

PREFABRICATED BARRIER SYSTEM UTILIZING UHPC CONNECTIONS

Quarterly Progress Report

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Submitted to:

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1. Introduction

Barriers are one of the essential components in bridges to ensure safety for vehicles and redirect the errant vehicles passing the bridge. Several attempts were taken place to develop prefabricated barriers with connection to the bridge deck using post-tensioned threaded rods and stainless-steel bars. However, those connections are associated with higher cost and durability issues. A new prefabricated barrier system utilizing UHPC connection to deck overhangs is proposed herein. A single-slope prefabricated barrier with grooves will be connected to deck overhang with dowels extended vertically from its end. The grooves in addition to 1 in. leveling pad will be filled using UHPC to connect the prefabricated barrier to bridge deck overhang. The use of UHPC allows for shorter development length of overhang extended dowels resulting in easy erection and simplification in reinforcement details of the barrier itself. Under this project, component and large-scale testing will be conducted along with extensive finite element models to ensure that the proposed prefabricated barrier system with UHPC connections meets TL-4 requirements.

2. Problem Statement

One durability issue regarding cast-in-place (CIP) barriers is the early-age cracking due to temperature gradients and curing conditions which can subject them to excessive risk of corrosion, leading to costly repair projects. In order to avoid this undesired phenomenon, a new detail is being developed using Ultra-High Performance Concrete (UHPC) to connect the prefabricated barriers to deck overhangs which can significantly reduce on-site construction time and enhances work zone safety.

3. Objectives and Research Approach

The main objectives of this project are:

- a) Development of new connections utilizing UHPC to connect prefabricated barriers to bridge deck considering geometry and fit-up issues.
- b) Conducting detailed finite element modeling on the proposed barrier system and connections.
- c) Conducting a proof of concept experimental work on component test for the proposed prefabricated barriers with UHPC connections.
- d) Conducting a proof of concept experimental work on large test for the proposed prefabricated barriers with UHPC connections.
- e) Assessment of the performance of the prefabricated barriers with UHPC connections compared to the most common barrier systems.
- f) Developing detailed finite element models for the proposed prefabricated barriers with UHPC connections for better understanding of system performance, therefore, extending the study to analyze other specimens which will not be possibly tested.

4. Description of Research Project Tasks

Description of tasks carried out to date are as following.

Task 1– Development of new connections using UHPC for Prefabricated Barrier Systems

In this task, a single-slope prefabricated barrier with grooves was considered to be connected to deck overhang with dowels extended vertically from its end. The vertical bars in the barrier will be spliced to the existing dowels in the deck using UHPC in the grooves which provides a continuous connection along the length of the barrier.

Progress: This task is completed, and the connections are designed and analyzed as shown in Figure 1. The researchers adopted a single slope barrier which passed crash testing at Midwest Roadside Safety Facility at the University of Nebraska Lincoln (UNL) using cast-in-place. The barrier will be a prefabricated unit and will be connected to bridge overhang using UHPC connection by splicing the vertical reinforcement in the barrier with dowel reinforcement extended from the bridge overhang forming U-shape connection as shown in Figure 1.

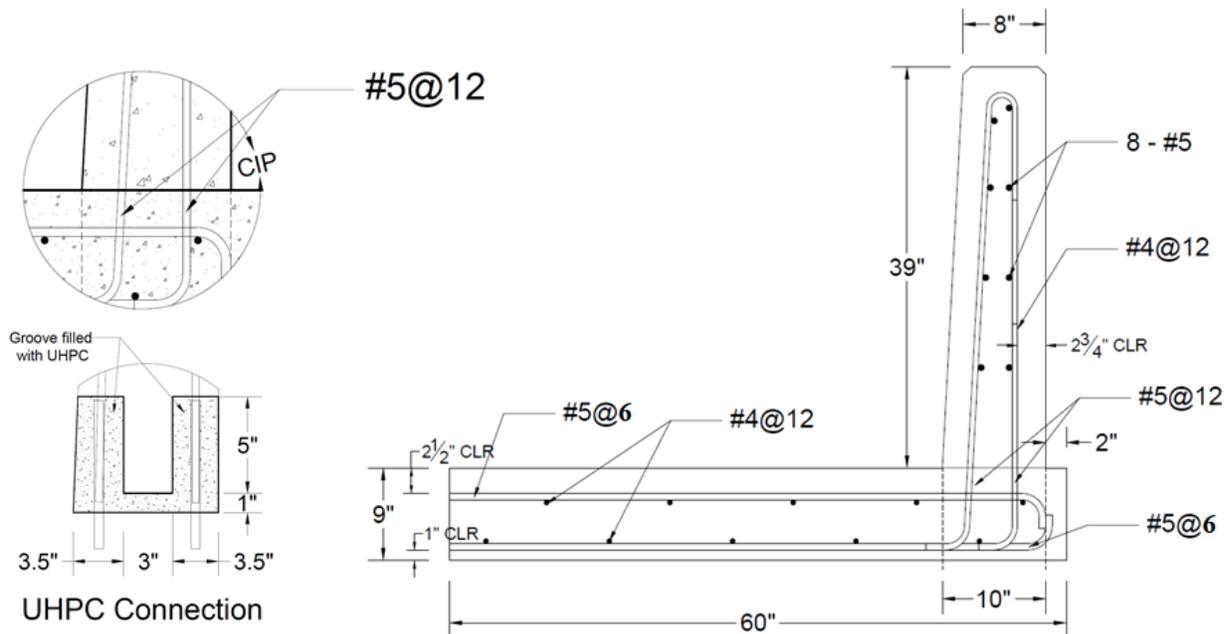


Figure 1 The CIP and Proposed connection between prefabricated barrier and deck overhang utilizing UHPC.

Task 2– Finite Element Analysis of the Proposed Prefabricated Barrier System

Progress: This task is completed and the design of test specimens are finalized.

In this task, a series of nonlinear finite element (NLFE) analyses were performed to evaluate the performance of the proposed connection. The CIP and prefabricated barrier system which were placed at the edge of 60-in long bridge overhang, were modeled in ATENA software and the results are presented hereinafter. The critical length of yield line failure pattern, L_c , for the CIP barrier, was calculated as 13.2 ft using yield line approach recommended by AASHTO. The length of the barrier should be longer than L_c to ensure that yield line failure mechanism would develop. For this study, it was found that longitudinal length of 20 ft is suitable to effectively simulate the estimated yield line failure pattern which is almost equal to the length of the deck resisting

transverse load ($L_c + 2H$). The focus of this task is to investigate the structural performance of the proposed prefabricated barrier systems subjected to transverse static loading according to Test Level Four (TL-4) based on AASHTO MASH.

A half model is adopted due to symmetrical load conditions and boundary conditions, as shown in Figure 2. Displacement controlled load is applied at nodes on the middle of the loading plate. The effect of the loading height was also investigated.

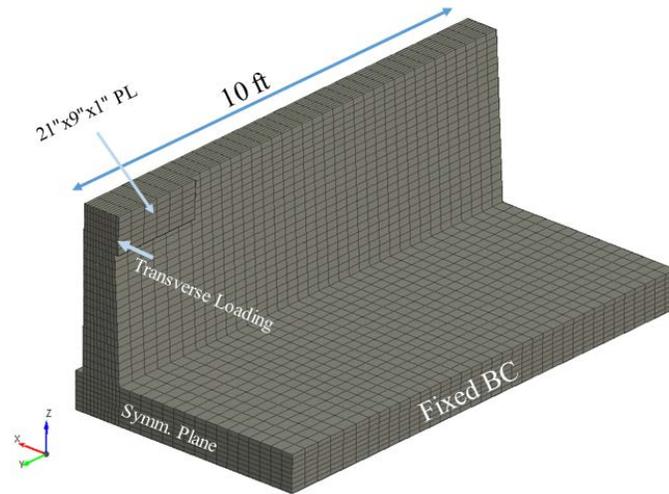


Figure 2 FE model representing static test for the CIP and prefabricated barrier.

After reaching the cracking moment of the deck, $M_{cr} = 1374$ kip-in, the stiffness of the system reduces significantly, and the damage started to occur in the barrier. This remains until the barrier reaches the ultimate capacity along with the development of yield line failure pattern. The lateral load-deflection curves of the CIP barrier under different loading heights are shown in Figure 3. The nominal capacity of the barrier was calculated as 56 kip using yield line method which is higher than the 50 kip obtained from the Finite Element Modeling.

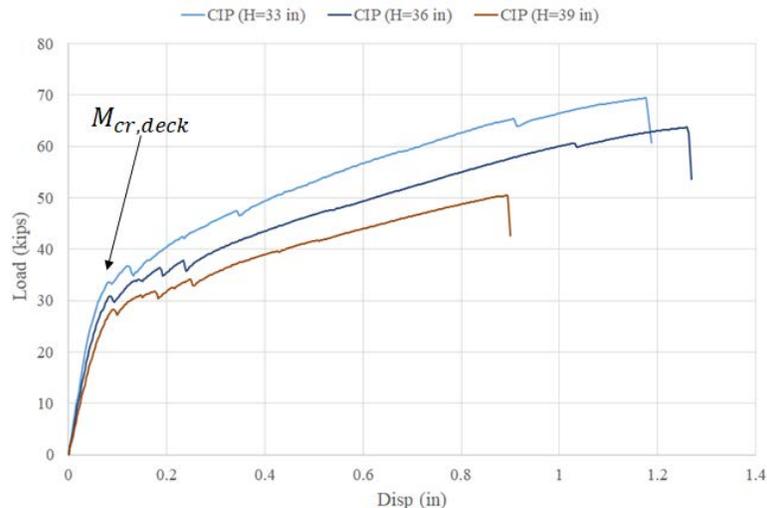


Figure 3 Load-Deflection Curves for the CIP barrier system under different loading heights.

Figure 4 shows the comparison between the load-deflection curves of the CIP and prefabricated barrier systems under loading at the height of 33 in.

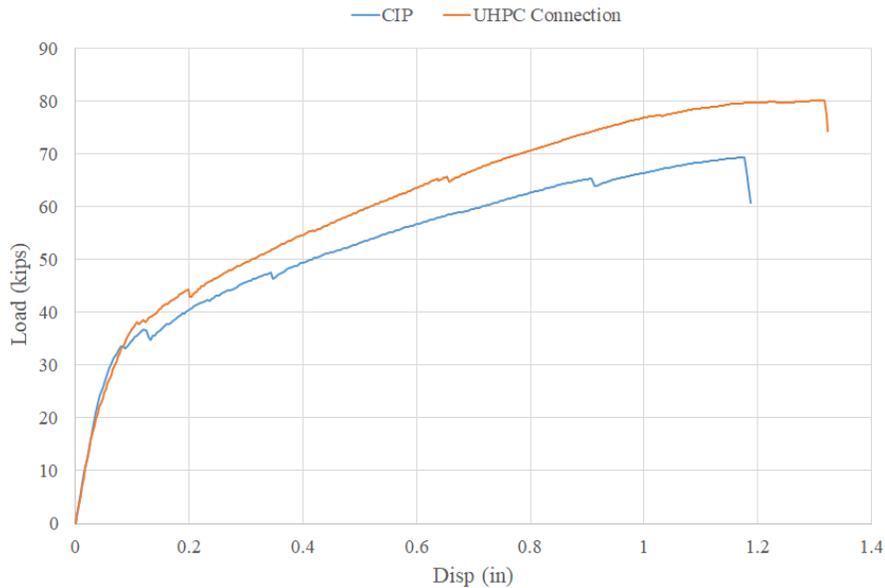


Figure 4 Comparison between the Load-Deflection Curves for the CIP and prefabricated barrier systems ($H_e = 33$ in).

The higher capacity of the UHPC with respect to CIP barrier can be attributed to shifting the yield line in the barrier about 6 in upward, leading to smaller L_c in prefabricated barrier (Figure 5).

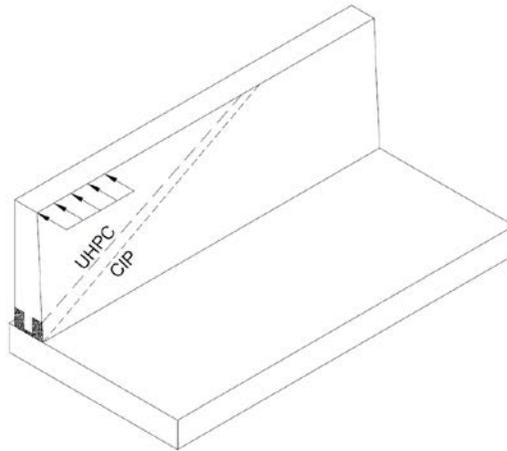


Figure 5 Development of the yield line failure pattern in CIP and UHPC based connections.

The results of the FE show that the UHPC connection will perform in a more desirable pattern with less damage in the deck if compared to CIP barrier while the barrier exhibits a desirable yield line failure pattern.

Task 3– Component Level Experimental Work

Progress: This task is in progress.

In this task, experimental work will be conducted on component level to verify the outcome of Task 2. Two 3 ft long specimens representing CIP and prefabricated barrier will be tested in a cantilever test setup, as shown in Figure 6.

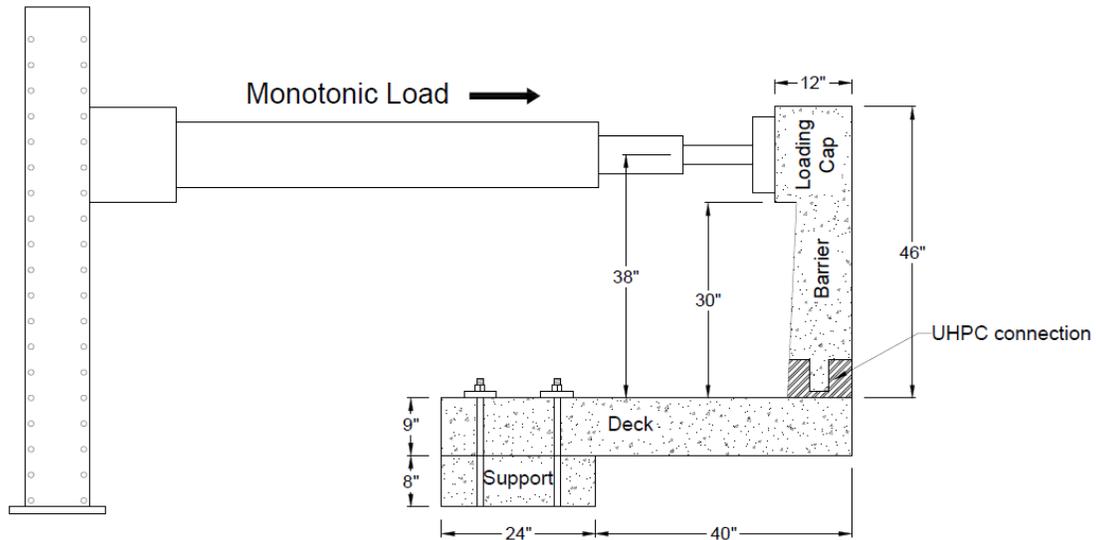


Figure 6- Test setup for the component level experimental work.

The formworks for the specimens were built and reinforcement cages were placed inside. It was chosen to cast the prefabricated barrier from side for ease of construction. The CIP barrier and deck overhang were cast together in order to avoid cold joint between them. Figure 7 shows the construction of the formworks. The specimens were instrumented using strain gauges in critical locations.

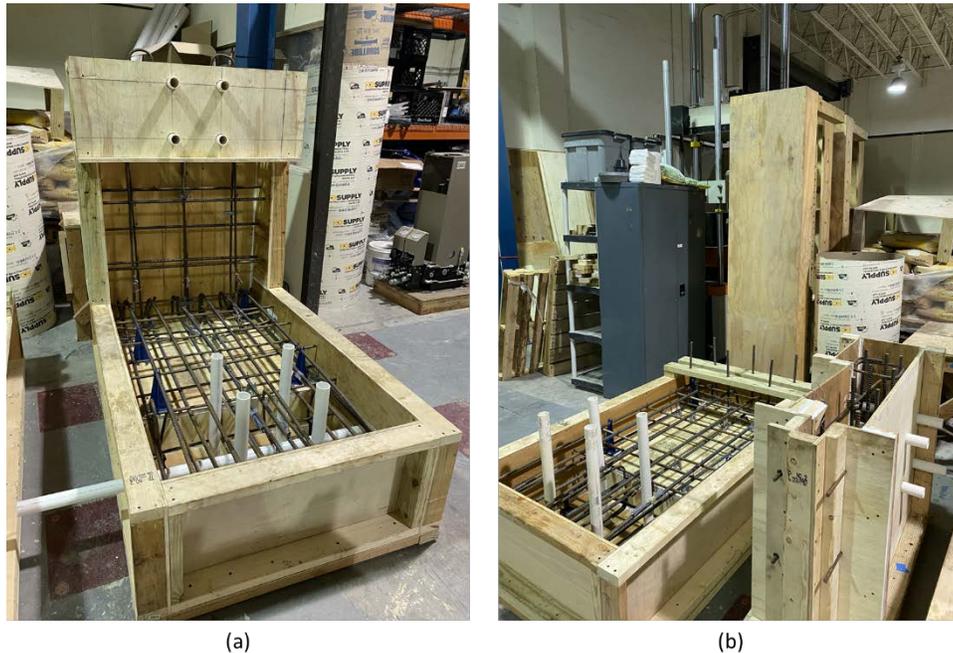


Figure 7- Construction of test specimens for a) CIP barrier b) Prefabricated deck and barrier.

During this reporting period, the CIP barrier specimen, and prefabricated barrier specimen were cast as shown in Figure 8. The prefabricated barrier was connected to the prefabricated bridge deck overhang as shown in Figure 8.

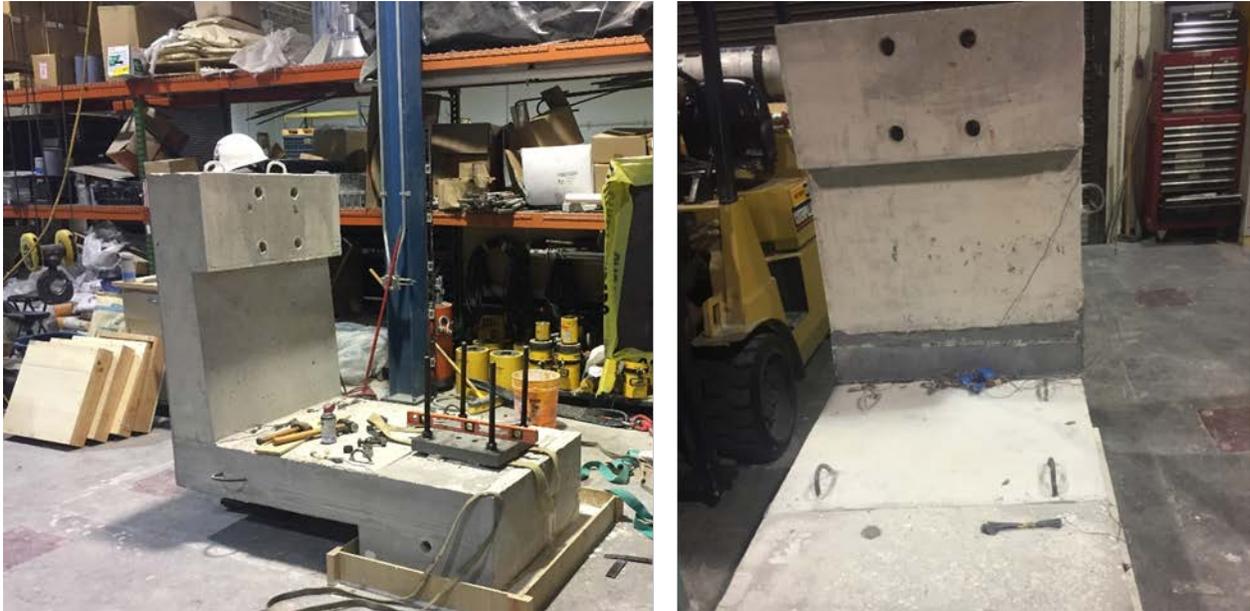


Figure 8- Constructed specimens, cast-in-place barrier (left) and prefabricated barrier with UHPC connection (right).

The experimental testing was conducted to compare the behavior of the UHPC connection under transverse loading (Figure 9). Displacement controlled monotonic load was applied to the barrier at height of 38" until failure. Figure 10 Shows the load-deflection curves for the cast-in-place and prefabricated barrier with UHPC connection.



Figure 9- Load test setup for a) cast-in-place barrier and b) prefabricated barrier with UHPC connection.

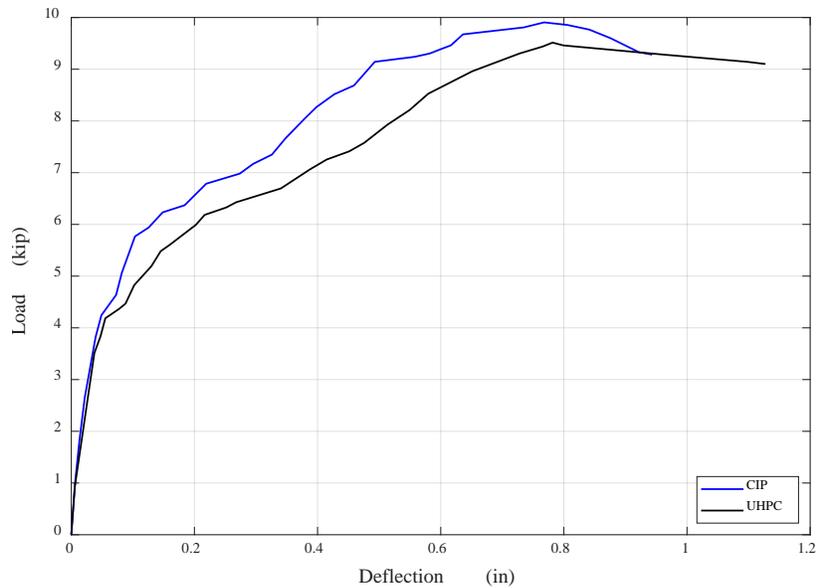


Figure 10- Load-Deflection curves for cast-in-place and prefabricated barrier with UHPC connection.

Based on the finding from this task, this task is extended, and modifications has been made to the connection. A more construction-friendly connection detail is designed and studied numerically.

Task 4– Large Scale Experimental Work

In this task, a full-scale specimen of the proposed prefabricated barrier system will be conducted to verify the outcome of tasks 2 and 3.

Progress: A full-scale experimental testing is planned to be conducted on a CIP and a prefabricated barrier system subjected to end loading. The critical length of yield line failure pattern, L_c , for the CIP barrier loaded at the end, was calculated as 6.1 ft using yield line analysis. The length of the barrier and supporting deck should be larger than L_c to ensure that yield line failure mechanism would be developed. It was found that the longitudinal length of 15 ft would be sufficient to effectively simulate the estimated yield line failure pattern at the end of barrier unit. It should be noted that this length is greater than the length of the deck resisting transverse load assuming 45° dispersion angle. So, the design length for each specimen is 15 ft which will be anchored to a strong floor as shown in Figure 11. The experimental testing will be performed on two specimens and the results will be presented in the next quarterly reports.

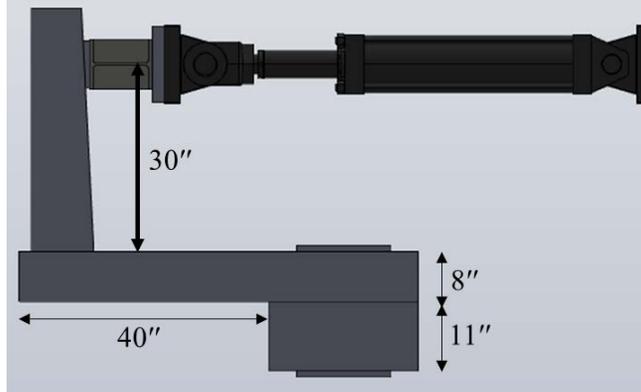


Figure 11 Planned experimental test setup detail for 15 ft long specimens loaded at their ends.

The scope of this task will be revised to include detailed numerical calibration of the tested specimen and barriers as part of full bridge to provide recommendation for future MASH crash testing. No progress to be reported yet.

Task 5– Assessment of the Performance of the Proposed Prefabricated Barrier System

In this task, full performance assessment of the proposed prefabricated barrier system will be conducted in addition, a comparison between the proposed prefabricated barrier system with the most common prefabricated barrier system.

Progress: Not started.

Task 6 – Final Report

In this Task, Full assessment of the findings from Task 1 throughout Task 5 will be conducted and a report will be published including design recommendations of the proposed prefabricated barrier system with UHPC connections.

Progress: Not started.

5. Expected Deliverables

Final report, journal articles, design guidelines, and five-minute video presentation will be the expected deliverables

6. Schedule

Item	% Completed
Percentage of Completion of this project to Date	70%

Research Task	2020				2021			
	Jan - Mar	Apr - Jun	Jul - Sep	Oct - Dec	Jan - Mar	Apr - Jun	Jul - Sep	Oct - Dec
Task 1- Development of new connections using UHPC for Prefabricated Barrier Systems	Proposed	Proposed			Completed	Completed		
Task 2- Finite Element Analysis of the Proposed Prefabricated Barrier System		Proposed	Proposed		Completed	Completed		
Task 3- Component Level Experimental Work			Proposed	Proposed	Completed			
Task 4- Large Scale Experimental Work							Proposed	Proposed
Task 5- Assessment of the Performance of the Proposed Prefabricated Barrier System								Proposed
Task 6 - Final Report								Proposed

■ Proposed
■ Completed

7. Reference

- American Association of State Highway and Transportation Officials. (2017). *AASHTO LRFD bridge design specifications*.