to ensure that the spacer has sufficient strength to transfer the imposed loads on the roof or wall to the structural frame without failure during the life of the building.

To avoid loosening due to shrinkage, timber spacers should not be through-fixed to the upper and lower layers, but should be separately fixed to each of these layers.

NOTE 1 Where timber spacers are used the type of preservative may have a corrosive effect.

The timber should be dried to less than the maximum moisture content for the species to prevent long term deterioration in a dry environment. This should be done before installation to reduce the risk of timber spacers for metal sheeting suffering from dimensional shrinkage and loosening of grip or withdrawal of screw fasteners due to drying out. The upper sheet should be separately fixed to the timber spacers to prevent this.

Reference should be made to BS 5268 for minimum fastener spacing and edge distances in timber.

*NOTE 2 See **7.10** for recommendations regarding the compatibility of preserved timber with metal and BS EN 1995-1-1.*

NOTE 3 Examples of spacer systems are shown in Figure 3.

NOTE 4 Metal spacer systems directly connected to profiled cladding can create cold thermal bridges which reduce locally the thermal insulation value of the cladding system. Thermal isolators may be included to provide a thermal break and reduce the risk of surface condensation.

For wall claddings – where flexible quilt insulation is used – it should be tucked beneath the spacer to minimize interruption of the insulation layer.

For metal roofing systems the insulation should not be draped over the spacer as further compression of the insulation might occur, thus affecting the integrity and weathertightness of the primary fasteners. Insulation should be cut and tucked beneath the spacer.

NOTE 5 Draping insulation over wall spacer bars may be required in some fire wall systems. It can lead to excessive distortion of the profiled outer sheet when the insulation is compressed between the weather sheet and the spacer. This in particular refers to weather sheets which are comprised of metal or other flexible materials.

NOTE 6 Some of these spacer systems and kits can be used for over-roofing.

Annex E (normative) Determination of the strength of attachment of a cladding system

E.1 General

The strength of attachment should be determined by the strength of the fastener and of the fixing assembly, whichever is the lesser; this includes the strength of all items in the load path through from weather sheet attachment to anchorage to the structure, and any intermediate items such as spacers or clips.

NOTE ECCS document 127 [34] gives a method of testing of fasteners within insulated or insulated sandwich panels.

E.2 Strength of attachment

The strength of attachment should be derived from the manufacturer's test data and should be the lesser value of:

a) ultimate detachment load;

b) service ability load, i.e. the load at which the fixing assembly no longer fulfils all of its design requirements; and

c) for limit state design the test results should be used to derive the characteristic value of strength V_{ch} (see **C.5.6.3**) and both the serviceability and ultimate limit state load using equations E.1 and E.2 as follows.

A simplified limit state equation should be used as follows:

$$W \times \gamma_f \leq \frac{V_{ch}}{\gamma_m} \quad (E.1)$$

where:

W is load

V_{ch} is characteristic performance value

γ_f is partial load factor

γ_m is partial material factor

NOTE This can also be written as:

$$W \times \gamma_f \times \gamma_m \leq V_{ch} \quad (E.2)$$

The load applied to the fixing assembly should be factored using the following partial load (γ_f) and material factors (γ_m) and compared with the appropriate characteristic strength:

a) Ultimate detachment

Values of partial load factor (γ_f) applied to loads should be:

1) Wind loads: 1.5

Values of partial material factors (γ_m) should be:

2) Pull-through: 1.33

3) Pull-out from steel ≥1.5 mm: 1.33

4) Pull-out from aluminium ≥2.0 mm: 1.33

5) Pull out from timber: 2.0

6) Pull out from masonry/concrete: 2.67

7) Spacer assembly: 1.33

8) Secret fix fixing assembly: 2.0

b) Serviceability

Values of partial load factor (γ_f) applied to loads should be:

9) Wind loads: 1.5

Values of partial material factor (γ_m) should be 1.0.

E.3 Pull-through strength of primary fasteners

The pull-through tests should be carried out in accordance with the testing arrangement, shown in Figure E.1, on the relevant combination of fastener and sheeting.

E.4 Pull-out strength of fastener from support (screw and shot fired fasteners)

Pull-out tests should be carried out in accordance with the testing arrangement shown in Figure E.1, on the relevant combination of fastener and support to which the fastener is anchored.

E.5 Secret fix systems

The attachment strength of secret fix systems should be derived from full scale tests on the profile.

NOTE 1 Full scale tests are required to simulate profile flexibility and its effect on attachment.

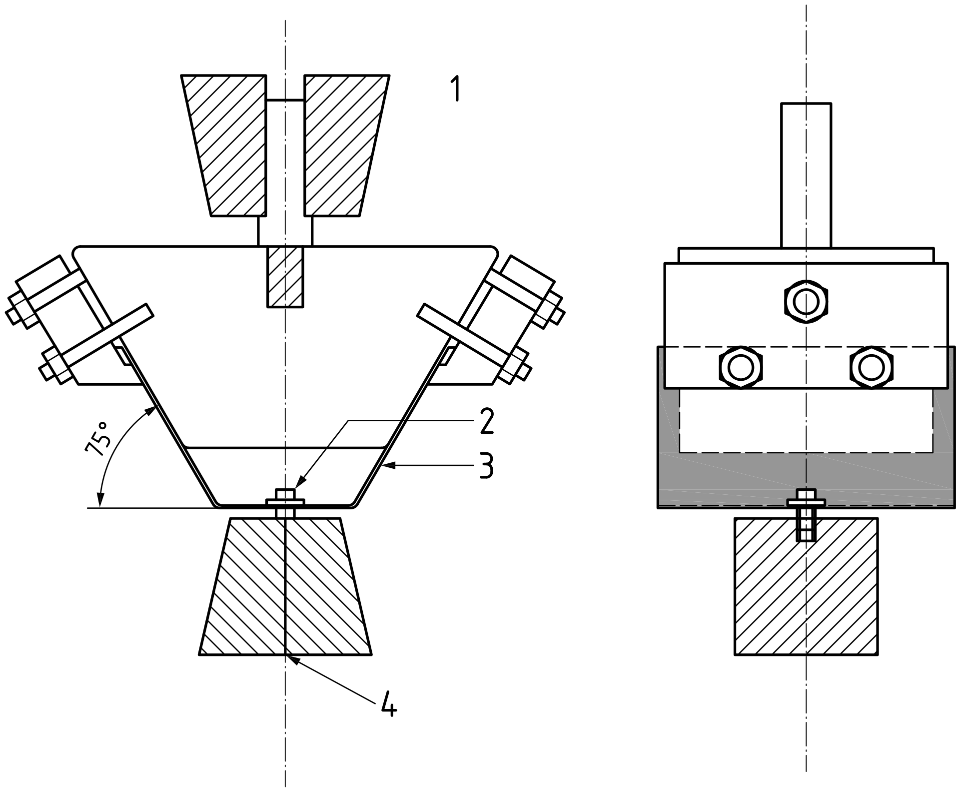
The test sample construction should consist of at least three panel cover widths with two assembled seams and be in double span. The load should be applied uniformly over the whole assembly.

The load and method of failure should be recorded.

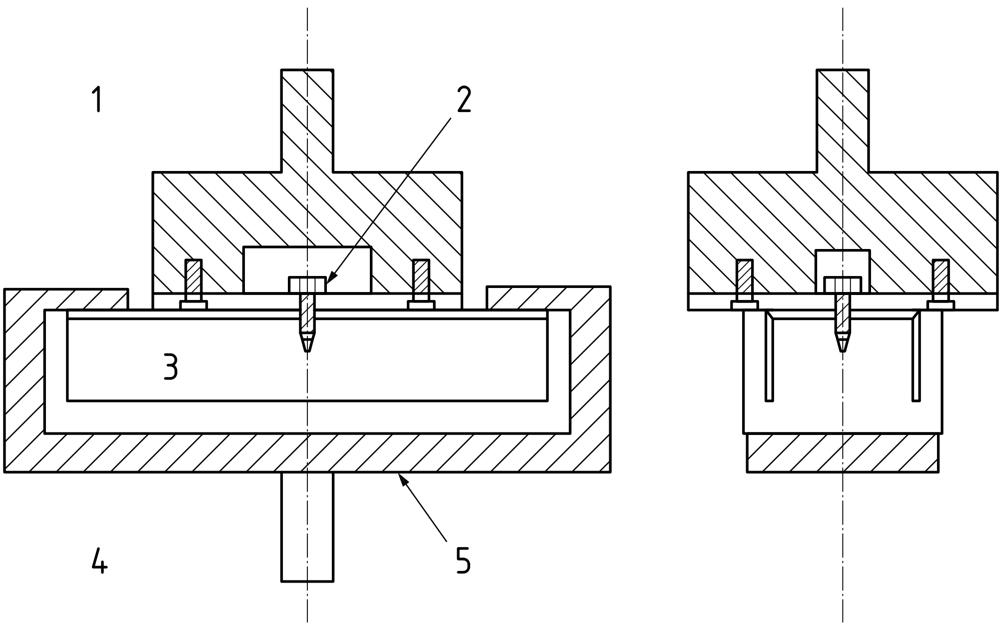
NOTE 2 Typical failure modes are when the fixing assembly disengages from any rib (sometimes a serviceability failure rather than complete collapse) or when the sheet separates at the interlocking rib.

The maximum load per fixing assembly should be derived by statistics from the uniform load.

Figure E.1 **Typical pull-through and pull-out test arrangements**



a) Typical pull-through test arrangement



b) Typical pull-out test arrangement

Key

1 Upper grip
2 Test sample
3 Metal substrate
4 Lower grip
5 Clamping device for substrate

E.6 Spacer systems

E.6.1 General

The characteristic strength of spacer systems should be derived using a range of tests as shown in **E.6.2** to **E.6.7**.

E.6.2 Test method to determine the in-plane sway stability of the spacer kit

E.6.2.1 General

COMMENTARY ON ***E.6.2.1***

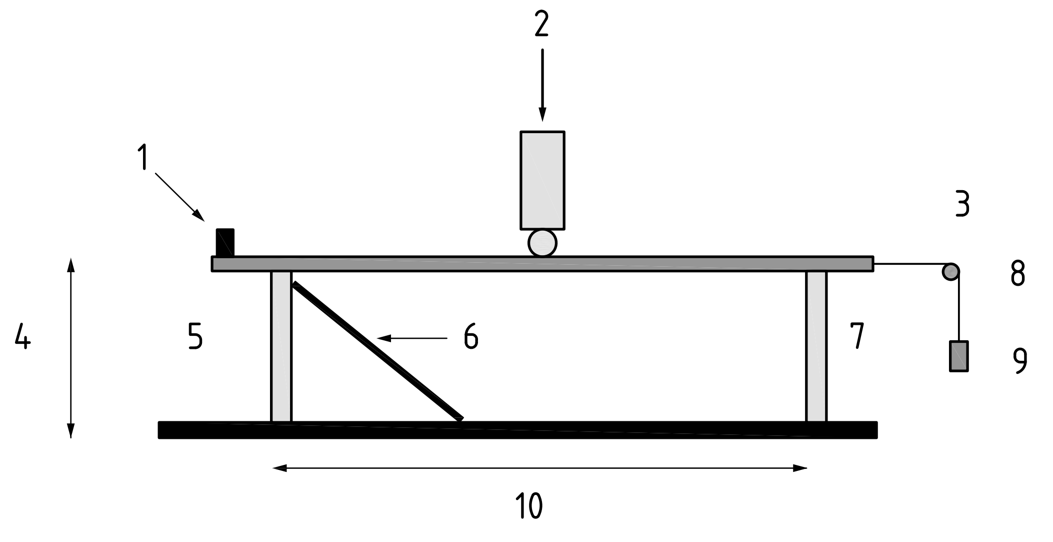
The test specimen is mounted in a test rig as shown in Figure E.2. The test specimen comprises one bay of the spacer kit, which includes a length of bar and two bracket assemblies.

The bracket assembly should be the deepest in the manufacturer's range, in order to represent the most onerous condition for the spacer kit in terms of its in-plane stability; the bracket height and spacing to be used in the tests may be determined from previous experience or by pre-testing.

NOTE The bar is connected to the brackets as it would be in service (following the manufacturer's installation instructions). The length of bar is selected so that it spans across the two brackets with sufficient overhang at each end. Each bracket is securely fastened at its base to a support structure.

The base should be bolted or clamped in position to form a rigid connection to the support; this prevents failure from occurring at the base.

Figure E.2 **Spacer kit in-plane sway stability test set-up**



Key

1	Sensor to measure horizontal displacement	6	Stabilizing member if appropriate
2	1.2 kN load applied by roller at mid-span	7	Bracket assembly
3	Horizontal load	8	Pulley
4	Maximum bracket assembly height	9	Weight
5	Bracket assembly	10	Maximum bracket spacing

Where appropriate, and specific to a particular spacer kit, stabilizing components (e.g. stronger bracket or diagonal bracing) should be included to provide appropriate stability for the spacer arrangement. The inclusion of such a component, often referred to as a sway bracket, should be in line with the manufacturer's recommendations. Only one such member should be provided per test specimen, with a standard bracket at the other end.

E.6.2.2 Test procedure

The test specimen should be first loaded horizontally at bar height with the prescribed notional horizontal force; this force may be applied through a weight and pulley arrangement, as shown in Figure E.2, or by another suitable means. It should be maintained constant throughout the test. The notional horizontal force should be applied to prescribe a horizontal displacement to the spacer kit to simulate an appropriate out of vertical tolerance.

A vertical force should be gradually applied at bar mid-span at a mean rate of 150 ± 50 N/s to a magnitude of 1.2 kN. When the vertical load has reached 1.2 kN the load should be maintained for a period not less than three minutes and the test specimen should be observed to see if collapse occurs; if no collapse occurs the load is then increased until collapse.

NOTE As the bracket assemblies can have differing horizontal stiffness depending on the direction of application of the in-plane notional horizontal force (0° or 180° directions), a pre test can be undertaken to determine the force direction which produces the worst case scenario.

The above test procedure should be repeated for at least three samples.

E.6.2.3 Notional horizontal force

*COMMENTARY ON **E.6.2.3***

The magnitude of the notional horizontal force depends upon the stabilizing arrangement for the spacer kit.

If the spacer kit is designed to provide sufficient in-plane stability without the need for an additional stabilizing component (e.g. strengthened bracket or bracing), the magnitude of the notional horizontal load should be 0.5% of the vertical load acting on one single bay of the spacer kit, i.e. 0.005 × 1.2 kN = 6 N.

NOTE 1 This is a relatively small force, which might best be applied by a weight and pulley system (weight equal to approximately 650 g).

For spacer kits that require one or more sway brackets (i.e. stabilizing components) to provide the appropriate in-plane stability, the notional horizontal force selected to act on the test specimen depends on the recommended interval between these brackets or similar stabilizing components; this interval should be clearly stated in the installation instructions provided by the manufacturer.

NOTE 2 In general, the notional horizontal force is equal to 0.005 × n × 1.2 kN, where n is the number of spans that each sway bracket is designed to stabilize. In this context, span refers to the span of the bar between brackets. Thus, if a spacer kit is designed to have a bracing member attached to every 10th bracket, the appropriate notional horizontal force for the in-plane stability test is 60 N.

E.6.2.4 Acceptance criteria

The spacer kit should be deemed to have passed the in-plane stbility test if it can support the combined horizontal and vertical loading without collapse for three consecutive tests.

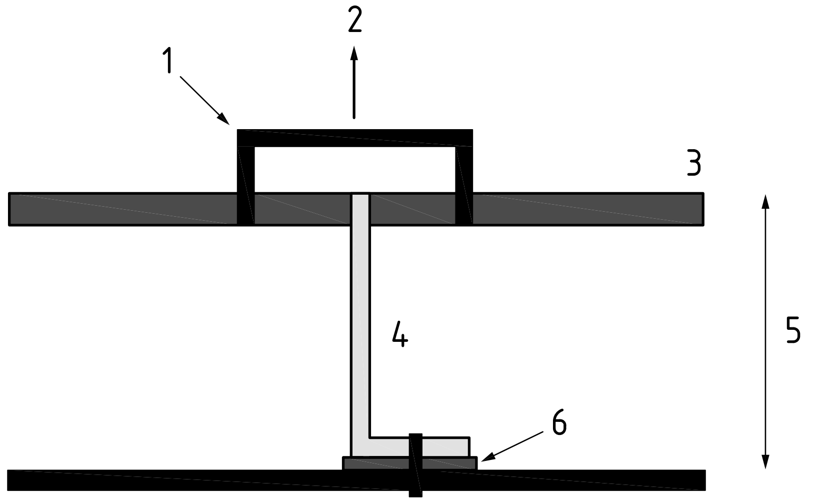
E.6.3 Test method to determine the detachment resistance of the bracket assembly

E.6.3.1 Test procedure

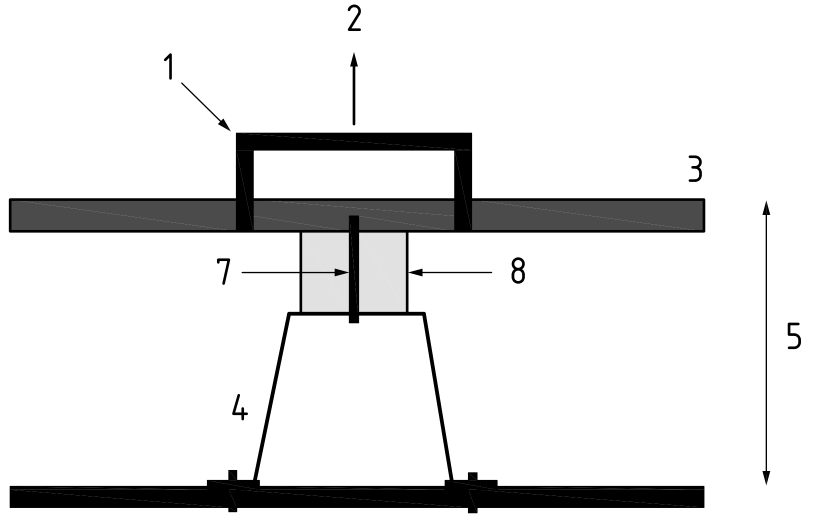
A tensile force should be applied to the assembly as in Figure E.3 by a hook attached to the short length of bar. The force should be applied gradually to the test specimen at a mean rate of 150 ± 50 N/s and measured to an accuracy of ±25 N. Once a force of at least 3.0 kN has been reached, it should be maintained for a period not less than three minutes and the test specimen observed for bracket assembly failure. If no failure occurs in the bracket assembly, the load should then be increased to failure.

The above test procedure should be repeated for at least six samples.

Figure E.3 **Space kit bracket detachment test set-up**



a) Bar and bracket system variant 1



b) Bar and bracket system variant 2

Key

1	Hook	5	Bracket height
2	3 kN tensile pull-out force	6	Pad
3	Metal bar	7	Fastener
4	Metal bracket	8	Plastic block

NOTE For variant types see Figure D.1.

E.6.3.2 Acceptance criteria

The spacer kit should be deemed to have passed the detachment resistance of the bracket assembly test if it can support a load of 3.0 kN without collapse for three consecutive tests.

E.6.4 Test method to determine the resistance of the bracket assembly to a vertical compression force

E.6.4.1 Test procedure

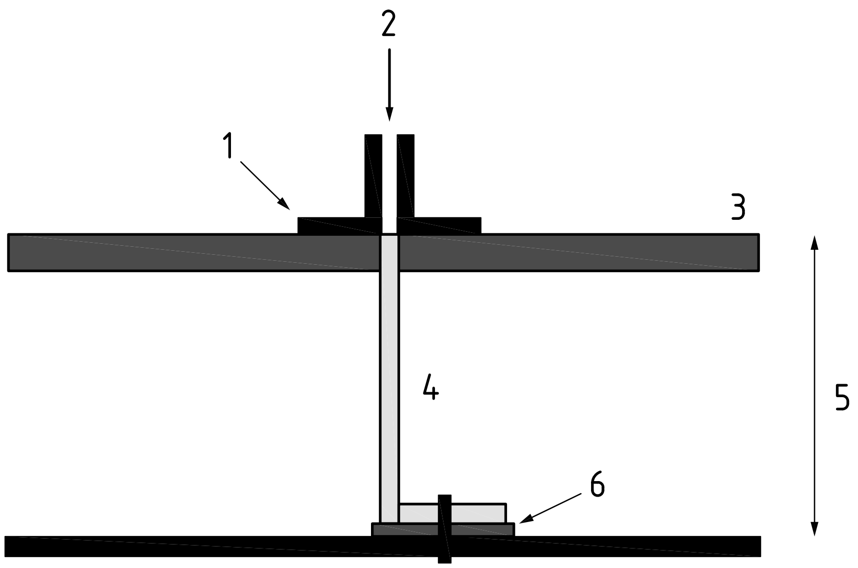
A compressive force should be applied to the bracket assembly (see Figure E.4). The force should be applied gradually to the test specimen at a mean rate of 150 ± 50 N/s and measured to an accuracy of ±25 N. For each increment of load, the corresponding vertical displacement of the top of the bracket assembly should be noted. Once a force of at least 1.2 kN has been reached, it should be maintained for a period not less than three minutes and the test specimen observed for bracket assembly failure. If no failure has occurred in the bracket assembly, the force should be increased until failure.

The above test procedure should be repeated for at least three samples.

E.6.4.2 Acceptance criteria

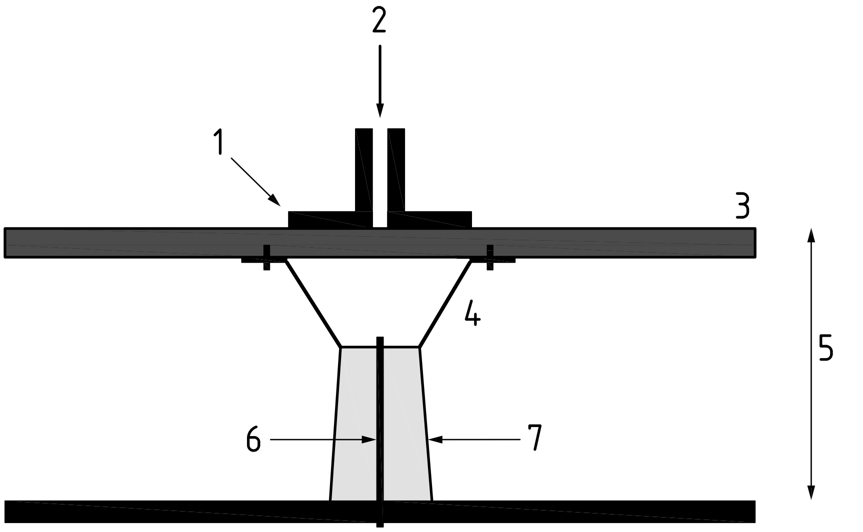
The spacer kit should be deemed to have passed the bracket compression test if it can support a load of 1.2 kN without collapse for three consecutive tests.

Figure E.4 **Spacer kit bracket compression test set up**



a) Bar and bracket system variant 1

Figure E.4 **Spacer kit bracket compression test set up**



b) Bar and bracket system variant 2

Key

1	Bolted assembly	5	Bracket height
2	1.2 kN compression force	6	Pad
3	Metal bar	7	Plastic block
4	Metal bracket		

NOTE For variant types see Figure D.1.

E.6.5 Methods to determine the resistance of the bar in bending when subjected to vertical loading – test specimen and set up

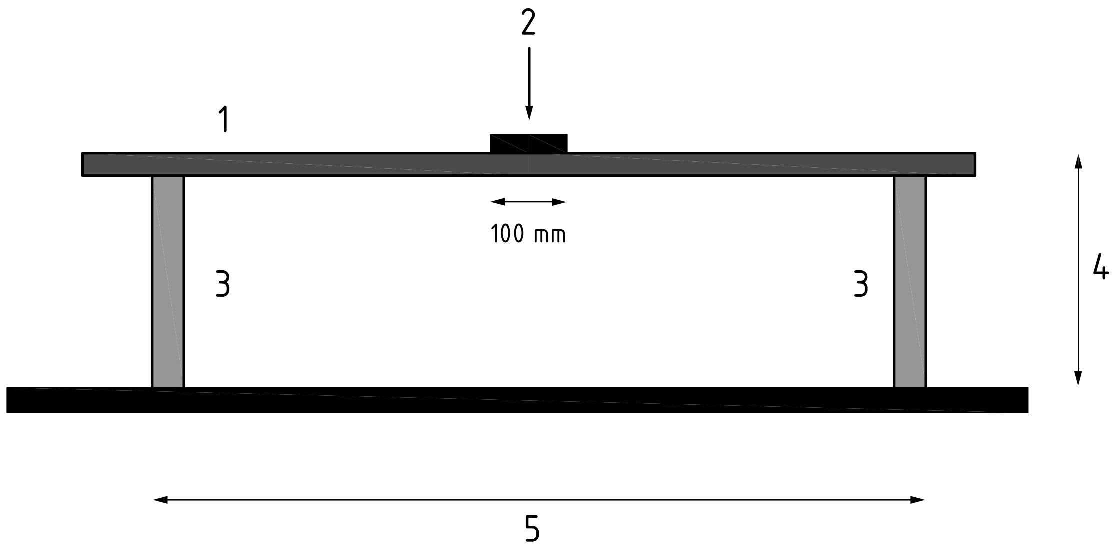
E.6.5.1 Test specimen and setup

Two alternative versions of the test setup are shown in Figure E.5; in both versions, a single spanning length of bar should be positioned between two supports at the desired span with a concentrated load applied by a jack to the mid span. In the first arrangement, support to the bar should be provided by a pair of bracket assemblies. The bracket assembly should be fastened at the base using a bolted connection to form a rigid base to the assembly connection which prevents failure occurring at the base of the bracket at the connection to test rig.

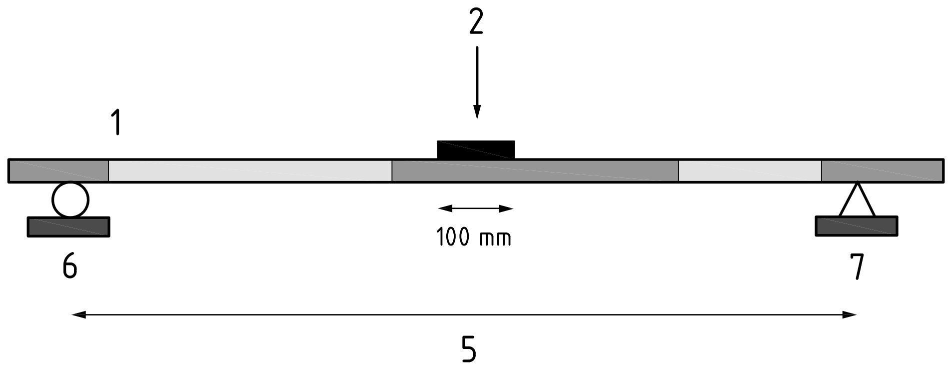
NOTE 1 This arrangement is preferred because the metal bar cross section is typically an unsymmetrical open section, which if tested alone, is usually awkward to support at its ends and rotates when loaded vertically, thereby requiring provision for additional end and side support.

NOTE 2 Where the bar has a closed symmetrical cross section (e.g. a square or rectangular hollow section) and is symmetrical about its minor axis, the test specimen to be tested can comprise of a bar only, where in this case the bar is supported directly onto a knife edge and roller support (see Figure E.5). The choice of test configuration is the responsibility of the manufacturer.

Figure E.5 **Spacer kit-bar bending test set-up**



a) Testing of bar assembled on bracket



b) Testing of bar assembled on separate support

Key

1	Bar	5	Bracket spacing
2	1.2 kN point load applied at mid-span	6	Roller support
3	Bracket assembly	7	Knife support
4	Bracket height		

E.6.5.2 Test procedure

A force increasing to at least 1.2 kN should be applied and the load maintained for a period not less than three minutes. The test force should be gradually applied (not dropped) at a mean rate of (150 ± 50) N/s and the corresponding vertical displacement at bar mid-span noted. The force applied should be measured to an accuracy of ±25 kN.

NOTE If the T bar has not collapsed, the load is then increased until collapse.

This test procedure should be repeated for at least three samples.

E.6.5.3 Acceptance criteria

The spacer kit should be deemed to have passed the bar bending test if it can support a vertical load of 1.2 kN without collapse for three consecutive tests.

E.6.5.4 Determination of the bending resistance of the bar by calculation

The adequacy of the metal bar in bending when subjected to a concentrated force at mid-span may alternatively be verified and assessed by performing structural calculations; the calculations should be in accordance with BS EN 1993 and BS EN 1999.

E.6.6 Detachment (pull-out) resistance of halter – test procedure

E.6.6.1 Test procedure

A tensile force should be applied to the test assembly by suitable means. This force should be applied to the test specimen at a rate of 5 mm/min until a value of load equal to 1.5 kN is achieved. Once a force of at least 1.5 kN has been reached, it should be maintained for a period not less than three minutes and the test specimen observed for halter failure or pull-out of the halter from the sheeting. If no failure occurs in the bracket assembly, the load should then be increased to failure.

The above test procedure should be repeated for at least three samples.

E.6.6.2 Acceptance criteria

The spacer kit should be deemed to have passed the halter detachment test if it can support a pullout load of 1.5 kN without collapse for three consecutive tests.

E.6.7 Resistance of halter under compression loading – test procedure

E.6.7.1 Test procedure

A compressive force should be applied to the test assembly by suitable means. This force should be applied to the test specimen at a rate of 5 mm/min until a value of load equal to 1.2 kN is achieved. Once a force of at least 1.2 kN has been reached, it should be maintained for a period not less than three minutes and the test specimen observed for halter failure. If no failure occurs in the halter, the load should then be increased to failure.

The above test procedure should be repeated for at least three samples.

E.6.7.2 Acceptance criteria

The spacer kit should be deemed to have passed the halter compression loading test if it can support a load of 1.2kN without collapse for three consecutive tests.

E.7 Interpretation of results

The characteristic strength values should be derived in accordance with equation **C.3** and limit state loads in accordance with **C.5.6.4**.

The load applied to the fixing assembly should be factored using a load factor of 1.4 and compared with the appropriate characteristic strength.

Annex F (normative) Water permeability of a complete profiled roof system

F.1 General

Where required, the water permeability (resistance to driving rain) of a complete profiled sheet roof system should be assessed, i.e. the assembly that is to be installed in a building, including the product and its coatings, factory-applied seals, standard joints, site-applied seals including the fasteners, and a method of fixing and support as intended for use.

The resistance classification of a low pitch (<40°) profiled sheet system to driving rain under pulsating air pressure should be determined according to the following method; profiled metal and translucent sheets may also be tested to this method.

F.2 Test method for water permeability – resistance to driving rain under pulsating pressure

F.2.1 Principle

Where required, the resistance of a low pitch profiled sheet system to driving rain under pulsating air pressure should be tested according to BS EN 12865.

F.2.2 Apparatus

The test apparatus should be in accordance with BS EN 12865.

F.2.3 Test specimens

The dimensions of the test specimen should be as specified in BS EN 12865. Both horizontal and vertical joints should be incorporated where these are an intrinsic part of the panel assembly.

F.2.4 Procedure

The test should be carried out in accordance with BS EN 12865:2001, procedure A.

F.2.5 Calculations and results

The criteria from BS EN 14509:2013, **A.11.5** should be used to define water tightness.

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