SMALL BRIDGES CONFERENCE 2015

TOPIC TITLE: Repair/Strengthening of a Six Span Timber Rail Bridge

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SYNOPSIS: This paper covers the investigation, contract documentation preparation, and the repair and strengthening of a six span timber rail bridge. The bridge forms part of a rail siding that is used to receive substantial quantities of steel and is critical to the operation of the Orrcon Steel plant in Brisbane. This paper firstly describes the findings of the visual inspections and timber soundings carried out at the bridge before giving an outline of the preparation of contract documents for the repair works. The site works carried out and materials used are then described; which included strengthening of headstocks, installation of anti-splitting bolts, strengthening of sniped corbels, strengthening piped corbels, replacing corbels, strengthening of sniped girders, strengthening of piped girders, replacing girders, placing of supplementary members on piles, splicing piles, splicing bracing, application of grease end treatment, treating components for timber pests, and timber preservative treatment. An outline of the future maintenance and monitoring program developed for the bridge is presented before the paper draws conclusions with particular respect to the results of the project, highlights, and points of difference.

1 - INTRODUCTION

Orrcon Steel is a leading Australian manufacturer and distributor of steel products. The organisation is responsible for the production of products for a range of industries; including construction companies, infrastructure engineering firms and steel fabricators, amongst others.

The vast majority of steel that comes into the Orrcon Steel site in Brisbane gets to the factory via a timber rail bridge (Figure 1), time of construction unknown.

Figure 1 - Orrcon Timber Bridge

The Orrcon Rail Bridge is a 26 m six span, single way rail timber bridge; crossing the Rocky Water Holed Creek in Salisbury, Brisbane. The height of the soffit of the bridge deck above ground level varies from approximately 1 m at the abutments to 4.5 m at the central pier. The superstructure consists of a steel footway on both the left hand side and right hand side of the rail tracks (Figure 2) and hardwood timber deck planks (sleepers) installed transversely. The deck planks are supported by three timber girders (390 – 470 mm diameter) in each span. In terms of the substructure, the girders are supported by three timber corbels (420 – 490 mm diameter) at each pier (no corbels at the abutments) and two timber headstocks (2 no. x 280 x 150 mm) at each abutment and pier (Figure 3). Each pier has three driven timber piles (400 – 490 mm diameter), with three of the piers being supported from lateral movement with two timber cross braces. The abutments are protected from scour and erosion with precast concrete planks acting as abutment sheeting.

Figure 2 – View of Top of Bridge Deck and Walkways

Figure 3 – View of Below Deck Components

On a normal weekday, one fully laden train crosses the bridge into the site, thus substantial quantities of steel coil are delivered each month. Each train consists of multiple wagons arriving on site (each wagon is 20.5 m in length, 4 axles and 74 tonnes fully lade) driven by one locomotive (22 m in length, 6 axles, 132 tonnes).

The Orrcon Steel factory at Salisbury runs 24 hours per day and thus the delivery of steel via the timber rail bridge is crucial to the efficient running and productive business of the facility. In addition, the bridge sits close to a nearby construction college and the approach to the bridge can be accessed by the general public; thus the bridge has become somewhat part of the aesthetics and heritage of the local community. However, an inspection by Queensland Rail (QR) had identified the bridge as being in a poor condition, with very little guidance on what repairs/maintenance were required by Orrcon Steel to maintain its serviceability.

Orrcon Steel commissioned GHD Pty Ltd (GHD) to carry out an initial investigation and provide a repair/strengthening design. Further to this, GHD provided services in relation to selecting contractors for tender, managing communication and RFIs during the tender period, evaluating tender submissions and award of contract.

Professional Bridge Services Pty Ltd (PBS) were the successful tendering contractor and were subsequently commissioned to carry out the site repair/strengthening works required to enable the structure to be returned to a serviceable state (with continued maintenance) in the medium term (25 years). Prior to commencing site works, PBS carried out a Level 2 inspection (including timber drilling) of the bridge in accordance with the guidance provided in the Queensland Government Department of Transport and Main Roads (TMR) 'Bridge Inspection Manual'[1], which allowed the scope of works to be re-visited and agreed prior to site mobilisation.

At completion of site works, GHD provided Registered Professional Engineer of Queensland (RPEQ) sign-off for the project and a plan was also developed by PBS/GHD in order to facilitate the ongoing maintenance and inspection of the structure; allowing the continued use of the rail bridge for delivering steel to the facility for the foreseeable future.

This paper gives some background into timber bridges in Queensland before describing the findings of the inspections and timber soundings carried out at the bridge. The challenges of the project are outlined and an outline of the contract documents used for the repair works is provided. The site works carried out and materials used are then described and an outline of the future maintenance and monitoring program developed for the bridge is presented. Finally, the paper draws conclusions with particular respect to the results of the project, highlights, and points of difference.

2 - TIMBER BRIDGES IN QUEENSLAND

Due to early plentiful supplies of very strong and durable hardwoods, timber initially became the traditional form of bridging used in Queensland from the early 1800's to the early 1900's. Layouts and details were standardised by 1925 and no changes to basic structure and member sizes have been made to the present time. The decline in available timber and the requirement for structures to withstand much heavier loadings than those to which the bridges were originally designed have resulted in the decline in rehabilitation of timber bridges, complete replacement with alternative materials often being the preferred option. TMR (road bridges) typically required girder logs which were 9 m long and 480 mm in diameter while piles could be 10 to 15 m in length. Such timber sizes have simply become difficult to source, requiring much longer lead times for supply. However, timber bridges were built into the early 1960's and it can be seen that these now form an ageing population with a mean age of some 60 years.

In terms of railway bridges, in Queensland alone it was estimated in 2004 that there were over 100 km's of rail bridges consisting of 17,000 spans[2]. In terms of roads, available records indicate that between 1925 and 1970, some 1300 timber bridges were built by TMR in Queensland[3]. In 2010 it was estimated that 366 TMR timber bridges are still in service[4], with the largest population on the lesser class roads. In addition, local governments have responsibility for a large number of timber road bridges that are deteriorating (of the $1.5 billion worth of total timber bridges under local council management in Australia, $0.98 billion of those timber bridges, or around 65% of timber bridges, were determined as being in a poor to very poor state[5]). At the current rate of replacement, it is apparent that there will be an ongoing need for timber bridge management in Queensland for another 20 to 30 years.

Apart from a small number of remaining "all girder" bridges (timber girders touching side by side to form a slab), the typical timber bridge superstructure consists of longitudinal round log girders with transverse sawn timber decking. The typical substructure consists generally of driven timber piles with timber headstocks and bracing, though a number of bridges with concrete substructures were built. Figures 4 and 5 show the main components of the traditional timber bridge in Queensland.

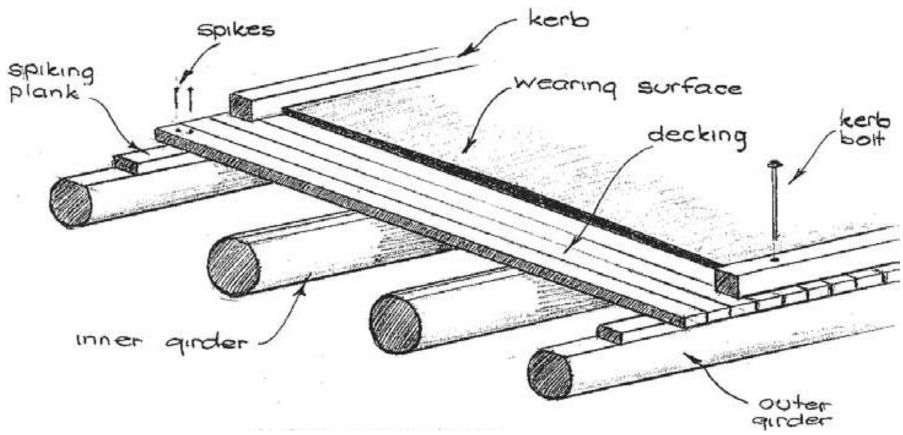


Figure 4 – Typical Superstructure Arrangement

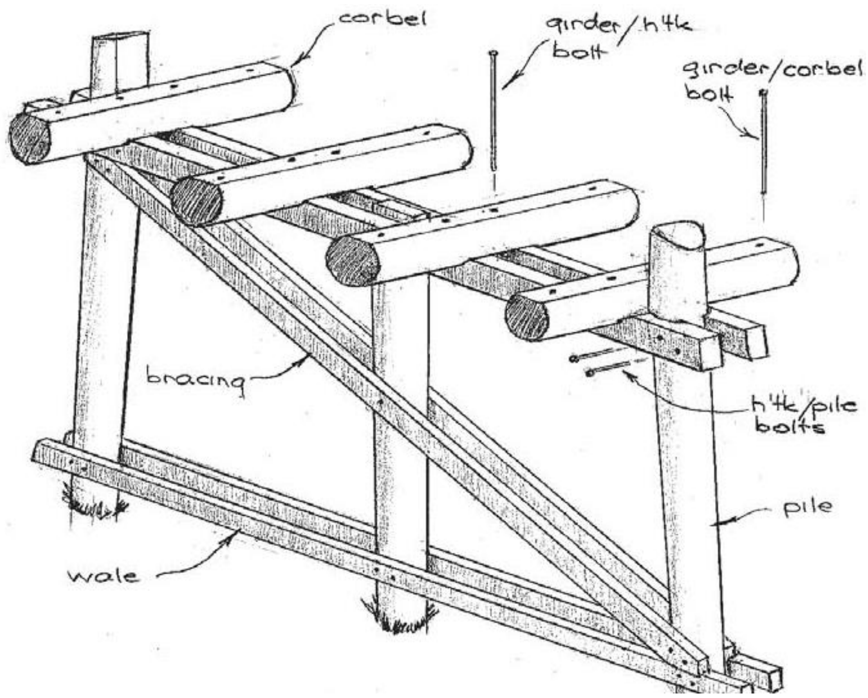


Figure 5 – Typical Substructure Arrangement

One design feature believed unique to Queensland bridges was the use of a spiking plank on top of the outer girders, with no connection of the decking to the inner girders. Cambering (jacking up of internal girders) was used to keep the deck/girder system tight and so reduce rattling. Because girder splitting initiated by deck spiking was absent, one source of girder deterioration was therefore eliminated.

A feature, common in all Australian States, is the use of timber corbels between girders and pier headstocks. Though there are potential structural benefits to girder capacity by introducing partial structural continuity at piers (provided the bolt system is tight), the main reason provided by early sources was that the time before girder replacement, necessitated by end deterioration of girders, could be extended because of the longer support provided by the corbel.

In many cases, the hardwood decking has been replaced by alternative forms such as plywood or steel troughing, while some use of prestressed concrete planking has been made in recent times. Concrete has sometimes been used for substructure components, such as abutments or pier sill bases, where there was inadequate depth for driven piles (generally 4.6 m minimum penetration).

In terms of the current approach to design of timber bridges in Queensland, because of the lack of advice from AUSTROADS on timber design, TMR has basically retained the concept of using the NAASRA Bridge Design Specification 76[6] requirements. Using working stress analysis, allowable bending stresses of 20.7 MPa for normal loads are used while for overload permit analysis, 31 MPa is allowed. As an alternative to the above approach, timber analysis based on using the current AS1720-1997[7] is considered appropriate. Loads, load factor and dynamic load allowance shall be taken from the current AS5100.2[8]. Both these documents are compatible as they are written in Limit State format. However, it would be prudent to note that a new Australian Standard AS5100.9[9], 'Design of Timber Bridges', has been written and is ready for public comment.

3 - INVESTIGATIONS INTO BRIDGE CONDITION

3.1 - Queensland Rail Visual Inspection

An inspection undertaken by Queensland Rail (QR) in June 2010 recommended[10] that rectification works be undertaken to the bridge, based on visual inspection only. Very little guidance was provided as to the specific repairs/maintenance that would be required in order to maintain the serviceability of the bridge.

3.2 - Rentokil Termite Inspections/Treatment

A subterranean termite visual inspection and management report[11], carried out by Rentokil in September 2013, stated that termite damage was present at the sleepers, piers and loose timbers at the bridge. A potential nest was also located near to the bridge. The activity was believed to be due to subterranean termites, Nasutitermes Walkeri. Such termite activity was considered low threat as Nasutitermes Walkeri are considered to usually cause only slight damage and thus normally not structural damage. The activity had reportedly been treated with a baiting system (Figure 6) and the potential nest eradicated, with quarterly monitoring recommended. The timber baiting and monitoring system maintenance service report carried out in January 2014[12] noted that there was nil activity at the bridge at the time of the maintenance inspection.

Figure 6 – Termite Bait Box

3.3 - GHD Initial Inspection and Load Test

GHD carried out a visual inspection with limited timber drillings and trial pits in February 2014. GHD reported[13] that the bridge overall is in a poor condition due to defects affecting its durability. The most significant issues were the piping of several corbels (Figure 7) and girders and the necking and splitting of some of the piles (Figure 8).

Figure 7 – Piped Corbel

Figure 8 – Deteriorated Pile

A total of 57 timber drillings were conducted on accessible locations and these discovered several pipes and soft areas within elements. Trial pit excavation was undertaken using hand tools at two piles and these concluded that there was no noticeable difference in the degree of deterioration below the ground surface at these pile locations.

In addition, the bridge was assessed visually and audibly for indications of distress (Figure 9) while loaded with a typical train delivering steel (multiple wagons plus one locomotive). No significant deflection or sounds of distress were observed.

Figure 9 – Train Passing Over Bridge

The report stated that, if left unchecked, the existing deterioration could lead to some elements justifying a condition rating of 4 (very poor) and the bridge becoming unserviceable in the short to medium term.

The report recommended that a maintenance regime should be developed in accordance with TMR's 'Timber Bridge Maintenance Manual' in order to return the bridge to a fair/sound condition (all elements rated as condition state 2). It was recommended that such a regime should include maintenance intervention options for the specific defects identified during the inspection, plus general routine maintenance.

3.4 - PBS Level 2 Inspection

In September 2014, PBS carried out a full level 2 inspection in accordance with the guidance provided in the TMR 'Bridge Inspection Manual'. This inspection included timber drilling of 'all' timber bridge components and recommendations and costs were provided[14] for repair/strengthening and termite/fungal treatment.

Overall, the structure was found to be in very poor condition, with severe defects having significant negative impact on the structure's integrity, functionality and durability. The report however concluded that with minor maintenance, and at a relatively low cost, the defects could be repaired and an overall condition state rating of two (fair – defects present, but such defects not affecting the durability or structural integrity of the bridge) could be achieved and the lifespan and durability of the structure enhanced. Such maintenance was recommended and a six monthly monitoring regime by a qualified person was also recommended.

There was evidence of subterranean termite activity throughout (Figure 10), causing severe structural damage to the majority of timber components. Although previous inspections indicated a termite genus of Nasutitermes, the findings of this inspection indicated that the termites are more likely Coptotermes Acinaciformis, which are arguably considered to be the most destructive termites in Australia. It was therefore highly recommended that invasive termite treatment be undertaken to eliminate further termite damage to the structure. It was recommended that the termite activity should then be monitored after treatment, with chemical injection re-applied if necessary.

Figure 10 - Termite Tunnelling and Mudding at Girder

It was reported that there was severe fungal decay throughout the majority of the bridge elements, evidenced by the surface of the girders, corbels, headstocks and piles being white and fibrous (a characteristic of White Rot, Figure 11). White Rot significantly reduces the mechanical strength properties of the timber. It was recommended that all timber components be treated with an anti-rot product to prevent further fungal attack.

Figure 11 – Piping and White Rot at End of Headstock

4 - CHALLENGES

Significant challenges presented themselves in carrying out this project; these included challenges from a technical, logistical, health and safety, environmental and societal perspective.

In terms of technical challenges, no design or construction drawings for the bridge were available, and the date of construction of the bridge was unknown. No reliable details of the condition of individual elements were made available during the desktop review of previous inspection reports. From a logistical point of view, the 24 hour production output of the factory needed to be maintained, and this in turn was dependent upon the continued access to the bridge by the steel coil delivery trains between 3 am and 10 am Monday to Friday. Therefore, specific technical repair techniques were required that could be carried out within limited working hour windows. Wholesale demolition and replacement was therefore not considered a viable option.

In addition, the structural stability of the bridge as a whole had to be considered during the repair/strengthening of individual elements; and the bridge needed to be serviceable at the completion of the repairs/strengthening at each element in case of inclement weather delaying works and also the potential for unplanned trains requiring access.

From a health and safety perspective, working on a live railway bridge required considerable thought in the design of the technical solution and its impact upon the health and safety measures required to be implemented during the construction phase of the works. To complicate matters, the site works needed compliance with the health and safety systems/procedures of several potential stakeholders.

The above issues provided an opportunity to justify a repair/strengthening option that would in effect be in compliance with the TMR 'Timber Bridge Maintenance Manual'; with the use of timber wherever possible in the repairs/strengthening adopted. The sustainability benefits arising from the repair/replacement option in comparison to wholesale demolition and reconstruction of the bridge brought with it many environmental benefits; such as minimising the carbon footprint of the works and recycling timber from previously demolished bridges.

From a societal perspective, the repair/strengthening works were designed to be carried out in such a way as to minimise the change in the aesthetics of the bridge, while of course minimising the impact of the site works on the surrounding infrastructure when compared to the haulage movements that would be associated with demolition and reconstruction. Of course, reinstatement of excavated material around the spliced piles and reinstatement of site boundary fences also took place in order to minimise the long term environmental impact of the works.

5 - CONTRACT DOCUMENTATION

In order to address the recommendations provided in the inspection reports, a set of tender documents were provided in order to allow Orrcon to invite Contractors to tender for the repair/strengthening works required. Upon completion of the tender process these documents were review/updated in light of the feedback given during the tender stage and then re-issued as the contract documents for the site works. The 'Contract Documents' for the project comprised the following:

- Technical specification;
- Bill of quantities;
- AS 2124[15] 'General Conditions of Contract' and its completed Orrcon Timber Bridge specific annexures;
- AS 2125[16] 'General Conditions of Tendering and Form of Tender'; and
- AS 2127[17] 'Form of Formal Instrument of Agreement'.

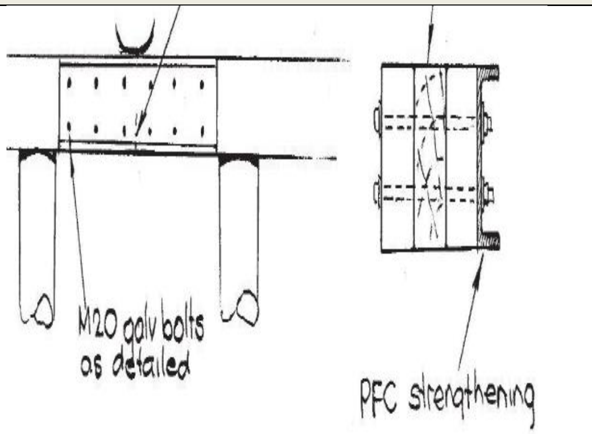
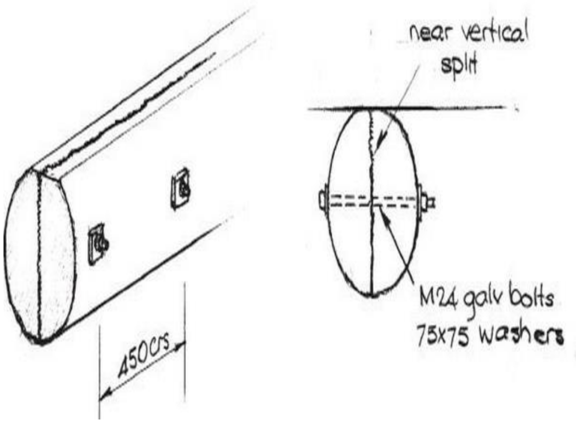
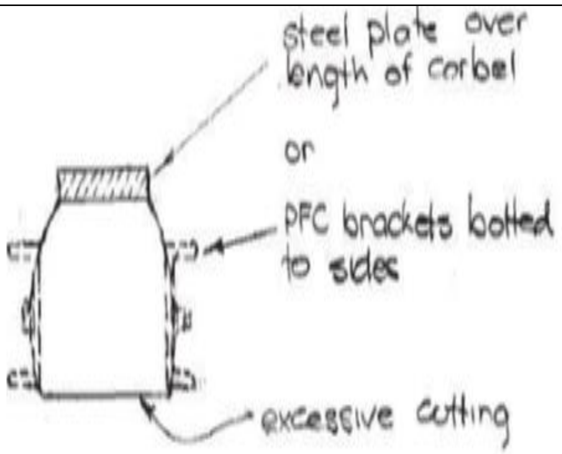
The Principal was Orrcon Manufacturing Pty Ltd, the Superintendent was Daniel Anstice (RPEQ) of GHD and the Contractor was PBS.

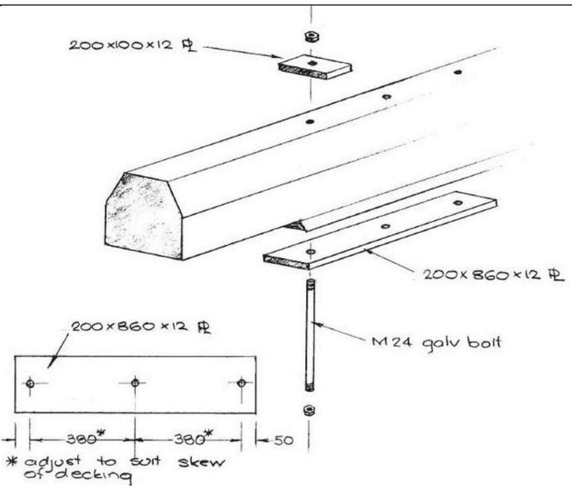
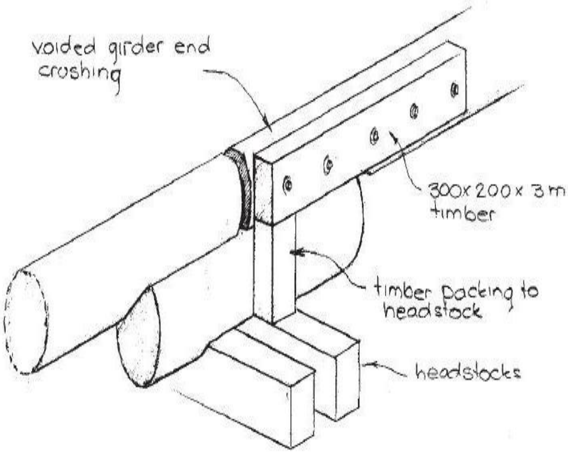
6 - SITE WORKS

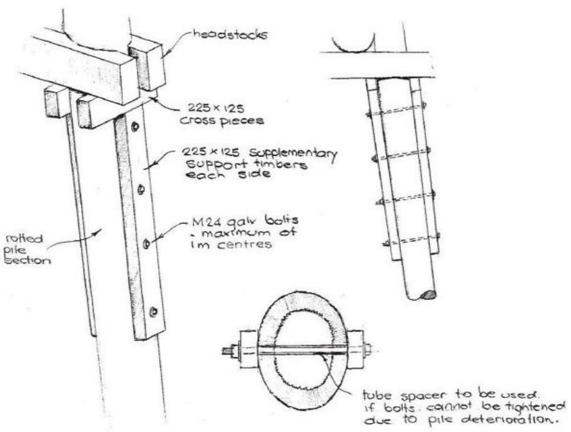
The challenges associated with this project have been outlined in detail in section 5 of this paper, not least (i) the requirement for the continued access to the bridge by the steel coil delivery trains between 3 am and 10 am Monday to Friday, (ii) the structural stability of the bridge as a whole had to be considered during the repair/strengthening of individual elements, and (iii) the requirement for compliance with the health and safety systems/procedures of several potential stakeholders. As also stated in section 5, the chosen repair/strengthening options were in compliance with the TMR 'Timber Bridge Maintenance Manual'. The works were carried out over a four week period in February 2015.

Table 1 below gives a summary of the site activities carried out:

Table 1 – Summary of Site Activities

Activity (TMR Timber Bridge Maintenance Manual Activity No.)	Diagram/Description of Activity	Photograph of Activity
6 no. headstocks strengthened by application of supplementary members (54T1)		
3 no. piles, 2 no. corbels had anti-splitting bolts applied (22T1)		
2 no. over-sniped and piped corbels strengthened (27T1)		

Activity (TMR Timber Bridge Maintenance Manual Activity No.)	Diagram/Description of Activity	Photograph of Activity
6 no. corbels replaced (27T2)	Replace corbel in accordance with activity no. 27T2 of the TMR Timber Bridge Maintenance Manual	
13 no. over-sniped girders strengthened (22T1)		
4 no. piped girders strengthened by application of supplementary members (22T3)		

Activity (TMR Timber Bridge Maintenance Manual Activity No.)	Diagram/Description of Activity	Photograph of Activity
3 no. girders replaced (22T2)	Replace girder in accordance with activity no. 22T2 of the TMR Timber Bridge Maintenance Manual	
1 no. pile strengthened by placing of supplementary members (56T3)		
5 no. piles spliced (56T2)	Splice pile in accordance with activity no. 56T2 of the TMR Timber Bridge Maintenance Manual.	

Activity (TMR Timber Bridge Maintenance Manual Activity No.)	Diagram/Description of Activity	Photograph of Activity
3 no. bracing members spliced (57T2)	Splice bracing in accordance with activity no. 57T2 of the TMR Timber Bridge Maintenance Manual.	
Application of grease end treatment to all member ends and new contact surfaces (100T2)	Apply preservative grease treatment to member ends and contact surfaces in accordance with activity no. 100T2 of the TMR Timber Bridge Maintenance Manual	
Treating all components for timber pests (110T1)	Given the high level of termite infestation, the initial treatment included a full foaming of the components and direct spray in lieu of the original proposed dusting of the internals of each component. A survey of the surrounding area didn't show signs of any termite nests, so it is assumed that the nest was contained within the timber components of the bridge (and was likely removed with component replacement during repair works). The termite treatment therefore consisted of the following: • Injection and foaming of various components utilising Termidor (insecticide) mixed with Termitafoam (foaming agent). • General spraying (external) of the components (with particular attention paid to the joints of the components) via pump spraying using Bixflex Ultra Low Odour (insecticide).	

Activity (TMR Timber Bridge Maintenance Manual Activity No.)	Diagram/Description of Activity	Photograph of Activity
Timber preservative treatment to all elements (100T1)	The timber preservative rods used in this project were Preschem Polesaver Rods which are slow release chalk like rods containing boron and fluoride to help prevent timber rot and termite attack. The rods are activated with moisture (which is the root cause of timber rot) and will stay intact in dry conditions. For this reason, it was recommended that the timber preservative rods be checked annually and replaced if required.	

In terms of the materials used, all fasteners were galvanised grade 8.8 M24 bolts (from an approved TMR supplier).

Timber supply was from a combination of sources (all TMR approved) with the following details:

- Running planks – spotted gum
- All corbels – spotted gum
- All piles – ironbark
- Girders – tallowwood and ironbark.

7 - FUTURE MAINTENANCE PROGRAMME AND MONITORING

7.1 - Termite Treatment

In order to ensure the continued durability and structural integrity of the bridge for the remainder of its planned service life (circa 25 years) a program has been put in place to ensure the bridge be rechecked for termites and retreated if required. It was recommended that both termite and timber preservative treatments occur at least annually to ensure the longevity of the bridge components.

7.2 - Future Inspections and Monitoring

It has been programmed going forward that Level 2 inspections shall occur annually (in conjunction with the timber preservative and termite treatment), the inspections to be carried out in accordance with the TMR ‘Bridge Inspection Manual’.

During future inspections, particular notice is to be taken of the components that have been strengthened during the present project, in order to ensure that the strengthening remains effective. There were a number of components that should be monitored during inspections and intervention required as per the following details.

During the repair works, a number of components were identified as being in worse condition than previously expected (given that termite activity occurs in irregular locations and defects can be worse in unusual areas not identified in normal inspection sampling).

A number of these components were already replaced during the repair works, but a number remain marginal and should be inspected for further deterioration.

Components to be monitored are as follows:

Priority 1 monitoring (will require replacement if condition deteriorates and likely in around 5 years):

- 2 no. girders;
- 3 no. piles; and
- 1 no. corbel.

Priority 2 monitoring (should be programmed for longer term future maintenance):

- 6 no. piles; and
- 2 no. corbels.

8 - CONCLUSIONS

8.1 - Results

- Successful completion of all stages of the project, from initial inspection through to completion of site works and RPEQ sign-off. The following stages were completed in order to transform a significantly deteriorated timber bridge of unknown age, into an appropriately strengthened structure that is suitable for the serviceability requirements to which it is currently subjected:
    - Initial inspection;
    - Level 2 inspection;
    - Repair/strengthening design;
    - Specification and scoping;
    - Tender procurement;
    - Contract Administration;
    - Repair/strengthening construction activities;
    - Preparation of site specific program for future inspections and monitoring; and
    - RPEQ sign-off of completed works. This essentially stated that the repair/strengthening works had been successfully completed as per the guidance laid out in the TMR 'Timber Bridge Maintenance Manual'. It also stated that the bridge now had an enhanced overall condition state rating of 2 (fair), in accordance with the guidance laid out in the TMR 'Bridge Inspection Manual'.

8.2 - Highlights

- No health and safety issues during works.
- Unusual opportunity to witness an ageing timber rail bridge undergo a realistic load test.
- Technically appropriate solution taken from design through to construction.
- Excellent relationships formed and maintained between consultant, client and contractor.

8.3 - Points of Difference

- Minimal impact on the environment; particularly when considered against the alternative of wholesale bridge replacement.
- Minimal societal and community impact occurred; due to retaining the original form of construction, i.e. the structure remains a timber bridge, and minimising disruption to the Orrcon factory and the surrounding roads and railway lines.
- Excellent example of collaborative working, a model case study for similar future projects.

9 - REFERENCES

[1]'Bridge Inspection Manual', Queensland Government Department of Transport and Main Roads (TMR), 2005.

[2]'An investigation into the rehabilitation of timber structures with fibre composite materials', Humphreys, M.F. and Francey, K.L., 2004.

[3]'Timber Bridge Maintenance Manual', Queensland Government Department of Transport and Main Roads (TMR) 2004.

[4]'Infrastructure Report Card 2010 – Queensland', Engineers Australia, 2010.

[5]'The Australian Local Government Association's (ALGA) National State of the Assets 2013 report', ALGA's 2013 National Local Roads and Transport Congress, 2013.

[6]'NAASRA Bridge Design Specification', National Association of Australian State Road Authorities, 1976.

[7]AS1720, 'Timber Structures', 1997.

[8]AS5100.2, 'Bridge Design – Design Loads', 2004.

[9]'The New Australian Standard AS5100 - Part 9: Timber Bridges', 9th Austroads Bridge Conference, Sydney, New South Wales, 2014.

[10]'Orrcon Bridge Inspection', Queensland Rail, June 2010.

[11]'Subterranean Termite Visual Inspection and Management Report', Rentokil, September 2013.

[12]'Timber Baiting and Monitoring System Maintenance Service Report', Rentokil, January 2014.

[13]'Timber Rail Bridge – Visual Inspection and Timber Soundings', GHD Pty Ltd, February 2014.

[14]'Level 2 Inspection Report', Orrcon Rail Bridge, Professional Bridge Services Pty Ltd, September 2014.

[15]AS2124, 'General Conditions of Contract', Standards Australia, 1992.

[16]AS2125, 'General Conditions of Tendering and Form of Tender', 1992.

[17]AS2127, ''Form of Formal Instrument of Agreement', 1992.