Project Summary

Texas Department of Transportation

0-4889: Sulfate Resistance of Concrete Exposed to External Sulfate Attack

Background

Sulfate attack is a complex form of deterioration that has damaged concrete structures throughout the world. Sulfate attack is particularly complex because the source of sulfates can be external or internal (delayed ettringite formation), and the distress can be chemical in nature, due to alteration of hydration of products, or physical in nature, due to phase changes in the penetrating sulfate solution. This project focused exclusively on external sulfate attack, but includes both chemical and physical manifestations of this form of attack. A major emphasis was placed on improving the sulfate resistance of concrete containing ASTM C 618 Class C fly ash.

The key technical issues that were evaluated include:

- sulfate resistance of concrete containing ASTM C 618 Class C fly ash,
- sulfate resistance of concrete exposed to gypsiferous soils,
- classification of construction sites based on sulfate exposure,
- resistance of concrete to physical sulfate attack, and
- correlation between laboratory tests and field performance.

What the Researchers Did

The research objectives were addressed in this project through a combination of laboratory tests, forensic and mechanistic evaluations, field studies, and the development of three outdoor sulfate exposure sites in Texas, shown in Figure 1.

Research Performed by:

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Figure 1 – Outdoor Exposure Sites Developed Under TxDOT Research Project 0-4889

These outdoor sites are critical in that they facilitate the generation of real-world field performance that can then be correlated with accelerated laboratory testing and integrated into relevant specifications.

A wide range of materials and mixture proportions were used to produce mortars and concretes exposed to various exposure conditions (static immersion in sulfate solutions, exposure to wetting/drying cycles, exposure to sulfate soils at outdoor sites, etc.). In addition, extensive field studies were performed on TxDOT structures throughout the state to determine the extent of sulfate attack and the specific mechanisms of deterioration.

What They Found

Some of the most important findings from this study include:

- Concrete containing Class C fly ash can be made sulfate resistant through the addition of small amounts of silica fume or ultra-fine fly ash or through the addition of small amounts of gypsum. In addition, increasing the Class C fly ash dosage to 60 to 70 percent yielded satisfactory sulfate resistance.
- Gypsum-containing soils were found to cause distress in concrete, although the deterioration is less severe than when exposed to magnesium or sodium sulfates.
- Test methods were evaluated and recommended for determining the severity of sulfate exposure and for evaluating the sulfate resistance of mortars and/or concretes.

What This Means

This research project has developed methods for TxDOT to better evaluate the potential for sulfate attack and has recommended various means to improve the sulfate resistance of concrete containing Class C fly ash. This means Class C fly ash can now be used safely and effectively in sulfate environments, whereas it was typically disallowed in such situations. This paves the way for the sustainable use of local resources in durable concrete structures.

For More Information:
0-4889-2 - Evaluation of Class C Fly Ash in Sulfate Environments

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