Summary of Final Report, BC-353-1
November 2001

SUBSTITUTION OF A CEMENT SOURCE WITHIN A MIX DESIGN

PROBLEM STATEMENT

In response to 23 CFR Part 637, Subpart B, Quality Assurance Procedures for Construction (1995), which prescribes the policies, procedures, and guidelines to assure the quality of materials and construction in all Federal-Aid highway projects on the National Highway System, the Florida Department of Transportation (FDOT) initiated QC 2000. QC2000 resulted in the modification of certain FDOT specifications in order to set forth the quality control requirements expected of FDOT contractors. FDOT Specifications, Section 346, Portland Cement Concrete, was among the modified sections.

A task team was developed to implement changes to Section 346 that would include the QC 2000 concepts of contractor quality control. The team included District Concrete Engineers and representatives from the State Materials Office, the State Construction Office, FHWA, and industry. During one of the team meetings, the members of industry suggested that the contractors be given the latitude to substitute materials in a currently approved concrete mix design. The industry representatives on this team were mostly producers, and they felt that they could avoid delays in production if they had the option to change material sources in the event that they experienced a material shortage. The team agreed to investigate the concept.

OBJECTIVES

According to Section 346, contractors are to do the following:

> Use concrete composed of a mixture of portland cement, aggregate, water, and, where specified, admixtures and pozzolan. Deliver the portland cement concrete to the site of placement in a freshly mixed, unhardened state.
>
> Obtain concrete from an approved concrete production facility's meeting the production and Quality Control (QC) of concrete provisions of this Section and Chapter 9.2 of the Materials Manual – Concrete Production Facilities Guidelines.

Consequently, the objective of this investigation was to study the material parameters, in cements obtained from different sources, that would affect fresh and hardened concrete properties. In addition to identifying those parameters and their impact on concrete durability, researchers were to recommend based on their findings whether the current FDOT standards needed to be modified.

FINDINGS AND CONCLUSIONS

All approved FDOT cement suppliers were contacted for material collection. Seven cements and their matching clinkers were collected from approved sources. A Class IV concrete mix design was selected and batched under hot weather conditions.

The as-received material was subjected to several characterization tests that included the following: mineralogical x-ray diffraction analysis, x-ray fluorescence for oxide chemical analysis, Blaine fineness, and particle size distribution using laser analysis. In addition, clinker morphology was assessed through optical microscopy. In assessing fresh and hardened concrete properties, three mixes per cement were prepared using a Class IV concrete mix design. The same mix design proportioning was maintained for all of the as-received cements, including admixtures' dosages. Several plastic properties were measured in this study; namely, air content, setting time, slump, slump loss, unit weight, and temperature. Hardened concrete properties that were assessed included concrete compressive strength and chloride ion penetration at different ages. Sulfate durability was also examined using mortar bars exposed to sulfate solution.

Characterization tests on the as-received material revealed variation in phase content, morphology, and reactivity among the cements studied in this project. Varying the cement source resulted in variation in the alkali sulfate content and in the calcium sulfate form and content (i.e., anhydrite, hemihydrate, and gypsum).

The findings in this study indicated that there was variation in plastic concrete properties under hot–weather mixing conditions. Reported initial slump values were between 2 – 3.75 inches while slump loss, over the extended mixing period of 90 minutes, was between 1 to 2 inches. In addition, variation in the initial set among Type II cements studied was 84 minutes. However, variation in air content was not significant [less than 1%]. Variation in compressive strength was approximately 700 psi at 28 days among the cements examined.

In addition, results from chloride penetration tests indicated variation in the durability rating from moderate to high chloride ion penetration among the cements included in this study. For sulfate durability, variation in mortar expansion was between 0.14% to 1% for the Type II cements studied at an age of 480 days.

Since the findings of this study indicated that substitution of Type II cement in a concrete mixture affects its plastic and hardened properties, it is recommended that laboratory or field trial batches be performed prior to permitting cement substitution in a mixture.

BENEFITS

The findings of this research have identified to the Department that cements of the same type cannot be substituted within a mix design without altering the plastic and hardened properties of the concrete. This information is of significant benefit because by restricting the substitution of Type II cements in an approved concrete mix design, a consistent material can be expected at the job site throughout the life of the project.

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