THE BRITE PROJECT

Innovation Case Study No 5

Australia's First Fibre-Reinforced Polymer Bridge Deck on the Road Network

This series of innovation case studies has been developed by the BRITE Project of the Cooperative Research Centre for Construction Innovation. The case studies demonstrate the benefits of innovation and successful implementation strategies in the Australian Building and Construction Industry. Many highlight the strengths of small and medium-sized businesses in regional areas.

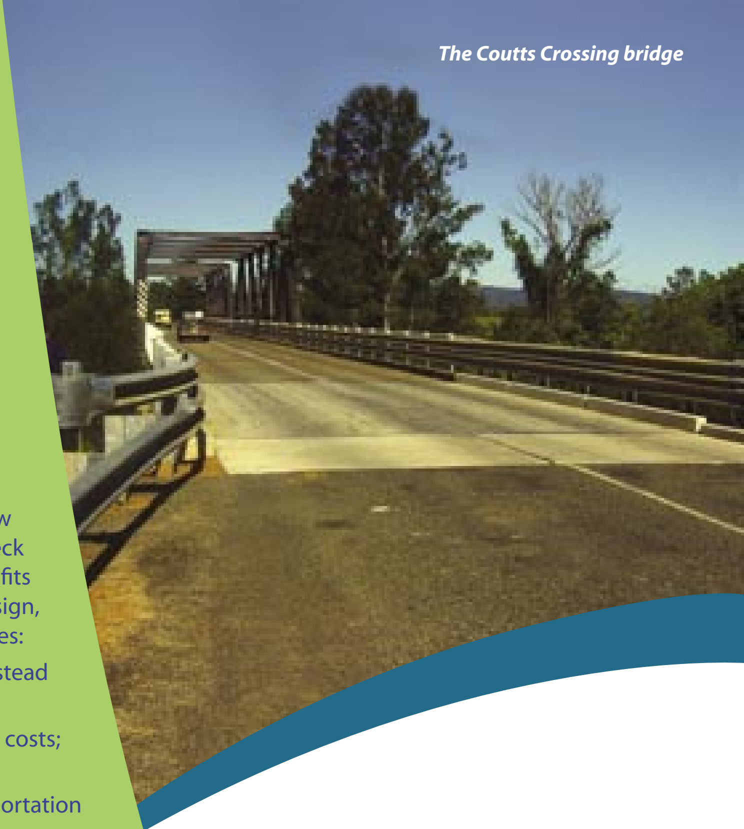
Who should read this? Participants in the building and construction industry, particularly bridge engineers and government road authorities.

CRC Australia

CRC Construction Innovation

BUILDING OUR FUTURE

Australia's First Fibre-Reinforced Polymer Bridge Deck on the Road Network



The Coutts Crossing bridge

In February 2003, the first fibre-reinforced polymer (FRP) (fibre composite) bridge deck was installed on the Australian road network, at Coutts Crossing, New South Wales. The new bridge deck design offered substantial benefits over traditional bridge deck design, including the following estimates:

- installation in only 5 days, instead of 8 to 10 weeks;
- 90% saving on traffic control costs; and
- 75% saving on bridge transportation costs.

Selected Project Participants

Client	Roads and Traffic Authority of New South Wales (RTA)
Diagnostic testing and consulting	Queensland Department of Main Roads (DMR)
Consulting engineers	Connell Wagner Pty Ltd
Prototype designers	Wagners Composite Fibre Technologies Pty Ltd (WCFT), Fibre Composites Design and Development (FCDD)
Manufacturer and installation	WCFT

Organisations consulted in preparing this report: RTA, WCFT, DMR, FCDD

Cover photo: *Constructing the Coutts Crossing bridge*

The Project

The bridge at Coutts Crossing spans the Orara River, in northern New South Wales. The FRP bridge deck was installed in 2003 to replace a timber span constructed in the 1930s. The Coutts Crossing bridge is 90 metres long and 7 metres wide. The FRP deck replaced 12 metres of the bridge length. It was commissioned by RTA, and was constructed and installed by WCFT. The FRP bridge deck was designed by Connell Wagner, drawing on an earlier WCFT - University of Southern Queensland (USQ), FCDD prototype design.

The Achievement

Coutts Crossing is Australia's first FRP bridge deck on a road network. It is also one of the first such bridge decks in the world. Although many fibre composite pedestrian bridges have been built as technology demonstrators overseas, the development of the FRP fibre composite bridge at Coutts Crossing pushed the boundaries of conventional bridge construction methods and materials as well as current fibre composite technology worldwide. The main achievement of the technology at Coutts Crossing was that bridge members were far bulkier and more robust than those found in existing FRP bridges worldwide, making them suitable for Australian conditions and carrying vehicular traffic. This achievement relies on the modular construction method pioneered in WCFT/FCDD's prototype bridge beam and applied at Coutts Crossing.

The Coutts Crossing bridge is the result of close collaboration between RTA and WCFT, which saw the parties share costs: RTA paying for the cost of a conventional bridge and WCFT making up the difference to pay for the FRP bridge, which was an extra 50%. The Coutts Crossing FRP bridge is a hand-made prototype and therefore was relatively costly to build. Research by the manufacturer, however, suggests that the installed cost of its FRP bridges will match that of conventional bridges when it commences full-scale manufacture early in 2004 and begins to reap economies of scale.

The Innovation

'tomorrow's infrastructure will not be built using today's technology'

The innovation lay in the modular construction of the FRP bridge deck and the hybrid engineering of the material usage. There are three basic shapes that make up a FRP beam – a hollowed-out glass square shape, a long carbon strip, and a rectangular concrete shape. These shapes are adhered with special adhesives to make a beam. The hollowed-out glass squares are adhered together to create a box section. The carbon strip is glued along the bottom of the box section and the concrete is then adhered on top of the glass box to complete the beam section. These beams are then glued together to make a deck section. A number of decks go to make up a complete bridge deck. Because the system is modular, if bridge length increases, more modules are used; if bridge length decreases, fewer modules are used.

The above components, and their mechanical interaction, constitute the particular composite mix (the FRP) employed at Coutts Crossing (and in the prototype bridge). This composite design has never before been used, and was developed specifically for bridges, to mimic a conventional concrete bridge deck, which is accepted best practice.

The Benefits

In general terms, composite fibre structures have a number of features that make them attractive for use in bridge structures, including high strength-to-weight and stiffness-to-weight ratios, corrosion and fatigue resistance, and tailorability. Replacement of heavier concrete and timber decks by lighter fibre composite decks also allows for an increase in traffic load, without an overall increase in load on the supporting structure. Fibre composite decks also have potential for use in areas where longer spans are necessary or where lower weight would translate into increased seismic resistance.

Additionally, fibre composites have significant benefits when used in so-called 'aggressive' environments, such as on the coast or in environments with snowfalls and de-icing salts, because the product is completely inert, i.e. non-corrosive and non-conductive. FRP bridges are expected to have much lower ongoing maintenance costs when used in such environments (while this is unproven at this stage, parties involved in the project believe this has enormous potential), and offer a similar, if not longer, lifespan to alternative bridge designs. Indeed, unlike the alternative bridge types (1) to (5) listed overleaf, FRP bridges can be factory produced and therefore should be of higher quality.

At this stage, composite materials are still quite expensive, largely because of the costs of resins. However, costs are expected to fall as mass production is undertaken. Current research is looking at ways to optimise the design to bring costs down even further.

Looking at the Coutts Crossing project in particular, several forms of superstructure replacement could have been used, including:

1. Doolan timber concrete composite decking;
2. M-Lock decking;
3. NSW conventional PSC planks with *in situ* concrete overlay;
4. Queensland conventional PSC planks without *in situ* concrete overlay; and
5. Other, less used proprietary decking systems.

Options (1), (2), and most of (5) could have been installed over much the same timeframe as an FRP deck; quicker than options (3) and (4). Hence, FRP savings in traffic management costs would have been marginal when compared with options (1), (2) and (5). However, the major advantage of the FRP structure over all the listed alternative superstructures was its light weight and the associated reduction in transportation and foundation costs this could deliver.

For the conditions associated with the Coutts Crossing project, (3) was considered the next best alternative to the FRP bridge and is the comparator used to derive benefit estimates. Time required to install (3) was estimated to be 8 to 10 weeks, while the FRP bridge was installed in 5 days, translating to substantial traffic management savings of approximately 90%. The lighter deck weight of the FRP bridge (55 tonnes compared to 114 tonnes) also saved 75% in transportation costs.

Normally, there would also have been an associated reduction of 27% in foundation costs; however, as the Coutts Crossing bridge was a demonstration project, the loading for a relatively heavy conventional prestressed concrete plank deck was used in design to reduce risks. It is expected that this measure will prove unnecessary in the future.

Indeed, the design at Coutts Crossing was conservative, since it was the first project of its kind, and it can be expected that weight and related cost savings will be greater on future projects.

The Implementation Process

'… innovation is a constant effort to stay outside your comfort zone'

The installation of the bridge deck at Coutts Crossing in February 2003 represented the culmination of more than five years of extensive collaborative research and development by a number of enthusiastic individuals and organisations, including state and federal government departments, private sector firms and the university sector. The Coutts Crossing project would not have been possible without this background research and development.

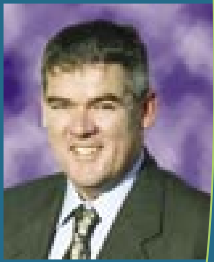
USQ's FCDD Group started research into fibre composite bridges in 1996. Shortly afterwards, Connell Wagner consulting engineers joined the research effort, with DMR becoming involved in 1998, contributing important practical design information. The bridge design moved away from the initial lightweight 'thin walled' approach to a slightly heavier, but more robust, bridge structure. Through the development of an innovative casting technology, a far more economical and practical solution was obtained in mid-2001.

In 2000, the Cooperative Research Centre for Advanced Composite Structures, in conjunction with RTA and the Commonwealth Department of Industry, Science and Resources, instigated a feasibility study to evaluate the suitability of advanced composite materials for Australian civil infrastructure applications. A generic design exercise established which particular technologies should be encouraged. This involved the generation of a performance specification that met RTA requirements and the submission of two conforming preliminary design concepts.

One of these was a concept developed by an Australian FCDD-led team. RTA selected this solution as the preferred alternative for demonstrating the appropriateness of the materials for Australian conditions. The economics of the design were potentially comparable with those associated with bridge construction using conventional materials. RTA also considered that the polymer composite design had other through-life advantages that increased its attractiveness.

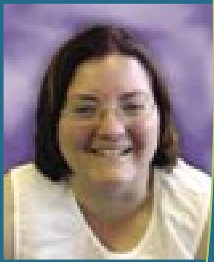
In 2001, a project team consisting of WCFT, FCDD, RTA and DMR completed the development of the concept and installed the first prototype on a quarry site at Wellcamp, near Toowoomba in Queensland, owned by Wagners Investments Pty Ltd (Wagners). WCFT played a key role in both the prototype bridge and the Coutts Crossing bridge. WCFT is a trading division of Wagners, a Toowoomba-based company with interests in concrete, quarries and transport. A relatively young company (formed in 1989), Wagners had a strong background in research and development, pouring millions of dollars a year into research activities. Wagners management sums up its approach to innovation as 'a constant effort to stay outside our comfort zone' and 'its belief that tomorrow's infrastructure will not be built using today's technology'.

Wagners first learned of fibre composites technology when USQ, which had placed a graduate engineer with the company, asked it to look at the feasibility of a lightweight semi-trailer as part of the graduate engineer's project. Wagners quickly saw the potential for other applications of fibre composite technology, including for rail sleepers, cross arms, power poles and bridges and beams. A research and development project on fibre composite bridges was launched and WCFT contributed significant up-front funding to develop the prototype bridge beam, which was matched dollar-for-dollar by an AusIndustry grant. WCFT (and Wagners) did not expect to make an immediate return on its investments in research, but could see a longer-term commercial return. Indeed, WCFT is planning to start operation of a production line early in 2004, which is expected to deliver the first fibre composite profits for the company. To date, WCFT has put many millions of dollars into research on fibre composite bridges.



Neil Wagner, Company Director, Wagners

'it is very rewarding to have clients involved in the technological transfer of new products .. without the road authorities' early input this project would not have been a success'



Louise Chandler, Engineer, Bridge Design, DMR

'To create innovation that benefits everyone, it is important for government, industry and universities to collaborate. One without the others only produces part of the puzzle. You need all the pieces to create the whole picture'

Rod Oates, Manager, Bridge Rehabilitation Projects, Bridge Section, RTA Technical Services

'this has been an important collaborative venture - a win/win situation for the RTA and their partners'

DMR was also an important contributor to the prototype development project, contributing the time of one of its bridge engineers, as well as testing equipment and a small cash payment to FCDD. The DMR engineer's role was two-fold. First, she contributed technical expertise to the project. Second, and very importantly, she ensured that the prototype was one that could later be transformed into a product commercially available to DMR for use on Queensland's road networks. The engineer ensured that the prototype met DMR's design, safety and environmental criteria and that it was constructed in a way that delivered a suitable cost structure for later use.

The prototype was completed in early 2002, and an extensive series of field tests followed, revealing that the concept exceeded expectations of its technical performance. The prototype bridge is still in use at Wagner's quarry, with an estimated 150 quarry trucks passing over it every day. 'Health' monitoring is ongoing. The prototype bridge project was awarded a 'Highly Commended' by the Institution of Engineers in September 2002.

The success of the prototype led to the proposal to place an FRP bridge on the road network. After initial project development by RTA, WCFT, and FCDD, a site was selected and it was decided to replace an existing timber span bridge at Coutts Crossing. Connell Wagner was engaged by WCFT to review and modify FCDD's fibre composite bridge concept to suit the site-specific requirements (essentially, however, the design was the same as the prototype). The new Coutts Crossing bridge is an innovative combination of fibre composite and conventional materials constructed and installed by WCFT. FCDD assisted RTA in its superintending responsibilities. Initial site testing shows that the bridge is performing well, and this will be periodically monitored by RTA over coming years.

WCFT treated the installation of the bridge at Coutts Crossing as a research and development project, largely because the RTA budget would only allow for the cost of an equivalent bridge constructed from traditional materials. WCFT has, however, been able to apply the experiences learned during the project, and expects that mass production will lead to profitable sales to road and traffic authorities in the near future. WCFT has a patent over the design cross-section of the individual beams as well as the manufacturing process used for construction of the bridge deck. WCFT believes that the collaborative history of the project involving DMR, RTA, FCDD and others has been invaluable in the commercial development of the technology. These partners steered WCFT in directions it might not have otherwise gone, and also provided essential technical and moral support.

The partners continue to conduct individual research projects on fibre composites, as exploring the full potential of the technology remains an on-going priority for them.

Overcoming Difficulties

Manufacture of the fibre composite bridge prototype proved to be a challenging task. The fibre composite industry is not new – it sells to the aerospace, marine and other industries – however the construction industry is a new market for fibre composites. Accordingly, material uniformity and product stability were still being developed during the prototype process. There are thousands of resins and fibres, all with different structural properties, that could have been used.

The first batch of pultrusions supplied to make the prototype bridge was rejected, as the product did not meet DMR and WCFT standards for bridge components. Another problem was encountered with the adhesive to connect the pultrusions. The heat distortion temperature was meant to be 100 degrees Celsius, but a chemical manufacturer up the supply chain had changed the chemical properties of the adhesive, so that the heat distortion temperature was only 60 degrees Celsius. The design team was, however, able to out-engineer this concern and accommodate the difference.

The DMR engineer involved in development of the FRP bridge describes the challenges in her USQ Masters thesis, which observes that the design of the fibre composite deck units evolved through several phases during the prototype development process. The use of combined modular sections to make bridge beams was a constant theme, however the type of modules, materials and design philosophy changed dramatically, as difficulties were encountered and overcome. In all, five designs were trialled.

Another difficulty – or perhaps more a challenge than a difficulty – was that so many parties were involved in the development and construction of the prototype bridge. These parties were from different backgrounds – academia, the private sector and government. At times, differences in objectives became apparent, particularly when the costs or quality of materials to be used were at issue. It appears that tensions were overcome by overwhelming goodwill and trust established between the parties during the development stage. Another element in the successful resolution of conflicts was the interest that the parties had in successful completion of the project – for example, WCFT in future commercial sales of its product, DMR in the future application of the technology to Queensland's bridges, and materials suppliers in supplying to manufacturers like WCFT in the future. Individuals interviewed for the case study indicated that the involvement of all the collaborators was essential to the success of the project.

Lessons Learned

- Innovations are fostered by collaborations between industry, academia and government.
- Companies believe that investing money in research and development can reap significant commercial benefits.
- Involvement of clients in the early stages of innovation development can improve outcomes.
- Linkages with university research bodies can yield commercial benefits for far-sighted companies.
- Goodwill and trust are essential in collaborative innovations.
- Public sector research and development grant schemes can yield tangible commercial benefits.
- Successful innovation often requires commitment, perseverance and a willingness to sacrifice short-term gain.

Transporting the Coutts Crossing bridge

Constructing the Coutts Crossing bridge

BRITE Project Partners:

CSIRO

QUT

University of Western Sydney
Bringing knowledge to life

ARUP

Queensland Government State Development

Queensland Government Department of Main Roads

Queensland Government Department of Public Works

BRITE Project Supporters:

acif Australian Construction Industry Forum

Construction Best Practice

ACEA The Association of Consulting Engineers Australia

CCF

Movement for Innovation M4I

Rethinking Construction

Further information:

Dr Karen Manley
Research Fellow
School of Construction Management and Property
Queensland University of Technology
GPO Box 2434
Brisbane Qld 4001
Australia

ph: 61 7 38641762
email: k.manley@qut.edu.au

www.brite.crcci.info

CRC Construction Innovation Vision
… 'to lead the Australian property and construction industry in collaboration and innovation'

2004