PUTTING RESEARCH TO WORK **BRIEF**

Which Aggregate Coatings Hurt Concrete Performance?

Aggregates used in concrete mixes are coated with complex combinations of mineral dust and clay. In northern Wisconsin, feldspar minerals typically combine with clays to form aggregate coatings, and in southern Wisconsin, coatings typically consist of carbonates derived from dolomitic aggregates. A single aggregate site may contain several types of clay and mineral dust, leading to numerous possible combinations of coatings. For years the concrete pavement industry has believed that some aggregate coatings have a negative effect on pavement performance.

A February 2003 WHRP research report (WisDOT Project 0092-00-07, "Effects of Aggregate Coatings and Films on Concrete Performance"; see the project page at http://www.whrp.org/Research/Rigid/rigid_0092-00-07/) showed that both the volume of aggregate coating and the mineral types involved can affect concrete performance in terms of field workability, aggregate-cement adherence, cracking and compressive strength.

Building on the previous research, this study is the second of four WHRP projects aimed at identifying the impacts of aggregate coatings on concrete mixtures and pavement performance, and recommending effective methods of managing these coatings.

What's the Problem?

WisDOT monitors coatings using the P200 method, in which aggregate is shaken over a No. 200 screen to remove dust (of any material, deleterious or not), and the department limits coatings in a concrete mix to 1.5 percent of its volume. To ensure acceptance for construction, aggregates are typically washed, which is time-consuming, expensive and creates a stockpile of unwanted fines. Because washing can remove potentially beneficial microfines as well as leave behind harmful clays that stick to aggregates, the current processes do not ensure concrete durability and performance.

WisDOT needed a clearer understanding of how specific clay coatings negatively affect concrete mixtures to help mitigate the coatings' effects or improve removal methods. This required evaluating a greater number of samples than used in the 2003 study, as well as isolating individual clay types.

Research Objectives and Methodology

This study sought to identify the primary ways in which clay microfine coatings of coarse aggregate inhibit concrete performance. The investigation had three goals: to understand the effect of clay coatings on concrete mixes; to evaluate monitoring methods, including the P200; and to evaluate concrete samples made with aggregates used in the field. The researchers performed the following tasks:

- Compared aggregate coated with four manufactured or controlled-mineralogy clays for:
  - Coating detachment during mixing.
  - Coating impact on aggregate-cement adherence, evaluated via scanning electron microscopy and compared to samples that used naturally occurring clay.
  - Coating impact on physical properties such as mixture stiffness, compressive strength, shrinkage and air entrainment.
- Compared the P200 method with the California Cleanness Test, the Methylene Blue Value test, and the Modified Methylene Blue Value test for controlling coatings of aggregates.
- Evaluated concrete samples made with naturally coated aggregates from the field.

Results

Researchers' findings related to the three tasks included:

Negative effects of clay coatings.

- *Cement-aggregate adherence.* Clays disrupt the aggregate-paste bond, preventing aggregate

Investigator

"This study puts us closer to developing ways to better handle the complex problems certain aggregate coatings present to making concrete. Fewer construction problems and longer-life pavements will be the result."

–Steven Cramer
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This research is helping WisDOT understand and manage the effects of clay coatings on aggregates used in concrete mixes, with a goal of minimizing the coatings' impact on concrete performance.

particles from adhering well to the cement paste. High-pH clays detach better during mixing than low-pH clays do.

• *Concrete mix hydration.* Even at below-P200 levels, clay disrupts concrete's ability to effectively manage water. Clays that don't stick to aggregates disperse into a mixture's water before the cement is added. Some clays absorb a lot of water, which forces crews to add extra water to keep the mix workable, but this reduces the cured concrete's compressive strength. Certain clays expand and shrink significantly as they absorb and lose water, increasing shrinkage cracking and freeze-thaw cracking.

Monitoring methods. The P200 index, which correlates coating volume with performance, predicts performance poorly because it does not distinguish between detrimental and innocuous coatings. The California Cleanness Test works somewhat better, but not as well as the Methylene Blue Value method, in which fines are soaked in a water solution with dye that adheres to certain clays. The Modified Methylene Blue Value method, which combines the MBV and P200 methods, most accurately predicts concrete quality in terms of slump, air content, shrinkage and durability. The challenge is that the Methylene Blue Value test is time-consuming and can be subjective for routine aggregate monitoring. An alternate screening test is needed.

Naturally coated aggregates. Two aggregates with mineral dusts and clay coatings were analyzed. Fresh and hard mixtures showed no deleterious effects under the curing conditions used, but the sample with certain calcium and sodium clays exhibited somewhat less workability and slump.

Benefits

This study may help change WisDOT's approach to aggregate coating management. If WisDOT develops a method for selective removal of coatings to retain beneficial dusts, it could reduce reliance on aggregate washing, saving money and possibly improving concrete performance. Concrete construction, durability and strength may also be improved by lowering limits of certain clay coatings.

Further Research

Investigators recommended that WisDOT analyze and revise the coating limits in its specifications according to the mineralogy of coatings, lowering limits for certain clays. Other recommendations are being studied in Project 0092-07-02, "Detecting Deleterious Fine Particles in Concrete Aggregates and Defining Their Impact."

This brief summarizes Project 0092-04-12, "Expanded Study on the Effects of Aggregate Coating and Films on Concrete Performance," 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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Rigid Pavements TOC Chair

"Different clay minerals that coat aggregates can have severely detrimental effects on concrete. This study helped us learn which clays have the greatest impact on performance."

–Jim Parry
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