The new bridge is 24-1/2 feet wide and 113 feet long, and was opened to traffic in February 2006.

Iowa Bridge Gives Glimpse Into The Future

— Wayne A. Endicott

All Photos: Kenneth F. Dunker, P.E., Office of Bridges and Structures - Iowa Dept. of Transportation and Brian P. Moore, P.E., Wapello County Engineer/Zoning Administrator.

Highway bridge features concrete beams without steel reinforcing thanks to ultra-high performance concrete

The Mars Hill Bridge in Wapello County, Iowa, seems to be a small, fairly nondescript highway bridge in the southern corner of the state. A mere 24½ feet wide and 113 feet long, such a structure probably wouldn't turn many heads most of the time. But what it represents has excited bridge engineers and public officials: a true breakthrough in the design and construction of precast bridge structures.

The bridge consists of three 110-foot-long precast modified 45-inch Iowa bulb tees topped by a site-cast concrete bridge deck. What makes the structure unique is that the prestressed structural members were cast using a new concrete mix called Ductal concrete, which is manufactured by Lafarge North America. The ultra-high performance concrete mix provides up to 30,000 psi compressive strength, allowing the bridge to be built without steel rebar.

Fact Sheet

Project: *Mars Hill Bridge*

Location: *Wapello County, Iowa*

Engineer: *Iowa Department of Transportation*

Owner: *Wapello County*

Precaster: *Lafarge North America, Winnipeg, Manitoba, Canada*

Size: *24½ feet wide by 113 feet long*

Components: *Three modified 45-inch Iowa bulb-tees manufactured with ultra-high performance concrete*

Cost: *$432,000*

The UHPC mix allowed the bridge to be built without conventional steel reinforcing.

Beams were cast at Lafarge North America's plant in Winnipeg and trucked to the site.

The concrete mix, patented by Lafarge, comprises cement, silica fume, silica flour, superplasticizer sand, steel fibers and a small amount of water. The material, first introduced in France more than 10 years ago, has been used in a variety of structures in the United States, as well as Canada, Europe, Asia and Australia. The Wapello County Bridge is the first highway bridge in North America to feature the technology, according to Dean Bierwagen, project engineer for the Iowa Department of Transportation.

The bridge was built in a collaborative effort between the Federal Highway Administration (FHWA), Iowa DOT, Iowa State University and Lafarge North America. The catalyst came in 2002, when Wapello County was approached by Iowa State University and Iowa DOT to enter into the joint project. The county took up the challenge quickly, says Wapello County Engineer Brian P. Moore. "We needed a replacement bridge and were intrigued with the possibilities this represented."

The county received a $300,000 grant through the FHWA's Innovative Bridge Research & Construction program to demonstrate the use of the ultra-high performance concrete. The County Board of Supervisors signed onto the project, entered into an agreement with the university, accepted the funding and had the state begin planning the project.

Longer, Thinner Beams Created

"The material provides an opportunity to design bridges that use longer, thinner beams than are possible with conventional concrete mixes," Bierwagen explains. "They are also lighter, using the 30,000-psi strength to achieve a more slender cross section without internal steel reinforcements. A further advantage is that the material is highly impermeable, which reduces the possibility of corrosion within the structure, promising an incredibly longer lifespan for structures that are subjected to moisture and the effects of road salt.

The high compressive strengths of the concrete mix presented some new challenges to the design team, Bierwagen says. "There just weren't any design specifications available

Cranes lower the third girder into position next to the first two girders placed, sequencing the placement from west to east.

to guide us in the design. In fact, the FHWA is looking to projects like this to help develop guidelines for the design of bridges using this material."

The modified bulb tees designed by Bierwagen and his team reduced the dimensions of the beams when compared with the typical Iowa bulb tee. The beams' web was changed from 6½ inches wide to 4½ inches, the bottom flange was changed from 7½ inches deep to 5½ inches and the top flange became 2¾ inches deep instead of 3¾ inches. The depth remained the same.

The nearly three-year duration for exploring the potential for Ductal concrete was necessitated by a testing process that was required before the bridge was built. The process also was delayed by an unforeseen circumstance. Originally, the plan was to have the beams cast in a facility located near the bridge. However, when local precasters were asked to bid on the project, it became apparent that the exotic nature of the material created some logical concerns. As a result, Lafarge proposed casting the beams in its Winnipeg plant.

Beams Tested Before Production

To test the validity of the beams' design, Lafarge cast a 71-foot-long test beam, according to Vic Perry, vice president and general manager for Ductal at Lafarge North America. Also to verify shear and flexural capacity, 10- and 12-inch-deep shear beams were cast. The testing, conducted by the Bridge Engineering Center in Ames, Iowa, verified calculations used by the beams.

The full-size bridge beams were prestressed using 0.6-inch-diameter low-relaxation strands. The only reinforcing

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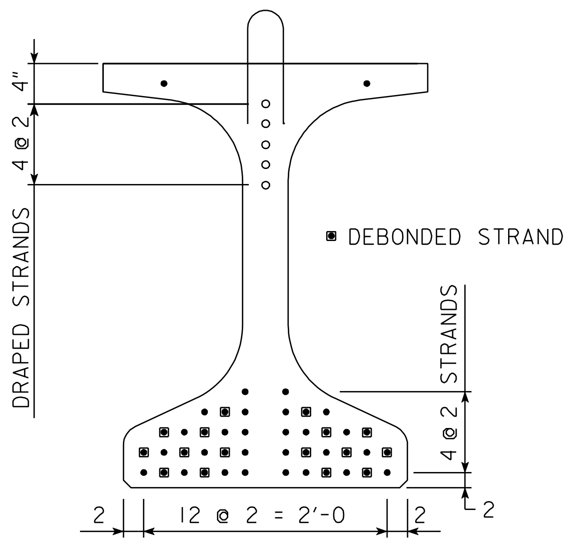


Prestressing-strand layout for the 110-foot-long beams is shown here. Note the absence of reinforcing bars.

steel used in the beams provides composite action between the beams and the 8-inch-thick, cast-in-place deck. Beam spacing is 9' 7" with 4-foot overhangs. The three, 110-foot production beams were cast in June and July of 2005, construction began in August and the bridge opened to traffic in February 2006.

The bridge represents the first incremental step in using UHPC to design effective bridges — and only a baby step at that. “We think it will be possible to build an entire bridge, including the deck, without rebar,” says Perry. “This bridge is the first step in that process. Ductal provides a real synergy with the prestressed concrete industry. It will provide the opportunity to create slender, long-span beams for more graceful bridges.”

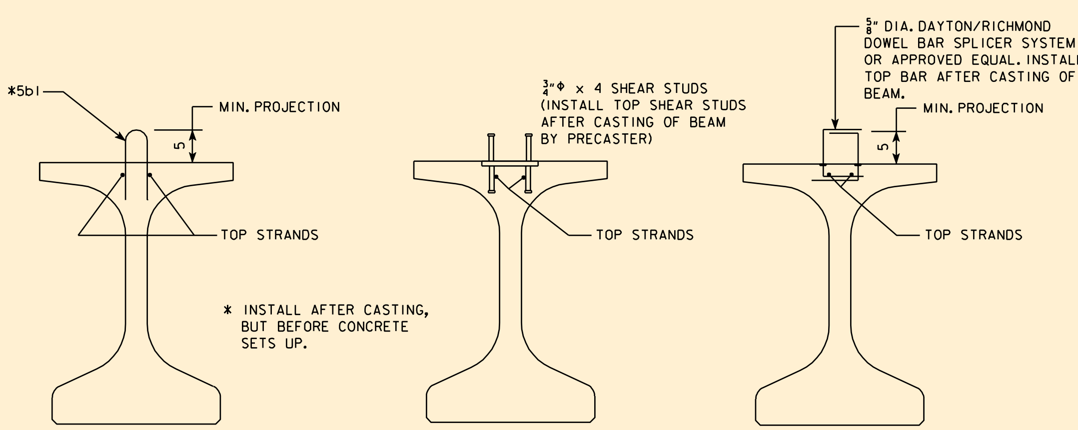
Besides providing greater strength of up to 30,000 psi compressive strength and 7,000 psi tensile strength, the low permeability of the concrete, plus the absence of steel reinforcing promises a more durable, longer lasting structure, he adds.

Moore says he quickly became a fan of the process. “I see a tremendous potential for this product. The use of the steel fiber and the elimination of mild reinforcing give us the potential for using a dense material without the concern of corrosion. This has proven to be a very successful project.” The next logical step is to build a bridge that not only includes the Ductal mix for the structural beams, but for the bridge deck as well. ■

For more information on this or other projects visit *www.pci.org/ascent*.

Composite Connection

The only steel reinforcement in the new Wapello County, Iowa, bridge is mild steel U-bars used to connect the cast-in-place deck to the precast beams (see diagram). The construction process required the top of the beams to be covered with plastic immediately after the placement of the concrete to prevent shrinkage cracks. The plastic was placed directly on the concrete.



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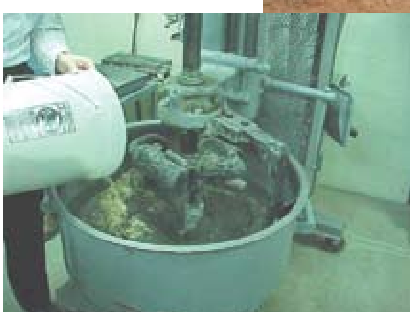

The bridge represents the first incremental step in designing UHPC bridges.