

Measurement of Pavement Condition Index-PCI



Sri Atmaja P. Rosyidi, Ph.D., P.Eng.

Associate Professor

Universitas Muhammadiyah Yogyakarta

Outlines:

- Theoretical Background
- Procedure of Data Analysis and PCI Calculation
- Case Study

References:

- ASTM D6433

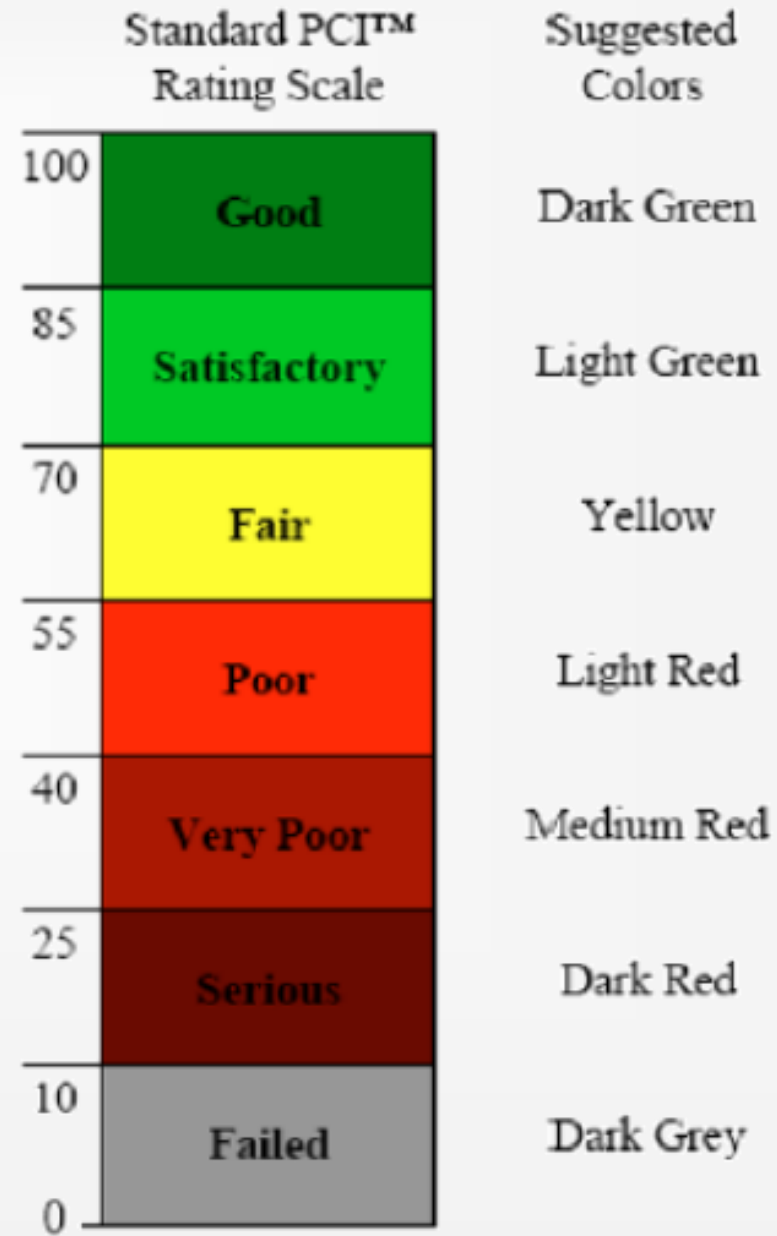
Theoretical Background:

- Pavement Condition Index

- The Pavement Condition Index (PCI) is a method for quantifying pavement condition through visual surveys.
- The PCI for roads and parking lots was developed by the U.S. Army Corps of Engineers.
- Terminology:
 - *pavement condition index* (PCI)—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.
 - *pavement condition rating*—a verbal description of pavement condition as a function of the PCI value that varies from “failed” to “excellent” as shown in below.

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

ASTM6433



... Cont'

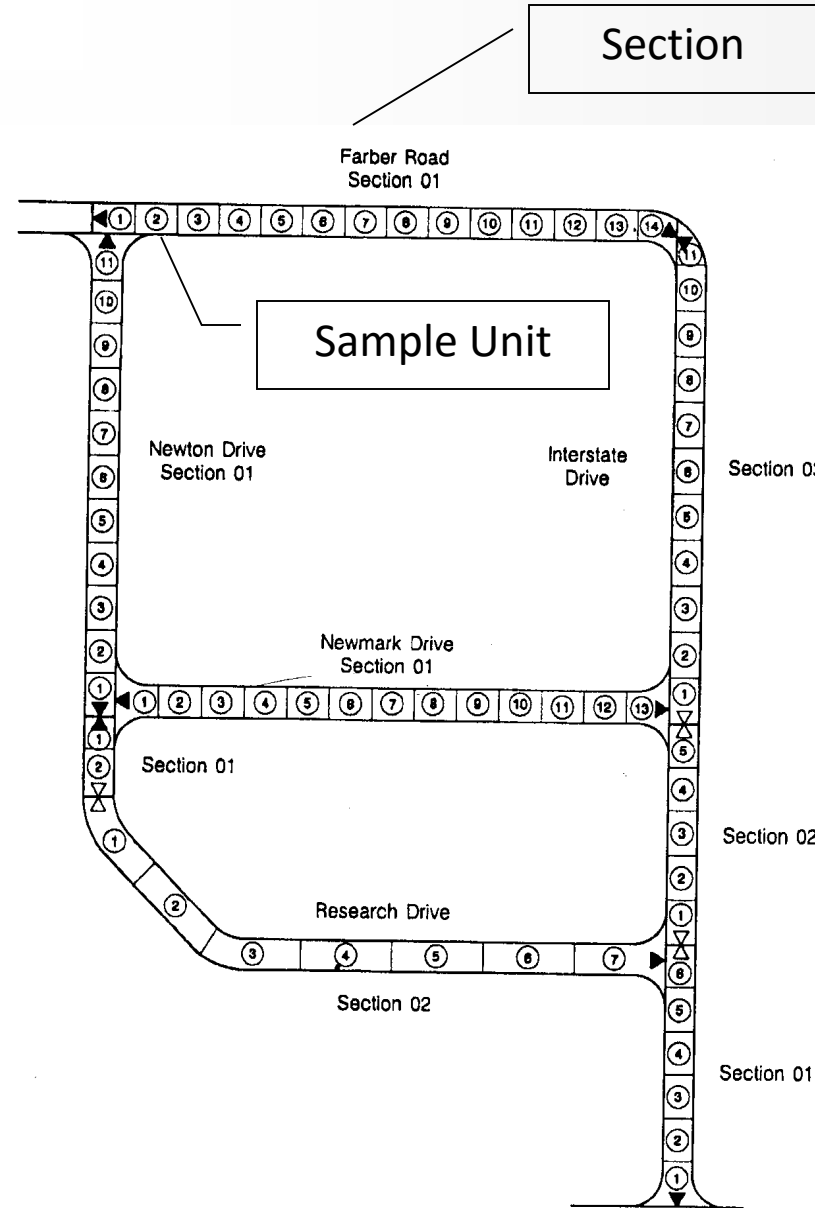
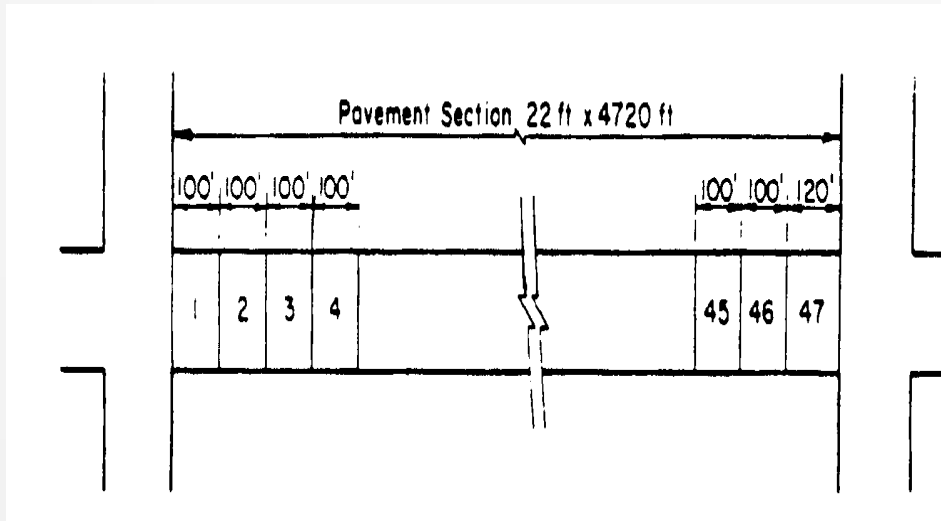
- *pavement distress*—external indicators of pavement deterioration caused by loading, environmental factors, construction deficiencies, or a combination thereof.
 - Typical distresses are cracks, rutting, and weathering of the pavement surface. Distress types and severity levels in ASTM D6433 detailed in Appendix X1 for AC, and Appendix X2 for PCC pavements must be used to obtain an accurate PCI value.
- 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 the structural integrity and surface operational condition (localized roughness and safety). The PCI cannot 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.
- Continuous monitoring of the PCI is used to establish the rate of pavement deterioration, which permits early identification of major rehabilitation needs. The PCI provides feedback on pavement performance for validation or improvement of current pavement design and maintenance procedures.

Sampling and Sample Units

- Identify branches of the pavement with different uses such as roadways and parking on the network layout plan.
- Divide each branch into sections based on the pavements design, construction history, traffic, and condition.
- Divide the pavement sections into sample units.
 - If the pavement slabs in PCC have joint spacing greater than 25 ft (8 m) subdivide each slab into imaginary slabs. The imaginary slabs all should be less than or equal to 25 ft (8 m) in length, and the imaginary joints dividing the slabs are assumed to be in perfect condition. This is needed because the deduct values developed for jointed concrete slabs are less than or equal to 25 ft (8 m).
- 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.

Terminology

Pavement Sample Unit—a subdivision of a pavement section that has a standard size range: 2500 SF ~ 1000 SF



Sample Units

			Sample Size, SF					
Pavement Section Length	Lane Width	Area, SF	1500	2500	3500			
	Divided Rd		Number of Samples			Sample Length, FT		
5280	10	52,800	35	21	15	150	250	350
5280	12	63,360	42	25	18	125	208	292
	Undivided Rd							
5280	25	132,000	88	53	38	60	100	140
5280	30	158,400	106	63	45	50	83	117
500	30	15,000	10	6	4	50	83	117

Sampling and Sample Units

Select the sample units to be inspected. The number of sample units to be inspected may vary from the following:

a number of sample units that provides a 95 % confidence level

All sample units in the section may be inspected to determine the average PCI of the section

Sampling and Sample Units Network Level

The minimum number of sample units (n) that must be surveyed within a given section

No. of Sample Units	No. of Units to be inspected
1 to 5	1
6 to 10	2
11 to 15	3
16 to 40	4
Over 40	10% Rounded up

- 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.
 - 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.
 - 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:

$$n = Ns^2 / \left(\frac{e^2}{4} (N - 1) + s^2 \right)$$

- e = acceptable error in estimating the section PCI; commonly, $e = 65$ 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 AC pavements and 15 for PCC 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.

- 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:

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

- 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.
- 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 additional 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 additional 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.

Calculation Procedure of PCI for Asphalt Concrete (AC) Pavement

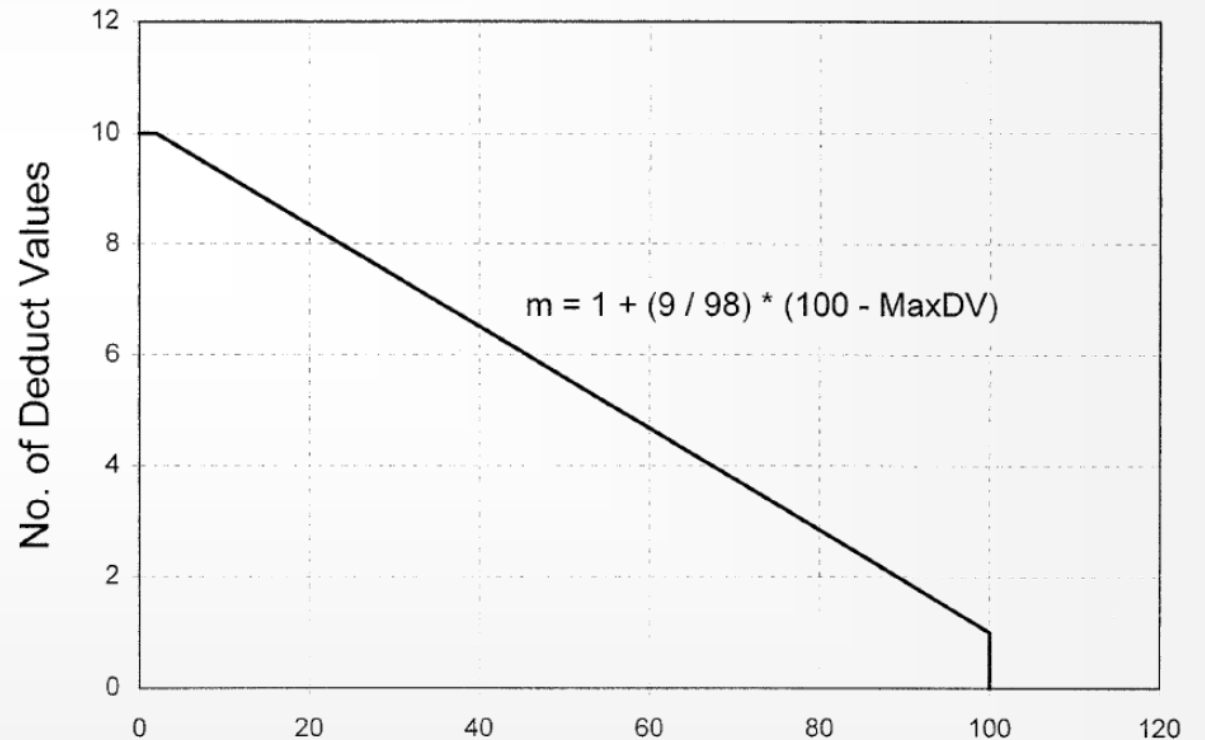
1. *Inspection Procedure* - The definitions and guidelines for quantifying distresses for PCI determination are given in Appendix (ASTM D6433) for AC pavements. Using this test method, inspectors should identify distress types accurately 95 % of the time. Linear measurements should be considered accurate 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.
2. 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.
3. Divide the total quantity of each distress type at each severity level from “**Point 2**” by the total area of the sample unit and multiply by 100 to obtain the percent density of each distress type and severity.
4. Determine the deduct value (DV) for each distress type and severity level combination from the distress deduct value curves.
5. Determine the maximum corrected deduct value (CDV). The procedure for determining maximum CDV from individual DVs is identical for both AC and PCC pavement types.

6. The following procedure must be used to determine the maximum CDV.
- 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 using the procedure described below.
 - List the individual deduct values in descending order.
 - Determine the allowable number of deducts, m , using the following formula:

$$m = 1 + \left(\frac{9}{98}\right)(100 - HDV) \leq 10$$

where:

m = allowable number of deducts including fractions (must be less than or equal to ten), and
HDV = highest individual deduct value.



Highest Deduct Value

FIG. 5 Adjustment of Number of Deduct Values

- 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.
- Determine maximum CDV iteratively:
 - Determine total deduct value by summing individual deduct values. The total deduct value is obtained by adding the individual deduct values.
 - Determine q as the number of deducts with a value greater than 2.0.
 - Determine the CDV from total deduct value and q by looking up the appropriate correction curve for AC pavements
 - Reduce the smallest individual deduct value greater than 2.0 to 2.0 and repeat calculation until $q = 1$.
 - Maximum CDV is the largest of the CDVs.
- Calculate PCI by subtracting the maximum CDV from 100, $PCI = 100 - \text{max CDV}$.

Calculation of PCI for Portland Cement Concrete (PCC) Pavement

1. For each unique combination of distress type and severity level, add up the total number of slabs in which they occur.
2. Divide the number of slabs from 2 by the total number of slabs in the sample unit and multiply by 100 to obtain the percent density of each distress type and severity combination.
3. Determine the deduct values for each distress type severity level combination using the corresponding deduct curve (Appendix ASTM).
4. Determine PCI by following the procedures using the correction curve for PCC pavements (ASTM Appendix) in place of the correction curve for AC pavements.

Case Study

- For example:

$$\text{Density} = \text{Total Quantity} / \text{Total Area} = (13) / (25 \times 100) = 0,0052 = 0,52 \%$$

$$\text{Total Severity} = (1 \times 5) + (1 \times 4) + (1 \times 4) = 13$$



FIG. X1.1 Low-Severity Alligator Cracking



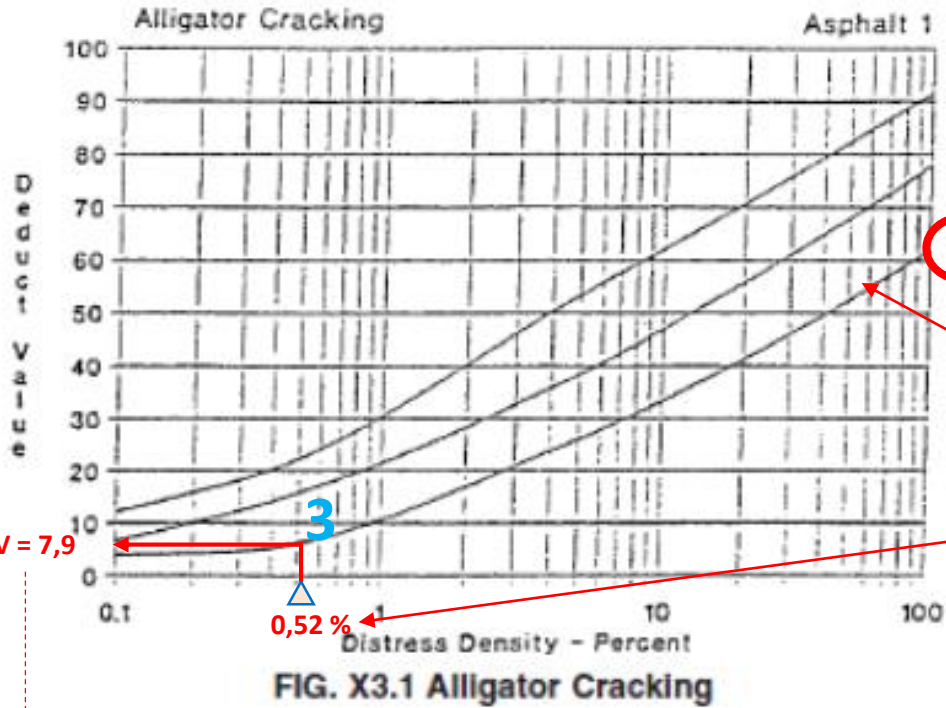
FIG. X1.3 High-Severity Alligator Cracking

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT								SKETCH:		
BRANCH <u>SPRINGFIELD</u> SECTION <u>001</u> SAMPLE UNIT <u>1</u>										
SURVEYED BY <u>KAK</u> DATE <u>10 Jul 93</u> SAMPLE AREA <u>2500 sq ft</u>										
1. Alligator Cracking		6. Depression		11. Patching & Util Cut Patching		16. Shoving				
2. Bleeding		7. Edge Cracking		12. Polished Aggregate		17. Slippage Cracking				
3. Block Cracking		8. Jt. Reflection Cracking		13. Potholes		18. Swell				
4. Bumps and Sags		9. Lane/Shoulder Drop Off		14. Railroad Crossing		19. Weathering/Ravelling				
5. Corrugation		10. Long & Trans Cracking		15. Rutting						
DISTRESS SEVERITY	QUANTITY							TOTAL	DENSITY %	DEDUCT VALUE
1L	1x5	1x4	1x4					13	0.52	7.9
1H	1x8	1x6						14	0.56	23.4
7L	32	15	18	24	41			130	5.20	7.5
8M	20	15	35	27	23	10	13	143	5.72	25.1
11H	3x4	2x5						22	0.88	17.9
13L	1							1	0.04	11.2
15L	4	9	8					21	0.84	6.9
19L	250							250	10.0	5.3

How to Measure—Alligator cracking is measured in square meters (square feet) of surface area. In this case – alligator cracking distress at each severity level is summed and entered in the “Total Severity” section as 13 ft² (1.2 m²) of low severity and 14 ft² (1.3 m²) of high severity.

Case Study

- For example:



ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT								SKETCH:		
BRANCH <u>SPRINGFIELD</u> SECTION <u>001</u> SAMPLE UNIT <u>1</u>										
SURVEYED BY <u>KAK</u> DATE <u>10 Jul 93</u> SAMPLE AREA <u>2500 sq</u>										
1. Alligator Cracking		6. Depression		11. Patching & Util Cut Patching		16. Shoving				
2. Bleeding		7. Edge Cracking		12. Polished Aggregate		17. Slippage Cracking				
3. Block Cracking		8. Jt. Reflection Cracking		13. Potholes		18. Swell				
4. Bumps and Sags		9. Lane/Shoulder Drop Off		14. Railroad Crossing		19. Weathering/Ravelling				
5. Corrugation		10. Long & Trans Cracking		15. Rutting						
DISTRESS SEVERITY	QUANTITY							TOTAL	DENSITY %	DEDUCT VALUE
1L	1x5	1x4	1x4					13	0.52	7.9
1H	1x8	1x6						14	0.56	25.1
7L	32	15	18	24	41			130	5.20	7.5
8M	20	15	35	27	23	10	13	143	5.72	25.1
11H	3x4	2x5						22	0.88	17.9
13L	1							1	0.04	11.2
15L	4	9	8					21	0.84	6.9
19L	250							250	10.0	5.3

How to Obtain—Determine the deduct value (DV) for each distress type and severity level combination from the distress deduct value curves in Appendix X3 – ASTM D6433.

Adjustment of Number of Deduct Values

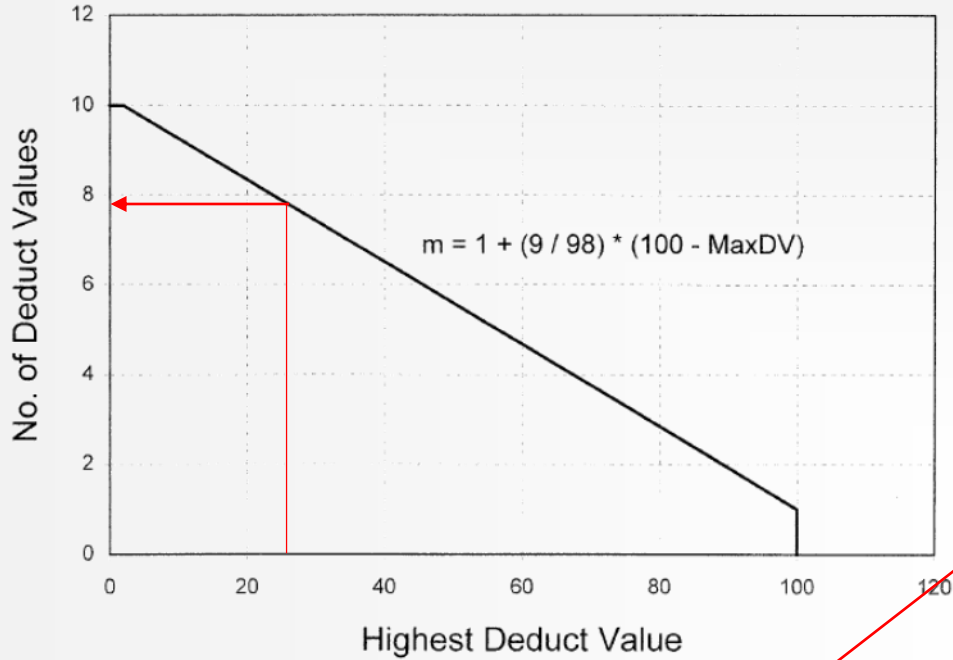


FIG. 5 Adjustment of Number of Deduct Values

$m = 1 + (9/98)(100 - 25.1) = 7.9 < 8$
 Use highest 7 deducts and 0.9 of eighth deduct.
 $0.9 \times 5.3 = 4.8$

Note: If less than m deduct values are available, all of the deduct values are used.

#	1 st	2 nd	3 rd	4 th	5 th	6 th	7 th	8 th	Total	q	CDV
1	25.1	23.4	17.9	11.2	7.9	7.5	6.9	4.8	104.7	8	51.0
2	25.1	23.4	17.9	11.2	7.9	7.5	6.9	2	101.9	7	50.0
3	25.1	23.4	17.9	11.2	7.9	7.5	2	2	96.0	6	46.0
4	25.1	23.4	17.9	11.2	7.9	2	2	2	90.5	5	47.0
5	25.1	23.4	17.9	11.2	2	2	2	2	84.6	4	48.0
6	25.1	23.4	17.9	2	2	2	2	2	75.4	3	48.0
7	25.1	23.4	2	2	2	2	2	2	59.5	2	44.0
8	25.1	2	2	2	2	2	2	2	38.1	1	38.0
9											
10											

Corrected Deduct Value:

- Determine the **allowable number of deducts**, m , from graph above, or using the following formula:

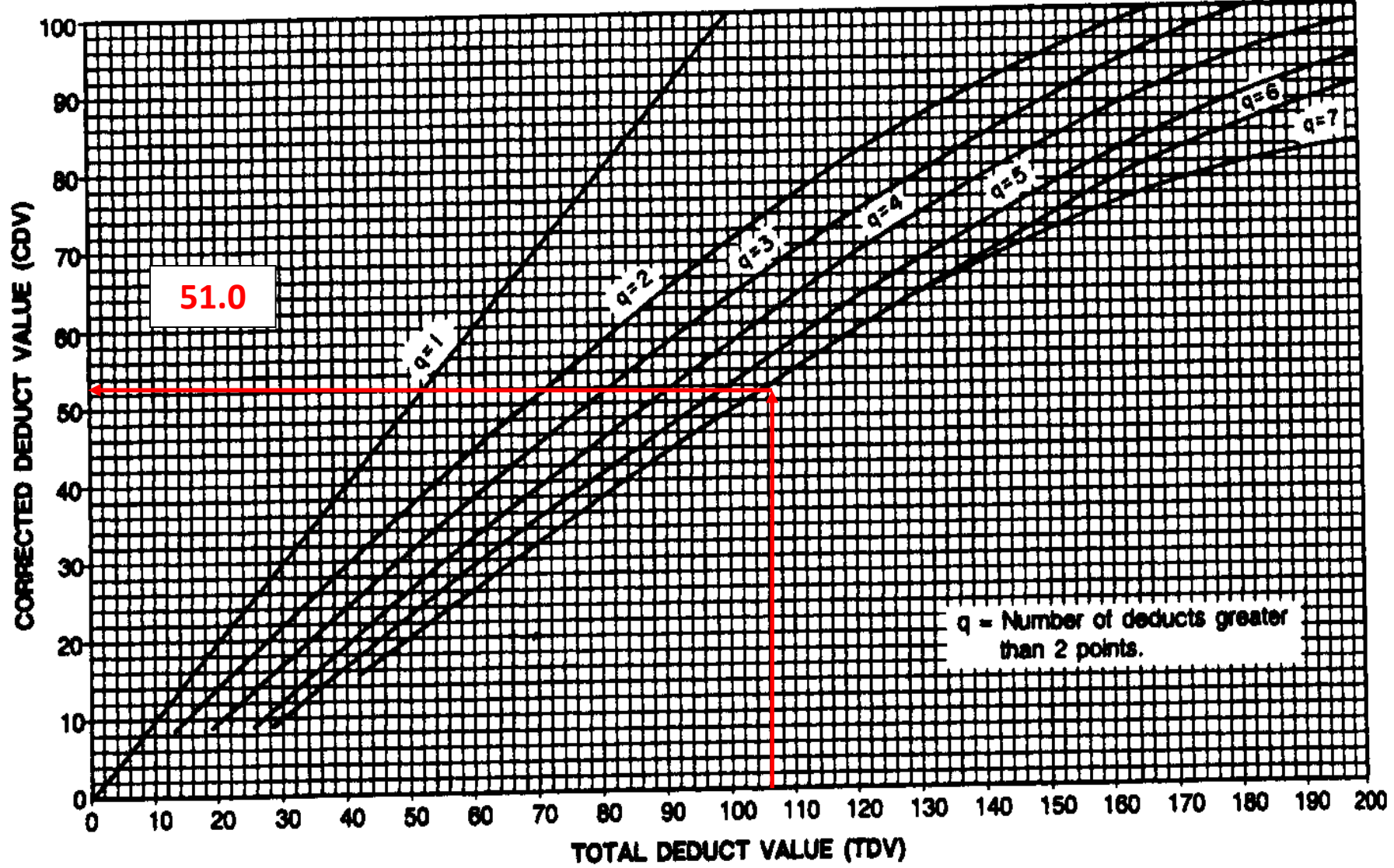
$$m = 1 + (9/98) * (100 - \text{Max DV}) \leq 10$$

$$m = 1 + (9/98) * (100 - 25.1) = 7.879 \approx 7.9 \leq 10$$

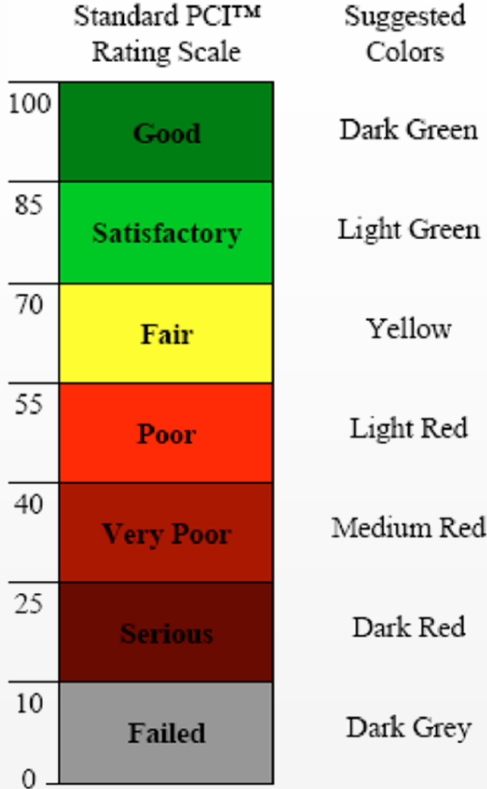
It means we use the allowable number of deducts is 7.9

→ **7 deducts** and **8th deduct** is formulated as 0.9 of 8th deduct value ($0.9 \times 5.3 = 4.8$)

ROADS AND PARKING LOTS: ASPHALT



Maximum CDV and PCI



$m = 1 + (9/98)(100 - 25.1) = 7.9 < 8$
 Use highest 7 deducts and 0.9 of eighth deduct.
 $0.9 \times 5.3 = 4.8$

#	Deduct Values									Total	q	CDV
1	25.1	23.4	17.9	11.2	7.9	7.5	6.9	4.8		104.7	8	51.0
2	25.1	23.4	17.9	11.2	7.9	7.5	6.9	2		101.9	7	50.0
3	25.1	23.4	17.9	11.2	7.9	7.5	2	2		96.0	6	46.0
4	25.1	23.4	17.9	11.2	7.9	2	2	2		90.5	5	47.0
5	25.1	23.4	17.9	11.2	2	2	2	2		84.6	4	48.0
6	25.1	23.4	17.9	2	2	2	2	2		75.4	3	48.0
7	25.1	23.4	2	2	2	2	2	2		59.5	2	44.0
8	25.1	2	2	2	2	2	2	2		38.1	1	38.0
9												
10												

PCI = 100 - Max CDV
= 100 - 51 = 49

For the 1st Sample Unit

Max CDV = 51
 PCI = 100 - Max CDV = 49

Determination of Section PCI

If all surveyed sample units are equal in size, the Section PCI is the average of the sample unit PCI.

If all surveyed sample units are not equal in size, then the PCI of the section (PCI_s) is calculated as the area weighted PCI of the surveyed sample units (PCI_r) using equation 5:

$$PCI_s = \overline{PCI_r} = \frac{\sum_{i=1}^R (PCI_{ri} * A_{ri})}{\sum_{i=1}^n A_{ri}}$$

Determination of Section PCI

Where:

PCI_s = PCI of the pavement section

PCI_r = area weighted PCI of randomly surveyed sample units,

PCI_{ri} = PCI of random sample unit i ,

A_{ri} = area of random sample unit i ,

R = Total number of inspected random sample units

Question

