NATIONAL COMPOSITES CENTRE

CATAPULT High Value Manufacturing

Response to the National Infrastructure Commission Call for Evidence, 13th November 2015

The Economic Case for using Fibre Reinforced Polymer (FRP) Composite Materials in infrastructure Connecting Northern Cities, London's Transport Infrastructure and Electricity Interconnection and Storage

Pre-amble

This submission describes the role which Fibre Reinforced Composite (composite) materials could play in a variety of infra-structure applications related to Connecting Northern Cities, London's transport infrastructure and some aspects of Electricity interconnection, particularly low-cost pylons. We have therefore taken the liberty of sending this to the three email addresses.

The National Composites Centre

FRP composite materials are strong, light and highly fatigue and corrosion resistant. The UK is a world leader in the application of composite materials which are used in a wide and increasing range of applications. Their usage is forecast to grow in the UK up to six-fold by 2030[1], largely on the back of the need for a step-change in the fuel efficiency and emissions of all forms of transport equipment.

The NCC is part of the Innovate UK-sponsored High Value Manufacturing Network which aims to help UK companies bring better products to market more quickly. It operates in the gap between universities and the point where companies are confident enough to invest heavily in new technologies; this is often referred to as the 'valley of death'.

The Centre is one of the most capable of its type in the world. It has the latest full-size industrial equipment and approaching 200 staff with expertise in material selection, design, simulation, sub-scale and fully scale prototyping and testing. It is currently working with many of the UK's leading companies and universities to develop the next generation of aircraft wings, jet engines, lightweight cars, oil and gas structures and a host of other applications.

The NCC is a not for profit organisation and has been specifically established to develop cost effective products and, where necessary, work with regulators to develop new standards to provide end-users with the confidence that products are fit for purpose.

Introduction

There are extraordinary challenges in maintaining and upgrading the UK's existing infrastructure whilst boosting the capacity to meet the challenges of a growing and increasingly mobile population. In addition to efforts to boost house building, and general construction, there are plans for huge public and private investment in National Infrastructure from 2014-15 including energy, (£275bn), transport (£142bn) and water (£23bn) projects[2].

[1] 2015 unpublished UK Trade and Investment Report: Present and Future value of the UK composite market
[2] National Infrastructure Plan 2014, HMT, Dec 2014

In the 19th and 20th centuries, the UK was a pioneer and innovator in the development of rail, road, water, sanitation and power distribution infrastructure. Some of that original infrastructure is still in use today and although much of it is now in need of replacement, it is a testament of the quality of design and materials used.

Other infrastructure, much of it installed in more recent times, has fared less-well and requires significant inspection, maintenance and repair at significant cost.

Unlike some other parts of the world, composites are not widely used in UK for bridges, gantries and tunnel linings for which they are well suited. This has implications for taxpayers and the supply-chain which is under-developed relative to other industrial economies.

Composites materials could make a significant contribution to upgrading infrastructure which would cost less to buy, install and maintain throughout its life.

Transport Applications in the North of England and in the London area

The scale of the challenges faced by Network Rail, Cross Rail, Highways England, London Underground, and in due course, HS2 are immense. Network Rail has to maintain around 40,000 bridges and 900 tunnels, many dating back to Victorian times as well as thousands of pieces of trackside infrastructure such as platforms, roofs, signals and cabinets. Similarly, Highways England has over 8000 bridges and 4000 gantries amongst other assets valued at £110 billion[3] and Local Authorities own an estimated 80,000 bridges between them[4].

The international academic case studies in Appendix 1 show that composite bridges can achieve a total life-cycle cost savings (*excluding* installation and decommissioning) of around 40% compared to those using traditional materials. The National Composites Centre believes these are conservative[5] figures in light of new composite manufacturing processes which have significantly reduced the initial cost of FRP structures.

The saving quoted do not include the costs of installing and commissioning the bridges which can be significantly lower than conventional bridges.

Composites are increasingly used internationally for tunnel linings (often using British materials) because of their resistance to water ingress and the speed of deployment.

Interestingly, a Technology Strategy Board funded competition led by London Underground and involving, amongst others, Atkins and the National Composites Centre, won the prestigious Stephenson prize in 2014 for developing a composite underground train door. It was estimated this would, if fitted to Central Line trains, save £5m pa in terms of lower energy costs, reduced track damage and the reduced time needed for passengers to get on and off the train[6].

[3] Meeting with Highways Agency
[4] Highways Agency estimate
[5] One rail industry consultant estimated that of the total 125 year life-cycle cost of steel infrastructure, only 10% was accounted for by the initial purchase price; the remaining 90% being for installation, inspection and repair.
[66] www.nccuk.com

As an example of an extreme application in another sector, a National Composite Centre study established it is possible to produce very large offshore structure with a mass of just 10% of the existing design which would reduce deployment costs and eliminate the need for painting[7].

Why use composite materials?

National infrastructure is expensive to build, install, inspect, maintain and repair. Much of it is built from steel and concrete, both of which are highly susceptible to corrosion. The Institute of Materials estimates the cost of this corrosion as being circa 3% of GNP or around £600 per person which is *'the equivalent to the entire infrastructure of the country disintegrating due to corrosion processes in about 30 years'*[8]

As well as having resistance to corrosion, composite structures are much lighter than traditional materials and can be installed quickly and with smaller (and cheaper) lifting gear. The footbridge at Dawlish railway station (which withstood the 2013 storm damage), is one of the few FRP bridges on the UK rail network due to its location is a salt-water environment.

It was installed during the course of one night with minimal disruption to the network. Similarly, a trunk road bridge in Frampton Cotterell in South Gloucestershire (which was assembled at the National Composites Centre and is shortlisted for a Prime Minister's award[9]) was installed over a weekend in the summer of 2014. Such bridges are the exception but do show that some infrastructure owners are willing to use them.

It is possible to fit sensors into composite structures to provide a remote structural health-monitoring capability. Whilst this would need to be undertaken as part of a wider systems-approach, it could help reduce the need for regular inspections in favour of a needs-based maintenance regime.

Barriers to the use of Composites Structures

The UK lacks a building code for composite bridges. This means that each one is custom designed and made as a one-off. Without a suitable code, there is no prospect of achieving the economies of scale needed for composites to be used routinely.

Some UK infrastructure owners have said that the importance of total life-cycle cost is not properly reflected in public procurement. One railways consultant[10] estimated that the initial purchase price for a bridge was probably around 10% of the total life time cost over 125 years. Whilst this is purely anecdotal, it does indicate the importance of this issue.

These factors, and a degree of conservatism, are barriers to innovation and largely preclude the use of materials which could reduce the costs of maintaining the national infrastructure.

In contrast, the Netherlands has developed a very successful composite bridge industry. This was established to address the need for lightweight lifting bridges over the many canals and was facilitated

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[7] NCC report for a client

[8] The Institute of Materials, Minerals and Mining http://www.iom3.org/corrosion-committee/corrosion-committee-board

[9] http://www.gazetteseries.co.uk/news/13803443.Innovative_Frampton_Cotterell_bridge_is_shortlisted_for_national_award/

[10] From a UK rail consultancy as part of an NCC study into the application of composites in large structures, 2014

with the support of large orders from national and local governments (including the City of Rotterdam which ordered 200 bridges in 2011[11]). A number of UK contractors have reported that Dutch suppliers can undercut them (by up to *70%*) which illustrates a serious lack of capacity and capability in the UK supply-chain.

Conclusions and recommendations

After many years of under investment, the UK is investing heavily in a wide range of infrastructure which will be expected to perform well into the 22nd century. The Government has established the National Infrastructure Commission in recognition of the need to deliver affordable solutions to meet the UK's needs.

The conservatism of the specifiers, a lack of design codes and procurement rules which often penalise innovation, are impeding the adoption of composite infrastructure which could save their owners and ultimately UK tax payers significant sums of money.

The UK is a global leader in the design and manufacture of infrastructure and is missing an opportunity to meet the domestic challenges and address the export market.

Our recommendation to the Commission are therefore as follows:

- Work with infrastructure owners, suppliers and prospective supply chain companies, professional bodies and organisations such as the National Composites Centre to understand the potential impact of having composites as an alternative to existing materials for infrastructure;
- Work with regulators and codes/standards setting agencies to establish new & appropriate standards for the design, installation, maintenance and decommissioning of composites infrastructure.
- Review procurement process to chance give greater emphasis to through-life costs
- Investigate the steps needed to develop the capacity of the UK composites supply chain;
- Educate procurers, architects, designers and engineers in the value of the material;
- Fund collaborative research and development (CR&D), taking into account cross-sector knowledge, to examine materials, processes and high-volume manufacturing techniques.
- Develop training courses for the manufacture and commissioning of composite structures.

The NCC is keen to assist the Commission's any way possible.

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[11] http://www.fibercore-europe.com/index.php?option=com_content&view=article&id=345:200-composite-bridges-for-rotterdam&catid=25&lang=en&Itemid=262

APPENDIX 1:

Example of the use of composites in bridge applications

'Composite bridges have very low weight and high strength to weight ratios, high tensile strength and high fatigue resistance. They do not exhibit chloride corrosion problems, which have been a continued challenge for bridge engineers. This results in lower maintenance costs. It has also been observed that FRP (fibre reinforced polymer) composites maintain their superior qualities even under a wide range of temperatures. Other highly desirable qualities of composites are high resistance to elevated temperatures, abrasion, corrosion, and chemical attack. Some of the advantages in the use of composite structures include the ease of manufacturing, fabrication, handling and erection which can result in short project delivery time'[12]

It is therefore strange that there are very few composite bridges in the UK compared to other developed countries in North America, Europe and Asia.

The major owners of the UK's transport-related infrastructure have all explored the use of composite materials (Highways Agency has just 3 FRP footbridges) or are receptive to doing so[13]. The barriers identified to the widespread use of composites include: a lack of codes/ standards for composite bridges; a perception that they are expensive; a lack of composite designers; and as the industry itself admits, an inherent conservatism.

Cost

There is a significant body of evidence in the USA, some dating back to 2003, which compares the life cycle costs, which includes initial purchase cost, maintenance and disposal costs, of bridges built with concrete and composite decks over their anticipated life-spans. These suggest the cost saving by using a composite bridge over a 75 year life span could amount to 10%- 30%[14]. This is almost certainly, conservative in light of developments in the cost of composite bridges relative to concrete (below). Further these figures are for mixed material bridges and all-composite bridges could have even more significant advantages.

A Japanese report[15] compared the costs of various types of concrete bridge decks (with varying degrees of corrosion protection) with a composite alternative. This showed that the composites option could be around 15% cheaper to buy than the most protected and expensive concrete option but its total '*life-cycle cost*' over 100 years would be 24% cheaper. It is worth noting too that the *life cycle cost* was 40% less than a standard concrete bridge.

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[12] Evaluation of the Economic Feasibility of Fiber-Reinforced Polymer (FRP) Bridge Decks, Sahirman, Creese, Setyawati. Industrial and Management Systems Engineering Department, West Virginia University, 2003

[13] Meeting with Network Rail, Highways England, Crossrail and London Underground, September 2014

[14] As footnote 5 above

[15] A Case Study of Life Cycle Cost based on a Real FRP Bridge, Iishizaki, Takeda, Ishuzuka and Shiomura, Nagaoka University of Technology, and Public Works Research Institute, Tsukuba, Ibaraki, Japan

Since these reports were published, there is significant evidence from studies, including one commissioned by the Highways Agency, which finds that composite bridges – if bought in batches of around 20 – can be *cheaper* to buy than equivalent concrete bridges. Undertaking a life-cycle analysis on this basis would suggest even more significant savings over the life of the asset.

It should be noted that the savings above do not take into account the time required to install or remove the bridges and the real costs of taking roads or railways out of commission for protracted periods of time.