CENTER OF EXCELLENCE FOR AIRPORT TECHNOLOGY

TECHNICAL NOTE

TECH NOTE NO:	30
TITLE:	Assessment of Selected Mineral Admixtures for Mitigating Alkali Silica Expansion
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Introduction

Alkali-silica reaction (ASR) is a common cause of premature deterioration in portland cement concrete, and sands in central Illinois have been shown to exhibit moderate expansion due to ASR (TN 29, Nelson and Struble). As discussed previously (TN 27, Nelson and Struble), in order to prevent damage in concrete containing reactive aggregate, it is necessary either to limit the alkali level in the concrete or to use admixtures that mitigate the expansion. Use of a low-alkali cement (<0.6% total alkali) is often sufficient to prevent damage. If a low-alkali cement is not available in the market area or if additional mitigation is desired, then it is necessary to use chemical or mineral admixtures. Several mineral admixtures are known to mitigate ASR expansion. These include fly ash; ground, granulated, blast furnace slag (hereafter called "slag"); silica fume; and metakaolin (a processed kaolinite clay). Potential admixtures must be tested to determine their effectiveness and dosage. The objective of the study described here was to assess whether selected mineral admixtures effectively mitigate against ASR expansion, to determine the dosage required for mitigation, and to provide recommendations for their use in the O'Hare Modernization Program (OMP).

Background information on ASR and on the role of mineral admixtures in mitigating ASR expansion is provided in TN 27.

Additional details on this study will be provided in the MS thesis of Francis Nelson, which will be released shortly as a Technical Note.

Materials

The cement, aggregate, and mineral admixtures used in this study were selected to be representative of materials available in the Chicago area and likely to be considered for use in the OMP.

The cement used in all experiments, the cement that is used in our concrete laboratory for routine tests, was a commercial portland cement (Holcim, Clarksville, MO). It is classified as a low alkali Type I according to the Standard Specification for Portland Cement (ASTM C 150).

The mineral admixtures selected for testing were all on the Illinois Department of Transportation list of approved materials. They were: two Class F fly ashes (Class F 1 and Class F 3), one Class C fly ash, one slag, one silica fume, and one metakaolin. The mineral admixtures were all used to replace some portion of the Portland cement, on a mass basis. One Class F fly ash and the slag were tested at several replacement levels, the other admixtures were tested at only one level.

The sand used in this study was Sand 5 as described in TN 29, where it was shown to produce moderate expansion, typical of all the natural sands tested. This is the sand used in our concrete laboratory for routine tests and thus is available in a large quantity.

Test Procedure

The tests were performed according to the ASTM Standard Test Method for Determining the Potential Alkali-Silica Reactivity of Combinations of Cementitious Materials and Aggregate (Accelerated Mortar-Bar Method) (C 1567). This procedure is basically the same as the procedure used in our previous study to assess reactivity of aggregates (TN 29). Mortar bars were prepared using a water-to-cement ratio of 0.47. For mixtures containing silica fume or metakaolin, a small amount of low-range water reducer (about 5 ml relative to the cement) was added for workability. Bars were stored in the molds for 24 hours in a moist room, demolded, and stored in a water bath at 80°C for 24 hours, after which their initial lengths were measured . All length measurements were made using a dial gauge mounted on a stand for this purpose and in comparison to the length of a reference bar. Bars were then immersed in a concentrated (1 N) sodium hydroxide (NaOH) solution and stored at 80°C during the remainder of the test. At least four subsequent readings were made for each bar to monitor expansion up to an age of 14 days. The difference between the initial and the subsequent length value was used to compute expansion as a per cent, relative to the nominal gage length.

Because ASR expansion is known to show some uncertainty, three bars were tested for each mortar. Results here are the average of those three bars.

The standard (ASTM C 1567) states that any combination of cement, aggregate, and mitigating material expanding less than 0.10% after 14 days is innocuous and has a low risk of deleterious expansion when used in concrete.

Results

The expansion values for the three individual bars prepared for each mortar differed by no more than 0.01, and often by only 0.005% (that is, typical values for three bars were 0.058%, 0.062%, and 0.059% for an average value of 0.059%). Expansion results for the various mortars are shown in Figures 1-3. Results shown there are for the average of the three individual bars prepared for each mortar. All samples produced some expansion and were still expanding after 14 days.

Expansion levels with fly ash are shown in Figure 1. The Class F fly ash reduced expansion slightly at 5% and sufficiently at 10% and 15% to provide effective mitigation. The two Class F samples showed similar expansion levels when tested at 15%

replacement. It appears that the amount of Class F 1 required for mitigation (that is, the amount that produces expansion below 0.10% at 14 days) is between 10% and 15%. The

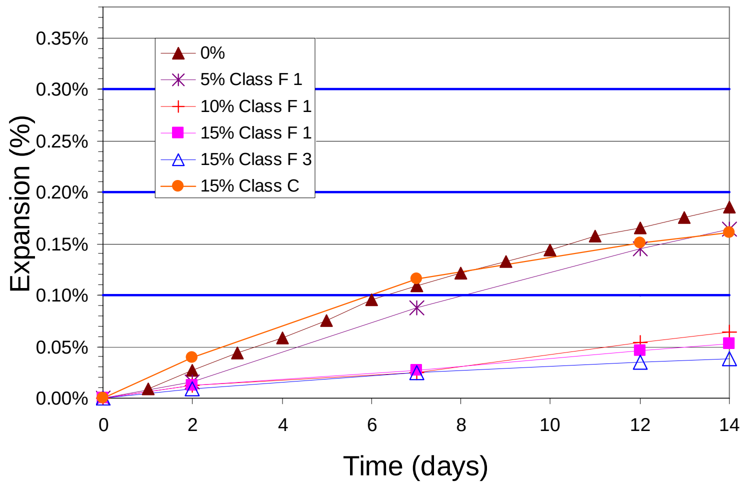

Figure 1. Expansion of mortars containing fly ash.

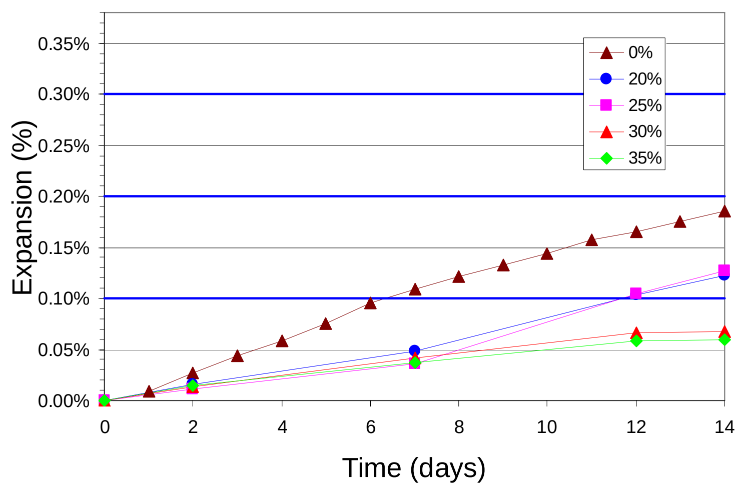

Figure 2. Expansion of mortars containing slag.

Class C ash produced only slight reduction at 15%, not effective mitigation. It is recognized that Class C ash does not generally provide effective mitigation and may even produce an increase in expansion.

Expansion levels with slag are shown in Figure 2. Addition of 20% and 25% of this slag reduced expansion but did not provide effective mitigation. Addition of 30% and 35% slag further reduced expansion and did provide effective mitigation.

Expansion levels with other admixtures (each at the single replacement level of 10%) are shown in Figure 3. Both silica fume and metakaolin reduced expansion considerably and provided effective mitigation, although the silica fume just barely met the 0.10% criterion. It is expected, however, that the OMP will probably not wish to utilize these materials due to their higher cost when compared with either fly ash or slag.

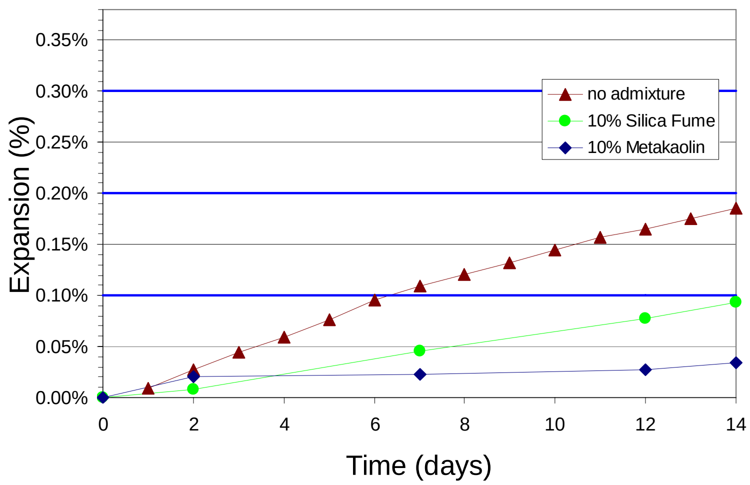

Figure 3. Expansion of mortars containing other admixtures.

Conclusions and Recommendations

Of the materials tested in this study, the Class F fly ash provided effective mitigation of a moderately reactive sand at replacement levels of 10% and higher, the slag provided effective mitigation at replacement levels of 30% and higher, the silica fume provided effective mitigation at a replacement level of 10%, and the metakaolin provided effective mitigation at a replacement level of 10%. The Class C fly ash did not provide effective mitigation at the level tested, 15%.

If it is necessary to use an aggregate producing more than 0.10% expansion when tested in this manner, it is recommended that a mineral admixture be required that is shown to be effective at reducing the expansion to a level less than 0.10%.