Clare County Road Commission Seeks Higher Performance at Lower Cost with Open-Recipe UHPC Formula

by Monica Schultes

The Kilgore Road Bridge Restoration Project in Kenockee, Mich., was one of the earliest field applications of a nonproprietary ultra-high-performance concrete (UHPC) in the United States. That early demonstration project in St. Clair County garnered national attention for its innovative use of open-recipe UHPC. With the successful completion of this project, the material has been used on several other similar projects.

Dewayne Rogers, managing director of the Clare County Road Commission (CCRC), was aware of the benefits of UHPC from his previous position in St. Clair County, and he was determined that Clare County, which is located in the center of Michigan's Lower Peninsula, would make use of the innovative construction material despite its reputation for being expensive and difficult to handle. He learned that the University of Michigan and the Michigan Department of Transportation (MDOT) were exploring how to translate the proven performance of proprietary UHPC to everyday use. An open recipe for UHPC was developed by Sherif El-Tawil, a University of Michigan professor of civil and environmental engineering, at the request of MDOT. That formula is now available to anyone interested in using it.[1,2]

Rogers was quick to use the open-recipe concept to produce robust concrete for maintenance purposes. "It was a challenge to raise our game and think creatively about our assets in the long term," he says.

In addition to proving the inherent strength and durability of nonproprietary UHPC, the research team wanted to study the material's impact on long-term maintenance. "UHPC is still more expensive than regular concrete, but if you consider the effect over the lifetime of a bridge, then the cost becomes very competitive," says Rogers. He adds, "There are substantial hidden cost savings. The extremely high strength of UHPC can result in a massive reduction in structural component weight, which reduces handling, transportation, and foundation costs. These savings add up and make the overall cost of UHPC structures competitive."

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Similar to projects across the United States that used proprietary UHPC mixtures, CCRC used the generic UHPC for closure pours between standard precast concrete elements. Rogers has also begun to precast concrete bridge elements using the open-recipe UHPC.

Mixture Workability

After extensive testing to prove the open-recipe UHPC performance characteristics, the University of Michigan research team focused on the workability of the concrete. Even with the cost savings, concrete production in the field needed to be streamlined and the workability of the generic UHPC would determine its ultimate success.

In the laboratory, the team had performed testing with a small drum mixer that replicated a concrete ready-mix truck. That method was then scaled up for field testing. "You have to change your mindset away from conventional concrete," states Rogers. "Conventional concrete has been around forever, and you have to vibrate and finish it. Neither are required for UHPC. You can put away your trowel."

The research team identified critical steps when preparing open-recipe UHPC. Careful consideration must be given to the mixing sequence, mixing time, mixing

Developed at the University of Michigan, the open-recipe ultra-high-performance concrete (UHPC) was carefully batched in small amounts on site (left) for deck closure pours for the Kilgore Road Bridge Restoration Project in Kenockee, Mich. This demonstration project was one of the earliest field applications of a nonproprietary UHPC in the United States. UHPC is placed in the closure joint after being batched with the light blue mixer visible in the background (center). The protruding all-thread rods visible in the photo on the right support the bottom formwork to prevent leakage during placement of the UHPC in the closure joints. All Photos: Clare County Road Commission.

The mixer used by Clare County Road Commission staff to batch the open-recipe ultra-high-performance concrete in the field.

speed, and temperature to achieve a homogenous batch.

It is critical to combine the materials in a specific order. Dry ingredients such as cement, silica fume, and sand are mixed first. Then water and high-range water-reducing admixtures are added and mixed into a slurry. The steel fibers are added last, and CCRC typically uses a screen to disperse fibers when adding them into the mixture. These procedures avoid common problems such as clumping of steel fibers or unmixed dry materials.

The CCRC maintenance crew was able to batch the dry ingredients, liquids, and steel fibers in the proper sequence to achieve the desired result. They demonstrated that with training and practice, the challenges of UHPC were not insurmountable.

Steel Fibers

A key ingredient in UHPC is steel fibers. While the fibers themselves are small, they have a big impact on cost. Because of the fibers, open-recipe UHPC is still more expensive than conventional concrete. As the cost of steel fibers drops with their increasing use, the cost of the open-recipe UHPC will also fall.

Many of the early projects were local bridges without much traffic, but now the CCRC is ready to move up to larger projects. Any obstacles in its usage can be easily identified and overcome, says Rogers. After some trial and error, contractors and precasters can master the new procedures.

Setting up for Success

With a focus on resiliency and a 100-year service life for bridge structures, Rogers had to experiment with the best way to use this potent technology. UHPC's proven ability to withstand the harsh environment in Michigan, along with its versatility and high strength, make it ideal for extending the service life of bridges. "It is ideally suited for northern and midwestern climates that experience freeze-thaw cycles, and for structures subjected to extreme temperatures and deicing chemicals—conditions common in Michigan," says Rogers. With this in mind, CCRC has already expanded the use of UHPC to precast bridge deck panels, which are made in a CCRC garage using ready-mix trucks to mix the UHPC.

The Clare County Road Commission has moved open-recipe ultra-high-performance concrete (UHPC) from the laboratory into the field. They used the UHPC mixture for a closure pour of concrete deck panels located on the Haskell Lake Road Bridge over the Clam River.

The Clare County Road Commission maintenance crew has used the open-recipe ultra-high-performance concrete (UHPC) to precast bridge deck panels in their garage. By paying careful attention to the mixing sequence, time, speed, and temperature, the crew has even been successful producing consistent batches when mixing the UHPC using ready-mix trucks.

Rogers has a passion for sharing his lessons learned with anyone who is interested in the CCRC projects. For example, he says that there are challenges on hot days when the UHPC sets up too fast, and on cold days when the curing time is extended. In addition, the flowability of UHPC requires well-constructed formwork to eliminate leakage. Threaded rods and nuts are typically used to ensure that the bottom formwork does not leak.

"It is important to consider the big picture," says Rogers. "We wanted to be innovative and look for ways to extend the life of our bridges. We were willing to pay slightly more in first costs for a bridge that will last 100 years." He predicts that once use of the open-recipe UHPC is more widespread, the cost will come down. In the meantime, CCRC is exploring ways to design with lighter precast UHPC components and cross sections.

While UHPC has been available in the United States, the proprietary materials were cost prohibitive. The generic, cost-optimized UHPC using local materials from local suppliers is an important step forward. Projects in Michigan will inspire the increased use of open-recipe UHPC designs and will encourage the widespread use of nonproprietary UHPC. While some new knowledge is required, contractors will be able to leverage their existing expertise for UHPC-based solutions.

References

1. El-Tawil, S., Y.-S. Tai, B. Meng, W. Hansen, and Z. Liu. 2019. *Commercial Production of Non Proprietary Ultra High Performance Concrete*. Lansing, MI: Michigan Department of Transportation. https://www.michigan.gov/documents/mdot/SPR-1670-2019_644044_7.pdf.
2. El-Tawil, S., Y.-S. Tai, J. A. Belcher, and D. Rogers. 2020. "Open-Recipe Ultra-High-Performance Concrete." *Concrete International* 42 (6): 33–38. https://www.concrete.org/publications/getarticle.aspx?m=icap&pubID=51725915.

A wheelbarrow was used to convey the open-recipe ultra-high-performance-concrete mixture from the mixer to the joints on the Haskell Lake Road Bridge repair project.

Haskell Lake Road Bridge repairs made use of generic ultra-high-performance concrete to withstand the harsh winters in Michigan. The surface of the bridge was diamond ground to level the closure joints, then an epoxy overlay was applied to protect the joints and provide a smooth riding surface.