PUTTING RESEARCH TO WORK

BRIEF

Defining the Impact of Aggregate Fine Particles on Concrete Pavement Performance

As concrete hardens, it develops mechanical properties such as strength and stiffness that depend in part on the ratios of the water, cement paste and aggregate gravel that compose it. While enough water must be added to concrete so it can be mixed, placed, compacted and molded during construction, too much water will lead to a weaker final product. This balance is further affected by aggregates that are typically coated with a dust of microfines, or small particles composed of various minerals. This dust can absorb water, increasing the amount required to hydrate concrete to the point of workability, and so weakening the final hardened structure.

Consequently, WisDOT's Standard Specifications regulate the level of microfines allowed in aggregates. Its PS200 test limits the amount of microfines passing a US #200 sieve to 1.5 percent of coarse aggregate weight, or 3 percent of fine aggregate weight when clays are present. Aggregates that do not pass this test must be washed before use to remove microfines.

What's the Problem?

Field experience and research indicate that WisDOT's current specifications for microfines may not be adequate. Mixtures with coarse aggregates that meet current microfine specifications and perform well in the laboratory may suffer from low strength and early cracking in the field.

One cause of this discrepancy may be that not all microfines have the same mineralogy; they are composed of different minerals with varying chemical structures and physical properties. Consequently, some microfines, especially those with high clay content, may have properties that make them more reactive than others, leading to a stronger than expected effect on cement hydration.

Concrete curing conditions also play a role in this discrepancy. Laboratory specimens are cured at the most favorable humidity and temperature conditions, allowing a sufficient hydration time to develop a strong microstructure. During field projects, one to eight hours may elapse between the pouring of concrete and the application of curing compounds to its surface, so that early curing occurs at a less favorable temperature and humidity.

Research Objectives

The objective of this study was to determine the effect of aggregate microfines on the strength and durability of finished concrete, particularly those associated with aggregates that are already in compliance with current WisDOT Standard Specifications.

Methodology

Researchers began by collecting aggregate samples from 28 locations in Wisconsin and processing them to meet WisDOT microfine specifications. Using X-ray diffraction and other methods, researchers analyzed the microfines in these materials for their mineralogy and clay content, and based on this analysis divided them into two groups. Microfines in Group A were rich in materials similar to dolomite, a sedimentary mineral found in crystals and consisting of calcium magnesium carbonate. Those in Group B were predominantly igneous minerals, consisting of aluminosilicates such as feldspar and quartz, and in some cases, clay.

Researchers then prepared concrete specimens using several aggregate samples from both groups. Each aggregate sample was prepared both unwashed and after washing to remove microfines, and each concrete specimen was cured under ideal and nonideal temperature and humidity conditions.

Investigator

"WisDOT specifications for aggregate microfines are reliable when specimens are cured under ideal laboratory conditions but may be inadequate for microfines high in clay content cured in the field."

–**Steven Cramer**
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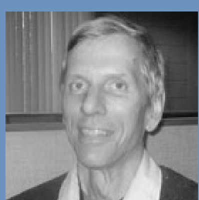
To measure concrete workability, researchers used the slump test in which an inverted cone-shaped mold is removed from soft concrete and the resulting slumping is measured.

Project Manager



"This project is an important step in understanding the role that microfine mineralogy plays in the field performance of concrete."

–James Parry
WisDOT Bureau of Technical Services
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Researchers measured the effects of microfines on the microstructure, workability, compressive strength and other properties of these fresh concrete samples both before and after they had fully hardened. Another test measured the fresh air content in the concrete to see if microfines interfered with air entrainment. During the normal process of producing concrete, air bubbles are deliberately entrained in concrete to form a matrix that increases its workability, hardness and freeze-thaw durability. Sometimes this entrainment is accomplished using detergent-like chemical additives called air-entraining agents, or AEAs.

Results

While dolomitic microfines at concentrations complying with the WisDOT limits had little effect on the workability of samples or the effectiveness of AEAs, igneous microfines—especially those with clay minerals—clearly impaired both. When cured under high humidity, the presence of either dolomitic or igneous microfines typically increased the compressive strength of hardened concrete and had other beneficial effects or only small negative effects on other mechanical properties. When cured in dry conditions, concrete samples—especially those igneous aggregates with clay minerals—had decreased compressive strength, decreased tensile strength, increased porosity and increased susceptibility to chloride penetration.

Researchers also investigated a new method for determining the suitability of an aggregate source for concrete production in the field. This method is similar to current laboratory methods that measure changes in conductivity (as cation exchange capacity, or CEC) to evaluate the harmfulness of microfines. The new method yields similar results to these laboratory tests while using significantly less instrumentation. The results of this study suggest that with additional development, this method might be used for field determination of CEC.

Implementation and Further Research

Based on these results, researchers recommend reviewing current specifications for allowable concrete microfine content, especially when microfines are high in clay content and curing conditions are not ideal.

This brief summarizes Project 0092-07-02, "Detecting Deleterious Fine Particles in Concrete Aggregates and Defining Their Impact," produced through the Wisconsin Highway Research Program for the Wisconsin Department of Transportation Research Program, P.O. Box 7915, Madison, WI 53707.

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