More Choices for Connecting Prefabricated Bridge Elements and Systems (PBES)

Quarterly Progress Report
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1. PROJECT ABSTRACT

Prefabricating bridge elements and systems (PBES) offers major time and cost savings, safety advantages, and can solve many constructability challenges as envisioned by the FHWA to revolutionize bridge construction in the US. Several types of PBES connections have been evolved in the last decade but many of these connections use Ultra-High performance concrete (UHPC). UHPC has superior mechanical properties but is very expensive and requires special expertise to work with it. Moreover, robust UHPC mixes are currently proprietary which sometimes limits DOTs that are trying to avoid sole-sourcing and bidding issues from using UHPC. Therefore, finding other alternatives and choices for PBES connections can be extremely beneficial. The goal of this project is to identify and proof-test potential alternatives to replace UHPC in PBES and ABC seismic and non-seismic connections. An experimental approach that consists of material and large-scale structural tests at UNR laboratories will be considered. The specific research objectives of this study are: (1) collect and select potential alternative materials (e.g. advanced grouts or polymer concrete) to replace UHPC in PBES connections; (2) characterize the material and mechanical properties of selected alternatives; (3) conduct large-scale testing to study the response of the alternative materials as used in structural ABC applications. One tentative application that focuses on deck panels' connections will be considered.

2. RESEARCH PLAN

2.1. STATEMENT OF PROBLEM

Prefabricating bridge elements and systems (PBES) offers major time savings, cost savings, safety advantages, and convenience for travelers. According to the FHWA, the use of PBES is also solving many constructability challenges while revolutionizing bridge construction in the US. In the past decade, innovative PBES connections have been evolved and many of these connections used Ultra-High performance concrete (UHPC). UHPC has superior mechanical properties and durability. However, some of the limitations associated with UHPC wide spread use include: the very expensive price tag, the expertise needed to work with UHPC, it is labor intensive, and most of the robust mixes are currently proprietary. Several DOTs see the proprietary nature of UHPC leads sometimes to sole-sourcing and in turn, bidding issues. Thus, there is a growing interest nowadays to find other alternatives and choices for PBES connections. The goal of this project is to identify potential alternatives to replace UHPC in PBES and ABC seismic and non-seismic connections. These alternatives can include special or advanced grout, polymer concrete, fiber concrete, etc. One selected material or alternative will be tested for at least two different PBES or ABC connection types.

2.2. RESEARCH APPROACH AND OBJECTIVES

Our approach for this proposed study is mainly an experimental approach that spans different types of material and large-scale structural tests at UNR laboratories. Two types of PBES connections that have traditionally used UHPC will be considered in this study to investigate and validate their structural response when new alternatives are used instead of UHPC. Note that benchmark response from conventional cast in place (CIP) construction or from research studies that tested such connections with UHPC will be used for new materials validation in this study. The first connection type is the most common ABC application that uses UHPC and can get more popular if other feasible options other than UHPC become available. This is the field joints used to connect precast deck slabs as shown in Figure 1. Precast slab panels can be conveniently connected to prestressed concrete or steel girders using shear studs (Shrestha et al. 2017). Then, advanced materials such as UHPC are used to connect the precast deck panels while maintaining acceptable load transfer mechanism (e.g. slab reinforcement lap splices).

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Fig. 1 – Field connections/joints for precast deck slabs (photo credit: Georgia DOT)

2.2.1. SUMMARY OF PROJECT ACTIVITIES

An experimental approach will be used and several research activities will be executed to accomplish the objectives of this study. A summary of the proposed research tasks is as follows:

- Task 1 – Literature search and selection of UHPC alternatives for ABC connections
- Task 2 – Material and mechanical characterization tests
- Task 3 – Development of experimental program and specimens design
- Task 4 – Experimental testing of deck slabs joints
- Task 5 – Summarize the results in a final report

2.2.2. DETAILED WORK PLAN

A detailed description of the proposed research tasks is presented in this section.

Task 1 – Literature search on and selection of non-proprietary UHPC and other cementitious alternatives for use in ABC joints:

A detailed literature search was conducted to determine possible and potential alternatives to replace UHPC for PBES connections. The literature search was divided into two main parts; (1) searching for alternative materials to replace UHPC in PBES Connections, (2) reviewing the previous experimental studies that were performed in PBES Connections.

- **Alternative materials to replace UHPC in PBES**

The main aim of this part of the literature is to select an alternative material to replace the UHPC in the PBES connections. Different materials have been searched as potential alternatives such as non-proprietary high performance and ultra-high performance fiber concrete, advanced grouts, ECC, and polymer concrete. After reviewing the mechanical properties of the materials, one type of polymer concrete (PC) named "T-17" seems to be promising. The selection of this closure material was based on some main aspects such as; it should provide simplified reinforcement configurations through the joints, provide smaller joints, provide better joint interface bonding and better long-term durability. Consequently, the closure material should satisfy the following mechanical properties; it should have good bond strength which can provide less rebar development length, less lap splice length and good bond to the existing precast concrete, it should have good flowability and less setting time, it should also provide high early strength and good durability properties.

The "T-17" polymer concrete has the good potential to replace the UHPC in the PBES connections. It was used before in many airports as a fast permanent repair to runways and taxiways because it can be cured to full hardness in less than 45 minutes.

The "T-17" polymer concrete has good features and advantages: wide application temperature range (14-100° F), fast setting (45 minutes at 70° F), high early strength (compressive strength of 2,500 psi @2hrs and 8,000-9,000 psi @24hrs), strong chemical bond, freeze-thaw resistant and high tensile strength (1.2 ksi). Table (1) shows some of the mechanical properties of the "T-17" polymer concrete.

Table 1 – mechanical properties of "T-17" polymer concrete.

T-17 Mortar (No Extension)		
Compressive Strength	8000 – 9000 psi (55 – 62 MPa)	ASTM C579 Method B
Flexural Strength	1800 – 2500 psi (13-17 MPa)	ASTM D790
Linear Shrinkage	<0.2%	DuPont
Tensile Strength	1000 – 1200 psi (6.90-8.25 MPa)	ASTM D638 Type I
Compressive Modulus	1.1-1.2 x 10^6 (7.50-8.50 GPa)	ASTM C579 Method B
Tensile Adhesion (pull-off concrete)	>250 psi (>1.7 MPa)	ACI 503R

- **Previous experimental studies**

A large number of research works was conducted on the field of PBES connections. Some of them focused into trying different materials in the PBES connections and investigate the overall performance to select the most proper closure material, while the others investigated several parameters in the PBES connections such as; the type of field connections, joint configuration, details of reinforcement and different loading schemes.

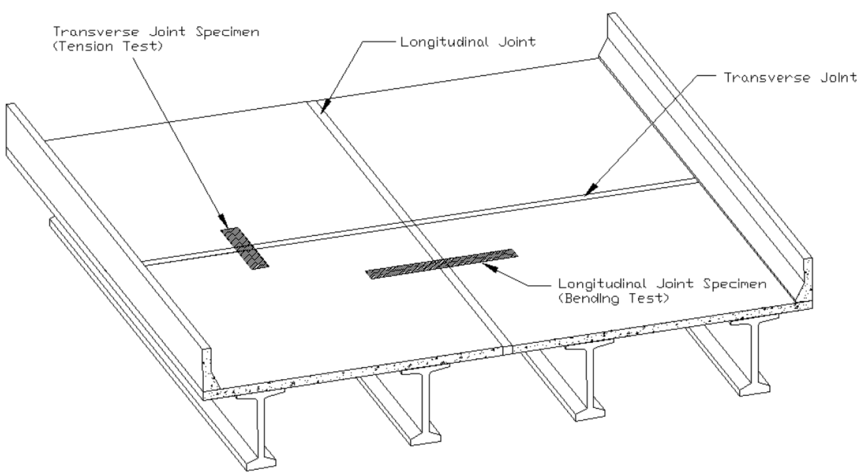
Our scope in this part of the study is to review and report the previous experimental and numerical studies in the precast bridge deck field joints. Through the last decade, many researches started working on using a willing material in the PBES connections named "UHPC" like the work done by Ben Graybeal (2010). While all the research before this period was directed into investigating the behavior of the PBES connections with using different materials such as advanced grouts, high performance concrete (HPC) and HPC with fiber reinforcement.

AASHTO conducted three research programs which focused specifically on advancing the state-of-the-art with regard to non-post-tensioned deck-level connections details between prefabricated concrete components.

The first research project “Full-Depth Precast Concrete Bridge Deck Panel Systems” and frequently referred to as NCHRP 12-65. A primary focus of this project was to develop an economical, non-post-tensioned transverse connection detail capable of developing the yield strength of straight lengths of mild steel.

The second project “Design and Construction Guidelines for Long-Span Decked Precast, Prestressed Concrete Girder Bridges” and frequently referred to as NCHRP 12-69. This research demonstrated that redesign of the traditional connection systems used in the longitudinal connections between decked girders could allow for a simpler connection.

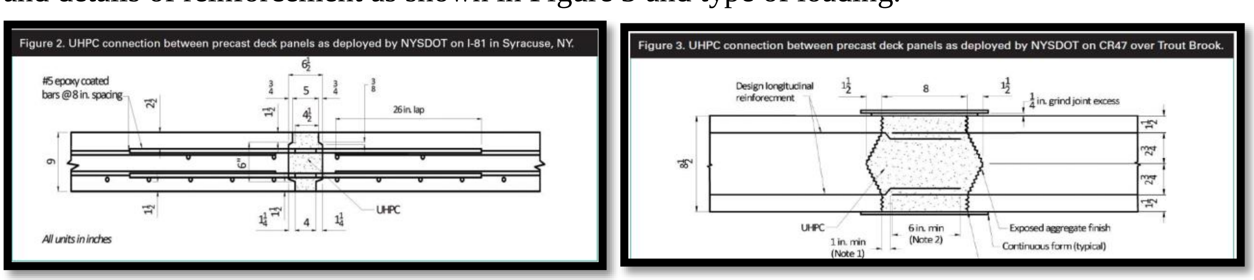
The third project “Cast-in-Place Concrete Connections for Precast Deck Systems” and frequently referred to as NCHRP 10-71. This project focused on both transverse and longitudinal connections between precast concrete components as shown in Figure 2.



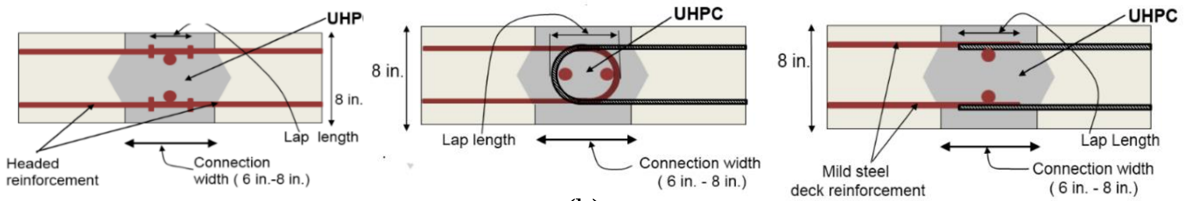
8.1.1: Orientation of joints and corresponding test specimens

Fig. 2 – Transverse and longitudinal field connections/joints for precast deck slabs.

Many variables were determined based on the literature to be investigated in our experimental work that will be reported in Task 3. Some of these variables are; the type of joint configuration and details of reinforcement as shown in Figure 3 and type of loading.



(a)



(b)

Fig. 3 – Precast bridge deck field connections: (a) different joint configurations (female-female shear keys), (b) details of reinforcement (headed rebars, loop splice, and straight splice).

Task 2 – Mechanical characterization of the selected UHPC-alternative material

Most of the new or evolving cementitious materials are extensively tested to characterize fresh and harden state properties with less focus on mechanical properties characterization. In this task, the mechanical properties of the selected materials from Task 1 will be further characterized. Various material tests will be considered to determine compressive strength, tensile strength, Young's modulus, and modulus of rupture from bending tests. Direct tension tests will be considered to better characterize tensile strength rather than using cylinders splitting tests or three- and four-point bending tests. Polymer concrete sheets were received and tension specimens will be prepared using water jet cutting. Figure 4 shows the cutting layout of the dog bone specimens and individual specimen's dimensions.

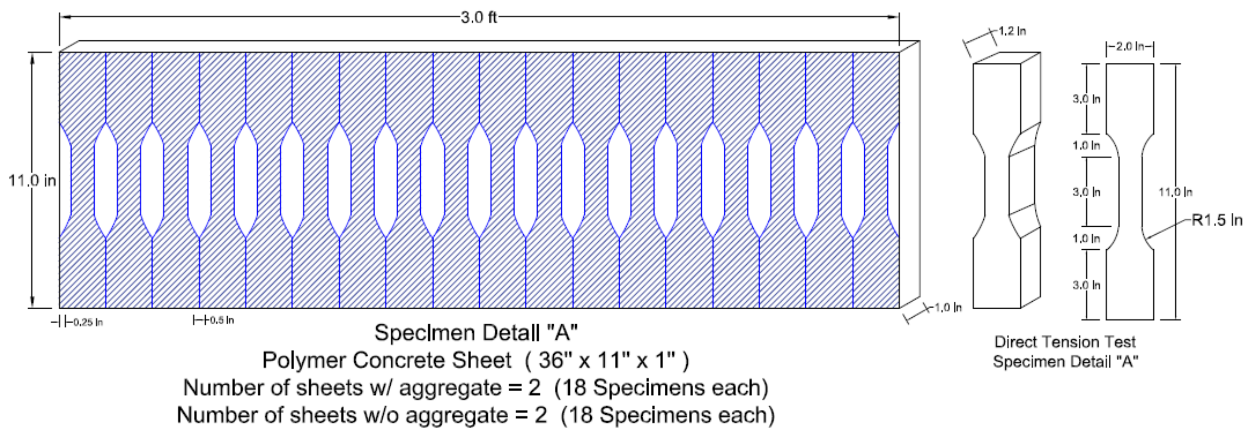


Fig. 4 – Polymer Concrete specimens' layout and dimensions for direct tension test

Task 3 – Development of experimental program and specimens design

The objective of this task is to work with the ABC-UTC and the project advisory panel to finalize the types of PBES and ABC connections, types of tests, and a number of specimens to consider using the alternative selected and tested materials from Tasks 1 and 2. Two types of connections and tests are preliminarily proposed which are: (1) deck panels' longitudinal connections which will be tested for flexure as outlined in Task 4; (2) deck panels' transverse connections which will be tested for flexure as outlined in Task 4. Five specimens will be constructed to conduct three transverse and two longitudinal joints tests. Specimens of similar layout and design as what has been tested by FHWA for UHPC deck panel joints will be replicated for comparisons.

Task 4 – Conduct experimental testing of precast deck slabs with new joint connection

Extensive precast deck panels with field and UHPC joints have been tested (e.g. Perry and Royce 2010, Graybeal 2010, Hartwell 2011). Testing procedures from previous studies will be adopted to conduct large-scale testing on deck panels connected using new alternative materials. The FHWA test setup and specimens dimensions (Figure 5) will be almost replicated for comparison purposes with UHPC (Gaybeal 2010). Construction of some of the panels for the test specimens has started at UNR as shown in Figure 6 and the finalized test setup at UNR is shown in Figure 7.

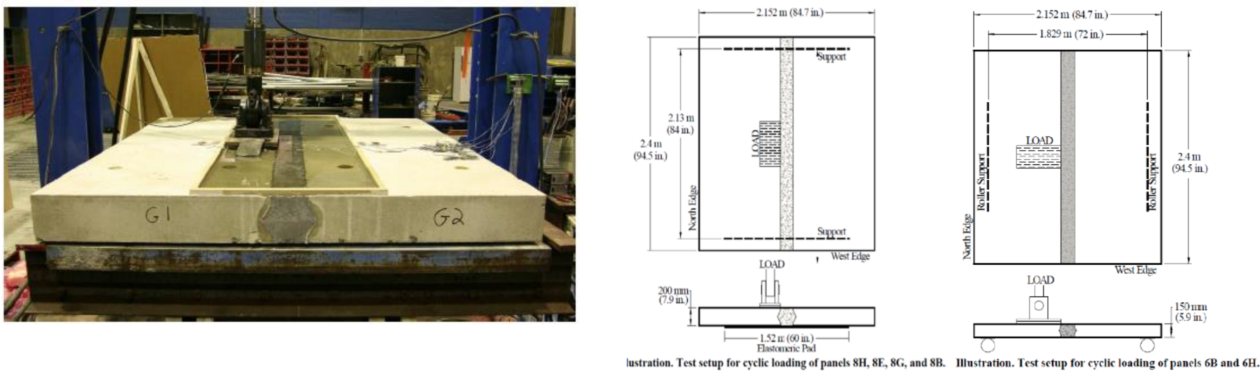


Fig. 5 – FHWA cyclic test setup for deck panels with UHPC joints (Graybeal 2010)

Fig. 6 – Construction of deck panels and specimens started at UNR

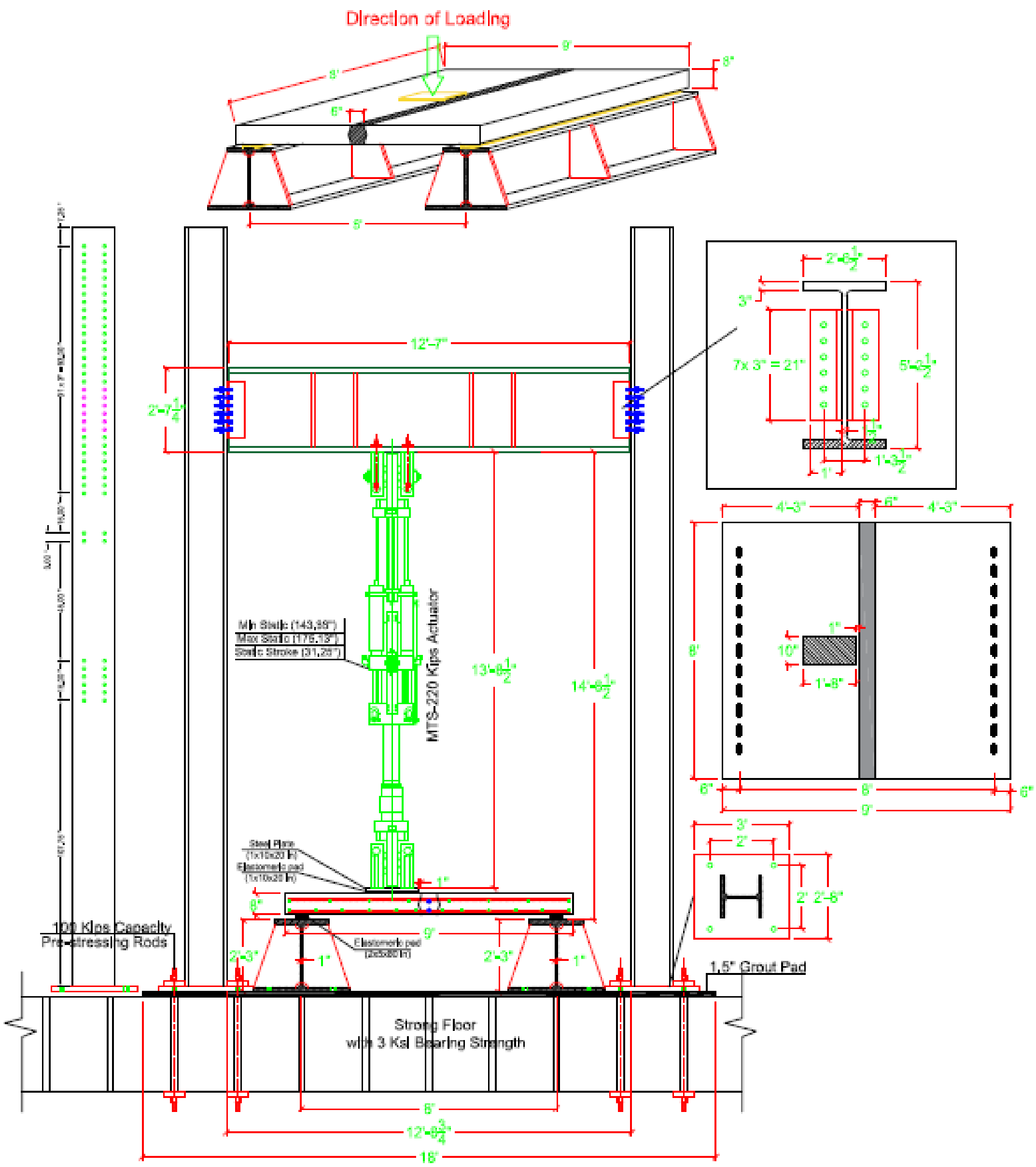


Fig. 7 – Deck panels test setup at UNR

Task 5 – Summarize the investigation and the results in a draft final report

A final report describing the details of different tasks will be prepared and submitted to the ABC-UTC steering committee for review and comments. Upon addressing the review comments, the report will be finalized and made widely available for dissemination.

2.3. ANTICIPATED RESEARCH RESULTS AND DELIVERABLES

2.3.1. Tentative ABC-UTC Guideline

One format to disseminate the results from this project is to develop an ABC-UTC guideline for selecting alternative choices to replace UHPC for PBES. The tentative or preliminary guideline can also include design guidelines on how to use such alternative materials for design.

2.3.2. A FIVE-MINUTE VIDEO SUMMARIZING THE PROJECT

Another format to disseminate the results of this project and contribute to workforce development and outreach is to develop a video and presentation slides to summarize the project. A webinar format can be sued to publish and make available such videos or presentations.

2.3.3. FINAL REPORT AND PUBLICATIONS

As mentioned before in the research plan, a comprehensive report will be developed to summarize all the experimental results. Data sets could also be produced and published using existing or new cyber infrastructure or data platforms if a unified one will be eventually used for ABC-UTC related projects. Publications in peer-reviewed journals and conference presentations will also be considered for delivering project results.

3. TIME REQUIREMENTS (GANT CHART)

To allow for the completion of all the project tasks, the study will be conducted over a period of 18 months (6 quarters) following the schedule in Table 1. The milestones are marked on the schedule, and the following notes explain the deliverables at these milestones.

a) Mechanical properties of the selected alternative material

b) The validity of material for deck joints

c) Final project report.

Table 1 – Gant schedule of major project tasks and milestones

Tasks	Year 1				Year 2	
	Q1	Q2	Q3	Q4	Q1	Q2
1.Literature search	X					
2. Mechanical characterization		X[a]				
3. Experiments and specimens design		X	X			
4. Deck panels joint tests			X	X	X[b]	
6. Final report and dissemination						X[c]

(blue)	Completed or work in progress	(red)	Remaining