Laidley Timber Rail Bridges Replacement

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ABSTRACT

Queensland Rail undertook a project to replace three existing ageing timber rail bridges west of Laidley, Queensland. The purpose of the project was to improve reliability, operational safety and efficiency of services on the rail corridor. In late 2014, Queensland Rail awarded a contract to JF Hull Holdings Pty Ltd (JFH) for the design and construction of new structures to replace the existing timber bridges. Kellogg Brown & Root (KBR) was engaged by JFH for the design component.

A key challenge in the project was to demolish the three existing timber bridges, install the new structures and restore the services in three separate 48-hour full track closures. The short timeframe track closures were planned by Queensland Rail to minimise disruption to freight and passenger train services. KBR and JFH examined risks associated with the project requirements and proposed an effective solution to replace the existing timber bridges with precast box culverts supported on precast base slabs which were joined together by cast in-situ stitches. The proposed precast structures enabled the construction team to install them in place within the short allocated timeframe. KBR design team carried out detailed design of precast base slabs with cast in-situ stitches, precast wing walls, cast in-situ apron slabs and cast in-situ kerbs. Construction staging was also undertaken in the design to allow installation of precast boxes, backfilling and track works prior to casting in-situ stitches to form complete base slabs. The precast box culverts were designed by a third party. Two large box culverts were designed to replace the three existing rail bridges. The new structures were required to be designed to support dual ballasted tracks with Queensland Rail QR-300A railway loading at each bridge location. Existing rail levels were to be maintained while flood efficiency of the new structures was improved after the construction. The main works to be carried out in the construction were demolition of the existing timber bridges, removal of unsuitable materials, subgrade improvement, installation of new structures, earth works and embankment formation at approaches, track works and restoration of the existing services.

KEYWORDS: Bridge replacement, precast box culvert, precast base slab, construction stage, cast in-situ stitch, 48-hour track closure

1 INTRODUCTION

Queensland Rail undertook a project to replace three existing deteriorating rail bridges located on the Main Line between Laidley and Forest Hill, west of Ipswich, Queensland. The bridge replacement was planned to minimise disruption to passenger and rail freight services on the line. Thus, Queensland Rail intended to close the line for 48 hours at each bridge location for the bridge replacement work. For the short allotted timeframe works, precast concrete structures with construction staging were adopted for the bridge replacement. The three rail bridges were replaced with precast box culverts supported by precast base slabs which were joined together by in-situ stitch pours at a later stage.

In November 2014, JFH was awarded a contract by Queensland Rail to carry out the design and construction of the new structures to replace the three existing rail bridges. KBR was engaged by JFH for the design component, except for the design of precast box culverts which was undertaken by a third party.

The construction works to be carried out for the bridge replacements were demolition/removal of the existing rail bridge structures, removal of unsuitable materials, subgrade improvement, installation of new structures, earth works and embankment formation at approaches, track works, scour protection and restoration of the existing services.

2 EXISTING STRUCTURES

The three existing bridges were located at chainage 83.190 km, 83.930 km and 84.000 km on the Main Line. All bridges were dual-track rail bridges. Table 1 and Figure 1 to 3 describe the approximate detailing of the existing structures.

Table 1: Existing bridge details

Bridge location	Structure description	Approximate length (m)	Figure
83.190 km	Timber superstructure Timber and concrete substructure	6 x 5.0 m spans = 30.0	Figure 1
83.930 km	Steel beams Concrete piers/abutments	3 x 2.1 m spans = 6.3	Figure 2
84.000 km	Timber superstructure and substructure	6 x 5.7 m spans = 34.2	Figure 3

Figure 1- Existing structure at 83.190 km

Figure 2- Existing structure at 83.930 km

Figure 3- Existing structure at 84.000 km

3 HYDRAULIC ASSESSMENT

The three existing rail bridges were proposed to be replaced by two culvert crossings. The bridges at 83.930 km and 84.000 km were replaced by one culvert crossing (eliminating the crossing at 83.930 km). Two upgrade options were studied as part of the hydraulic assessment:

- Base concept upgrade: increasing the total waterway area by 30% at each bridge location.
- Alternate option upgrade: reduced the number of culverts at each location by two and reduced culvert height at 83.190 km by 200 mm.

From the hydraulic assessment, the Base concept upgrade caused afflux issues on the downstream side whereas the Alternate option upgrade reduces the impact of the culvert crossings on water levels both upstream and downstream whilst still increasing the waterway efficiency of the crossings. The Alternate option upgrade was preferred and proceeded to detailed design. The upgrade proposed replacing the existing rail bridge at 83.190 km by 11 cells of 2764 x 1300 mm box culvert and the existing bridges at 83.930 km and 84.000 km by a crossing comprising 20 cells of 2350 x 900 mm box culvert. The two existing timber bridges at 8.930 km and 84.000 km which were 40.5 m long altogether, were replaced by a 57.18m long culvert. Table 2 presents the proposed upgrade option of waterway crossings which was adopted for the detailed design. The culvert sizes presented in this table were preliminarily chosen by the hydraulic engineer to perform the hydraulic analysis.

Table 2: Upgrade crossing culvert details

Bridge location	**Number of culverts**	**Culvert width (mm)**	**Culvert height (mm)**	**Total waterway area (m2)**
83.190 km	11	2670	1300	38.24
83.930 km	N/A*	N/A*	N/A*	N/A*
84.000 km	20	2350	900	42.3

* Crossing eliminated

The hydraulic assessment also showed that the upgraded culvert crossings conveyed more flow than the existing bridges resulting in an increase in water level on the downstream (eastern) side of the embankment and a reduction in water level on the upstream (western) side of the embankment. This result is proven in both the 100 and 2000 year ARI events. Overtopping of the railway occurs at the 84.000 km culvert crossing in both the 100 and 2000 year ARI events whereas no overtopping occurs at the crossing at 83.190 km in the 100 year ARI event.

Scour protection was studied using Queensland Urban Drainage Manual (QUDM, DEWS, 2013), AustRoads (2010) and AustRoads (2013) for the 100 year ARI event as per Queensland Rail specifications. From the assessment, scour protection is required at both upgraded crossings at inlet, outlet and approach embankments.

4 GEOTECHNICAL CONDITION AND SUB-BASE DESIGN

Subsurface conditions were investigated at each bridge site by drilling and sampling 4 boreholes to depths of 4.5 m. The investigation works were carried out by a different JFH sub consultant. The subsurface profile generally comprises surficial clayed sandy gravel and clays to the termination of testing.

From the preliminary analysis, an allowable bearing capacity of 200 kPa was required to support dead weights and railway loads for the culverts at both locations. It was advised that a factor of safety (FoS) of 3.0 was to be adopted for long-term bearing capacity and for a short-term load, a factor of safety of 2.0 could be used. It was envisaged that the design immediate settlement would be around 5 mm. To achieve a 200 kPa allowable bearing capacity and to reduce potential settlement, the project geotechnical engineer recommended removal and replacement of sub-base material to be undertaken under the proposed culvert base slabs. The recommended nominal excavation depths below the underside of base slab were required to replace the existing soil of 1.0 m for the culverts at 83.190 km and 1.2 m for the culverts at 84.000 km. Thickness and sub-base material were designed as follows:

- 100 to 150 mm thick base course gravel
- 250 mm thick 200-80 crushed rock layer
- 700 to 750 mm thick single layer of 200-80 crushed rock

Details of design sub-base is illustrated in Figure 4.

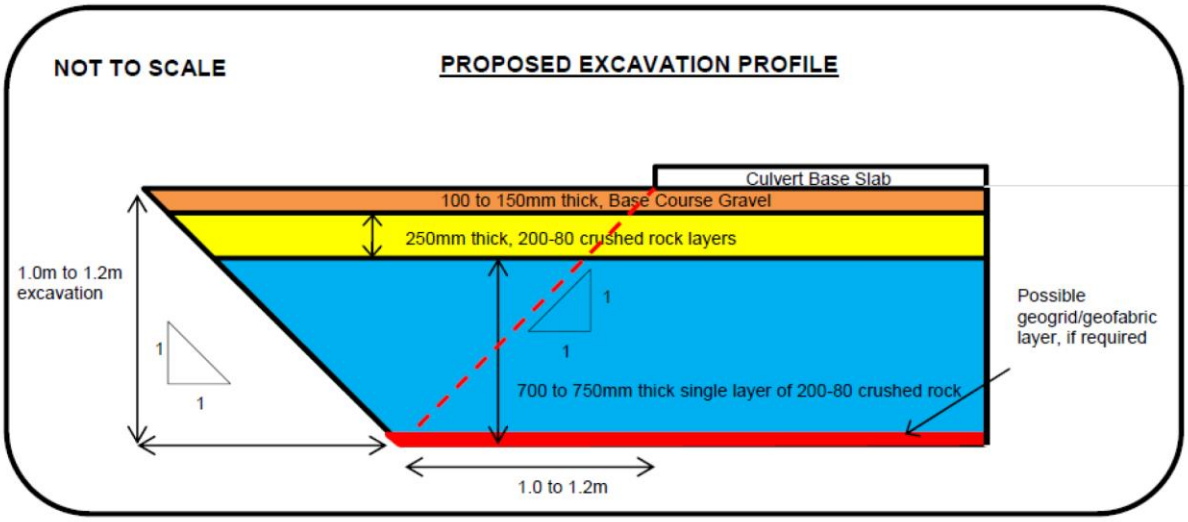

Figure 4- Sub-base profile (Source: Soil Surveys)

5 DESIGN OF CULVERT BASE SLABS

The culverts at both locations were required to be designed to support dual ballasted tracks with Queensland Rail QR-300A railway loading. The tracks centres are spaced 3.66 m apart. Average intensity of live loads on top of the culverts was calculated in accordance with AS 1597.2-2013, Australian Standard Precast Reinforced Concrete Box Culverts. 100 year design life and concrete exposure classification B2 were adopted for design of all structural elements. All concrete elements were designed in accordance with Australian Bridge Design Standard, AS 5100.5-2004.

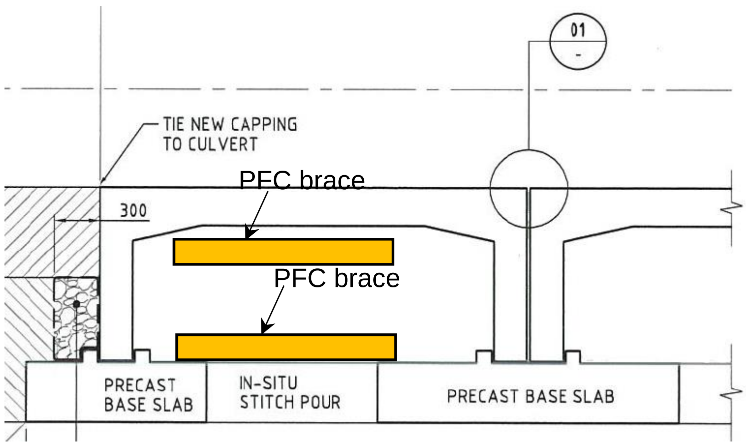

Figure 5- Typical base slab, bracing and stitch pour

Due to the restricted 48-hour track closure, it was proposed to install the precast box culverts on precast reinforced concrete base slabs which were arranged transversely under the culvert legs. The sizes of precast slab are 1200x8800 mm for the first and last slab, and 2200x8800mm for the intermediate slab. All slabs are 400mm thick. The precast base slabs were designed as strip footings to support dead load, superimposed dead load and live load. Bearing pressure under soffit of the precast base slabs was checked to ensure that it does not exceed the allowable bearing capacity. The gaps between the precast base slabs were temporarily braced by a series of steel channel beams connecting all precast base slabs. The steel beams were connected to the precast base slabs by anchor bolts. The purpose of using bracing was to enhance longitudinal restraint of the precast base slabs against lateral earth pressure behind each culvert end and braking/traction force generated by train loading. The gaps were filled later with cast in-situ concrete to form a complete continuous base slab and the channel beam braces were removed a minimum of 14 day after casting in-situ stitch pours. Transverse expansion joints were also provided across the base slabs to accommodate slab longitudinal movements while load transfer to adjacent slabs is maintained through dowel bars. Two expansion joints were required for the culvert slab at 83.190 km whereas four expansion joints were needed for the culvert slab at 84.000 km.

Because the culvert at 84.000 km is 57.180 m long (20 Nos. x 2840 mm), the bridge replacement work was unable to be completed within the 48-hour shutdown. Two construction stages were planned for the bridge replacement work within two separate 48-hour shutdowns at this location. Stage 1involved complete removal of the existing bridge, earthworks, sub-base construction, installation of base slabs and culverts, and track works for approximately 37 m long (13 culvert units) in the first 48-hour track closure. Stage 2 included installation of culverts and track works for the last 7 culvert units in the second 48-hour track shutdown.

As mentioned earlier, the crossing at 83.930 km was eliminated. The existing bridge was demolished and replaced with typical rail embankment formation.

6 CONSTRUCTION SEQUENCE

Due to the timeframe restriction for the bridge replacement works, KBR design team proposed the following construction sequence for both culvert locations.

1. Detach and remove existing ballast, sleepers and tracks from defined construction area
2. Demolish and remove all parts of existing bridges
3. Excavate and remove unsuitable materials
4. Backfill and compact crushed rock sub-base and base course
5. Install precast base slabs and temporary braces
6. Install precast culvert units
7. Install precast wing walls and temporary brackets
8. Backfill behind first and last culver units and wing walls
9. Construct rail formation at both approaches
10. Install ballast, sleepers, tracks and walkways

Tracks are then ready for service

11. Cast stitch pours between precast base slabs
12. Fill rock, cast blinding concrete and apron slab upstream and downstream
13. Remove temporary braces a minimum of 14 days after casting stitch pours
14. Clean up

7 CONCLUSION

The two deteriorating rail bridges in Laidley were replaced by two large box culverts. The small rail bridge was demolished and replaced with a normal rail embankment; the waterway crossing was eliminated in this location. The proposed precast structures and construction staging/sequencing enabled the construction team to complete the bridge replacement works within the short allocated timeframe without any delays. The bridge replacement works were completed in August 2015.

Figure 6- Culvert at 83.190 km

8 ACKNOWLEDGEMENTS

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11 AUTHOR BIOGRAPHY

Sunthara obtained his bachelor's degree in civil engineering in 1993 at the Kharkov Institute of Municipal Engineers in Ukraine. In 2000, he pursued a postgraduate study at the University of New South Wales in Sydney and obtained his master's degree in structural engineering. Sunthara has been working as a structural engineer in Cambodia and Australia. His main duties involve structural design of bridges and civil structures.