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Building a Bridge of (and to) the Future

By HENRY FOUNTAIN

PITTSFIELD, Me. — The Neal Bridge is barely a bump in the road for motorists roaring down Route 100 south of this central Maine town. It's a modest bit of the nation's infrastructure — two lanes wide and 34 feet long, enough to span a small stream.

The bridge is newer than most, as suggested by the still-black asphalt and the fresh galvanized gleam of the guardrails. But it's what is underneath that really makes the bridge stand out.

Rather than steel or concrete beams, the structure consists of 23 graceful arches of carbon- and glass-fiber fabric. These are 12-inch-diameter tubes that have been inflated, bent to the proper shape and stiffened with a plastic resin, then installed side by side and stuffed with concrete, like giant manicotti. Covered with composite decking and compacted soil, the arches support a standard gravel-and-asphalt roadway.

The bridge is the first of what its designers, about 50 miles up the road at the University of Maine in Orono, hope will be many of its type, combining composite materials with more conventional ones like concrete. With an estimated 160,000 of the nation's 600,000 road bridges in need of repair or replacement, if it or other hybrid designs catch on, they could mark a breakthrough in the use of fiber-reinforced plastics, known as F.R.P., on highways.

"This was an experiment for us," said Habib J. Dagher, director of the university's Advanced Structures and Composites Center, where the design was developed over seven years. "It was time to get out of the lab and see if it really works."

The bridge, built last November for about $600,000, is being monitored with deflection sensors and other instruments, and so far is holding up under the daily onslaught of traffic. "It went amazingly well," Dr. Dagher said. "We learned a lot. It turned out to be $170,000 less expensive than a precast bridge."

It worked so well, in fact, that it attracted the attention of the Obama administration; Transportation Secretary Ray LaHood toured the center in August. And a second, similar bridge was completed in late summer, farther north, in Anson. The fiber-arch design was the lowest of seven bids.

Long the stuff of surfboards and pleasure boats, and more recently used in aircraft wings and other components, plastic polymers reinforced with fibers were first researched for use in bridges in the 1980s. Civil engineers were attracted to them for the same reasons other designers were — their strength, light weight and corrosion resistance.

But the materials have not exactly revolutionized highway infrastructure. F.R.P. strips and sheets have been used to repair concrete or steel on existing bridges, or to strengthen structures against earthquakes. Glass-fiber rods have replaced steel in some reinforced concrete work, because corrosion of steel rebar from road de-icing chemicals destroys concrete.

When it comes to larger-scale structural components, however, fiber-reinforced plastics have had less of an impact. They have mostly been used in bridge decking, where corrosion resistance is critical and the lighter weight allows for a higher "live" load of vehicles. Only a handful of bridges have major support beams made from them.

One reason F.R.P. components haven't caught on, experts say, is that engineers and contractors have little experience with the materials, and full standards guiding their use in highway construction have not been developed.

Engineers "have to deal with life-safety issues," said John P. Busel, director of the composites growth initiative of the American Composites Manufacturers Association. "They have a desire to understand how materials fully develop and how they fully last before they specify them."

The materials also do not always interact well with others. One problem with F.R.P. bridge decks, for example, is that the road surface — asphalt or concrete, applied as an overlay — can wear out quickly, said Lijuan Cheng, an assistant professor of engineering at the University of California, Davis.

But the main argument against using fiber-reinforced plastics has been economic.

"No. 1 is the upfront cost issue," said Paul Ziehl, an associate professor of engineering at the University of South Carolina. "That's a tough one to get around."

Dr. Ziehl, who helped design and test F.R.P. beams used on a small bridge in Texas, said the problem was that no two projects were the same. "If you're going to design things that really make sense from an optimized engineering standpoint, they are going to be one-of-a-kind items at first, until economies of scale kick in," he said. The beams for the Texas bridge, for example, were custom designed and built using a labor-intensive method.

"The construction industry is very persnickety about cost," Mr. Busel said. With F.R.P. decks, he added, "we're more expensive, sometimes twice as expensive," as conventional ones. What contractors need to understand, he said, is that there are transportation, labor and equipment savings from using lighter components, and potential maintenance savings, too.

Such savings were all part of the goal for the University of Maine's design, Dr. Dagher said. Little costly F.R.P. material is used — it serves largely as a shell for the concrete, which is cheaper. The tubes help protect the concrete from de-icing chemicals, potentially reducing maintenance costs, and no internal rebar is needed. "It's exoskeleton reinforcement," Dr. Dagher said.

The arches are not the only hybrid design in use. John Hillman, an engineer and president of HC Bridge Company in Wilmette, Ill., has developed straight beams that combine polymers with concrete and steel. The basic beam consists of a rectangular F.R.P. tube with an arch-shaped conduit formed inside it. The conduit is filled with concrete, which provides compressive strength, and steel rods along the bottom of the tube provide tensile strength. The beams have been used on a test railroad bridge in Colorado and several road bridges in Illinois and New Jersey.

“Everything about the beam is designed to be compatible with conventional means of construction,” said Mr. Hillman, who has been working on the design for 14 years. “We’re very close right now to parity with concrete and steel on an installed-cost basis.”

Mr. Hillman’s beams still have to be delivered by truck, although they are light enough that several can be carried on one flatbed. The University of Maine arches, on the other hand, can be fabricated on site — the fabric inflated, bent around a simple form and infused with resin using a vacuum pump. Before they are filled with concrete they are light enough to be installed quickly, without the need for large cranes or other heavy-duty equipment. The second bridge was built in nine working days, Dr. Dagher said.

A spinoff company is working on more plans, including an 800-foot project that consists of multiple short spans. “We see single 300-foot spans in the future,” Dr. Dagher said. “We’re excited about taking this to the next level.”