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FRP composites
 Advancing sustainable solutions for infrastructure
 By John P. Busel



For more than 20 years, fiber-reinforced polymer (FRP) composite products used in new bridge construction and rehabilitation have provided bridge engineers and owners with innovative and cost-effective solutions. In several instances, composites preserve historic landmarks while ensuring structural integrity. In new construction, features such as light weight, corrosion resistance, and prefabrication have contributed to the goals of accelerated bridge construction by reducing assembly and installation time, thereby resulting in lower costs for deploying FRP composites technology. In rehabilitation, features such as speed and minimal disruption to the structure while in service have provided bridge owners with solutions for extending the service life of bridge structures. The technology continues to evolve with better products and solutions for many new applications.

Bridge decks

The Broadway Bridge in Portland, Ore., has been carrying cars, trucks, buses, bicyclists, and pedestrians across the Willamette River for more than 90 years. Opened on April 22, 1913, it is one of only three Rall-type bascule bridges still operating in the United States, and according to Multnomah County, the bridge owner, it is by far the largest. This historic bridge averages 33,000 vehicles per day. Not surprisingly, in February 2003, as the bridge approached its 90th anniversary, the Multnomah County Bridge Section, which manages and maintains the Broadway and five other Willamette River bridges in Portland, embarked on a major renovation project aimed at upgrading the structure to ensure its continued service well into the 21st century.

While the Rall-type opening mechanism is unusual, it poses the same requirements for its double-leaf movable span as most other bascule bridges. The deck must be light enough to allow opening of the

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bridge using reasonably sized counterweights, lift motors, and gear sets, while providing the strength required to support modern vehicle loads. At that time, the Multnomah County planners wanted to replace the steel grating with a new decking that offered light weight; a solid surface with good traction in wet, snowy, or icy conditions; a quiet ride; and low maintenance requirements. The contractor installed the full 11,790 square feet of decking using 32 FRP composite panels measuring approximately 46 feet by 8 feet each.

More recently, the city decided to install rails for street cars on the bridge as part of the Portland Streetcar Loop Project. This modification of the bridge required removal of part of the FRP deck that had been installed in 2004. The Broadway Bridge is one of the few bridges in the country that has two types of FRP decks installed on it. In August 2010, the two-piece, mechanically fastened ZellComp FRP bridge deck, designed by ZellComp Inc., Durham, N.C., was installed on the Broadway Bridge in Portland.



Figure 1: FRP composite deck bottom sections are installed between new rail lines on the Broadway Bridge in Portland, Ore
Photo: ZellComp Inc.

The ZellComp FRP deck was selected as the replacement deck primarily because of the system's performance record and its ability to be adjusted onsite. This project was unusual because the FRP composite deck had to be installed between the new rail lines (Figure 1), and the deck design offered the flexibility that was needed. The modular design and capacity for onsite adjustment allowed the contractor to install the deck in a short amount of time to allow the bridge to be opened, allowing marine traffic to pass over this important waterway. More than 3,400 square feet of the ZellComp deck was installed on the Broadway Bridge. The installation contractor was Hamilton Construction, serving as a subcontractor to Stacy and Witbeck. The engineering firm of record for the deck replacement portion of the project was Hardesty & Hanover and for the bridge project was David Evans and Associates Inc.

"Our number-one concern in installing this bridge deck was the safety of drivers, pedestrians, cyclists, and streetcar passengers," said Dan Richards, president and CEO of ZellComp. Beginning in July 2011, another ZellComp FRP deck will be installed on the Morrison Bridge, also in Portland. At more than 17,000 square feet, the FRP deck on the Morrison Bridge will be the largest FRP deck ever installed in the United States and one of the largest in the world.

Reinforcement in concrete

Glass fiber-reinforced polymer (GFRP) composite rebar are used to address corrosion issues typically found with steel rebars. FRP rebar has been used as cast-in-place, non-prestressed reinforcement in concrete members. FRP composite rebar, manufactured using pultrusion, are totally resistant to chloride ion attack, offer a tensile strength of 1-1/2 to 2 times that of steel, weigh only 25 percent of the weight of equivalent-size steel rebar, are electrically non-conductive, are electromagnetic neutral, and are thermal insulators. Hundreds of bridges in the United States and Canada have used FRP rebar successfully in bridge deck applications.

The use of FRP composite rebar in concrete bridge decks has increased in recent years because of the publication of the American Concrete Institute (ACI) design guideline documents ACI 440.1R-06, material and construction standards ACI 440.5 and ACI 440.6, and the AASHTO LRFD Bridge Design Guide Specifications for GFRP-Reinforced Concrete Bridge Decks and Traffic Railings. GFRP bars have been installed in a wide variety of applications such as decks, parapets, sidewalks, abutments, and traffic barriers for bridges, sea walls, tunnel soft-eyes, light and heavy rail train beds, and in building applications for MRI rooms in hospitals.

The Oregon Department of Transportation currently is replacing a deteriorating and structurally deficient timber bridge that carries the Oregon Coast Highway (U.S. 101) over Millport Slough in Lincoln City, Ore. The existing bridge was an eight-span, timber bridge with a concrete deck and supported by timber piles. Due to badly deteriorated piles, the bridge needed to be replaced with materials best suited for coastal exposure. The new bridge is a four-span, 390-foot-long, and 75-foot-wide precast, prestressed girder bridge. GFRP rebar was used for the top and bottom transverse deck reinforcement and the bottom longitudinal reinforcement. The FRP rebars used were manufactured by Pultrall Inc., Thetford Mines, Quebec, Canada. The first phase pour was completed in July 2010, and the second phase pour was done in June 2011. The project is expected to be completed by the end of September. The lightweight nature of the FRP bars reduces labor and provides a beautiful installation, as shown in Figure 2. The new structure is expected to provide a long service life in this difficult marine environment.

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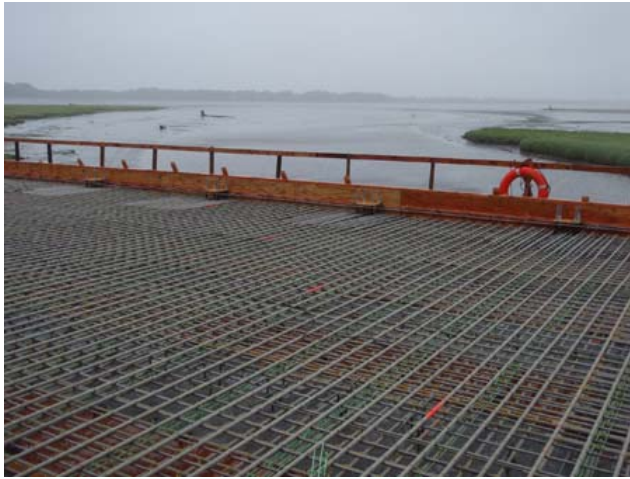


Figure 2: Glass fiber-reinforced polymer composite rebar was used for the top and bottom transverse deck reinforcement and the bottom longitudinal reinforcement on the U.S. 101 bridge over Millport Slough in Lincoln City, Ore.
Photo: Pultrall Inc.

Bridge girders

Developed at the University of Maine, AEW Advanced Structures and Composites Center, Orono, Maine, and manufactured by Advanced Infrastructure Technologies Inc. in Orono, the Bridge-in-a-Backpack innovative bridge system utilizes a carbon fiber outer shell that is manufactured using a composites process called vacuum infusion to form a hollow composites shell in the form of an arch, which is then filled with self-consolidating concrete onsite. This hybrid technology marries the strength characteristics of carbon FRP (CFRP) composites with the durability and compressive strength of concrete. The total system comprises the FRP composite arches, durable composites decking, and fill that is compacted on top of the decking (Figure 3).



Figure 3: Bridge-in-a-Backpack technology uses corrugated composite decking attached to CFRP arch tubes filled with self-consolidating concrete.
Photo: Advanced Infrastructure Technologies Inc.

The Bridge-in-a-Backpack technology exemplifies the benefits of FRP composites with its high strength-to-weight that translates to lower installation equipment and transportation costs compared with precast technology, and eliminates the time and cost of formwork. The inherent corrosion-resistant properties of FRP composites, along with a smaller carbon footprint compared with traditional materials, provide bridge engineers with a sustainable solution. The system can be deployed in single spans from 25 to 70 feet, and multiple-span designs exceeding 800 feet.

In June 2011, the Bridge-in-a-Backpack system was installed on the Ashby West Road Bridge over the Scott Reservoir Outlet in Fitchburg, Mass. The 12-inch-diameter CFRP composite tubes, weighing about 200 pounds, were hand carried to the bridge, making for a unique installation compared with traditional materials. The span — 38 feet long (footing to footing) and 36 feet wide — used 15 tubes. The contractor planned to complete the bridge installation in 70 days. This installation joins eight other bridges built in Maine, with more to be installed in the near future.

In recent years, another new innovation in bridge girder designs has attracted the attention of many bridge owners and engineers. Originally designed to be a girder for Class 1 railroad bridges for BNSF Railway Company, the Hybrid Composite Beam (HCB) developed by HC Bridge Company LLC, and its founder, John Hillman, has contributed significantly to the ideals of accelerated bridge construction. The HCB, an award-winning structural member that utilizes concrete, steel, and FRP composites, exploits the best of all materials where the strength and stiffness of concrete and steel are combined with the lightweight and corrosion-resistant advantages of FRP composites. This innovative technology is best

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demonstrated on the recently completed Knickerbocker Bridge in Boothbay, Maine (see article on page 25).

Built in 1930, the existing Knickerbocker Bridge was a two-lane highway bridge comprised of a 38-span timber bridge approximately 535 feet long. Its location over the Back River in Boothbay is only 4 feet above high tide. Key factors for a bridge replacement solution required long-term durability and corrosion resistance. Maine Department of Transportation, the bridge owner, after monitoring composites technology and the extensive testing performed at University of Maine AEW, decided the HCB was the right solution to replace the planned precast box beams. The HCB is manufactured by Harbor Technologies in Brunswick, Maine, using a composites manufacturing process called vacuum infusion to make the FRP shell. This is then combined with a tension reinforcement using galvanized prestressing strand along the bottom of the beam, and a compression reinforcing internal arch using self-consolidating concrete. The construction documents were prepared by Calderwood Engineering of Richmond, Maine, with assistance on the HCB design from Teng & Associates Inc., Chicago.

Each 70-foot-long beam for the bridge weighed only 5,000 pounds. Four HCBs could be shipped on a single truck instead of one truck per beam as would have been required for precast concrete beams. The beams were erected using a small crane instead of mobilizing a heavy-lift crane for typical precast concrete beams. The lightweight nature of the HCB contributed to cost savings from transportation of the beams to the site, installation time for the beams, and the use of less expensive equipment to install the beams, among other things.

The first half of the deck was cast in October 2010, and after working through the winter to complete the remaining piers, the contractor completed installation of the second half of the HCB superstructure in April 2011. The bridge was officially opened to traffic on June 11, 2011. This installation represents the longest composites vehicular bridge in the world using FRP composite beams as well as being the first to be made with continuous live load. The added benefit was that the HCB solution was no more expensive than a conventional concrete box beam bridge. This installation adds to two other installations — the 57-foot-span High Road Bridge (2008) in Lockport Township, Ill.; and the 31-foot-span Route 23 Bridge (2009) in Cedar Grove, N.J. Three more bridges were planned for construction in Missouri during 2011.

Summary

All of these composites products are further demonstrated by the use of composites external reinforcement systems to strengthen, seismically upgrade, and rehabilitate more than 10,000 concrete installations used in bridges, buildings, and other structures to extend the service life and upgrade the many deteriorated structures.

The materials technology embraced by FRP composites supports accelerated bridge construction and provides bridge owners and engineers with cost-efficient, long-term durability solutions to our aging infrastructure. In the Federal Highway Administration's Every Day Counts program, composites inspire innovation with different designs using similar materials; encourage ingenuity because it allows designers to think outside the box; facilitates invention by making existing techniques, systems, and methods better; and propels imagination into new frontiers to make an engineer's or contractor's vision a reality. FRP composites meets the desired goals of using green construction materials, providing a sustainable solution, and ensuring that bridges built and rehabilitated today will last for future generations.

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