

Executive Summary, Research Readiness Level Assessment, and Technology Transfer

Ultra-High-Performance Concrete (UHPC) for Bridge Deck Overlay and Structural Repair

Research Objectives

The objective of this project is to develop an NDOT UHPC mixture specific for overlay and structural deck repair applications using local materials, evaluate its fresh, mechanical, and durability properties using laboratory testing and mockup specimens, and implement it in demonstration projects.

Research Benefits

Through bridge deck overlay and structural deck repair, UHPC is expected to improve the long-term performance of NDOT bridge decks and have a lower life-cycle cost than conventional materials due to their durability and structural performance. It is expected to extend the service life of the overlay beyond the 75-year service life of the bridge structure. This project will be a key component of the NDOT Roadmap of UHPC. The success of this project will provide the necessary knowledge for UHPC as an overlay or structural repair material for bridge decks, which will greatly encourage producers and contractors to adopt this innovative approach.

Principal Investigator

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Background

Recently developed NDOT non-proprietary UHPC mixture for precast and cast-in-place applications does not meet the specific requirements for deck overlay (e.g., interface bond with existing deck, high thixotropy, workability retention, sloped construction, and increased fiber content). The current project will, therefore, primarily focus on bridge deck overlay and structural deck repair, which completes the NDOT roadmap for promoting the use of UHPC in bridge applications. Besides the high (early- and ultimate-) compressive and tensile strength, UHPC is expected to provide much better resistance to freeze-thaw cycles, chloride ion penetration, and shrinkage-induced cracking than conventional concrete and asphalt overlay, and structural repair materials. Mixtures and guidelines are urgently needed to be developed to better control the workability and stability of UHPC in both static and dynamic conditions for successful UHPC overlay construction.

Conclusion

Ultra-high-performance concrete (UHPC) is an advanced cementitious material known for its exceptional strength and durability, making it an ideal material for bridge deck overlays and repairs that address the common issue of premature deck deterioration. Conventional UHPC is typically flowable and self-leveling, which makes it unsuitable for deck surfaces with cross-slopes and/or sloped vertical profiles. Therefore, a highly thixotropic UHPC that responds well to vibration while remaining stable on sloped surfaces is needed for overlay applications. Mixtures with varying binder content, water-to-binder ratio, fiber content, and dosages of admixtures were developed and evaluated. Two of the most effective and economical mixtures were selected for full-scale mockup construction and testing.

Six full-scale sloped slabs were prepared using three surface preparation methods: surface retarder for fresh concrete, fine milling, and typical milling for hardened concrete to simulate field conditions for overlay applications. The structural performance of the composite slabs and the bond between UHPC overlays and concrete substrates were tested to evaluate the effectiveness of each surface preparation method. Flexural tests were conducted under both positive and negative bending, and the experimental results were compared with predictions according to the latest AASHTO UHPC Guide Specifications. The two UHPC mixtures developed in this study were further evaluated for their workability, mechanical, and durability properties. They showed excellent performance compared to the UHPC overlay mixes reported in the literature. The study also confirmed the constructability of the developed mixtures using traditional construction equipment. Recommended ranges for various workability indicators were proposed based on the performance of the UHPC mixtures included in the study and mockup evaluation. The three surface preparation methods investigated were sufficient to achieve an adequate bond between UHPC overlay and deck slab. Flexural test results of the slabs also demonstrated the significant contribution of UHPC to the flexural capacity of the deck slab in negative-moment regions and the adequacy of the developed prediction models.

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Final report is available:
[HERE](#)

NDOT Recommendations Based Off Research Project – 2026 – RRL3

This research provided the NDOT with two non-proprietary UHPC mixtures, using 2% and 3% steel fibers respectively, using locally available Nebraska materials. The mixtures showed adequate workability, mechanical properties, and durability properties in laboratory and mock-up testing; however, a full-scale field implementation has yet to be conducted. In the follow up project [SPR-FY27\(071\)](#), Implementation of UHPC Bridge Deck Overlays in Nebraska, NDOT-specific construction and QA/QC guidelines will be developed and implemented in pilot projects.

- As provided by Wally Heyen, Lead TAC Member

Research Readiness Level (RRL) Assessment

Level 3: Development

Follow up upon completion of FY27(071), in 2028.

RRL 3

Technology Transfer

Webinars/Presentations

- Gerges, M., Aitbayeva, A., Hu, J., and Morcous, G., Effect of Surface Preparation on Bond Strength and Flexural Performance of Bridge Decks Overlaid with Non-Proprietary UHPC, 105th Transportation Research Board (TRB) Meeting, Washington DC, January 11-15, 2026. [Poster Presentation]
- Aitbayeva, A., Gerges, M., Morcous, G., and Hu, J., Workability Tests for UHPC Overlay Mixture Development and Evaluation, 104th Transportation Research Board (TRB) Meeting, Washington DC, January 5-9, 2025. [Podium Presentation]
- Gerges, M., Aitbayeva, A., Hu, J., and Morcous, G., Flexure Capacity Prediction of Bridge Deck Overlaid or Repaired with UHPC, 104th Transportation Research Board (TRB) Meeting, Washington DC, January 5-9, 2025. [Podium Presentation]

**This brief summarizes Project SPR-FY24(034)
“Ultra-High-Performance Concrete for Bridge Deck Overlay and Structural Development”
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