NEW MEXICO DEPARTMENT OF TRANSPORTATION

RESEARCH BUREAU

Innovation in Transportation

Feasibility Analysis of Ultra High Performance Concrete for Prestressed Concrete Bridge Applications

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June 2012

Prepared for:
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In Cooperation with:
The US Department
of Transportation
Federal Highway Administration

Implementation Plan NM09MCS-01

JUNE 2012

FEASIBILITY ANALYSIS OF ULTRA HIGH PERFORMANCE CONCRETE FOR PRESTRESSED BRIDGE APPLICATIONS

IMPLEMENTATION PLAN

The research proposed herein is a continuation of two phases of a project intended to implement ultra high performance concrete (UHPC) in precast, prestressed bridge girders in New Mexico. In Phase I of this research, case studies were conducted to investigate the advantages of implementing UHPC in bridge superstructure design. Due to the benefits that UHPC has to offer, this feasibility study resulted in recommendations to move forward with the development of mixture proportions for UHPC produced from materials local to New Mexico (Phase II). The UHPC mixture proportions developed in Phase II incorporated fine angular sand with a No. 4 top size, silica fume, fly ash, and elevated curing temperatures for both wet and dry cure periods. These mixture proportions and curing practices were optimized to produce UHPC that is economical and producible in New Mexico for implementation into prestressed concrete bridge design. Additionally, the durability of the optimized mixture for resistance to alkali-silica reaction, freezing and thawing, and delayed ettringite formation was established and the results demonstrate that the UHPC has excellent durability properties.

SCOPE OF WORK

Task 1: Creep and Shrinkage.

Shrinkage in concrete can decrease the load carrying capacity of structural members and long-term durability of the concrete. In prestressed concrete, shrinkage leads to prestress losses, reducing the precompression of the member which can cause premature cracking and excessive deflections at service conditions.

Shrinkage of concrete consists of plastic shrinkage, autogenous shrinkage, drying shrinkage, and carbonation shrinkage. Most shrinkage occurs early in the hydration process; however, for concrete mixtures with low water-to-cementitious (w/cm) ratios, the process may last longer. Carbonation shrinkage progresses into the concrete very slowly. However, carbonation shrinkage is very small compared to long term drying shrinkage and is often neglected. Aggregate helps to restrains shrinkage, consequently, concrete produced with smaller aggregate tends to exhibit more shrinkage than concrete produced with larger aggregate. Due to the removal of coarse aggregate and the increased cementitious materials content of UHPC, shrinkage could be significantly greater than normal and high strength concretes. Curing conditions can also affect shrinkage of concrete. To achieve the high compressive strengths and durability properties of UHPC, a heated wet and dry curing period is required. This curing regimen could lead to reduced post-curing shrinkage; however, early age shrinkage could still be substantial.

Creep is permanent deformation caused by sustained loading. Similar to shrinkage, creep can do significant damage to a structure. Creep can lead to excessive deflections, buckling, and/or serviceability problems. For prestressed elements, creep can increase prestress losses.

Similar to shrinkage, coarse aggregate and curing can play important roles in the creep behavior.

Before UHPC can be incorporated into prestressed concrete girders in New Mexico, it is important that there is a fundamental understanding of the creep and shrinkage behavior of the UHPC mixture developed using local materials. Due to the removal of large aggregate and a heated curing regimen, the shrinkage and creep behavior could be significantly different than normal or high strength concretes. Following ASTM Standard C 157/C 157M, Standard Test Method for Length Change of Hardened Hydraulic-Cement Mortar and Concrete, the shrinkage of the UHPC mixture will be investigated. This test will allow for assessment of the potential for volumetric expansion/contraction of concrete (non-load induced). To investigate creep behavior, ASTM Standard C 512-02 (Standard Test Method for Creep of Concrete in Compression) will be followed. In this test, the load-induced time-dependent compressive strain at selected ages for concrete under specified environmental conditions will be determined. The results from this study will aid in the development of methods for designers to estimate the expected creep and shrinkage of the UHPC that uses materials local to New Mexico.

Task 2: Mixing, Curing, and Testing Specifications.

For implementation of UHPC in design, precast plants will need mixing, curing, and testing specifications to insure the quality, strength, and durability of UHPC. Thus, there is a need to adapt the New Mexico Standard Specifications for Highway and Bridge Construction for UHPC, namely:

- 509: Portland Cement Concrete Mix Designs;
- 510: Portland Cement Concrete;
- 517: Precast Concrete Structures; and
- 518: Prestressed Concrete Members.

These specifications will be modified to incorporate UHPC, and thus, give precasters the tools necessary for the quality production of UHPC.

Task 3: Large Scale Testing of Girder Specimens.

Two large scale prestressed concrete girder specimens will be cast, cured, and tested in flexure loading. The length of the girders will be approximately 25 – 35 ft as recommended by the NMDOT Bridge Design Bureau. The actual shape and dimensions of the section will be determined at a later date by the researchers, NMDOT, and the precaster. It is anticipated that the test girders will be chosen to match those that will be used in an actual bridge replacement in New Mexico. These girders will be instrumented to measure prestress losses following curing, and force-deformation during the flexural tests. Results from these tests will be used to provide design recommendations for use of UHPC in prestressed concrete bridges in New Mexico. Additionally, as the girder specimens are being cast, the mixing, curing, and testing specifications developed as part of Task 2 will be evaluated and modified as needed to successfully produce UHPC at local precast plants.

Task 4: Develop an Implementation Plan for Phase IV Research.

Using the information obtained from the research conducted as part of Phases I, II, and III, additional required research, if necessary, will be identified for the implementation of UHPC. Pending a positive outcome from the proposed experimental program, a plan will be developed for designing, constructing, and monitoring a New Mexico prestressed UHPC bridge.

Task 5: Documentation.

A final report and a web-ready multi-media presentation will be provided at the end of Phase III.

Deliverable:
Task 1: Creep and shrinkage test results and appropriate methods to estimate the creep and shrinkage expected from the UHPC mixture developed using materials local to New Mexico.

Task 2: Adapted standard specifications for implementation of UHPC into prestressed concrete bridge design in New Mexico.

Task 3: Design recommendations developed based on the results of the experimental findings from large-scale flexural tests of bridge girders.

Task 4: Implementation plan.

Desired Results:
Positive results from this research will lead to the first UHPC bridge designed and constructed in United States using materials local to the region.

TIMELINE

The proposed research is to be conducted over a 36-month period as shown in the following timeline:

Proposed Phase III – Timeline

		Year 1												Year 2												Year 3											
Quarter		**1**			**2**			**3**			**4**			**5**			**6**			**7**			**8**			**9**			**10**			**11**			**12**		
Month		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Milestone	**Task 1**	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Task 2	X	X	X	X	X	X							X	X	X	X															X	X	X	X		
	Task 3				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
	Task 4																														X	X	X	X	X	X	X
	Task 5																														X	X	X	X	X	X	X
Deliverables	**Quarterly progress reports**			X			X			X			X			X			X			X			X			X			X			X			
	Final Report																																				X
	Implementation Plan																																				X
	Multi-media Report																																				X
Contract Termination																																					X

BUDGET

The proposed budget is based on the participation of faculty members, graduate research assistants, and undergraduate research assistants from the Department of Civil Engineering at New Mexico State University (NMSU). The total budget is $293,100 over a 36-month (3-year) period. The funds are requested in yearly increments: Year 1 - $108,100; Year 2 - $115,000; Year 3 - $70,000. Anything not spent during the prior year should be carried over into the following year. The proposed budget is to carry out the various tasks associated with the Feasibility Analysis of Ultra High Performance Concrete for Prestressed Concrete Bridge Applications Phase III. The budget includes the following expected costs:

- NMSU faculty (Weldon, Jáuregui, and Newtson) salaries, graduate research assistant salaries, undergraduate salaries, and related fringe benefits.
- Travel expenses for faculty and graduate research assistants participating in the project, including precast plants visits, project meetings, and conferences.
- Equipment and instrumentation necessary for conducting the required tests (e.g., creep frames, strain gauges, etc.)
- Reproduction costs of the reports and materials as part of the project.
- Material required for the project including sand, admixtures, etc.
- Video conferencing costs for quarterly meetings.
- A facility and administrative (F&A) rate of 20% will be used in the preparation of the budget, according to the cap established by the NMDOT Research Bureau in the document *"Information and Instructions for Preparing Proposals in the NMDOT Transportation Research Program"* for various vendor-type contracts.

Once the final tasks and deliverables have been agreed upon, a detailed budget will be supplied from the Office of Grants and Contracts at NMSU.

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