RESEARCH SPOTLIGHT

Project Information

REPORT NAME: Commercial Production of Non-Proprietary Ultra High Performance Concrete

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MDOT research develops generic ultra-high performance concrete for mixing in field

Ultra-high performance concrete (UHPC) is very strong and extremely durable; it can last decades longer than regular concrete, which itself performs well for many decades. MDOT currently acquires UHPC from a manufacturer that closely guards its components and mixing process, keeping the concrete too expensive and impractical for many bridge uses. A previous MDOT study developed a generic Michigan UHPC mixture (MI-UHPC), but it mixed poorly in the field. To fully implement MI-UHPC, researchers developed a new procedure for successfully mixing UHPC in the field, where it will provide outstanding performance for the lifetime of a bridge.

PROBLEM

Near the end of the MI-UHPC mixing process, crews add steel fibers through a grate over the mixing barrel.

UHPC is a dense concrete mixture that allows little or no water to penetrate the material and provides strength for decades longer than regular concrete. Prized for its durability, it is also a proprietary mixture provided by a commercial developer at high expense. Unlike most concrete, UHPC arrives at a construction site in packaged components from its supplier that are then mixed on site by specialists. In a previous study, researchers developed a generic mixture for MDOT that performed very well in laboratory testing of small batches mixed in a food blender. Mixed in larger batches in a field mixing barrel, MI-UHPC came together poorly; as ingredients

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> *"We can now make a nonproprietary UHPC with generic ingredients from standard products. It is mixable with standard equipment, without specialty crews and special tools, without us having to pay several thousand dollars per cubic yard for proprietary mixtures."*
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> Project Manager

were added to improve mixability, field mixers became overwhelmed and unable to turn the material over.

RESEARCH

A team of researchers from the University of Michigan studied the MI-UHPC mixture to determine why the material did not scale up well in mixing. Investigators examined the mixture's various components, evaluating functional needs of each ingredient to ensure that viable materials could be used from multiple local, Michigan-based producers.

After establishing the viability of local ingredients for MI-UHPC, researchers evaluated field-scale mixing approaches to identify the right combination of procedures and materials to create and apply the new concrete in the field. They identified material properties of the new UHPC for engineering design and specifications in its form as a fresh mixture, as concrete after short-term use, and as concrete after long-term use.

The research team then took the updated recipe and materials for MI-UHPC to the Kilgore Road bridge restoration project in Kenockee, where crews built closure pours between deck slabs. Based on this pour in St. Clair County and on testing and material characterization, the research team formalized the MI-UHPC recipe, mixing procedure and mechanical properties for MDOT design and construction specifications.

RESULTS

In its earlier form, MI-UHPC employed silica fume with high carbon content. Carbon particles are fine, which increased the demand for water. This made less water available for the other components of the mix, thus compromising field mixing.

The new MI-UHPC entails mixing materials in a specific order. Dry ingredients, including cement, silica fume and sands, are mixed for five minutes. Ice and high-range water reducer (HRWR) are added and mixed into a thick slurry. More silica sands are gradually added and mixed in for five more minutes. Finally, steel fibers are added and the material is mixed to optimal fluidity for five to eight minutes. The researchers noted that, while crews may err on the side of adding extra HRWR material to maintain workability, this may slightly weaken mechanical properties but causes no damage to long-term UHPC performance. However, excessive HRWR should be avoided because it may cause fiber segregation.

In all variations due to multiple suppliers of some material, the MI-UHPC achieved compressive and peak tensile strengths higher than required for field-cast UHPC. Partial substitution of cement with slag cement, an industrial byproduct, made the material greener and at the same time improved mixture self-consolidation, air voids and porosity.

IMPLEMENTATION

Mixed in the field, this new MI-UHPC saves hundreds of dollars per cubic yard over the proprietary mixture. The material's high freeze-thaw resistance, its near-full impermeability to chloride penetration, and its strain hardening under tension make it a low-maintenance, extremely durable material that prevents cracks from widening. The closure pours at the Kilgore Road bridge project were about 6 inches wide, yielding significantly thinner and more damage-resistant joints than regular concrete, which would have required about an 18-inch joint width. MI-UHPC has now been used in five bridges in St. Clair County – some of the earliest uses of a truly generic UHPC in the nation – and it offers MDOT new technology to develop ultra-long-span and ultra-durable structures. MDOT may begin recommending UHPC's wider use. If similarly adopted nationwide, generic UHPC may trigger a demand for Michigan-manufactured steel fibers, a key ingredient of MI-UHPC, extending the economic benefits of the technology to Michigan industry.

Research Administration

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This final report is available online at
https://mdotjboss.state.mi.us/SpecProv/getDocumentById.htm?docGuid=60e168ca-3681-4c3e-a902-20fc621e98b0.

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