

### Design Method

A trussed rafter is an engineered framework consisting of structural members forming triangles. The framework derives its inherent strength from this triangulation.

The members around the perimeter of the trussed rafter are known as chords (top and bottom, also called rafters and ceiling ties), and the internal members providing the internal triangles are known as webs (sometimes also called struts and ties).

A true trussed rafter is formed only when the webs form triangles between the top and bottom chords. Attic frames and Raised-Tie trusses (see section 1.7 and 3.16) do not provide this triangulation and are therefore technically not trussed rafters.

When designing non-standard trussed rafters, it is beneficial to ensure the full triangulation as above, please refer to MiTek's System Design Office if in doubt.

### Principles of Design

When loading is applied to a trussed rafter (from tiles, ceiling construction snow etc), two main kinds of force are generated in the members:

1. Bending Moment
2. Axial Force

Bending moment causes neighbouring sections of timber to tend to rotate relative to each other (see figure 21a).

Axial force may be either tensile, i.e. pulling adjoining sections of timber away from each other, or compressive, i.e. crushing adjoining sections of timber into each other (see figure 21b and 21c).

A compressive force may cause the member to buckle (bending sideways out of the plane of the trussed rafter) and this may need to be counteracted by bracing (see sections 2.5 and 3.7) or by increasing the section of timber required for the affected member.

Within a trussed rafter, members will be subject to either axial force alone or a combination of axial force and bending moment. The design of a trussed rafter must allow for these effects, together with the differing forces produced by different types of load (see section 2.7 on Loading and Load cases.)

Figure 21a

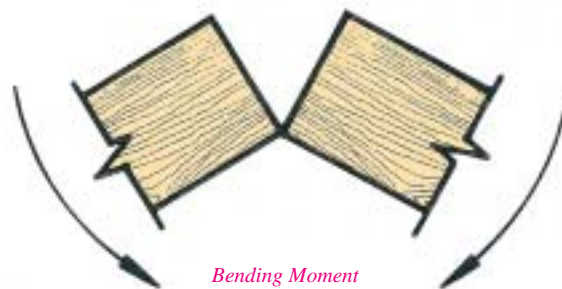


Figure 21b

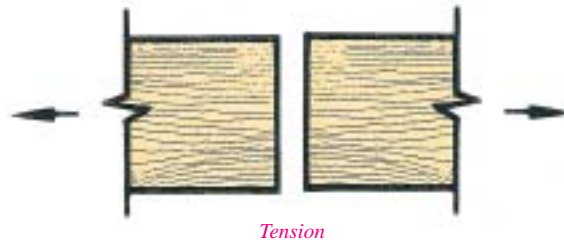
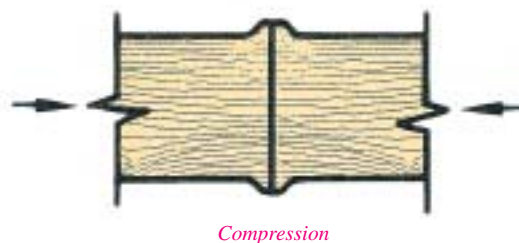


Figure 21c



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### Bending Moments

Bending moments are generally induced in the Chord members due to the loadings (tiles, ceiling, snow etc) placed directly onto them. It is unusual for Web members to be subject to bending moments.

The magnitude of the bending moment in a particular chord is largely due to the Panel Length (the distance between the joints at each end of the member, usually measured horizontally, also known as the Bay

Length). The general rule is, the longer panel length the greater the bending moment and hence the larger the section of timber required to safely resist the bending moment.

Further, BS. 5268-3 defines the maximum bay lengths permitted in Table 3, a copy of which is given below:

**BS 5268 Table 3: Maximum Bay Lengths of Rafters and Ceiling Ties**

Depth of member	Maximum length (measure on plan between node points)			
	35mm thick		47mm thick	
	Rafter	Ceiling Tie	Rafter	Ceiling Tie
Mm	m	m	m	m
72	1.9	2.5	3.3	3.3
97	2.3	3.0	3.6	4.3
120	2.6	3.4	3.9	5.0
145	2.8	3.7	4.1	5.3

The choice of a different truss type, with a smaller panel length (and hence more webs), will usually yield a smaller section of timber required.

The method of calculation relating to bending moment is as follows:

The applied bending stress (calculated from the bending moment divided by the section modulus of the timber being considered) is compared with the permitted bending stress for the particular timber

grade or strength class.

The resulting ratio:

$$\frac{\text{Actual bending stress}}{\text{Permitted bending stress}} < 1$$

This ensures that the actual bending stress in the timber cannot exceed the permitted stress, causing the timber to fail.

### Axial Force

Axial forces within the trussed rafter are calculated by analysing the whole frame. The greater the number of panels (webs) the greater the axial forces can be. Also, the lower the pitch of the top chord the greater can be the axial force.

As mentioned previously, axial force can be either tensile or compressive and, if compressive, can lead to problems with out-of-plane buckling.

In a similar way to bending moment, the actual axial stress in the timber (calculated from the axial force divided by the area of the timber section), is compared with the permitted axial stress of the timber grade or strength class being used.

This ensures that the timber never exceeds its permitted axial stress limit.

Generally, web members will be subjected only to axial force, whereas chord members will be subject to a combination of bending and axial stresses.

For chord members therefore, the calculation becomes:

$$\frac{\text{Actual bending stress}}{\text{Permitted bending stress}} + \frac{\text{Actual axial stress}}{\text{Permitted axial stress}} < 1$$

To ensure that the timber section is within its defined limits for both bending and axial stress.

This ratio is known as the combined stress index (CSI) or stress summation.

$$\frac{\text{Actual axial stress}}{\text{Permitted axial stress}} < 1$$

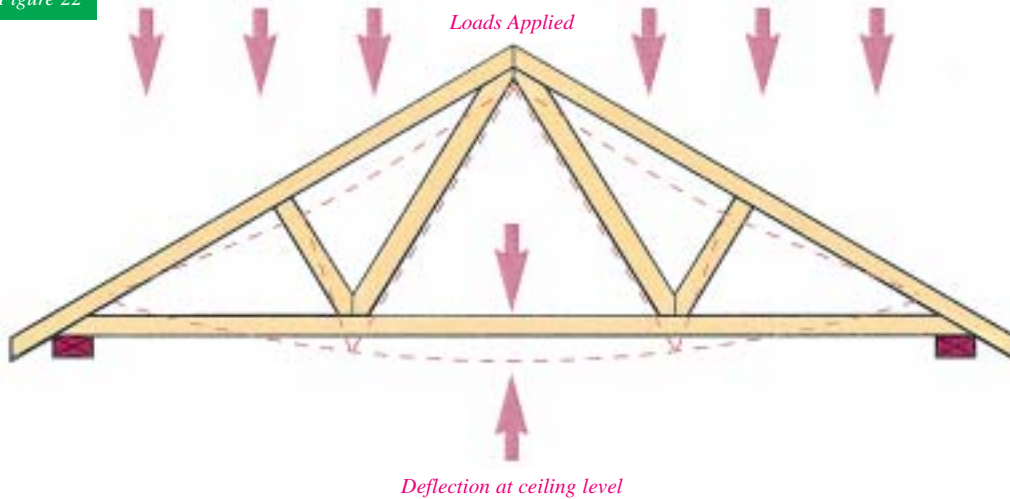
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### Deflection

Another important criterion in the design of trussed rafters, which must be considered, is the amount of deflection, or movement of the truss when loading is applied to it. (See figure 22).

BS.5268-3 section 6.5.7 clearly defines how to calculate deflection and the permissible limits on rafters, ceiling ties and on overhangs and cantilevers.

Figure 22



This therefore defines the amount of movement under the differing load conditions permitted.

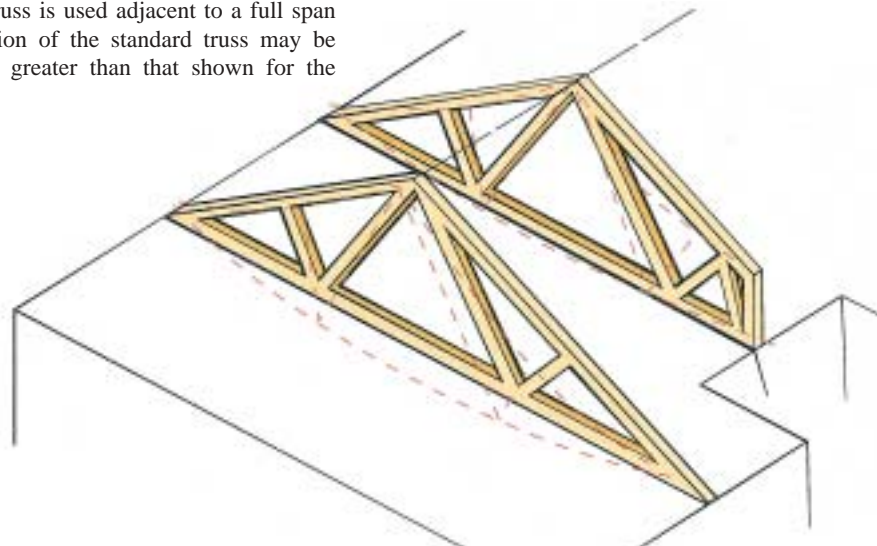
In this situation, the Designer should ensure that the difference in anticipated deflection between the two trusses is kept within limits, to avoid problems in producing a smooth line for the ceiling constructions underneath.

Additionally, the Trussed Rafter Designer should be aware of the problems which may arise due to **DIFFERENTIAL DEFLECTION**.

This problem of differential deflection between adjacent units is one of the most common causes of site problems and, once the roof is erected, one of the most difficult to rectify. The remedy is for the Designer to be fully aware of the potential problem **at the design stage**.

Differential deflection may occur between two adjacent trusses within a roof when either the support conditions or the loading conditions change. For example, in a hip end or corner condition (see sections 2.8 and 3.5) the heavily loaded girder truss may show more anticipated deflection than the truss immediately behind it in the hip sequence. Or, where a bobtail (stub) truss is used adjacent to a full span truss, the deflection of the standard truss may be anticipated to be greater than that shown for the bobtail.

Figure 23



### Design Method

The design of joints using Mitek nailplate connectors is governed by the British Board of Agreement Certificate 90/2386 and WIMLAS Certificate 038/96.

Within the approval certificates the conditions of use, assessment of fitness for purpose, sizes of available nailplates, methods of joint assembly, relevant loadings etc are specified. It is not intended in this document to reproduce in part or in whole the contents of the Certificates; copies of these are available on request from MiTek.

However, to give an insight into the method of joint design using the nailplates, the Designer should note that each nailplate joint must be assessed for shear

strength and lateral resistance to the forces placed upon its integral teeth.

The values for shear and tensile strength are given in the relevant Certificate, as are the values for the nail anchorage loads. It should be noted that the lateral resistance of a nailplate joint depends upon:

- 1.The number of effective nails in the joint.
- 2.The species of timber used and its condition (moisture content).
- 3.The duration of the loading applied.
- 4.The direction of bearing of the nails in relation to the grain of the timber (load to grain).
- 5.The direction of the loading in relation to the connector plate (load to nail).

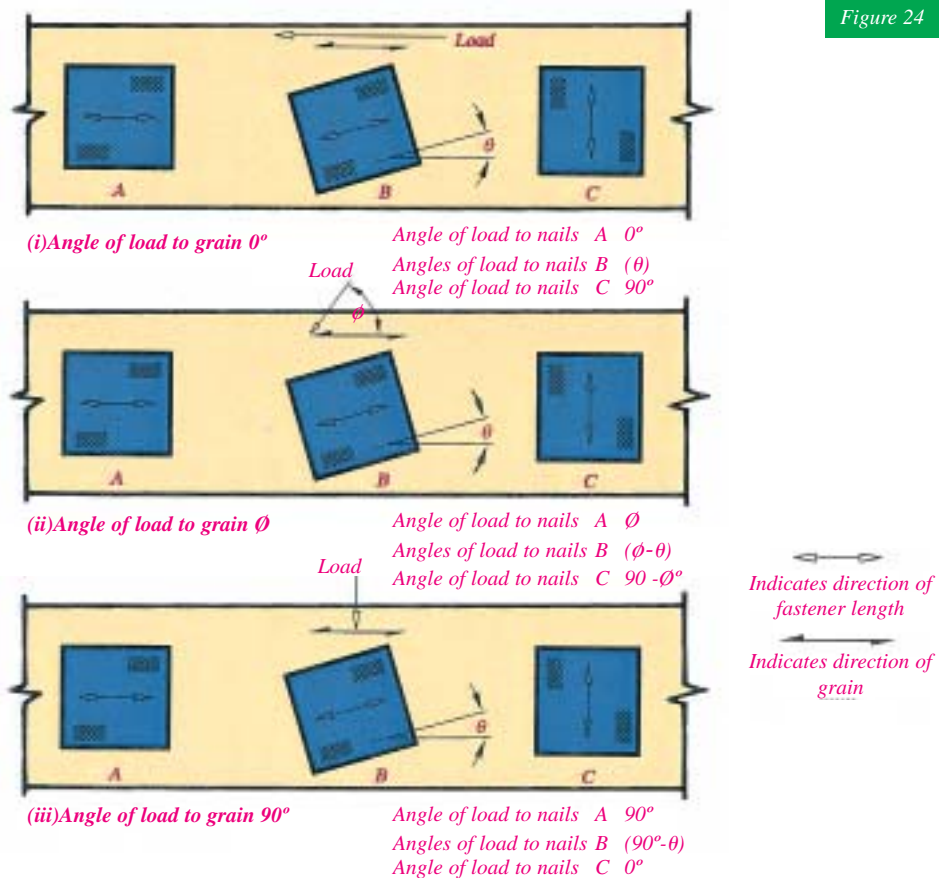


Figure 24

It should be noted that, when designing a nailplate joint, the approval Certificates define certain ineffective areas at the ends and edges of the timber in which the nails are to be ignored for the design.

Further, the species of timber used and the duration of loading causing the forces must be taken into account.

Finally, the actual position of the nailplate on the joint will affect the permitted values for each nail.

It can be seen that this leads to a highly complex interaction, as several different load durations, combined with a number of possible nailplate orientations and a large number of available sizes of nailplate makes the most economical choice of any particular nailplate a difficult decision.

By its nature, the solution of this interaction is now largely handled by MiTek's sophisticated computer programs although manual design is still necessary for very special applications.

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#### Splice Joints

Due to the need to make long span trusses from shorter lengths of timber, butt joints called SPLICES often need to be introduced in the top and bottom chord members.

between 10% and 25% of the panel length in which the splice occurs for triangulated trussed rafters. In other frames and when splices are outside of the code 'zone' the software will design the splice to resist shear, axial and moment forces.

These joints, like all other nailplate joints, need to be properly designed in accordance with the above factors. Splice joints will normally occur in positions

Some typical joint details are given in figure 25.

Figure 25

