Executive Summary and Research Readiness Level Assessment

Colloidal Silica: Cement Enhancing Admixture Product Evaluation

Research Objectives

This research investigated the potential to use colloidal silica (CS) as a cement enhancing admixture in NDOT's concrete mix designs. Engineers had two objectives in this study:

1. Determine if CS can enhance high, early strength for use in patching and repairs.
2. Determine if CS can maintain or improve ASR mitigation as F-ash content is decreased.

Research Benefits

- Provided answers through four NDOT testing standards to test different CS addition or replacement levels cements if CS is a viable option for replacement.
- Provided a cost analysis of materials needed to replace Class F - fly ash (F-ash) to determine if the use of CS is cost effective to NDOT.

Principal Investigators

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Background

As Class F- fly ash (F-ash) becomes scarce, PCC engineers will look to other supplemental cementitious materials (SCM) to replace F-ash and its ASR mitigating properties. Colloidal silica (CS), or nano-silica, has been shown to mitigate ASR at certain replacement levels; however, CS cannot be a full replacement of F-ash. Engineers at the Nebraska Department of Transportation (NDOT) learned of CS from a presentation given by Intelligent Concrete, Inc. at the 2019 Nebraska Concrete Professionals Association Conference and decided to investigate the potential use of CS in NDOT concrete mix designs.

Conclusion

Colloidal silica shows promise in its SiO_2 ability to mitigate against ASR when used as a replacement of F-ash at both 2% and 3% levels. The 3% replacement of F-ash in a 78% Type I/II and 22% F-ash blended cement showed the greatest reduction in C1567 expansion. This indicates that CS is a viable option for replacing F-ash to mitigate ASR. Furthermore, the C_aO/SiO_2 ratio of a cement can be determined through chemical analysis and colloidal silica blends can be designed at specific ratio levels known to NDOT PCC engineers to provide adequate ASR mitigation.

Strength Activity Index and Set Time testing with Type IP cement showed that cements with CS were comparable to the Type IP control used in the study. No significant advantage for compressive strength or set time was gained by adding CS at the 1% level.

Strength Activity Index and Set Time testing with Type I/II CS at 2% and 3% replacement with cement showed a strength gain increase over the control of nearly 1000 PSI at 28 days, and reduced the set time by 45 to 55 minutes from the control. This may provide some value to projects that need to open quickly.

Despite CS's successful test results, the cost of CS is too high to use in normal NDOT mix designs and construction activities. Utilizing CS at the 3% level results in about a 66% cost increase for a cubic yard of concrete from $125/yd3 to $195/yd3. Based on cost estimates provided in the Spring of 2020, 30%-wt. colloidal silica will increase the cost of concrete by $23 for every 1% replacement of Class F fly-ash.

The NDOT PCC engineer recommends that CS can be a tool for concrete or ready-mix suppliers to remediate F-ash deficient cements. When CS is more cost effective than transporting a IP cement that fails NDOT specifications and/or if it will prevent the IP cement from being removed from Nebraska's Approved Products List.

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Final report is available at:
NDOT Research Website

NDOT Recommendations Base off Research

Future research will prepare the Department to remediate cements not meeting Quality Assurance standards by providing the PCC engineer with additional tools to improve the long-term performance of concrete structures.

If the use of CS becomes feasible in the future, the PCC engineer proposes testing using colloidal silica as a 3% replacement of F-ash in a mix design. Future testing should include testing CS concretes for all mechanical and durability properties such as: compressive strength, modulus of elasticity, flexure strength, freeze-thaw, NDOT Wet & Dry, and shrinkage. Researchers should also investigate the ability to use colloidal silica in a mix design that conforms to the Department specifications.

Water requirements when using CS requires further investigation to better understand how colloidal silica affects workability.

By Wally Heyen, PCC Engineer

Research Readiness Level (RRL) Assessment

RRL 2

Level 2: Applied Research/Proof Concept
-Research/Technology developed in a laboratory environment.

This brief summarizes of In-House Research Project
"Colloidal Silica: Cement Enhancing Admixture Product Evaluation"
Nebraska Department of Transportation Research Program