



Designation: E3303 – 21

Standard Practice for Generating Pavement Surface Cracking Indices from Digital Images¹

This standard is issued under the fixed designation E3303; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice covers the quantification of pavement surface cracking from digital 2D images or 3D data (or both) of the pavement surface.

1.2 The objectives of this standard are to eliminate human subjectivity and intervention in the process of generating cracking indices, to define cracking metrics and other required parameters objectively, and to enable all users of the standard to produce the same cracking indices given the same cracking data.

1.3 The cracking indices are unitless and are calculated in a straightforward manner from fundamental measurements of length, width, and area as defined in this standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.* Specific precautionary statements are given in Section 7.

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*²

E1656/E1656M Guide for Classification of Automated Pavement Condition Survey Equipment

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

¹ This practice is under the jurisdiction of ASTM Committee E17 on Vehicle - Pavement Systems and is the direct responsibility of Subcommittee E17.42 on Pavement Management and Data Needs.

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² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

3.1.1 *analysis interval*—a transverse strip of pavement that subdivides the road in the longitudinal direction into shorter intervals for analysis purposes. These intervals are recommended to have a fixed length of 2.00 m (6.56 ft) based on measured distance for asphalt and continuously reinforced concrete pavements. These intervals are recommended to have variable lengths delineated by slab joints for jointed concrete pavements.

3.1.2 *analysis tile*—a rectangular region of pavement which is used as an element for analysis purposes. For asphalt concrete pavement, it is recommended to use analysis tiles created by the intersection of the road zones with analysis intervals of 2.00 m (6.56 ft). For jointed concrete pavement, analysis tiles are recommended to have a length equal to the slab length and a width equal to the lane width. For continuously reinforced concrete, analysis tiles are recommended to have a length of 2.00 m (6.56 ft) and a width equal to the lane width. The area shall be expressed as either m^2 or ft^2 .

3.1.3 *asphalt concrete pavement (ACP)*—pavement surface constructed of aggregate mixture with an asphaltic mastic binder. This term also refers to surfaces constructed of tars, chip seal surfaces, and similar materials for purposes of this practice.

3.1.4 *chainage distance*—the interpolated distance that must be assigned to each analysis interval or segment to match the pavement section length.

3.1.5 *continuously reinforced concrete pavement (CRCP)*—pavement surface constructed of aggregate mixture with portland cement binder with continuous longitudinal steel reinforcement.

3.1.6 *crack*—a fissure of the pavement material at the surface that is a minimum of 1 mm (0.04 in.) in width.

3.1.7 *crack density*—the total sum of the crack lengths within the area being analyzed divided by the area being analyzed (expressed as m/m^2 or ft/ft^2). The term “crack intensity,” used by some practitioners, is synonymous.

3.1.8 *crack length*—the distance, measured in m or ft, traced along all polylines composing the crack.

3.1.9 *crack width*—the average gap (distance, measured in mm or in.) between the two long edges of a crack on the

pavement surface, ignoring any spalling or wearing away of pavement at the surface.

3.1.10 *fatigue cracking*—a series of interconnecting cracks caused by fatigue failure of the asphalt concrete pavement. The term “alligator cracking,” used by some practitioners, refers to medium and high-severity fatigue cracking.

3.1.11 *jointed concrete pavement (JCP)*—pavement surface constructed of aggregate mixture with portland cement binder including nonreinforced and reinforced jointed pavement.

3.1.12 *lane center*—a longitudinal line running down the center of the travelled lane. When lane markings are present, it is located at the midline between the two inside edges of the lane markings. When lane markings are not present, the lane center is considered to be the centerline of the driven vehicle path, relying on the operator to choose a valid survey path.

3.1.13 *lane width*—the total sum of the widths of the five road zones.

3.1.14 *measured distance*—the physical distance or length measured along a road in the driving direction, that is, by the collection vehicle’s distance-measuring instrument. There will normally be small variations in the measured distance for multiple runs of the same section.

3.1.15 *pattern cracking*—a grouping of multiple interconnected cracks.

3.1.16 *pattern threshold*—a numerical value defining the limit at which point the density of cracking within the analysis tile becomes pattern cracking as opposed to linear cracking.

3.1.17 *pavement section*—a contiguous pavement area typically having uniform construction, maintenance, usage history, and condition managed as a single entity for reporting information and planning work.

3.1.18 *pavement section area*—the pavement section length multiplied by the representative average width of the section considered for the analysis. What can be considered a representative width of the section is discussed in 4.2.

3.1.19 *pavement section length*—the total predetermined, known length of a pavement section. The length of a section will always be identical for multiple runs of the same section.

3.1.20 *pavement surface cracking index (PSCI)*—a numerical, dimensionless rating of the pavement cracking that ranges from 0 to 100, with 0 being the worst possible condition and 100 being the best possible condition.

3.1.21 *pavement surface cracking metric (PSCM)*—a numerical, dimensionless measure of the pavement cracking defined as area of open fissures within the area being analyzed divided by the total area being analyzed. It is equivalent to crack density multiplied by weighted crack width. PSCM values will typically range from 0 for a road with no cracking to about 10 % for a road with heavy cracking.

3.1.22 *road zone*—one of the five strips of pavement created by the wheelpaths and the areas between and outside the wheelpaths. The term “measurement zone” is synonymous. The road zones are shown in Fig. 1.

3.1.22.1 *central zone (zone 3)*—a longitudinal strip of pavement 0.75 m (30 in.) wide and centered in the lane.

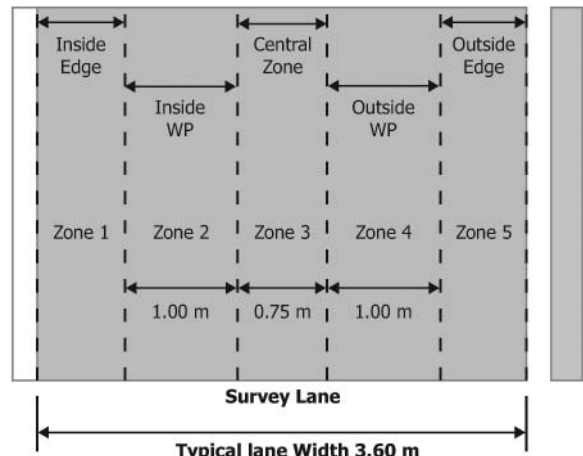


FIG. 1 Road Zones

3.1.22.2 *inside edge (zone 1)*—a longitudinal strip of pavement between the inside wheelpath and the nearest lane edge.

3.1.22.3 *inside wheelpath (zone 2)*—a longitudinal strip of pavement 1.00 m (39 in.) wide, starting from the edge of the central zone on the opposite side of the shoulder.

3.1.22.4 *outside edge (zone 5)*—a longitudinal strip of pavement between the outside wheelpath and the nearest lane edge.

3.1.22.5 *outside wheelpath (zone 4)*—a longitudinal strip of pavement 1.00 m (39 in.) wide, starting from the edge of the central zone on the side of the shoulder.

3.1.23 *split crack*—part of a crack belonging to a single analysis tile. A crack that extends over two or more analysis tiles should be divided into split cracks, each belonging entirely to a single analysis tile.

4. Summary of Practice

4.1 Analyses are conducted for a defined area of pavement designated as a section.

4.2 The entire surface area of a section is not necessarily surveyed; instead, a single lane or sometimes multiple lanes through the section may be surveyed and considered to represent the average condition of the entire section.

4.3 Each collected lane may be further subdivided into analysis tiles. Analysis tiles are defined based on the goals of the analysis, and may be delineated by image frames, slab joints, a fixed analysis interval, road zones, or a combination of these. Within each analysis tile, the crack length and crack width of each crack are recorded.

5. Significance and Use

5.1 The PSCI provides a measure of the cracking observed on the pavement surface. It provides a quantitative and rational basis for rating pavement surface cracking to aid in determining maintenance and repair needs and priorities. Periodic monitoring of the PSCI can be used to establish feedback on pavement performance for validation or improvement of current pavement design and maintenance procedures. The PSCI is calculated from the PSCM.

5.2 The PSCM uses the openness or aperture size of the pavement surfacing caused by cracking as the objective function. This is a measure of the surface integrity due to cracking that relates to the area that could potentially admit surface water.

5.3 It also relates to the loss of horizontal tensile integrity at the surface because that is proportional to the total length of cracks and to interparticle load transfer, which is related in part to crack width.

5.4 It is, however, a purely physical dimensional measure and has no prior dependency on cause or type of cracking.

5.5 Any evaluation of the cause of the cracking, or of its impact on pavement performance, would be made independently together with other factors relevant to the particular purpose, as elaborated later.

5.6 Sealed cracks, potholes, and patching are not included in the PSCM and PSCI calculations.

6. Apparatus

6.1 The equipment must meet at least class C3331 resolution specifications according to Guide **E1656/E1656M**. That is, the vehicle or other data collection device must be capable of measuring the crack width with a repeatable precision (see Section 9). To achieve the best results, the measured data should have a longitudinal sampling interval of 2 mm (0.079 in.), a transverse sampling interval of 2 mm (0.079 in.), and transverse coverage of at least 3.65 m (12 ft).

7. Hazards

7.1 Traffic is a hazard in any pavement condition survey.

8. Calculation of PSCM and PSCI

8.1 PSCM is calculated from measurements of crack length, crack width, and pavement section area.

8.2 PSCI is a translation of the PSCM to a 0 to 100 scale.

8.3 The PSCM of any analysis tile is calculated as:

$$PSCM = 100 \frac{L \cdot w}{A} = 100 \cdot \rho \cdot w \quad (1)$$

where:

$PSCM$ = pavement surface cracking metric,
 A = analysis tile area,
 L = total length of cracking in analysis tile area A ,
 w = average weighted width of cracking in tile area A , and
 ρ = crack density (L/A).

$$L = \sum_{i=1}^N l_i \quad (2)$$

$$w = \frac{1}{L} \sum_{i=1}^N l_i \cdot w_i \quad (3)$$

Or, equivalently:

$$PSCM = 100 \cdot \frac{\sum_{i=1}^N l_i \cdot w_i}{A} \quad (4)$$

where:

l_i = crack length of the i^{th} crack,

w_i = crack width of the i^{th} crack,

A = analysis tile area over which the cracking was observed, and

N = number of cracks within analysis tile area A .

8.3.1 Measurements of area, length, and width must use consistent units of measure (that is, m and m^2 or ft and ft^2). Crack widths must be converted from typical units of millimeters or inches to meters or feet.

8.4 The PSCM may be calculated for analysis tiles and for the pavement section. The PSCI is only calculated for the pavement section. The PSCM and PSCI may be calculated for the pavement section directly without subdividing the surveyed lane into analysis tiles, provided the area A chosen for analysis is the entire surveyed lane (or what is considered the representative pavement section area).

8.5 The PSCM of the pavement section is calculated as the weighted average of the PSCM of each analysis tile as follows:

$$PSCM = \frac{1}{A_{\text{section}}} \sum_s A_s \cdot PSCM_s \quad (5)$$

where:

$PSCM_s$ = PSCM of the s^{th} analysis tile,

A_s = area of the s^{th} analysis tile, and

A_{section} = sum of the areas of all analysis tiles (A_s), also equivalent to the pavement section area.

8.6 In the case where all analysis tiles have the same area, such as when a fixed analysis interval has been chosen with no subdivision for road zones, the PSCM for the section becomes the simple average of the PSCM values for each analysis tile, as follows:

$$PSCM = \frac{1}{N} \sum_s PSCM_s \quad (6)$$

where:

$PSCM_s$ = PSCM of the s^{th} analysis tile, and

N = total number of analysis tiles.

8.7 When the PSCM for the pavement section has been determined, PSCI is calculated as follows:

$$PSCI = 100 \times e^{-0.45PSCM} \quad (7)$$

where:

$PSCM$ = PSCM for the pavement section, and

$PSCI$ = pavement surface cracking index.

8.8 PSCI values cannot be summed or aggregated readily in the same way that the PSCM values can. **Fig. 2** shows the PSCI as a function of the PSCM.

9. Precision and Bias

9.1 There are two measurements that serve to express precision in the evaluation of a standard test method. They are commonly referred to as “repeatability” and “reproducibility” and provide the boundaries between which precision exists. Repeatability addresses variability between replicate tests