PUTTING RESEARCH TO WORK

BRIEF

Minimizing Shrinkage Cracking in Concrete Bridge Decks

Concrete is a durable construction material that is commonly used in Wisconsin bridge decks. However, concrete is prone to developing cracks that can reduce its service life. Shrinkage cracking, which occurs as concrete loses moisture and shrinks as it dries, is one common type of cracking. Cracked concrete typically needs to be repaired to prevent further deterioration caused by freezing and thawing, and to prevent corrosion of steel reinforcing materials. This corrosion is caused by water infiltrating the concrete through cracks, especially water containing chloride ions from deicing salts.

Cracking can significantly reduce the service life of concrete bridge decks, pavements and other concrete structures. If cracking due to concrete shrinkage could be eliminated, a bridge's service life could be two to three times longer, and costly repairs could be avoided; bridge deck repair or replacement costs an estimated $30 to $40 per square foot.

What's the Problem?

Wisconsin DOT has attempted to control cracking in high-performance concrete using high-range water-reducing admixtures and steel fibers, but these measures have had limited success in reducing deck cracking. Using shrinkage-reducing admixtures in concrete mixes is advocated as one of the most effective ways of reducing shrinkage cracking. SRAs work by reducing capillary tension in concrete pores, decreasing volume changes as the concrete dries. However, one study reported that these admixtures may increase curing time, reduce the compressive strength of concrete, and affect the concrete's air void system. Before WisDOT tests SRAs in the field, further research is needed to verify the effectiveness of these admixtures and their effects on other properties of the concrete.

Research Objectives and Methodology

The objective of this research was to investigate the effectiveness of SRAs for reducing autogenous shrinkage (shrinkage produced independently of external influence) and drying shrinkage in concrete mixtures made with and without fly ash. The researchers also sought to study the effects of SRAs on other properties of concrete, including slump, air content, compressive strength, splitting tensile strength, and chloride ion penetrability.

The researchers identified three shrinkage-reducing chemical admixtures and evaluated them in laboratory tests over two years. Their tasks included:

- Documenting each admixture's capability of reducing autogenous and drying shrinkage.
- Determining each admixture's effect on air-entrained concrete, including slump, air content, initial setting time, compressive strength, splitting tensile strength, and chloride ion penetrability.
- Evaluating the effects of using different aggregate types in concrete containing SRAs.
- Developing recommendations for use of each admixture, including the dosage rate.

Researchers tested the admixtures using three base concrete mixtures and several additional mixtures. The three base mixtures were:

- WisDOT Grade A, which contained no supplementary cementitious materials.
- WisDOT Grade A-FA, in which Class C fly ash replaced 35% of the cement.
- High-cementitious concrete, which contained 30% more cement and fly ash than Grade A-FA concrete. Class C fly ash replaced 35% of the cement in this mixture as well.

These three concrete mixtures were made with crushed quartzite stone. In addition, researchers used Grade A-FA mixture proportions to create additional concrete mixtures with two more types of coarse aggregates (semi-crushed river gravel and crushed dolomitic limestone).

Investigator

"Shrinkage-reducing admixtures show promise in minimizing shrinkage cracking. This study provides guidance for testing them in the field."

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Researchers measured shrinkage-reducing admixtures' effect on concrete properties using laboratory tests that gauged compressive strength, left, splitting tensile strength, right, and other properties such as slump, air content and chloride ion penetrability (Fig. 4-17 and 4-18 of the final report).

For each admixture tested, researchers used three dosage rates: zero, the average recommended dosage rate, and the maximum recommended dosage rate.

Results

The three SRAs showed similar performance in reducing the drying shrinkage and autogenous shrinkage of concrete, eliminating much of the initial drying shrinkage. The admixtures reduced the four-day drying shrinkage for Grade A and A-FA concrete mixtures by up to 67 to 83%, and reduced the 28-day drying shrinkage by up to 48 to 66%. Specific findings included:

- In most cases, two of the SRAs worked like water-reducing admixtures and often increased the concrete's strength and its resistance to chloride ion penetration. The third SRA sometimes decreased the concrete's strength, and did not considerably affect chloride ion penetrability.
- None of the SRAs caused changes in air content or slump of fresh concrete mixtures during the first hour.
- Using crushed dolomitic limestone in the concrete mixture led to the lowest early-period drying shrinkage, followed by semi-crushed river gravel and crushed quartzite stone. Over time, however, the level of drying shrinkage became similar among the three aggregate types, with river gravel often leading to the highest late-period drying shrinkage. Use of 30% more cement and fly ash resulted in either similar or higher autogenous shrinkage, and either similar or lower drying shrinkage.

The final report includes recommended dosage rates for each admixture for the concrete mixtures tested.

Implementation and Benefits

WisDOT engineers recommend conservative implementation of the research results, since the results of the laboratory tests conducted in this study need to be verified in the field. In addition to reducing shrinkage, WisDOT may want to continue to explore alternative reinforcement materials. Since coating traditional rebar with epoxy has not been a foolproof protection for the steel, it may be wise to evaluate seriously the increased resistance to chloride ion penetration of stainless steels in comparison to their increased costs.

This brief summarizes Project 0092-04-13, "Reducing Shrinkage Cracking of Structural Concrete Through the Use of Admixtures," produced through the Wisconsin Highway Research Program for the Wisconsin Department of Transportation Research Program, 4802 Sheboygan Ave., Madison, WI 53707.

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Project Manager

"This research is a first step toward providing WisDOT with another alternative for reducing shrinkage cracking in concrete bridge decks."

–Jim Parry
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Brief prepared by
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