FRP Composites - State-of-Art in Pedestrian Bridges

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Background

Born largely out of aeronautical and aerospace engineering, fibre reinforced composite materials have succeeded in permeating broad markets from naval architecture to automotive, general manufacturing to specialized products, and the leisure industry. Significantly however, the industry is generally not single project orientated, rather it is centered upon mass production. As a consequence the sometimes complex process of product development frequently cycles through concept / prototype design / testing iterations to be efficiently resolved.

Infrastructure benefits by this process for the development of some elements, however, given the nature of construction industry procurement, a direct design approach is invariably required. Additionally, infrastructure most often requires products that are generally much larger than those used in the manufacturing sector, adding another dimension to the possibilities for FRP.

The great challenge, and opportunity, for FRP composites in infrastructure therefore lies in three distinct areas;

- effectively exploiting the attributes of FRP
- extending the scale of composite manufacture to satisfy size demands
- addressing the procurement process

Over the past 10-20 years the rate of development of FRP materials and manufacturing processes has been exponential. Growing demand has fostered numerous radically different manufacturing methods which in turn continues to create demand for newer and more specialised materials. Additionally, awareness of the importance of utilizing natural renewable resources has encouraged the efficient use of natural fibres and matrix materials. All of these influences have served to increase the scale of the industry with resultant competitive (lower cost) outcomes.

The use of FRP in large-scale structures such as bridges can be categorized in two ways;

- there are those projects in which FRP may be considered comparative with orthodox materials (leading to like-for-like assessments), and,
- those that take broader, holistic advantage of FRPs unique attributes.

Certainly, attributes related to; Strength / Stiffness / Lightweight (primary and secondary structure) /Durability (corrosion, impact and fire resistance) / Low embodied energy / Re-cyclability / Aesthetic design possibilities (finishes and colouration) / Extreme formability / Opportunity for complete pre-fabrication / minimization of secondary framing, are available for application to bridges.

Like-for like comparisons:

Like-for-like material comparisons are common in construction. Unrelated attributes are the subject of multi objective assessment from which the appropriateness or otherwise of materials are determined. Most often, final selections are cost based. In this, FRP offers many attributes worthy of consideration, these include;

A recent example of like-for-like material comparison is the Centennial Pioneer Park Pedestrian Bridge, Gosnells, WA - a 21 metre span bridge over the Canning River in Perth's eastern suburbs. The project was initially conceived as either a steel and/or concrete structure - however a fuller review indicated FRP a worthy and preferable alternative.

Issues affecting this decision included;

- the opportunity to minimize site works and potential disruption/damage to the highly valued river and extended parkland surrounds
- the need to facilitate the manoeuvring of materials through relatively dense bush land
- the need to reduce interference of river flow by minimising foundation and general embankment construction
- the desire to achieve a low maintenance structure
- the opportunity for the local authority to engage with design by way of sculptural form and colouration effects.
- dealing with sacred indigenous ground
- the potential to contribute to a standardized solution for bridges of this type and size

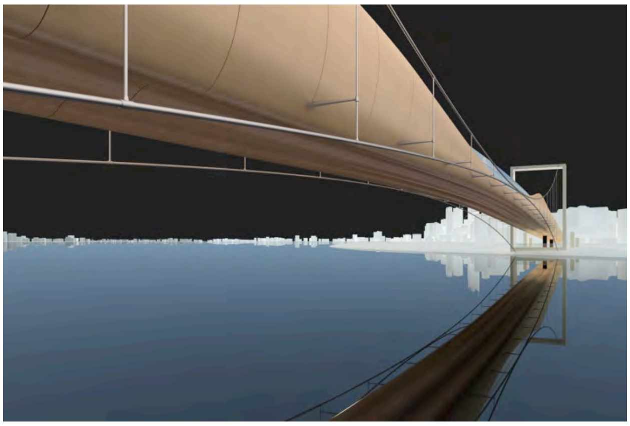
The FRP outcome was found to best meet all of these objectives within an affordable, competitive budget.

Designed to AS 5100 Bridge Design Code, the structure comprised two insitu concrete footings, each incorporating two anchorage points, and a superstructure component fabricated off site.

Handrails, non-slip surfacing and bearings were incorporated in the fabricated single unit superstructure.

Weighing just 3 tonne, the superstructure was delivered and installed on a Sunday morning in 4 hours. Having been transported several hundred metres along bush pathways by a pair of articulated mobile cranes, it was launched from one embankment.

On the other hand; because of the lightweight nature of FRP material, the ability to fabricate forms that resolve the structure efficiently, FRP presents an opportunity for structures that would otherwise either not be possible or at least would be prohibitively expensive using orthodox materials.



Unique possibilities:

By exploiting FRPs attributes, in particular its lightweight and formability, the Heirisson Island Sculpture Park Footbridge illustrates potential in the design of unique bridge structures. The design, shortlisted by the City of Perth for a 160 metre span across the Swan River, takes advantage of an extreme low weight deck, combining it with a pre-tensioned cable truss system. Loads are predominantly imposed actions rather than self weight, so often the dominant load with bridges of such span. And, given the location's deep silt foundation condition, support reactions are more than halved, substantially reducing sub-structure and pylon costs.

The primary structure comprises a cable truss pre-tensioned to balance randomly distributed imposed loads applied via the vertical cable ties. Structural demand on the deck thereby being reduced to short spans between the cable ties. A unique solution made possible because of the extraordinary lightweight FRP deck.

With mold manufacture being a significant cost component, the design optimizes this by linearizing the deck. Fluted soffit beams facilitate spanning between transom beams at the vertical ties. Sculptural form of the balustrades has been obtained by mold reduction, that is, sections of the mold are closed off rather than altered or constructed anew. This has enabled a longitudinal sweeping form at effectively no additional cost.

The river's high saline environment presents a severe corrosion concern for metallic material, the use of FRP clearly is an attractive option with significant savings in maintenance costs.

A further example of **unique possibilities** is presented by the FRP solution in the proposed Kings Park Link Bridge, Perth. The opportunity to create an imaginative, playful structure joining the children's hospital to the park has been met by applying FRP in a variety of unique art/engineering forms. In association with Formworks Architecture the structure has been designed to tight budget constraints. This has been addressed by rationalizing the overall complexity of form by reducing the deck into discrete efficiently produced sub-elements.

The broad aesthetic/ sculptural approach is a representation of bubbles emanating from the hospital flowing high into the adjacent parkland.

The formability of FRP has made possible the integration of structure and art through the entire bridge. Supports vary from partial to full circular barrel vaults. At times these are significant structural components (as with those adjacent the dual carriageway over which the bridge passes), elsewhere they are minor supports forming part of a playground or simply independent sculptural elements.

The meandering plan layout predominately comprises linear elements; these are of common cross section thereby requiring just one mold. Lengths are simply varied by blocking the mold.

Curved transitional sections are similarly rationalized, minimizing the number of molds. All deck sections have post-fixed balustrades and workshop applied anti-slip surfacing. The tapered soffit is to be embossed as part of an art relief motif.

The barrel vault supports comprise hollow (coreless) FRP construction. At roadway abutments these are concrete filled, acting compositely with the FRP shells to form structural arches; importantly providing resistance against vehicular impact loads.

The vaults are finished with high gloss polyurethane artwork with corners and edges rounded providing a safe comfortable playground environment.

The opportunity to include infused and applied rich colouration, along with an embedded lighting scheme, adding to the already strong social impact of the bridge's design.

Commercial Attractions:

Worldwide, recent projects have demonstrated sufficient commercial advantage in using FRP for many small bridge projects. What remains is that designers learn to judiciously exploit the varied attributes of FRP and to apply them effectively to meet project imperatives.

Efficiency in the production of elements can be derived variously. Examples of mass produced standard componentry is available throughout many industries. The pultrusion process produces continuous constant cross section elements to a high and reliable quality. Such sections are becoming common in bridge decks in Europe, Australia and elsewhere where they are used as primary longitudinal beams. Standardised molding enables non-linear elements to be efficiently produced using numerous production techniques.

Extreme variation in material properties is available, meeting specific application needs. Formulation of laminates / cores / and overall composition allows properties such as fire, abrasion and impact resistance, extreme crushing strengths, infused colour and numerous others to be selected for specific project applications.

Often overlooked is the substantial advantage achieved in structures as a result of not requiring sub-structures. The opportunity to do away with secondary framing is inherent in FRP structures, where monocoque construction is an obvious choice as is inbuilt primary framing. Such designs minimize or negate material interfacing, detailing complexity, assembly logistics and interfacing tolerance, and add to durability and the reduction of maintenance.

Current developments using natural fibre and matrix materials adding to the environmental importance of choice when considering low embodied energy, renewable resources and pollution reduction.

Procurement:

Bridge procurement processes generally do not afford either time or resources for developmental work outside that typically required for orthodox material design. FRP materials are currently available to fulfill such needs for elements, however in complete structure and holistic applications a different approach is required. This is because FRP is not a material of generally fixed isotropic mechanical properties, as with steel, concrete, masonry etc., and because the production of structures requires an integrated approach to manufacture and design. This significant reliance on design development affects the procurement process resulting in two fundamental methodologies.

Design and Construct Tendering

- An appropriate approach for discrete structures such as single span bridges where considerable benefit can be had in providing tenderers the opportunity to apply manufacturing processes best suited to their skills and efficiency. There is, perhaps surprisingly, great variation in such preferences that lead to effective commercial solutions.
- D+C procurement requires that specifiers are competent in extracting the full gambit of opportunity that FRP possesses. Constructing design briefs requires a sound knowledge of these possibilities - frequently early informal discussion with manufacturers can prove invaluable in this regard.

Traditional Design, Documentation & Specification Tendering

- Large and sophisticated structures, in particular those unique solutions integrated with materials other than FRP, are not suited to design and construct tendering. This is because the overall design involves skills and technologies not routinely available to FRP manufacturers. For these projects it is most appropriate to fully document and specify the entire FRP works, as tenderers are most unlikely to be willing to speculate on large and complex design solutions. Notwithstanding, there is potentially significant benefit in having manufacturers contribute to the design/manufacture approach to elements, following their experience and preferences. This process may need to be facilitated during the tender review stage, requiring critical review by experienced designers.

Both of the above approaches have been successfully applied in Australia. The FRP manufacturing industry is largely comprises of companies derived from boat building or aeronautical industries. Fortunately, both are highly expert at construction of quality complex structural forms, providing a skilled industry base for infrastructure projects.

Quality control and specification standards are available via international standards and codes of practice. Base material and composition assessment is achieved by destructive and non-destructive testing available through NATA registered bodies.

The way forward:

Given the clear lead by other industries, worldwide examples and industry momentum there is no doubt of the appropriateness and readiness of FRP as a routine medium for the construction of bridges. It remains for designers and specifiers to take advantage the opportunities FRP provides.

With the technology and local skills available, establishing and becoming familiar with procurement is perhaps, in the first instance, the most significant issue to address. With competitive tendering in Australia, transportation logistics remains the only obstacle to size.

Recent projects have been successfully undertaken confirming the arrival of this exciting new generation material in infrastructure development.