

Developments in FRP bridge design

David Kendall, Managing Director of Optima Projects Ltd, reviews a recent Network Group for Composites in Construction (NGCC) conference discussing some exciting developments in fibre reinforced plastic (FRP) bridges.

The conference organised by the Network Group for Composites in Construction (NGCC), and held at the Building Centre in London in February, showed the progress that has been made since a similar conference was held three years ago.

An architect's perspective

Mark Whitby from Ramboll presented a keynote review of 20 previous and future

bridges, manufactured from steel, concrete and aluminium. These showed dramatic, sculptural forms and in many respects cutting-edge design and engineering, but a distinct lack of FRP in their manufacture.

Whitby explained that FRP is not generally considered as a candidate material by bridge engineers, as they tend to stick to tried and tested materials with which they are familiar. However, he admitted that many of the bridges he showed

could have been made from FRP and that this may have provided technical and economic benefits, certainly once through-life costs are considered.

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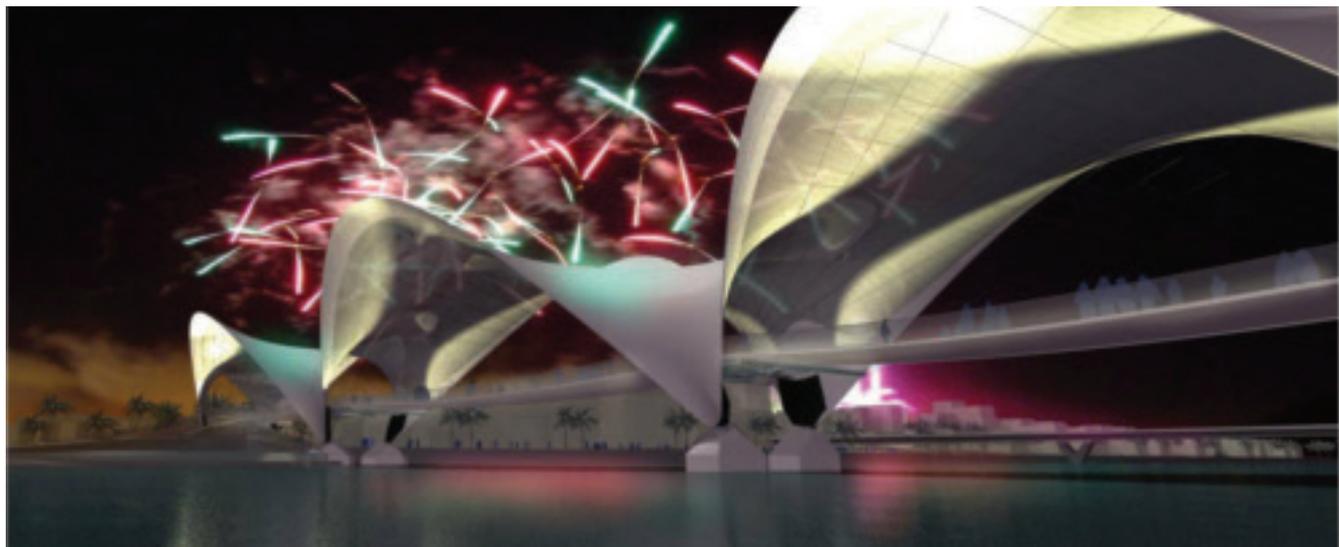


Figure 1: Lusail Marina Bridge – a future candidate for FRP?



Figure 2: Bradkirk FRP footbridge. (Picture courtesy of Birse Rail.)

Greater awareness and knowledge of FRP materials is still needed within the construction industry. Hopefully some future projects, such as the bridge shown in Figure 1, will include FRP.

UK railway bridges

Brian Bell from Network Rail showed a perspective from an end-user and asset owner, reviewing recent applications of FRP in the rail sector.

Network Rail has been very innovative in the last decade, promoting and initiating

research into the use of FRP for strengthening existing structures and for new build applications. As a major bridge owner it has taken a very proactive role in encouraging the use of FRP and is now beginning to see the benefits as the technology matures and its use increases.

Bell explained how the low mass of FRP solutions has delivered benefits in terms of faster, safer and easier installation, reducing time on site, and therefore reducing disruption, and providing cost savings. The increased use of prefabrication has also delivered greater certainty in programme durations, with

less risk of overruns on site, which is critical during limited track possessions.

Network Rail has now completed around 30 FRP strengthening projects, 4 new-build FRP bridges and an FRP aqueduct. These have utilised mainly pultruded materials due to the availability of standard profiles, but also include a moulded footbridge (see Figure 2).

Viability of FRP bridges

The viability of FRP bridges was demonstrated by David Kendall, from Optima Projects.

Technical viability of FRP foot and road bridges was easily proven by reviewing some existing projects demonstrating the ability to produce moderate span structures. The ability to manufacture much larger spans was addressed by presenting a conceptual design for a 330 m clear span carbon fibre reinforced plastic (CFRP) footbridge structure and showing large marine structures of similar scale.

The financial viability of FRP footbridges was shown by reviewing the costs of 15 different FRP bridges and where possible making comparisons to alternatives in other materials. It was shown that bridges such as Bradkirk (Figure 2) could be more economic than a steel alternative, if the initial tooling costs can be spread over several projects. Costs for the existing bridges included in the survey are shown in Figure 3.

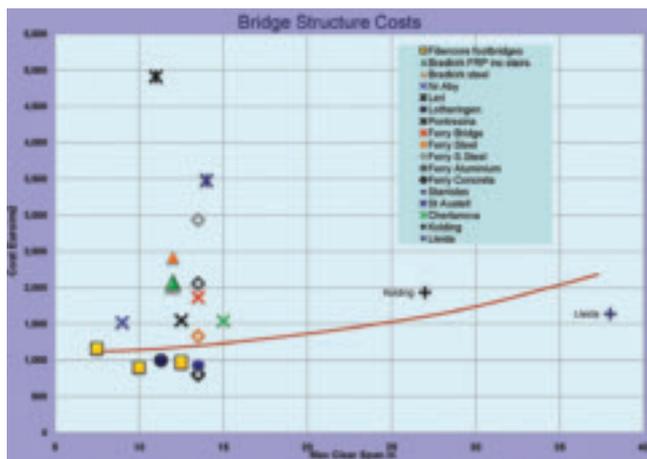


Figure 3: Financial viability of existing FRP footbridges. (Source: Optima Projects.)

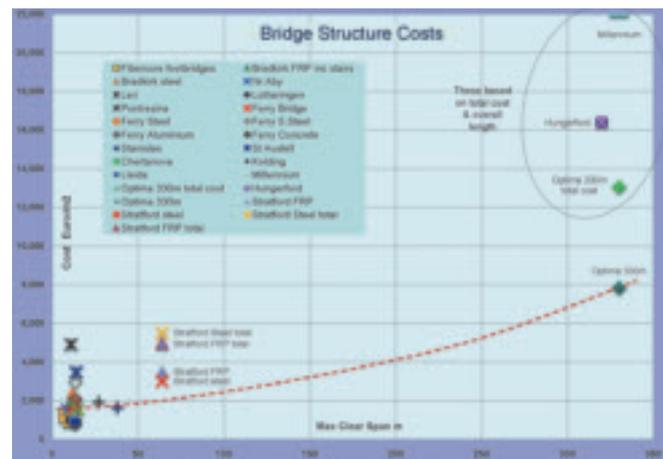


Figure 4: Financial viability of long-span FRP footbridges. (Source: Optima Projects.)



Figure 5: Standen Hey FRP road bridge. (Picture courtesy of Network Rail.)

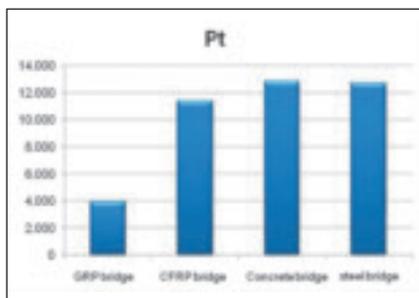


Figure 6: Ecological impact of different materials. (Source: DSM.)

In carrying out the survey most manufacturers commented that if volumes could be increased to allow series production, then efficiencies could result in 15-30% cost reductions.

The financial viability of larger footbridges was addressed in two studies, firstly looking at Optima's 330 m clear span CFRP bridge, and in a second study by Gurit for a 128 m long two span bridge. Both studies concluded that the installed cost would be

lower with an FRP superstructure, as shown in Figure 4. It was concluded that both moulded and pultruded FRP can provide cost-effective solutions, but that it is essential to have efficient designs to achieve this.

UK's first FRP road over rail bridge

Neil Farmer from Tony Gee and Partners showed that the previous bridge at Standen Hey consisting of steel beams supporting timber decking was in very poor condition, after 44 years of service, a long way short of the 120 year design life generally required for bridges. The bridge was 4 m wide and 9.1 m span and it was decided to replace it with a new FRP structure.

A series of options were investigated based on various standard pultruded profiles and the final structure was designed from two layers of the Fiberline ASSET profile, bonded together and spanning longitudinally without any supporting beams. A third layer of ASSET profiles were added along the edges with a single cell filled with polymer concrete to form a robust kerb. The whole bridge was delivered and installed in a single section as shown in Figure 5.

Farmer concluded that the project was successful, but future savings could be made as volume increases. It is believed



Figure 7: Carbon FRP bridge produced by Fibercore, spanning 24.5 m.



Figure 8: Road bridge in Spain produced by Acciona Infraestructuras, consisting of moulded FRP primary beams and concrete decks.

that the concept could be developed to provide larger structures with multiple spans and on-site joints.

Dynamic assessment

The Bridkirk Footbridge (Figure 2) was installed in 2009 and consists of two 12 m spans and two staircases all moulded with fire retardant epoxy and glass fibre reinforcements. Each 12 m span weighs less than 2 tonnes, which is significantly lighter than any conventional alternative. For footbridges over the railway there are concerns regarding possible dynamic response due to aerodynamic loads from passing trains. Menaga Mohan and Francisco Santos from Gurit carried out an on-site dynamic assessment of the Bradkirk Bridge and presented their results.

Several accelerometers were attached to the bridge deck and parapets. The natural frequencies of the structure were measured by jumping on the structure and recording dynamic response and these were found to correlate reasonably well with predictions from finite element analysis (FEA). The response from passing trains was also

recorded for 12 trains with speeds ranging from 44 to 70 mph. It was interesting that the maximum response occurred with a train at 51 mph, rather than for the fastest train, possibly indicating a better fit between the aerodynamic pulse and the structure natural frequency at this speed. The maximum deflection of the bridge deck due to a passing train was only 0.15 mm and the presenters commented that the bridge felt safe and comfortable without any excessive vibration being felt as trains passed below.

Glass reinforced plastic (GRP) had significantly lower ecological impact.

It was concluded that the dynamic behaviour of the bridge was acceptable, but it is believed greater data is still required, ideally derived from direct pressure measurements, for the design of larger span lightweight bridges over the railway.

FRP bridges in Holland

Mel Foster from Fibercore Europe presented details of the moulded FRP bridges that they produce in Holland using resin infusion. Fibercore manufactured 23 bridges in 2009, expects to make 150 in 2010, and hopes to be making 2000 per year by 2013.

Details were shown of a life cycle analysis of different materials for bridge construction, showing that glass reinforced plastic (GRP) had significantly lower ecological impact as shown in Figure 6.

A number of different bridges were presented, such as the 24.5 m long carbon fibre bridge in Figure 7.

Road bridges in FRP in Spain

A different approach to road bridge construction has been developed by Acciona Infraestructuras in Spain, details of which were presented by Carlo Paulotto. The company has developed a system of moulded hollow primary beams constructed from hybrid carbon/glass prepregs, supporting cast in-situ concrete decks.



Figure 9: Launder Aqueduct fabricated from pultruded panels.

A road bridge has been constructed using this system with three spans of 10 m, 14 m and 10 m, as shown in Figure 8.

Aqueduct reconstruction in FRP

Andrew Kenchington from Tony Gee and Partners presented details of a 35 m long three-span aqueduct, fabricated from Composites pultruded panels. The structure was fabricated in three sections by Pipex with bonded joints made on site prior to installation. The complete aqueduct weighed 6.5 tonnes and the supporting trestles were also fabricated from FRP pultrusions, as seen in Figure 9.

GRP decking

Wendel Sebastian of the University of Bristol presented details of ongoing research into bonding GRP pultruded bridge decks to prestressed concrete beams. The effectiveness of the bond to achieve full composite action between deck and beams is being evaluated with full scale testing including the fatigue loading from passing vehicles.

A manufacturer's view

Peter Thorning from Fiberline Composites presented the view of a pultruder. Fiberline has now produced over 2000 bridges and

decks in FRP and believes that there is significant room for growth.

Fiberline has developed a range of pultruded bridge deck profiles, but proposes that there is still potential for improvements in the designs and refinement of manufacturing processes to produce more economic structures. Greater volume of production will also bring efficiencies and economies as the market grows and the company's vision is for FRP to become a mainstream construction material.

Several completed projects were shown, including the Holländer Bridge in Germany, measuring 3.5 m wide by 99 m long and using a pultruded deck in conjunction with steel beams, as shown in Figure 10.

Thorning also showed environmental comparisons between different materials, demonstrating that FRP solutions consumed less energy and resulted in lower pollutants than conventional alternatives such as steel, aluminium or concrete.

Progress

The conference was deemed to be a great success and demonstrated the progress that has been made over the last few years. It is clear that there are numerous advantages in using composites for bridge structures and most importantly their durability will reduce future maintenance requirements and therefore minimise disruption to transport networks. The bridges that have already been built clearly demonstrate the viability of using FRP for such structures and a common theme in the conference was that if volume and demand is increased then cost can be reduced with more refined designs and optimised production. It is also apparent that the weight savings will be even more beneficial for larger structures, so hopefully we will see FRP utilised for much larger bridges in the future. ■

Further information

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Figure 10: The Holländer Bridge in Germany uses Fiberline pultruded decks in conjunction with steel beams.