A WHOLE new cast

by Wayne A. Endicott

Innovative concrete used on Iowa bridge eliminates reinforcement and creates new concept for precast concrete bridges

When Neil Armstrong took his first historic step on the moon in 1969, he declared it to be "One small step for a man, one giant leap for mankind." Perhaps the bridge builder's equivalent of that "giant leap" was taken recently on a small rural stretch of highway in Wapello County in the southeastern corner of Iowa, where a new concrete material offers great potential for future bridge designs.

The Wapello County Mars Hill Bridge comprises three 110-ft-long precast concrete modified 45-in.-deep Iowa bulb-tee beams topped with a cast-in-place concrete bridge deck. The concrete offers such considerable strength that the beams were built without any shear reinforcement. The ultra-high performance concrete (UHPC), called "Ductal," was supplied by Lafarge North America and achieves up to 30,000 psi compressive strengths, with ductility.

Originally developed in France a decade ago, UHPC is produced with materials commonly found in concrete such as cement, silica fume, sand, high-range water-reducer, and water, plus other unique materials like ground quartz and steel or PVA (polyvinyl alcohol) fibers.

profile

MARS HILL BRIDGE / WAPELLO COUNTY, IOWA

ENGINEER: Iowa Department of Transportation, Ames, Iowa

GENERAL CONTRACTOR: Bloomfield Bridge and Culvert, Inc., Bloomfield, Iowa

PRECASTER: Lafarge Canada Inc., Winnipeg, Manitoba, Canada, a PCI-Certified Producer

BRIDGE DESCRIPTION: 24-ft 6-in.-wide by 113-ft-long single-span bridge

Lafarge cast the Ductal beams at its Winnipeg, Manitoba, Canada plant. The beams were then trucked to the site for installation. Photos in this article courtesy of Kenneth F. Dunker and Brian P. Moore.

The beam dimensions were reduced compared to typical Iowa bulb tees.

Depending on the curing process, compressive strengths higher than 18,000 psi can be achieved, according to Brian Moore, Wapello County Engineer. The UHPC that was used for the bridge contained steel fibers (approximately 2 percent by volume), eliminating the need for nonprestressed reinforcement.

The Wapello County bridge represents the first highway bridge in North America to utilize the material, although it has been used in other applications. In addition to eliminating the need for structural reinforcing steel, a bridge built with UHPC can be built with longer, thinner, more aesthetically pleasing beams, according to Dean Bierwagen, Project Engineer for the Iowa Department of Transportation (IDOT).

Collaborative Effort

The bridge resulted from a collaborative effort among several groups, including the Federal Highway Administration (FHWA), IDOT, Iowa State University (ISU), and Lafarge. The county became involved when IDOT and ISU proposed that it could help prove the efficacy of the UHPC construction system for a highway bridge. County officials needed to replace an existing bridge at the Mars Hill location and thought it would make a strong candidate, according to Moore.

Using UHPC for the design gained impetus when the county received a $300,000 award through the FHWA's Innovative Bridge Research and Construction Program to demonstrate the use of the concrete. The project got the go-ahead from the Wapello County Board of Supervisors, which then entered into an agreement with the university after accepting the award.

A major hurdle concerned design specifications, Bierwagen says, since there were no other existing highway bridges in North America that demonstrated the new concrete's high compressive strength. That was one of the primary reasons the FHWA showed such interest in the project. "The FHWA is looking for projects like this that can aid in developing guidelines for the design of future bridges employing this material."

As design proceeded, Bierwagen's team reduced the dimensions of the beams compared to typical Iowa bulb tees. The web thickness was reduced from 6½ in. to 4½ in., the bottom flange from 7½ in. to 5½ in., and the top flange dimension from 3¾ in. to 2¾ in.

An 8-in.-thick cast-in-place concrete deck was used on top of the modified bulb-tee beams.

PRECAST CONCRETE MODIFIED 45-IN.-DEEP IOWA BULB-TEE BEAMS TOPPED WITH A CAST-IN-PLACE CONCRETE BRIDGE DECK / WAPELLO COUNTY, OWNER

STRUCTURAL COMPONENTS: Three modified 45-in.-deep Iowa bulb-tee beams cast with ultra-high performance concrete topped with an 8-in.-thick cast-in-place concrete deck

BRIDGE CONSTRUCTION COST: $432,000

The concrete's attributes could change the way bridge engineers approach designs.

Exploration Took Three Years

Because of the material's unique attributes, exploring the potential of the Ductal concrete continued for nearly three years. This resulted from an extensive testing program, which was further challenged by the need to certify the ability of a suitable precasting plant to manufacture the beams.

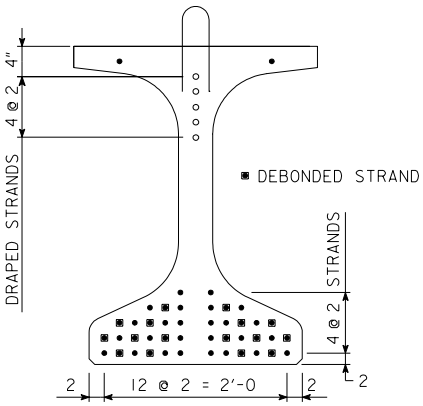
So that IDOT and other project collaborators could gain confidence with the technology, a test mix was made at its Materials Laboratory in Ames, Iowa. Once the laboratory tests were completed, the process of certifying a plant to cast the beams began. Plant inspections of local precasting plants and test batches were performed at two local plants.

Bids received from those plants following the testing phase were higher than expected, owing to the steep learning curve. To help overcome that concern and take it out of the equation, the team selected Lafarge's precast team in Winnipeg, Manitoba, Canada, which possessed valuable knowledge and prior experience with the material.

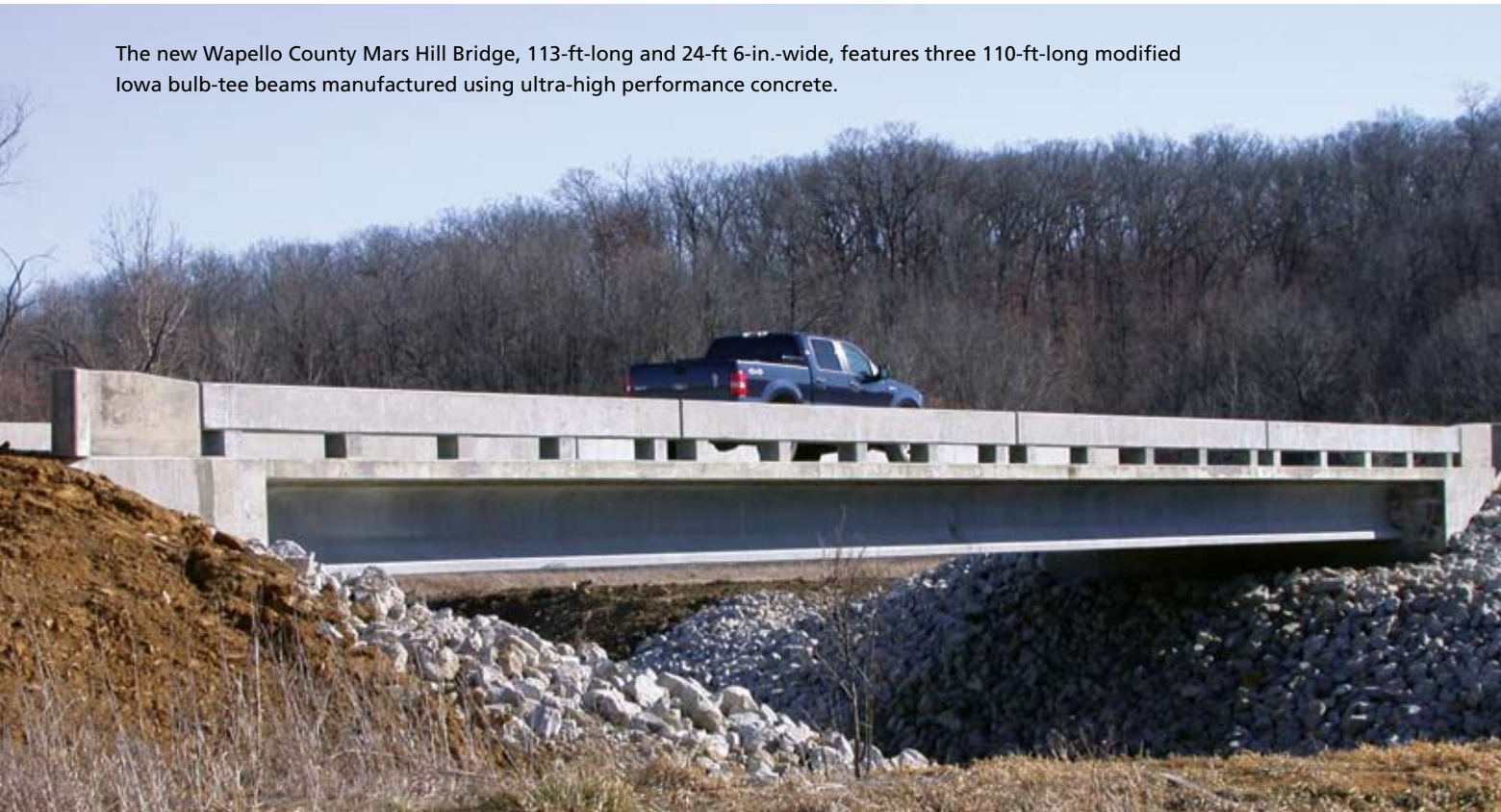
The next stage involved casting a 17-ft-long test beam. Also, to verify shear and flexural performance, 10- and 12-in.-deep shear beams were cast. Testing verified the service performance under flexure and the ultimate shear strength, so the go-ahead was given to cast the 110-ft-long production beams.

The full-size bridge beams were prestressed using 0.6-in.-diameter, low-relaxation strands. Eliminating the shear reinforcement meant the only nonprestressed reinforcement in the beams was U-bars connecting the 8-in.-thick cast-in-place deck to the precast beams. The final beam design section had 49 prestressing strands stressed to 72.6 percent of ultimate strength. To reduce stresses at the ends of the beams, five strands were draped along with the debonding of 16 other strands, Bierwagen says.

The U-bar option was chosen over two other possible connection systems. One involved the installation of top shear studs after beams were cast and the other used a dowel-bar splicing system installed after casting. These options were examined to develop the best method to achieve an acceptable shear transfer between the beam and the cast-in-place concrete, while facilitating the required casting and curing procedures. Once cast, the beams were immediately covered with a plastic sheet to complete the curing process.



Each beam contains forty-seven 0.6-in.-diameter, low-relaxation prestressing strands in the bottom flange stressed to 72.6 percent of ultimate strength. No shear reinforcement was used.



The new Wapello County Mars Hill Bridge, 113-ft-long and 24-ft 6-in.-wide, features three 110-ft-long modified Iowa bulb-tee beams manufactured using ultra-high performance concrete.

One crane at each end removed the beams from their transport vehicles and set them into place.

The material's high compressive strength allowed bridge designers to create a lower profile bridge by using longer, thinner beams.

Highly Impermeable Concrete

In addition to designing lighter weight beams with more slender cross sections and no reinforcement, this revolutionary concrete provides an added advantage in that it is highly impermeable, thereby reducing the threat of corrosion within the structure. "This should provide a longer lifespan for bridges subjected to moisture and the effects of road salt," Bierwagen points out.

This project represents only the beginning of the use of this UHPC system in bridge designs, which could change the way bridge engineers approach designs, says Vic Perry, Vice President and General Manager for Ductal at Lafarge North America. "We think it will be possible to build an entire bridge, including the deck, without reinforcement. This bridge represents a first step in that process. Ductal provides a real synergy with the prestressed concrete industry." The material also provides an opportunity to create slender, long-span beams and more graceful bridges without the need for reinforcing bars, he notes.

The FHWA is looking for projects like this to aid in developing guidelines.

Another key advantage was the speed with which the bridge was completed after the testing was verified. Casting the 110-ft-long beams was completed in June and July of 2005, and construction began in August. By the following February, the bridge was opened to traffic. The beam spacing was 9-ft 7-in., with 4-ft overhangs, creating a 24-ft 6-in.-wide completed structure.

Moore is not bashful about his admiration of the system. "I see a tremendous potential here. The use of steel fibers and the elimination of reinforcement allow us to use a dense material without the concerns of corrosion." Lauding the success of the project, Moore, like Perry, suggests that the next logical step is to create an entire bridge, including the deck, with Ductal concrete. The successful Mars Hill Bridge project has the team that created the bridge already looking for more projects that can take advantage of the system, Moore says. This includes a bridge in Buchanan County.

For more information on this project visit www.wapellocounty.org/roads/marshill.htm or other projects, visit www.aspirebridge.org.

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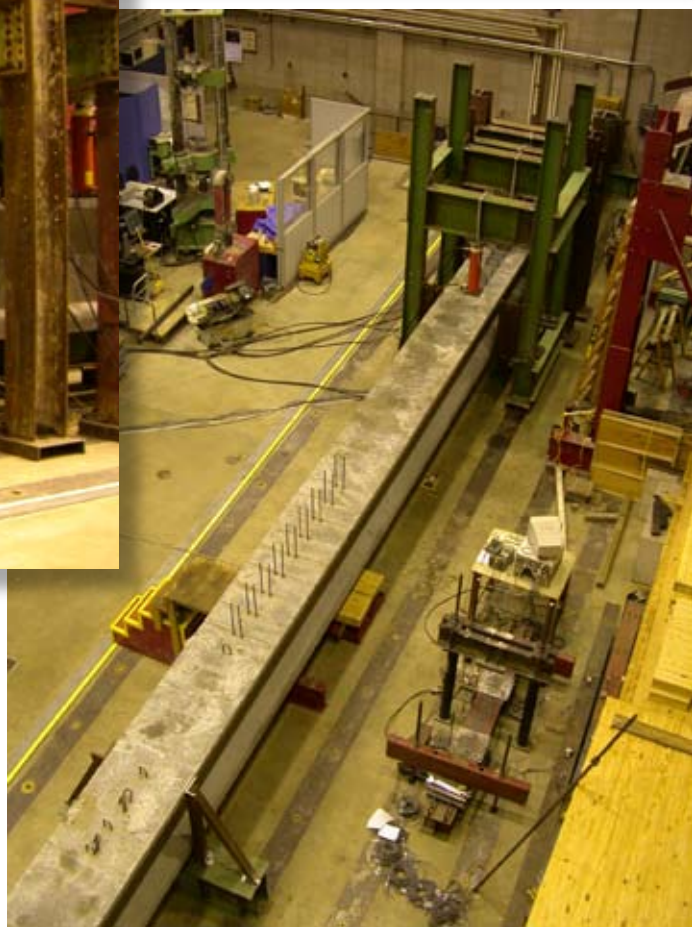

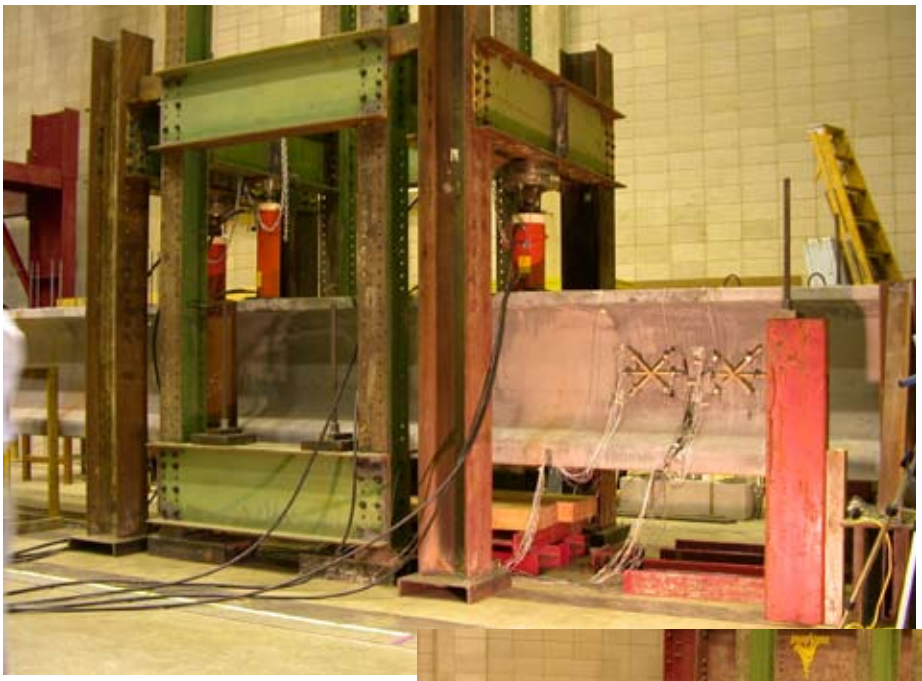

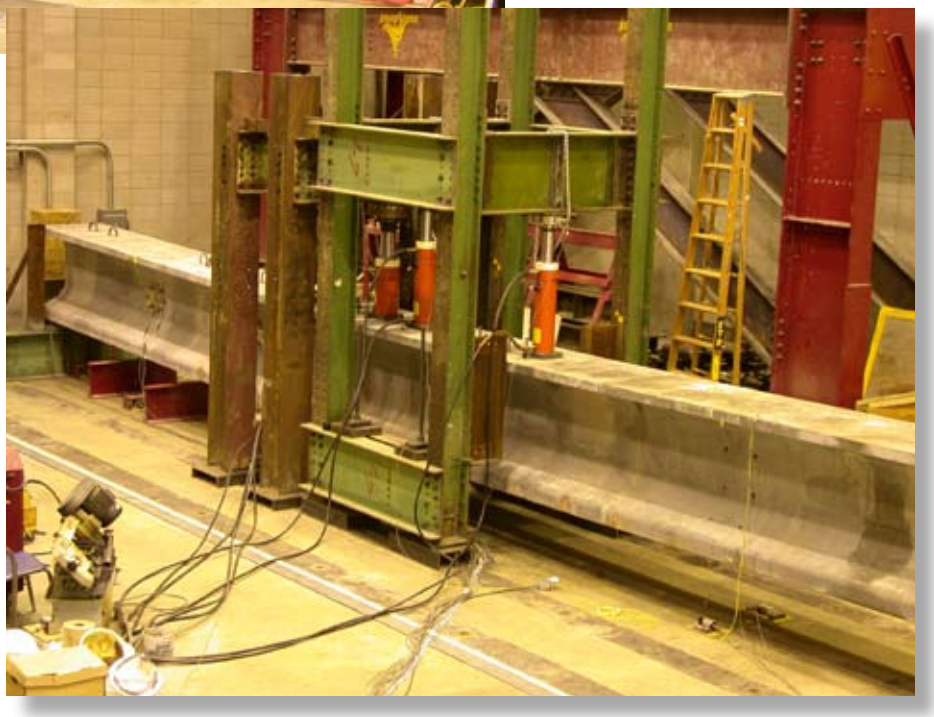

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