Abstract
The Queensland Department of Main Roads (QDMR) has been actively involved in fibre composite bridge research for several years. The Taromeo Creek Bridge project is the most recent research project developed by Wagners Composite Fibre Technologies (CFT) and QDMR. Taromeo Creek Bridge is the first fibre composite bridge deck to be put into service on the Queensland state-controlled road network. One of the main focuses of the research is to develop a range of economically viable fibre composite bridge deck solutions.

Introduction
QDMR is involved in fibre composite bridge research for a number of reasons. Previously, research has concentrated on evaluating state-of-the-art fibre composite bridge technologies from engineering and manufacturing perspectives. As well as satisfying engineering objectives, the Taromeo Creek Bridge project ventures to understand the economics of fibre composite bridges in the Australian context.

QDMR objectives for the project are described below.
- Identify niche applications of fibre composite bridge technology that may allow such technologies to be nurtured and developed until they become more applicable to general bridge applications
- More fully understand the current nature of the fibre composite industry in Australia
- Identify growth needs of the industry such that this emerging industry is compatible with Main Roads requirements
- Identify issues associated with combining fibre composite superstructure technologies with conventional bridge technologies

In addition, subsequent investigations (beyond the current project) will allow QDMR to evaluate the long-term performance of fibre composite bridge structures [1].

Taromeo Creek Bridge is located on the D’Aguilar Highway in Blackbutt, Queensland (see Figure 1). The new fibre composite bridge replaced an old timber bridge. Traditionally, the old timber bridge would have been replaced with a prestressed, precast concrete deck unit bridge. The new bridge configuration consists of one 10m span and one 12m span with no skew and a slight grade. This bridge was chosen for the first fibre composite deck unit site in Queensland because the bridge geometry was simple and the spans lengths were achievable by previous fibre composite project standards.

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Design of the fibre composite deck units

Initially, the research concentrated on the design and engineering of the deck units. The design of the bridge was a combined effort from QDMR Bridge Design and Wagners CFT. The substructure was designed by QDMR Bridge Design and consisted of conventional reinforced concrete headstocks on driven, prestressed, precast concrete piles. The proposed superstructure was fibre composite deck units designed by Wagners CFT and reviewed by QDMR. The design criteria developed by QDMR included the following:

- SM1600 loading criteria for ultimate strength
- T44 serviceability loading criteria for deflection limits
- 9.2m between kerbs
- Standard QDMR steel bridge rails and posts and concrete kerbs

This project aimed to transform this technology into a product which can become more economically viable. To do this, a hybrid of different material technologies was considered. The materials used in the deck cross section consist of a standard QDMR reinforced concrete deck, glass pultruded webs and a fibre composite/steel tensile flange (see Figures 2 & 3).

The transverse connection of adjacent decks also required an innovative approach. The transverse connection consisted of a top joint in the concrete deck and two different systems on the bottom. The top joint was a looped reinforced concrete joint with a dowel bar locking the two together. The bottom joint consisted of two trial systems - one being a carbon strip across the decks and the other a small composite pultrusion spacer between the two decks.

Integration of new materials into a highly developed and standardised design system produced a bridge that easily conformed to standard construction detailing and techniques. Some examples of standard techniques adapted to the fibre composite deck units were:

- The deck units were supported on elastomeric rubber strips, similar to those used by the Roads and Traffic Authority in New South Wales
- Each deck was held down with 2-M24 bolts, in a similar fashion used with conventional deck units
- The reinforced concrete deck, kerbs and rails were all based on a QDMR standard design
- The deck was reinforced with standard Grade 500 steel.
As the fibre composites webs were relatively thin when compared with conventional concrete decks, shear failure of the decks at the supports needed to be addressed. To provide enough robustness and shear capacity, extra pultrusions were added at the ends of the units. A less expensive solution to this problem is still being researched.

**Testing**

To confirm the assumptions made in the design of the fibre composite units, a testing program was developed. The designed failure mode of these fibre composite deck units is based on a pseudo-ductile behaviour.¹ The concept for this design was to yield the steel first, followed by bending failure of the composites. To provide confidence to QDMR as the asset owner, the testing program included:
- Destructive bending
- Glue line shear
- Fatigue testing for 2 million cycles under serviceability loads

The fatigue testing did not show any signs of deterioration when loaded to the serviceability condition. The fibre composite beams actually gained stiffness during the fatigue testing.

This is most likely due to the fact that the composites were not fully cured when placed in the fatigue testing machine. As the unit cured with time, the stiffness increased.

A number of different glue line shear tests were developed to examine the bond of the different materials. No problems were detected at the small scale testing level.

Full destructive bending tests of the design concept was necessary to ensure the failure mode assumed in the design worked in reality (see Figure 4).

Provision of a ductile failure mode through yielding of the steel and then bending failure of the fibre composites was only partly achieved. The steel did yield (see Figure 5). However, a longitudinal shear failure occurred between the concrete compression flange and the fibre composite modules rather than a bending failure. As can be seen from Figure 5, the beam continued to carry load, even though the concrete flange was not connected to the fibre composite modules. Loading stopped due to excessive deflections, not failure of the beam.

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¹ Pseudo-ductile behaviour is a progressive failure of different materials with different failure strains.
Figure 5. Load/Moment vs. Strain

Figure 6 shows that the beam will be capable of giving appropriate warning of failure due to the large deflections.

Figure 6. Load/Moment vs. Deflection
Overall, the testing program provided QDMR with enough evidence to confidently install the fibre composite deck units on the state-controlled road network.

**Installation**

Taromeo Creek Bridge construction was procured as a sole invitee contract, with a lump sum price for the supply, transport and installation of the fibre composite deck units. The price of the supply, transport and installation of the fibre composite deck units was $1,500/m². This is more than twice the price of conventional prestressed, precast concrete deck units. It is expected that costs can be reduced with volume production, converting the product from hand-made to an industrial process. Figure 7 shows the installation of the fibre composite decks on site.

A number of small problems occurred on site during the installation of the fibre composite units due to the order in which the units were placed, but this issue will be corrected on subsequent jobs. The biggest problem experienced with the design was the top transverse jointing system employed. In this case, the wing walls were poured prior to installing the decks. Consequently, this left a finite space for the fitting of the units. The rebar jointing system employed required access from the side to slip the protruding reinforcing bars past each other. However, as the wing walls were in place, no side access was available. The protruding lap bars were bent sideways to allow the units to be placed into position.

Another unforeseen problem that occurred during installation was the misalignment of the fibre composite decks with the wing walls. This was due to the fact that no allowance was made for the shear connecting aggregate on the top of the fibre composite webs and the amount of cover required to the bottom layer of steel. For future reference, it should be noted that the shear aggregate diameter should be added to the cover to give the total depth of the section.
**Conclusion**
Queensland’s first fibre composite bridge on Taromeo Creek Bridge in Blackbutt was the culmination of previous research developed by Wagners CFT in conjunction with QDMR. The project combined previous fibre composite bridge research with current bridge design standards and construction techniques. An extensive testing program provided supporting evidence that the basic design philosophy was correct. Installation of the deck units presented unforeseen problems, however these are easily corrected for the next project. Overall, the project was successful and has provided valuable information to both Wagners CFT and QDMR to appreciate how fibre composite will fit into the Australian bridge construction market.

**References**

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