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TRI-SERVICE PAVEMENTS WORKING GROUP (TSPWG) MANUAL

RISK ASSESSMENT PROCEDURE FOR RECYCLING PORTLAND CEMENT CONCRETE (PCC) SUFFERING FROM ALKALI-SILICA REACTION (ASR) IN AIRFIELD PAVEMENT STRUCTURES

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This TSPWG Manual supersedes Air Force Engineering Technical Letter (ETL) 07-6 ,dated 14 August 2007.

FOREWORD

This Tri-Service Pavements Working Group (TSPWG) Manual supplements guidance found in other Unified Facilities Criteria, Unified Facility Guide Specifications, Defense Logistics Agency Specifications, and Service specific publications. All construction outside of the United States is also governed by Status of Forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA.) Therefore, the acquisition team must ensure compliance with the most stringent of the TSPWG Manual, the SOFA, the HNFA, and the BIA, as applicable. This TSPWG Manual provides guidance for performing risk assessment of recycled portland cement concrete (PCC) suffering from alkali-silica reaction (ASR) in airfield pavement. The information in this TSPWG Manual is referenced in technical publications found on the Whole Building Design Guide. It is not intended to take the place of service-specific doctrine, technical orders (TOs), field manuals, technical manuals, handbooks, Tactics, Techniques, and Procedures (TTPs) or contract specifications, but should be used along with these to help ensure pavements meet mission requirements.

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TRI-SERVICE PAVEMENTS WORKING GROUP (TSPWG) MANUAL

NEW SUMMARY SHEET

Document: TSPWG Manual 3-250-07.07-6, *Risk Assessment Procedure for Recycling Portland Cement Concrete (PCC) Suffering from Alkali-Silica Reaction (ASR) in Airfield Pavement Structures.*

Superseding: ETL 07-6, *Risk Assessment Procedure for Recycling Portland Cement Concrete (PCC) Suffering from Alkali-Silica Reaction (ASR) in Airfield Pavement Structures*, 14 August 2007.

Description: This Tri-Service Pavements Working Group (TSPWG) Manual provides guidance and a framework for assessing the risk of incorporating recycled portland cement concrete (PCC) undergoing Alkali-Silica Reaction (ASR) into an airfield pavement structure.

It applies to all Department of Defense (DoD) organizations with airfield pavement concrete construction, maintenance, and repair responsibility.

Reasons for Document:

This TSPWG Manual provides a basis for balancing the risks and benefits of recycling ASR-PCC material for a specific project for engineers to apply a systematic approach to the decision-making process rather than proceeding solely on the basis of the lack of documented problems elsewhere, and to ensure the material in this TSPWG Manual is available to all Services.

Impact: The primary effect of ASR on most airfield pavements is an increase in maintenance to deal with the foreign object damage (FOD) hazards, associated with defects, such as spalling and cracking, and repairs to adjacent structures and pavements damaged from ASR swelling that shortens the life in air field pavements. The following benefits should be realized.

- The construction cost of new or replacement PCC pavements may be substantially reduced, as opposed to traditional demolition and replacement of damaged airfield pavements, if the existing PCC with ASR is crushed and recycled as base, subbase, fill, or drainage material within the replacement airfield pavement, or if crack and seat or rubblization rehabilitation techniques are used.

- Rehabilitation techniques such as crack and seat, or rubblization may also be appreciably quicker than conventional techniques and can reduce the time an airfield pavement is out of service. Since the DoD has a large number of air fields that may have ASR damaged PCC pavements, the potential savings across the DoD are very significant.

- Supplemental information on the operation, maintenance and repair of pavements as well as airfield damage repair will be available to all Services.

- Maintenance or upgrading of this supplemental information will include inputs from all Services.

Unification Issues:

None

Note: Use of the name or mark of any specific manufacturer, commercial product, commodity, or service in this publication does not imply endorsement by the Department of Defense (DoD).

TABLE OF CONTENTS

CHAPTER 1 INTRODUCTION 1
1-1 BACKGROUND 1
1-1.1 Alkali-Silica Reaction 1
1-1.2 Effects of ASR 1
1-1.3 Construction Costs 2
1-1.4 Arguments for Allowing Recycling of ASR-PCC 2
1-1.5 Concerns About Recycling ASR-PCC 2
1-1.6 Questions.. 4
1-2 PURPOSE AND SCOPE. 4
1-3 APPLICABILITY 4
1-3.1 Coordination 4
1-3.2 Intended Users 4
1-4 BEST PRACTICES 5
1-5 GLOSSARY.. 5
1-6 REFERENCES 5
CHAPTER 2 OBJECTIVES 7
2-1 OBJECTIVE 7
2-2 CAUTIONS. 7
CHAPTER 3 RISK MANAGEMENT (RM) PROGRAM.RISK MANAGEMENT 9
3-1 INTRODUCTION 9
3-2 BENEFITS AND RISK.. 9
3-3 EXPERIENCE.. 9
3-4 STEPS OF AN RISK MANAGEMENT ASSESSMENT. 9
CHAPTER 4 IDENTIFY THE HAZARD 13
4-1 POTENTIAL ADVERSE OUTCOMES.. 13
4-2 POTENTIAL HAZARDS. 13
CHAPTER 5 ASSESS THE RISK.. 15
5-1 ASSESS THE RISK 15
5-2 HAZARD SEVERITY CATEGORIES. 15
5-3 HAZARD SEVERITY RATING. 15
5-4 PROBABILITY OF OCCURRENCE 15

5-5 ASR-PCC RISK ASSESSMENT. ... 16

5-6 HAZARD SEVERITY ADJUSTMENT FOR SITE-SPECIFIC PAVEMENT FEATURES. ... 16

5-7 PROBABILITY ADJUSTMENT TO REFLECT THE ASR OF THE EXISTING PAVEMENT ... 17

5-7.1 Highly Reactive Pavements. ... 17

5-7.2 Low Reactive Pavement. ... 21

5-8 PROBABILITY ADJUSTMENT TO REFLECT LOCAL MOISTURE CONDITIONS ... 22

5-9 SUMMARY OF RISK ASSESSMENT. ... 22

CHAPTER 6 ANALYZE RISK CONTROL MEASURES ... 23

6-1 INTRODUCTION ... 23

6-2 THICKNESS OF THE RECYCLED MATERIAL ... 23

6-3 BLENDING RECYCLED ASR ... 23

6-4 WATER ... 23

6-5 TESTING ... 23

6-6 OTHER FACTORS. ... 24

CHAPTER 7 MAKE CONTROL DECISIONS ... 25

7-1 RISK CONTROL OPTIONS ... 25

7-2 DEFINITION OF RISK. ... 25

7-3 RISK ... 25

7-4 ECONOMICS ... 25

7-5 IMPACT ON THE FLYING MISSION. ... 26

CHAPTER 8 IMPLEMENT RISK CONTROLS ... 27

CHAPTER 9 CONCLUSION ... 29

9-1 DECISION ... 29

9-2 RISK ASSESSMENT ... 29

9-3 GENERAL METHODOLOGY ... 29

APPENDIX A EXAMPLE OF A RISK ASSESSMENT ... 31

A-1 BACKGROUND ... 31

A-2 SETTING THE INITIAL AVERAGE RISK LEVEL ASSESSMENT ... 31

A-3 ADJUSTING FOR HAZARD SEVERITY ... 31

A-4 ADJUSTING FOR ASR REACTIVITY IN THE EXISTING PCC ... 31

A-5 ADJUSTING FOR MOISTURE CONDITIONS. ... 32

A-6 ADJUSTING FOR RISK CONTROL MEASURES. 32
A-7 MAKING THE FINAL DECISION. 32
APPENDIX B GLOSSARY 33
APPENDIX C REFERENCES.. 35

FIGURES

Figure 3-1 Example of Differential Heaving on a Rigid Pavement Caused by Volume Change in Underlying Base And Fill Layers..................... 10
Figure 3-2 Example of Localized Heaving in a Flexible Pavement Caused by Volume Change in the Underlying Base Course 11
Figure 5-1 Minor ASR Cracking in 5-Year-Old Pavement (Left Photograph); Patching Needed 3-Years Later (Right Photograph)........................... 18
Figure 5-2 Examples of Damage to Adjacent Asphalt From ASR-Induced Expansion in Adjacent PCC Pavement 19
Figure 5-3 Examples of Large Volume Changes Suggesting Highly Reactive ASR Pavements... 20
Figure 5-4 Example of Low Reactivity ASR at Travis AFB 21

TABLES

Table 5-1 Risk Assessment Matrix Reflecting the Probability of an Event and the Severity of the Event... 16

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CHAPTER 1 INTRODUCTION

1-1 BACKGROUND.

1-1.1 Alkali-Silica Reaction.

Alkali-Silica Reaction (ASR) is a complex chemical reaction between the alkalis present in portland cement concrete (PCC) and certain, but not all, forms of silica in the concrete's fine or coarse aggregate. This reaction causes certain physio-chemical alterations of the aggregate, and forms a gel that imbibes water leading to volumetric expansion (internal swelling) of the PCC in which there is a high probability of internal fracturing and premature deterioration within the concrete. If sufficiently severe, ASR can lead to widespread concrete cracking creating popouts and spalling; an increase in concrete volume that damages adjacent non-reacting buildings, pavements, and utility systems; and blowups or tenting of pavement slabs. Blowups from ASR on airfields are rare because of the thickness of the pavements. ASR is a slowly developing phenomenon, with damage within 5 to 10 years considered to be rapid and damage within 10 to 20 years considered more typical. The slowness of this reaction makes it problematic to test and assess pavements for ASR issues. However, once ASR symptoms develop, they can lead to ever increasing maintenance costs and may dictate premature replacement of the ASR-afflicted pavement.

The Services have jointly strengthened provisions in the Department of Defense (DoD) guide specifications for new airfield concrete pavements, which should significantly reduce the incidence of ASR on new military airfield pavements. Independent government quality assurance testing of concrete materials is mandatory for these provisions to be effective.

1-1.2 Effects of ASR.

The primary effects of ASR on most airfields is an increase in maintenance to deal with the foreign object damage (FOD) hazards associated with defects such as spalling and cracking, and repairs to adjacent structures and pavements damaged by ASR swelling. When maintenance efforts can no longer keep pace with the ASR damage, complete pavement replacement is necessary.

At the time of this publication, ASR damage has been identified on airfield pavements at twenty Air Force, six Navy, and three Army airfields, consequently, the DoD has a significant volume of pavements that are candidates for a risk assessment for recycling as outlined in this TSPWG Manual. TSPWG 3-260-02.06-2, *Alkali-Aggregate Reaction in Portland Cement Concrete (PCC) Airfield Pavements*, provides more information on ASR, how to identify it, appropriate maintenance procedures for pavements with ASR, and procedures to avoid ASR in new airfield PCC pavement.

1-1.3 Construction Costs.

Construction costs of new or replacement PCC pavements may be substantially reduced if the existing concrete pavement with ASR is crushed and recycled as base, subbase, fill, or drainage material within the replacement airfield pavement, or if crack and seat or rubblization rehabilitation techniques are used. In one existing Air Force $50,000,000 runway replacement project, the projected savings of recycling the existing ASR-PCC were approximately ten percent of the total project cost. Rehabilitation techniques such as crack and seat or rubblization may also be appreciably quicker than conventional techniques and can reduce the time an airfield pavement is out of service. Since the DoD has a number of ASR damaged pavements, the potential savings across the Services is significant.

1-1.4 Arguments for Allowing Recycling of ASR-PCC.

The arguments for allowing recycling of ASR-PCC are summarized in these four points:

- The alkali-silica chemical reaction in these older pavements may have consumed most of the reactive constituents, and the damage may be over or nearly over.
- In crushing or cracking and seating or rubblizing the ASR-PCC, more volume is created between particles or in the network of cracks. Any future growth that occurs because of the ASR gel absorbing water can be accommodated within this increased open volume in the new structure.
- Classical testing studies of ASR in concrete have examined the growth of laboratory specimens in terms of a few tenths of a percent expansion or less. Such miniscule volume changes have little practical effect in pavement structures (e.g., a 0.5 percent vertical expansion of a 12 inch (in) (304 millimeters (mm)) layer of recycled material would be only 0.06 in, (1.524 mm)). The emphasis on ASR assessments for conventional concrete is to avoid cracking of the rigid concrete material. This is not an issue in crushed, unbound materials.
- If the recycled ASR-PCC is used at depth in a pavement structure, the overlying material would provide a compressive vertical load that might help counter any expansion.

Unfortunately, knowledge of ASRs is incomplete, and well-documented laboratory and field trials of ASR-PCC use in pavement structures are not available.

1-1.5 Concerns About Recycling ASR-PCC.

Paragraph 1-1.5 counters paragraph 1-1.4, which details concerns about recycling ASR-PCC.

- It is not possible to predict when the ASR phenomenon is complete, nor examine a sample of concrete to determine if the reaction is complete or if it will continue. The technology does not yet exist, but is a topic of ongoing research.

- Crushing or cracking existing ASR-PCC provides more volume for expansion, but also makes the recycled material more pervious. Past studies of military airfields in the southeastern and southwestern United States found that moisture content in airfield pavements tends to increase after construction, often approaching 95 to 98 percent saturation in plastic materials. When ASR damaged PCC is recycled and placed within the pavement structure, far more moisture will be available to the recycled material than when it was a surfacing material. With more moisture available, the ASR process may accelerate or restart.
- If recycled PCC continues to react, two possible adverse effects may develop. First, the increase in volume may lead to swelling of the recycled layer, with resulting surface upheaval and damage to adjacent structures and pavements. Secondly, the individual fragments of the recycled concrete containing aggregates and concrete matrix may break down as swelling within the fragments continues. This would tend to make a finer material over time: a clean gravel base that is classified at construction as a clean gravel (GW) aggregate by the Unified Soil Classification System could deteriorate to become a silty gravel (GM) or gravelly silty sand (SM) material. This could lead to a loss in strength, especially when the material is saturated. It could also make the material more prone to pumping failures under rigid pavements, or it could make the material frost-susceptible.
- There is no way to project the behavior of laboratory specimens to behavior in the field of a particular problem with durability tests like those performed to study ASR problems.
- Classical studies of ASR have dealt with bound materials that have tensile strength to resist internal swelling. PCC crushed for recycling no longer has inherent tensile strength to resist swelling. Consequently, while the PCC is in a bound state, it resists swelling of which may be a fraction of a percent, but when the PCC is crushed and placed as particulate matter, potential for swelling may increase.
- Reliable data on swelling of recycled ASR-PCC in the field is not available. A different chemical durability problem involving reactions between sulfates and components of PCC (sulfate attack) uses laboratory tests with expansion measurements of tenths of a percent… the same order of magnitude used with ASR laboratory specimens. At Holloman Air Force Base (AFB), a sulfate-resistant concrete airfield pavement was crushed and recycled as a well-graded base and fill material. This material underwent sulfate attack, with resulting heaving of overlying asphalt and concrete pavements, and damage to building foundations and walls and to utility and drainage structures. Both ASR and sulfate attack are water driven reactions, but the sulfate attack chemical reaction is totally different

from ASR; therefore, the Holloman AFB case provides no insight into whether recycled ASR-PCC will continue to react. It does, however, illustrate that a crushed, dense-graded recycled concrete placed in a pavement structure did swell sufficiently to cause significant damage. ASR and sulfate attack reactions are in the same order of magnitude for volume change. Therefore, do not dismiss the potential for a crushed, well-graded material to swell significantly from chemical induced volume changes, whether from ASR, sulfate attack, or other volume change reaction.

- If a recycled ASR concrete is placed as an open-graded drainage layer within the pavement, deterioration of individual particles of recycled material may lead to blockage of the drainage layer and may result in settlement as smaller particles settle into a more compact arrangement after deterioration.

1-1.6 Questions.

As paragraphs 1-1.4 and 1-1.5 illustrate, there are no answers to the questions of whether or not (1) ASR-PCC will continue to react when recycled in the pavement structure; and (2) if it does react, what the effect on the pavement will be. The prudent course is to recognize that adverse reactions to recycling are possible, and then assess the risk.

1-2 PURPOSE AND SCOPE.

This Tri-Service Pavements Working Group (TSPWG) Manual provides guidance and a framework for assessing the risk of incorporating recycled ASR-PCC into an airfield pavement structure. Incorporating such reacting recycled material into the pavement structure can significantly reduce construction costs for new or reconstructed pavements.

1-3 APPLICABILITY.

1-3.1 Coordination.

The Pavements Discipline Working Group (DWG) provided coordination for this manual.

1-3.2 Intended Users.

- All pavement engineers and other units responsible for design, construction, maintenance, and repair of airfield pavements.
- Air Force, U.S. Army Corps of Engineers (USACE) and Navy offices responsible for design, construction, maintenance, and repair of airfield pavements.
- All designers and construction contractors building airfield pavements.

1-4 BEST PRACTICES.

The Best Practices listed in Appendix A are considered to be guidance and not requirements. The main purpose is to communicate proven facility solutions, systems, and lessons learned, but may not be the only solution to meet the requirement.

1-5 GLOSSARY.

Appendix B contains acronyms.

1-6 REFERENCES.

Appendix C contains a list of references used in this manual. The publication date of the code or standard is not included in this document. Unless otherwise specified, the most recent edition of the referenced publication applies.

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CHAPTER 2 OBJECTIVES

2-1 OBJECTIVE.

This TSPWG Manual provides guidance and a framework for assessing the risk of incorporating recycled ASR-PCC into an airfield pavement structure. Incorporating such reacting recycled material into the pavement structure can significantly reduce construction costs for new or reconstructed pavements. Use of fracture technology (e.g., crack and seat, rubblization) is becoming more common and popular for pavement rehabilitation. Several projects have used ASR-reacting concrete without any problems noted to date (i.e., differential swelling, pavement roughness, or strength loss attributable to ongoing ASR in recycled PCC). However, documentation of initial conditions, detailed study of the materials in question, and lack of long-term performance data make these results difficult to project to other locations and materials. Innovative Pavement Research Foundation (IPRF) Report 03-5, *Evaluation, Design and Construction Techniques for the Use of Airfield Concrete Pavement as Recycled Material for Subbase*, cautions engineers dealing with aggressive ASR in airfields to conduct a detailed benefit and risk analysis when evaluating project options. This TSPWG Manual provides a basis for balancing the risks and benefits of recycling such material for a specific project for engineers wishing to apply a systematic approach to the decision-making process rather than proceeding solely on the basis of the lack of documented problems elsewhere.

2-2 CAUTIONS.

Interim guidance in this TSPWG Manual reflects consensus opinions on the best practices to assess the risk of including ASR-PCC in airfield pavements. This field of knowledge is evolving, and new data or research may eventually provide a better quantitative basis upon which to assess the risk of airfield pavement construction with these materials. This TSPWG Manual provides only a qualitative assessment of risk for recycling ASR-PCC in base, subbase, fill, or drainage layers of an airfield pavement, or using crack and seat or rubblization techniques to convert the in-situ pavement into a base course to be overlaid with asphalt concrete (AC). It does not cover recycling ASR-PCC as aggregate in a new PCC or AC, nor does it address alkali-carbonate reaction, a rarer alkali-aggregate phenomenon that has yet to be observed in any DoD airfield pavements. If either of these recycling concepts is proposed, contact the Pavements Design Working Group or their designated representative for guidance. Recycling PCC that is not undergoing ASR into the airfield pavement structure is a good and desired construction practice, as long as the recycled material is structurally sound and durable in its intended role.

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CHAPTER 3 RISK MANAGEMENT (RM) PROGRAM.RISK MANAGEMENT

3-1 INTRODUCTION.

Risk Management (RM) is a decision-making process to systematically evaluate possible courses of action, identify risks and benefits, and determine the best course of action (COA) for any given situation. Establish the requirement to integrate and sustain RM throughout the decision-making process in accordance with the project's authoritative guidance. This TSPWG Manual provides guidance on how to implement an RM assessment for using recycled ASR-PCC within a Services airfield pavement structure.

3-2 BENEFITS AND RISK.

Potential benefits include reduced initial construction costs or more rapid construction. The risk is possible future closure of the airfield for maintenance or complete reconstruction if the ASR continue in the recycled PCC.

3-3 EXPERIENCE.

Based on experience with disruptions caused by materials swelling within the pavement, surface distortions is the most likely symptoms of problems with recycled ASR-PCC. These experiences included sulfate attack on recycled PCC, sulfate attack on stabilized materials, and volume change of various waste products used in pavement. These events were not ASR-related, but they do illustrate what may happen with unexpected volume change within the pavement structure. For rigid pavements, the damage appears as unevenness between slabs or cracked slabs (Figure 3-1). Repairs typically involve grinding the surface or removing and replacing affected slab(s). For flexible pavements, the damage is often localized swelling (Figure 3-2); in some cases, it becomes a linear raised or humped area which can resemble a giant mole burrow across the pavement. The swelling may run preferentially along joints, where there is more water ingress. Repair usually requires cutting out and patching heaved areas. If the recycled material is in a drainage layer, deterioration of the material may result in surface settlement and depressions. Other potential problems are frost heave in seasonal frost areas, localized loss of strength and shear failures, and pumping on rigid pavements. If deterioration occurs in the recycled material, close and repair the affected pavement feature. This might take a week or more, depending on the exact nature of the problem, and might be required annually or even more often, or only every few years. In two instances, volume change in materials within the runway structure led to complete removal down through the affected material and reconstruction (Tampa civil airport due to expansive steel slag in the base course and a Laughlin AFB auxiliary field that experienced sulfate attack of a lime-stabilized base).

3-4 STEPS OF AN RISK MANAGEMENT ASSESSMENT.

These are the basic steps of an RM assessment:

- Identify hazards.

- Assess hazards.
- Develop controls and make decisions.
- Implement controls.
- Supervise and evaluate.

The remainder of this TSPWG Manual will provide guidance on implementing those RM steps for a specific project where designers are considering using recycled ASR-PCC.

Figure 3-1 Example of Differential Heaving on a Rigid Pavement Caused by Volume Change in Underlying Base and Fill Layers

Figure 3-2 Example of Localized Heaving in a Flexible Pavement Caused by Volume Change in the Underlying Base Course

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CHAPTER 4 IDENTIFY THE HAZARD

4-1 POTENTIAL ADVERSE OUTCOMES.

Paragraph 1-1.5 summarizes the potential adverse outcomes when recycled ASR-PCC is used within the airfield pavement structure, emphasizing the uncertainty of the results of recycling ASR-PCC. No reliable prediction of the results is available to the decision maker at this time — nor is any research ongoing within DoD to provide an answer in the near future. Therefore, decisions must be made with incomplete information.

4-2 POTENTIAL HAZARDS.

Basically, the potential hazards are (1) the recycled ASR-PCC within the pavement structure may increase in volume, causing disruption to the pavement surface and adjacent pavements and structures, or (2) individual fragments of the recycled material may break down, leading to potential loss in strength, frost susceptibility, pumping under rigid pavements, and settlement.

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CHAPTER 5 ASSESS THE RISK

5-1 ASSESS THE RISK.

Many RM processes suggest that risk be assessed on a combination of hazard severity and probability of occurrence.

5-2 HAZARD SEVERITY CATEGORIES.

Suggested hazard severity categories are *catastrophic*, *critical*, *moderate*, and *negligible*. The definitions are in terms of effect on mission, serviceman death or injury, and system loss or damage. For an airfield pavement, the hazard severity will be a combination of mission degradation and system damage. As a baseline, the hazard severity for this TSPWG Manual's assessment of the use of ASR-PCC within the airfield pavement structure will be *critical*. This presumes that a major airfield pavement feature, if damaged, would require extended closure of the affected airfield pavement for repairs and would constitute a major impediment to the flying mission and significant damage to the pavement system.

5-3 HAZARD SEVERITY RATING.

Which specific pavement feature is involved (e.g., runway at an airfield with only one runway versus a runway at an airfield with parallel runways) will play a role in determining the hazard severity rating. An adjustment on hazard severity for specific airfield conditions will be made later in the analysis.

5-4 PROBABILITY OF OCCURRENCE.

The probability of occurrence is particularly difficult to assess because we are uncertain of the results. The suggested rating guidance that seems most useful in this case is:

- **Frequent**: Continuously experienced.
- **Likely:** Occurs regularly.
- **Occasional:** Occurs several times in the life of the system.
- **Seldom:** Can be expected to occur in the life of the system.
- **Unlikely:** Unlikely, but could occur in the life of the system.

If the "system" in question is all DoD airfield pavements containing recycled ASR-PCC, then there are various arguments to support a case for *occasional*, *seldom*, and *unlikely* probability ratings. Unfortunately, no current research or test information conclusively identifies the "right" answer. Certainly, there are some slow-reacting and not very reactive aggregates that can probably be recycled safely. There are also certainly some very reactive aggregates (colloquially termed "hot" aggregates) that you should be very hesitant to recycle. For this TSPWG Manual, *seldom* will be the probability of occurrence as a reasonable base estimate of the situation. Later, adjustments will be made for adverse site conditions and specific ASR characteristics of the concrete.

5-5 ASR-PCC RISK ASSESSMENT.

Table 5-11 shows a risk assessment matrix, with a suggested risk priority list (i.e., a risk level with a 10 is more serious than one with an 11). For recycling ASR-PCC in the airfield pavement with a probability of occurrence of *seldom* and a hazard severity of *critical*, the initial average risk level assessment would be *medium* (block 11 with yellow highlighting). This means that if the average DoD-wide prospect of recycling ASR-PCC within the airfield pavement structure is considered, then it would be a medium risk. In paragraphs 5-6 through 5-8, this initial average risk assessment will be modified for specific site considerations.

Table 5-1 Risk Assessment Matrix Reflecting the Probability of an Event and the Severity of the Event

)			Probability				
			Frequent	Likely	Occasional	Seldom	Unlikely
			A	B	C	D	E
Severity	Catastrophic	I	1	2	6	8	12
	Critical	II	3	4	7	11	15
	Moderate	III	5	9	10	14	16
	Negligible	IV	13	17	18	19	20

Risk Levels: Extremely High - 1, 2, 3
High – 4, 5, 6, 7, 8
Medium – 9, 10, 11, 12, 13
Low – 14, 15, 16, 17, 18, 19, 20

5-6 HAZARD SEVERITY ADJUSTMENT FOR SITE-SPECIFIC PAVEMENT FEATURES.

Select a hazard severity level by base operations personnel together with the airfield manager. The initial hazard severity selection of *critical* was based on anticipation that the closure of the feature for repairs would have a significant impact on the flying mission. This would be the expected result if a runway or primary taxiway had to be closed for a week. If alternative pavements are available to carry out the mission, such as a parallel runway or alternate ways to route taxiing aircraft, then the hazard severity could be reduced to *moderate* and the overall risk level would drop to *low*. On the other hand, if the pavement in question is the only instrumented runway at a base with frequent bad weather, then the impact of closure could be very serious, and a hazard severity rating of *catastrophic* might be warranted, raising the risk level to *high*. Areas such as intersections of runways and taxiways may require special consideration because closure of these pavements for repair would affect two pavement features. For minor pavements such as ramps or ladder taxiways, the impact of closing these areas for a week might be minor, and a hazard severity of *negligible* could be appropriate. Each project needs its hazard severity level adjusted individually to reflect the actual impact that a pavement failure would have on the base's flying mission.

5-7 PROBABILITY ADJUSTMENT TO REFLECT THE ASR OF THE EXISTING PAVEMENT.

ASR development in concrete is a complex function of aggregate characteristics, cement chemistry, and environmental conditions. The initial probability rating of *seldom* assumes a moderately reactive PCC pavement that is to be recycled. Such a pavement will typically begin to show significant ASR symptoms at an age of 10 to 20 years. These symptoms will include extensive cracking and relatively modest volume changes that will develop spalling at joints, extrusion of joint sealant, and minor displacement of adjacent structures, such as jamming of grates in trench drains and small upheaval of asphalt concrete shoulders. Patching probably has been frequent in the 15- to 20-year range. When considering older pavements that may be 30 or 40 years old, past maintenance records and Pavement Condition Index (PCI) assessments help develop an estimate of how severe the ASR has been on the specific PCC. Adjust the probability of occurrence in Figure 5-1 to the left to *occasional* for highly reactive pavements and to the right to *unlikely* for pavements showing low levels of reactivity. Paragraphs 5-7.1 and 5-7.2 help classify highly reactive and low reactivity pavements.

5-7.1 Highly Reactive Pavements.

A highly reactive pavement will show symptoms of ASR less than 10 years after placement and may require patching within this period. Figure 5-1 shows minor ASR cracking on a pavement. The damage is not severe now, but it occurred five years after placement. This specific pavement required patching at eight years of age to reduce FOD hazards. This pavement would be rated as highly reactive because ASR symptoms and repairs began less than 10 years after placement. Pavements that show large volume changes, even if they did not appear until the 10- to 20-year point, should also be considered as potentially highly reactive. Figure 5-2 shows examples of heaving of AC that suggests serious potential problems if the adjacent ASR-PCC were recycled into an airfield pavement structure. Figure 5-3 shows differential displacement of several inches between slabs that are undergoing ASR, and also shows a repaired AC area adjacent to a PCC section that has expanded several inches. These photographs suggest a highly reactive material. When contemplating recycling an existing ASR-PCC pavement that began showing symptoms early in its life (10 years or less) or that shows large volume change potential, consider this material highly reactive and raise its probability rating to at least *occasional*.

Figure 5-1 Minor ASR Cracking in 5-Year-Old Pavement (Left Photograph); Patching Needed 3-Years Later (Right Photograph)

5-7.1.2 Early development of ASR.

Because of the early development of ASR symptoms in this pavement, it would be considered a highly reactive pavement. Photos in Figure 5-2 suggest a highly reactive pavement.

Figure 5-2 Examples of Damage to Adjacent Asphalt from ASR-Induced Expansion in Adjacent PCC Pavement

Figure 5-3 Examples of Large Volume Changes Suggesting Highly Reactive ASR Pavements

5-7.1.3 Large Volume Changes.

In Figure 5-3, top photo, two pavement slabs are displaced by several inches. In the bottom photo, the PCC has grown from the visible joint in the AC and damaged the adjacent pavement. An AC repair patch to the damaged AC from this growth is visible to the left of the PCC.

5-7.2 Low Reactive Pavement.

Some pavements that develop ASR do so only after a long time and may develop only mild symptoms. Maintenance for ASR issues on such pavements has probably been minimal or nonexistent. Figure 5-4, shows an example where the pavement is over 25 years old. ASR cracking remains relatively tight, with minimal raveling and spalling, and with only modest displacement of the asphalt shoulder. In this case, lowering the probability rating of using this PCC in a recycled application to *unlikely* would be reasonable.

Figure 5-4 Example of Low Reactivity ASR at Travis AFB

Cracking is generally tight with minor FOD issues in this pavement that is over 25 years old. Small volume change has caused minor upheaving of the AC shoulder. The only maintenance on this ramp has been sweeping to minimize the hazard caused by the slow generation of FOD.

5-8 PROBABILITY ADJUSTMENT TO REFLECT LOCAL MOISTURE CONDITIONS.

ASR is a moisture-driven reaction. Unfortunately, even in arid desert environments, ample moisture content is available to trigger and sustain ASR activity in conventional concrete. If the proposed recycled ASR-PCC is to go into a pavement structure that has historically experienced at least seasonally wet conditions, increase the probability of occurrence one level (e.g., from the base of *seldom* to *occasional*). This high moisture exposure may result from conditions such as a high groundwater table; a perched groundwater table; capillary rise from a near-surface water table; condensation of water vapor; poor or blocked drainage; or thaw periods in seasonal frost areas. Even in arid regions, local geologic conditions such as basins, playas, or sabkhas can seasonally result in a high water table near or above the natural ground level. On the other hand, if conditions are likely to be dry and stay dry within the pavement structure, reduce the probability of occurrence from *seldom* to *unlikely*. Traditionally, military airfield pavement design has allowed a reduction in pavement thickness for favorable moisture conditions when the annual rainfall is less than 15 in (396 mm) and the water table is permanently deeper than 15 feet (4.57 meters). Such rainfall and water table conditions may be used as indicators of a reduction in the probability of occurrence for adverse reactions in recycled ASR-PCC.

5-9 SUMMARY OF RISK ASSESSMENT.

The typical initial average risk assessment for recycling ASR-PCC within an airfield pavement structure as base, subbase, or fill, or as part of a crack and seat or rubblization rehabilitation technique is *medium*. This is based on a hazard severity rating of *critical* and a probability of occurrence of *seldom* in the risk assessment matrix in Table 5-1. Adjust this initial average risk assessment for specific site conditions. Use consultations with operational and command elements to adjust the hazard severity rating as appropriate for the specific criticality of the pavement feature being analyzed (paragraph 5-6.). Also adjust the probability of occurrence for specific site conditions such as particularly high or low alkali-silica reactivity in the concrete being recycled (paragraph 5-7.) and particularly wet or dry conditions (paragraph 5-8.).

CHAPTER 6 ANALYZE RISK CONTROL MEASURES

6-1 INTRODUCTION.

Generally, the only option available to control the risk, other than outright rejection of recycling the ASR concrete into the pavement, is to find ways to limit the probability of occurrence or to mitigate the likelihood or extent of adverse effects if the recycled ASR concrete deteriorates. Paragraphs 6-1 through 6-4 describe some possible mitigation methods.

6-2 THICKNESS OF THE RECYCLED MATERIAL.

Limit the thickness of the recycled material. If a limited thickness of only approximately 6 inches (152 millimeters) of the material is used, then likelihood of adverse effects will be reduced. Also, the deeper the material is in the pavement, the less significant any adverse effects will be.

6-3 BLENDING RECYCLED ASR.

Blend the recycled ASR concrete with other aggregates or materials that are not suffering from ASR. This approach is simply diluting the potentially reactive material.

6-4 WATER.

Limit available water. Trying to limit water from accessing pavement has proven easier in concept than in practice. Water arrives as vapor, as condensation on the underside of surfaced areas, through capillary processes, and by infiltration, causing problems. Attempts to control moisture access to the pavement for other moisture related problems such as D-cracking, frost damage, and sulfate attack have had very limited success. Although conceptually sound, this mitigation method is not recommended simply because it is difficult, if not impossible, to accomplish in the field.

6-5 TESTING.

Test the material proposed for recycling. If the material to be recycled shows no deterioration and no swelling in a vigorous laboratory test, it is reasonable to lower the probability of occurrence by one rating (e.g., from *seldom* to *unlikely*). Unfortunately, there is no accepted test method or criteria to evaluate the potential deterioration in the ASR concrete proposed for recycling. The tests used to most accurately assess conventional concrete for ASR (or at least those thought to most accurately do this) run for one or two years before an answer is available. Usually this is useful for research, but not for construction. To get timely results, laboratory tests are often run under accelerated test conditions, which usually means under more extreme temperatures and under severe saturation or chemical exposure conditions. The results of such tests are available sooner, but how these results relate to field conditions is unclear as such accelerated test conditions may trigger reactions that would never appear in the field. Nevertheless, some reasonable testing provides additional insight into the probability of adverse deterioration. Potential tests are being researched, but currently there is no accepted standard test or criteria. Evaluate any proposed test or criteria and either accept or reject on a case-by-case basis. Consult the Pavements Design Working Group or their designated representative for assistance. If testing is proposed to aid in evaluating the recycling of ASR-PCC into an airfield structure, observe the following guidelines:

- Use the actual concrete proposed for recycling in the testing. Tests from other locations or previous tests at the same air base are not a substitute.
- Ensure a qualified concrete petrographer is part of the analysis team examining and evaluating the test specimens.
- Crush the proposed concrete to the proposed gradation for use in the field, and test specimens compacted to the expected field density.
- Expose samples to soaking, under conditions of elevated temperature, in a high alkali solution. Ensure that each litre of solution contains 1.41 oz (40.0 g) of NaOH dissolved in 0.24 gal (900 mL) of water, and is diluted with additional distilled or deionized water to obtain 0.26 gal (1.0 L) of solution. The volume proportion of sodium hydroxide solution to the recycled ASR-PCC in a storage container is 4 volumes of solution to 1 volume of recycled ASR-PCC.
- Continue tests for not less than 30 days. Longer tests would be more valid than shorter ones.
- For any sign of swelling, increase the probability of occurrence rating by at least one level (e.g., from *seldom* to *occasional*). Because of the severity of the test and the uncertainty of how well it represents field behavior, it is appropriate to raise the probability rating only one level.
- Assess any change in gradation or weakening of fragments by the analysis team petrographer and design engineer. Also assess whether the deterioration of the fragments would have an adverse effect. For example, production of sand-sized particles for a base under a rigid pavement would have little or no impact on pumping potential, but generation of large quantities of material passing the No. 200 sieve might very significantly increase the potential for pumping in the pavement.
- If tests show no potential for swelling and no degradation of the material under these severe test conditions, reduce the probability of occurrence one rating.

6-6 OTHER FACTORS.

Other miscellaneous factors may affect the risk. Some pavement designs, such as asphalt surfaces, are easier to maintain for minor pavement surface problems where one could simply mill and overlay. The coarser fractions of crushed materials generally have fewer weak particles and contaminants, so some beneficiation of the recycled concrete may be feasible by removing the finer fractions. General stockpiles of potentially recyclable PCC that comes from multiple projects may be hard to control and assess. For airfield paving projects, it is prudent to have specific knowledge of the origin and condition of the PCC proposed for recycling.

CHAPTER 7 MAKE CONTROL DECISIONS

7-1 RISK CONTROL OPTIONS.

Available risk control options are fairly limited. Reduce the amount of recycled material susceptible to deterioration by using it in thin sections, or by blending it with non-reactive materials; however, this may reduce the economic benefit of the recycling. Attempts to control moisture access to the recycled material are probably impractical and overly optimistic; therefore, this is not recommended as a control measure. Finally, while tests are run to assess reactivity of the proposed material, no accepted tests or criteria are currently available for this purpose. Any answers from tests are perhaps best thought of as suggestive rather than conclusive. The assigned initial average probability of occurrence rating of *seldom* is considered a reasonable and not overly conservative estimate based on current knowledge. Reduce this probability rating only with caution.

7-2 DEFINITION OF RISK.

Risk is an expression of consequences in terms of the probability of an event occurring, the severity of the event, and the exposure of personnel or resources to potential loss or harm. The hazard in question is deterioration of ASR-PCC recycled within the airfield pavement structure that could lead to damage, closure, and periodic repair of the airfield pavement. It is possible, although probably a remote possibility, that the pavement would have to be closed, the pavement including all recycled ASR-PCC would have to be removed, and a replacement pavement would have to be built. The loss that might be suffered by the Services includes increased maintenance costs, repair or replacement costs, and the impact of closure of the airfield pavement for repairs or replacement.

7-3 RISK.

Essentially, all risks of recycling ASR-PCC in an airfield pavement is borne by the Services. It is unlikely that any damage will be visible within the one-year contract warranty period normally provided by contractors on airfield pavements. Therefore, if adverse deterioration does occur, neither the designer nor the contractor are likely to be held liable for any loss suffered by the Services for using recycled ASR-PCC. When evaluating potentially optimistic predictions from designers, contractors, material producers, or their consultants, remember that they are exposed to no risk if there is an adverse reaction.

7-4 ECONOMICS.

The benefit of recycling ASR-PCC in the pavement structure is economic. By recycling ASR-PCC, it is possible for the Services to significantly reduce construction costs or, in some cases, speed construction. The DoD also has a significant quantity of ASR-affected airfield pavements that need or will need to be rehabilitated. If they cannot be recycled, then there is also a significant cost in disposing of the material.

7-5 IMPACT ON THE FLYING MISSION.

The crux of the issue is whether the cost savings that are realized can adequately balance the possible need to close airfield pavements for maintenance, repair, or replacement if deterioration continues in the recycled material. This has a potential major impact on the flying mission at a base, an impact that is probably far more critical than the actual cost of any maintenance, repair, or replacement project.

CHAPTER 8 IMPLEMENT RISK CONTROLS

Once the pavement has been finished, implement a monitoring program to watch for adverse pavement behavior. At least annually, inspect the pavement by a knowledgeable pavement engineer walking the entire scope of the project. Conduct at least nine transverse elevation and three longitudinal elevation profile runs when the project is finished, and annually thereafter. Determine whether any adverse behavior is developing from using recycled ASR concrete. Maintain the elevation profiles, along with the pavement engineer's visual assessment and analysis of the profiles, in a permanent file for the facility.

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CHAPTER 9 CONCLUSION

9-1 DECISION.

The decision to use or not use ASR-PCC in an airfield pavement structure impacts many parties at the base and the Pavements Discipline Working Group (DWG). If ASR-PCC is proposed for recycling, crack and seat, or rubblization, the pavement designer should prepare a risk assessment as outlined in this TSPWG Manual and submit it to the Base for approval. Coordinate with affected base-level organizations and submit the coordinated risk assessment package to gain approval from the DWG or their designated representative before using recycled ASR-PCC on airfield pavement. Each Service may establish unique requirements for coordination and approval.

9-2 RISK ASSESSMENT.

As a general rule, ensure the risk assessment for recycling ASR-PCC into a DoD airfield pavement offers significant economic benefit and is in the low risk assessment category to be viable. It is critical that this risk assessment be based on judgment of actual conditions and not be driven by project pressures and budgets. Risk assessments offer good advice on trying to balance natural inclinations to be overly optimistic, with similar tendencies to be overly conservative. This is a classic case requiring mature professional judgment and balance in arriving at a reasonable assessment; and with this assessment, there are unknowns and risks regardless of the decision.

9-3 GENERAL METHODOLOGY.

While this TSPWG Manual applies specifically to DoD airfield pavements, the general methodology may be used for any pavement; however, pavements such as roads, streets, and industrial and privately owned vehicle parking lots are not mission-critical elements. Far more latitude in recycling ASR-PCC is possible for these applications than is possible for an airfield pavement project.

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APPENDIX A EXAMPLE OF A RISK ASSESSMENT

A-1 BACKGROUND.

An airfield has a runway that displays ASR damage consisting of moderate cracking and spalling, moderate shoulder upheaval, and damage to airfield lights. The damage began appearing as a network of fine cracks approximately six years ago, and the pavement is now 18 years old. The base has a parallel runway. The runway is located in an area where the water table often rises within the pavement structure during the spring thaw period. If the existing ASR-PCC can be crushed and recycled as base course for the new pavement, large savings are possible.

A-2 SETTING THE INITIAL AVERAGE RISK LEVEL ASSESSMENT.

The initial average risk level assessment is *medium*, block 11 (reference paragraph 5-5).

			Probability				
			Frequent	Likely	Occasional	Seldom	Unlikely
			A	B	C	D	E
Severity	Catastrophic	I	1	2	6	8	12
	Critical	II	3	4	7	11	15
	Moderate	III	5	9	10	14	16
	Negligible	IV	13	17	18	19	20

Risk Levels: Extremely High - 1, 2, 3
High – 4, 5, 6, 7, 8
Medium – 9, 10, 11, 12, 13
Low – 14, 15, 16, 17, 18, 19, 20

A-3 ADJUSTING FOR HAZARD SEVERITY.

(Reference paragraph 5-6.) The base agrees that because there is a parallel runway, the hazard severity can be reduced to *moderate* to give a risk assessment of *low*, block 14.

			Probability				
			Frequent	Likely	Occasional	Seldom	Unlikely
			A	B	C	D	E
Severity	Catastrophic	I	1	2	6	8	12
	Critical	II	3	4	7	11	15
	Moderate	III	5	9	10	14	16
	Negligible	IV	13	17	18	19	20

Risk Levels: Extremely High - 1, 2, 3
High – 4, 5, 6, 7, 8
Medium – 9, 10, 11, 12, 13
Low – 14, 15, 16, 17, 18, 19, 20

A-4 ADJUSTING FOR ASR REACTIVITY IN THE EXISTING PCC.

(Reference paragraph 5-7.) The PCC shows the expected reactivity. The development of ASR at 10 to 20 years after PCC placement and moderate levels of damage are consistent with the original definitions. No adjustment is needed for alkali-silica reactivity in the existing PCC. The risk level assessment remains as *low*, block 14.

A-5 ADJUSTING FOR MOISTURE CONDITIONS.

(Reference paragraph 5-8.) Because of the seasonally wet conditions, it is prudent to increase the probability rating to *occasional*, giving a risk level assessment of *medium*, block 10.

			Probability				
			Frequent	Likely	Occasional	Seldom	Unlikely
			A	B	C	D	E
Severity	Catastrophic	I	1	2	6	8	12
	Critical	II	3	4	7	11	15
	Moderate	III	5	9	10	14	16
	Negligible	IV	13	17	18	19	20

Risk Levels: Extremely High - 1, 2, 3
High – 4, 5, 6, 7, 8
Medium – 9, 10, 11, 12, 13
Low – 14, 15, 16, 17, 18, 19, 20

A-6 ADJUSTING FOR RISK CONTROL MEASURES.

(Reference Chapter 7.) No risk control measures using blending or thin sections are desired to maximize potential cost savings. There is insufficient time for tests to be run before the contract has to be awarded. Therefore, no further adjustments are to be made, and the risk level assessment remains as *medium*, block 10.

A-7 MAKING THE FINAL DECISION.

A-7.1 Compare all identified benefits to all identified costs. Balancing costs and benefits may be a subjective process and open to interpretation. Ultimately, the balance is determined by the appropriate decision authority.

A-7.2 In this case, the question that the decision-making authority answers is whether a *medium* risk, with the attendant possible airfield pavement closure costs, is sufficiently counterbalanced by the possible savings. Such decisions are made on a case-by-case basis, and there is no generic answer.

Note: If moisture had not been an issue so that the probability remained at *seldom*, and tests had been run that showed no swelling and no degradation (paragraph 6-4), the probability would have dropped to *unlikely*. With the *moderate* severity level, the overall risk level assessment would have been *low*, block 16. This is significantly better than the *medium* risk level assessment (block 10) rating in the example, and would make using the recycled ASR concrete much more attractive.

APPENDIX B GLOSSARY

AC	asphalt concrete
AFCEC/COSC	Air Force Civil Engineer Center, Civil Branch
AFB	Air Force Base
AFI	Air Force Instruction
AFPAM	Air Force Pamphlet
ASR	alkali-silica reaction
ASR-PCC	PCC that is undergoing an alkali-silica reaction
BCE	Base Civil Engineer
COA	course of action
DoD	Department of Defense
ETL	Engineering Technical Letter
FOD	foreign object damage
g	gram
gal	gallon
GM	silty gravel
GW	clean gravel
IPRF	Innovative Pavement Research Foundation
L	liter
mL	milliliter
MAJCOM	Major Command
oz	ounce
PCC	portland cement concrete
PCI	pavement condition index
RM	risk management
SM	silty sand
TSPWG	Tri-Service Pavements Working Group

TTP	Tactics, Techniques, and Procedures
USACE	U.S. Army Corps of Engineers

APPENDIX C REFERENCES

IPRF 03-5, *Evaluation, Design and Construction Techniques for the Use of Airfield Concrete Pavement as Recycled Material for Subbase*
http://www.iprf.org/products/main.html