INTERIM CALTRANS AUTOMATED PAVEMENT CONDITION SURVEY

California Department of Transportation

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Pavement Evaluation Manual
AUTOMATED Pavement Condition Survey

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Electronic version may be obtained on the PCS Web site
List of Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tr>
<td>AASHTO</td>
<td>American Association of State Highway and Transportation Officials</td>
</tr>
<tr>
<td>APCS</td>
<td>Automated Pavement Condition Survey</td>
</tr>
<tr>
<td>ASTM</td>
<td>American Society for Testing and Materials</td>
</tr>
<tr>
<td>CRCP</td>
<td>Continuously Reinforced Concrete Pavement</td>
</tr>
<tr>
<td>CTB</td>
<td>Cement Treated Base</td>
</tr>
<tr>
<td>CTPB</td>
<td>Cement Treated Permeable Base</td>
</tr>
<tr>
<td>EB</td>
<td>Eastbound</td>
</tr>
<tr>
<td>GPS</td>
<td>Global Positioning System (not geographical)</td>
</tr>
<tr>
<td>HMA</td>
<td>Hot Mix Asphalt</td>
</tr>
<tr>
<td>IRI</td>
<td>International Roughness Index</td>
</tr>
<tr>
<td>HOV</td>
<td>High-Occupancy Vehicle</td>
</tr>
<tr>
<td>JPCP</td>
<td>Jointed Plain Concrete Pavement</td>
</tr>
<tr>
<td>LCB</td>
<td>Lean Concrete Base</td>
</tr>
<tr>
<td>LWP</td>
<td>Left Wheelpath</td>
</tr>
<tr>
<td>MPD</td>
<td>Mean Profile Depth</td>
</tr>
<tr>
<td>NB</td>
<td>Northbound</td>
</tr>
<tr>
<td>OGFC</td>
<td>Open Graded Friction Course</td>
</tr>
<tr>
<td>PCC</td>
<td>Portland Cement Concrete</td>
</tr>
<tr>
<td>PCS</td>
<td>Pavement Condition Survey</td>
</tr>
<tr>
<td>PDS</td>
<td>Pavement Data Segment</td>
</tr>
<tr>
<td>PM</td>
<td>Postmile</td>
</tr>
<tr>
<td>PMS</td>
<td>Pavement Management System</td>
</tr>
<tr>
<td>QA</td>
<td>Quality Assurance</td>
</tr>
<tr>
<td>QC</td>
<td>Quality Control</td>
</tr>
<tr>
<td>RHMA</td>
<td>Rubberized Hot Mix Asphalt</td>
</tr>
<tr>
<td>ROW</td>
<td>Right-Of-Way</td>
</tr>
<tr>
<td>RWP</td>
<td>Right Wheelpath</td>
</tr>
<tr>
<td>SB</td>
<td>Southbound</td>
</tr>
<tr>
<td>WB</td>
<td>Westbound</td>
</tr>
</tbody>
</table>
List of Symbols

$H_F$ Fault height
$L_{PDS}$ Length of a pavement data segment
$i, is, iw$ Index variables
$L_{Crack_i}$ Length of the $i$th crack
$P_{sealed}$ Percentage of cracks sealed (by length)
$P_{wide}$ Percentage of wide unsealed cracks (by length)
$R_{APA}$ Asphalt patch area ratio
$R_{PDA}$ Patch-digout area ratio
$R_{POA}$ Punchout area ratio
$R_{WPC}$ Wheelpath cracking length ratio
$R_{XC}$ XC-cracking length ratio
$R_{XF}$ XF-cracking length ratio
$R_{XJ}$ XJ-cracking length ratio
$w_{lc}$ Mean width of a longitudinal crack (non-wheelpath)
$w_{tc}$ Mean width of a transverse crack
$W_{Lane}$ Width of a lane
$\delta_{max}$ Maximum deviation of a transverse crack from its linear approximation
$\theta$ Angle between the linear approximation of a crack and the lane centerline
Chapter 1

Automated Pavement Condition Survey

1.1. Scope of APCS

Introduction - Automated Pavement Condition Survey

The Automated Pavement Condition Survey (APCS) is a network-level inventory of pavement surface distresses and conditions for the state highway network. The APCS consists of two processes:

- Automated collection of pavement condition data. Data to be collected include surface profiles, pavement surface images, and forward perspective right-of-way (ROW) images. All of these data are collected using van-mounted equipment operating at highway speeds.

- Data analysis to quantify pavement distresses, conditions and ride quality. These values are recorded in the pavement management system (PMS) database.

The APCS data are used in the PMS for other processes, including:

- Calculation, categorization and reporting of distress severity and extent, and pavement condition indicators to assist the Department with pavement management decisions, including maintenance and project programming.
Objectives of the APCS

The network-level data are used with other information in the PMS to accomplish the two following objectives:

- To develop pavement performance models used to predict the future condition of the network for different management scenarios, and
- To identify appropriate levels of pavement treatment, including pavement preservation, rehabilitation or reconstruction.

In addition, the data produced by the APCS are used to report the current condition of the pavement network and perform a number of other analysis and reporting functions for the PMS.

APCS data flow

The APCS data flow is shown in Figure 1-1. The APCS data are collected by a van-mounted system that uses various profile and image collection technologies integrated with georeferencing systems including global positioning systems (GPS), inertial referencing systems and distance measuring instruments. Data collected in the field is organized and evaluated to produce:

- Raw data consisting of geo-referenced pavement images (including downward perspective and ROW images) and pavement surface profile data;

- Analyzed values for the smoothness (International Roughness Index [IRI] and macrotexture [Mean Profile Depth or MPD]) in the wheelpaths, and measurements of pavement distresses such as cracking, rutting and faulting, and other conditions.

After going through quality assurance processes, this information is recorded into the Department Pavement Management System (PMS) database for short segments of the network, referred to as data segments (see Section 2.4), along with information regarding pavement structure, maintenance and rehabilitation history, traffic and climate. Together these data can be further processed, evaluated for longer lengths of the network, referred to
as pavement management segments (see Section 2.4), and formatted to support decision making by the Department.

Benefits of APCS

The APCS replaces the previous manual visual pavement condition data collection procedure primarily conducted from the shoulder of the road. The APCS is intended to reduce safety
risks and enhance the ability of the Department to collect data on the entire network by taking advantage of new technologies.

Distress definitions and condition indicators in APCS

The distress definitions in the APCS have been modified from previous versions of the pavement condition survey manual, considering the advantages and disadvantages of APCS compared to conventional manual pavement condition survey. Pavement distress types included in this manual for collection at the network-level and the measurement of each distress were selected based on:

- Usefulness for programming appropriate actions following pavement policy based on safety, comfort, and cost-effectiveness in use of Department resources;

- Usefulness in explaining pavement performance based on understanding of the mechanisms that cause pavement deterioration.

1.2. Scope of This Manual

An APCS consists of field data collection, desktop analysis and evaluation, and reporting in the prescribed format. The pavement images collected, and pavement surface profile data measured, along with the associated geo-referencing information, are considered the measurement data of the APCS. Quantified pavement condition parameters including smoothness indices and distress (type, severity and extent) are the outputs of the APCS. The scope of this manual includes definitions for:

- Pavement condition measurement and data analysis and evaluation (Chapter 2). Definitions are provided for pavement data segments on which data are collected and stored, and for pavement management segments, which are groups of continuous pavement data segments.

- The measurement of each distress type or condition within each pavement data segment, including measurement from pavement images (Chapters 3, 4 and 5) and from surface profiles (Chapter 6);
• The calculation and reporting requirements for severity and extent of each distress type and condition indicators for each pavement management segment based on the measurements on the associated data segments (Chapters 3 to 6).

1.3. How to use this manual

The main body (Chapters 3 to 6) of this manual is organized by the distress types and condition indicators. Sub-sections for each distress type/condition indicator present:

• Definition of the distress or the condition indicator;

• Measurement of the distress or condition at the pavement data segment level for recording in the PMS database; and

• Definition of the severity bins, and calculation and reporting of the extent of the distress or condition at the pavement management segment level.

Those responsible for collecting data and analysis of the raw data to provide inputs to the Department PMS database, should familiarize themselves with the definitions of the distresses and condition indicators, and their measurement at the pavement data segment level. This group includes data collection contractors, consultants to the department and automated pavement condition survey equipment and software developers.

Department pavement managers and engineers should have an understanding of the measurements and distress and condition definitions. Department pavement managers should also be familiar with the calculation and categorization of distresses and condition indicators at the pavement management segment level.
Chapter 2

General Definitions

2.1. Units for Measurement and Reporting

The SI (metric) system of units is used for measurement and distress quantification. Data are stored in metric units in the PMS database and converted to US customary units for reporting network pavement conditions.

2.2. Pavement Surface Types

For the purposes of APCS, pavements are rated according to the surface material types regardless of the underlying structures. Different distress types and condition indicators apply to different types of pavements. Structural characteristics are considered when the APCS data are analyzed with the corresponding pavement structure information in the PMS database.

Pavement image-based measurement and reporting of distresses and conditions for flexible surfaced pavements, jointed plane concrete pavements (JPCP) and continuously reinforced concrete pavements (CRCP) is documented in Chapters 3, 4, and 5 of this manual, respectively. Pavement surface profile-based condition indicators of all the three surface types are covered in Chapter 6.

For highway lanes consisting of two pavement surface types, please see Section 2.7 (Mixed Lanes).

Flexible surfaced pavement

If the pavement surface is an asphaltic material, it is considered a flexible surfaced pavement. Flexible surface types include, but are not limited to:
• Hot Mix Asphalt (HMA);
• Open-graded friction course (OGFC);
• Rubberized Hot Mix Asphalt, open-graded or gap-graded (RHMA-G, RHMA-O);
• Chip seal;
• Slurry seal;
• Bonded Wearing Course (BWC).

Rigid surfaced pavement
There are two types of rigid surfaced pavements: JPCP and CRCP.

2.3. Pavement Structure Types
Flexible surfaced pavements are made up of a variety of different types of pavement structures which include:

• Flexible pavement, which consists of some type of a flexible surface layer or multiple layers with aggregate base, subbase or only subgrade below;
• Composite pavement, which consists of some type of HMA (with or without other flexible surface layers) with underlying JPCP or CRCP;
• Semi-rigid pavement, which consists of HMA (with or without other flexible surface layers) and CTB, LCB or CTPB base, or
• Various other structure types.

Rigid surfaced pavements may have a variety of different base and subbase layers beneath the JPCP or CRCP.
2.4. Data Segment and Management Segment

A pavement data segment is the smallest unit of length for measuring distresses and conditions defined in this manual and recorded in the PMS database. As shown in Table 2-1, the standard length of a data segment is 10 meters, except that pavement surface image based distresses and conditions for JPCP are rated on a slab by slab basis, so the data segment lengths vary by slab length.

Table 2-1 Data segment lengths

<table>
<thead>
<tr>
<th>Surface Type</th>
<th>Distresses/conditions based on pavement images</th>
<th>Distresses/Conditions based on pavement surface profiles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexible</td>
<td>10 meters</td>
<td>10 meters</td>
</tr>
<tr>
<td>JPCP</td>
<td>Per Slab</td>
<td>10 meters</td>
</tr>
<tr>
<td>CRCP</td>
<td>10 meters</td>
<td>10 meters</td>
</tr>
</tbody>
</table>

Pavement data segment lengths are per slab for pavement surface images and 10 meters for pavement surface profiles.

Pavement management segments are identified in the PMS database for pavement management purposes. In the longitudinal direction, a pavement management segment is made up of a number of continuous data segments in the same lane with the same pavement structure (materials and layer thicknesses), maintenance and rehabilitation history, traffic volume, and climate conditions (Figure 2-1). The minimum length of a pavement management segment is 150 m (0.1 mile), or about 15 data segments, or about 35 JPCP slabs. Distress severity and extent measurements and pavement condition indicators of each management segment are calculated based on measurements for the data segments that are within the management segment.
All pavement data segments and management segments are one lane wide within the traveled way. Lateral boundaries are defined by the lane limit lines. Pavement management segments on two-lane routes generally have the same beginning and ending points for both lanes. Management segments for multi-lane highways have the same beginning and ending points for all lanes in one direction of travel with some exceptions for HOV lanes and lane additions.

2.5. Linear Reference

The Department’s PMS primarily uses the district-county-route-post mile-traffic direction-lane number convention for identifying locations in the state highway system. Additionally, all collected data are linked to longitude and latitude values measured by the GPS unit installed on the image acquisition and profile measurement vehicles. The data segments are referenced by the linear reference location and GPS coordinates of the midpoint along the centerline of each data segment. The location of a management segment is indicated by its beginning and an ending district-county-route-post mile-direction-lane. The beginning and ending points of each management segment and their GPS coordinates are derived from the locations of the data segments.

The linear reference system used in the APCS should follow the current version of the California State Highway Log. Typically, the post mile on each route is reset to zero at each southern and western county line. The direction (eastbound [EB] westbound [WB], southbound [SB] or northbound [NB]) of a data segment or a management segment indicates the general traffic direction of the route/lane. However, there are exceptions to these general rules for direction definitions and resetting of the post mile each time a route passes a county line. Lane numbers in each direction are numbered from the centerline or median of the roadway to the outside shoulder beginning with the number 1.

For instance, 03-Col-33-PM24.560-EB-Lane# 1 refers to a location in District 3 in Colusa County along Route 33, post mile 24.560, in the #1 lane measured from the median in the eastbound direction. This route has an east-west overall direction, and post mileage values increase as the road goes east. For routes with a North-South overall direction, post mileage values usually increase as the road goes north.
Post miles are recorded in the APCS with at least three decimal places. The longitude and latitude values are reported in degrees with at least eight decimal places.

2.6. Lane and Wheelpath

The term lane refers to the lane for which boundaries are marked by lane limit lines. There are two wheelpaths in each lane, defined as the left wheelpath (LWP) and the right wheelpath (RWP). The geometrical definition of wheelpaths is shown in Figure 2-2. The length of the data segment and the width of the lane are denoted as $L_{PDS}$ and $W_{Lane}$ respectively. Both wheelpaths are parallel to the centerline of the lane and their inner edges are 0.45 m (1.5 ft) from the centerline. Each wheelpath is 0.9 m (3 ft) wide. For a typical 3.6 m (12 ft) lane the distances between the outer edges of the wheelpaths and the lane limit lines are typically more than 0.3 m (1 ft).

![Figure 2-2 Geometrical definition of wheelpaths. Not to scale](image-url)
2.7. Mixed Lane

In some instances, two surface material types coexist in the same data segments, or a longitudinal joint separates two columns of JPCP slabs or CRCP strips in a data segment, typically due to road widening. This condition is defined in the PMS database as a mixed lane, except for the following two situations:

- If one of the surface materials is less than 1 m wide in the current data segment, it is not rated as a mixed lane.

- If a lane covers two different types of flexible pavement surface materials, it is not considered a mixed lane. If the construction joint between the two flexible pavement strips is opened or has apparent defects, it is considered a longitudinal crack.

There are two types of mixed lanes: flexible-rigid mixed lanes (HMA-JPCP mixed lanes and HMA-CRCP mixed lanes) and rigid-rigid mixed lanes (JPCP-JPCP mixed lanes, CRCP-CRCP mixed lanes and JPCP-CRCP mixed lanes). For pavement image-based distress and condition evaluation, only one type of pavement surface can be evaluated for each mixed lane data segment following the rules below, and the other pavement surface type present in the segment is not included in the analysis and reporting. For pavement surface profile-based distress, condition and ride quality evaluation, calculations are performed on profiles as measured.

- Flexible-rigid mixed lanes.

If both flexible surface and rigid surfaces are present in the same lane and more than 50% of the area of either wheelpath is flexible surfaced, the data segment is rated as a flexible surfaced pavement and the rigid portion of the lane is not rated.

If the flexible surfaced portions of both wheelpaths are less than 50%, then rate this lane as a rigid surfaced pavement (either JPCP or CRCP), and ignore the distresses and conditions of the flexible surfaced portion.
Rigid-rigid mixed lanes

Rigid-rigid mixed lanes occur where the lane limit lines significantly deviate from the longitudinal joints between slabs/strips. When JPCP slabs are on both sides of the longitudinal joint, the slab occupying more than half of the data segment area is termed the primary slab of the data segment, and the other secondary slab. Only the conditions and distresses of the primary slab are rated, and the conditions and distresses of the secondary slab in the same data segment are ignored.

If CRCP strips are on both sides of the longitudinal joint, only the strip with more than half the width of the lane is rated for pavement image-based distresses and conditions, and distresses/conditions on the other strip are ignored.

When one side is CRCP and the other is JPCP, the side with the greater area will be rated.

Special rules for mixed lanes

For flexible-rigid mixed lanes and rigid-rigid mixed lanes rated as JPCP, the pavement images might not cover an entire slab that is one lane wide, and crack extension calculations as described in Section 2.8 must be performed before JPCP crack categorization can be performed.

When calculating

- patch area ratio of a mixed lane rated as flexible surfaced pavement,
- asphalt patch area ratio of a mixed lane rated as JPCP, and
- asphalt patch area ratio and punchout area ratio of a mixed lane rated as CRCP,

only the area of the pavement type that defines the mixed lane should be used in the equations.
2.8. Crack Extension in JPCP

For each crack in a JPCP slab, two endpoints can be identified. The locations of the endpoints in the slab are important for categorization of the crack. In the following two situations, visible cracks on images of JPCP surfaced slabs need to be extended before distress categorization and measurement can be taken. In this manual, distress categorization criteria for JPCP are equally applicable to fully developed or full visible cracks, and to extended partially developed or partially visible cracks. For distress categorization and measurement purposes, the intersection points of an extended crack and joints or other cracks are used as the endpoints.

Partially developed cracks

Typically, crack endpoints are at joints or other cracks. If one or both of the endpoints of a crack are inside the slab and do not reach a joint or a crack, then the crack should be extended, so that both of its endpoints are at joints or other cracks. Cracks shorter than \( \frac{1}{2} W_{\text{Lane}} \) are not extended or considered for distress categorization and measurement.

Figure 2-3 shows an example of extending a partially developed crack to a joint and another crack. The current endpoints of Crack, are points \( a \) and \( b \), and the length of Crack, is \( L_{\text{Crack}_i} \). To extend this crack from point \( b \), find the best linear approximation of the crack segment (\( \frac{1}{5} L_{\text{Crack}_i} \) long) adjacent to point \( b \), and extend this straight segment until it intersects one of the four joints or another crack. In this example, the extension of the crack intersects joint BC at point \( b' \). Similarly, the crack can be extended from the other endpoint \( a \) to point \( a' \) on Crack,.

Cracks on partially visible slabs

In a mixed lane, the JPCP slab to be rated is often partially visible in the pavement images. Typically, a longitudinal joint of the slab is fully visible, the two transverse joints are partially visible and the other longitudinal joint is invisible in the images (Figure 2-4).
Crack extension should be performed by linearly extending 1/5 of the length of the visible portion of the crack (Figure 2-4). In the primary slab, any crack longer than half of the lane width ($L_{Crack} > 1/2 W_{Lane}$) should be extended to the assumed slab joints or other existing cracks. Cracks shorter than $1/2 W_{Lane}$ are not extended, and not considered for distress categorization and measurement. The locations of the assumed joints should be determined by extending the partially visible transverse joints and assuming the width of the slab to be equal to the width of the lane.
2.9. Features at Segment Boundaries

Certain geometrical features and distresses occur at pavement data segment boundaries. The feature is physically shared by two adjacent data segments, but must be rated as a feature of only one of the data segments. Examples include longitudinal joints or cracks that follow the lane limit lines. Criteria for rating these features at segment boundaries include:

Figure 2-4 Extending cracks on partially visible slabs
Note: The visible portion of the primary slab is shaded in this figure
• Longitudinal features and distresses on two-lane highways dividing the two directions of a highway should be rated with the direction that the post mile value increases. These features and distresses include longitudinal joints and longitudinal cracking (non-wheelpath) between the two lanes.

• Longitudinal features and distresses dividing adjacent lanes in the same traffic direction should be rated with the lane (data or management segment) to the outside (right) of the feature or distresses with respect to the traffic direction. These features and distresses include longitudinal joints and longitudinal cracking (non-wheelpath) between two lanes in the same traffic direction.

• Longitudinal features and distresses that follow the edge of travel way should be rated with the lane adjacent to the shoulder. This applies to the median and the outside shoulders for divided roadways.

• Transverse joints between JPCP slabs (i.e. data segments) should be rated with the lead or ahead slab (data segment).

For example, each data segment of the outer lane of a JPCP with a rigid shoulder includes two longitudinal joints, one transverse joint at its back or trailing edge and one shoulder that are evaluated as part of its data record.

2.10. Spalling

Spalling is a condition that applies to cracks and joints in JPCP and CRCP, where the edges of the joint or crack have been broken off, effectively widening the joint or crack. Spalling is measured by two methods: by visual observation of images and by cross-sectional area calculations from pavement surface profiles. For image analysis, a joint or crack is considered spalled if it is observed that the edges of the joint or crack have been broken off and the width of the joint or crack at the pavement surface is greater than 50 mm. The definition of a spalled joint or crack as determined by pavement surface profiles is described in Section 6.5.
Chapter 3

Flexible Surfaced Pavement
Image-Based Distress/Condition Measurement and Reporting

This chapter documents distress types and pavement condition measurements based on pavement images for flexible surfaced pavements. Sub-sections for each distress type or condition are: 1) definition, 2) measurement at the pavement data segment level, and 3) calculation of distress severity-extent or condition indicators at the management segment level.

The lane type must be first categorized according to the general definitions in Chapter 2 before rating a data segment for distresses and conditions. The contents of this chapter also apply to flexible-rigid mixed lanes rated as flexible surfaced pavements.

3.1. Distress Types and Conditions Based on Pavement Images

Table 3-1 summarizes the distress types and conditions measured for flexible surfaced pavements based on pavement images.
Table 3-1 Flexible pavement distress types and conditions (based on pavement images)

<table>
<thead>
<tr>
<th>Condition</th>
<th>Quantitative measurement</th>
<th>Qualitative parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lane type</strong></td>
<td></td>
<td>Indicate type:</td>
</tr>
<tr>
<td></td>
<td>Width(^1) of the asphalt portion if mixed lane. Record zero if not a mixed lane.</td>
<td>- Normal flexible surface lane; - HMA-JPCP mixed lane; - HMA-CRCP mixed lane.</td>
</tr>
<tr>
<td><strong>Shoulder type</strong></td>
<td></td>
<td>Record type:</td>
</tr>
<tr>
<td></td>
<td>Width of shoulder:</td>
<td>- N/A;</td>
</tr>
<tr>
<td></td>
<td>- 0-0.6m;</td>
<td>- Rigid shoulder;</td>
</tr>
<tr>
<td></td>
<td>- 0.6-3.0m;</td>
<td>- Flexible shoulder;</td>
</tr>
<tr>
<td></td>
<td>- &gt;3m.</td>
<td>- No shoulder.</td>
</tr>
<tr>
<td><strong>Distress</strong></td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td>Transverse cracking</td>
<td>Number of:</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>- Sealed cracks;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Unsealed narrow cracks;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Unsealed wide cracks.</td>
<td></td>
</tr>
<tr>
<td>Longitudinal cracking (non-wheelpath)</td>
<td>Length ratio of:</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>- Sealed cracks;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Unsealed narrow cracks;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Unsealed wide cracks.</td>
<td></td>
</tr>
<tr>
<td>Wheelpath cracking(^2)</td>
<td>Wheelpath crack length ratio (R_{WPC})</td>
<td>Indicate sealed/not sealed/NA(^3).</td>
</tr>
<tr>
<td>XF-cracking</td>
<td>XF-crack length ratio (R_{XF})</td>
<td>Indicate: sealed/not sealed/NA(^3).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Indicate: wide/narrow/NA(^3).</td>
</tr>
<tr>
<td>Potholes</td>
<td>Number of potholes.</td>
<td>N/A</td>
</tr>
<tr>
<td>Patches and digouts</td>
<td>Patch-digout area ratio (R_{PDA})</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Note: \(^1\) Measured at the midpoint of the data segment.  
\(^2\) Report the two wheelpaths separately.  
\(^3\) NA= not applicable, if the condition/distress does not exist in the data segment.

Distress severity-extent values and condition indicators reported for pavement management segments

Table 3-2 summarizes the definitions of the severity bins for flexible surfaced pavements distresses and the associated extent measurement, as well as the reporting requirements at
the pavement management segment level. Typically, three levels of severity are identified for each distress type, namely low severity (L), moderate severity (M) and high severity (H), if this distress is significant in the current data or management segment.

For certain conditions, the concept of distress severity is inapplicable, but the classification, measurement and reporting requirements are organized in the same way as for distresses.

Note: the information shown in the highlighted column of Table 3-2 is for example purposes only. The severity bins and condition categories for reporting for pavement management segments are to be determined by the Department at a later date.
Table 3-2 Distress severity and extent values and conditions for flexible surfaced pavement management segments

<table>
<thead>
<tr>
<th>Condition</th>
<th>Severity bins / condition categories</th>
<th>Extent measurement</th>
<th>Other quantities to report</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lane type</td>
<td>Three categories:</td>
<td>Percentage of data segments of each lane type.</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>- Flexible surface;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- HMA-JPCP mixed lane;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- HMA-CRCP mixed lane.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shoulder type</td>
<td>Four categories:</td>
<td>Percentage data segments in each category.</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>- N/A;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- No shoulder;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Flexible shoulder;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Rigid shoulder.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distress</td>
<td>Severity bins / condition categories</td>
<td>Extent measurement</td>
<td>Other quantities to report</td>
</tr>
<tr>
<td>Transverse</td>
<td>Three categories:</td>
<td>Average number per 328 ft (100 m) lane length for each category.</td>
<td>N/A</td>
</tr>
<tr>
<td>cracking†</td>
<td>- Sealed;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Unsealed narrow;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Unsealed wide.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Longitudinal</td>
<td>Three categories:</td>
<td>Average longitudinal crack length ratio for each category.</td>
<td>N/A</td>
</tr>
<tr>
<td>cracking</td>
<td>- Sealed;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Unsealed narrow;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Unsealed wide.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wheelpath</td>
<td>Four severity levels:</td>
<td>Percentage data segments at each severity level.</td>
<td>Percentage of total crack length sealed.</td>
</tr>
<tr>
<td>cracking†</td>
<td>- N: No wheelpath crack;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- L: 0.05&lt;$R_{WPC}$≤1.0;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- M: 1.0&lt;$R_{WPC}$≤2.0;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- H: $R_{WPC}$&gt;2.0.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>XF-cracking</td>
<td>Four severity levels:</td>
<td>Percentage data segments at each severity level.</td>
<td>Percentage of total length sealed. Percentage of unssealed wide cracks.</td>
</tr>
<tr>
<td></td>
<td>- N: No XF-crack;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- L: 0.05&lt;$R_{X F}$≤2.0;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- M: 2.0&lt;$R_{X F}$≤4.0;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- H: $R_{X F}$&gt;4.0.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potholes</td>
<td>N/A</td>
<td>Percentage of data segments with one or more potholes.</td>
<td>N/A</td>
</tr>
<tr>
<td>Patches and</td>
<td>N/A</td>
<td>Mean patch area ratio.</td>
<td>N/A</td>
</tr>
<tr>
<td>digouts</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: † Report the two wheelpaths separately.
3.2. Lane Type

Definition

The definitions of different types of mixed lanes are described in Section 2.7.

Measurement for data segments

Indicate whether the data segment is:

- A flexible surfaced pavement (i.e. asphaltic materials cover the full width, or the width of the rigid portion is less than 1 m);
- An HMA-JPCP mixed lane rated as flexible surfaced pavement; or
- An HMA-CRCP mixed lane rated as flexible surface pavement.

If it is a mixed lane, record the width of the flexible surface portion measured at the midpoint of the centerline, in meters to the first decimal place.

Measurement and reporting for management segments

Report the percentage of data segments that are flagged as flexible surfaced pavement, HMA-JPCP mixed lane, and HMA-CRCP mixed lane in the management segment, respectively. Report to nearest percent.

3.3. Transverse cracking

Definition

Transverse cracks are non-load associated cracks, approximately perpendicular to the lane centerline and usually extend across the full lane/road width.

A crack is categorized as a transverse crack if it meets all the following criteria (see Figure 3-1).

- For normal flexible surfaced lanes, the crack extends across both wheelpaths in the transverse direction, i.e. the left end of the crack is outside the left edge of the left
wheelpath and the right end of the crack is outside the right edge of the right wheelpath. For flexible-rigid mixed lanes, the crack extends across the full width of the flexible portion of the lane.

- When the crack is approximated by a straight line, empirically or numerically, the acute angle ($\theta$ as shown in Figure 3-1) between the linear approximation of the crack and the lane centerline should be larger than 75°.

- The maximum deviation ($\delta_{\text{max}}$ as shown in Figure 3-1) of the crack from its linear approximation is less than 10 cm in the longitudinal direction.

In some instances, a transverse crack will intersect a transverse boundary dividing two successive data segments in the same lane with the transverse crack partially appearing in both data segments. In this case, include the transverse crack in the data segment that has more than half of the total crack length.

![Figure 3-1 Criteria for transverse cracks](image)
Measurement for data segments

Each transverse crack is categorized by 1) whether it is sealed and 2) its mean crack width $w_c$ if not sealed, into the following three categories:

- **Sealed cracks**: more than half of the crack length has been sealed. Width is not measured for sealed cracks.

- **Unsealed narrow crack**: less than half of the crack length has been sealed, and $w_c \leq 6$ mm.

- **Unsealed wide crack**: less than half of the crack length has been sealed, and $w_c > 6$ mm.

The mean crack width $w_c$ of a transverse is calculated as the average of its widths measured at the three transverse quarter-points (Figure 3-2). The mean width of the crack is $w_c = (w_1 + w_2 + w_3)/3$.

For each pavement data segment, record the number of transverse cracks in each category.

![Diagram of a transverse crack with measurements](image)

**Figure 3-2** Mean transverse crack width.
Not to scale

Measurement and reporting for management segments

At the pavement management level, the extent of transverse cracking in each of the categories is defined as the average number of transverse cracks in that category in every 328 ft (100 m) of the management segment. The extent values are reported to the first decimal
place and are obtained by multiplying the average number of cracks per 10m data segment by 10, since 100 m of a management segment consists of ten data segments.

3.4. Longitudinal cracking (non-wheelpath)

Definition

Longitudinal cracks are non-load related cracks outside of the wheelpath. A crack is categorized as a longitudinal crack if it meets all the following criteria (see Figure 3.3):

- The crack length in the data segment is more than half of the data segment length (i.e. $1/2L_{PDS}$).
- If the crack is approximated by a straight line, either empirically or numerically, the acute angle ($\theta$ in Figure 3-3) between the linear approximation line and the lane centerline is not larger than 15°.
- Less than 20% of the length of the crack is in one of the wheelpaths.

In the example shown in Figure 3-3, two cracks meet all of the criteria for longitudinal cracks. A third crack (thick dashed line) is not a longitudinal crack because more than 20% of its length is in the left wheelpath. Based the distress definitions in Sections 3.5 and 3.6, the portion of the third crack in the left wheelpath is included in the wheelpath cracking measurement, and the portion outside of the wheelpaths is included in the XF-cracking measurement.
Measurement for data segments

Each longitudinal crack is categorized by 1) whether it is sealed and 2) its mean crack width $w_c$ if not sealed, into the following three categories:

- **Sealed cracks**: more than half of the crack length has been sealed. Width is not measured.

- **Unsealed narrow crack**: less than half of the crack length has been sealed, and $w_c \leq 6$ mm.

- **Unsealed wide crack**: less than half of the crack length has been sealed, and $w_c > 6$ mm.

The mean crack width $w_r$ of a longitudinal crack is calculated as the average of its widths measured at the quarter-points (2.5 m apart) of the data segment in the longitudinal direction, i.e. $w_r = \sum_{i=1}^{N_p} w_i$, where $N_p$ is the number of quarter-point lines of the data segment that the crack intersects, and $w_i$ is the measured crack width value at the $i^{th}$ quarter-point. In the
example shown in Figure 3-4, the longitudinal crack goes through the entire data segment, and $N_p=5$.

For each pavement data segment, record the longitudinal crack length ratio of longitudinal cracks in each of the above categories. The longitudinal crack length ratio is the ratio of total length of longitudinal cracks in each category to the length of the data segment. Report the values to the second decimal place.

Measurement and reporting for management segments

At the pavement management level, the extent of longitudinal cracking in each of the categories (sealed, unsealed narrow, and unsealed wide) is the average longitudinal crack length ratio of the category in the management segment. The extent values are reported to the second decimal place.
3.5. Wheelpath cracking

Definition

Generally, wheelpath cracking is caused by repeated traffic loading. Initially it appears as thin crack extending longitudinally in the wheelpath. Eventually, more cracks develop and become interconnected to form a pattern similar to the skin of an alligator. In APCS, all cracks and portions of cracks within the boundaries of wheelpaths are considered as wheelpath cracking, except for cracks that are identified as transverse cracks. Portions of longitudinal cracks that are in the wheelpath are also included in the wheelpath cracking measurement.

Measurement for data segments

Wheelpath cracking is measured and reported separately for the right and left wheelpaths. Wheelpath cracking is quantified by the wheelpath crack length ratio ($R_{WPC}$) which is the ratio of the total length of all wheelpath cracks in each wheelpath to the length of the data segment ($L_{PDS}$). Wheelpath crack length ratios are recorded to the second decimal place. If the crack length ratio for a wheelpath in a data segment is not greater than 0.05, record the wheelpath crack length ratio as zero to eliminate insignificant cracking and random errors in image analysis.

Wheelpath cracking in a wheelpath of a data segment is flagged as sealed if the rater estimates that over half of the total wheelpath crack length is sealed.

Measurement and reporting for management segments

Note: the information shown highlighted below is for example purposes only. The severity bins and condition categories for reporting for pavement management segments are to be determined by the Department at a later date.

Four severity levels are defined for wheelpath cracking as follows:
No wheelpath cracking: the wheelpath crack length ratio of a data segment as measured is not greater than 0.05. In this situation, the wheelpath crack length ratio should be reported as zero at the data segment level.

• Low severity: the wheelpath crack length ratio of a data segment is greater than 0.05, but not greater than 1.00;

• Moderate severity: the wheelpath crack length ratio of a data segment is greater than 1.00, but not greater than 2.00;

• High severity: the wheelpath crack length ratio of a data segment is greater than 2.00.

The extent of wheelpath cracking at each severity level is the percentage of data segments in the management segment that have wheelpath crack length ratios within the prescribed range. The extent values are reported to the nearest percent. For each pavement management segment, the severity-extent measurements of wheelpath cracking for the left and the right wheelpaths are calculated and reported separately, and the average values are also reported.

For each wheelpath, also report the percentage of sealed wheelpath cracking, calculated using the following equation (1).

\[ P_{\text{sealed}} = \frac{\sum_{i}^{N_s} R_{\text{WPC, is}}}{\sum_{i}^{N} R_{\text{WPC, i}}} \times 100\% \quad (1) \]

where \( P_{\text{sealed}} \) is the (length) percentage of sealed wheelpath cracking; \( i \) and \( is \) are index variables; \( N_s \) = the number of pavement data segments flagged as sealed for the current wheelpath; \( N \) = the total number of pavement data segments in the current pavement management segments; \( R_{\text{WPC, is}} \) = the wheelpath crack length ratio of the \( is^{th} \) data segment that is flagged sealed; \( R_{\text{WPC, i}} \) = the wheelpath crack length ratio of the \( i^{th} \) data segment.

Record the calculated value to the nearest percent.
3.6. XF-cracking

Definition
All cracks and portions of cracks outside of the two wheelpaths are categorized as XF-cracking, except for the portions of cracks defined as transverse (Section 3.3) and longitudinal cracks (Section 3.4) outside of the wheelpaths.

Measurement for data segments
XF-cracking in each pavement data segment is quantified by the parameter XF-crack length ratio $R_{XF}$, which is the ratio of the total length of all XF-cracks to the length of the data segment ($L_{PDS}$). XF-crack length ratios are recorded to the second decimal place. If the XF-crack length ratio for a data segment is less than 0.05, record the XF-crack length ratio as zero to eliminate insignificant cracking and random errors in image analysis.

XF-cracking in a data segment is flagged as sealed if the rater estimates that more than half the total XF-crack length in the data segment is sealed.

If the XF-cracking length ratio of a data segment is between 0.05 and 4.00, then the median XF-crack width $w_{XF}$ is determined from the measured crack width $w$ at ten points chosen along the XF-cracks. The ten points must be uniformly distributed among the XF-cracks, with the exception that intersection points between cracks and points on the longitudinal and transverse cracks are to be avoided. Record whether the median crack width is greater than (flag as wide) or not greater (flag as narrow) than 6 mm. Figure 3-5 shows an example of wheelpath crack median width measurement.

If XF-cracking in a data segment is flagged as sealed, then no width measurement is needed and the width measurement is recorded as wide regardless of the crack width.

If the XF-crack length ratio of a data segment is greater than 4.0, then no width measurement is needed and the width measurement is recorded as wide regardless of the crack width.
Identified XF-cracks

The $i$th crack width measurement

Cracks other than XF-cracks

Figure 3-5 Median width measurement of XF-cracking in a data segment

Measurement and reporting for management segments

Note: the information shown highlighted below is for example purposes only. The severity bins and condition categories for reporting for pavement management segments are to be determined by the Department at a later date.

Four severity levels are defined for XF-cracking as follows:

- **No wheelpath cracking:** the wheelpath crack length ratio of a data segment as measured is not greater than 0.05. In this situation, the XF-crack length ratio should be reported as zero at the data segment level.

- **Low severity:** the XF-crack length ratio of a data segment is greater than 0.05, but not greater than 2.00;
Moderate severity: the XF-crack length ratio of a data segment is greater than 2.00 but not greater than 4.00;

High severity: the XF-crack length ratio of a data segment is greater than 4.00.

The extent of XF cracking at each severity level is defined as the percentage of data segments in the management segment that have XF-crack length ratios within the prescribed range. The extent values are reported to the nearest percent.

For each management segment, also report the percentage of sealed XF-cracking, calculated using the following equation (2).

\[
P_{\text{Sealed}} = \frac{\sum_{i=1}^{N_s} R_{XF_{i,s}} \times 100\%}{\sum_{i=1}^{N} R_{XF_{i,j}}} \tag{2}
\]

where \(P_{\text{Sealed}}\) is the (length) percentage of sealed XF-cracking; \(i\) and \(is\) are index variables; \(N_s\) = the number of pavement data segments flagged as sealed for XF-cracking; \(N\) = the total number of pavement data segments in the current pavement management segments; \(R_{XF_{i,s}}\) = the XF-crack length ratio of the \(is^{th}\) data segment that is flagged sealed; \(R_{XF_{i,j}}\) = the wheelpath crack length ratio of the \(i^{th}\) data segment.

For each management segment, also report the percentage of unsealed wide XF-cracking, calculated using the following equation (3).

\[
P_{\text{Wide}} = \frac{\sum_{i=1}^{N_w} R_{XF_{i,w}} \times 100\%}{\sum_{i=1}^{N} R_{XF_{i,j}}} \times 100\% - P_{\text{Sealed}} \tag{3}
\]

where \(P_{\text{Wide}}\) is the (length) percentage of unsealed wide XF-cracking; \(i\) and \(iw\) are index variables; \(N_w\) = the number of pavement data segments flagged as wide for XF-cracking; \(N\) = the total number of pavement data segments in the current pavement management segment; \(R_{XF_{i,w}}\) = the XF-cracking length ratio of the \(iw^{th}\) data segment that is flagged wide; \(R_{XF_{i,j}}\) = the XF-cracking length ratio of the \(i^{th}\) data segment; \(P_{\text{Sealed}}\) = the length percentage of sealed XF-cracking.
3.7. Example: Categorizing Cracks on a Flexible Surfaced Pavement Data Segment

Figure 3-6 shows an example of categorizing cracks on a flexible surfaced pavement data segment. All of the cracks from an example pavement image are shown in Figure 3-6 (a). In each of Figure 3-6 (b) through (d), one or two types of cracks are shown as thick solid lines, while other crack types are illustrated with thin dashed lines as follows:

Figure 3-6 (b) identifies a transverse crack ① and a longitudinal crack ②. Crack ② is not a transverse crack because the angle between its linear approximation and the centerline is smaller than 75°. Crack ④ is not a longitudinal crack since more than 20% of its length is in the left wheelpath.

Figure 3-6 (c) identifies wheelpath cracks including portions of Crack ②, Crack ③ and Crack ④. Figure 3-6 (d) identifies XF-cracks including portions of Crack ② and Crack ④.

No portion of transverse crack ① is included in wheelpath crack measurement. No portion of longitudinal crack ③ is included in XF-cracking measurement.

3.8. Example: Calculating and Reporting for a Pavement Management Segment

The following example shows the calculation and reporting of distress severity-extent for flexible surfaced pavement management segment. The distress types included in this example are transverse cracking and wheelpath cracking.

The pavement management segment shown in Figure 3-7 consists of 27 data segments and is 270 m (900 ft) long. The measurements of wheelpath cracking for each data segment shown in the figure include the wheelpath crack length ratio $R_{WPC}$ and whether wheelpath cracking is sealed. The measurement of transverse cracking for each data segment is the number of transverse cracks in the three categories: sealed cracks, unsealed narrow cracks, and unsealed wide cracks.
The calculation of severity-extent for wheelpath cracking is shown in Table 3-3.

(a) Cracking pattern in a data segment
(b) Transverse and longitudinal cracks
(c) Wheelpath cracking
(d) XF-cracking

Figure 3-6 Example of categorizing cracks in a pavement data segment
Table 3-3  Example of calculating extent of wheelpath cracking on a pavement management segment.

<table>
<thead>
<tr>
<th>Severity</th>
<th>( R_{WPC} )^ range</th>
<th>Left wheelpath</th>
<th>Right wheelpath</th>
<th>Average Extent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Number of Data Segments</td>
<td>Extent</td>
<td>Number of Data Segments</td>
</tr>
<tr>
<td>None</td>
<td>( R_{WPC} \leq 0.05 )</td>
<td>9</td>
<td>33%</td>
<td>7</td>
</tr>
<tr>
<td>Low</td>
<td>0.05 &lt; ( R_{WPC} \leq 1.00 )</td>
<td>2</td>
<td>7%</td>
<td>4</td>
</tr>
<tr>
<td>Moderate</td>
<td>1.00 &lt; ( R_{WPC} \leq 2.00 )</td>
<td>11</td>
<td>41%</td>
<td>5</td>
</tr>
<tr>
<td>High</td>
<td>( R_{WPC} &gt; 2.00 )</td>
<td>5</td>
<td>19%</td>
<td>11</td>
</tr>
</tbody>
</table>

Note: 1. \( R_{WPC} \) = the wheelpath crack length ratio.
2. If the original measured value of \( R_{WPC} \) for a data segment is not greater than 0.05, then report the value to be zero.
3. In this example, \( 2/27 \times 100\% = 7\% \), where 2 is the number of pavement data segments in the left wheelpath that have crack length greater than 0.05 but not greater than 1.00; 27 is the total number of data segments in the pavement management segment.

In the left wheelpath, no data segment is flagged as sealed, and the percentage of total wheelpath crack length sealed should be 0%.

In the right wheelpath, eleven data segments are flagged as sealed. Based on equation (1), the percentage of sealed wheelpath cracking is 90%.

The calculations of severity-extent for transverse cracking are shown in Table 3-4.
Figure 3-7 Example of calculating distress severity-extent of a pavement management segment with 27 data segments based on distress measurements on pavement data segments.
Table 3-4  Example of calculating severity and extent for transverse cracking in a pavement management segment

<table>
<thead>
<tr>
<th>Severity/Condition</th>
<th>Number of transverse cracks</th>
<th>Extent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sealed</td>
<td>2</td>
<td>0.7(^1)</td>
</tr>
<tr>
<td>Unsealed narrow</td>
<td>4</td>
<td>1.5</td>
</tr>
<tr>
<td>Unsealed wide</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Note:  \(^1\)In this example, \(2/270\times100=0.7\), where 2 is the number of transverse cracks in the pavement management segment that are narrower than \(\frac{1}{4}\) inch (6 mm); 886 ft (270 m) is the length of the pavement management segment; 328 ft (100 m) is the unit length on which the average count of transverse cracks is to be reported.

3.9. Potholes

Definition

Potholes are bowl-shaped holes in the pavement surface. If the longest dimension of a pothole is less than 100 mm (four inches), then it is not rated. If the longest dimension of the pothole is greater than 1 m (3.3 ft), then it is considered a patch. Patched potholes are considered potholes, but not patches.

Measurement for data segments

Potholes in a pavement data segment are counted in the current data segment.

Measurement and reporting for management segments

Multiple severity levels for potholes are not applicable.

Report the percentage of data segments with one or more potholes to the nearest percent.

Report the average number of potholes per 328 feet (100 m) lane length in the pavement management segment to the first decimal place.
3.10. Patches and Digouts

Definition

Patches and digouts are isolated areas of the flexible pavement surface where the original pavement surface material has been overlayed or removed and replaced. Patched potholes smaller than 1.0 m in diameter are considered potholes, not patches.

Patches and digouts are rated regardless of whether or not they are cracked and/or have potholes.

Measurement for data segments

Patches and digouts in each pavement data segment are measured by the patch-digout area ratio (denoted as $R_{PDA}$), which is the percentage of the total data segment area covered by patches or digouts. If the asphalt patch area ratio for a data segment is less than 1%, record the ratio to be zero (i.e. no patch) to eliminate insignificant patching and random errors in image analysis. Record patch area ratio values in percentages to the first decimal place. All patches are included in the measurement wherever they occur in the lane.

Measurement and reporting for management segments

Multiple severity levels for patches and digouts are not applicable.

Report the mean patch area ratio (i.e. the average patch area ratio of all the data segments within the management segment) in percentage to the first decimal place.

3.11. Shoulder type

Definition

Shoulder types are identified and reported based on ROW pavement images.
Measurement for data segments

Record the shoulder type of the data segment. The shoulder can be to the left or right of the data segment. The shoulder type of a flexible surfaced pavement data segment can be:

- Not applicable (if this lane is not adjacent to a shoulder);
- Rigid shoulder (portland cement concrete);
- Flexible shoulder (HMA or other asphaltic materials);
- No shoulder.

Record the approximate shoulder width:

- 0 to 0.6 m;
- 0.6 m to 3 m;
- Wider than 3 m.

Measurement and reporting for management segments

Report the percentage of data segments with each category of shoulder type, to the nearest percent.
Chapter 4

JPCP

Image-Based Distress/Condition Measurement and Reporting

This chapter documents distress types and pavement condition indicators measured based on pavement images for JPCP. Sub-sections for each distress type or condition are: 1) definition, 2) measurement at the pavement data segment level, and 3) calculation of distress severity-extent or condition indicators at the management segment level.

The lane type must be first categorized according to the general definitions in Chapter 2 before rating a data segment for distresses and condition indicators. The contents of this chapter also apply to flexible-rigid or rigid-rigid mixed lanes rated as JPCP.

4.1. Distress Types and Conditions Based on Pavement Images

Table 4-1 summarizes the distress types and condition indicators for JPCP based on pavement images, and their measurements for pavement data segments.
Table 4-1 JPCP pavement distress types and conditions (based on pavement images)

<table>
<thead>
<tr>
<th>Condition</th>
<th>Quantitative measurement</th>
<th>Qualitative parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data segment length</td>
<td>Record length of the slab.</td>
<td>N/A</td>
</tr>
<tr>
<td>Lane type</td>
<td>Width(^1) of the primary slab if mixed lane. Record zero if not a mixed lane.</td>
<td>Indicate type:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Normal JPCP;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- HMA-JPCP mixed lane;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- JPCP-JPCP mixed lane;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- JPCP-CRCP mixed lane.</td>
</tr>
<tr>
<td>Shoulder type</td>
<td>Record width of shoulder:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- 0-0.6m;</td>
<td>- Not applicable;</td>
</tr>
<tr>
<td></td>
<td>- 0.6-3.0m;</td>
<td>- Rigid shoulder;</td>
</tr>
<tr>
<td></td>
<td>- &gt;3m.</td>
<td>- Wide rigid shoulder;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Flexible shoulder;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- No shoulder.</td>
</tr>
<tr>
<td>Longitudinal joint</td>
<td>N/A</td>
<td>Indicate: sealed/not sealed;</td>
</tr>
<tr>
<td>condition</td>
<td></td>
<td>Indicate: spalling/no spalling.</td>
</tr>
<tr>
<td>Transverse joint</td>
<td>N/A</td>
<td>Indicate: sealed/not sealed;</td>
</tr>
<tr>
<td>condition</td>
<td></td>
<td>Indicate: spalling/no spalling.</td>
</tr>
</tbody>
</table>

### Distress

<table>
<thead>
<tr>
<th>Distress</th>
<th>Quantitative measurement</th>
<th>Qualitative parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longitudinal cracking</td>
<td>Number per slab</td>
<td>Indicate: sealed/not sealed/NA(^2);</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Indicate: spalling/no spalling/NA(^2).</td>
</tr>
<tr>
<td>Transverse cracking</td>
<td>Number per slab</td>
<td>Indicate: sealed/not sealed/NA(^2);</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Indicate: spalling/no spalling/NA(^2).</td>
</tr>
<tr>
<td>Corner cracking</td>
<td>Number per slab</td>
<td>Indicate: sealed/not sealed/NA(^2);</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Indicate: spalling/no spalling/NA(^2).</td>
</tr>
<tr>
<td>XJ-cracking</td>
<td>Number per slab</td>
<td>Indicate: sealed/not sealed/NA(^2);</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Indicate: spalling/no spalling/NA(^2).</td>
</tr>
<tr>
<td>Asphalt patches</td>
<td>Asphalt patch area ratio (R_{APA})</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Note:  
\(^1\) Measured at the midpoint of the data segment.  
\(^2\) NA=not applicable, if this type of distress does not exist in the current data segment.

Table 4-2 summarizes the definitions of the severity bins for JPCP distresses and the associated extent measurement, as well as the reporting requirement at the pavement
management segment level. Typically, three levels of severity are identified for each distress type, namely low severity (L), moderate severity (M) and high severity (H), if this distress is significant in the current data or management segment.

For certain condition indicators, the concept of distress severity is inapplicable, but the classification, measurement and reporting requirements are organized in the same way as for distresses.

Note: the information shown in the highlighted column of Table 4-2 is for example purposes only. The severity bins and condition categories for reporting for pavement management segments are to be determined by the Department at a later date.
### Table 4-2 Distress severity-extent values and conditions for JPCP surfaced pavement management segments

<table>
<thead>
<tr>
<th>Condition</th>
<th>Severity bins / condition categories</th>
<th>Extent measurement</th>
<th>Other quantities to report</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean data segment length</td>
<td>N/A</td>
<td>Report average data segment (slab) length, and standard deviation.</td>
<td>N/A</td>
</tr>
<tr>
<td>Lane type</td>
<td>Four categories:</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Normal JPCP surface;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- HMA-JPCP mixed lane;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- JPCP-JPCP mixed lane;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- JPCP-CRCP mixed lane.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shoulder type</td>
<td>Five categories:</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Not applicable;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Rigid shoulder;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Wide rigid shoulder;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Flexible shoulder;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- No shoulder.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Longitudinal joint condition</td>
<td>N/A</td>
<td>Percentage length sealed. Percentage length with spalling.</td>
<td>N/A</td>
</tr>
<tr>
<td>Transverse joint condition</td>
<td>N/A</td>
<td>Percentage length sealed. Percentage length with spalling.</td>
<td>N/A</td>
</tr>
<tr>
<td>Distress</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Longitudinal cracking</td>
<td>Three categories:</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Sealed;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Unsealed;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Spalled.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transverse cracking</td>
<td>Three categories:</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Sealed;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Unsealed;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Spalled.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Condition</td>
<td>Severity bins / condition categories</td>
<td>Extent measurement</td>
<td>Other quantities to report</td>
</tr>
<tr>
<td>--------------------------</td>
<td>---------------------------------------</td>
<td>-------------------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------</td>
</tr>
<tr>
<td>Corner cracking</td>
<td>Three categories:</td>
<td>Percentage of slabs with corner cracking in each category.</td>
<td>Percentage of sealed corner cracks. Percentage of corner cracks with spalling.</td>
</tr>
<tr>
<td></td>
<td>- Sealed;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Unsealed;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Spalled.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>XJ-cracking</td>
<td>Three categories:</td>
<td>Percentage of slabs with XJ-cracking in each category.</td>
<td>Percentage of sealed XJ-cracks. Percentage of XJ-cracks with spalling.</td>
</tr>
<tr>
<td></td>
<td>- Sealed;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Unsealed;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Spalled.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asphalt patches</td>
<td>Four severity levels:</td>
<td>Percentage of slabs at each severity level.</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>- N: $R_{APA} \leq 0.01$;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- L: $0.01 &lt; R_{APA} \leq 0.05$;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- M: $0.05 &lt; R_{APA} \leq 0.90$;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- H: $R_{APA} &gt; 0.90$.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1st stage cracking</td>
<td>N/A</td>
<td>Percentage of slabs with 1st stage cracking.</td>
<td>N/A</td>
</tr>
<tr>
<td>3rd stage cracking</td>
<td>N/A</td>
<td>Percentage of slabs with 3rd stage cracking.</td>
<td>N/A</td>
</tr>
</tbody>
</table>

### 4.2. Data segment length

**Definition**

For JPCP surfaced pavement, the lengths of data segments are the measured lengths of the JPCP slabs.

**Measurement for data segments**

For each data segment (JPCP slab), record the slab length in meters to the first decimal place.

**Measurement and reporting for management segments**

For each management segment, calculate the mean data segment length and the standard deviation and report them in feet to the first decimal place.
4.3. Lane Type

Definition

The definitions of different types of mixed lanes are described in Section 2.7.

Measurement for data segments

Indicate whether this data segment is

- A normal JPCP surfaced pavement (i.e. both wheelpaths are on the same JPCP slab);
- An HMA-JPCP mixed lane rated as JPCP surfaced pavement;
- A JPCP-JPCP mixed lane; or
- A JPCP-CRCP mixed lane rated as JPCP.

If the data segment is an HMA-JPCP mixed lane, record the width of the JPCP portion measured at the midpoint. If it is either a JPCP-JPCP or a JPCP-CRCP mixed lane, record the width of the primary slab measured at the midpoint. Width measurements are recorded in meters to the first decimal place.

Measurement and reporting for management segments

Report the percentage of data segments that are flagged as “normal JPCP surfaced pavement”, “HMA-JPCP mixed lane”, “JPCP-JPCP mixed lane”, and “JPCP-CRCP mixed lane” in the management segment. Report to the nearest percent.

4.4. Longitudinal cracking

Definition

A longitudinal crack has one endpoint located on each of the two transverse edges of a slab. Examples of longitudinal cracks, Crack $L_1L'_1$ and Crack $L_2L'_2$ are shown in Figure 4-1.
Measurement for data segments

Record the number of longitudinal cracks in each data segment.

If the rater estimates that more than half of the total length of all the longitudinal cracks in the slab has been sealed, then flag sealed; otherwise, flag not sealed.

If the rater estimates that spalling is present for more than half of the total length of all the longitudinal cracks in the JPCP slab, then flag spalling; otherwise, flag no spalling.

Measurement and reporting for management segments

Report the percentage of data segments (slabs) that have at least one longitudinal crack, and for which longitudinal cracking is flagged as sealed, not sealed, and spalled, respectively.

Report the percentage ratio of the number of data segments with longitudinal cracking labeled as sealed to the number of all the data segments with longitudinal cracking.

Report the percentage ratio of the number of data segments with longitudinal cracking labeled as spalling to the number of all the data segments with longitudinal cracking.

Report all five values to the nearest percent.
Figure 4-1 Illustrations of various types cracks in JPCP surface pavement slabs
4.5. Transverse cracking

Definition

A transverse crack has one endpoint located on each of the two longitudinal edges of a slab and lies completely within the middle half of the slab. An example of a transverse crack, Crack $T_1T_1'$, is shown in Figure 4-1.

Measurement for data segments

Record the number of transverse cracks in each data segment.

If the rater estimates that more than half of the total length of all the transverse cracks in the slab has been sealed, then flag sealed; otherwise, flag not sealed.

If the rater estimates that spalling is present on more than half of the total length of all the transverse cracks in the JPCP slab, then flag spalling; otherwise, flag no spalling.

Measurement and reporting for management segments

Report the percentage of data segments (slabs) that have at least one transverse crack, and for which transverse cracking is flagged as sealed, not sealed, and spalled, respectively.

Report the percentage ratio of the number of data segments with transverse cracking labeled as sealed to the number of all the data segments with transverse cracking.

Report the percentage ratio of the number of data segments with transverse cracking labeled as spalling to the number of all the data segments with transverse cracking.

Report all the five values to the nearest percent.
4.6. Corner cracking

Definition

A corner crack has one endpoint located on a transverse edge and the other one on a longitudinal edge, and the entire crack is within one quadrant of the slab. Examples of corner cracks, \( C_{11}' \) and \( C_{22}' \) are shown in Figure 4-1.

Measurement for data segments

Record the number of corner cracks in each data segment.

If the rater estimates that more than half of the total length of all the corner cracks in the slab has been sealed, then flag sealed; otherwise, flag not sealed.

If the rater estimates that spalling is present for more than half of the total length of all the corner cracks in the JPCP slab, then flag spalling; otherwise, flag no spalling.

Measurement and reporting for management segments

Report the percentage of data segments (slabs) that have at least one corner crack, and for which corner cracking is flagged as sealed, not sealed, and spalled, respectively.

Report the percentage ratio of the number of data segments with corner cracking labeled as sealed to the number of all the data segments with corner cracking.

Report the percentage ratio of the number of data segments with corner cracking labeled as spalling to the number of all the data segments with corner cracking.

Report all the five values to the nearest percent.

4.7. XJ-Cracking

Definition

XJ cracking includes any cracks that cannot be classified as longitudinal cracking, transverse cracking or corner cracking. Examples of XJ-cracks, \( CX_1X_1' \), \( CX_2X_2' \), \( CX_3X_3' \),
and Crack $X_3X'_3$ are shown in Figure 4-1. Crack $X_1X'_1$ is an XJ-crack instead of a transverse crack because endpoint $X_1$ is not in the middle half of the slab. Crack $X_2X'_2$ and Crack $X_4X'_4$ are XJ-cracks because one endpoint of each of them is on a crack, not an edge. Crack $X_3X'_3$ is an XJ-crack instead of a corner crack because it is not completely within one quadrant of the slab.

Measurement for data segments

Record the number of XJ-cracks in each data segment.

If the rater estimates that more than half of the total length of all the XJ-cracks in the slab has been sealed, then flag sealed; otherwise, flag not sealed.

If the rater estimates that spalling is present for more than half of the total length of all the XJ-cracks in the JPCP slab, then flag spalling; otherwise, flag no spalling.

Measurement and reporting for management segments

Report the percentage of data segments (slabs) that have at least one XJ-crack, and for which XJ-cracking is flagged as sealed, not sealed, and spalled, respectively.

Report the percentage ratio of the number of data segments with XJ-cracking labeled as sealed to the number of all the data segments with XJ-cracking.

Report the percentage ratio of the number of data segments with XJ-cracking labeled as spalling to the number of all the data segments with XJ-cracking.

Report all the three values to the nearest percent.

4.8. Asphalt Patches

Definition

Asphalt patches are areas on JPCP slabs where the original concrete has been fully or partially overlaid or removed and replaced with an asphaltic material (usually HMA or cold mix asphalt).
Measurement for data segments

Asphalt patching in a JPCP data segment is measured as the asphalt patch area ratio $R_{APA}$, which is the ratio of the area of the JPCP slab that has been patched with asphaltic materials to the total slab area. If the slab is only partially visible (e.g., the primary slab in a rigid-rigid mixed lane), the asphalt patch area ratio is the ratio of the visible area of the slab that has been patched. Report asphalt patch area ratios to the second decimal place. If the asphalt patch area ratio for a data segment is less than 0.01, record the ratio to be zero to account for insignificant patching and random errors.

Measurement and reporting for management segments

Note: the information shown highlighted below is for example purposes only. The severity bins and condition categories for reporting for pavement management segments are to be determined by the Department at a later date.

Four severity levels are defined for asphalt patches on JPCP slabs based on asphalt patch area ratio:

- No asphalt patch: the asphalt patch area ratio of a data segment as measured is not greater than 0.01. In this situation, the $R_{APA}$ value should be reported as zero at the data segment level;
- Low severity: the asphalt patch area ratio of a data segment is greater than 0.01 but not greater than 0.05;
- Moderate severity: the asphalt patch area ratio of a data segment is greater than 0.05 but not greater than 0.90;
- High severity: the asphalt patch area ratio of a data segment is greater than 0.90.

The extent of asphalt patching at each severity level is defined as the percentage of JPCP slabs that have asphalt patch area ratios within each severity range. The extent values should be reported to the nearest percent.
4.9. 1\textsuperscript{st} Stage Cracking

\textbf{Definition}

A slab has 1\textsuperscript{st} stage cracking if it has only one crack that is not a corner crack. This crack can be a longitudinal crack, a transverse crack, or a XJ-crack.

\textbf{Measurement for data segments}

Flag 1\textsuperscript{st} stage cracking if true.

\textbf{Measurement and reporting for management segments}

Report the percentage of data segments (slabs) within the management segment that are flagged 1\textsuperscript{st} stage cracking to the nearest percent.

4.10. 3\textsuperscript{rd} Stage Cracking

\textbf{Definition}

A slab has 3\textsuperscript{rd} stage cracking if it has at least one longitudinal crack and at least one transverse or XJ-crack.

\textbf{Measurement for data segments}

Flag 3\textsuperscript{rd} stage cracking if true.

\textbf{Measurement and reporting for management segments}

Report the percentage of data segments (slabs) within the current management segment that are flagged 3\textsuperscript{rd} state cracking to the nearest percent.
4.11. Longitudinal Joint Condition

 Definition
The condition of longitudinal joints associated with JPCP slabs is evaluated and reported. In certain situations, multiple longitudinal joints are associated with one JPCP slab. See Section 2.9 for details.

 Measurement for data segments
If the rater estimates that more than half of the total length of the longitudinal joints associated with the JPCP slab has been sealed, then flag sealed; otherwise, flag not sealed.

 If the rater estimates that spalling is present for more than half of the total length of all the longitudinal joints of the JPCP slab, then flag spalling; otherwise, flag no spalling.

 Measurement and reporting for management segments
Report the percentage ratio of data segments for which the longitudinal joint conditions are flagged as sealed.

 Report the percentage ratio of data segments for which the longitudinal joint conditions are flagged as spalling.

 Report both values to the nearest percent.

4.12. Transverse Joint Condition

 Definition
The condition of transverse joints associated with JPCP slabs is evaluated and reported.

 Measurement for data segments
If the rater estimates that more than half of the length of the transverse joint associated with the JPCP slab has been sealed, then flag sealed; otherwise, flag not sealed.
If the rater estimates that spalling is present for more than half of the length of the transverse joint of the JPCP slab, then flag spalling; otherwise, flag no spalling.

Measurement and reporting for management segments

Report the percentage ratio of data segments for which the transverse joint conditions are flagged as sealed.

Report the percentage ratio of data segments for which the transverse joint conditions are flagged as spalling.

Report both values to the nearest percent.

4.13. Shoulder type

Definition

Shoulder types are identified and reported based on ROW pavement images.

Measurement for data segments

Record the shoulder type of the data segment. The shoulder can be to the left or right of the data segment. The shoulder type of a JPCP data segment can be:

- Not applicable (if this lane is not adjacent to a shoulder);
- Rigid shoulder (portland cement concrete);
- Wide rigid shoulder (the lane and the shoulder are on the same slab);
- Flexible shoulder (HMA or other asphaltic materials);
- No shoulder.

Record the approximate shoulder width:

- 0 to 0.6 m;
- 0.6 m to 3 m;
- Wider than 3 m.
Measurement and reporting for management segments

Report the percentage of data segments with each category of shoulder type, to the nearest percent.
Chapter 5

CRCP

Image-Based Distress/Condition Measurement and Reporting

This chapter documents distress types and pavement condition measurements based on pavement images for CRCP. Sub-sections for each distress type or condition are: 1) definition, 2) measurement at the pavement data segment level, and 3) calculation of distress severity-extent or condition indicators at the management segment level.

The lane type must be first categorized according to the general definitions in Chapter 2 before rating a data segment for distresses and condition indicators. The contents of this chapter also apply to flexible-rigid or rigid-rigid mixed lanes rated as CRCP.

5.1. Distress Types and Condition Based on Pavement Images

Table 5-1 summarizes the distress types and condition indicators for CRCP based on pavement images, and their measurements for pavement data segments.
Table 5-1  CRCP distress types and condition (based on pavement images)

<table>
<thead>
<tr>
<th>Condition</th>
<th>Quantitative measurement</th>
<th>Qualitative parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lane type</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Width1 of the CRCP portion</td>
<td></td>
<td>Indicate type:</td>
</tr>
<tr>
<td>mixed lane. Record zero if</td>
<td></td>
<td>- Normal CRCP lane;</td>
</tr>
<tr>
<td>not a mixed lane.</td>
<td></td>
<td>- HMA-CRCP mixed lane;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- JPCP-CRCP mixed lane;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- CRCP-CRCP mixed lane.</td>
</tr>
<tr>
<td><strong>Shoulder type</strong></td>
<td></td>
<td>Record type:</td>
</tr>
<tr>
<td>Record width of shoulder:</td>
<td></td>
<td>- Not applicable;</td>
</tr>
<tr>
<td>0-0.6m; 0.6-3.0m; &gt;3m.</td>
<td></td>
<td>- Rigid shoulder;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Wide rigid shoulder;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Flexible shoulder;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- No shoulder.</td>
</tr>
<tr>
<td><strong>Longitudinal joint</strong></td>
<td>N/A</td>
<td>Indicate: sealed/not</td>
</tr>
<tr>
<td>condition</td>
<td></td>
<td>sealed.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Indicate: spalling/no</td>
</tr>
<tr>
<td></td>
<td></td>
<td>spalling.</td>
</tr>
<tr>
<td><strong>Distress</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Longitudinal cracking</td>
<td>Longitudinal crack length</td>
<td>Indicate: sealed/not</td>
</tr>
<tr>
<td>ratio</td>
<td></td>
<td>sealed/NA2.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Indicate: spalling/no</td>
</tr>
<tr>
<td></td>
<td></td>
<td>spalling/NA2.</td>
</tr>
<tr>
<td>Transverse cracking</td>
<td>Number per data segment</td>
<td>Indicate: sealed/not</td>
</tr>
<tr>
<td></td>
<td></td>
<td>sealed/NA2.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Indicate: spalling/no</td>
</tr>
<tr>
<td></td>
<td></td>
<td>spalling/NA2.</td>
</tr>
<tr>
<td>XC-cracking</td>
<td>XC-crack length ratio</td>
<td>Indicate: sealed/not</td>
</tr>
<tr>
<td></td>
<td></td>
<td>sealed/NA2.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Indicate: spalling/no</td>
</tr>
<tr>
<td></td>
<td></td>
<td>spalling/NA2.</td>
</tr>
<tr>
<td>Punchouts</td>
<td>Punchout area ratio</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>$R_{POA}$</td>
<td></td>
</tr>
<tr>
<td>Asphalt patches</td>
<td>Asphalt patch area ratio</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>$R_{APA}$</td>
<td></td>
</tr>
</tbody>
</table>

Note:  
1 Measured at the midpoint of the data segment.  
2 NA=not applicable, if this type of distress does not exist in the current data segment.
Table 5-2 summarizes the definitions of the severity bins for CRCP distresses and the associated extent measurement, and categories for pavement condition indicators, as well as the reporting requirement at the pavement management segment level. Typically, three levels of severity are identified for each distress type, namely low severity (L), moderate severity (M) and high severity (H), if this distress is significant in the current data or management segment.

For condition indicators, the concept of distress severity is inapplicable, but the classification, measurement and reporting requirements are organized in the same way as that for distresses.

Note: the information shown in the highlighted column of Table 5-2 is for example purposes only. The severity bins and condition categories for reporting for pavement management segments are to be determined by the Department at a later date.
Table 5-2 Summary of distress severity-extent values and condition indicators to be reported for CRCP management segments

<table>
<thead>
<tr>
<th>Condition</th>
<th>Severity bins / condition categories</th>
<th>Extent measurement</th>
<th>Other quantities to report</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lane type</td>
<td>Four categories:</td>
<td>Percentage of data segments of each lane type.</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>- Normal CRCP lane;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- HMA-CRCP mixed lane;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- JPCP-CRCP mixed lane;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- CRCP-CRCP mixed lane.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shoulder type</td>
<td>Five categories:</td>
<td>Percentage length of each shoulder type.</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>- Not applicable;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- No shoulder;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Rigid shoulder;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Wide rigid shoulder;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Flexible shoulder.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Longitudinal joint condition</td>
<td>N/A</td>
<td>Percentage length sealed. Percentage length with spalling.</td>
<td>N/A</td>
</tr>
<tr>
<td>Distress</td>
<td>Severity bins / condition categories</td>
<td>Extent measurement</td>
<td>Other quantities to report</td>
</tr>
<tr>
<td>Longitudinal cracking</td>
<td>N/A</td>
<td>Percentage of data segments with longitudinal cracking. Average longitudinal crack length ratio.</td>
<td>Percentage of sealed longitudinal cracks. Percentage of longitudinal cracks with spalling.</td>
</tr>
<tr>
<td>Transverse cracking</td>
<td>N/A</td>
<td>Average number per 328 ft (100 m) lane length.</td>
<td>Percentage of sealed transverse cracks. Percentage of transverse cracks with spalling.</td>
</tr>
<tr>
<td>XC-cracking</td>
<td>Four severity levels:</td>
<td>Percentage data segments at each severity level.</td>
<td>Percentage of sealed XC-cracks. Percentage of XC-cracks with spalling.</td>
</tr>
<tr>
<td></td>
<td>- N: $R_{XC} \leq 0.05$;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- L: $0.05 &lt; R_{XC} \leq 2.0$;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- M: $2.0 &lt; R_{XC} \leq 4.0$;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- H: $R_{XC} &gt; 4.0$.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Punchouts</td>
<td>Four severity levels:</td>
<td>Percentage of slabs at each severity level.</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>- N: $R_{POA} \leq 0.01$;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- L: $0.01 &lt; R_{POA} \leq 0.05$;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- M: $0.05 &lt; R_{POA} \leq 0.30$;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- H: $R_{POA} &gt; 0.30$.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Condition</td>
<td>Severity bins / condition categories</td>
<td>Extent measurement</td>
<td>Other quantities to report</td>
</tr>
<tr>
<td>--------------------</td>
<td>--------------------------------------------------------------------------------------------------------</td>
<td>----------------------------------------------------------</td>
<td>----------------------------</td>
</tr>
<tr>
<td>Asphalt patches</td>
<td>Four severity levels:</td>
<td>Percentage of slabs at each severity level.</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>- N: $R_{APA} \leq 0.02$;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- L: $0.02 &lt; R_{APA} \leq 0.05$;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- M: $0.05 &lt; R_{APA} \leq 0.90$;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- H: $R_{APA} &gt; 0.90$.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 5.2. Lane Type

#### Definition

The definitions of different types of mixed lanes are described in Section 2.7.

#### Measurement for data segments

Indicate whether the data segment is

- A normal CRCP (i.e. both wheelpaths are on the same CRCP strip);
- An HMA-CRCP mixed lane rated as CRCP;
- A JPCP-CRCP mixed lane rated as CRCP; or
- A CRCP-CRCP mixed lane.

For mixed lanes, record the width of the strip measured at the midpoint of the data segment. Width measurements are recorded in meters to the first decimal place.

#### Measurement and reporting for management segments

Report the percentage of data segments that are flagged as normal CRCP, HMA-CRCP mixed lane, JPCP-CRCP mixed lane, and CRCP-CRCP mixed lane in the management segment. Report to the nearest percent.
5.3. Longitudinal cracking

Definition

A crack on CRCP is classified as a CRCP longitudinal crack if it meets the following criteria:

- The crack length in the current data segment is more than half of the data segment length (i.e. $1/2L_{PDS}$).
- If the crack is approximated by a straight line, either empirically or numerically, the acute angle between the linear approximation line and the lane centerline is not larger than 15º.

Isolated short cracks in the longitudinal direction are categorized as XC-cracks.

Measurement for data segments

Record the longitudinal crack length ratio in each data segment, which is the ratio of the total longitudinal crack length to the length of the data segment. Report the value to the second decimal place.

If the rater estimates that more than half of the total length of all the longitudinal cracks in the data segment has been sealed, then flag sealed; otherwise, flag not sealed.

If the rater estimates that spalling is apparent for more than half of the total length of all the longitudinal cracks in the data segment, then flag spalling; otherwise, flag no spalling.

Measurement and reporting for management segments

Report the percentage of data segments that have at least one longitudinal crack.

Report the percentage ratio of the number of data segments with longitudinal cracking labeled as sealed to the number of all the data segments with longitudinal cracking.

Report the percentage ratio of the number of data segments with longitudinal cracking labeled as spalling to the number of all the data segments with longitudinal cracking.

Report all the three values to the nearest percent.
Also report the average longitudinal crack length ratio of the management segment to the second decimal place.

5.4. Transverse cracking

Definition

A crack on CRCP is classified as a CRCP transverse crack if it meets the following criteria:

- For normal CRCP surfaced lanes, the crack should extend across the full width of the lane. For mixed lanes rated as CRCP surface pavement, the crack should extend across the full width of the CRCP strip in the lane.

- If the crack is approximated by a straight line, either empirically or numerically, the acute angle between the linear approximation line and the lane centerline should be larger than 75°.

- The maximum deviation of the crack from its linear approximation should be less than 10 cm in the longitudinal direction.

If a transverse crack intersects a transverse boundary dividing two adjacent data segments in the same lane, the transverse crack partially appears in both data segments. In this case, include the transverse crack in the data segment that has more than half of the total crack length.

Measurement for data segments

Record the number of transverse cracks in each data segment.

If the rater estimates that more than half of the total length of all the transverse cracks in the data segment has been sealed, then flag sealed; otherwise, flag not sealed.

If the rater estimates that spalling is apparent for more than half of the total length of all the transverse cracks in the data segment, then flag spalling; otherwise, flag no spalling.
Measurement and reporting for management segments

Report to the first decimal place the average number of transverse cracks in every 328 ft (100 m) of the management segment. The value is obtained by multiplying the average crack number per data segment by 10, since 100 m of a management segment consists of ten data segments.

Report the percentage ratio of the number of data segments with transverse cracking labeled as sealed to the number of all the data segments with transverse cracking.

Report the percentage ratio of the number of data segments with transverse cracking labeled as spalling to the number of all the data segments with transverse cracking.

Report all both values to the nearest percent.

Note: Special caution should be taken when interpreting reported measurements of transverse cracking for CRCP. More transverse cracks (or equivalently shorter transverse cracking spacing), especially immediately after construction, could indicate higher amounts of steel use, which generally results in better expected performance. Therefore, data segments or management segments with more transverse cracks are not necessarily in worse conditions than segments with less transverse cracks are. However, gradual or sudden increases of transverse cracks during the service life could be a sign of condition deterioration.

5.5. XC-cracking

Definition

Any cracking that is not classified as longitudinal cracking or transverse is categorized as XC-cracking.

Measurement for data segments

XC-cracking in each pavement data segment is quantified by the parameter XC-crack length ratio $R_{XC}$, which is the ratio of the total length of all XC-cracks to the length of the data segment ($L_{PDS}$). XC-crack length ratios are recorded to the second decimal place. If the
XC-crack length ratio for a data segment is less than 0.05 as calculated by the image analysis, record the XC-crack length ratio to be zero to account for insignificant cracking and random errors in image analysis.

XC-cracking in a data segment is flagged as sealed if the rater estimates that more than half of the total length of all the XC-cracks in the current data segment has been sealed.

If the rater estimates that spalling is present for more than half of the total length of all the XC-cracks in the data segment, then flag spalling; otherwise, flag no spalling.

Measurement and reporting for management segments

Note: the information shown highlighted below is for example purposes only. The severity bins and condition categories for reporting for pavement management segments are to be determined by the Department at a later date.

Four severity levels are defined for XC-cracking:

- No XC-cracking: the XC-crack length ratio of a data segment as measured is not greater than 0.05. In this situation, the XC-crack length ratio should be reported as zero at the data segment level.
- Low severity: the XC-crack length ratio of a data segment is greater than 0.05, but not greater than 2.00;
- Moderate severity: the XC-crack length ratio of a data segment is greater than 2.00 but not greater than 4.00;
- High severity: the XC-crack length ratio of a data segment is greater than 4.00.

The extent of XC-cracking at each severity level is defined as the percentage of data segments that have XC-crack length ratios within the prescribed range.

Report the percentage ratio of the number of data segments with XC-cracking labeled as sealed to the number of all the data segments with XC-cracking.

Report the percentage ratio of the number of data segments with XC-cracking labeled as spalling to the number of all the data segments with XC-cracking.

Report all the three values to the nearest percent.
5.6. Punchouts

Definition

Punchouts are polygonal areas defined by cracks and/or pavement edge/joints. The longest dimension of a punchout in the transverse direction should be shorter than half of the lane width $W_{Lane}$. Examples of punchouts are shown in Figure 5-1. Punchout group ① consists of four punchouts, enclosed by four closely spaced transverse cracks, two cracks in the longitudinal direction (which are not necessarily longitudinal cracks), and one of the joints/edges. Punchout ② is enclosed by two cracks and one longitudinal joint/edge. Punchout ③ is enclosed by two transverse cracks and a longitudinal joint and a crack in the longitudinal direction.

Figure 5-1 Examples of punchouts on CRCP
Measurement for data segments

Punchouts in each pavement data segment are measured by the punchout area ratio (denoted as $R_{POA}$), which is the ratio of the total punchout area to the data segment area. Punchout area ratios should be recorded to the second decimal place. If the punchout area ratio calculated is smaller than 0.01, then record the ratio to be zero (i.e. no punchout presents) to account for insignificant numbers or random errors. For mixed lanes rated as CRCP, the punchout area ratio is the ratio of the punchout area on the CRCP strip being rated to the area of the CRCP strip.

Measurement and reporting for management segments

Note: the information shown highlighted below is for example purposes only. The severity bins and condition categories for reporting for pavement management segments are to be determined by the Department at a later date.

Four severity levels are defined for punchouts on CRCP:

- No punchout: the punchout area ratio as measured is not greater than 0.01;
- Low severity: the punchout area ratio of a data segment is greater than 0.01, but not greater than 0.05;
- Moderate severity: the punchout area ratio of a data segment is greater than 0.05, but not greater than 0.30;
- High severity: the punchout area ratio of a data segment is greater than 0.30.

The extent of punchouts at each severity level is defined as the percentage of data segment that have punchout area ratios within the prescribed range. The extent values are reported to the nearest percent.
5.7. Asphalt Patches

Definition

Asphalt patches are areas on CRCP where the existing concrete has been overlayed or removed and replaced with asphalitic material (usually either HMA or cold mix asphalt).

Measurement for data segments

Asphalt patching in a pavement data segment is measured by the asphalt patch area ratio $R_{APA}$, which is the ratio of the area of the data segment that has been patched with asphalitic materials. If the CRCP strip being rated is only partially visible (e.g. in a mixed lane), the asphalt patch area ratio is the ratio of the visible area of the strip that has been patched. Record asphalt patch area ratios to the second decimal place. If the asphalt patch area ratio for a data segment is less than 0.01 as calculated by the image analysis, record the ratio to be zero (i.e. no patch) to account for insignificant patching and random image analysis errors.

Measurement and reporting for management segments

Note: the information shown highlighted below is for example purposes only. The severity bins and condition categories for reporting for pavement management segments are to be determined by the Department at a later date.

Four severity levels are defined for asphalt patches on CRCP:

- No asphalt patch: the asphalt patch area ratio of a data segment as measured is not greater than 0.01;
- Low severity: the asphalt patch area ratio of a data segment is greater than 0.01, but not greater than 0.05;
- Moderate severity: the asphalt patch area ratio of a data segment is greater than 0.05, but not greater than 0.90;
- High severity: the asphalt patch area ratio of a data segment is greater than 0.90.
The extent of asphalt patching at each severity level is defined as the percentage of data segments that have asphalt patch area ratios within the prescribed range. The extent values are reported to the nearest percent.

5.8. Shoulder type

Definition
Shoulder types are identified and reported based on ROW pavement images.

Measurement for data segments
Record the shoulder type of the data segment. The shoulder can be to the left or right of the data segment. The shoulder type of a CRCP data segment can be:

- Not applicable (if this lane is not adjacent to a shoulder);
- Rigid shoulder (portland cement concrete);
- Wide rigid shoulder;
- Flexible shoulder (HMA or other asphaltic materials);
- No shoulder.

Record the approximate shoulder width:

- 0 to 0.6 m;
- 0.6 m to 3 m;
- Wider than 3 m.

Measurement and reporting for management segments
Report the percentage of data segments with each category of shoulder type, to the nearest percent.
Chapter 6

Pavement Surface Profiles
Distress and Condition Measurement

This chapter documents pavement condition indicators to be calculated based on pavement surface profile measurements for all the three pavement types, namely flexible surfaced pavement, JPCP and CRCP. Sub-sections for each distress type or conditions are: 1) general requirements, 2) measurement at the pavement data segment level, and 3) calculation of distress severity and extent or conditions at the management segment level.

For the purposes of evaluating distresses and conditions based on pavement surface profiles, data segments for all pavement surface types are 10 m long.

6.1. International Roughness Index (IRI)

General requirements

International Roughness Index (IRI) is measured and calculated for all pavement surface types from the longitudinal pavement surface profiles in each wheelpaths. Measurements are based on ASTM E950-98 (2004) Standard Test Method for Measuring the Longitudinal Profile of Traveled Surfaces with an Accelerometer Established Inertial Profiling Reference. The longitudinal sampling rate must be less than or equal to 25 mm, and the vertical measurement resolution must be less than or equal to 0.1 mm.

IRI values are calculated in accordance with ASTM E1926-08 Standard Practice for Computing International Roughness Index of Roads from Longitudinal Profile Measurements, or using a Department approved software package.
Calculation and reporting for data segments

The IRI values are reported for each wheelpath in each data segment (10 m long), with results rounded to the nearest in/mi.

Calculation and reporting for management segments

Note: the information shown highlighted below is for example purposes only. The severity bins and condition categories for reporting for pavement management segments are to be determined by the Department at a later date.

Three severity levels for IRI values (in inches/mile) are:

- Low severity: the IRI value of a data segment is not greater than 95 inches/mile;
- Moderate severity: the IRI value of a data segment is greater than 95 inches/mile but not greater than 170 inches/mile;
- High severity: the IRI value of a data segment is greater than 170 inches/mile.

The extent of pavement surface roughness at each severity level is defined as the percentage of data segments (10 m long for all surface types) within the management segment that have reported IRI values within each range. The extent values are reported to the nearest percent.

In addition to the severity-extent measurements, also report the mean and standard deviation of IRI value over all the data segments in the management segment.

6.2. Mean Profile Depth

General requirements

MPD is only calculated for the right wheelpath on flexible surfaced pavements, and it requires the use of longitudinal profile data with a maximum longitudinal sampling interval of 1 mm with a laser spot size of not more than 1 mm, and vertical resolution less than or equal to 0.05 mm. MPD is calculated following ASTM E 1845-01 (2005) Standard Practice for Calculating Pavement Macrotexture Mean Profile Depth for every 100 mm length of wheelpath. Mean Profile Depth (MPD) can provide an indication of surface raveling.
texture, and bleeding. Note that the MPD calculation is affected by the effects of wheelpath cracking and potholes.

Calculation and reporting for data segments

MPD values calculated for the 100 mm long segments are averaged for each data segment length, and the mean value is recorded for the data segment in mm to the first decimal place.

Calculation and reporting for management segments

Note: the information shown highlighted below is for example purposes only. The severity bins and condition categories for reporting for pavement management segments are to be determined by the Department at a later date.

Three severity levels for MPD values are:

- Low severity: the MPD value of a data segment is not greater than 0.02 inches;
- Moderate severity: the MPD value of a data segment is greater than 0.02 inches but not greater than 0.04 inches;
- High severity: the MPD value of a data segment is greater than 0.04 inches.

The extent of MPD at each severity level is defined as the percentage of data segments that have reported mean MPD values within the prescribed range. Report extent values to the nearest percent.

6.3. Measurement of Rut Depth

General requirements

Rut depths are measured for the two wheelpaths separately, and for all pavement surface types (rigid surfaced pavements are rutted by tire chain wear). Rut depth is measured using a system that is capable of measuring transverse profiles across the entire lane width with a lateral sampling interval less than or equal to 25 mm, and a longitudinal sampling interval less than or equal to 150 mm. The measurement and calculation method must produce the

Calculation and reporting for data segments

60 to 70 transverse profiles must be measured for each data segment. Within each data segment, record mean, standard deviation, and maximum value of rut depth to the nearest mm for the two wheelpaths separately.

Calculation and reporting for management segments

Note: the information shown highlighted below is for example purposes only. The severity bins and condition categories for reporting for pavement management segments are to be determined by the Department at a later date.

Three severity levels for rut depth values are:

- Low severity: the mean rut depth of a data segment is not greater than 0.25 inches;
- Moderate severity: the mean rut depth of a data segment is greater than 0.25 inches, but not more than 0.5 inches;
- High severity: the mean rut depth of a data segment is greater than 0.5 inches.

The extent of rut depth at each severity level is defined as the percentage of data segments that have reported mean rut depth values within the prescribed range. Report the extent values to the nearest percent.

In addition to the severity-extent measurements, also report the mean rut depth for all rut depth measurements in the management segment.
6.4. Measurement of Joint and Transverse Crack Fault Height

General requirements

Joint and transverse crack fault heights are measured for JPCP only. Regardless of the lane type of each data segment, fault heights are measured and reported if the right wheelpath is on JPCP. The profile data collection requires the same sampling as described in Section 6.2 (Mean Profile Depth) of this APCS manual, and elimination of the low pass filter and spiking trigger. Note that fault measurements on rigid surfaces that have deep longitudinal tinning are less reliable than those with other surface textures, and thus should be interpreted with caution. Fault height calculation is performed following AASHTO R 36-04 Evaluating Faulting of Concrete Pavements.

Calculation and reporting for data segments

Record the number of faults and the average fault height in mm (to the first decimal place) for each data segment.

Calculation and reporting for management segments

Note: the information shown highlighted below is for example purposes only. The severity bins and condition categories for reporting for pavement management segments are to be determined by the Department at a later date.

Three severity levels are defined as below:

- Low severity: the mean fault height in a unit length of pavement is not more than 0.18 inches;
- Moderate severity: the mean fault height in a unit length of pavement is more than 0.18 inches, but not more than 0.25 inches;
- High severity: the mean fault height in a unit length of pavement is more than 0.25 inches.
The extent of fault height at each severity level is defined as the percentage of data segments that have recorded mean fault height values within the prescribed range. Report the extent values to the nearest percent.

In addition to the severity-extent measurements, also report the mean fault height in inches and average number of faults in every 383 ft (100 m) of the management segment.

### 6.5. Measurement of Spalling

#### General requirements

Spalling is measured for JPCP cracks and transverse joints, and CRCP cracks and construction joints in the wheelpath. The profile data collection requires the same sampling as described in Section 6.2 (Mean Profile Depth) of this manual. The profile data is used calculate the area of the spall at the transverse joint or crack. Only spalling with cross-sectional area greater than 500 mm$^2$ is recorded. Regardless of the lane type of each data segment, spalling are measured and reported if the right wheelpath is on JPCP or CRCP.

#### Calculation and reporting for data segments

Record the number of spalls, and average spall area in mm$^2$ for each data segment.

(Note: this is an experimental item, which will be evaluated in correlation with the spalling identification from images described in Section 2.10.)

#### Calculation and reporting for management segments

Multiple severity levels are inapplicable to spalling area measurement.

For each management segment, report the average number of spalls in every 383 ft (100 m) of the management segment to the first decimal place. Also report the mean spalling area in inch$^2$ to the first decimal place.
Appendix: Example photos of distresses

(This is a place holder.)