APPLICATION GUIDE

Expressed Hardwood Structures

Trusses, Cathedral Ceilings, Post and Beam Frames

SCOPE

This guide provides ideas and design information to assist in the development of expressed native timber structures in buildings. Basic information on how to determine structural form, typical connections and timber use are included.

EXPRESSED INTERNAL STRUCTURES

The use of hardwoods as expressed internal structural elements represents the most ‘complete’ application of hardwood in construction. The three major attributes of Australian hardwood- high strength to weight, durability and beauty are all ‘expressed’ in the final result.

Combined with the natural fire resistance properties of many hardwoods, these attributes make high value applications, such as structures for public buildings, a natural choice for the material.

The success of specialist, non-domestic structures depends on the fusion of design and engineering disciplines. The structural form is dependant as much on the desired feel of the space as it is on structural requirements. Australian timbers offer a wide range of options and may also be successfully blended with other building materials such as steel, concrete and glass.

POPULAR STRUCTURAL SYSTEMS FOR EXPRESSED CONSTRUCTION

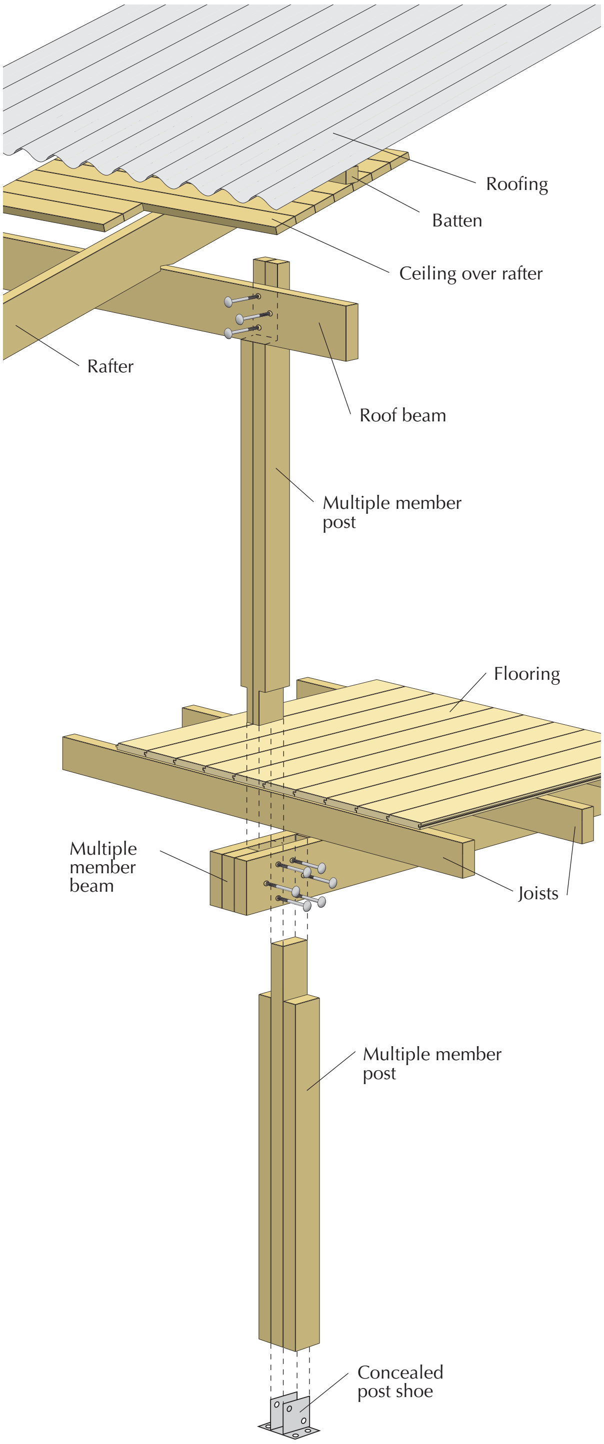
Post and Beam Frames

Probably the oldest structural system, yet still favoured by today’s designers. Traditionally using large end-section timbers, post and beam structures have been favoured for building everything from shearing sheds to eight storey city buildings. Many examples over 100 years old still stand behind their nineteenth century brick facades throughout our major cities.

Post and beam structure

Although large end-section timbers are still available to order, today's precision milled, kiln dried hardwoods are ideal for multiple member post and beam structures. The use of timber to timber connection systems enables slim, robust and beautiful structures to be constructed practically and economically. Where large end sections are required, glue laminated hardwood offers almost unlimited potential.

Figure 1: Typical multiple member post and beam construction

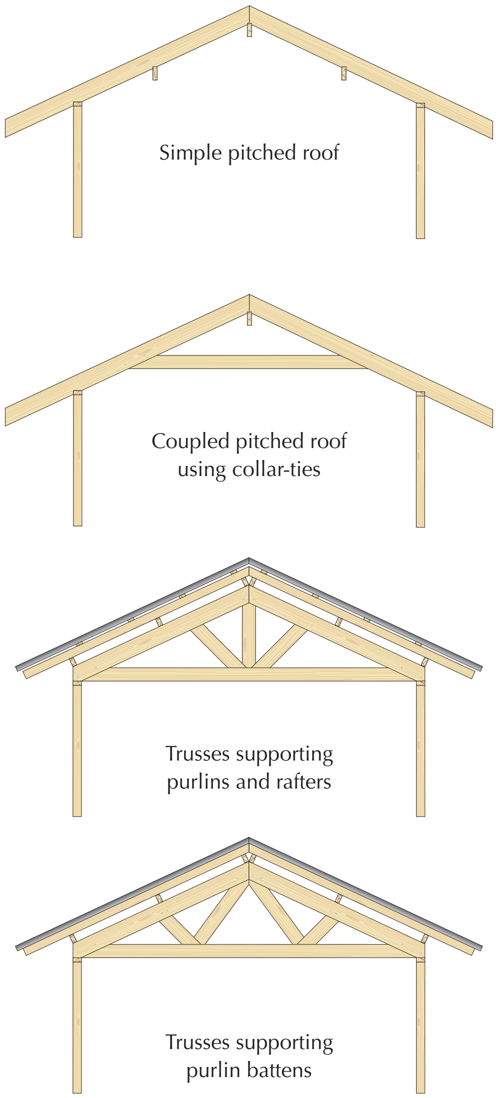


COMMON EXPRESSED ROOF STRUCTURES

(Refer to Figure 2)

- Simple pitched roof – using rafters spanning between ridge beam, intermediate beams and wall.
- Coupled pitched roof – using collar-ties.
- Trusses supporting purlins and rafters.
- Trusses supporting purlin battens.

Figure 2: Common expressed roof structures



PITCHED ROOF STRUCTURES

Often used in conjunction with a post and beam system for efficient construction. Can work equally well with conventional stud framing support. It should be noted that where the rafters are not ‘tied’ together via conventional ceiling joists, an alternative must be considered to resist the spreading of the rafters under roof loads. To prevent this, a collar tie must be included, and rafter sizes are generally increased to retain rigidity in the structure. If this increase in size is undesirable, then an extra tie can be located near the base of the rafters, and this can be made of timber, wire or steel rod.

Simple Pitched Roof

The most common method of achieving a so-called ‘cathedral ceiling’ uses rafters simply spanning between ridge and intermediate beams and external walls. Ceiling linings can be fixed to either the top or bottom face of the rafters.

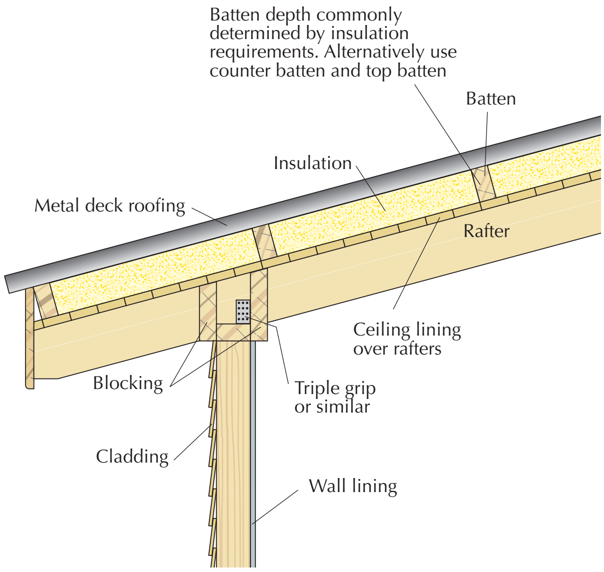
Ceiling Above Rafters

Has the advantage of concealing joins in ceiling materials – commonly lining boards, plywood or cement based panel products. If using lining boards, shorter lengths can be utilised. Progressive cover needs to be maintained to prevent water damage and staining.

Fixing of rafters to beams also needs careful detailing, as common methods such as the use of nail plate connectors are not appropriate. The use of long (up to 150mm) type 17 screws and coach screws are common methods of achieving required tie down. AS1684 should be utilised to calculate the loads to be resisted. Assistance can be sought from structural engineers for specific requirements.

The depth of battens is determined largely by insulation requirements. A 70 x 45mm on edge is common. Alternatively, counter battens over rafters with standard battens over can be used. Refer to Figure 3.

Figure 3: Ceiling above rafters

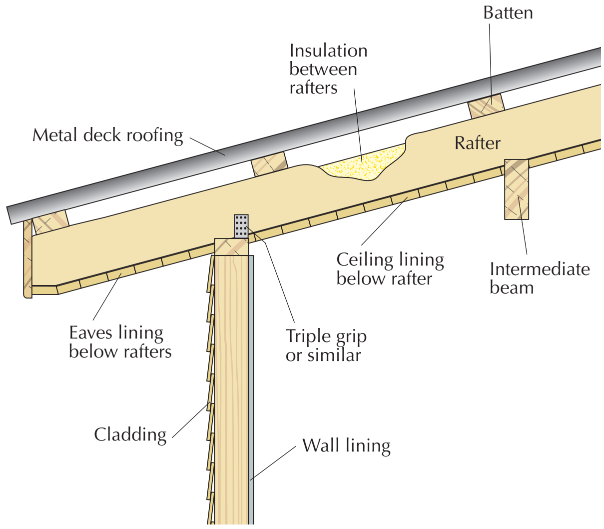


Ceiling Below Rafters

As rafters are concealed within the ceiling lining and supporting beams, trusses or other primary structural members are expressed. The depth of the rafters is available for insulation, and ceiling installation is done after the roof covering. Concealing of rafter/support connection is still required for best appearance. Refer to Figure 4.

Connections for these members are simple, and utilise nail requirements akin to site-pitched roof construction. Structural detailing may make use of the previously mentioned post and beam construction. As shown in Figure 2, this involves a pitching beam and ridge beam to support the rafters. In addition, intermediate beams may be necessary to reduce the span of long rafters.

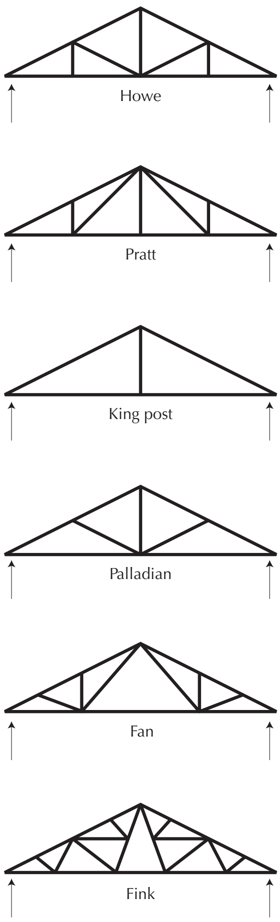
Figure 4: Ceiling below rafters



ARCHITECTURAL TRUSSES

Architectural trusses are often used as part of a 'cathedral ceiling' system. Aesthetically, this part of the structure creates an eye-catching appearance, and typical options are shown in Figure 5. Many of these designs, were patented during the 19th century, and still bear the name of the original designers e.g., Pratt, Howe etc.

Figure 5: Typical truss designs



Trusses get their strength via triangulation, which bands elements together to act in structurally advantageous ways. For instance, each member can be assigned to work in a network of tension and compression members, and by doing this, greater structural efficiency is possible. For the types of trusses described above, compression members often dictate the size of the elements, and for this reason, designs that have short compression members, or restraint against lateral buckling, are generally more efficient than trusses with long compression members.

In trying to maximise the visual impact of trusses, it is common to space them in the order of 3 to 6 metres apart, to distinguish them as individual features. To make this possible, purlins are used to span between trusses for the purpose of supporting in-fill rafters (i.e. between the trusses). As a result, the truss chords (top) take extra bending from the purlin loads. This can require larger top chords than desired, and if there is a need to reduce this size, the problem can be solved by incorporating more webs into the truss (i.e. more top chord support), thus allowing a smaller chord to be used.

Some truss designs involve situations where the bottom chord is raised to give a greater feeling of space – as shown in Figure 6. The main disadvantage of this type of truss is that larger and stronger members are required to deal with flexure in the top chord, resulting from the acquired loads brought about by the raised bottom chord. As a result, care must be taken to ensure that the desired appearance and budget can still be is attained. If appropriate, a more attenuated option is the scissor truss – as shown in Figure 7. It uses the inner members to create ties that are always in tension - even under wind reversal loads – these create a notional ceiling line and may be made from timber, cable or steel rod.

Figure 6: Truss with raised bottom chords

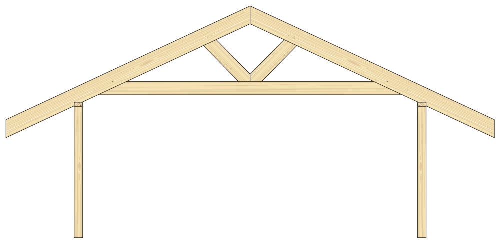
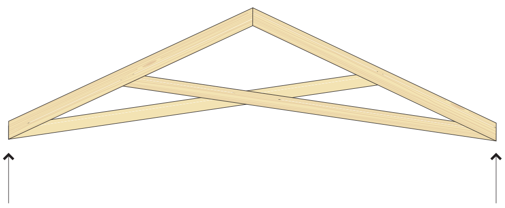


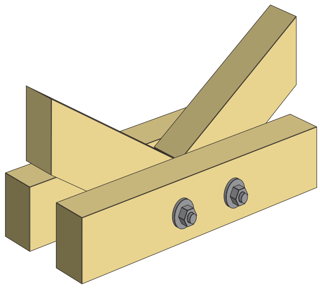
Figure 7: Scissors truss configuration



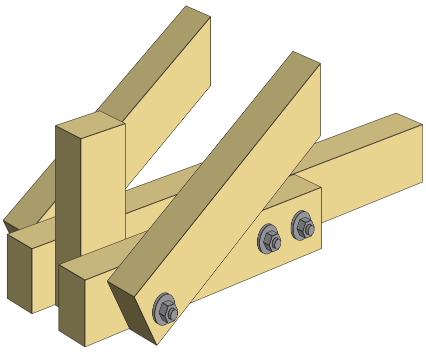
CONNECTIONS

Connections greatly influence appearance, economy and ease of construction. A key issue is the number of members intersecting at a connection (i.e. truss nodes). For instance, there are various configurations that can broadly be grouped into: single web and single chord connections; double web and single chord connections; single web and double chord connections; and more complex connections. A number of these options are shown in Figure 8.

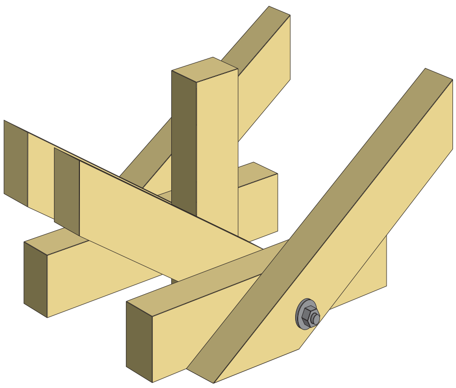
Figure 8. Alternative truss connection systems



An eccentric joint where care needs to be exercised in the design (refer Ozeiton and Baird)



A five member joint where the central web load travels via the connecter and the chord members to reach the outer (inclined) webs. This means that the load is applied close to 90° to the grain



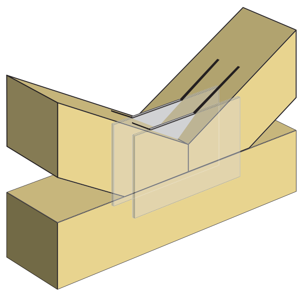
A seven member arrangement as could be employed in a Palladian or fan truss

Steel Plates used with Nails or Screws

Truss members are commonly joined with metal plates that incorporate nails or screws. Nails are the most economical option, and are commonly used in mass production situations. Here, 'nail plates' are pressed into place, and the many small nails serve to distribute the load over a broad area. As a result, there is better transfer of stresses, reduced impact from imperfections such as knots, and less concern about using low strength timbers. In contrast, bolts concentrate the load, and are therefore structurally less efficient.

In some cases where aesthetics dictate, greater effort may be made to conceal the plate connectors. Here, the plates may be cut into insertion slots in the webs and chords - as shown in Figure 9. This also provides an efficient structural design. During fabrication, it is also useful to take advantage of machine driven nails which can penetrate steel plates up to 2mm in thickness . For thicker plates, screws may be necessary, and can be efficiently applied using self-drilling screws. Screws are typically Type 17 wood screws – often termed 'batten screws' – and come in a number of head types to facilitate driving. The ability to drive these screws is somewhat dependent on the depth and density of the substrate timber. For instance, there are limitations with the use of self-drilling screws in hardwood, and in such instances, pre-drilling is required.

Figure 9: Interleaved plate connection



Bolts with Steel Side Plates

Under this scenario, thick steel side plates or gussets are used in conjunction with bolts to transfer the load. Here, gussets may become long and obtrusive due to the need to space bolts far enough apart to spread the load. Plates can also be expensive to fabricate as the plate must mimic the complex shapes of the member intersections. If appropriate, a way around this issue is to use hidden plates – as discussed previously.

Bolts and Timber Connections

In traditional trusses, connections are often made using bolts which hold multiple chord and web components together like a pin joint (Refer to Figure 8). Though common in older structures, these types of connections have difficulty in developing sufficient rigidity, and also cause eccentric loading. It is hard to prevent this, but the usual method of managing the problem is to make a more compact joint by using a large number of small diameter bolts. As a result, this method tends to be more expensive than the steel plate options discussed previously.

Timber to Timber Connections

A wide range of options prevail for multiple member timber trusses. Timber to timber is very efficient and economically fabricated on-site using screw fixings. The following photos reflect some examples of this form of construction.

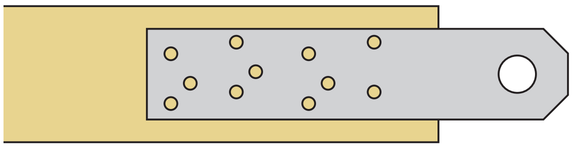
Timber to timber connections with concealed steel plates

Timber to timber connections

Spliced Members

On some occasions, splices are necessary in long chord members. In such instances, splice locations should be chosen to coincide with areas of low loading. Such positions are best determined by a structural engineer, but as a guide, if the chord is in compression the splice should be at the node where lateral restraint can be provided. An economical method of splicing tension members is to use Type 17 screws in conjunction with a metal plate – as shown in Figure 10. Note the use of a staggered screw pattern to reduce the chance of splitting.

Figure 10: Staggered screw pattern in connector plate



WHICH TIMBER TO USE

Both seasoned and unseasoned hardwood can be used for truss fabrication. Even so, size availability may limit the use of large solid sections, and create the need to use multiple smaller sections, instead.

Table 1 (seasoned hardwood) and Table 2 (unseasoned hardwood) give an idea of cross sectional sizes, lengths and stress grades available. In reading these tables it is notable that seasoned timbers tend to offer higher grades; but unseasoned timbers tend to offer slightly longer lengths.

In addition to solid timber members, engineered timber products can also be used for truss fabrication. These include nail plated hardwood and glue laminated hardwood.

- Nail plated hardwood utilises kiln dried solid timber that is combined together to form longer and/or deeper members by virtue of metal plates connecting pieces together. These are generally available in all species of hardwoods, but care should be taken to ensure the nail plates are suitable for the intended appearance requirements. In addition, nail plated hardwoods are not recommended for use where directly exposed to external environments.
- Glue laminated hardwood (Glulam) utilises small strips of timber which are glued together. A key benefit of this product is the capacity to create curved elements and to remove many natural imperfections in the timber. It is generally available in Tasmanian Oak, Spotted Gum, mixed hardwoods and Cypress. There is also a limited supply of Brushbox and hybrid beams utilising hardwood flanges and softwood webs. Check with suppliers for sizes and strength specifications as these vary for each manufacturer.

Table 1: Timber availability – Seasoned hardwood

mm	70	90	120	140	170	190	240
35	✓	✓	✓	✓	✓	✓	✓
45	✓	✓	✓	✓	✓	✓	✓

Notes:

1. ✓ – Indicates commonly available sizes.
2. 70 and 90mm thickness are generally made up by vertically nail laminating.
3. Lengths can be ordered in 300mm increments up to 6 metres in length; longer lengths may be available upon enquiry with suppliers.
4. Stress grade timbers are generally available in F17 and F27.
5. Seasoned hardwood is gauged to size, and often provides a good quality finish approaching a ‘dressed finish’ – check with suppliers for details.

Table 2: Timber availability – Unseasoned hardwood

mm Nom.	75	100	125	150	175	200	225	250	275	300
38	✓	✓	✓	✓	✓	✓	✓	✓	✗	✗
50	✓	✓	✓	✓	✓	✓	✓	✓	✗	✗
75	✓	✓	✓	✓	✓	✓	✓	✗	✗	✗
100	✓	✓	✓	✓	✗	✗	✗	✗	✗	✗

Notes:

1. ✓ – Indicates commonly available sizes.
2. ✗ – Indicates additional sizes, usually available on order only.
3. Stress grades are generally available in F11, F14 and F18. There are also limited instances of F8 and F22.
4. Lengths can be ordered in 300mm increments up to 6 metres. Lengths up to 6.9m are frequently available. Over 6.9m should be checked with suppliers.

RELATED DOCUMENTS

(From this Series of Timber Development Association Publications)

- Fire Requirements for Non-Domestic Fit-Out (including information on BCA requirements for fire and other issues).
- Technical & Detailing Guide for Hardwoods and Cypress (including information on moisture management, durability, appearance and structural issues).

ACKNOWLEDGMENTS

- AS1720 Timber Structures – Design Methods, Standards Australia, Homebush, 1997.
- Timber Manual, National Association of Forest Industries Ltd., Canberra.

Expressed hardwood truss ceiling

Expressed hardwood post and beam structure

Australian Hardwood Network

For additional assistance please contact the Timber Advisory Service

1800 044 529

or visit the following websites:
www.timber.net.au
www.australianhardwood.net

TDA
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