TECHSUMMARY September 2016

State Project No. 30000680 / LTRC Project No. 12-4C

Evaluation of Portland Cement Concrete with Internal Curing Capabilities

INTRODUCTION

Proper curing is the key to durable and sustainable concrete structures. When a concrete mixture is designed, delivered, poured, and consolidated, curing is the last and the most critical part for a quality final product. Insufficient curing of concrete will cause cracking in the concrete and in turn leads to a non-durable and non-sustainable concrete structure. Current Louisiana specification requires all concrete decks to be water cured for 10 days. Based on the field experience, this is a very expensive operation and the most difficult one to enforce and monitor. Therefore, there is a great need to develop a new concrete mix that has a self-curing capability, which will reduce the time demand for water curing, minimize or eliminate cracks in the concrete deck, and help achieve durability and sustainability in concrete structures.

This project was undertaken to quantify and document the beneficial use of internal curing via saturated lightweight aggregate fines.

OBJECTIVE

The objective of this research was to investigate internally cured concrete produced for bridge structures in Louisiana's environment to improve the quality of concrete structures. This research investigated the use of differing percentages of lightweight aggregate for internal curing benefits as well as additional methods for determining available moisture on saturated lightweight aggregates.

SCOPE

To meet the objectives of this project, samples were produced in laboratory conditions at two water-to-cement (w/c) ratios and then tested. Fresh properties of slump, air content, and set time were measured for each mixture. Hardened concrete properties of compressive and flexural strength, modulus of elasticity, ring shrinkage, and surface resistivity were measured for each mixture. Samples were produced and cured in 50 percent relative humidity and 100 percent relative humidity conditions. Compressive strength was measured at 7- and 28-days of age. Flexural strength, surface resistivity, and modulus of elasticity were measured at 28-days of age. Two field trial placements for bridge deck concrete were also conducted, one in North Louisiana on U.S. 80 near Ada and the other in Western Lafayette Parish on West Congress Street.

LTRC Report 569

Read online summary or final report:
www.ltrc.lsu.edu/publications.html

PRINCIPAL INVESTIGATOR:
Tyson Rupnow, Ph.D., P.E.
225.767.9124

LTRC CONTACT:
Tyson Rupnow, Ph.D., P.E.
225.767.9124

FUNDING:
SPR: TT-Fed/TT-Reg

Louisiana Transportation Research Center

4101 Gourrier Ave
Baton Rouge, LA 70808-4443

www.ltrc.lsu.edu

To meet the objective of alternative ways of measuring lightweight aggregate surface moisture, the research team conducted a series of paper towel tests, oven tests, and centrifuge tests.

METHODOLOGY

Materials in the study include type I/II portland cement. Mixtures incorporated No. 67 limestone and a natural sand as the coarse and fine aggregate, respectively. The coarse to fine aggregate ratio was kept near 60:40. These mixtures incorporated 600 lb. of total cementitious materials content with water to cementitious material (w/cm) targeted at 0.35 and 0.45. A polycarboxylate superplasticizer was incorporated to ensure workability of the mixtures and a minimum dose of a lignin based air entraining agent was used as required by DOTD specifications. A locally available lightweight expanded clay material was used for the saturated fines and was incorporated at 5, 10, 15, 20, and 25 percent replacement of the fine aggregate, by volume. Fresh properties were measured with ASTM C1611, ASTM C231, and ASTM C403. Hardened concrete properties were measured with ASTM C39, ASTM C78, ASTM C469, ASTM C1581, and DOTD TR 233. The West Congress Bridge in Lafayette, LA, and the U.S. 80 bridge over the KCS railroad were constructed with portions of the structure incorporating ICC as field projects.

CONCLUSIONS

The results of this project warrant the following conclusions. The centrifuge test method is superior to the paper towel test method in terms of expediency and repeatability of results. The laboratory results showed that the fresh concrete properties are unaffected by the use of lightweight fine aggregate for internal curing purposes. The compressive strength and modulus of elasticity results were determined to be the same or slightly higher when using lightweight fine aggregate for internal curing purposes. Flexural strength of concrete containing large amounts of lightweight fine aggregate was shown to be reduced slightly compared to the control. The surface resistivity values of the ICC were shown to increase indicating better hydration of the concrete mixture.

Field trial placements showed that the ICC performs well. The West Congress project showed reduced cracking at one year over the control sections, and the Ada project showed significantly less cracking over the control about nine months after placement of the ICC sections. The section placed without curing compound has yet to crack for the 150 pcy ICC mixture placement, and this is the worst case scenario. The reduced cracking will lead to longer service life and a more durable structure. In both cases, the contractor noted easier finishability characteristics and that, "ICC is just like normal concrete." Based upon the laboratory and field results, a standard lightweight fine aggregate replacement rate between 225 and 275 pcy is suggested for implementation.

RECOMMENDATIONS

The following recommendations are put forth as a result of this study. A study should be undertaken to determine the precision and bias of the centrifuge test method. Pending successful results, a TR procedure should be developed for the test method. Training materials for the test method include a half-day course with hands-on training and an instructional video. The Department should incorporate ICC into the specifications where appropriate and a standard 225 to 275 pcy replacement rate is suggested. A wet cure of 7 days is also still recommended. Although the Bentz equation can predict the quantity needed exactly, a standard replacement rate can be much more easily incorporated into Departmental specifications.

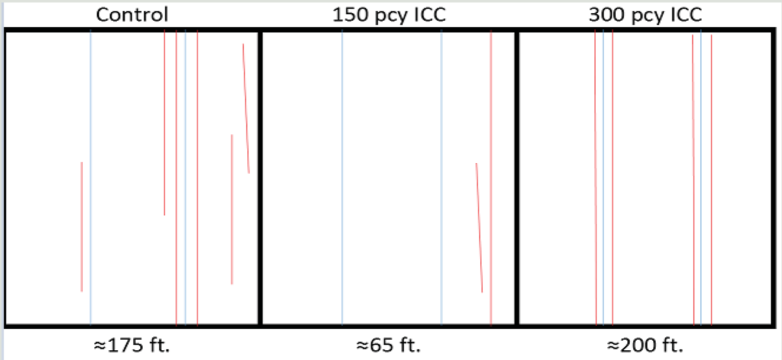

Figure 1
U.S. 80 Bridge deck layout with cracks (red) and support column locationss (blue)