8th Australian Small Bridges Conference

MASTER® BUILDERS SOLUTIONS

FRP Rehabilitation and Strengthening Design of Small to Medium Span Bridges

8th Australian Small Bridges Conference
Surfers Paradise, 27-28 Nov 2017

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FRP rehabilitation & strengthening design of small to medium span bridges.

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

Introduction

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- 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)

A new approach…FRP has now been in use for over 17 years in Australia!

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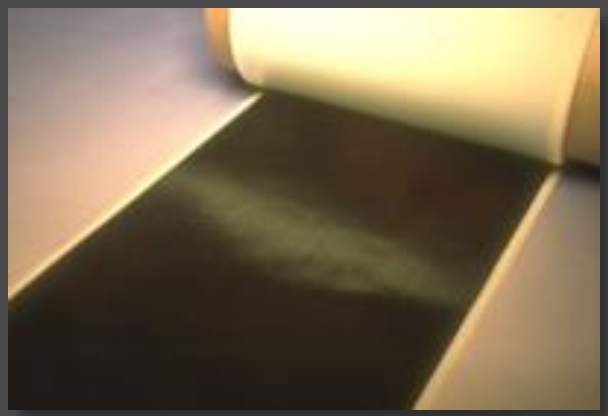
- Existing solutions available included steel plate bonding, increase in section size, external PT, bonded deck overlays & sometimes replacement
- A group of inspired material experts and leading bridge design engineering professionals were open to a new technology, normally reserved for the aerospace 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



Queensland
Brisbane City Council - Bowen Bridge, Brisbane

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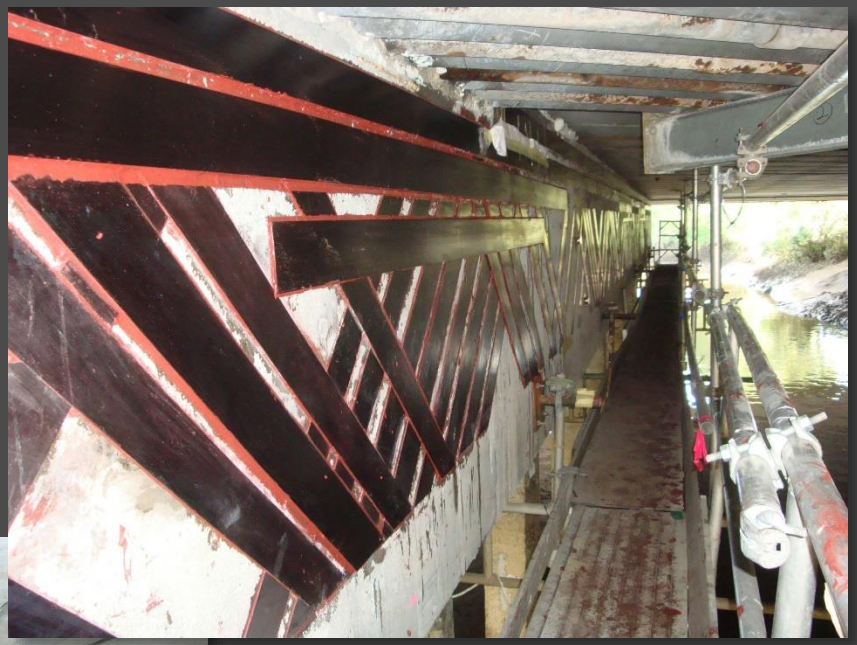
- Scope: FRP Shear strengthening of Headstocks
- Key Learnings:
  - Complex shear detail - experienced consultant
  - Multilayer application - competent applicator
  - Tidal river – flood contingency!



Victoria
VicRoads - Little River Bridge (Geelong Freeway)

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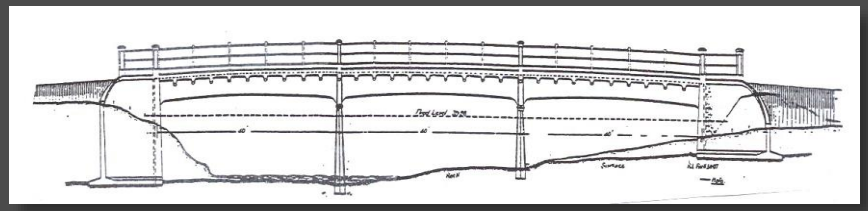
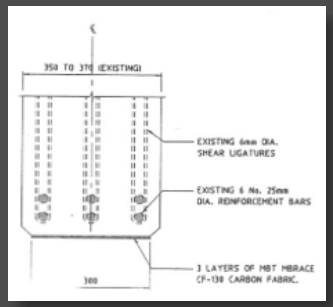
- Scope: FRP Flexural strengthening of curved beams
- Key Learnings:
  - Installed cost – FRP lowest, with quickest installation
  - Ease of construction – FRP lightweight, no mechanical fixings
- Best practices included:
  - Detailed specification with competent design
  - Adequate preparation and quality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





Victoria
VicRoads–Warrigal Rd Overpass/Monash Freeway

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

Victoria
Hobsons Bay City Council – Kororoit Creek Rd

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

Victoria
Melbourne City Council – Arden St Bridge

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

Victoria
Melbourne Airport – Service Culverts

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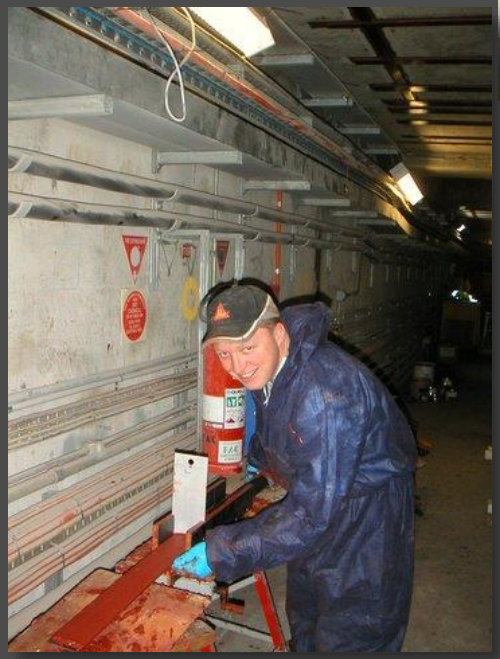
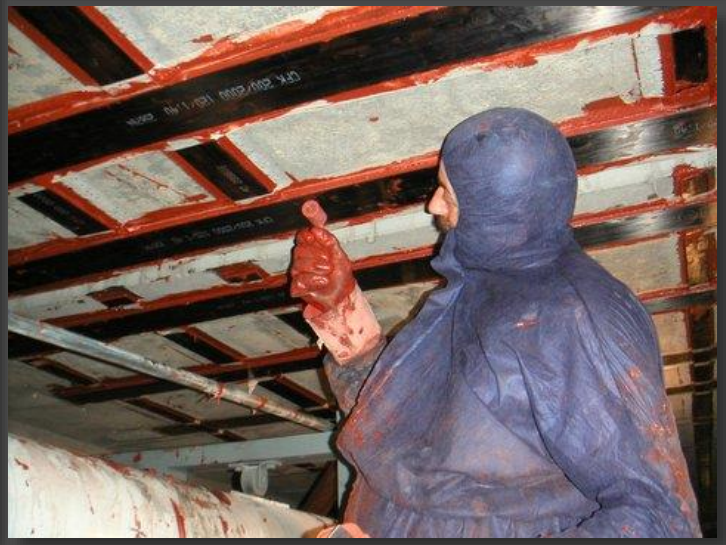
- Scope: FRP Flexural strengthening of culvert roof (for A380 aircraft)
- Key Learnings:
  - Planning – Logistics required with >3 km of tunnels
  - Surface preparation – dustless grinding
- Best practices included:
  - Masking of laminate edges for cleaner finish
  - Epoxy jig delivering correct amount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





Western Australia
Main Roads WA - Greenough River Bridge

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- Scope: FRP Flexural strengthening of deck (top and underside) and additional steel piers
- Key Learnings:
  - Hot weather application (> 30^0C) – Material storage, night work.
  - Remote site – Adequate allowance for wastage
- Best practices included:
  - Traffic management - Half bridge closure to allow traffic movement
  - Vertical laminates or FRP rod sections used for top deck

Other bridges around Australia
Key learnings

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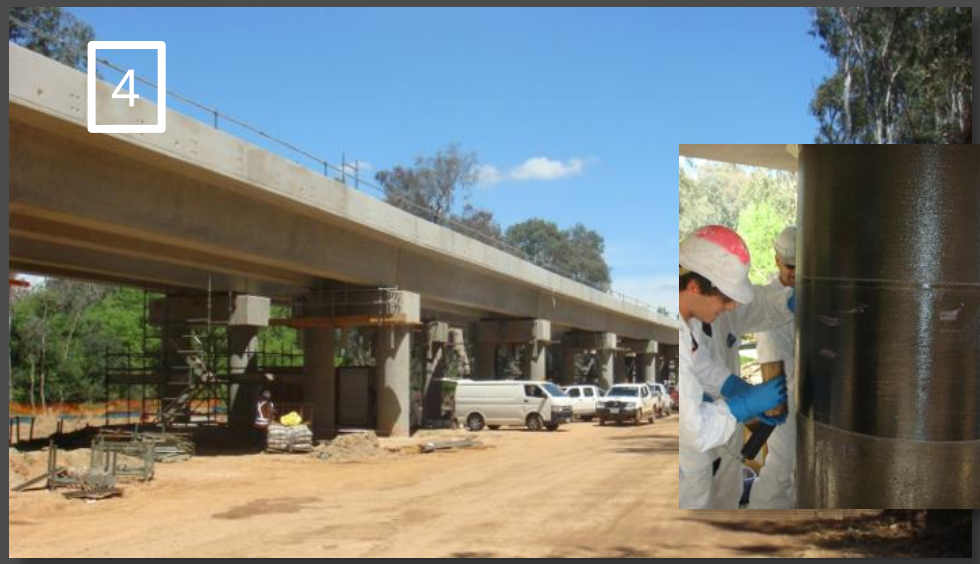
- Melbourne Water pipe bridge
  - 1. Lack of reinforcement
  - 2. CF fabric wrap
  - 3. Completed historic rehabilitation

- NSW - New Rail Bridge
  - 4. Incorrectly detailed column ligatures discovered after built
  - 5. Economical CF fabric wrap solution



Other bridges around Australia
Key Learnings

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

- DIER Tasmania
  - 4. Levelling of uneven substrate

Key considerations with FRP use

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- 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

Key considerations with FRP use

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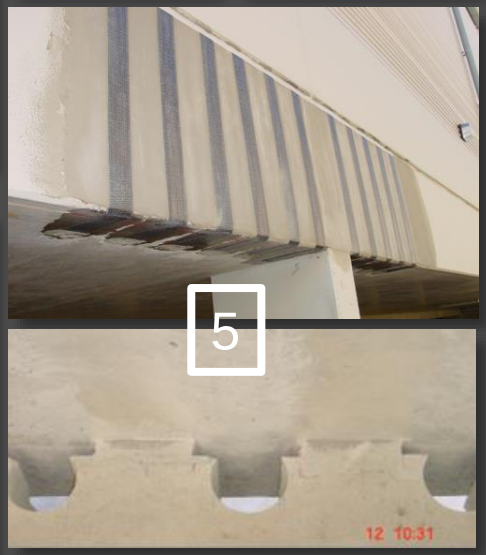
- Examples of Axial/Shear Enhancement
- Best practices:
  - 1. Quick and easy – Access/Labor
  - 2. Impact resistance – Aramid
  - 3. Low installed cost – Less space
  - 4. Rapid emergency repairs
  - 5. Easy fix for design/construction errors
    - Inadequate shear ligatures
    - Core holes drilled through slab



Key considerations with FRP use

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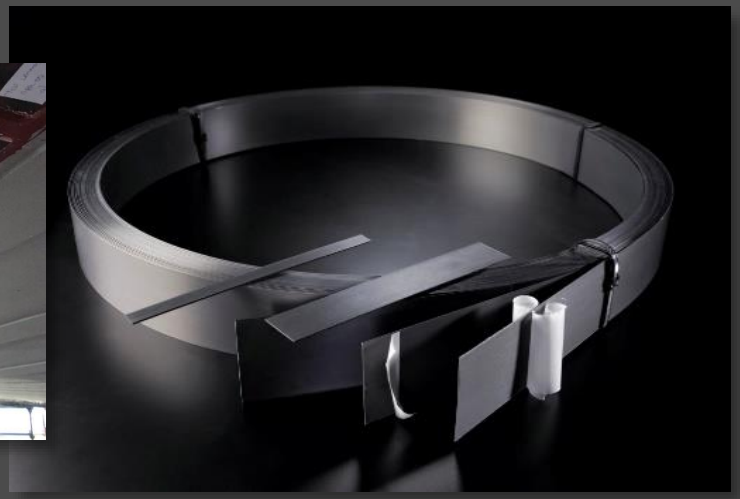
- Supply planning – Early ordering to ensure in-full and on-time delivery
- Quality Assurance – Documented, audited, full applicator training & trialing
- Quality Control – Testing frequency to match project requirements
- Health, Safety & Environment – Smart access systems, full PPE, peel-ply laminates (reducing solvent and sanding of laminate surface)



Design with AS 5100.8 and beyond?

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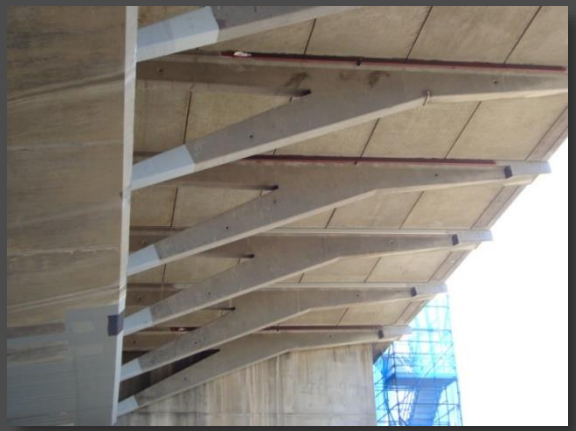
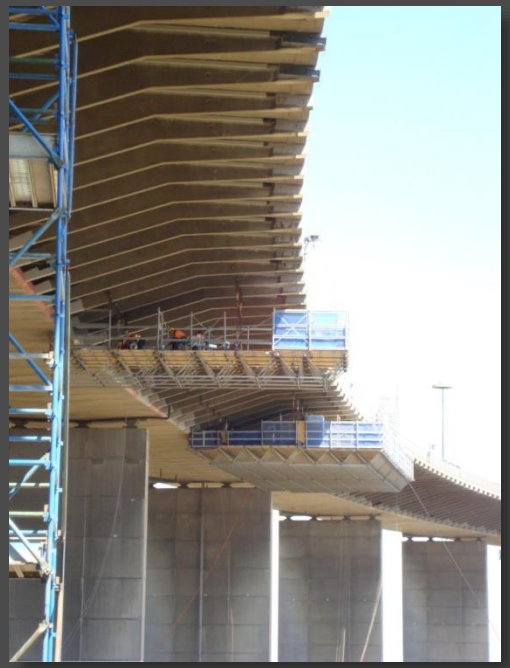
- The revised Australian Bridge design code was published March 2017, unleashing local FRP designs:
  - AS 5100.8 entitled “Rehabilitation and Strengthening of Existing Bridges”
    - Includes Appendix A on “Fibre Reinforced polymer (FRP) Strengthening”, for the first time in an Australian Standard
    - 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

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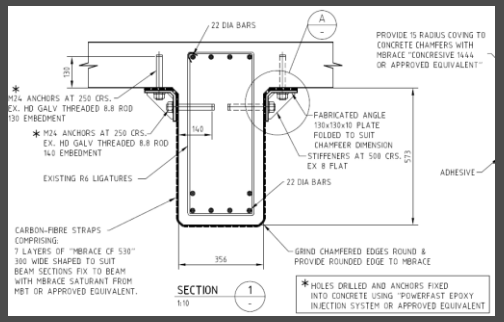
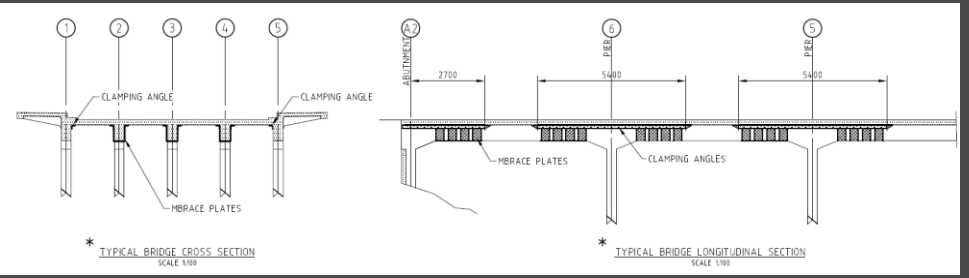
- Investigate the existing structure and environment
  - Check that the structure is strong enough to accept a bonded system (minimum 1.5 MPa tensile adhesion strength)
  - Check surface roughness, existing contaminants and adverse environmental conditions
- Designers needs to understand the requirements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





Summary & Conclusions

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- 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

Acknowledgements

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- I would like to gratefully acknowledge the following for their dedication and ongoing contributions to the successful design and use of FRP in Australia:
  - Mr Fred Andrews-Phaedonos and Mr Yew-Chin Koay (VicRoads)
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  - Mr John Hilton (Aurecon)

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