

Structural use of timber —

Part 3: Code of practice for trussed rafter roofs

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Committees responsible for this British Standard

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- Building Employers' Confederation
- Chartered Institute of Building
- Department of the Environment (Building Research Establishment, Princes Risborough Laboratory)
- Department of the Environment for Northern Ireland
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- Department of the Environment (Property Services Agency)
- Greater London Council
- Health and Safety Executive
- Incorporated Association of Architects and Surveyors
- Institute of Clerks of Works of Great Britain Inc.
- Institute of Wood Science
- Institution of Civil Engineers
- Institution of Structural Engineers
- International Truss Plate Association
- National House-building Council
- Royal Institute of British Architects
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- Timber Trade Federation
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Foreword

This Part of BS 5268 has been prepared under the direction of the Civil Engineering and Building Structures Standards Committee.

Other Parts of this British Standard code of practice are as follows.

- *Part 1: Limit state design, materials and workmanship (for later publication);*
- *Part 2: Code of practice for permissible stress design, materials and workmanship;*
- *Part 4: Fire resistance of timber structures;*
- *Section 4.1: Method of calculating fire resistance of timber members;*
- *Section 4.2: Method of calculating fire resistance of timber stud walls and joisted floor constructions¹⁾;*
- *Part 5: Preservative treatments for constructional timber²⁾;*
- *Part 6: Code of practice for timber frame wall design¹⁾;*
- *Part 7: Recommendations for the calculation basis for span tables¹⁾.*

Since the publication of the first code of practice for trussed rafters, increases in the levels of roof insulation have made it necessary to reconsider the environmental conditions which may exist within the roof space, to avoid possible problems associated with condensation. As a result new clauses have been introduced dealing with thermal insulation and recommending minimum levels of ventilation. Changes in the design of compression members resulting in the method recommended in BS 5268-2 have also been considered with regard to the design of trussed rafters and together with other amendments which experience has indicated are necessary, have resulted in a revised method of design. In addition, to avoid problems which previously have arisen with roofs in service, a new section has been included dealing with the design of trussed rafter roofs as a whole. In particular, the areas of responsibility of the trussed rafter designer and the building designer have been defined and specific recommendations are given for bracing to ensure overall roof stability. Finally, the span tables in the first code of practice for trussed rafters were for timber stress graded in accordance with rules which have been superseded by BS 4978. New span tables, based on experience gained from trussed rafters in service together with extensive testing of trussed rafters fabricated with M50 and M75 stress graded timber, have therefore been included. Span tables for GS graded timber as well as for North American timber sizes have also been included in this code of practice.

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.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 50, 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.

¹⁾ In preparation.

²⁾ Revision in preparation.

Section 1. General

0 Introduction

For the purposes of this Part of BS 5268 trussed rafters are assumed to be light-weight triangulated frameworks, spaced at intervals generally not exceeding 0.6 m and made from timber members of the same thickness fastened together in one plane by metal fasteners or plywood gussets. The metal fasteners may be either punched metal plates with integral teeth or plates with holes, through which single nails are driven into the timber. The plywood gussets may be nailed or glued to the timber members. Trussed rafters normally span between external loadbearing walls without the need for intermediate supports from internal walls, lintels or purlins. Ridge boards are not required, but adequate bracing of the whole roof and satisfactory connections to the supporting structure are essential to ensure overall stability.

As most trussed rafters will be fabricated under factory conditions using specialized equipment, attention should be directed towards achieving standardization of designs which will lead to efficient production and marketing.

It should be emphasized that trussed rafters are engineered components and satisfactory performance can only be ensured by proper attention to the specification and selection of material, adequate control of production operations and satisfactory storage and handling, together with correct erection procedures and fixing on site.

The design of trussed rafters and trussed rafter roofs is based on the results of extensive research and testing and on experience gained with the use of trussed rafter roofs in the United Kingdom and other countries. It should be entrusted to chartered civil or structural engineers, or other suitably qualified persons experienced in timber engineering. The fabrication and erection of trussed rafters should be carried out under competent supervision.

1 Scope

This Part of BS 5268 provides guidance on the design, fabrication and use of trussed rafters for pitched roofs. It is intended primarily for dwellings, but it is applicable also to other buildings where the environment or service conditions are similar. It recommends maximum spans for a range of member sizes and roof pitches for two common configurations of monopitched and duopitched roofs. These spans may be used under certain specific conditions without further calculation or proof testing. Design guidance is given for these and other configurations together with consideration of bracing requirements and overall roof design.

NOTE 1 Special design consideration should be given to partially triangulated configurations of trussed rafters, e.g. attic trussed rafters.

NOTE 2 The titles of the publications referred to in this standard are listed on the inside back cover.

2 Definitions and symbols

For the purposes of this Part of BS 5268 the definitions given in BS 6100-4 and the symbols given in clause 3 of BS 5268-2:1991 apply, together with the following.

principal trussed rafter

a trussed rafter upon which the integrity of the structure depends, e.g. girder trusses

3 Assessment of structural adequacy

The following methods of establishing the structural adequacy of trussed rafters are equally acceptable, subject to the limitations in this Part of BS 5268.

- Engineering calculations based on acceptable methods of analysis, including those given in section 4, using data on material properties and joint strength characteristics as given in BS 5268-2. This may need to be supplemented by additional data provided by a recognized testing authority. See clause 44.
- Load testing of trussed rafters in accordance with the procedure described in section 8.
- Fabrication and use in accordance with section 9.

The design and details of parts and components should be compatible so that the required overall stability of the structure is achieved.

NOTE This is best ensured by making one person responsible for this compatibility when some or all of the design details are not made by the same designer.

Section 2. Materials

4 Timber

4.1 Species of timber

The species of timber used in the fabrication of trussed rafters should be capable of forming satisfactory joints, and adequate data should be available to permit safe joint design. Some of the species of timber suitable for trussed rafter construction are listed in Table 1, and span tables for particular grades of those species are given in section 9 (see Table 13 and Table 14).

Table 1 — Species of timber

Standard name	Origin
Whitewood Redwood	Europe
Hem-fir Douglas fir-larch Spruce-pine-fir	Canada
Southern pine Hem-fir Douglas fir-larch	USA
Scots pine Corsican pine	Britain
NZ radiata pine	New Zealand

NOTE Tests have shown that British grown Sitka spruce of M75 stress grade may be used in accordance with Table 13 and Table 14 for M50, Table 1, species.

4.2 Grade of timber

All timber used in the fabrication of trussed rafters should be stress graded prior to fabrication in accordance with BS 4978 or as recommended in BS 5268-2 for timber stress graded outside the United Kingdom. In addition to the specified stress grade requirements, timbers should meet the following criteria related to a moisture content of 20 %.

- Spring: 5 mm maximum per 3 m length
- Bow: 10 mm maximum per 3 m length
- Twist: 1 mm maximum per 25 mm width per 3 m length
- Cup: 2 mm maximum per 100 mm width of face
- Wane: as specified for SS grade in BS 4978
- Fissures: as specified for SS grade in BS 4978

All timber resawn from stress graded stock should be regraded before use.

NOTE Additional requirements concerning the location of knots, wane and fissures, which should be considered during timber selection are given in 23.1.

4.3 Sizes of timber

Timber normally should be sized in accordance with BS 4471-1. In addition, the finished timber sizes for ceiling ties and rafters should be not less than 72 mm in depth for members of at least 35 mm thickness, and 69 mm in depth for members of at least 38 mm thickness, related to a moisture content of 20 %. Similarly, internal web members should not have finished sizes of less than 60 mm in depth and 35 mm in thickness, related to a moisture content of 20 %.

Deviations in the finished thickness and depth from the specified dimensions of members should not exceed + 1.0 mm or – 0.0 mm, related to a moisture content of 20 %.

NOTE Additional requirements concerning the maximum length of members are given in clause 13.

4.4 Finger jointed timber

Finger jointed timber may be used in the manufacture of trussed rafters provided it complies with 14.1 and the recommendations in BS 5268-2. The finger joints should be manufactured in accordance with BS 5291, except that only adhesives of performance type WBP, as defined in BS 1204-1, should be used.

Where trussed rafters are designed with randomly finger jointed timber and punched metal plate fasteners with integral teeth, allowance should be made for a finger joint to occur within the area of a fastener. In such cases, for fasteners having teeth or bursts with an average length not greater than 15 mm, the efficiency rating of the finger joint in bending and tension, as determined by tests in accordance with BS 5291, should be multiplied by the appropriate modification factor given in Table 2. This reduced efficiency rating should be not less than:

- a) the efficiency rating recommended in BS 5268-2 for timber of the stress grade specified in the trussed rafter design, or
- b) the efficiency rating required to make the sum of the stress ratios of actual to permissible stress less than or equal to 1.0 at any position where a finger joint may occur.

Table 2 — Modification factors for finger joint efficiency ratings

Finished thickness of timber ^a	Modification factor	All other finger profiles
	Finger profile:	
	Length 15 mm	
	Pitch 3.8 mm	
	Tip width 0.5 mm	
mm		
35	0.80	0.70
47	0.85	0.80

^a Linear interpolation for other thicknesses is permitted.

The efficiency ratings, determined in accordance with BS 5291, for finger joints subject only to axial compression need not be reduced.

NOTE Efficiency ratings, determined in accordance with BS 5291, for some common profiles of finger joints are given in BS 5268-2.

5 Plywood

5.1 General

Any of the types and grades of plywood for which grade stresses are published in BS 5268-2, except the American C-D grade, are suitable for gussets for trussed rafter construction. The particular type and grade of plywood assumed in the design of the joints should be specified.

5.2 Glued plywood gussets

In addition to complying with the requirements of the particular type and grade of plywood specified in BS 5268-2, glued plywood gussets should meet the following defect limitations.

- No hole or dead knot greater than 9 mm diameter should be present in either the face or back of the plywood.
- Splits in either the face or back of the plywood should not be longer than one-quarter of the length of the side to which they are parallel.

6 Fasteners

Punched metal plate fasteners with either integral teeth or holes, through which separate nails are driven, should be manufactured from hot-dip galvanized plain sheet or coil in accordance with grade Z2 of BS 2989:1982. Alternatively, where a greater resistance to corrosion is required, bare austenitic stainless steel of a grade defined in BS 1449-2 may be used.

Hot-dip galvanized steel should have the following mechanical properties determined from tests as described in BS 2989:

- an ultimate tensile strength of between 310 N/mm² and 450 N/mm² inclusive;
- a minimum yield stress of 220 N/mm²;
- a minimum elongation of 20 % at 50 mm.

The steel may be made by any process except the air, or mixed air/oxygen, bottom blown basic converter processes, and the mass of zinc coating should meet the requirements of coating type G275 in BS 2989. The surface finish should be type M or N as defined in BS 2989 with a suitable surface protection which may be either a chemical passivation treatment and/or oiling.

All nails used in roof construction, including those used with galvanized punched metal plate fasteners or plywood gussets, should be coated protectively by hot-dip galvanizing, sherardizing or other suitable treatment against corrosion.

Irrespective of the tolerances given in Table 10 of BS 2989:1982, which should be observed in respect of the nominal thickness of metal, punched metal plate fasteners with an actual thickness of less than 0.91 mm, including the zinc coating, should not be used.

All punched metal plate fasteners should bear a mark which readily identifies the fastener manufacturer or supplier.

The fastener manufacturer should exercise adequate control to maintain a satisfactory standard of product with respect to quality of steel, plate and coating thickness and teeth profile. No significant cracks should occur at teeth-plate junctions and teeth should have an adequate degree of ductility at these points.

No changes should be made in fastener materials, manufacture or design without assessing the effects of the changes on the performance characteristics of the fastener.

7 Adhesives

The adhesives used for glued plywood gusset joints and for finger joints in members should comply with performance type WBP as defined in BS 1204-1.

Special precautions may be necessary when gluing timber treated with a wood preservative or flame retardant. The species of timber, adhesive and wood preservative or flame retardant should be compatible.

Section 3. Functional requirements

8 Environment

8.1 General

Roofs incorporating trussed rafters should be designed to ensure that the moisture content of the timber in service does not exceed 18 % for any significant period and the fasteners are at a minimum risk from condensation. Guidance on the prevention of condensation in roofs is given in BS 5250.

Trussed rafters using metal fasteners should not be used where there is likely to be aggressive chemical pollution unless special precautions are taken to ensure durability of the roof timbers and fasteners. Consideration should also be given to the possibility of corrosion of fasteners in contact with some types of insulation materials.

Reasonable access to the roof space should be provided to allow periodic inspection of the timber and fasteners.

8.2 Thermal insulation

In the majority of trussed rafter roofs, the insulation required to comply with the statutory regulations for thermal transmittance (*U* value) is provided by placing the insulating material between the ceiling tie members on top of the ceiling board. Placing the insulation at this level results in a *cold roof space*. Alternatively, the insulating material may be placed at rafter level which will result in a *warm roof space*.

NOTE A *warm roof space* is normally constructed where habitable rooms are to be provided within the roof.

8.3 Ventilation

It is essential that *cold roof spaces* are effectively ventilated to the outside to prevent condensation which may cause rot in roof timbers and corrosion of metal fasteners. In addition, to minimize ingress of water vapour into the roof space from rooms below, all joints and service entry holes in the ceiling construction should be sealed effectively.

The location and size of ventilation openings should be determined by the building designer, taking particular account of possible blockage by insulating materials, sound transmission, spread of fire and entry of birds, driving rain or snow. Openings should be located near ceiling level in the eaves or external walls enclosing the roof space, or both, and should be equally distributed between at least two opposite sides of the roof. Additional ventilators may also be placed in the ridge.

The size and number of openings either may be calculated, taking account of all the relevant factors but disregarding any fortuitious ventilation through the roof covering, or they may be specified in accordance with the recommended minimum openings given in Table 3. These are expressed as the minimum width of a continuous gap but, alternatively, a series of discrete openings of an equivalent total area may be specified, provided the least dimension of any opening, gap or mesh is not less than 4 mm.

Table 3 — Minimum ventilation openings

Pitch of roof	0 to 15°	Above 15°
	mm	mm
Low level ventilation at ceiling level. Minimum width of continuous gap on at least two opposite sides of roof	25	10
High level ventilation for monopitch roofs at or near the ridge. Minimum width of continuous gap	5	5

The ventilation of monopitched roofs at ceiling level only may allow air to stagnate at the apex of the roof. To prevent this, high level or ridge ventilation, equivalent in total area to that given in Table 3, should be provided, in addition to the ventilation at ceiling level.

Similarly, air stagnation may occur in duopitched roofs of more than 20° pitch or 10.00 m span and consideration should be given to the provision of additional high level or ridge ventilation equivalent to a continuous gap 3 mm wide.

Where insulating material is close to the roof covering, as at the eaves, or where it is placed at rafter level to form a *warm roof space* it is essential to provide an air gap of not less than 25 mm between the top of the insulation and the underside of the roof covering or sarking. This gap, which should allow uninterrupted air circulation immediately above the insulation, should be ventilated to the outside at the eaves and, when the insulation is placed at rafter level, also at the ridge. The minimum opening at the eaves to provide adequate ventilation of the air gap above the insulation in a *warm roof space* should be not less than that given in Table 3 for low level ventilation, and the ridge ventilation should be not less than that provided by a continuous gap 3 mm wide. In normal circumstances further ventilation of *warm roof spaces* is not required.

9 Loading

Trussed rafters should support safely, without excessive deflection, the dead and imposed loads specified in BS 6399-1 the imposed roof loads specified in BS 6399-3 and the wind loads specified in CP 3:Chapter V-2. In addition, they should be capable of resisting, without damage, the forces and deflections arising from transportation and erection, assuming that reasonable care is exercised during these operations.

NOTE Recommendations regarding combinations of loads and their magnitude which should be considered when designing trussed rafters are given in clause 15.

10 Deflection

The maximum deflection of the ceiling tie in the long term, due to the uniformly distributed dead and imposed loads on the rafter and ceiling tie members, should not exceed 0.003 of the span of the trussed rafter (L_s in Figure 6), unless it is cambered to take account of deflection due to dead load. When this is the case, the deflection under the uniformly distributed imposed loads should not exceed 0.003 of the trussed rafter span. In addition, for trussed rafters which are not cambered, the maximum long term deflection at any node point due to the rafter and ceiling tie dead loads should not exceed 12 mm for trussed rafters with spans of 12.00 m and less, or 15 mm for spans of 15.00 m. Limiting deflections for trussed rafters with spans between 12.00 m and 15.00 m may be derived by linear interpolation.

11 Preservative treatment

The risk of rot or insect attack in timber of well ventilated pitched roofs is regarded by BS 5268-5 as low, except in those areas specified in the Building Regulations as subject to infestation by the house longhorn beetle (*Hylotrupes bajulus* L). Where preservative treatment is required, it should satisfy the requirements of the Building Regulations. The preservative treatment of trussed rafters, other than in these specified areas, may be regarded as unnecessary except as an insurance against the cost of possible repairs. The type of preservative used should neither increase the risk of corrosion of punched metal plate fasteners or nails, nor adversely affect glued joints. The recommendations of BS 5268-5 in this respect should be followed.

Where cross cutting is carried out after treatment, all sawn ends should be given the appropriate treatment required by the relevant preservative or treatment specification before assembly.

Organic solvent type preservatives lend themselves to modern industrialized techniques for the fabrication of trussed rafters, since punched metal plate fasteners may be pressed into the timber shortly after treatment. When copper/chrome/arsenic (CCA) preservative is used, the timber is re-wetted by the process. Therefore CCA salt formulations should be used only where proper control can be exercised over the treatment, fixing (curing), drying and subsequent protection of the trussed rafters, because of the possible risk of corrosion of punched metal plate fasteners and nails. It is essential that the correct fixing (curing) time recommended by the preservative manufacturer is observed, and that the moisture content of the timber on assembly does not exceed 22 %. To avoid re-wetting during storage or transport, CCA treated trussed rafters should, at all times, be kept covered and well ventilated.

Galvanized punched metal plate fasteners and nails should not be used in timber which has been treated with a flame retardant unless the formulation is a non-salt (i.e. organic) type.

Section 4. Design of trussed rafters

12 General

The design of trussed rafters should be based on the following assumptions:

- a) the dead and imposed loads and the forces due to wind act in the plane of the trussed rafter;
- b) members are initially straight and are restrained in a straight condition in the completed roof structure;
- c) trussed rafters are erected and maintained in a vertical position, parallel to each other, at the correct spacing with restraint against lateral movement.

It is recognized that a rigorous theoretical analysis of the forces, moments and deflections generally will not be possible. However, a suggested analytical method of design is given in clause 16.

Alternatively, other methods of structural analysis may be used, including the use of load/slip and moment/rotation characteristics of individual joints where these have been established from tests.

13 Limitations

To take account of practical factors regarding the use of trussed rafters on site and the limit of experience of their behaviour under test and in service, the length of members and span need to be restricted and the following limits should be observed. Where necessary, intermediate values may be obtained by linear interpolation.

- a) The thickness of trussed rafters should be a minimum of 35 mm up to 11 m span and 47 mm for 15 m span. Within and above this range of spans the minimum thickness should be obtained by linear interpolation or extrapolation. The thickness may be made up from appropriate timber or multiple trussed rafters consisting of two or more trussed rafters, each not less than 35 mm thick, and permanently fastened together at the manufacturer's works.
- b) The maximum bay length (see note to 15.4) of any rafter or ceiling tie member, when measured on plan, should not exceed the appropriate value given in Table 4.
- c) The overall length of any internal member between node points should not exceed the appropriate value given in Table 5. This restriction is supplementary to that determined by the slenderness ratio of internal members subject to compressive forces.

Table 4 — Maximum bay length of rafters and ceiling ties

Depth of member	Maximum length (measured on plan between node points)			
	35 mm thick		47 mm thick	
	Rafter	Ceiling tie	Rafter	Ceiling tie
mm	m	m	m	m
72 ^a	1.8	2.4	3.0	3.0
97	2.3	3.0	3.3	4.0
120	2.5	3.4	3.6	4.7
145	2.8	3.7	3.8	5.0

^a The maximum bay length for 35 mm by 72 mm timber should also apply to 38 mm by 69 mm timber.

Table 5 — Maximum length of internal members

Depth of member	Maximum length (measured between node points)	
	35 mm thick	47 mm thick
mm	m	m
60	2.4	3.2
72	3.6	4.8
97	4.5	6.0

14 Permissible stresses, fastener loads and nail spacing

14.1 Stresses

The grade stresses for plywood and timber, including that which is finger jointed in accordance with 4.4 should be those given in BS 5268-2 appropriate to the dry exposure condition and the particular stress grade and species or strength class used. These grade stresses should be modified in accordance with BS 5268-2. The geometrical properties of sections should be in accordance with BS 5268-2.

14.2 Joints

The permissible loads for punched metal plate fasteners with integral teeth or separate nails should be determined from tests³⁾ carried out on actual joints. Where design data derived from such tests is published in a current Agrément Certificate it may be used without further testing provided the conditions of use specified in the certificate are met. Alternatively for punched metal plate fasteners with separate nails and nailed plywood gussets the appropriate nail loads and spacings in BS 5268-2 should be used. However tests have shown that for 1 mm thick punched metal plate fasteners nailed with 3.35 mm × 30 mm round wire nails or 3.75 mm × 30 mm square twisted nails the minimum nail spacings given in Table 6 are satisfactory and may be used in preference to those in BS 5268-2.

Table 6 — Minimum nail spacing for metal to timber joints

Spacing	Distance
End distance parallel to grain	10 <i>d</i>
Edge distance perpendicular to grain	5 <i>d</i>
Distance between lines of nails, perpendicular to grain	7 <i>d</i>
Distance between adjacent nails in any one line, parallel to grain	10 <i>d</i>
where: <i>d</i> is the nail diameter (in mm)	

The permissible loads for all jointing devices should take account of the effects due to the gaps permitted between abutting members, the orientation of the teeth or nails with respect to grain and the angle of load to grain and teeth.

Joints fabricated with glued plywood gussets should be in accordance with BS 5268-2.

15 Loads

15.1 Dead loads

An estimate should be made of the actual dead load acting on the trussed rafter. Where the common type of concrete interlocking tile is used, the dead load on the rafter members should be taken as 0.685 kN/m², measured along the slope. This consists of 0.575 kN/m² for the weight of the tiles and 0.110 kN/m² for the combined weights of felt, battens and rafter.

The normal dead load on the ceiling tie, including self weight, should be taken as 0.25 kN/m². In addition, unless there is specific information to the contrary, allowance should be made for a water tank, of the same capacity and method of support given in Figure 2, equivalent to a concentrated load of 0.45 kN at each of the two ceiling tie node points nearest the tank in each trussed rafter.

These loads are summarized in Table 7 and Table 8.

Account should also be taken of the weight of any plant or special services which are supported permanently by the trussed rafters.

15.2 Imposed and wind loads

Where no access is provided to a roof (other than that necessary for cleaning or repair) the imposed loads applicable to rafter members are specified in BS 6399-3. However, for roof pitches greater than 30° the specified point load may be disregarded.

The imposed loads specified in BS 6399-1 for ceiling tie members are a uniformly distributed load of 0.25 kN/m² over the whole ceiling area and a concentrated load of 0.9 kN placed in order to produce maximum stresses in the affected members. In exceptional circumstances, where no access to the roof space is provided, both the uniformly distributed and concentrated imposed loads may be disregarded.

The wind loads acting on roofs should be calculated in accordance with CP 3:Chapter V-2 as appropriate for **class B** structures, irrespective of the greatest horizontal or vertical dimensions of the roof.

These loads are summarized in Table 7 and Table 8.

15.3 Handling load

In addition to the service loads, trussed rafters will be subjected to handling loads during transportation and erection. To take account of this, joints between members should be capable of sustaining a force of 1.5 kN in any direction in the plane of the trussed rafter.

15.4 Load combinations

The loads which should be considered in design are summarized in Table 7 and Table 8.

Load type 3 should be assumed to act at the centre of the rafter bay in which it produces the most adverse effect.

³⁾ To be in accordance with European Union of Agrément MOAT No. 16.

Load type 7 should be assumed to act either at the centre of a ceiling tie bay or at a node point, whichever produces the most adverse effect. In design it may also be assumed that not less than 75 % of this concentrated load is supported directly by the ceiling tie to which it is applied, the remainder being carried by neighbouring trussed rafters due to load distribution through the plasterboard or other equivalent boarding attached to the ceiling tie.

NOTE A "bay" is any length of rafter or ceiling tie member which is bounded by two adjacent joints, i.e. nodes, connecting that rafter or ceiling tie member to other members in the trussed rafter.

Referring to Table 7 and Table 8 the following load type combinations should be considered taking account of the different durations of loading in accordance with BS 5268-2:

- a) 1 + 5 + 6: long term duration;
- b) 1 + 5 + 6 + 2: medium term duration;
- c) 1 + 5 + 6 + 2 + 7: short term duration;
- d) 1 + 5 + 6 + 3: short term duration;
- e) 1 + 5 + 4: very short term duration;
- f) 1 + 5 + 6 + 7 + 4: very short term duration;
- g) 1 + 5 + 6 + 7 + 4 + 2: very short term duration.

Table 7 — Summary of rafter loads

Type	Load	Position on rafter	Duration
1	<i>Dead</i> 0.685 kN/m ² UDL (measured along the slope) or actual known loads	Full length	Long term
2	<i>Imposed</i> Uniformly and asymmetrically distributed loads as specified in BS 6399-3	As described in BS 6399-3 dependent upon load type	Medium term ^a
3	0.9 kN concentrated load as specified in BS 6399-3	Centre of any bay	Short term
4	<i>Wind</i> Wind calculated according to CP 3:Chapter V-2 for Class B structures	Full length	Very short term

^a NOTE In the case of local drifted snow loadings reference should be made to 5.3 of BS 5268-2 regarding modifications to grade stresses and fastener loads.

Table 8 — Summary of ceiling tie loads

Type	Load	Position on ceiling tie	Duration
5	<i>Dead</i> 0.25 kN/m ² UDL plus 2 × 0.45 kN concentrated loads for water tank or actual load if greater plus plant and special services	Full length At 2 nodes nearest water tank As appropriate	Long term Long term Long term
6	<i>Imposed</i> 0.25 kN/m ² UDL	Full length	Long term
7	0.9 kN concentrated load	Centre or either end of any bay. (See 15.4.)	Short term

NOTE The weight of water tanks and their contents together with any other permanent plant or special services should be considered as dead load in accordance with BS 6399-1.

16 Method of design

16.1 Bending moments and axial forces

These should be determined using a recognized method of analysis taking account of the combined effect of axial forces and flexural deformation. It should be assumed that there is no fixity at the joint unless satisfactory published information is available which describes the degree of fixity present.

As an alternative to a rigorous analysis the simplified method in 16.2 may be used.

16.2 Simplified analysis

This method should only be used for fully triangulated trussed rafters.

Axial forces should be determined assuming a pin-jointed framework.

Bending moments should be determined assuming that members are continuous throughout their length with pin supports at the nodes. Deflection at the nodes and partial fixity at the joints should be allowed for by a reduction of 10 % in the bending moment which would occur at the nodes with no deflection and no joint fixity. These reduced node moments should be used to calculate bending moments between nodes.

For trussed rafters supported in accordance with item k) of clause 42, bending moment coefficients, which take account of the 10 % reduction in node moments, are given in Table 9 for all node and mid-bay positions in members with equal bay lengths and loads shown.

Where the trussed rafter supports are not in accordance with item k) of clause 42, allowance should be made for bending moments induced by the eccentricity of forces.

NOTE Provided all loads on members are symmetrically disposed between nodes, including members with bays of unequal length and/or loads of different intensities in adjacent bays, the difference between the bending moment at mid-bay and the maximum moment adjacent to it is not significant and may be disregarded in this simplified analysis.

16.3 Members

The design of members should be in accordance with the recommendations of BS 5268-2. Each member should be capable of resisting safely the appropriate direct forces and bending moments. Generally, the stresses at all mid-bay positions and at all internal nodes of multi-bay members should be checked.

Compression members should be designed on the following criteria.

- For buckling within the plane of the trussed rafter, the effective length of compression members subjected to bending moments should be taken as the distance between points of contraflexure. Where the simplified analysis in 16.2 is used, this distance should be taken as 0.8 of the bay length for mid-bay checks of multi-bay members and 0.2 of the sum of adjacent bay lengths for node checks.
- The effective length of internal compression members should be taken as 0.9 of the distance between nodes.
- Considerable restraint against rafter members buckling in a direction perpendicular to the plane of the trussed rafter is normally provided by the tiling battens, if they are adequately nailed and effectively restrained (see clause 18, and 30.2). However, lateral and torsional instability can reduce the capacity of rafters to sustain combined bending and compression forces and unless the analysis takes full account of this instability the applied stresses at mid-bay should be such that:

$$\frac{\sigma_{m,a,||}}{\sigma_{m,adm,||}} + \frac{\sigma_{c,a,||}}{\sigma_{c,adm,||}} \leq 1$$

where

- | | |
|---------------------|--|
| $\sigma_{m,a, }$ | is the applied bending stress due to bending in the plane of the trussed rafter; |
| $\sigma_{m,adm, }$ | is the permissible bending stress for members not subject to axial compression; |
| $\sigma_{c,a, }$ | is the applied compression stress; |
| $\sigma_{c,adm, }$ | is the permissible compression stress with respect to lateral buckling (i.e. in the weaker direction). |

When calculating $\sigma_{c,adm,||}$ for rafter members in diagonally braced roofs, the restraining effect of the tiling battens should be disregarded and the effective length, in metres, should be taken as:

$$0.01bL_{bay}$$

where

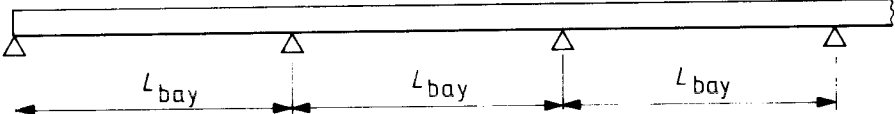
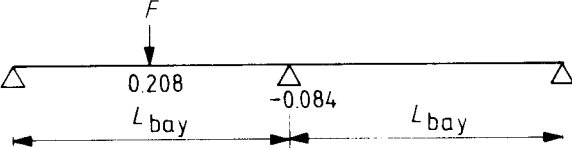
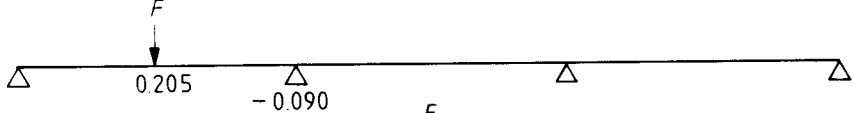
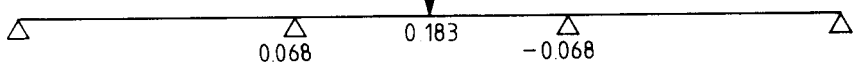
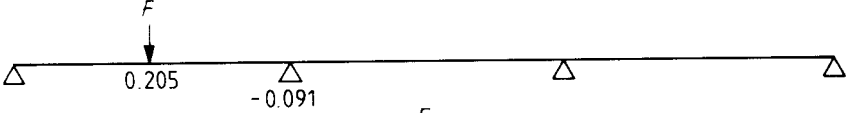
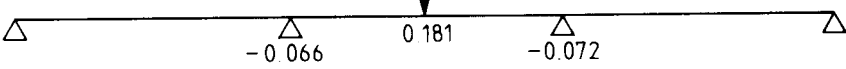
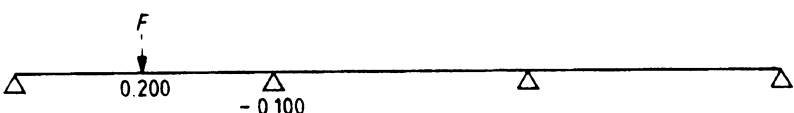
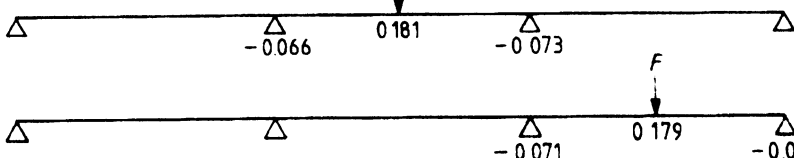
- | | |
|-----------|---|
| b | is the thickness of the member (in mm); |
| L_{bay} | is the length of the rafter bay along the slope (in m); |

The slenderness ratio (L_e/i) thus calculated should be not less than 50 in calculating $\sigma_{c,adm,||}$ where

- L_e is the effective length of the rafter derived from the above expression (in m);
- i is the radius of gyration of the rafter member about its weaker axis (in m).

Special consideration should be given to lateral and torsional stability where purlins are used instead of tiling battens and the bracing system is unconventional.

Table 9 — Bending moment coefficients (K_m)

Number of bays	K_m
2 3 4 5	Uniformly distributed load Bending moment (M) = $K_m w L_{bay}^2$ w = load/unit length  0.069 - 0.113 0.080 - 0.090 0.035 0.077 - 0.096 0.045 - 0.064 0.078 - 0.095 0.042 - 0.071 0.054
	Concentrated load Bending moment (M) = $K_m F L_{bay}$ Load F is located midway between supports  0.208 - 0.084
	 0.205 - 0.090
	 0.068 0.183 - 0.068
	 0.205 - 0.091
5	 - 0.066 0.181 - 0.073
	 0.200 - 0.100
	 - 0.066 0.181 - 0.073

The stress modification factors recommended in BS 5268-2 are applicable to trussed rafter design but the load-sharing factor of 1.1 should not be used for bending stresses in ceiling ties unless binders or boarding other than plaster-board are provided to ensure adequate load distribution.

Principal trussed rafters should be designed as multiple trussed rafters having two or more plies. They should be permanently fastened directly together and designed using load-sharing factors applied to the grade stresses and the minimum modulus of elasticity appropriate to the number of plies as shown in Table 10. Special consideration should be given to the effects of torsion created by eccentric loading.

Table 10 — Load-sharing factors for principle trussed rafters

Number of plies	Load-sharing factor	
	for stresses	for modulus of elasticity
2	1.1	1.14
3	1.1	1.21
4 or more	1.1	1.24

16.4 Joints

Joints should be designed to resist, in tension, compression and shear, the axial forces in abutting members subjected to the loadings given in 15.4. In addition, all joints should be able to sustain the handling load given in 15.3.

The arrangement of members in a joint should be such that the longitudinal axis of each member passes through or close to a common point. When this is not the case, the resulting eccentricity should be allowed for in the design of both the fasteners and the jointed members. Common joints are shown in Figure 1; where eccentricities are small they may be ignored.

Compression joints should be designed assuming that loads are only transferred between members by the punched metal plate fasteners or plywood gussets and not by direct bearing through the timber.

Plated or gusseted butt joints in the rafter and ceiling tie members of trussed rafters should be designed to fully resist the axial forces, shear forces and bending moments which occur at the joint. However, where a butt joint is located at a distance of between $0.1 L_{\text{bay}}$ and $0.25 L_{\text{bay}}$ from a node point, i.e. at a position of low bending moment, in a fully triangulated trussed rafter, the effect of the bending moment may be allowed for empirically in the design of the punched metal plate fasteners or plywood gussets used at the joint, by multiplying the axial force in the member by the appropriate factor as follows:

a) $1 + 0.2 L_{\text{bay}}$ for bays subject to a concentrated load of 0.9 kN;

b) $1 + 0.1 L_{\text{bay}}$ for all other cases,

where

L_{bay} is the bay length (in m) measured along the rafter or ceiling tie bay in which the butt joint occurs.

Irrespective of the theoretical design requirements, and in order to ensure a butt joint sufficiently robust to withstand normal forces during transportation and erection, the minimum dimensions of the punched metal plate fasteners or plywood gussets on a butt joint should be as follows:

1) width: not less than $0.7 h$;

2) length: not less than $(0.8 h + 80 \text{ mm})$,

where

h is the depth of member (in mm).

Subject to practical limitations imposed by the configuration and size of members, all joints should be designed with the provision of a specified tolerance to allow for the possible misplacement of the punched metal plate fasteners or plywood gussets. The tolerance required to ensure that joints are assembled with a satisfactory level of performance will depend on the degree of control exercised during fabrication and should be assessed from experience with the particular jointing system, assembly equipment and fabricator. Unless this experience indicates that a larger tolerance is necessary, the joint design should allow for a minimum misalignment of $\pm 5 \text{ mm}$ simultaneously in two directions parallel to the edges of the punched metal plate fastener or plywood gusset.

Irrespective of any design or fabrication requirements, the minimum overlap of a punched metal plate fastener or plywood gusset on to a rafter or ceiling tie member should be not less than any of the following:

- a) $(0.2b + 15)$ mm, where b is the dimension of the punched metal plate fastener or plywood gusset, in millimetres, measured at right angles to the rafter or ceiling tie member;
- b) 30 mm;
- c) $0.25 \times$ the depth of the member (in mm).

16.5 Deflection

Calculations of deflection should take account of axial strain in the members, bending in the ceiling tie and slip at the joints unless glued plywood gussets are used when joint slip may be ignored.

For simplicity, when calculating joint slip it may be assumed that the nails or teeth are loaded to the maximum permissible value and the average slip at this load should be used to calculate the slip component of the total deflection. Values for slip at maximum load for punched metal plate fasteners should be obtained from tests on actual joints.

The deflection, u_n , (in mm) of a node point due to axial strain and joint slip is given by:

$$u_n = \sum \frac{FF_u L_m}{AE} + \sum F_u s n$$

where

- F is the force in the member due to the design load;
- F_u is the force in the member due to a unit load applied at the node points whose deflection is to be calculated;
- L_m is the length of the member;
- A is the cross-sectional area of the member;
- E is the appropriate modulus of elasticity;
- s is the slip of the nail or tooth at maximum permissible load;
- n is the number of components of slip per member. It may be assumed that each end of each member in a rafter or ceiling tie has one component of slip and each end of the internal members has two.

The calculated deflection should be multiplied by 1.25 to allow for long term effects due to creep deflection and joint movement.

For trussed rafters fabricated in accordance with this Part of BS 5268, having punched metal plate fasteners or nailed plywood gussets and ceiling tie members with three bays of equal length, the maximum long term deflection u_t (in mm) of the ceiling tie is given by:

$$u_t = 1.25 \left(1.15 u_n + \frac{L \cdot 6.43 w L_s^4}{EI \times 10^6} \right)$$

where

- u_n is the average deflection of the ceiling tie node points (in mm) excluding the 1.25 long term effect factor;
- w is the uniformly distributed dead and imposed load acting on the ceiling tie (in kN/m);
- L_s is the span of the trussed rafter (in mm);
- E is the appropriate modulus of elasticity of the ceiling tie (in N/mm²);
- I is the second moment of area of the ceiling tie (in mm⁴).