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EFFECT OF SULFUR TRIOXIDE CONTENT ON CONCRETE STRUCTURES USING FLORIDA MATERIALS

PROBLEM STATEMENT

Recently, several Florida Department of Transportation (FDOT) concrete suppliers shut down because the sulfur trioxide content of their concrete exceeded the maximum set by AASHTO and ASTM standards. The sources of sulfur trioxide (SO_3) in cements are various; however, the major source is typically calcium sulfate(s). Calcium sulfates are an additive used to control the setting and early hydration of Portland cements. Sulfur trioxide content in clinker or cement can be of variable reactivity. If it is present in a nonreactive form, cement producers, in order to control tricalcium aluminate hydration, incorporate calcium sulfates in amounts that can result in the production of cements with marginally higher SO_3 content than the maximum limits set through standards.

Though current standards have maximum set limits for SO_3 content in Portland cement, the standards contain provisions for optimum sulfur trioxide content that can exceed the set maximum. Optimal SO_3 content is established based on maximum strength at one day. However, recent research indicates that optimal SO_3 content for strength may be different than optimal SO_3 content for durability or for placement. The effects of sulfur trioxide content on long-term durability and various properties of concrete using Florida materials need to be evaluated.

OBJECTIVES

The objective of this research is to determine the effect of sulfur trioxide (SO_3) content on the durability of structural concrete. Using several Portland cements, collected from approved FDOT cement suppliers, researchers assessed the effect of SO_3 content on the fresh and hardened properties of paste, mortar, and concrete. Additionally, long-term durability effects were studied. The as-received cements and mineral admixtures were subjected to various characterization testing, including mineralogical x-ray diffraction for cement phase quantification (Rietveld refinement). Other characterization testing employed/addressed the following:

- x-ray spectroscopy for oxide chemical composition of mineral admixtures and cements
- differential scanning calorimetric testing
- setting time
- Blaine fineness.

Durability tests for mortar and concrete included the following:

- mortar expansion and mortar strength measurements in lime and sulfate
- drying shrinkage
- concrete strength measurements in lime and sulfate
- setting times for concrete
- surface resistivity for concrete
- open circuit potential for steel rebars in different concrete mixes

FINDINGS AND CONCLUSIONS

The findings of this study indicate that there is a need to maintain low SO_3 content for cements to achieve better long-term concrete durability. The results of strength measurements conducted for a period of 360 days indicate that increasing the SO_3 content beyond 3.0% results in a significant strength loss when the cementitious system is exposed to a sodium sulfate environment. Loss in strength between 1,000 to 3,000 psi was documented in this study for all of the cements studied. The rate of strength loss at elevated SO_3 content was more pronounced relative to higher tricalcium silicate content of the cement. Moderate alkali and tricalcium aluminate content cements showed lower strength loss or expansion on sulfate exposure at ambient temperatures. The study also indicated that ASTM C1038 might not accurately assess the durability of cementitious systems at longer ages.

Expansion measurements indicate that increasing the SO_3 content of cements increases expansion. This was the case for cements with lower alkali and tricalcium aluminate content. The effect seems to be more significant with increasing tricalcium silicates content. The results also indicate that incorporation of mineral admixtures in the concrete and mortar significantly improves the durability of a cementitious system with high sulfur trioxide content.

Since the findings of this study indicate that increasing SO_3 content accelerates the rate of deterioration for most of the cements considered in this study, it is recommended that a limit on the maximum allowable SO_3 content in cements has to be unconditionally enforced. It is also recommended that a study be initiated to address the roles of alkalis and tricalcium aluminate content of cements on the long-term durability of concrete.

BENEFITS

The findings of this study provide FDOT with the scientific data necessary to make decisions about cement production facilities and ready mixed concrete producers with regard to elevated levels of sulfur trioxide content. The ultimate benefit, therefore, is to enable decision-making that will result in better and longer-lasting products.

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