PAVEMENT DISTRESS IDENTIFICATION MANUAL

for the

NPS ROAD INVENTORY PROGRAM

Cycle 4, 2006-2009

Prepared by Federal Highway Administration

national park service

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PREFACE

The Federal Highway Administration (FHWA), Road Inventory Program (RIP) for the National Park Service (NPS), collects roadway condition data on paved asphalt surfaces including roads, parkways, and parking areas in national parks nationwide. The road surface condition data is collected using an automated data collection vehicle called ARAN (Automated Road ANalyzer).

The FHWA RIP is implemented based on the premise that an accurate pavement surface condition assessment can be accomplished using automated crack detection technology as applied to digital images. Various methods of pavement condition assessment have been developed over the years with varying degrees of accuracy and acceptance. The use of digital photography to record pavement images and subsequent crack detection and classification has undergone continuous improvements over the past decade. Digital cameras with increasingly superior resolution have become more affordable, and the proprietary programming code and algorithms have been improved in crack detection software.

With the use of quality digital photography and automated crack detection software, FHWA RIP is tasked with executing a pavement condition assessment on about 5,400 miles of National Park Service roads and parkways. Foremost in setting up the basis of pavement distress identification is employing the distress identification protocols used by FHWA. There is no single distress identification system that is universal among entities doing distress identification. For the purpose of the NPS RIP, FHWA employs distress identification protocols that are specific to this program.

FHWA has referenced the *"Distress Identification Manual for the Long-Term Pavement Performance Program", Publication No. FHWA-RD 03-031, June 2003,* as the point-of-reference for distress types on NPS pavement. In truth, the FHWA RIP distress types are similar to those described in the LTPP manual with some modifications. This document, *"Distress Identification Manual for the NPS Road Inventory Program, Cycle 4, 2006-2008"* was developed using the *"Distress Identification Manual for the Long-Term Pavement Performance Program"* as a guideline. Definitions of severity levels based on crack width contained in this document adhere to the LTPP Distress ID Manual. Modifications have been made to the definition of Alligator Cracking and determination of Alligator Cracking severity. This manual also addresses Rutting and Roughness and its application to RIP.

In 2006, FHWA RIP will begin the fourth cycle of data collection in national parks. For Cycle 4, data will be collected in approximately 86 national parks totaling an estimated 5,400 miles of paved roads and approximately 5,000 paved parking areas. The data is used to support the National Park Service road maintenance program and Pavement Management System (PMS) developed and maintained by FHWA.

This **"Distress Identification Manual for the NPS Road Inventory Program"** will be used as a reference in crack detection and classification, determination of distress severity and extent, and in the calculation of distress index values for the FHWA RIP Cycle 4.

SURFACE DISTRESSES

Surface distresses are measured in the primary lane only. In the classification and measurement of all surface condition data, results will be reported in the database in record intervals of 0.02 miles (105.6 feet) along the route.

Surface distresses determined from digital video images
- Transverse Cracks
- Longitudinal Cracks
- Alligator Cracks
- Patching/Potholes

Surface distress measured by ARAN
- Rutting

Surface distress data are classified as listed above, measured for severity, and quantified for extent. Classification, severity, and extent of these five surface distresses comprise the three main elements for calculation of SCR (Surface Condition Rating).

Additional condition data measured by ARAN
- Roughness (IRI)

Roughness is measured by FHWA's ARAN and provided to Contractor as International Roughness Index (IRI).

Each of the five surface distresses is assigned a computed surface distress index
- Transverse Crack Index
- Longitudinal Crack Index
- Alligator Crack Index
- Patching/Pothole Index
- Rutting Index

IRI is assigned a computed Roughness Condition Index (RCI)

Using the SCR (computed from the five surface distresses) and the RCI, an overall Pavement Condition Rating (PCR) is computed. The formula for PCR is:

PCR = (0.60 * SCR) + (0.40 * RCI)

A detailed description of each distress index formula, roughness index formula, SCR and PCR is provided in this document.

Each classified surface distress will fall into one or more s*everity*…LOW, MEDIUM, or HIGH based on criteria listed. For each severity, an e*xtent* is established based on the measured quantity of the distress within that severity. Within each *Severity* individual distresses are assigned a *Maximum Allowable Extent* (MAE). For example, LOW severity transverse cracking may be allowed up to 15.1 cracks within a 0.02 interval before it reaches MAE and fails.

The MAE and index formulas are based on a scale of 0-100. A PCR index value of 100 would indicate a "perfect" road with no measurable distresses or rough ride. A PCR value of 60 is determined to be *terminable serviceability* and the road is considered failed. The range of index values with condition descriptors is:

POOR (<=60), FAIR (61 - 84), GOOD (85 - 94) , EXCELLENT (95 - 100)

Index values are computed based on cumulative deducts of the measured severities. As shown in the index formulas below, as any single severity reaches MAE, the index computes to a value of 60 and the road fails for that 0.02 interval.

> **Note:** Under certain conditions, index values may compute to less than 0 or greater than 100. In this instance, < 0 defaults to 0. Index values > 100 default to 100.
> For all indices, a higher value indicates a better road condition, and a lower value indicates a poorer road condition.

Table 1 summarizes the different types of distresses measured.
TABLE 1: Distress Summary

ASPHALT-SURFACED PAVEMENT DISTRESS TYPES with RUTTING and ROUGHNESS				
DISTRESS TYPE	**UNIT OF MEASURE…**	**…CONVERTED TO**	**DEFINED SEVERITY LEVELS?**	**MEASURED BY**
Alligator Cracking	**Square Feet**	**Percent of Lane Per 0.02 Mile**	**Yes**	**Contractor (Video Analysis)**
Transverse Cracking	**Linear Feet**	**Number of Cracks Per 0.02 Mile**	**Yes**	**Contractor (Video Analysis)**
Longitudinal Cracking	**Linear feet**	**Percent of Lane Length Per 0.02 Mile**	**Yes**	**Contractor (Video Analysis)**
Patching/Potholes	**Square Feet**	**Percent of Lane Per 0.02 Mile**	**No**	**Contractor (Video Analysis)**
Rutting	**Inches**	**Rut Depth Per 0.02 Mile**	**Yes**	**FHWA (Data Collection Vehicle)**
Roughness	**IRI**	**RCI**	**No**	**FHWA (Data Collection Vehicle)**

ALLIGATOR CRACKING

Description

Alligator cracking may be considered a combination of fatigue and block cracking. It is a series of interconnected cracks of various stages of development. Alligator cracking develops into a many-sided pattern that resembles chicken wire or alligator skin. It can occur anywhere in the road lane. Alligator cracking must have a quantifiable area.

Severity Levels

LOW
An area of cracks with no or very few interconnecting cracks and the cracks are not spalled. Cracks are <= 0.25 in (6mm) in mean width. Cracks in the pattern are no further apart than 1 foot (0.328 m). May be sealed cracks with sealant in good condition and a crack width that cannot be determined.

MEDIUM
An area of interconnected cracks that form a complete pattern. Cracks may be slightly spalled. Cracks are >0.25 in. (6 mm) and <= 0.75 in. (19 mm) or any crack with a mean width <= 19 mm and adjacent low severity cracking. Cracks in the pattern are no further apart than 6 in. (150 mm).

HIGH
An area of interconnected cracks forming a complete pattern. Cracks are moderately or severely spalled. Cracks are >0.75 in (19mm) or any crack with a mean width <= 0.75 in (19mm) and adjacent medium to high severity random cracking.

A combination of observed crack width and crack pattern is used to determine overall severity of alligator cracking. Based on above description of each severity, the highest level of crack width and crack pattern determines overall severity. Table 2 illustrates this.

TABLE 2: Alligator Crack Severity Levels

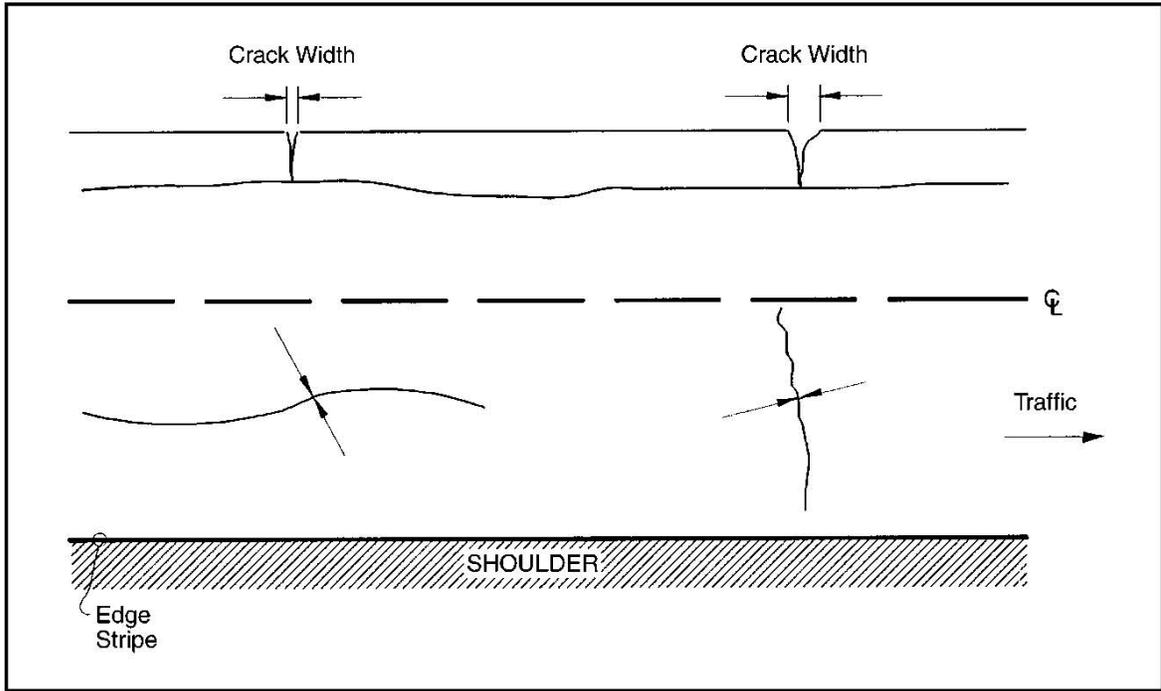| ALLIGATOR CRACKING SEVERITY LEVELS		Crack Pattern		
		LOW	**MED**	**HIGH**
Crack Width	**LOW**	L	M	H
	MED	M	M	H
	HI	H	H	H

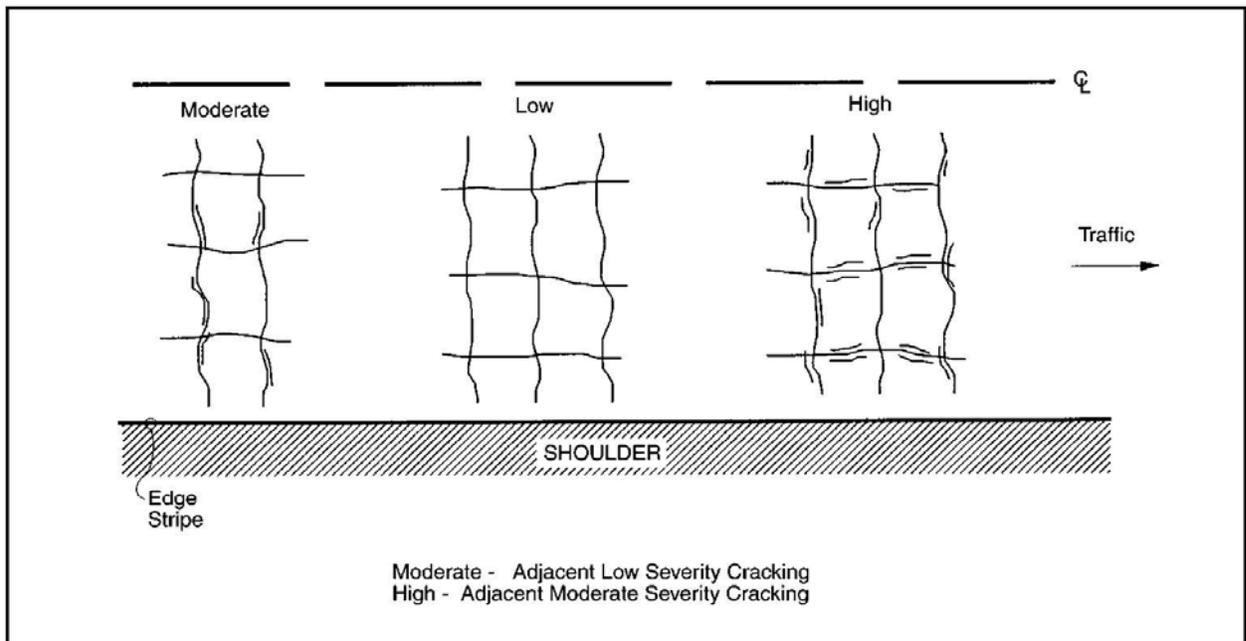**FIGURE 1: Measuring Crack Width on Asphalt Pavement**

FIGURE 2: Effect on Severity Level of Alligator Cracking due to Associated Random Cracking
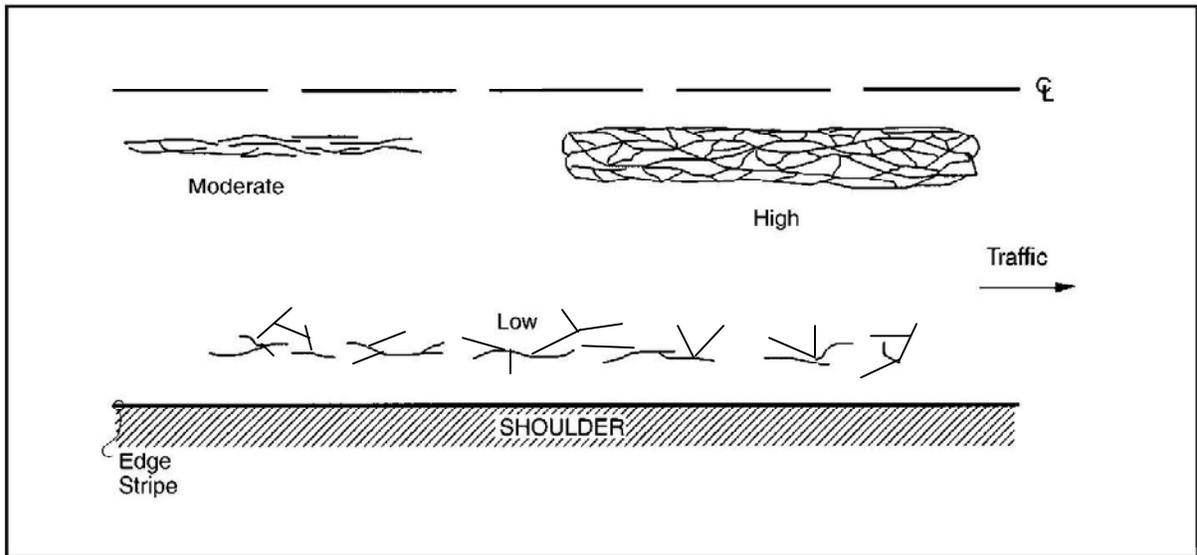
FIGURE 3: Alligator Crack Patterns of Differing Severity

FIGURE 4: High Severity Alligator Cracking

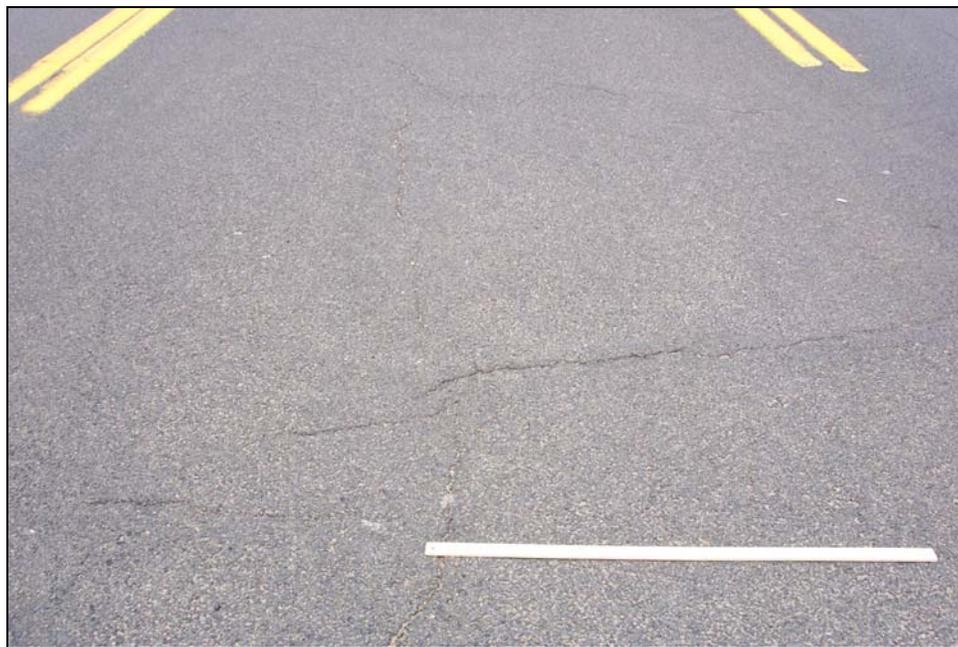**FIGURE 5: Medium Severity Alligator Cracking**

**FIGURE 6: Low Severity Alligator Cracking with Few
or No Interconnecting Cracks**

LONGITUDINAL CRACKING

Description

Longitudinal cracking occurs predominantly parallel to the pavement centerline. It can occur anywhere within the lane. Longitudinal cracks occurring in the wheelpath may be noteworthy.

Severity Levels

LOW
Cracks with a mean width of < 0.25 in. (6 mm). Sealed cracks with sealant in good condition and a width that cannot be determined.

MED
Cracks with a mean width > 0.25 in. (6 mm) and <= 0.75 in. (19 mm). Also, any crack with a mean width < 0.75 in. (19 mm) and adjacent random low severity cracking.

HIGH
Cracks with a mean width > 0.75 in. (19 mm). Also, any crack with a mean width < 0.75 in. (19 mm) and adjacent random medium to high severity cracking.

FIGURE 7: High Severity Longitudinal Cracking

FIGURE 8: Medium Severity Longitudinal Cracking

FIGURE 9: Low Severity Longitudinal Cracking

TRANSVERSE CRACKING

Description

Transverse cracking occurs predominantly perpendicular to the pavement centerline. It can occur anywhere within the lane.

Severity Levels

LOW
Cracks with a mean width of < 0.25 in. (6 mm). Sealed cracks with sealant in good condition and a width that cannot be determined.

MED
Cracks with a mean width > 0.25 in. (6 mm) and <= 0.75 in. (19 mm). Also, any crack with a mean width < 0.75 in. (19 mm) and adjacent random low severity cracking.

HIGH
Cracks with a mean width > 0.75 in. (19 mm). Also, any crack with a mean width < 0.75 in. (19 mm) and adjacent random medium to high severity cracking.

FIGURE 10: High Severity Transverse Cracking

FIGURE 11: Medium Severity Transverse Cracking

FIGURE 12: Low Severity Transverse Cracking

PATCHING AND POTHOLES

Description

Patching is an area of pavement surface that has been removed and replaced with patching material or an area of pavement surface that has had additional patching material applied. Patching may encompass partial lane or full lane width   On full lane width patching, the total, contiguous length of patch may not exceed 0.30 mi. (4.84 km). (Any full-lane patch exceeding 0.30 mi. in length is considered a pavement change). Patching must have a quantifiable area.

Potholes are bowl-shaped holes of various sizes occurring in the pavement surface.

Severity Levels

There are no stratified severities for Patching/Potholes. They either are present or they are not.
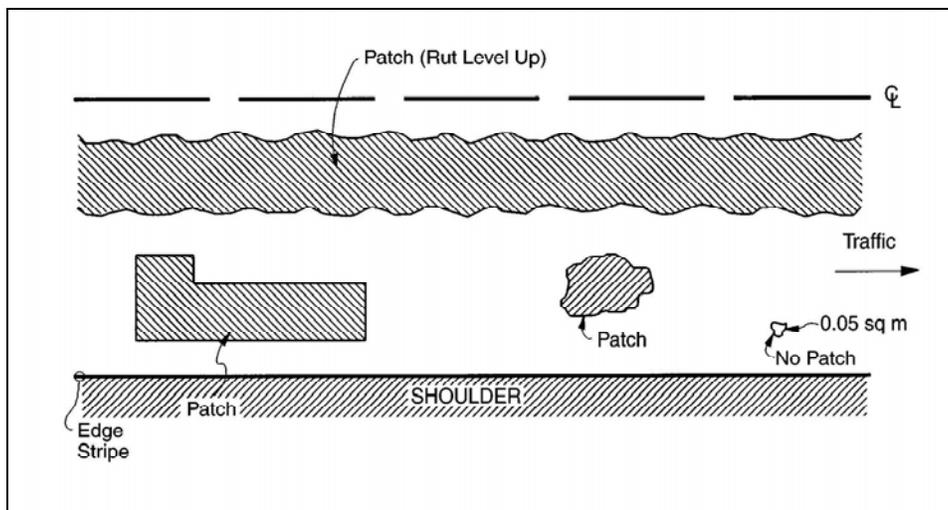

FIGURE 13: Patching Variations

FIGURE 14: Patching

FIGURE 15: Patching

FIGURE 16: Pothole Surrounded by Alligator Cracking

FIGURE 17: Full and Partial-Width Road Patching

RUTTING

Description

Rutting is a longitudinal surface depression in the wheelpath.

Severity Levels

LOW
Ruts with a measured depth ≥ 0.20" and ≤ 0.49"

MED
Ruts with a measured depth ≥ 0.50" and ≤ 0.99"

HIGH
Ruts with a measured depth ≥ 1.00"

Ruts < 0.20" are not included in the distress calculations.
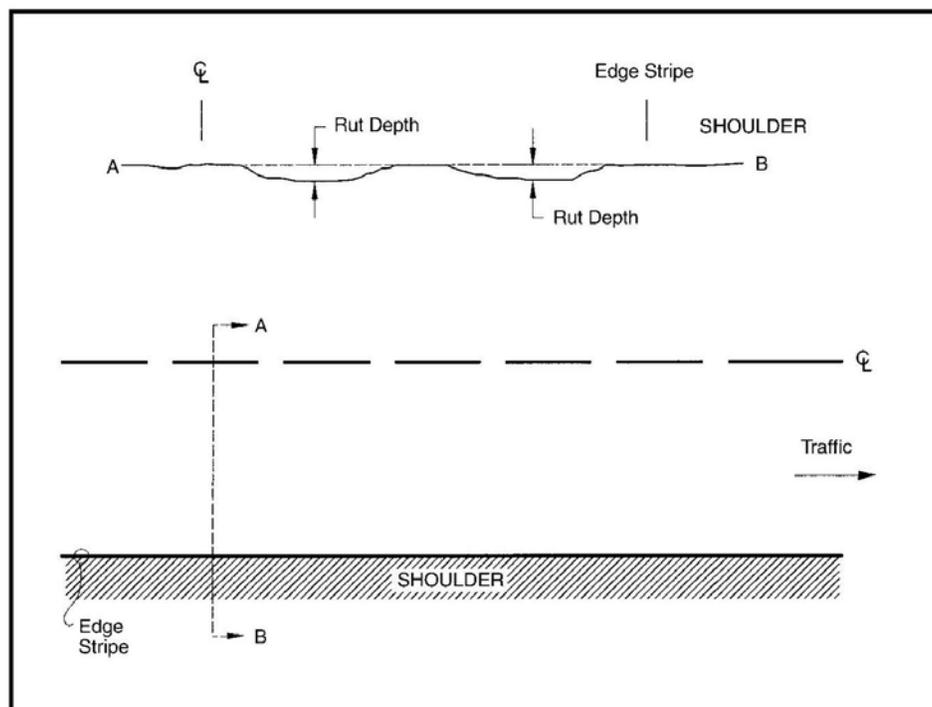

FIGURE 18: Measuring Rutting

FIGURE 19: High Severity Rutting

FIGURE 20: Medium Severity Rutting

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FIGURE 21: Low Severity Rutting

ROUGHNESS

Description

Roughness is the measurement of the unevenness of the pavement in the direction of travel. It is measured in units of IRI (International Roughness Index), inches per mile, and is indicative of ride comfort.

Severity Levels

There are no stratified severity levels for roughness.

IRI Range Description		
Rating Category	**IRI Value Range**	**RIP Index (RCI) Value Range**
Excellent	<= 127	95 - 100
Good	128 - 154	85 - 94
Fair	155 - 240	61 - 84
Poor	> 240	<= 60

SURFACE TYPES

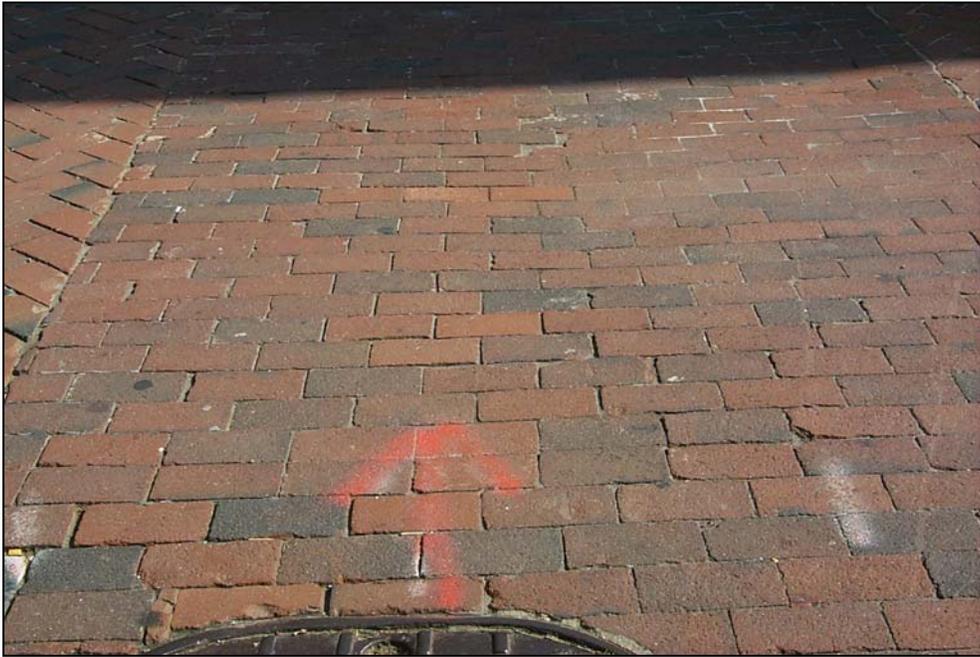

FIGURE 22: Asphalt Surface Type

FIGURE 23: Brick Surface Type

FIGURE 24: Cobblestone Surface Type

FIGURE 25: Concrete Surface Type

INDEX FORMULAS

Note**:** All index formulas listed below contain MAE applicable to 0.02 mile (105.6 feet) interval.

Alligator Crack Index

AC_INDEX = 100 – 40 * [(%LOW / 70) + (%MED / 30) + (%HI / 10)]

Where :

The values *%LOW*, *%MED* and *%HI* report the percentage of the observed pavement (0.02 mile, primary lane) that contains alligator cracking within the respective severities. These values range from ≥ 0 to ≤ 100.

%LOW = Percent of total area (primary lane, 0.02 in length), low severity
%MED = Percent of total area (primary lane, 0.02 in length), medium severity
%HI = Percent of total area (primary lane, 0.02 in length), high severity

Percent of total area is computed as:

$$\frac{\text{square foot area of alligator crack severity}}{0.02 \text{ mile} * \text{lane width}}$$

In AC_INDEX, the denominators 70, 30, and 10 are the Maximum Allowable Extents (MAE) for each severity. In other words, we will allow up to 70% of low severity alligator cracking for a 0.02 interval before failure, 30% for medium severity, and so on. As you can see, if any single severity reaches MAE the resulting index value is 60, or failure.

Longitudinal Crack Index

LC_INDEX = 100 – 40 * [(%LOW / 350) + (%MED / 200) + (%HI / 75)]

Where:

The values *%LOW*, *%MED*, and *%HI* report the length of longitudinal cracking within each severity as a percent of the section length (0.02 mile, primary lane). These values are ≥ 0 and can exceed 100.

%LOW = Percent of interval length (primary lane, 0.02 in length), low severity
%MED = Percent of interval length (primary lane, 0.02 in length), medium severity
%HI = Percent of interval length (primary lane, 0.02 in length), high severity

Percent of interval length is computed as:

$$\frac{\text{length of respective longitudinal cracking}}{0.02 \text{ mile (105.6 feet)}}$$

In LC_INDEX, the denominators 350, 200, and 75 are the Maximum Allowable Extents (MAE) for each severity. In other words, we will allow up to 350% of low severity alligator cracking for a 0.02 interval before failure, 200% for medium severity, and so on. As you can see, if any single severity reaches MAE the resulting index value is 60, or failure.

Transverse Crack Index

TC_INDEX = 100 – {[20 * ((LOW / 15.1) + (MED / 7.5))] + [40 * (HI / 1.9)]}

Where:

The values *LOW*, *MED* and *HI* report a count of the total number of transverse cracks (reported to three decimals) within each severity level, where one transverse crack is equal to the lane width. These values are ≥ 0.

LOW = Number of cracks in interval (primary lane, 0.02 in length), low severity
MED = Number of cracks in interval (primary lane, 0.02 in length), medium severity
HI = Number of cracks in interval (primary lane, 0.02 in length), high severity

Number of cracks is computed as:
$$\frac{\text{Total length of transverse cracks}}{\text{Lane width}}$$

In TC_INDEX, the denominators 15.1, 7.5, and 1.9 are the Maximum Allowable Extents (MAE) for each severity. In other words, we will allow up to 15.0 low severity transverse cracks for a 0.02 interval before failure, 7.5 cracks for medium severity, and so on. As you can see, if any single severity reaches MAE the resulting index value is 60, or failure.

Patching Index

PATCH_INDEX = 100 – 40 * (%PATCHING / 80)

Where:
The value *%PATCHING* reports the percentage of the observed pavement (0.02 mile, primary lane) that contains patching/potholes. This value ranges from ≥ 0 to ≤ 100.

%PATCHING = Percent of total area (primary lane, 0.02 in length)

Percent of total area is computed as:
$$\frac{\text{square foot area of patching/potholes}}{0.02 \text{ mile } * \text{ lane width}}$$

There are no severity levels for patching. It either exists or does not.

In PATCH_INDEX, the denominator 80 is the Maximum Allowable Extent (MAE) for each severity. In other words, we will allow up to 80% patching for a 0.02 interval before failure. As you can see, if patching/potholes reaches MAE the resulting index value is 60, or failure.

Rutting Index

RUT_INDEX = 100 – 40 * [(%LOW / 160) + (%MED / 80) + (%HI / 40)]

Where:

10 ARAN rut depth measurements are taken per 0.02 interval for each of 2 wheel paths (left and right), resulting in a total of 20 measurements taken for both wheel paths. The values *%LOW*, *%MED* and *%HI* report the percentage of the 20 measurements within that severity. These values range from ≥ 0 to ≤ 200.

%LOW = Percent of ARAN-measured ruts in both wheelpaths (20) within a single wheelpath, low severity
%MED = Percent of ARAN-measured ruts in both wheelpaths (20) within a single wheelpath, medium severity
%HI = (Percent of ARAN-measured ruts in both wheelpaths (20) within a single wheelpath, high severity

Percent of rut measurements within each severity is computed as:
$$\frac{\text{Number of ruts within each severity}}{10} * 100$$

In RUT_INDEX, the denominators 160, 80, and 40 are the Maximum Allowable Extents for each severity. In other words, we will allow up to 160% low severity ruts for a 0.02 interval before failure. As you can see, if any single severity reaches MAE the resulting index value is 60, or failure.

Roughness Condition Index

RCI = 32 * [5 * (2.718282 ^ (-0.0041 * AVG IRI))]

Where:

The value *AVG IRI* reports the average value of the Left IRI and Right IRI measurements for the interval (0.02 mile, primary lane). This value can range from approximately 40 to over 1000.

Average IRI is computed as:
$$\frac{\text{Left wheelpath IRI} + \text{Right wheelpath IRI}}{2}$$

Surface Condition Rating Index

SCR = 100 - [(100 - AC_INDEX) + (100 - LC_INDEX) + (100 - TC_INDEX) + (100 - PATCH_INDEX) + (100 - RUT_INDEX)]

Where:

See above for determinations of AC_INDEX, LC_INDEX, TC_INDEX, PATCH_INDEX and RUT_INDEX.

The threshold for failure for this index is SCR = 60.

Pavement Condition Rating Index

PCR = (0.60 * SCR) + (0.40 * RCI)

Where:

See above for determinations of SCR and RCI.

The values 0.60 and 0.40 function as weights within the formula.

Note: If SCR equals zero (which means that the road surface condition is very poor), then the formula simply reduces to: PCR = 0.40 * RCI.

If RCI equals zero (which means that this value was not available for some reason), then the formula becomes: PCR = SCR.

The threshold for failure for this index is PCR = 60.

References

1. *"Distress Identification Manual for the Long-Term Pavement Performance Program",* Publication No. FHWA-RD 03-031, June 2003

2. *Quality Assurance Manual,* FHWA-NPS Road Inventory Program, 2005

GLOSSARY

TERM	DEFINITION
AC_INDEX	Alligator Crack Index
Hi	High Range of Severity
IRI	International Roughness Index
LC_INDEX	Longitudinal Crack Index
lf	Linear Feet
Low	Low Range of Severity
MAE	Maximum Allowable Extent
Med	Medium Range of Severity
PATCH_INDEX	Patch Index (includes potholes)
PCR	Pavement Condition Rating
RCI	Roughness Condition Index
RUT_INDEX	Rut Index
SCR	Surface Condition Rating
sf	Square Feet
TC_INDEX	Transverse Crack Index