SOME FRP STRENGTHENING PROJECTS IN AUSTRALIA

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ABSTRACT

This paper discusses the FRP strengthening work in several bridge projects in Australia. The projects are the Southern Link Upgrade, M80 Ring Road Upgrade, Oyster Channel Bridge and Shepherd Bridge. The strengthening work was to improve the capacity of various bridge elements including pier crossheads, precast I-beams, box girders, T-beams and pedestals. Several anchorage types were used and are described, including steel plates with anchor bolts, steel brackets, FRP U brackets and diagonal FRP patches. Comments on the difficulties in design and construction are also made.

KEYWORDS
FRP, bridge strengthening.

INTRODUCTION

Bridges are expected to last for a long period of time. They are usually designed and built to the current design requirement at the time however history tells us that over the years traffic using bridges tends to get heavier. The trucks become bigger, and their total and axle weights increase significantly. In Australia, in the 1940s to 1970s, the design truck was an approximately 20 tonne vehicle. In the 1970s to 1980s, the design truck was increased to approximately 44 tonnes. Since the 1990s Australian bridges have been required to be designed for SM1600 which is virtually a 160 tonne vehicle. Due to this continual increase in the load, there always exists a need to strengthen existing bridges for heavier traffic. In addition to increased loading, the strengthening demand can also be due to damage or corrosion to existing structures, errors in design and required modification to existing structures.

The number of projects involving fibre reinforced polymers (FRP) strengthening has been increasing rapidly in the last decade. The main reason for this is the increasing awareness of the strengthening technique amongst engineers and builders, and an increasing appreciation of the many advantages that it offers.

This paper describes some of the recent bridge strengthening works using FRP in Australia. The authors were involved in the projects mentioned herein mainly as design engineers.

SOUTHERN LINK UPGRADE

Southern Link is a toll road connecting the West Gate Bridge and Monash Freeways in Melbourne. The link comprises two tunnels and various bridge structures. The Southern Link bridge structures comprise mainly the Morshead Overpass, the Burnley Viaduct, the Gardiners Creek Viaduct and the Yarra Bridge. The original bridge structures were designed and built in 1960 and adopted the design codes of the day and a design live loading of H20-S16-44 loading. Widening of the bridges was undertaken around 1999, and this was designed for the heavier T44 loading. Both these loadings are now superseded by the SM1600 loading in the current bridge design code AS5100.

The original bridge structures were strengthened in 2008-2011 to accommodate heavier traffic loads. Strengthening work involved the use of various techniques including FRP strengthening, external prestressing, steel plating and section enlargement. In this project, there was a significant amount of FRP strengthening work to strengthen bridge I girders, bridge box girders and crossheads. Some of the main FRP strengthening works are described below. They were designed to ACI 440.2R-08 “Guide for the Design and Construction of Externally
Bonded FRP Systems for Strengthening Concrete Structures”. The project specification on FRP strengthening was based on State road authority (VicRoads) Standard Specification Section 688.

Morshead Overpass crossheads

Morshead Overpass carries Southern Link over Punt Road in Melbourne. It borders the eastern bank of the Yarra River. It provides four west bound lanes (towards the Domain Tunnel) and one eastbound lane. The original overpass has a mixture of bridge forms. Between Piers 6 to 9, it has three centre spans comprising steel I-girders with concrete deck. Between the West Abutment and Pier 5, and between Piers 10 to 16, it has approach spans consisting of pretensioned concrete I beams with concrete deck. The span length is approximately 18.3m. The widening structures have a similar structural form to the main steel spans with steel girders and a concrete deck. The approach spans in the widening consist of pretensioned concrete T beams and a concrete deck.

The crossheads supporting the original and widening girders were found to be deficient. The crosshead at Piers 7 and 8 were deficient in both flexure (hogging) and shear. Consequently, these were strengthened using MBrace laminates and MBrace fabrics. Because of the slope of the bottom soffit, the shear strengthening strips were placed not vertically but inclined to be normal to the soffit. This orientation also increases the intersecting angle between the strips and potential shear cracks and therefore improves the efficiency of the shear strengthening system. The horizontal laminates were bonded on the side of the crosshead because of the presence of bearing pedestals at the top of the crosshead (Figure 1).

The crossheads on some of the original piers were deficient in flexure (sagging). They were strengthened with CFRP laminates bonded on the sides of the beam. This is due to that fact that the soffit of these crossheads is a concave surface. At some locations, the CFRP ends were anchored by a mechanical anchorage, which comprised a steel plate bolted to concrete using two anchors (Figure 2). The steel plate was bonded to CFRP by adhesive. This system has proved to be efficient in preventing debonding from the strip ends (Pham, 2005).
The original portion of the viaduct was completed in 1962. Burley Viaduct was then extensively modified during freeway widening around 1999. Assessment of the Viaduct found that a number of crossheads required to be strengthened. They were subsequently strengthened using CFRP strips for shear and prestress strands or stress bars for flexure. The CFRP shear strengthening details were similar to those used for Morshead Overpass crosshead at Piers 7 and 8. However, unlike Morshead Overpass, the CFRP system was provided by Sika (Figure 3).

Gardiners Creek Viaduct beams

Gardiners Creek Viaduct forms part of the Southern Link between Yarra River and east of Glenferrie Road. It was widened around 1999 and again in 2007. Its original deck comprises prestressed precast I-beams made continuous by post tensioning, and joined by an in-situ reinforced concrete slab. The superstructure has span lengths of typically around 30m.

The original I-beams were strengthened in various locations using MBrace laminates and fabrics. To anchor longitudinal laminates, CFRP U straps or steel U brackets were used. Some details of this strengthening work are shown in Figures 4 and 5.
The M80 Ring Road is a freeway connecting the northern and western suburbs to various freeways in Melbourne. It has been upgraded and widened since 2009. Several bridges on the section from Tilburn Road to Furlong Road of the M80 were strengthened to accommodate a larger design traffic load and to allow for widening requirements. FRP strengthening using bonded CFRP was used at St Albans Road Overpass and the Western Highway Viaduct.

**St Albans Road Overpass box girders**

This bridge crosses St Albans Road and Bendigo rail line. The bridge has two separate carriageways. Each is 16 m wide between traffic barriers. The north carriageway also carries a 2.5m shared footway. Each carriageway is a two-span continuous single concrete box structure. The length of each span is approximately 50m. The bridge was built by incremental launching.

Strengthening using carbon fibre reinforced polymer composites (CFRP) was done to mitigate some deficiencies of the existing twin box girders. It involved bonding CFRP laminates on the soffit and web of the concrete boxes using epoxy. The laminates were installed inside the boxes which eliminated the requirement for extensive falsework. The laminates were anchored at their ends using various forms of steel brackets with anchor bolts (Figure 6). The CFRP system was provided by Sika.
Western Highway Viaduct

The existing bridge over Western Highway and Kororoit Creek is twin post-tensioned concrete box girders originally constructed in-situ on falsework. The bridge spans are 37, 44, 44, 44, and 44m including spans over both carriageways of the Western Highway (spans 4 & 5) and Kororoit Creek (spans 1 & 2). The bridge is built on a horizontal curve with a radius of 750m.

The strength assessment confirmed that strengthening was required at Pier 4 and near the North Abutment end. Shear strengthening using CFRP was done to the box girders. This involved bonding CFRP strips on the web of the concrete box using epoxy (Figure 7).
OYSTER CHANNEL BRIDGE BEAMS

Oyster Channel Bridge is a 70 year old reinforced concrete structure providing the road access to Yamba in northern New South Wales. To extend the life of the bridge, it was repaired and strengthened in 2005. It was the first use by the New South Wales road authority (Roads and Maritime Services) of strengthening with CFRP.

The existing T-beams were found to be deficient in shear. They were strengthened using Sika CarboShear L laminates. To improve the anchorage of the shear strips, additional diagonal FRP overlays were installed on the top of the strips (Figure 8 and Figure 9).

SHEPHERD BRIDGE CROSSHEADS AND PEDESTALS

Shepherd Bridge carries Footscray Road (Docklands Highway) over the Maribyrnong Creek in Melbourne. The bridge is a mixture of bridge forms with the centre three spans comprising steel I-girders with a concrete deck and approach spans comprising either reinforced concrete beams and concrete slab deck, or reinforced concrete portal frames. The bridge was designed and built in the 1950’s and was designed for the loading of that time, namely H20-S16-44. In order that heavier vehicles can travel over this bridge, some strengthening of some of the bridge components will be required. The proposed strengthening is described below.
Reinforced concrete beams used on this bridge were from 6 to 10 m long. Some of them are proposed to be strengthened in flexure by bonding CFRP laminates on the beam’s soffit or sides. The laminates are to extend as close to the bearings as possible to avoid end debonding (Figure 10a).

Some pedestals are to be repaired by wrapping CFRP fabrics. The fabrics are to provide the required confinement to prevent cracking due to concentrated loading from bearings (Figure 10b).

Some bridge pier crossheads were found to be deficient for the new proposed design loads. They are to be repaired by bonding CFRP laminates and fabrics. A typical strengthening arrangement is shown in Figure 11.

**DISCUSSION**

Strengthening bridge structures using FRP composites has proved to be a viable solution. The main advantage of this technique is the ease in installation and therefore cost saving in labour and access. As more bridges are strengthened with FRP’s, contractors will gain more experience and confidence and this system will become even more cost-effective.

The main difficulties that tend to be encountered are surface preparation, anchorage of FRP, inadequate design guidance and lack of understanding in its durability. To prepare the concrete surface so that its soundness, levelling, and roughness are satisfactory can be a difficult task when dealing with poor existing concrete. Anchorages tend to vary between projects due to uniqueness of bridge work. There is not adequate design guidance in designing anchorages and the design tends to be based on first principles. While VicRoads
Specification 688 provides a good reference, some construction requirements are not clearly defined. Another difficulty in specifying FRP strengthening is the uncertainty in its durability. Field observations and examples of deterioration of FRP retrofitted structures are very limited. However, durability of FRP strengthening has been an active field of research and the understanding on this topic is improving.

Design of FRP strengthening is a great deal about detailing to control debonding. It is worth noting that not all deficiencies can be strengthened using FRP. A good understanding of the materials, construction procedures, and the behaviour of the strengthened system is very important for a successful project. Construction of CFRP strengthening requires detailed documentation and good quality assurance procedures. Trials and tests are also often required before suitable materials and application procedures can be found.

REFERENCES

ACI 440.2R-08 (2008) “Guide for the design and construction of externally bonded FRP systems for strengthening concrete structures” *American Concrete Institute*.


The opinions expressed in this paper are those of the authors, and they do not necessarily reflect in any way those of the road authorities or other organisations referred to herein.