

Code of practice for

Flat roofs with continuously supported coverings

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Department of The Environment (Building Research Establishment)	Lead Development Association
Felt Roofing Contractors Advisory Board	Metal Roof Deck Association
Fibre Building Board Development Organization Ltd.	Structural Insulation Association
	The Wood Wool Slab Manufacturers Association
	Timber Trade Federation

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Foreword

This British Standard code of practice has been prepared under the direction of the Elements and Components (of diverse materials) for Buildings Standards Committee. This code deals with the design of flat roofs combining various types of continuously supported roof coverings, insulating materials and structural decks.

While other codes of practice and standards dealing with various roof coverings, insulation, ceilings and structural decks are available separately, this code deals with the design, performance requirements and construction of the flat roof as a whole.

Experience has shown that condensation is one of the principal causes of failure of flat roofs. Furthermore, this risk has increased in recent years, following the progressive raising of thermal insulation standards and the measures adopted to improve energy conservation in the design and operation of buildings, which have combined to increase indoor vapour pressures and temperatures. Particular attention is therefore given in this code to the prediction and control of condensation and to the importance of careful construction to avoid trapped water.

BS 5250 covers basic data for the control of condensation in dwellings. The section on condensation in this code deals in a more comprehensive manner with warm roofs for all buildings.

Recommendations for the use of wood chipboard in flat roofs are given in BS 5669. It is intended that, when similar guidance on the use of other flat roof decking materials is available, all such guidance will be transferred to this code.

It has been assumed in drafting this code that the design of flat roofs is entrusted to competent designers and that construction is carried out under the direction of qualified supervisors.

The numbers in square brackets in the text of this standard relate to the bibliographic references in Appendix D.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

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Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 36, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

Section 1. General

1 Scope

This code gives recommendations on the design and application of flat roofs with continuously supported roof coverings. Weathertightness, drainage, thermal and sound insulation, condensation control, structural support, fire precautions, maintenance and repair are considered.

Flat roofs are defined as those with roof coverings at slopes not exceeding 10° to the horizontal. The recommendations given in this code may also be applied to roofs with slopes marginally greater than 10° provided the design conditions are similar, but for steep roofs many of the recommendations may not apply.

This code does not deal with roofs with self-supporting coverings, nor with those for special purposes such as roof gardens, surfaces subject to heavy traffic, cold stores, and high temperature enclosures, nor with slated or tiled roofs.

NOTE The titles of the publications referred to in this standard are listed on the page 36.

2 Definitions

For the purposes of this British Standard, the definitions given in BS 2717 apply.

3 Types of flat roof

A flat roof is typically a multilayer construction of roof covering, thermal insulation and structural deck, incorporating drainage outlets and gutters. In addition, it may incorporate vapour barriers, screeds, surface paving, surface reflective treatment, ventilators, ceiling materials and attachments such as handrailing, gantry rails and lightning conductors.

Flat roofs may be divided into the following types, according to the position in which the principal thermal insulation is placed (see Figure 1).

- a) The cold roof (also known as cold deck), in which the principal thermal insulation is placed at or immediately above the ceiling, resulting in the roof covering and structural deck being substantially colder in winter than the interior of the building.
- b) The warm roof (also known as warm deck sandwich construction), in which the principal thermal insulation is placed immediately below the roof covering, resulting in the structural deck and ceiling being at a temperature close to that of the interior of the building.
- c) The inverted roof (also known as warm deck inverted construction, or externally insulated roof, or protected membrane roof), in which the principal thermal insulation is placed above the roof covering, resulting in the roof covering, structural deck and ceiling being at a temperature close to that of the interior of the building.
- d) Hybrid types of flat roof, combining the features of two or more of the roof types described above, are sometimes used. Examples include structural decks with high thermal insulating properties combined with additional insulation, and existing roofs to which thermal insulation is added. Hybrid roofs are not covered in this code; however, such roofs should in principle be designed to ensure that adequate condensation control is achieved.

Further guidance on factors affecting the choice of roof type is given elsewhere [1, 2].

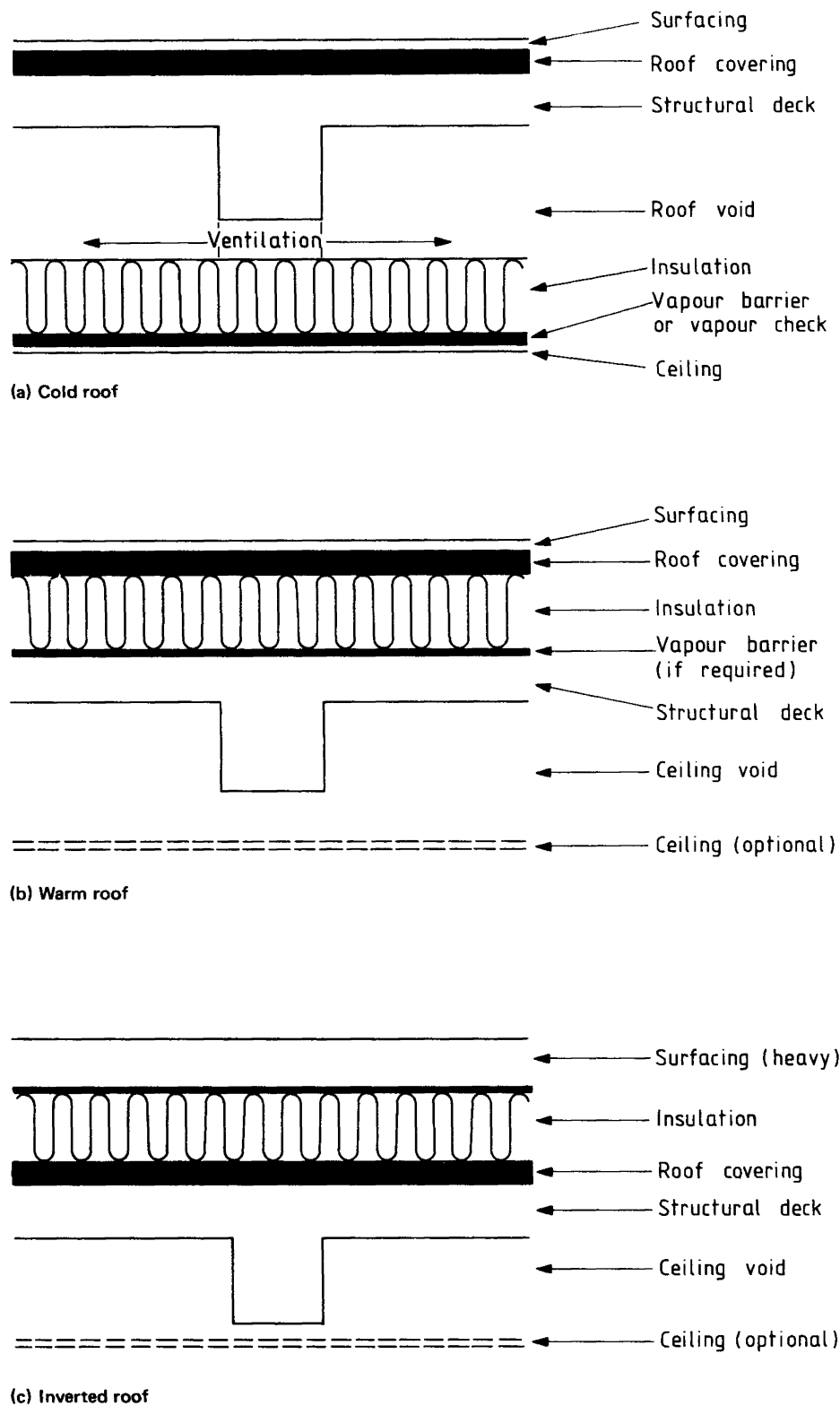


Figure 1 — Types of flat roof (diagrammatic only)

Section 2. Materials and components

4 Specifications for materials and components

Recommendations for materials and components that are covered by British Standard specifications and codes of practice are included in this section. For materials and components not so covered, evidence of their satisfactory performance and suitability for use in particular conditions should be obtained and carefully assessed. For certain materials and components, guidance is available from Agrément certificates.

5 Roof coverings

Recommendations for fully supported roof coverings and their conditions of use are given in the following codes of practice.

Material	Code(s) of practice
Lead	CP 143-11
Zinc	CP 143-5
Copper	CP 143-12
Aluminium	CP 143-15
Semi-rigid asbestos bitumen (SRAB)	CP 143-8 and CP 143-16
Built-up bitumen felt	CP 144-3
Mastic asphalt	CP 144-2 and CP 144-4

6 Structural components

6.1 Timber and boarding. Timber and timber boarding should comply with the requirements and recommendations of the following British Standards.

Material	British Standard(s)
Preferred dimensions for softwood	BS 4471-1 and BS 4471-2
Timber species and structural design	CP 112-2
Preservative treatment	BS 5268-5
Plywood	CP 112-2, BS 1088, BS 1455
Woodwool slabs	BS 1105
Fibre building boards	BS 1142
Wood chipboard	BS 5669

6.2 Troughed metal or asbestos-cement decks.

Proprietary systems of troughed decks designed to be used in combination with continuously supported roof coverings should be checked for evidence of satisfactory performance (see clause 4, **16.2.2** and **16.3.2**). Troughed or other profiled decks designed to act as self-supporting roof coverings are normally unsuitable for combining with continuously supported roof coverings.

6.3 Steel structures. Recommendations on the structural use of steel are given in BS 449-2 and Addendum No. 1 to BS 449-2.

6.4 Aluminium structures. Recommendations on the structural use of aluminium are given in CP 118.

6.5 Concrete structures. Recommendations on the structural use of concrete are given in CP 110, CP 114, CP 115 and CP 116.

7 Thermal insulation

The following table lists the common thermal insulation materials and the relevant specifications.

Material	British Standard
Screeds	
Insulating screeds	No BS
No-fines concrete	BS 882-2
Lightweight aggregates	BS 3797
Foamed slag	BS 877-2
Clinker aggregate	BS 1165
Mats, boards and blocks	
Expanded polystyrene board	BS 3837
Rigid urethane foam	BS 4841
Isocyanurate foams	No BS
Resin bonded mineral fibre slabs	No BS
Mineral fibre roof mats	BS 5803
Cork slab	No BS
NOTE Slabs normally consist of pure granulated cork compressed into slab form, steam baked and held together by the natural cork gum.	
Woodwool slabs	BS 1105
Fibre building boards	BS 1142
Cellular glass	No BS

In addition, various loose fill and in situ foamed insulation may also be suitable as thermal insulation, but these are not covered by British Standards.

8 Vapour barriers and vapour checks

8.1 Vapour barriers. A vapour barrier may consist of one or more layers of sheet material such as plastics sheet, aluminium foil, mastic asphalt or roofing felt. Alternatively, the thermal insulation or structural deck may, according to the design, act as a vapour barrier. Vapour barriers are normally regarded as materials having a vapour resistance of not less than 15 MN s/g ($\mu L = 2.88$ m). However, the most commonly-used materials have a vapour resistance in excess of 200 MN s/g ($\mu L = 38$ m).

Vapour barriers should be durable against water vapour and resistant to perforation. Where the structural deck is air-permeable, the vapour barrier and its fixings should have adequate strength to resist wind uplift (see 16.2.1). For warm roofs, a vapour barrier consisting of a coated bituminous roofing felt complying with BS 747 and weighing not less than 14 kg per 10 m² roll or a metal-cored vapour barrier felt or a 12 mm thick one-coat mastic asphalt is often used (see CP 144-3 and CP 144-4).

8.2 Vapour checks. Vapour resistant materials of low diffusion resistance, particularly where the reduced resistance through vapour leakage at joints and perforations cannot be avoided in practice are known also as vapour checks.

8.3 Effective vapour resistance. Vapour leakage through unsealed joints or perforations reduces significantly the effective vapour resistance of vapour barrier materials.

To achieve reliable high vapour resistance, the vapour barrier should be laid on a smooth, solid substrate. In the case of discontinuous substrates such as troughed decks, a high vapour resistance may be achieved by using a high strength, high performance roofing felt together with a second layer of roofing felt complying with BS 747 to ensure full sealing of lap joints and to minimize the risk of damage.

In cold roof construction, it is normally possible only to provide a vapour check even when materials having a high vapour resistance are used, because of unavoidable leakages at joints and perforations.

Where necessary, the effect of vapour leakage should be taken into account in determining the effective vapour resistance (see B.3).

The vapour diffusion properties of roofing materials may be determined by the methods of test described in BS 2972, for inorganic thermal insulation materials; BS 3177, for flexible sheet materials; BS 4370-2, for rigid cellular materials.

9 Rooflights

Prefabricated rooflights are not covered by British Standards. Manufacturers should provide evidence of satisfactory performance in regard to weathertightness, strength, light transmission, thermal insulation, fire rating and method of fixing (see clause 21).

10 Roof surface protection

Recommendations for certain types of roof for surface protection against damage from traffic and to provide solar reflectivity are given in the relevant codes of practice for roof coverings.

Solar reflective treatments include overlaid light-coloured mineral aggregate, suitable solar reflective paints, metal foil facings, or asbestos-cement or concrete tiles.

The extent and nature of the traffic to which the roof would be subjected (including traffic for maintenance purposes) should be established at the design stage and an appropriate wearing surface provided. Suitable wearing surfaces include asbestos-cement or concrete tiles, concrete paving slabs or, in the case of mastic, asphalt, an additional course of paving grade material.

For ballasting inverted roofs, loose laid concrete paving slabs complying with BS 368, or large aggregate should be used. A small gap should be left at vertical faces, the gap being filled with gravel or other suitable material. The dead weight (and, for aggregate, the aggregate size) should be adequate to prevent removal or displacement by the combined effects of flotation by immersion in water, flowing water and wind, of both the insulation and the surfacing. The aggregate should be not less than 19 mm nominal size graded as "single-sized aggregate" as defined in BS 882.

11 Ceilings

Ceiling materials should comply with the requirements and recommendations of the following British Standards.

Material	British Standard
Plaster (in situ)	BS 5492
Gypsum plasterboard	BS 1230
Fibre building boards	BS 1142
Plywood boards	CP 112-2
Various materials for suspended ceilings	CP 290

12 Rainwater goods

Pre-formed rainwater gutters, pipes and accessories should comply with the requirements and recommendations of the following British Standards.

Material	British Standard
Aluminium	BS 2997
Asbestos cement	BS 569
Cast iron	BS 460
PVC, unplasticized	BS 4576
Galvanized	BS 1091
Wrought copper and wrought zinc	BS 1431

Gutters that are formed in situ in the roof covering material are covered in the relevant codes and standards listed in clause 5.

Recommendations for the selection and design of rainwater goods are given in CP 308.

13 Lightning conductors

Recommendations for the design and choice of materials for lightning conductors are given in CP 326.

Section 3. Design

14 General considerations

The roof covering, including joints, parapets, abutments, gutters and outlets, should remain watertight under the external action of rain, snow, ice, dead and imposed loads, wind loads, solar and night radiation, and the internal environment of the building. Reference should be made to the appropriate codes of practice for the detailed design and application of alternative roof covering materials (see clause 5).

Adequate drainage should be provided to avoid ponding of rainwater by laying the roof covering to falls in one or more directions, directing the run-off to outlets, gulleys and gutters of sufficient capacity.

Except for unheated buildings, thermal insulation is required for thermal comfort, energy conservation and to satisfy statutory requirements. Thermal insulation acting in conjunction with other elements of the roof induces temperature and water vapour pressure differences across the roof layers according to their thermal and vapour resistances and their relative positions; these differences may result in condensation within the roof or on the ceiling. To avoid harmful condensation, design for thermal insulation performance should always be carried out together with an analysis of condensation risk, with particular attention to the positioning of insulating materials and, where necessary, providing vapour barriers or vapour checks, ventilation and choice of materials resistant to the effects of condensation.

The structural deck and its connections to the building should be of adequate strength and stiffness. Adequate falls for the roof covering should be maintained for the most unfavourable dead and imposed load combinations.

Thermal and moisture movements and their effect on the roof covering, thermal insulation, ceiling and structural supports should be considered. Protective treatments against corrosion or biological attack may be required. Fire precautions and sound insulation measures may be necessary.

The satisfactory performance of a flat roof is also critically dependent on careful and competent construction, particularly in avoiding or minimizing the amount of trapped water within the roof. Where necessary, measures for drying out the roof during and after construction should be taken.

The design of the roof should be considered in relation to its compatibility with the building as a whole.

15 Falls

15.1 General. Flat roofs should be designed to avoid ponding of water, except that some degree of temporary flooding during heavy storms may be permitted where the roof is designed for such conditions (see CP 308).

15.2 Minimum falls. The minimum finished falls, as given in the relevant codes of practice for roof coverings, are given in Table 1.

Table 1 — Minimum finished falls

Covering	Minimum finished fall at any point
Aluminium, copper and zinc	1 : 60
Lead	1 : 80
Mastic asphalt or built-up bitumen felt	1 : 80
Semi-rigid asbestos bitumen sheet:	
roll cap system	1 : 60
rib system	1 : 75

15.3 Design falls. To ensure that the minimum finished falls are achieved, allowance should be made for deflection of the structural deck under dead and imposed loads and for construction inaccuracies and thus the falls assumed for design should be steeper than the finished falls. The design falls should be determined by considering the overall and local deflections, the direction of falls and type of roof covering, but in the absence of detailed analysis, falls of twice the minimum finished falls should be assumed for design purposes.

15.4 Direction of falls. The arrangement of falls depends on the roof area and shape, the drainage capacity and position of gutters and outlets (see clause 25 and CP 308). Where two-directional falls intersect, the minimum finished fall should be maintained in the mitre. For long buildings and where mining subsidence precautions are necessary, the roof area may require to be subdivided between movement joints with separate areas of falls.

15.5 Formation of falls

15.5.1 Sloping deck. For roof coverings with a simple one-directional fall draining to one edge or two opposite edges, the fall may be formed by sloping the upper surface of the supporting structure, e.g. by constant depth beams or joists laid at a slope (giving a sloping soffit) or tapered beams with horizontal soffits. In timber construction, falls may be formed by tapered timber firrings. The minimum depth of firrings should be not less than 20 mm. Alternatively, timber purlins of varying depth or packed to falls, may be used (see also A.2.7).

15.5.2 Screed. In concrete construction, falls are generally provided by a screed laid over the concrete deck. Lightweight screeds also provide thermal insulation.

Owing to the risk of water absorption during construction, dry and wet screeds, except for bitumen bonded screeds, should not be used with timber structural decks, nor placed above a vapour barrier.

15.5.3 Wet screeds. Wet screeds should be of the types listed in Table 2.

Table 2 — Wet screeds

Type	Approximate density
	kg/m ³
Cement/sand	2 000
Cement/sand on hollow blocks	varies
No-fines concrete ^a	1 800
Lightweight aggregate concrete ^a	1 100
No-fines lightweight aggregate concrete ^a	700
Air entrained cement/sand	550

^a Requires a cement/sand topping screed of not less than 13 mm thick.

Wet screeds should normally be not less than 50 mm thick and not more than 200 mm thick (including the topping screed). Precautions should be taken in laying to control shrinkage cracking by laying the screed in bays with a length or width not exceeding 3 m.

15.5.4 Dry screeds. Dry screeds should be of dense or lightweight aggregate either bitumen bound or loose laid, together with a sand/cement topping screed, and should be laid to falls in one or both layers.

15.5.5 Pre-formed insulation boards. Pre-formed insulation boards, particularly those of foamed plastics, should be individually formed or pre-cut to one- or two-directional falls or mitres.

16 Roof structure

16.1 Loading

16.1.1 Dead and imposed loads. Dead and imposed loads should be calculated in accordance with the recommendations of CP 3:Chapter V-1.

In calculating the amount of dead load to be allowed for in the design, provision should be made for additional or different roof coverings that may be used in subsequent repairs.

The amount of imposed load varies according to use: where no access is provided other than that necessary for cleaning and repair; where access is provided in addition to that necessary for cleaning and repair; and where the roof is used for special purposes such as car parking or crowd loading. Consideration should also be given to the likelihood of change of use.

16.1.2 Wind loads. Wind loads appropriate to the exposure, roof height, building shape, and location in the UK should be calculated in accordance with the recommendations of CP 3:Chapter V-2. Except for temporary roofs, wind loads should be calculated on the basis of the statistical factor $S_3 = 1.0$. The gust-averaging period to be used should be class A for the roof covering and its immediate fixings and rooflights, and class B or class C (according to size of building) for the structural deck.

Uplift forces are developed over the whole flat roof area by wind action, with local uplift pressures on the edge strips and around obstructions (such as rooflights and flues) of up to two-and-a-half times the pressure in the general roof areas. In addition, internal pressures are developed on the underside of the roof by wind action, which may be upwards or downwards, according to the internal air flow balance through openings in the building. Further guidance on suitable pressure coefficients for internal surfaces is given in CP 3:Chapter V-2 and elsewhere [3].

16.2 Strength

16.2.1 Roof covering. The roof covering should have adequate strength or be otherwise protected to resist, without failure and perforation, the dead and imposed loads, wind loads and sharp point loads such as foot traffic and stone chippings.

The resistance to wind uplift may be calculated from the strength characteristics of the bonding agent or fixing devices and from the dead weight resistance of the covering.

If the roof covering and supporting deck are substantially airtight, sufficient vacuum resistance against wind uplift may be developed. Imperforate concrete decks and sand/cement screeds should normally be sufficiently air-impermeable, but boarded constructions with square-edged or tongued joints not otherwise sealed should be regarded as wholly air-permeable. For air-permeable decks, the wind uplift pressure is exerted on one or more layers of the roof that are substantially air-impermeable, such as the vapour barrier or roof covering; in such cases, the wind uplift pressure (less the appropriate dead weight) should be resisted by adequate mechanical or bonded connections between the air-impermeable layer and the deck.

16.2.2 Structural deck. The structural deck should be designed in accordance with the recommendations of the following British Standards.

Material	British Standard(s)
Aluminium	CP 118 ^a
Concrete:	
reinforced	CP 110, CP 114
prestressed	CP 110, CP 115
precast	CP 110, CP 116
Steel	BS 449-2, Addendum No. 1 to BS 449-2 ^a
Timber	CP 112-2
^a See also 6.2.	

Roof structural members should be designed for the most unfavourable combination of dead, imposed and wind loads. In addition to the design of individual structural elements, the roof should have:

- adequate stability under stress reversal that may occur assuming maximum wind load and zero imposed load (and minimum dead load during construction);
- adequate resistance against wind uplift;
- adequate lateral stability in itself and as part of the building, particularly where the roof deck is required to provide lateral support to the columns or walls, or act as wind bracing.

16.3 Stiffness

16.3.1 Roof covering. The roof covering should be isolated from movement or be capable of accommodating, without failure, deformations induced by the dead, imposed and wind loads, and thermal, moisture and structural movements.

16.3.2 Structural deck. The structural deck should be of such stiffness that, under the dead and imposed loads specified for the deck, the minimum falls on the roof covering are maintained; the roof covering, ceiling, partition walls, doors and windows are not damaged or unsightly; and excessive vibration does not occur. Adequate stiffness against wind load should also be provided, but the effect of wind load on maintaining minimum falls may be ignored.

No specific recommendations can be given for the maximum permissible deflection of structural decks, as this will depend on the type of structure, roof covering, finishes, ceiling and other building elements to which the roof relates. In Table 3 the normally permissible deflections stated in the relevant standards or codes of practice are given as a guide.

Table 3 — Permissible deflections

Material	Permissible deflection as a multiple of the span
Aluminium	1/200 to 1/360 ^a
Concrete	1/250
Steel	1/240 to 1/360 ^a
Timber	1/333

^a According to type of structural element and finishes.

For boarded construction, the local deflection of the boarding between joist supports should be taken into account and, where relevant, superimposed on the deflection of the supporting joists.

Structural elements such as lattice beams, trusses and concrete beams or slabs may be pre-cambered to counteract part of the deflection under load. In such cases, the maximum permissible deflection may, at the discretion of the designer, be based on the imposed loads and wind loads only. The pre-camber should normally not exceed the predicted dead load deflection, to avoid excessive gaps between the ceiling and the internal walls.

Prestressed concrete beams or slabs normally develop camber induced by prestressing forces. Where high prestress at large eccentricity is used and the ratio of imposed to dead loads is large, such camber may continue to increase over a long period. Care should be taken in design to avoid this effect.

16.3.3 Movement joints. Large roofs may need to be subdivided into smaller independent areas, separated by gaps to accommodate thermal, moisture and structural movements. The maximum length between movement joints varies with the temperature range, the coefficient of thermal expansion, the flexibility of the roof covering, structural deck and walls, and the thermal response rate of the building. Movement joints in the roof are often arranged to coincide with similar joints in the walls, or vice versa. Special provisions may be required for structures subject to significant differential settlement or mining subsidence.

Movement joints should be of the twin kerb upstand type, positioned at the high point of falls. Flush movement joints in mastic asphalt or built-up bituminous felt should be avoided where possible, but where they are unavoidable, care should be taken to ensure that a secure connection can be made between the joint and the roof covering.

The roof deck on either side of the movement joint should be adequately stiffened to avoid excessive differential deflection.

Further guidance on thermal and moisture movements and stresses is given elsewhere [4, 5].

The unrestrained thermal and moisture movements of certain structural deck materials are given in Table 4.

16.4 Differential movement between roof covering and deck. In addition to the provisions in 16.3.3 for movements of the roof as a whole, differential movements between the roof covering and substrate (or the overlaid insulation in inverted roofs) should be taken into account in design to avoid failure of the roof covering.

Such differential movements are mainly thermally induced, the outdoor surface of the roof being exposed to daily and seasonal fluctuations of temperature of the air, to wind, and to solar and night sky radiation effects, while the lower layers of the deck remain at temperatures closer to the relatively steady indoor conditions. Thus, differential movement and stress reversals occur frequently in the roof covering.

The amount of differential movement increases with the differences in temperature, coefficient of linear expansion and thermal mass between the roof covering and adjacent layers. If differential movement is partly or wholly restrained by connecting the adjacent layers together, bending, compression or tension and shear stresses are induced in the materials and connections; with intermittent connections, such stresses are likely to be reduced but less uniformly distributed.

Sheet roof coverings (metal and semi-rigid asbestos bitumen) can normally accommodate differential movements because of the deformability of the closely spaced seam joints and clips. Detailed recommendations given in the code of practice for the relevant sheet roof covering should be followed.

For mastic asphalt roof coverings, independent movement of the mastic asphalt should be allowed to occur as freely and uniformly as possible by providing a loose laid isolating membrane under the mastic asphalt (see CP 144-4).

Built-up bituminous felt roof coverings are normally intermittently or continuously bonded or mechanically fixed to the substrate and thus bending, compression or tension and shear stresses are developed in the roof covering and connections due to the restraint imposed. The roof covering should be capable of resisting such frequent movements and stresses for its design life and the severity of movements or stresses controlled by appropriate methods of bonding or fixing and the provision of suitable expansion joints where necessary (see CP 144-3).