Construction of the Asset Polymer Composite Bridge for Heavy Traffic Loads

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Outline

- Introduction
- Background
- Composite deck
- Composite girders
- Comparison Theory/Tests
- Bridge construction
- Loading field test
- Summary and Conclusions
- Acknowledgements
Introduction

Drivers for FRP composites in bridges
FRP composites have the following potential advantages in bridge construction:

Reduced mass:
- Easier, faster and more economic installation - smaller cranes required
- Ability to bring larger sections to site reducing assembly time and cost
- Less disruption during installation
- Reduction in size and cost of supporting structure, bearings, cables, etc
- Reduced energy in transportation to site
Introduction

Advantages of FRP composites in bridges, cont.

Superior durability:
• Resistant to atmospheric degradation, de-icing salts, chemicals from spillages, etc
• Reduction in maintenance requirements, through-life costs and disruption

Ability to mould complex forms:
• New aesthetic possibilities
• Geometrically more efficient solutions

Desirable electrical and thermal properties:
• Can be electrically non-conductive (without carbon fiber), which may be advantageous near electrical installations such as railway lines
Construction has followed the evolution in materials.

- Stone
- Straw/mud
- Cast iron compression
- Cast iron tension
- Reinforced concrete
- Advanced composites
- Stay cables
Background

Acronym: ASSET (Advanced Structural SystEm for Tomorrows Infrastructure)
Client: European Commission
Architect: N/A
Category: Civil (optionally Project Development)
Value USD: 4,5 million (50% EC funding)
Background

The ASSET profile used for bridge deck. Manufactured by the pultrusion process, Fiberline – Denmark. Square profiles reinforced by carbon fibres used for load-carrying beams. Special profiles used for side paneling.

Each of the four main supporting beams, 520 x 480 mm, are constructed of four profiles reinforced by glass and carbon fibres and bonded together.

The decking system bonded together are positioned and glued onto the supporting beams. The profiles can be mounted on concrete beams as well as on steel beams.

The side paneling consist of maintenance-free and corrosion-resistant high composite profiles.

The edge beams, footpath and the two crossbeams at each end of the bridge are made of concrete, whereas the crash barrier is made of steel.

The wearing surface is made of polymer concrete, but asphalt is also an option.
Background - Technical Data

**Bridge size:** 10m span x 6.8m width over the River Cole, on the B4508, in Oxfordshire

**Traffic Capacity:** ASSET profile designed for full UK and European traffic loading, including concentrated wheel loads

**Structure:** 34 no. ASSET profiles made from glass fibre and spanning transversely between 4 no. carbon fibre/glass fibre composite main beams, 11m long and spaced 2m apart; bridge abutments and parapets consist of conventional reinforced concrete construction.

**Adhesive:** Deck created by adhesive bonding 34 ASSET profiles side by side; bonded using an epoxy adhesive to the main beams; composite main beams consist of 4 GFRP square hollow sections bonded together plus CFRP resin infused to the top and bottom flanges for additional flexural rigidity.

**Weight:** Total bridge weight approx. 37 tonnes; composite components approx. 12 tonnes - a third of the weight of a reinforced concrete bridge of the same dimensions and load capacity. Weight of the bridge deck 100 kg/m².

**Construction:** Bridge deck will be constructed and bonded in an environmentally controlled site factory adjacent to the existing bridge. Complete with concrete diaphragms and parapets, will be lifted in place onto the bridge bearings using a medium sized crane

**Surfacing:** Polymer concrete and epoxy-based wearing surface
Background

The new prototype bridge – High degree of innovation

The Original West Mill Bridge

The New West Mill Bridge
Bridge Deck
Testing of single profile

Testing of Sub-decks
Composite Girders
Manufacturing of West Mill Composite Beams

- Theoretical calculations
- Full-scale manufacturing
- Full-scale design
- Proof-testing
Composite Girders

Manufacturing of prototype girders

Outlet, placed at the centre of the beam, 2 m to each end.

Inlet, dia 16 mm, along the whole beam.

Reinforcement, flow-layer and parting-film

Bag

Grinding of surfaces

Assembly of GFRP profiles

Gridning of flanges

Vacuum infusion of carbon fibre fabric

Carbon fibre

Glass fibre
Composite Girders

Testing of prototype girders

Beam 2: Carbon

Buckling under the load
Composite Girders

Full-scale Manufacturing

Applying adhesive

Vacuum pressure is applied. Resin is moving.

Just before applying pressure to the beam.

Removing the vacuum infusion system.
Composite Girders

Proof-testing

Section A-A

Beam A
Beam B
Beam C
Beam D
Composite Girders

Proof-testing

Load, $F$, [kN]

Beam height, $h$, [mm]

Strain distribution, $\varepsilon$, [$\mu$]s

Mid-deflection, $\delta$, [mm]
Comparison Between Theory and Test

\[
EI_{\text{theory}} = \frac{PL^2a}{48 \cdot \delta_{\text{theory}} \left(3 - \frac{4a^2}{L^2}\right)}
\]

\[
\delta_{\text{flexure}} = \frac{PL^2a}{48 \cdot EI \left(3 - \frac{4a^2}{L^2}\right)}
\]

\[
\delta_s = \frac{Pa}{G_{\text{mod}} A_{\text{web}}}
\]

\[
\alpha = \frac{E_{\text{CFRP}}}{E_{\text{GFRP}}}
\]

\[
I_C \approx \frac{32}{12} th^3 + 4t(h-t)h^2 + 4cht \left(h + t_c \right)^2
\]

<table>
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<th>Beam</th>
<th>( P_{\text{test}} ) [kN]</th>
<th>( \delta_{\text{test}} ) [mm]</th>
<th>( (EI)_{\text{test}} ) [Nm²]</th>
<th>( (EI)_{\text{theory}} ) [Nm²]</th>
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<td>1.30 \cdot 10^8</td>
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<tr>
<td>B</td>
<td>369.5</td>
<td>51.8</td>
<td>1.40 \cdot 10^8</td>
<td>1.30 \cdot 10^8</td>
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<tr>
<td>C</td>
<td>369.2</td>
<td>51.7</td>
<td>1.40 \cdot 10^8</td>
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</tr>
<tr>
<td>D</td>
<td>368.8</td>
<td>50.7</td>
<td>1.43 \cdot 10^8</td>
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Bridge’s Construction

Different suggestions for bridge furniture and connection
Bridge’s Construction

Solution for the edge beam and end fascia
Bridge’s Construction

A large amount of work was focussed on the bonding process

Pre-bonding

Sub-decks

Work site
Bonding was performed “indoor” in a site factory
Bridge’s Construction

Bonding the sub-decks together and then to the composite girders
Bridge’s Construction

Adding end fascia to ASSET decking, then filling with concrete

Grinding and cleaning

End fascia

Edge beam
Loading test

To verify theoretical calculations load tests were undertaken
Loading test

FOS attachment to the deck and beams
Loading test

- Truck driven centrally on the bridge stopping at every meter
- Level of strain reflects position of sensors relative to loading
Future of ASSET
New GFRP Bridge across UK motorway

Rapid construction and reduced disruption for road users were important considerations in the decision of the UK Highways Agency to span the M6 motorway in Lancashire with a new lightweight bridge made of GRP composite.

“The innovative bridge, which is 52 metres long and built using the ASSET bridge deck profiles, is two-thirds the weight of the one it replaces, but is stronger and offers cost savings through reduced future maintenance.

The motorway bridge replaces a 40-year-old life-expired bridge and is designed to carry vehicles up to 40 tonnes. The Highways Agency points out that the new bridge has a superior strength/weight ratio to steel or concrete and is non-corrosive to water and salt.
Future of ASSET

“The Highways Agency wishes to promote wider use of GRP and stimulate further development of the technology, thereby paving the way for improved cost effectiveness. Wider experience of the materials is needed by the construction industry. And, as with all construction, workmanship is a key issue.”

“The Highways Agency will also consider widening the application of GFRP to other infrastructure applications. The Agency believes that accelerating the use of GFRP will have major benefits in future motorway widening schemes and bridge rehabilitation across the network”.

Conclusions

- Many details discussed before the bridge’s final solution
- Sections bonded
- Tests show excellent bond force transfer
- GFRP composite girders with CFRP flanges
- Vacuum infusion technique used
- Bonding procedure time consuming – can be improved
- Normal construction works for the retaining walls and abutments
- The process of construction can be speeded up

Acknowledgement

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