Research Brief

Wisconsin Highway Research Program
Project 0092-19-02
June 2022

Internal Curing of Bridge Decks and Concrete Pavement to Reduce Cracking

Research Objectives

- Evaluate materials available in Wisconsin for use in internally cured concrete
- Evaluate the performance of fresh and hardened concrete with and without internal curing
- Determine the impact of using internally cured concrete on concrete durability and sustainability of bridge deck and pavement placements

Research Benefits

- Using internally cured concrete in pavements will reduce rehabilitation costs
- Incorporating a special provision into WisDOT manuals will allow concrete producers and contractors to become familiar with internally cured concrete.

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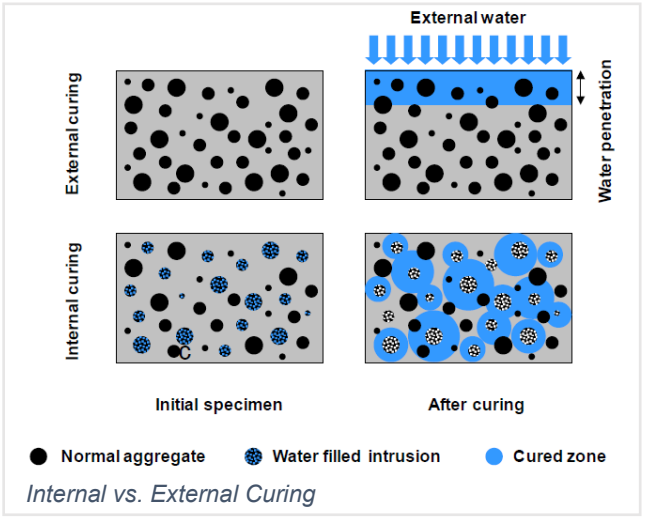
Background

Volumetric changes in concrete bridge decks and pavements can often result in cracking or warping, leading to reduced performance and durability. Changes in the moisture content of hardened concrete or the self-desiccation of cementitious materials with a relatively low water-to-cementitious materials ratio (w/cm) cause these volumetric changes.

Internal curing (IC) is a proven technology able to provide additional water to enhance the hydration of cement and pozzolans in the mixture, resulting in improved mechanical properties and improved durability. Additionally, since the IC water is not accessible during batching, distress associated with self-desiccation (autogenous shrinkage) and drying shrinkage is mitigated. IC can be achieved by utilizing lightweight fine aggregate (LWFA) or super absorbent polymers (SAP).



Internal vs. External Curing

This research project sought to evaluate different LWFA and SAP materials available in Wisconsin for use in internally cured concrete (ICC); evaluate the performance of fresh and hardened concrete with and without IC; and determine the potential impact of using ICC on the concrete durability and sustainability of bridge deck and pavement placements, respectively.

Methodology

The research team conducted two experimental phases to assess internal curing agents' influence on the properties of concrete. First, a study on mortar involved designing 17 different mortar mixtures to evaluate the effect of IC agents on autogenous shrinkage (ASTM C1698) and compressive strength (ASTM C109). Mortar mixtures were designed with w/cm ratios of 0.35 and 0.45 to investigate the efficacy of LWFA and SAP on autogenous shrinkage at different w/cm ratios. Three different replacement levels of LWFA corresponding to 80 percent, 100 percent and 120 percent of the required IC water were considered for each LWFA type.

"Internal curing of concrete has been demonstrated to reduce cracking in concrete bridge decks and pavements. This research gives the department tools to implement this technique in the future."
– William Oliva, WisDOT

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WisDOT Research website

The second phase evaluated 12 different concrete mixtures to investigate the effects of IC agents on concrete performance: six were designed for pavement applications (PA mixtures) and the remaining six were designed for bridge deck applications (BD mixtures). Two control mixtures, two LWFA mixtures and two superabsorbent polymer (SAP) mixtures were considered for both pavement and bridge deck uses. Data from LWFA and SAP mixtures were compared to control mixtures at each w/cm level for both pavement and BD categories.

Results

All mixtures in the study on mortar exhibited an initial expansion in the early ages (less than one day); the control mixture exhibited an initial expansion that was followed by significant autogenous shrinkage that increased monotonically with time. The 28-day shrinkage strain was found to be dependent on the LWFA replacement level. All SAP mixtures exhibited expansion at early ages, but it was significantly lower compared to the control mixture. This study indicated that SAP desorbs fluid faster than LWFA, and using SAP with a higher absorption capacity will likely further reduce autogenous shrinkage. In the concrete study, incorporating LWFA resulted in a slightly lower compressive strength, which is more pronounced at higher w/cm. Hardened concrete properties showed a general improvement when IC was incorporated. The use of ICC resulted in a substantial increase in the resistance against cracking of bridge deck concrete mixtures under restrained conditions. In non-restrained conditions, shrinkage was comparable to the control concrete mixtures. The life cycle cost analysis (LCCA) showed that the service life of bridge decks can be extended by using ICC, and that the LCCA of an ICC pavement can be reduced compared to a control scenario.

Recommendations for implementation

WisDOT manuals should incorporate a special provision to allow for concrete producers and contractors to become familiar with ICC in Wisconsin. The special provision provides sufficient flexibility to the producer and contractor to place ICC successfully while providing sufficient performance assurance to WisDOT.

To ensure that cracking in bridge decks is significantly mitigated, the researchers recommend that in addition to ICC, project specifications consider evaluating the potential for cracking using the restrained shrinkage method.

The benefit of ICC in pavements correlates with reduced rehabilitation costs during service. The monitoring of the ICC concrete performance should be conducted once ICC is incorporated and successfully executed in various pavement projects.

This brief summarizes Project 0092-19-02,
"Internal Curing of Bridge Decks and Concrete Pavement to Reduce Cracking"
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