
Code of practice for

Performance and loading criteria for profiled sheeting in building

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This code of practice represents a standard of good practice and therefore takes the form of recommendations. Compliance with it does not confer immunity from relevant statutory and legal requirements.

Foreword

This code of practice has been prepared expressly to assist everyone dealing with profiled sheeting to understand the requirements in 'performance terms' when this type of sheeting is used in building construction. The code endeavours to bring a common understanding between manufacturers, suppliers, designers, installers and client/users

The code deals with the combined effect of all the loading and performance criteria on the selection of the sheeting, and indicates areas for finding a solution. The code identifies those requirements that are governed by statutory regulations. It should be noted that the information on regulations is given only as a guide and the actual regulations should be consulted.

Attention is drawn to the fact that, in some instances, there are specific codes of practice and British Standards governing the manufacture and use of particular types of profiled sheeting, which should be read in conjunction with this document (see clause 2). It is intended that these codes and standards will be aligned with this code.

The code has been based, as far as possible, upon the C.I.B. Master List. Readers will notice that the references to performance in certain areas are incomplete and further information is required. It is intended that future revisions will incorporate further information as it becomes available.

British Standard Code of practice for

Performance and loading criteria for profiled sheeting in building

Section one. General

1. Scope

This code of practice deals with design, performance and loading criteria for profiled weathering sheeting, in a range of materials, used in building. It does not, however, deal with sheeting when combined with other materials so as to form built-up roof or floor decking.

Composite materials are not included but many of the principles apply.

Special attention is given to identifying the various regulations that govern the use of profiled sheeting.

2. References

The titles of the standards publications referred to in this code of practice are listed on the inside back cover.

Where the manufacture or use of sheeting is covered by other British Standards, the requirements of these standards or codes should be observed.

3. Definitions

For the purposes of this code of practice the following definition applies.

profiled sheeting. Sheetting formed longitudinally with regularly spaced shaping to give a corrugated or troughed cross section.

Section two. Materials, fixings, sealants and accessories

4. Materials for profiled sheets

Profiled sheet is currently made of metals such as aluminium, hot-dip zinc-coated steel and stainless steel and of other materials such as asbestos cement, bituminous fibre, glass and plastics.

Plastics include GRP (glass fibre reinforced polyester) and UPVC (unplasticized polyvinyl chloride).

Sheets may have a variety of applied protective or decorative coatings, e.g. PVC, acrylic, alkyd or asbestos-bitumen. Metal sheets may be precoated with other metals or alloys, e.g. hot-dip zinc-coated steel, given conversion coatings or be anodized (aluminium). Stainless steel sheeting may be used in the form of either solid stainless steel sheet or stainless clad mild steel.

Sheets should comply with the quality requirements of the relevant British Standards or, if none are relevant, with authoritative publications. Authoritative publications are listed in table 2 against various profiles for the more important sheeting materials. Some mechanical properties of sheeting materials are listed, together with suitable tests, in table 1. Tests for other properties of sheeting are noted in the relevant sections.

5. Appearance

A wide variety of finishes, textures, colours and degrees of opacity are available, many of which are listed in appendices D and E together with the important limitations on their use.

Stainless steel may be produced in a number of standard finishes (see BS 1449 : Part 4). In addition, a wide range of durable colour finishes, derived by chemical treatment to reinforce the naturally passive surface film, are available.

Colours of applied finishes should preferably be specified in accordance with the requirements of BS 4800.

The degree of opacity for plastics and glass should be agreed between the purchaser and the manufacturer (see clause 18).

The appearance of sheeting changes, sometimes dramatically, with time (see clause 19).

6. Profiles and dimensions

A large number of profiles is currently available in widths that can be easily handled. The maximum length supplied varies considerably, depending principally upon the method of manufacture or the ease with which the material can be transported and handled.

The recommendations in BS 4943 for coordinating sizes for corrugated sheeting materials should be followed.

Details of British Standard profiles are shown in the documents listed in table 2. Many other profiles are available and details are obtainable from the manufacturers.

Where sheets of different materials are lapped, the profiles at the lap should enable the sheets to nest.

The approximate weights of sheeting materials should be obtained from the relevant British Standards (see table 2) or from the manufacturers.

Table 1. Mechanical properties

Material		Density		Tensile strength		Compressive strength		Elastic modulus	
		kg/m ³	Test	N/mm ²	Test	N/mm ²	Test	GN/m ²	Test
Metal	Aluminium	2700		175 to 245	BS 18 Part 1	As tensile strength		70	
	Hot-dip zinc-coated steel	7800	To find mass of zinc coating: BS 3083 or BS 2989	300 to 560	BS 18 Parts 2 and 3	410 to 480		210	
	Stainless steel	7900		470 to 700	BS 18 Parts 2 and 3	470		210	
Asbestos cement	Unreinforced	1400 to 1500	BS 4624	15.7 N/mm ² to 19.6 N/mm ² *				N/A	
Glass	Plain			Information available from manufacturer's strength charts				N/A	
	Wired							N/A	
GRP	Translucent	1500 to 1700		70 to 170		100 to 200		5 to 25	
	Opaque	2000		70 to 170		100 to 200		5 to 25	
UPVC	Transparent	1400	BS 2782 : Part 3	70 N/mm ² to 112 N/mm ² *			BS 2782 : Part 3	0.33	BS 2782 : Part 3
	Translucent	1400		70 N/mm ² to 112 N/mm ² *			BS 2782 : Part 3	0.33	BS 2782 : Part 3
	Opaque	1400		70 N/mm ² to 112 N/mm ² *			BS 2782 : Part 3	0.33	BS 2782 : Part 3
Bituminous fibre								0.014	

*Flexural strength.

Table 2. British Standard profiles and related documents

Sheet material Profile groups	Aluminium	Hot-dip zinc-coated steel	Protected metal (surface coating)	Plastics			Asbestos cement	Bituminous fibre	Glass
				GRP	UPVC	Acrylics			
Symmetrically corrugated	BS 4868 CP 143 : Part 1	BS 3083	—	Matching aluminium steel and asbestos cement BS 4154	Matching aluminium steel and asbestos cement BS 4203	—	BS 690 : Part 3 CP 143 : Part 14	No code or standard	Refer to glass codes and standard
Asymmetrically corrugated				Matching asbestos cement	—	—	BS 690 : Part 3 CP 143 : Part 14	—	—
Asymmetrical trapezoidal (troughed)	BS 4868 CP 143 : Part 1	CP 143 : Part 10		Matching aluminium and steel BS 4154	—	—	—	—	—
Symmetrical trapezoidal (troughed)	BS 4868 CP 143 : Part 1	—	—	Matching aluminium and steel BS 4154	Box profiles BS 4203	—	—	—	—

7. Fixings

Fixings should, where practicable, comply with the requirements of BS 1494 : Part 1 and BS 4174 as indicated in table 13. Aluminium fixings should comply with the requirements of BS 1494 : Part 1, using the materials indicated by an asterisk in table 3.

All other fixings such as nails, plastics-headed bolts, rivets and special hook bolts should be of stainless steel or be galvanized, sherardized, zinc-plated, aluminium-coated or cadmium-plated to the same standard as required of fixings to BS 1494.

Selection of fixings should be in accordance with clause 23.

Material for stainless steel threaded fasteners and fixings should comply with the requirements of grades 304, 305 or 316 of BS 1449 : Part 2 or BS 970 : Part 4.

8. Sealants

There are situations that will require sealing, cushioning and gap filling, and a wide range of sealants such as strips, mastics, joint filling compounds and foam fillers is available.

The functions and selection of sealants is dealt with in clause 24.

9. Accessories

A wide range of accessories is available in various materials, including ventilators, roof lights, expansion joints, barge boards, finials or ridge ends, ridge and hip cappings, flashings and soakers (apron, cover, corner, raking and stepped), various filler or closure pieces (corner, eaves, ridge, and skew eaves) and rainwater goods. They are commonly available in materials and profiles to match the sheeting. Non-standard items can also be obtained to order.

Accessories should, where practicable, comply with the requirements of the appropriate British Standards listed below. Otherwise they should be in accordance with the requirements of this code (see clause 25).

Aluminium

BS 1470 in temper appropriate to the duty and forming operations required: NS3, NS4, S1C, S1A, S1 for accessories made from sheet.

BS 1474, HE9 and HE30 in temper appropriate to the duty and forming operations required and E1C, for extruded accessories.

BS 2997 for aluminium rainwater goods.

Asbestos cement

BS 690 : Parts 5 and 6 for accessories.

BS 569 for rainwater goods.

Cast iron

BS 460 for rainwater goods.

Hot-dip zinc-coated steel

BS 2989 and BS 1091 for accessories and rainwater goods made from sheet.

Lead

BS 1178: not less than 30 kg/m² for gutters and 20 kg/m² for flashings.

Zinc

BS 849 : Part 2: not thinner than 0.8 mm for flashings.

BS 1431 for rainwater goods.

Asbestos fibre-based bitumen sheet flashings are available.

Plastics accessories should comply with the quality requirements of this code.

The selection of material for accessories should be in accordance with the recommendations given in clause 25.

Section three. Design considerations

10. General

The purpose of this design is the achievement of acceptable probabilities that the sheeting being designed will not become unfit for the use for which it is required.

Users of this code will include suppliers of sheeting, sometimes the manufacturer, specifiers (including designers), installers and finally client/users. While each may find a particular clause of more relevance than another, it is considered desirable that all these people should have a working knowledge of the whole of section three.

It is vitally important that all concerned with the sheeting should exchange information at an early stage and that drawings and specifications (see clauses 26 and 27) should be prepared in sufficient detail to afford proper guidance in the preparation of estimates and the execution of work. Where bills of quantity form part of the contract, they should be prepared in accordance with a recognized standard method of measurement.

The selection of a suitable profiled sheet should be made after consideration of the economic, functional and aesthetic factors involved. Section three considers the functional factors involved. When considering functional

Table 3. Materials for aluminium fixings

Fixing	NS3—H8 to BS 1470	NS4—H6 to BS 1470	NB6—H4 to BS 1473	HG9—TD to BS 1475	HB20—TH to BS 1473	HE20—TF to BS 1474	HS30—TF to BS 1470	HE30—TF to BS 1474
Roofing bolts, hook bolts and drive screws and roofing screws			*		*			
Nuts				*				*
Washers	*	*		*				*
Roofing clips		*				*	*	*
Sheeting clips						*		*

factors, regulations are inevitably of concern and may be of overriding importance. The more important regulations, together with other documents giving guidance, are listed in table 4.

Regulations in the United Kingdom are imposed by Acts of Parliament (Public Health, Safety, London Building Acts, Building (Scotland) Act, 1959, etc.) and these control the use of sheeting in building. Statutory Undertakings (e.g. British Rail, Electricity, Gas, Water, National Coal Board, British Road Services), the Crown and the Department of Education and Science, etc., may call for special requirements. Authorities are responsible for interpretation and enforcement of the regulations; provided that the authorities can satisfy themselves that standards of safety for occupants are maintained, local authorities, the Department of the Environment and the Secretary of State for Scotland are permitted to make 'relaxations' of the regulations if the circumstances permit.

The authorities may require evidence of compliance with British Standard tests or alternatively they may accept an Agrément Certificate. The Agrément Board is an independent authority established by the Government to examine new materials and methods of construction to determine their suitability for various applications. Agrément Certificates are valid for 3 years only but can be renewed.

Table 1 compares some mechanical properties of materials; precise values should be obtained from the manufacturer or from the results of tests.

11. Strength of sheeting

11.1 Design criteria. Manufacturers should make available to users of corrugated sheeting materials the following information about their products, preferably in graphic or tabulated form as shown in (a) and (b).

(a) Safe load/span tables

Profile type			
Load (kN/m ²)	Vertical load	Suction load	Point load (on 125 mm ²)
Span (mm)			
1200			
1500			
2100			
2700			
3000			
3300			
4500			

Permissible loads should be stated and in addition the table should indicate the controlling factors, e.g. working stress, deflection, local failure at fixings. (See appendix B.)

(b) Section properties: sample format

Profile type	
Effective width (mm)	
Mass per metre length (kg)	
Area (mm ²)	
Modulus of section Z (mm ³)	
Inertia of section I (mm ⁴)	
Least dimension N/A_y (mm)	

The above information can be determined by first calculating the physical properties, and should be corrected before publication by using the test procedure given in appendix A.

The safe load/span tables should also be the result of tests against calculated values, with particular attention being paid to the factors causing failure. Such factors should be reflected in the tables.

The permissible load-bearing capacity of the material and its modulus of elasticity should be determined from tests of the material, indicating the factor of safety adopted (see appendix A) determined from the deflection and creep characteristics of the material.

The information given by manufacturers should be sufficiently comprehensive to enable users either to select sheeting using the safe load/span tables or to adjust the span to suit particular loading conditions, in accordance with CP 3 : Chapter V : Parts 1 and 2 or control deflection using the section properties, see (b) above.

11.2 Loads on roof and vertical sheeting. The anticipated loading should be a combination of the dead load (mass of material), imposed loading (snow, etc.) and windloading, based on the worst possible conditions assessed in accordance with CP 3 : Chapter V : Parts 1 and 2. Reference to the explanatory notes prepared by the Building Research Establishment* will be helpful in this respect.

11.3 Loads on roof and vertical sheeting to assist manufacturers in the design of their products. While assisting the designer/specifier in selecting sheeting for a particular use, 11.1 and 11.2 do not guide the manufacturers in determining what is likely to be the most universally acceptable product, 'a standard sheet'. The strength of the material and its characteristics will be critical in determining the profile. The following information is given to assist manufacturers in design.

Dead load, i.e. self mass of the material, should be calculated from BS 648 on the actual known mass.

Imposed load, snow load or loading imposed during maintenance is usually taken for roofs of slope up to 10° as 0.75 kN/m².

*Wind Loading Handbook (C. Newberry and K. Eaton) HMSO.

Table 4. Governing regulations and authoritative documents

Clause	Governing regulations					Authoritative documents			
	Building Regulations, England and Wales	Building Standards, Scotland	Building Regulations, Northern Ireland	Greater London Council Constructional By-Laws	The Thermal Insulation (Industrial Building) Regulations	British Standards	BS Codes of practice	Building Research Establishment Digests	Additional authoritative documents
10 General									
11 Strength of sheeting	1972 Part D	1971 Part C	1973 Part D	1972 Parts 2, 4 and 6		*BS 449 on diaphragm action			'CONSTRADO' guides on diaphragm action
12 Behaviour in fire	1972 Part E. Amended 1973	1971 Part D. Amended 1973	1973 Part E	1972 Parts 6, 12 and 13	1972 Parts 4 and 5	BS 476 : Parts 3	CP 3 : Chapter IV Parts 1, 2 and 3	No. 69 No. 93	Rules of the Fire Offices Committee for Standards 1—5 Constructions and Rules of the Fire Offices Committee Construc- tion of Buildings Class 1—3
13 Thermal transmission	1972* Part F. Amended 1974	1971* Part J	1973 Part F		1972 Part 3		CP 3 : Chapter IV CP 3 : Chapter VIII	No. 108 No. 93	Thermal Insulation (Industrial Buildings) Regulations, 1972
14 Acoustics	1972* Part G	1971* Part H	1973 Part G				CP 3 : Chapter III	No. 128 No. 93	
15 Weathertightness									
16 Condensation							BS 5250	No. 110	
17 Temperature								No. 68	
18 Light transmission								No. 41 No. 42	Code of Practice for Interior Lighting, of the Illuminating Engineering Society of Great Britain
19 Durability						BS 2569 : Parts 1 and 2	CP 3 : Chapter IX CP 2008	No. 69 No. 70 No. 71	
20 Compatibility of materials								No. 71	

*Applies to domestic buildings only.

Continued

Table 4 (concluded)

Clause	Governing regulations					Authoritative documents			
	Building Regulations, England and Wales	Building Standards, Scotland	Building Regulations, Northern Ireland	Greater London Council Constructional By-Laws	The Thermal Insulation (Industrial Building) Regulations	British Standards	BS Codes of practice	Building Research Establishment Digests	Additional authoritative documents
21 Protection against lightning and induced electrical charges							CP 326		
22 Other effects									
23 Selection of fixings						BS 1494 : Parts 1 and 2			
24 Selection of sealants									
25 Selection of accessories									
26 Detailing requirements									
27 Quality control									ISO/R 390
28 Performance specifications: guide for drafting									
32 Safety	Health and Safety at Work Act, 1974 Factories Act, 1961 Construction (General Provisions) Regulations, 1961 Construction (Working Places) Regulations, 1966 Construction (Lifting Operations) Regulations, 1961 Asbestos Regulations, 1969								

A second consideration for small concentrated loads, e.g. ladders, is usually taken as 0.9 kN concentrated over an area measuring 125 mm x 125 mm. (See 6.1 and 6.2 of CP 3 : Chapter V : Part 1 : 1967.)

For roofs with a slope greater than 10° up to and including 30°, 0.75 kN/m² should be allowed and 0.9 kN over an area measuring 125 mm x 125 mm. (See 6.3 and 6.5 of CP 3 : Chapter V : Part 1 : 1967.) For slopes over 30° see figure 1.

Wind loading

For 53 % of the principal cities in the United Kingdom the basic speed is within the range 43 m/s to 47 m/s. For manufacturers designing a standard sheet, a value of 45 m/s should be used.

Wind loading should be calculated in accordance with CP 3 : Chapter V : Part 2, which has four basic requirements, wind speed and factors S_1 , S_2 and S_3 . For the purpose they can be assessed as follows:

- basic wind speed 45 m/s;
- topography factor S_1 of 1.0;
- ground roughness factor S_2 of 1.09;
- statistical factor S_3 of 1.0.

Designers using sheets for a particular purpose should determine purlin centres, fixings, etc., by reference to the anticipated wind speeds applicable to the location.

11.4 Loading on roofs and vertical sheeting to assist designers and specifiers

11.4.1 Dead load. A self mass of sheeting should be supplied by the manufacturer of the product used.

11.4.2 Uniformly distributed roof loading (other than wind loading). To take account of maintenance, access, snow, etc., uniformly distributed loading will vary with the pitch of the roof, which also varies the accessibility of personnel and should be as shown in figure 1.

11.4.3 Concentrated superimposed loading. Roofs should be designated to sustain the effect of uniform or concentrated loading whichever imposes the greater stress. The concentrated loads should be as follows.

- (a) *Roofs between 0° and 45° pitch.* Allowance should be made for a load of 0.9 kN acting vertically on a square with a 125 mm side measured on the roof slope.
- (b) *Roofs greater than 45° pitch.* No allowance need be made for concentrated loads.

11.4.4 Wind loads. Wind loads should be calculated in accordance with CP 3 : Chapter V : Part 2. The pressure coefficients vary with the shape and size of the building and are given in that code for normal rectangular buildings, multispan pitched roof buildings and buildings having

unusual plan shapes or large openings. The Building Research Advisory Service supply information to enable an assessment of wind loading to be made for buildings not covered by CP 3 : Chapter V : Part 2.

It should be noted that wind loads can often exceed the normal imposed loads; suction loads due to wind can be extremely high near the edges of roofs and walls, especially at overhanging eaves.

11.4.5 Loads on curved roofs. The imposed load on a curved roof should be calculated by dividing the roof into not less than five segments and then calculating the load on each, appropriate to its mean slope. Wind loads on curved roofs cannot be determined from CP 3 : Chapter V : Part 2 because surface roughness and discontinuities have such a marked effect upon the air flow and reference should be made to the Building Research Establishment Advisory Service.

11.4.6 Other loads. Where loading other than that specifically mentioned in 11.4.1 to 11.4.2 is anticipated, due allowance should be made. For example, impact load could be applied to vertical sheeting due to the stacking of goods or due to body impact. In this particular case the Agrément Board Partition Test may be used to assess the suitability of sheeting in this application.

12. Fire

12.1 Basic considerations. Buildings should comply with the governing regulations (see table 4), which are principally concerned with preventing loss of life. Appendix C is a guide to Part E of the Building Regulations, the most frequently used regulations.

Fire insurance companies, although concerned with loss of life from the financial aspect, are principally concerned with fire damage and may insist on additional measures to reduce this.

It is essential that the requirements for the behaviour of sheeting in fire are clearly established since they may be of overriding importance.

12.2 Loss of life. Governing regulations may restrict the use of sheeting according to its classification under one or more of the following.

- (a) *Non-combustibility.* Sheeting (including composite sheeting) may be classified 'combustible' or 'non-combustible' under BS 476 : Part 4. Combustible materials cannot be upgraded by impregnation or surface treatment.

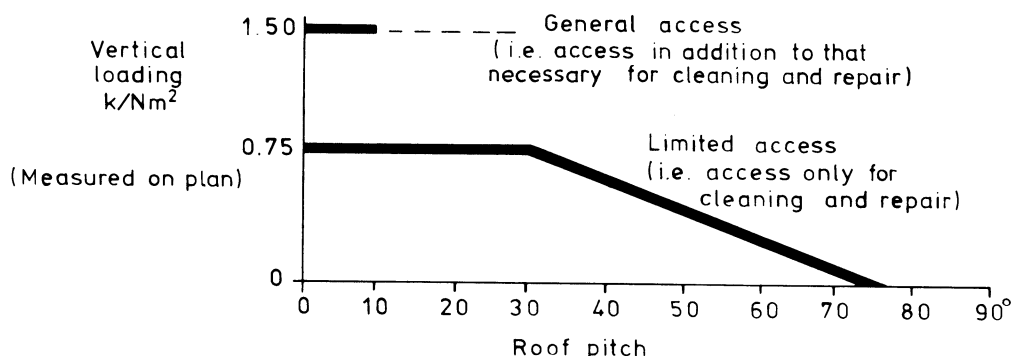


Figure 1. Uniformly distributed loads on roofs

(b) *Fire resistance period.* Complete elements of structure (i.e. including sheeting, fixing, rails, linings, etc.) should remain stable, resist penetration of flame and hot gases and limit the transfer of heat from one side to another (functions known as stability, integrity and insulation) for at least the fire resistance period required by the governing regulations, usually quantified as ½, 1, 2, 3, 4, or 6 h. The fire resistance period may be established by testing by the procedures specified in BS 476 : Part 8.

It should be noted that with many buildings clad with profiled sheeting a large percentage of the total area can be designated as 'unprotected areas' and freed from the necessity of having a specified fire resistance. Reference should be made to the relevant sections of the governing regulations for details.

(c) *Class of surface*

(1) *Class 0.* Governing regulations rate surfaces of materials as class 0 if they reach a certain performance under (e) below or are classified as non-combustible in accordance with BS 476 : Part 4.

(2) *Classes 1, 2, 3 and 4.* BS 476 : Part 7 classifies the flame spread across surfaces as class 1, class 2, class 3 or class 4.

These classifications are usually requirements for internal surfaces of walls and ceilings (or, where there is no ceiling, across the underside of the floor or roof deck). It should be noted that surfaces may be uprated by impregnation or the use of intumescent coatings but such treatment can adversely affect the strength, weathering and handling properties.

(d) *Roof designation.* Governing regulations do not generally require roofs to have fire resistance under (b) above but they may have to be designated in relation to external fire. Designations from AA through to DD are related to tests in BS 476 : Part 3. The first letter denotes fire penetration performance and the second denotes surface spread of flame performance (not related to performance under (c) above). The designation is accompanied by Ext. F (tested on the flat) or Ext. S (tested on the slope) and by X if any dripping occurred or mechanical failure or holes formed during the tests, i.e. Ext. F AC. X.

(e) *Fire propagation performance.* BS 476 : Part 6 classifies combustible materials with an index of performance (*I*) and subindices of performance (*i*₁, *i*₂, and *i*₃) according to their contribution towards the growth of a fire by heat generation.

(f) *Ignitability.* materials are classified in BS 476 : Part 5 as 'easily ignitable' (X) or 'not easily ignitable' (P). A report on ignitability must be included with results of tests carried out in accordance with BS 476 : Part 6 (see (e) above).

(g) *Fire performance of thermoplastics.* Plastics may be classified by their performance in various tests to BS 2782 according to their burning rate, (test 508A), their 'flammability' (tests 508C and D) and their 'softening point' (test 102C).

Sheeting may be required to:

(h) comply with specifications that are 'deemed to satisfy' the requirements of the classification; or

(i) be identical to sheets that have previously been tested satisfactorily to the British Standard fire tests (a) to (g) above, by an approved testing station or, in some cases by the Agrément Board; or

(j) if (h) and (i) are not applicable, sheeting may have to be submitted to the British Standard fire tests (a) to (g) above.

Where a fire occurs in a building it is often desirable for smoke and hot gases to be allowed to escape by the early operation of a special venting system. Where such venting is absent or inadequate and a fire develops, failure of the roof sheeting may assist in checking fire spread.

It should be noted that, where flammable materials are present, toxic gases may be produced on combustion.

Table 5 shows the classifications that are generally obtainable for each material.

12.3 Fire damage. In buildings where the risk of loss of life is small, governing regulations may permit large areas that have no fire resistance to have high rates of flame spread, to be insulated with heat-sensitive plastics foam or to be fitted with plastics materials that burn quickly and give off large volumes of smoke. In the event of fire, the extent of the damage might be considerable and could require the replacement of materials or stock a long way from the flames. This damage will not be limited to plastics: unprotected asbestos-cement may shatter and metal sheeting may distort when heated to high temperatures. As well as having concern for these aspects, insurance companies may insist on fire compartmentation additional to the requirements of the governing regulations.

The Fire Offices Committee has rules classifying buildings into groups. These groups are Classes I to III, which at present apply to certain buildings in the plastics industry, and Standards I to V, which apply to buildings in general. Early consultation with the fire insurers is strongly recommended to expedite implementation of the requirements for the various Classes and Standards. The Fire Offices Committee also has special requirements relating to roof-lights generally, including rooflights of plastics materials.

13. Thermal transmittance

The thermal transmittance, *U*-value, is a measure of the heat transfer from the air on one side to that on the other side of a wall or roof. The *U*-values should not be greater than those prescribed in the relevant governing regulations (see table 4).

The insulation required to maintain these *U*-values is intended to ensure economical use of fuel, to reduce condensation (see clause 16) and to minimize solar heat gain (see 17.3). The *U*-values prescribed at present are normally attained relatively easily but there is wide agreement to aim for better standards of insulation, particularly in habitable buildings.

The effect of ventilation in buildings should be considered; this is particularly important when considering dissipation of excess heat inside the building, caused by solar heat gain or by hot industrial processes.

The *U*-values of the chosen construction can deteriorate rapidly if water or condensation is allowed to soak the insulation.

Table 5. Typical classifications under BS 476 and BS 2782

Fire classification	Sheet material									
	Metal		Asbestos cement	Glass		GRP		UPVC		
	Aluminium	Steel (including stainless steel)	Unreinforced	Plain	Wired	Translucent	Opaque	Transparent	Translucent	Opaque
Roof designated	AA	AA	AA			AA to AC		Not designated but AA for reinforced		
Class of surface	0	0	0			1 to 3	1 to 3	Cannot be tested		
Combustibility	Non-combustible	Non-combustible	Non-combustible	Non-combustible	Non-combustible	Combustible	Combustible	Combustible	Combustible	
Ignitability	P	P	P	P	P					
Performance of plastics								*		

*Material to regulation E16(2) (a) available.

Metal sheets by themselves have virtually no thermal resistance and can normally be discounted in calculating the U -values of construction. Aluminium, however, has low emissivity surfaces while still bright and therefore radiates less heat and so makes a contribution to the U -value, particularly if combined with a cavity. Bituminous fibre and plastics also make an accountable contribution but it is still very small compared with the benefit derived from even a thin insulation board. It should be noted that the conductivity of plastics is sufficiently low for differential expansion problems to occur with very thick sheets (see 17.2).

The location of insulation and the selection of insulation material is a matter for individual choice. Insulation can be sandwiched between two sheets, prebonded to the inside face of profiled sheets or separately fixed over or under purlins. Insulation can also be placed in a suspended ceiling. Under-purlin lining and suspended ceilings may have advantages in controlling condensation if the internal temperatures change rapidly. Organic boards should not be used on exposed sites or in any location where there is danger of ingress of water.

Some data on the properties of many commonly used materials, together with guidance on the method of calculating U -values, is contained in 'Thermal Insulation of Buildings' published by HMSO, also in the 'Guide to Current Practice' of the Institution of Heating and Ventilating Engineers and in various codes of practice (see table 4). The thermal properties of some materials used for profiled sheets are shown in table 6, together with recommended tests.

Most governing regulations prescribe insulation values for dwellings, other residential buildings and industrial buildings. They do not prescribe insulation for unheated

buildings such as some farm buildings, boiler houses or buildings adequately heated as a result of a manufacturing process.

Table 6. Thermal properties of single sheets

Material	Conductivity (k), W/(m °C)*	Transmittance (U), W/(m ² °C) 'Normal exposure'
Aluminium	140 to 190	2.6 to 3.8
Hot-dip zinc-coated steel	46	8.5 (1.6 mm thick)
Stainless steel Austenitic Ferritic	16 23	No values available†
Asbestos cement	0.4 to 0.43	6.1 (6.0 mm thick)
Glass		7.0 (6.0 mm thick)
UPVC	0.25	6.5 (1.4 mm thick)
GRP	0.2 to 0.28	4.5 to 6.0 1.5 mm thick)
Bituminous fibre	0.06	

*Derived from W m/(m² °C).

†Bright surface finish will reduce heat loss by radiation. It would be expected that the U -value would be similar to the level for aluminium.

14. Acoustics

Buildings should comply with the governing regulations listed in table 4. The table also lists Building Research Establishment Digests and other HMSO publications that discuss ways of combating noise.

The acoustic properties of a cladding material are its ability to act as a barrier to the transmission of sound (sound insulation) and the efficiency with which it suppresses the reflections of any sound incident upon its surface (sound absorption).

It is possible to compare the acoustic properties of materials by sealing a sample of material in a suitable test wall between transmission and reception rooms. By using a variable audio-frequency oscillator and amplifier/loudspeaker unit to transmit sound through the material, and measuring the reception with a microphone and decibel meter, the sound reduction of the material at various frequencies can be determined.

The sound reduction achieved using single skin sheets is given in table 7. These values represent the reduction in airborne sound such as aircraft noise, and not impact noise such as rain. Rain noise may be reduced by a separate covering on the roof, such as a layer of gravel, an insulation layer or fine mesh aluminium screen above the deck or by a suspended ceiling beneath the deck.

The provision of a combined acoustic absorbent and thermal insulator, such as mineral wool slabs on the underside of the roof, will be of considerable benefit in reducing reverberant noise levels within the building when activities are noisy.

Table 7. Sound reduction of single sheets (mean values)

Material	Sound reduction
Aluminium	18 dB (1.6 mm thick)
Hot-dip zinc-coated steel	28 dB (1.6 mm thick)
Stainless steel	No information*
Asbestos-cement	26 dB (6.0 mm thick)
Glass	30 dB (9.0 mm thick)
UPVC	15 dB (1.4 mm thick)
GRP	
Bituminous fibre	20 dB (3.0 mm thick)

*The characteristics, for practical purposes, would be expected to be similar to those of mild steel.

15. Weathertightness

The degree of exposure, whether sheltered, normal or exposed (see DD 4), should be considered when designing for weathertightness. In general, weathertightness is concerned with the penetration of wind and rain through joints, etc. Workmanship is of prime importance as far as weathertightness is concerned. Particular care should be taken at laps, mitred corners and flashings and where fitting other accessories. It is considered that less penetration is likely to result from capillary action than from open joints, and for this reason sheets should be fitted as tightly as possible at the laps.

The principal factors that improve the weathertightness of uncovered sheeting are:

- an increase of roof pitch;
- an increase of end lap;
- an increase of side lap;
- sealing of end laps;
- sealing of end laps and side laps;
- reduction in spacing of seam fastenings (not applicable to asbestos-cement);
- increase in the width of troughs to improve water shedding;
- elimination or reduction of end laps by the use of longer sheets.

Recommendations for lapping sheets at various commonly used pitches for normal exposure are included in table 8.

When sheets are to be used in exposed conditions, if unusual profiles are to be used or if dust or vapour proof laps and fixings are required, the advice of the manufacturer should be sought. When large thermal movement of the sheeting is anticipated, the end laps should be increased and allowance made for expansion in the fastening, rather than placing reliance on sealants. The amount of side lap required will depend upon the profile. It may be necessary, in addition, to seal and seam fasten the side laps. For vertical sheeting a side lap of one corrugation is generally sufficient.

Where curved sheets are fitted, the amount of end lap should vary according to the pitch of the sheets at each lap.

Wherever possible, accessories should be chosen from stock patterns and carefully fitted to make a watertight joint; special fittings, if required, should also be designed to fit closely.

Where it is difficult to assess the weathertightness of sheeting it may be desirable to carry out tests, and attention is drawn to BS 4315 : Part 3.

Reference should be made to 23.6 for selection of sealing washers to be used with fixings.

16. Condensation

Condensation occurs when warm humid air is cooled below its dew point. Surface or superficial condensation occurs on a cold surface. Interstitial condensation occurs when humid air diffusing through a layer of thermally insulating material reaches a cold region.

Roofs are especially vulnerable to condensation. Warm humid air rises and is trapped at ceiling level, while the roof may be chilled below external air temperature by the loss of radiant heat to the sky at night.

If condensation problems are to be avoided, the first consideration should be to control the moisture excess in the interior air. If this contains no more moisture than the external air, condensation cannot occur.

At its simplest, there should be enough ventilation to carry away all the moisture that is evaporating within the building, otherwise it must condense somewhere. The practical problem is to provide the right amount of ventilation. Excess ventilation carries away heat and will chill the inside of the building. Ideally roof ventilators or extract fans should be automatically controlled, by comparing the dew point of the internal air with the external temperature. Otherwise, a simple hygrostat against the undersurface of the roof, set to turn on the fans at 80 % relative humidity, may be adequate.

Table 8. Recommended minimum end laps for normal exposure

ELS denotes end laps sealed; ALS denotes all laps sealed.

Minimum angle of lap to horizontal* (normally that of roof slope)	Asbestos-cement	Hot-dip zinc-coated steel†	Aluminium	GRP	UPVC	Bituminous fibre
75° to 90°	150 mm	100 mm	100 mm	100 mm	100 mm	100 mm
22½° to 75°	150 mm Classes 1, 2, 3 and 4	150 mm	150 mm	150 mm	150 mm	150 mm
20° to 22½°	150 mm ELS Classes 1, 2, 3 and 4 300 mm Classes 1, 2, 3 and 4	150 mm	150 mm	150 mm ALS	225 mm	150 mm
17½° to 20°	150 mm ELS Classes 1, 2, 3 and 4 300 mm Classes 1, 2, 3 and 4	150 mm	150 mm	150 mm ALS	225 mm	150 mm
15° to 17½°	150 mm ELS Classes 1, 2, 3 and 4 300 mm Classes 1, 2, 3 and 4	150 mm	150 mm	150 mm ALS	225 mm	150 mm
10° to 15°	150 mm ELS Classes 3 and 4 150 mm ALS Classes 1 and 2	150 mm ELS	225 mm ELS	Consult manufacturer	300 mm or 150 mm ALS	175 mm
5° to 10°	150 mm ALS Classes 3 and 4	Consult manufacturer	Consult manufacturer	Consult manufacturer	300 mm or 150 mm ALS	200 mm
Less than 5°	Consult manufacturer	Consult manufacturer	Consult manufacturer	Consult manufacturer	Consult manufacturer	Consult manufacturer

* Each range includes its lower limit.

† No information is available for stainless steel but, for practical purposes, the characteristics would be expected to be the same as those for mild steel.

Alternatively, air from ceiling level may be recirculated downwards through a dehumidifier. This avoids the waste of warm air and even recovers the latent heat of the water vapour.

Even with good control, some condensation is almost inevitable in winter in buildings where wet processes are used and when moist conditions occur during construction, e.g. during drying-out of cement or plaster. In these situations moisture-sensitive materials such as plasterboard and fibreboard should be avoided in the roof construction.

It is not practicable to keep humid internal air away from the roof structure by vapour barriers and sealed joints. A roof is usually subject to wind suction; air is likely to be sucked out between the laps, and replaced in the ceiling void by humid internal air. To reduce the moisture content of the air in the void, vents in the roof area should be provided to the exterior at opposite eaves.

Roof lights are most prone to condensation, and provision for drainage is advisable. Double lights will reduce the incidence of condensation.

Absorbent coatings may be useful to absorb temporary condensation during periods of excessive vapour generation, but such coatings are no substitute for adequate design.

17. Temperature

17.1 Design temperatures. The following is a guide to the temperature changes that can be expected in the United Kingdom.

(a) *Annual.* The annual range of external air temperature is generally about 30 °C; it is rarely more than 50 °C and the maximum recorded figure is 55 °C.

(b) *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 figure is 24 °C.

(c) *Surface.* The temperature of sheeting surfaces depends upon, in addition to the air temperature and direct radiation from the sun or other heat source, the thermal capacity of the sheeting, any thermal insulation

immediately behind the sheeting, the colour and reflectivity of the exposed surface, the temperature behind the sheeting and the cooling effect of convected air. The surface temperature ranges shown below will rarely be exceeded during any 24 h period. These ranges are for the summer period since the range is normally greatest in the summer.

- + 40 °C down to + 10 °C for clear glass;
- + 45 °C down to + 10 °C for asbestos-cement;
- + 45 °C down to + 10 °C for coloured bituminous fibre;
- + 45 °C down to + 10 °C for hot-dip zinc-coated steel;
- + 60 °C down to + 10 °C for stainless steels;
- + 50 °C down to + 10 °C for plain aluminium;
- + 50 °C down to + 10 °C for transparent plastics;
- + 60 °C down to + 10 °C for pale opaque plastics;
- + 60 °C down to + 10 °C for pale-coloured metal;
- + 70 °C down to + 10 °C for medium-coloured metal;
- + 80 °C down to + 10 °C for dark-coloured metal;
- + 90 °C down to + 10 °C for black plastics.

The surface temperature should be considered with regard to thermal movement (see 17.2) and other thermal effects limiting use (see 17.4).

Table 9 gives, for various materials, the maximum temperature ranges likely to occur in roof sheeting during any 24 h period. Corresponding changes in length of 8 m sheets are also given, together with advice on their fixing.

It is to be noted that the temperature ranges listed in the table are all bounded by a (summer) minimum of 10 °C. It may be desirable to take account of this during installation (see section four).

17.2 Expansion and contraction

17.2.1 Flexible sheets (steel, aluminium, plastics, etc.).

Where sheets less than 8 m long are used in a temperate climate such as that of the United Kingdom, thermal movements lengthwise can either be ignored or be accommodated by oversize holes or flexible fixings (see table 9). Sheets more than 8 m long should be secured by non-rigid fixings. Thermal movement across the width of the sheet is accommodated by the flexibility of the profiled cross section.

17.2.2 Inflexible sheets (asbestos-cement, glass, etc.).

Thermal movement along the length of the sheet should be accommodated by non-rigid fixings (see clause 23). Thermal movement across the sheet should be accommodated by the provision of a movement joint for any continuous run of sheeting over 45 m and under 75 m, and one further joint for each additional 30 m (or part thereof). Joints should be formed wherever possible with the special accessories that are available for many types of sheet (see clause 26).

17.2.3 Laminated panels. With laminated panels, problems may arise from differential expansion of the layers.

17.2.4 Thin sheets. Thin sheets will have low thermal capacity and thus will expand and contract with daily temperature change more quickly than thicker sheets. The experienced manufacturer is best able to estimate the proportion of movement that can be absorbed by the sheet flexing as against movement at the fixing. Annual changes in temperature are likely to be accommodated by creep in the materials, and special provision is unlikely to be necessary.

Table 9. Temperatures, sheet movements and fixing recommendations

Material	Maximum 24 h temperature change (°C)	Coefficient of linear expansion per °C	Approximate maximum 24 h change in length of 8 m sheet (mm)	Recommendations for fixing sheets up to 8 m long
Aluminium (mill finish or light-coloured)	50	23×10^{-6}	10	No special requirement
Aluminium (dark-coloured)	70		13	Oversize holes or non-rigid fixings
Steel (hot-dip zinc-coated or light-coloured)	50	12×10^{-6}	5	No special requirement
Steel (dark-coloured)	70		7	
Stainless steel	50 to 70	—	11 (ferritic grades) 18 (austenitic grades)	No special requirement
Asbestos-cement	40	8×10^{-6}	3	Non-rigid fixings
Glass (clear)	30	8×10^{-6}	2	Non-rigid fixings
GRP (light-coloured)	50	18×10^{-6} to 32×10^{-6}	8 to 13	No special requirement (sheet very flexible)
UPVC (light-coloured)	50	50×10^{-6} to 70×10^{-6}	20 to 28	Non-rigid fixings
Bitumen fibre	40	*	—	No special requirement
Any dark-coloured material	70 to 80	—	—	Generally, non-rigid fixings

17.3 Solar heat gain

17.3.1 General. Most of the sun's heat arrives as short wavelength radiation corresponding to visible light, which heats the internal air of a building indirectly either by heating the roof structure or, after passing through glazing, by heating any unshaded interior surfaces. In hot weather this can lead to considerable discomfort; apart from the heating effect, a layer of warm air just below a hot ceiling reduces air circulation. Solar heat gain is mainly through the roof.

17.3.2 Unglazed areas. An outer surface of low absorptivity (pale colours and bright aluminium, which reflect most solar radiation) will substantially reduce solar heat gain.

In general, bright metallic surfaces reflect infrared radiation from heating appliances very well but reflect solar radiation to a lesser extent. They radiate less heat and tend to remain hotter than dull surfaces.

Insulating a roof structure is another way of reducing solar heat gain (and reducing heat loss during colder periods, see clause 13). However, it may lead to over-heating of the upper surface and thus more rapid deterioration of that surface (see 17.4) unless a surface of low absorptivity is used to reflect most of the solar radiation.

Reflective efficiency depends upon maintaining the light colour of the surface. Pollution deposits, leaves, dust and moss growth will darken the surface. Such roofs should be designed to be well washed with rain or provided with regular maintenance cleaning to retain reflectivity (see clause 34).

17.3.3 Glazed areas. Where large areas of translucent or transparent sheeting are used, solar heat gain is likely to over-heat the building, i.e. at daylight factors above 5 % which would, in shed-type roofs, be produced by an area of glazing as small as 10 % plan area.

Apart from altering the extent and location of the glazing, solar heat gain may be reduced by providing movable blinds, heat-absorbing glass sheeting, diffused sheeting or additional ventilation.

For a given light transmission, the solar heat gain within a building will be greater with plastics than with glass sheeting.

Glazing should also be considered with respect to its light transmission (see clause 18), its thermal insulation (see clause 13) and condensation (see clause 16).

17.4 Temperature limitations. The temperature ranges in which sheeting may safely be used are given in table 10 for various materials and finishes; comments are included on the effects of temperatures outside the safe ranges.

Table 10. Temperature limitations

Sheet material		Safe temperature range (°C)	Comments
Aluminium		−80 to 10	Above 100 °C gradual loss of strength. No embrittlement or other adverse effects (at low temperatures)
Hot-dip zinc-coated steel		−20 to 200	
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
Metal-coated metal		*	
Organic-coated steel or aluminium	Acrylics Alkyds	−50 to 100	Above safe range coating discolours and deteriorates
	PVC organisol solution vinyl PVC plastisol	−50 to 80	
	Fluorides PVF [†] , PVF2, PVF2 acrylic	−50 to 100	Below safe range coating becomes susceptible to mechanical damage
	Asbestos/bitumen steel	* to 60	
	Asbestos-impregnated metal with polyester resin finish	−20 to 65	Above 65 °C discoloration may occur Below −20 °C coating becomes brittle
	Other	–	Available for special applications: consult manufacturer
Asbestos-cement		−25 to 200	
Glass		*	
Plastics	GRP	−20 to 65	Above 65 °C discoloration may occur Below −20 °C resin may become brittle
	UPVC	−20 to 65	Above 65 °C softening and creep occurs. Below −20 °C embrittlement occurs. Only light-coloured sheets are recommended
Bituminous fibre		*	Below −35 °C becomes brittle

* Information not yet available.

† Polyvinyl fluoride.