BRIDGES FOR LIFE

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ABSTRACT

Fiber reinforced polymer composites (FRP) have unique properties, such as, high strength, light weight, corrosion resistance, fatigue resistance, which make FRP very attractive for highway bridge design and construction. FRP has attracted the interest and attention of the research community, government and private industry in finding ways to successfully integrate FRP in structural applications. The use of FRP in highway bridge construction is still very limited. It is necessary to make the first costs and life-cycle costs of FRP projects more attractive to the bridge owners.
Keywords: fiber reinforced polymer, FRP, high strength, corrosion resistance, structural applications, life-cycle costs.

1 INTRODUCTION

Bridge durability is a key influencing factor in determining the life-long performance, economy and sustainability of highway bridges. In pursue of durability, the Federal Highway Administration (FHWA) in cooperation and collaboration with the American Association of State and Highway and Transportation Officials (AASHTO) and the National Cooperative Highway Research Program (NCHRP) has been promoting and supporting research, development, deployment and education in high-performance materials, such as, high performance concrete (HPC), high performance steel (HPS) and fiber reinforced polymer composites (FRP), in bridge design and construction. These high performance materials are making big impact in new construction and in the renewal of the aging highway infrastructure.

The FHWA Innovative Bridge Research and Construction (IBRC) and Innovative Bridge Research and Deployment (IBRD) programs have provided funds to encourage the States to incorporate HPC, HPS, FRP and other innovative construction materials and methods in highway construction projects. These programs have been very successful in expanding the use of high performance materials in highway bridges. Figure 1 shows the different types of projects constructed under the IBRC program from 1998–2006. It is clear that FRP has attracted a lot of interest from the State Departments of Transportation.

2 PROPERTIES OF FRP

FRP has unique properties, such as high strength, light weight, corrosion resistance, high toughness, etc., which make it very attractive for strengthening, repair and seismic retrofit of bridges and structures, and in new construction. FRP has great potential for providing engineering solutions to rebuilding our aging infrastructure. It has attracted the interest and attention of the research community, government and private industry to find ways to successfully integrate FRP in structural applications. The collective effort has resulted in many new developments and field applications of FRP. In recent years, FRP has been used as rebars and prestressing tendons in concrete structures, sheets and laminates for strengthening concrete and steel members, wraps and shells for seismic retrofit of concrete columns, structural shapes for bridges and decks. FRP decks are the most commonly applications at this time. States are looking for using FRP to improve durability and extend the service life of bridge decks significantly. Figure 2 shows an example of an FRP deck being installed. There are a few FRP pedestrian bridges (See Figure 3), but complete FRP highway bridges are very limited.

3 FHWA STUDY TOUR FOR FRP

Under the FHWA International Technology Scanning Program, a team of U.S. bridge engineers and advanced composite experts conducted a 2-week study tour of Europe and Japan in October 1996. The purpose of the tour was to assess the state of technology in the use of FRP in bridge design and construction. The technical findings of the study group were summarized under three categories: (1) new construction, (2) strengthening of existing structures, and (3) seismic retrofit.

3.1 New Structures

All countries visited had built FRP new structures. The FRP structures were one-of-a-kind demonstration projects to show the application of the technology. These projects were subsidized by the public and private sectors. The study group visited three bridges constructed of FRP.

(1) The first one was the Aberfeldy Footbridge located in U.K. and completed in June 1992. The bridge was 113 m long with a main span of 63 m. The superstructure/deck and towers were made from pultruded E-glass and polyester sections. The cables were made from dry parallel aramid fibers in polyethylene sheathing.

(2) The second one was the Bonds Mill Bascule Bridge located in U.K. and completed in 1994. The bascule bridge was 8.2 m long and 4.3 m wide for lane of traffic. The superstructure comprised of a six-cell box girder built with modular cellular pultruded GFRP. The cells of the box were filled with epoxy foam to provide stiffness.

(3) The third one was the Experimental Cable-stayed Pedestrian Bridge in Japan. The bridge was built entirely of FRP with the purpose of demonstrating the feasibility of construction of entire FRP bridge system. The bridge was monitored to assess the short- and long-term durability and performance of the bridge. The FRP cable-stayed bridge consisted of three spans. The main span was 11.0 m and the side spans were 4.5 m each.

3.2 Strengthening of Existing Structures

The study group found extensive use of FRP for strengthening existing structures. There were commercial systems developed in the countries visited. The manufacturers marketed ready-to-use systems, which included materials, design and application specifications, installation methods, quality control and qualify assurance procedures. The strengthening technology was similar to that researched and deployed in the U.S for strengthening, renovation or repair of deficient bridges.

3.3 Seismic Retrofit

The strengthening or rehabilitation FRP technologies could also be used for seismic retrofit of columns with inadequate splice lengths of reinforcing bars, inadequate shear capacity or lack of confinement reinforcement. The 1995 Kobe earthquake prompted accelerated research and development of FRP seismic retrofit systems for existing concrete columns. FRP seismic retrofit systems have been used extensively in Japan and the U.S.

4 THE US-JAPAN WORKSHOP IN SAPPORO, JAPAN

The US-Japan Workshop on Life Cycle Assessment of Sustainable Infrastructure Materials to be held in Sapporo, Japan, October 21-23, 2009, has some notable and rewarding goals in identifying the gaps and assessing the life cycle impact of sustainable infrastructure materials, more specifically FRP, on the durability, economy and sustainability of bridges. FRP has been researched, developed and deployed for aerospace and civil applications for a very long time. The application to highway bridges is still relatively limited – limited to smaller bridges, to structural components in hybrid new bridge construction and rehabilitation, such as, deck slabs, reinforcing bars, prestressing/post-tensioning strands and tendons, cables, plates, sheets, laminates, and so on.

Important outcomes of the workshop are to provide better and wider understanding of the properties and life cycle cost of FRP, effective tools for bridge owners to determine the cost-effectiveness of alternatives in using and not using FRP, and practical methods for design and construction of FRP highway bridges to meet the social, economic, environmental and sustainable needs of the communities.

5 CLOSING REMARKS

The workshop is expected to produce a set of recommended practical methods and tools for bridge owners to perform life-cycle assessment (LCA) of highway bridges, accounting for construction, maintenance, rehabilitation and replacement. LCA involves in comparative studies of different alternatives of bridge design and construction with varied materials and bridge configurations. LCA considers durability, service-life performance, life-cycle costs, and overall economies. Additionally, LCA must address educational, environmental, quality and sustainability effects on the life-cycle costs.

Having the government agencies,

academia, practitioners and industry work together, we can take full advantage of a new generation of innovative and advanced composite materials in highway bridge design and construction to assure a safe, durable, efficient, cost effective and sustainable transportation infrastructure.

6 FIGURES

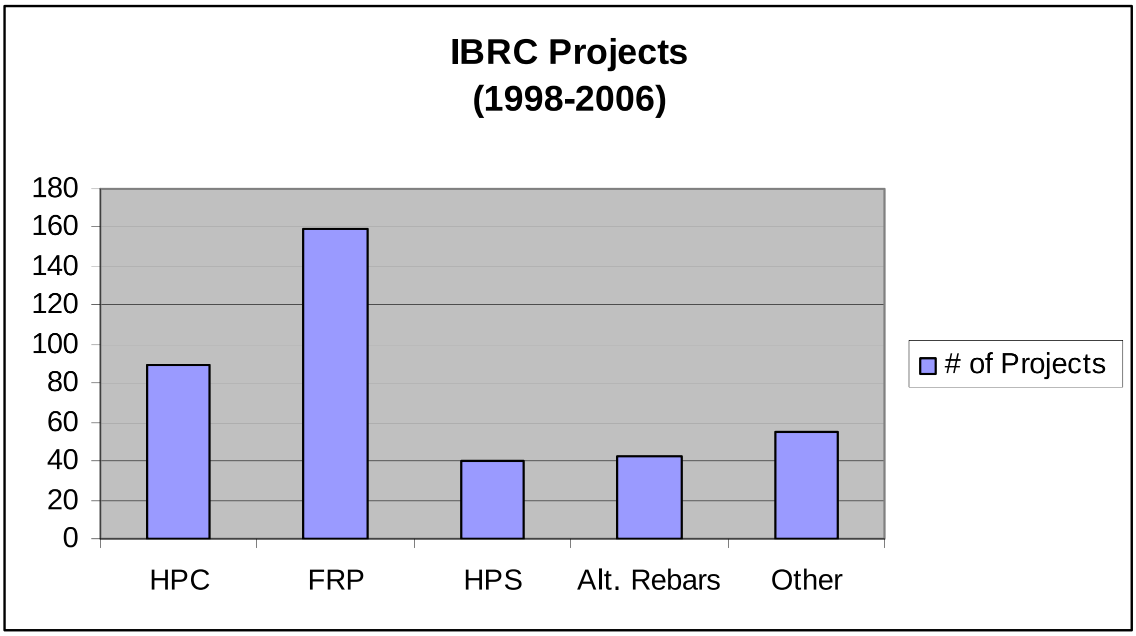

Figure 1 Innovative Bridge Research and Construction (IBRC) Projects completed between 1998–2006.

Figure 2 Fiber reinforced polymer bridge deck.

Figure 3 All fiber reinforced polymer pedestrian bridge.