Completed in 2006, the Mars Hill Bridge in Wapello County was the first bridge in the nation built with ultra-high performance concrete (UHPC).

RESEARCH SOLUTIONS

Building Iowa's bridges with affordable ultra-high performance concrete

Ultra-high performance concrete (UHPC) is prized for its superior strength and durability. These qualities have made it an emerging choice for bridge construction and repair, but high material cost has historically made it cost-prohibitive for many practical applications. Following extensive investigations, researchers at Iowa State University developed a more affordable nonproprietary UHPC mixture using readily available materials. Tests indicate that the mixture's strength and durability are comparable to proprietary mixtures at one-third of the cost, offering a promising alternative for Iowa bridge structures.

THE NEED

Concrete is the primary construction material for many of Iowa's bridges, from piers to beams to riding surfaces. These concrete components require periodic maintenance and repair to address damage caused by heavy traffic loads, temperature fluctuations, and chloride deicers. But closing bridges to repair or replace damaged concrete creates hardships for residents, businesses, and drivers across the state.

UHPC offers the potential to significantly reduce these issues. Engineered for optimized performance, UHPC is much stronger and more durable than conventional concrete. Well over a decade ago, Iowa was the first state in the nation to build a bridge with UHPC. Despite UHPC's superior performance, the cost of this proprietary material has prevented it from being widely used in bridge construction and repair. This research project sought to create a comparable UHPC mixture made with widely available materials that would be more affordable for Iowa DOT and for cities and counties across the state.

(continued)

"This research proved that a nonproprietary UHPC mix is a viable and cost-effective option for bridge construction and repair. Now we need to work out some details and get it out there."

— **MICHAEL NOP,**
Iowa DOT Bridge Project Development Engineer

RESEARCH APPROACH

With the goal of identifying the optimal formulations for nonproprietary UHPC, researchers at Iowa State University first developed several base mixtures using locally available portland cement, regular and masonry sand, silica fume (an ultrafine powder), and steel fibers (straight, twisted, and hooked) in various proportions. They tested the mixtures for flowability, strength, and chloride resistivity, a measure representing the risk of chloride penetrating into the concrete.

Next, researchers made adjustments to a set of selected UHPC mixtures to examine the effects of sand-to-cement ratio, silica-to-cement ratio, and silica fume type. They also further explored the effects of various dosages of steel microfibers, steel macrofibers, and five types of less expensive synthetic fibers: nylon, polypropylene, polyvinyl alcohol, alkali-resistant glass, and carbon.

To determine which nonproprietary UHPC mixtures would be the best options for bridge construction and repair, researchers assessed the strength and durability of UHPC samples made with various mixture designs. They conducted tests covering a range of performance measures, including workability; compressive, tensile, and flexural strengths; permeability; and freeze-thaw resistance.

WHAT IOWA LEARNED

From this study's extensive exploration and testing of different types and proportions of mixture ingredients, researchers developed a nonproprietary UHPC mixture that performed comparably to two proprietary UHPC mixtures—at just one-third of the cost.

To guide agencies in using nonproprietary UHPC, researchers provided specific recommendations for the strongest and most durable UHPC mixtures and proportions. This included the ideal ranges for sand-to-cement, water-to-cement, and silica fume-to-cement ratios. The findings also spelled out the optimum steel content, including what amounts and combinations of straight, twisted, and hooked steel fibers worked best.

Combining synthetic fibers with steel fibers, which resulted in better mixtures than those made with steel fibers alone, was among the innovations introduced as an outcome of this research. Since synthetic fibers are less expensive than steel fibers, using this combination makes nonproprietary UHPC an even more cost-effective choice.

PUTTING IT TO WORK

There are many potential uses in bridge construction and repair for cost-effective UHPC mixtures that have comparable properties to proprietary mixtures.

As a next step, Iowa bridge engineers plan to further test and implement nonproprietary UHPC mixtures for deck overlays, beam end repairs, and other projects. These projects will allow Iowa DOT and county engineers to assess the short- and long-term performance of nonproprietary UHPC in the field and better understand its production and construction requirements.

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ABOUT THIS PROJECT

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