Research Brief

Wisconsin Highway Research Program
Project 0092-15-08
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Better Concrete Mixes for Rapid Repair in Wisconsin

Research Objectives

- Evaluate performance of rapid-repair concrete in Wisconsin
- Identify high-quality concrete rapid-repair mixtures with long service lives and high performance in Wisconsin's wet freeze-thaw climate
- Analyze life-cycle costs of CIP rapid repair for the laboratory tested mixtures
- Recommend improved mixtures in comparison with precast concrete pavement

Research Benefits

- Confirmed that Wisconsin's current CIP rapid-repair concretes perform adequately
- Recommended mixture improvements to alleviate construction difficulties
- Determined that increasing the durability of rapid repair concretes could cut maintenance and rehabilitation costs by nearly 50 percent over standard eight-year service life repairs

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Background

Increasing demands on Wisconsin's highway system impact the lifespan of roadways, resulting in more frequent lane closures for maintenance and repairs, creating additional user-delay. Rapid-repair strategies such as precast and cast-in-place (CIP) concrete patches aim to minimize the duration of traffic disruptions and lower costs.

The Wisconsin Department of Transportation (WisDOT) uses high early strength (HES) portland cement concrete in its rapid-repair CIP operations. The mix has a high cement content, accelerators, superplasticizers, air entraining admixtures and other mixture constituents that give it high strength gain and a fast curing time but also makes it more susceptible to high shrinkage and inadequate air void systems. This repair strategy costs less up front than precast patches but has a potentially shorter service life if the CIP is not optimal. The goal of this research was to identify strategies to reduce life-cycle costs by evaluating the performance of existing rapid-repair pavements and identifying mixtures with longer service lives capable of withstanding Wisconsin's punishing freeze-thaw climate.

Methodology

Wisconsin concrete suppliers were surveyed to obtain information on rapid-repair mix designs, challenges and approaches. A field review of 12 recent rapid-repair pavement projects in Wisconsin evaluated field performance. Based on information from the field reviews and informal survey, 13 rapid-repair mixture candidates were proposed, made and tested in the lab.

Sets of three 4x8-inch cylinder samples were cured in a wet room at 73° F then strength tested at four, six, eight, 10, 12, 24 and 36 hours and 28 days after mixing according to AASHTO T 22. Air-dry shrinkage testing was conducted on sets of three 4x4x10-inch prisms according to ASTM C 157. Twelve-inch diameter, three-inch thick cylindrical samples were cured for 28 days before being submitted to 60 freeze-thaw cycles according to ASTM C 672.

Rapid-repair patches were visually inspected in the field.

"Adjusting WisDOT concrete mix specifications to allow dry flake calcium chloride as an alternative to liquid calcium chloride solutions will yield workable, high quality concrete with lower shrinkage potential than mixes with higher water-cement ratios."

– James Parry, WisDOT

Interested in finding out more?

Final report is available at: WisDOT Research website.

Results

The field review showed significant durability issues in only one project, where severe scaling occurred. Durability issues that occur in rapid-repair pavements are more likely due to difficulties associated with construction or mix procedures than with WisDOT's specifications.

The cohesiveness of tested mixes was satisfactory with no segregation issues. In mixes using two percent calcium chloride, workability was lost very quickly, and it became difficult to consolidate cylinders by hand-rodding within 40 minutes of mixing the cement with water.

The average strengths of the concretes after eight hours ranged from 837 to 4,763 psi. Only the mixes using calcium chloride and a water-cement ratio of 0.32 met WisDOT's average strength requirement for special HES concrete of 3,000 psi within eight hours. The average strengths after 28 days ranged between 7,463 and 10,845 psi.

Shrinkage values of mixes not containing calcium chloride were between 600 and 700 x 10^{-6} after 28 days. Most of the mixes containing calcium chloride had shrinkage values between 800 and 1,000 x 10^{-6} after 28 days.

Assuming an acceptance limit of 500 g/m^2 after 60 cycles, all the mixes in this research performed satisfactorily except for the samples cured with the poly-alpha-methylstyrene curing compound.

Recommendations for Implementation

Durability issues occurring in rapid-repair pavements are more likely due to construction or mix procedure difficulties than to WisDOT specifications. Dry calcium chloride has the potential to ease these difficulties, if it can be mixed uniformly with the concrete to control slump, or if upper slump limits are raised to six inches. Concrete using portland cement with calcium chloride accelerator can surpass the WisDOT compressive strength requirement of 3,000 psi within eight hours of construction and have satisfactory scaling resistance. If the strength requirement of 3,000 psi can be extended to within 10 hours of construction, a non-chloride accelerator may be a preferable alternative, as it has excellent scaling resistance and only slightly higher shrinkage than non-accelerator concrete.

Increasing the durability of rapid repair concretes could cut facility maintenance and rehabilitation costs by nearly 50 percent over standard eight-year service life repairs; however, given current constraints with field concrete, precast repairs may stand as the more efficient method.

This brief summarizes Project 0092-15-08,
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