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 Some of the contents are out-of-date.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 TWO

TIMBER SUBSTRUCTURES
TABLE OF CONTENTS

SECTION TWO

2. TIMBER BRIDGE SUBSTRUCTURES

2. 1 GENERAL
   2. 1.1 Scope
   2. 1.2 Objectives
   2. 1.3 Definitions

2. 2 SUBSTRUCTURE TYPES AND COMPONENTS

2. 3 INSPECTION PROCEDURES
   2. 3.1 Objectives and General Requirements
   2. 3.2 Inspection Records
   2. 3.3 Annual Visual Inspection
      2. 3.3.1 Inspection Under Transient Loading
      2. 3.3.2 Structural Defects and Damage
      2. 3.3.3 Timber Deterioration
   2. 3.4 Detailed Inspection
      2. 3.4.1 Excavation for Detailed Inspection
      2. 3.4.2 Special Consideration for Possible Buried Piles
      2. 3.4.3 Timber Boring
      2. 3.4.4 Special Consideration for Abutments

2. 4 MAINTENANCE
   2. 4.1 Objectives and General Requirements
   2. 4.2 Preventative Maintenance
   2. 4.3 Annual Maintenance
   2. 4.4 Three Year Maintenance
   2. 4.5 Treatment of Fungal and Insect Attack

2. 5 REHABILITATION AND REPAIRS
   2. 5.1 Timber Sheeting at Abutments
      2. 5.1.1 Temporary Repairs
      2. 5.1.2 Replacement of Sheeting Components
   2. 5.2 Timber Piles and Posts
      2. 5.2.1 Temporary Repairs to Piles and Posts
      2. 5.2.2 Replacement of Timber Posts
      2. 5.2.3 Splicing Timber Piles Above Ground
      2. 5.2.4 Repair of Timber Piles At (or Below) Ground
      2. 5.2.5 Frequency of Pile Splices
   2. 5.3 Repairs/Replacement of Capwales
      2. 5.3.1 Temporary Repairs to Capwales and Headstocks
      2. 5.3.2 Temporary Support During Repairs


<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. 5.3.3 Repair and Replacement of Capwales and Headstocks</td>
<td>23</td>
</tr>
<tr>
<td>2. 5.4 Rehabilitation of Timber Abutments</td>
<td>24</td>
</tr>
<tr>
<td>2. 5.4.1 Rehabilitation of an Existing Timber Abutment</td>
<td>24</td>
</tr>
<tr>
<td>2. 5.4.2 Replacement of an Existing Timber Abutment</td>
<td>27</td>
</tr>
<tr>
<td>2. 5.5 Rehabilitation of Timber Piers</td>
<td>28</td>
</tr>
<tr>
<td>2. 5.5.1 Rehabilitation of an Existing Timber Pier</td>
<td>28</td>
</tr>
<tr>
<td>2. 5.5.2 Replacement of an Existing Pier</td>
<td>29</td>
</tr>
<tr>
<td>2. 6 ENGINEERING EVALUATION</td>
<td>29</td>
</tr>
<tr>
<td>2. 6.1 Design Specifications</td>
<td>30</td>
</tr>
<tr>
<td>2. 6.2 Timber Capacities</td>
<td>30</td>
</tr>
<tr>
<td>2. 6.2.1 Duration of Load Factor $k_1$</td>
<td>30</td>
</tr>
<tr>
<td>2. 6.2.2 Strength Sharing Factor $k_9$</td>
<td>30</td>
</tr>
<tr>
<td>2. 7 DETAILING AND DURABILITY</td>
<td>31</td>
</tr>
<tr>
<td>2. 7.1 Preventative Maintenance</td>
<td>31</td>
</tr>
<tr>
<td>2. 7.1.1 Timber Selection</td>
<td>31</td>
</tr>
<tr>
<td>2. 7.1.2 Construction Detailing</td>
<td>31</td>
</tr>
<tr>
<td>2. 7.1.2.1 Notches and Section Changes</td>
<td>32</td>
</tr>
<tr>
<td>2. 7.1.2.2 Bolting and Alternate Attachments</td>
<td>33</td>
</tr>
<tr>
<td>2. 7.1.3 Preservative Protection</td>
<td>35</td>
</tr>
<tr>
<td>2. 7.1.4 Flashing Protection</td>
<td>35</td>
</tr>
<tr>
<td>2. 8 SPECIFICATIONS</td>
<td>36</td>
</tr>
<tr>
<td>2. 9 MATERIAL SUPPLY</td>
<td>36</td>
</tr>
</tbody>
</table>
LIST OF FIGURES

Figure 2.2-1 Typical Timber Pile Support – Wakool River Bridge 3
Figure 2.2-2 Timber Pile Abutment - Anderson Creek 3
Figure 2.2-3 Timber Columns (or Bent) on Concrete Foundation - Corowa Bridge 4
Figure 2.2-4 Cast Iron Tubular Pier Columns - St Albans Bridge 4
Figure 2.3.3.2-1 Typical Areas for Structural Failure and Damage 6
Figure 2.3.3.2-2 Typical Bearing Failure at Capwale - Anderson Creek 7
Figure 2.3.3.2-3 Typical Crushing and Fracture of Capwale 7
Figure 2.3.3.3-1 Typical Areas for Deterioration 8
Figure 2.3.3.3-2 Typical Pile Deterioration at top 8
Figure 2.3.3.3-3 Typical Pile Deterioration at Ground 9
Figure 2.3.4.4-1 Deterioration Behind Abutment - St Albans Bridge 12
Figure 2.5.1.1-1 Temporary Repair to Sheeting - Round Piles 14
Figure 2.5.1.1-2 Temporary Repair to Sheeting - Square Post 15
Figure 2.5.1.2-1 Single Sheeting Replacement 16
Figure 2.5.1.2-2 Multiple Sheeting Replacement- Round Piles 16
Figure 2.5.1.2-3 Multiple Sheeting Replacement- Square Posts 17
Figure 2.5.2.1-1 Pile (or Post) Repair Not Recommended 18
Figure 2.5.2.1-2 Temporary Posts for Damaged Pile (or Post) 18
Figure 2.5.2.3-1 Typical Pile Splice 19
Figure 2.5.2.3-2 Recommended Detail at Pile Splice 20
Figure 2.5.3.1-1 Heavy Splice for Capwale or Headstock 22
Figure 2.5.3.2-1 Temporary Support of Girders 23
Figure 2.5.3.3-1 Replacement of a Length of Capwale or Headstock 23
Figure 2.5.4.1-1 Precast Concrete Abutment Sheeting - Korns Crossing 25
Figure 2.5.4.1-2 Rehabilitation of Existing Timber Abutment 26
Figure 2.5.4.1-3 Cast in Place Concrete Abutment Wall - Lignum Creek 26
Figure 2.5.4.2-1 Cut Off Piles and Abutment Formwork - Pound Crossing 27
Figure 2.5.4.2-2 Cast in Place Concrete Abutment - Pound Crossing 28
Figure 2.5.5.2-1 Concrete Footing Supported on Existing Timber Piles With New Timber Bent - Pound Crossing 29
Figure 2.7.1.2.1-1 Unnecessary Deep Notch for Pile Bracing 32
Figure 2.7.1.2.1-2 Required 1 in 5 Taper 33
Figure 2.7.1.2.1-3 Trimmed Round Timber Posts - Pound Crossing Bridge 33
Figure 2.7.1.2.2-1 Steel Channel Attachments for Capwale 34
Figure 2.7.1.2.2-2 Steel Strap Attachment of Headstock - Morongola Crk 34
Figure 2.7.1.2.2-3 Angle Bracket with Coach Screws 35
Figure 2.7.1.4-1 Flashing on Pile Top 36

(iii)
2. TIMBER BRIDGE SUBSTRUCTURES

2.1 GENERAL

2.1.1 Scope

Section 2 covers the design, construction and maintenance of all timber bridge substructure systems and specified components as outlined in Subsection 2.2. 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 substructures.

2.1.2 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 substructures 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

2.1.3 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 substructures.
**Bent**
Timber columns and beam supported on an independent foundation as shown in Figure 2.2-3

**Bracing**
Component providing stability to a member or group of members such as the timber cross bracing shown in Figure 2.2-3

**Capwales**
Pair of horizontal timber components (typically 300 mm x 150 mm) at the top of piles or posts providing bearing for the superstructure as shown in Figure 2.2-1

**Headstock**
Single horizontal timber component (typically 300 mm x 300 mm) at the top of piles or posts providing bearing for the superstructure as shown in Figure 2.2-2

**Piles**
Round timber poles driven into the ground to provide support for a structure

**Substructure**
Defined in Section 1.

### 2.2 SUBSTRUCTURE TYPES AND COMPONENTS

A brief review of the more common types of timber substructures and components follows. This review provides a means of defining the terminology being used. In most cases, the words in italics are noted to be the accepted terms normally used in the field when referring to the substructure type, components or system under consideration. These terms are defined in Subsection 2.1.3.

While there are many types of timber substructures the most common form utilises round timber *piles* as shown in Figure 2.2-1. Traditionally, these are combined with a pair of timber capwales (typically 300 mm x 150 mm), as shown in the figure, which are notched into the tops of the piles to provide a support bearing for the superstructure components.
The lateral resistance of driven piles allows the use of simple timber sheeting to retain the fill at the abutments as shown in Figure 2.2-2. This figure also shows the alternate timber support bearing using a solid timber headstock on top of the piles.

![Figure 2.2-1 Typical Timber Pile Support – Wakool River Bridge](image1)

While the timber pile is the most common form of substructure, there are several other variations some of which will be presented later in this section. One other frequent form of timber substructure uses timber bents (columns or posts) which sit upon an independent foundation such as the concrete pad shown in Figure 2.2-3. They are generally sawn rectangular posts but can also be round. This figure also shows the typical timber cross bracing nearly always used on this type of support to provide lateral stability. This type of bracing is also typical for piles with long exposed lengths (above ground) or on structures which may be subjected to high lateral loads such as those caused by flooding.

![Figure 2.2-2 Timber Pile Abutment - Anderson Creek](image2)
In addition to these simpler forms of timber substructure, the same design style has also been used for the support of larger superstructures such as timber trusses. These may use heavier components or simply utilise multiple rows of piles or columns to provide a larger support area.

In addition, for some of the larger and taller piers, many older bridges have cast iron tubular pier columns as shown in Figure 2.2-4.
2. 3 INSPECTION PROCEDURES

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

2. 3.1 Objectives and General Requirements

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

2. 3.2 Inspection Records

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

2. 3.3 Annual Visual Inspection

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

2. 3.3.1 Inspection Under Transient Loading

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

The following specific substructure areas shall be observed for excessive movements:

- local movements of headstocks or capwales at their supports/connections with the piles or post, with emphasis on loose bolts and bearing failure (crushing)
- overall bending or deformation of the headstocks or capwales between the piles or posts, with emphasis on possible fractures or deterioration which may be exposed during movement
- vertical movement of piles with respect to the ground with particular emphasis on individual piles which may move more than others
- vertical movement of other foundations such as temporary timber bearers supported directly on the ground or on concrete footings, with particular emphasis on possible differential movements
- lateral movement, or sway, particularly for tall piers and column or post systems, with emphasis on loose connections at the bracing
- movements at previously reported problem areas
- movements at previously repaired areas
2. 3.3.2 Structural Defects and Damage

All components and connections shall be visually inspected for obvious structural defects and damage caused by loading or flooding. These should include:

- member fractures due to loading with particular emphasis on bending failure of capwales and headstocks between the piles or posts
- local crushing of timber at bearing points with particular emphasis on:
  - bearing of capwales and headstocks at piles or posts
  - bearing of superstructure components on the capwales and headstocks
  - end bearing of posts or columns at the base
- evidence of pile failure at abutments (at or near ground level) as indicated by movement of the abutment or individual pile away from the approach
- bulging of abutment sheeting
- loose connections and/or enlarged holes around bolts
- deterioration of cast iron piers
- evidence of damage caused by flooding with particular emphasis on signs of collision damage

Some of the critical areas for structural failure or damage are shown in Figure 2.3.3.2-1 and several examples are shown in Figures 2.3.3.2-2 and 2.3.3.2-3.

![Figure 2.3.3.2-1 Typical Areas for Structural Failure and Damage](image-url)
Figure 2.3.3.2-2  Typical Bearing Failure at Capwale - Anderson Creek

Figure 2.3.3.2-3  Typical Crushing and Fracture of Capwale

2. 3.3.3  Timber Deterioration

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

- sapwood in all components, particularly round components
- ground contact areas with particular emphasis on:
  - base of piles at ground or waterline
  - timber sheeting
  - timber bearers supported directly on the ground
areas where water is trapped or does not dry out readily with particular emphasis on:
- interfaces between components
- holes at connections
- ends of members, particularly piles and posts
- under flashing and behind other protective coatings

Some of the critical areas for deterioration are displayed in Figure 2.3.3.3-1 and several examples of exposed deterioration are shown in Figures 2.3.3.3-2 and 2.3.3.3-3.

![Figure 2.3.3.3-1 Typical Areas for Deterioration](image)

![Figure 2.3.3.3-2 Typical Pile Deterioration at top](image)
2.3.4 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 three year maintenance activities and extending the visual inspection to hidden areas
- exposing questionable areas with particular emphasis on;
  - buried portions of piles to at least 1.5 m depth
  - piles and posts at water level (inspect at low water level)
  - buried portions of timber bearers supported directly on the ground
  - behind sheeting and other abutment components
- boring of main structural components such as piles, posts, capwales headstocks and selected abutment sheeting. (Some critical areas for deterioration are shown in Figure 2.3.3.3-1)

2.3.4.1 Excavation for Detailed Inspection

While the costs associated with excavation generally inhibit most agencies from performing this type of inspection, it is critical for ground contact areas. In order to reduce the costs, it can be effective to carry out random excavations. Generally, if decay or insect attack exists, it will be present in more than one area/component. If deterioration is discovered, then additional excavations can be carried out.

At least two piles should be inspected in each group (pier or abutment) but not less than every third pile. Each pile should excavated to at least 1.5 m depth and test bored near the bottom of the excavation. Each excavation should be refilled and compacted before the next pile is excavated in the same pile group.
Over-excavation of a pile group can lead to possible instability and weakening of the system, particularly for abutments. Records should indicate which piles have been excavated for inspection and different piles should be selected for subsequent inspections.

Buried timber bearers supported directly on the ground should be excavated to the bottom (bearing) face only or the bearing capacity of the soil may be compromised. Subsequently, the member can be test bored from the side.

Abutment sheeting can generally be evaluated effectively by test boring from the outside without the need for excavation. More details are provided in Subsection 2.3.4.3.

2. 3.4.2 Special Consideration for Possible Buried Piles

One additional important point should be considered for older timber bridges. The use of concrete footings and timber bearing beams (bearers supported directly on the ground) at ground level to support timber posts was not a common form of construction, unless specifically shown in the bridge design records. Experience indicates that these conditions may point to the existence of old timber piles below ground which have been cut off at some time in the past. Subsequently, the old piles have been used as a base support for a concrete footing or timber bearing beam.

Therefore, where concrete footings or timber bearing beams exist, particularly in a bridge which also has traditional timber piles, excavations should be performed to determine whether old timber piles exist.

2. 3.4.3 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 substructures. Boring shall be performed, but not be limited to, the following areas:

- all piles at ground level
- excavated piles (as indicated in Subsection 2. 3.4.1) at a minimum of 1.2 m below ground
- piles and posts adjacent to bolt holes with the bore hole intersecting within 30 mm of the bolt at the centre of the member (at only one or two locations per member)
- within 75 mm of the top of a pile or post and the bottom of a post
- within 75 mm from the end of any member where the end is not exposed for visual inspection
- headstocks and capwales at pile/post supports (generally this should be adjacent to the bolt attachment)
- sheeting (see notes below) in random locations adjacent to piles/posts
Except as noted below for timber sheeting, care should be taken to avoid drilling completely through the members and horizontal bores should be inclined slightly upwards. All bore locations should be clearly marked on the members.

Generally, it is also possible to evaluate timber sheeting by probing between individual planks to test the integrity of the timber near the back face. Signs of softening or material loss should be followed by boring. It is likely that bores in sheeting will extend completely through the members as it is the back face which deteriorates. Through holes should be left unplugged to allow drainage and rapid drying.

Generally, test boring of components with a minimum section of 100 mm or less (excluding abutment sheeting) 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.

2. 3.4.4 Special Consideration for Abutments

Abutment components are the most susceptible to deterioration as they provide ground contact with abundant moisture and oxygen. The supply of moisture comes through the fill. The deterioration is typically all at the back face of the components against the fill and rarely visible on the exposed faces. A typical situation is shown in Figure 2.3.4.4-1 where the back side of the piles are deteriorated. It should be noted that while the front face of the sheeting appeared in fair condition, many sheeting components failed during the excavation work and had to be replaced.

Where temporary or remedial repairs are necessary to piles or sheeting, as discussed in Subsection 2.5, this should be used as an opportunity to perform extra detailed inspections. In addition, when it is necessary to excavate behind an abutment to carry out extensive repairs, a full excavation should be carried out and all sheeting replaced to the ground line. All piles should be inspected on their rear sides.
Section 1 outlines the basic maintenance procedures for all timber bridge types and these also apply to timber substructures. This subsection highlights specific additional considerations for timber substructures.

2. 4.1 Objectives and General Requirements

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

2. 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 2.7 reviews a number of considerations specifically applicable to timber substructures.
2. 4.3 Annual Maintenance

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

Routine maintenance should include:

- removal of fire hazards from the proximity of the bridge with emphasis on grass and brush near the abutments and under the bridge
- all accessible bolted connections should be retightened with particular emphasis on the attachment of headstocks and capwales
- preservative protection should be reapplied where possible and spot checks should be performed on abutment components to see whether further work is needed
- minor collision or flood damage should be repaired. Major damage should be reported and remedial repairs carried out if possible

2. 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 substructures:

- retightening of all bolted connections including timber bracing
- exposing timber piles and other ground contact members, as outlined in Subsection 2.3.4.1, for retreatment with preservative protection
- difficult areas which cannot be exposed easily can be flooded with preservative (this must be carried out with proper attention to protecting the environment)
- All flashing should be removed to expose the members for inspection, cleaning and retreatment

2. 4.5 Treatment of Fungal and Insect Attack

The general requirements outlined in Section 1 should be applied to timber substructures and any fungal and insect infestation must be treated. A specialist should be engaged if termite damage is discovered.

2. 5 REHABILITATION AND REPAIRS

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

2. 5.1 Timber Sheeting at Abutments

There are high costs associated with excavation for the replacement of even one piece of timber sheeting at the abutments. Therefore, it is necessary to maintain and repair the sheeting for as long as possible until such time as the entire system can be replaced at the same time. As outlined in Subsection 2.7, other forms of sheeting should be used to enhance durability.

In general and particularly where the work involves more than one component, repairs/replacement should be carried out after a prolonged dry period. Wet conditions can seriously increase the forces being exerted by the backfill. Where damage is extensive, or failure is possible under wet conditions, then temporary repairs should be undertaken as an interim measure.

2. 5.1.1 Temporary Repairs

Under wet conditions the existing sheeting should not be removed. Drilling of primary components such as piles and posts for temporary repairs should be avoided as this will reduce their future durability.

A typical temporary repair for round piles is illustrated in Figure 2.5.1.1-1. Usually it is possible to fit a wedge shaped timber behind the pile adequately enough to support a temporary beam (see below). The timber blocks with tapered ends are fitted with bolts and then driven tightly between the pile and the sheeting (and held in place by toe nailing to the sheeting if necessary). The timber beam is sized, drilled to match the bolts in the blocks, fitted and bolted tightly. Small jacks or other means are then used to engage the beam and put pressure on the damaged sheeting. Blocking is then driven between the beam and sheeting to maintain pressure.

![Figure 2.5.1.1-1: Temporary Repair to Sheeting - Round Piles](image-url)
For square members, it is necessary to use attachments to the posts as shown in Figure 2.5.1.1-2. Here either steel angle brackets or timber blocking and coach screws can be used and the coach screws can be put back into place after use to seal the holes.

Figure 2.5.1.1-2  Temporary Repair to Sheeting - Square Post

The extent of the repairs will be dictated by the damage and more than one beam can be used to retain multiple sheeting with a continuous vertical blocking member. The intent in both cases is not to try to push the sheeting back into place, but only to restrain further movement until proper repairs can be carried out.

2. 5.1.2 Replacement of Sheeting Components

In most instances, under dry conditions, single pieces of sheeting can be removed one at a time without affecting the stability or integrity of the backfill. However, restricted access behind the piles or posts makes it virtually impossible and impractical to replace the entire length of a component in one piece.

The type of repair is dictated by the integrity of the timber itself. If the damage is very local, it may be possible to provide a simple repair by securing the replaced component to the adjacent members as shown in Figure 2.5.1.2-1.
However, where more than one component requires replacement, it is necessary to properly secure the sheeting to the piles or posts as shown in Figures 2.5.1.2-2 and 2.5.1.2-3. The extent of the attachment to the pile (or post) will depend on the distance between the piles and the height of the backfill. In most instances, 75 mm thick timber blocking should be used with M20 coach screws. The coach screws should penetrate at least 100 mm into the pile or post. In the case of round piles, it is sometimes possible to cut back on angle at one pile as shown in Figure 2.5.1.2-2.

Figure 2.5.1.2-2  Multiple Sheeting Replacement- Round Piles
2.5.2 Timber Piles and Posts

Timber piles and posts are the primary components of the substructure and repairs must be properly designed to ensure adequate strength. Even temporary repairs must be given proper attention.

2.5.2.1 Temporary Repairs to Piles and Posts

Temporary repairs to damaged piles and posts must establish adequate support for the structure. Simply providing external splints to the member as shown in Figure 2.5.2.1-1 is not adequate. Depending on the cause of the damage, this rarely provides enough strength.

If the damage is caused by deterioration (insect or decay), it is likely the surrounding timber will not provide adequate strength for the attachment of the splints and these members will have to be quite large. If the damage is a structural fracture this means that a serious overstress condition exists, the cause of which must be investigated. In either case, the member should not be spliced as shown in Figure 2.5.2.1-1.
Even as a temporary repair, additional supports should be provided on each side of the damaged component as shown in Figure 2.5.2.1-2. The temporary posts should be established on adequate bearing areas to minimise settlement and this should be engineered if possible. However, the bearing areas should be established below the ground surface to a depth of not less than 300 mm, or firm undisturbed ground. All organic soils should be removed.

It is likely that these temporary supports will still settle under load. Therefore, it is important that all the components be secured together and to the structure so that they do not move out of alignment. The repairs should be monitored frequently (daily at first) until proper repairs can be carried out.
2. 5.2.2 Replacement of Timber Posts

Timber posts are supported on independent foundations and therefore they can usually be replaced in one length. Replacement of timber posts can usually be achieved by using the temporary support system shown in Figure 2.5.2.1-2. Individual posts should be replaced one at a time.

2. 5.2.3 Splicing Timber Piles Above Ground

Timber piles are driven and, therefore, it is difficult to drive a new pile under the structure. In order to drive new piles, it is necessary to partially remove the superstructure.

Generally, damage above ground is repaired by splicing in a new section as shown in Figure 2.5.2.3-1. Details of the connection are dependent on the location of the splice and the forces that are to be transmitted through the pile. The connection must be properly engineered.

![Figure 2.5.2.3-1 Typical Pile Splice](image)

The interface between the two components represents a moisture trap and a typical location for future deterioration. Hence, flashing along with a gel or grease type remedial preservative should be provided as detailed in Figure 2.5.2.3-2. This will assist in preventing moisture ingress and improve the durability of the repair. This type of splice should not be located within 200 mm of the ground.
2.5.2.4 Repair of Timber Piles At (or Below) Ground

Typically, deterioration of piles occurs at or near ground level where both moisture and oxygen are abundant. Generally, any type of splice in a timber pile should not be located within the range of 200 mm above ground to 1200 mm below ground, except as noted below.

Without oxygen, the potential for deterioration is usually very low. Experience has shown that the following conditions usually represent a low potential for deterioration:

- usually 1200 mm to 1500 mm below ground
- below a permanent water table
- in non-porous soils such as clay

Under these types of conditions, a pile may be spliced underground using details similar to those given in Figure 2.5.2.3-2 without the flashing. The interface should be liberally coated with a gel or grease type remedial preservative and bandaged over the joint with a geotextile fabric to help contain the treatment. The two timber components should be secured using heavier steel components which are also galvanised to help offset the potential deterioration of the steel. The spliced area should be backfilled and compacted with non-porous soil such as clay in order to reduce oxygen access.

It should be noted that while in most cases the potential for deterioration in piles is low at 1200 mm to 1500 mm below ground, this is not always the case. Some piles may be in very porous soil or coarse fill. This can allow changing moisture conditions and the access of oxygen. In such cases, it may be necessary to excavate further before splicing or new piles may need to be driven.
2. 5.2.5 Frequency of Pile Splices

While the types of splices described in Subsections 2.5.2.3 and 2.5.2.4 can provide a fairly long term solution, splices should not be applied to too many piles in the same structure. Driven timber piles not only provide resistance to vertical loads, but also provide lateral resistance to horizontal loads caused by flooding, vehicles (braking) and earth pressure at the abutments. A spliced pile, unless engineered with a fairly heavy splice detail, provides very little lateral resistance (bending at the splice). Therefore, if too many piles are spliced in the same pile group, particularly near ground level, the integrity of the structure can be seriously affected. Splicing should be limited to no more than 1 in 4 piles in a group unless an overall engineering assessment of the substructure is carried out.

2. 5.3 Repairs/Replacement of Capwales

Timber capwales are the traditional form of bearings used with timber piles and posts. They are also primary components of the substructure and repairs must be properly designed to ensure adequate strength. Even temporary repairs must be given proper attention.

2. 5.3.1 Temporary Repairs to Capwales and Headstocks

Damaged capwales and headstocks must be repaired adequately enough to support the superstructure components. Seriously damaged components should be supported at, or adjacent to, the damaged location using temporary posts similar to those shown in Figure 2.5.2.1-2.

However, minor damage including localised fractures may be temporarily spliced with external (side) members. However, in order to reinstate bending strength, substantial splicing components as shown in Figure 2.5.2.3-1 are required. Steel channels or plates should be used which will require shorter bolts than would be the case if heavy timbers were used. A stronger connection is provided by minimising the bending forces on the bolts. As a rule of thumb, the depth and length of the splicing component should be at least 0.9 and 5 times the depth of the timber component, respectively, as shown in the figure. A splicing member should be used on each side of the timber component. The bolting arrangement should be properly engineered and minimum M20 bolts are to be used.
This type of splice should not be used as a long term solution. This type of bolted splice is typically very susceptible to the effects of repeated loads which will eventually enlarge the bolt holes so that the splice loses its integrity.

2.5.3.2 Temporary Support During Repairs

During major repairs of capwales and headstocks, the superstructure must be properly supported and temporary posts can be used as shown in Figure 2.5.3.2-1. As discussed in the previous sections, the size and depth of the temporary bearing at the ground will depend on the site conditions. The top support must be continuous under the girders being supported and a post must be situated directly under each girder.
2. 5.3.3 Repair and Replacement of Capwales and Headstocks

Short lengths of damaged capwale or headstock can be replaced as long as the new components extend to the supports as shown in Figure 2.5.3.3-1. The new component should be properly secured to the existing capwale or headstock and the pile or post support. A steel channel or plate be used as shown in the figure.

Figure 2.5.3.3-1 Replacement of a Length of Capwale or Headstock
Under the following conditions, capwales should be replaced entirely with a new headstock:

- where the capwale is seriously damaged in several locations
- where the tops of piles or posts are also damaged
- where failure of capwale bearings has occurred (Figure 2.3.3.2-2)

Replacing the capwales with a headstock allows removal of the tops of the piles and posts which typically contain deterioration from the upper area. A headstock also provides a greater bearing area.

2. 5.4 Rehabilitation of Timber Abutments

When it becomes necessary to carry out major rehabilitation of abutments, a number of methods which provide improved strength and durability are available. In addition to supporting the superstructure, the abutment must also provide resistance to the lateral earth pressure. The proximity of the timber components to the soil behind the abutment also make it a high risk area for deterioration.

The following subsections provide two examples of possible rehabilitation methods for timber abutments. These represent the two extremes depending on the condition of the existing components and the anticipated life expectancy of the bridge as a whole.

In general, it is assumed that the work would be done with the bridge closed to traffic. However, it is feasible to carry out either option under traffic depending on the site conditions.

2. 5.4.1 Rehabilitation of an Existing Timber Abutment

Rehabilitation of an existing timber abutment assumes that the basic structure will still use timber components and retain the existing members which are still in good condition.

Regardless of the existing components that might be retained, the following modifications should be considered:

- timber headstocks instead of capwales
- new concrete abutment sheeting
- new driven piles to replace deteriorated piles
- new concrete sill wall behind the abutment
- free draining backfill

Timber headstocks provide a better bearing area than capwales and they can be accessed easily for replacement. The rear capwale at an abutment is difficult to replace.
Use of concrete sheeting instead of timber is preferable as the contact area with the backfill represents the highest hazard area for timber deterioration. It is also the hardest and most expensive area to access and repair. An example of concrete sheeting made from precast panels is shown in Figure 2.5.4.1-1.

![Precast Concrete Abutment Sheeting - Korns Crossing](image)

**Figure 2.5.4.1-1**  Precast Concrete Abutment Sheeting - Korns Crossing

Another improvement to durability at the abutment is the introduction of a concrete sill wall designed as a small retaining wall, as shown in Figure 2.5.4.1-2. This provides a means of further separating the timber bridge from the approach by introducing an open deck joint. This reduces moisture access to the bridge from the approach as well as providing a barrier to insect attack.
Figure 2.5.4.1-2  Rehabilitation of Existing Timber Abutment

An example of a cast in place abutment wall behind a timber abutment is shown in Figure 2.5.4.1-3. Here the wall is cast integrally with the wing walls.

Figure 2.5.4.1-3  Cast in Place Concrete Abutment Wall - Lignum Creek

The above type of rehabilitation is intended as a medium to long term solution depending on the condition of the existing piles. New piles should be driven to replace any deteriorated components.
2. 5.4.2 Replacement of an Existing Timber Abutment

Where the existing timber components, including the piles, are deteriorated, the abutment should be replaced entirely with concrete, except as discussed below.

As previously discussed in Subsection 2.5.2.4, deterioration in timber piles at ground level does not generally extend beyond 1200 mm to 1500 mm below ground. This should be confirmed by site inspection.

In the case where the piles are in good condition at a specific level below ground, they can be used as the base of a new concrete abutment. Typically, the piles are cut off below ground level as shown in Figure 2.5.4.2-1 and the abutment is formed over the piles. The tops of the timber piles should be treated with preservative and wrapped in a geotextile fabric. The concrete abutment should be designed as a combined soil bearing and pile supported system. The ground at the base of the excavation, on which the concrete will be supported, should not be disturbed during excavation.

![Cut Off Piles and Abutment Formwork - Pound Crossing](image)

**Figure 2.5.4.2-1 Cut Off Piles and Abutment Formwork - Pound Crossing**

This approach reduces the foundation costs by eliminating the need for driving new piles or providing extensive concrete footings. The applicability of this approach will depend on the soil conditions.

The abutment should include integral concrete wing walls, as shown in Figure 2.5.4.2-2, with the overall structure designed to counteract the earth pressure forces behind the abutment.
Figure 2.5.4.2-2  Cast in Place Concrete Abutment - Pound Crossing

If the piles are not in good condition, a concrete abutment should still be used. If the timber piles are deteriorated well below ground level, this means that an environment exists which is not only a hazard to timber but could also represent a hazard to steel piles. If possible, a concrete spread footing should be designed or, if necessary, steel piles rather than timber piles should be used.

In any case, the use of a concrete abutment provides a high degree of durability by eliminating timber components in contact with the approach fill. It also provides the means for an open deck joint as described in Subsection 2.5.4.1, as well as isolated bearings for the timber superstructure.

2. 5.5 Rehabilitation of Timber Piers

Timber piers, while not subjected to exactly the same conditions as abutments, do have many similarities. In particular, they exhibit the same potential for low deterioration levels below the ground. In contrast to the earth pressure on abutments, most piers are subjected to horizontal forces during flood conditions.

2. 5.5.1 Rehabilitation of an Existing Timber Pier

In general, where most of the existing timber components are in good condition, it would be appropriate to replace only the deteriorated components. This can provide a medium to long term life expectancy. However, any existing capwales should be replaced with headstocks as they provide better support conditions. Deteriorated timber piles should also be replaced with new driven piles as splicing is only considered to be remedial repair (short to medium term).
2. 5.5.2 Replacement of an Existing Pier

Where the majority of timber components are deteriorated, including the piles, a similar approach to that at the abutment is to be taken with a few exceptions.

If the piles are found to be in good condition at a specific level below ground, then they are to be used as a base for a new concrete foundation similar to that at the abutment. However, in this case, the piles are to be capped with only a concrete footing or beam which is to extend to at least 300 mm above ground level similar to that shown in Figure 2.5.5.2-1. This would support a new timber bent (post and headstock) as shown in the figure.

![Concrete Footing Supported on Existing Timber Piles With New Timber Bent - Pound Crossing](image1.png)

**Figure 2.5.5.2-1** Concrete Footing Supported on Existing Timber Piles With New Timber Bent - Pound Crossing

This approach provides a system which is very durable as it separates the timber components from the ground. This reduces moisture access and provides a barrier against insect attack.

2. 6 ENGINEERING EVALUATION

Section 1 outlines the basic requirements for the engineering design and evaluation of timber bridges. This current subsection highlights a number of considerations directly related to timber substructures.
2. 6.1 Design Specifications

The design of foundations shall satisfy the design requirements and loads specified in Sections 2 and 3 of the Austroads Bridge Design Code. The design of the timber elements in foundations shall be in accordance with AS1720 as outlined in Section 1.

2. 6.2 Timber Capacities

The 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 foundations.

2. 6.2.1 Duration of Load Factor k₁

For the design of timber elements not subject 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 foundations.

Generally, the forces due to dead load in most timber elements of a bridge are quite small compared to those caused by live loads. However, substructure components supporting large superstructures may be subjected to very high dead load forces. Therefore, dead load should also be considered by itself (or combined with other permanent loads) using a k₁ factor of 0.57 for permanent loading.

Timber abutments are subject to earth pressure forces in addition to the live and dead loads transmitted from the superstructure. Earth pressure is a permanent load. Therefore, these elements should also be evaluated for combinations of earth pressure and dead loads using a k₁ factor of 0.57 for the timber.

Some timber components may also be subject to normal water flow (not occasional flooding) which is considered to be a permanent load. This must also be considered in combination with dead loads and earth pressure using the k₁ factor of 0.57 for the timber.

2. 6.2.2 Strength Sharing Factor k₉

The modification factor for strength sharing is applicable to many substructure systems. The following provides some examples as a guide to the design of timber substructures.

Timber sheathing elements mutually support the earth pressure forces and, since they are not joined together, are considered to be a discrete parallel system as defined in AS1720. However, the application of the k₉ factor is affected by the loading as the earth pressure varies over the height of the
abutment. The designer should divide the height of the abutment into groups of elements so that the design force does not vary significantly within each group.

Piles and posts under axial (compression) loads also represent a discrete parallel strength sharing system. The derivation of the $k_9$ factor would be based on the following:

- $L =$ the effective unsupported length of the pile or post
- $S =$ spacing between piles or posts
- $n_{\text{com}} = 1$
- $n_{\text{mem}} =$ the number of piles or posts assumed to mutually share the load under consideration

2. 7 DETAILING AND DURABILITY

Section 1 provides some typical details that apply to all timber bridge systems including substructures. This subsection provides some additional details for common timber substructures and components.

2. 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 considerations specifically applicable to timber substructures.

2. 7.1.1 Timber Selection

All timber components in substructures should be selected to provide the highest durability as they are located in the greatest risk areas and are generally difficult and expensive to replace. Primary members such as piles, posts, capwales and headstocks should be Durability Class 1 as identified in AS1720 Part 2. Other ground contact members such as abutment sheeting should also be Durability Class 1. The additional cost and supply time required are generally more than offset by the future costs of repair and replacement.

2. 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 substructures:

- avoiding unnecessary notches in piles and posts with particular emphasis on abrupt changes in section
- use headstocks as opposed to capwales to provide more bearing area and avoid notching piles and posts
- allow spaces between the abutment sheeting to facilitate drainage and drying
- avoid drilling piles and posts by using alternate attachments
- apply preservative protection between contact surfaces particularly the bearing under headstocks and capwales
- apply preservative to all bolt holes during assembly

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

2. 7.1.2.1 Notches and Section Changes

Care should be taken when providing flat surfaces in piles and posts for bracing to avoid abrupt section changes. Deep notches such as the one shown for the bracing in Figure 2.7.1.2.1-1 represent poor durability. This creates a water trap and also prevents access for inspection and retreatment.

![Figure 2.7.1.2.1-1 Unnecessary Deep Notch for Pile Bracing](image)

In general, areas which require section changes or flat surfaces for connections should be tapered using a 1 in 5 slope as shown in Figure 2.7.1.2.1-2.
For timber posts, it is also practical to trim round members along their full length as shown in Figure 2.7.1.2.1-3.

Figure 2.7.1.2.1-3 Trimmed Round Timber Posts - Pound Crossing Bridge

2. 7.1.2.2 Bolting and Alternate Attachments

All bolt holes represent moisture traps and should be preservative treated as outlined in Section 1. Coach screws should be used, wherever possible, instead of bolts to provide tighter holes and reduce the chances of moisture entry.
Alternate means of attachment should be considered to replace some of the traditional methods of attachment in order to avoid drilling through the primary timbers. Figure 2.7.1.2.2-1 shows one example where the capwale-pile connection utilises steel channel and coach screws. The same type of attachment can be used on headstocks.

Figure 2.7.1.2.2-1 Steel Channel Attachments for Capwale

Another style of attachment for a headstock is shown in Figure 2.7.1.2.2-2 which uses a flat steel strap with a M20 threaded rod welded to the side. The strap can be attached to the piles or post using coach screws and the rod extends up through the headstock.

Figure 2.7.1.2.2-2 Steel Strap Attachment of Headstock - Morongola Crk

Another alternative attachment for a headstock is shown in Figure 2.7.1.2.2-3. This uses steel angle brackets with coach screws in both the headstock and
pile (or post). The proposed flashing on top of the pile can be flattened under the angle bracket.

![Diagram](image.png)

**Figure 2.7.1.2.2-3 Angle Bracket with Coach Screws**

### 2. 7.1.3 Preservative Protection

Section 8 provides details on preservative types and applications and Section 1 outlines the general requirements. In substructures, particular attention should be given to the ends of piles and posts as well as at the interface between components. A gel or grease type remedial preservative is to be used under the bearings of capwales and headstocks as well as under flashing on the top of horizontal surfaces.

The back face of timber sheeting, which will be in contact with the fill, should be coated with a heavy layer of preservative. If possible, the backfill directly in contact with the sheeting should be free draining to reduce washing of the preservative. Alternatively, a protective waterproof textile should be attached to the back face before backfilling.

However, as outlined in Subsection 2.5 (Figure 2.5.4.1-2), it is preferrable that timber sheeting be replaced with other materials to minimise ground contact of the timber components.

### 2. 7.1.4 Flashing Protection

Flashing provides direct moisture protection for timber components and can considerably improve the longevity of timber in exposed conditions. However, as discussed in Section 1, if it is not properly installed and maintained, it can represent a moisture trap. In substructures flashing should only be applied to the tops of piles and posts as shown in Figures 2.7.1.4-1 and 2.7.1.2.2-3. The flashing should not be perforated by holes and it should either be removable for inspection and retreatment or fully sealed to prevent moisture ingress.
Figure 2.7.1.4-1  Flashing on Pile Top

As outlined in Section 1, flashing should not be used on surfaces where water will eventually gain access. This is particularly true for the tops of capwales and headstocks which would be perforated by bolt holes. It is also true for the ends of these members.

2. 8 SPECIFICATIONS

Section 1 lists the relevant specifications applicable to timber bridge construction. These specifications are directly applicable to timber substructures.

2. 9 MATERIAL SUPPLY

Section 1 provides the basic material supply requirements for timber bridges. Except as noted below, these requirements are directly applicable to timber substructures.

The timber supply requirements outlined in Section 1 shall apply to timber substructure components (and replacement components) except that timber piles, abutment sheeting and other components in ground or water contact shall always be Durability Class 1 or Hazard Level 5 as defined in Section 8.

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