The Trussed Rafter Manual is a comprehensive reference guide to trussed rafter roof design, specification and construction. It is specifically designed to meet the information needs of all the members of the project team, from feasibility planning, through the detail design stage, to erection and completion on site. Consequently, the Manual will be of use to a broad range of specifier groups, including architects, engineers, contractors, developers and also students.

Gang-Nail Systems Ltd, in conjunction with their UK and Eire network of fabricators, have been at the forefront of trussed rafter technology for 40 years. Their ongoing involvement in the development of British Standards and Eurocodes is a testament to this fact. The Manual not only draws upon this accumulated wealth of knowledge and experience, but also incorporates work carried out by the Building Research Establishment, Trussed Rafter Association and British Standards Institution.

Gang-Nail’s role within the construction industry is to support a network of timber trussed rafter manufacturers, by manufacturing and supplying punched metal plate connectors, and developing the applications software necessary to design and supply prefabricated trussed rafters to the highest specification.

The extent to which primary product manufacture is combined with a sophisticated and highly developed range of support services for client fabricator companies is seldom realised. Parallel developments in both the design and client services offered by Gang-Nail Fabricators has meant the combined resources of the System Owner and Fabricator network can respond to the most demanding requirements from the roofing sector.

Since the establishment of Gang-Nail Systems Ltd the range and complexity of projects designed, supplied and erected under the System by fabricator companies has progressed rapidly. Housing applications are well known, with an estimated 95% of new build housing utilising prefabricated trusses. Less well known is the extent to which trussed rafter roof structures are now part of the non-domestic building scene. The aesthetic and architectural appeal of pitched roofs has spawned a rich variety of commercial and industrial applications, including offices, shopping centre, superstores, hospitals, schools, hotels and light industrial buildings. An estimated 45% of the annual output from the trussed rafter industry is presently directed towards these types of project.

Gang-Nail’s preparation of The Trussed Rafter Manual has taken this continuing trend into account by approaching its subject not only in the context of domestic dwelling requirements, but also in terms of what can be achieved on larger scale developments.

It is important to recognise that The Trussed Rafter Manual sets out to inform and guide the project team and not to replace the Structural Engineer. It is essential that the Building Designer, who is assumed to have ultimate responsibility for all aspects of the project, considers and approves the information given in relation to the specific project under consideration. If used in this way the aim of the Manual will have been fulfilled, and its rightful position on the desk of all relevant parties will be assured.
The modern trussed rafter roof has evolved in form over the past forty years. The speed with which it can be manufactured and erected, along with its efficiency of material use has meant that it is now used in the vast majority of domestic roofs and increasingly for commercial construction projects. Before providing detailed guidance on all aspects of trussed rafter roof design and construction, a brief description is provided in this section of the basic structural mechanics of trusses, the materials which are used, and the responsibilities of the various parties involved in their design. Roof trusses are primarily made up of tension and compression members; so what are tension and compression members and how do they behave?

**Tension Members**
A member subject to a tension force is being pulled or stretched; it is said to be in tension. Common examples of a tension member are a car tow rope and the rope supporting a child’s swing. The ability of a member to restrain tension forces depends on the raw material strength of the member and its cross-sectional area. Illustrated in Figure 1.01 is the force a 50mm x 50mm member can withstand and a 100mm x 50mm member, which being twice the area carries twice the force.

**Compression Members**
A member subject to a compression force is being pushed or compressed; it is said to be in compression. Common examples of compression members are columns or the leg of a table. Unlike the tension member the ability of a member to resist an applied compression force is not only dependent on raw material strength and cross-sectional area, but also member length and minimum breadth. A simple experiment will demonstrate this. Hold a 300mm long ruler vertically on the desk and push down on it. At a relatively small load it will buckle. Repeat the experiment with a 150mm long scale rule, it will take a much greater force before it buckles. If we were to take a 10mm length of the scale rule and subject to compression, it would eventually crush at a relatively enormous load and is said to fail in compression as opposed to buckling. This experiment demonstrates the principle that as member length increases so load carrying capacity decreases. Similar experiments, keeping length and cross-sectional area constant would show that load capacity decreases as the cross-section changes from a square to a long rectangle (Figure 1.02).

**Trussed Rafters**
To support an 8m span roof with beams at 600mm centres requires 100mm x 350mm timber members. The equivalent trussed rafter, assuming a pitch of 30°, would use much smaller member sizes and only a quarter of the timber (Figure 1.04). How is this possible?

Consider two rafter members - AB and BC - in contact at B and restrained from moving at A and C (Figure 1.05). It is possible to suspend a weight W from node B, placing AB and BC in compression; the rope is in tension. Combining these two findings indicates that load capacity is dependent upon the slenderness ratio; that is Member Length

\[ \text{Slenderness Ratio} = \frac{L}{D} \]

Minimum Cross-sectional Dimension

If we rigidly supported the 25mm x 100mm member laterally at mid-point in the 25mm direction, the length over which it can buckle is halved and hence its slenderness ratio would be equal to that for the 50mm x 50mm section and the allowable load would increase from 4.8kN to 12.6kN (Figure 1.03). This explains the importance of lateral bracing and demonstrates why, when requested by the Trussed Rafter Designer, lateral braces must be correctly installed.
This example illustrates that the members in a truss are subjected to axial forces (i.e., tension or compression). Since members can resist axial forces more easily than they can bending forces, smaller timber sections can be used in a truss than an equivalent beam.

**Combined Stress Index**

In reality, trussed rafter chords receive load along their entire length and they are therefore subject to bending forces. The same basic theory, however, still applies, except that instead of all the member strength being used for axial forces (tension or compression), some of it is required to resist the bending forces. The design calculation for the trussed rafter will state the Combined Stress Index (C.S.I.) for each member, which should not exceed 1.0. A value of 1.0 says the member is stressed to the maximum permitted value: in tension, compression, bending, or a combination of these. Some examples are as follows:

- Rafter C.S.I. = 0.81 81% of the strength of the rafter is being used to resist combined bending and compression forces
- Ceiling Tie C.S.I. = 0.49 49% of the strength of the tie is being used to resist combined bending and tension forces
- Tension Web C.S.I. = 0.73 73% of the strength of the web is being used to resist tension forces

**Connector Plates**

Gang-Nail punched metal plate fasteners are manufactured from galvanised mild steel. Rows of integral nails are pressed out to project at right angles to one face of the plate (Figure 1.08). The slots so formed define the length direction of the fastener. One nail is formed from each slot, with alternative rows of nails facing in opposite directions. The nails are formed with a slightly dished cross-section.

The use of Gang-Nail connector plates is covered by British Board of Agreement Certificates. The fasteners are stamped with the identification mark: GN20, GN14 or GN80X.

**GN20**

GN20 plates are available in widths of 50mm, 63mm, 76mm, 101mm, 127mm and 152mm and lengths from 71mm up to 1220mm, although the maximum length normally used is 401mm.

The fasteners are manufactured from carbon steel of nominal 1mm finished thickness and protected against corrosion by hot-dip galvanising with a minimum zinc coating weight of 275 g/m². The steel specification is in accordance with BS EN 10326.

Some typical joints with their load carrying capacities are given in the diagrams shown as Figure 1.09.

**GN14**

GN14 plates are available from 18 gauge (1.2mm thick) plate manufactured from high strength steel and normally used for splices.

**GN80X**

An 18 gauge (1.2mm thick) plate manufactured from high strength steel and normally used for splices.

**Field Splice Plates**

A plate with one half consisting of Gang Nails and the other holes to receive square twist nails. Used to fix a 2 part truss together on site e.g. top hat attic truss.

---

**Field Splice Plate**

**FIGURE 1.08 THE GANG-NAIL CONNECTOR PLATE RANGE**

- GN20
- GN80X
- GN14
- Field Splice Plate

**FIGURE 1.09 TYPICAL JOINTS**

Note: Plate details are for a 10° pitch 8m span 8m truss. Actual forces not shown.
### Timber

All timber used in the manufacture of trussed rafters must be stress graded. Some of the common species are given in Table 1.01, taken from BSS268:Part 3.

<table>
<thead>
<tr>
<th>Timber</th>
<th>Origin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whitewood</td>
<td>Europe</td>
</tr>
<tr>
<td>Hem-fir</td>
<td>Canada</td>
</tr>
<tr>
<td>Douglas fir-larch</td>
<td>USA</td>
</tr>
<tr>
<td>Southern pine</td>
<td>America</td>
</tr>
<tr>
<td>Scots pine</td>
<td>Britain</td>
</tr>
</tbody>
</table>

European redwood and whitewood are imported as a mixed parcel of timber, the majority of which is whitewood. These timbers form the bulk of all trussed rafters, namely BS5268:Part 3: Code of Practice for trussed rafters - design, materials and workmanship - provides basic stress grades and joint strengths given in BS5268:Part 2 are for long-term loading. Timber can however sustain greater loads for a period of a few minutes than for a period of several years and BS5268:Part 2 reflects this fact in quoting load duration factors by which the grade stresses can be modified. These factors are given in Table 1.02 and apply to all strength properties but not moduli of elasticity or shear moduli (see also Section 3).

#### Moisture Contents

Timber is prepared on all faces, often to what the timber will have. For webs, a depth of 60mm is permissible, 72mm to 244mm for 47mm thick timbers. The most common widths of timber are 35mm or 47mm, the normal grades of European redwood/whitewood timbers shall be stress graded. Some of the common species are given in Table 1.01, taken from BSS268:Part 3.

<table>
<thead>
<tr>
<th>Timber</th>
<th>Origin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whitewood</td>
<td>Europe</td>
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<tr>
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</tr>
<tr>
<td>Southern pine</td>
<td>America</td>
</tr>
<tr>
<td>Scots pine</td>
<td>Britain</td>
</tr>
</tbody>
</table>

Where cross cutting is carried out after treatment, all sawn ends should be given the appropriate treatment required for the relevant preservative or treatment specification, before assembly. Organic solvent type preservatives lend themselves to modern industrialised techniques for the fabrication of CCA preservative should not be used because of the possible risk of corrosion of punched metal plate fasteners and nails. Galvanised punched metal plate fasteners and nails should not be used in timber which has been treated with a flame retardant.

#### Load Duration

The load duration factors by which the grade stresses can be modified. These factors are given in Table 1.02 and apply to all strength properties but not moduli of elasticity or shear moduli (see also Section 3).

<table>
<thead>
<tr>
<th>Duration of loading</th>
<th>K3 Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long term</td>
<td>1.00</td>
</tr>
<tr>
<td>Medium term (e.g. dead + snow, dead + temporary imposed)</td>
<td>1.25</td>
</tr>
<tr>
<td>Short term (e.g. dead + imposed + wind, dead + imposed + snow + wind)</td>
<td>1.50</td>
</tr>
<tr>
<td>Very short term (e.g. dead + imposed + wind)</td>
<td>1.75</td>
</tr>
</tbody>
</table>

### Treatment of Timber

The risk of rot or insect attack in the timber of well ventilated pitched roofs is regarded by BS5268:Part 5 as low, except in those areas specified in the Building Regulations as subject to infestation by the house longhorn beetle (Hylotrupes bajulus L.). 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. Where preservative treatment is required, it should satisfy the requirements of the Building Regulations. The type of preservative used should neither increase the risk of corrosion of punched metal plate fasteners or nails. The recommendations of BSS268:Part 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 for the relevant preservative or treatment specification, before assembly.

#### Design Responsibilities

To avoid misunderstanding and confusion, it is essential that in contracts involving trussed rafters both the supplier and customer clearly understand the legal responsibilities of each party. On every project, no matter how small, a person must be given the overall responsibility of Building Designer and clearly defined as such. As this person requires detailed knowledge of the design assumptions for the entire building it is generally impractical for the Trussed Rafter Designer or Roof Designer to assume this role. To assist in the clear understanding of the above functions, the definitions of the various parties involved is stated.

The Building Designer may be the owner of the building, his appointed architect, a structural engineer appointed by the owner or his architect or, in the case of small buildings, the actual builder. The Building Designer should ensure that the design of the roof as a whole, and its connection to, and compatibility with, the supporting structure and adjacent elements of the building are satisfactory with regard to the overall stability of the complete structure. The Building Designer should note also any stability requirements specified by the Trussed Rafter Designer or Roof Designer to assume this role. To assist in the clear understanding of the above functions, the definitions of the various parties involved is stated.

The design of the roof should be checked by the Building Designer to determine if an adequate margin of safety exists against uplift due to wind forces and, when required, adequate holding down fixings are specified both on the trusses and the wall plates or bearings. The Building Designer is responsible for detailing the bracing necessary to provide the restraint required by the Trussed Rafter Designer.
The Trussed Rafter Designer designs and details the individual trussed rafters, clearly stating their size, loading and support conditions, stating the points of lateral restraint required to prevent buckling of compression and rafter members and, where necessary, internal members. The Trussed Rafter Designer should receive information from the client or his agent as listed in Clause 11.1 of BSS5268:Part 3 and provide information in return as listed in Clause 11.2 (Further guidance is given in Section 8). The Trussed Rafter Designer is usually the truss fabricator and his supporting System Owner.

The Roof Designer may be appointed by the Building Designer to carry out that part of the Building Designer’s duties which relate to the roof structure. The Roof Designer would normally liaise with the Trussed Rafter Designer to ensure that all structural aspects of the roof are considered. He would also require information from the Building Designer with regard to wind loading, location and size of shear or buttressing walls and deflection criteria.

It is recommended that the above terms of Building Designer, Trussed Rafter Designer and Roof Designer are used in contractual documents for the sake of clarity of meaning.

SECTION 1
TRUSS MECHANICS, MATERIALS AND RESPONSIBILITIES

SECTION 2
ROOF AND TRUSS FORMATIONS

Following an introduction to basic roof and truss shapes, common modifications are discussed along with factors which influence the choice of truss. Detailed guidance on forming the roof is given in Section 4, in particular hip systems and roof intersections.

Roof Shapes
It is now fully accepted that trussed rafters provide an economic structural roof solution. With more emphasis being place on the appearance of buildings they also allow the architect virtually free expression when designing the roofscape.

Domestic Roofs - Roofs for housing and similar type buildings may be a variety of shapes. The shapes are dictated primarily by the floor plan, followed by architectural and engineering considerations. Illustrated in Figure 2.01 are some of the more common basic shapes which can occur in isolation or in combination with other shapes.

Commercial and Industrial Roofs - In principle, the variety of shapes and layouts depicted for domestic type roofing apply also to commercial and industrial buildings. Spans may, however, be larger and loads considerably higher, making it necessary to treat each project on its merits.

Ideally the Gang-Nail fabricator should be consulted at the feasibility stage.

FIGURE 2.01 BASIC ROOF SHAPES

- Deep pitch gable end
- Monopitch gable end
- Asymmetrical gable end
- Hip end
- Detached barn hip end
- Gable and "T" intersection
- Hip corner equal ridge height
- Hip corner equal roof span
- Rectangular pyramid
- Recessed or dog-leg "T" intersection
- Hipped "T" intersection
- Attic roof with dormer
- Mansard roof

- Related to with dormer

Common Truss Modifications

Increasingly, on domestic and on most commercial/industrial projects, standard trusses must be modified to suit architectural and structural requirements. Stubbed, cantilevered and extended chord trusses are by far the most common modifications required and these are discussed in detail.

Stubbed Trusses

Where a full profile truss is truncated, as in Figures 2.05 and 2.06, it is referred to as a stubbed truss. Since stubbed trusses usually occur with full profile trusses, they are normally derived from the geometry of the profile truss (e.g. Truss B in Figure 2.05). This is for several practical and economic reasons:

1. Helps to maintain rafter alignment (see later).
2. Minimises production 'downtime' in resetting the jig, since only a few adjustments are required.
3. The majority of timber components are common to trusses A and B, which reduces cutting time.
4. Alignment of webs helps detailing and installation of the stability bracing and services.

Truss Shapes and Spans

The selection of truss shape is dependent on span, loadings, rafter alignment (discussed later) and timber size limitations. It is therefore best left to the fabricator to decide on the profile to be used. As an indication, however, the most common truss profiles are shown in Figures 2.02 and 2.03. The normal economic span is shown, although greater spans can be achieved.

The required dimensions and reference points for duopitch and monopitch trussed rafters are shown in Figure 2.04. It is worth emphasising the following points:

1. The outside face of the wall plate is often located at the Setting Out Point (S.O.P.) and consequently span overall supports equals span overall S.O.P.'s. The two spans should however be thought of as being separate since in all modified trusses they will not be equal.
2. The overhang and soffit width are not the same dimension. Both are measured to the back of the fascia, but the former is from the S.O.P. and the latter the outside face of the brickwork. For trussed rafters, the required overhang dimension and end cut should be given.

The names for monopitch trussed rafters are derived from the number of bays the top and bottom chords are divided into. For example, a 2 on 1 (or 2/1) will have 2 top chord bays and 1 bottom chord bay.
The structural treatment of cantilevered trusses varies with increasing cantilever distance:

1. **Standard Heel**
   BS5268:Part 3: permits a small cantilever on normal heel joints without further modification, as shown in Figure 2.09.

2. **Modified Heel**
   In some instances, cantilevers greater than (1) can be accommodated by modifying the heel joint, as shown in Figure 2.10. Limitations depend on loads and timber sizes, but the support will always be local to the heel joint.

3. **Cantilever Web**
   Where the support occurs outside of (1) and (2), a cantilever web is added to strengthen the bottom chord, as shown in Figure 2.08. The maximum cantilever distance permitted is normally limited to the lesser of a quarter of the setting out points span, or the first internal node point.

In some instances a cantilever causes the outer bottom chord bay to be in compression and a lateral brace may be required, as shown in Figure 2.11. The Trussed Rafter Designer will advise when this is to be provided.

To be specific, stubbed trusses should be referred to as, for example, stubbed fink or stubbed 2 on 2 monopitch trusses, depending on the profile they are derived from.

A range of support and end conditions are described in Section 5.

**Cantilevered Trusses**

A cantilevered truss occurs where the main body of the truss, not just the rafter overhang, projects outside the support, as shown in Figure 2.08. When referring to cantilevered trusses, the profile name should be used. For example, Figure 2.08 shows a cantilevered fan truss. At the standard profiles can be cantilevered at one or both ends.
Hip end and roof intersections present specific problems and should be discussed with a Gang-Nail fabricator.

Structurally, the extended legs support the weight of the roof and resist the large bending forces imposed upon them. Additionally, the horizontal deflections that occur on raised tie trusses must be contained to a figure the supporting structure can accept. (For most structures it is recognised that 6mm can be tolerated at each support.) To achieve this, the extended legs must be strengthened using one of the following three methods:

1. **Increased Depth of Chord**
   The simplest solution is to increase the depth of the extended chord member. Figure 2.14 compares a standard fink and raised tie trussed rafter of equal span. It can be seen that the top chord has increased from 72mm to 169mm in depth.

2. **Add Scabs**
   Preferably the scabs should be nailed to the truss by the fabricator, since they are a vital part of the structure and represent over 50% of the bending strength of the extended leg. Where they are to be site fixed, a nailing pattern must be obtained from the fabricator and strictly adhered to.
   For some designs, bolts may be specified instead of nails. Bolts should be treated against corrosion and supplied complete with two plate washers to prevent the nut and bolt head from being drawn into the timber.

3. **Superchord**
   The extended chord can be reinforced by nailing or bolting additional members (scabs) to it, as shown in Figure 2.15. Repeating the above example results in a 145mm deep top chord with one scab or 120mm top chord with two scabs.

When specifying cantilevered trusses, the dimensions given in Figure 2.08 should be provided. Since traditionally the cantilever distance has been measured to either the centreline or the outside face of the wall plate, all the dimensions shown should be provided to ensure no misunderstanding occurs.

**Extended Chord Trusses**
Extended chord trusses occur in two principal forms, either extended top chords or extended bottom chords, as shown in Figure 2.12. In both cases, the support occurs on the extended member. They are predominantly used in conjunction with the fink or queen post truss but, with the exception of scissor and flat trusses, can be applied to other truss families.

Since the bottom chord, or tie member, does not occur at wall plate level but is raised, extended top chords are commonly referred to as raised tie trusses. The lower eaves height produces a cottage effect, allowing the new structure to blend in with period properties and, consequently, is attractive to some planning authorities. Other applications are to allow increased internal room height or as a design feature.

The extended bottom chord is normally used over dormer windows in raised tie roofs, as shown in Figure 2.13. It is also useful where the distance between the support wall varies. Designed for the maximum case, the extended leg can be cut back on site to take up the reducing span.
It is particularly suited to extended chord trussed rafters (Figure 2.17) offering not only significant economies in manufacture and delivery but also providing the architect with greater freedom in design.

**Figure 2.17 Superchord on extended chord trussed rafters**

As an alternative to reinforcing the extended legs, it may be preferable to use cross wall construction, as shown in Figure 2.18. By supporting the body of the truss on the beams, the load is relieved from the extended leg allowing smaller timber sections to be used and longer rafter extensions.

**Figure 2.18 Cross wall construction**

To specify extended chord trusses provide the dimensions, as illustrated in Figure 2.19. Try to avoid extended legs greater than 0.9m, unless alternative methods of support can be provided.

**Figure 2.19 Dimensioning extended chord trusses**

**Figure 2.20 Raised tie support detail**

Where additional timber ends are needed to seal the top of the truss, it may be necessary to use deck planks as well as the extended legs. To ensure adequate depth means to suit either a ceiling or suspended aluminium batten.

**Figure 2.21 Rafter alignment**

Where more than one design of trussed rafter is employed on a roof, the rafters for the various sections must align. This is referred to as line-up and is illustrated in Figure 2.21. There are two ways to align rafters. The preferred solution, and by far the simplest, is to make the top chord depth on trusses A, B, and C all the same.

The fabricator if provided with the correct information would normally make this adjustment automatically. To compensate for the increased chord depth, truss A would be revised to a 2 on 2 monopitch profile, thereby saving a web member. The alternative solution is to cantilever truss A a sufficient distance to "line-up" the rafter, but practical problems are such that this approach is rarely adopted.

**Figure 2.21 Rafter alignment**

Independent designs for trusses A, B and C

Truss A

- 25 x 72
- 25 x 97

Truss B

- 35 x 72
- 25 x 97

Truss C

- 35 x 97

Different top chord depths can cause misalignment, but not ideal, means relocation of bearing more difficult.
Handling and Site Access

Trussed rafters can be large, flexible, heavy units and it is important to consider the handling of them and site access at an early stage. Where cranes cannot be used, unit weight is important. Illustrated are the weights of three typical trussed rafters.

**TABLE 2.01: MAXIMUM BAY LENGTH OF RAFTERS AND CEILING TIES**

<table>
<thead>
<tr>
<th>Depth of member (measured on plan between node points)</th>
<th>35mm thick</th>
<th>47mm thick</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rafter, Ceiling tie</td>
<td>m</td>
<td>m</td>
</tr>
<tr>
<td>mm</td>
<td>m</td>
<td>m</td>
</tr>
<tr>
<td>72</td>
<td>1.9</td>
<td>2.5</td>
</tr>
<tr>
<td>97</td>
<td>2.3</td>
<td>3.0</td>
</tr>
<tr>
<td>120</td>
<td>2.6</td>
<td>3.4</td>
</tr>
<tr>
<td>145</td>
<td>2.8</td>
<td>3.7</td>
</tr>
</tbody>
</table>

**TABLE 2.02: MAXIMUM LENGTH OF INTERNAL MEMBERS**

<table>
<thead>
<tr>
<th>Depth of member (measured between node points)</th>
<th>35mm thick</th>
<th>47mm thick</th>
</tr>
</thead>
<tbody>
<tr>
<td>mm</td>
<td>m</td>
<td>m</td>
</tr>
<tr>
<td>60</td>
<td>2.4</td>
<td>3.5</td>
</tr>
<tr>
<td>72</td>
<td>3.6</td>
<td>5.2</td>
</tr>
<tr>
<td>97</td>
<td>4.5</td>
<td>6.0</td>
</tr>
</tbody>
</table>

**Timber Sections**

To ensure the trussed rafter has sufficient robustness to withstand reasonable site handling, BS 5268: Part 3 requires that it should be a minimum of 35mm thick for spans up to 11m and 47mm thick for a 16m span.

Within and above this range of spans the minimum thickness should be obtained by linear interpolation or extrapolation. The trussed rafter may be manufactured to the required thickness as one unit or consist of two or more rafters, each not less than 35mm thick, permanently fastened together at the fabricator’s works. The maximum bay and web lengths are also limited to those given in Tables 2.01 and 2.02.
Trussed rafters are precisely engineered structural components, the design of which is dependent on the loads adopted. The following serves to assist the specifier in understanding and evaluating design loads.

### Dead Loads

Dead loads are the loads that make up the permanent structure. They include:

- **Roof Finishes**: Roof finishes vary in weight from light aluminium sheetings which are less than 100N/m², to natural slate tiles, such as York stone, which can exceed 2500N/m². Manufacturers of roof tiles give ‘laid weights’. BS5268:Part 3 suggests a value of 575N/m² for common concrete interlocking tiles. An additional allowance of 110N/m² for felt, battens and the rafter is usually adequate. Thus, total dead load for concrete interlocking tiles is:
  - Laid Weight = 575N/m²
  - Felt, Battens, Rafter = 110N/m²
  - Total = 685N/m²

- **Ceiling Finishes**: A load of 250N/m² will take account of 12mm plasterboard, skim coat, noggings, insulation and selfweight of the ceiling joist. Where suspended ceilings are proposed, the weight should be obtained from the ceiling manufacturer.

- **Water Tanks**: BS5268:Part 3 requires an allowance to be made for a water tank unless there is specific information to the contrary. For suspended tanks, a 900N per truss is applied as two node point loads of 450N.

### Roof Loadings

Three types of loadings apply to flat roof structures. They include:

1. **Dead Loads**: Are the loads due to the permanent structure of the roof. These loads consist of the weight of the membrane, insulation, light roofing coverings, plasterboard to the faces of the rafters, and the weight of moveable partitions, furniture, people, stored materials and snow on the roof.

2. **Imposed Loads**: Are generally due to fixtures and fittings. For example, the weight of climbing ropes in schools to the provision of bath lifts in hospitals, schools and offices. Service loads can be significant if the building is part of a complex, such as an industrial estate. To ensure that the particular truss will be erected in the specified position on site. The only practical solution is to agree with the services engineer, at the outset, a uniformly distributed load to be used either over the whole area or over the bay structure. They include:

   - **Ceiling Tie Loads**: To provide a horizontal fire barrier, additional or thicker layers of plasterboard may have to be nailed to the ceiling. Vertical barriers can be achieved by nailing two layers of plasterboard to the face of a truss. In both cases the fabricator must be informed so that the extra loads are included in the design.

3. **Wind Loads**: The wind load to be applied is detailed in BS6399:Part 3. It depends on the geographical location and altitude of the site, together with the roof geometry. This information must be provided by the specifier.

### Medium-Term Loads

Medium-term loads, as above, plus an imposed load of 1.5N/m² over the floor area for domestic buildings. Greater values will be required for other types of use and details should be provided by the specifier.

### Long-Term Loads

Long-term loads comprise dead loads on the top chord and dead plus permanent imposed load on the bottom chord. The tank load, if applicable, is placed in the bay where the tank is to be situated. For the calculation of the load on the trusses, a check is made on three periods of loading: long, medium, and short-term. These loading conditions are summarised in Table 3.01.

### Attic Trussed Rafters - Special Loading Considerations

- Attic trussed rafters support extra dead and imposed loads.

- **Dead Loads - Floor boarding**: Will be required on the bottom chord and plasterboard to the walls and ceiling.

- **Imposed Loads**: BS5299:Part 1 requires an imposed load of 1.5N/m² over the floor area for domestic buildings. Greater values will be required for other types of use and details should be provided by the specifier.

<table>
<thead>
<tr>
<th>Location</th>
<th>Duration</th>
<th>Dead</th>
<th>Imposed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Centre of Bay</td>
<td>Very short term</td>
<td>Dead</td>
<td>Imposed</td>
</tr>
<tr>
<td>250N/m² UDL</td>
<td>Long-term</td>
<td>PLUS</td>
<td>PLUS</td>
</tr>
<tr>
<td>2 x 450N concentrated loads for water tank or actual load if greater</td>
<td>Long-term</td>
<td>PLUS</td>
<td>PLUS</td>
</tr>
<tr>
<td>At 2 nodes nearest water tank</td>
<td>Long-term</td>
<td>Service / fittings loads</td>
<td>Service / fittings loads</td>
</tr>
<tr>
<td>900N man load</td>
<td>Short-term</td>
<td>900N man load reduced where appropriate to 675N</td>
<td>900N man load reduced where appropriate to 675N</td>
</tr>
</tbody>
</table>

**TABLE 3.01: SUMMARY OF LOADS AND LOAD CASES**
This section builds on the introduction to trussed rafters given in Section 2, ‘Roof and Truss Formations’ and provides more detailed guidance on forming the rooftops. Features, such as hips and roof intersections, are described along with trusses that require special consideration, such as the scissor and attic families.

**T Intersections and Valley Infill**  
Where two roofs intersect at 90°, a T intersection is formed. The oncoming ridge can be below, equal to, or above the main ridge, and spans and roof pitches can vary. (Figure 4.01).

Case 1 is considered in Figure 4.02, but the principles remain the same for Cases 2 and 3. The intersection is formed by the use of diminishing valley frames, collectively referred to as a valley set.

The valley frames transfer the rafter loads down onto the underlying trusses in a uniform manner. To achieve this they require vertical webs at approximately 1200mm centres and must be erected in firm contact with each rafter they cross. Since the tile battens are omitted in the overlay roof area, supplementary members must be provided to laterally restrain the rafters of the supporting trusses. Typically, tile battens are nailed to the underside of the truss top chord, extending 1200mm beyond the valley line.

**FIGURE 4.02 ROOF INTERSECTION**
(9) Maximum economy will be achieved by allowing the fabricator to select the framing method that best suits his manufacturing process. With the exception of the site infill hip end, hip systems are all based around girder and intermediate trusses of the same profile using flying rafters. This is fully described for the standard centres hip (Figures 4.05 and 4.06). Brief details are also given for other hip systems.

**Standard Hip**

There are five alternative methods of framing the standard hip end:

(1) Standard Centres Hip—most common up to 11m; girder position fixed.

(2) Standard Set Back Hip—similar to (1) with girder position flexible.

(3) Girder Based Hip—alternative to (1).

(4) Site Infill Hip— for small hips to 6m span.

(5) Two Stage Hip—for large hips in excess of 11m span.
**Standard Centres Hip**

The most common form of construction for a hip end is the standard centres hip system. This comprises a number of identical flat top hip trusses, spaced at the same centre as the main trusses, and a multiple girder of the same profile supporting monopitch trusses off the bottom chord (Figures 4.05 and 4.06). The flying rafters on the hip and monopitch trusses are usually supplied full length and cut back on site to ensure that they meet the hip board.

**Figure 4.05 Standard Centres Hip System**

- **Ledger rail detail**
- **Mono truss fixed to girder using truss clip**
- **Mono truss supported at multiple girders truss on truss shoes** - See Detail B
- **Corner infill using trusses**
  - Where corner is not provided using boxed truss detail but be provided by the truss supplier

**Figure 4.06 Corner Infill Using Mono Trusses**

- **Corner infill using mono trusses**
  - Mono truss supported on hip girder truss B
  - Bottom chord by truss hanger and fixed to top chord as Figure 4.05
  - See Figure 4.05

- **Mono truss supported at girders**
  - Boxed truss detail but be provided by the truss supplier

**Figure 4.07 Standard Centres Hip System**

- **All trusses positioned at standard centres**
- **Flying rafters**
- **Mono truss supported on hip girder truss B**
- **Bottom chord by truss hanger and fixed to top chord as Figure 4.05**
- **See Figure 4.05**

- **For corner infill see Figure 4.05**
- **Mono truss supported at girders**
  - Boxed truss detail but be provided by the truss supplier

**SECTION 4 FORMING THE ROOFSCAPE**

The corner areas of the hip are completed by using site cut rafters onto the hip board and infill ceiling joists spanning onto the hip girder. The horizontal top chords of the hip trusses require lateral bracing back to the hip girder.
**Standard Set Back Hip**

The standard set back hip is virtually identical to the standard centres hip, except that the position of the hip girder can be chosen to avoid obstructions, such as chimneys, or to ensure the girder is not supported on a lightweight lintel.

**Girder Based Hip**

The girder based hip is supported by a Howe girder at the apex. This, in turn, supports flat top trusses spanning from the end wall. To reduce the amount of site infill timbering, mono trusses can be used, spanning from the side walls onto a multiple flat top truss.
Site Infill Hip
The site infill hip is the basic form of hip end construction, consisting of a multiple girders at the apex position supporting the hip boards and loose ceiling joists. Site cut rafters span from the wall plate onto the hip board to form the roof slopes. No trusses are used in the hip end area. This form of construction is limited to a maximum span of 6 metres.

Two Stage Hip System
For spans greater than 11 m, the load on the hip girder is excessive and/or the corner infill area is too large. The two girder hip system solves both of these problems. From the framing plan it can be seen that a shallow girder is used to support the monopitch area and a deeper girder carries load from the flying rafters, with intermediate trusses of each profile being used.
**Dutch or Barn Hip**

This form of hip end takes its name from the traditional Dutch barn roof. The gable wall is built up above the ceiling line and a truncated hip end formed. The result is an attractive roof line, relatively simple to achieve and falling between the gable end and hip end in terms of cost.

The trusses used in the hip section are a flat top hip truss with flying rafters cut back on site to meet the hip board.

**Louvred Hip**

The louvred hip end is made up of the lower part of a hip end, terminated at the ridge with a vertical face. The construction is straightforward, using a girder truss at the vertical face which supports the hip monopitch trusses off the bottom chord. A vertical web is provided to support the hip board, with corner framing as for a standard hip. The minimum span for the monopitch truss is span/4.

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**SECTION 4**

**FORMING THE ROOFSCAPE**

**FIGURE 4.11 DUTCH OR BARN HIP SYSTEM**

Generally the set back (see Figure 4.11) is less than a quarter of the main span and a girder is not required; all trusses being spaced at standard centres.

The depth of the hip truss is dictated by the height above ceiling level of the gable wall. The return slope is constructed from site cut rafters, spanning from the gable wall up to the hip board. To provide lateral restraint to the top chords of the hip trusses, it is important to brace them back to the gable wall.

**FIGURE 4.12 LOUVRED HIP SYSTEM**

Mono truss to be supported on girder truss B bottom chord by truss hanger and laterally restrained at the top.

For corner see Figure 4.65

Circular web positioned to provide stiff for hip board support

See detail A

Mono truss to be supported on girder truss B bottom chord by truss hanger and laterally restrained at the top.

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**SECTION 4**

**FORMING THE ROOFSCAPE**
Cranked or Dogleg Intersection
A cranked or dogleg intersection occurs when two roofs meet at an angle between 90° and 180°. Normally the intersecting roofs have the same span and pitch, but some variation can be accommodated so long as the ridge heights match.

The framing plan (Figure 4.16) shows the typical arrangement whereby girders are positioned on the intersection line and at the end of each leg, these being used to support loose infill. For small spans, girders A and B may be formed using two or three of the standard profile trusses nailed together. However, for larger spans, and to simplify erection, all three girders should have vertical webs and matching profiles. For further guidance on the choice of girder and the infill timbers, reference should be made to Section 6. Although detailed for a duopitch roof, monopitch and asymmetric roofs can be treated in a similar manner.

Except in situations where there are several identical dogleg turns, using stubbed trusses as a replacement for site infill would be too costly. Where this is proposed, special fixings will be required to support the stubbed trusses on the diagonal girders.

FIGURE 4.16 FRAMING A CRANKED OR DOGLEG INTERSECTION

Hip Corners
A hip corner is formed when two roofs meet at right angles to each other. Common variations are shown in Figure 4.13.

There are two common framing systems:

As for hip ends, these two systems are very similar and only the former is illustrated in Figure 4.14 for a corner with equal spans and equal pitch.

FIGURE 4.14 STANDARD CENTRES HIP CORNER SYSTEM

Girder hanger fixed to vertical webs of girder D to support multiple A and B trusses.

Mono truss to be supported on hip girder truss B bottom chord by truss hanger and fixed to top chord as Figure 4.05

FIGURE 4.13 HIP CORNER – COMMON VARIATIONS

(a) Equal span and roof pitch
(b) Unequal spans with equal roof pitch
(c) Unequal spans with matching ridge heights

FIGURE 4.15 CRANKED OR DOGLEG INTERSECTION

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FORMING THE ROOFSCAPE
 FORMING THE ROOFSPACE

As spans increase and the design of purlins in solid timber becomes more difficult, it may be necessary to introduce trussed purlins at the ridge to support monopitch trusses (Figure 4.17). This increases the prefabricated area and reduces the site framed area.

**Scissor Trusses**

The term scissor truss is used to describe a truss with a sloping bottom chord. The three recognised variations are shown in Figure 4.18. These trusses are used either to increase internal headroom without raising the eaves or as a feature in, for example, a church building.

**Multipart Trusses**

In some cases the dimensions of a truss exceed those that can be manufactured, delivered or erected as one unit (see Section 2). To overcome this problem, it is possible to produce and deliver trusses in two or more parts and erect the required profile on site. Connections can either be in the horizontal or vertical plane.

**Attic Trussed Rafters**

The attic or room-in-the-roof trussed rafter is a simple means of providing the structural roof and floor in the same component (Figure 4.23b). This offers considerable advantages over loose timber construction:

1. There are no restrictions on ground floor layout since the trusses span onto external walls.
2. Attic trusses are computer designed and factory assembled units, resulting in increased quality assurance.
3. Complex, labour intensive site joints are not required.
4. Attic trusses can be erected quickly, offering cost savings and providing a weathertight shell earlier.
5. Freedom to plan the first floor room layout.
6. A complete structure is provided, ready to receive roof finishes, plasterboard and floorboarding. If we compare an 8m fink truss (Figure 4.23a) with an equivalent 8m attic truss (Figure 4.23b), it can be seen that the chord timbers have increased in width and depth.

There are two reasons for this:

1. The attic truss supports approximately 60% more load than a fink truss of the same span and pitch. This difference in load is made up of plasterboard ceilings and wall construction, full superimposed floor loading and floor boarding.
2. The lack of triangulation in an attic truss will result in increased timber sizes. Predominantly 44mm or 47mm thick timber is used, with depths ranging from 145mm to 245mm.
An indication of span, pitch and room widths which would result in comfortable designs are given in Figure 4.25. All cases outside of these should be discussed with your Gang-Nail fabricator.

### Attics - Good Practice

The application of a few basic principles at the concept stage of a project can result in substantial cost savings by maximising the use of prefabricated components and minimising loose infill areas.

Where only two supports are available for attic trussed rafters, the bottom chord tends to hang off the rafters and the vertical webs are in tension. A central support adds considerably to the stiffness of the bottom chord, such that it often props the rafter and places the vertical webs in compression.

![Figure 4.23 Equivalent Purlin and Attic Trussed Rafter](image)

![Figure 4.25 Structural Feasibility Guide to Attic Trussed Rafter](image)

![Figure 4.26 Building Layout to Suit Attic Trussed Rafter](image)

1. Dormer windows and stairwell openings are formed by placing multiple girders each side of the openings (see Figure 4.26) and loose framing in between. Place stairwells parallel to the trusses and position windows opposite each other.
(2) For T intersections, detail a corridor link between the room areas. This will reduce the site framing required and also allow the use of a girder truss in some cases where a loadbearing wall is not provided (Figure 4.27). In the non-preferred arrangement a loadbearing wall is essential.

(3) Make use of loadbearing ground floor walls to add extra support to the attic trusses. To be effective they should occur within the centre fifth of the span and will have most influence when placed near mid-span (Figure 4.28).

(4) It is easier to construct attic roofs with gable ends as opposed to hip ends. Nevertheless, hip ends can be used, although the number of supports available influences the ease with which this can be achieved.

(i) Three supports. Where a central support is provided, the rooms can be easily extended into the hip area (Figure 4.30a). It is possible to go beyond but this would involve multiple girders with framing between them (Figure 4.30b).

(ii) Two supports. Minimum site framing is achieved by stopping the room at the apex of the hip (Figure 4.29a). Alternatively, a multiple attic truss can be provided at the hip to support site framing spanning onto a normal hip girder. In this case, the room extends into the hip area and dormer windows can be provided in the end elevation (Figure 4.29b).
(5) Gable windows are easier to construct and usually cheaper than dormer windows. Small rooflights can be accommodated within the standard truss spacing.

A typical dormer window and framing details are shown in Figure 4.31. Multiple trusses must be located each side of the opening which, ideally, should not be wider than 1200mm. Larger openings are possible but they require larger infill areas at additional cost.

(6) Where possible, keep the overall height below the transportable limit. Local conditions may influence this but, generally, 4m is an accepted value. Above this height the unit is made in two parts. Unlike the two-part trusses described earlier, these units must be structurally connected on site to act as one (Figure 4.32). Details of the required connection will be provided by the truss supplier.

Attic Truss Modifications
The lack of triangulation in attic trusses requires that modifications, such as stubbed ends and cantilevers, are treated with care. The rules given in Section 2 do not apply.

1) Stubbed Ends. To maintain stability the modified attic truss relies on its outer triangles. If these are removed the truss will collapse (Figure 4.34). The amount the attic truss can be stubbed depends on span, pitch, room width and local wind pressures. No simple rules can be given and each case must be treated individually.

2) Cantilevering. Small cantilevers of less than 600mm can often be accommodated, but it is prudent to check with the Gang-Nail fabricator.

Attic Partitions
All internal partitions should be constructed using timber studs and plasterboard or some other lightweight partitioning material. Blockwork should not be used. Normally an allowance for the weight of the partitions is included in the design of the truss. It is therefore unnecessary to provide additional strength under walls as is the case with loose floor joists. To provide support to partitions running parallel to trusses, nogging should be used as shown in Figure 4.35.

Attic Bracing
The principles of bracing are described in detail in Section 7. These apply to attic roofs, although it is worth emphasising the treatment of the diagonal brace (see Figures 7.09 and 7.10).
Attic Services
The lower void area is an ideal place to locate service runs, allowing lateral runs to be positioned between the bottom chords (Figure 4.36). In some instances, access for maintenance is provided into this area via a small fire resistant hatch in the wall.

The structural action of an attic trussed rafter is entirely different to that of a floor joist. The accepted practice of notching floor joists is totally unacceptable for an attic trussed rafter. This could easily halve the strength of the member. DO NOT NOTCH OR DRILL ANY MEMBER.

Girder Trusses and Site Infill
To minimise manufacturing costs and to avoid confusion on site, it is common practice to use standard trusses nailed together to form girders rather than produce separate girder designs. The number of trusses required to form the girder is dictated by the width of roof that the girder supports, i.e.

Number of trusses = Width of supported roof
standard truss centres

To illustrate this, consider the following example (Figure 4.37):

The result, in this case 1.4, must always be rounded up. In our example, therefore 2-ply girders are required.

This approach is only valid where the maximum width supported by any girder does not exceed three times the standard truss spacing. Where specific designs for the girder are provided, larger openings can be accommodated. Infill must be supported at every node point by purlins and binders (Figure 4.38a) or by infill joists located at uniform centres along the bottom chord (Figure 4.38b).

Where this cannot be achieved, advice should be obtained from the Trussed Rafter Designer. For example, the stairwell in Figure 4.39 prevents a binder being located at node A, hence the staircase and floor may impose an unacceptable point load at X.

SECTION 4 FORMING THE ROOFSCAPE

SECTION 4 FORMING THE ROOFSCAPE
Figures 4.40 and 4.41 show acceptable methods for framing around windows and stairwells and give recommended connections and support details.

**Alternative Forms of Attic Construction**

**Cross Wall Construction**

Cross wall construction, as shown in Figure 4.42, is particularly suited to floor plans with large dormer windows or where the layout of the staircase and windows prohibit economic use of attic trusses. (see Figure 4.26).

**Attic Frame Construction**

This form of construction is illustrated in Figure 4.43. It is particularly suitable where a concrete floor slab is provided and large room widths are required. It is not recommended for most domestic attic roofs for three main reasons:

1. The saving in the cost of the frames compared to a full attic truss, is outweighed by increased erection costs.

2. The design of the frames is dependent upon the support conditions and the stiffness of the floor joists provided by others.

3. The horizontal thrust from the frames must be transmitted into the floor joists and through the splice joint in the joists. These connections will be structurally significant, since they would be required to transmit in excess of 6kN.
Satisfactory performance from trussed rafters is dependent upon the provision of proper bearings to support and restrain them without causing damage. All too often this detail is neglected, yet it is neither difficult to understand nor expensive to provide. This section will assist the specifier in ensuring that good practice is followed.

**Eaves and Support Details**

Figure 5.01 provides illustrations of a range of standard eaves and support details.
**SUPPORT CONDITIONS**

**Truss Fixing Details**

Gang-Nail trussed rafters are precision engineered computer designed components, manufactured under quality controlled factory conditions. The same care should be taken on site when fixing the trusses and it is strongly recommended that truss clips are used to secure the trussed rafters to the wall plates or bearing. (Figure 5.02).

**Figure 5.02 Truss Clips**

N/A. No holes must be used.

Trussed rafters should be driven through the holes in the fasteners.

Where a truss is to be supported by a trussed rafter girder, a truss hanger should be used. The hanger legs should be wrapped over the bottom chord of the girder or nailed to the web members, as shown in Figure 5.03. All nail holes should be used.

**Figure 5.03 Truss Hanger Support**

(a) All holes to be used.

Trussed rafters should be driven through the holes in the fasteners.

Where a truss is to be supported by a trussed rafter girder, a truss hanger should be used. The hanger legs should be wrapped over the bottom chord of the girder or nailed to the web members, as shown in Figure 5.03. All nail holes should be used.

**Figure 5.04 Restraint Against Uplift**

Trussed rafters should be supported only at the designed bearing points. It is advisable, therefore, to erect internal non-loadbearing walls after the roof tiling has been completed. This allows deflection to take place under dead load and reduces the risk of cracks appearing in ceiling finishes. Alternatively, if partitions are of brick or block, the final course can be omitted until the tiling has been completed.

Where non-loadbearing partitions are pre-made or site assembled, they should be an easy fit and must not be forced against the underside of the trussed rafter. (See also Section 9 ‘Site Practice’).

**Multiple Trussed Rafters**

The eaves details shown earlier in this section also apply to multiple trussed rafters, but the extra thickness and loads associated with these units frequently necessitate alternative fixing details.
Fixing to Wall Plate
Truss clips for multiple units are not available. The preferred fixing method uses framing anchors or heavy duty angle brackets (Figure 5.05). Where wind uplift must be resisted, twisted straps are also required.

Girder Support
In general, where a multiple truss is supported by a trussed rafter girder, a metal hanger should be used. This should satisfy the following criteria:

1. Adequate safe working load.
2. Sufficient bearing length to support the oncoming truss.
3. Correct width of hanger to suit the oncoming truss. A hanger which is too wide should never be used with packs, as this will result in flexing of the bearing surface and lead to cracks in the ceiling finishes.
4. The hanger fixing must be in accordance with the manufacturers’ requirements and the Trussed Rafter Designer should approve the fixing proposed.

A range of medium and heavy duty girder hangers are shown in Figures 5.06 and 5.07. They provide a range offering safe working loads up to 40 kN and are suitable for most applications where members meet at 90°.

The medium duty girder hanger is suitable for supporting two or three 35mm thick trussed rafters nailed together to form a girder, up to a safe working load of 17kN.

The range of heavy duty girder hangers are suitable for two, three and four ply girders of timber thickness 35mm and 47mm.

They provide a range offering safe working loads up to 40kN and are suitable for most applications where members meet at 90°.

A 25mm horn should be detailed on the oncoming girder to allow for the projecting bolt heads.

Where girders intersect at an angle other than 90°, or where several members come together, special hangers can be fabricated. An adequate fixing area must be provided on the support girder and torsional forces must be restrained. Metalwork is usually finished by hot dipped galvanising, but a paint finish, to the Client’s specification, can be provided.
In line with the objective of this manual, to provide a comprehensive reference guide to the design of trussed rafter roofs, this section considers a number of special details that occur. Fire precautions are reviewed, the required connections between the walls and roof are given, together with support details for water tanks and services. Particular emphasis is devoted to the detailing of loose infill areas, including framing to dogleg turns.

**Water Tank Location and Support**

Even a small domestic cold water storage tank weighs a third of a tonne, whilst a large tank, say for a hospital building, can exceed 10 tonnes. The following will enable the Building Designer to make adequate provision for a tank in the majority of buildings:

- Advise the Trussed Rafter Designer of the size and location of the tank.
- For domestic 230 litre or 300 litre net capacity tanks, specify the tank support timbers in accordance with Figure 6.01, stating whether load is spread over three or four trusses.
- For larger tanks, agree the support points with the Trussed Rafter Designer and design the support timber in accordance with BS5268: Part 2.
- Where headroom is limited joist hangers can be used, as Figure 6.02.
- Chipboard is not recommended for the tank platform. Plywood or timber is preferred.
- Where tanks cannot be located within the web configuration, they are usually supported between multiple trusses (Figure 6.03).
- Where extra head height is required, for showers and the like, the tank must not be supported off the webs or hung from the rafters. A framework must be designed following the principles of Figure 6.01. A typical detail is given in Figure 6.04, which transfers the load to the node points assumed by the trussed rafter design.
- Figure 6.05 illustrates the alternative locations for the tank in an attic truss. The space is sometimes limited requiring smaller tanks to be used in tandem to provide the required capacity.

**Support Provided by Masonry**

The design of a wall support or a hanger built into the wall, requires a knowledge of the types of masonry and mortars employed, the structural action of the wall and considerable masonry design experience. Delegating this responsibility to the Trussed Rafter Designer is therefore both wrong and potentially dangerous. The design of all masonry fixings must always remain the responsibility of the Building Designer.

Where trussed rafters are to be fixed to or supported on masonry, reactions will be provided by the Trussed Rafter Designer. Where these reactions are too large to suit proprietary masonry hangers, horn supports can be used. At internal support walls care should be taken to ensure these do not penetrate the masonry, unless secondary fire protection is provided at the ends of the timber.

**SECTION 5**

**SUPPORT CONDITIONS**

**SECTION 6**

**SPECIAL DETAILS**

In Figure 6.01, the load path from the tank is transferred to the node points assumed by the trussed rafter design. A typical detail is given in Figure 6.04, which transfers the load to the node points assumed by the trussed rafter design. A framework must be designed following the principles of Figure 6.01. A typical detail is given in Figure 6.04, which transfers the load to the node points assumed by the trussed rafter design. Figure 6.05 illustrates the alternative locations for the tank in an attic truss. The space is sometimes limited requiring smaller tanks to be used in tandem to provide the required capacity.
Support for Services

As discussed in Section 3, loads from services fall into two categories, i.e. major items, which have to be treated individually, and service runs, such as pipework and ducting, for which an allowance is made of a uniformly distributed load.

**Major Items**

If major equipment is to be collected together in a plant room, support should be provided independent of the roof structure. If, however, a more discrete layout is adopted, items such as fans, control panels, and air handling units, can readily be supported by the trussed rafter roof system.

Support on the bottom chord follows identical principles to those for cold water storage tanks discussed earlier. Support from the top chord requires more care in the design of the hanger fixings and should only be considered where support on the bottom chord is impractical. Nailed fixings designed in accordance with BS5268: Part 2 should normally be used.

Bolted fixings are only applicable where a high degree of site supervision is assured, and the chord size is increased in depth to allow for the loss in strength due to the bolt hole.

**Service Runs**

Figures 6.06 to 6.08 detail a number of ways of supporting service runs. Normally, a pipe or duct will be supported every three or four trusses. For multiple runs this can lead to overloading if all services are supported on the same truss.

A more even distribution of load is achieved by staggering the supports (Figure 6.06a) or by using timber stools which spread the load onto the node points of two trusses (Figure 6.07).
**Access to Services**

Some buildings, for example hospitals, require a large number of the services to be located in the roof. In these situations the provision of an access walkway may be necessary. This can usually be achieved within normal web configurations (Figure 6.09a and b). Details, such as Figure 6.09c, should be avoided. The lack of triangulation in this form results in an inefficient trussed rafter, requiring twice the amount of timber.

**Site Infill**

It is impractical and uneconomic to prefabricate some sections of a roof. These areas are constructed using loose timbers, often referred to as either site infill, loose timbering, site framing or stick built. Support is nearly always provided by trussed rafter girders or multiple trusses. These girders support purins and binders at every node point which, in turn, support the infill rafters and ceiling joints. It is essential that all nodes are used, otherwise the girders can be severely overstressed. The procedure is best described by example, the following cases being considered in detail:

- Small infill areas, e.g. hatch and chimney trimming
- Cranked or dogleg turns
- Large infill areas

Responsibility for detailing these areas rests with the Building Designer, who should ensure that the Trussed Rafter Designer has correctly allowed for the loads on girders generated by the infill timber.

**Small Infill Areas**

Every effort should be made to accommodate openings within the trussed rafter design spacing. Where this cannot be achieved the spacing of the trusses adjacent to the opening may be increased as shown in Figure 6.10, where:

- S is the design spacing of the trussed rafters;
- B is the distance between the centres of the trimming trussed rafter and the adjacent trussed rafter;
- C is the nominal width of the required opening, and does not exceed $2 \times S$.

Loose timbers will be required to support the tiles and ceiling around the opening. Typical details for framing around a chimney are given in Figure 6.11, but the principles apply to other openings also.
Where the two trimming trusses each side of the opening are nominally fixed together with nails at 600mm centres along all members, an opening of up to three standard spacings may be used as in Figure 6.12.

The purlins in this case must be 47mm x 169mm, installed vertically using metal hangers as in Figure 6.13. The binders and ridge board should be increased to 47mm x 169mm and the trimmer to 47mm x 120mm.

The above recommendations for chimney openings assume:
- that the purlin, binder and ridge board are C24 or better;
- a fink profile truss of 12m maximum span at 600mm centres;
- standard loading on the rafter and ceiling tie equivalent to concrete interlocking tiles with a plasterboard ceiling;
- for all cases where the roof pitch is less than 25° the purlins are installed vertically and supported on 2-ply trusses, as Figures 6.12 and 6.13;
- the infill rafter and ceiling joist are detailed by the Building Designer.
- depending on the design of the chimney flue and stack, appropriate clearance is allowed between timber and chimney.
Cranked or dogleg turns
Cranked or dogleg turns, as described in Section 4, involve large areas of loose infill (Figure 6.14).

Girder C should be a similar profile to Girder B to ensure that the node points line up when locating the purlins and binders. Where for small spans and/or small turn angles the total UDL load on Purlin 1 is not greater than 4.5kN, Girder B can be a multiple of truss A. For larger intersections, where the purlin loads exceed 4.5kN, it is recommended that the profiles of Girders B and C should be chosen to have vertical webs, similar to Figure 6.15. The vertical web width can then easily be increased to accommodate the fixing for the purlin. The number of bays is dependent on span and pitch but generally 2 metres is a comfortable bay size.

Girder C should be a similar profile to Girder B to ensure that the node points line up when locating the purlins and binders. Where for small spans and/or small turn angles the total UDL load on Purlin 1 is not greater than 4.5kN, Girder B can be a multiple of truss A. For larger intersections, where the purlin loads exceed 4.5kN, it is recommended that the profiles
It is a simple matter to check the purlin load, as the following example.

Assume:
- Roof Covering: Concrete interlocking tiles (836 N/m² on roof)
- Main Span: 8 m
- Pitch: 25°
- Angle turned: 45°
- Girder Profile: Fink

Top Chord Load - Dead 85 = 736 N/m² on Plan
  Imposed = 736 N/m²
  Total 1576 N/m² on Plan

Assume: Girder B is a multiple of A and check load on purlin 1.
- Maximum Purlin Span = 7/4 x 8 x tan 22.5 = 2.48 m
- Looe Rafter Span = 8/4 = 2.0 m

Therefore load on purlin
- 2.48 x 2 x 160 = 7.5 kN - 4.5 kN

Hence vertical webs required. Use Howe profile for Girders B and C, as Figure 6.15.

**Large Infill Areas**

Large infill areas occur where, in order to house substantial water storage tanks, for example, an uninterrupted roof void is required free of any internal web members. Girders are located both sides of the zone, supporting the infill timbers and also if required the items of plant, as figure 6.16. The details follow similar principles to those discussed already, except that heavy-duty hangers may be required where the binders also support the plant loads.

**Wide Eaves Soffits**

The majority of roofs project a small distance beyond the face of the external walls. This is normally referred to as a soffit and is achieved by providing a rafter overhang as discussed in Section 2 and illustrated in Figure 6.17a. Where larger soffits are required, they are usually provided by either the appropriate rafter overhang or by cantilevering the truss, as in Figure 6.17b.

Detail 'b' is far easier to achieve than Detail 'a', since it is controlled by the span of the trussed rafter and often a cantilever of Span/4 can be achieved. Detail 'a' on the other hand is controlled by the rafter size and typically for depths up to 145 mm and standard loads, the overhang can be nine times the rafter depth for C24 and TR26 where the spacing of the trussed rafters does not exceed 600 mm and the roof pitch is not greater than 35°.

With some soffit details it is possible to extend the scope of Detail 'a' by framing the overhang (Figure 6.17c), details of which must be provided by the Building Designer.
Gable Ladders

Gable Ladders are used at gable ends to provide an overhanging verge. As shown in Figure 6.19, a gable ladder consists of two rafter members joined together and supported by cross noggings built into the brickwork. The gable ladder should be nailed to the last truss only after the gable wall is built up and able to provide support. It should never be allowed to hang unsupported. The last truss should be located such that the ladder projection (a) is not greater than the supported distance (b).

Where the gable ladder width exceeds the truss spacing, additional support will be required for the tile battens. Internoggings should be used, staggered to assist nailing (Figure 6.20a). Where the rafter depth is at least 120mm, the alternative shown in Figure 6.20b may be used.

Cantilevered Hip Ends

Where cantilevered hip ends are planned, the Building Designer should ensure that adequate support can be provided for the corner infill area. Two possible methods are shown in Figure 6.18. For small cantilevers a structural hip board is used, propped off the corner of the wall and cantilevering out to support eaves beams. For larger cantilevers, the hip board is replaced by a diagonal girder. The eaves beams in either case support the loose rafters and adequate eaves depth must be allowed to accommodate the beams.

Large rafter overhangs on hip ends present similar problems to those already discussed and structural eaves beams will often be required.
If the tiling battens are to be discontinued over a party wall (Figure 6.21c), then lateral restraint must be provided in addition to that required to transfer longitudinal bracing forces. This should consist of straps (or equivalent), adequately protected against corrosion, with a minimum cross sectional area of 50mm². These straps should be spaced at not more than 1.5m centres and fixed to two rafter members and nogging on each side of the party wall by 3.35mm x 50mm long wire nails.

Extraneous Support

Trussed rafters must only be supported at the positions assumed in design if overstressing, unsightly roof lines, or damage to the finishes are to be avoided. Two particular problem areas are party walls and internal partitions.

Party walls should be stopped 25mm below the tops of rafters to allow the roof to deflect without sitting on the wall. This will prevent an unsightly hump appearing in the ridge line, where this detail is not followed. Fire stopping this detail is discussed later. It is advisable to erect non-loadbearing walls after the tiling has been completed.

This allows deflection to take place under dead load, thereby reducing the risk of cracks appearing in the ceiling finishes or distress being caused to the trussed rafters (Figure 11.14b). Alternatively, if partitions are of brick or block, the final course can be omitted until tiling has been completed.

Fire Precautions

The control of the spread of fire within a building is an extensive subject fully described in Approved Document B2/3/4 Fire Spread. The following is therefore confined to items shown by experience to merit special mention.

Preventing Fire Spread Between Dwellings

It is a requirement of the Building Regulations that fire should be prevented from passing from one dwelling or compartment to the adjacent dwelling or compartment. The Building Research Establishment has noted two areas in a roof where this principle is often neglected or inadequately carried out; at boxed eaves and at the junction between the roof and wall.

Boxed Eaves it is important to recognise that fires are known to have spread between dwellings in the manner shown in Figure 6.22. This can be prevented by adopting the following principles, which ensure that there is a complete separation in the plane of the wall between dwellings that cannot be bypassed by fire.

• Design to simplify the shape of the void to be closed. Consider extending the separating wall to the outer face of the external wall within the eaves (A, Figure 6.23).

• Do not carry the separating wall over an uninterrupted wall plate: movements in the timber will disrupt the brickwork or blockwork.

Lateral Support to Walls at Roof Level

The trussed rafter roof structure should be connected adequately to external masonry or timber frame walls and any other vertical load bearing elements of a building. As explained in Section 7, this is to provide the necessary lateral support to walls at roof level. The responsibility for the design of these connections rests with the Building Designer.

Generally, connections should be made to the rafter with 30mm x 9mm thick galvanized steel straps, fixed to at least two trusses and a nogging with 3.35mm x 50mm long wire nails (Figure 6.21a). On gable walls they should be spaced at not more than 2m centres at rafter and ceiling tie levels. Party walls should have restraining straps at ceiling tie level (Figure 6.21b), with the strap connected to two or more trusses on each side of the wall.

The Building Designer should pay particular attention to:

• Gable ladders wider than twice the truss spacing. These require special details.

• Wind uplift, which should be carefully checked on all gable ladders. Straps to prevent movement will often be required.
A trussed rafter can only perform correctly if each member within it remains intact. For this reason they should never be taken through a compartmental wall as in Figure 6.26a. A fire in Zone B that seriously weakens the truss will result in a total collapse of the roof over Zones A and B. The correct solution is to provide the truss in two structurally separate parts (Figure 6.26b).

Junction between Roof and Wall—There are three common defects that allow fire to bypass the separating wall (Figure 6.24):

- No attempt is made to prevent it.
- Mineral wool pushed between the top of the wall and the underside of the sarking felt after roofing has been completed, leaving an unsealed gap between the felt and the roof.
- After battening, a mortar bed is trowelled onto the wall under and between the battens; this method also leaves unsealed voids beneath the tiles. Since the battens are supported by the mortar where they cross the wall, it also leads to subsequent hogging of the roof at the separating wall and possible displacement of the tiles.

As in the previous case, it is essential that there is a complete separation in the plane of the wall which cannot be bypassed by fire. To achieve this:

- Ensure that the top of the separating wall—when trimmed to the slope of the roof and mortared if necessary to achieve a fair line—is about 25mm below the top edges of the adjacent rafters. This will minimise the risk of hogging of the roof.
- Select for fire-stopping a rock-wool, slag-wool or glass fibre quilt that is resilient enough to fill irregular spaces, but not so resilient as to lift or dislodge tiles.
- Ensure that, before felting and battening, the quilt is laid down on the top edge of the separating wall, with the edges tucked between faces of the wall and adjoining rafters to keep it in place initially (A, Figure 6.25).

**Fire Compartments**

A trussed rafter can only perform correctly if each member within it remains intact. For this reason they should never be taken through a compartmental wall as in Figure 6.26a. A fire in Zone B that seriously weakens the truss will result in a total collapse of the roof over Zones A and B. The correct solution is to provide the truss in two structurally separate parts (Figure 6.26b).

**Fire Resistance of Attic Trusses**

The floor of an attic truss must provide the modified half hour fire resistance, except where constructed over a garage when the full half hour fire resistance is required. The most practical way of achieving this is to provide a suitable ceiling lining over the full extent of the attic trusses. The use of methods involving plasterboard caps, nailed locally to the truss to mask the connector plates, is discouraged. It is difficult to ensure that the plasterboard caps are fitted initially and replaced if damaged or removed during construction.

Several ways to achieve the fire resistance are given by the plasterboard manufacturers. The Building Designer must advise the Trussed Rafter Designer of the elected method, to ensure any additional load is allowed for in the design of the truss.
Before considering these in detail, it is important to understand the reason why diagonal bracing members are required in items 2 to 5. Figure 7.01 a shows a single rectangular framework which can be distorted with little effort. Even a multi-bay framework, as shown in Figure 7.01 b, offers negligible resistance. The addition of a diagonal member, as in Figure 7.01 c, rigidly braces the framework and holds it square, even when subjected to large forces. For the purposes of trussed rafter roofs, the brace will be equally effective if placed on either diagonal.

**Longitudinal Bracing (or Binders)**

Longitudinal bracing assists in restraining the trussed rafters and holding them in their correct position, particularly during tiling and fixing of plasterboard. When correctly fitted, longitudinal bracing adds to the overall roof stability. It runs at right angles to the trusses and should extend the whole length of the roof, finishing tight against a party or gable wall.

Longitudinal bracing should be installed at every unsupported node point. Adjacent to the rafters the brace should be fixed to the web, allowing the diagonal rafter brace to pass through as shown (Figure 7.02).

**Stability Bracing**

The following details will enable the Building Designer to fully detail the stability bracing on a wide range of roofs.

For the majority of trussed rafters, spaced at 600mm or less, stability bracing will be adequate if:

1. All bracing members are of the minimum size 22mm x 97mm, of a species listed in Table 7.01 and free from major strength reducing defects. Table 7.01 is taken from BS5268:Part 3.

2. Where bracing members are provided in two pieces, they are lap jointed over at least two trussed rafters and nailed as indicated in (iii).

3. All bracing members are nailed to every trussed rafter they cross with at least 3 nails 35mm diameter x 65mm galvanised round wire nails.
Rafter Diagonal Bracing and Tiling Battens

The rafter diagonal brace provides the bracing restraint to prevent the rafters from buckling sideways (lateral buckling). Tiling battens distribute this bracing effect into every rafter ensuring all rafters are restrained at tile batten centres (top chord restraint distance), producing a laterally stiff component.

The Building Designer must ensure that the top chord restraint distance assumed in design by the Trussed Rafter Designer, is not exceeded on site. One particular area requiring special attention is beneath overlay roofs, considered in Figure 4.02.

The rafter diagonal brace is nailed to the underside of rafters, is fixed at the wall plate and runs up to the ridge at an angle of approximately 45° to the rafters (Figure 7.05 on following page). The bracing should extend over the whole length of the roof, with a minimum of four braces being provided. It may be omitted from no more than two trussed rafters between bracing sets and single trussed rafters adjacent to the face of gable and party walls.

The diagonal bracing should continue from the apex to the wall plates. To achieve this, additional bracing to that fixed to the rafters will sometimes be required. For monopitch and stubbed trusses, where the end vertical web is not laterally restrained at its top by connection to a masonry wall or by being clad in plywood or a similar rigid sheet material, additional diagonal bracing is required: this is fixed to the inside face of the end vertical (Figures 7.06 and 7.07).
SECTION 7

BRACING

An alternative sometimes used on attic trusses is to fix plywood diaphragms between the rafters over the room area (Figure 7.10). A simple ‘rule of thumb’ is to add sufficient diaphragm to allow the line of action of the brace to be continuous.

For cantilevered trusses, the additional brace should be provided on the cantilever web as illustrated in Figure 7.08. Where small cantilevers require heel modifications only (see Section 2) the normal rafter diagonal brace will suffice, except that a detail similar to that in Figure 7.04 will be required where supplementary chords occur.

For raised tie and attic trussed rafters, the diagonal brace on the underside of the rafter protrudes into the room area. This is easily overcome by packing out the rafters using 22mm thick timber (Figure 7.09).

Tiling battens and boarding should be in accordance with the recommendations of BS5534; Particular reference should be made to the strength and stiffness of battens or boarding in relation to their primary function of supporting dead, imposed and wind loads. When necessary, advice may be sought from the tile manufacturer.

Battens should not be less than 1.2m in length and be continuous over at least two spans. They should be fixed to every rafter member which they cross, or on which they are jointed, with nails of the appropriate size and type specified by BS5534.

Web Chevron Bracing

Web chevron bracing provides additional lateral stability to the trussed rafters and is required on duopitch spans above 8m and monopitch spans above 5m.

Where rigid insulation is installed on top of the rafters, the tiling batten fixings can no longer be assumed to provide the necessary lateral restraint. In this case, additional battens are required on the undersides of the rafters to perform the lateral restraint function (Figure 7.11).

The ends of battens should be sawn square and butt jointed centrally on a rafter member. Thus, adequate bearing and nailing can be provided for each end of each batten. Butt joints in battens should be arranged so that not more than one batten in four is jointed on any one rafter member. Cantilevering or splicing of battens between rafters should not be permitted.

Battens on boarded roofs must be supported on counter battens running in the opposite direction. This increases ventilation under the tiles and allows free drainage, thereby preventing rainwater from reaching the underlay. Counter battens must be fixed through to the rafters and not to the boarding alone.

Where rigid insulation is installed on top of the rafters, the tiling batten fixings can no longer be assumed to provide the necessary lateral restraint. In this case, additional battens are required on the undersides of the rafters to perform the lateral restraint function (Figure 7.11).
**SECTION 7**

**BRACING**

**Web Lateral Brace**

Web lateral braces are a function of the design of the trussed rafter and should be requested by the Trussed Rafter Designer. They are required on compression members to prevent lateral buckling resulting from the compression force and/or the length of the member.

Web lateral braces must continue along a complete section of roof and be equally spaced along the web in instances where more than one brace is required. The longitudinal member is the “distributor” of the bracing restraint into every trussed rafter. The bracing effort is provided by raking braces fixed at either end and repeated at 6m intervals (Figure 7.15).

**Sarking**

Where certain sarking materials are directly fixed to the top face of the rafter members, rafter diagonal bracing, chevron bracing and longitudinal bracing at rafter level may be omitted. This is allowable if the sarking material is moisture resistant, made from plywood (minimum thickness, 9mm) or chipboard (minimum thickness, 12mm). The boards should be laid with staggered joints and nailed at no less than 200mm centres to every truss they cover with 3mm diameter x 50mm long galvanised round wire nails. It is also acceptable if the sarking material comprises timber boarding of minimum thickness 16mm, nailed to each truss with two 3mm diameter x 50mm long galvanised wire nails. The boarding must be tightly abutted at its edges and no more than one board in four may be jointed to any one rafter member.

Cantilevering or splicing of boarding or sheet materials between rafters should not occur, except where adequate noggings are provided to support the free edge.

Extra care will need to be exercised during erection to ensure that stability, vertically and straightness are maintained until the sarking has been fixed.

**Hip Ends**

BS5268: Part 3 Appendix A accepts that in certain circumstances hip ends provide a satisfactory alternative to stability bracing in the hip end area. Where the length of roof between hip ends exceeds 1.8 metres however, this section should be braced.

**Wind Bracing**

As fully described in Appendix A of BS5268: Part 3, experience has shown that, for a wide range of domestic structures, standard stability bracing used in conjunction with a plasterboard ceiling will provide sufficient wind bracing to the structure. This section therefore considers wind bracing for structures outside of the parameters of Appendix A. The need to seek advice from an experienced timber engineer is emphasised, although the following general guidance can be given. The options available are:

(i) Designed bracing.
(ii) Plywood diaphragms.
(iii) Wind girders.
(iv) Reinforced supporting structure.

**Designed Bracing** - Applying standard engineering principles, a bracing system can be designed using timber members and site connections. This often presents detailing problems in transferring forces between members and is not often used.

**Plywood Diaphragms** - A very rigid structure can be achieved by nailing plywood, to a staggered pattern, continuously over the rafters or to the underside of the ceiling tie member. In Scotland, where boarded sarking is usually provided on the roof, this method is particularly suitable, since the additional costs would be small.

**Wind Girders** - Probably the most common method, employing flat chord trusses placed horizontally on the bottom chords of the main roof trussed rafters (Figure 7.17). These “wind girders” span between the cross walls and absorb the wind forces on the sides of the building. Installation of the wind girders is simplified where a suspended ceiling is provided, since the girders can be nailed directly to the underides of the trussed rafters.
For hip ends or where the cross walls also require bracing, special details are required. To design the wind girders, the Trussed Rafter Designer needs to be given the load per metre and the amount the walls are permitted to deflect laterally, since it is often deflection rather than stress that controls the design. The typical lateral deflection permitted by Building Designers for a 4m high wall is 12mm.

Reinforced Support Structure - For reinforced concrete or steel frame buildings, the simplest solution may be to allow the structural frame to provide the lateral wind resistance.

**Multipart Trusses**

As noted in Section 9, the erection of a two-part truss, where no structural continuity is assumed, must be done in two stages. The first stage is to erect and fully brace the lower section, treating it as an independent roof, as illustrated by the example given in Figure 7.18.

Erection of the lower section fully braced will result in a very rigid structure on which the upper section can be constructed. The bracing of the upper section follows standard principles with the addition that since the bottom chord is not plasterboarded, diagonal ceiling bracing should be provided on all but the very small spans.

**LATERAL BRACING**

The sloping top chord will be restrained laterally by the tiling butters. For the horizontal top chord the trussed rafter designer must state the restraint assumptions. Restraint at mid bay and node points has been assumed.

**CHEVRON BRACING**

The span is greater than 8m so chevron bracing will be required.

**WEB BRACING**

The trussed rafter designer will state the webs requiring lateral bracing, but for length reasons alone, diagonal compression webs will normally be braced.
**SECTION 8**

**SPECIFICATION AND QUOTATION REQUIREMENTS**

**Specification**
The following is a model specification for illustrative purposes only. It offers guidance for the majority of situations but should not be viewed as the only acceptable criteria which can be used.

**Trussed Rafters**
Trussed rafters are lightweight frameworks, usually triangulated and spaced at intervals of 600mm. They shall be made from timber members of the same thickness fastened together in one plane by connector plates. Except where modified by this specification trussed rafters shall satisfy the requirements of BS5268:Part 3.

**Timber**
Where finger jointed timber is to be used, the Trussed Rafter Designer shall state this clearly on all calculations and drawings. Finger jointed timber shall not be introduced after the calculations have been approved without the written approval of the Building Designer. All timber dimensions referred to in calculations or shown on drawings shall be the actual sizes required, and not the nominal sizes.

**Connector Plates**
Punched metal plate connectors shall be manufactured by Gang-Nail Systems Limited and comply with current Agrement certificates.

**Preservative Treatment**
Copper/Chrome/Arsenic (CCA) preservative shall not be used. Where preservative treatment is specified, it must be of the organic solvent type. Timber treated with fire retardants shall not be used.

**Information Required by the Trussed Rafter Designer**
The specification gives a general description of what is required but it is also necessary for the client or his agent to provide specific detailed information. The following list is an extension of that given in BS5268:Part3.

(a) The height and location of the building, with reference to any unusual wind conditions.
(b) The external profile of the trussed rafter, including any allowances required for tolerances.
(c) The span of the trussed rafter.
(d) The pitch or pitches of the roof.
(e) Drawings showing fire walls, the position and type of support, roof shapes and any special requirement.
(f) The type and weights of roof tiles or covering, including sarking, insulation and ceiling materials.
(g) The size and approximate position of any water tanks to be supported on the trussed rafters.
(h) The overhang of rafters at eaves and other eaves details.
(i) The positions and dimensions of hatches, chimneys and other openings.
(j) The service use of the building with reference to any unusual environmental conditions and, if required, the type of preservative treatment.
(k) The spacing of trussed rafters and special timber sizes where these are required to match existing construction.
(l) The load per square metre to be allowed for services and the proposed support method, if applicable.
(m) The type, position, load and method of support for any plant, fittings, partitions, etc., supported by the trussed rafters.

**Quotation**
Apart from very straightforward cases, trussed rafter fabricators prefer not to receive Bills of Quantities but clear roof drawings and a trussed rafter specification. Ideally, the drawings should show only the outline of the truss, leaving the designer to decide on the web configuration, hip system, etc. This will always produce the most economic solution, since it allows the tenderer to use his expertise and tender a solution that fits his methods and equipment.

If trussed rafters are to be incorporated into Bills of Quantities, they should not be broken down into timber, plates, labour, etc., but itemised as complete units, along with the information described previously.

As explained in Section 9, trussed rafters should not be stored at the fabricators works or on site for long periods. The timing of production runs must therefore be linked to delivery dates. When obtaining quotations for housing sites or large contracts, an indication of the call-off (i.e. the number of trusses required in each delivery) must be given; not just the total number required, if claims for extra costs are to be avoided. This is brought about by the fact that the manufacturing cost for trussed rafters is composed of two elements:

**Set-Up** - This is a fixed cost for the time taken to set-up the jig; independent of the number of trusses produced.

**Production** - The cost of producing the trussed rafters; proportional to the number of trusses produced.

It will therefore be seen that unit production costs increase as the number of trusses decrease.

**Information Provided by the Trussed Rafter Designer**
BS5268: Part 3 requires the Trussed Rafter Designer to provide his client with the following information. This provides a checklist for the client to ensure that the trussed rafters supplied are suitable for their intended use:

(1) Finished sizes, species, stress grades or strength classes of members.
(2) The types, sizes and positions of all jointing devices, with tolerances or the number of effective teeth or nails required in each member at each joint.
(3) The positions and sizes of all bearings.
(4) Loadings and other conditions for which the trussed rafters are designed.
(5) The spacing of trussed rafters.

* NOTE: Details of the permanent bracing necessary to ensure the overall stability of the complete roof structure and supporting walls should be provided by the Building Designer.
In this section each site operation is considered and recommendations given to ensure that trussed rafters are handled, erected and fixed correctly. The causes and remedies of some common misalignments are discussed, and accepted tolerances are given.

**Delivery**

Delivery is made to site on suitable transport provided by the Gang-Nail truss fabricator. The truss fabricator will normally bear responsibility for the trussed rafters up to the point where they are off-loaded onto site: thereupon they become the responsibility of the contractor.

The delivery should be checked to ensure that it complies with the specification and that the quantities and dimensions are correct. Any discrepancies must immediately be brought to the attention of the supplier.

**Site Storage**

Site storage is intended to be temporary prior to erection. The fabrication and delivery of trussed rafters should, therefore, be organised to minimise the storage time both at the manufacturer’s premises and on site. Where storage on site is likely to exceed two weeks, or during bad weather, trussed rafters should be protected by a waterproof cover which is arranged so as to allow free access of air for ventilation.

Trussed rafters should at all times be stored to avoid contact with the ground and vegetation and should be so supported as to prevent any distortion. Preferably, they should be stored vertically, on bearers located at the points of support assumed in the design, and with suitable props to maintain them in the vertical position.

Some manufacturers and builders prefer however to invert the trussed rafters and support them in special frameworks clear of the ground. When trussed rafters are stored inverted, support must generally be provided near to the rafter node points (Figure 9.02). If approved in writing by the Trussed Rafter Designer, they may also be supported at the ceiling tie node points.

**Horizontal Storage**

Where trusses are laid flat, bearers should be placed to give level support at close centres, sufficient to prevent long-term deformation of all truss members. If subsequently bearers are placed at different heights, they should be vertically in line with those underneath.

**Erection Procedure**

The Builder should consider, in conjunction with the Building Designer, the erection procedures to be used and the provision of temporary bracing, rigging and any other specialised equipment required to enable the trussed rafters to be erected safely, without damage, in accordance with design requirements and having due regard to possible windy conditions.

Supports should be prepared as indicated in Section 5 to the correct level and position. Guidance on trussed rafter bracing is given in Section 7, but the contractor must refer to the specific details issued by the Building Designer.

The following procedure illustrated in Figure 9.05 is suggested for most domestic size roofs. It is assumed that the wall plates have been checked and are level and that the correct holding-down fixings have been made by the builder. The erection team must also have studied and fully understood all relevant drawings and details before work commences.
After erection, a maximum bow of 10mm may be permitted in line between the apex and eaves joint. In the complete roof to prevent the bow from increasing. Any trussed rafter member, provided it is adequately secured.

BS5268:Part 3 are shown in Table 9.01. Be taken to erect trussed rafters as near vertical as possible, straightness and vertical alignment. Whilst every effort should be made to ensure the ceiling and rafter plane is achieved. Immediately prior to fixing the permanent bracing and tiling, all trussed rafters should be checked for battens or sarking, all trussed rafters should be checked for temporary bracing. (Figure 9.05), but these should be installed on both sides of the roof.

Mark the position of each trussed rafter along both wall plates. (a) Mark the position of each trussed rafter along both wall plates.

Erect the first trussed rafter, designated A, at the position which will coincide with the uppermost point of the diagonal brace (F) when it is installed later. Use the temporary raking braces (B) fixed to the rafter members and the wall plates to hold this trussed rafter in the correct position, straight and vertical. For clarity, only one raking brace is shown in Figure 9.05, but these should be fixed to both rafter members and be of sufficient length to maintain the trussed rafter in position during the erection of the remaining trussed rafters.

Erection Tolerance

Immediately prior to fixing the temporary bracing and tiling battens or sarking, all trussed rafters should be checked for straightness and vertical alignment. Whilst every effort should be made to ensure the ceiling and rafter plane is achieved. Immediately prior to fixing the permanent bracing and tiling, all trussed rafters should be checked for.

Fixing

Gang-Nail trussed rafters are computer designed components, manufactured under quality controlled factory conditions. The same care should be applied when fixing the trusses and it is strongly recommended that truss clips are used to secure the trussed rafter to the wall plates or bearing points (Figure 9.06).

Skew nailing should only be considered where the workmanship on site is of a sufficiently high standard to ensure that the fasteners, joints, timber members and bearings will not be damaged by careless positioning or overdriving of the nails. The minimum fixing at each bearing position should consist of two 4.5mm x 100mm long galvanised round wire nails, which are skew nailed from each side of the trussed rafter into the wall plate or bearing. Where nailing through the punched metal plate cannot be avoided, the nails should be driven through the holes in the fasteners.

Trussed rafters should be supported only at the designed bearing points. It is advisable, therefore, to erect internal non-loadbearing walls after the roof tiling has been completed. This allows deflection to take place under dead load and reduces the risk of cracks appearing in ceiling finishes. Alternatively, if partitions are of brick or block, the final course can be omitted until the tiling has been completed.

Where non-loadbearing partitions are pre-made or site constructed using timber studding, they should be an easy fit to the truss. (See also Section 5 ‘Support Conditions’).

Erection of Hip Ends

Section 4 describes in detail the general arrangement of a number of hip ends and hip corners. The procedure outlined here is for the erection of a standard centres hip end, but the principles can be applied to other hip layouts.

The hip girder is a primary structural member made up of two or three hip trusses nailed together. It is strongly recommended that the girder is nailed together by the supplier to ensure it performs correctly. Where the units are supplied loose for nailing together on site, the correct number of plies and the nailing pattern stipulated by the supplier must be followed.

The erection sequence (Figure 9.09) is then as follows:

(1) Fix the first standard truss a distance of half its span along the wall plate measured to the face of the truss. (Figure 9.09a).

(2) Complete the erection of the standard trusses and brace them.

(3) Fix the ledger rail to the first standard truss at a height to suit the hip board.

(4) Measure the span of the monopitch truss and transpose this dimension onto the wall plate. A simple check is to measure from the mark to the face of the truss A. It should be equal to (Number of Intermediates + 1) x truss spacing. Thus, for 2 intermediates, and truss centres of 600:

(5) Erect the girder and intermediate trusses using temporary bracing. (Figure 9.09c).

After erection, a maximum bow of 10mm may be permitted in any trussed rafter member, provided it is adequately secured in the complete roof to prevent the bow from increasing. For rafter members, this maximum bow is measured from a line between the apex and eaves joint.

Under conditions where wind uplift forces are greater than the dead load, the truss clip and anchorage strap should be used (Figure 9.07).

The manufacturer will attempt to locate the splice joints in the chord members symmetrically about the centreline. In the example shown in Figure 9.08, this is often not possible and erection instructions will be issued stating clearly where the splice joints are to be located in the final structure.

The central monopitch girder can be erected by the following principles. The principles can be applied to other hip layouts.

(7) Nail a truss shoe to the bottom chord of the girder and fix the central monopitch truss. (Figure 9.09a).

(8) Erect the hip boards, carefully cutting the birdsmouth support at the wall plate, girder and ledger. (Figure 9.09a).

(9) Complete the erection of the monopitch trusses, trimming the flying rafters as necessary and nailing all flying rafters to the hip board. (Figure 9.09a).

TABLE 9.01 MAXIMUM PERMISSIBLE DEVIATIONS FROM VERTICAL

<table>
<thead>
<tr>
<th>Plane of trussed rafter (mm)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4 or more</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deviation from vertical (mm)</td>
<td>10</td>
<td>15</td>
<td>20</td>
<td>25</td>
</tr>
</tbody>
</table>

N.B. All nails, unless noted, should be used.
Erection of Two-Part Trusses

Section 4 describes the various types of two-part trusses that can occur. For erection purposes, these can be divided into those that are structurally connected and those which are independent.

Structurally Connected

The structural connection can be horizontal or vertical, although the latter seldom occurs. The units can be joined together prior to erection or erected using temporary supports and then connected together. The choice of method is influenced by a number of factors, including design, access, building height and lifting capacity. The chosen method should therefore be agreed between the Trussed Rafter Designer, Building Designer and Contractor following the principles outlined earlier.

Structurally Independent

An important point to note, and one that should be strictly adhered to, is that the erection and bracing of the lower section should be completed before commencing erection of the upper section. For both sections, the erection principles described earlier should be applied, and the bracing should be in accordance with Section 7.

Tolerances

The objective of each stage in the construction cycle is to produce a functional building that is pleasing to the eye. To achieve this, it is necessary to understand the tolerances that can occur at each stage and how they relate to one another.

Trussed Rafter Design

BS5268: Part 3 requires that within each specified design, the overall horizontal and vertical dimensions of a trussed rafter (Figure 9.10) should not deviate from the specified dimensions by more than the following:

- For spans not greater than 7.50m: ±6mm
- For spans greater than 7.50m but not greater than 12.0m: ±9mm
- For spans greater than 12.0m: ±12mm

In addition, within any continuous roof the differences between the overall horizontal and vertical dimensions of similar trussed rafters should not exceed 10mm. For these purposes a continuous roof is defined as any unbroken length of roof over a building, as distinct from the roof areas over separate dwellings. Although not specifically referred to by BS5268: Part 3, it is reasonable also to expect all other node points not to vary by more than 10mm from one another in any one continuous roof.

The timber must also satisfy the deviation allowance of BS5268: Part 3, which permits the maximum spring to be 5mm per 3m length (Figure 9.11). The jig will largely remove any spring at the node points and it is therefore only realised at mid-bay. Rarely is an accumulation of nodal deviation and spring a problem to the alignment of finishes.

The effect of manufacturing tolerances can be doubled by ‘handing’ trusses (Figure 9.12). This is sometimes done by accident during erection, or by instruction from misguided supervisory staff who believe the handing of chord splices produces a stronger roof. The design of a splice joint takes account of all stress criteria and trusses should never be handed but erected relative to their neighbour as they were in the jig.

Some manufacturers mark one rafter so it is easy on site to see if trusses have been handed. Another convenient check is to compare the bottom chord splices. Since the trusses will have been manufactured with common splice positions, they can often be used to indicate where handing has occurred.
Support Structure

Unless some form of factory manufactured frame is used, building dimensions will often be found to vary by ±25mm in plan dimension and ±25mm in level. In a large number of cases these tolerances are taken up during roof construction without detriment to the finishes or structure, for example Figure 9.13. In some instances, or with some building shapes, these tolerances do cause poor alignment and remedial action will be required (Figure 9.14).

Erection

This can be divided into setting out measurements and the actual erection. Dealing with the setting out aspect first, it must be appreciated that since the trussed rafters are factory made, they must be located in the correct position or they may not fit the roof geometry.

Obviously the problem does not exist for a straight run of trusses but will be noticeable for hip ends and other roof shapes where the trusses are not all parallel. The hipped roof in Figure 9.15 shows clearly the result of poor positioning of the apex truss. To prevent this problem the Building Designer should produce a layout plan, providing clear setting out information which must be adhered to on site.

Although the individual tolerances have, for simplicity, been treated in isolation, it is their interaction that influences the ceiling or rafter alignment. It has not been possible to obtain authoritative tolerances for plasterboard and tiles, but experience suggests that differences in level between adjacent members at 600mm spacing of 10mm are rarely a problem as isolated cases. Where problems are highlighted, building tolerances and erection are usually the major contributory factors and, with reasonable care, it should be possible to largely eradicate these. Site staff are encouraged to check all possible tolerances before rejecting the trusses, as rarely are the trusses the main cause of any misalignment.

Remedial Work

Even experienced members of the project team frequently underestimate the strength of trussed rafters and in particular Gang-Nail connector plates. Given in Figure 9.17 is a joint using small Gang-Nail connectors and a joint of equivalent strength using nailed plywood gussets. This clearly demonstrates the strength of the Gang-Nail connector plates and why it is important to refer any truss damage to the supplier, to enable a properly engineered repair solution to be designed.

In no circumstances should a trussed rafter be cut or otherwise modified or repaired except in accordance with precise written or drawn instructions issued and approved by the Trussed Rafter Designer.
Ceiling Joist
beyond its bearing.
The part of a structural member or truss that extends
Cantilever loads.
compensate for anticipated deflection caused by applied
An upward vertical displacement built into a truss in order to
Camber
integrity of a building as a whole.
The person responsible for the structural stability and
Building Designer
Bracing
The lower member of a truss, normally horizontal, which
carries the ceiling construction, storage loads and water tank.
Bracing
See STABILITY BRACING.
Building Designer
The person responsible for the structural stability and
integrity of a building as a whole.
Camber
An upward vertical displacement built into a truss in order to
compensate for anticipated deflection caused by applied
loads.
Cantilever
The part of a structural member or truss that extends
beyond its bearing.
Ceiling Joist
See BOTTOM CHORD.
Chevron Bracing
Diagonal bracing nailed to the truss in the plane of specified
webs to add stability.
Chords
See BOTTOM CHORD and TOP CHORD.
Combined Stress Index (C.S.I.)
Measures how much of the strength of a member is
being used by the design.
Concentrated Load
A load applied at a point.
Connector Plate/Fastener/Nail Plate
Metal plate having integral teeth punched from the plate
material. Used for joining timbers in one plane with no overlap.
Supplied by system owners and the subject of an Agreement
Certificate. Not usually for site application.
Cripple Rafter/Jack Rafter
An attic rafter completing the roof surface in areas such as the
corners of hip ends.
Dead Load
The permanent load produced by the fabric of the
building.
Deflection
The deformation caused by the loads.
Design Load
Collectively the loads for which the unit is designed.
Duo/Dual-Pitch Truss
A truss with two top chords meeting at an apex and not
necessarily being at the same pitch on both sides.
Dwangs
See NOGGING.
Eaves
The line where the rafter meets the wall.
Extended Rafter/_raised Tie Truss
A truss which is supported at a point on the extension
of the rafter, beyond the point where the bottom chord
meets the top chord. N.B. Such trusses must be the subject
of a special design.
Fabricator
A company engaged in the manufacture of trussed rafters.
Fastener
See CONNECTOR PLATE.
Fink Truss
Named after the original designer. A duoptich truss, the two
top chords having the same pitch and the webs
forming a letter W. The most common truss type used for dwellings.
Firing Piece
A tapered timber member used to give a fall to flat roof
areas.
French Heel
A heel joint where the top chord sits on the top of the
bottom chord.
Gable End
The end wall (parallel to the individual trusses) extended up vertically to the plane of the top chords of the trusses.
Gable Ladder
Components used to bridge across a gable end to form the roof overhang.
Gang-Nail
Registered tradename of Gang-Nail Systems Limited.
Girder Truss
A truss comprising two or more individual trusses fixed
together and designed to carry exceptional loads such
as those imparted by other trusses.
Hanger
A metal component designed to provide a connection
between a truss or other component and its support.
Heel
The part of a truss where the top and bottom chords
intersect, normally where a truss is supported.
Hip Board
See STUB END.
Hip Corner
A corner turn in a building incorporating a hip end.
Hip End
An alternative to a gable end. The end wall is finished to the
same height as the adjacent walls. The roof inclines from the
end wall usually at the same pitch as the main trusses.
See HIP SET.
Hip Set
The trusses and possibly loose timber forming a hip end.
Horn/Nib
The projection of the bottom chord of a trussed rafter
built into masonry as a bearing. Used on monopitch
and stub end trusses.
Improved Load
The load produced by occupancy and use including
storage, people, moveable partitions and snow, but not wind.
Internal Member/Web
A timber member used to transmit forces between
chords.
Intersection
The area where one roof meets another.
Jack Rafter
See CRIPPLE RAFTER.
Jig/Pedestal
Equipment used in the laying out and clamping in position of the
components of a truss prior to pressing.
Live Load
A term often used instead of Imposed Load.
Longitudinal Bracing
Component of STABILITY BRACING.
Loose Timber
Members not forming part of a truss but necessary for
the formation of the roof. See CRIPPLE RAFTER.
Monopitch Truss
A truss in the form of a right-angled triangle, having a
single top chord.
Nail Plate
See CONNECTOR PLATE.
Nib
See HORN.
Node
Point on a truss where members intersect.
Nogging
Timber pieces fitted at right angles between the chords
of trusses to form fixing points for ceiling materials.
Overhang
Measurement on plan from the intersection point of
the underside of top and bottom chords to the end cut
of the rafter.
Padstone
A concrete slab built in a wall to distribute the pressure
from a concentrated load onto a large area of wall.
Part Profile
See STUB END.
GLOSSARY OF TERMS

Peak
See APEX.

Pedestal
See JIG.

Permissible Stresses
Design stresses for grades of timber published in BS5268:Part 2

Pitch
The angle of the chord (usually rafter) to the horizontal measured in degrees.

Plate
See CONNECTOR PLATE.

Plate Location/Position Tolerance
Acceptable deviation from specified location. Design allowance is 5mm in both orthogonal directions. May be specified greater.

Pole Plate
Timber, often the same size as the wall plate and laid on top of the wall plate to assist support of infill timbers.

Press
Hydraulic equipment used to embed connector plates into timber.

Purlins
Timber members spanning over trusses and supporting cladding such as galvanised corrugated steel sheet. Also, spanning between trusses and supporting loose rafters.

Quarter Point
The point on the rafter where an internal member/web connects in a “FINK” type trussed rafter.

Rafter
See TOP CHORD.

Rafter Diagonal Bracing
Component of STABILITY BRACING.

Raised Tie Truss
See EXTENDED RAFTER TRUSS.

Reducing Trusses
See VALLEY FRAMES.

Remedial Detail
A modification produced by the Trussed Rafter Designer to overcome a problem with the trussed rafter after its manufacture.

Return Span
The span of a truss being supported by a girder.

Ridge
The line formed by truss apexes.

Ridge Board
Timber running along a ridge and sandwiched between oncoming loose rafters.

Roof Designer
The person responsible for the design of the roof as a whole so that it is stable in itself and is capable of transmitting wind forces on walls and roof to suitable buttressing walls. The Roof Designer is appointed by the Building Designer or can be the Building Designer himself.

Room-in-the-Roof
See ATTIC TRUSS.

Scab
Additional timber connected to a truss to effect a splice, extension or local reinforcement.

Setting-Out-Point
The point on a truss where the undersides of the top and bottom chords intersect.

Skew Nailing
Driving nails at angles into the surfaces to be joined, method of fixing trussed rafters to wall plate by use of nails applied through chords.

Span
Span over all wall plates. The distance between the outside edge of the two supporting wall plates and sometimes equal to overall length of bottom chord.

Spandrel Panel
Timber frame, triangular panel forming gable wall above ceiling line.

Splice
A joint between two in-line members employing a metal connector plate or glued finger joint.

Stability Bracing
An arrangement of loose timbers installed in the roof space to provide lateral support to truss members and to the trusses.

Strap
Metal component designed to fix trusses and wall plates to walls. Heavy duty type for lateral fixing and standard used for holding down.

Stub End
A truss type formed by the truncation of a normal triangular truss.

Superchord
A means of providing deep chord members by connecting together two members at their edge using Gang-Nail connector plates, used to locally reinforce extended chord trusses and attic trusses.

System Owner
Owner of an integrated system of truss design and manufacture. Provides fabricators with application software, design expertise and fabrication machinery. In addition to the manufacture of nail plates (e.g. Gang-Nail System Ltd)

Temporary Bracing
An arrangement of diagonal loose timbers installed for safety during erection. Often incorporated with permanent STABILITY BRACING.

Third Point
Point on a ceiling joist where an internal member/web connects in “Fink” truss.

Tie
See BOTTOM CHORD

Timber Stress Grading
The classification of timber into different structural qualities based on strength.

Top Chord/ Rafter
The uppermost member of a truss normally carrying the roof covering and snow.

Tosh Nailing
See SKEW NAILING.

TRA
Trussed Rafter Association. Organisation which represents the truss industry.

TRADA Quality Assurance Scheme
Formalised method of quality control in the manufacture of trusses administered by the Timber Research and Development Association.

Trimmer
A timber member used to frame openings.

Truss/Trussed Rafter
A lightweight framework, normally triangulated, spaced at intervals generally not exceeding 0.6m and made from timber members of the same thickness fastened together in one plane by metal fasteners or plywood gussets.

Trussed Rafter Designer
The person responsible for the design of the trussed rafter as a component and for specifying the points where bracing is required.

Truss Clip
A metal component designed to provide a structural connection of trusses to wall plates, to resist wind uplift forces and to eliminate the disadvantages of skew nailing.

Uniformly Distributed Load (UDL)
A Load that is uniformly spread over the full length of a member.

Valley Board
A raking member from ridge to corner in valley construction.

Valley Jack Trusses/Valley Set
Infill frames used to continue the roofline where one roof intersects another.

Verge
The line where the trussed rafters meet gable wall.

Wall Plate
A timber member laid along the supporting walls on which the roof trusses bear. Not less than 75mm wide.

Web
See INTERNAL MEMBER

Web Longitudinal Bracing
A component of STABILITY BRACING.

Wind Bracing
An arrangement of loose timbers or other structural system installed in the roof space to form diaphragms in the planes of the rafters and ceiling ties to transmit wind forces to suitable shear walls.