R&T UPDATE
Concrete Pavement Research & Technology

Alkali-Silica Reaction: Old Issue, New Cause

Interim Procedure for Screening and Mitigation of ASR Accelerated by Airfield Pavement Deicers for New Concrete Pavement Construction

Results of preliminary research investigating premature deterioration of concrete airfield pavements points to acceleration of ASR by Potassium Acetate deicers as the cause. It is unlike the traditional occurrence of ASR because it is caused by the presence of deicing chemicals, not simply the mixture components. Affected pavements are around 10 years old. The deterioration from the ASR gel-product occurs near the pavement surface, where the deicers penetrate the concrete, and not distributed throughout the pavement's depth like traditional ASR.

Surface deterioration on airfield pavements is unacceptable since it may lead to foreign object damage (FOD), where loose fragments are pulled into jet engines, damaging aircraft and compromising aircraft safety. The Federal Aviation Administration (FAA) has requested a solution to avoid this potential new deterioration mechanism. While there remains much to be learned about this new form of ASR, initial research through the IPRF/FAA research program has led to an interim procedure, which is described herein. Additional research will refine this procedure.

Research performed at Clemson and Purdue Universities suggests that the screening test normally used to identify reactive aggregates may not be accurate if the materials will be used in pavements subject to the suspect deicer chemicals. The *Standard Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method)*, ASTM C 1260, likely under-predicts the potential for deleterious concrete deterioration in this environment.

Airfield Pavement Deicers

The deicers that are being evaluated include Potassium Acetate (KA), Sodium Acetate (NaA) and Sodium Formate (NaF). Potassium Acetate is an anti-icing agent in liquid form that is applied to the pavement before a storm event. Sodium Acetate and Sodium Formate are granular products applied on top of snow and ice as a melting agent; therefore, they have the benefit of dilution in melt water. Compared to the standard sodium hydroxide (NaOH) soak solution, KA and NaF are more aggressive than the NaA.[1] Sodium Formate is not used extensively, so the data presented in this R&T Update is limited to the two most popular types of deicers, KA and NaA.

Accelerated ASR

Figure 1 provides a comparison of expansion rates of mortar bars made up of a known highly reactive coarse aggregate, and high alkali cement soaked in solutions of Potassium Acetate (KA), Sodium Acetate (NaA) and Sodium Hydroxide (NaOH) at 80°C.

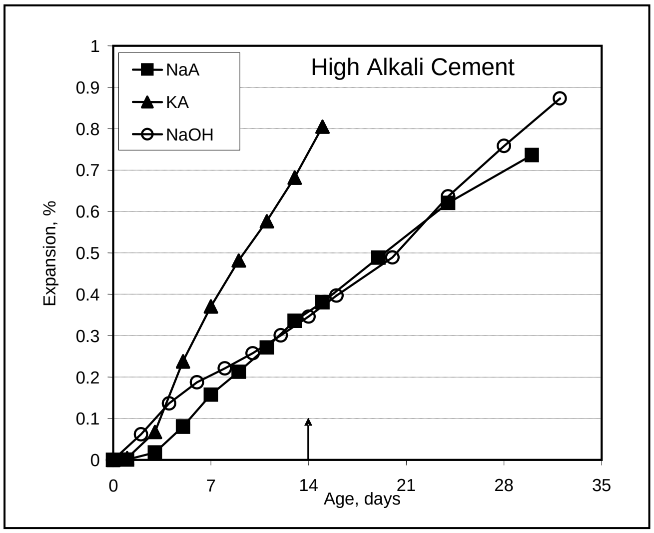

Figure 1. Mortar Bar Expansion in Presence of Deicing Chemicals Compared to the Standard Sodium Hydroxide.

NOTE: These results are from mixtures containing known reactive aggregates, high alkali cement, and no mitigation. Results with other materials will vary.

REFERENCE: See Reference 2.

Accelerated ASR as a result of deicer and aggregate reactivity has been correlated to surface deterioration on some airfield concrete pavements.[2] The research study has replicated this deterioration in the laboratory. In most instances, surface deterioration is often correlated to the deicer application patterns used by airfield maintenance personnel. The phenomenon is primarily seen in pavements less than 10 years old; but, less aggressive forms of deleterious activity also appear in pavements constructed long before the introduction of chemical deicers to the airfield industry. There are pavements on which deicer chemicals are being applied without adverse impact. At this time, the difference in response of pavements to these deicers has not been explained.

Modified Test Procedure

The interim approach to materials screening and mitigation evaluation is presented in the decision trees summarized in Figures 3, 4 and 5.

Each specific combination of materials presents a unique result, and therefore each combination of materials must be evaluated. To perform this evaluation, a modified ASTM C 1260 or C 1567 protocol is suggested to be used with the substitution of a deicing agent as the soak solution. Experience to date suggests that if the test includes using Potassium Acetate, then the other forms of chemical acceleration of ASR are usually satisfied. A protocol is available in Reference 3, available on www.iprf.org.

The initial step is to prepare a set of mortar bars using the coarse aggregate fraction for one set and the fine aggregate fraction for the second, each prepared as described in ASTM C 1260 or C 1567. The cement used for the testing should be the same used for the production concrete. If the expansion of the mortar bars exceeds 0.10% after soaking in a solution of Potassium Acetate deicer for 28 days[†], mitigation is required. Mitigation can be in the form of changing aggregate sources or including admixtures (chemical or mineral) as a part of the concrete mix proportions.

If the fine fraction mortar bars exhibit an excessive expansion rate, it may be a false positive. If the mineralogy of the fine fraction does not support the results reflected by testing, the test condition might be mitigated by combining the materials that will be used for the production concrete and running another mortar bar test on the combination.

[†] The actual test length in this procedure is 30 days when the two days for sample preparation are included. The standard duration is 16 days, but FAA requires 28 days of soaking to evaluate the expansion rate. FAA also requires the same expansion rate of 0.10% as required in the standard C 1260 or C 1567.

Mitigation for New Airfields

Figure 2 provides a summary of mitigation findings from the research study using aggregates similar to those used to evaluate reactivity given in Figure 1. Based on limited samples, the research findings imply that ground granulated blast furnace slag (GGBFS) at the 40% test dosage, and Class C or F fly ashes with higher lime contents were not as effective in mitigating the acceleration of ASR in the presence of airfield pavement deicers for highly reactive aggregates.[3] However, it is well known that different aggregates have different levels of reactivity with different cements, pozzolans, and slags at different dosages. If any supplementary cementing material is proposed as a mixture component, the materials test protocol in Figure 4 should be followed to determine if an effective mitigation dosage can be developed.

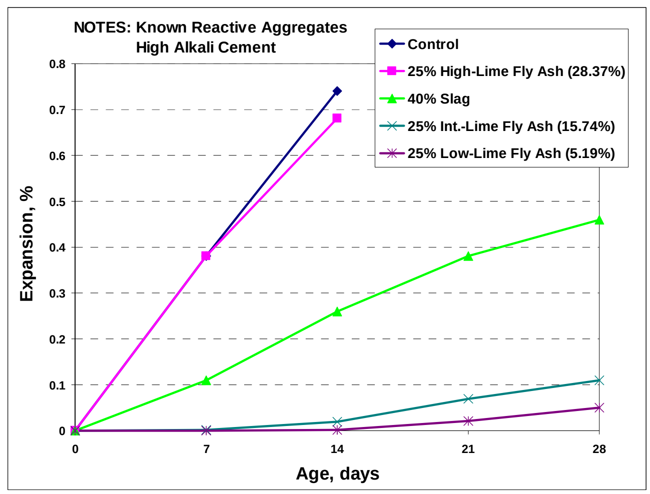

Figure 2. Effect of Certain Dosages of Fly Ash and Slag on Mortar Bar Expansion in the Presence of Potassium Acetate

REFERENCE: See Reference 2.

The study results showed that for Class F fly ash (CaO<15%) to be effective for mitigation, replacement rates greater than 15% are probably necessary.

When using Class F fly ash or other supplementary cementing materials, the impact of high replacement quantities (>20% cement replacement) on the plastic properties of production concrete must be considered. Class F fly ash, for example, can slow the rate of strength gain. Strengths for opening to traffic may not be met in the time desired. In many situations, it may be prudent to increase the thickness to allow for the lower "early strength." Concrete with high replacement quantities of fly ash must be evaluated for workability, finishability, and higher than normal dosage of air-entraining agents.

When reducing the quantity of cement, the mitigation of ASR and provision of overall durability must be maintained. A lower cement content, in combination with a fly ash for example, provides less alkali for ASR, but strength requirements must also be evaluated. Strength should not govern mixture proportioning; ASR mitigation and durability should be the primary consideration. Consideration should also be given to allow the use of 90-day strengths with correlations to 28-day strength for payment.

When the measured expansion is greater than 0.30% after mitigation has been included, it is reasonable that another aggregate source be considered. This is based upon experience and should not be used as "limiting" criteria.

Lithium Nitrate can be effective as an admixture for fresh concrete to mitigate traditional ASR and when Potassium Acetate (KA) and Sodium Acetate (NaA) are being used for deicing (Figure 5). The normal dosage is the amount necessary to maintain a 0.74 molar ratio. This is equal to 0.55 gallons per pound of sodium equivalent from the cement per cubic yard. When used within these dosage rates, the impact on the properties of plastic concrete are minimal. Total water and air content must be monitored.

Conclusion

All of the procedures described herein should be considered interim recommendations for developing a new concrete mixture that will be exposed to acetate based deicers. Certain requirements will be refined with further research:

- 28-day versus 14-day expansion test requirement
- 0.10% expansion threshold
- Effect of alkali loading in relation to the 0.30% expansion threshold
- Supplementary cementitious materials mitigation effectiveness (various types and dosages)
- Concentration of deicer test solutions
- Correlation with field concrete performance
- Performance with mildly and moderately reactive aggregates
- Appropriateness of a modified ASTM C 1260 or ASTM C 1567 to evaluate mitigation by lithium admixtures

A technique for assessing the potential for airfield deicer accelerated ASR of existing airfield concrete pavements is also currently being studied.

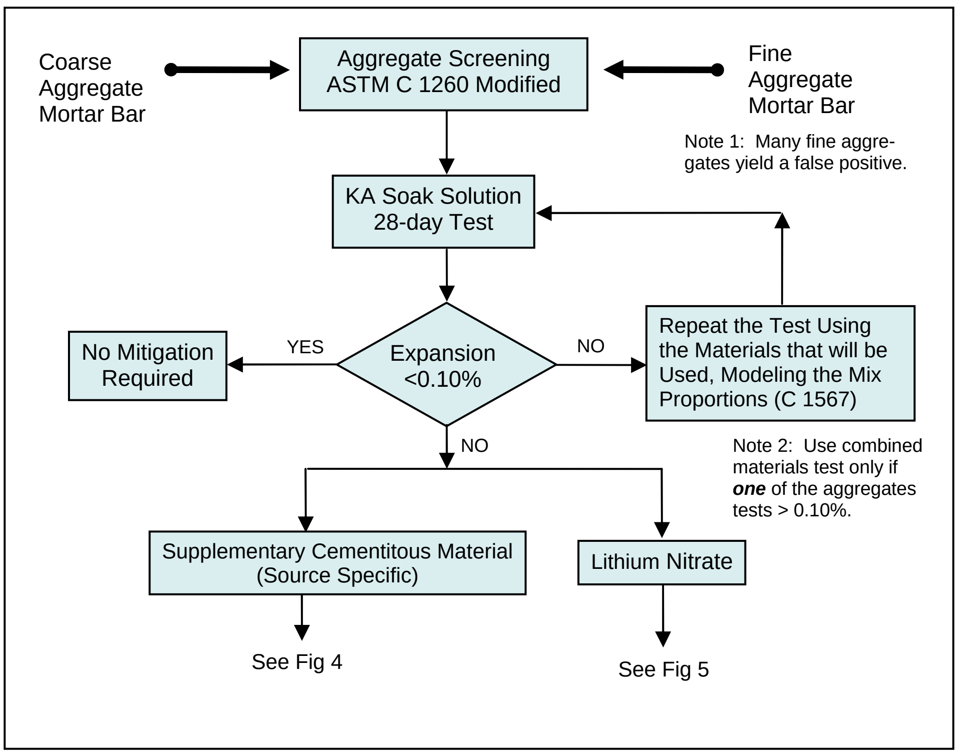

Figure 3. Aggregate Screening for Accelerated ASR Potential from Airfield Deicer Chemicals (Interim Approach)

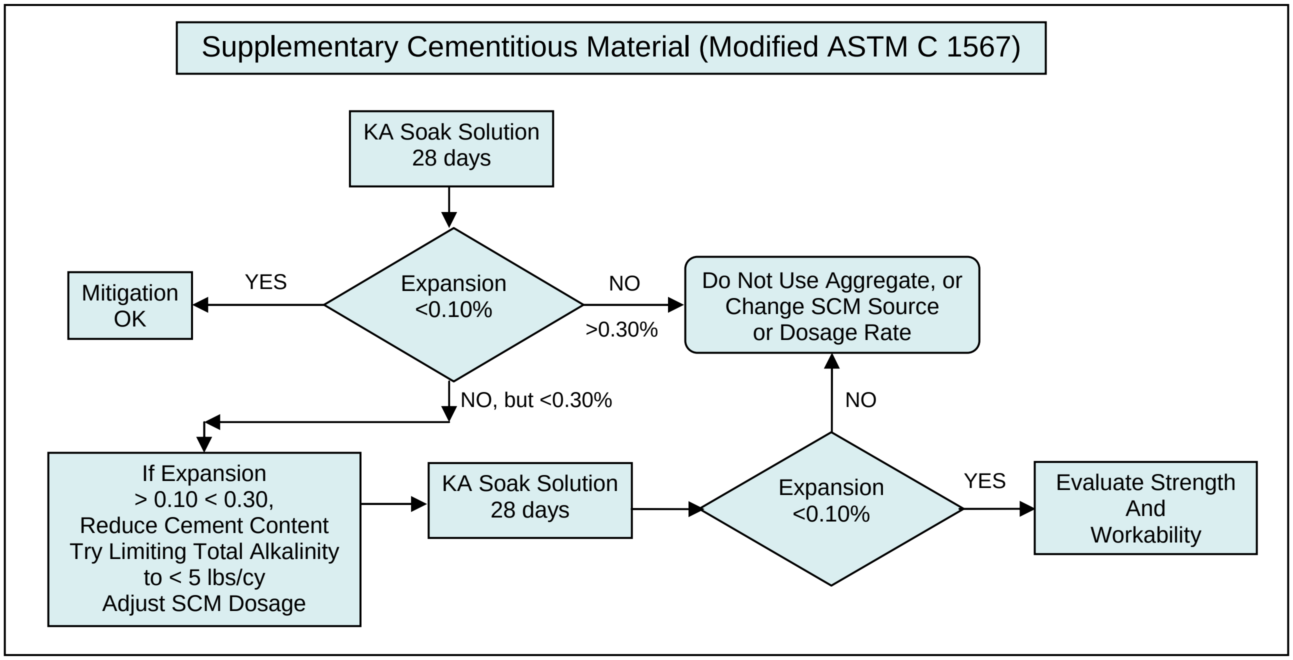

Figure 4. Mitigation of ASR Using Supplementary Cementitious Materials Using the Modified ASTM C 1567 Test (Interim Approach)

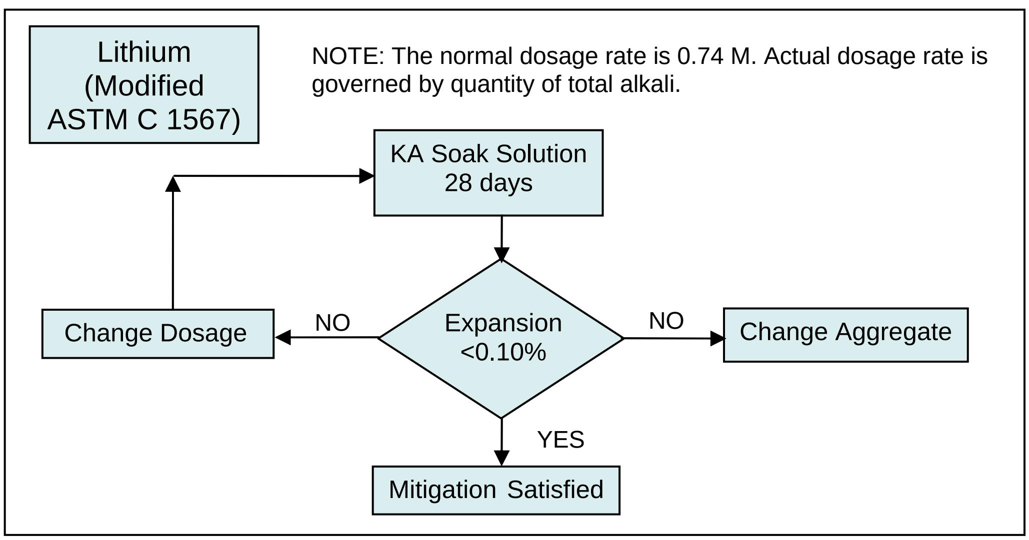

Figure 5. Lithium Used as a Mitigation Admixture Using the Modified ASTM C 1567 Test (Interim Approach)

References

1. *Potential for Development of Alkali-Silica Reaction (ASR) in the Presence of Airfield Deicing Chemicals*, Rangaraju, P.R., Sompura, K., Olek, J., Diamond, S., and Lovell, J., Proceedings of the 8th International Conference on Concrete Pavements, Colorado Springs, Colo., August 14-18, 2005, pp. 1269-1289.

2. Prasada Rangaraju, PhD, PE; Jan Olek, PhD, PE; *Potential for Acceleration of ASR in the Presence of Pavement Deicing Chemicals*; 20% Review Meeting, IPRF Project 01-G-002-03-9, Clemson University, Clemson, SC; November 5, 2004.

3. Prasada Rangaraju, PhD, PE; Jan Olek, PhD, PE; *Investigation into Mitigation of ASR in the Presence of Airfield Deicing Chemicals;* 60% Review Meeting, IPRF Project 01-G-002-04-8, Clemson University, Clemson, SC; September 8, 2005.