MONTANA
Department of Transportation
Research

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Project Summary Report
FHWA/MT-23-002/9925-818

FEASIBILITY OF NON-PROPRIETARY ULTRA-HIGH PERFORMANCE CONCRETE (UHPC) FOR USE IN HIGHWAY BRIDGES IN MONTANA: IMPLEMENTATION

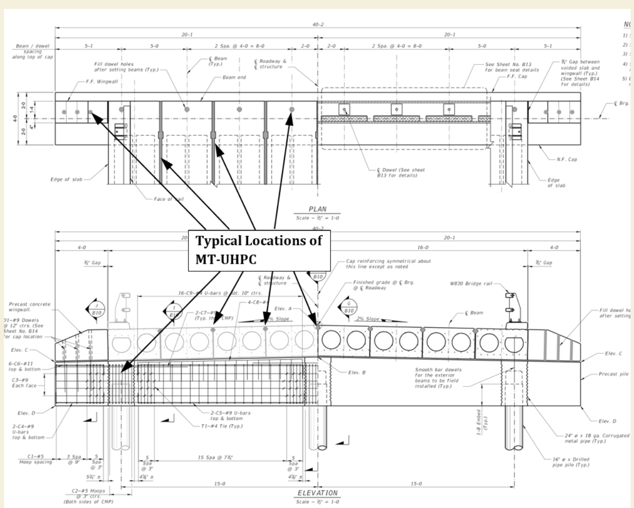
https://www.mdt.mt.gov/research/projects/mat/high_performance_concrete.aspx

Introduction

Ultra-high performance concrete (UHPC) has mechanical and durability properties that far exceed those of conventional concrete. However, using UHPC in conventional concrete applications has been cost prohibitive, with commercially available/proprietary mixes costing significantly more than conventional concrete.

Previous research conducted at MSU included (1) the development of nonproprietary UHPC mixes that are significantly less expensive than commercially available mixes and are made with materials readily available in Montana, (2) an investigation into several items related to the field batching of these mixes, (3) an exploration into the potential variability in performance related to differences in constituent materials, and (4) the investigation of rebar bond strength and the subsequent effect this has on development length.

This previous research was successful and clearly demonstrated the feasibility of using MT-UHPC in Montana bridge projects.



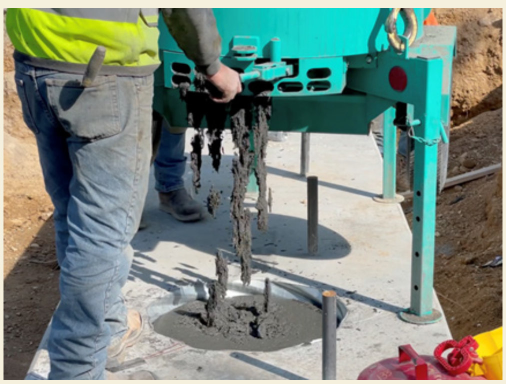
Location of MT-UHPC in Bridges.

The focus of this project was on the field implementation of MT-UHPC. Specifically, MT-UHPC was used in all field-cast joints on two ABC bridges spanning Trail Creek on Highway 43 near Lost-Trail Pass outside of Wisdom, MT.

What We Did

The objectives of this research were realized through the following tasks:

- A comprehensive literature review was conducted to evaluate the state-of-the-practice and recent advances in UHPC. This review focused on the implementation of UHPC in actual bridge applications. It was aimed at learning from the mistakes made in prior UHPC applications and utilizing techniques found to be successful.
- Constituent material sources were selected by the contractor and approved by MSU for use in the MT-UHPC. The properties of the materials were documented and compared to materials previously used by MSU.
- Implementation-related research was conducted to ensure the successful field application of MT-UHPC. Specifically, mixing methods and temperature effects were investigated, and a maturity curve was developed to predict early strength gain in the field.
- Trial batches of MT-UHPC were performed and placed in mockup bridge joints. This was done on site using the same methods and under the same environmental conditions expected on the day of construction.
- Montana UHPC was successfully implemented in the replacement of the Trail Creek bridges. It was used for all field-cast connections, including the pile-to-pile cap connections, the connections between the beams and caps, the wing walls, and the longitudinal shear-keys between adjacent beams.



MT-UHPC being placed into pile cap sockets.

MT-UHPC being placed into keyways.

What We Found

Based on this investigation, the following conclusions were made:

Conclusions from the preliminary implementation research.

- MT-UHPC can be batched consecutively without cleaning the mixer in between batches.
- Batch sizes should be limited to 3 ft^3 when mixing MT-UHPC with IMER Mortarman 360s.
- MT-UHPC should be placed at low temperatures and when material temperatures are low to reduce the risk of the material stiffening and premature setting (which was observed to occur at elevated temperatures).

- Cure temperature should be accounted for when estimating the compressive strength of the material in the field, as temperature was observed to greatly affect the rate of strength gain. Specifically, increased temperatures resulted in a higher rate of strength gain and decreased temperatures delayed strength gain.
- Maturity curves developed in this research may be used to accurately estimate compressive strength of MT-UHPC in the field, regardless of cure temperatures.

Conclusions from the trial batches and joint mockups.

- MT-UHPC was successfully batched and mixed in the field using the exact materials, mixers, and methods to be used in the actual bridge project. The flows of the trial mixes were around 10 inches, and the compressive strengths exceeded the minimum specified 28-day strength of 12 ksi, with an average strength of 16.1 ksi.
- The methods used to form and place the UHPC in the connection mockups were primarily successful. However, the UHPC in the sloped-keyway mockup demonstrated the need for top forming the keyways, as the UHPC in these connections overflowed at the low end and fell short on the high end.
- Grinding the UHPC before it reaches a strength of 1 ksi resulted in a rough surface on the UHPC and steel fibers being pulled from the material. It is recommended that the MT-UHPC reach at least 3 ksi prior to grinding, as is specified in the Special Provisions.

Conclusions from bridge construction.

- Pre-mixing and bagging the dry constituent materials (i.e., cement, fly ash, silica fume, and sand) was an effective/efficient strategy for the implementation of MT-UHPC in the field.
- The on-site batching and mixing methods worked well. However, the use of larger mixers should be investigated. The 3-ft^3 limit per batch resulted in an excessive number of mixes per application, which slowed progress on the bridge.
- The MT-UHPC was successfully mixed, batched, placed, and cured under varied environmental conditions. Specifically, temperatures ranged from the low 20s to the upper 80s (°F), and moderate winds were present. That being said, these varied environmental conditions did affect the behavior/performance of the UHPC. Specifically, low temperatures were observed to cause issues with mixing if the mixers were not warmed up prior to batching, and were observed to increase cure times. Whereas, elevated temperatures can cause mixes to setup prematurely in the mixer, and can cause mixes to stiffen up quickly during placement. Wind was observed to reduce workability during placement.
- The maturity method provided an efficient and accurate means for estimating the early strength of the MT-UHPC in the field, significantly reducing the number of cylinders required for testing and allowing for a more rapid indication of when the UHPC reaches the required strength for construction loads, which is especially important in accelerated bridge construction projects such as this.
- The top-forming method used on this project could be improved. The method used resulted in several locations with an insufficient depth of UHPC, requiring epoxy coating after grinding.
- The Special Provisions developed for this project were a good starting point for implementing MT-UHPC in a bridge construction project in Montana. However, they should be updated and modified for future projects to incorporate some of the key findings from this inaugural project.
- It was imperative to establish a good working relationship with the contractor and establish good lines of communication. The contractor on this project, Dick Anderson Construction, was a pleasure to work with, making this project possible.

Bridge with epoxied MT-UHPC keyways.

Overall, this project was a successful demonstration of using a nonproprietary UHPC in field-cast joints for an accelerated bridge construction project. All placed UHPC had adequate flows, gained strength quickly, and reached the required minimum compressive strengths.

What The Researchers Recommend

This study affirms the effective use of nonproprietary UHPC for accelerated bridge projects, offering a practical tool for future MDT bridge repairs and construction. Future research should consider larger batches and mixers, developing thixotropic mixes for overlays, and eliminating fly ash from the MT-UHPC mix due to its growing scarcity.

More Info:

The research is documented in Report FHWA/MT-23-002/9925-818

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