Key Issues and Budget Constraints with Replacing Rural, Low Traffic Volume Bridges. Case Study: Steel I-Beam Bridge Replacements using Glued Laminated Timber

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ABSTRACT

In October of 2017, Wood Research and Development (WRD) was commissioned to inspect several bridge sites in the Cassowary Coast Regional Council (CCRC). Accurate bridge dimensions, elevations and the overall condition of the structural elements were collected and sent through to the design team in Caboolture. This information was critical for the design engineers as the existing abutments were to be reused where possible and the glulam timber replacement designs had to marry into the existing road profile within 50mm +/-.

By mid-November a purchase order was issued for the supply and installation of treated glulam bridges. By March of 2018, the delivery of all the material was achieved and in May after the wet season was over the bridges were delivered to site ready for installation. Over the 2 weeks that followed Timber Restoration Systems (TRS) worked with the CCRC bridge crew to successfully demolish and replace four bridges with a maximum road closure duration of 2 days.

This presentation touches on some of the key issues and budget constraints that work in tandem with replacing ageing bridges in rural communities that service a low volume of traffic and a small percentage of people within the community. A case study that discusses the recent replacement of several steel I Beam bridges for the CCRC is presented and shows how TRS worked through these issues and constraints with CCRC.

The case study dives further into the overall timeline of the project from inspection and design through to prefabrication and shipping, construction and installation. Learning outcomes include how TRS dealt with the fast-paced work environment to turn around a project of this scale as well as the successful navigation of the key issues and budget constraints such projects entail.

1 INTRODUCTION

Wood Research and Development (WRD) was commissioned by Cassowary Coast Regional Council (CCRC) to inspect and design replacement bridges for four steel I-Beam bridges utilizing the existing abutments where possible, maintaining/increasing creek flow clearance and keeping within 50mm tolerances of the existing road elevation. The material of choice to design and construct the superstructure, deck and kerb system was the tried and tested Pentachlorophenol (Penta) treated Glued Laminated Douglas Fir (Glulam).

Since 2010, WRD and Timber Restoration Systems (TRS) have worked closely with CCRC to replace and restore 32 of their ageing timber, steel and concrete bridges with new Penta treated glulam bridges and hybrid alternatives. Many of the existing substructures have been retained to support the refurbished asset due to the lightweight nature timber has to offer.

Cassowary Coast Regional Council has begun replacing their ageing corroding steel bridges after just 20 years of service to the community. The new Penta treated glulam structures have a design life of 100 years with minimal maintenance. Where corrosion and rust were particularly bad, 316 stainless steel fasteners and brackets were used to connect the glulam section together and hold down the structure.

2 THE CASE STUDY

2.1 Inspection

In October of 2017, WRD Bridge technicians travelled to CCRC to inspect four steel girder bridges up for replacement - Seres Road Bridge, South Ramleh Road Bridge, Koombooloo Creek Bridge and Cowley Creek Road Bridge. King Road Bridge, a two-span hardwood timber bridge, was also inspected at this time. Measurements were taken for each of the 5 bridges which was then sent through to the design team. The condition of the I-Beam superstructure for Seres Road, South Ramleh Road and Koombooloo Creek bridges was very poor. The lower flanges in all 3 bridges were delaminating and could be peeled away with ease.

Seres Road Bridge:

- 14.3m Single Span
- 4.3m wide hardwood timber deck with timber running planks
- Four 610UB Steel I-Beams

Figure 1 – Seres Road Bridge: The hold down fasteners have rusted away. The protective paint was beginning to flake away and rust had set in eating away at the connection plate.

Koombooloo Creek Bridge:

- 10.5m Single Span
- 3.6m wide hardwood timber deck with timber running planks
- Three Steel I-Beams
- Heavy skew in both abutments

Figure 2 – Koombooloo Creek Bridge: The hold down connection plates and fasteners have rusted away. The bottom flange of these steel I-Beams had delaminated and peel away at the touch.

Koombooloo Creek Bridge had the worst affected set of I-Beams since it is located only metres away from the Pacific Ocean coast line. It was recommended that stainless steel 316 fasteners and brackets be adopted for the Koombooloo Creek Bridge given its location; a worthwhile investment to reduce maintenance and replacement costs later in the asset's life.

The Koombooloo Creek Bridge services a caravan park which in peak season accommodates a lot of tourists. It was crucial that the existing bridge be removed, and the replacement bridge be installed in a 12-hour window to avoid holding up the tourists.

South Ramleh Road Bridge:

- 12m Single Span
- 4.0m wide hardwood timber deck with timber running planks
- 3 Steel I-Beams

Figure 3 – South Ramleh Road Bridge: The top flange had begun to rust away where the paint had flaked and left the raw steel exposed. The bottom flange, near stagnant water all year round, was in poor condition and beginning to delaminate.

Cowley Creek Road Bridge:

- 16.7m Dual Span Steel I-Beam with plywood deck
- 4.4m wide
- Four 460UB Steel I-Beams
- A new dual lane clear span replacement option has been designed and prefabricated on site ready for installation

Figure 4 – Cowley Creek Road Bridge: Notice the crack in the existing concrete headstock. This is partially due to significant undermining under the wingwall attached to the headstock.

The Cowley Creek Road Bridge is currently a two-span single lane bridge with a concrete substructure, built back in the 1960's with four steel I-beams and a timber plywood deck and kerb system. CCRC wanted to change the bridge to a dual lane clear span structure. The replacement design utilised the existing abutments by extending them using screw piles for the foundation support. However, while prefabricating the glulam superstructure, deck and crashproof rail system, a dilapidation survey was completed on the substructure which, due to further concrete deterioration, condemned the existing substructure from supporting the new bridge. New abutments have been designed to replace the existing with works about to commence on site.

2.2 Design and CAD

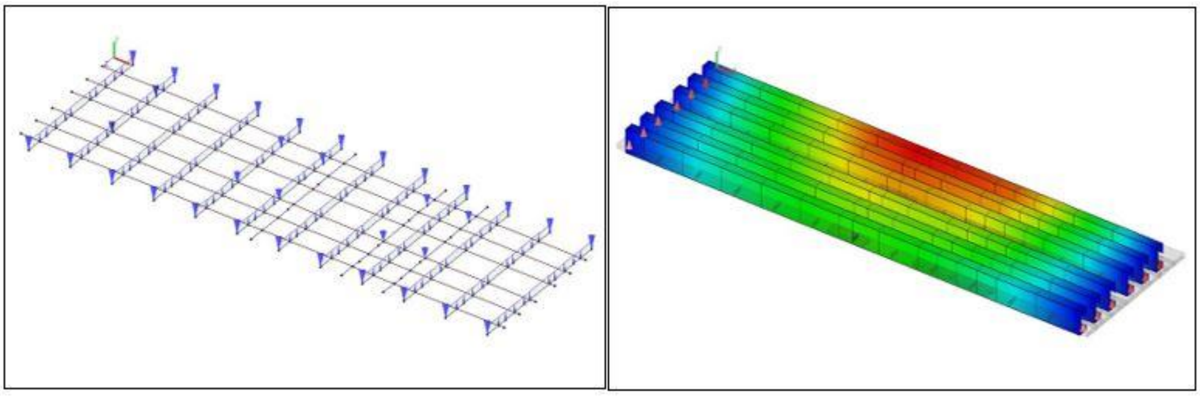

Figure 5 – Multiframe design of Seres Road Bridge.

Each bridge was designed in Multiframe 4D to meet the design brief. Each bridge has been designed to marry into the existing road profile, support an asphalt overlay and T44 Live loadings. The bridges design life of 100 years was to be met and lateral loading was to be considered and accounted for when overtopping events occurred during the wet season.

Once the bridges were designed, the specifications were sent to the drafting team to draw. Each bridge spent roughly 1 week being drafted and once ready the drawings were issued to the client for final review along with a revised cost firm quote for approval. Shortly after being issued the revised quotes and CAD drawings, a purchase order and material deposit was received for the tailored bridge designs.

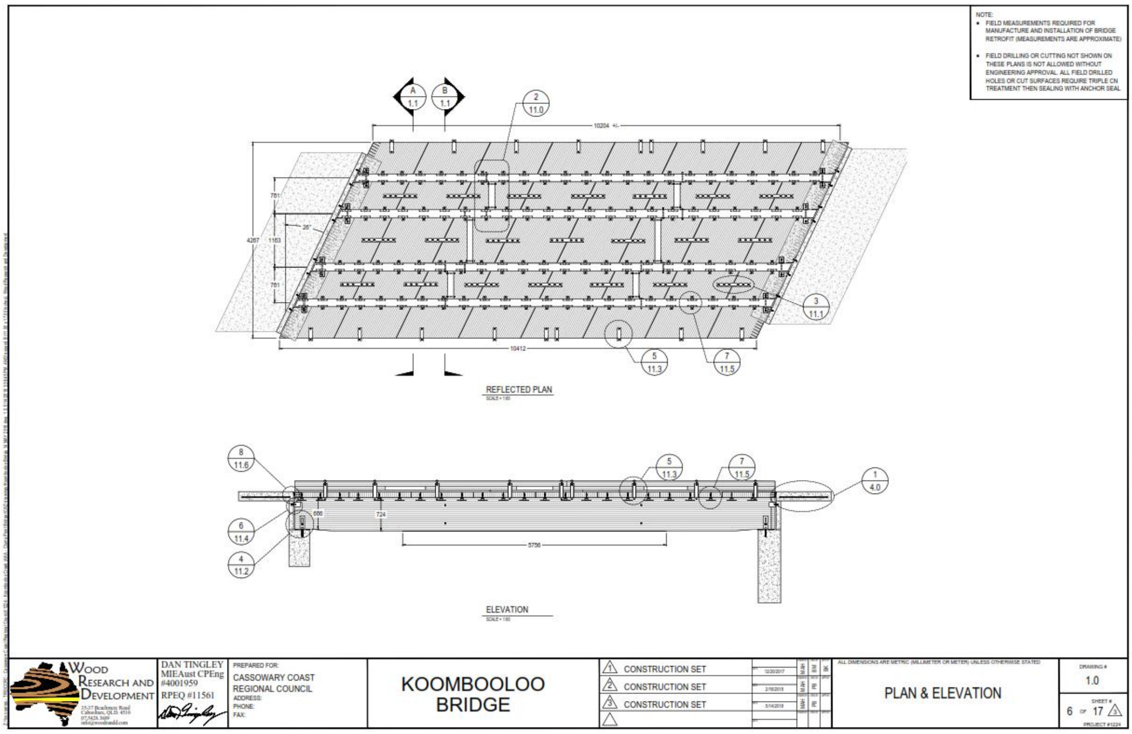

Figure 6 – CAD drawing of Koombooloo Creek Bridge

The new replacement Penta treated, incised glulam superstructure and deck replacements are lightweight and stout in their design to marry into the existing road elevation. This design is 36% less costly than typical steel replacements. Another significant saving to the client is the ability to reuse the existing abutments. Typically, substructures are 60% the cost of a bridge and require expensive detours or side tracks. Having the ability to reuse a substructure to support the lightweight timber minimizes traffic disruptions as well as the disruption to the surrounding environment and associated costs to suit.

2.3 Prefabrication, Shipping and Delivery to Australia

Figure 8 – Prefabrication of the bridges in Jefferson, Oregon.

Each glulam bridge is built from glulam billets that are procured by TRS' facility in Jefferson, Oregon. Shop drawings are supplied to the technicians who transfer all the relevant connection and design details onto the billets ready for fabrication. All these details are cut, drilled and test fitted prior to being sent to the treatment plants. By cutting and drilling prior to treatment, you guarantee the glulam elements will be thoroughly treated and brightwood will be unexposed.

Once treated, the glulam beams and panels are stacked into 40ft containers and trucked to the loading docks where they'll be loaded onto vessels headed for Australia. Longer beams, anything over 12m, must be bundled together and loaded onto the tops of the containers as breakbulk items.

The vessels are typically on the water for 4-6 weeks and only a certain number per year handle breakbulk items.

Figure 9 – Delivery of the glulam components to TRS' Caboolture office in Queensland.

Once the vessel arrives in Brisbane the containers and breakbulk items must clear Customs. Once cleared they're loaded onto semi's and delivered to TRS' Caboolture yard in Queensland. The containers are opened and left to air for 24 hours before the unpacking begins.

2.4 Transportation to site and Construction

Once the containers have aired out, the glulam is unpacked and stacked in the yard. Multiple bridges are often in one container so once each item is removed the contents are cross checked with the plans and stacked ready for its trial layout. Generally, it takes a full day to unpack and stack a container which typically holds 44,000lbs (approx. 20T) worth of material (US weight limit threshold without needing specialized trucks and trailer combinations for transportation).

Figure 9 shows both the delivery of the breakbulk glulam girder, bundled and wrapped, and a 40ft container ready to be unpacked and stacked.

Figure 10 –Trail Layout of the Koombooloo Creek bridge and loading for transportation to site

Each bridge that leaves the Caboolture yard is test fitted and bundled ready for delivery to site. This ensures all components are in hand before mobilization commences. By checking and double-checking, this avoids shortages on site that prove costly, since some of the elements are specially fabricated.

Semi trailers and B-Doubles are commonly used to transport the bridges to site. Each timber component is stacked according to a trailer plan which is calculated to distribute the load evenly across the length of the trailer.

Figure 11 – Demolition and installation of the Seres Road Bridge in CCRC

A timber solution can be prefabricated on site whilst the existing structure is being demolished and be ready in certain cases for an afternoon lift and install. The Seres Road bridge was testimony to this. A 200T crane was on site the morning after the bridge was demolished, ready to lift the old I-beams out and the 14T glulam replacement bridge into position.

Koombooloo Creek Bridge's superstructure was built off to the side of the road ready to be craned into place using a 25T Franna. Once fabricated, the next morning TRS and the CCRC bridge crew demolished the old deck and kerb system, removed the steel superstructure and replaced it with the prefabricated glulam superstructure, lifted and installed 8 glulam deck panels, installed the concrete relieving slab and reopened the road in a 12hr day shift. It's critical that the pre-site inspection is done with precision accuracy, especially when dealing with heavy skews and the existing abutments. Should these measurements have been out, reopening the road within 12 hours of closing it would not have been achieved. Trimming the glulam is never an option as it exposes brightwood which can reduce the life of the treated glulam bridge if not properly maintained.

South Ramleh Road Bridge and King Road Bridge were stick built as the road corridor allowed for road closure and both abutments required repair and replacement works. King Road, previously a 2-span hardwood timber structure, was replaced with a single span treated glulam bridge superstructure on new precast concrete footings keyed in behind the old timber pile bents. The clear span alternative opened the creek for better channel flow.

South Ramleh Road Bridge was installed on refurbished concrete abutments. A backfilled bypass, which was piped to allow for stream flow in rain events, was constructed upstream for traffic to utilize whilst the bridge was shut.

Cowley Creek Road Bridge has been prefabricated on an adjacent property where it awaits to be lifted into place using a 250T All Terrain Crane in Far North Queensland. New concrete abutments, which will be formed and poured in-situ once the existing structure has been demolished, are in the design and planning stage at present and will be installed after the wet season.

Figure 12 – Fabricated Cowley Creek Road Bridge on site awaiting installation.

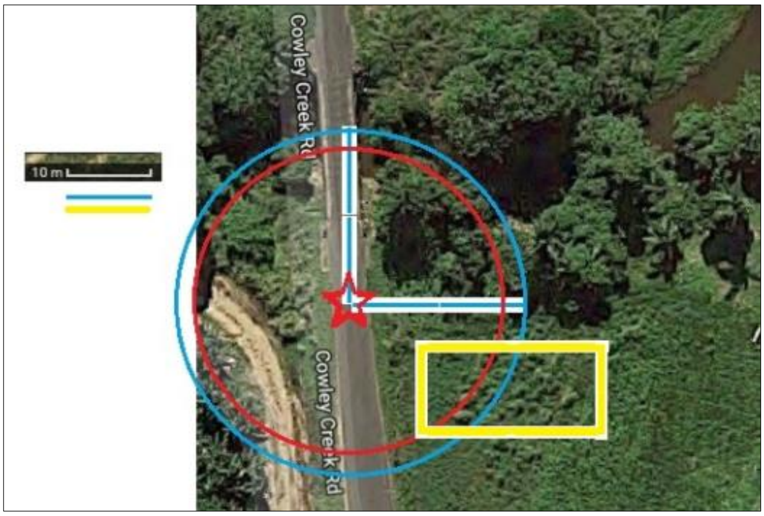

Figure 13 – Cowley Creek Road Bridge staging area and single lift radii with the 250T All Terrain Crane.

3 KEY ISSUES AND BUDGET CONSTRAINTS

When replacing bridges on low volume rural roads, there are several constraints and issues that present as a challenge to be dealt with;

1. Due to budget constraints on low usage roads, these back road bridges lack the maintenance regimen for the environment they are in. The high moisture, acidic and/or salt air environment is severely detrimental to I-Beam superstructures.
2. The poor condition offers a lower level of service to the community (reduced load rating, increased maintenance).
3. Some of these bridges are heavily relied on. No alternative access and/or lengthy detours are available and thus often expensive or environmentally disturbing by-passes are required should the bridge be put out of service.
4. Lack of knowledge of how to service and maintain these bridges. In high humidity and/or salt air environments, steel I-beams require constant attention to their protective coatings. If rust becomes prevalent, sandblasting and repainting/galvanising becomes a significant cost to the maintenance of the bridge especially if it needs to be done off-site. This is often overlooked in the 5-10 year maintenance plan.
5. Dealing with the different expectations of the bridge's level of service. i.e. community expectation vs. council's expectation.
6. Minimise mistakes from a design and/or construction aspect to ensure brightwood is not exposed. Don't rely on maintenance to alleviate mistakes.
7. Ensure all bridge components, fasteners, brackets and timber, are accounted for prior to sending the bridge to site. Any missed items are costly to resolve once on site.
8. Environmental issues that come with heavy excavations or machinery work at creek level. Having the ability to reuse the substructure reduces the amount of site disturbance and level of disruption to the surrounding environment as well as saves costs.

Budget constraints make it harder to service these bridges;

1. Bridges that service few rate payers have limited funds to maintain and repair the asset.
2. In some cases, a bridge that is put out of service immediately, due to a L3 report or failure, may not have the funds available for quick repair and may not be available for quite some time.
3. Replacing the bridge completely, substructure, superstructure and deck writes off any residual current value the structure holds. Having the ability to reuse the substructure or repair/replace elements in kind means that the residual current value is not written off. This has advantages in that not as much money is required to repair the asset back in future years.

Council and TRS have a developed a good working relationship where TRS bridge technicians are subcontracted into the CCRC bridge crew. This keeps the bridge crew active within the council, working on projects with TRS under a subcontract arrangement which helps ease the costs of replacing these bridges within the community.

4 CONCLUSION

Rural roads in low usage areas suffer from neglect from a number of causes – budget constraints and a lack of maintenance (out of sight, out of mind). Using steel I-beams, many bridge builders and owners believed that the steel provided a long term solution requiring minimal maintenance if any. However, this presentation has shown that high humidity, acidic and/or salt air environments can have harmful effects on steel such as delamination of the flanges and connections without regular maintenance.

By providing prefabricated treated glulam bridges to Councils, TRS have been able to present a model that allows Council crews to assemble and install within a timeframe that minimises road closure. Whilst a bridge repair/replacement is welcome by the community, for many of these rural communities, a bridge closure is a major impediment to their daily lives with detours being quite winding and long.

Being able to reuse the existing substructure obviously saves significant costs, but very importantly, it also saves time and environmental issues. Having a lightweight bridge superstructure and a fabrication system that Council crews can easily assemble converts to both a quick construction and installation and a grateful community.

5 ACKNOWLEDGEMENTS

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Wood Research and Development Pty Ltd

6 AUTHOR BIOGRAPHY

Patrick (Pat) Bigg graduated from University of Tasmania with a Bachelor of Engineering (Civil) in 2014. Following a year in Tasmanian Local Government, he joined Wood Research and Development in 2016 as a Timber Structures Engineer where he has specialised in the design of bridge elements, complex connections within timber structures and Multi-frame modelling of structures.

Following several stints as site engineer for bridge retrofit and renewal projects, Pat has now taken up the position of General Manager Australia for Timber Restoration Systems.