NOTE: JULY 2018

The Timber Bridge Manual is a reference document only. Some of the contents are out-of-date.

It is recommended to seek advice from RMS Bridge and Structural Engineering (Rehabilitation Design) prior to use.

TIMBER BRIDGE MANUAL
Edition 1 Revision 0 – June 2008

SECTION THREE

TIMBER TRUSS BRIDGES
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## SECTION THREE

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3. TIMBER TRUSSES

3.1 GENERAL

3.1.1 Scope

Section 3 covers the design, construction and maintenance of all timber truss bridges and specified components as outlined in Subsection 3.2.

This section is to be read in conjunction with Section 1- General and other sections as may be specified. Section 1 provides the basic requirements and procedures for timber bridges and their components. This section provides specific additional requirements relating to timber truss bridges.

3.1.2 Objectives

The objectives of this section are to outline the requirements of, and to provide guidance in relation to, the design, construction and maintenance of timber truss bridges and their components with specific emphasis on:

- Inspection procedures
- Preventative and routine maintenance
- Rehabilitation and repairs
- Engineering design and evaluation
- Detailing and durability
- Specifications
- Material supply

3.1.3 Definitions

Section 1 contains an extensive list of definitions pertaining to common terminologies, phrases and components related to timber bridges. This subsection provides additional definitions related specifically to timber trusses.

*Anchor Block*
Term referring to the end attachment for a tension member, specifically for a diagonal bar in a DeBurgh truss (see Figure 3.2.1.5-3)

*Cast Iron Shoe*
Term referring to the end bearing component for a compression member, specifically a spheroidal graphite cast iron joint component for timber diagonals and some end principals (see Figure 3.2.1-1)
**Bottom Chord**
The lower horizontal member of a truss (see Figure 3.2.1.1-1)

**Butting Block**
Timber component used to support the ends of timber compression members (see Figure 3.2.1.2-2)

**Compression Member**
Truss member loaded primarily in compression such as the end principals, top chords and timber diagonals (see Figure 3.2.1.1-1)

**Cross Girder**
Primary transverse bending member in a truss supporting the deck system (see Figure 3.2.1.1-1)

**Deck System**
The assembly of deck components supported by the cross girders (typically stringers, decking and sheeting)

**Diagonals**
A general term referring to truss members placed on an angle (typically excludes the end principals which are referred to separately)

**End Principal**
The primary end (diagonal) timber member in a truss (see Figure 3.2.1.1-1)

**Joint (truss or member)**
A term referring to the truss location (typically along a top or bottom chord) where members intersect or come together (see Figure 3.2.1.1-1)

**Keyway (keyed)**
A term referring to a notch or rectangular cut in a timber component fitted with a mating timber or steel component designed to transfer longitudinal forces between the two components (see Figure 3.3.3.3-2)

**Laminated**
A term referring to the joining together of more than one component to form a single member (see Figure 3.3.4.2-1)

**Panel Point**
A term referring to the main joints in a truss as shown in Figure 3.2.1.1-1

**Panel**
The area between the panel points (or joints) in a truss

**Shear Keys**
See Keyway
Sway Brace
Diagonal member located outside the truss extending between the top chord and the extended cross girder designed to resist sway of the truss (see Figure 3.2.1.1-1)

Tension Member
Truss member loaded primarily in tension such as vertical bars, and bottom chords (see Figure 3.2.1.1-1)

Top Chord
The upper horizontal member of a truss (see Figure 3.2.1.1-1)

Verticals
The vertical members in a truss (see Figure 3.2.1.1-1)

3.2 STRUCTURE TYPES AND COMPONENTS

A review of the more common types of timber trusses and components follows. This review provides a means of defining the terminology being used. Words in italics are noted to be the accepted terms normally used in the field when referring to the truss type, components or system under consideration. These terms are defined in Subsection 3.1.3.

3.2.1 Timber Truss Designs

There are basically five types of timber truss designs which were built in NSW beginning in the mid 1800s. Their basic outlines are shown in Figure 3.2.1.1-1. The following presents an example of each truss type along with its basic features. Additional specific details for some of the trusses will be presented throughout this section as they relate to the different requirements for inspection and maintenance.

It should be noted that reference is made to cast iron and steel in the following figures and discussion. While it is assumed that most metal components in the older bridges are cast iron, it is possible that the round bars could also be threaded rolled steel in some of the newer designs. In many cases the bars are referred to as steel only for consistency.
3.2.1.1 Typical Terminology

Prior to considering each of the truss types, it is necessary to clarify some of the typical terminologies. Figure 3.2.1.1-1 defines the typical terminology for the components of timber trusses used in this manual. These basically apply to all truss designs except that some components are not contained in some trusses as will be described in the subsequent sections.
3.2.1.2 Old Public Works Department (PWD) Design 1860-1886

The PWD design (Figure 3.2.1-1) is one of the oldest timber truss designs in NSW and only a few are still in existence. The Clarencetown bridge shown in Figure 3.2.1.2-1 is a typical example of an old PWD design which remains in service.

Typical features include:

- large section timber components
- solid timber top chord
- solid timber end principals and diagonals
- laminated timber bottom chords
- vertical steel bar tension members
- very long end principal
- timber butting blocks at joints
- cast iron sway braces

The end principal is supported at the end of the bottom chord by a long timber butting block. The two components are bolted together and the original design used three timber notches (as shear keys) as shown in Figure 3.2.1.2-2 to transfer the forces from the end principal to the bottom chord.

![Figure 3.2.1.2-2 Typical End Butting Block PWD Truss](image)

At the top chord, the primary internal diagonals also bear against timber butting blocks as shown in Figure 3.2.1.2-3. Typically this timber component is only bolted to the main top chord member. At the bottom chords the diagonals simply bear against the sides of the timber cross girders as shown in Figure 3.2.1.2-1.

![Figure 3.2.1.2-3 Typical Member Joint - Clarendon Bridge](image)

Except for the end butting block (Figure 3.2.1.2-2), the type of joint system used in this design results in a fairly flexible truss as the members tend to shift at their ends. Some modifications for upgrading this design will be outlined in Subsection 3.5.
This design also uses fairly closely spaced timber cross girders as shown in Figure 3.2.1.2-4 which directly support the timber decking and sheeting without the need for longitudinal timber girders.

![Figure 3.2.1.2-4 Close Up of Clarencetown Bridge](image)

The cross girders are supported on the bottom chord of the truss with many (so called intermediate) members between the main panel points. These intermediate cross girders create high bending moments in the bottom chords of the truss. The significance of these bending moments is outlined in Subsection 3.6 and methods of upgrading the deck system to eliminate intermediate cross girders are outlined in Subsection 3.5.

### 3. 2.1.3 McDonald Truss 1886-1893

The McDonald truss shown in Figures 3.2.1-1 and 3.2.1.3-1 is very similar to the PWD design except that it uses some different styles for the timber members. Most primary members are composed of several pieces spaced apart for stability. This provides improved durability by reducing contact surfaces as well as better access for inspection and maintenance. Typical features include:

- smaller section timber components
- solid timber top chord
- timber end principals and diagonals
- laminated timber bottom chords
- vertical steel bar tension members
- very long end principal
- timber butting block at end principal
- cast iron shoes at top chord joints
- cast iron sway braces
This design also uses a timber butting block supporting the end principal as shown in Figure 3.2.1.3-2. This particular butting block is shorter than the previous PWD design and has both a timber notch and steel key rebated into the components.

The design also uses cast iron shoes at the top chord joints. These are notched (keyed) into the timber as shown in Figure 3.2.1.3-3, resulting in a stronger and more rigid performance than that used in the PWD truss. The internal diagonals bear directly against the sides of the timber cross girders the same as in the case of the PWD design.
This design represented a considerable improvement over the PWD design. Primarily the rigidity of the connections significantly reduces the movements at the joints.

However, the design also has closely spaced timber cross girders which directly support the timber decking and sheeting. As with the PWD design, the intermediate cross girders create significant bending moments in the bottom chords.

3. 2.1.4 Allan Truss 1893-1929

The Allan truss shown in Figures 3.2.1-1 and 3.2.1.4-1 is similar to the previous design except that it uses steeper and shorter end principals with cast iron shoes instead of timber butting blocks for the end principals. Typical features include:

- smaller section timber components
- spaced timber top chord
- spaced timber end principals and diagonals
- laminated timber bottom chords
- vertical steel bar tension members
- shorter end principal
- all cast iron shoes
- cast iron sway braces
This design uses cast iron shoes keyed into the timber members at all joints in the top and bottom chords. The typical detail is shown in Figure 3.2.1.4-2. Here the blocks have protruding keyways which are rebated into the timber chord. This provides strong and rigid joints for all members leading to improved performance.

It also supports a slightly different deck system which has timber cross girders located only at the main panel points as indicated in Figure 3.2.1-1. These cross girders support longitudinal timber girders which in turn support the decking and sheeting (similar to Figure 3.2.1.1-1).

3. 2.1.5 De Burgh Truss 1899-1905

The De Burgh truss shown in Figures 3.2.1.5-1 and 3.2.1.5-2 is a different type of design to all the other timber trusses in NSW and was the first to use a steel bottom chord. Typical features include:

- small section timber components
- spaced timber top chord
- all cast iron shoes in the top chord
- cast iron sway braces
- steel bar diagonals
- steel bottom chords
- spaced vertical timber (compression) members

The load transfer through the truss is different from the earlier truss designs. The bottom and top chords are tension and compression members, respectively, which is similar to the typical truss designs. However, the vertical and diagonal members are compression and tension members, respectively, which is the reverse of the other timber truss designs. It was adopted by De Burgh to provide a stiffer cross section.

The use of a composite design using twin steel plate (bottom) and timber (top) chords represented a more efficient use of materials. Timber is basically much weaker in tension (for large sections) as its tensile strength is significantly affected by defects (eg: knots and slope of grain). As well, the need to splice timber in tension required elaborate (and inherently weak) joints. In contrast, timber is very strong in compression. Therefore, the use of timber in compression and steel in tension was found to be an excellent marriage of materials.

![De Burgh Truss - St Albans](image)

**Figure 3.2.1.5-1** De Burgh Truss - St Albans

The vertical timber members are of quite small cross section, as shown in Figure 3.2.1.5-2, and are spaced apart to provide stability. The top chord is composed of two components which are also spaced apart. This facilitates inspection, maintenance and member replacement. However, the bottoms of the vertical timbers are highly susceptible to deterioration as will be discussed later in the section.
Figure 3.2.1.5-2  Close Up of St Albans Bridge

As there are no timber diagonals, there is no need for substantial cast iron shoes. The diagonal bars are secured easily to the bottom steel chord and are extended through the top timber chord as shown in Figure 3.2.1.5-3. The top attachment is secured using a cast iron *anchor block* which is keyed into the timber to provide a strong rigid connection.

Figure 3.2.1.5-3  Cast Iron Anchor Block - St Albans

As with the Allan truss, the timber cross girders are situated only at the main panel points as shown in Figure 3.2.1-1. Therefore, the traditional deck system uses longitudinal timber girders which support timber decking and sheeting similar to that shown in Figure 3.2.1.1-1.
3. 2.1.6 Dare Truss - 1903-1936

The youngest timber truss design is the Dare truss shown in Figure 3.2.1.6-1. Except for slight differences in some of the timber component details, this design is basically the same as an Allan truss with a steel bottom chord. Typical features include:

- small section timber components
- spaced timber top chord
- spaced timber end principals and diagonals
- steel bottom chords
- vertical steel bar tension members
- short end principal
- all cast iron shoes
- cast iron sway braces

Figure 3.2.1.6-1  Dare Truss - Korns Crossing

All of the points outlined in Subsection 3.2.1.4 for the Allan truss apply to the Dare truss except that the steel bottom chord comprises twin channels as shown in Figure 3.2.1.6-2. As with the De Burgh truss, this composite design of steel and timber represented a more efficient use of materials and an inherently stronger bridge. The design also uses timber cross girders at the main panel points along with timber girders, decking and sheeting.
3. 3 INSPECTION PROCEDURES

Section 1 outlines the basic inspection procedures for all timber bridge types and these procedures also apply to timber trusses. This subsection highlights specific additional considerations for timber truss bridges.

3. 3.1 Objectives and General Requirements

The basic objectives and requirements outlined in Section 1 must be considered during the inspection of timber trusses.

3. 3.2 Inspection Records

Detailed inspection records as outlined in Section 1 must be maintained for all inspections.

3. 3.3 Annual Visual Inspection

Annual inspections should be carried out on all timber trusses and should be done together with the annual maintenance as outlined in Section 1.

3. 3.3.1 Alignment and Geometry

The overall alignment and geometry of the trusses, as well as the level of the deck surface, should be observed as these can indicate hidden problems. Particular emphasis should be given to the vertical and longitudinal alignment of the truss. Figure 3.3.3.1-1 shows a particularly serious example of a truss which is out of alignment. Such deformation can be caused by a number factors including loose sway braces, failure of components or even over-loading.
Figure 3.3.3.1-1  Top Chord Deformation - Euminbah Bridge

Figure 3.3.3.1-2 shows the uneven deck surface on the Clarendetown bridge. This was caused by a number of factors including sagging of the truss bottom chord (see Subsection 3.3.3.3) and deterioration/failure of some deck components.

Figure 3.3.3.1-2  Uneven Deck Surface - Clarendetown Bridge

These are only two examples and while most timber bridges inherently display uneven geometries when compared to steel and concrete bridges, this should not be visually apparent. Any obvious deformations and misalignments should be recorded with photographs. As well, attempts should be made to measure (quantitatively) the deformations.

For top chords, a stringline should be extended between the end points of the truss and deviations from this straight line along the member should be recorded.
The same procedure can be performed to measure the sag of the bridge but a steel wire should be used and adjustment for the sag of the wire must be made. To estimate the sag of the wire, it is usually adequate to visually align the two end points and have someone hold a ruler at the midpoint as shown in Figure 3.3.3.1-3.

![Figure 3.3.3.1-3 Determining Sag of Wire](image_url)

These measurements can be valuable (even in the short term) as they provide a means of determining if the condition is progressive when compared with future inspections.

3.3.2 Inspection Under Transient Loading

The basic requirements for inspection under transient loads are outlined in Section 1.

The following specific truss areas shall be observed for excessive movements and other considerations as noted;

- overall vertical and lateral (sway) displacement of the trusses with particular emphasis on differentials between the trusses (ie one moving more or differently than the others)
- apparent lateral or longitudinal movement of the deck
- local movements at truss joints with particular emphasis on relative movements between components, especially between notched and/or keyed components (ie butting blocks, cast iron shoes and other joints)
- movements at other connection details
- inconsistency of local deck movement under the moving wheel loading (apparent local deformation around the wheel should be uniform along the truss span)
- signs of structural damage or deterioration which may be exposed during movements
- movements at previously reported problem areas
- movements at previously repaired areas
3. 3.3.3 Structural Defects and Damage

All components and connections shall be visually inspected for obvious structural defects and damage. These should include:

- member fractures due to loading with particularly emphasis on primary truss components
- failure or movement at shear keys
- local crushing of timber at bearing points with particular emphasis on:
  - ends of timber truss members at joints
  - timber at notches and shear keys
  - cross girders on bottom chords
  - truss support bearing (bottom chords, corbels)

- evidence of loose connections and/or enlarged holes around bolts
- evidence of vehicle collision damage
- deformation or buckling of members

Some of the typical areas for structural failure or damage are shown in Figure 3.3.3.3-1.

![Figure 3.3.3.3-1 Typical Areas for Structural Damage](image)

It should be noted that in timber truss members composed of several components bolted together, failure of one component can sometimes be indicated by lateral deformation of the member as the forces are carried eccentrically.
Crushing at the ends of timber truss members is usually precipitated by deterioration as moisture cannot dry readily in these areas. This is particularly true at the bottoms of the vertical timbers in De Burgh trusses.

The failure of shear keys can be caused by several factors in both timber notches and cast iron shoes as shown in Figure 3.3.3.3-2. The timber is subjected to both high bearing stresses as well as horizontal shear as shown in the figure. The steel keys are also subjected to high stresses. It is important to closely inspect for signs of timber crushing and shear of the timber as well as possible fracture of the casting. If failure or movement is suspected, the detail should be closely observed under transient loading. The interface should be marked to facilitate visual confirmation of movement.

![Figure 3.3.3.3-2 Typical Failure at Shear Keys](image)

Figure 3.3.3.3-3 shows a visible movement of the cast iron shoe at the joint between the end principal and the butting block. This is caused by the lack of a shear connection between the butting block and the bottom cord. This movement precipitated sagging of the truss span.
3. 3.3.4 Timber (and Metal) Deterioration

All truss components shall be inspected for deterioration caused by decay and/or insect attack. These should include:

- sapwood in any components (typically the durability class of these members inhibits the use of components with sapwood)
- areas where water is trapped or does not dry out readily with particular emphasis on:
  - ends of members at joints (particularly vertical members)
  - interfaces between components in built-up members
  - holes at connections
- under flashing and behind other protective coatings
- corrosion of bars at, or near, joints and within timber components

Some critical areas for deterioration are shown in Figure 3.3.3.4-1.

![Figure 3.3.3.4-1 Typical Areas for Deterioration](image)
It is important to note that the typical areas for deterioration are not usually apparent during visual inspection. Some critical areas will be identified in Subsection 3.3.4. However, serious internal deterioration may manifest itself through member crushing, deformations or visible movements at joints and connections.

This is particularly true at the ends of compression members where deterioration precipitates crushing. These areas require close inspection.

Serious deterioration in the bottom chords of the Clarendtown bridge was evidenced by excessive deformation of the chord as shown in Figure 3.3.3.4-2.

![Deformed Bottom Chord - Clarendtown Bridge](image)

**Figure 3.3.3.4-2**  Deformed Bottom Chord - Clarendtown Bridge

### 3. 3.4 Detailed Inspection

In addition to the annual visual inspection, a more detailed inspection must be carried out every three years and should include:

- integration of the inspection with the 3 year maintenance activities and extending the visual inspection to hidden areas
- exposing questionable areas with particular emphasis on:
  - under flashing
  - between timber interfaces
  - around bars where they pass through timber members
  - around bolts
- boring of main structural components including all truss members and cross girders
3. 3.4.1 Timber Boring

The standard methods and identification for timber test bores are outlined in Section 1 and shall be applied to the boring of timber trusses and cross girders. Boring shall be performed, but not be limited to, the following areas:

- all timber components within 75 mm of their ends (where the end is not exposed for visual inspection) except as noted below
- adjacent to timber interfaces in components bolted together which cannot be exposed for visual inspection (as outlined below)
- adjacent to bolt holes or bars with the bore hole intersecting within 30 mm of the hole at the centre of the member at one or two locations per member.
- within 50 mm of the bottom end of vertical members (specifically in De Burgh trusses)
- in random locations adjacent to truss joints

Care should be taken to avoid drilling completely through members and horizontal bores should be inclined slightly upwards. All bore locations should be clearly marked on the members.

Where possible, bores should be perpendicular to the member surface so that the measurements outlined in Section 1 are relative to the section dimensions. However, in truss members at joints, it is preferable that the members be drilled from the underside which will require bores to be at an angle to the member. Some example bore directions are shown in Figure 3.3.4.1-1 and these are non-all-inclusive. In these situations, the bore information is to be accompanied by the angle of the bore measured from the perpendicular as shown.

![Figure 3.3.4.1-1 Sample Bore Directions](image)

Generally, boring of components with a minimum section of 100 mm or less should be limited. These members are usually too small to accommodate extensive internal deterioration without some external evidence. Random checks should be performed adjacent to bolts and near ends which are not exposed.
Some additional information is provided in Subsection 3.3.4.2.

3. 3.4.2 High Risk Areas

The high risk areas are between timber components bolted together, at the ends of members in contact with other surfaces, in members at bearings and, particularly, in members with no flashing protection.

Deterioration in members composed of components bolted together typically initiates between the surfaces where moisture penetrates and does not readily dry out. However, as shown in Figure 3.3.4.2-1, these members still respond as if they were one section with the deterioration spreading out within the limits of the outside surfaces. As a result, it is important to bore near the interface area as shown in Figure 3.3.4.2-2 where the bores are within 50 mm of the interfaces.

![Figure 3.3.4.2-1 Examples of Deterioration in Laminated Member](image1)

Another critical area which has previously been mentioned is at the bottom of vertical timber members such as those in De Burgh trusses. In these trusses the bottom of the member is supported on a flat plate which holds moisture against the end of the member. In addition, the cross girders of the deck system are fitted tightly between the verticals, as shown in Figure 3.3.4.2-3, along with timber blocking. This creates multiple interfaces between the timber components and is one of the poorer details of the De Burgh design. Typically, deterioration of these verticals is not visibly apparent and is usually contained on the inner surfaces as shown in Figure 3.3.4.2-4. This type of deterioration usually becomes apparent by
visible crushing of the outside timber fibres near the base. CAUTION is advised when boring the verticals in De Burgh trusses as the cross section is quite small and boring can reduce the member strength. Small 12 mm holes are to be used.

**Figure 3.3.4.2-3**  Bottom of Timber Verticals - St Albans (De Burgh Truss)

**Figure 3.3.4.2-4**  Decay at Bottom of Timber Vertical - St Albans

Proper flashing and protection systems are essential to timber truss components. Any damaged or poorly maintained protection system can cause more harm than good.

Metal flashing used on the tops of timber truss components can leak and allow moisture to remain on the tops of the covered members. In addition, this flashing can provide protection for termites which can live and travel underneath its cover. Therefore, it is important that the areas under flashing be inspected.

The same applies to poorly maintained paint and other protective coatings. Figure 3.3.4.2-5 shows severe deterioration under the paint surface on a timber member. This deterioration was only evident through the external projection of the fruiting body of the fungi. It is of value to use a small hammer to gently sound
painted timber surfaces in order to discover any soft areas of decay. The paint should not be damaged unless deterioration is discovered.

Figure 3.3.4.2-5  Deterioration Under Poorly Maintained Paint - St Albans

Generally, the inspection of truss components requires close scrutiny as the deterioration will rarely be readily visible.

3. 3.5 Primary Non-Redundant Members

While inspecting timber trusses, it is important to note that specific primary members are generally non-redundant. This means that failure of these components can lead to collapse of the bridge. Unlike steel trusses, which can sometimes withstand failures of some critical members through the inherent strength of rigid connections and member continuity, a timber truss has little redundancy in its construction.

The critical primary members include:

- end principals
- end butting blocks and end joints
- bottom chord
- top chord

Failure of any of these members will more than likely cause total collapse of the bridge under its own weight. Therefore, following the discovery of any serious failure or deterioration, the bridge should be closed to traffic or a load limit applied until the extent of the damage has been fully assessed.

3. 4 MAINTENANCE

Section 1 outlines the basic maintenance procedures for all timber bridge types and these also apply to timber trusses. This subsection highlights specific additional considerations for timber trusses and cross girders.
3. 4.1 Objectives and General Requirements

- The primary objectives of, and general requirements for, maintenance activities are outlined in Section 1.

3. 4.2 Preventative Maintenance

As outlined in Section 1, maintenance should begin with preventative measures to enhance durability through proper materials selection as well as design and construction detailing. In addition to the basic engineering and construction detailing outlined in Section 1, Subsection 3.7 reviews a number of considerations specifically applicable to timber trusses and cross girders.

3. 4.3 Annual Maintenance

Routine maintenance should be carried annually on all timber trusses as outlined in Section 1. This subsection reviews a number of considerations specifically applicable to timber trusses.

Routine maintenance should include:

- removal of fire hazards, with emphasis on grass and brush, from the proximity of the bridge.
- removal of debris from the deck system and on top of members (particularly bottom chords and the exposed ends of cross girders)
- all bolted connections that are accessible should be retightened with particular emphasis on connections at joints and the end butting blocks (PWD and McDonald trusses)
- spot checks should be performed on less accessible bolts and sway braces to determine if further work is required
- preservative protection should be reapplied where possible and spot checks should be performed on covered components to see if further work is needed
- minor collision damage should be repaired. Major damage should be reported and remedial repairs carried out possible
- nuts on bolts in the trusses members should be lubricated to facilitate removal during three year maintenance

3. 4.4 Three Year Maintenance

Every three years more thorough maintenance work should be carried out in conjunction with the detailed inspection as outlined in Section 1. This subsection reviews a number of considerations specifically applicable to timber trusses:

- remove all accessible bolts in truss members and retreat the holes with preservative
• retighten all bolted connections including the sway braces
• expose all hidden areas for retreatment
• difficult areas which cannot be exposed easily can be flooded with preservative (this must be performed with proper attention to protecting the environment)
• all flashing should be removed to expose the members for inspection, cleaning and retreatment
• joints in flashing should be resealed
• loose and flaking paint or other coatings should be repaired or replaced

3. 4.5 Treatment of Fungal and Insect Attack

The general requirements outlined in Section 1 should be applied to timber trusses and any fungal and insect infestation must be treated. A specialist should be engaged if termite damage is found in truss or cross girder components. Simply replacing these members will not ensure removal of the infestation. It is important to determine the location of the termite (nest) source and have it removed.

3. 5 REHABILITATION AND REPAIRS

Section 1 outlines the general aspects of rehabilitation and repairs to timber bridges. This subsection deals with repairs and rehabilitation related specifically to timber trusses and their components. Each typical component type is mentioned in terms of both temporary (emergency) repair and replacement.

The examples given are provided only as a general guide. The requirements at any particular site will depend on a variety of conditions.

3. 5.1 Cross Girders - General

The five types of timber trusses have three different cross girder configurations and these require slightly different approaches to repair and/or replace. As a basis for the subsequent information, each type of cross girder is briefly described below.

3. 5.1.1 Cross Girders -PWD and McDonald Trusses

The PWD and McDonald trusses have similar cross girder geometries with two cross girder types; primary (larger) members at panel points and smaller cross girders between panel points as shown in Figure 3.5.1.1-1 (left). The sides of these cross girders provide bearing for the truss diagonals and the vertical steel bars pass through the members as shown in Figure 3.5.1.1-1 (right). These conditions make it difficult to replace these members. It is necessary to remove the vertical bars and relieve the forces being exerted by the truss diagonals.
3. 5.1.2 Cross Girders - Allan and Dare Trusses

The Allan and Dare trusses have similar cross girder geometries as shown in Figure 3.5.1.2-1. The girders are located at main panel points only where the vertical bars are located. However, the bars are located to each side of the cross girder which facilitates their replacement.

3. 5.1.3 Cross Girders - De Burgh Truss

In the DeBurgh truss the cross girders are also located at the main panel points where the vertical timber members are located as shown in Figure 3.5.1.3-1. However, the cross girders sit between (and are secured to) the vertical timbers as shown in the figure. This makes it difficult to replace these girders as it is necessary to partially disassemble the vertical member.
3.5.2 Temporary Repairs to Cross Girders

In the case of a severely damaged cross girder, it is generally inadvisable to attempt to splice the member over part of its length. Effective splices in bending members are difficult to achieve and usually unreliable.

As a temporary measure, an additional cross girder should be placed on either side of the damaged member to support the deck system as shown in Figure 3.5.2-1. These additional members should positioned as close to the existing member as possible and both should be at least the same size cross section as the existing member. Installation may be facilitated by using the techniques for girder replacement described in Subsection 3.5.3.
The same applies for the smaller intermediate cross girders in the PWD and McDonald trusses.

It may be necessary to trim the depth of the temporary cross girders at the supports in order to fit them in place. However, this should be minimised and should not exceed 10% of the depth of the member.

It should be noted that these temporary members, supported on the bottom chord between panel points, will introduce additional moments into the bottom chords of the Dare, Allan and De Burgh trusses.

### 3. 5.3 Cross Girder Replacement

While the different style trusses do require some specific procedures and equipment, the majority of operations are the same. The following outlines the general procedure for replacement of a cross girder in a timber truss bridge. Subsequently, additional requirements are outlined in relation to PWD, McDonald and De Burgh trusses.

#### 3. 5.3.1 General Procedure for Cross Girder Replacement

The general procedure for cross girder replacement is as follows:

- fit rollers to facilitate installation of temporary cross girders (Figure 3.5.3.1-1)
- temporary cross girders should be as close as practical to the existing member but leave a clear space of not less than 300 mm
- temporary cross girders should be at least 90% of the depth of the existing member
- remove any protruding fixings from the existing deck system which will conflict with the installation of the temporary cross girder
- install temporary cross girders on each side of the existing member to support the existing deck system
- secure temporary cross girders and shim to support (take the weight of) the deck system on each side of the existing member
- remove/release all deck fixings to the existing cross girder
- remove any protruding elements on the existing cross girder which would conflict with the rollers or other clearances for removal (cut all bolts flush)
- shim the temporary cross girders to raise the deck clear of the existing cross girder by at least 30 mm (PWD and McDonald trusses) or
- shim each longitudinal stringer in turn to raise the deck clear of the existing cross girder by at least 30 mm (other trusses)
- check for and remove any connections between the interface of the deck and the top of the existing cross girder (cut all bolts flush)
- install temporary fixings and apply procedures as outlined in Subsections 3. 5.3.2 or 3. 5.3.3
- remove sway brace connections
- install temporary rollers at existing cross girder and tighten to lift cross girder (minimum 10 mm clear)
- remove cross girder from one side using a winch and take the weight with a Hiab (truck mounted crane) as the girder extends beyond the truss
- clean and retreat (timber) or repaint (steel) bearing areas on bottom chords
- check bearing area geometry for clearances (see Figure 3.5.3.1-2) and adjust new cross girder to suit
- a rubber pad may be used to accommodate rivet heads
- taper leading edge of cross girder (Figure 3.5.3.1-3) and lubricate bearings on bottom chord
- install new cross girder from one side using a winch and take the weight with a Hiab (truck mounted crane) as the girder extends beyond the truss
- where side brackets are used to support longitudinal stringers
  - position new girder on bearings and lower deck system to just clear (or lightly touch top of the girder)
  - measure and mark side attachment holes
  - displace girder to facilitate drilling of holes
- position girder on bearings, secure and reattach sway braces
- lower deck and secure (drilling with care to avoid old bolts in deck system)
- where longitudinal stringers are resecured through to the top of the sheeting use M24 bolts and 100 mm x 100 mm x 10 mm washer plates
- remove temporary cross girders

Figure 3.5.3.1-1  Temporary Rollers to Install Cross Girders
3.5.3.2 Special Considerations - PWD and McDonald Trusses

Replacement of cross girders at the main panel points for the PWD and McDonald trusses will require additional procedures and equipment as outlined below. As previously shown in Figure 3.5.1.1-1, the diagonal members bear against the sides of the cross girder and the vertical bars pass through the cross girder.

Where multiple cross girders are to be replaced, temporary Bailey trusses should be used to support the timber trusses. The use of Bailey trusses is described in Subsection 3.5.4.5.

To replace an individual cross girder, it will be necessary to remove the vertical bars. The force in these members can be replaced using external bars as shown in Figure 3.5.3.2-1. The dead load forces in the existing bars should be determined by engineering analysis and the same total force should be applied to the temporary system.
The dead load forces in the diagonals must also be determined by engineering analysis. The same force must be applied to support the horizontal component of this force on either side of the cross girder. A schematic representation of a possible hydraulic jacking system is shown in Figure 3.5.3.2-2.

The sizes of clamps, plates, bolts and jacks must be properly engineered to suit the conditions. However, a single system can be designed to apply to all cross girders. The system should facilitate locking of the tensioning bars so that the jacks can be released. No further work should be carried out with only the hydraulic jacks engaged.

**Special Note:** Traditionally the method for restraining the diagonals has been to secure them back to the bottom chord without applying any specific force.
Subsequently, the existing wedges on both sides of the cross girder are driven out. This procedure should not be used as it results in the introduction of internal displacements in the truss because the diagonals will move as they engage the securing devices. This slight movement cannot be recovered and will result in sagging of the truss as well as redistribution of internal forces. While this may not be critical during the replacement of one cross girder, there is a cumulative effect if multiple girders are replaced.

3. 5.3.3 Special Considerations - De Burgh Truss

Replacement of a cross girder in a De Burgh truss entails removal of the bolts at the base of the timber verticals (Figure 3.5.1.3-1) which pass through the verticals and the cross girder as well as a timber packer above the cross girder. This will allow the timber verticals to be spread apart slightly to facilitate installation of the replacement cross girder. This applies only if the girder width is the same as the spacing between the verticals.

In the case of some De Burgh trusses, the cross girder width is greater than the clearance between the verticals and the member is rebated (notched) to fit as can be seen in Figure 3.5.3.3-1. It is also likely that current evaluation would indicate that the cross girder cannot be reduced in width. Therefore, it is necessary to temporarily remove two verticals on one side of the cross girder. It should be noted that the remaining two verticals will have reduced stability and loads on the bridge should be restricted. Further information regarding loads during repairs is outlined later in this section.

![Notched End of Cross Girder at Verticals-St Albans Bridge](image)

3. 5.3.4 Strengthening and Upgrading of Cross Girders and Deck

Generally, the original cross girders (section size and grade) in timber truss bridges will not satisfy the current design loads. Any planned replacement program should be preceded by an engineering assessment to determine if an increase in strength is required.
Since the existing cross girder grades are generally F22 and F27, any increase in strength using a timber member would require an increase in section size (usually depth). In order to maintain the same deck elevation, it may be possible to taper the cross girder at the supports as shown in Figure 3.5.3.4-1. This will depend on the design strength required at the support. Alternatively, if the same deck components are used, the deck elevation will have to be increased. The sway brace modification indicated in the figure will be discussed in Subsection 3.5.6.

Figure 3.5.3.4-1 Improvements To Deck System and Sway Braces

Many existing timber truss bridges in NSW are undergoing rehabilitation using new stress laminated timber (SLT) decks as shown in Figure 3.5.3.4-1. This upgrade generally includes new steel cross girders and upgraded traffic barrier systems as shown in Figure 3.5.3.4-2. Additional information regarding the use of SLT decks is provided in Section 5.

Figure 3.5.3.4-2 New Steel Cross Girders, Traffic Barrier and SLT deck
St Albans Bridge
3. 5.4 Repairs/Replacement of Truss Components -General

There are number of considerations which apply to all truss types and components. Some general information follows before consideration of the individual truss components.

Subsequently, each truss component is dealt with in turn with respect to temporary repairs, procedures for member replacements and alternatives for strengthening and upgrades. In each case, special considerations are noted for certain truss designs.

3. 5.4.1 Engineering Evaluation

In all instances where truss components or connections are to be released, removed or replaced, an engineering evaluation should be carried out to ensure the integrity and strength of the bridge is maintained. This is particularly important if the work is to be carried out under traffic. However, component replacement should generally be carried out with the bridge closed and a temporary Bailey used as outlined in Subsection 3.5.4.5.

The evaluation should include all temporary support systems and equipment used in the work as well as the structure’s geometry during each stage of the work. The evaluations should also generate the theoretical member forces under the dead weight of the bridge.

3. 5.4.2 Component Replacement - Installation and Engagement

As follows in the subsequent sections, it will be necessary in some cases to provide full support for the truss (using a Bailey as outlined in Subsection 3.5.4.5) in order to effect certain repairs. In this situation the timber truss is usually recambered and tightened to ensure that all the members are properly engaged before the temporary support system is removed. This is the most effective means of component replacement and should be used whenever possible.

However, there are some instances where it is desirable (economically), and also possible, to carry out component replacements while the truss is still supporting the bridge. This is generally the case for truss members composed of several components, where the remaining components can carry the dead load while only one component is removed at a time. In these cases, it is imperative that the new components are installed in such a way that they will carry their share of the weight of the bridge.

For example, regardless of the member type (ie top chord, end principal, bottom chord), if the new element is simply cut to length, installed and bolted to the adjacent (loaded) components, it will not be carrying its share of the weight of the bridge. In fact, it can even require a significant level of live load (ie: vehicles) before it engages (through the bolts) and begins to carry load. Depending on the
member type, this can create eccentric forces resulting in overstress and failure of the remaining elements and also introduce deformation in the truss. In addition, a similar effect can be introduced where the new element is installed green (ie: not seasoned) while the existing components are seasoned. As the new element dries and shrinks, its engagement (ie: load share) changes. The latter is most significant in compression members.

The primary examples of these situations are for bottom chords, top chords and other compression members, including the timber verticals in De Burgh trusses. The following two sections outline several alternate methods to overcome some of these problems

**3. 5.4.3 Unloading Members for Component Replacement**

In theory, it would be desirable to impart the theoretical loading to the truss to unload the member (or part of a member) as shown in Figure 3.5.4.3-1. Subsequently, when the component has been replaced, the temporary system is released and all components would be engaged.

![Figure 3.5.4.3-1 Theoretical Unloading Members for Component Replacement](image)

While this approach is not simple, it is the most effective way of ensuring the proper long term performance of the truss and to avoid the use of a Bailey. However, the figure above is a schematic representation and the actual devices and attachment will require proper engineering design.

For vertical bars and the vertical timbers in De Burgh trusses, this approach is easily applied as will be outlined in the subsequent sections.

**3. 5.4.4 Loading Compression Components Using Wedges**

It should be noted that the following approach is less effective than that proposed in the previous section and will not guarantee proper performance. However, it is more practical and can be applied using simple tools.
The basic objective is shown in Figure 3.5.4.4-1 for the top chord of a truss. However, the approach can be applied to any compression member. Basically, the new component is cut short allowing for the installation of thin steel plates and steel wedges as shown in the figure. These wedges are driven tight and fixed in position to ensure the new component is engaged. The method to achieve the proper fit is outlined below.

**Special Note:** Timber wedges should not be used as they would be loaded perpendicular to the grain. The compressive strength of hardwood perpendicular to the grain is 1/3 of the strength in the longitudinal direction in timber.

![Figure 3.5.4.4-1 Tightening of Compression Members Using Wedges](image)

In order to achieve a proper fit, it is necessary to perform several steps. As shown in the above figure, it is desirable that, with the member and wedges tight, there be certainty that the wedges extend through the full depth of the component. The following procedure (with reference to Figure 3.5.4.4-2) should be applied:

- remove the damaged length of component and square the ends of the existing timber
- measure the length required for the new component
- determine the theoretical width of the gap required to accommodate the plates and wedges in the *initial position* as shown in Figure 3.5.4.4-2
• cut the new component over length by at least 10 mm to 15 mm as shown in Figure 3.5.4.4-3
• position the new component against the bearing at one end and bolt only enough to hold it in position
• install a temporary clamp lightly snug at the end where the wedges are to be installed
• fit the wedges without the 5 mm plates and drive them to a snug fit only
• check all ends of timber for square fit
• measure the gap and mark for final cutting to achieve initial position accounting for both the plates and wedges
• trim the new component to length
• install and fix the 5 mm plates to the ends of the timber components as shown in Figure 3.5.4.4-2
• reinstall the component as before
• lubricate the steel shims, install and drive them to a tight fit
• secure shims in place by spot welding to the 5 mm plates and each other in a manner which will allow removal for future tightening

Figure 3.5.4.4-2 Initial Position With Wedges Snug
This procedure can easily be used for any compression member, including the timber verticals in De Burgh trusses.

3. 5.4.5 Temporary Bailey Bridge Support

Temporary Bailey bridging is the recommended method for supporting the full length of a truss during major repairs. This applies regardless of whether or not the bridge is open to traffic. It is rarely feasible or practical to attempt to support a timber truss from the ground up.

Where a Bailey truss system is to be used, it shall be designed and/or approved by an engineer prior to installation including all attachments to the bridge. The design should provide for all loads including the weight of the deck and truss as well as construction equipment and traffic, where applicable. Where the bearing supports for the Bailey are located on part of the existing structure, all the supporting components in the bridge shall be assessed and any necessary modifications shall be designed by an engineer.

Notwithstanding the above requirements, the following sequence of figures outlines the basic application of a Bailey bridge support system applied at the Clarencetown bridge (PWD truss).

Typically, a Bailey is erected on one side of the bridge only to facilitate rehabilitation of the truss on that side. A typical installation is shown in Figure 3.5.4.5-1. In this case the Bailey was designed to support both the weight of the bridge as well as traffic during the work. The existing bridge geometry and span will dictate whether it is possible to maintain an acceptable traffic lane.
It is important that the supports for the Bailey be properly established. They should be located directly over the foundations which support the existing bridge and the load point on the deck should be blocked underneath to transmit the forces directly through to the foundations. The forces applied to the Bailey supports can be very large and a slight misalignment at the Clarendtown bridge caused the support to begin to rotate as shown in Figure 3.5.4.5-2.

Typically, the Bailey is used to directly support the cross girders of the truss by drilling holes through the deck and installing steel hangers as shown in Figure 3.5.4.5-3. Generally, a hanger is installed for each cross girder except in the case of PWD and McDonald trusses. The latter have a larger number of more closely spaced cross girders. Hangers are generally installed at every other cross girder (or wider spacing) with a longitudinal beam integrated to support the ones in between as shown in the figure.
To take the load of the deck onto the Bailey, each hanger is tensioned in turn using hydraulic jacks as shown in Figure 3.5.4.5-4. A maximum jacking load at each point should be specified by the designer. The process may require up to three or four passes along the bridge to eventually lift the cross girders so that they clear the bottom chord of the truss. It should be noted that the cross girders must be lifted far enough to allow proper rehabilitation of the truss. In most cases, the rebuilt truss will be recambered which will raise the elevation of the bottom chord.

Since the cross girders are supported by the Bailey, the timber truss can be dismantled using the cross girders to support the individual elements as shown in Figure 3.5.4.5-5.
The Bailey is also used to support the scaffolding as shown in Figure 3.5.4.5-6. All of these considerations are important in the design of the Bailey and the details of its installation.

3.5.5 End Principals

The end principals are one of the most critical elements of the truss and failure will more than likely cause complete collapse of the bridge. Minor damage or deterioration may be repaired temporarily as outlined in Subsection 3.5.5.1.
If an end principal has major damage and is displaying signs of failure (ie: crushing, deformation or displacement), the bridge must be closed to traffic. The following should also be classified as major damage:

- the solid (one piece) component of a PWD truss has damage which extends through the whole cross section
- laminated members where both (or all) components of the member are damaged at the same location

3. 5.5.1 Temporary Repairs

The strength of the end principal is usually governed by stability (ie: failure will be by buckling of the member). Therefore, any repairs must re-establish the overall rigidity along the length of the member. Minor damage away from the ends of the member may be externally spliced, as shown in Figure 3.5.5.1-1, on all (exposed) sides of the member. The splice should extend for at least 1 ½ times the damaged length on each side of the damaged area, but not less than 1 ½ times the maximum section dimension.

Since the component should be scheduled for replacement, it is acceptable to drill and bolt through the component. While some basic geometry is given in the figure for guidance, the proposed splice should be checked by an engineer, particularly for stiffness. The stiffness and strength of the splicing components should be at least equal to the existing section.
Damage or crushing near the ends of the member represents a difficult situation as there is generally no practical method to attach external strengthening at the joint. The solid members in PWD trusses should be scheduled for replacement immediately and bridge closure or load restriction should be considered.

Damage at the end of a single piece of a multiple component member may be repaired as shown in Figure 3.5.5.1-2 where the damaged length is replaced with a new piece. The bridge should be closed during repairs and the added length should be loaded (engaged) as outlined in Subsection 3.5.4.4.

Figure 3.5.5.1-1 Typical Splice of End Principal
In this situation the external splice is primarily required to maintain alignment of the new section of timber. The stiffness should not be less than ½ of the component being repaired. If the damaged length is more than 1 ½ times the depth of the component, it should be treated as an instance of major damage as specified in Subsection 3.5.5.

3. 5.5.2 Replacement of Components

Replacement of the solid end principals as used in PWD trusses should only be performed using a Bailey support system as outlined in Subsection 3.5.4.5.

Replacement of a single piece of a multiple component member may be carried out using one of the methods outlined in Subsections 3.5.4.3, 3.5.4.4 or 3.5.4.5.
3. 5.5.3 Strengthening and Upgrading

Generally, the strength of the end principals in the youngest truss designs (Dare and Allan) satisfy the current design loads. The De Burgh truss does not have a specific end principal.

However, the PWD and McDonald trusses have very long members which have low theoretical capacities due to stability (buckling) problems. There are two possible methods of improving the strength, both of which must be confirmed by theoretical calculations. These are as follows:

1. The section size can be increased to provide greater stiffness over the length of the member. The ends of the member can still be tapered to fit the existing end bearings and this will not significantly reduce its resistance to buckling

2. An additional lateral support can be provided at approximately mid-length by extending a cross girder and installing a sway brace as shown in Figure 3.5.5.3-1.

![Figure 3.5.5.3-1 Additional Sway Brace for PWD and McDonald Trusses](image)

3. 5.6 Top Chords

The top chords in PWD and McDonald trusses were designed using solid members, however there are some trusses that have had the top chords replaced...
by two component members. All other truss types have top chord members composed of at least two components.

The top chords are also critical elements of the truss and failure will more than likely cause serious deformation or even complete collapse of the bridge. Minor damage or deterioration may be repaired temporarily as outlined in Subsection 3.5.6.1.

If a top chord has major damage and is displaying signs of failure (ie: crushing, serious deformation or displacement as defined below), the bridge shall be closed to traffic or load restrictions applied.

Timber top chords are typically never very straight (laterally) due to the inherent variability of the material and the construction details. The following defines three levels of (lateral) deformation measured from a straight line between the ends of the top chord (full truss length):

1. **Acceptable** - centreline of top chord is within 1/4 of its width from the straight line at any point
2. **Temporarily Acceptable** (repairs required) - centreline of top chord is within 1/2 of its width from the straight line at any point
3. **Serious Deformation** (repairs required) - centreline of top chord falls outside 1/2 of its width from the straight line at any point

### 3. 5.6.1 Temporary Repairs

Generally, stability (buckling) is the major consideration in top chord repairs. Splicing of external members should provide adequate stiffness. Temporary repairs to top chords may be carried out using the approach described for end principals in Subsection 3.5.5.1.

### 3. 5.6.2 Replacement of Components

Except as noted below, solid top chords of PWD and McDonald trusses should be replaced full length in accordance with the original design. The truss should be supported using a Bailey as described in Subsection 3.5.4.5.

It may be feasible to replace a solid member with a two component member. This should be properly assessed by engineering evaluation including the design of an acceptable splice detail. In this case, the components need not be full length. However, splices should be restricted to the original locations and the joints in each component should be staggered.

In top chords composed of two or more components, it has been accepted practice to replace lengths of components with splices at any location. However, if a member has multiple splices in the same vicinity in more than one component, its stability is severely affected. Splices should be restricted to the original
locations with only one splice in any one panel (between the top chord joints). Component replacement should follow the applicable methods given in Subsection 3.5.4 to ensure that the new component is properly engaged.

3. 5.6.3 Strengthening and Upgrading

Once again the strength of the top chords in timber trusses is governed primarily by lateral stability. Therefore, to upgrade the system, it necessary to improve the stiffness of the member or the effectiveness of the lateral (sway brace) support.

It is possible to increase the section size of top chord components. The larger sections can be tapered at joints or other areas where they must meet the original geometry. The overall stiffness will be improved as the localised section reductions will have minimal effect on the stiffness.

An alternative, and more practical solution, is to improve the lateral support provided by the sway braces. There are several approaches which progressively improve the situation as follows:

1. Replace existing sway braces with heavier sections and stronger connections. Hollow steel sections are recommended.
2. Extend the cross girders to increase the angle of the brace as previously shown in Figure 3.5.3.4-1.
3. Replace the cross girders with a stiffer section (preferably steel) to reduce the effects of loads on the cross girder which cause movement of the sway brace.

All of these options are practical and have been used on existing trusses. An example of an upgrade at the Wakool River bridge is shown in Figure 3.5.6.3-1. Rehabilitation of this bridge included using steel cross girders and an increased sway brace angle (as well as a new SLT deck). The original sway braces can be seen in the background.
3. 5.7 Timber Bottom Chords

Bottom chords composed of several timber components are also critical members in timber trusses and usually govern the capacity of most timber truss designs. They usually contain at least three components with the butt joints staggered at different locations along the length of the member. The locations of butt splices are critical to the member capacity and new splice locations should not be introduced without proper engineering evaluation.

Damaged components should be scheduled for replacement as soon as practical. Where the damage is causing deformation, joint slippage or other visible effects, the bridge should be closed to traffic or load restrictions applied.

3. 5.7.1 Temporary Repairs

Effective temporary repairs to timber bottom chords are generally difficult to achieve. External timber splice components should not be used as the necessary thickness of the timber components creates large eccentric loads on the bolts.

Temporary splices should use external steel components and their length and attachment should be determined by engineering evaluation. It is impractical to
provide a basic detail here as the complexity of the existing splices, joint details and other attachments make each repair unique to the situation at hand.

In extreme emergencies, the following guidelines may be used for repair but should be followed up with an engineering evaluation:

- Splice plates should be applied to both sides of the member.
- The depth of the plates should be equal to at least 80% of the depth of the component being spliced.
- Total cross sectional area of the steel splice plates (together) should be equal to 20% of the cross sectional area of the timber component being spliced (ie. ratio of 1 to 5).
- The splice plates should extend beyond the damaged area by an amount equal to at least twice the depth of the component but not less than that required for the bolting details outlined below.
- Plates should be attached using M24 bolts extending through the member.
- As a “rule of thumb” at least 8 bolts should be installed (in pairs) at each end of the plates with a longitudinal spacing of not less than 250 mm (however, guidance should be taken from any existing steel splices that exist in the bridge in question).

3.5.7.2 Replacement of Components

Although there are multiple components in timber bottom chords, replacement of a single piece of a member cannot be carried out with the truss under any load. It could even be dangerous to dismantle the chord while it is carrying the weight of the bridge itself, even after engineering evaluation. Where deterioration exists, it is likely that there is more deterioration than can be seen.

Member component replacements must be carried out using a temporary Bailey support truss as outlined in Subsection 3.5.4.5. All components should be renewed unless they are entirely clear of all signs of decay or insect attack. This includes surface decay and insect tracks even if the member is solid. In the long term, the costs associated with using a Bailey and replacing all components usually outweigh the possible savings by reusing timber which has a limited life.

However, where individual component replacement is to be carried out, it should follow the applicable methods given in Subsection 3.5.4 to ensure that the new component is properly engaged.

3.5.7.3 Strengthening and Upgrading

Strengthening of bottom chords is difficult to achieve using increased section sizes because the member capacity is based upon the smallest cross section at any
location along the member. Therefore, if a section size increase cannot be maintained along the full length of the member, the strength will not be increased.

Depending on the support and joint details, it may be possible to increase the section along the full length by increasing the width of the components or adding another component. However, the modification should be properly engineered to ensure that the additional component is properly engaged at the joints so that it carries its full share of the load.

It is also possible to strengthen the chord by integrating some steel components into the member without having to increase its width or depth. A method of upgrading an existing timber bottom chord using external post-tensioning was tested/developed by the RTA in the early 1990s. The concept involves the attachment of steel shoes, one on each side of the bottom chord, as shown in Figure 3.5.7.3-1, which are keyed into the timber and secured at, or adjacent to, the joints. Post-tensioning bars are secured to these shoes and are tensioned slightly to relieve some of the permanent force in the bottom chord (dead load), and also to share the effects of traffic load. The method is viable, but the details require proper engineering design and Bridge Engineering should be contacted for design assistance. It should be noted that installation requires remarkably little work and should generally not require bridge closure.

It should be noted that current heritage considerations could preclude use of this method as a permanent means of strengthening timber bottom chords. In the first instance, the NSW Heritage Office should be consulted.

3.5.8 Steel Bottom Chords

Steel bottom chords were only used in DeBurgh and Dare trusses. While these members are referred to as steel, it is also possible that they may be cast iron. It is particularly important to establish whether this is the case as old cast iron components are not suitable for welding. As with timber bottom chords, these members are also critical and any damage or deterioration can seriously affect the capacity of the truss.
Typically, the bottom chord members in DeBurgh trusses consist of two flat plates as shown in Figure 3.5.8-1 with channel shaped sections near the ends of the span. In Dare trusses they consist of two channel shaped members as previously shown in Figure 3.2.1.6-2.

![Figure 3.5.8-1 Steel Bottom Chord DeBurgh Truss - St Albans Bridge](image)

In most instances these members have not been identified as representing any critical problems as long as they are properly maintained, with particular emphasis on the protective coating, particularly under the cross girder bearings. However, any damaged or deteriorated components should be properly investigated and an engineering evaluation should be undertaken before repairs and/or replacement are carried out.

### 3. 5.8.1 Temporary Repairs

Temporary or emergency repairs are difficult to achieve without drilling the existing components. Drilling holes in the existing components can affect the strength of these components if proper attention is not given to the existing details. The strength of these tension members is usually governed by the existing net section (ie: taking into account existing holes in the components for splices or other joint connections).

Temporary splices should use external steel components and the length and attachment should be determined by engineering evaluation. It is impractical to provide a basic detail here as the complexity of the existing splices, joint details and other attachments make each repair unique to the situation at hand.

In extreme emergencies, the following guidelines may be used for repair but should be followed up with an engineering evaluation:

- splice plates or other steel sections should be applied to both sides of the component to balance the forces and minimise eccentricities
• the depth of the splice components should be at least equal to the depth of the component being spliced
• The splice components should be placed tight against the sides of the existing component, or as close as possible
• where a splice component must be spaced away from the existing component, the same spacing should be applied to both sides to maintain symmetry
• total cross sectional area of the steel splice components (together) should be at least equal to the cross sectional area of the component being spliced
• the thickness of each (of the two) splice components should not be less than ½ the thickness of the component being spliced
• the length of the splice components shall be such that they extend beyond the damaged area an amount equal to at least twice the depth of the component, but not less than that required for the bolting details outlined below
• splice components should be attached using bolts of a diameter which require holes no larger than the existing (rivet) holes
• each bolt should extend through the member
• as a “rule of thumb” bolts should be installed (in pairs) at each end of the plates with a longitudinal spacing of not less than the spacing of the rivets in the existing bottom chord splices
• the number of bolts should not be less than the number of rivets used in the existing bottom chord splices

3. 5.8.2 Replacement of Components

Damaged or deteriorated components should be replaced with new steel components of the same size and shape. The latter should be attached at existing splice locations using bolts to replace the existing rivets. The bolts should be of a diameter equal to at least the shank diameter of the existing rivets.

Unless a detailed engineering evaluation is carried out, the existing rivet holes should not be enlarged by more than 5% of the existing diameter in order to provide a tight fit for the new bolts while not affecting the strength of the existing component.

Single pieces of a two component steel bottom chord may be replaced without using a Bailey support truss as long as the following conditions are satisfied:

• the bridge is closed to traffic
• the remaining component is not damaged
• removal of existing rivets, pins and/or connections does not affect the integrity of the other component(s), this should be assessed by an engineer
• the damaged component is precompressed using a method similar to that shown in Figure 3.5.4.2-1.
If both member components are damaged or the bridge must remain open to traffic, the truss should be supported using a Bailey truss system as outlined in Subsection 3.5.4.5.

3. 5.8.3 Strengthening and Upgrading

There are three possible methods to strengthen an existing steel bottom chord:

- replace all components with new higher grade steel of the same section
- apply external strengthening over the full length of the bottom chord by:
  - adding additional steel components
  - introducing post tensioning

The first option is labour intensive and quite expensive although it might be adopted where the heritage value of the bridge must be maintained.

External strengthening can be applied using two methods, both of which must be properly engineered and detailed.

The first method uses simple steel plates attached directly to the existing components which should satisfy the following conditions:

- individual lengths should be suitably lapped and spliced over the full length of the truss so that it can carry load independent of the existing component
- the new component should also be suitably attached at (or directly adjacent to) the panel points (bottom chord joints) so that it interacts with the other truss members (diagonals and verticals)

External post tensioning could be applied similar to the method shown in Subsection 3. 5.7.3. In this case, brackets of the type shown in Figure 3.5.7.3-1 would be bolted to the existing bottom chords at (or adjacent to) the bottom chord joints.

3. 5.9 Steel and Iron Bars

All timber trusses use round (bar) tension members which, in all but DeBurgh trusses, are oriented vertically. The methods of repair and replacement are similar for all trusses except in the case of the diagonal members used in the DeBurgh truss.
3. 5.9.1 Vertical Bars

Vertical bar tension members are typical for all trusses except the DeBurgh truss. Typically, these members consist of at least two bars although some larger span trusses may use three bars and smaller spans may have single bars at some locations.

3. 5.9.1.1 Temporary Repairs

It is relatively simple to provide temporary or emergency repairs to vertical bar tension members in timber trusses. Regardless of the bar type or attachment, temporary external bars can be installed adjacent to the existing member as shown in Figure 3.5.9.1.1-1.

![Figure 3.5.9.1.1-1 Temporary Vertical Bars](image)

**Figure 3.5.9.1.1-1 Temporary Vertical Bars**

At least four bars should be used as a temporary system regardless of the number of bars in the existing member. These bars should be placed in pairs symmetrically about the existing vertical member and as close as possible to the (vertical) member. The gross cross sectional area of the (four) temporary bars should be equal to twice the total cross sectional area of the existing bars.

The attachment (bearing) plates for the temporary bars (top and bottom) should be heavy enough to ensure proper distribution of the forces to the top and bottom chord members without bending excessively or causing damage to the existing members. As a "rule of thumb" each of the plates should have a width (along the member) equal to that of the existing bearing plates (but not less than 150 mm) and the plate thickness should be greater than the maximum of the following limits:

- 1/6 of the width of the plate
- 1/10 of the distance between centres of the two bars attached to the plate
- 30 mm

The plate size must be followed up with an engineering evaluation.
3. 5.9.1.2 Replacement of Components

Replacement of bars under traffic can be carried out using the same temporary support system described in the previous section. This will enable the unloading and re-engagement of the bars to ensure that they are properly loaded. However, these temporary bars must be properly tensioned to ensure that they carry the load before the old bars are removed. This can be accomplished by using a hydraulic jack and plate system as shown in Figure 3.5.9.1.2-1. The required load must be established by engineering evaluation.

![Figure 3.5.9.1.2-1 Section Through Temporary Vertical Bars](image)

Sometimes it may be possible to replace the bars one at a time without temporary support (and with the bridge closed) as outlined below. This would be applicable only with PWD, Allan and Dare trusses. Although the McDonald truss has double bar members they are located outside the alignment of the truss as shown in Figure 3.5.9.1.2-2. In this situation the remaining bar and plate system would become unstable with the removal of one bar. However, to change one bar at a time, it will still be necessary to unload and reload the bars to ensure that they are properly engaged. This can usually only be accomplished if the existing bars have
lock nuts which, when removed, provide some extra thread at the ends to allow the attachment of an extension bar for jacking purposes. It should be noted that simply tightening the nuts at the ends, even with a torque wrench is not adequate.

Figure 3.5.9.1.2-2  External Vertical Bars McDonald Truss - Galston Gorge

3. 5.9.2 Diagonal Bars (De Burgh Truss)

The diagonal bars in DeBurgh trusses represent a more difficult situation as they transfer horizontal components of the loads to the top and bottom chords. The attachments to the top chords use cast iron anchor blocks keyed into the top timber chords as previously shown in Figure 3.2.1.5-3. The attachment to the bottom chord uses pins which are fitted through the bottom chord member as shown in Figure 3.5.9.2-1.
3. 5.9.2.1 Temporary Repairs

It is difficult to provide an effective temporary attachment for external bars to replace the bars in a DeBurgh truss. While it is possible to key a temporary plate into the timber of the top chord adjacent to the existing anchor block, it is very difficult to attach to the bottom chord without drilling holes in the components. The latter is undesirable as it will affect the future strength of the member.

Where a single bar is damaged or deteriorated, load restrictions should be applied and arrangements made to replace the member.

Where multiple or all of the bars are damaged or deteriorated, the bridge should be closed or load restrictions applied, depending on the severity of the damage, and arrangements made to replace the members.

3. 5.9.2.2 Replacement of Components

It is difficult to provide a temporary system to unload the existing bars for replacement in a DeBurgh truss. If possible, a Bailey support truss as outlined in Subsection 3.5.4.5 should be used if numerous components are to be replaced in the bridge.

To replace individual bars, it will be necessary to close the bridge and provide a tensioning system using a chain and pulley or similar system as shown in Figure 3.5.9.2.2-1. Protection should be provided to the timber in the top chord to prevent crushing. Packing should be provided between the two steel components of the bottom chord to prevent them from being forced together and the edges should be protected from damage. To prevent slippage of the bottom attachment,
it should be tied back to the pin at the joint as indicated. The capacity of this tensioning system should be equal to at least 1.5 times the calculated dead load force in the bars.

It should be noted that this approach will be less effective in unloading and reloading of the bars, to ensure that they are properly engaged and sharing the member forces, than using a Bailey support system.

![Diagram of Temporary Tension Diagonal DeBurgh Truss]

Figure 3.5.9.2.2-1  Temporary Tension Diagonal DeBurgh Truss

3. 5.9.3  Strengthening and Upgrading of Bars (All Trusses)

The most effective method for strengthening or upgrading the tension bars in all trusses is to replace them with higher grade material.

3. 5.10  Butting Blocks and Shear Keys (PWD and McDonald Trusses)

Both PWD and McDonald trusses use large timber butting blocks with shear keys to support the lower ends of the end principal as previously shown in Figures 3.2.1.2-2 and 3.2.1.3-2. These butting blocks and particularly the shear keys, play an extremely important role in the strength of the bridge.

Some of the typical defects and failures of these shear keys were outlined in Subsection 3.3.3.3. Any deterioration or failure of the butting block system, particularly the shear keys, must be rectified immediately. Failure of the shear keys can result in movement of the butting block which can result in serious sag of
the truss, and possibly collapse if the integrity of the end principal support is compromised.

3. 5.10.1 Temporary Repairs

The force exerted by the end principal on the butting block is very large and it is extremely difficult to provide a fully effective temporary repair for a failed system (where the butting block has moved). If the butting block has moved and the truss has sagged, it will be necessary to install a temporary Bailey support system as outlined in Subsection 3.5.4.5 to effect repairs. In an extreme emergency, the butting block can be tied back to the bottom chord of the truss as shown in Figure 3.5.10.1-1. This approach cannot be used to move the butting block back into position and will only assist in preventing further movement. It may also be necessary to tie down the end principal as shown in the figure if the butting block has moved enough to compromise the integrity of end principal. These are only temporary measures and the bridge should be closed until a Bailey is in place.

![Figure 3.5.10.1-1 Temporary Ties for Failure at Butting Block](image)

In cases where it is not possible to fully close the bridge for an extended period and where there may be delays in installing a Bailey, additional strength can be provided as shown in Figure 3.5.10.1-2. This uses an additional timber block on the bottom chord under the end principal which is keyed into the bottom chord. The block is tied to the end butting block using a heavy steel section (on both sides) which is also provided with shear keys on the back side rebated into the timber. The latter is required in order to provide the high strength necessary to support the end principal. While not shown, vertical bolting of the additional timber block is also required. The overall set up must be properly engineered for the conditions at hand and this will depend on the load restrictions applied to the bridge.
3.5.10.2 Replacement of Components

Replacement of components should only be performed using a Bailey support system as outlined in Subsection 3.5.4.5.

Unless otherwise approved by engineering design, all components should be replaced with at least the same size and grade of timber, and the bolting and shear key details should be as on the original design drawings. In this regard, it is advised that in a number of existing bridges, it has been discovered that the original design details have not been carried through during past repairs. The correct details should be confirmed. As a “rule of thumb” each butting block should have at least three shear keys/notches similar to those shown in Figure 3.5.10.2-1 for the PWD truss. McDonald trusses typically have shorter butting blocks but still usually have three notches or keys.

It should be noted that, in all cases, it is likely that the original shear key details will not satisfy the current design loads. Additional information is provided in the next paragraph as well as in Subsection 3.6.

Figure 3.5.10.2-1 Typical Keys (Notches) - End Butting Block - PWD Truss
3. 5.10.3 Strengthening and Upgrading

Most of the original shear key details for both PWD and McDonald trusses will likely not satisfy current requirements when evaluated using the current design standards (AS1720) and the Austroads design loads. Additional design information is presented in Subsection 3.6.

While there are a number of methods that can be used to strengthen shear transfer between the butting block and the bottom chord, these will differ depending on a number of conditions such as:

- are the details to be strengthened in existing timber components and what are these details?
- are the timber components being replaced so that new details can be introduced?
- what is the governing (weakest) strength condition; timber shear or timber crushing (as will be outlined in Subsection 3.6)?

Therefore, it is difficult to provide any specific details for general use as it is necessary for the conditions to be properly evaluated and detailed by engineering design. However, there are a number of alternative methods that can be used depending on the situation at hand. The following sections outline a number of possible scenarios.

In each case, it is important to note that the keys (notches) and/or shear blocks must be installed with accurate fabrication. All bearing or contact areas must bear evenly and make contact at the same time. No shimming or filler materials should be used to fill gaps.

It is also necessary to provide vertical bolting of the components. This is not shown on the accompanying figures in order to maintain clarity. Typically, the vertical bolting should be provided using pairs of M20 bolts (with standard square washers) at spacings of not more than 750 mm along the members.

3. 5.10.3.1 Upgrading End Bearing Strength of Existing Shear Keys

In existing timber components where the weakest design strength is found to be end bearing of the keys (which results in crushing of the timber), the capacity can be strengthened by introducing deeper steel shear blocks at each of the existing notches as shown in Figure 3.5.10.3.1-1. This increases the bearing area while minimising the reduction in the length of the timber shear zone.
3. 5.10.3.2 Improved Bearing Strength Using New Shear Keys

In trusses where new timber components are now to be installed and the original weakest design strength was end bearing of the keys (crushing of the timber), capacity can be strengthened in a number of ways by introduction of:

- deeper timber notches using the original design style
- deeper steel shear blocks as previously shown in Figure 3.5.10.3.1-1
- smaller steel shear keys but increase the quantity as shown in Figure 3.5.10.3.2-1

It should be noted that while the smaller steel keys may require less cutting and are easier to fit individually, it is more difficult to accurately cut the grooves so that all keys bear at the same time. Therefore, this will require accurate guides and templates to be used with quality tools such as high speed routers.
3. 5.10.3.3 Upgrading Shear Strength of Existing Components

In existing timber components where the weakest design strength is found to be horizontal shearing of the timber, it is generally not possible to upgrade the strength by modifying the existing details. If the shear keys are evenly spaced along the butting block, then the maximum strength in shear is governed by the total length of the butting block. As long as the total length of the shear zones in both the butting block and the bottom chord are the same, the maximum shear strength has been achieved. Some additional information on this condition is outlined in Subsection 3.6.

However, if the shear keys are unevenly spaced, then the shear strength will be governed by the shortest length of shear zone and the full shear potential will not be achieved. While there are ways that this can sometimes be improved, the method and details will be entirely dependent on the actual existing details. Some guidance should be obtained from Subsection 3.6.

It is also possible to improve the strength of an existing system using the method previously presented in Figure 3.5.10.1-2. However, this is not aesthetically pleasing and would usually be in conflict with potential heritage values for many timber trusses.

3. 5.11 Shear Key Connectors - Steel and Castings

A variety of other styles of shear keys are used throughout the different truss designs. Many of these have been shown in previous figures including:

- Figure 3.2.1.3-3 Cast Iron Shoe – Galston Gorge
- Figure 3.2.1.4-2 Cast Iron Shoes – Makool River Bridge
- Figure 3.2.1.5-3 Cast Iron Anchor Block – St Albans

They all have the same feature which includes the rebating of a steel (or cast) component into the timber to provide a high shear strength to transfer load. This type of shear connector is probably one of the best connectors used in timber.

Generally, it is very unusual for this type of connector to fail except through deterioration of the timber or extreme overloads. However, there are some general methods for repair, replacement and strengthening which can be applied to nearly all truss styles.

3. 5.11.1 Temporary Repairs

For a typical steel shoe used in many timber trusses, temporary shear strength can be re-established by rebating a steel plate into the timber directly in front of the shoe as shown in Figure 3.5.11.1-1. The plate is held in place against the timber using coach screws or through bolts.
In cases where there is not be enough clearance in front of the shoe it will be necessary to provide a more detailed attachment as shown in Figure 3.5.11.1-2. In this situation, it would be better to provide discrete shear keys in the plate as the potential shear zone projects into the damaged area. It will also require a reasonably strong attachment to the existing shoe to transfer the load.

In all cases, details should be properly engineered to ensure the existing shoe is not damaged and that adequate strength is provided.

While every situation will be different, it should be possible to take some guidance from these two alternatives to satisfy most conditions.

Replacing any of these components would be undertaken using the same methods previously outlined for replacement of the members (eg: principals and diagonals) to which they are attached.
3. 5.11.3 Strengthening and Upgrading

Strengthening and upgrading will depend on the existing details as well as where the critical (weak) component is located.

Where the weakness is in the steel/iron component, it should be replaced with a similar shape using a higher grade steel.

Where the weakness is in the timber at the shear keys, it is necessary to determine how much additional bearing and/or shear strength is required before a suitable detail can be determined. Each situation will be unique depending not only on the existing shear key details, but also the location in the truss and clearances to other components.

Therefore, it is not possible to provide any specific details. However, one option may be to apply external strengthening using additional components taking guidance from the methods shown previously in Figures 3.5.11.1-1 and 3.5.11.1-2

3. 5.12 Internal Timber Diagonal Members

Internal timber diagonals are generally easier to repair and/or replace than the end principals. Guidance for temporary repairs, replacement and strengthening should taken from the information and details provided in Subsection 3.5.5.

3. 5.13 Timber Vertical Members (De Burgh Truss)

The timber verticals in a DeBurgh truss are unique to this truss design. They are composed of four relatively small section size components as shown previously in Figure 3.5.3.3-1. They are also very susceptible to deterioration at the bottom as described and shown in Subsection 3.3.4.2.

3. 5.13.1 Temporary Repairs

Usually these members require temporary repairs because of deterioration at their bottoms as exhibited by visible crushing of the timber.

Temporary repairs can be carried out using an additional vertical post positioned adjacent to the member as shown in Figure 3.5.13.1-1. If more than one vertical is damaged, a post should be placed on both sides of the member. These temporary posts should be as close as possible to the existing member and should have a section size with a least dimension equal to at least twice that of the existing (individual) component. They should be properly engaged to carry load by using steel wedges similar to the method described in Subsection 3.5.4.4.
3.5.13.2 Replacement of Components

Members should be replaced with at least the same size, grade and quality as the existing components. If possible, the bottoms of posts should be cut square (ready for use) and placed in a bath of liquid preservative for several days to enhance durability. Subsequently, any trimming of the member should be performed at the other end. Regardless, a thick layer of gel or grease type remedial preservative should be applied to the base of each new post just before it is installed.

Only one vertical shall be replaced at a time and the others shall be suitably clamped together to prevent movement. The new posts should be installed and engaged using the procedure outlined in Subsection 3.5.4.4.

3.5.13.3 Strengthening and Upgrading

As with many other timber compression members, the capacity of these members is usually governed by buckling. In addition, the typical details in these trusses allow installation of larger members to improve stiffness. The ends can be tapered at the bearings without compromising the improved stability.
3. 5.14 Timber Bearings and Corbels

Timber bearings and corbels under trusses are usually the last components to receive attention. This results from the fact that they are generally the most difficult to repair and replace as they support the entire weight of the bridge. The most typical failure of both components is due to deterioration which leads to progressive crushing. The consequences of this type of failure are not generally catastrophic depending on the extent of the deterioration.

3. 5.14.1 Temporary Repairs

Depending on the extent of the deterioration, it is usually more practical to leave the members until they can be replaced. The deterioration, whether decay or insect attack, should be properly treated to arrest the deterioration and retreatment should be maintained on a regular basis until the members can be replaced.

With corbels, it is sometimes possible to strengthen a weak or failed member using external steel sections as shown in Figure 3.5.14.1-1. However, generally, it is not possible to straighten the original component. In addition, the deteriorated condition of the member usually reduces its effectiveness as the bolting must transfer fairly high loads to the timber causing crushing.

![Steel Channel Strengthening of Corbel – Clarencetown Bridge](image)

3. 5.14.2 Replacement of Components

Replacement of the corbels and bearings should always be considered during major repairs, particularly when the bottom chords are to be replaced using the Bailey support system outlined in Subsection 3.5.4.5.

However, it is necessary to carefully plan the support system for the temporary Bailey to ensure that it does not prevent access to the truss bearings and,
possibly, the corbels. This is important as usually the Bailey is supported on top of the bridge deck as previously shown in Figure 3.5.4.5-2. Blocking is provided under the deck, between components, to transfer the reaction loads from the Bailey directly through to the pier. In most instances, this traps some of the bridge members so that the bearings cannot be removed.

In some cases, it may not be possible to support the Bailey and still allow access to the bearings. In these cases, it will be necessary to investigate a method of jacking the truss span off the pier to allow the bearings to be replaced.

All components should be replaced with the same size, grade and, particularly, quality in terms of durability. Considering the difficulty and cost of replacement, the highest durability class of timber should be used. It may also be practical to consider using galvanised steel members to improve longevity.

3. 5.14.3 Strengthening and Upgrading

Rarely do timber truss bearings require strengthening as they are usually adequate even for today’s design loads. If necessary, larger members may be provided or even steel components can be used.

The true performance of, and the loads carried by, corbels are not really well defined. Therefore, it is not possible to determine theoretically if a corbel needs strengthening. However, the need to strengthen may be derived from field performance observations such as:

- if the existing members have proven to be too flexible
- if the existing members have failed other than through deterioration

It may be possible to install larger sections depending on the clearances to other components or even to use steel sections.

3. 6 ENGINEERING EVALUATION

Section 1 outlined the basic requirements for the engineering design and evaluation of timber bridges. This subsection highlights a number of considerations directly related to timber trusses.

3. 6.1 Design Specifications

Design of timber truss components shall satisfy the requirements and loads specified in Section 2 of the Austroads Bridge Design Code. Design of the timber elements in trusses shall be in accordance with AS1720 as outlined in Section 1. Steel and iron components should be evaluated in accordance with AS4100 Steel Structures.
3. 6.2 Timber Capacities

Basic determination of timber capacities using AS1720 is outlined in Section 1 and, except as noted below, shall be applied to the design of timber components in trusses.

3. 6.2.1 Duration of Load Factor $k_1$

Generally, for the design of timber elements in bridges not subjected to earth pressure, water flow or high dead load forces, the duration of load factors specified in Section 1 for the live plus dead load combination are usually applicable. However, the following points should also be considered during the design of timber trusses.

Generally, the forces due to dead load in most timber elements in a bridge are quite small compared to those caused by live loads. However, components in large span trusses, particularly primary members (e.g., top chords, bottom chords and end principals) and bearing components may be subjected to very high dead load forces. Dead load should, therefore, also be considered by itself (or combined with other permanent loads) using the $k_1$ factor of 0.57 for permanent loading.

3. 6.2.2 Strength Sharing Factor $k_9$

The modification factor for strength sharing is applicable to many truss components and systems. The following identifies some typical examples as guide to the design of timber trusses.

Many timber truss members are composed of multiple timber components and, except for tension members, these would all be considered strength sharing systems for the purpose of design and evaluation. However, it is important to determine whether the member represents a combined or discrete parallel system.

3. 6.2.2.1 Compression Members

In most cases, compression members with multiple components should be taken as discrete parallel systems for the purposes of determining $k_9$. Nearly all compression members (top chords, end principals and other diagonals) are detailed with the components spaced apart as typified in Figure 3.6.2.2.1-1. Even though they are joined at intervals along the length, this does not properly represent a combined parallel system.
The four timber verticals in a DeBurgh truss as shown in Figure 3.6.2.2.1-2 are also a discrete parallel system. Even the top chord in the DeBurgh truss, which can be seen to have two components in the figure, should be taken as a discrete parallel system. While the two components are very close together, they are not secured to each other in a continuous manner along the length of the member.

As a “rule of thumb” for a timber compression member in a truss to be considered a combined parallel system, the components should be in contact with each other and bolted together along the length of the member. The bolting should be in a
staggered pattern and at a spacing of not more than 1.5 times the depth of the member.

3. 6.2.2.2 Bottom Chord Bending (Tension)

The strength sharing factor $k_9$ is not applicable to tension members. However, it should be applied to the bending component for a member subjected to bending and tension. Both the PWD and McDonald trusses have intermediate cross girders supported between the panel points as previously shown in Figure 3.2.1.2-4. These intermediate members introduce significant bending moments into the bottom chord.

The PWD and McDonald trusses also have multiple component bottom chords which are bolted together continuously over the length of the member. These would be considered combined parallel systems and the $k_9$ value would be directly equal to the $g_{31}$ value specified in AS1720 for the number of elements in the member.

Where the capacity is determined at a component splice (ie: where one component of a 3 component member is butted and spliced), the number of components for determining $g_{31}$ is reduced by one.

3. 6.2.2.3 End Bearing in Multiple Timber Shear Connectors

Another particularly important strength sharing system not identified or specifically covered by AS1720 is the effective end bearing performance of multiple shear key connectors which was introduced in Subsection 3.5.10. Some important additional information is provided in Subsection 3.6.3 where, although the use of a $k_9$ factor is not promoted for design purposes, it is suggested for use in evaluating existing structures.

3. 6.3 Special Considerations for the Design of Timber Shear Keys

AS1720 does not specifically cover multiple timber shear key connectors of this type. Shear plates and split ring connectors are the closest comparison and their capacities are derived through testing from which the characteristic strengths (for the overall connector) are tabulated for different sizes and timber types.

The type of shear connector used in timber trusses requires the use of basic design calculations to generate the design strengths. The following provides some guidance for design and evaluation:

In basic terms, the shear strength of the system is governed by both the length of the timber being sheared (shear zones) and the (timber) bearing area of the keys as shown in Figure 3.6.3-1. Therefore the weakest link can either be shearing of the timber or crushing of the timber at the notches.
Figure 3.6.3-1 Timber Shear and End Bearing in Timber Shear Keys

3. 6.3.1 Timber Shear in Shear Key Connectors

There are three important features to consider in determining the shear strength of a shear key type of connection. The slope of the grain, the length of the shear zone and the controlling shear zone.

The first consideration is that the timber has essentially a parallel grain structure as the shear will follow the grain. If the grain is sloped, particularly inclining to the surface, the timber will simply shear straight to the surface creating a wedge as shown in Figure 3.6.3.1-1. To ensure a quality grain structure only high grade timber of minimum F27 should be used. The grading rules severely limit slope of grain for these timbers.

Another important design consideration is the determination of the effective length of the timber shear zone. No guidance is provided in AS1720 in this regard. To simplify understanding, it is useful to look at a single shear key as shown in Figure 3.6.3.1-2. The potential length of the timber shear zone in the figure, represented by the dotted line running to the end of the member, is very long. It would be unreasonable to consider that the timber would shear uniformly along the full length (and width of the member) as shown in the figure.

In reality, such a connection would fail in a non-uniform manner and the real shape of the shear plane and failure mode would be different every time. Even
with the confining action of the timber butting block on the top, the failure would probably run to the surface at some point or the sheared timber would begin to separate as shown in the figure. Therefore, a reasonable limit for length of the shearing zone to be used in the determination of the shear strength must be assumed.

![Diagram showing possible failures and potential length of shear zone.](image)

**Figure 3.6.3.1-2** Single Shear Key

It is practical to consider that the shear strength would increase as the depth of the key (notch) is increased or, inversely, the closer the shear line is placed to the surface, the greater the chance that the failure line will run to the surface. With these previous points in mind, as a “rule of thumb”, the length of the shear zone should be taken as no more than 10 times the depth of the key as shown in Figure 3.6.3.1-3.

![Diagram showing assumed length of shear zone.](image)

**Figure 3.6.3.1-3** Assumed Length of Shear Zone

Another important design consideration is the determination of the governing timber shear zone(s). First, as will be outlined in the next section, the total shear force is assumed to be distributed evenly between the shear keys. Therefore, if there are three keys and the shear force is \( V \), then each key will resist \( V/3 \) regardless of the length of the shear zone for each. This is important to acknowledge as it means that the shortest shear zone in the system will be the most highly stressed and will fail first. Unlike some failure modes, shear along the
grain when loaded directly in a system like this is brittle or sudden, not gradual. Therefore, the most highly stressed area will not gradually transfer load to the other areas as it fails.

As an example, using Figure 3.6.3.1-4, the shortest shear zone is equal to $L$ and so the total assumed (maximum) shear strength of the three keys is based on $3 \times L$ even though the sum of the three shear zone lengths is greater. Therefore, it is essential to evenly distribute the shear keys along the length of the interface between the components in order to efficiently use the full potential shear strength as shown in Figure 3.6.3.1-5. At the same time the spacing of the keys should be about 10 times the depth of the key (notch).

![Figure 3.6.3.1-4 Governing Shear Zone](image)

![Figure 3.6.3.1-5 Example of Recommended Shear Key Layout](image)

### 3. 6.3.2 End Bearing in Shear Key Connectors

End bearing on the timber keys (notches) has several features which must be considered. The keys must be accurately located so that all keys are engaged at the same time. The acceptable tolerance for fabrication would vary depending on the shear key size, type and quantity. However, as a “rule of thumb” the largest gap between the vertical faces at a key should be less than 1 mm once the components have been assembled. No spacers or other fillers should be used unless approved.
Compression failure of the timber in end bearing at the keys is a soft or yielding failure. The gradual mode of failure is such that the most highly stressed end bearing will yield and transfer load to other keys (as will others) until all the keys are sharing the load (within a reasonable tolerance). This will counteract the small (within 1 mm) inaccuracies in fabrication. For this reason, the design of a shear key system should be selected so that end bearing (not shear) governs the design so that the end bearings will yield and redistribute load before shear becomes critical.

End bearing of the keys is effectively a compression parallel to the grain similar to compression members. This, coupled with the mutual sharing of the load and the yielding (soft) failure make this a realistic situation for application of the strength sharing factor used in AS1720. However, the formula for determining the bearing strength parallel to the grain in AS1720 does not include the strength sharing factor $k_9$.

At this time, the factor should not be applied for the design of new components. However, it is suggested that it be considered for existing shear key connectors in cases where the theoretical strength does meet the current design loads. The shear key system should be considered as a combined parallel system using the method given in AS1720 where, in effect, $k_9$ will be directly equal to $g_{31}$.

### 3.7 DETAILING AND DURABILITY

Section 1 provides some typical details applying to all timber bridge systems, including trusses. This subsection provides some additional details for timber trusses and components.

#### 3.7.1 Preventative Maintenance

As outlined in Section 1, maintenance should begin with preventative measures to enhance durability through proper materials selection as well as design and construction detailing. In addition to the basic engineering and construction detailing outlined in Section 1, this section reviews a number of factors specifically applicable to timber trusses.

#### 3.7.1.1 Timber Selection

All timber components in trusses as well as cross girders should be selected to provide the highest durability as they are expected to provide a long service life. In addition, as demonstrated in the preceding sections, the majority of components require special procedures and equipment for replacement. All primary truss members and cross girders should be Durability Class 1 as identified in AS1720 Part 2.
3. 7.1.2 Construction Detailing

Proper construction detailing must be provided in order to avoid water traps and unnecessary stress concentrations. In line with the considerations outlined in Section 1, the following areas should be given specific attention in timber trusses and cross girders:

- avoiding unnecessary notches in new timber components with particular emphasis on abrupt changes in section
- avoid drilling through cross girders and other components by providing alternate attachments
- apply preservative protection between contact surfaces particularly between laminated timber members, under cross girder bearings, and under flashing
- apply preservative to all bolt holes during assembly

The following subsections provide a number of specific details that should be considered.

3. 7.1.2.1 Notches and Section Changes

Care should be taken when making section changes in timber components to avoid stress concentrations and to allow access for inspection and treatment.

In general, areas which require section changes should be tapered using a 1 in 5 slope as shown for new larger timber members in Figures 3.7.1.2.1-1 and 3.7.1.2.1-2. The taper should begin at least 20 mm away from any contact surface as shown in Figure 3.7.1.2.1-2.

![Figure 3.7.1.2.1-1 Required 1 in 5 Taper for Cross Girders](image-url)
In general, unless there are clearance requirements or aesthetics to consider, it should not be necessary to trim down new components over the full length to match the original members. Larger members will always be a benefit to an existing truss.

3. 7.1.2.2 Bolting and Alternate Attachments

All bolt holes represent moisture traps and should be preservative treated as outlined in Section 1. For cross girder attachment, through holes should be avoided wherever possible. The use of coach screws instead of bolts provides tighter holes and reduces the chances of moisture entry.

In timber bottom chords, it may be possible to use angle brackets as shown in Figure 3.7.1.2.2-1. With steel bottom chords a coach screw from the underside can replace the through bolt as shown in Figure 3.7.1.2.2-2. The benefit in both cases is that the holes are under the cross girder providing improved protection. The sizing of the attachment should be properly engineered for the design (braking) loads. However, a minimum of M20 coach screws should be used to enhance durability.
Similar types of attachment should also be used to secure deck components to the cross girders as shown in Figure 3.7.1.2.2-3.
3. 7.1.3 Preservative Protection

Section 8 provides details on preservative types and applications and Section 1 outlines the general requirements. In trusses, particular attention should given to:

- bolt holes in truss components
- ends of truss components where they bear at the joints
- interfaces between multiple component members
- under the bearings of cross girders (Figure 3.7.1.2.2-1)
- where deck components bear on the cross girders (Figure 3.7.1.2.2-3)
- under flashing on the top of horizontal surfaces

Gel or grease type remedial preservatives should be used between surfaces and in holes, particularly in areas which will be difficult to access in the future.

3. 7.1.4 Flashing Protection

Flashing provides a direct moisture protection for timber components and can considerably improve the longevity of timber in exposed conditions. All top chord truss members should be flashed as shown in Figure 3.7.1.4-1 and, if possible, even diagonal members can be flashed. However, it is important that the flashing provides adequate protection against moisture ingress as it will also prevent rapid drying in cases where water penetrates the protection.
Figure 3.7.1.4-1  Typical Flashing on Truss Members - Korns Crossing

The timber surface under the flashing should be treated with a gel or grease type remedial preservative and the flashing should not be perforated by holes. It should also be raised to provide some air circulation and detailed to be removable for inspection and retreatment.

As outlined in Section 1, flashing should not be used on surfaces where water will eventually gain access. This particularly true for the tops of bottom chords where the cross girders and truss joints prevent the flashing from being continuous.

3. 8 SPECIFICATIONS

Section 1 lists the relevant specifications applicable to timber bridge construction. These include the applicable Australian Standards, Sections of the Austroads Bridge Design Code as well as the current RTA Construction and Materials Specifications.

3. 9 MATERIAL SUPPLY

Section 1 outlines the basic material supply requirements for timber bridges. Except as noted below or specified otherwise, the material requirements and specifications outlined in Section 1 shall apply as minimum requirements for timber truss components. With new designs or major rehabilitation works, it is assumed that design drawings and/or specific construction specifications will be supplied.
3. 9.1 Timber Supply - Member Replacements

All primary timber truss components and timber cross girders shall always be Durability Class 1. In general, unless otherwise specified, all replacement timber components for existing bridges shall be of equal size and grade. Only hardwood shall be used to replace existing hardwood members.

3. 9.2 Steel Components

All steel components should be hot dip galvanised or otherwise protective treated.