Externally bonded FRP reinforcement for structural strengthening

Neil Farmer
Executive Director
Tony Gee and Partners LLP
Tony Gee and Partners

- Consulting civil, structural and geotechnical consulting engineers – we are designers
- 400+ people, 7 UK offices and 3 overseas
- Designers of new FRP composite structures
- Designers of >200 projects strengthening buildings, bridges and other structures
- Involved with production of FRP composites design guidance documents for construction applications
Contents

1. Types of FRP Composites for external strengthening
2. Why they have been used
3. How to install them
4. Case studies
5. How we design with FRP composites
6. Inspection and testing advice
Composites in construction

- Composites are a mixture of hardened matrix and a reinforcement
- In timber the matrix is a resin and the fibres are naturally occurring
- In reinforced concrete construction the matrix is concrete and the reinforcement is steel
- With modern fibre reinforced composites the matrix is a resin and the reinforcement is manufactured fibres
Fibres

• **Carbon** - The BEST fibre for **strengthening**, expensive, virtually inert, very low creep, limited availability, extreme temperature resistance, most brittle of the three

• **Aramid** - Expensive, absorbs water, tough, good in impact situations, good in vibration damping, relatively high creep, very light

• **Glass** - the ECONOMIC choice, low creep, good temperature resistance, susceptible to strong acids and bases, very inexpensive. Subject to stress corrosion, readily available
Resins

There are five basic resin types used in composites

- **Epoxies** - best resistance, adhesion, fatigue - more expensive, low odour and VOC
- Phenolics - good fire resistance - poor mechanics
- Polyurethanes - good abrasion resistance - poor temperature performance, toxicity problems
- Polyesters - workhouse of the trade - inexpensive - good general properties - VOC and odour problems
- Vinylesters - good fatigue, moderate price, good chemical resistance, VOC and odour problems
Strips or Laminates

- Pultruded carbon fibres
  5 microns diameter
- Epoxy resin
- Oven baked
- Surface preparation
Wraps - Hand lay-up

• Fabrics of Carbon, Glass, Aramid (Kevlar)
• Woven Mats
• Wet Applied or Dry Applied
Lightweight FRP Composites
Strong and Stiff
FRP Composites

![Graph showing stress-strain relationship for CFRP and Steel]
Why they have been used to strengthen structures?

- Traditional materials are not durable indefinitely
- Change of use giving an increased loading
- Inadequate design or construction
- Structural modification
- Structural and fire damage
- Seismic loading
- Reinforcement corrosion (If cause treated)
- Loss of prestress force
- Impact and blast protection
Save Time

- Lightweight
- Flexible - Easier to manoeuvre around existing structure
Aesthetically Neutral
Reduced Disruption

• Footway, rail and road closures avoided or minimised
• No large or noisy plant or equipment
• Dust contained by vacuum extraction
• Demolition risks eliminated
Costs Less

• No demolition costs
• No utility diversions
• No re-build costs
• Durable materials – minimal maintenance
How are FRP Composite strips installed?
Surface Preparation
Strip Preparation
Cleaning and Adhesive Application
Strip Installation
UK Strengthening Examples

• Calverley River Bridge, Leeds
• King Street Rail Bridge
• St. Thomas’s Hospital, London
• Allders Department Stores
Calverley River Bridge
Calverley River Bridge
Calverley River Bridge
Calverley River Bridge
Calverley River Bridge

Before
• 380 kN per beam
• 1240 kN per beam

After
• 590 kN per beam
  – 55% strength gain
• 1300 kN per beam
  – 5% strength gain
• Full HA + 45 HB
King Street Rail Bridge
King Street Rail Bridge
King Street Rail Bridge

Before
• 17 tonne limit
• Props

After
• 40 tonne vehicles
• Clear span

The Historic Bridge Awards 2001

“This Award is made to
The King Street Railway Bridge
Strengthening Project
In recognition of the exceptional skill and care
which were applied to its design and execution

Client: Flintshire County Council
Designer: Tony Gee & Partners

English Heritage
Railtrack
St Thomas’ Hospital

- Women’s Unit rebuild (£14.5m)
- Reconstruction of maternity, neonatal and gynaecology
- Extensive new services penetrations
Allders Department Stores

- Department stores in Croydon and Portsmouth
- Remodelling required large voids
- CFRP strengthening avoided removing services
- Works completed outside trading hours
How do we design with FRP composites?

• Do not substitute FRP materials for steel, concrete, or other traditional materials
• Consider them as the unique material that they are
• Take specialist advice
Failure Modes

Interlaminar shear failure within FRP
Fatigue failure of metallic reinforcement
Design Guidance

• Concrete Society – TR 55 3rd edition
  – Best Practice design guide – 2012,
• CIRIA – C595
  – Strengthening metallic structures using externally bonded fibre-reinforced polymers - 2004
• Others
  – FiB, ACI, ISIS, Swedish, Japanese, ASCE, ASTM etc
Inspection and Monitoring

Strengthening concrete structures using fibre composite materials: acceptance, inspection and monitoring
Summary

• Strong lightweight strengthening solution
• Minimal visual impact
• 19 years of usage in the UK
• Low cost installation
• Backed by extensive R & D
• World leading expertise in the UK
  – Email ac@tonygee.com
  – Website www.tonygee.com