INNOVATIVE ASSET MANAGEMENT

A USER FRIENDLY GUIDE FOR REHABILITATION OR STRENGTHENING OF BRIDGE STRUCTURES USING FRP COMPOSITES

Abe Nezamian and Sujeeva Setunge
CRC for Construction Innovation
School of Civil and Chemical Engineering, RMIT University,

Research Project 2002-005-C

- Decision support tools for rehabilitation of concrete Infrastructure using FRP composites (CRC-CI Research Project 2002-005-C)
- The guideline forms part of suite of reports covering the design of FRP strengthening system for rehabilitation of reinforced concrete bridge structures

Challenges in Keeping Bridges in Good Operation Condition

Issues:

- Fast rate of deterioration due to environmental conditions
- New design features for modern vehicles sizes and weights
- Construction and detailing errors

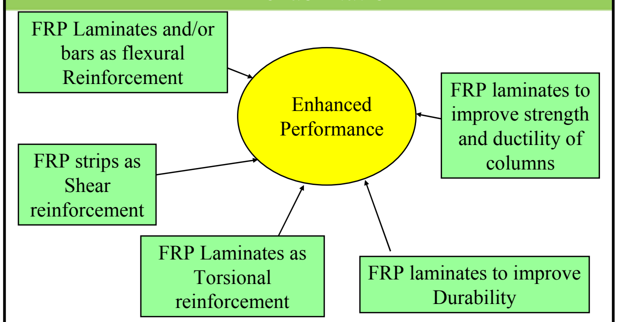
New Technology Options in Bridge Rehabilitation

- Fibre Reinforced composites
- Defined as polymer matrix reinforced with fibres
- Combination of resin's stability and strength of Fibres
- Glass, aramid and carbon fibres
- Pre-cured systems, wet lay-up systems and pre-preg systems

Advantages of Using FRP

- Immunity in corrosion
- Low weight
- Resulting in easier application in confined spaces
- Elimination of the need for scaffolding and reduction in labour costs or stopping the traffic and bridge operation
- Very high tensile strength (both static and long term, for certain types of FRP material)
- Large deformation capacity
- Unlimited availability in FRP sizes, geometry and dimensions

Role of Fibre Reinforced Polymer Composites in Rehabilitation



Review of FRP Strengthening

- Literature review of FRP strengthening techniques
  - ✓ Applicability of the strengthening techniques
  - ✓ Summary of strengthening system
  - ✓ The design guidelines
  - ✓ General information
- Case study
  - ✓ Comparison of the design guidelines
  - ✓ Design example for flexural strengthening
  - ✓ Design example for shear strengthening

Review of Strengthening Techniques
Summary of strengthening techniques

Strengthening Method	Design Action	Type of FRP	Special Considerations
Wet lay up of FRP sheets to the tension zone of the soffit of a beam or slab	Flexural strengthening	Sheets or strips	Debonding
Attaching prefabricated FRP sheets to the tension zone of the soffit of a beam or slab	Flexural strengthening	Sheets or strips	Debonding
Attaching prestressed FRP strips to the tension zone of the soffit of a beam or slab	Flexural strengthening	Strips	Anchorage
Fusion-bonded pin-loaded straps	Flexural and shear strengthening	Pin-loaded Straps	Equipment availability
In-situ fast curing using heating device	Flexural strengthening	Strips	-
Bonding FRP strips inside concrete slits	Flexural strengthening	Strips	-
FRP impregnation by vacuum to the tension zone of the soffit of a beam or slab	Flexural Strengthening	Strips	Equipment availability

Review of Strengthening Techniques
Summary of strengthening techniques

Strengthening Method	Design Action	Type of FRP	Special Considerations
The different types of wrapping schemes to increase the shear strength of a beam or column	Shear strengthening	Sheets	Direction of fibers
Automated winding of wet fibers under a slight angle around columns or other structures,	Shear and axial compression strengthening	Sheets	Equipment availability
Prefabricated U or L shape strips for shear strengthening	Shear strengthening	Strips	Direction of fibers
Prefabricated FRP shells or jackets for the confinement of circular or rectangular columns	Axial compression strengthening and ductility enhancement	Sheets	-
FRP wrapping for axial compression strengthening and ductility enhancement	Axial compression strengthening and ductility enhancement	Sheets	-
FRP wrapping for torsional strengthening	Torsional strengthening	Sheets	Direction of fibers

User Friendly guide – Why ?

- No local guidelines on design with FRP
- USA or Euro draft guidelines need to be adopted in conjunction with the Austroads Bridge design code and AS3600
- Asset owners do not like to rely on manufacturer's recommendations
- The research needs were clearly identified by the industry partners
- Manufacturers were consulted for information on their specific product

Content Summary

- General
- Materials
- Recommended construction requirements
- General design considerations
- Flexural strengthening
- Shear strengthening
- Axial compression and ductility enhancements
- Design examples

General

- Scope and limitation
- Background
- Structural assessment
- Applications and use
- Commercially available FRP systems

Materials

- Resins, adhesive and fibers
- Physical and Mechanical properties
- Design material properties
- Available FRP materials in Australia
- Time-dependant behavior

Recommended Construction Requirements

- Shipping and storage
- Techniques for FRP strengthening
- Temperature, humidity and moisture considerations
- Equipment
- Substrate repair and surface preparation
- Reinforcement details

Design Concepts

- Serviceability limit state
- Ultimate limit state
- Accidental situations
- Special design considerations
- Durability
- Fire
- Strengthening limits
- Ductility

Flexural Strengthening

- Initial situation
- Design assumptions
- Design for strength
- Nominal strength
- Design for serviceability
- Creep-rupture and fatigue stress limits
- Anchorage
- Special cases

Shear and Torsion Strengthening

- General design considerations
- Wrapping scheme
- Shear strength
- Nominal Strength
- Strengthening in torsion

Axial Compression and Ductility Enhancement

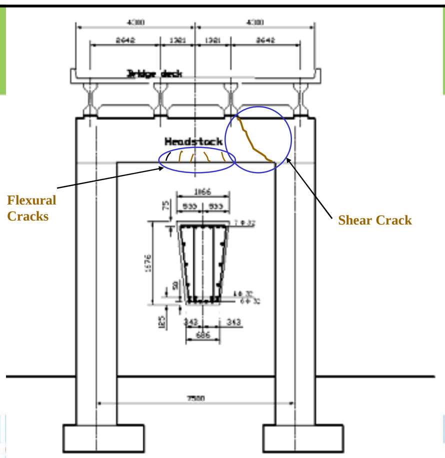
- Nominal axial strength
- Serviceability considerations
- Tensile strengthening
- Ductility

Design Examples

- Flexural strengthening
- Shear strengthening
- Axial compression strengthening

Case study

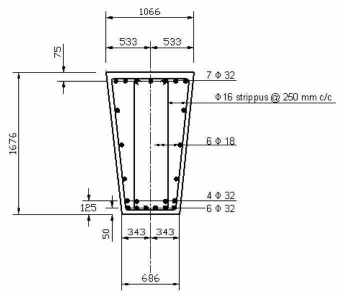
- Strengthening of reinforced concrete headstocks
- Specific project: Tenthill creek bridge



BRIDGE STRUCTURAL ANANLYSIS

- **<u>Targeted Ultimate Strength:</u>**
- **Flexural Strength of 5520 kN-m**
- **Shear Strength of 2425 kN**

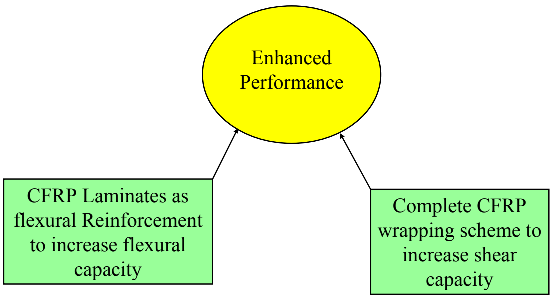
Code based structural capacity



Code based structural capacity

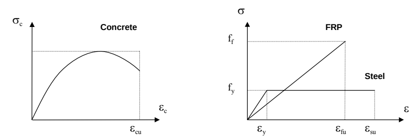
- **V * = 2425 kN > *φ Vu* =2065 kN need strengthening**
- **(M)* = 5520 kN-m > *φ Mu* =3840 kN need strengthening**

FRP strengthening



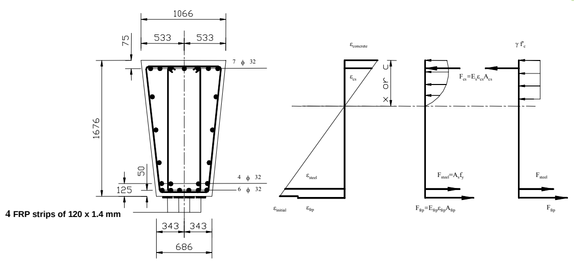
Flexural strengthening
Assumptions

- Idealised stress-strain curves for constitutive materials at ULS



- These curves, along with the basic assumptions of the section analysis, form the basis for the ultimate strength ultimate state analysis of a concrete element strengthened in flexure.

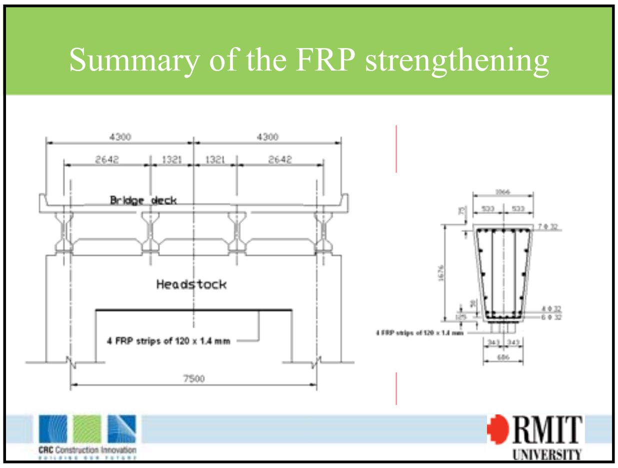
Section analysis

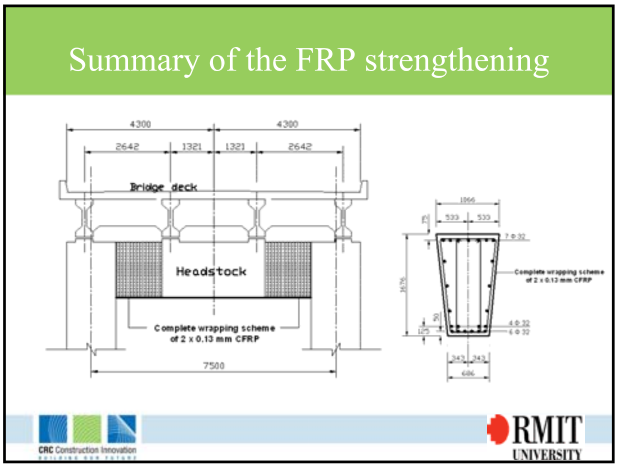


The section design for failure mode of yielding steel followed by concrete crushing

Summary of the FRP strengthening

- The flexural strength of the headstock can be increased from 3800 kN-m to 5854 kN-m by bonding four FRP strips of 120 x 1.4 mm to the tension face of the beam section (bottom fibre) of the headstock with fibres oriented along the length of the member
- The shear strength of the headstock can be increased from 2065 kN to 2711 kN by complete wrapping of the beam with carbon fibres oriented along the transverse axis of the beam section.


Summary of the FRP strengthening
4300
4300
2642
1321
1321
2642
Bridge deck
Headstock
4 FRP strips of 120 x 1.4 mm
7500
1676
533
533
343
343
686
4 FRP strips of 120 x 1.4 mm
CRC Construction Innovation
RMIT
UNIVERSITY


Summary of the FRP strengthening
4300
4300
2642
1321
1321
2642
Bridge deck
Headstock
Complete wrapping scheme
of 2 x 0.13 mm CFRP
7500
1066
533
533
Complete wrapping scheme
of 2 x 0.13 mm CFRP
343
343
686
CRC Construction Innovation
RMIT
UNIVERSITY


Thank you for
your undivided
attention