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RESEARCH PROJECT TITLE

Impacts of Internally Cured Concrete
Paving on Contraction Joint Spacing

SPONSORS

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Impacts of Internal Curing on the Performance of Concrete Materials in the Laboratory and the Field

tech transfer summary

This research aimed to assess whether joint spacings could be increased in slabs containing lightweight fine aggregate (LWFA) as a source of internal curing.

Objective

The objective of this project was to investigate the effects of internal curing on the performance of practical concrete mixtures designed for the construction of jointed plain concrete pavements (JPCPs) in Iowa.

Background

Concrete curing involves techniques and methods to maintain the moisture and temperature of fresh concrete within desired ranges at early ages, which allows concrete to develop strength and durability. Various curing regimes, including external wet curing, insulation membrane curing, and internal curing, can be used for different applications and design characteristics.

Internal curing is designed to provide water reservoirs inside the concrete that aid curing without affecting the water-to-cementitious materials (w/cm) ratio of the mixture. Lightweight aggregates (LWAs) are commonly employed in the US to achieve internal curing.

Internally cured (IC) concrete has several advantages over conventionally cured concrete:

- Improved hydration in terms of uniform moisture distribution
- Reduced autogenous, plastic, and drying shrinkage, reducing the likelihood of shrinkage cracking
- Reduced concrete permeability and enhanced resistance to sulfate attack
- Improved strength and permeability at the interface transition zone (ITZ)
- Reduced modulus of elasticity (MoE) and enhanced residual stress relaxation due to the presence of LWAs
- Reduced moisture gradient along the concrete section, reducing warping in pavements
- Reduced coefficient of thermal expansion (CTE) and thermal conductivity, reducing temperature gradients throughout the concrete and reducing curling in pavements

Internal curing is especially advantageous for mixtures with a w/cm ratio lower than 0.42, where the risk of desiccation is high and external water cannot easily penetrate into the concrete.

Research Description

Sections of a sidewalk were constructed on the Iowa State University campus using the following:

- Mixture containing lightweight fine aggregates (LWFAs) to achieve internal curing
- Control mixture

Some slabs at the ends of the IC and control sections had 8 ft joint spacing, while other slabs had 12 ft joint spacing.

Type I/II portland cement and Class C fly ash were used to prepare both the control and IC mixtures. Crushed limestone with a one-inch nominal maximum aggregate size was used as coarse aggregate, and river sand was used as fine aggregate. An air entraining agent was incorporated into the mixtures, and some mixtures contained a commercially available water reducing admixture. Mix proportions traditionally used for sidewalk construction were used.

To create the IC mixture, about 20% of the volume of fine aggregate was replaced by LWFA to provide 7% internal curing water by mass of cementitious materials. The LWFA was a commercially available product.

The control and IC mixes were prepared and delivered by a local ready-mix supplier, with the LWFA saturated prior to batching.

Samples of the mixtures were taken at the time of placement and sent to the laboratory for testing. Similar mixtures using the same materials were also prepared in the laboratory for comparison and additional testing.



Sample collection for laboratory specimen testing of the mixtures placed in the field



Concrete and embedded sensor placement for field testing



IC section of sidewalk constructed for field testing

Tests were conducted to determine the moisture content and pore water pressure in the fresh concrete. And, a wide range of standard laboratory and field tests were conducted to determine the early-age and hardened properties of both mixture types:

- Workability of fresh concrete, slump test (ASTM C143)
- Air content of fresh concrete, pressure method (ASTM C231)
- Semi-adiabatic calorimetry (ASTM C1753)
- Compressive strength (ASTM C39)
- Static MoE (ASTM C469)
- Splitting tensile strength (ASTM C496)
- Electrical surface resistivity (AASHTO T 358)
- Rate of water absorption (ASTM C1585)
- Bulk water absorption of dried concrete specimen (ASTM C642)
- Bulk water sorption of dried concrete specimen (ASTM C1757)
- CTE of concrete (AASHTO T 336)

In addition, sensors were embedded in the sidewalk concrete to monitor moisture and temperature over time, and measurements were taken periodically throughout the winter of 2016–2017 to observe the dimensional stability of the slabs.



Installation of sensors at the top and bottom of the slab before it gets placed (left) and digital height gauge used with portable device for profile measurements (right)



Measurements to monitor deflection/slab surface profile over time

An inexpensive and portable device that was developed at Iowa State University in 2016 was used to monitor curling and warping in the field.

The profile of the surface of the concrete pavements was measured in the early morning and late evening at 7 days and used as a baseline for later measurements. The measurements were repeated at the same points at 18, 76, and 96 days.

Additionally, saw joints were monitored to study how they cracked in the control and IC concrete sections. The uncracked joint at one end of the 8 ft slab in the control section was also examined using ultrasonic shear-wave tomography to ensure there were no invisible subsurface cracks.

Key Findings

Replacing 20% of the volume of fine aggregate with LWFA for internal curing yielded the following results:

- The workability of the fresh IC concrete decreased slightly due to the replacement of river sand with LWFA.
- The initial setting time and heat generation were not significantly affected.
- The risk of plastic shrinkage decreased due to the lower pore water pressure in the IC concrete.
- The electrical resistivity and relative permittivity were higher at early ages due to the stored water in the LWFA.
- The permeability of the cement paste improved due to the effect of the porous LWFA on the absorption/desorption properties of IC concrete.
- The CTE decreased by more than 10%.
- The MoE decreased by 15%.
- Warping was reduced in the IC concrete slab, likely because the moisture provided by the LWFA led to a 50% lower moisture gradient through the thickness of the slab.

Implementation Benefits and Readiness

Internal curing can improve the strength and durability of concrete and lead to longer lasting pavements. Because internal curing improved the strength and durability properties of the IC mixtures, pavements constructed using these mixtures would be expected to last longer.

Besides the improved mechanical properties, benefits of this approach also include reduced risk of moisture gradients, thus reducing the potential for warping.

Replacing a portion of the fine aggregate with LWFA to achieve internal curing may increase the initial investment by 2.7%. However, the lower amounts of curling and warping displacement in the IC slabs suggest that longer panels can be accommodated and/or the slabs will last longer under traffic.