DEPARTMENT OF DEFENSE
UNITED STATES OF AMERICA

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS AIR FORCE CIVIL ENGINEER SUPPORT AGENCY

9 FEB 2006

FROM: HQ AFCESA/CESC
139 Barnes Drive Suite 1
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SUBJECT: **Engineering Technical Letter (ETL) 06-2: Alkali-Aggregate Reaction in Portland Cement Concrete (PCC) Airfield Pavements**

1. Purpose. This ETL provides guidance on identification, maintenance, and avoidance of alkali-aggregate reaction problems in Air Force Portland cement concrete (PCC) airfield pavements. It provides testing protocols for identifying potentially reactive aggregate and required mitigation actions if such aggregates are used in PCC for airfields.

Note: The use of the name or mark of any specific manufacturer, commercial product, commodity, or service in this ETL does not imply endorsement by the Air Force.

2. Application. The requirements of this ETL are mandatory.

2.1. Authority: Air Force Policy Directive (AFPD) 32-10, *Air Force Installations and Facilities*, and Air Force Instruction (AFI) 32-1023, *Design and Construction Standards and Execution of Facility Construction Projects*.

2.2. Coordination: Major command (MAJCOM) pavement engineers.

2.3. Effective Date: Immediately.

2.4. Intended Users:

- Air Force MAJCOM pavement engineers
- Base civil engineers (BCE), RED HORSE, and other units responsible for design, construction, maintenance, and repair of airfield pavements
- U.S. Army Corps of Engineers (USACE) and Navy offices responsible for Air Force design and construction

3. Referenced Publications.

3.1. Air Force:

- AFPD 32-10, *Air Force Installations and Facilities*, available at http://www.e-publishing.af.mil/
- AFI 32-1023, *Design and Construction Standards and Execution of Facility*

Construction Projects, available at http://www.e-publishing.af.mil/

3.2. Joint:

- Unified Facilities Guide Specification (UFGS) 02753, *Concrete Pavement for Airfields and Other Heavy-Duty Pavements More Than 10,000 Cubic Yards*, available at http://www.ccb.org/docs/ufgshome/UFGSToc.htm

3.3. Government:

- Federal Highway Administration Publication No. FHWA-RD-03-047, *Guidelines for the Use of Lithium to Mitigate or Prevent Alkali-Silica Reaction (ASR)*, available at http://www.tfhrc.gov/pavement/pccp/pubs/03047/

3.4. American Society for Testing and Materials (ASTM):

- ASTM C 150, *Standard Specification for Portland Cement*, available at http://www.astm.org
- ASTM C 295, *Standard Guide for Petrographic Examination of Aggregates for Concrete*, available at http://www.astm.org
- ASTM C 441, *Standard Test Method for Effectiveness of Pozzolans or Ground Blast-Furnace Slag in Preventing Excessive Expansion of Concrete Due to the Alkali-Silica Reaction*, available at http://www.astm.org
- ASTM C 595, *Standard Specification for Blended Hydraulic Cements*, available at http://www.astm.org
- ASTM C 618, *Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete*, available at http://www.astm.org
- ASTM C 856, *Standard Practice for Petrographic Analysis of Hardened Concrete*, available at http://www.astm.org
- ASTM C 989, *Standard Specification for Ground Granulated Blast-Furnace Slag for Use in Concrete and Mortars*, available at http://www.astm.org
- ASTM C 1260, *Standard Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method)*, available at http://www.astm.org
- ASTM C 1293, *Standard Test Method for Determination of Length Change of Concrete Due to Alkali-Silica Reaction*, available at http://www.astm.org
- ASTM C 1567, *Standard Test Method for Determining the Potential for Alkali-Silica Reactivity of Combinations of Cementitious Materials and Aggregate (Accelerated Mortar Bar Method)*, available at http://www.astm.org

4. Acronyms and Terms:

AFB	- Air Force Base
AFCESA	- Air Force Civil Engineer Support Agency
ANG	- Air National Guard
ASR	- alkali-silica reaction
ASTM	- American Society for Testing and Materials
BCE	- base civil engineer
CaO	- calcium oxide
DOD	- Department of Defense

ERDC - Engineer Research and Development Center
ETL - Engineering Technical Letter
FHWA - Federal Highway Administration
FOD - foreign object damage
IPRF - Innovative Pavement Research Foundation
MAJCOM - major command
Na_2O_{eq} - sodium oxide equivalent
PCC - Portland cement concrete
RED HORSE- Rapid Engineers Deployable - Heavy Operations Repair Squadron
UFGS - Unified Facilities Guide Specification

5. Objective. This ETL provides information on the resurgence of destructive alkali-silica reaction (ASR) in Air Force PCC airfield pavements, briefly reviews the mechanism of the ASR reaction, explains how to identify ASR in the field, summarizes Air Force experience in trying to maintain pavements with ASR, and discusses available alternatives to avoid ASR in new pavements. The other form of alkali-aggregate reaction known as alkali-carbonate reaction is rare and has not been observed in Air Force pavements. Suggestions are provided for identifying when such a reaction may be a problem and if additional help is needed with this potential problem.

6. Cautions. This ETL provides interim guidance and reflects consensus opinions on best practices to minimize and mitigate ASR problems on Air Force airfields. This is an evolving field of knowledge and following this ETL guidance will not necessarily prevent ASR in all cases. Guidance and criteria from older standard texts, reports, references, manuals, and guide specifications may be out of date and no longer valid. HQ AFCESA should be contacted for assistance and clarification on ASR issues.

7. Background.

7.1. In the last decade, the Air Force has suffered destructive ASR to airfield pavements on at least nineteen air bases in nine states and two foreign countries. Where this destructive reaction between the alkalis in the concrete and certain types of aggregate has occurred, the airfield pavement generally requires extensive and on-going maintenance and poses increased foreign object damage (FOD) hazard to aircraft. ASR has been identified in every state in the U.S. except one.

7.2. ASR in concrete was first described in 1940. The military issued guidance for controlling ASR in airfield pavements based on research conducted in the 1940s and 1950s. However, by the mid-1990s, pavements built in accordance with that guidance were showing damage from ASR—in some cases in as little as five years after construction. In response to these problems, ad hoc modifications were made to UFGS 02753, *Concrete Pavement for Airfields and Other Heavy-Duty Pavements More Than 10,000 Cubic Yards*, to try to limit new ASR problems. The existing guidance in the UFGS and this ETL is interim guidance only. There are active research programs underway on ASR in pavements through the Federal Aviation Administration (FAA) -sponsored Innovative Pavement Research Foundation (IPRF) program, by state departments of transportation, and other organizations. As these efforts provide new information, Air Force guidance will be modified to reflect this new knowledge. It is important to recognize that the guidance in this ETL represents the best current recommendations for dealing with ASR in Air Force pavements, but it is not the final answer.

7.3. Several factors have contributed to the re-emergence of ASR as a pavements problem, including the following:

7.3.1. Changes in Portland cement manufacturing processes led to an increase in alkali content of commercially available conventional Portland cement from an approximate average of about 0.4 percent in the past to around 1.2 percent today. This increase was partially driven by the increase in energy costs starting in the 1970s which favored shifting from a wet-grind process to a dry-grind process and partially by stricter modern air emission standards. Portland cements that are specially manufactured to be designated as *low alkali* must have 0.60 percent or less alkali content (sodium oxide equivalent [Na_2O_{eq}] as defined in ASTM C 150, *Standard Specification for Portland Cement*). However, previous research recognized that this limit was not completely effective—alkali contents between 0.45 and 0.60 percent may react whereas contents of 0.40 percent or less rarely did. The 0.60 percent alkali limit represents a compromise between economic production and technical considerations. Today, modern low-alkali cements almost invariably crowd this 0.60 percent allowable upper limit for the same reasons the average alkali content of regular cements has increased. Use of low-alkali cements alone is not sufficient to protect against ASR.

7.3.2. Aggregates that passed available tests for reactivity have reacted over long periods of time and have caused cracking and expansion in concrete.

7.3.3. Serious damage to concrete from alkali-aggregate reaction has occurred in places where it was previously unknown.

7.3.4. Certain slow-reacting aggregates have been identified that were not previously understood or recognized.

7.3.5. Modern concrete mixtures typically include a complex mix of other ingredients (e.g., admixtures, pozzolans) besides the traditional Portland cement and aggregates that may impact these ASR reactions. Alkalis may be provided by internal ingredients (e.g., Portland cement, fly ash, admixture, aggregates, mix water) or external sources (e.g., deicing salts, ground water, seawater). At present there is no consensus on how to effectively set or even measure a limit on the combined alkali content from all sources (e.g., Portland cement, fly ash, air entraining admixture). As air emission standards tighten, the alkalinity of products such as Portland cement or fly ash will tend to rise.

7.3.6. Aggregates are increasingly scarce in many areas today, and there is often pressure to use aggregates from new sources or aggregates of marginal quality. These aggregates may not have been adequately assessed for potential reactivity.

7.3.7. As a matter of policy, the military has increasingly shifted responsibility for concrete and its constituents to the contractor and conducts relatively few independent tests on any of the cement, aggregates, or other constituents used in concrete for military airfields. Previously, government laboratories performed all aggregate testing and approval, identified approved sources of aggregates, and developed the concrete mixture proportions for military airfields. Not all contractors and concrete producers have proven ready for this shift in responsibility. Previously, government laboratories had lengthy periods to carry out laboratory testing and approval of potential aggregate sources before construction bids were solicited. In contrast, the contractor now must carry out such assessments very rapidly in order to prepare bids and, if the successful bidder, avoid delaying construction.

7.3.8. There is evidence that certain anti-icing and deicing chemicals used on airfield pavements may accelerate ASR and may hinder the effectiveness of some ASR mitigation methods.

7.3.9. Alkali-aggregate reactions are relatively slow, and it may take years or decades for symptoms to appear in the pavement. Consequently, it is practically impossible to hold the contractor responsible for placing such defective material. Correspondingly, there is little incentive for the contractor to take adequate measures to protect against alkali-aggregate reactions since such measures tend to increase the construction and testing cost and make the contractor less competitive in the low-bid military construction arena. This is a particular concern for design-build contracts that are becoming increasingly popular in the military for procurement of airfield pavements and many other facilities.

8. What is Alkali-Aggregate Reaction? There are two types of recognized alkali-aggregate reaction: alkali-silica reaction (ASR) and the much rarer alkali-carbonate reaction. In each case, alkalis that are present in the concrete in the Portland cement, fly ash, admixtures, aggregates, or other sources react with siliceous minerals in the fine or coarse aggregate (ASR) or with some dolomitic carbonate aggregates (alkali-carbonate reaction). This reaction forms a hydrophilic (water-loving) gel around the aggregate particles that absorbs water and causes internal expansive pressure in the concrete. Alkali-aggregate reaction can be harmless or very destructive, with severe cracking and popouts that pose a severe FOD hazard to aircraft and concrete expansion that damages adjacent pavement, shoulders, and structures. Only ASR has been encountered on Air Force bases and will be the focus of this ETL. Three items are necessary for ASR to develop: reactive aggregates, alkalis, and water.

8.1. Aggregates. Reactive aggregates have been identified in almost every state in the U.S. They are found widely around the world and are common in many areas of

Southwest Asia. In the continental United States, the following types of aggregates have reportedly caused destructive ASR reaction problems:

Atlantic Seaboard (Maine to Georgia): primarily metamorphic rocks such as gneiss, granite-gneiss, schist, quartzite, metagraywacke, metavolcanics, chert.

Southern States (Florida to Texas): primarily chert and quartzite with some opaline and chalcedonic carbonates and shales.

Midwest (Ohio to Minnesota and Missouri): opaline to chalcedonic carbonates, shales, and sandstones.

Great Plains (North Dakota to Oklahoma, and Colorado): opaline to chalcedonic carbonates, shales, and sandstones.

Basin and Range (Montana to Arizona): glassy to cryptocrystalline rhyolite to andesite volcanics and chert.

Pacific Coast (Washington to California): glassy to cryptocrystalline rhyolite to andesite volcanics, chert, opaline sedimentary rocks.

Aggregates throughout the U.S. and the world have been found to be reactive. No fine or coarse aggregate to be used in military airfield pavement concrete can be assumed automatically to be non-reactive. Because the Portland cement alkali contents have increased and modern concrete mixtures are increasingly complex with a variety of admixtures and pozzolans, past experience with an aggregate is not sufficient to judge if it will be reactive or not. An aggregate that was not reactive in the past may react with the higher alkali content typical of modern cements and concrete mixtures. The long ASR reaction time of years or even decades further complicates trying to use past history for acceptance of an aggregate as non-reacting. Consequently, all aggregates to be used in Air Force PCC airfield pavements must be tested as described in this ETL.

8.2. Low-alkali cements were the traditional defense against ASR when reactive aggregates were used in concrete mixtures. However, military airfield concrete mixtures with low-alkali cements have recently suffered destructive ASR reactions. Simply specifying low-alkali cement alone cannot be assumed adequate protection for all aggregates.

8.3. Even in arid regions, adequate water is present to support ASR reactions in concrete pavements. Water vapor from under the pavement is often sufficient to maintain ASR reactions and attempts to seal the pavement to prevent water entry have not been successful.

9. Field Symptoms of ASR. The ASR gel (Figure 1) around or within the reacting aggregates absorbs water and increases in volume. This can lead to cracking as the tensile strength of the concrete is exceeded, surface popouts from internal compressive forces caused by gel growth, and overall expansion of the mass of concrete.

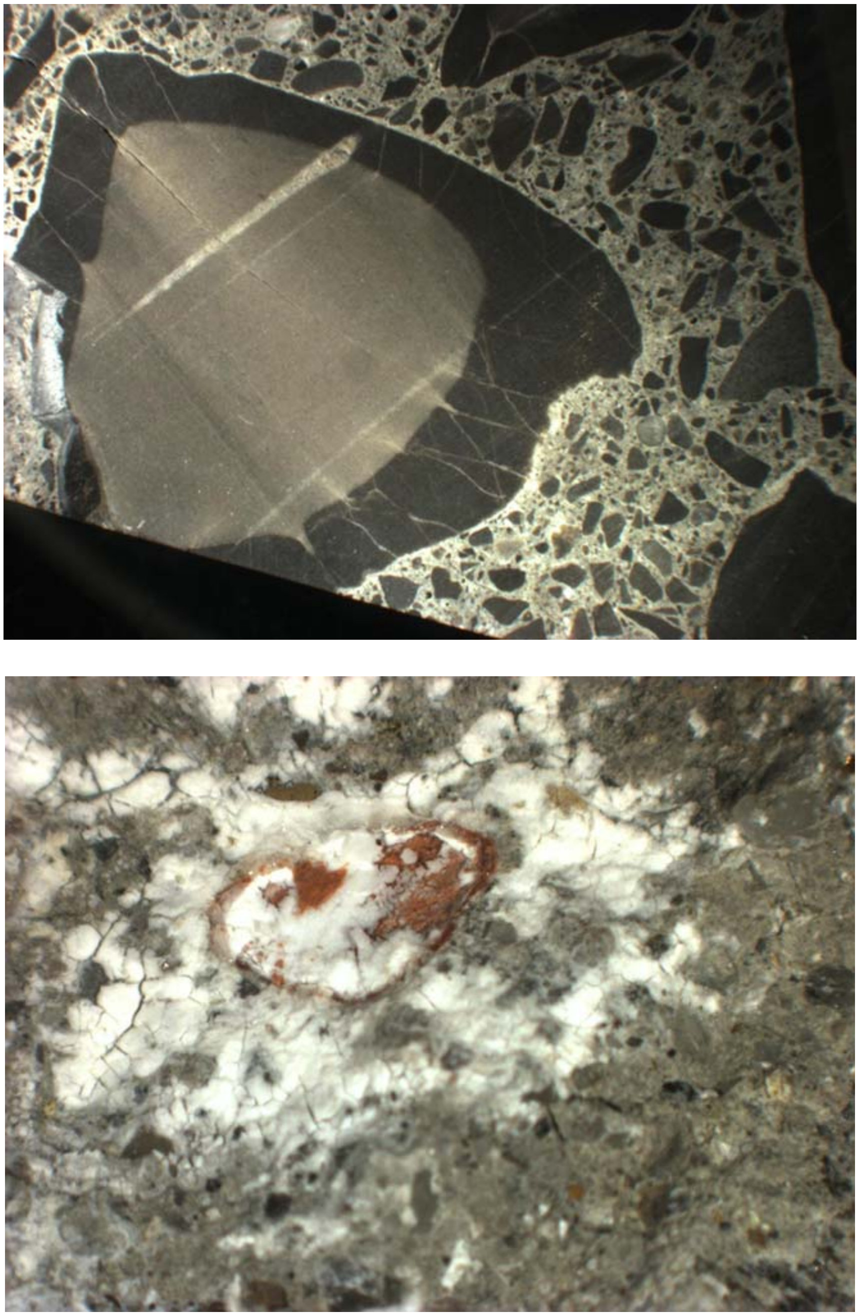

Figure 1. Examples of Alkali-Aggregate Gel. It may appear as a dark rim around an aggregate particle (top) or as a light-colored deposit on or within the aggregate or in the surrounding matrix (bottom). Note cracks caused by the expansion of the gel in the aggregates and paste.

9.1. Cracking. There are many causes of cracking in concrete, ranging from induced load to poor slab geometry to premature loss of water. Concrete cracking caused by

ASR tends to develop some characteristic patterns that help identify it. As the reacting aggregates increase in volume within the concrete matrix, the accumulating concrete expansion exceeds the strength of the concrete. This develops a characteristic map cracking such as seen in Figures 2 through 4. In runways, taxiways and similar geometries, the mass of concrete along the feature's length provides restraint in the longitudinal direction so the greatest concrete expansion tends to be laterally. This forms predominately longitudinal cracking such as seen in Figures 2 and 3. Where there is no particular preferred direction of restraint, as in a ramp, the cracking pattern will be more random. This is seen in Figure 4. The presence of reinforcing steel may also lead to restraint and influence crack patterns. ASR-induced cracks may contain deposits that range from white to transparent and may be waxy to hard (Figure 5). These deposits may be ASR gel or they may be other deposits from totally different sources. It is impossible to know its origin without a chemical analysis of the material. Consequently, neither the presence nor the absence of such visible deposits can be considered as any indication that ASR is or is not present.

Figure 2. ASR-induced Cracking on Taxiway, Holloman AFB. Note cracks are preferentially longitudinal and continue across transverse joints.

Figure 3. ASR-induced Cracking in Taxiway at Channel Island ANG Facility. Note cracks are preferentially longitudinal and continue across transverse joints.

Figure 4. ASR-induced Cracking in Ramp at Tinker AFB. Note cracks are random (without the preferential longitudinal orientation seen in Figures 1 and 2) and continue across joints.

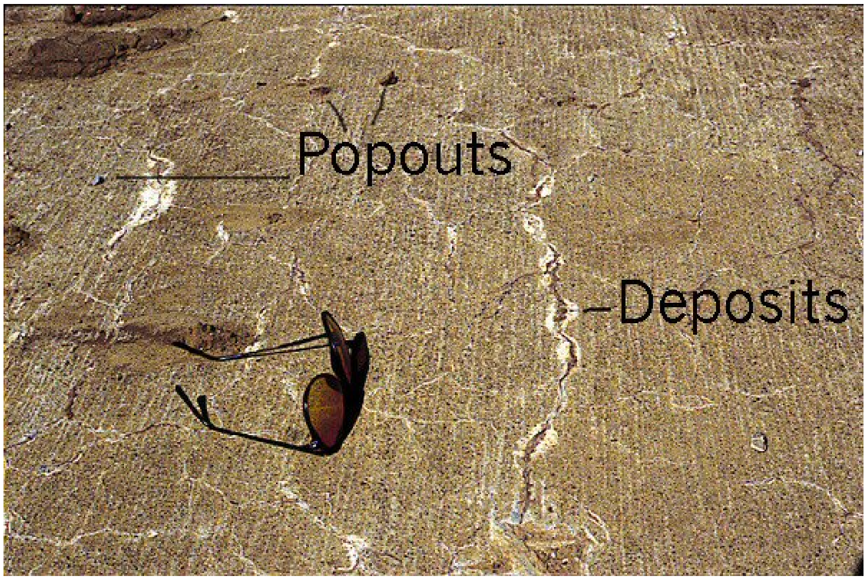

Figure 5. Example of Popouts and Deposits at Cracks, Tinker AFB. The deposits may or may not be related to ASR and require a chemical analysis if their origin is to be determined.

9.1.1. Cracking from ASR can easily be confused with plastic shrinkage cracking and D-cracking. Plastic shrinkage cracking often forms polygonal map cracking similar to the ASR cracking in Figure 4. It is a construction defect caused by excessive moisture loss from the concrete at early ages. Plastic shrinkage cracking forms immediately after construction and is usually clearly noticeable within a few days or weeks. On the other hand, ASR cracking will not appear for a number of years. Plastic shrinkage cracking is often a relatively minor surface blemish and extends only a fraction of an inch below the surface, although in extreme cases it can be deeper. In contrast, ASR cracking is prevalent throughout the concrete mass.

9.1.2. D-cracking is caused by freezing-and-thawing deterioration of certain vulnerable coarse aggregates. The cracking forms where moisture is most abundant in the slab—adjacent to joints and on the bottom of the slab. As cracking progresses, more water can enter the pavement and deterioration expands further into the slab. D-cracking tends to form cracks parallel to the joints as seen in Figure 6. In Figure 2, the ASR cracks run parallel to the longitudinal joint on the left side of the figure and continue across the transverse joint. In D-cracking, additional cracking would have formed parallel to the transverse joint and the result would have been the characteristic roughly C-shaped cracking that follows the joint patterns. D-cracking is most commonly encountered with certain limestone aggregates but may also be seen in other predominately sedimentary rocks.

9.1.3. It is important to recognize the difference in cracking caused by ASR and these other totally different sources of cracking. Plastic shrinkage cracking appears at very early ages and is often (although not always) relatively shallow. ASR cracking takes years to develop and occurs throughout the reacting concrete. D-cracking tends to parallel the joints in a distinctive C-shape, whereas ASR cracking crosses joints.

Figure 6. D-cracking at Grissom AFB (Not to be Confused with ASR-induced Cracking). Note general C-shape of cracks that are roughly asymptotic to joints and that do not cross transverse joints as seen in Figures 2 and 3.

9.2. Popouts. As the compressive forces within the concrete increase, individual aggregate particles may be dislodged. These particles—or popouts—then pose a potential aircraft FOD hazard. Figure 5 shows an example of popout fragments from ASR. Popouts also develop in concrete that has aggregates such as chert or shale that are vulnerable to freezing or contain other unsound particles.

9.3. Expansion. The internal expansive forces increase as the ASR gel absorbs water, the concrete volume increases and the concrete in the field literally grows. This leads to differential movements, closing of expansion joints, damage to adjacent structures, spalling at joints, and similar problems. In an extreme example at Andrews AFB, Maryland, the expansive forces were severe enough to cause an entire lane of parking ramp slabs to fail and tent up (similar to concrete pavement blowups occasionally observed on roads) in one morning. Figure 7 shows an example of differential movement between two slabs caused by ASR expansion in the concrete. Such movement on airfields may be a few inches or a foot or more. In Figure 8, the asphalt shoulder has been upheaved by the ASR expansion in the adjoining concrete. Structures such as trench drains within the pavement may suffer serious misalignment or breakage and the compressive forces at the joint may cause severe spalling. In Figure 9, note that in the ASR-induced cracking in the concrete to the left of the drain, the expansion joint between the concrete and trench wall is squeezed closed; spalling is developing in the concrete because of high compressive stresses from the expanding concrete, and the trench grate is tightly jammed as the trench walls have been forced inward. A forklift will be needed to pull the trench drain grate free. Any structures adjacent to pavement undergoing ASR volume expansion are vulnerable to damage. Expansion joints that are normally used to isolate the structures from the normal thermal and moisture movements of the concrete pavement will be unable to cope with the magnitudes of movement encountered in ASR-driven volume expansions. Figure 10 shows a terminal building column pushed out of alignment by the ASR expansion in the adjacent pavement. The building had to be abandoned.

Figure 7. Misalignment of Slabs Caused by Differential ASR Expansion, Kirtland AFB.

Figure 8. Asphalt Shoulder Heaving Caused by ASR Expansion in Adjacent Concrete at Seymour-Johnson AFB.

Figure 9. Trench Drain Damage from ASR Expansion, Holloman AFB.

Figure 10. Building Column Pushed out of Alignment by ASR Volume Expansion in Adjacent Concrete Pavement, Albuquerque, NM.

9.4. Any one or some combination of these symptoms may be present in concrete that is undergoing destructive ASR reactions. However, one may see cracking without significant concrete expansion as at Holloman AFB, New Mexico; or one may see expansion with negligible cracking as at Ft. Campbell Army Airfield, Kentucky; or one may observe all the distresses together as at the Channel Island ANG, California site. Concrete expansion as shown in Figure 7 is rare unless there is a destructive ASR reaction. ASR cracking is distinctive but can be confused with other non-ASR related causes. Similarly, popouts can have a non-ASR cause. If the distinctive ASR type expansion or cracking is present, then laboratory testing should be performed to confirm that ASR is present.

10. Identifying ASR.

10.1. Visual Observations. One should observe the concrete for symptoms of ASR described in paragraph 9. Excessive concrete expansion causing upheaval and damage to adjacent structures is strongly suggestive of ASR. Look for upheaved shoulders, buckled pavements, expansion joints that are squeezed shut, damaged utility trenches and other structures, and development of spalling from excessive compressive stresses. The internal volumetric expansions will generally cause cracking that is relatively distinctive as discussed in paragraph 9.1. Be careful not to confuse plastic shrinkage cracking and D-cracking with ASR cracking. Finally, one may observe popouts and possibly deposits at cracks. These may be caused by factors other than ASR so they are only somewhat corroborative if the expansion and cracking symptoms are also present. The field observations can only state that the symptoms of ASR are present. Only laboratory examination can make a definitive finding whether ASR is present or not.

10.2. Laboratory. Laboratory examination by an experienced petrographer is the most reliable method of determining whether ASR reactions are occurring in concrete. Petrography is the field of geology dealing with identification and classification of rocks and minerals. Concrete petrography is a specialized subfield using many of the same techniques as classic petrography but including detailed understanding of concrete with techniques to assess various physical and chemical phenomena unique to the concrete environment. ASTM requires the petrographer doing petrographic examinations for concrete (ASTM C 295, *Standard Guide for Petrographic Examination of Aggregates for Concrete*, and ASTM C 856, *Standard Practice for Petrographic Analysis of Hardened Concrete*) to have five years' experience specifically in concrete petrography—this should be verified for all petrographic work done for the Air Force. The quality and usefulness of any petrographic examination is entirely dependent on the skills of the petrogropher. Concrete cores are obtained from the suspect concrete and sent for examination to a laboratory qualified to conduct the examination under ASTM C 856. Such examinations are relatively expensive, and the number of laboratories capable of providing such services is limited. The Concrete Branch of the Geotechnical and Structures Laboratory of the U.S. Army Engineer Research and Development Center (ERDC) at the Waterways Experiment Station, Vicksburg, Mississippi maintains concrete laboratory test facilities and personnel capable of conducting such examinations for the military on a cost-reimbursable basis. For Air Force applications, petrographic examination by the ERDC Concrete Branch will be the preferred diagnostic tool for ASR.

10.3. Diagnostic Staining Systems.

10.3.1. Uranyl-Acetate Solution. If a prepared concrete surface is treated with uranyl-acetate solution and exposed to ultraviolet light, the ASR gel appears as bright yellow or green. The test requires experienced technicians, proper interpretation, does not distinguish between the harmless presence of ASR gel and destructive damage developing from ASR reactions, and fluorescence may be caused by other sources than ASR gel. Consequently, this is an ancillary test and cannot be relied upon to diagnose ASR. The uranyl-acetate solution contains a low-dosage radioactive compound and may be subject to safety and disposal restrictions.

10.3.2. Sodium Cobaltinitrite and Rodamine Solutions. Sodium cobaltinitrite reacts with lithium in the ASR gel to form a yellow precipitate while some rodamine compounds react with calcium-rich ASR gels to form a pinkish precipitate. This is a patented process, and a commercial kit (*ASR Detect*) based on this technology is marketed by James Instruments, Inc. The technology has the potential to serve as a rapid field screening or as an aid in a more detailed petrographic examination. The manufacturer's claims for this proprietary commercial kit have not been independently verified for Air Force use.

11. Maintaining Pavements with ASR. At present, technology does not exist that can stop ASR reactions that are occurring in airfield pavements. The reactive constituents are already in the pavement, and moisture to fuel the destructive expansion is readily available to pavements, even in arid regions. The only certain method of dealing with destructive ASR-affected pavements is to remove the affected concrete and replace it with new concrete that is not susceptible to ASR. Maintenance efforts should treat ASR symptoms.

11.1. If the reactions are relatively slow and destructive effects are minor, maintenance may be all that is needed to get the full design life out of the pavement. Increased sweeping efforts will be required as popouts develop and as ASR cracking and expansion lead to spalling and loose fragments. Partial-depth and full-depth patches can be used to temporarily fix the areas that become unacceptable. Figure 2 shows an example where ASR cracking has progressed to the point where FOD debris will soon be generated, and patching should be considered in the near future. Patching should be recognized as simply a stopgap measure to reduce FOD hazards in the immediate future as deterioration will continue in the surrounding pavement in coming years.

11.2. Patching of ASR-affected pavements should follow conventional Air Force directives for airfield pavement patching. Either conventional PCC or proprietary patching materials can be used. Good patching practices should be followed, e.g., saw cut around repair area, remove to sound concrete, meticulously clean the repair surface, properly mix, place, and cure the patching material, and reestablish all joints. The ASR reactions will continue in the concrete around the patch (and may even be enhanced by addition of new alkalis in the patching materials) and deterioration will continue in the original concrete. It may be particularly difficult to patch some ASR pavements because it may be hard to locate sound concrete—in such cases, full-depth patches will be necessary. In arid regions, the evaporative process seems to concentrate alkalis in the upper portion of the pavement. This accelerates damage in the upper region of the pavement, but sound concrete may exist below the worst-damaged concrete. At Holloman AFB, ASR gel coated all internal cracks, fissures, and voids and was present throughout the upper region of the concrete (Figure 11). This gel appeared as a white haze on all repair surfaces and proved impossible to remove by washing, brushing, waterblasting, and sandblasting. Because of this, it was almost impossible to get a good bond with patching materials. Failure rates for some patching efforts exceeded 80 percent. Recent patches have been going deeper (minimum 6 inches [152 millimeters]), and this seems to have helped somewhat. While patching ASR-damaged pavements can correct existing surface deficiencies, the patching conditions are difficult and on-going ASR deterioration will cause continuing future problems.

Figure 11. ASR Gel—Appearing as Light, Hazy Coating on Shallow Patching Repairs at Holloman AFB—Was Impossible to Remove and Caused Many Patch Bond Failures.

11.3. In the 1980s, Pease AFB, New Hampshire, used thin bonded overlays to reduce FOD hazards on pavements deteriorating from ASR, and these patches largely remain functional today. Selected slabs were milled 3 inches (76 millimeters) and a 3-inch (76-millimeter) -thick fully bonded overlay was placed. Pease AFB had much thicker pavements than structurally needed at the time because of a mission change so the overlays were purely to correct surface FOD problems. As expected, underlying longitudinal cracks (originally from over-vibration by vibrators during construction and unrelated to ASR) reflected through the overlay rapidly, but FOD debris generation was significantly reduced.

11.4. Expansion is particularly difficult to deal with as it causes damage to adjacent and imbedded structures and pavements. Expansion joints can be cut into the pavement to absorb the expansion, but these will eventually close and have to be recut. At Seymour-Johnson AFB, 1.5-inch (38-millimeter) -wide expansion joints have closed in about two years and 4-inch (101-millimeter) -wide joints have closed to 1 inch (25 millimeters) in five to ten years. In extreme cases—such as Ft. Campbell Army Airfield where expansion joints were being closed in a matter of months—an entire row of concrete slabs was removed and replaced with a flexible pavement. The repair to this flexible pavement is then arguably easier and more rapid than to damaged PCC. At Travis AFB, California, utility cuts in a ramp undergoing ASR were put under such pressure over the years that the concrete in the utility cuts was crushed. Saw cuts at joints to facilitate removing this pavement during ramp rehabilitation saw slabs dropping as much as 0.75 inch (19 millimeters) when cut. The compressive forces from ASR expansion in this ramp were sufficient to bow the slabs upward. There is no good solution to dealing with expansion. First try cutting expansion joints and recutting them, possibly wider, as they close. If this fails, try removing a lane of slabs and replacing with asphalt concrete as was done at Ft. Campbell Army Airfield, Kentucky. Neither of these are satisfactory solutions, but ignoring the expansion can lead to structural damage to adjacent structures and pavements, crushing of imbedded structures, and possible buckling of slabs (as happened at Andrews AFB [paragraph 9.3] and which the Travis AFB ramp must have been approaching).

11.5. Surface treatment of the concrete with very-low-viscosity methyl methacrylate was tried at Seymour-Johnson AFB, North Carolina. This low-viscosity material soaks into the upper surface of the concrete and into cracks to make the surface more impervious and strengthen the concrete to reduce spalling and raveling debris. The treatment is expensive and after eight years there was no noticeable difference in treated and untreated areas. It is not recommended for Air Force use. Treatment with other more economical concrete sealers such as silanes or siloxanes offers negligible hope as the surface-sealing approach using methyl methacrylate proved ineffective.

11.6. There is some potential for topical solutions of lithium salts to reduce surface compressive forces and perhaps reduce FOD debris generation. Significant penetration into the concrete by the lithium salts is highly unlikely. It is most likely to have benefit for mitigating shallow surface problems and is unlikely to affect deeper reactions and large-scale volume changes in the pavement. Repeat treatments may be needed, and there has been some work to encourage deeper penetration into the concrete using vacuum impregnation or electrochemical methods. Tests indicate these salts are not corrosive for aircraft. The technique has been tried on several highways but results are inconclusive at present. Details of field trials on several highway projects may be found in FHWA Publication No. RD-03-047, *Guidelines for the Use of Lithium to Mitigate or Prevent Alkali-Silica Reaction (ASR)*. On-going trials at Ft. Campbell Army Airfield suggest there may be some reduction in popouts following topical treatment with lithium, but the monitoring of the trial is not yet finished; no conclusion or recommendation on its use is possible at this time. Topical application of lithium salts for ASR mitigation should be considered an experimental technology if used on Air Force pavements.

11.7. Attempts to dry the concrete or seal out moisture to impede continued ASR expansion show little promise for pavements because of the exposed environment of concrete pavement and ready availability of water vapor under the pavement.

11.8. Overlays.

11.8.1. Conventional overlays are candidate repair and rehabilitation methods for pavements undergoing destructive ASR reaction. The ASR reaction in concrete will continue as long as alkalis, reactive minerals, and water are present. Once any of these are consumed, the reaction should end and the material should be stable. At present we do not have the technical understanding to reliably predict when the alkali-silica reaction will end or even ascertain for a specific concrete if it has ended. Consequently, one must expect that the expansion and deterioration of the original pavement will continue and may significantly reduce the effective life of the overlay. Fully bonded concrete overlays could be considered as a means of mitigating surface problems for several years and perhaps longer, as in the case of Pease AFB. Both partially bonded and unbonded concrete overlays should improve the situation, but the potential increased interaction between the ASR-affected lower pavement and a partially bonded overlay suggests an unbonded overlay may have better long-term success. Flexible overlays are possible as a stop-gap to correct serious surface deterioration, but it is only a temporary measure. Expansion in the underlying ASR-affected pavement below flexible or rigid overlays can be expected to continue to damage adjacent pavements and structures and the overlay may also be affected.

11.8.2. Cracking and seating or rubblizing the original pavement and then overlaying with asphalt offer uncertain alternatives. The cracking and seating or rubblizing allow easier penetration of water into the concrete that would speed the ASR reaction. However, it also generates some additional void space in the cracks that may absorb some expansion. The on-going ASR reaction within the individual fragments of concrete may cause further breakdown and change in properties of the cracked and seated or rubblized concrete. There is insufficient experience with overlays for ASR-damaged pavements to provide sound advice at this time. HQ AFCESA should be consulted if cracking and seating or rubblizing procedures are being considered to rehabilitate ASR-damaged pavements.

11.9. Recycled concrete from concrete undergoing ASR reactions should not be recycled in any application within the airfield pavement structure, e.g., use as aggregate in PCC mixtures, as base course aggregate, or in drainage layers. More work with mitigation methods is needed before ASR-reacting concrete can be recycled into the concrete for critical facilities like airfield pavements. If the ASR-reacting concrete is recycled into a base, subbase, drainage layer, or fill, it will be crushed to a gradation appropriate for its use and will be used under a pavement surfacing. The crushing makes the recycled concrete far more permeable than before, and placing it in the pavement structure exposes it to a potentially much wetter environment than before. Since we are unable to ascertain if the ASR has ended, cannot predict when it might end, and will be using the ASR-reacting recycled concrete in an environment where one of the critical reaction ingredients (water) is likely to be more readily available than before recycling, we must presume that the ASR reaction will continue. If the ASR continues, gel will continue to form and imbibe water, causing a volume increase. This is occurring at an aggregate particle level so that a fragment of recycled concrete aggregate contains one or more reacting fine or coarse aggregate particles within a cementitious matrix that may contain other non-reacting aggregate particles. Hence, the ASR-induced volume change that occurs is within the individual recycled concrete fragment. This could potentially lead to expansion in the recycled concrete layer (which might vary with severity of ASR or gradation) and to possible degradation of the layer and reduction in strength (e.g., a recycled GW-gradation might deteriorate to a GM-gradation with lower California Bearing Ratio [CBR] values, especially when wet, and might be susceptible to frost heave). Whether either of these results would actually occur in the field is uncertain, but an Air Force airfield pavement is not the place to experiment to find out. Any use of recycled ASR-reacting concrete should be in applications where the potential recycled-concrete expansion or possible degradation over time would not be detrimental (e.g., use as aggregate on a gravel surfaced perimeter road might be acceptable). More research is needed before ASR-reacting concrete is recycled within an Air Force airfield pavement structure. HQ AFCESA should be contacted for assistance if an ASR-reacting concrete is being proposed for recycling.

12. Avoiding ASR in New Construction. There is no consensus in the technical community on how ASR-susceptible aggregates can be identified or on how new concrete mixtures should be proportioned and tested to prevent ASR in the field. Essentially, those laboratory tests that do the best job evaluating alkali-silica-susceptible concretes and mitigation methods take a year or more to run which is not compatible with construction schedules. To get results in a timelier manner, other tests use accelerated testing conditions that are then hard to relate to field conditions. Similarly, the important factors for determining the effect of total alkalis from all sources and effectiveness of countermeasures remain open to discussion. There is no perfect test and our understanding of the complexities of the chemical reactions is imperfect. Research is actively being pursued by a number of civil organizations. There is no Department of Defense (DOD) research on ASR so Air Force guidance must be based on results of this on-going civil research as it becomes available and on Air Force field experience. In the interim, all Air Force concrete airfield pavements will ascribe to the following philosophy:

(1) All concrete aggregates will be tested in accordance with ASTM C 1260, *Standard Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method)*, to determine if they are potentially reactive or non-reactive.

(2) The preferred Air Force policy is to build airfield pavements with non-reactive aggregates, especially if deicing and anti-icing chemicals will be used on the pavements—but this is not always feasible.

(3) If a potentially reactive aggregate must be used in an Air Force airfield pavement, then a low-alkali cement is mandatory plus active mitigation methods must also be used. The effectiveness of the selected mitigation method and the amount needed will be shown by testing in accordance with ASTM C 1567, *Standard Test Method for Determining the Potential for Alkali-Silica Reactivity of Combinations of Cementitious Materials and Aggregate (Accelerated Mortar Bar Method)*, or

equivalent.

Actual implementation of this philosophy through the DOD concrete airfield pavement guide specification (UFGS 02753) is more complicated and is discussed in the following paragraphs.

12.1. Identifying Potentially Reactive Aggregates. All aggregates shall be tested in accordance with ASTM C 1260. If expansion exceeds 0.08 percent after soaking 14 days in a sodium hydroxide solution, the aggregate shall be presumed to be potentially reactive. Each aggregate source shall be tested separately and also as a combined gradation representative of the contractor’s proposed proportions for various aggregates in the concrete mixture.

12.1.1. ASTM C 1260 uses a mortar bar composed of 1 part cement to 2.25 parts aggregate with particles between the No. 4 and No. 50 sieves (coarse aggregates have to be crushed to provide this material) and a water-to-cement ratio of 0.47. After two days of curing, initial length measurements of the bar are made and the mortar bars are placed in 1-normal sodium hydroxide solution at 176 °F (80 °C) for 14 days. Length measurements are periodically made, and if at the end of the 14 days’ soaking in sodium hydroxide (16 days after casting) the length has increased by more than 0.08 percent, the aggregate is considered potentially reactive.

12.1.2. All aggregate sources must be tested for ASR reactivity. Acceptance based on past performance is not allowed. The cement chemistry and concrete mixtures have significantly changed in recent decades and ASR reactions may take a decade or more to appear. Hence, the reliability of any assessment of past performance that must match evolving cement and concrete mixture chemistry to aggregate properties (that may not be consistent within a deposit), age, and exposure conditions is problematic at best.

12.1.3. Commentary on determining classification of potentially reactive and non-reactive aggregates:

12.1.3.1. ASTM C 1260, *Standard Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method)*. ASTM C 1260 is reasonably rapid and gives generally usable results. However, it may exclude some aggregates that will not react in the field and may include some that will. The military allowable expansion limit of 0.08 percent or less in UFGS 02753 is tighter than the criterion of less than 0.10 percent expansion used in some specifications. This does not imply any overly conservative stance, however. Existing allowable limits are largely based on requirements to control cracking in the field. For relatively thick Air Force airfield pavements that are of such large areal extent, smaller volumetric changes from ASR may cause distress that would not be a problem for thinner and smaller civil structures. Such civil structures comprise much of the base experience for setting the current allowable limits. In addition, the acceleration of the ASR reaction in the test by elevated temperatures and high chemical concentrations tries to forecast conditions some years ahead in the life of the concrete. It is not clear that this is adequate for forecasting the behavior of critical Air Force airfield pavements that may be in use for 30, 40, 50 or more years. There have been proposals to tighten the expansion limit further or to evaluate test results after 28 days of soaking rather than 14 days. However, no sound technical basis exists to make either selection at present. ASTM 1260 tests with the UFGS allowable expansion limits is the best compromise of accuracy and speed of testing needed to be compatible with construction currently available for determining potentially reactive aggregates for Air Force airfield pavements.

12.1.3.2. ASTM C 1293, *Standard Test Method for Determination of Length Change of Concrete Due to Alkali-Silica Reaction*. This is generally the preferred test method for identifying ASR-reactive aggregates. This test measures length change in a concrete prism made with high-alkali cement and stored at high humidity at 100 °F (38 °C) and requires at least a year to run. This length of testing is incompatible with modern construction procurement processes. UFGS 02753 makes no mention of the test, but if results of ASTM C 1293 testing should for some reason be available, they would be superior to ASTM C 1260 for identifying reactive aggregates. While this is generally accepted as the best available test, even when run for two years, there is still uncertainty about its ability to predict behavior for large-volume airfield pavements during long service lives.

12.1.3.3. Cement and Combined Gradation Effects. The ASTM C 1260 mortar bars are soaked in a sodium hydroxide solution so the alkali content of the cement used in the test probably has at most a minor effect. UFGS 02753 requires testing the combined grading which is not required under ASTM C 1260. Guidance on interpretation of the results with the combined aggregate gradation is not currently available. The test results on the individual fractions of coarse and fine aggregates will be considered of primary importance in determining if an individual aggregate is potentially reactive or not for Air Force projects. If anomalous results are obtained from the combined gradation testing, HQ AFCESA should be consulted for assistance in interpreting the results.

12.1.4. The assistance of a qualified concrete petrographer may prove useful in interpreting the significance and limitations of ASTM C 1260 testing on any particular aggregate.

12.2. The Air Force preference is to build airfield pavements with non-reactive aggregates, and a potentially reactive aggregate would ideally be replaced with a non-reactive one. This is not always possible. Non-reactive aggregates may be economically unavailable or delays in finding, testing, procuring, and transporting non-reactive aggregates for a specific project may cause unacceptable delays to the construction.

12.3. If a potentially reactive aggregate will be used in Air Force concrete airfield pavements, a low-alkali cement is mandatory and additional active mitigation measures are required. The effectiveness of the mitigation must be established by testing and simply using a prescribed formula (e.g., 25 percent Class F fly ash) is not adequate mitigation for Air Force airfield pavements. Cements, fly ashes, ground granulated blast-furnace slags, and aggregates all have individually varying chemical compositions. Consequently, there is no universal formula for how much fly ash or slag to use in the concrete mixture because of this chemical variability. For the same reason, the testing must use the actual proposed project materials. The proportion of the mitigating material needed must be individually determined by acceptable results from appropriate testing.

12.3.1. UFGS 02753 (May 2004) requirements for testing and assessing mitigation results are currently out of date for Air Force projects and will be revised in the near future. In the interim, future Air Force concrete airfield pavements that use potentially reactive aggregates will be required to meet the following mitigation requirements:

(1) Low-alkali cement is mandatory;

(2) Class F fly ash, ground granulated blast-furnace slag, and lithium admixtures are acceptable mitigation materials;

(3) The percentage of fly ash or slag used in the concrete mixture will reduce the expansion of the mortar-bar specimen to 0.08 percent or less after 14 days' soaking (16 days after casting) when tested in accordance with ASTM C 1567;

(4) Each reactive aggregate source must be tested individually, and the selected mitigation material and amount of mitigating agent must reduce expansion to 0.08 percent or less after 14 days' soaking (16 days after casting) for each aggregate source when tested in accordance with ASTM C 1567.

12.3.2. Commentary on mitigation methods if potentially reactive aggregates are used.

12.3.2.1. UFGS 02753 requires use of low-alkali cement for all PCC airfield pavements unless it is economically impractical or low-alkali cement is unavailable. However, it is important to realize that if potentially reactive aggregates are used in the airfield pavement concrete, the use of low-alkali cement is never optional. Low-alkali cement use is mandatory, or if not available, alternate non-reactive aggregates must be used. However, it is important to remember that, as described in paragraph 7.3.1, simply using low-alkali cement does not automatically confer protection against ASR developing in the concrete pavement. Consequently, additional mitigation methods are also mandatory.

12.3.2.2. UFGS 02753 allows use of blended cements as specified in ASTM C 595, *Standard Specification for Blended Hydraulic Cements*, but provides no guidance on their use. These cements consist of two or more cementitious materials such as Portland cement, fly ash, natural pozzolan, ground granulated blast-furnace slag, or silica fume. Blended cement use in North America is still relatively limited compared to some other areas of the world. Blended cements may be specified to have low reactivity for use with potentially reactive aggregates. However, the assessment of this low reactivity for blended cement is determined using ASTM C 441, *Standard Test Method for Effectiveness of Pozzolans or Ground Blast-Furnace Slag in Preventing Excessive Expansion of Concrete Due to the Alkali-Silica Reaction*, which has very different test methodologies from those of ASTM C 1260 and ASTM C 1567. Blended cements have the potential for providing superior resistance to ASR, but appropriate protocols for determining this are not agreed upon at this time. If blended cements are proposed for an Air Force project with potentially reactive aggregate, HQ AFCESA should be consulted for guidance and independent testing by the Army ERDC Concrete Branch at the Waterways Experiment Station would be prudent.

12.3.2.3. ASTM C 1567 is a modification of ASTM C 1260 (paragraph 12.1.3.1) and is designed to assess the ability of pozzolans and ground granulated blast-furnace slag to control destructive internal expansions due to alkali-silica reaction in aggregates intended for use in concrete. It also is an imperfect test but represents the best compromise of technical accuracy and speed of testing available today. The test shall be run with the contractor’s proposed low-alkali cement, mitigating additive (e.g., fly ash, Class N pozzolan, ground granulated blast-furnace slag) in the proportions proposed by the contractor for his mixture proportion. If length change after 14 days of soaking (16 days after casting) is equal to or less than 0.08 percent, the countermeasure shall be deemed to be adequate; if the expansion is greater than 0.08 percent, more of the proposed additive, alternate aggregate sources, or alternate countermeasures must be used and tested. The ASTM C 1567 mortar bars are soaked in a sodium hydroxide solution so the alkali content of the cement used in the test probably has at most a minor effect. This test is only valid for the specific combinations of pozzolan, slag and reactive aggregates tested. It is not valid for tests of cements and aggregates only (i.e., no pozzolans and/or slag). This test may underestimate the expansion of cementitious systems if the pozzolans have greater than 4.0 percent sodium oxide equivalent. Such materials are best evaluated with ASTM C 1293.

12.3.2.4. ASTM C 1293 is the preferred test method for assessing effectiveness of ASR-mitigating materials. However, the recommended test period for evaluating the mitigation effectiveness of supplementary cementitious materials such as fly ash is two years. This is incompatible with current construction procurement processes. UFGS 02753 makes no mention of the test, but if results of ASTM C 1293 testing should for some reason be available, they would be superior to ASTM C 1567 for assessing effectiveness of fly ash, natural pozzolans, etc., for mitigation of ASR.

12.3.2.5. ASTM C 1567 is not effective for assessing lithium admixtures. These admixtures tend to leach out in the artificially high alkalinity of the test and provide an invalid assessment of the effectiveness of lithium. Lithium admixtures appear to be highly effective in countering ASR but may significantly increase the concrete mixture costs. They are often most economical when used in conjunction with other mitigation materials. If lithium compounds are proposed for use as an admixture to counter ASR in Air Force airfield pavements, HQ AFCESA should be consulted for up-to-date guidance, and the dosage of lithium will generally be as recommended by the manufacturer.

12.3.2.6. Pozzolans. Fly ash has been the most common countermeasure used and often 25 to 30 percent fly ash replacement for Portland cement has proven effective. Class F fly ash does better than Class C fly ash, and low calcium oxide (CaO) Class F fly ash does better than higher CaO content fly ashes. There is less experience with the natural Class N pozzolans on military jobs. UFGS 02753 allows use of Class F or N pozzolans to mitigate ASR and limits the CaO content of Class F fly ash to 8 percent. This lower-limit Class F fly ash is not always available, however, and this limit may have to be waived. In general, it is best to use the lowest CaO content Class F fly ash that is readily available. Some suggested guidance for chemical composition of fly ash and suggested minimum fly ash content based on Canadian recommendations is shown in Table 1. The suggestions in Table 1 have not been adequately evaluated by DOD and are offered to provide interim suggestions if higher than desired CaO fly ashes must be used.

Table 1. Suggested Minimum Fly Ash Replacement Based on Chemical Composition and Canadian Recommendations.

Fly Ash		Suggested Minimum Cement Replacement by Fly Ash, Percent by Mass
Alkali Content, Percent Na_2O_{eq}	**CaO Content, Percent**	
< 3%	< 8%	25%
	8 to 20%	30%
	> 20%	Not recommended
3–4.5%	< 8%	30%
	8 to 20%	35%
	> 20%	Not recommended
> 4.5%	Any	Consult HQ AFCESA

Note: If the CaO limit on fly ash needs to be waived to allow greater then 8 percent CaO, HQ AFCESA should be consulted. The proposed fly ash and final dosage rate must pass ASTM C 1567, but if the CaO content of 8 percent has been waived, the minimum fly ash contents in Table 1 may be desirable even if a lower fly ash content passes ASTM C 1567.

12.3.2.7. Ground Granulated Blast-Furnace Slag. This product is increasingly available in some sections of the U.S. Generally, it will require a higher proportion replacement of the Portland cement than fly ash. This will typically be on the order of 40 to 50 percent replacement. UFGS 02753 allows use of this material to counter ASR.

12.3.2.8. Silica Fume. This material can be effective in countering ASR, but introduces some other complexities in the batching, mixing, and pavement construction process. Typically it requires at least 7 percent by cement mass to be effective for ASR mitigation. It requires less material than either fly ash or ground granulated blast-furnace slag. It is not listed in UFGS 02753 as an acceptable ASR mitigation method. However, in the Middle East and other areas where fly ash and ground granulated blast-furnace slag are not readily available and ASR is a common problem, silica fume has been used on several Air Force paving projects to help provide ASR resistance.

13. Deicing and Anti-icing Chemicals. Ongoing research by the Innovative Pavement Research Foundation (IPRF) at Clemson University found that the deicing and anti-icing chemicals (potassium acetate, sodium acetate, potassium formate, and sodium formate) can cause increased expansion in ASR-susceptible aggregate and may trigger it in aggregates that previously did not show signs of ASR. The nature of the reactions associated with these increased expansions remains imperfectly understood and is the topic of continuing research. Observation of distress associated with use of deicing and anti-icing chemicals at civil airports corroborate the initial findings of the Clemson laboratory work. Interim results of this IPRF research are posted on their website (http://www.iprf.org/products/main.html) and new information will be posted as it becomes available. Air Force bases that use these deicing and anti-icing chemicals could compound an existing ASR problem if they have one and will have to take extra precautions if they plan new construction with ASR-reactive aggregates.

13.1. The effect of anti-icing and deicing chemicals on ASR in PCC is an active area of research, and there is no consensus on how serious the problem may be and what countermeasures should be taken. In the interim, Table 2 can be used to determine if additional specialized testing is warranted to determine additional mitigation that may be needed to cope with exposure to anti-icing and deicing chemicals. The relation between deicing and anti-icing chemicals and ASR is a rapidly evolving field and Table 2 is simply an interim suggested practice. HQ AFCESA can be consulted for the most current guidance.

Table 2. Suggested Testing Requirements for New Concrete to be Exposed to Anti-Icing or Deicing Chemicals and Using Aggregate Sources That Have Been Previously Used on the Airfield Pavements.

	Existing Pavements Have ASR		**Existing Pavements Do Not Have ASR**	
Have anti-icing and/or deicing chemicals been used in the past?	Yes	No	Yes	No
ASTM C 1260 shows the aggregate proposed for use is:				
Potentially reactive	A	A	C	B
Non-reactive	A	B	D	C

A. High risk of increased ASR if anti-icing and deicing chemicals used; additional testing recommended.

B. Moderate risk of increased ASR if anti-icing and deicing chemicals used; additional testing desirable.

C. Little risk of increased ASR if anti-icing and deicing chemicals used; additional testing not recommended.

D. Negligible risk of increased ASR if anti-icing and deicing chemicals used; additional testing not recommended.

Note: If the aggregate source is new and was never previously used for concrete pavements on the base, past history of exposure to deicing chemicals and development of ASR are of no help. For new aggregate sources, if the aggregate tests as potentially reactive it should be treated as case A, and if non-reactive it should be treated as case B.

13.2. The additional testing in Table 2 is the IPRF interim test protocol found at http://www.iprf.org/products/main.html. This is essentially the ASTM C 1260 test, but samples are soaked for 28 days in the specific anti-icing or deicing chemicals to which the concrete will be exposed rather than sodium hydroxide. Acceptable results are less than 0.10 percent expansion after 28 days' soaking. For aggregates that test as potentially reactive by ASTM C 1260, the mitigating agent and dosage to be used in the concrete pavement must pass the interim test protocol for each anti-icing or deicing agent that may be used at the base and it must also pass ASTM C 1567 as outlined in paragraph 12.3.1. If the aggregate is non-reactive, it is only required to pass the IPRF interim test protocol.

13.3. The IPRF interim test protocol with anti-icing and deicing chemicals may increase the amount of fly ash or ground granulated blast-furnace slag needed to mitigate ASR above that found in ASTM C 1567. The CaO content of fly ashes seems to have a major impact on expansion in this test. Hence, if a specific fly ash is having trouble passing the test, changing to a lower CaO content fly ash may help.

13.4. Topical applications of lithium salts may have a potential beneficial effect in countering the effects of surficial applications of these anti-icing and deicing chemicals, but this has not been verified.

14. Impact of Fly Ash, Slag, and Natural Pozzolans on Other Properties of the Concrete Mixture. Generally, these products impart a variety of desirable properties to the concrete mixture, e.g., reduced shrinkage, lowered cost, and lower permeability. However, when used in large quantities such as for countering ASR, the workability and finishability of the concrete mixture may be appreciably different from conventional mixtures. In addition, some of these products may require a higher air-entraining dosage to maintain the desired air content. These materials gain strength more slowly than Portland cement, but their ultimate strength will be as high or higher. Strength compliance for Air Force concrete pavements can be set at 90 days if operational requirements do not mandate an earlier opening of the pavement to traffic. This will allow additional time for strength gain in these supplementary cementitious materials. In the past, military airfield pavements were accepted based on 90-day strength, but changes in cement chemistry that reduced long-term strength gain and the desire to allow earlier acceptance of the concrete for contractual reasons led many specifications to use 28- or 14-day strengths. With slower-strength-gain materials such as fly ash and ground granulated blast-furnace slag, it is advantageous to allow longer cure periods for strength acceptance when possible.

15. Alkali-Carbonate Reaction. Alkali-carbonate reaction has not been identified on Air Force bases. This reaction is significantly different from ASR. Low-alkali cements, fly ashes, and slags are not effective in its control. Fortunately, alkali-carbonate reaction appears to occur only with a few readily identifiable aggregate characteristics. Petrographic examination should be used specifically to judge if carbonate reaction is a likely problem whenever dolomitic rocks are proposed as aggregate for concrete. If petrographic examination finds potentially alkali-carbonate reactive components in the proposed aggregate, the aggregate source should be disqualified for use in concrete for Air Force airfields. If no other aggregate sources are reasonably available, HQ AFCESA should be consulted for more detailed guidance. Alkali-carbonate reaction is a relatively rare problem and has not arisen in previous Air Force pavement construction.

16. Testing Requirements. The re-emergence of ASR as an Air Force airfield pavement problem with potential additional issues with alkali-carbonate reaction and potential destructive effects of anti-icing and deicing chemicals has greatly increased the complexity and sophistication of testing that must be conducted by the contractor under current military airfield procurement methods. These testing requirements can cause significant delays in the start of the project—it is prudent to recognize this and allow additional time at the start of the contract. This testing is costly and cannot be waived. Concrete mixture proportioning for Air Force airfield pavements requires a sophisticated process to ensure proper constructability, durability, and strength. Assessment of the adequacy of bids for airfield paving work should recognize that the contractor is responsible for carrying out this critical task and should ensure it is adequately addressed. The new requirements for testing to identify potentially reactive aggregates and mitigate ASR are complex, cumbersome, and expensive. However, the potential damage and maintenance costs of dealing with ASR in Air Force airfield pavements justify these precautions for new concrete.

17. Point of Contact. Recommendations for improvements to this ETL are encouraged and should be furnished to the Pavements Engineer, HQ AFCESA/CESC, 139 Barnes Drive, Suite 1, Tyndall AFB, FL 32408-5319, DSN 523-6334, commercial (850) 283-6334, e-mail AFCESAReachbackCenter@tyndall.af.mil

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