Development of a Materials-Related Distress Rating System for Portland Cement Concrete Airfield Pavements

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Introduction

The Pavement Condition Index (PCI) procedure is the standard used by the aviation industry to visually assess pavement condition. In fact, the U.S. Federal Aviation Administration's (FAA's) Advisory Circular (AC) 150/5380-6B, *Guidelines and Procedures for Maintenance of Airport Pavements* "recommends that airports follow American Society for Testing Materials (ASTM) D 5340, *Standard Test Method for Airport Pavement Condition Index Surveys* when conducting preventive maintenance inspections," which employs the PCI procedure.

During a PCI survey, visible signs of deterioration within a selected sample unit are observed and recorded by distress type, severity, and quantity. The results of the PCI survey, aggregated into a score from 100 to 0 with 100 being a pavement that is distress-free, provide engineers with a consistent, objective, and repeatable tool to represent and communicate the overall condition of a pavement.

However, it has been noted that the PCI procedure does not adequately address materials-related distress (MRD), which Van Dam et al. (2002) refer to as "pavement distresses that are directly related to the interaction between the concrete materials used to construct the pavement and the environment." MRDs are further broken down by their primary cause: MRD due to physical mechanisms include paste freeze-thaw deterioration, deicer scaling/deterioration, and freeze-thaw deterioration of aggregate, and MRD due to chemical mechanisms include alkali-silica reactivity (ASR), alkali-carbonate reactivity (ACR), external sulfate attack, internal sulfate attack, and corrosion of embedded steel. Recent interest has focused on the role deicers may play, both physically and chemically, in the development and progression of MRD (Van Dam et al. 2006; Rangaraju and Olek 2007; Sutter et al. 2008).

Regardless of the primary mechanism at work, early indications of MRD do not correspond well to the identification of distresses in the PCI procedure for airfield PCC pavements, where there are three primary distress calls that may be related to MRD: "D" cracking; Scaling, Map Cracking, and Crazing; and Shrinkage Cracks. Furthermore, other PCI distresses may be the result of the presence of MRD (such as blowups, patching, and spalling), but the distinct characteristics of MRD are not specifically called out. For this reason, a complementary survey procedure is needed to note the emergence and progression of MRD to assist airfields in planning for future maintenance and rehabilitation needs.

This paper describes a procedure that has been prepared to better identify, quantify, and record the presence and severity of MRD on airfield PCC pavements. The work described in this paper was conducted under IPRF Project No. 01-G-002-06-6. It is based predominantly on the

performance of concrete pavements exhibiting MRD and interviews and surveys conducted with airport design and maintenance personnel at two airports. The procedure is documented in a guide, whose development is discussed in greater detail in this paper.

Project Objectives

The primary general objective of the project under which this work was conducted was to develop a pavement survey procedure to complement the PCI, focusing on the unique manifestations of MRD. The procedure and associated MRD rating (MRDR) protocol were developed based on current knowledge of the development and progression of MRD. The MRDR protocol is designed to be used for the identification of pavement repair/ rehabilitation decision points consistent with surface conditions that dictate pavement management actions intended to minimize the potential for the generation of foreign objects and debris (FOD) that could damage aircraft operating on the pavement. Specific objectives of this study included the following:

- Development of the MRDR tool for assessing the presence and severity of MRD. This tool must be able to be used to track progression of MRD over time through repeated applications of the procedure.

- Develop an understanding of the risk associated with MRD development and progression and subsequently use this understanding to make recommendations for the timing of strategies intended to minimize the rate of FOD generation. The risk assessment must include the identification of MRDR decision points that are timely with respect to the budget process.

- The MRDR must possess the sensitivity necessary to thoroughly define the various MRD manifestations, including what observable or measurable features constitute the initial signs of MRD, what manifestations of MRD result in the worst "rate of surface deterioration," and how the owner can predict the time between the initial identification of MRD and the decision point when mitigation must be employed.

- Define how "risk" is assigned and "unacceptable risk" judged. Risk association must be based upon an empirical knowledge of the pavements that are the subject of this study.

This paper describes the development of the MRDR tool and presents the results of applying the MRDR protocol at two airports affected by MRD.

Development of the MRD Identification Guide

The results of a literature review were combined with the research team's experience, identifying the following common manifestations of MRD:

- Staining of the concrete, often near joints and/or cracks.
- Pattern cracking.
- Perpendicular cracking.
- Parallel cracking.

- Exudate in cracks.
- Signs of expansion.
- Joint disintegration and scaling.

A preliminary version of the MRDR tool was then developed, using descriptions and photographs of each of the distresses at different severity levels. The draft MRDR tool was applied at a single airport as part of the development of the MRDR methodology concurrent with the PCI, and the results from that survey were used to substantially modify the draft MRDR tool. Pavements at a second airport were then evaluated with the revised version of the MRDR tool, and the results of this second inspection were used to slightly modify the protocol which was then applied again to the first airport. The final tool was then reapplied at each of the airports the following spring to verify repeatability, reasonability, and objectivity, as well as establish MRD progression trends.

Progression of MRD

The occurrence and subsequent progression of distress at the two airports occurred in three distinct slab locations: corner, joint, and interior, as illustrated in figure 1. As can be seen, each location is numbered. Grouping distresses into these locations not only simplified the data collection process, it provided additional information to more accurately develop repair strategies and also helped determine the progression of distress.

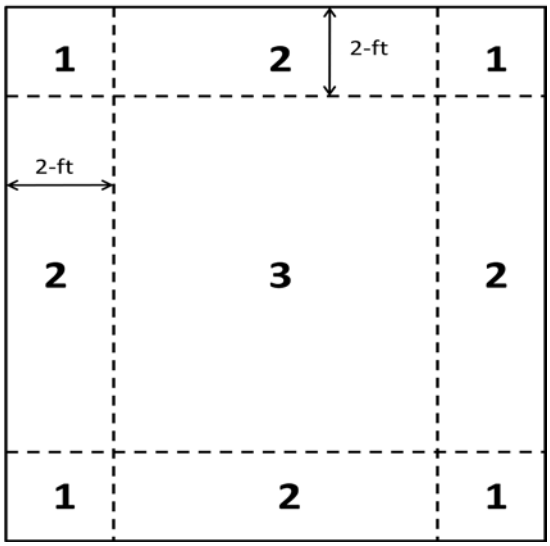

Figure 1. Locations where MRD distress was observed (1: corner, 2: joint, and 3: interior).

The primary distress progression sequences in the corner location, as shown in figure 2, and along a joint, as shown in figure 3, are as follows:

Staining ⟹ *Tight Parallel/Perpendicular Cracking* ⟹
Open Parallel/Perpendicular Cracking ⟹ *Joint Disintegration*

Although the sequence is the same, it was observed that progression rate differed between the airports. In both cases, it was the joint disintegration, whether at a corner or joint, that ultimately leads to the highest level of FOD risk.

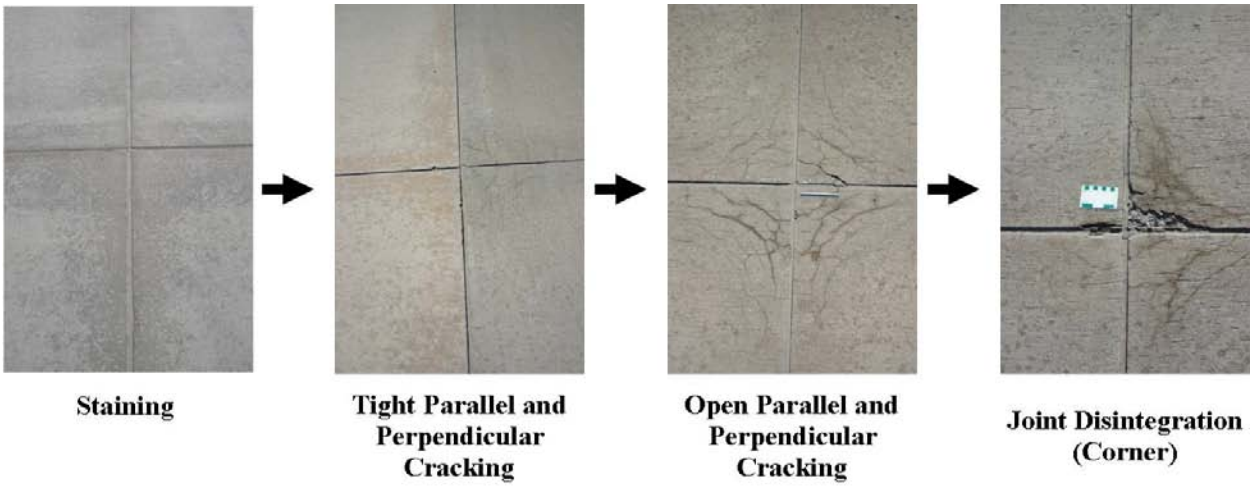

Figure 2. Illustration of MRD progression sequence for corner location.

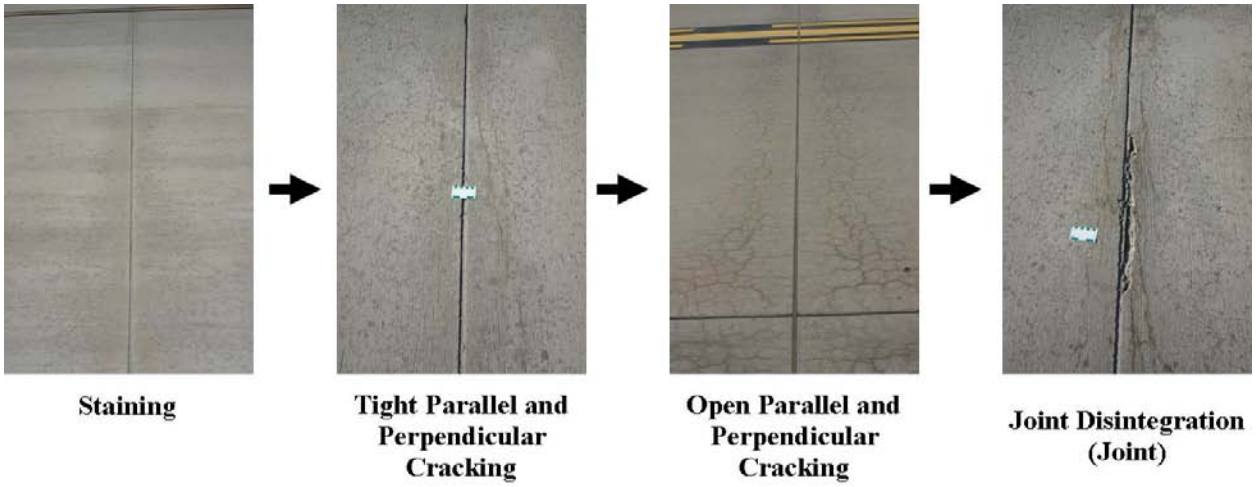

Figure 3. Illustration of MRD progression sequence for joint location.

A secondary distress progression sequence, illustrated in figure 4, was identified for the interior locations as follows:

Staining ⟹ *Tight Pattern Cracking* ⟹ *Open Pattern Cracking* ⟹ *Scaling*

In the pavements evaluated, staining of the slab interior was not always a precursor to pattern cracking. Further, interior slab staining was a readily observable feature at Airport A, but not at Airport B. As a result, although staining is illustrated in the progression sequence, the role it plays is unclear. This MRD sequence is considered secondary as it is occurs more slowly and is

typically less severe than MRD occurring at corners and joints. But as it advances it will create FOD risk, as evidenced by the scaling shown in figure 4.

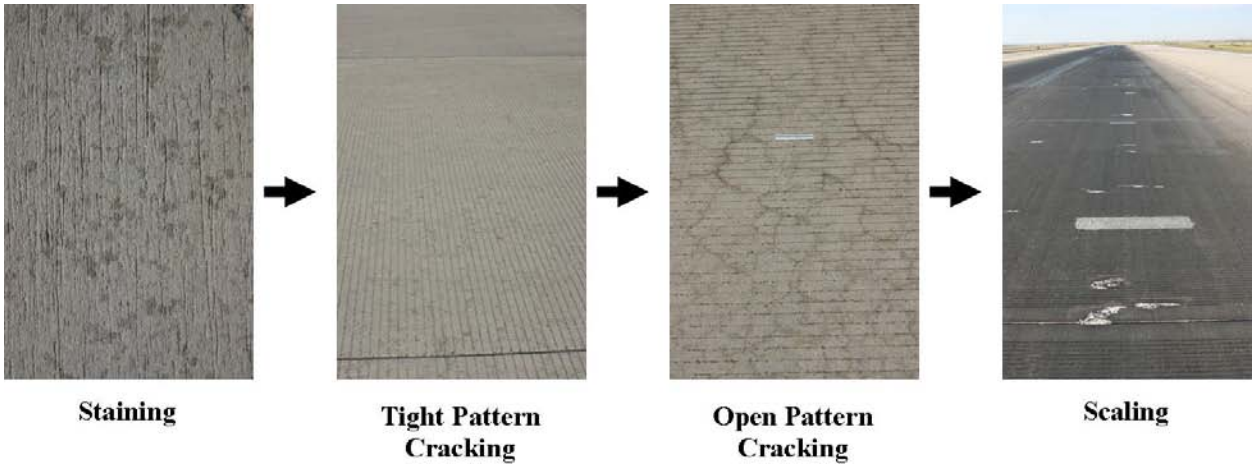

Figure 4. Illustration of MRD progression sequence for interior location.

Other MRD progression sequences that were observed, but which played a lesser role, included surface deterioration in areas with surface honeycombing, deterioration of patches that had been used to repair disintegrated and scaled areas, and expansion which was responsible for shoving fixtures, closing and misaligning joints, and causing blow ups.

MRD Progression Rate at Two Airports

After establishing the MRD progression sequences, the rate of progression was estimated. Interviews were conducted and questionnaires distributed to maintenance and engineering personnel at both airports. Each individual was asked to independently assess the progression sequence and estimate the transition time between condition states. Participants were asked to estimate the number of years expected before a given distress required repair (the choices were Now, 1 to 3 years, 4 to 6 years, or within 10 years) and how long it would take for the distress to progress from one severity state to the next (e.g. tight pattern cracking to open pattern cracking, joint staining to tight perpendicular/parallel cracking, and so on). In total, six individuals participated from Airport A and eight from Airport B.

There was considerable variability in the information collected in the questionnaires. This is reflected in the data presented in tables 1 and 2 and plotted in figure 5, which shows the range and average estimated years before repair is required for various distress manifestations for Airport A and Airport B, respectively. For example, when shown a picture of corner staining, individuals from Airport A estimated it would require repair in 1 to 3 years (on average in 2.0 years) before repair was necessary. In contrast, of the eight individuals at Airport B who evaluated the same photograph, two answered it would require repair in 1 to 3 years, three 4 to 6 years, and three within 10 years, averaging to 6.8 years.

Table 3 shows the results to questions in which respondents were asked to estimate the time it would take for the distress to go from one severity state to the next. For example, when shown

Table 1. Estimated years to required repair for Airport A.

Distress	Description	Years Before Repair Required		
		Worst Case	Average	Best Case
Staining (Corner)	N/A	1 to 3	2.0	1 to 3
Parallel/Perpendicular Cracking (Corner)	Tight	Now	1.8	4 to 6
	Open	Now	0.3	1 to 3
Joint Disintegration (Corner)	N/A	Now	0	Now
Staining (Joint)	N/A	Now	1.75	1 to 3
Parallel/Perpendicular Cracking (Joint)	Tight	Now	2.2	4 to 6
	Open	Now	1.8	4 to 6
Joint Disintegration (Joint)	N/A	Now	0.3	1 to 3
Staining (Interior)	N/A	Now	4.0	Within 10
Pattern Cracking (Interior)	Tight	1 to 3	5.7	Within 10
	Open	1 to 3	3.9	4 to 6
Scaling	N/A	Now	1.3	1 to 3

Table 2. Estimated years to required repair for Airport B.

Distress	Description	Years Before Repair Required		
		Worst Case	Average	Best Case
Staining (Corner)	N/A	1 to 3	6.8	Within 10
Parallel/Perpendicular Cracking (Corner)	Tight	Now	4.9	Within 10
	Open	Now	3.3	Within 10
Joint Disintegration (Corner)	N/A	Now	1.8	Within 10
Staining (Joint)	N/A	1 to 3	7.4	Within 10
Parallel/Perpendicular Cracking (Joint)	Tight	Now	4.0	Within 10
	Open	Now	2.0	4 to 6
Joint Disintegration (Joint)	N/A	Now	2.8	Within 10
Staining (Interior)	N/A	4 to 6	8.3	Within 10
Pattern Cracking (Interior)	Tight	1 to 3	6.4	Within 10
	Open	1 to 3	5.5	Within 10
Scaling	N/A	Now	1.6	4 to 6

Table 3. Average years for transition from one severity state to next for Airports A and B.

Location	Sequence	Average Years	
		Airport A	Airport B
Corner	Staining to parallel/perpendicular cracking (tight)	3.5	4.9
	Parallel/perpendicular cracking (tight) to parallel/perpendicular cracking (open)	2.6	4.0
	Parallel/perpendicular cracking (open) to joint disintegration	2.5	3.1
	Estimated time from staining to repair	8.6	12.0
Joint	Staining to parallel/Perpendicular cracking (tight)	4.0	2.0
	Parallel/perpendicular cracking (tight) to parallel/perpendicular cracking (open)	3.0	2.0
	Parallel/perpendicular cracking (open) to joint disintegration	2.6	2.1
	Estimated time from staining to repair	9.6	6.1
Interior	Staining to pattern cracking (tight)	3.5	3.5
	Pattern cracking (tight) to pattern cracking (open)	2	5.2
	Pattern cracking (open) to joint disintegration	2.8	5.4
	Estimated time from staining to repair	8.3	14.1

photographs of tight pattern cracking and open pattern cracking, respondents from Airport A estimated on average it would take 2.0 years whereas respondents from Airport B estimated it would take 5.2 years. For each location (corner, joint, or interior), the total time for MRD to progress from staining to repair (needed when joint deterioration/scaling occurred) is determined by summing the time for each transition. For Airport A, for example, these are 8.6, 9.6, and 8.3 years for corner, joint, and interior locations, respectively.

Even considering the variability, some interesting trends are observed between the MRD manifestations at the two airports. In general, the MRD at Airport A as reported by the airport personnel is more aggressive than at Airport B, with the time to repair being shorter for every MRD manifestation shown in figure 5. The results in table 3 are consistent with this observation except at the joint location, where the MRD progression from staining to repair was more aggressive at Airport B than Airport A.

Evaluating the data in table 3, it appears that for Airport B distress progression at the joint location is the most critical, progressing from staining to repair required in 6.1 years. This conclusion is not as strongly drawn from the data plotted in figure 5, which suggests that the corner and joint locations are both of similar concern for Airport B. Regardless, interior manifestations of MRD are not considered as critical as signs of MRD which occur at corners and joints for Airport B.

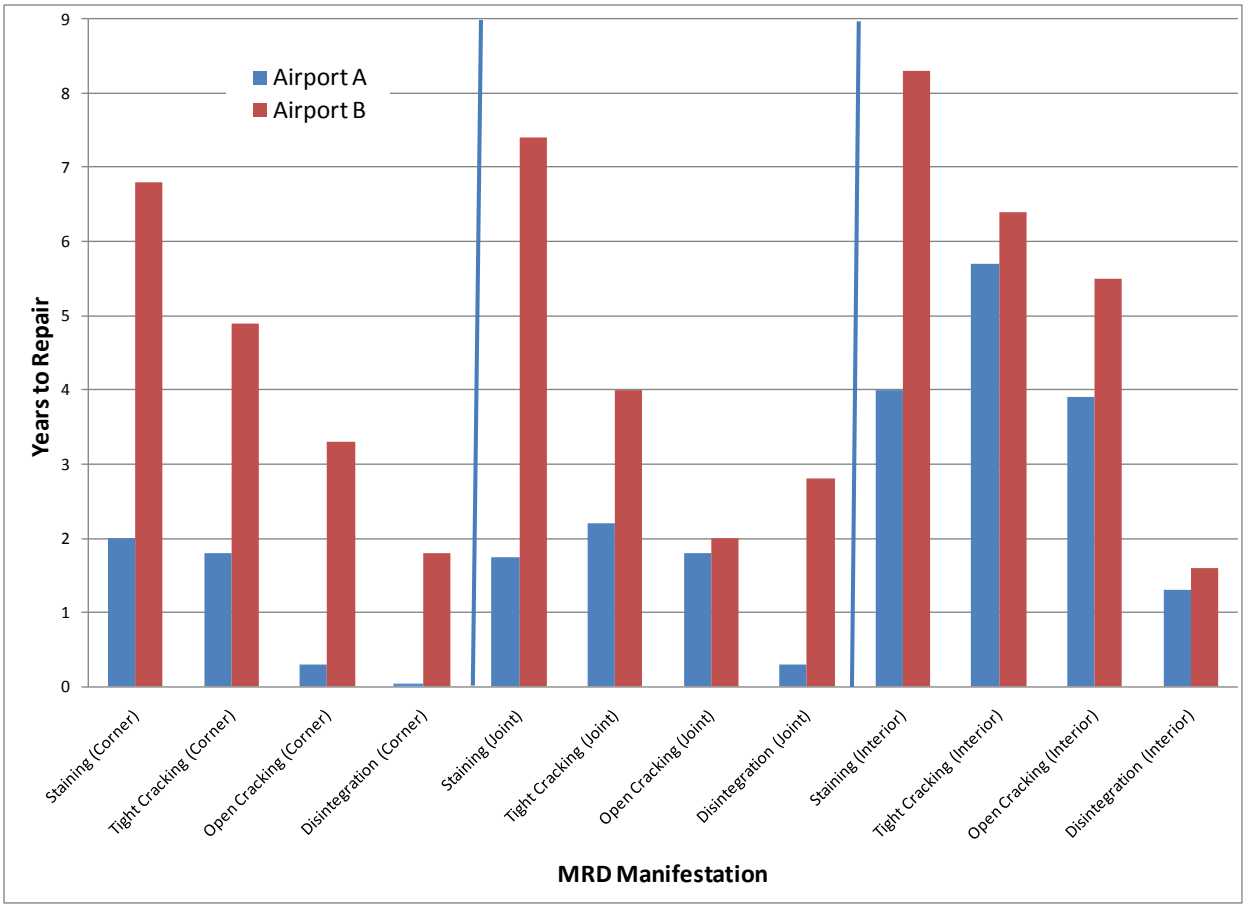

Figure 5. Estimated time to repair for various MRD manifestations at Airports A and B.

The data for Airport A is less clear, other than the previously stated observation that the MRD is perceived to be more aggressive than that occurring at Airport B. Figure 5 suggests that the corner location is the most critical, followed by the joint location. The progression from staining to repair and tight cracking to repair is almost identical for the corner location, suggesting that there is little time between the occurrence of staining and cracking (it is possible that some of the subtleties may have been lost in the photographs included in the survey, and thus respondents assumed that the cracking was present with the staining). It is even more ambivalent for the joint and interior locations, as in both instances the time to repair from staining was actually rated as being shorter than from tight cracking to repair. Again, difficulty in interpreting the photographs in the questionnaire is likely responsible for some of this confusion. But when comparing the results in figure 5 to those presented in table 3, it is seen that the time from staining to repair is estimated to be roughly 9 years regardless of the location for Airport A.

In addition to difficulties in interpreting photographs, the variability in the survey results is also at least partially the result of the differing experiences of each respondent, as some are field maintenance personnel responsible for conducting the repairs whereas others are engineers working primarily in the design office. Thus, for the same distress, it was common for one respondent to say it should be repaired now whereas another stated the same distress wouldn't require repair for 10 years.

Quite possibly the single largest factor contributing to the variability in the survey results is the lack of a standardized method to identify and quantify this type of distress data. Simply looking at photographs of a distress provides only a snapshot of what is occurring, as there is no basis to actually measure the rate of progression from year to year. In addition, there is no repeatable and objective method for field personnel to adequately communicate to those in the office the type of distress present, nor its severity and extent. Without such a methodology, it was impossible to adequately describe current conditions, let alone project those conditions into the future to assist in the development of a maintenance/rehabilitation plan based on MRD manifestations. This helped to highlight the importance of developing an objective, comprehensive, and repeatable system for evaluating MRD-affected airfield pavements.

The presence of characteristic distresses and a definitive progression of MRD manifestation were observed at the two airports under study. These enabled the development of a MRDR protocol that has widespread applicability at other airports with PCC pavements exhibiting MRD.

MRDR Protocol

The MRDR protocol is a stand-alone pavement evaluation procedure that is similar in application to the PCI procedure described in ASTM D5340 (ASTM 2005). The MRDR protocol is presented in its entirety in a separate stand-alone document: *Guide to Field Evaluation of MRD-Affected Concrete Pavements* (Van Dam et al. 2009). The procedure can be conducted at both the project and the network level, and it can either be used independently to specifically evaluate an MRD problem or as a supplement to the conventional PCI pavement survey. As a supplement to a conventional PCI survey, the MRDR procedure is only "triggered" when the following observations indicate that the potential for MRD exists:

- Perpendicular cracking along joints.
- Parallel cracking along joints and corners.
- Crack or joint staining.
- Pattern cracking.
- Visible exudate in or around cracks.
- Signs of expansion

The MRDR protocol calls for the identification and close examination of sample units that are considered representative of the overall pavement being inspected. An additional MRDR form is used to identify and record the type, severity, and location of MRD-associated distress and indicators.

Table 4 summarizes the slab locations, severity levels, and specific comments used to define each MRD indicator. Each indicator is described in more detail in the guide itself, along with photographs illustrating various conditions and/or levels of severity, as appropriate. In general, the MRD manifestations listed (identified with a lettered distress code, as shown in table 4) correspond to the previously discussed distress progression, with staining (*I*) leading to cracking (*A*, *F*, and *G*) which ultimately causes FOD producing distress (*B* and *H*). Severity levels are used to differentiate tight cracks (low-severity) from open cracks (medium-severity). Signs of expansion (*K*) are recorded because they are a direct result of many MRDs and patching (*J*) is noted as repairs are an indication of what has been done to maintain serviceability.

Table 4. Summary of MRDR distress types.

Distress Code	Distress Type	Location[1]	Severity[2]	Comments
A.	Pattern cracking	3	L, M	There is no high severity pattern cracking, as it progresses into scaling. Designated with a (D) if discoloration is present.
B.	Scaling	3	N/A	The end result of pattern cracking. When recorded, no other distress is recorded for that slab location except patching.
C.	Popouts	3	L, M, H	High-severity popouts in this procedure are equal to low-severity popouts in the PCI procedure.
D.	Surface honeycombing	3	L, M, H	Reflects how open the surface is to ingress of water and deicers.
E.	Sliver spalling	1, 2	N/A	The presence of sliver spalling is noted if greater than 1 ft in length. Sliver spalling is not recorded if perpendicular cracking or parallel cracking is present.
F.	Perpendicular cracking	1, 2	L, M	There is no high-severity perpendicular cracking, as it progresses into joint disintegration. Designated with a (D) if discoloration is present.
G.	Parallel cracking	1, 2	L, M	There is no high-severity parallel cracking; it progresses into joint disintegration. Designated with a (D) if discoloration is present.
H.	Joint disintegration	1, 2	N/A	The end result of perpendicular and/or parallel cracking. When recorded, no other distress is recorded for that slab location except patching.
I.	Staining	1, 2, 3	N/A	Staining is not recorded in a location where pattern cracking, parallel cracking, or perpendicular cracking has progressed to medium severity or if scaling or joint disintegration is recorded.
J.	Patching	1, 2, 3	L, M, H	Severity is assigned to patch only. Adjacent distress is recorded appropriately and separately.
K.	Expansion	N/A	N/A	A single rating is given for the entire sample unit based on observations within and immediately outside the sample unit.

[1] Location: 1 = Corner 2 = Joint 3 = Interior.
[2] Severity: L = Low M = Medium H = High

The remaining indicators (*C*, *D*, and *E*) might not be directly linked to an MRD, but at least contribute indirectly. Surface honeycombing (*D*) was clearly associated with the occurrence of cracking and deterioration, and in one case, required patching to eliminate a FOD risk. Popouts (*C*) are recognized in the PCI procedure as being potentially problematic, but the MRDR protocol records popouts at a much lower threshold than the PCI method, with high-severity being equivalent to low-severity in the PCI. This was done to allow tracking of the progression of popouts from a very early stage. The final MRD indicator, sliver spalling (*E*), is the minor break up of concrete along the joint. Such spalling is not recorded in the PCI method but is thought to possibly be significant as an indicator of weak and/or damaged concrete and by recording it at an early stage, progression can be monitored.

SUMMARY AND RECOMMENDATIONS FOR FUTURE WORK

Summary

Based on a review of the literature, there are numerous MRDs that can affect concrete airfield pavements. Although their underlying mechanisms differ, the physical manifestations are often similar, and include staining of the joints, cracking that runs parallel and perpendicular to the joints ultimately leading to joint disintegration, pattern cracking over the slab surface that can progress into scaling, and signs of expansion. Although the PCI has proven to be a useful tool to assist in planning and programming pavement maintenance, repair, and rehabilitation, it is not well suited to identifying or tracking the subtle signs of MRD that can quickly create FOD risk. Furthermore, the PCI goes back and forth between the potential identification of actual MRDs (e.g., D-Cracking) and the identification of symptoms of MRDs (e.g., scaling, map cracking, and crazing; popouts; and spalling). The addition of a new PCI distress under consideration by ASTM—ASR—does not appear to change this. As such, a new tool is required that considers both the unique manifestations of MRD and the locations on the slab surface where MRDs occur.

Two airports affected by MRD were studied to develop the materials-related distress rating protocol introduced in this report. These airports are within close geographic proximity and their pavements share similar construction, ages, and designs and materials. MRD progression sequences were identified at the two airports for slab corner, joint, and interior locations. For these airports, MRD initiated with staining, followed by tight cracking which progressed to open cracking, and ultimately joint disintegration of slab scaling resulted leading to a high risk of FOD. Other MRD progression sequences are observed, but play a lesser role. These include surface deterioration in areas with surface honeycombing, deterioration of patches that had been used to repair disintegrated and scaled areas, and expansion which has shoved fixtures, closed and misaligned joints, and caused blow ups. The proximity and similarity of these two airports suggest there are many opportunities to expand the applicability of this procedure.

Surveys of 14 maintenance and engineering personnel at the two airports confirmed the MRD distress sequence. The MRD at Airport A is perceived by airport personnel to be more aggressive than at Airport B, with the time required before repair being shorter for the MRD manifestations at corner and interior locations, and with MRD progression at the joint location being more aggressive at Airport B than Airport A. There was considerable variability in the survey responses, at least partially the result of the lack of a standardized method to gather and

discuss MRD manifestation data. A larger sample size including numerous airports and the use of a rigorous inspection tool would help to further refine this important aspect of the MRDR.

In response to the shortcomings noted with regards to the PCI method and to address the needs of airport personnel to collect condition data on MRD-affected pavements in a repeatable manner, the MRDR was developed. Inspected slabs were divided into three locations (corner, joint, and interior) and eleven MRD indicators were identified and severities assigned. The indicators were purposefully named to be descriptive of the manifestation without linking it to causation to avoid misdiagnosis of the underlying mechanism in the field (cause can only be determined through petrographic analysis conducted in the laboratory). The method, which is described in detail in a companion paper[1], establishes a sampling rate of 40 percent of the slabs within a given sample unit for network-level analysis, balancing the need for accuracy with timeliness. These slabs must be equally distributed among the paving lanes, as the condition of paving lanes clearly demonstrated bias in the pavements studied.

The collected field data is combined into a single MRDR value for each sample unit using weighting factors. The MRDR values for each sample unit are then averaged to determine the MRDR for the pavement section. If no MRD is present, the MRDR would be 0 (zero). There is no upward boundary to the MRDR, but a practical limit is approximately 3000. The weighting factors have been established so that an MRDR below 25 indicates that the pavement section should be monitored, but no immediate maintenance, repair, or rehabilitation activity is required. Once the MRDR increases to between 25 and 100, it is expected that routine maintenance activities will be required to minimize the risk of FOD. For pavement sections with MRDR values in excess of 100, major repair or rehabilitation is likely needed to correct an impending or existing FOD risk.

The MRDR protocol was applied to the two airports in fall 2008 and again in spring 2009. The results of these surveys demonstrated that the method is implementable and repeatable. In all cases, the MRDR was determined to be far more sensitive to MRD than the PCI method. Relationships were determined between the PCI and the MRDR, with the best correspondence existing for Airport A. A key finding is that in some cases the PCI classifies pavement sections as *very good* to *excellent* while the MRDR indicates that immediate repair or rehabilitation is needed to address a high risk of MRD-associated FOD, corresponding to the experience of airport personnel responsible for maintenance activities.

Although the time between the surveys was approximately 6 months, deterioration rates were determined both for the PCI and MRDR. Although both indices measured a decrease in pavement condition, the MRDR again proved to be much more sensitive to changes in pavement condition than the PCI. In some cases, a dramatic increase in the MRDR was observed, suggesting that a pavement section is rapidly moving towards a high FOD risk condition. Unfortunately, the time between inspections was too short to determine any long-term trend and since all the pavements were constructed at about the same time, no performance curves could be established.

[1] Paper entitled, "Application of a Materials-Related Distress Rating System for Portland Cement Concrete Airfield Pavements" submitted separately.

In the future, the research team believes that the MRDR protocol will play an important part in the evaluation of concrete pavements affected by MRD. As is current practice, the network-level PCI surveys will help establish future maintenance, repair, and rehabilitation priorities. If in the course of the PCI survey signs of MRD are observed, the MRDR protocol will be triggered. The resulting MRDR values indicate whether continued monitoring, maintenance, or more extensive repair or rehabilitation is warranted. The cause of the MRD should also be determined through a forensic investigation that includes petrographic analysis (Van Dam et al 2002). Over time, the use of the MRDR protocol will allow airports to track the progression of MRD distress and the future risk of FOD, allowing them to cost-effectively apply treatments to maintain serviceability.

The development of the MRDR addresses a definite gap that exists in current visual inspection indices for airfield pavements. The MRDR protocol has proven to be repeatable and implementable, and to have the increased sensitivity necessary to detect subtle manifestation of MRD in affected concrete pavements. Once validated and implemented, the MRDR will become an important tool in the process for planning future pavement maintenance, repair, and rehabilitation activities for MRD-affected pavements.

Recommendations for Future Work

MRD is a problem across the country, and there is an urgent need for a widely applicable procedure that can help pavement managers to address the presence of MRD on their PCC pavements. This research was limited both by its relatively brief duration and by its lack of geographic, environmental, and materials diversity. The following additional activities are recommended to complete the MRDR protocol validation and implementation process:

- The MRDR protocol was developed primarily by observing MRD at only two airports that were in close geographical proximity one to another. The pavements studied were of similar age and shared similar design, materials, and construction. Thus, although the MRDR is well calibrated for application on these two airports, it has not been validated beyond this narrow set of conditions. Full validation requires applying the MRDR to a larger group of geographically distributed airports representing various climatic zones. Pavements to be included in the validation study should have a broad range of ages, materials, and MRD manifestations.

- The pavements surveyed in this study are close to the same age and the time between the two surveys was less than a year. Thus, the MRDR values represent two snapshots of condition closely spaced in time, providing little insight regarding the progression of MRD. To complete the validation process, in addition to evaluating more airports it is also important that the surveys be repeated on the same sample units over a longer time, perhaps 3 to 4 years.

- Once these additional data are collected, it is recommended that the distress definitions, progression sequences, weighting factors, and trigger values be re-evaluated. These will either result in a revised procedure that is broadly applicable in an extended range of conditions or in additional guidelines for customizing a procedure for local application.

- A training workshop, ideally sponsored by the FAA, should be developed and taught to familiarize airports and consultants with the new protocol. Without such training it is unlikely that the MRDR will gain widespread acceptance.