WOODINFORMATION

Trussed rafters

Trussed rafters are individually designed prefabricated structural components made from strength-graded timber members of the same thickness, joined together with punched metal plate connectors. They provide a structural framework to support the roof fabric of a building, room ceilings and, in some cases, floors. They are generally spaced at 600 mm centres or less, taking the place of the 'common rafter' in a traditional or 'cut' roof, hence the term 'trussed rafter'. They should not be confused with more heavily built 'trusses', which are normally spaced at 1.8 m centres, and which have common rafters and common ceiling ties between them.

Trussed rafters are widely used as an economical means of roof framing, using standard components produced by an efficient factory process. They can be erected rapidly on site and are suitable for a wide range of building types. Although most commonly used for domestic buildings, with around 90% of all new-build housing using them, they are increasingly important on commercial and industrial buildings, such as offices, shops and hotels, where the availability of long spans and the ability to create a wide range of shapes provide a versatile solution for many roofs.

When incorporated correctly in a building, trussed rafters provide a structure designed by engineering calculations or proved by test, in conformity with established design codes. The calculations and methods of test assume that when trussed rafters are installed in a roof they will be supported against movement in their weaker direction. Although design codes give span tables for common standard configurations, trussed rafter designs are generally provided by 'system owners', who supply proprietary punched metal plates to their licensees undertaking the work of fabrication. Orders for trussed rafters may be placed with any of a large number of fabricators around the UK.

Trussed rafters are available in a variety of standard profiles but more complex designs can also be made to create interesting and varied roofscapes. See Figure 1.

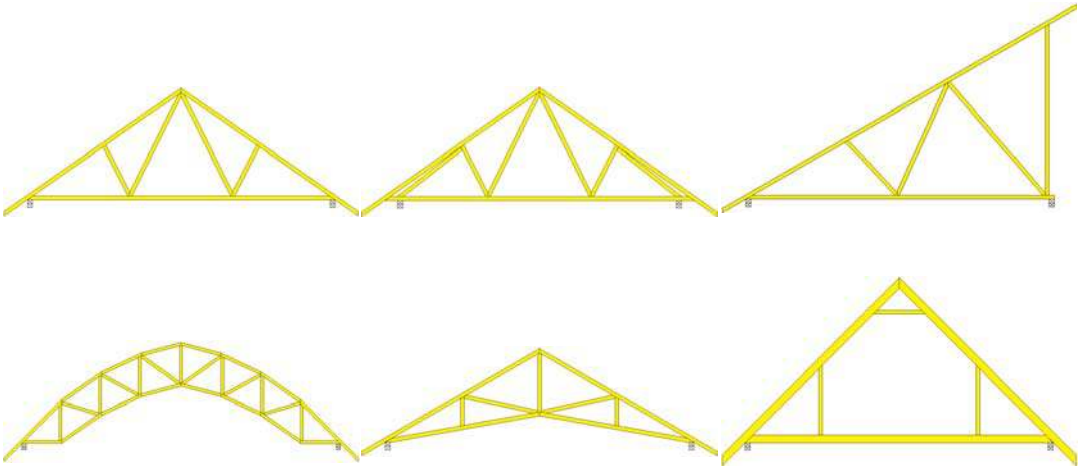

Figure 1: Examples of types of trussed rafter

Clockwise from top left: Fink truss, Double Cantilevered truss, Monopitch truss, Room in the Roof truss, Scissor truss, Vaulted truss.

Room in the Roof (RiR or Attic) trussed rafter

The 'room in the roof' (RiR) or attic trussed rafter is a simple means of providing a structural roof and floor in the same component so creating a useable loft space for storage or an additional habitable room. With the ever-increasing demand for building space, and the current trend to build more multi-storey houses and apartments, attic trusses are a tried and tested solution for creating living areas within the roof. Where they are used to create a habitable room, the building designer will need to allow for the appropriate domestic loading in the design. Attic trusses offer a number of advantages:

- They can be designed to span between external walls with no restrictions on lower floor layout. However, greater spans and room in the roof widths can be achieved by utilising internal load-bearing walls
- Increased living space without increasing the building footprint
- Freedom to plan the room layout within the roof space.

Standards and quality control

It is now a legal requirement for suppliers of trussed rafters for permanent incorporation in construction works to be able to demonstrate that their products comply with the Construction Products Directive. The most straightforward way of achieving this is by complying with the harmonised standard, *BS EN 14250 Timber structures - Product requirements for prefabricated structural members assembled with punched metal plate fasteners*. This also allows the supplier to apply the CE mark, although this is not yet compulsory in the UK.

Design and fabrication of trussed rafter roofs is undertaken in line with the guidance in *BS 5268-3 Structural use of timber - Code of practice for trussed rafter roofs*. The code accepts three methods for establishing structural adequacy:

- Engineering calculations, including a simple approach given in the Code, using data on material properties and joint strength characteristics given in BS 5268-2. These may need to be supplemented by additional data provided by a recognised testing authority.
- Load testing in accordance with the procedure laid down.
- Fabrication and use in accordance with Annex B of the standard which includes span tables for two configurations of truss - a fink design and a monopitch construction. These spans may be used under specific conditions, without further calculation or proof testing.

BM TRADA Certification operates a third party quality assurance certification scheme for the fabrication of trussed rafters, based on the requirements of *ISO 9001: 2000 Quality management systems – Requirements* and the technical requirements laid down in BS EN 14250 and BS 5268-3. Trussed rafters supplied by scheme members will be marked or labelled with the BM TRADA Q-MARK and the scheme mark. Many trussed rafter fabricators belong to the Trussed Rafter Association which requires them to have third party quality assurance certification and Professional Indemnity Insurance.

Materials

The main species suitable for trussed rafters are listed in BS 5268-3, see Table 1. All timber must be strength graded in accordance with BS EN 14081 or as recommended in BS 5268-2. BS 5268-3 and BS EN 14250 contain additional limitations on distortion. The span tables in BS 5268-3 are based on strength classes C16, C22, C24, C27, and TR26 which is a special strength grade for trussed rafters, used for most components produced in the UK.

Although most trussed rafters are jointed by punched metal plate fasteners, BS 5268-3 provides for the use of nailed or glued plywood gussets as an alternative. This is rarely carried out commercially.

Table 1. Species of timber - as in BS 5268-3

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
Radiata pine	Chile

Finger jointed timber

BS 5268-3 permits finger-jointed timber to be used. The joints must be manufactured in accordance with BS 5268-2 and BS EN 385 *Finger jointed structural timber. Performance requirements and minimum production requirements* using adhesive which conforms to Type 1 specification. Where finger joints fall in a random position, their efficiency rating in bending and tension is reduced, to allow for the possibility of a finger joint occurring within the area of a fastener.

Punched metal plate fasteners

Metal plate fasteners should be manufactured from either hot dip zinc coated steel or austenitic stainless steel. Metal plate fasteners should not be less than 0.9 mm nor more than 2.5 mm in thickness. BS 5268-3 requires the fastener manufacturer to maintain a third party certified quality control system to ensure that the steel quality, coating thickness and tooth profile meet the required standards. To comply with BS EN 14250, plates must be manufactured in accordance with (pr)EN 14545.

Preservation

A properly designed and constructed trussed rafter roof is not at significant risk from decay or insect attack, except in areas where roof timbers must be preserved, to prevent infestation by the house longhorn beetle. These areas are defined in the Building Regulations.

If preservative treatment is required, an approved water-borne micro-emulsion preservative is best suited to modern fabrication methods for trussed rafters. The use of water-borne copper-containing preservatives involves re-wetting the timber, and BS 5268-3 emphasises the need for careful control if this method is applied. It is essential that the type of preservative used should not increase the risk of corrosion of metal plate fasteners.

Trussed rafter design

Trussed rafters are designed using software provided under license by the connector plate 'system owner'.

BS 5268-3 lists the information which is required by the trussed rafter designer and fabricator, and the information which the designer or fabricator should supply to the client. The trussed rafter designer should supply details of the positions, fixings and sizes of lateral supports necessary to prevent buckling of compression members. However, the building designer, not the truss designer, is responsible for ensuring that the design of the entire roof and the supporting structure will provide stability of the whole building.

BS 5268-3 includes both a simplified design method and an alternative, more rigorous, analysis procedure. Recommendations for design loads are given and, unless it is known that they are not needed, water tank loadings must be included. Design procedures follow the principles of BS 5268-2, but with an additional calculation on lateral buckling of the rafter. A calculation method for deflection is included, incorporating guidance from tests.

Spans

For trussed rafters made up from 35 mm thickness timber the maximum overall span is 11 m and for 47 mm thickness, it is 16 m. Greater spans are possible; the minimum timber thickness required is determined by linear interpolation or extrapolation. The required thickness may be achieved from appropriate timber or from multiple trussed rafters, each not less than 35 mm thickness, permanently fastened together in the factory. Further information on spans for individual rafter and ceiling members can be found in Annex B of BS 5268-3.

Fabrication and marking

Every trussed rafter should be marked clearly to enable identification of the producer, the materials used and the standard to which it was produced. This marking should be placed on the face of the timber and be clearly visible. Due to manufacturing tolerances, where symmetrical trussed rafters are produced they should be clearly marked to indicate a 'common production end' (ie one consistent end in respect of the production jig).

BS EN 14250 also requires the location of support areas and any points at which internal bracing is required to be shown on the structural member or in an accompanying document. The marking on the structural member should be placed so that it can be used as a reference for installation.

If the fabricator is a member of the BM TRADA Certification Q-Mark Trussed Rafter Scheme, a stamp or label will indicate their membership of this third party quality assurance certification scheme. In addition where trussed rafters are made to BS EN 14250 and the manufacturers have undergone the appropriate assessment, the trussed rafters may be 'CE' marked.

Roof design

BS 5268-3 emphasises the responsibility of the building designer, who may be the building owner, or his appointed architect or engineer, or the builder in the case of small buildings, to ensure that the design of the roof and supporting structure will provide stability of the complete building. The building designer is responsible for detailing all elements of bracing required in the roof and suitable fixings for both the trussed rafters and the wall plates to provide restraint against uplift.

Trussed rafter roof structures normally provide lateral support to the external walls. For most domestic buildings, not more than three storeys high, the use of galvanized mild steel straps at 2 m centres, fixed to rafter or ceiling tie members in at least three trussed rafters is recommended.

Trussed rafters are usually supported on timber wall plates and preferably fixed with proprietary fixings. Skew nailing is also permitted but, if this method is used, it is essential that a high standard of workmanship is maintained to avoid damage.

Bracing

Trussed rafters must be braced to create a rigid and stable roof structure. If the bracing is omitted, wrongly positioned or badly fixed, it may result in distortion or failure of individual trusses, or even the whole roof. The building designer and not the trussed rafter supplier is responsible for designing and detailing all elements of roof bracing. Roof bracing performs three distinct functions:

- Temporary bracing – used to restrain the trusses during erection.
- Truss stability bracing – permanent bracing which holds the trusses upright, straight and prevents any out of plane buckling of the members. It ensures that the roof acts in a robust, stable manner with adequate overall stiffness. Such bracing is typically provided by a combination of longitudinal bracing at node points, tiling battens, rafter diagonal bracing, web chevron bracing and lateral bracing.
- Wind or wall bracing – bracing added into the roof in addition to truss stability bracing, to stabilise the wall from wind loads and to ensure imposed loads are safely transmitted to other suitably braced parts of the building. It typically consists of diagonal bracing at rafter or ceiling level, together with lateral restraint straps to the gable walls.

Figure 2 illustrates elements of roof bracing.

Standard bracing details are given in Annex A of BS 5268-3 for spans up to 17 m and, provided that the design criteria and conditions of use are observed, no further calculations are required. Where no standard bracing solution is available, Annex A describes the principles and procedures for designing an appropriate bracing system. The spans for which the standard bracing is suitable vary according to the pitch of the roof and the anticipated maximum wind speed. All roofs must have diagonal rafter bracing and longitudinal bracing at the apex and at all other nodes. BS 5268-3 does allow some intermediate longitudinal members to be omitted. However, in this case, temporary battens must be installed to ensure correct alignment during erection of the trusses, and the space between braced nodes must not exceed 4.2 m on rafters and 3.7 m on ceiling ties.

Additional chevron bracing is required in duopitch roofs exceeding 8 m span, and in monopitch roofs over 5 m span. Monopitch roofs also require bracing on the vertical face, if this is not tied to masonry at the top, or clad with plywood or other suitable rigid sheet material.

All bracing members should have a minimum width of 89 mm with a minimum depth of 22 mm observing a minimum cross sectional area of 2134 mm^2. Bracing members should be nailed to trussed rafters with two x 3.35 mm diameter nails, which are at least 32 mm longer than the bracing thickness. Bracing members may be jointed by overlapping over at least two trussed rafters. Alternatively the use of sarking, on top of the rafters, eliminates the need for bracing, provided the sarking is moisture resistant plywood or OSB (minimum thickness 9 mm), or chipboard (minimum thickness 12 mm), or 16 mm timber boarding.

Water tanks

Wherever possible water tanks should be supported independently of trussed rafters but if this is not possible, the additional loads of the tank and its contents should be allowed for in the design to avoid excessive deformation of the trusses.

Hatch, chimney and other openings

Every effort should be made to accommodate openings within the trussed rafter design spacings. Where this cannot be achieved BS 5268-3 gives guidance on increased trussed rafter spacings.

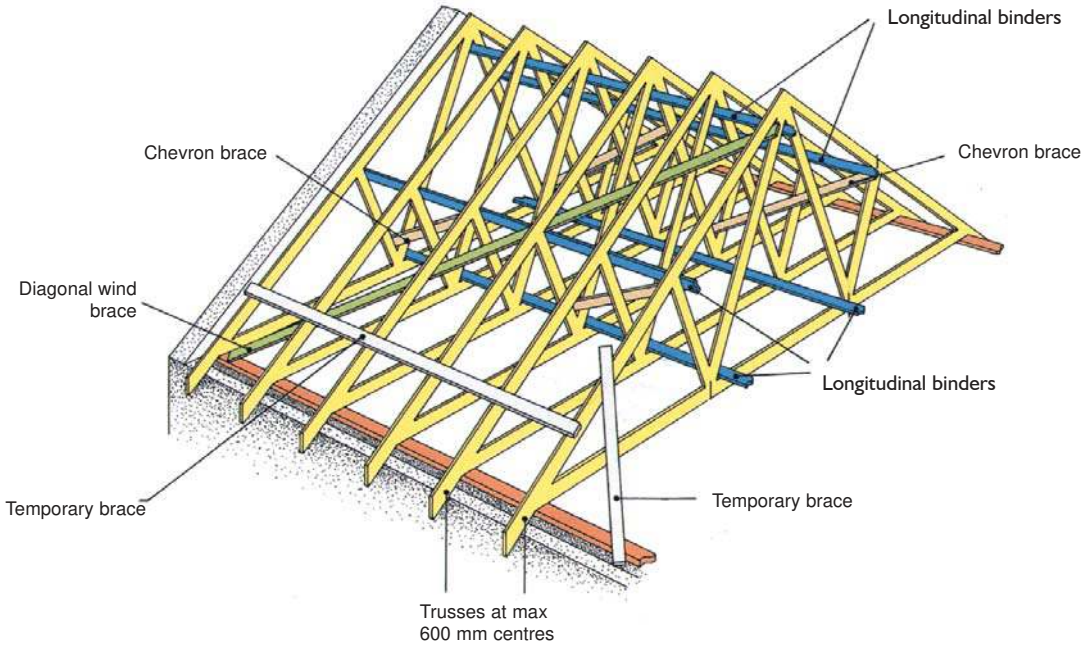

Figure 2 The elements of Roof bracing

(Drawing © Trussed Rafter Association) See BS 5268-3 for plan layouts and fixing details

Thermal insulation and ventilation

Trussed rafter roofs should be insulated to conform to the requirements for thermal transmittance. In the majority of trussed rafter roofs the insulation is placed between and over the ceiling members. Where a room in the roof is provided, the insulating material may be placed at rafter level, with an airspace above. In both cases, a cold roof is formed and, to prevent condensation, ventilation is required above the insulation. Ventilation and insulation requirements are given in the building regulations for the appropriate area.

An alternative to the ventilated cold roof is the warm roof, where the insulating material is placed above the rafters. In this case, all structural timber is within the heated space and therefore not at risk of damage by condensation. However if an insulation board is placed on top of the rafters this reduces the effect of the tiling battens in restraining the rafters and the building designer must take this into account in considering the overall roof stability.

Handling, storage and installation

Trussed rafters are engineered components and they must be handled and stored with care. Ideally delivery should be arranged to minimise storage time on site. Single rafters should be carried vertically, unless support can be provided at every joint. Undue sagging or flexing when handling should be avoided. They should be stored off the ground, preferably vertically on bearers at the design load-bearing positions, with props for support. If they are stored in a horizontal position, they should be supported at each joint and at intervals along long spans.

Trussed rafters should not be cut, trimmed, notched or repaired without the specific approval of the trussed rafter designer. If components are damaged, check with the supplier before installation. Although limits are given in BS 5268-3 for deviation from the vertical of the trusses as erected, the text states that every effort should be made to erect them as near vertical as possible. Adequate temporary bracing must be provided; this must not be removed until the permanent bracing has been installed.

To reduce 'hogging' over separating walls, the walls should be finished 25 mm below the underside of the tiling battens and the remaining space filled with compressible non-combustible material where necessary. Detailed guidance on the installation of trussed rafter roofs can be found in the Trussed Rafter Association 'Site Installation Guide'.

References

British Standards

BS 4978: 1996 Specification for softwood grades for structural use. (Under revision 2007).
BS 5268-2: 2002 Structural use of timber. Code of practice for permissible stress design, materials and workmanship (Under revision 2007).
BS 5268-3: 2006 Code of practice for trussed rafter roofs.
BS 5268-5: 1989 Preservative treatments for constructional timber (Obsolescent).
BS 8417: 2003 Preservation of timber. Recommendations.
BS EN 385: 2001 Finger jointed structural timber. Performance requirements and minimum production requirements.
BS EN 14081-1: 2005 Timber structures. Strength graded structural timber with rectangular cross section. General requirements.
BS EN 14081-2: 2005 Timber structures. Strength graded structural timber with rectangular cross section. Machine grading. Additional requirements for initial type testing.
BS EN 14081-3: 2005 Timber structures. Strength graded structural timber with rectangular cross section. Machine grading. Additional requirements for factory production control.
BS EN 14081-4: 2005 Timber structures. Strength graded structural timber with rectangular cross section. Machine grading. Grading machine settings for machine controlled systems.
BS EN 14250 : 2004 Timber structures – product requirements for prefabricated structural members assembled with punched metal plate fasteners.
BS EN ISO 9001: 2000 Quality management systems. Requirements.
prEN 14545 Timber structures - Connectors - Requirements. (Not yet published as EN).

TRADA Publications

Wood Information Sheets

0-12 Room in the roof construction for new dwellings.
1-10 Principles of pitched roof construction.
1-25 Structural use of timber: An introduction to BS 5268-2: 2002.
4-7 Timber strength grading and strength classes.
4-12 Care of timber and wood based products on building sites.

Trussed Rafter Association Publications

Technical Handbook and Site Installation Guide. TRA. SFG G12. 2005.
PDS1 – Room in the Roof Trussed Rafters.
PDS2 – Some basic trussed rafter profiles.
PDS3 – Guidelines for the storage and erection of trussed rafters on site.
PDS4 – Standard bracing of simple duopitched trussed rafter roofs for dwellings.
PDS5 – Standard bracing of Room in the Roof trussed rafter roofs.
PDS6 – Creating roofscapes with trussed rafters.
PDS7 – Chimney and hatch openings in trussed rafter roofs.
PDS8 – Loft conversions with trussed rafter roofs.
PDS9 – Health and safety policy for the loading, haulage, delivery and erection of trussed rafters on site – A definition of responsibilities.

Details and prices of all TRADA Technology and TRA publications are available at www.trada.co.uk or contact TRADA Publishing, telephone 01494 569602.

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