Executive Summary, Research Readiness Level Assessment, and Technology Transfer

Repair/Preservation of Concrete Compression Members in Bridges Using Ultra-High-Performance Concrete (UHPC)

Research Objectives

The objective of this project is to develop procedures for using UHPC in the repair/preservation of concrete bridge components including the design and construction guidelines for immediate implementation. Two demonstration projects that include the repair of deteriorated concrete bridge pier and girder end will be conducted to help bridge engineers and contractors gain the design and construction experience of using UHPC in the repair/preservation. This will also include addressing issues like surface preparation, formwork design, placing and curing methods of UHPC, and installing interface anchors between UHPC and CC. The lessons learned from these two projects will be disseminated via presentations and publications for technology transfer.

Research Benefits

Two demonstration repair/preservation projects are expected to be implemented by NDOT during the project duration. Several candidate projects were studied, and two projects were tentatively selected for demonstration and technology transfer. Constructability issues, such as traffic control, repair duration, and cost will be also evaluated in these demonstrations.

Principal Investigator

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Background

According to the 2021 Infrastructure Report Card, there are currently 42% of all Unites States bridges that are at least 50 years old, and 46,154 of the nation's bridges are considered structurally deficient and require repair/preservation or replacement. Traditional repair/preservation methods, such as fiber reinforced polymer (FRP) wrapping, steel encasement, or reinforced concrete encasement, are either complex, time consuming, costly, or have short service life.

The preliminary literature review has indicated a very limited but promising use of UHPC in the repair/preservation of concrete bridge components, such as piers, pier caps, and girder ends. Although UHPC has excellent mechanical and durability properties, there is lack of guidelines on the design approach and construction procedures for using UHPC as a repair material to encase deteriorated/damaged concrete components.

Conclusion

As of 2024, approximately 36% of bridges across the United States require repair or replacement, with 7% classified as structurally deficient. The estimated cost to address these deficiencies exceeds $260 billion. In recent years, Ultra-High-Performance Concrete (UHPC) has emerged as a repair material for infrastructure preservation, drawing increased attention from transportation agencies and researchers worldwide. The Federal Highway Administration (FHWA) has notably advocated for UHPC's adoption in bridge preservation initiatives, recognizing its exceptional mechanical properties and durability.

This report presents a comprehensive literature review on the application of UHPC as a repair and strengthening material for bridge compression members. While significant progress has been made in employing UHPC for bridge decks and joints, its use in repair or strengthening bridge columns/piles remains relatively underexplored. To address this gap, the study introduces an analytical model designed to predict the axial and flexural capacities of reinforced or prestressed concrete compression members encased with UHPC jackets. The model is formulated based on strain compatibility and integrates idealized UHPC material behavior in both tension and compression, consistent with the latest UHPC design specifications. In addition, an experimental program was conducted to evaluate the structural benefits of UHPC encasement in compression members. The investigation consisted of two phases. Phase I assessed the confinement effect of UHPC on small-scale concrete cylinders with varying jacket thicknesses, revealing notable enhancements in compressive strength and ductility. Phase II focused on full-scale reinforced concrete columns subjected to axial loading and bending, examining the bond behavior at the UHPC–conventional concrete (CC) substrate interface under different surface preparation methods and the influence of transverse reinforcement within the UHPC jacket. Results confirmed a strong interfacial bond and underscored the role of transverse reinforcement in delaying failure and improving overall structural performance. The report concludes with a detailed design example, demonstrating the model's applicability and its predictive accuracy in estimating strength gains due to UHPC jacketing. Collectively, this study provides both a practical design framework and novel experimental insights, reinforcing UHPC's potential to enhance structural performance and extend the service life of aging bridge infrastructure.

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Interested in finding out more?
Final report is available:
HERE

NDOT Recommendations Based Off Research Project – 2025 – RRL4

This research provides valuable insight into the application of NDOT's non-proprietary ultra-high-performance concrete (UHPC) mix as a patching material for the repair of deteriorated bridge components. The Department intends to apply these findings in two upcoming repair projects. Project Broken Bow – Merwyn, scheduled for letting in November 2025, will employ UHPC for column repair and encasement, an application directly addressed in this study. Project Doniphan – I-80, scheduled for letting August 2026, will utilize UHPC for girder end encasement. Guidance for girder deck encasement using UHPC is primarily informed by the FHWA publication "Design and Construction of UHPC-Based Bridge Preservation and Repair Solutions" (FHWA-HRT-22-065), with this research serving a supplementary and context-specific role.

- *As provided by Fouad Jaber, Lead TAC Member*

Research Readiness Level (RRL) Assessment

RRL 4

Level 4: Implementation

Research demonstrated. Benefits of implementation will be followed up in 5 years.

Technology Transfer

Transportation Research Board (TRB) papers and Publications

- Hedia, M. H., and Morcous, G. (2024) "Capacity of Reinforced/Prestressed Concrete Compression Members Strengthened/Repaired Using UHPC Encasement", Transportation Research Record (TRR), May. https://trid.trb.org/View/2381810

Webinars/Presentations

- "Strengthening Conventional Concrete Using Ultra-High-Performance Concrete (UHPC)", FHWA EDC Webinar for Bridge Preservation and Repair, FIU, April 26, 2023.

Journal Papers Submitted for Review and In Progress Journal Papers and Theses

- Kodsy, A., and Morcous, G. (2023) "Predicting Strength of Non-Prestressed Concrete I-Beams Repaired/Strengthened in Flexure and Shear Using Ultra-High-Performance Concrete (UHPC)", Elsevier Structures Journal, December. https://www.sciencedirect.com/science/article/pii/S2352012423017587

This brief summarizes Project SPR-FY23(024)
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