Truss facts book
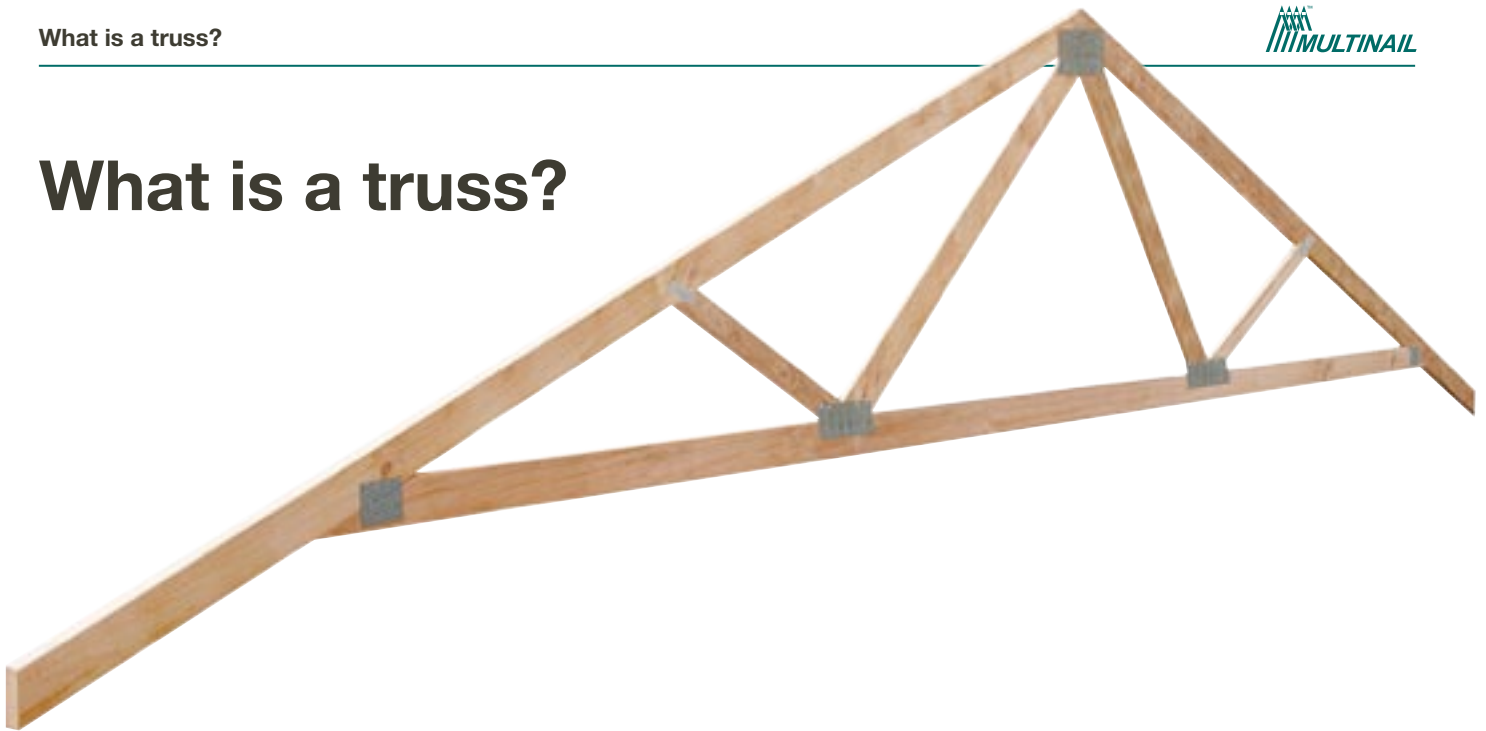
An introduction to the history design and mechanics of prefabricated timber roof trusses.

MULTINAIL

Table of contents

What is a truss?

A "truss" is formed when structural members are joined together in triangular configurations.

The truss is one of the basic types of structural frames formed from structural members. A truss consists of a group of ties and struts designed and connected to form a structure that acts as a large span beam.

The members usually form one or more triangles in a single plane and are arranged so the external loads are applied at the joints and therefore theoretically cause only axial tension or axial compression in the members. The members are assumed to be connected at their joints with frictionless hinges or pins that allow the ends of the members to rotate slightly.

Because the members in a truss are assumed to be connected to frictionless pins, the triangle formed is the only stable shape. Studies conducted on the truss show it is impossible for the triangle to change shape under load, unless one or more of the sides is either bent or broken.

Shapes of four or more sides are not stable and may collapse under load, as shown in the following images:
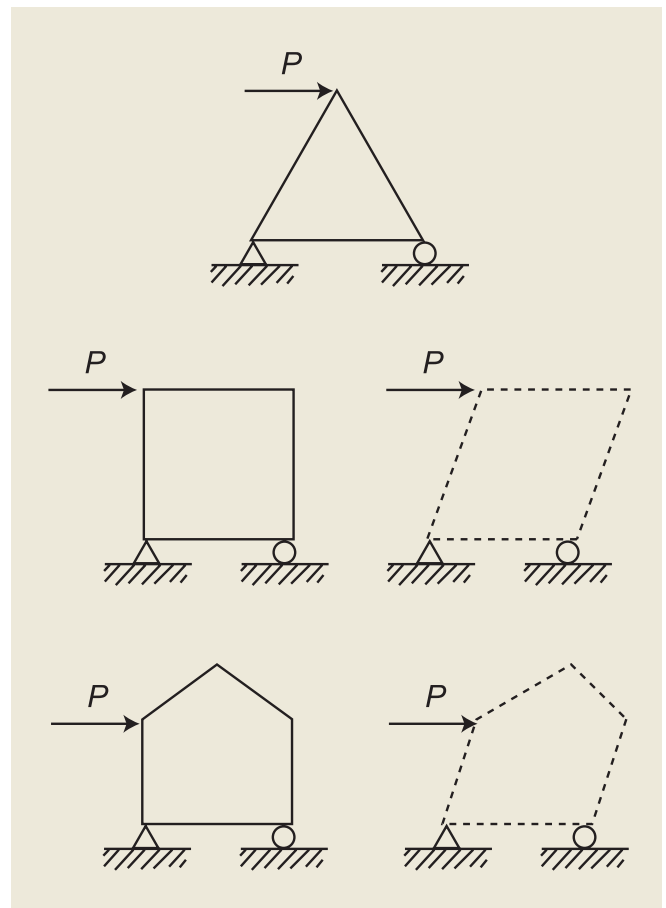
These structures may be deformed without a change in length of any of their members.

The evolution of trusses

In only a few decades, timber trusses have almost completely replaced traditional roof construction methods.

Their advantage in allowing greater freedom of design and in speeding up construction, while reducing the impact of external influences including weather and building site theft, are major factors contributing to their success.

Since 1979, Multinail has pioneered development of the engineering technology that made these changes possible and ensures Multinail Fabricators continue to provide the highest quality products at competitive price.

Multinail also produce all the specialised hardware for manufacturing building components including roof trusses, wall frames and floor trusses, and also offers a large range of high production machines and equipment used during fabrication.

History...

Before the 1940's, trusses were primarily constructed for large buildings and bridges and manufactured from heavy steel, with wood members limited to timbers with bolted connections.

World War II, saw the demand for speedy military housing construction that required less labour-intensive practices and reduced job site time for framing roofs. Timber members were used to meet these new requirements, and connected together using glued and nailed plywood gussets, or simply nailed to joints, to form "wood trusses'".

This method continued after the war, with the boom of single family housing. To further reduce the labour-intensive practice of cutting plywood gussets and then gluing or nailing the gussets to the timber, a light gauge metal plate was created with pre-drilled holes that allowed nails to be hammered through.

As the pre-drilled metal plates were inadequate and still labour intensive, Arthur Carol Sanford developed an alternative - the truss plate. His truss plate was the first to use stamping to create triangular teeth embedded at the truss panel points to transfer the structural loads across the joints.

In 1979, one of America's leading building industry magazines "Automation in Housing and Systems Building News'" honoured Arthur Carol Sanford for "his singular invention of the toothed metal connector plate in 1952".

Sanford made other contributions to the growing truss industry, including contributing to the development of the rolling press, a method where fabricators use extremely high pressures to embed nailplates into timber during truss manufacture. The strength of the joints constructed using this method generates trusses with predictable engineering properties.

Pre-fabricated timber trusses have extended from a simple collection of individual timber members to become complete building components for building entire roofs or floors.

Today…

Over the next decade truss plates naturally progressed from the early truss plates that required hand-applied nails to modern truss plates that require no nails.

As part of the nailplate progression, the Multinail Truss Plate was developed.

Multinail nailplates are manufactured from G300 steel with a galvanised coating of 275 grams per square metre. Stainless steel nailplates are also available, and nailplates can also be powder-coated or have additional galvanising applied if required.

Multinail nailplates incorporate many refinements, especially in the tooth shape that is designed to grip the timber more securely. The bending and twisting of teeth during manufacture was carefully designed to aid the transfer of forces across the finished joint. This also increase the joint's resistance to damage during handling when forces may be applied from virtually any direction.

The reliability of Multinail trusses results from the following factors:

- Truss plate - made from high grade steel to exacting tolerances that maintains the reliability and performance essential to safe truss construction.

- Quality of engineering design - based on Multinail's years of effort, talent and experience.

- Methods for cutting and assembling timber members - using automated saws and computer aided controls helps ensure members and joints fit accurately.

- Care taken by Multinail fabricators to ensure trusses are manufactured in strict accordance with designs and handled appropriately.

Over time, the "wood truss" has become a highly-engineered, prefabricated structural product using two very reliable resources, Wood and Steel.

The predicted life of nailplates depends on the protection of the nailplates from the weather, wind and other corrosive elements including salt spray and chemicals.

The universal truss plate

Engineered design

Manufacturing an engineered truss requires accurate cutting, jigging and pressing. Fabricators do not want timber splitting or truss plate teeth bending during pressing as this can result in production delays, site calls and increased costs of repairs and rebuilding.

Timber splitting, teeth bending and associated problems can be eliminated by using Multinail's Universal Truss Plates.

The Universal Truss Plate is the ideal choice for fabricators as they are designed to provide excellent holding power (with eight teeth per square inch) at a low cost per truss.

Multinail was also the first company to introduce South East Asia to the concept of eight teeth per square inch in nailplates.

At Multinail, we didn't just stop there. If you look carefully at the Universal Truss Plate, you can notice a uniquely-designed tooth shape that gives the nailplate full penetration and holding power - other companies have tried to copy this method but have been unable to reproduce.

Proven

Extensive tests in Australia and Asia have proved the versatility of the Universal Truss Plate.

The Universal Truss Plate is suitable for use with high density woods (e.g. Ironbark and Karri from Australia, Kapur and Selangur Batu from Malaysia) as well as other high and low density hardwood timbers and low density woods (e.g. Radiata Pine and Oregon).

How it works

The Universal Truss Plate provides high density tooth concentration that ensures high strength transfer. When combined with the universal tooth shape, this virtually eliminates teeth bending or wood splitting.
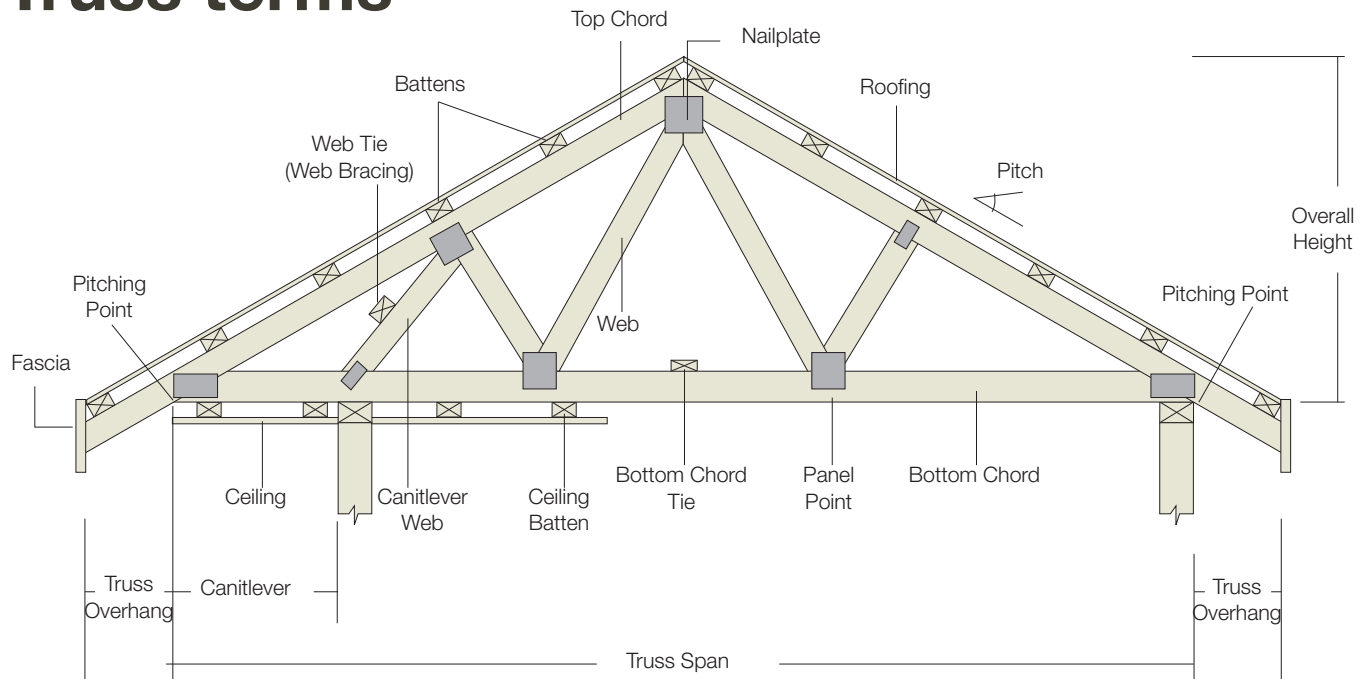
The Universal Truss Plate produces tight fitting joints that help resist rough truss handling during delivery or on site.

Features

- Long teeth;

- Low plate cost per truss;

- Penetrates high density hardwoods;

- Eliminates tooth bending and wood splitting;

- High force transfer per unit area;

- High holding power in hardwoods and softwoods and

- Prime quality galvanised steel.

Truss terms

A labelled truss diagram showing: Top Chord, Nailplate, Battens, Roofing, Web Tie (Web Bracing), Pitch, Pitching Point, Overall Height, Fascia, Web, Pitching Point, Ceiling, Canitlever Web, Ceiling Batten, Bottom Chord Tie, Panel Point, Bottom Chord, Truss Overhang, Canitlever, Truss Overhang, Truss Span

Truss
A prefabricated, engineered building component which functions as a structural support member.

Member
Any element (chord or web) of a truss.

Apex
The point on a truss at which the top chords meet.

Axial force
A force (either compression or tension) that acts along the length of a truss member. Measured in newtons (N) or kilo newtons (kN)

Axial stress
A measure of the intensity of an axial force at a point along a member, calculated by dividing the axial force at that point by the cross-sectional area of the member. Measured in mega pascals (MPa).

Battens
Structural members which are fixed perpendicular to the top chords of a truss to support roofing material or to the bottom chords to support ceiling material and to restrain truss from buckling.

Bending moment
A measure of the intensity of the combined forces acting on a member; ie, the reaction of a member to forces applied perpendicular to it (including the perpendicular components of applied forces). The maximum bending moment is generally towards the centre of a simple beam member.

Bending stress
A measure of the intensity of the combined bending forces acting on a member, calculated by dividing the bending moment by the section modulus of the member. Measured in mega pascals (MPa).

Bottom chord
The member which defines the bottom edge of the truss. Usually horizontal, this member carries a combined tension and bending stress under normal gravity loads.

Butt joint
A joint perpendicular to the length of two members joined at their ends.

Camber
An vertical displacement which is built into a truss to compensate for the anticipated deflection due to applied loads. All trusses spanning relatively large distances are cambered.

Cantilever
Where the support point of the truss is moved to an internal position along the bottom chord of the truss.

Combined stress
The combined axial and bending stresses which act on a member simultaneously; ie, the combination of compression and bending stresses in a top chord or tension and bending stresses in a bottom chord which typically occur under normal gravity loads.

Concentrated or point load
A load applied at a specific point; ie, a load arising from a man standing on the truss.

Cut-off

The term used to describe a truss which is based on a standard shape but cut short of the full span.

Dead load

The weight of all the permanent loads applied to member of a truss; ie, the weight of the member itself, purlins, roofing ceilings, tiles, etc.

Deflection

The linear movement of a point on a member as a result of the application of a load or combination of loads. A measure of the deformation of a beam under load.

Eaves overhang

The extension of the top chord beyond the end of the truss to form the eaves of a roofing structure.

Heel

A point on a truss where the top and bottom chords join.

Hip joint

The joint between the sloping and horizontal top chords of a truncated truss.

Interpanel splice

A splice in a member (at a specified distance from a panel point).

Laminated beam or truss

Two or more members or trusses mechanically fastened to act as a composite unit. Lamination allows the achievement of increased strength without the use of solid, larger section timber.

Lateral or longitudinal tie

A member connected at right angles to a chord or web member of a truss to restrain the member.

Live load

Temporary loads applied to the truss during maintenance by workers and during constructions.

Load duration coefficient

The percentage increase in the stress allowed in a member based upon the length of time that the load causing the stress is on the member. (The shorter the duration of the load, the higher the Load Duration Coefficient). (K1)

Manufacturing details

Drawings which contain the data for truss fabrication and approval by local building authorities. (Produced automatically by the software used by Multinail Fabricators.)

Mitre cut

A cut in one or more members made at an angle to a plane of the truss. I.e. the top or bottom chords of a creeper truss are mitred at 45 degrees at the end of the truss where they meet the hip truss.

Overhang

The clear extension of a chord beyond the main structure of a truss.

Panel

The chord segment of a truss, usually top or bottom chord, between two panel points.

Panel point

The connection point between a chord and web.

Panel point splice

A splice joint in a chord which coincides with a panel point.

Pitch

The angular slope of a roof or ceiling. Also the angular slope of the top or bottom chords of a truss which form and/or follow the line of a roof or ceiling.

Plumb cut

A vertical cut. A plumb cut is perpendicular to a horizontal member. All splices are plumb cut.

Purlin

A structural member fixed perpendicular to the top chord of a truss to support roofing.

Span

The distance between the outer edges of the load-bearing walls supporting the trusses.

Splice joint

The point at which top or bottom chords are joined (at or between panel points) to form a single truss member.

Support reactions

Those forces (usually resolved into horizontal and vertical components) which are provided by the truss supports and are equal and opposite to the sum of the applied forces.

Top chords

The generally sloping members of a truss which define its top edge. Under normal gravity loads, these members usually carry a combined compression and bending stress.

Truncated girder station

The position of a truncated girder. Defined in terms of its distance from the end wall.

Webs

Members which join the top and bottom chords, and together with them, form a truss by which structural loads are transferred to the truss support.

Wind loads

Winds loads are the forces applied to roof trusses by virtue of wind blowing on the structure, typically (but not always) upwards; ie, opposite to dead loads.

Truss numbering system

Multinail uses a simple, flexible and very versatile system of member and joint numbers to identify all members and connectors.

LH　Left heel

RH　Right heel

TO　Always allocated to the apex

BSO　Always allocated to the joint immediately below the apex joint

T1R　Joint immediately to the right of TO joint

T2R　Joint immediately to the right of T1R joint

T1L　Joint immediately to the left of TO joint

T2L　Joint immediately to the left of T1L joint

TCR　Top chord on the right hand side of TO joint

TCL　Top chord on the left hand side of TO joint
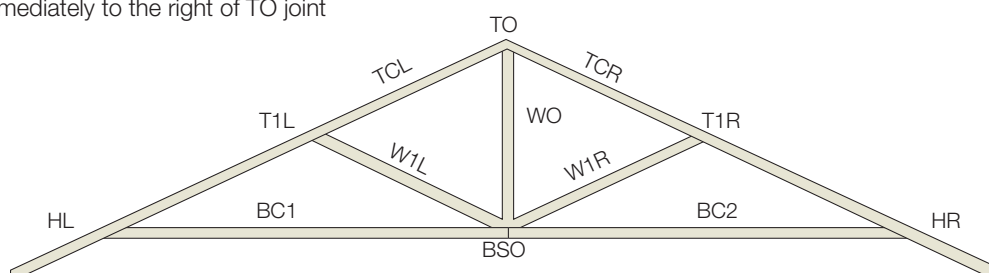
A variation to this Numbering System occurs when the Top Chord contains a splice. The Top Chord is then allocated two denotations:

TC1-R　The upper Top Chord on the right hand side of the TO joint

TC2-R　The lower Top Chord on the right hand side of the TO joint and on the right hand side of the splice

If the Top Chord contains three members, than the next Top Chord would be marked TC3-R, etc.
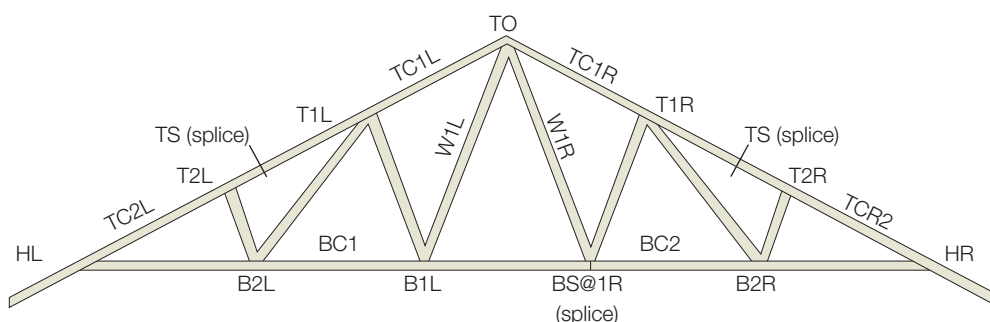
Bottom Chords

For the bottom chord, the numbers and markings are similar. If the truss does not have a BO joint, then the joints are marked as B1R, etc. and B1L from an imaginary line from the TO connector. Hence, the more joints, the more numbers to each side of this imaginary line.

With standard trusses, there is normally only one splice joint per bottom chord and the size and stress grade of each member is the same, thus the bottom chords are numbered BC1 and BC2 as it is not critical to which side of the truss it is positioned.

For trusses with multiple bottom chords such as Cathedral trusses in which there may be up to five bottom chords (and each may be a different size), the members are numbered from the left hand side of the truss and are marked as BC1, BC2… BC5. This numbering reflects the manner in which the truss drawing is developed.

Splices

When a chord is spliced between panel points, it is marked as LTS1 (being the first splice in the top chord on the left hand side of the TO position). Similarly to RTS1.

When the chord is spliced at a panel point, the joint is marked as LTS2 or LBS3 relevant to the joint number in the top or bottom chord.

Webs

Webs (the internal truss members) are marked according to their position in relation to the apex joint TO and the vertical web under this joint, or the imaginary line from the TO position.

Thus, webs to the left of TO are marked W1L, W2L, etc. and webs to the right of this line are marked W1R, W2R, etc.

Note that it is possible that there may be more webs on one side than the other of the TO position.

Truss shapes

These diagrams indicate the approximate shapes of the trusses in most common use. The choice of truss shape for a particular application depends upon the loading and span requirements (general spans mentioned are for 90mm top and bottom chords).
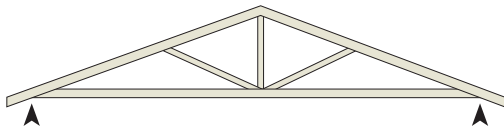
Kingpost truss
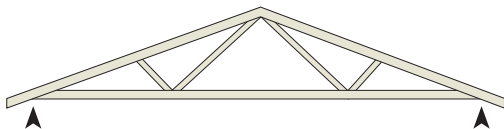For spans approximately 4m. Used primarily in house and garage construction.
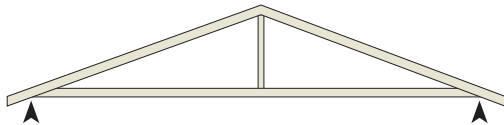
Queenpost truss
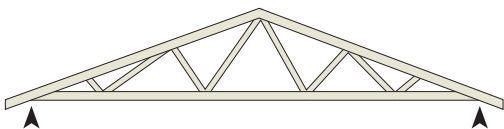For spans approximately 6m. Used mainly for house construction.

A-truss
For spans approximately 9m. This is the most commonly used truss for both domestic and commercial applications.

B-truss
For spans approximately 13m. Used primarily in residential and smaller commercial buildings, this truss is generally preferred to the A-truss for larger spans since it offers greater strength (additional web members) at lower cost due to the reduction in size of top and bottom chord timber.

C-truss
For spans approximately 16m. Used principally for commercial and industrial buildings. Can be constructed with lower strength timbers.
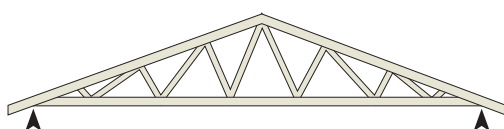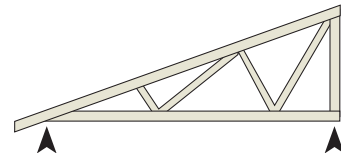
Half A-truss
For spans up to 6m. Used for residential construction where the trusses may form a decorative feature.
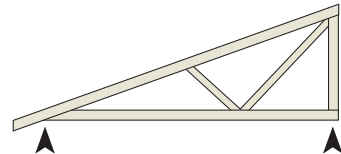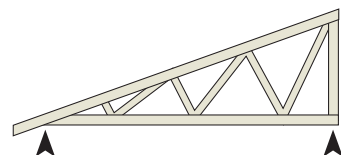
Half B-truss
For spans up to 9m. Uses are similar to those for the A-truss.

Half C-truss
For spans up to 11m. Uses are similar to those for the A-truss but tends to be preferred to the half A-truss for reasons given under C-truss.
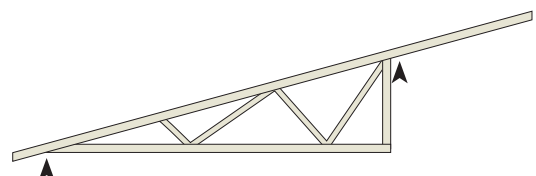
Truncated truss
Spans depend on depth. There are two types of Truncated truss - the truncated girder truss and the standard truncated truss. Together they facilitate hip roof construction.
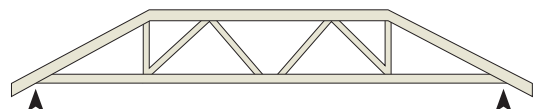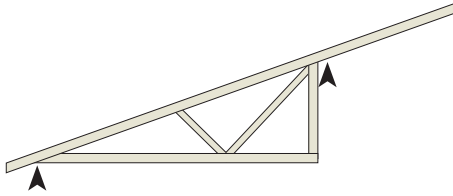
Hip truss
A half truss with an extended top chord which is used to form the hip ridge of a hip roof.
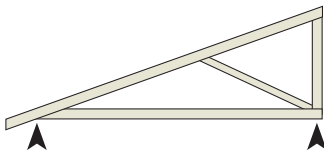
Jack truss

Similar to the half A-truss but with an extended mitred top chord which overlies a truncated truss to meet the extended top chord of a Hip truss.
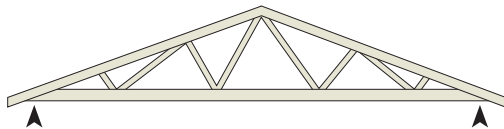
Pitched warren

Generally used for industrial or commercial buildings to achieve low pitch with high strength over large spans.

Creeper truss

Similar to a jack truss but mitre cut to intersect the Hip truss between the outer wall and the truncated girder.

Dual pitch truss

Non-standard truss used to achieve special architectural effects. The left top chord is a different pitch to the right top chord.
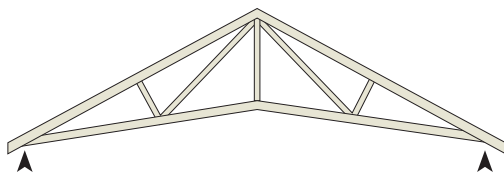
Girder truss

Special truss of any standard truss shape used to support other trusses which meet it at right angles. (The standard shape is maintained but girder truss members are generally larger in both size and stress grade.) Girder can be any shape and carry trusses at any angles.
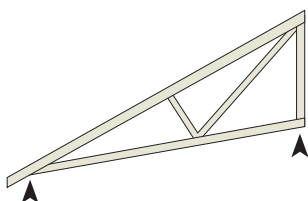
Cut-off truss

Any truss, the shape of which forms part of a standard truss. As the name implies, the cut-off truss has a shorter span than that of the standard truss on which it is based; it is terminated by a vertical member along the line of the 'cut-off'.

Bowstring truss

Used for large span industrial and commercial buildings including aircraft hangars, where the roof profile is curved. Bowstrings can be used everywhere domestic included.

Scissor truss

Not a standard truss design but often used to achieve special vaulted ceiling effects, sometimes with relatively wide spans.
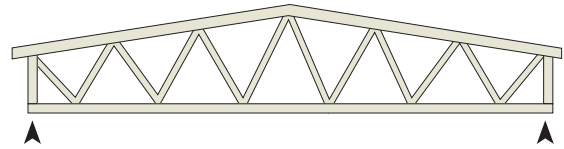
Howe truss

For spans up to 12m. Used mainly for applications which involve high loading of the bottom chord (in preference to the A-truss).

Half scissor truss

As its name implies, one-half of the standard scissor truss used for industrial, commercial and residential buildings.

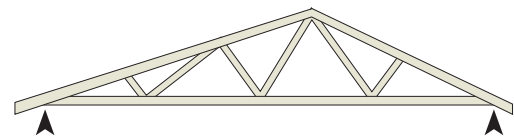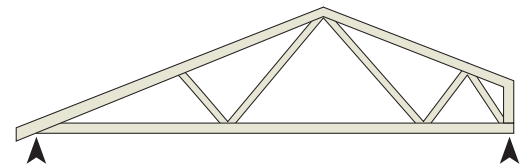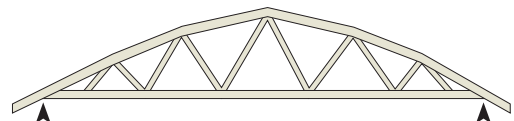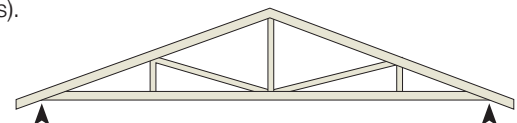## Pratt truss

For spans up to 12m. May be used in preference to Howe truss for circumstances of high bottom chord loading.
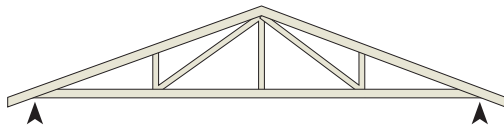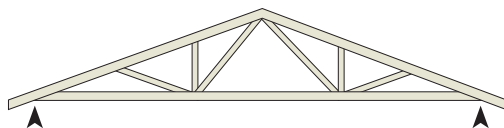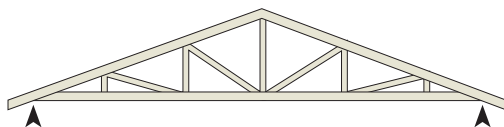
Fan fink truss

For spans up to 9m. Used mainly for applications which involve high loading of the top chord (eg, where the truss is exposed and the ceiling load is carried on the top chord).

Double howe truss

For spans up to 20m. Used for the same reasons as the Howe truss (in preference to the B-truss).

Parallel chorded

As its name implies, the top and bottom chord are parallel. Used for both floor and roof applications.
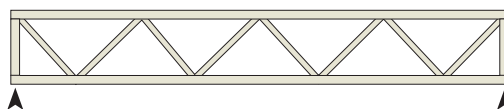
Attic truss

Special purpose truss to simplify attic construction.
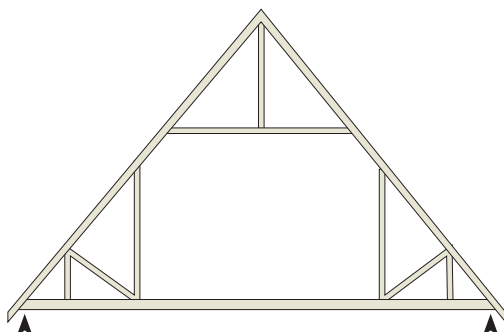
Portal frame

A standard commercial and industrial design for wide spans.
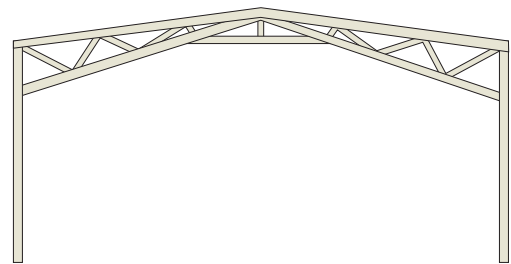
Inverted cantilever

Used to achieve special architectural effects in churches, restaurants, motels, etc.
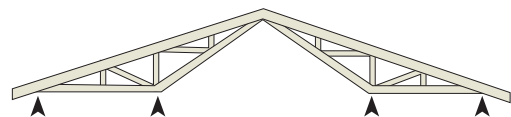
Cathedral truss

A non-standard truss used mainly in residential buildings to achieve a vaulted ceiling effect.
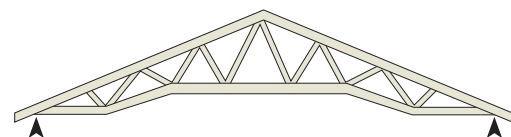
Bell truss

A standard truss used to achieve a bell-shaped roofline. E.g. 4 top chord at different pitches.
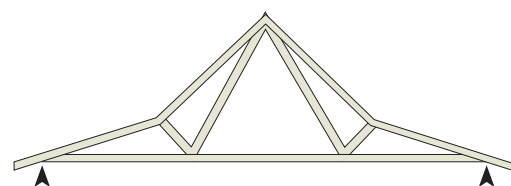
Truss systems

Gable end

The Gable is one of the simplest and most common roof types. Gable ends may be either flush or may overhang the end wall of the building with overhangs being either "open" or "boxed".

Gable ends can be formed with a cutdown truss - a truss of reduced height sometimes supported along its length by the end wall. This truss can in turn support either verge rafters (for a flush gable) or an outrigger superstructure where an open gable overhangs the end wall.

There are several possible forms of superstructure shown in the diagrams. For example, the outrigger purlins may be supported by the top chords of the cutdown truss extending inwards to intersect the top chords of the next truss and extending outwards to end in verge rafters.

Alternatively under-purlins can be used, attached to the lower edges of the top chords of the last two or three trusses.

A boxed gable can be constructed using a standard truss as the end truss fixed to cantilevered beams supported by the building's side walls. The cantilevered beams should extend at least 2.5 times the cantilever distance and must be specifically designed for the expected load.

The position of the gable truss on the end wall is determined by structural demands as well as by requirements for conveniently fixing purlins and roofing material, ceiling material, gable end battens and cladding.

Hip

Jack truss

Hip truss

Creeper truss

Truncated girder

Truncated standard

Standard trusses
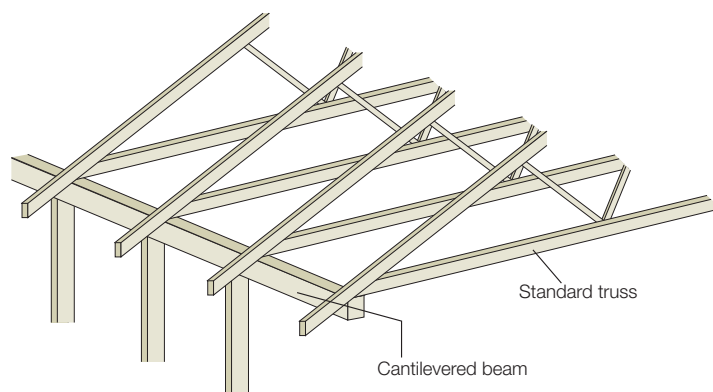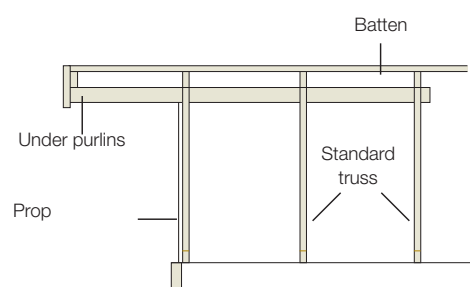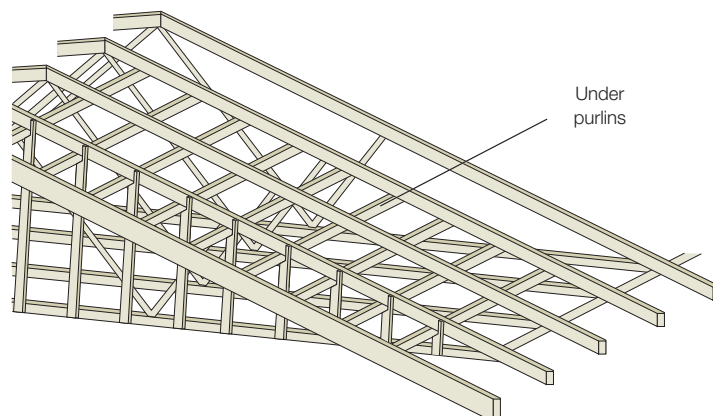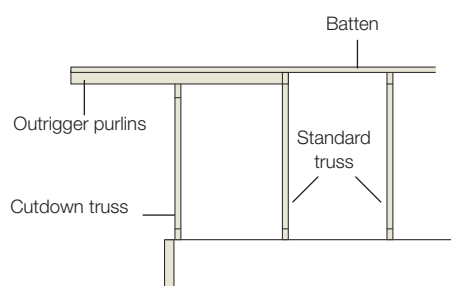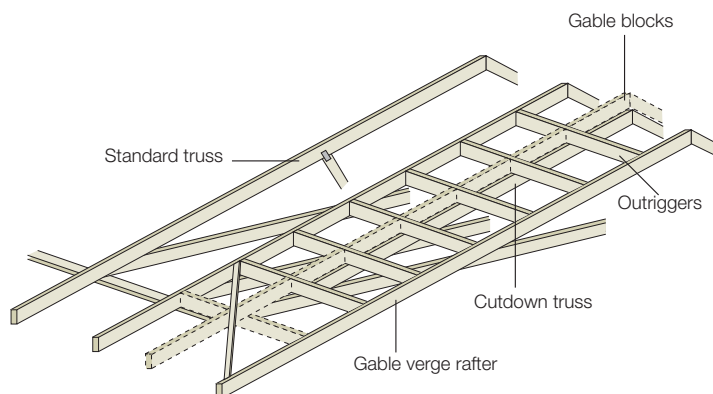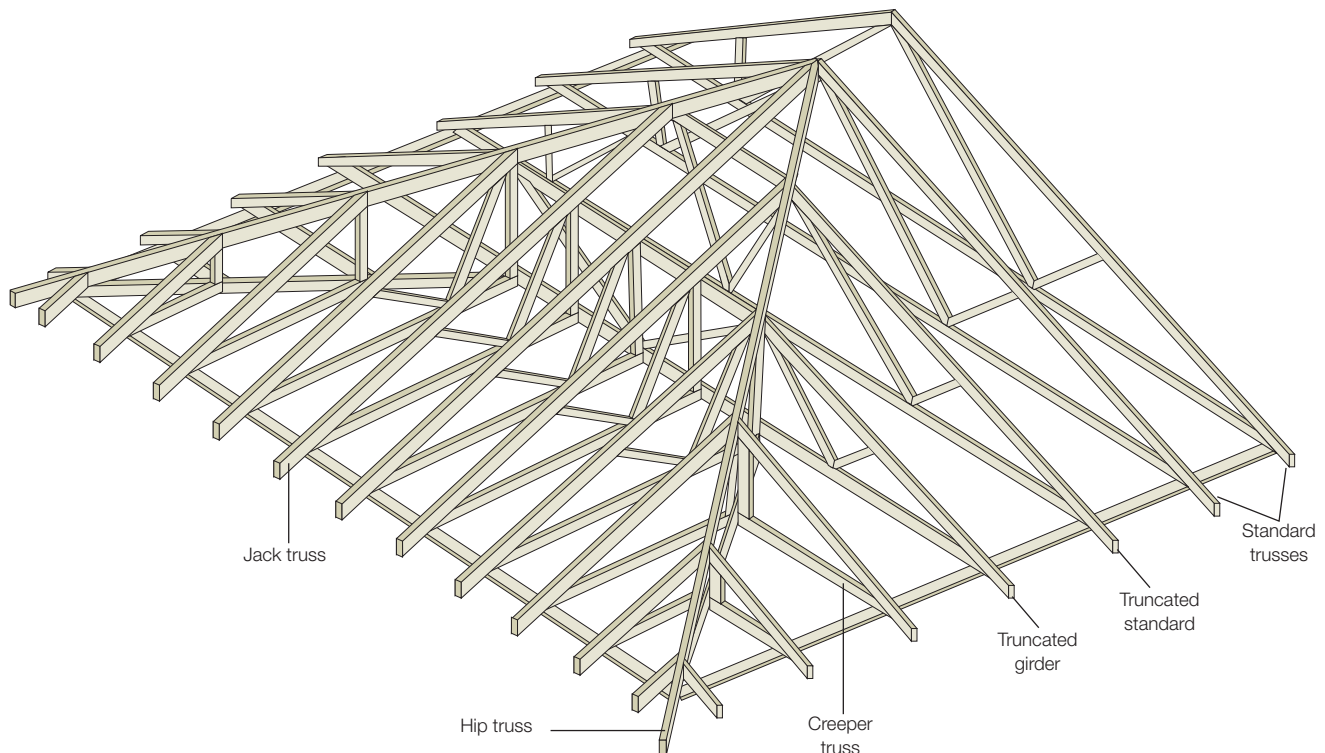
The hip roof truss system is built around a truncated girder that transfers the weight of the hipped roof sections to the side walls. The system design specifies a girder station - the distance where the Truncated Girder is located relative to the end wall.

The trusses that form the hips of the roof (called the "hip trusses") are supported at their outer ends by the corners of the end or side walls and at their inner ends by the truncated girder. Their top chords which form the hips are extended to meet the ridge line.

On the end wall side of the truncated girder, the roof structure is formed by jack trusses (between the end wall and the truncated girder) and creeper trusses (between the side walls and each of the hip trusses).

On the internal side of the truncated girder, the roof structure is formed by truncated trusses of increasing height towards the end of the ridge. The top chords of the jack trusses extend over the truncated girder and truncated standard trusses.

The hip roof truss system allows the construction of traditional roof design without needing to locate load-bearing walls to support the hipped roof sections.

A number of variations are possible and are usually derived by intersecting the first hip system with another or different type of truss system.

Standard truss

Jack truss

Truncated girder

Truncated standard
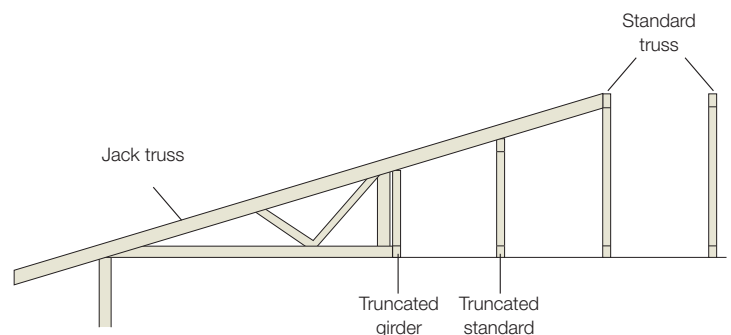
Dutch hip
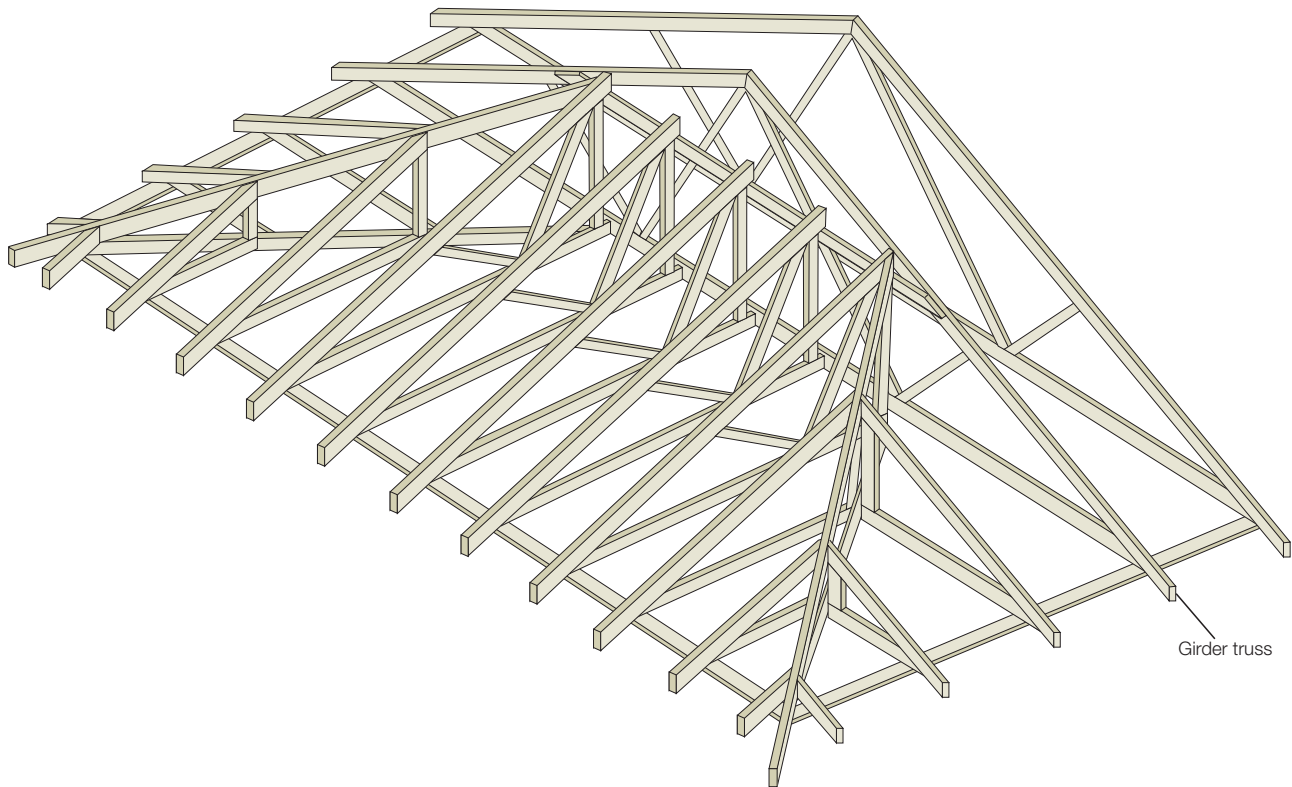
Girder truss

The dutch hip truss system is built around a special girder truss with a waling plate fixed to one side.

As with the other girder trusses, it is placed at the specified girder station. The roof structure is similar to the hip truss system; however there is no need for truncated trusses - rather than continuing over the girder truss, the top chords of the jack trusses sit on the waling plate.

The result is a roof structure that combines some features of the hip roof with features of the gable.

Girder truss

Standard truss

Jack truss

Waling plate
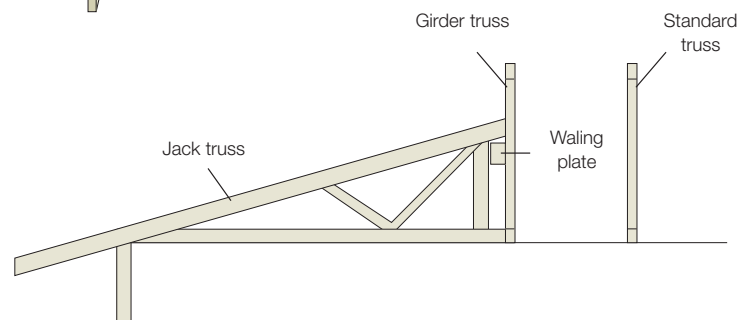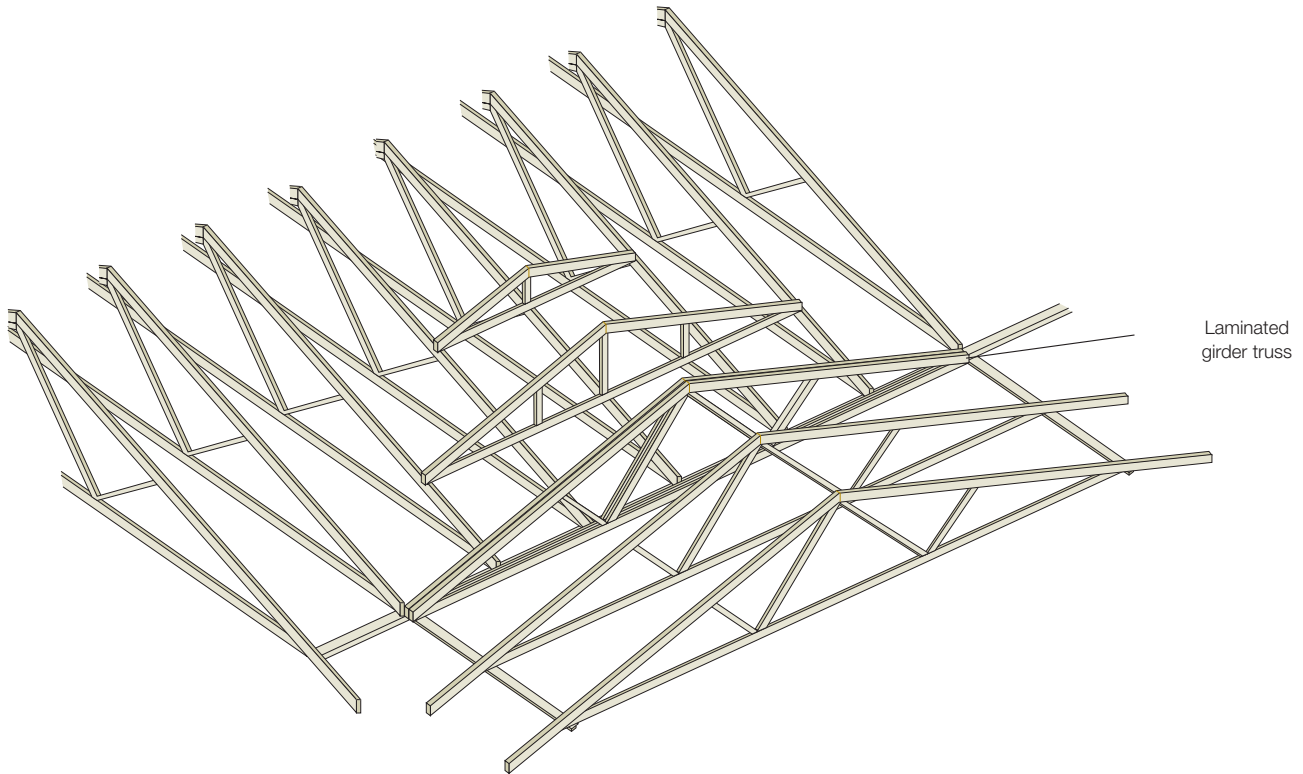
Girder and saddle

The girder and saddle truss eliminates the need for a load-bearing wall at the intersection of two gables in the roof structure.

In this system, a girder truss placed parallel to the trusses in the second roof is used at the intersection to support the ends of the trusses forming the first roof. Truss boots are usually fixed to the girder truss to transfer the load from the trusses to the girder and through the girder to the side walls.

The secondary roof line is continued past the girder truss by saddle trusses that diminish in size.
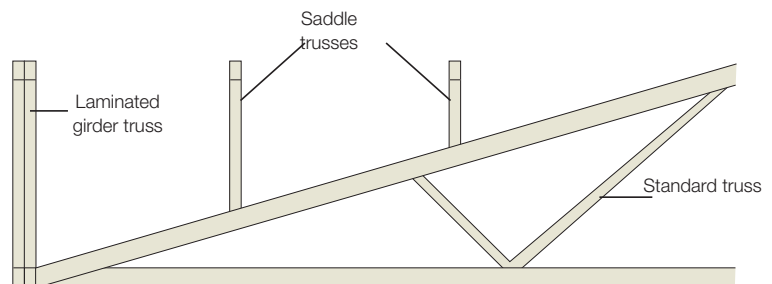
Special truss systems

Chimneys

The diagrams show typical roof structure treatment around chimneys with standard trusses used at either side of the chimney. The intervening cutoff trusses are supported by beams fixed to the side walls of the chimney.

Cutoff trusses supported by beam

Cutoffs

Cutoff trusses are created when the truss must be stopped short of its normal span (e.g. to allow for a chimney). This is supported at one end by the heel in the standard manner and at the other by the bottom chord immediately below the end member. Double cutoff trusses can be formed by modifying standard truss designs at both ends.

Chimney

Cutoff trusses

Chimney

Beam   Parallel chorded girder trusses

Chimney

Cutoff trusses

Beam or parallel chorded girder trusses
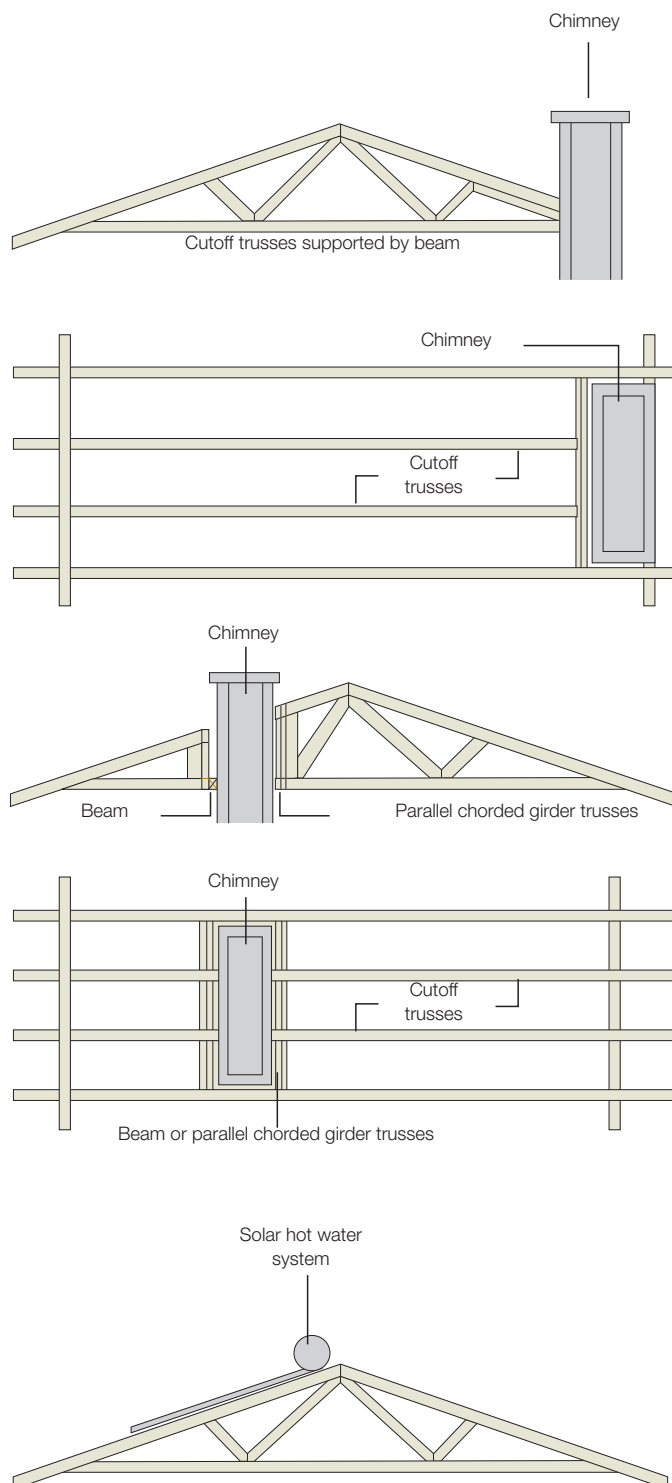
Hot water systems

Special provision must be made in the design and fabrication of trusses that carry additional loads such as those imposed by Hot Water Systems.

Solar hot water system

Solar hot water systems

Special provision should be made in the design and fabrication of a roof truss system to carry the additional load imposed by a solar hot water system.

Where this load will be carried by an existing roof not specifically designed for the purpose, a solar hot water heater with a capacity of up to 300 litres may generally be installed on the roof system provided the trusses within a roof length of approximately 3600mm are suitably modified. Details of these modifications (which take the form of strengthening both the chords and joints of each truss) can be obtained from Multinail Fabricators.

Cantilever

A cantilever exists where a truss is supported inside its span rather than at the end of its bottom chord (i.e. at the heel). A truss may be cantilevered on one side only, or on both.

The diagrams show the three main types of cantilever:

The maximum length of cantilever that can be handled using standard design information is limited (e.g. trusses with cantilever distances up to 1/5 nominal span for Type A Trusses, 1/6 nominal span for Type B Trusses and a combined distance of 1/4 the nominal span for any truss). Larger cantilevers demand special design.

A. Where the bearing of the truss falls wholly within the solid length of the heel joint, the standard truss requires no alteration.

Cantilever

B. Where the bearing of the truss is relatively close to the heel but outside of the solid length of the heel joint, a supplementary top chord is required to convert a standard truss into a cantilever truss.

Cantilever

C. Where the distance between the heel joint and the bearing of the truss is relatively large, additional members must be used.

Cantilever

Truss design

Introduction

This section provides a brief introduction to the techniques for truss design; it is not intended as a comprehensive guide.

The design of the truss members can begin immediately after determining the anticipated loadings (i.e. Dead Load, Live Load and Wind Load) .

Truss analysis

For truss shapes, where members and joints form a fully triangulated system (i.e. statically determinant trusses), truss analysis makes the following assumptions;

i) Chords are continuous members for bending moment, shear and deflection calculations. Negative moments at joint (nodes) areas evaluated using Clapyron's Theorem of Three Moments and these moments are used to calculate the shear and deflection values at any point along the chord, for distributed and concentrated loads.

ii) Member forces can be calculated using a "pure" truss (i.e. all members pin-jointed) and calculated using either Maxwell Diagram or equilibrium of forces at joints.

iii) Total truss deflection used to evaluate truss camber and to limit overall deflections can be calculated using the system of virtual work. Again, the members are considered as pin-ended and a dummy unit load is placed at the required point of deflection.

Truss loading combination and load duration

The following load combinations are used when designing all trusses:

a) SW + DL: permanent duration

b) SW + DL + SLL: short term live load combination

c) SW + DL + MLL: medium term live load combination

d) SW + DL + WL: extremely short duration

Where,   SW   = Self Weight (timber trusses)

   DL   = Dead Loads (tiles, plaster)

   SLL, MLL   = Live Loads (people, snow)

   WL   = Wind Loads

Each member in the truss is checked for strength under all three combinations of loadings. Dead loads plus live loads and dead loads plus wind loads may constitute several separate combinations in order to have checked the worst possible combination.

Load duration

The limit state stress in a timber member is depends on the load duration factor (K^1). For a combination of loads, the selected load duration factor is the factor corresponding to the shortest duration load in the combination.

For trusses designed according to AS1720.1-1997, the duration of a load considered to act on a truss is of major importance for dead loads only; the load is considered permanent and thus factor K^1 at 0.57 is used. For dead and wind load combinations, the wind load duration is considered as gusts of extremely short duration and K^1 of 1.15 (for timber) is used. For dead and live load combinations several load cases may have to be checked due to differing load durations. In general, live loads are taken as applicable for up to 5 hours with a K^1 of 0.94 (for timber). Live loads on overhangs are applicable for up to 5 hours with a K^1 of 0.97. Either may be critical.

Design of truss members

Truss webs are designed for axial forces and chords, for axial forces plus bending moments and checked for shear and deflection between web junctions.

Webs

Tension webs are checked for slenderness and the nett cross-sectional area is used to evaluate the tension stress. The cross-sectional area is taken as the product of the actual member depth and the thickness - less 6mm to allow for timber fibre damage by the Multinail Connector Plate.

Compression webs are also checked for slenderness. Effective length is used for buckling of the web in the plane of the truss and out of the truss plane.

Chords

Tension chords are designed for strength and stiffness and must withstand combined tension and bending. The slenderness of the member is checked as tension webs and also as a beam. The shear of the member is also checked but is usually critical only on heavily loaded members (e.g. girder trusses).

The stiffness criteria is to limit the deflection of a chord between the panel points. The long term deflection is calculated for dead loads only, as the instantaneous deflection under this load multiplied by duration factor (from AS1720) is determined by the moisture condition of the timber. The limit on this deflection is (panel length) ÷300.

Live load and wind load deflections are calculated separately without consideration of the dead load deflection. Deflection is limited for live and wind loads to overcome damage to cladding materials and to reduce unsightly bows in the roof or ceiling.

Compression chords are also designed for strength and stiffness. The strength of compression chords depends largely on the lateral restraint conditions of the chords. The combined compression and bending stresses in the members are checked using the index equation in AS1720. Shear stress is also checked as for tension chords.

Deflections are checked as for tension chords and designed for similar allowable values.

Modification factors used in design

The following is a typical calculation for bending strength. The capacity in bending (ϕM) of unnotched beams, for strength limit state, shall satisfy -

$$(\phi M) \geq M^*$$

where:

$$(\phi M) = \phi k[f'_b Z]$$

and,

M^*	=	design action effect in bending
ϕ	=	capacity factor
k	=	$k_1 \times k_4 \ \ldots \ \times k_{12}$ and is the cumulative effective of the appropriate modification factors
f'_b	=	characteristic strength in bending
Z	=	section modulus of beam about the axis of bending ($bd^2/6$)

Standard and complex design

Both standard truss designs and complex truss designs can be generated by Multinail Fabricators or Multinail Engineers.

When a complex design is generated by the Fabricator for a quotation job, it is standard practice for a copy of the input and output to be checked by an engineer - either an independent consultant or a Multinail Engineer - before manufacturing the truss.

For large projects (e.g. hospitals, schools, offices, etc.) the entire project is initially analysed and an overall truss and bracing layout completed. Each truss is then individually analysed, designed, drawn to scale, costed and presented with full cutting and jig layout dimensions to ensure accurate and uniform manufacture.

Trusses are usually analysed and designed for dead, live and wind loads; however the analysis and design may be extended to include concentrated point loads as required. Trusses can also be analysed and designed for snow load, impact loads, moving loads, seismic loads, etc.

If the drawing specifies the purpose of the structure and the anticipated loads, all the loads will be considered during truss analysis and design and clearly itemised on the drawing. Computations can also be supplied if required.

Basic truss mechanics

Introduction

The Australian Standard AS1720.1 "Timber Structures Code" outlines the design properties of timbers for bending, tension, shear and compression.

Multinail software checks that truss member stresses do not exceed the allowable values and, if required, larger members or higher strength timber are considered to help ensure stresses do not exceed allowable values.

Stress levels in nailplates are checked against the allowable tooth pickup and steel strength values that Multinail has determined over the years with different timbers.
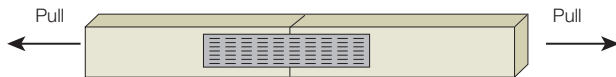
Tension

A member in tension is subject to tensile stress (e.g. tow rope or chain).

**Tension Stress (in a member)**

= P/A in MPa

Where: P = Load in Newtons

A = Area in Square mm

Compression

A member in compression is tending to buckle or crush. Long compression members buckle and are weaker than short ones which crush. The allowable compression stress for a particular timber depends on the "slenderness ratio" which is the greater of length/width or length/depth.
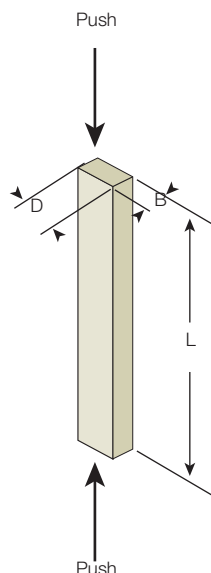
Bending

Beams are subject to bending stress (e.g. scaffold plank, diving board, etc.). The actual bending stress f_b = Bending/Section Modulus.
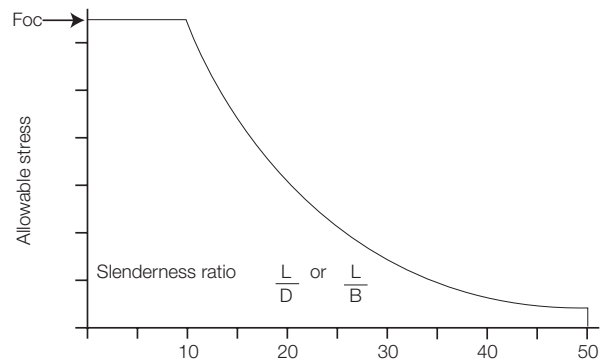
The Section Modulus (Z) is the resistance of a beam section to bending stress. This property depends upon size and cross sectional shape and for a uniformly rectangular shaped beam:

$$Z = \frac{bd^2}{6}$$

Where: b = width in mm
d = depth in mm

NOTE:

'Z' depends on the square of 'd', so doubling the depth increases the strength of the beam four times.

For example:

Increasing 125 x 38 to 150 x 38 gives a sectional modulus of 1425003 which is stronger than a 125 x 50 which has a section modulus of 130208 mm^3.

The depth is simply more important than the width. Deep beams require more careful lateral restraint.

The Bending Moment depends on the load and the length of the beam.

For example:

Consider a simply supported beam carrying a Point Load 'P' at midspan.
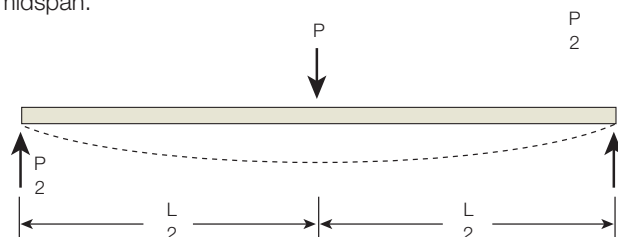
The maximum bending moment $= \frac{P}{2} \times \frac{L}{2} = \frac{PL}{4}$

By doubling the length (L) or load (P), you double the bending moment.

Deflection

During the analysis process when designing a truss, a number of deflection calculations are made to determine:

A) Chord inter-panel deflection

The actual deflection of the timber chord between panel points is calculated and compared to the allowable deflection by the Australian Standard or stricter limits that may be applied.

B) Joint deflection

Each joint within the truss is checked for vertical and horizontal deflection. In a flat (i.e. horizontal) bottom chord truss, there is no horizontal deflection in the bottom chord panel points and only some small horizontal deflection in that top chord panels.

The deflection calculated in the bottom chord panel points is used to calculate camber built into the truss during manufacture.

NOTE:

For trusses without horizontal bottom chords, the horizontal deflection is very important as it may cause the supporting structure to deflect outwards.

Care must be taken in applying the truss loads, fixing the truss to the bearing point and maybe even design of the supporting structure, to resist these loads.

Joint   Inter-panel deflection
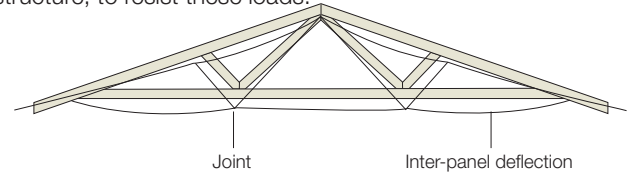
Truss action

A truss is like a large beam with each member in tension or compression, the chords acting as beams between the panel points as well as carrying axial load.

At any joint, the sum of the forces acting must be zero (otherwise motion would occur) - this enables the forces to be determined.

For example:
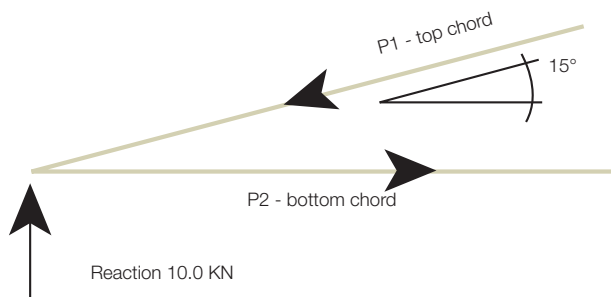
By measuring (or scaling) or by using simple trig. The forces are found to be 37.3 kN tension in the bottom chord and 38.6 kN compression in the top chord.
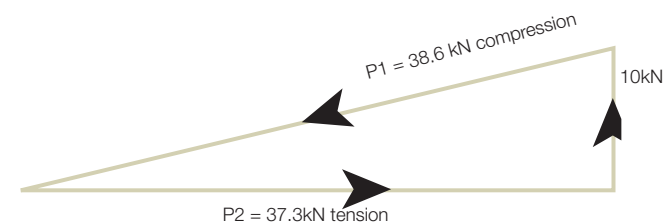
The following diagrams show typical Tension (T) Compression (C) forces in the modulus of a truss under uniformly distributed gravity loads.
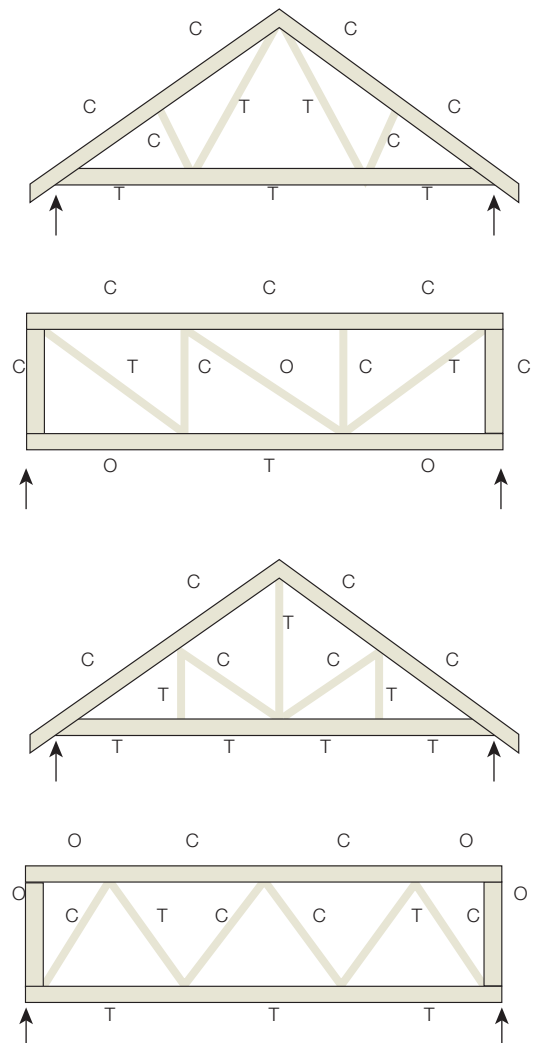
Design loads

The following details contain the basic dead, live and wind loads used for all truss design. The loads are used in as many combinations as required to achieve the most adverse loads on a particular truss.

Dead loads are those loads considered to be applied to a truss system for the duration of the life of the structure. They include the weight of roof sheeting and purlins, ceiling material and battens, wind bracing, insulation, self-weight of the truss, hot water tanks, walls, etc.

Loads are considered in two major combinations:

a. Maximum dead load value - used for calculations involving all dead and live load combinations and for wind load (acting down on the truss) which is an additional gravity load.

b. Minimum dead load value - used in combination with wind load causing maximum possible uplift on the structure, thus achieving the largest stress reversal in the truss members.

The following tables show examples of loads used for truss details.

NOTE:

This information is subject to changes according to Code requirements.

Tiles   =   Approximately 55kg/m2

Sheet Roof   =   Approximately 12kg/m2

Plaster   =   Approximately 10kg/m2

Live loads (from AS1170 Part 1)

Top chord live loads

For non-trafficable roofs (from AS1170 – Part 1 Section 4.8).

Where the area supported by the truss exceeds 14m2, a value of 0.25KPa live load is applied over the plan area of the roof.

If the supported area is less than 14m2, the value of live load is taken as:

$$= \frac{1.8}{\text{(Supported Area)}} + \quad 0.12\text{KPa}$$

The supported area is usually the product of the truss span and spacing.

Bottom chord live loads

(From AS1170 – Part 1 Section 3.7.3)

The load is assumed as that of a man standing in the centre of a particular panel of the truss bottom chord. The value is taken as 1.4kN where the internal height of the truss exceeds 1200mm and 0.9kN for height less than 1200mm.

For exposed trusses (section 4.8.3.2), the bottom chord load is taken as 1.3kN applied at each end panel point in turn and centrally in a panel where the internal height exceeds 1200mm.

For exposed Industrial and Commercial Buildings (Section 4.8.3.1) the bottom chord load is taken as 4.5kN applied at each bottom chord panel point, taken one at a time.

Wind load

1. Basic wind velocity Vp

Basic wind velocity Vp is determined from Table 3.2.3 for capital cities in AS1170 Part 2. For other areas, the following basic wind velocities can be used in timber structures:

Region A   -   41m/sec;
Region B   -   49m/sec;
Region C   -   57m/sec;
Region D   -   69m/sec

2. Design wind velocity Vz

$Vz = V \times M(z, cat) \times Ms \times Mt \times Mi$

Where: $M(Z, cat)$ = Terrain-Height Multiplier
(Table 3.2.5.1 and Table 3.2.5.2)

Ms = Shielding Multiplier
(Table 3.2.7)

Mt = Topographic Multiplier
(Table 3.2.8)

Mi = Structure Importance Multiplier
(Table 3.2.9 in AS1170 Part 2)

3. Wind pressure (P)

Wind Pressure (P) = $0.0006 \times Vz^2$ (KPa)

4. Examples

Assuming a house with an eaves height of less than 5 metres and in a Category 2 Region C area.

The Wind Load is calculated as follows:

Basic Wind Velocity   =   57.0 (m/sec)

$M(z, cat)$ =   0.91

Ms =   1.0

Mt =   1.0

Design Wind Velocity   =   57 x 0.91 x 1 x 1 = 52(m/sec)

Wind Pressure (P)   = $52^2 \times 0.0006$

P   =   **1.6224 (KPa)**

The results are summarised in the following

Case	Int. + Ext.	TC Size	Web1 Size	Uplift (KN)
1	0.8	100*38-F11	75*38-F11	3.662
2	1.2	125*38-F11	100*38-F11	6.340
3	1.3	100*38-F11	125*38-F11	6.972
4	1.7	125*38-F11	175*38-F11	9.631

Other design criteria

Roof Span   -   10 metres

Roofing   -   Sheeting

Ceiling   -   Plasterboard

Roof Pitch   -   15°

Truss Spacing   -   900mm

Timber   -   Green Hardwood

Web Configuration   -   A Type

The Wind Uplift force of each truss at support is calculated as follows:

Wind Uplift = (P-DL) x Spacing x (Int. + Ext.) x Span/2

Where:

Dead Load = DL, including roofing and ceiling material and self weight of truss.

NOTE:

This information is provided as a guide only.

Wind load calculation changes occur continuously and you must carefully consult the relevant Codes and other sources before undertaking this task.

Multinail's TrusSource (Truss Design Software) performs these calculations automatically, based on the latest Code refinements and "best practice'" design criteria.

Terrain categories

The surrounding terrain affects the wind forces acting on a structure. The design wind velocity depends upon whether the structure is exposed, is on an open or hilly terrain with or without scattered obstructions of varying heights, or is in a well wooded or heavily built up area such as suburbs, industrial areas, cities, etc. These and many other factors affect the wind forces on the structure.

To assist in the selection of the terrain category, the following sketch and notes have been produced. Also refer to AS1170 – Part 2 for more detailed explanations.

NOTE: For structures located in areas with gradual terrain changes (e.g. from a low category number to a high category number, or conversely a high category number to a lower category number), the structure is subject to either a reduction or increase in the design wind velocity. This relationship is called fetch/height. For details refer to AS1170 – Part 2.

Category 1

Exposed open terrain with few or no obstructions. Average height of obstructions surrounding structure less than 1.5m. Includes open seacoast and flat treeless plains.

Category 2

Open terrain with well scattered obstructions having heights generally 1.5m to 10m. Includes airfields, open parklands and undeveloped, sparsely built-up outskirts of towns and suburbs.

Category 3

Terrain with numerous obstructions the size of domestic houses. Includes well wooded areas, suburbs, towns and industrial areas fully or partially developed.

Seismic loads

The Australian Standard for Earthquakes AS1170.4 considers houses as ductile structures. In order to determine whether seismic loading affects the structure, a number of factors must be known including the acceleration coefficient that depends on the geographic location of the structure; and the site factor that depends on the soil profile.

When considering seismic loading, the connection of the wall supporting members to the roof trusses must be capable of resisting horizontal forces generated by the seismic activity.

According to Australian Loading Code, AS1170.4-1993, only ductile structures in the highest earthquake design category - H3 - require the design of the connection to resist a horizontal force at the top plate equal to approximately 5% of the dead load reaction. All other earthquake design categories for domestic structures require no specific earthquake design requirements.

In general, if a structure needs to withstand seismic loads, you should consult a Multinail engineer.
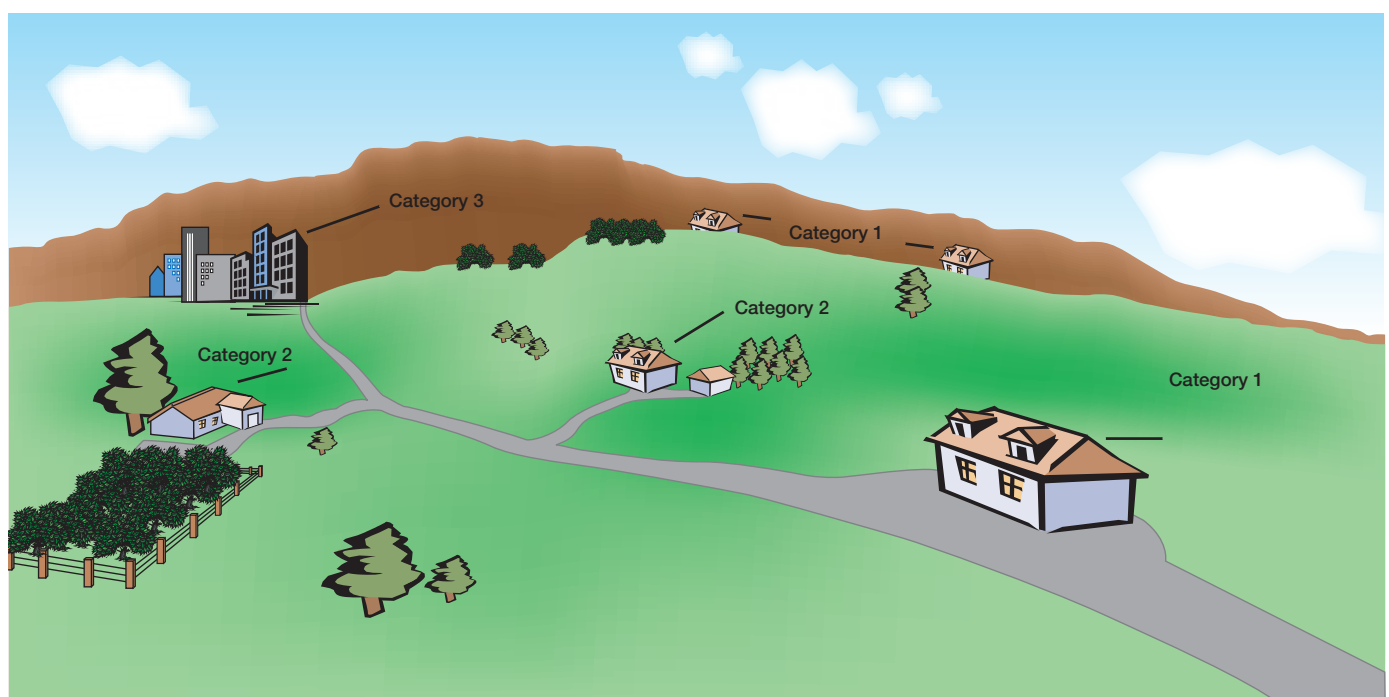
Truss handling and erection

All trusses are to be erected in accordance with the Australian Standard AS4440, 'The Installation of Nailplated Timber Trusses'.

Before trusses are erected they must be checked to ensure that:

- They comply with the requirements of the job (i.e. roofing and ceiling material, additional unit loads including hot water tanks, solar heaters, air conditioners, etc.).

- All relevant documents received with the trusses comply with the intended use of the trusses.

- The quality of all trusses are scrutinised (i.e. checked for damage during transport, broken members, missing plates, etc.). Any damage or poor quality in truss manufacture should be immediately reported the fabricator.

DO NOT attach any fall arrests or guardrail system to the trusses unless you receive explicit written approval from the truss fabricator.

Wall frames (see Framing Code AS1684) must also be checked to ensure they will be able to adequately support and hold down the trusses and their associated roof, ceiling or floor loads. The building must be stable horizontally before, during and after construction.

Inspection and storage
Trusses should be inspected on arrival at site. Any damaged trusses should be reported immediately and not site repaired without the approval of the truss fabricator.

Trusses may be transported either vertically or horizontally provided that in either case they are fully supported. Bundles (or individual trusses) should be stored flat and kept dry. Gluts or packers should be placed at 3000mm maximum spacing to support the trusses off the ground.

Temporary bracing
All trusses are required to be braced (temporary and/or permanently) and stabilised throughout the installation of the roof truss system.

As with any construction site, a risk assessment must be undertaken as truss installation invariably involves working at heights. All relevant workplace safety practices must be followed.

Permanent bracing
Before loading, the roof trusses must be permanently braced back to a rigid building structure, usually the supporting walls, to prevent rotation or buckling of the trusses.

Permanent bracing relies upon the roof bracing along with the roof battens to effectively restrain the loads in the trusses and the wind loads.

Battens
Battens to be attached to every lamination of every truss and not joined at girders.

Installation tolerances
Trusses must be installed straight and vertical and in their correct position. The best method for ensuring the correct truss positioning is to mark the locations on the top plate in accordance with the truss layout prior to truss erection.

Alterations
A timber truss is an engineered structural component, designed and manufactured for specific conditions. Timber trusses must not be sawn, drilled or cut unless explicit written approval from the truss manufacturer is received. Unauthorised alterations may seriously impair the truss strength and could lead to failure of the structure.

Weather
Trusses should be kept dry while they are waiting to be erected. Exposure to weather conditions can cause damage to trusses which can result in gaps between the timber and nailplate.
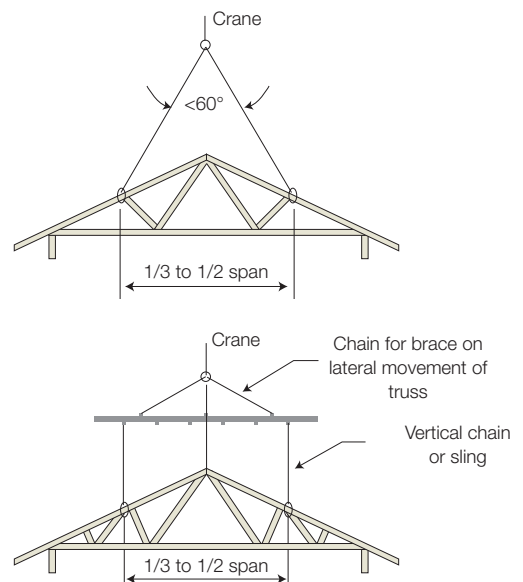
Bowing
Trusses must be erected with minimal bow in the truss and chord members. The bow must not exceed "the length of bowed section/200" or 50mm (whichever is the minimum).

Leaning
Trusses must be erected so that no part of the truss is out of plumb with a tolerance not exceeding the lesser of "height/50" or 50mm.

Lifting
When lifting, take special care to avoid truss joint damage. If it is necessary to handle a truss on its side, take precautions to avoid damage due to sagging. Use spreader bars (with attachment to panel points) where the span exceeds 9000mm.

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