An *IPRF* Research Report

Innovative Pavement Research Foundation

Airport Concrete Pavement Technology Program

Report IPRF-01-G-002-06-6(G)

Field Guide for Identification of

Materials Related Distress and Projected Pavement Life Concrete Airfield Pavement

Programs Management Office
5420 Old Orchard Road
Skokie, IL 60077

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Field Guide for Identification of Materials Related Distress and Projected Pavement Life Concrete Airfield Pavement

Prepared by

applied pavement TECHNOLOGY

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1. INTRODUCTION

The Pavement Condition Index (PCI), as described in ASTM D5340, *Standard Test Method for Airport Pavement Condition Index Surveys* (ASTM 2009), is widely used to evaluate pavement performance. The results of a PCI survey are used for a number of different purposes, including planning and programming at the network level and generating information used in a project-level rehabilitation design. However, for concrete pavements, the PCI procedure is of limited use in evaluating concrete pavements exhibiting early signs of materials-related distress (MRD), which are distresses that are a direct result of the properties of the material and its interaction with prevailing environmental conditions. The PCI procedure specifically identifies only one type of concrete pavement MRD—durability (D) cracking—while it recognizes several other distress types that may or may not be associated with MRD (scaling, map cracking, pop-outs, and spalling). As a result, concrete pavements in the early phases of MRD manifestation often exhibit acceptable PCI condition ratings, yet the rapid progression of the MRD may necessitate the need for major maintenance, rehabilitation, or reconstruction in the near future. As a result, it is imperative that the presence and severity of MRD be identified, quantified, and recorded in a systematic fashion so that timely repair and rehabilitation activities can be effectively programmed in order to maintain the serviceability of the pavement and avoid the development of unacceptable foreign objects and debris (FOD).

This guide has been prepared to provide a tool to better identify, quantify, and record the presence and severity of MRD on concrete airfield pavements. It provides guidance for conducting a visual assessment of prevailing pavement conditions to obtain a materials-related distress rating (MRDR), based on descriptions and photographs of the type, severity, and extent of distresses that have been associated with various MRDs in concrete pavements. This guide is not intended to identify specific MRD types (e.g., alkali-silica reactivity [ASR], durability cracking, paste freeze-thaw deterioration, sulfate attack, and so on); such identification can only be definitively established through an investigation that includes petrographic analysis (ASTM C856). Rather, this guide is intended to be used by airfield personnel to assist in identifying whether a pavement has an MRD problem. When the MRDR procedure is routinely applied, it can aid in the detection of potential MRD problems and help identify when a pavement will require maintenance and repair as well as when it may need more substantial rehabilitation (or perhaps even reconstruction).

2. FIELD PROCEDURE

The MRDR inspection procedure is a stand-alone pavement evaluation procedure that produces a numerical MRD rating. 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 evaluation procedure described in ASTM D5340 (ASTM 2009). As a supplement to a conventional PCI survey, the MRDR procedure is only "triggered" when certain observations indicate that the potential for MRD exists. These observations (defined later in this document) include the following:

- Perpendicular cracking along joints.
- Parallel cracking along joints and corners.
- Staining of the pavement surface, particularly near joints and crack.[1]
- Pattern cracking.
- Exudate[1] or discoloration of cracks.
- Signs of expansion.

When performed as a supplement to the PCI survey, the MRDR procedure typically adds 5 to 10 minutes to the evaluation time for each sample unit.

The MRDR procedure calls for the identification and close examination of a sample unit (or a series of sample units) that is considered representative of the overall pavement being inspected. Once the MRDR procedure is triggered, an additional MRDR form is used along with the detailed evaluation process described in this guide to identify and record the type, severity, and location of MRD-associated distress and indicators.

2.1 MRDR Field Application

The PCI is a commonly used tool to support the management of airfield pavements. In the application of the PCI, all airfield pavements being managed (defined as the network) must be subdivided into identifiable parts called *branches* (referred to as facilities for military airfields) that are a single entity and perform a distinct function (e.g., runways, taxiways, aprons, and so on are separate branches). Each branch is further subdivided into manageable units called *sections* (referred to as "features" for military airfields) that are distinct and uniform areas of the branch that have common construction, maintenance, condition, and use. For example, a taxiway may be divided into numerous sections if parts of it were constructed at different times or with different materials or cross sections, or are exposed to different traffic patterns, or if the condition is dramatically different from one part to the next.

Each section is then subdivided into individual *sample units* that consist of 20 ± 8 slabs. It is these individual sample units that are inspected at a statistically-based inspection frequency to draw conclusions regarding the overall condition of the section. For large areas of pavement

[1] Staining of the concrete, especially in the vicinity of joints or cracks, and exudate (a clear or colored substance exuding from a crack) may be the result of a chemical reaction and/or dissolution of the hydrated cement paste; the presence of either is an indicator of a materials-related reaction within the concrete.

being inspected for network-level analysis, the sampling rate is reduced to as low as 10 percent of the sample units.

The network definition maps that already exist for airfields for conducting PCI surveys should be used in conducting the MRDR inspection. An example of such a network definition map is shown in figure 1. Individual branches (apron, runway, taxiways) are clearly shown on this network definition map, as are the various sections demarcated in red (for example, the apron has been divided into four distinct sections – APRON-10, APRON-20, APRON-30, and APRON-40). Additionally, each section has been further sub-divided into individual sample units shown in blue.

During subsequent PCI surveys, every attempt is made to resurvey sample units that have been surveyed in the past. This assists in tracking the progression of deterioration over time and in identifying the risks associated with worsening performance. Similarly, the same sample units should be inspected in subsequent MRDR inspections to establish an MRD progression rate. If distinct differences in performance, material changes, or traffic patterns are evident in a section, it should be separated into two or more "new" sections, permitting a more specific assessment of risk and repair strategies.

During an inspection, the data are collected manually, with the inspector simply recording distress observed in a select number of slabs in the sample unit. A PCI/MRDR inspection form is provided in Appendix A (to facilitate the conduct of the surveys, it is recommended that the PCI form be printed on one side and the MRDR form on the reverse side). This form can be photocopied and used for MRDR inspections.

A supplemental MRDR form, based on a checklist style, is also provided in Appendix A. This form can be easily adapted to a data entry form for a handheld computing device if desired. A step-by-step outline of the inspection procedure is included in the next section.

2.2 MRDR Inspection Procedure

2.2.1 General Process

The following steps should be taken to complete the MRDR inspection:

1. Conduct a PCI survey, either as part of a network-level inspection or as a stand-alone (project-level) survey.

2. Determine if an MRDR inspection is warranted based upon the observed distress.

3. If an MRDR inspection is warranted, determine the number of sample units that need to be surveyed.

4. Conduct the MRDR inspection.

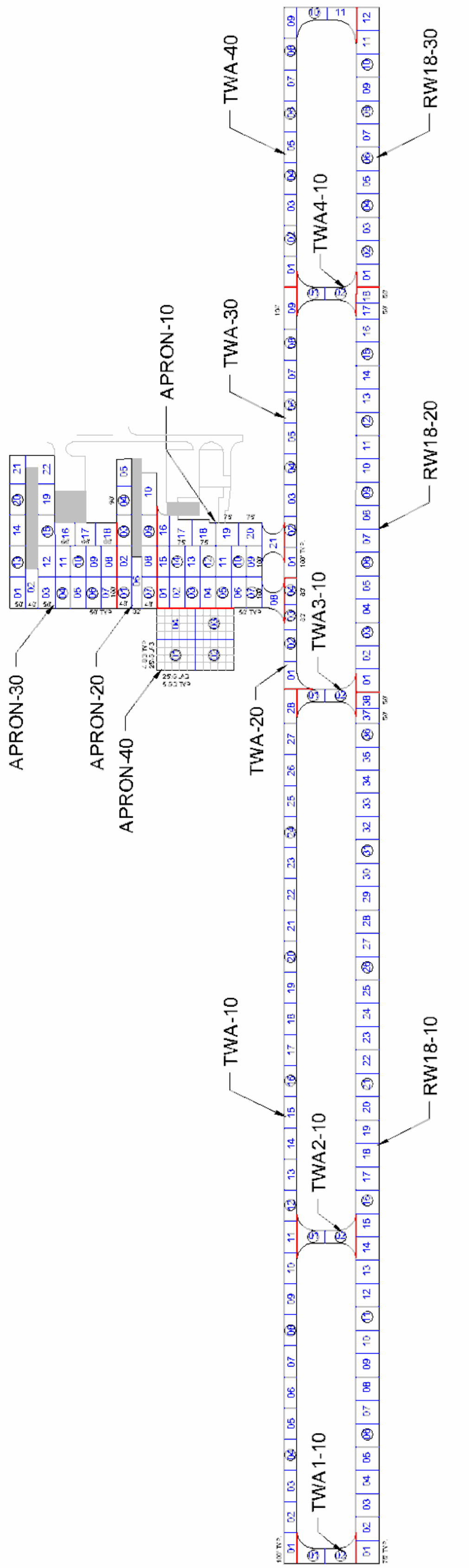


Figure 1. Example of network definition map with selected sample units.

The first step in the MRDR inspection procedure is to conduct a PCI survey of the sample unit in accordance with ASTM D5340. Conducting the PCI survey allows the progression of PCI distress to be calculated from information collected during previous PCI surveys. It also allows the inspector to scan the slabs within the sample unit for signs of MRD. Appendix A includes an example of a PCI form that may be used to record the PCI data.

The second step is to determine if an MRDR inspection is warranted. In the course of conducting the PCI survey, the inspector should note whether potential MRD indicators, such as the following (these are described in detail later), are evident:

- Staining near joints and/or cracks.
- Pattern cracking.
- Perpendicular cracking.
- Parallel cracking.
- Exudate and/or discoloration of cracks.
- Signs of expansion.

A short checklist for noting the presence of these potential MRD indicators is provided at the bottom of the PCI form. If one or more of the indicators are observed during the PCI survey of the sample unit, it is recommended that the MRDR inspection be conducted using the MRDR inspection form. As previously described, the PCI form and the MRDR form can be printed two-sided on a single piece of paper, greatly simplifying the management of the forms in the field and ensuring that the sample unit PCI data on one side corresponds to the same sample unit MRDR data on the reverse side.

The third step in the process is to calculate the number of sample units within a section (feature) to be inspected using the MRDR procedure. If the MRDR inspection is being conducted as part of a network-level PCI survey, it is recommended that the same sampling rate used for the PCI network-level survey be used for the MRDR procedure. Recommended sampling rates, shown in table 1 (where *N* is total number of sample units within the section and *n* is the number of sample units to survey), are based on the ASTM D5340 network-level survey procedure. It is also recommended that the same network definition be used and sample units inspected as for the PCI survey. The benefit of this is two-fold. For one, it avoids confusion and expedites conducting the survey procedure. Secondly, it provides a convenient way to track the progression of MRD over time and identify how this progression impacts the PCI on a sample unit basis, which will prove useful in the development of improved MRD prediction models.

Although the MRDR has been developed specifically for network-level analysis, there might be benefit in applying this tool to support a project-level analysis, particularly if details regarding the type, severity, and extent of MRD are being used to formulate a repair or rehabilitation plan. In such cases, the sampling rate must be increased significantly from what is used at the network level, and it is recommended that all (100 percent) of the sample units be inspected; however, the actual sampling rate for this application will be set by the project manager. All other aspects of the inspection will remain the same.

Table 1. Recommended MRDR network-level sampling rates.

N	n
1 – 3	all
4	3
5 – 7	4
8 - 10	5
11 - 16	6
17 - 28	7
29 - 64	8
65 - 90	9
> 90	10%, but < 32

The fourth and final step of the process is to conduct the MRDR inspection on slabs within the selected sample units. A typical concrete sample unit consists of 20 slabs, but sample units containing between 12 and 28 slabs are allowed. Analysis of data obtained in the development of this procedure indicates that a reasonable estimate of MRDR for network-level analysis can be obtained by inspecting roughly 40 percent of the slabs within each sample unit. Thus, for a sample unit containing 20 slabs, 8 slabs will need to be inspected. Due to potential variations in materials and construction used in individual paving lanes, at least two slabs should be inspected in each identified paving lane in an alternating staggered pattern, with a minimum of 40 percent of the slabs being inspected. It is emphasized that this is not random sampling, and in fact, randomized sampling is inappropriate. An example of a recommended inspection pattern for a typical 20-slab sample unit (4 slab by 5 slab) is shown in figure 2.

The remaining discussion in this section focuses on the inspection of an individual slab, a process that is repeated for all slabs inspected in the sample unit and in all subsequent sample units.

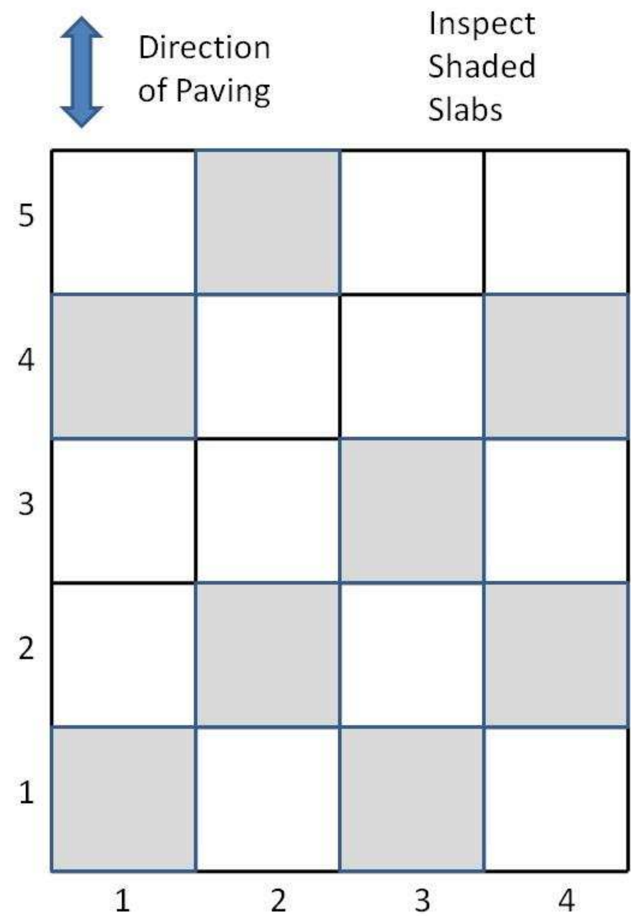


Figure 2. Recommended slab locations for a network-level inspection in a typical 20-slab sample unit.

2.2.2. MRDR Inspection Procedure for a Given Slab

The MRDR inspection form is similar to the PCI survey form, having a project identification area and a list of distress manifestations near the top, a 7 by 5 grid representing up to 35 slabs within the sample unit covering most of the page, and a summary table along the right side to "tally" the inspection results. However, there are two important differences between the MRDR and the PCI rating forms. The first is the MRD distress manifestations listed are consistent with the development of materials-related distress, being labeled alphabetically "A" through "K" to avoid confusion with the numerically labeled PCI distresses. The second difference is that each of the cells representing individual slabs within the 7 by 5 grid is subdivided into the following nine sub-areas corresponding to specific locations where signs of MRD may appear:

- Corners (four positions): Location 1.
- Joints (four positions): Location 2.
- Interior (one position): Location 3.

The corner location is defined as a 2-ft square at each corner, while the joint location lies 2 ft inward from the joint and along its length. The remaining slab area is defined as the interior location. Figure 3 illustrates how a typical slab is subdivided into the three locations.

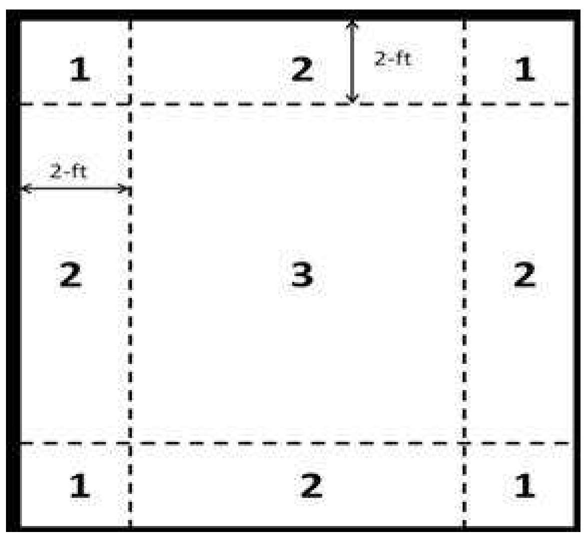


Figure 3. Typical slab layout showing the three locations (1: corner, 2: joint, and 3: interior).

As previously mentioned, each type of MRD indicator has a letter designation and many are further defined by their observed severity level. When conducting the survey, the type and severity of each MRD indicator is recorded within the nine slab locations, or may be indicated as "not present" using a dash. Cracking with discoloration (exudate and/or discoloration directly associated with the crack) is further identified with a "(*D*)" designation. Descriptions of each type of MRD indicator and severity level, along with photographs, are included in the next section of this guide. This information will assist the inspector in conducting an MRDR inspection.

In their early stages, some of the distresses may be difficult to see. The MRDR inspection may involve pre-wetting the pavement (with water or ethanol) and/or approaching the affected pavement from different directions to find the best way to enhance the visibility of the distresses. Poor or artificial lighting conditions may compromise the ability of the inspector to see the subtle initial indicators of MRD, and thus should be avoided if possible.

The MRDR procedure should be repeated for remaining slabs in the sample unit that are to be inspected and then repeated as needed for the remainder of the sample units within the section being surveyed in accordance with the sampling rate previously discussed.

2.3 MRD Definitions

The MRDR procedure identifies observable surface characteristics that indicate a materials-related distress may be present. In the extreme, MRD will produce, or have the potential to produce, FOD that may pose a risk to aircraft. The most significant and commonly observed signs of MRD in concrete airfield pavements are listed below, presented by location within the slab where they appear.

<u>Interior Locations</u>

A. Pattern cracking (with or without discoloration).
B. Scaling.
C. Popouts.
D. Surface honeycombing.

<u>Joint and Corner Locations</u>

E. Sliver spalling.
F. Perpendicular cracking (with or without discoloration).
G. Parallel cracking (with or without discoloration).
H. Joint disintegration.

<u>Any Location</u>

I. Staining.
J. Patching.
K. Expansion.

MRD indicators *A* through *D* are recorded exclusively at interior locations (location 3), indicators *E* through *H* are recorded exclusively at corner (location 1) and joint (location 2) locations, and indicators *I* and *J* can be recorded at any of the three locations. Indicator *K* (expansion) is a unique manifestation as it is not rated on a slab-by-slab basis, but instead is made as a single assessment for the entire sample unit. In order to make this assessment, the inspector must not only examine all slabs within the sample unit, but also inspect the slabs immediately adjacent to the sample unit and review the condition of the abutting shoulders, identifying any signs of expansion (such as joint misalignment, joint closure, shoved fixtures, or blow-ups). Any of these signs of expansion are noted in the separate box included on the inspection form.

Although MRD indicators A through D are only recorded for interior locations, it is known that they can occur over the entire slab area, including corners and joints. For example, popouts and pattern cracking are likely to be distributed randomly over the entire slab surface whereas scaling and surface honeycombing could occur within 2 ft of a joint. For this procedure, these MRD indicators are only identified for the slab interior to clearly demarcate those distresses that are observed over the entire slab surface from those that are isolated to corner and joint locations. Popouts and surface honeycombing that occur within 2 ft of corners and joints are considered together with those same distresses occurring in the slab interior, and are only recorded for the slab interior. On the other hand, what appears to be pattern cracking occurring within 2 ft of corners and joints is identified as perpendicular cracking and/or parallel cracking, as appropriate. Similarly, what appears to be "scaling" occurring within 2 ft of the joint or corner is recorded as joint disintegration.

MRD indicators *A*, *C*, *D*, *F*, *G* and *J* are further described with low- (L) and medium- (M) severity ratings, while indicators *C, D,* and *J* also have a high- (H) severity rating associated with them. And, as previously mentioned, distresses characterized by cracking (that is, *A*, *F*, and *G*) should be further denoted with a "(*D*)" if discoloration (either exudates or discoloration directly associated with the cracking) is present. For example, low-severity parallel cracking with discoloration is noted as *G-L(D)*, whereas medium-severity perpendicular cracking without discoloration is noted as *F-M*.

Often multiple indicators occur simultaneously in the same location. For example, perpendicular cracking and parallel cracking often occur together along joints and corners. For low and medium severity, only the highest severity of each indicator should be recorded. There is no high severity rating for perpendicular cracking or parallel cracking, as they progress into joint disintegration once FOD exists. As such, if joint disintegration is present, no other distress is recorded for that specific location except patching. Similarly, there is no high-severity rating for pattern cracking, as it progresses into scaling once FOD exists and thus no other distress is recorded for that specific location except patching.

Table 2 summarizes the slab locations, severity levels, and specific comments used to define each distress type. Each distress type is described in more detail in the following text, along with photographs illustrating various conditions and/or levels of severity, as appropriate.

Table 2. Summary of 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)[3] 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)[3] 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)[3] 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
[3] (D) denotes discoloration directly associated with the crack due to the presence of exudate or some other material filling the crack or discoloring the crack edges. This is not to be confused with Staining (I) which is a separate MRD indicator that characterized by a general darkening of the concrete surface.

2.3.1 A. Pattern Cracking

2.3.1.1. Description
Pattern cracking (see figure 4) is a network of interconnected cracks, each enclosing an area of several square inches up to a square foot.

2.3.1.2. Possible Causes
Pattern cracking may be a manifestation of MRD, but may also be a remnant of plastic shrinkage or poor consolidation.

2.3.1.3. Link to MRD
The appearance of pattern cracking on the surface of a pavement could be the result of materials-related chemical reactions causing expansion within the pavement, which could lead to further cracking and/or scaling.

2.3.1.4. Progression and Severity Levels
The severity levels are defined as follows:

- Low-severity is very fine to fine, tightly closed cracking that is visible when the pavement is wetted (figure 4(a)) or dry (figure 4(b)).

- Medium-severity is a well-defined pattern and some of the cracks have opened as shown in figure 4(c)

Note that there is no high-severity pattern cracking.

2.3.1.5. Explanation of Rating
Pattern cracking is rated by severity level and is only recorded for the interior slab location (location 3). Discoloration, if observed, is also noted with a (D).

2.3.1.6. Differentiation
Pattern cracking is only recorded in interior locations (location 3) whereas perpendicular cracking and parallel cracking are only recorded at corners (location 1) and joints (location 2). If the cracks are spalling or pieces missing, it is classified as scaling.

(a) Pattern cracking (low-severity) – Very fine pattern cracking that is barely visible and may only be seen when wetted.

(b) Pattern cracking (low-severity) – Fine, tightly closed, cracking that is readily visible when dry. This cracking also has discoloration.

(c) Pattern cracking (medium-severity) – Well-defined pattern and some of the cracks have opened. Discoloration is also present.

Figure 4. Pattern cracking.

2.3.2 B. Scaling

2.3.2.1. Description
Scaling is the breakdown of the top surface of the pavement. A pavement that is scaling produces loose pieces of FOD that may damage aircraft. Scaling is depicted in figure 5.

2.3.2.2. Possible Causes
Scaling can be associated with the progression of pattern cracking resulting from MRD such as freeze-thaw deterioration or alkali-aggregate reactivity. The application of chemical deicers may contribute to the progression of scaling. It may also result from over-finishing or poor consolidation of the concrete surface.

2.3.2.3. Link to MRD
Scaling could be an indication of potential materials-related reactions.

2.3.2.4. Progression and Severity Levels
No severity level is recorded for scaling; it is only recorded if FOD potential exists. Scaling can be a result of deteriorating pattern cracking, beginning as small localized areas on a pavement surface that grow larger as distress continue to occur.

2.3.2.5. Explanation of Rating
No severity level is recorded for scaling. The distress is only recorded for the interior location (location 3). If recorded, no other MRD distresses are recorded in the slab interior except patching.

2.3.2.6. Differentiation
Scaling only occurs in interior locations (location 3) and thus must be differentiated from joint disintegration which occurs only at corners (location 1) and joints (location 2). It must also be differentiated from popouts and surface honeycombing and from spalling within the PCI procedure. It is often associated with pattern cracking.

(a) Scaling – Small, localized areas where the surface has flaked off.

(b) Scaling – Small interior area has broken free and there is potential for more surface area loss in the cracked area.

(c) Scaling – Interior areas have broken free with the potential for more scaling in cracked area.

Figure 5. Scaling.

2.3.3. C. Popouts

2.3.3.1. Description
Popouts are small pieces of concrete that break loose from the pavement, leaving small holes behind, as shown in figure 6.

2.3.3.2. Possible Causes
Popouts are most often caused by freeze-thaw (F-T) deterioration of poor or unsound aggregates or by clay balls disintegrating near the pavement surface. They can also be the result of reactive aggregates located near the surface that expand due to chemical reactions occurring within the concrete.

2.3.3.3. Link to MRD
Potentially reactive or F-T susceptible aggregates that fracture near the pavement surface can indicate a materials-related problem exists in the concrete.

2.3.3.4. Progression and Severity Levels
The number of popouts is expected to increase with time if their cause is linked to a materials-related distress. Popouts are individually counted and severity levels are determined as follows:

- Low-severity if distress density is less than one popout/yd^2 of the slab interior.
- Medium-severity if the distress density is between one and three popouts/yd^2 of the slab interior.
- High-severity if the distress density is greater than three popouts/yd^2 of the slab interior.

2.3.3.5. Explanation of Rating
Popouts are rated by the number observed over the interior slab surface. The distress is only recorded for the interior location (location 3).

2.3.3.6. Differentiation
Popouts must be distinguished from scaling and surface honeycombing.

(a) Popout from aggregate – Reactive aggregates that have expanded near the surface and leave an opening on the surface.

(b) Popout from clay ball – Deleterious materials that have disintegrated and left an opening on the surface of the pavement.

Figure 6. Popouts.

2.3.4. D. Surface Honeycombing

2.3.4.1. Description

Surface honeycombing is the presence of voids on the concrete surface that are clearly the result of construction. Figure 7 shows several photos of honeycombing.

2.3.4.2. Possible Causes

Surface honeycombing is an artifact of construction, normally caused by poor finishing, inadequate vibration, and/or the use of an unworkable mix. As a result, the concrete surface is not tightly finished, leaving clearly visible voids.

2.3.4.3. Link to MRD

While not a direct sign of MRD, surface honeycombing provides a path for moisture and deicer ingress into the pavement. This may cause or accelerate many MRDs, including F-T deterioration and alkali-aggregate reactivity, both of which are driven by moisture as a damage mechanism.

2.3.4.4. Progression and Severity Levels

To be recorded, a minimum of five "voids" per ft^2 must be observed, each having a minimum diameter of 0.5 in. The severity levels are defined as follows:

- Low-severity is a localized area of less than 1 yd^2 (figure 7(a)).
- Medium-severity is recorded for areas greater than 1 yd^2 but less than half the slab (figure 7(b)).
- High-severity is recorded when more than half the slab is affected (figure 7(c)).

2.3.4.5.Explanation of Rating

Surface honeycombing is rated by the severity level that is observed over an entire slab. The distress is only recorded for the interior location (location 3).

2.3.4.6. Differentiation

Surface honeycombing must be differentiated from popouts and scaling.

(a) Surface honeycombing (low-severity) – Small areas less than 1 yd^2 in size where minor openings in the surface resemble small popouts.

(b) Surface honeycombing (medium-severity) –Isolated areas between 1 yd^2 and half the slab area where the surface is not closed.

(c) Surface honeycombing (high-severity) – Large areas (greater than half the slab) in which the surface is open. Note patching is also present.

Figure 7. Surface honeycombing.

2.3.5. E. Sliver Spalling

2.3.5.1. Description

Also described as edge fraying, this distress is the minor break up of concrete along the joint (see figure 8), allowing potential material or moisture infiltration. It is not associated with perpendicular or parallel cracking.

2.3.5.2. Possible Causes

Sliver spalling can be caused by mechanical wearing along a joint from vehicles or equipment. It can also be caused by weakening of the concrete near the joint during construction, such as from the joint sawing operation or poor edge finishing techniques.

2.3.5.3. Link to MRD

Sliver spalling disrupts the sealant along the joint, which allows infiltration of moisture and incompressibles into the pavement. Sliver spalling could be an early indicator of potential materials-related problems from expansive movements or loss of strength.

2.3.5.4. Progression and Severity Levels

Unlike what is done in the PCI procedure, a minimum distance from the joint edge is not required to record sliver spalling. No severity level is defined for sliver spalling, but a minimum continuous length of 1 ft is required for it to be recorded.

2.3.5.5. Explanation of Rating

There is no severity rating for sliver spalling. It is rated by slab location either along joints (location 2) or in corners (location 1).

2.3.5.6. Differentiation

Sliver spalling must be differentiated from joint disintegration and expansion. Sliver spalling is not recorded if perpendicular cracking or parallel cracking is recorded in the same location. Sliver spalling should also be differentiated from the conventional PCI spalling distress.

(a) Sliver spalling – Continuous areas are affected along joints or in corners that are greater than 1 ft in length.

(b) Sliver spalling – Large, continuous areas are affected that are greater than 1 ft in length.

Figure 8. Sliver spalling.

2.3.6. F. Perpendicular Cracking

2.3.6.1. Description

Perpendicular cracking (see figure 9) propagates perpendicularly outward from a joint. These cracks can be located at either longitudinal or transverse joints.

2.3.6.2. Possible Causes

Perpendicular cracking may be an early sign of MRD. They may also be a result of plastic shrinkage, poor consolidation, settlement, or restrained movement.

2.3.6.3. Link to MRD

Perpendicular cracking could be the result of expansive forces caused by alkali-aggregate reactivity.

2.3.6.4. Progression and Severity Levels

Perpendicular cracking first appears as fine cracks perpendicular to the joint and over time may develop into a series of longer, wider cracks. The severity levels are as follows:

- Low-severity perpendicular cracking is defined as fine cracks with no visible opening (see figures 9(a) and 9(b)).
- Medium-severity perpendicular cracking is defined as cracks that are visibly opened (see figure 9(c)).

2.3.6.5. Explanation of Rating

Perpendicular cracking is rated by severity level. It is only recorded at corner (location 1) and joint (location 2) locations and must be perpendicular to the joint. This distress can be associated with parallel cracking. Discoloration, if observed, is noted with a (D).

2.3.6.6. Differentiation

Perpendicular cracking must be differentiated from parallel cracking. Its location differentiates it from pattern cracking. If FOD potential exists (because of spalling or missing pieces of concrete), it is classified as joint disintegration.

(a) Perpendicular cracking (low-severity) – Fine cracks perpendicular to a joint with discoloration (D).

(b) Perpendicular cracking (low-severity) – Fine cracks perpendicular to a joint with discoloration (D).

(c) Perpendicular cracking (medium-severity) – Cracks are open and discoloration (D) is observed, but no FOD potential exists.

Figure 9. Perpendicular cracking.

2.3.7. <u>G. Parallel Cracking</u>

2.3.7.1. Description
Parallel cracking are cracks running roughly parallel to joints and/or running around corners. Several examples of parallel cracking are shown in figure 10.

2.3.7.2. Possible Causes
Parallel cracking is most often a sign of MRD. Confined movement can also cause this type of distress.

2.3.7.3. Link to MRD
Parallel cracking could be the result of physical damage (e.g., F-T) or chemical reactivity (e.g., ASR). Both are fueled by moisture which is available near joints.

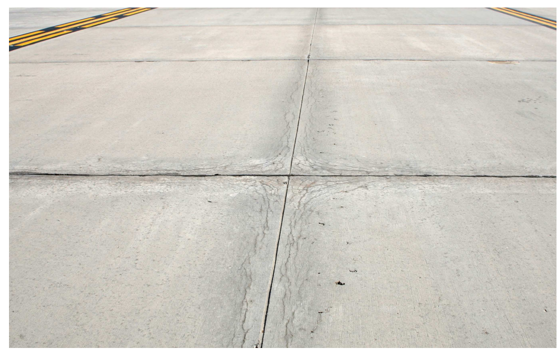
2.3.7.4. Progression and Severity Levels
Parallel cracking first appears as fine cracks running parallel to the joint and rounding corners. In time, it can develop into a network of cracks. Two severity levels are provided for this distress:

- Low-severity parallel cracking is defined as fine cracks with no visible opening (see figure 10(a)).
- Medium-severity parallel cracking is defined as cracks that are visibly opened (see figure 10(b)) or may have formed a network (see figure 10(c)).

2.3.7.5. Explanation of Rating
Parallel cracking is rated by severity level and is only recorded at corner (location 1) and joint (location 2) locations. It runs parallel to joints and around corners, as shown in figure 10. Discoloration of the crack, if observed, is noted with a (D).

2.3.7.6. Differentiation
Parallel cracking must be differentiated from perpendicular cracking. Location differentiates it from pattern cracking. If spalled or pieces missing (what would normally be rated as "high" severity), it is classified as joint disintegration.

(a) Parallel cracking (low-severity) – Tightly closed cracking running parallel to joint and around corner. Discoloration (D) would be noted, as would staining (I).



(b) Parallel cracking (medium-severity) – Open cracks running parallel to joint and around corner. In this case, exudate is present so Discoloration (D) would also be noted.

(c) Parallel cracking (medium-severity) – Open, parallel cracking at joints and around corner. Medium-severity perpendicular cracking is also present. Discoloration (D) would also be noted.

Figure 10. Parallel cracking.

2.3.8. H. Joint Disintegration

2.3.8.1. Description

Joint disintegration is the crumbling, deterioration, and loss of concrete at a joint. Typically, where joint deterioration is present, the concrete can be easily removed, producing high amounts of FOD. Joint disintegration is shown in figure 11.

2.3.8.2. Possible Causes

This distress is most likely caused by the weakening, and ultimate disintegration, of the concrete as a result of a physical process (e.g. F-T cycles) or an adverse chemical reaction (e.g. ASR). Chemical deicers can contribute to the formation and/or acceleration of this distress type. Low concrete strength or poor consolidation can also result in joint disintegration.

2.3.8.3. Link to MRD

Materials-related expansive reactions are most often the cause of the disintegration of the pavement along joints.

2.3.8.4. Progression and Severity Levels

No severity level is recorded for joint disintegration since it is only recorded if FOD potential exists. Joint disintegration is often the result of deteriorating perpendicular cracking and/or parallel cracking, and can begin as small localized deteriorated areas along the joint that can grow larger as distress continue to occur.

2.3.8.5. Explanation of Rating

Joint disintegration is only recorded for corner (location 1) and joint (location 2) locations. If recorded, no other MRD distresses should be recorded in the same area of the slab except patching.

2.3.8.6. Differentiation

Joint disintegration must be differentiated from sliver spalling and expansion. Location differentiates it from scaling.

(a) Joint disintegration – Areas along joints are crumbling. Note that cracking is not parallel cracking.

(b) Joint disintegration – Concrete along joint is crumbling/falling apart due to progression of parallel cracking. Note the visual difference between this distress and sliver spalling (no additional cracking).

(c) Joint disintegration – High FOD potential over a large area.

Figure 11. Joint disintegration.

2.3.9. I. Staining

2.3.9.1. Description

Staining is the unusual discoloration of the pavement that is observed at joints and corner locations and/or at interior locations (see figure 12)

2.3.9.2. Possible Causes

Staining may be the result of deterioration and/or a materials-related reaction, which has led to leaching onto the concrete surface, resulting in discoloration.

2.3.9.3. Link to MRD

Staining can be a precursor to the development of serious distress, as it may indicate that the concrete lacks physical and/or chemical stability. However, not all staining is necessarily a sign of MRD.

2.3.9.4. Progression and Severity Levels

No severity level is defined for staining. It is simply identified as being present and linked to a specific location.

2.3.9.5. Explanation of Rating

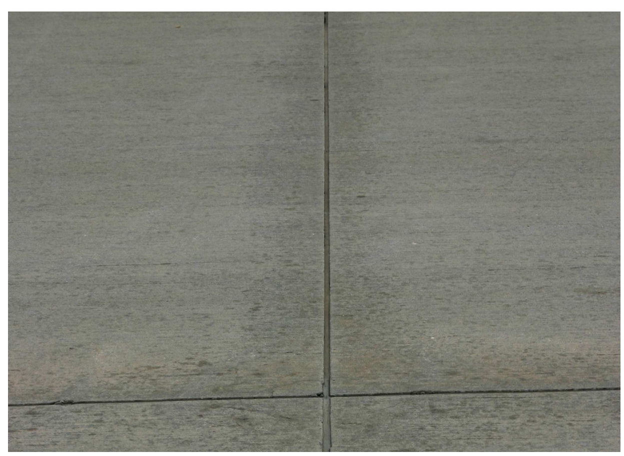
Staining is recorded separately for corners (location 1), joints (location 2), and slab interior (location 3). Figure 12(a) shows staining over the slab area. Staining may also be observed in localized areas, in particular along joints (see figures 12(b) and 12(c)) and cracks. It is often easily identified by looking along the length of a pavement joint, as shown in figure 12(c).

2.3.9.6. Differentiation

Staining should be differentiated from the various types of cracking distresses and identified separately. Staining is not recorded if medium-severity pattern cracking, perpendicular cracking, or parallel cracking is present or if scaling or joint disintegration is identified in the same location.

(a) Staining (location 3) – Lightly colored marks, blotches, or areas on a pavement not consistent with the normal pavement surface.

(b) Staining (location 2) – Staining at joint.



(c) Staining (locations 1 and 2) – Stained areas along joint and corners. Low-severity parallel cracking (G) at corner would also be noted.

Figure 12. Staining.

2.3.10. J. Patching

2.3.10.1. Description
Patching is the replacement of a failed area of the pavement with a repair material. Patching is noted in all locations where a repair has been made. Severity is based solely on the condition of the patch. Deterioration in the slab area adjacent to the patch is defined independently. Figure 13 shows patches in various stages of deterioration.

2.3.10.2. Possible Causes
Patching that has deteriorated could be the result of improper patch placement, expansion from the surrounding pavement, or material incompatibility.

2.3.10.3. Link to MRD
Deteriorating patching is often the result of continuing degradation of the repaired pavement, which may be an indication that an overriding materials problem is affecting the surrounding pavement.

2.3.10.4. Progression and Severity Levels
Patching severity levels are based solely on distress observed in the patch itself and are defined as follows:

- Low severity is a patch in good condition and free of distress, being used primarily to note the presence of the repair (see figure 13(a)).
- Medium severity is when cracking in the patch is observed, but no FOD potential currently exists, as shown in figure 13(b).
- High-severity is when the distress in the patch poses a FOD potential, requiring repair (see figure 13(c)).

2.3.10.5. Explanation of Rating
Patching is rated by severity level and is recorded for the most severely distressed patch within each slab location.

2.3.10.6. Differentiation
None.

(a) Patching (low-severity) – The patch is present with no observable distress. Note that scaling (B) would also be recorded for this location.

(b) Patching (medium severity) – Patch is intact, but cracked. Note that there is no current FOD potential.

(c) Patching (high-severity) – Distress in patch has begun to spall and poses FOD potential.

Figure 13. Patching.

2.3.11. K. Expansion

2.3.11.1. Description
Expansion describes a series of pavement conditions that have developed due to movement of the slabs. Examples include misalignment of adjacent joints (where differential movements are occurring, see figure 14(a)), excessive closure of joints (see figure 14(b)), or shoving of (or damage to) in-pavement fixtures or adjacent structures (see damage to light marker in figure 14(a)). Another example includes the development of blow-ups (see figure 14(c)), which occur at joints and result in an uplift of broken pieces, producing a high potential for FOD and tire damage.

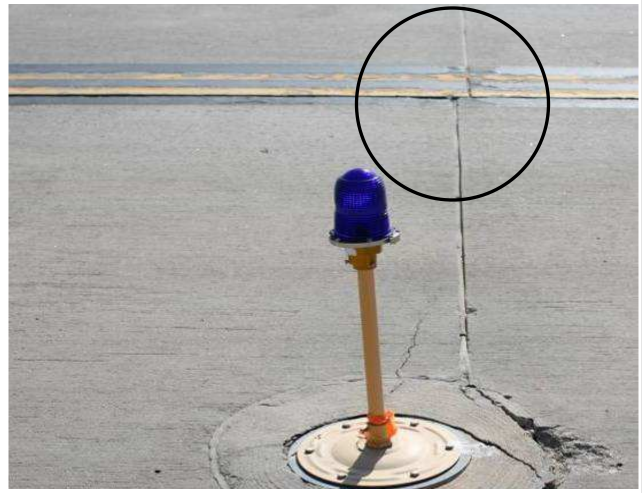
2.3.11.2. Possible Causes
Expansion results when the concrete is moving due to excessive microcracking and/or swelling of a reaction product as is the case with alkali-silica reactivity.

2.3.11.3. Link to MRD
The movement could be the result of expansive materials-related reactions.

2.3.11.4. Progression and Severity Levels
No severity levels are recorded for expansion.

2.3.11.5. Explanation of Rating
Expansion is not recorded on a slab-by-slab basis, but instead is assigned as an overall rating for the entire sample unit. Signs of expansion, including joint misalignment, compressed sealant, facilities or structures that have been shoved, or blow-ups, are noted within and immediately adjacent to the sample unit including the shoulder. Occurrences are recorded in the box included as part of the inspection form.

2.3.11.6. Differentiation
Blow-ups need to be differentiated from sliver spalling and joint disintegration.



(a) Expansion – Shown in the circle is joint misalignment, which indicates an expansive movement, but the rater should confirm that the joints were originally aligned.

(b) Expansion – Expansion has closed the joint and caused sealant to bulge out.

(c) Expansion - Adjacent slabs pushing against each other along joint caused this blow-up.

Figure 14. Expansion.

3. CONDUCTING AN MRDR INSPECTION

In this section, five examples are presented to illustrate how the MRDR inspection procedure is conducted. Due to limitation in the use of photographs rather than actual pavements, only the MRD indicators captured in the image are evaluated in these examples and thus it is assumed that these are representative of the entire location. However, in the field, observed MRD indicators are recorded for each slab location and for approximately 40 percent of the slabs in each sample unit, although more slabs or all the slabs within a sample unit can be inspected for project-level analysis.

Appendix B presents three sample MRDR Inspection Forms that have been filled out to illustrate how the MRD indicators observed over an entire sample unit are recorded and tabulated. The examples in Appendix B are used in the next section to illustrate the calculation of the MRDR.

3.1 Example 1: Interior Location

Figure 15 is a photograph of an interior slab location. As an interior location, the MRD indicators specifically applicable to this location are *A* through *D* (pattern cracking, scaling, popouts, and honeycombing) and *I* through *K* (staining, patching, and expansion) would also be considered. The only MRD indicator observed is pattern cracking (MRD Indicator *A*). Although many of the cracks are fine and closed, some cracks are observed to be open; therefore this is considered medium-severity pattern cracking. Further, there is noticeable discoloration/exudate associated exclusively with the cracking. Thus, the observed pattern cracking is recorded as *A-M(D)*.

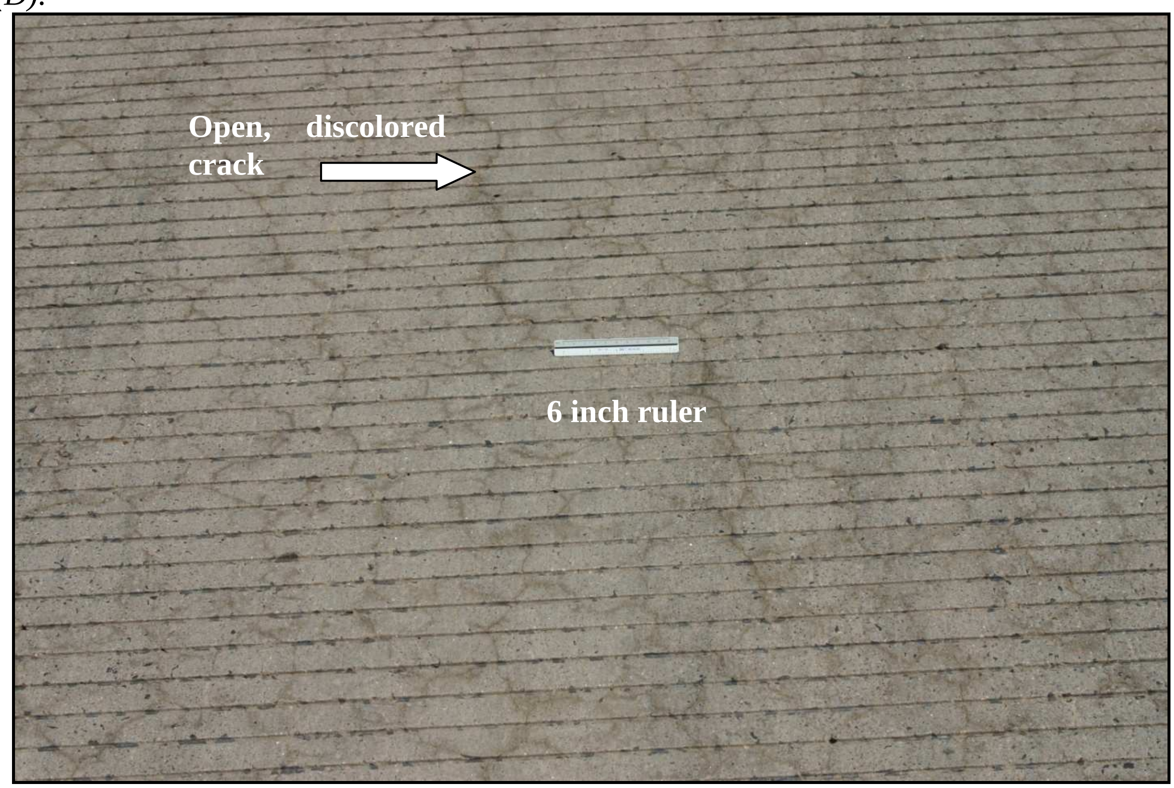


Figure 15. Example 1: interior slab location.

3.2 Example 2: Interior Location

Figure 16 shows a section of runway, with the touchdown zone blackened from tire rubber. Concentrating on the interior of the slab enclosed by the red lines, the MRD indicators specifically applicable to this location are *A* through *D* (pattern cracking, scaling, popouts, and honeycombing), and *I* through *K* (staining, patching, and expansion) would also be considered.

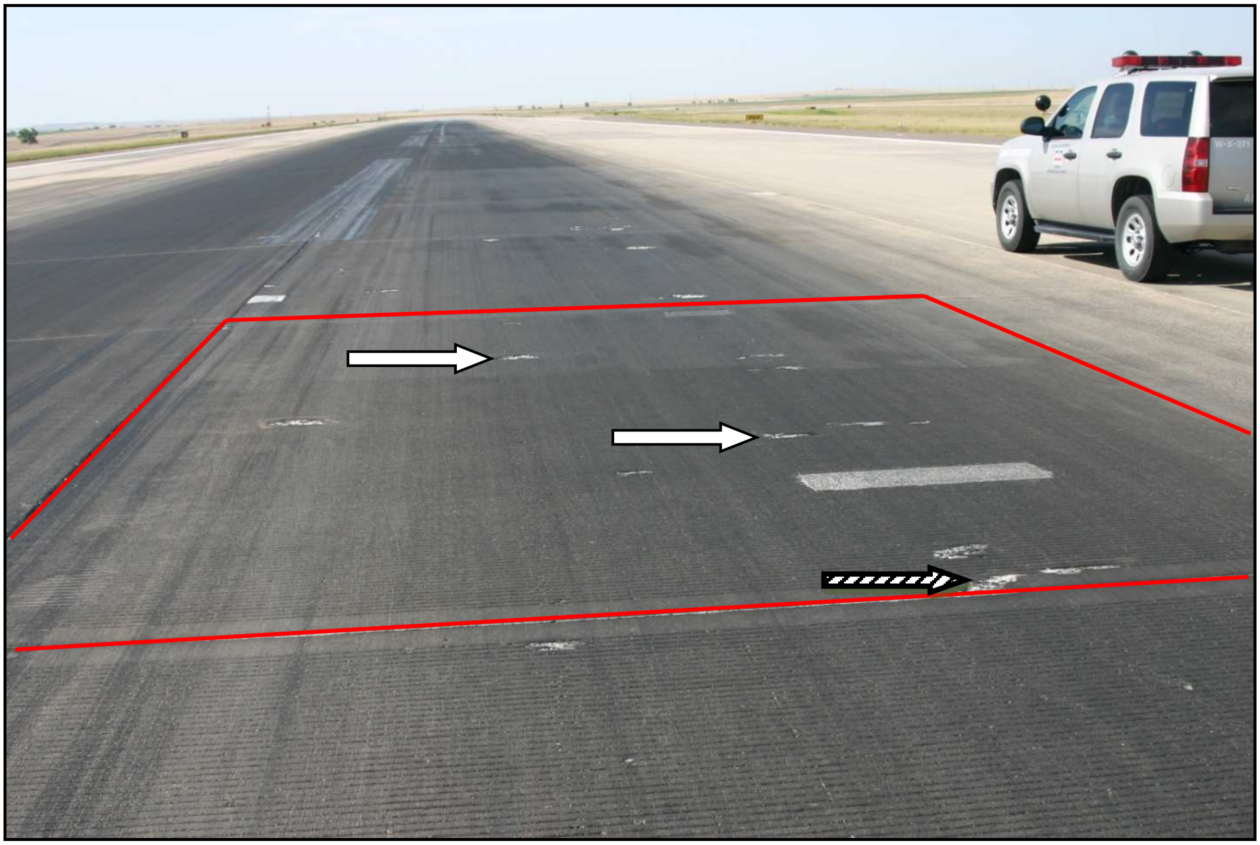


Figure 16. Example 2: interior of slab on runway touchdown zone blackened with tire rubber.

The MRD indicator that is clearly visible, as illustrated with the white arrows, is scaling (MRD indicator *B*). Even though pattern cracking (MRD Indicator *A*) is present (although not readily visible in figure 16), it would not be recorded since scaling is observed. The patch (MRD Indicator J) seen as the white rectangle on the right side of the figure is free of distress. Thus, the distresses recorded for this slab interior are *B* and *J*-*L*. It is worth noting that "scaling" is also visible in some joint locations, such as that identified by the cross-hatched arrow In this case, the inspector would identify joint disintegration (MRD Indicator *H*) for that joint location if the "scaling" was within 2 ft of the joint. This would be in addition to the scaling recorded for the slab interior.

3.3 Example 3: Joint Location

Figure 17 shows tightly closed cracking along a joint. The MRD indicators specifically applicable to the joint location are *E* through *H* (sliver spalling, perpendicular cracking, parallel cracking, and joint disintegration), and *I* through *K* (staining, patching, and expansion) would also be considered. The cracking present is fine and closed, running both parallel and perpendicular to the joint. Therefore this is low-severity perpendicular cracking (MRD Indicator *F*) and low-severity parallel cracking (MRD Indicator *G*). The cracks also appear discolored, being filled with exudates or other deposit, so the distresses observed are identified as *F-L(D)* and *G-L(D)*. The inspector would have to determine whether staining (MRD indicator *I*) is present as well by looking at the joint from different angles.

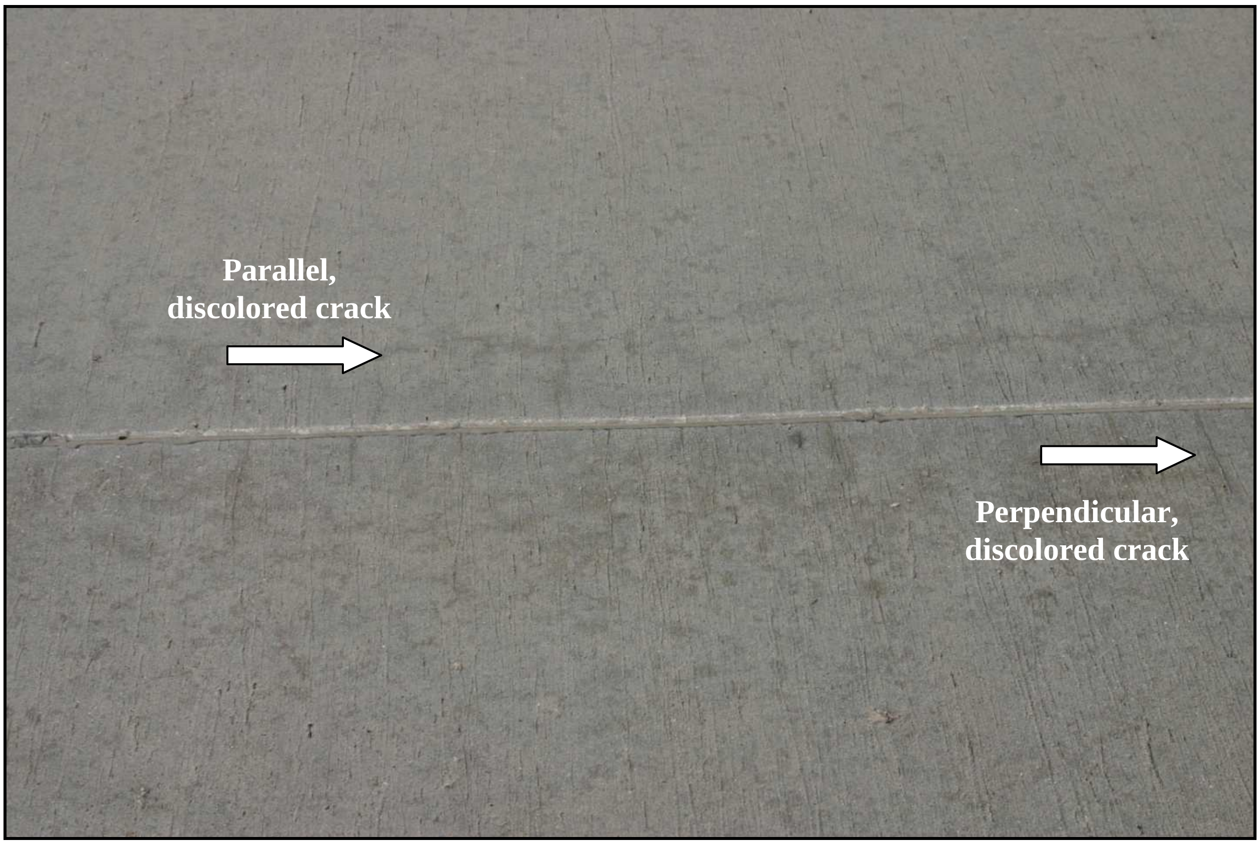


Figure 17. Example 3: tightly closed cracking along joint.

3.4 Example 4: Joint Location

Figure 18 shows open cracking along a joint. The MRD indicators specifically applicable to this location are *E* through *H* (sliver spalling, perpendicular cracking, parallel cracking, and joint disintegration), and *I* through *K* (staining, patching, and expansion) would also be considered. The cracking present is open, running parallel to the joint, and is discolored with exudate. Therefore this is medium-severity parallel cracking (MRD Indicator *G*) and is identified as *G-M(D)*. Staining (MRD Indicator *I*) of the joint is also clearly visible, but because the parallel cracking has progressed to medium-severity, staining is not recorded. Further, popouts (MRD

Indicator *C*) are visible. These are not identified for a joint location; instead, the number of popouts observed over the entire slab surface is assessed and the observation is recorded for the slab interior location with severity assigned based on the overall density of popouts observed.

Figure 18. Example 4: opened cracking along joint.

3.5 Example 5: Corner Location

Figure 19 shows cracking at four adjacent corners, illustrating how pavement condition can be highly variable, even within a small area, especially between adjacent paving lanes. The distress types specifically applicable to a corner location are *E* through *H* (sliver spalling, perpendicular cracking, parallel cracking, and joint disintegration), and *I* through *K* (staining, patching, and expansion) would also be considered. The cracking present at corners #1 and #2 is very fine and closed, and is both perpendicular and parallel to the joint, pointing to both perpendicular cracking (MRD Indicator *F*) and parallel cracking (MRD Indicator *G*). No discoloration is associated with the cracking, but the concrete is obviously stained. The indicators observed at corners #1 and #2 are therefore identified as low-severity perpendicular cracking (*F-L*), low-severity parallel cracking (*G-L*), and staining (*I*).

Corner #3 has more severe cracking than corners #1 or #2, with the perpendicular and parallel cracks having opened and appearing discolored with white exudate. The distress at corner #3 is thus identified as *F-M(D)* and *G-M(D)*. Although staining is also apparent, it is not recorded due to the presence of medium-severity cracking. Corner #4 is similar to corner #3, having open cracks running perpendicular and parallel to the joints, and also is discolored. More significantly, it poses an immediate FOD risk, with pieces missing from the corner. Therefore it is identified as joint disintegration (MRD Indicator *H*). No other distress is recorded for corner #4.

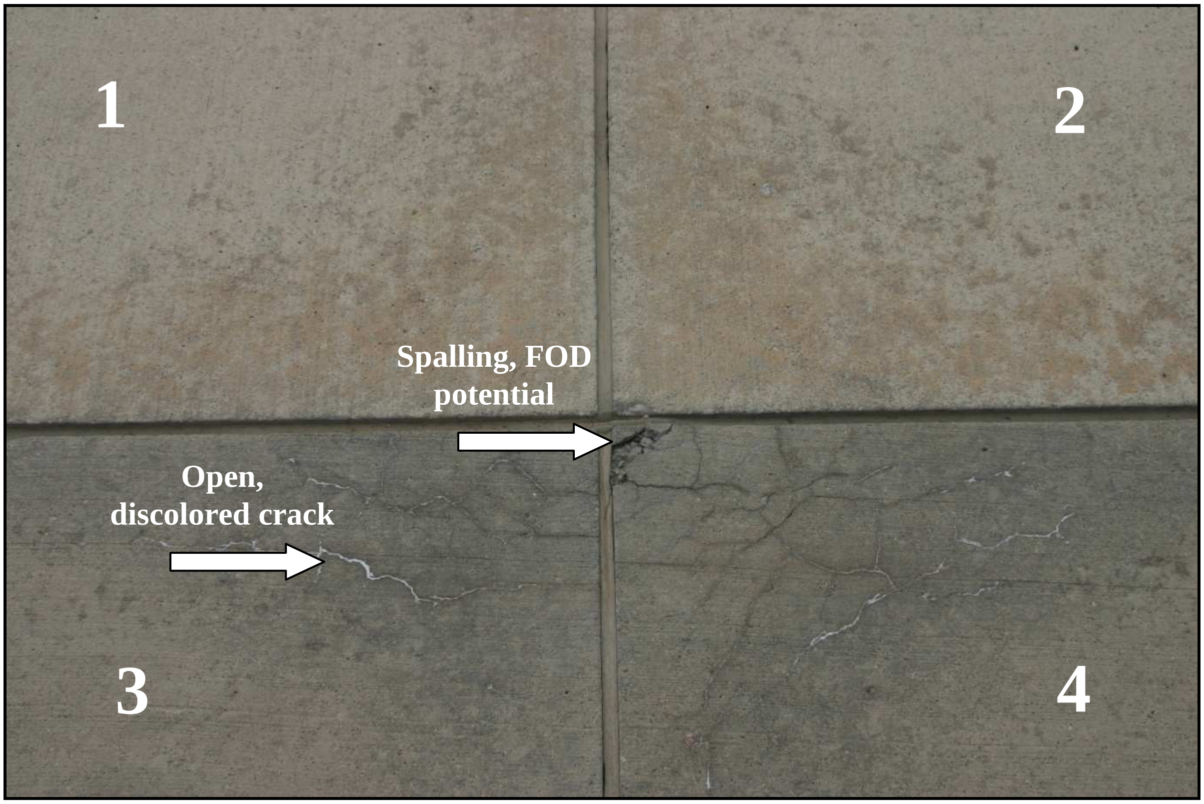


Figure 19. Example 5: cracking at slab corner with each corner numbered.

4. CALCULATING A MATERIALS-RELATED DISTRESS RATING (MRDR)

Once the MRD indicators are recorded and tabulated, the MRDR is calculated for the sample unit, and the average MRDR for all sample units is computed for the section. Unlike the PCI, which is on a scale of 0 to 100, with 100 being a pavement that is free of distress, the MRDR starts at 0 (no MRD indicators recorded) and increases as the amount and severity of distress increases, with no specified upper limit (although 3000 is the practical upper limit). Thus a new pavement that is completely free of distress would have a PCI of 100 and an MRDR of 0. Over time and as distresses develop, the PCI would decrease through the application of deduct values. If MRD is present and becoming more prevalent and/or of higher severity with time, the MRDR would increase. Conceptually, the relationship between the two ratings is illustrated in figure 20 for a pavement exhibiting progressive MRD.

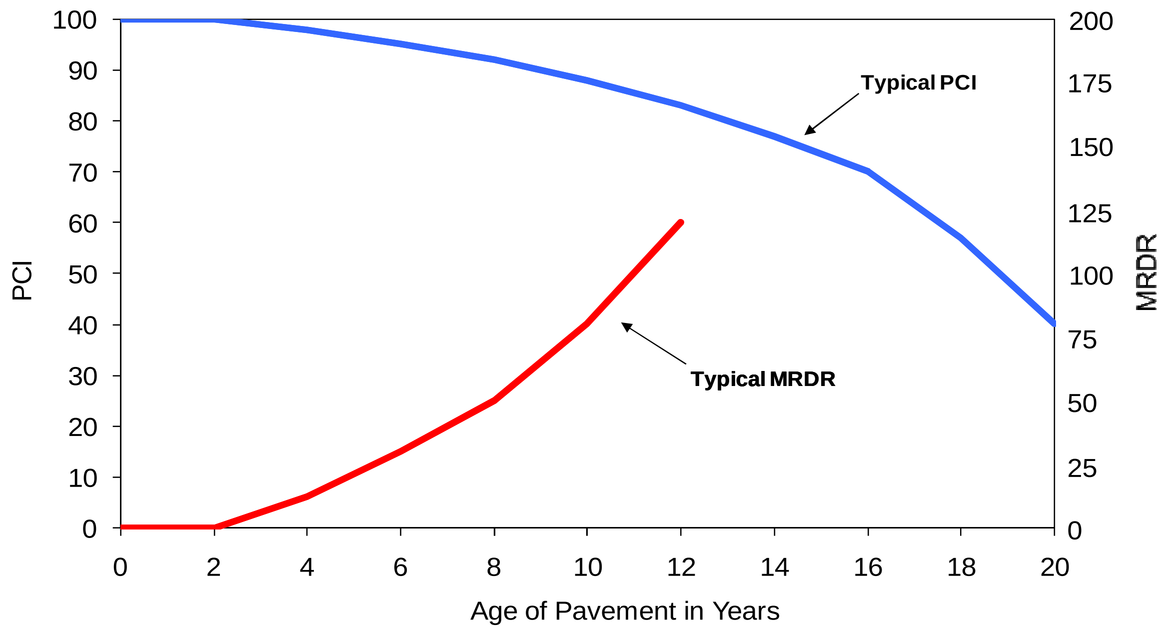


Figure 20. Conceptualization of relationship between PCI and MRDR.

What is also illustrated in figure 20 is that if MRD is the predominant distress present, the MRDR will be more sensitive to the development of MRD than the PCI. As previously discussed, early manifestation of MRD, especially staining and fine cracking, are either not noted in the PCI method or have very low deduct values associated with them. The MRDR procedure has been developed to capture these early signs of MRD using the weighting factors presented in table 3. For each sample unit, the percent of locations affected (density) by an MRD indicator of a given severity is calculated and multiplied by the appropriate weighting factor. These values are tallied to derive the MRDR for that sample unit, and the MRDR of all sample units surveyed within a given section are averaged to determine the section MRDR. In addition, the MRDR is computed separately for each slab location (corner, joint, and interior), meaning it is possible to determine which part of the slabs is most severely affected.

Table 3. MRD indicator weighting factors used to calculate MRDR.

MRD Indicator	Location	Distress Severity		
		Low	Medium	High
A: Pattern Cracking	Interior (3)	10	50	
A-D: Discoloration	Interior (3)	10		
B: Scaling	Interior (3)			500
C: Popouts	Interior (3)	5	20	40
D: Surface Honeycombing	Interior (3)	10	50	250
E: Sliver Spalling	Corner (1)	25		
	Joint (2)	25		
F: Perpendicular Cracking	Corner (1)	5	50	
	Joint (2)	5	50	
F-D: Discoloration	Corner (1)	5		
	Joint (2)	5		
G: Parallel Cracking	Corner (1)	10	100	
	Joint (2)	10	100	
G-D: Discoloration	Corner (1)	10		
	Joint (2)	10		
H: Joint Disintegration	Corner (1)			500
	Joint (2)			500
I: Staining	Corner (1)	10		
	Joint (2)	10		
	Interior (3)	5		
J: Patching	Corner (1)	25	50	500
	Joint (2)	25	50	500
	Interior (3)	25	50	500
K: Expansion	N/A			200

The weighting factors in table 3 reflect the risk posed by a given MRD indicator with a given severity level to produce FOD over time. In general, indicators with low weighting factors [e.g. staining (I), low-severity pattern cracking (A-L), and so on] have little current risk of producing FOD, but might be the initial expression of a distress if they continue to progress. The weighting factors for MRD indicators of medium-severity are significantly higher, signifying that although little FOD potential exists at the moment, a significant risk of FOD exists in the near future (1 to 2 years). The high weighting factors for MRD indicators characterized by loose or missing concrete (e.g. scaling (B), joint disintegration (H), high-severity patching (J-H), and so on) reflect the high risk of FOD that currently exists.

The MRDR weighting factors have been calibrated to set a "trigger" point of 25 for the initiation of maintenance activities to preserve the pavement in a low FOD risk condition. A second "trigger" point of 100 has been established to indicate that significant action, such as major repair or rehabilitation, is warranted because of the increased risk from FOD. These two points are illustrated in figure 21, which also shows a typical PCI performance history as well as the traditional PCI decision point.

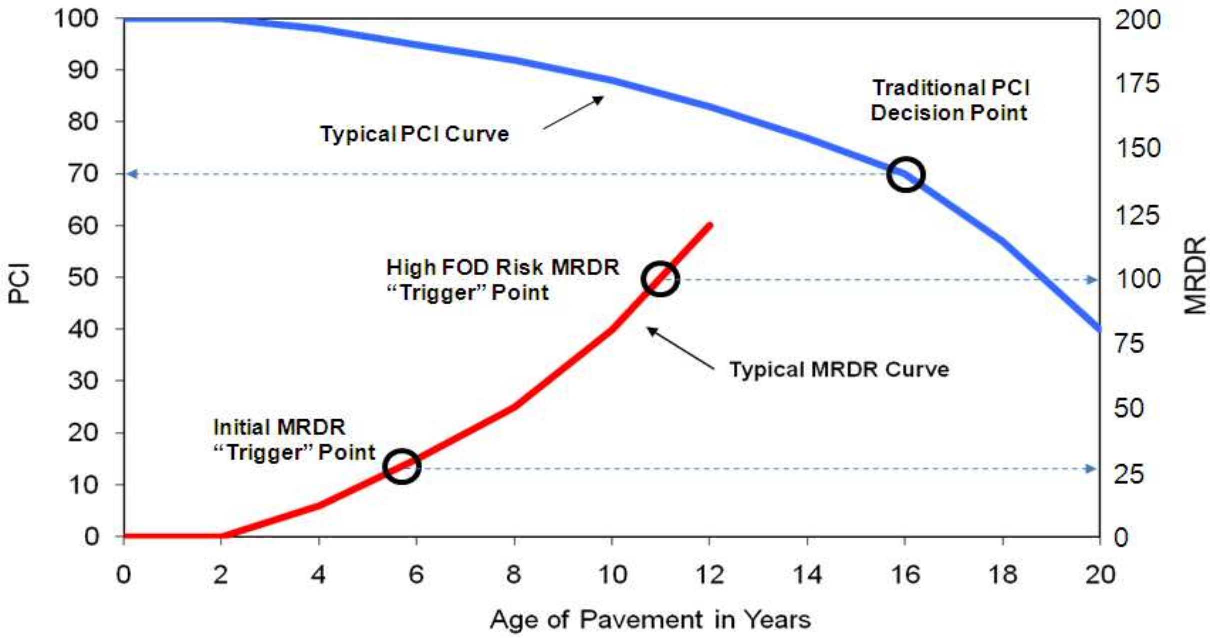


Figure 21. Illustration of trigger points for PCI and MRDR.

It should be clear that the MRDR incorporates risk management concepts, which are very important to the airport owner/operator. The FAA's System Safety Handbook (FAA 2000) addresses risk identification and control in great detail. In the MRDR, which is closely tied to FOD and FOD potential, airports have a tool to identify and quantify risk. The overall MRDR and where it lies in relation to trigger points, the weighting factors assigned to the individual MRDs, and the change in MRDR over time, all can help to manage risk. While this is not sufficient to control risk, the MRDR should be an essential tool in the overall process of identifying and managing risk.

The following examples, based on the data filled in the forms provided in Appendix B, are used to illustrate the calculation of the MRDR.

4.1 Calculating the MRDR: Example 1

Example 1 in Appendix B presents the MRDR form recorded for a sample unit (R/W 14R, Section 2, SU #26 consisting of 20 slabs). For a network-level MRDR survey, 40 percent of the 20 slabs are inspected. The 8 slabs (0.4 x 20) that were inspected are demarcated on the grid, and the codes for each MRD indicator are written into the appropriate locations as shown. Only two MRD indicators were observed: staining (I) of the joints and corners and low-severity pattern cracking (A-L) over the slab interiors. The results are tallied under the table labeled "TOTALS" on the right side of the form.

To calculate the MRDR, the density of the MRD indicators must first be determined. As 8 slabs were inspected, the total number of slab interiors (location 3) is 8. All of these slab interiors were affected by low-severity pattern cracking (A-L) as tallied under the "Totals" column on the right-side of the MRDR inspection form. Thus the "density" of the low-severity pattern cracking (A-L) is 1.0 (8 slabs affected divided by 8 slab interiors total). The total number of slab corners (location 1) and joints (location 2) is 32 each (8 slabs each with 4 corners and 4 joints). Thus the density of the staining (I), which was observed at every corner and joint as indicated in the tally on the right-side of the MRDR inspection form, is also 1.0. The weighting factor in table 3 for staining (I) at joints and corners is 10 and for low-severity pattern cracking (A-L) it is also 10. The calculation of the MRDR is as follows:

$$\text{Density} \times \text{Weighting Factor} = \text{MRDR} \qquad \text{(Equation 1)}$$

Using this approach, the results shown in table 4 were obtained for a total MRDR of 30.0. The overall MRDR suggests that this pavement should be evaluated for feasible maintenance activities that will slow down the rate of deterioration and the progression of MRD.

Table 4. Summary of MRDR calculation for Example 1.

Distress Type	Location	Density	Weighting	MRDR
A-L	3	1.0	10	10.0
I	1	1.0	10	10.0
	2	1.0	10	10.0
			Total MRDR	**30.0**

4.2 Calculating the MRDR: Example 2

Example 2 in Appendix B is hypothetically from the same branch and section as Example 1, only it is a different sample unit (SU #36). In this example, the MRD indicators observed are more serious, both in the types of indicators observed and their severity. As in the previous example, all MRD indicators are recorded on the form and the totals are tallied. The following notes are provided to help understand how the distresses were recorded:

- Note that if the cracking observed (whether A, F, or G) is medium severity, staining (I) is not recorded.
- Note that if joint disintegration (H) is observed, no other MRD indicator is recorded in that location (unless there happens to be patching (J)).
- Three MRD indicators are so prevalent that they are approaching the limit of what can be manually entered into the spaces on the form for the corner location. If more indicators are present than can be easily recorded, the supplemental checklist-style MRDR form illustrated in Example 3 should be used.

Using the same approach to calculate the MRDR described in Example 1, the occurrence of each MRD indicator has been tallied on the right-side of the MRDR inspection form. For example, 27 corners (location 1) were observed to have staining (I). Since a total of 32 corners (8 slabs with 4 corners each) were inspected, the density of staining (I) is 27 divided by 32, or 0.84. Similar density calculations are made for all observances of MRD indicators and the results shown in table 5 are obtained. The total MRDR is 69.3. The data can be broken down by location, indicating that approximately 56 percent (39.0) of the MRDR is associated with the corners, 15 percent (10.3) with the joints, and 29 percent (20.0) with the slab interiors. Looking at the distribution of distress in the form in Appendix B also shows that most of the distress is associated with the first column, which represents the paving lane directly to the right of the centerline of the runway.

Table 5. Summary of MRDR calculation for Example 2.

Distress Type	Location	Density	Weighting	MRDR
A-L	3	0.75	10	7.5
A-M	3	0.25	50	12.5
F-L	1	0.0625	5	0.3
	2	0.0625	5	0.3
F-M	1	0.0313	50	1.6
G-L	1	0.0625	10	0.6
G-M	1	0.125	100	12.5
I	1	0.84	10	8.4
	2	1.0	10	10.0
H	1	0.0313	500	15.6
			Total MRDR	**69.3**

The overall MRDR of this pavement indicates that routine maintenance and repair should be underway to keep this pavement in serviceable condition. The occurrence of joint deterioration (H) in one corner demands immediate treatment as this distress indicator poses an immediate FOD risk. If this sample unit is representative, and depending on the performance history of the pavement, the airport should begin the process of programming this facility for major repair/rehabilitation in the next few years.

4.3 Calculating the MRDR: Example 3

Example 3 in Appendix B is for a sample unit in an advanced stage of joint/corner deterioration due to MRD. The survey conducted was in support of a project to restore serviceability, and thus all of the slabs were inspected for the project-level analysis. It is readily apparent that the supplemental MRDR form will be required, as the amount of observed distress exceeds that which can legibly be recorded within the space available on the regular form. Thus, for Example 3, in the upper right-hand corner of the regular form, the question “Supplemental Form Used?” is answered “Yes.” For this case, one supplemental form was used as indicated.

As before, the sample unit is drawn in the grid provided on the regular form, but it can be further subdivided to indicate which slabs are recorded on which supplemental form. The supplemental forms only have a 20-slab capacity (4 slabs x 5 slabs), and thus sometimes two or more supplemental forms must be used to represent each sample unit. Clearly indicating this on the regular form will avoid confusion in subsequent data analysis. Also note that the regular form is used to tabulate the MRD indicators recorded on the supplemental forms.

As shown in Example 3 in Appendix B, data are recorded on the supplemental form simply by checking boxes that represent each appropriate MRD indicator and severity level. Further, a "D" check box is provided for pattern cracking (A), perpendicular cracking (F), and parallel cracking (G) to note whether discoloration is present. As indicated previously, the MRD indicators from the two supplemental forms are tallied and listed on the regular MRDR form.

Using the same approach to calculate the MRDR as described in Examples 1 and 2, the results shown in table 6 are obtained. As a severely distressed sample unit, the total MRDR is 141.7. The data can be broken down by location, indicating that approximately 85 percent (119.8) of the MRDR is associated with the corners, 15 percent (21.9) with the joints, and 0 percent (0) with the slab interiors.

The overall MRDR of this pavement indicates that the project to repair or rehabilitate this pavement section is justified, with the risk of FOD currently present at 11 percent of the corners (joint disintegration [H]) and another 44 percent of the corners will pose a FOD risk in the near future having medium-severity parallel cracking (G). In this case, the high level of distress will likely necessitate a rehabilitation alternative be sought to restore serviceability and maintain safety.

Table 6. Summary of MRDR calculation for Example 3.

Distress Type	Location	Density	Weighting	MRDR
F-L	1	0.5375	5	2.7
F-M	1	0.15	50	7.5
G-L	1	0.45	10	4.5
	2	0.35	10	3.5
G-M	1	0.4375	100	43.8
	2	0.15	100	15.0
H	1	0.1125	500	56.2
I	1	0.425	10	4.2
	2	0.3375	10	3.4
J-L	1	0.0375	25	0.9
			Total MRDR	**141.7**

5. THE MRDR AS A MANAGEMENT TOOL

5.1 Introduction

The MRDR provides a numerical indicator of the presence and severity of materials-related distress on an existing concrete pavement. As such, it represents a "snapshot" of the current pavement condition. The MRDR can serve several purposes. For example, the current MRDR can be used to indicate when normal maintenance or repair may be needed, or when more substantial rehabilitation (or perhaps even reconstruction) may be required. Moreover, the tracking of MRDR results over time can help identify rates of deterioration so that projected future pavement conditions may be used to aid in the planning and programming of capital improvement expenditures. This chapter briefly describes the use of the MRDR as a management tool and provides an overview of some of the treatments that may be used to address materials-related distresses.

5.2 Interpreting the MRDR

As described in chapter 4, the MRDR is computed for individual sample units and then the average MRDR for the section is computed. The MRDR scale starts at 0 (representing a pavement free of any signs of materials-related distress) and increases with increasing quantities and severities of MRD. Although there is no upper limit for the MRDR, a practical upper limit may be taken as 3000. Nevertheless, a narrow range of values occurring at the lower end of the scale are indicative of MRD problems and, consequently, will be useful in managing these pavements. Generally speaking, MRDR values less than 25 are not of critical concern (but should be closely monitored), MRDR values between 25 and 100 suggest that maintenance may be needed soon, and MRDR values greater than 100 indicate the need for major repair or rehabilitation. Thus, MRDR values of 200, 500, 1000, or even 2000 indicate pavements with increasing levels of distress, yet each is probably in need of major repair or rehabilitation. Figure 22 illustrates the interpretation of MRDR values.

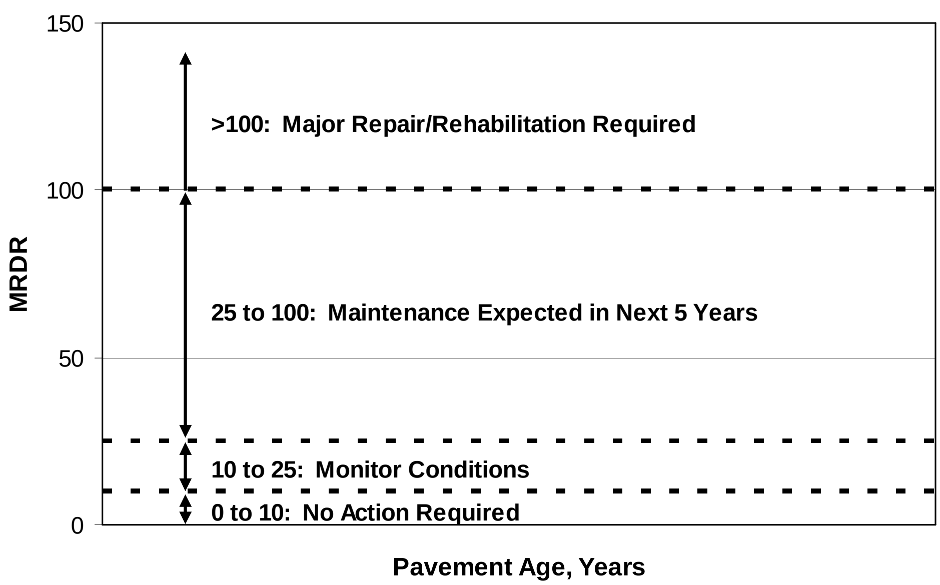


Figure 22. Interpretation of MRDR values.

Taken a step further, table 7 summarizes possible treatments associated with the range of MRDR values shown in figure 22. For each primary MRDR range category, possible or typical signs of MRDR are noted, the interpretation of the MRDR is provided, and some of the possible treatments are listed. These treatments range in magnitude and intrusiveness from preventive measures (such as joint sealing or surface sealers) to reactive repair techniques (full- and partial-depth) to structural overlays and reconstruction. The preventive measures seek to eliminate or reduce the rate of deterioration on pavements that are not exhibiting severe levels of deterioration. Reactive repair techniques are intended to address specific areas of deterioration (cracking/spalling) that compromise the integrity of the pavement or present a major FOD issue. Overlays and reconstruction options may be most appropriate where widespread deterioration is present and virtually no other approach is available to address the performance problems.

Table 7. Summary of possible treatments for MRDR categories.

MRDR	Possible Signs of MRDR	Interpretation	Possible Treatment(s)
0 to 10	• None • Slight staining of corners • Low-severity perpendicular cracking	No Action Required	• None
10 to 25	• Staining of joints/corners • Low-severity pattern cracking • Low- to medium-severity popouts • Low-severity perpendicular cracking • Low-severity parallel cracking	Monitor Condition	• None • Joint sealing • Surface sealers
25 to 100	• Medium-severity pattern cracking • High-severity popouts • Medium-severity perpendicular cracking • Medium-severity parallel cracking • Medium-severity patching	Maintenance Expected in Next 5 Years	• Joint sealing • Surface sealers • Partial-depth repairs • Full-depth repairs
> 100	• Scaling • Joint disintegration • High-severity patching • Expansion	Major Repair/Rehabilitation or Reconstruction	• Partial-depth repairs • Full-depth repairs • Structural HMA overlay • Unbonded PCC overlay • Reconstruction

The type and severity of MRD will in large part drive the type of treatment that will be required, but other factors—such as the type of facility and the potential FOD hazard—must also be considered. However, the resultant MRDR value itself does not identify the specific type of MRD or the actual distress manifestations, meaning that a separate project-level survey is required to identify specific repair activities, repair areas, and quantities, and a petrographic analysis would be required to identify the specific type of MRD (Van Dam et al. 2002, Walker et al. 2006).
Detailed information on the design, materials, and installation/construction of the different treatments are found in a number of references (Van Dam et al. 2002; UFC 2001a: UFC 2001b; FAA 2007). A brief summary of some of these treatments is provided in the next section.

5.3 Overview of Maintenance/Repair/Rehabilitation Treatments

5.3.1 Joint/Crack Sealing

Excess moisture feeds the adverse reactions that result in the development of materials-related distresses in concrete pavements. This is a primary reason why many MRDs first appear at joints and cracks, where moisture has ready access to penetrate the concrete. The sealing of joints and cracks, typically using either a hot-poured polymeric sealant or a silicone sealant, is one way of reducing the amount of surface water that can infiltrate the pavement. However, joint and crack sealing will have little or no effect if the source of the moisture is from beneath the pavement.

Joint and crack sealing is most effective when performed on pavements that exhibit primarily staining distress and have little to no cracking or disintegration due to MRD. Joint and crack sealing typically has a service life of 3 to 10 years, depending on the type of sealant and the quality of the installation procedures. Figure 23 shows an airport joint resealing project using a silicone sealant.

Figure 23. Joint resealing with silicone sealant (courtesy John Roberts, IGGA).

5.3.2. Surface Sealers

Surface sealers include a range of materials that are placed to reduce or prevent the ingress of moisture, deicers, and other constituents that may contribute to damaging reactions in the concrete (Sutter et al. 2008a). Concrete surface sealers may be divided into the following families:

- Water repellants, which penetrate concrete pores to some degree and coat pore walls rendering them hydrophobic (e.g., silanes, siloxanes).
- Pore blockers, which have sufficiently low viscosity to penetrate and seal the pores in concrete while leaving little or no measurable coating on the surface of the concrete (e.g., resins, linseed oil).
- Barrier coatings, which are too viscous to penetrate pores to measurable depths but form surfacing coatings of significant thickness and block the pores (e.g., epoxies, urethanes, and acrylics).

Although all surface sealers can slow the penetration of water and deicing chemicals, a recent study found that siloxane sealants were particularly effective; silane sealants were also effective, but to a lesser extent (Sutter et al. 2008b).

The application of any surface sealer should be done only on concrete that is clean and allowed to dry for at least 24 hours at temperatures above 60 ^{o}F. Application rates and traffic opening times should be in accordance with manufacturers' recommendations. The effectiveness of surface sealers is lost after they are exposed to traffic and environmental forces, and may need to be reapplied after 3 to 5 years (Sutter et al. 2008b). However, surface sealers may also temporarily reduce the pavement surface friction, so their use should be carefully considered depending on the need to maintain a high level of surface friction on a given pavement facility.

5.3.3. Partial-Depth Repairs

Partial-depth repairs are intended to address localized areas of deterioration that are limited to the upper one-third of the slab. These repairs consist of removing the deteriorated concrete and then replacing it with an approved patching material, achieving a strong bond between the existing pavement and the new patch material. Partial-depth repairs are most commonly performed along transverse and longitudinal joints, although they can be placed in slab interior locations as well.

Partial-depth repairs may not be an ideal repair for many MRDs because they are intended to address deterioration limited to the upper one-third of the slab, and in many cases the deterioration goes deeper. If that is the case, the placement of a full-depth repair may be more appropriate. Additionally, partial-depth repairs are sensitive to proper construction and installation procedures, and may quickly exhibit cracking and debonding it not properly constructed, including establishing good bond between the patching material and the substrate and ensuring that the joint is properly formed and sealed. When placed adjacent to pavement exhibiting MRD, it is less likely that the patch will remain in place over time.

A wide variety of materials are available for use in partial-depth repairs. These include conventional cementitious materials as well as many proprietary rapid-setting and high-early strength materials designed to reduce closure times. Material selection depends on available curing time, ambient temperature, cost, and size of the repairs. Figure 24 shows the placement of a partial-depth repair on a concrete airfield pavement with both the longitudinal and transverse joint being formed through the use of inserts.

5.3.4. Full-Depth Repairs and Slab Replacement

Full-depth repairs address more severe pavement deterioration than partial-depth repairs, and also are more reliable, exhibiting better long-term performance. These repairs consist of the removal of isolated deteriorated areas of concrete through the entire depth of the slab and replacement with a high-quality repair material.

Figure 24. Partial-depth repair placement (courtesy Gary Mitchell, ACPA).

Full-depth repairs are a widely used means of repairing localized deterioration at joints or cracks, but for larger areas of deterioration, complete slab replacement may be a more cost-effective option. However, it should be recognized that either full-depth repairs or slab replacements do not directly address the MRD problem, and continued deterioration is likely to occur in the original concrete outside of the repaired area.

The joints in full-depth repairs should generally match those that are present in the original pavement; in other words, if dowel bars or tiebars were used at the transverse or longitudinal joints, then they should also be used in the same joints making up the full-depth repair or slab replacement. In some cases, a full-depth repair that is smaller than the original panel size may be constructed using tiebars to tie the repair slab to the existing panel, as illustrated in figure 25.

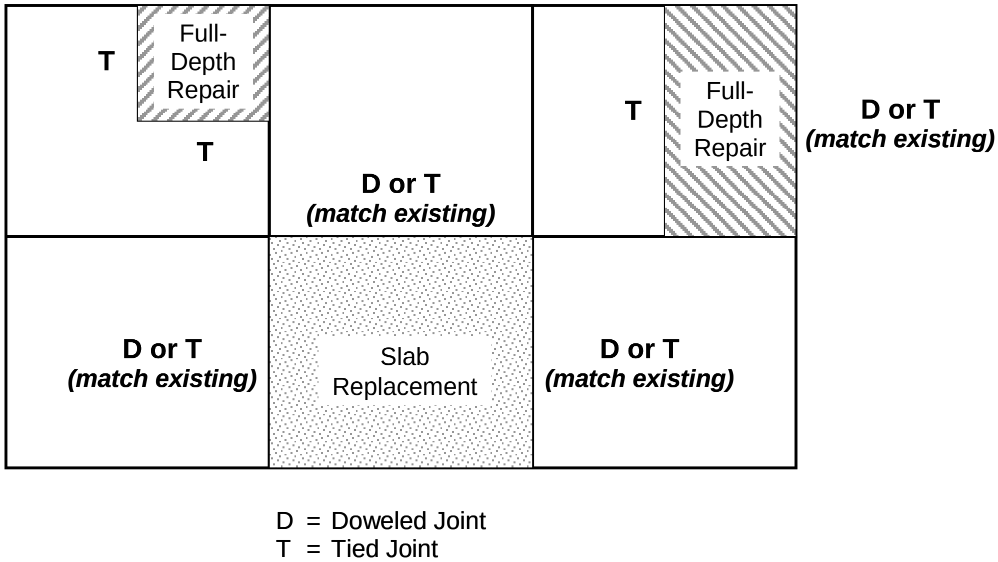


Figure 25. General jointing schematic for full-depth repairs on airfield pavements.

Cementitious patching materials are commonly used for full-depth repairs, and these can be modified to meet virtually any opening time requirement. Many full-depth repairs are opened to traffic in as little as 4 to 8 hours.

Some agencies have been experimenting with precast full-depth repairs. These are panels that are cast and cured off-site and then transported to the project and placed at pre-determined locations. The advantages of precast repairs include greater control over the concrete and its curing, minimal weather restrictions on placement, and reduced closures and delay times (since no on-site curing of the concrete is required). Precast panels have been used in some areas where very short work windows are available, and in some cases a cracked or damaged slab has been replaced with a precast panel in as little as 4 hours. Figure 26 shows a conventional full-depth repair operation and figure 27 illustrates the placement of precast slabs.

Figure 26. Conventional full-depth repair.

Figure 27. Precast full-depth slab replacement (courtesy Shiraz Tayabji).

5.3.5. Overlays

Overlays—either hot-mix asphalt (HMA) or unbonded PCC—may be effective rehabilitation options for pavements with MRD. Either overlay type can provide immediate improvements in serviceability and potentially enhanced long-term performance, but HMA overlays are more susceptible to reflection cracking and their performance is more dependent on the type and amount of pre-overlay repair work that is performed. Specifically, the performance of an HMA overlay requires that all badly deteriorated areas (generally moderate- and high-severity distresses) be repaired, which could become very costly in the case of MRD. In severe cases of MRD, fracturing of the concrete slabs prior to overlay may help achieve increased levels of performance for HMA overlays.

Unbonded PCC overlays are less sensitive to the underlying pavement conditions and can be an effective rehabilitation method for concrete pavements with MRD. Moreover, because they eliminate the need for pavement breakup, removal, disposal, and reworking of the foundation materials, they are an attractive alternative to complete reconstruction of the pavement facility. However, they are more expensive and will significantly raise the grade, which will affect shoulders, sideslopes, and elevations with other adjacent or intersecting pavements. Bonded PCC overlays are not recommended for existing concrete pavements exhibiting MRD.

The ultimate performance of an MRD-affected PCC pavement that is overlaid should be carefully considered before an overlay is selected as a repair or rehabilitation alternative. In certain scenarios an overlay may trap moisture inside the pavement structure, perhaps accelerating the deterioration of distresses driven by available moisture.

5.3.6. Reconstruction

In severe cases of MRD, the pavement may ultimately reach a condition in which total reconstruction is the most appropriate rehabilitation option. This is the only solution that directly addresses the MRD problem in the pavement, provided that a durable mix design and effective construction methods are used in the new pavement. In this process, it is imperative that the causes of the original MRD deterioration be identified and avoided in the new pavement. Critical information on mix design procedures and recommended construction practices are provided elsewhere (Van Dam et al. 2002; Kosmatka, Kerkhoff, and Panarese 2002; Kohn et al. 2003; Taylor et al. 2006).

When the existing pavement is reconstructed, the material from the old pavement can be recycled and used in a number of different construction applications, such as fill, granular base or subbase, and even in the new concrete if the initial causes of the MRD deterioration are identified and addressed. New construction technology allows for much of the concrete recycling process to be done on grade, reducing costs and environmental impact.

5.4 Summary

This chapter provides information on the application of the MRDR as a management tool for concrete pavements. Suggested treatment methods associated with different MRDR levels are provided, and may include routine or preventive maintenance activities (such as joint sealing) to more substantial repair, overlay, or reconstruction activities. A general overview of several of the treatment methods is provided.

6. CLOSING REMARKS

This *Guide to Field Evaluation of MRD Affected Concrete Pavements* describes a detailed approach that can be used to conduct a visual assessment and obtain a materials-related distress rating, or MRDR, for concrete airfield pavements. This guide is intended to be used by airfield personnel to assist in identifying whether a pavement has an MRD problem. When the MRDR procedure is routinely applied, it can help in early detection of potential MRD problems and identify when a pavement will require maintenance and repair, as well as when it may need more substantial rehabilitation (or perhaps even reconstruction), to minimize the risk of FOD. Examples are provided to not only assist the user in applying the procedure to properly identify and record observed MRD indicators but also to illustrate the calculation procedure for computation of the MRDR.

Although this procedure has been developed to be broadly applicable, it is noted that it is based on the study of two airfields in a single geographic region. As such, airfields located in other regions or those suffering MRD that is not similar to that seen in the pavements included in the study may need to modify the approach to better suit their specific needs. This is particularly true of the weighting factors used to calculate the MRDR and the established “trigger” points for maintenance and major rehabilitation, as these have been specifically calibrated to the airfields under study. It is also true of the sampling rate, which has only been verified as applicable for the two airfields used to develop this procedure.

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APPENDIX A: PCI/MRDR INSPECTION FORMS

PAVEMENT CONDITION INDEX (PCI) INSPECTION FORM
CONCRETE SURFACED PAVEMENTS

PCI

PROJECT ____________________ INSPECTION DATE ____________________
AIRPORT ____________________ INSPECTION CREW ____________________

BRANCH ______________ **SAMPLE UNIT** ______________ SLAB SIZE, TYP ______________
SECTION ______________ SAMPLE UNIT SIZE ______________ (R)ANDOM/(A)DDITIONAL ______________

61 BLOWUP (L,M,H)
62 CORNER BREAK (L,M,H)
63 CRACK., LONG., TRANS., AND DIAG. (L,M,H)
64 DURABILITY ("D") CRACKING (L,M,H)
65 JOINT SEAL DAMAGE (L,M,H)
66 PATCHING, SM. (L,M,H)
67 PATCHING, LG. AND UTIL. CUTS (L,M,H)
68 POPOUTS (N/A)
69 PUMPING (N/A)
70 SCALING, MAP CRACK., CRAZING (L,M,H)
71 SETTLEMENT OR FAULTING (L,M,H)
72 SHATTERED SLAB (L,M,H)
73 SHRINKAGE CRACKS (N/A)
74 SPALLING, LONG. AND TRANS. JOINT (L,M,H)
75 SPALLING, CORNER (L,M,H)

7						
6						
5						
4						
3						
2						
1						
	1	2	3	4	5	6

TOTALS		
TYPE	SEV.	QTY.
65		ALL

Signs of MRD Present?	Yes	No	Descriptors
Staining along joints?	☐	☐	Discoloration that does not appear natural
Staining near cracks?	☐	☐	Discoloration of cracks that does not appear to be moisture
Pattern Cracking?	☐	☐	Defined pattern cracking over majority of slab
Perpendicular Cracking near joints?	☐	☐	Small cracks perpendicular to a joint
Parallel Cracking along joints?	☐	☐	Cracking running parallel to joints not associated with spalling
Exudate from cracks?	☐	☐	Clearly visible deposit on pavement surface at cracks
Expansion at joints or fixed structures?	☐	☐	

If yes is checked for any, conduct MRD survey on other side.

APPLIED PAVEMENT TECHNOLOGY, INC. PAVEMENT CONDITION INDEX (PCI) FORM

MATERIALS RELATED DISTRESS RATING (MRDR) INSPECTION FORM
CONCRETE SURFACED PAVEMENTS

MRDR

PROJECT ____________________ INSPECTION DATE ____________________
AIRPORT ____________________ INSPECTION CREW ____________________

BRANCH ______________ **SAMPLE UNIT** ______________ SLAB SIZE, TYP ______________
SECTION ______________ SAMPLE UNIT SIZE ______________ (R)ANDOM/(A)DDITIONAL ______________

Interior
A. Pattern Cracking (L, M, +D)
B. Scaling (N/A)
C. Popouts (L, M, H)
D. Surface Honeycombing (L, M, H)

Joints and Corners
E. Sliver Spalling (N/A)
F. Perpendicular Cracking (L, M, +D)
G. Parallel Cracking (L, M, +D)
H. Joint Disintegration (N/A)

Overall
I. Staining (N/A)
J. Patching (L, M, H)

K. Expansion	Yes	No
Joint Misalignment?	☐	☐
Joint Closure?	☐	☐
Shoved Fixtures?	☐	☐
Blow-Ups?	☐	☐

1 Corners
2 Joints
3. Interior

1	2	1
2	3	2
1	2	1

7					
6					
5					
4					
3					
2					
1					
	A	B	C	D	E

TOTALS

TYPE	AREA 1	AREA 2	AREA 3

APPLIED PAVEMENT TECHNOLOGY, INC. MATERIALS RELATED DISTRESS RATING (MRDR) INSPECTION FORM

MATERIALS RELATED DISTRESS RATING (MRDR) INSPECTION FORM
CONCRETE SURFACED PAVEMENTS

MRDR

Applied Pavement Technology, Inc.

PROJECT ____________________ INSPECTION DATE ____________________
AIRPORT ____________________ INSPECTION CREW ____________________

BRANCH____________ **SAMPLE UNIT**____________
SECTION____________ SAMPLE UNIT SIZE____________ SHEET ____ of ____

1 Corners
2 Joints
3. Interior

1	2	1
2	3	2
1	2	1

Interior
A. Pattern Cracking (L, M, +D)
B. Scaling (N/A)
C. Popouts (L, M, H)
D. Surface Honeycombing (L, M, H)

Joints and Corners
E. Sliver Spalling (N/A)
F. Perpendicular Cracking (L, M, +D)
G. Parallel Cracking (L, M, +D)
H. Joint Disintegration (N/A)

Overall
I. Staining (N/A)
J. Patching (L, M, H)

K. Expansion	Yes	No
Joint Misalignment?	☐	☐
Joint Closure?	☐	☐
Shoved Fixtures?	☐	☐
Blow-Ups?	☐	☐

	1			2			3			4		
5	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I
	F L MD G L MD J L MH E H I	A L MD C L MH D L MH J L MH B I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	A L MD C L MH D L MH J L MH B I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	A L MD C L MH D L MH J L MH B I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	A L MD C L MH D L MH J L MH B I	F L MD G L MD J L MH E H I
	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I
4	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I
	F L MD G L MD J L MH E H I	A L MD C L MH D L MH J L MH B I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	A L MD C L MH D L MH J L MH B I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	A L MD C L MH D L MH J L MH B I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	A L MD C L MH D L MH J L MH B I	F L MD G L MD J L MH E H I
	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I
3	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I
	F L MD G L MD J L MH E H I	A L MD C L MH D L MH J L MH B I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	A L MD C L MH D L MH J L MH B I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	A L MD C L MH D L MH J L MH B I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	A L MD C L MH D L MH J L MH B I	F L MD G L MD J L MH E H I
	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I
2	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I
	F L MD G L MD J L MH E H I	A L MD C L MH D L MH J L MH B I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	A L MD C L MH D L MH J L MH B I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	A L MD C L MH D L MH J L MH B I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	A L MD C L MH D L MH J L MH B I	F L MD G L MD J L MH E H I
	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I
1	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I
	F L MD G L MD J L MH E H I	A L MD C L MH D L MH J L MH B I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	A L MD C L MH D L MH J L MH B I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	A L MD C L MH D L MH J L MH B I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	A L MD C L MH D L MH J L MH B I	F L MD G L MD J L MH E H I
	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I	F L MD G L MD J L MH E H I

Totals			
	Area		
Type	1	2	3

APPLIED PAVEMENT TECHNOLOGY, INC. MATERIALS RELATED DISTRESS RATING (MRDR) INSPECTION FORM

APPENDIX B: ILLUSTRATIVE EXAMPLES

MATERIALS RELATED DISTRESS RATING (MRDR) INSPECTION FORM

MRDR

CONCRETE SURFACED PAVEMENTS

PROJECT Example #1 INSPECTION DATE 4-30-09
AIRPORT Anywhere International INSPECTION CREW BGA & DGP

Supplemental Form Used? ☒ No ☐ Yes No. ____

BRANCH R/W 14R **SAMPLE UNIT** 24 SLAB SIZE, TYP 18.75 × 20
SECTION 2 SAMPLE UNIT SIZE 20 slabs (R)ANDOM/(A)DDITIONAL R

Interior
A. Pattern Cracking (L, M, +D)
B. Scaling (N/A)
C. Popouts (L, M, H)
D. Surface Honeycombing (L, M, H)

Joints and Corners
E. Sliver Spalling (N/A)
F. Perpendicular Cracking (L, M, +D)
G. Parallel Cracking (L, M, +D)
H. Joint Disintegration (N/A)

Overall
I. Staining (N/A)
J. Patching (L, M, H)

K. Expansion	Yes	No
Joint Misalignment?	☐	☒
Joint Closure?	☐	☒
Shoved Fixtures?	☐	☒
Blow-Ups?	☐	☒

1 Corners
2 Joints
3. Interior

1	2	1
2	3	2
1	2	1

	A	B	C	D	E
7					
6					
5		I I I I A-L I I I I			
4	I I I I A-L I I I I			I I I I A-L I I I I	
3			I I I I A-L I I I I		
2		I I I I A-L I I I I		I I I I A-L I I I I	
1	I I I I A-L I I I I		I I I I A-L I I I I		

TOTALS

TYPE	AREA 1	AREA 2	AREA 3
A-L			8
I	32	32	

APPLIED PAVEMENT TECHNOLOGY, INC. MATERIALS RELATED DISTRESS RATING (MRDR) INSPECTION FORM

MATERIALS RELATED DISTRESS RATING (MRDR) INSPECTION FORM

MRDR

CONCRETE SURFACED PAVEMENTS

PROJECT Example #2 INSPECTION DATE 4-30-09
AIRPORT Anywhere Intl INSPECTION CREW BGA & DGP

Supplemental Form Used? ☒ No ☐ Yes No. ____

BRANCH R/W 14R **SAMPLE UNIT** 36 SLAB SIZE, TYP 18.75 by 20
SECTION 2 SAMPLE UNIT SIZE 20 slabs (R)ANDOM/(A)DDITIONAL R

Interior	Joints and Corners	Overall
A. Pattern Cracking (L, M, +D)	E. Sliver Spalling (N/A)	I. Staining (N/A)
B. Scaling (N/A)	F. Perpendicular Cracking (L, M, +D)	J. Patching (L, M, H)
C. Popouts (L, M, H)	G. Parallel Cracking (L, M, +D)	
D. Surface Honeycombing (L, M, H)	H. Joint Disintegration (N/A)	

K. Expansion	Yes	No
Joint Misalignment?	☐	☒
Joint Closure?	☐	☒
Shoved Fixtures?	☐	☒
Blow-Ups?	☐	☒

1 Corners
2 Joints
3. Interior

1	2	1
2	3	2
1	2	1

	A	B	C	D	E
7					
6					
5		I I I I A-L I I I I			
4	I F-L G-L, I, H I F-L, A-M, I G-M, I, F-M G-M			I I I I A-L I I I I	
3			I I I I A-L I I I I		
2		I I I I A-L I I I I		I I I I A-L I I I I	
1	G-M, I, I G-L I F-L, A-M, I G-M, I, F-L I		I I I I A-L I I I I		

TOTALS

TYPE	AREA 1	AREA 2	AREA 3
A-L			6
A-M			2
I	27	32	
F-L	2	2	
F-M	1		
G-L	2		
G-M	4		
H	1		

APPLIED PAVEMENT TECHNOLOGY, INC. MATERIALS RELATED DISTRESS RATING (MRDR) INSPECTION FORM

MATERIALS RELATED DISTRESS RATING (MRDR) INSPECTION FORM **MRDR**

CONCRETE SURFACED PAVEMENTS

PROJECT Example #3 INSPECTION DATE 4-30-09

AIRPORT Anywhere Int'l INSPECTION CREW BGA & DGP

Supplemental Form Used? ☐ No [✓ Yes] No. 1

BRANCH TW B **SAMPLE UNIT** 7 SLAB SIZE, TYP 15 x 15

SECTION 2 SAMPLE UNIT SIZE 20 (R)ANDOM/(A)DDITIONAL R

Interior
A. Pattern Cracking (L, M, +D)
B. Scaling (N/A)
C. Popouts (L, M, H)
D. Surface Honeycombing (L, M, H)

Joints and Corners
E. Sliver Spalling (N/A)
F. Perpendicular Cracking (L, M, +D)
G. Parallel Cracking (L, M, +D)
H. Joint Disintegration (N/A)

Overall
I. Staining (N/A)
J. Patching (L, M, H)

K. Expansion	Yes	No
Joint Misalignment?	☐	☒
Joint Closure?	☐	☒
Shoved Fixtures?	☐	☒
Blow-Ups?	☐	☒

1 Corners
2 Joints
3. Interior

1	2	1
2	3	2
1	2	1

	A	B	C	D	E
7					
6					
5					
4					
3			SHEET 1		
2			→		
1					

TOTALS

TYPE	AREA 1	2	3
F-L	43	–	–
F-M	12	–	–
G-L	36	28	–
G-M	35	12	–
H	9	–	–
I	34	27	–
J-L	3	–	–

APPLIED PAVEMENT TECHNOLOGY, INC. MATERIALS RELATED DISTRESS RATING (MRDR) INSPECTION FORM

MATERIALS RELATED DISTRESS RATING (MRDR) INSPECTION FORM

MRDR

Applied Pavement Technology, Inc.

CONCRETE SURFACED PAVEMENTS

PROJECT Example #3 INSPECTION DATE 4-30-09
AIRPORT Anywhere Int'l INSPECTION CREW BGA & DGP
BRANCH TWB **SAMPLE UNIT** 7
SECTION 2 SAMPLE UNIT SIZE 20 SHEET 1 of 1

1 Corners
2 Joints
3. Interior

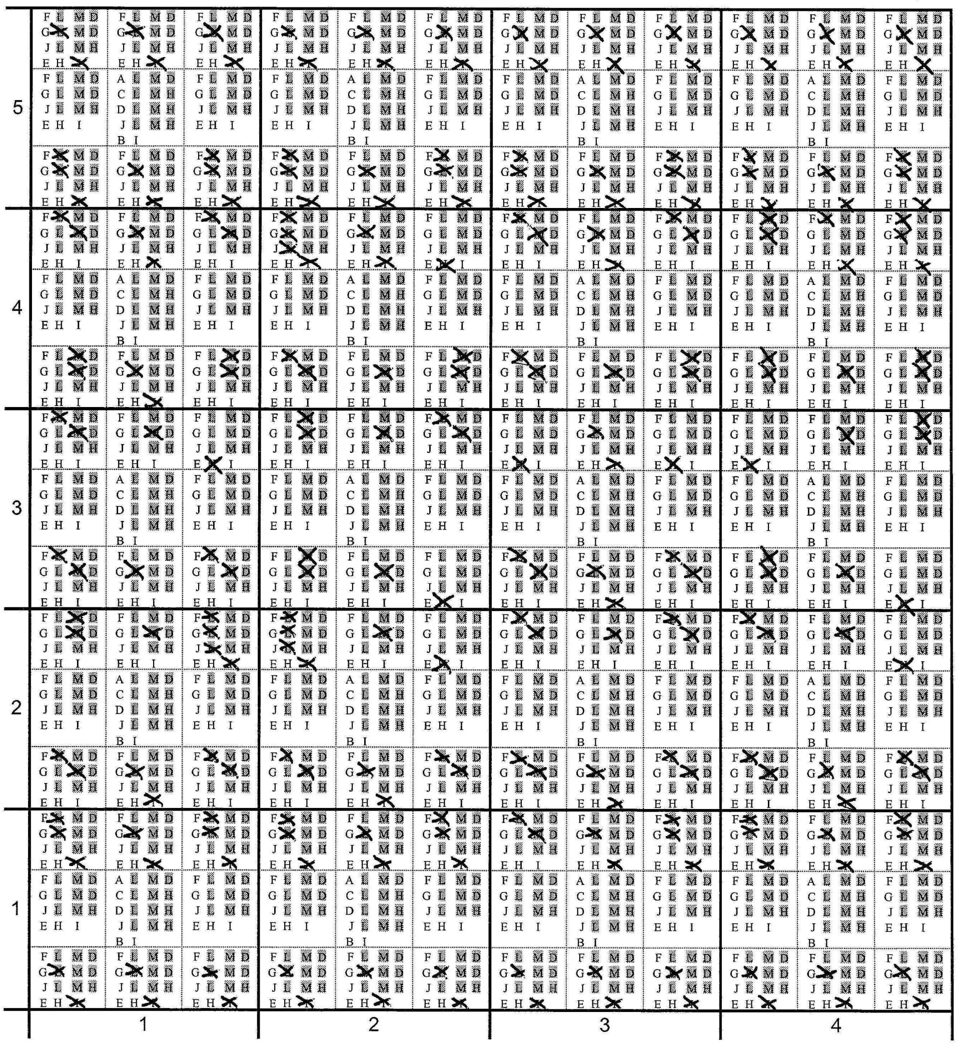
1	2	1
2	3	2
1	2	1

Interior
A. Pattern Cracking (L, M, +D)
B. Scaling (N/A)
C. Popouts (L, M, H)
D. Surface Honeycombing (L, M, H)

Joints and Corners
E. Sliver Spalling (N/A)
F. Perpendicular Cracking (L, M, +D)
G. Parallel Cracking (L, M, +D)
H. Joint Disintegration (N/A)

Overall
I. Staining (N/A)
J. Patching (L, M, H)

K. Expansion	Yes	No
Joint Misalignment?	☐	☒
Joint Closure?	☐	☒
Shoved Fixtures?	☐	☒
Blow-Ups?	☐	☒



Totals

Type	Area 1	2	3
F-L	43	-	-
F-M	12	-	-
G-L	36	28	-
G-M	35	12	-
H	9	-	-
I	34	27	-
J-L	3	-	-

→

APPLIED PAVEMENT TECHNOLOGY, INC. MATERIALS RELATED DISTRESS RATING (MRDR) INSPECTION FORM