CENTER FOR TRANSPORTATION RESEARCH

PROJECT SUMMARY

Texas Department of Transportation

0-6906: Chemical Solutions to Concrete Durability Problems

Background

The reinforced concrete infrastructure in Texas has been plagued by various durability-related issues over the years, including deterioration from alkali-silica reaction (ASR), delayed ettringite formation (DEF), corrosion of reinforcing steel, and excessive shrinkage cracking. For many of these problems, fly ash has been the remedy of choice; however, with changes in fly ash quality and quantity spurred by new emissions standards and changes in fuel sources, there is a concern that fly ash may not be as available or effective in the future. The need to evaluate other solutions to the problem of reinforced concrete durability—besides the traditional use of fly ash—motivated this project, which evaluated alternatives such as the use of corrosion inhibitors, ASR and/or DEF inhibitors, integral water repellants, and gypsum as an additive to improve sulfate resistance of Class C fly ash.

What the Researchers Did

The research team reviewed and synthesized published literature related to chemical solutions to concrete durability problems. Based on this review, a wide range of materials were selected and procured for the project, including corrosion inhibitors (calcium nitrite, calcium nitrate, others), ASR and/or DEF inhibitors (lithium nitrate), integral water repellants, nano-particles (silica and dispersible C-S-H), and gypsum as an additive to improve sulfate resistance of Class C fly ash. These materials were tested under a comprehensive laboratory testing program, with tests including heat of hydration, strength, electrical resistivity, corrosion potential, chloride diffusivity, sorptivity, and expansion (due to ASR, DEF, or sulfate attack). Corresponding field specimens were stored at three different outdoor sites in Texas and evaluated for ASR and/or DEF, as well as for corrosion potential (marine site). Lastly, the research team performed a forensic evaluation of a bridge deck in Amarillo, focusing on possible causes of cracking and remedies for future decks.

What They Found

Significant laboratory and field data were generated during the course of this project. Although some of the tests are ongoing and may require additional time to determine whether a given material improves the long-term durability of concrete, some general observations can be made at this time:

- Lithium nitrate was found to delay the time to ASR- and/or DEF-induced expansion, but the performance in field exposure blocks was not as promising as accelerated laboratory tests.
- Saturating lightweight fine aggregate (LWFA) with lithium nitrate as an attempt to time-release lithium nitrate was found to show

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little benefit over just using lithium nitrate as a chemical admixture added to the mix water.

- The use of LWFA (saturated with water) was shown to delay and decrease expansion due to ASR and/or DEF. The specific benefits of using a given LWFA to avoid ASR and/or DEF requires additional emphasis and future testing.
- Overall, the use of corrosion inhibitors was found to be beneficial in delaying the corrosion of reinforcing steel. The use of the calcium nitrate and calcium nitrite admixture significantly reduced chloride ingress, resulting in a notable decrease in the diffusion coefficient. The observed improvement was directly related to admixture dosage and was consistently observed across lab and field samples.
- The use of integral water repellants was not found to be effective in improving the transport properties most relevant to concrete durability. Although some marginal improvements were attained for some products in some tests, in general, the improvement was not found to be significant enough to fully prevent deleterious mechanisms from occurring.
- Nano products were found to slightly improve the transport and durability properties of concrete, but degree of improved performance appears to be slight when compared to controls and may not justify the use of the products tested. Based on results, the products may be better tailored to address specific issues (e.g., early age strength with nano-CSH) rather than to provide broad improvements in durability.
- The use of gypsum to improve sulfate resistance of concrete containing Class C fly ash shows promise but requires further time to monitor the laboratory and field specimens cast during this project.
- A forensic evaluation of a bridge deck in the Amarillo District identified the potential causes of excessive cracking observed in decks cast over precast panels. Potential admixture compatibility and dosage issues, excessive rebar cover depth, and delayed curing were identified as factors likely contributing to the observed cracking.

What This Means

Several products evaluated in this project show some potential for improved durability and increased service lives for concrete infrastructure. Although no single product was able to improve all durability aspects (like Class F fly ash), opportunities may arise for some of the products to be used in targeted applications to address specific durability requirements.

For More Information

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