R&T UPDATE
Concrete Pavement Research & Technology
#11.01

Mitigating Deicer Induced Distress Potential

A Revision of an Interim Procedure

Background

In 2004, the conventional thinking was that an alkali-based deicer could be the cause of what appeared to be an accelerated Alkali Silica Reaction (ASR) in concrete pavement. Airfield pavements, less than 15 years old, exhibited surface distress similar in appearance to much older ASR distressed pavement. Airports that applied Potassium Acetate (Ka) deicer observed that pavements treated with Ka had a unique distress early in the life of the pavement and that pavements that were not treated had no distress. The association of Ka and an accelerated ASR was a logical concept.

A laboratory study [1,2] compared the expansion of mortar bars, using known reactive aggregate, soaked in either a field application concentration of Ka deicer or the standard ASTM C1260 protocol. The higher expansions of the mortar bars soaked in Ka as compared to the standard ASTM C1260 protocol was defined (Figure 1). A subsequent study, using mortar bars made from the same reactive aggregates, identified Class F (low lime) fly ash as a probable mitigator of the reaction that resulted in the expansion. The mitigation study was accomplished using ASTM C1567 protocol with the soak solution being Ka deicer (6.4M, as applied in the field).

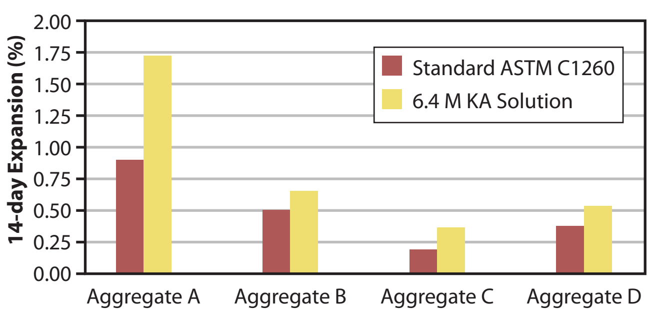


Figure 1. Measured expansion of mortar bars made of reactive aggregates.

The 2005 Interim Screening Procedure (Federal Aviation Administration [FAA] EB-70)

The positive association of known reactive aggregates and higher mortar bar expansion rates experienced with a Ka soak solution led to the publication of a protocol [2,3] intended to screen aggregates for sensitivity to Ka deicer. The screening protocol required that aggregates, both coarse and fine, be tested individually using the standard ASTM C1260 protocol and duplicate mortar bars soaked in a solution of Ka. An aggregate identified as having an expansion equal to or greater than 0.10%, in either soak solution, required mitigation. Mitigation could be in the form of changing aggregate sources, using fly ash, slag cement or lithium, or reducing the total alkali content by reducing the cement content.

Laboratory Observations and Field Conditions – The Missing Link

In the laboratory, the positive association of Ka and mortar bar expansion was factual. In the field, unexpected results in screening were witnessed. Some aggregates determined to be slightly reactive based upon ASTM C1260 testing (an expansion greater than 0.10% but less than 0.20%) exhibited little or no response to a Ka soak solution. The opposite was also seen. The use of a low lime (less than 10% CaO) Class F fly ash for mitigation of expansion in a Ka soak solution was favorable at substitution rates between 20% and 25%. Some contractors found that a full dose of lithium was not required based upon the results of screening. There was considerable inconsistency witnessed in the screening results when using EB-70; but more importantly, the link between screening results in the form of mortar bar expansion and pavement performance was missing.

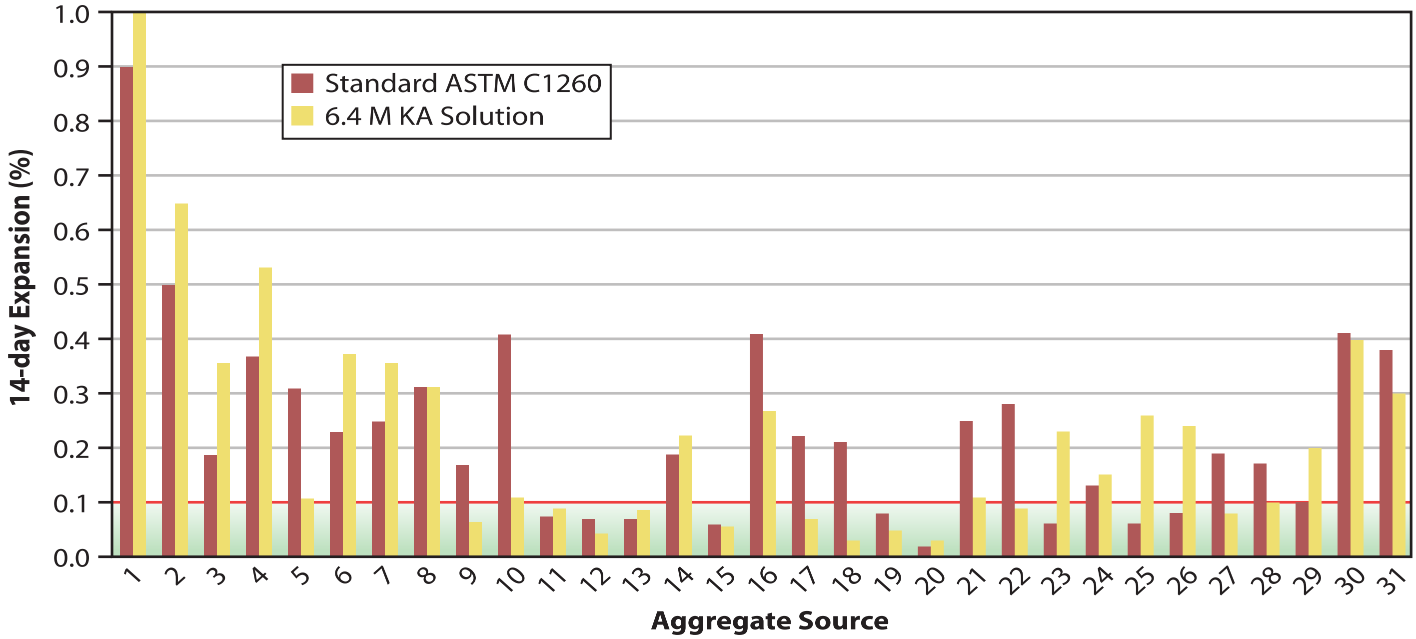


Figure 2. Measured expansion of mortar bars made from 31 different aggregates.

Forensic investigations on select pavement features at six airports, four with early pavement distress and two with no apparent distress, started in 2006. The intent was to identify the mechanism that results in early pavement distress and the possible link with Ka deicer. Of the six airports included in the study, ASR was prominent at three, Alkali Carbonate Reaction (ACR) was found at one and two airports lacked any positive evidence of ASR or ACR. Where ASR was present, the condition was seen to be for the full section (depth) of concrete. In all cases, the penetration depth of the Ka was found to be minimal, less than ½-inch. Pavement distress at the surface of the pavements was determined to be related to poor combinations of material choices and freeze-thaw damage.

Investigations of pavement distress at other airports continue. And, the link that relates Ka deicer – expansion of the mortar bars in a Ka soak solution and early pavement distress – has not been established. The general observation is that there is poor enforcement of material specifications and selection of material combinations.

A Screening Protocol for the Interim

The lack of consistency between the expansion of mortar bars soaked in Ka using EB-70 and those tested using the standard soak solution in ASTM C1260 protocol is a concern. To further understand the issue, the original four aggregates (numbered 1 through 4) and twenty-seven other aggregates (numbered 5 through 31) were incorporated into mortar bars. Using ASTM C1260 as a baseline of measure, the variability of mortar bar expansion in a Ka soak solution, as witnessed in the field, as compared to the mortar bar expansion of like specimens in a 1N NaOH solution was duplicated in the laboratory (Figure 2).

Mortar bars were made from each of the 31 aggregates and soaked in a solution made up of a 3M Ka + 1N NaOH[1] (Figure 3). Those mortar bars with an expansion greater than 0.10%, when using the standard ASTM C1260 protocol, were again identified. But, the magnitude of the expansion was generally much greater in the new soak solution. Those mortar bars determined to be innocuous under ASTM C1260 were again determined to be innocuous. In only one instance, aggregate 19, did the mortar bar soaked in the 3M Ka + 1N NaOH define an expansion greater than 0.10% when the baseline mortar bar had an expansion less than the 0.10% threshold.

Nineteen of the 31 mortar bars were also evaluated for mitigation potential using the 3M + 1N NaOH soak solution and the ASTM C1567 protocol. The baseline was the standard ASTM C1567 using the standard 1N NaOH as the soak solution (Figure 4). The aggregates included in the mortar bars were 1 through 4 and 17 through 31. The results suggest that a substitution of 25% Class F (low lime) fly ash will mitigate the expansion when the mortar bar is soaked in the 3M + 1N NaOH soak solution. Class C fly ash was not effective. With limited testing, there was no effective mitigation with slag cement at a 40% substitution rate. The results for lithium were mixed and not consistent. Additional research is required to develop a standard method of test for evaluation of the effectiveness of lithium in the presence of Ka deicer.

[1] The concentration of the field applied airfield Ka deicer used in EB-70 is 6.4M.

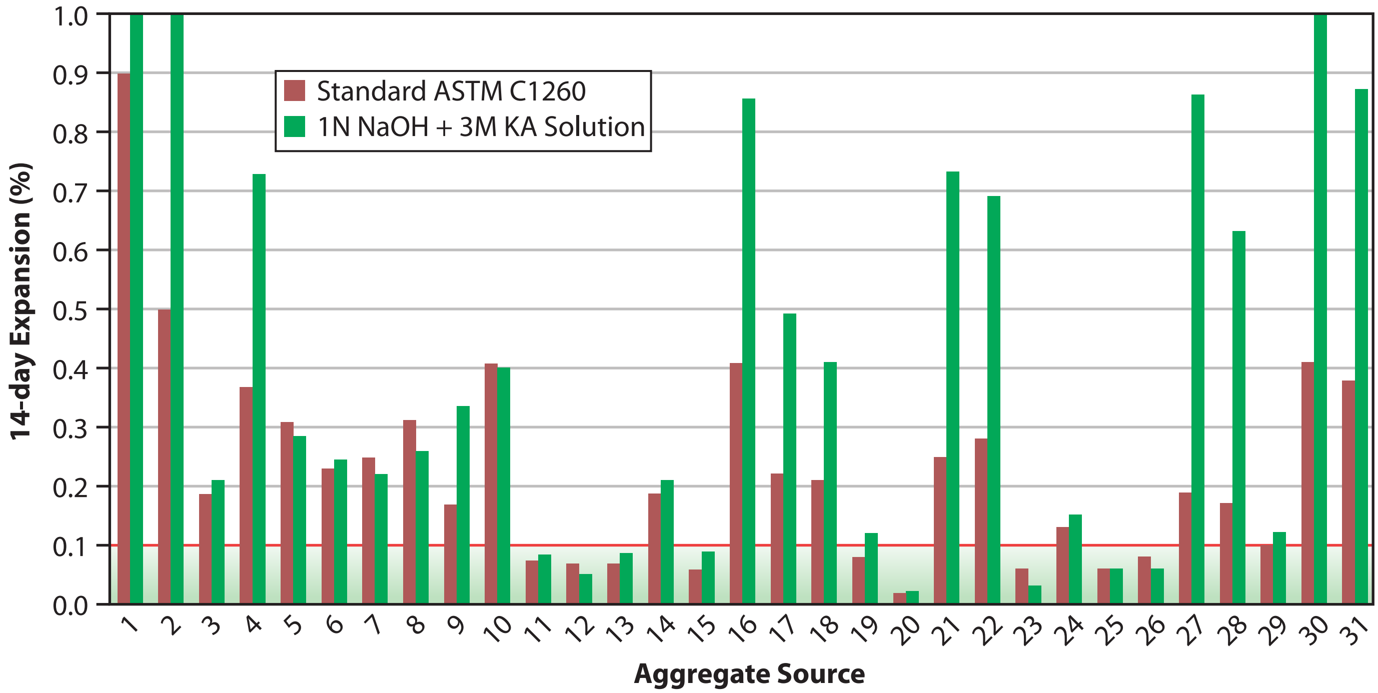


Figure 3. Measured expansion of companion mortar bars of Figure 2 with a soak solution of 3M Ka + 1N NaOH.

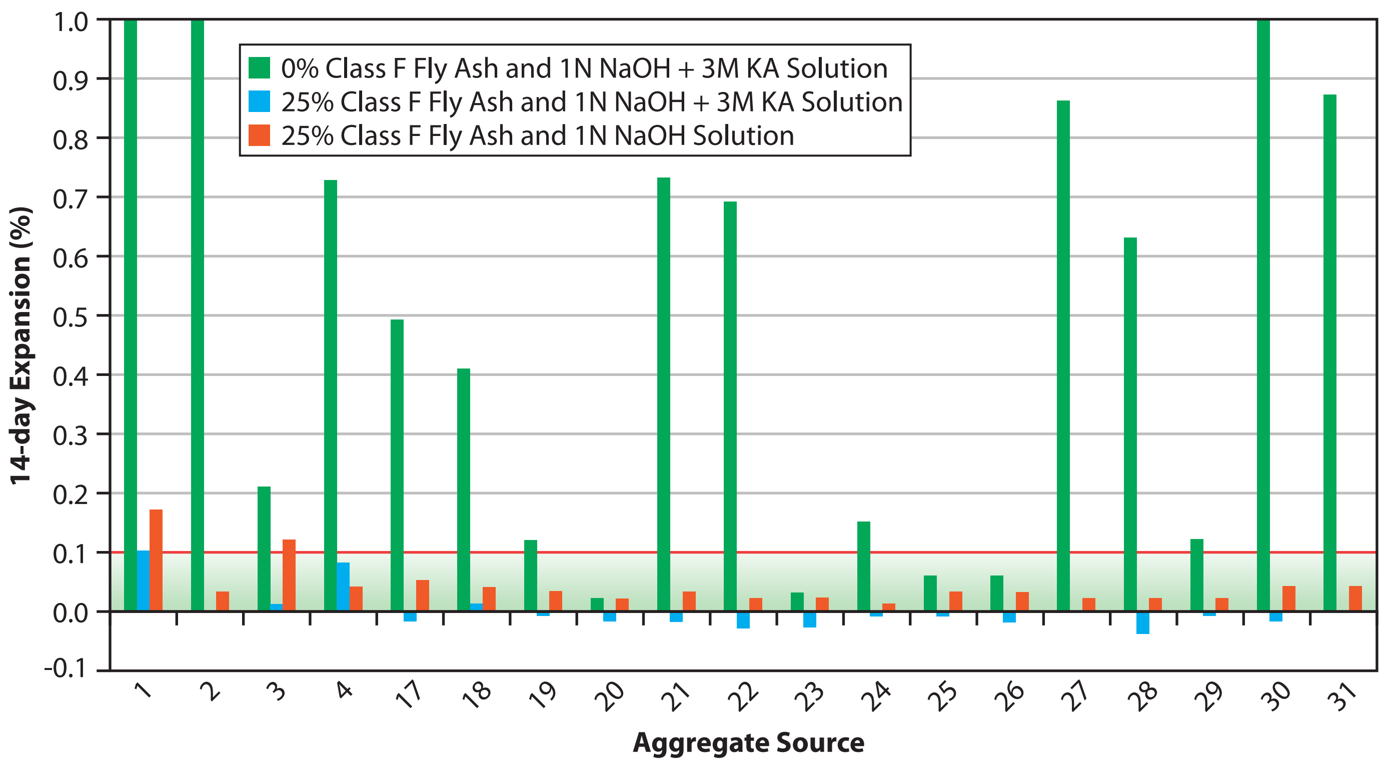


Figure 4. Measured expansion of mortar bars selected from the original 31 incorporating fly ash.

During the study involving a new soak solution, the baseline was ASTM C1260 and C1567. The correlation of the baseline data and the data for the new soak solution at 14 days and 0.10% expansion was good. The correlation using a 28-day soak was poor.

Reagent Grade Ka vs. Commercial Grade Deicers

The commercially available Ka deicers are patented and there is variability in the chemical make-up. In an effort to evaluate the influence that the deicers may have on the results of mortar bar tests, a parallel investigation was accomplished. A select number of mortar bars were soaked in a reagent grade Ka. There was no significant difference in the measured expansion of the bars soaked in the reagent grade Ka when compared to those immersed in a soak solution of commercial Ka deicer product.

Summary and Recommendations

Based upon the findings from pavement at six airports, the link between Ka deicer and ASR is found to be inconclusive. However, the expansion of mortar bars soaked in a Ka deicer as compared to companion bars soaked in a 1N NaOH solution cannot be ignored and further research is required. The studies are changing focus with interest being changed to look at the deicer and cement paste.

The lack of consistency in the results of screening aggregates for Ka deicer sensitivity reported at several construction projects has been repeated in the laboratory. Airports and contractors report confusion and duplication of effort in EB-70.

In response to these two issues, a refined screening protocol is proposed that will eliminate the requirement to prepare duplicate mortar bars. Changing the soak solution to a 3M Ka + 1N NaOH allows for screening of aggregate for both ASR potential and deicer sensitivity at the same time. The effective mitigation of both ASR and Ka sensitivity can be determined using ASTM C1567 and changing to the new soak solution. The current research indicates that a low lime Class F fly ash can be effective; Class C fly ash is not effective and slag cement may not be effective at dosage rates less than 40%. There must be more research on mortar bar testing and mitigation of expansion potential with lithium in the presence of Ka.

The use of the current Federal Aviation Administration (FAA) Engineering Brief (EB) No. 70, Accelerated Alkali-Silica Reactivity in Portland Cement Concrete Pavements Exposed to Runway Deicing Chemicals, 2005 [4], should be discontinued. A refined protocol using the soak solution of 3M Ka + 1NaOH should be used (see Appendix B) until a conclusive statement can be made relative to Ka deicer and the surface durability of concrete airfield pavement.

In these studies, there was a better correlation with the baseline result measured when using ASTM C1260 when the soak time was 14-days. When a 28-day soak time of mortar bars was used in the refined protocol, the correlation of the results was poor. The refined protocol should be implemented using the ASTM C1260 standard soak time of 14-days and limit of expansion of less than 0.10%.

References

1. Rangaraju, P.R. and Olek, J., "Potential for Acceleration of ASR in the Presence of Pavement Deicing Chemicals," IPRF-01-G-002-03-9, 2007, http://iprf.org/products/IPRF%2003-9%20FINAL%20REPORT.pdf.
2. Rangaraju, P.R., "Mitigation of ASR in Presence of Pavement Deicing Chemicals," IPRF-01-G-002-04-8, 2007, http://iprf.org/products/IPRF%2004-8%20FINAL%20REPORT.pdf.
3. "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," ACPA R&T Update #6.04, 2005, http://www.pavement.com/Downloads/RT/RT6.04.pdf.
4. "Engineering Brief No. 70, Accelerated Alkali-Silica Reactivity in Portland Cement Concrete Pavements Exposed to Runway Deicing Chemicals," FAA EB-70, 2005, http://www.faa.gov/airports/engineering/engineering_briefs/media/EB_70.pdf.

Appendix A:
Preparation of 3M Potassium Acetate (KA) + 1N Sodium Hydroxide (NaOH) Soak Solution for Use in the Modified ASTM C1260 and Modified ASTM C1567

Materials

Potassium Acetate (KA or, in formula notation, CH_3COOK)—USP or technical grade with at least 99% purity may be used. Alternatively, commercial grade potassium acetate deicer solution may be used, provided the concentrations are determined by chemical analysis. Most commercial grade potassium acetate deicer solutions have a potassium acetate concentration of 50% by weight of the solution. These commercial grade deicer solutions also contain small amounts of other functional ingredients such as corrosion inhibitors and coloring agents.

Sodium Hydroxide (NaOH)—USP or technical grade may be used provided the Na+ and OH- concentrations are shown by chemical analysis to lie between 0.99N and 1.01N.

Water—Water used to prepare soak solutions shall be understood to mean reagent water conforming to Type IV of ASTM D1193.

Preparation of Solution

3M Potassium Acetate (KA) + 1N Sodium Hydroxide (NaOH) Solution—When the soak solution is prepared using reagent grade chemicals, each liter of the soak solution shall contain 294.45 g of anhydrous CH_3COOK and 40.0 g of NaOH dissolved in 800 mL of water, and shall be diluted with additional distilled or deionized water to obtain 1.0 L of solution. The volume proportion of the solution to mortar bars in a storage container shall be 4 ± 0.5 volumes of solution to 1 volume of mortar bars. The volume of a mortar bar may be taken as 184 mL. Include sufficient solution to ensure complete immersion of the mortar bars.

Appendix B:
2011 Interim Procedure for Screening Aggregates and Mitigating Deicer Distress Potential

The recommended screening procedure for aggregates used in airfield concrete pavements in an effort to select sound aggregates and mitigate deicer induced distress is a multi-step process (see Figure B-1):

Deicer Induced Distress Potential:

If deicing (or anti-icing) chemicals will be used on the pavement, a modified aggregate screening test should be used. The intent is not to replace the standard sodium hydroxide soak tests but, rather, to use the protocol to screen for both ASR and deicer induced potential.

Both deicer-based test methods presented below use a 3M potassium acetate (KA) deicing agent + 1N sodium hydroxide (NaOH) soak solution (see Appendix A) and both tests should be run for 16-days after casting (14-day soak) as described in the ASTM C1260 and ASTM C1567 standards.

a. **Modified ASTM C1260:** Mortar bars, one with coarse and one with fine aggregate, are tested independently. It is assumed that each aggregate has already been screened for freeze thaw durability.

   i. If the 16-day expansion is *less than* 0.10%, the respective aggregate is accepted as innocuous for both ASR potential and deicer-induced distress.

   ii. If the 16-day expansion *equals or exceeds* 0.10% for an aggregate, a mitigation technique is required. Mitigation can be in the form of changing aggregate sources or including admixtures (chemical or mineral[2] [e.g., Class F fly ash[3]]) in the mortar bars. The aggregate is then tested using a modified ASTM C1567.

b. **Modified ASTM C1567:** Again, mortar bars, one with coarse and one with fine aggregate, are tested independently.

   i. If the 16-day expansion is *less than* 0.10%, the mitigation agent is considered effective in minimizing the potential for a deleterious reaction in the concrete mixture in the presence of deicers.

   ii. If the 16-day expansion *equals or exceeds* 0.10%, action such as reducing the cement content[4] by limiting the total alkalinity to <5 lb/yd^3 or adjusting the dosage of the SCM(s) is necessary and the aggregate is retested per modified ASTM C1567.

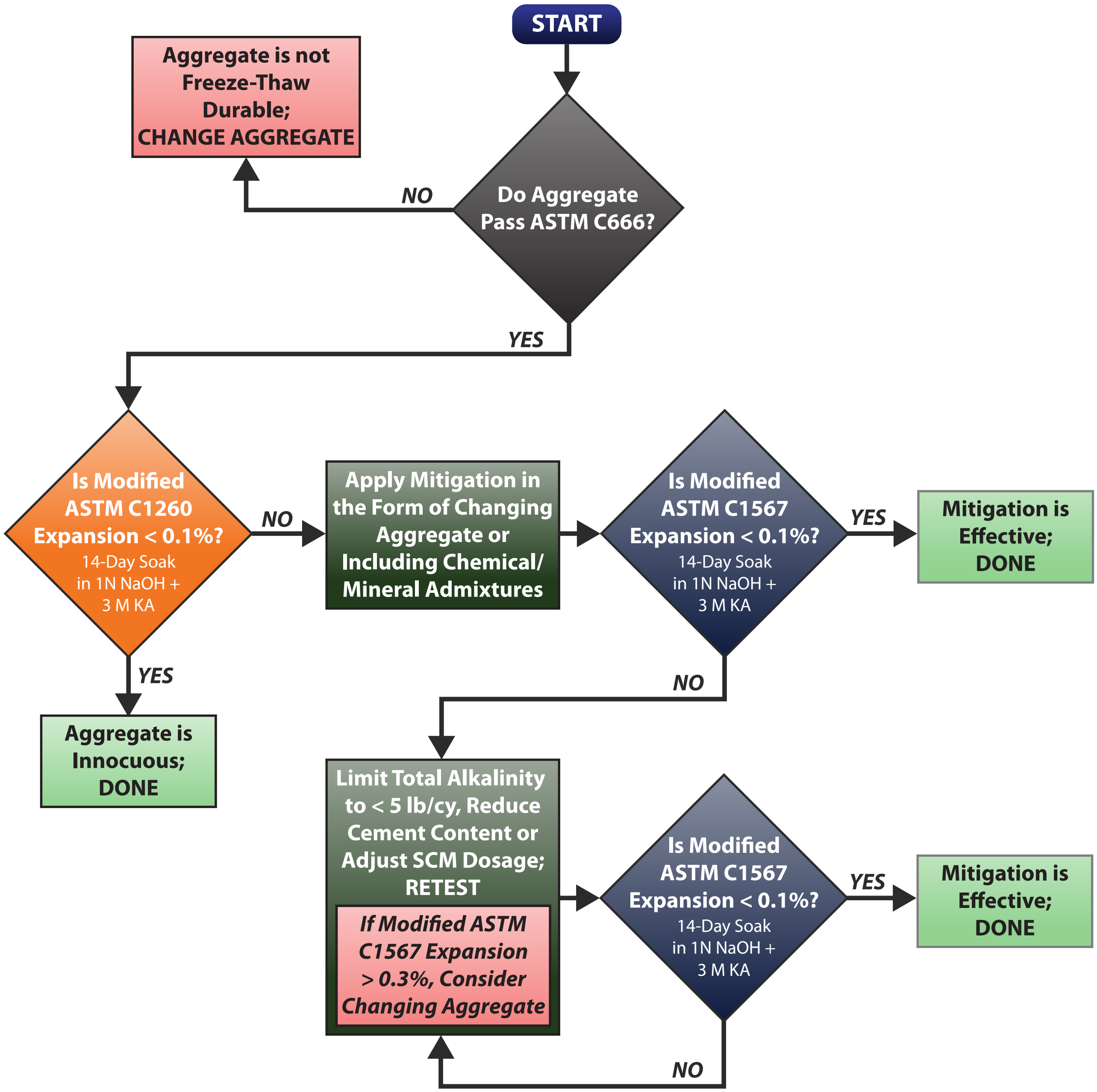
   iii. If the 16-day expansion *exceeds* 0.30% after mitigation has been included, it is reasonable that another aggregate source be considered. This threshold is based upon experience and should not be used as a "limiting" criterion.

---

[2] When reducing the quantity of cement, the mitigation of ASR and provision of overall durability must be maintained. 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 be the sole parameter to govern mixture proportioning; ASR mitigation and durability should be the primary consideration.

[3] When using Class F fly ash or other supplementary cementing materials (SCMs), the impact of high replacement quantities (>35% cement replacement) on the plastic properties (e.g., workability, finishability, effects on air-entraining, etc.) of production concrete must be considered. Class F fly ash 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." Consideration should also be given to allow the use of 90-day strengths with correlations to 28-day strength for payment.

[4] When the cement content of the concrete is being reduced for the purpose of limiting alkali, it is necessary to modify either ASTM C1260 or ASTM C1567 for the evaluation of the mitigation. A laboratory experienced in screening aggregates using mortar bars or other tests should be employed.



NOTE:
- The modified ASTM C1260 and modified ASTM C1567 tests are conducted on the coarse and fine aggregate separately.
- NaOH = Sodium Hydroxide
- KA = Potassium Acetate

Figure B-1. Recommended screening procedure for aggregates used in airfield concrete pavements.

9450 W Bryn Mawr Ave, Suite 150, Rosemont, IL 60018
Tel.: 847.966.2272; Fax: 847.966.9970; www.acpa.org