



Standard Practice for Pavement Condition Index Surveys for Interlocking Concrete Roads and Parking Lots¹

This standard is issued under the fixed designation E2840; 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 is used to assess the condition of roads and parking lots surfaced with interlocking concrete pavement through visual surveys using the Pavement Condition Index (PCI) method of quantifying pavement condition.

1.2 The PCI for roads and parking lots was developed by the U.S. Army Corps of Engineers (1, 2). It is further verified and adopted by DOD and APWA. This standard is an adaptation of the PCI method for interlocking concrete pavements.

1.3 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

2. Terminology

2.1 Definitions of Terms Specific to This Standard:

2.1.1 *additional sample, n*—a sample unit inspected in addition to the random sample units to include non representative sample units in the determination of pavement condition index. This includes very poor or excellent samples that are not typical of the section and sample units. If a sample unit containing an unusual distress is chosen at random, it should be counted as an additional sample and another random sample unit should be chosen. If all sample units are inspected, then there are no additional samples.

2.1.2 *interlocking concrete pavement, n*—discrete, hand-sized paving units with rectangular or dentated shapes manufactured from concrete and conforming to ASTM C 936. Either type of unit shape is placed in an interlocking pattern with various jointing and bedding materials over an unbound or bound base layer.

2.1.3 *pavement branch, n*—a branch is an identifiable part of the pavement network that is a single entity and has a distinct function. For example, each roadway or parking area is a separate branch of a pavement network.

2.1.4 *pavement condition index (PCI), n*—a numerical rating of the pavement condition that ranges from 0 to 100 with 0 being the worst possible condition and 100 being the best possible condition.

2.1.5 *pavement condition rating, n*—a verbal description of pavement condition as a function of the PCI value that varies from “failed” to “excellent” as shown in Fig. 1.

2.1.6 *pavement distress, n*—external indicators of pavement deterioration caused by loading, environmental factors, construction deficiencies, or a combination thereof. Typical distresses include depressions, damaged pavers, horizontal creep and faulting. Distress types and severity levels detailed in Appendix X1 must be used to obtain an accurate PCI value.

2.1.7 *pavement sample unit, n*—a sample unit is a subdivision of the pavement section. Each pavement section is divided into sample units for the purpose of pavement inspection. The sample units for inspection shall be $2500 \text{ ft}^2 \pm 1000 \text{ ft}^2$ ($225 \text{ m}^2 \pm 90 \text{ m}^2$).

2.1.8 *pavement section, n*—a contiguous pavement area having uniform construction, maintenance, usage history, and condition. A section should have the same traffic volume and load intensity.

2.1.9 *random sample, n*—a sample unit of the pavement section selected for inspection by random sampling techniques.

3. Summary of Practice

3.1 The pavement is divided into branches that are then divided into sections. Each section is divided into sample units. The type and severity of pavement distress is assessed by visual inspection of the pavement sample units. The quantity of distress is measured as described in Appendix X1 and Appendix X2. The distress data is used to calculate the PCI for each sample unit. The PCI of a pavement section is determined based on the PCI of the inspected sample units within the section.

4. Significance and Use

4.1 The PCI is a numerical indicator that rates the surface condition of the pavement. The PCI provides a measure of the present condition of the pavement based on the distress observed on the surface of the pavement, which also indicates

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Standard PCI™ Rating Scale		Suggested Colors
100	Good	Dark Green
85	Satisfactory	Light Green
70	Fair	Yellow
55	Poor	Light Red
40	Very Poor	Medium Red
25	Serious	Dark Red
10	Failed	Dark Grey
0		

FIG. 1 Pavement Condition Index (PCI), Rating Scale, and Suggested Colors

the structural integrity and surface operational condition (localized roughness and safety). The PCI does not measure structural capacity nor does it provide direct measurement of skid resistance or roughness. It provides an objective and rational basis for determining maintenance and repair needs and priorities. Regular monitoring of the PCI is used to establish the rate of pavement deterioration, which permits early identification of major rehabilitation needs. The PCI can also provide feedback on pavement performance for validation or improvement of current pavement design and maintenance procedures.

4.2 The PCI procedure for interlocking concrete pavements was developed by surveying many sample units. Additional

verification of the accuracy and repeatability of the PCI procedure for interlocking concrete pavements remains to be performed.

5. Apparatus

5.1 *Data Sheets*, or other field recording instruments that record the date, location, branch, section, sample unit size, distress types, severity levels, quantities, and names of surveyors. Example data sheets are shown in Fig. 2 and Fig. 3.

5.2 *Hand Odometer Wheel*, that reads to the nearest 0.1 ft (30 mm).

5.3 *Straightedge or String Line*, 10 ft (3 m).

5.4 *Scale*, 12 in. (300 mm) that reads to 1/16 in. (1 mm). An additional 12 in. (300 mm) ruler or straightedge is needed to measure faulting.

5.5 *Layout Plan*, for network to be inspected.

6. Hazards

6.1 Traffic is a hazard as inspectors may walk on the pavement to perform the condition survey.

7. Sampling and Sample Units

7.1 Identify branches of the pavement with different uses such as roadways and parking on the network layout plan.

7.2 Divide each branch into sections based on the pavement type, construction history, traffic, and condition.

7.3 Divide the pavement sections into sample units.

7.4 Individual sample units to be inspected should be marked or identified in a manner to allow inspectors and quality control personnel to easily locate them on the pavement surface. Paint marks along the edge and sketches with locations connected to physical pavement features are acceptable. It is necessary to be able to accurately relocate the sample units to allow verification of current distress data, to examine changes in condition with time of a particular sample unit, and to enable future inspections of the same sample unit if desired.

7.5 Select the sample units to be inspected. The number of sample units to be inspected may vary from the following: all of the sample units in the section, a number of sample units that provides a 95 % confidence level, or a lesser number.

7.5.1 All sample units in the section may be inspected to determine the average PCI of the section. This is usually precluded for routine management purposes by available manpower, funds, and time. Total sampling, however, is desirable for project analysis to help estimate maintenance and repair quantities.

7.5.2 The minimum number of sample units (n) that must be surveyed within a given section to obtain a statistically adequate estimate (95% confidence) of the PCI of the section is calculated using the following formula and rounding n to the next highest whole number (see Eq 1).

**INTERLOCKING CONCRETE PAVEMENT
ROADS AND PARKING LOTS
CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT**

BRANCH _____ **DATE** _____

SECTION _____ **SAMPLE UNIT** _____

SURVEYED BY _____ **SAMPLE AREA (ft², m²)** _____

DISTRESS NUMBER AND TYPE

- | | | |
|--|--|--|
| 1. Damaged Pavers
2. Depressions
3. Edge Restraint
4. Excessive Joint Width | 5. Faulting
6. Heave
7. Horizontal Creep
8. Joint Sand Loss/Pumping | 9. Missing Pavers
10. Patching
11. Rutting |
|--|--|--|

DISTRESS/ SEVERITY	QUANTITY				TOTAL	DENSITY (%)	DEDUCT VALUE

SKETCH

NOTES: _____

FIG. 2 Blank Interlocking Concrete Pavement Condition Index Sheet

INTERLOCKING CONCRETE PAVEMENT ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT								
BRANCH Mill Street _____					DATE Sept. 8, 2010			
SECTION Main to Maple Streets _____					SAMPLE UNIT All			
SURVEYED BY D. R. Smith					SAMPLE AREA [ft ²] [m ²] 3000 ft ²			
<u>DISTRESS NUMBER AND TYPE</u>								
1. Damaged Pavers 2. Depressions 3. Edge Restraint 4. Excessive Joint Width			5. Faulting 6. Heave 7. Horizontal Creep 8. Joint Sand Loss/Pumping			9. Missing Pavers 10. Patching 11. Rutting		
DISTRESS/ SEVERITY	QUANTITY					TOTAL	DENSITY %	DEDUCT VALUE
1 L	22					22	0.73	0.40
4 M	32	33				65	2.17	12.71
3 L	42	2				44	1.47	2.94
11 L	10					10	0.33	2.96
8 L	7	2				9	0.30	0.09
2 L	1	2	3			6	0.20	2.99
SKETCH 								

NOTES: _____

FIG. 3 Completed Interlocking Concrete Pavement Condition Index Sheet

$$n = Ns^2 / ((e^2/4)(N - 1) + s^2) \quad (1)$$

where:

- e = acceptable error in estimating the section PCI; commonly, $e = \pm 5$ PCI points;
- s = standard deviation of the PCI from one sample unit to another within the section. When performing the initial inspection the standard deviation is assumed to be 10 for interlocking concrete pavements. This assumption should be checked as described below after PCI values are determined. For subsequent inspections, the standard deviation from the preceding inspection should be used to determine n ; and,
- N = total number of sample units in the section.

7.5.2.1 If obtaining the 95% confidence level is critical, the adequacy of the number of sample units surveyed must be confirmed. The number of sample units was estimated based on an assumed standard deviation. Calculate the actual standard deviation (s) as follows (see Eq 2):

$$s = \left(\sum_{i=1}^n (PCI_i - PCI_s)^2 / (n - 1) \right)^{\frac{1}{2}} \quad (2)$$

where:

- PCI_i = PCI of surveyed sample units i ,
- PCI_s = PCI of section (mean PCI of surveyed sample units), and
- n = total number of sample units surveyed.

7.5.2.2 Calculate the revised minimum number of sample units (Eq 1) to be surveyed using the calculated standard deviation (Eq 2). If the revised number of sample units to be surveyed is greater than the number of sample units already surveyed, select and survey more random sample units. These sample units should be spaced evenly across the section. Repeat the process of checking the revised number of sample units and surveying more random sample units until the total number of sample units surveyed equals or exceeds the minimum required sample units (n) in Eq 1, using the actual total sample standard deviation.

7.5.3 Once the number of sample units to be inspected has been determined, compute the spacing interval of the units using systematic random sampling. Samples are spaced equally throughout the section with the first sample selected at random. The spacing interval (i) of the units to be sampled is calculated by the following formula rounded to the next lowest whole number:

$$I = N/n \quad (3)$$

where:

N = total number of sample units in the section, and

n = number of sample units to be inspected.

The first sample unit to be inspected is selected at random from sample units 1 through I . The sample units within a section that are successive increments of the interval i after the first randomly selected unit also are inspected.

7.6 A reduced sampling rate than the above mentioned 95% confidence level can be used based on the condition survey objective. The following table provides an example used by some agencies for selecting the number of sample units to be inspected for other than project analysis:

Given	Survey
1 to 5 sample units	1 sample unit
6 to 10 sample units	2 sample units
11 to 15 sample units	3 sample units
16 to 40 sample units	4 sample units
over 40 sample units	10%

7.7 Additional sample units only are to be inspected when non-representative distresses are observed. The location of these sample units is determined during the survey by the inspector.

8. Inspection Procedure

8.1 The definitions and guidelines for quantifying distresses for PCI determination are given in Appendix X1. Using this test method, inspectors should identify distress types accurately 95% of the time. Linear measurements should be considered accurate when they are within 10% if remeasured, and area measurements should be considered accurate when they are within 20% if remeasured. Distress severities that one determines based on ride quality are considered subjective.

8.2 Individually inspect each sample unit chosen. Sketch the sample unit, including orientation. Record the branch and section number and the number and type of the sample unit (random or additional). Record the sample unit size measured with the hand odometer. Conduct the distress inspection by walking over the sample unit being surveyed, measuring the

quantity of each severity level of every distress type present, and recording the data. Each distress must correspond in type and severity to that described in Appendix X1. The method of measurement is included with each distress description. This procedure should be repeated for each sample unit to be inspected. An example of a blank Interlocking Concrete Pavement Condition Survey Data Sheet for Sample Unit is included in Fig. 1 and a completed data sheet is shown in Fig. 2.

9. Calculation of PCI

9.1 Add up the total quantity of each distress type at each severity level, and record them in the “Total Severities” section. The units for the quantities may be either in square feet (square meters), linear feet (meters), or number of occurrences, depending on the distress type.

9.2 Divide the total quantity of each distress type at each severity level by the total area of the sample unit and multiply by 100 to obtain the percent density of each distress type and severity.

9.3 Determine the deduct value (DV) for each distress type and severity level combination from the distress deduct value curves in Appendix X3.

9.4 Determine the maximum corrected deduct value (CDV). The following procedure must be used to determine the maximum CDV.

9.4.1 If none or only one individual deduct value is greater than two, the total value is used in place of the maximum CDV in determining the PCI; otherwise, maximum CDV must be determined as follows.

9.4.2 List the individual deduct values in descending order. Determine the allowable number of deducts, m , using the following formula (see Eq 4):

$$m = 1 + (9/98)(100 - HDV) \leq 10 \quad (4)$$

where:

m = allowable number of deducts including fractions (must be ≤ 10),

HDV = highest individual deduct value.

9.4.3 The number of individual deduct values is reduced to the m largest deduct values, including the fractional part. If less than m deduct values are available, all of the deduct values are used.

9.4.4 Determine maximum CDV iteratively.

9.4.4.1 Determine total deduct value by summing individual deduct values. The total deduct value is obtained by adding the individual deduct values.

9.4.4.2 Determine q as the number of deducts with a value greater than 2.0.

9.4.4.3 Determine the CDV from total deduct value and q by looking up the appropriate correction curve (Appendix X3).

9.4.4.4 Reduce the smallest individual deduct value greater than 2.0 to 2.0 and repeat until $q = 1$. The maximum CDV is the largest of the CDVs.

9.5 Calculate PCI by subtracting the maximum CDV from 100: $PCI = 100 - \max \text{CDV}$.

10. Determination of Section PCI

10.1 If every sample unit is surveyed then the PCI of the section is the average of the PCIs of the sample units. If additional sample units are surveyed then a weighted average is used as follows:

$$PCI_S = (N - A)(PCI_R)/N + A(PCI_A)/N \quad (5)$$

where:

PCI_S = weighted PCI of the section,
 N = total number of sample units in the section,
 A = number of additional sample units,
 PCI_R = mean PCI of randomly selected sample units, and

PCI_A = mean PCI of additional selected sample units.

10.2 Determine the overall condition rating of the section by using the section PCI and the condition rating scale.

11. Report

11.1 Develop a summary report for each section. A summary lists section location, size, total number of sample units, the sample units inspected, the PCIs obtained, the average PCI for the section, and the section condition rating. Additional reporting and documentation may be developed at the discretion of the user.

APPENDIXES

(Nonmandatory Information)

X1. DISTRESS TYPES AND SEVERITIES

X1.1 Damaged Pavers (1)

X1.1.1 *Description:* Damaged pavers describe the condition of the pavers. Unit damage includes paver distresses such as a crack, chip, or spall. Cracks appear as thin jagged lines generally less than 1/8 in. (3 mm wide). Chips and spalls appear at portions of the edges and/or surface. Damage would be indicative of load related damage such as inadequate support causing shear breakage, etc., or weathering.

X1.1.2 *Identification:* Damaged pavers would include paver distresses such as a crack, chip or spall. Cracked pavers with little to no opening will not affect ride quality or performance.

X1.1.3 *How to Measure:* Damaged pavers are measured in square feet (meters) of surface area. Random isolated pavers



FIG. X1.1 Low Severity Damaged Pavers



FIG. X1.2 Medium Severity Damaged Pavers

that are only cracked with little or no opening are not recorded. The severity is evaluated by degree of distress.

X1.1.4 Severity Levels:

Severity Level	Description
Low	One or two cracks with no separation, chips or spalls in the pavers
Medium	Advanced cracking with no separation, spalling, or chips in the pavers but pavers are not disintegrated
High	Pavers are in cracked into multiple pieces or are disintegrated from cracks, chips and/or spalls



FIG. X1.3 High Severity Damaged Pavers



FIG. X1.4 Low Severity Depression

X1.2 Depressions (2)

X1.2.1 Description: Depressions are areas of the pavement surface that have elevations that are lower than the surrounding areas. Depressions are typically not load-related and caused by settlement of the underlying subgrade or granular base. Settlement is common over utility cuts and adjacent to road hardware. Depressions can cause roughness in the pavement, and when filled with water, can cause hydroplaning of vehicles.

X1.2.2 Identification: Visual examination is not always a reliable technique for detection of depressions, especially for low severity depressions. The most reliable method to identify depressions is to utilize a 10 ft (3 m) straight edge. Changes in shades of color on a pavement surface can give the impression of differential elevation where none exists. The apparent depth of differential elevation is often exaggerated by shadows in the early morning and late afternoon, as well as the chamfer on the paver edges. Standing water and stains can be used to visually identify a depression, however, the boundaries and depth should be established using the straight edge. Be careful to distinguish heaves from depressions.

X1.2.3 How to Measure: Depressions are measured in square feet (meters) of surface area. The maximum depth of depression defines the severity. Depressions larger than 10 ft (3 m) across should be measured with a string line.

X1.2.4 Severity Levels:

Severity Level	Maximum Depth of Depression
Low	3/16 in. to 1/2 in. (5 – 13 mm)
Medium	1/2 to 1 in. (13 – 25 mm)
High	> 1 in. (25 mm)



FIG. X1.5 Medium Severity Depression