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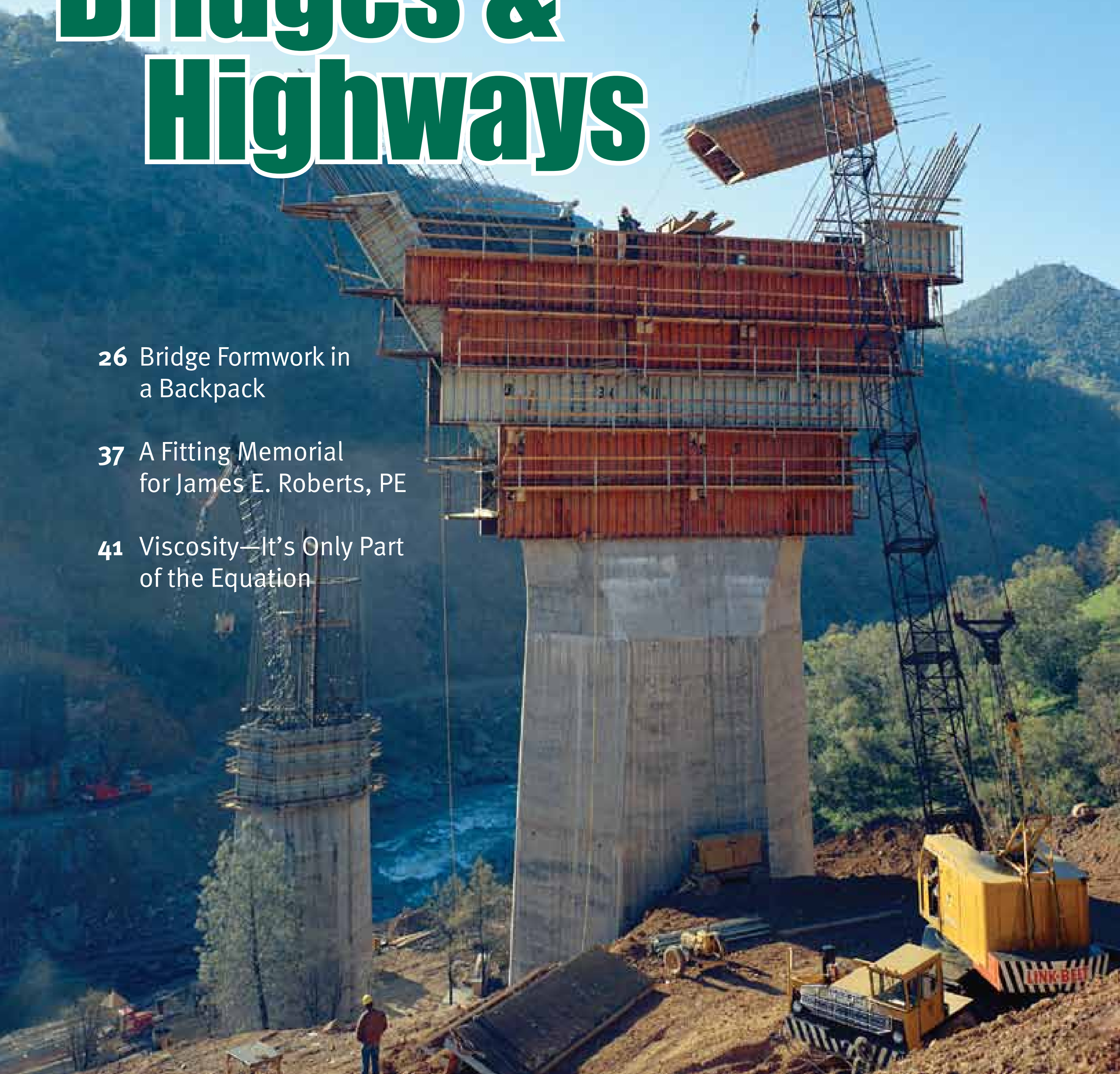
Bridges & Highways



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Bridge Formwork in a Backpack

Innovative composite technology used to construct arches

After a braided fiber sleeve is placed over the air bladder, the bladder is inflated and the assembly is placed on a form of the desired geometry. Forming and infusion can be performed in a shop or in the field (*Photo courtesy of AEWC Center*)

In late 2008, the Maine Department of Transportation (DOT) built a buried arch bridge constructed with composite materials to replace a 70-year-old deteriorated structure. What makes the Neal Bridge in Pittsfield, ME, unique is that it's the first of its type to use rigidified inflatable composite arches produced at the University of Maine (U-Maine).

Researchers at the university's AEWC Advanced Structures & Composites Center have developed the Bridge-in-a-Backpack™, a lightweight, corrosion-resistant system for short- to medium-span bridge construction using fiber-reinforced polymer (FRP) composite arch tubes that act as reinforcement and formwork for cast-in-place concrete. Bridge-in-a-Backpack arches are lightweight, easily transportable, rapidly deployable, and do not require the heavy equipment or large crews needed to handle traditional construction materials.

BACKGROUND

U-Maine's AEWC Center team, led by Director Habib Dagher, Professor of civil/structural engineering, conceived the bridge design as a novel use of composite materials to simplify construction and reduce the maintenance and life-cycle costs associated with buried structures. The lightweight carbon fiber composite arches are manufactured by inflating a bladder within a tubular (braided) carbon textile, bending the unit to the proper bridge vertical profile, and then infusing the textile with a thermosetting resin. The composite arches provide three simultaneous functions for the concrete: they serve as stay-in-place forms, external reinforcement, and protective shells against freezing-and-thawing damage.

The system capitalizes on the inherent property of an arch to transform vertical loads to internal axial forces, the superiority of concrete in sustaining compressive loads, and the versatility and strength of composite materials. During accelerated fatigue testing, concrete-filled arches were subjected to the equivalent of 50 years of truck traffic over an interstate bridge. Results showed that the concrete arches retained their full capacity after fatigue testing had been completed.

Specimens were subjected to static testing to failure and their load deflection response and ultimate strengths were studied. Excellent correlation was seen between experimental and predicted results, providing a high level of confidence in the modeling technique. The arch structure forms three plastic hinges and maintains peak loading during strength testing. Further tests have demonstrated that the arches are extremely ductile

when compared with conventional reinforced concrete.

INSTALLATION

While the Neal Bridge arches were manufactured at the AEWC Composites lab at U-Maine, it is possible that arches used on future projects will be constructed at the job site. Arches would arrive rolled up (sized to fit in a duffle bag, inspiring the name "Bridge-in-a-Backpack"). Once unrolled, the braided fiber sleeve would be placed over an air bladder, and the bladder would be inflated. The assembly would then be placed on an arch form, and the sleeve would be infused with resin. A composite arch would be ready for installation after the resin cured overnight.

Each Neal Bridge arch has a 12 in. (305 mm) diameter and spans 35 ft (11 m). Twenty-three arches, spaced at approximately 2 ft (0.6 m) on center, were built for use in the 44 ft (13.5 m) wide bridge. After the arches were trucked to the site, they were lowered into place with a truck-mounted boom crane and manually set. All 23 arches were placed in a single day. Once in place, the arch bases were encased in a shallow concrete footing.

A 4 in. (102 mm) deep corrugated FRP decking was installed over the arches with self-tapping screws that became concrete anchors once the arches were filled with concrete. The arch tubes were filled with a self-consolidating, expansive cement concrete mixture pumped into the arches through fill pipes preinstalled in the top of each arch. About 1 hour was needed to fill the arches with a total of 26 yd^3 (20 m^3) of concrete.

Concrete was also placed over the corrugated decking. Once hardened, the concrete deck and the anchors previously screwed through the composite tubes formed a lateral force-resisting diaphragm. Twenty-four hours after the concrete was placed, composite spandrel walls were erected.

Arches cure on the form (*Photo courtesy of AEWC Center*)

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Arches for the Neal Bridge being placed in position (*Photo courtesy of AEWC Center*)

Installation of the composite decking (*Photo courtesy of AEWC Center*)

Completed superstructure for the Neal Bridge (*Photo courtesy of AEWC Center*)

Head walls were constructed with an FRP sheet pile system and the wing walls were constructed from a prefabricated concrete T-wall retaining wall system. Paving was placed on about 4 ft (1.2 m) of a granular sand backfill that was compacted over the arch structure. Construction of the superstructure was completed in 2 weeks, including installation of sensors to be used by U-Maine researchers to monitor the bridge's performance.

FUTURE DEVELOPMENT

Because the new system has standard details at the foundation, head walls, wing walls, and backfill,

Neal Bridge in service, Pittsfield, ME (*Photo courtesy of AEWC Center*)

construction costs are competitive with standard construction. These joint-free, steel-free structures are, however, expected to provide 100-plus years of service, with very little maintenance.

Since the Neal Bridge was constructed, the McGee Bridge in Anson, ME, was built using the new technology. Lessons learned from the Neal Bridge project were applied, resulting in thinner arch walls, increased arch spacing, a lighter weight headwall, and improved headwall details. Superstructure construction was reduced to 1 week on the second bridge, which was completed in September 2009.

Advanced Infrastructure Technologies, LLC—a private company commercializing the Bridge-in-a-Backpack—has plans to build five bridges with spans from 24 to 60 ft (7 to 18 m) in the next 2 years as part of the Governor's Composites Initiative in the state of Maine.

For more information, visit **www.aewc.umaine.edu** and **www.aitbridges.com**.

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