

FRP Rehabilitation and Strengthening Design of Small to Medium Span Bridges

Andrew Sarkady, Business Development Manager, BASF Australia Ltd

ABSTRACT

Various Australian bridge projects will be discussed to highlight particular aspects of the design, detailing and construction related to FRP rehabilitation and strengthening.

These include:

Queensland

- Brisbane City Council - Bowen Bridge

Victoria

- VicRoads - Little River Bridge & Warrigal Rd Overpass
- Hobsons Bay & Melbourne City Councils – Kororoit Creek Rd Bridge & Arden St Bridge
- Melbourne Water – Maribyrnong River Pipe Bridge
- Melbourne Airport – Service Culverts

NSW

- Albury/Wodonga Rail Bridge

ACT

- Tuggeranong Parkway & William Slim Bridges

Tasmania

- DIER - Devonport Rail Overpass, Ouse River Bridge & Emu River Bridge

Western Australia

- Main Roads WA - Greenough River Bridge

Other topics will be discussed including

- Key considerations with FRP design and use
- Design with AS 5100.8 and beyond!
- Conclusions & Acknowledgements

1. INTRODUCTION

In the late 1990's, Australian Bridge asset owners were faced with a number of challenges, specifically around strengthening of existing bridge stock, including:

- Increasing mass load limits and configuration of truck vehicles
- Increasing volume of traffic with population growth
- Aging infrastructure (largely designed & built in the previous 30 years)
- Large numbers of bridges with possible capacity issues
- Increasing focus on durability and design/service life
- New technologies with minimal local track record
- Limited budgets (money & time)

Existing solutions available included steel plate bonding, increase in section size, external PT, bonded deck overlays & sometimes replacement. A group of inspired material experts and leading bridge design engineering professionals were open to a new technology, normally reserved for the aerospace industry, F1 cars and snow ski's. It involved the use of externally bonded FRP (fibre reinforced polymer) for infrastructure, adopted in the late 1980's in USA, Europe and Japan, particularly for seismic retrofitting. FRP has now been used successfully on Australian infrastructure for over 17 years.

2. PROJECT CASE STUDIES AND EXAMPLES OF BEST PRACTICE

Queensland – Brisbane City Council – Bowen Bridge, Brisbane

- Scope: FRP Shear strengthening of Headstocks
- Key Learnings:
 - o Complex shear detail - experienced consultant
 - o Multilayer application - competent applicator
 - o Tidal river – flood contingency!

Victoria – VicRoads – Little River Bridge, Geelong Freeway

- Scope: FRP Flexural strengthening of curved beams
- Key Learnings:
 - o Installed cost – FRP lowest, with quickest installation
 - o Ease of construction – FRP lightweight, no mechanical fixings
- Best practices included:
 - o Detailed specification with competent design
 - o Adequate preparation and quality control
 - o Wet-on-wet, continuous process, to ensure interlayer adhesion
 - o Complete understanding of ambient conditions and appropriate material storage

Victoria – VicRoads – Warrigal Rd Overpass, Monash Freeway

- Scope: FRP Flexural strengthening of Headstocks
- Key Learnings:
 - o Tight Clearances – Measure before design
 - o Active cracks – Joint sealant treatment
- Best practices included:
 - o Access – Traffic and safety
 - o Traffic speed restrictions during application
 - o Coating – Anti-carbonation coating

Victoria – Hobsons Bay City Council – Kororit Creek Rd, Altona

- Scope: FRP Flexural & Shear strengthening of beams plus bonded concrete deck overlay
- Key Learnings:
 - o Flexibility in design detailing - Existing reinforcement locations vs clamping angle bolts
 - o Cost and time implications for over 5000 epoxied starter bars!
- Best practices included:
 - o Planning – Pre-cutting of fabric and good storage
 - o Proper equipment used – PPE & ribbed roller for fabric

Victoria – Melbourne City Council – Arden St & McAuley Rd Bridges, North Melbourne

- Scope: FRP Shear strengthening of beams plus installation of pier Cathodic Protection (CP) system
- Key Learnings:
 - o Preparation – Know your (rough) substrate
 - o Cracks – Understand the extent of cracking & inject where required (generally >0.3 mm width)
- Best practices included:
 - o Full containment of breakout
 - o Epoxy smoothing layer & crack injection
 - o Easy access system

Victoria – Melbourne Airport – Service Culverts, Tullamarine

- Scope: FRP Flexural strengthening of culvert roof (for A380 aircraft)
- Key Learnings:
 - o Planning – Logistics required with >3 km of tunnels
 - o Surface preparation – dustless grinding
- Best practices included:
 - o Masking of laminate edges for cleaner finish
 - o Epoxy jig delivering correct amount of adhesive

Western Australia – MainRoads WA – Greenough River Bridge, Geraldton

- Scope: FRP Flexural strengthening of deck (top and underside) and additional steel piers
- Key Learnings:
 - o Hot weather application (> 30^oC) – Material storage, night work.
 - o Remote site – Adequate allowance for wastage
- Best practices included:
 - o Traffic management - Half bridge closure to allow traffic movement
 - o Vertical laminates or FRP rod sections used for top deck

3. OTHER AUSTRALIAN BRIDGES – KEY LEARNINGS

Melbourne Water pipe bridge

1. Lack of reinforcement
2. CF fabric wrap
3. Completed historic rehabilitation

NSW - New Rail Bridge

4. Incorrectly detailed column ligatures discovered after built
5. Economical CF fabric wrap solution

Roads ACT bridges

1. Cold temperature application
2. I-Beam shear detail
3. Live traffic conditions

DIER Tasmania

4. Levelling of uneven substrate

4. KEY CONSIDERATIONS WITH FRP USE

Examples of Flexural Strengthening

Best practices:

1. Peel-ply, reduced solvent, better EHS
2. Quality control – Epoxy jig
3. Priming – Varying substrates
4. Identification labels – Warning for following trades & Accurate “As-built” documentation
5. Thin sections- Nil impact on finishes

Examples of Axial/Shear Enhancement

Best practices:

1. Quick and easy – Access/Labor
2. Impact resistance – Aramid
3. Low installed cost – Less space
4. Rapid emergency repairs
5. Easy fix for design/construction errors- Inadequate shear ligatures and core holes drilled through slab

Other

Supply planning – Early ordering to ensure in-full and on-time delivery

Quality Assurance – Documented, audited, full applicator training & trialing

Quality Control – Testing frequency to match project requirements

Health, Safety & Environment – Smart access systems, full PPE, peel-ply laminates (reducing solvent and sanding of laminate surface)

5. DESIGN WITH AS 5100.8 AND BEYOND?

The revised Australian Bridge design was published in March 2017, unleashing local FRP designs:

- AS 5100.8 entitled “Rehabilitation and Strengthening of Existing Bridges”
- Includes Appendix A on “Fibre Reinforced polymer (FRP) Strengthening”, for the first time in an Australian Standard
- Based on local and international best practice, research & standards from USA, UK & Europe
- Covers flexure, shear, torsion and axial confinement design, as well as application guidance

Future work includes:

- AS 5100.8 commentary
- More on anchorage details & design
- Long term durability
- Fire protection
- Alternate fibre & resin systems
- FRP strengthening of steel structures
- Pre-stressed FRP Applications

Key considerations with FRP design

- Investigate the existing structure and environment
 - o Check that the structure is strong enough to accept a bonded system (minimum 1.5 MPa tensile adhesion strength)
 - o Check surface roughness, existing contaminants and adverse environmental conditions
- Designers needs to understand the requirements of the code and the material limitations
 - o Until familiar, consult early with experienced suppliers to ensure designs are optimized (most economical) and feasible
 - o Detailing is important – check buildability and allow for some flexibility for unknown/unexpected as built conditions
- Documentation
 - o Provide accurate & concise drawings & specifications
- Quality Assurance
 - o Include adequate site testing
 - o Allow for ongoing monitoring

6. SUMMARY & CONCLUSIONS

Over the last 17 years, FRP has been used in 100's of Australian projects including bridges, buildings and other structures. Some valuable lessons have been learned, reinforcing the need for:

- Comprehensive and competent design, at an early stage to ensure the most cost effective solutions
- Clear and concise designs (drawings & specifications)
- Strict application and quality control procedures, utilizing experienced contractors & smart access systems
- Adopting high quality materials, suitable for purpose
- The importance of ongoing research, development, innovation & monitoring of long term performance

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