LOUISIANA TRANSPORTATION RESEARCH CENTER

Technical Summary

LTRC Report 708

SIO No. DOTLT1000422
LTRC Project No. 22-1C

Influence of Internal Curing on Concrete's Permeability in Simulated Field Conditions

Introduction

State highway agencies (SHAs) have started to implement more internally cured concrete (ICC) mixtures in the design and construction of pavements and structures. Coincidentally, the push for performance-based specifications on concrete's transport properties prompted research to understand the impact of internal curing on surface resistivity (see AASHTO T358). LTRC recently conducted a ruggedness study examining the impact of pre-wetted internal curing aggregates (ICAs) on resistivity, and the results showed that ICAs did not have a detrimental impact on resistivity at the 28 and 56 day test periods. However, the curing conditions established in the AASHTO T358 standard require that concrete remains fully saturated at all times in a moist room or cabinet prior to testing. These curing conditions can significantly obscure the true impact of internal curing and make it difficult to assess its benefits. As such, this study proposed to simulate the realistic condition by limiting the 100% relative humidity (RH) moist room curing conditions to the first 7 days followed by a lab environment for the next 21 days. Surface resistivity was measured until 56 days of age were reached. An additional test method, bulk diffusion (ASTM C1556), was employed to validate the surface resistivity results. Finally, internal RH was also measured to monitor concrete's degree of hydration over time.

Objective

The objectives of this study were to:

1. Assess the influence of internal curing on concrete's transport properties under more realistic curing condition
2. Validate the results from surface resistivity with bulk diffusion testing.

Scope

To fulfill the objectives of this study, 12 mixtures were prepared to produce concrete samples with and without saturated fine ICAs. Two curing conditions (28 days at 100% relative humidity (RH) moist room vs 7 days at 100% RH moist room followed by a 21 day lab environment) were applied to assess the benefits of internal curing with saturated fine ICAs.

Methodology

One ICA source made from expanded shale and clay was used in this study. The ICAs were soaked for 72 hours prior to being used for concrete mixing. The centrifuge method was employed to help provide moisture correction within the concrete mixture design. In order to evaluate the internal curing (IC) effect for different cementitious systems, Type I portland cement, Class C fly ash, and grade-100 ground granulated blast furnace slag, were selected for the mix design which also included a No. 57 coarse aggregate gradation and a 60/40 coarse-to-fine aggregate ratio. Finally, a superplasticizer was used to ensure workability. The experimental design is shown in Table 1.

Principal Investigator
Zhen Liu, Ph.D., P.E.
225-767-9138

LTRC Contact
Samuel B. Cooper III, Ph.D., P.E.
225-767-9164

Funding
SPR: TT-Fed/TT-Reg - 6

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

Factor	Levels	Description
Water/cementitious materials (w/cm)	2	0.35, 0.45
Total Cementitious Content	1	575 lbs/yd³
ICA Dosage	2	0, 250 lbs/yd³
Cementitious Systems and Designations	3	• 100% Type I cement (100TI) • 70% Type I cement and 30% Class C fly ash (70TI/30C) • 50% Type I cement and 50% slag (50TI/50S)
Superplasticizer Dosage	1	• 13 oz/cwt for 0.35 w/cm • 5 oz/cwt for 0.45 w/cm
Curing Conditions	2	• 7 day 100% RH followed by 21 days of lab environment (named as hybrid curing in this study) • 28 day 100% RH (named as 100% RH curing in this study)

Table 1. Experimental design

Conclusions

In order to investigate the influence of realistic curing condition on the properties of internally cured concrete, two different water-to-cementitious materials ratios and three different cementitious systems were applied to produce concrete samples in this study. A hybrid curing procedure with the first 7 days in a 100% RH moist room and 21 days in a lab environment was used to simulate field condition. Through the comparison of compressive strength, surface resistivity, bulk diffusion, and relative humidity tests, it was found that:

- The hybrid curing condition (i.e., 21 days of lab environment after 7 days of 100% RH curing) produced a higher compressive strength than the 100% RH curing condition, except for the mixtures 50TI/50S/0ICA (w/cm of 0.35) and 50TI/50S/250ICA (w/cm of 0.45). The application of saturated fine ICAs reduced the strength magnitude variation between the two different curing conditions (hybrid curing vs 100% RH curing).
- At the age of 56 days, the mixtures with saturated fine ICAs had either equal or higher surface resistivity than those without saturated fine ICAs for the hybrid curing condition.
- For w/cm of 0.35, the hybrid curing condition produced a higher apparent coefficient of chloride diffusion for the 100TI and 50TI/50S mixtures. However, the application of saturated fine ICAs was able to lower the apparent coefficient of chloride diffusion for these mixtures.
- At the age of 7 days, the mixtures with saturated fine ICAs had a higher relative humidity than those without saturated fine ICAs, indicating that saturated fine ICAs were able to supply water to the surrounding matrix. For w/cm of 0.35, the mixtures with saturated fine ICAs also had a higher relative humidity than those without saturated fine ICAs (except for mixtures with cementitious system 70TI/30C) at the age of 56 days, which shows that saturated fine ICAs were able to continuously supply water to the surrounding matrix.

Recommendations

The results of this study show that the application of saturated fine ICAs reduced the compressive strength magnitude variation between the 100% relative humidity (RH) moist room curing condition and the hybrid curing condition, and produced either equal or higher surface resistivity to the mixtures for the hybrid curing condition at the age of 56 days. For the combination of w/cm of 0.35 and the hybrid curing condition, the application of saturated fine ICAs also produced a lower apparent coefficient of chloride diffusion for mixtures with cementitious system 100TI and 50TI/50S. Hence, internal curing could be employed to reduce concrete's permeability when the mixtures are properly designed.