FHWA RESEARCH PROGRAM ON LIGHTWEIGHT HIGH-PERFORMANCE CONCRETE – CURRENT PROJECT STATUS

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ABSTRACT

FHWA's Structural Testing Laboratory completed the fabrication of 27 prestressed lightweight high-performance concrete (LWHPC) girders and 40 reinforced LWPHC splice beams designed to investigate the use of this type of concrete in highway bridges. The girders and beams used specified density concrete mixes with expanded shale or expanded slate coarse aggregate, granite coarse aggregate, and natural sand fine aggregate. The concrete mixes had 28-day compressive strengths that ranged between 7,400 psi and 10,500 psi. The research program has the purpose of (i) investigating the performance of LWHPC produced using aggregates representative of those available in North America, (ii) investigating the transfer length, development length, and shear strength of precast/prestressed LWHPC members, (iii) studying development and splice length of mild steel reinforcement used in LWHPC, and (iv) investigating prestress losses in LWHPC girders.

This paper describes the current status of the research project including the physical testing which has been completed. After all testing is completed, the result of the study will be to recommend changes to the AASHTO LRFD Bridge Design Specifications relevant to LWHPC.

Keywords: Lightweight concrete, High-performance concrete, Specified density concrete, Transfer length, Development length, Shear strength

INTRODUCTION

There are many advantages to using lightweight concrete, such as reduced transportation costs, longer spans, and/or smaller and potentially less expensive members. The current AASHTO LRFD Bridge Design Specifications[1] define lightweight concrete as having an equilibrium density less than or equal to 120 pcf. Normal weight concrete is defined as having an equilibrium density from 135-155 pcf. Concretes in the gap of densities between 120-135 pcf are commonly referred to as "specified density concrete" and are not directly addressed by the AASHTO specifications. Specified density concrete typically contains a mixture of normal weight and lightweight coarse aggregate and has benefits similar to lightweight concrete; however since the AASHTO specifications do not address specified density concrete, they do not allow designers to take full advantage of the potential use of LWHPC.

There has been considerable research in recent years on the behavior of high-performance concrete (HPC) containing normal weight aggregate. These research efforts have been used to expand the applicability of the AASHTO LRFD Bridge Design Specification for normal weight concrete to compressive strengths up to 18 ksi. However, there has been considerably less research on HPC containing lightweight aggregates, especially on structural members with compressive strengths in excess of 6 ksi. In addition, the limited research on lightweight HPC (LWHPC) has been focused on equilibrium densities less than 125 pcf. This leaves a gap in experimental data for specified density concretes.

This paper gives the current status of an ongoing research program conducted by the Federal Highway Administration (FHWA) at the Turner-Fairbank Highway Research Center (TFHRC). The purpose of the research program is to investigate the performance of LWHPC with concrete compressive strengths in the range of 6 to 10 ksi and equilibrium densities between 125 pcf to 135 pcf. The research program will use LWHPC with three different lightweight aggregates that are intended to be representative of those available in North America. The program will use the tests from 27 precast/prestressed LWHPC girders to investigate transfer length and development length of prestressing strand, the time-dependent prestress losses, and shear strength of LWHPC. The development and splice length of mild steel reinforcement used in girders and decks made with LWHPC will be investigated using 40 reinforced concrete (RC) beams. While the FHWA program is focused on structural behavior, it will also have a material characterization component that will include tests to determine compressive strength, elastic modulus, splitting tensile strength, creep, shrinkage, coefficient of thermal expansion, and durability of the concrete mixes used in the structural testing program. The result of the research program will be to recommend changes to the AASHTO LRFD Bridge Design Specifications relevant to LWHPC.

CURRENT PROJECT STATUS

The fabrication of 27 precast/prestressed girders and 40 RC splice beams was complete in June of 2008. The girders and beams have been described in previous papers[2-3]. During the summer of 2008, all the girders and beams were transported to TFHRC. LWHPC concrete cylinders made during the casting of the girders and beams as well as samples of the prestressing strand were also shipped to TFHRC. Concrete decks were cast on 18 of the girders in the fall of 2008. The forms for the remaining nine girder decks have been started, with deck casting expected in summer of 2009.

The 40 RC splice beams were tested from October 2008 to February of 2009. The beams used four different concrete mix designs, three mixes used in the girders and an additional mix with a design compressive strength of 4 ksi. Variables investigated included rebar size (#4, #6, #8, #11), splice length, confinement reinforcement, and lightweight aggregate type. The analysis and data reduction of these tests has been started. The completed analysis will include comparisons of the test results to several descriptive models available in the literature and to U.S. building and bridge code design equations.

Recently, the first four girders to be tested as part of the investigation of development length have been brought into the lab. The main variables investigate include number of strand, strand size, amount of shear reinforcement, and lightweight aggregate type. These tests on a total of 12 girders are expected to be completed by the end of the year. The shear tests on the remaining 15 girders will begin following the completion of the development length girder tests.

Other research that has been completed includes density measurements, long-term loss measurements, and strand transfer length measurements. Equilibrium density and oven-dry density measurements are being taken on one-hundred 6 inch by 12 inch cylinders. The oven-dry measurements have been completed, and the cylinders being used for the equilibrium density measurements are in an environmentally controlled room. Long-term losses are being measured using five vibrating wire strain gages distributed through the cross-section of the girder and deck at midspan of six BT-54 LWHPC girders that will eventually be tested in shear. Strand transfer length measurements were taken during girder fabrication, before and after the release of the prestressing. One final transfer length measurement will be made before each girder is tested.

CONCLUDING REMARKS

The FHWA study on LWHPC has made considerable progress in the last year. The 27 prestressed girders and 40 RC splice beams that are a part of this study have been fabricated and shipped to TFHRC. All 40 splice beams have been tested and the development length tests are underway, with the shear tests to follow. Other measurements including concrete density and long-term losses have been made during the last year and will continue to be measured. Completion of the girder testing is expected by the end of 2010.

REFERENCES

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