AD-A057 148 CONSTRUCTION ENGINEERING RESEARCH LAB (ARMY) CHAMPAI--ETC F/G 13/2
DEVELOPMENT OF A PAVEMENT CONDITION INDEX FOR ROADS AND STREETS--ETC(U)
MAY 78 M Y SHAHIN, M I DARTER, S D KOHN

UNCLASSIFIED CERL-IR-M-232 NL

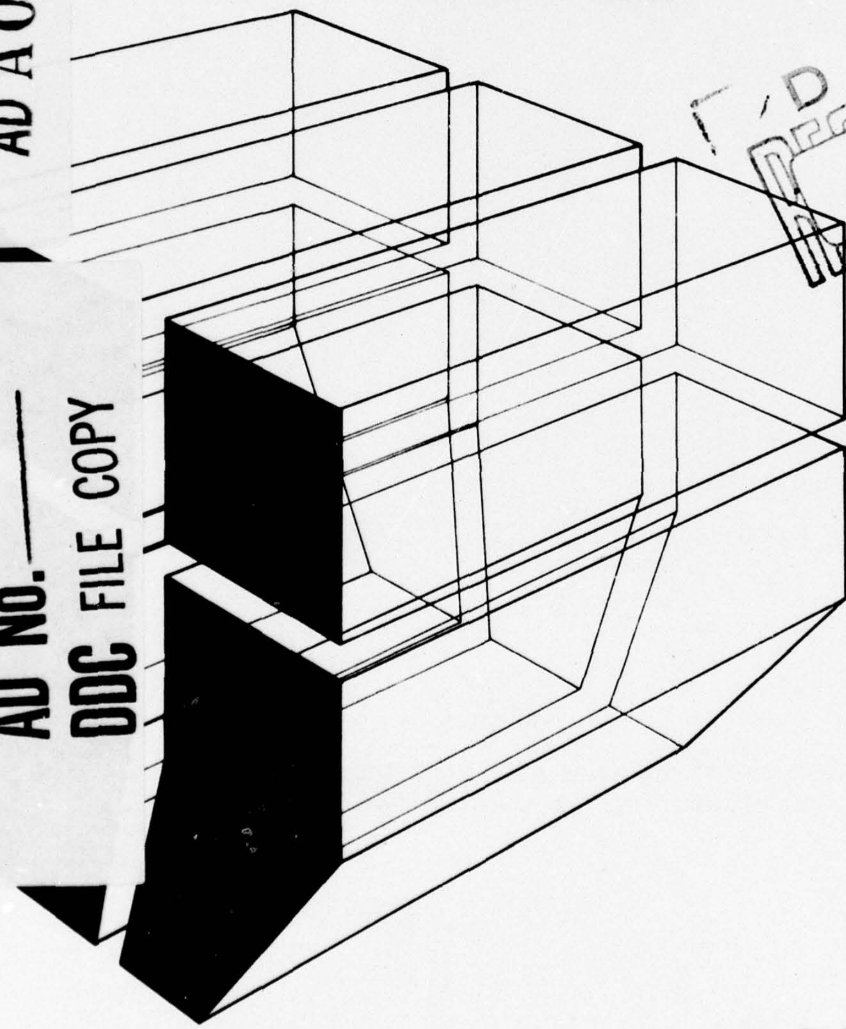
1 OF 3
AD
A057 148

construction
engineering
research
laboratory

INTERIM REPORT M-232
May 1978

DEVELOPMENT OF A PAVEMENT CONDITION INDEX FOR ROADS AND STREETS

LEVEL II



by
M. Y. Shahin
M. I. Darter
S. D. Kohn

CERL

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER: CERL-IR-M-232	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle): DEVELOPMENT OF A PAVEMENT CONDITION INDEX FOR ROADS AND STREETS.		5. TYPE OF REPORT & PERIOD COVERED: INTERIM rept.
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): [redacted] Y. Shahin, M. I. Darter, S. D. Kohn (Mohamed, Michael, Stone)		8. CONTRACT OR GRANT NUMBER(s): 112p.
9. PERFORMING ORGANIZATION NAME AND ADDRESS: CONSTRUCTION ENGINEERING RESEARCH LABORATORY, P.O. Box 4005, Champaign, IL 61820		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: FY77 OM&A Program 728012.14
11. CONTROLLING OFFICE NAME AND ADDRESS		12. REPORT DATE: May [redacted]78
		13. NUMBER OF PAGES: 111
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report): Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Copies are obtainable from National Technical Information Service
Springfield, VA 22151

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

pavement condition index
concrete
asphalt surface

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report describes the preliminary development of a pavement condition index (PCI) for rating jointed concrete and asphalt-surfaced roads and streets. The PCI, which measures pavement structural integrity and surface operational conditions, is calculated by measuring pavement distress types, severities, and densities obtained during pavement inspection. The PCI procedure presented in this report will be further field-tested and verified.

405 279

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE 78 08 07 007 UNCLASSIFIED

FOREWORD

This work was performed for the Directorate of Facilities Engineering, Office of the Chief of Engineers (OCE), as part of the FY77 OM&A Program 728012.14, Facilities Investigation Studies, "Automated Pavement Maintenance and Repair Management System." The OCE Technical Monitor is Mr. L. H. Price.

The work was conducted by the Engineering and Materials Division (EM), U.S. Army Construction Engineering Research Laboratory (CERL). The CERL Principal Investigator is Dr. M. Y. Shahin.

The contributions of Ms. F. M. Rozanski of CERL, who assisted in writing this report, are acknowledged.

Dr. G. R. Williamson is Chief of EM. COL J. E. Hays is Commander and Director of CERL, and Dr. L. R. Shaffer is Technical Director.

CONTENTS

FIGURES

TABLES

Number **Page**

DEVELOPMENT OF A PAVEMENT CONDITION INDEX FOR ROADS AND STREETS

1 INTRODUCTION

Background

The U.S. Army Construction Engineering Research Laboratory (CERL) is developing a computerized system to help Facilities Engineering personnel manage the maintenance and repair of pavements.[1-3] The system, called PAVER, includes (1) a pavement inspection procedure, (2) a set of input forms for entering relevant pavement information into a computerized data base, (3) a set of report outputs for retrieving information, and (4) a computer interactive program for performing economic analysis between various maintenance and repair alternatives.

To further help the pavement engineer evaluate pavement and determine M&R requirements, a need was identified for developing a method to determine a pavement condition index (PCI) based on data gathered from the pavement inspection.

CERL has developed a method for the Air Force for determining the PCI for airfield pavements [4,5] which has been successfully field-tested by several Air Force Major Commands and is expected to be formally adopted. The development of PCI for road and streets is partially based on experience gained in developing the PCI for airfields, [6,7] which provided valuable input for improving distress definitions for roads and streets.

Objective

The objective of this study is to develop a PCI for pavement condition rating of roads and streets, which will provide the pavement engineer with:

1. A standard method for condition rating of pavement sections in terms of structural integrity and surface operational condition.

2. A method for comparing the condition of different pavement sections on the installation in order to determine maintenance and repair (M&R) needs and priorities.

3. A feedback on pavement performance (condition history) determined from accumulation of PCI data for many years. Knowledge of pavement performance and previously applied M&R will assist the pavement engineer in validating and/or improving M&R policies.

Approach

This study was accomplished by the following steps:

1. Selecting a pavement condition index scale and the corresponding condition ratings

2. Defining distress types and severities for asphalt- and concrete-surfaced roads

3. Developing deduct curves for determining the deduct values for each combination of distress type, severity, and amount

4. Developing correction curves for correcting the sum of deduct values when there is more than one combination of distress type and severity

5. Determining the PCI as the maximum possible score minus the corrected sum of the deduct values

---

[1] D. W. Rand, *Pavement Evaluation III* (Maine Department of Transportation, Materials and Research Division, August 1973), pp 73-78.

[2] M. Y. Shahin, M. I. Darter, F. M. Rozanski, and R. Stark, *Development of an Installation Surfaced Area Maintenance and Repair Management System*, Technical Information Pamphlet C-49/ADA017328 (Construction Engineering Research Laboratory [CERL], September 1975).

[3] M. Y. Shahin, M. I. Darter, and F. M. Rozanski, *Pavement Inspection Reference Manual*, Technical Information Pamphlet C-48/ADA017329 (CERL, September 1975).

[4] M. Y. Shahin and F. M. Rozanski, *Automated Pavement Maintenance and Repair Management System*, Interim Report C-79/ADA042582 (CERL, June 1977).

[5] M. Y. Shahin, M. I. Darter, and S. D. Kohn, *Development of a Pavement Maintenance Management System, Vol I, Airfield Pavement Condition Rating*, Report Number AFCEC-TR-76-27 (Air Force Civil Engineering Center [AFCEC], November 1976).

[6] M. Y. Shahin, M. I. Darter, and S. D. Kohn, *Development of a Pavement Maintenance Management System, Vol II, Airfield Pavement Distress Identification Manual*, Report No. AFCEC-TR-76-27 (AFCEC, November 1976).

[7] D. A. Voss, R. L. Terrel, F. Finn, and D. Hovey, *A Pavement Evaluation System for Maintenance Management*, a paper prepared for presentation at the Western Summer Meeting, Highway Research Board, Olympia, Washington (August 1973).

6. Field testing, revising, and improving the distress definitions, deduct curves, and correction curves so that the distress definitions represent actual field conditions and so that the PCI represents the collective judgment of experienced pavement engineers regarding the pavement structural integrity and surface operational condition.

Scope

This report describes the preliminary development of the pavement condition rating procedure for roads and streets. Since the procedure has been field-tested only once, further tests will be required before it is finalized. During that time, the procedure will be extended to be applicable for surfaced parking lots, storage areas, and hard stands.

Mode of Technology Transfer

Technology transfer will be by incorporation into the computerized PAVER system in FY78 and incorporation into an Army Technical Manual in FY79.

2 CONCEPTS AND THEORY

Introduction

Several factors affect a pavement's condition: (1) structural integrity (the ability of a pavement to hold together under current traffic), (2) structural capacity (the maximum load a pavement can carry), (3) roughness, and (4) skid resistance/hydroplaning potential.

To accurately reflect the pavement's condition, a condition index should consider all of these factors. Direct measurement of these condition indicators requires expensive equipment and highly trained personnel. Indirect measurement, however, can be accomplished by measuring observable distress in the pavement. One advantage of this method is that very little equipment is required (a measuring wheel and a straight edge). In addition, if the distress types are carefully defined and described in an inspection manual, nearly anyone can collect the needed data with a minimum of training. Another advantage is that the observation and recording of existing distress provides the principal information needed for determining maintenance and repair requirements. A pavement condition index based on existing distress is therefore closely related to the amount of work required to repair the pavement.

Figures 1 and 2 show how observable pavement distresses relate to condition indicators in concrete and asphalt pavements, respectively. Structural capacity and localized roughness can be measured by observing certain types of distresses, such as rutting and cracking. Skid resistance/hydroplaning is inferred from distresses such as bleeding and polished aggregate.

The following text describes the theory used to develop the PCI based on observable pavement distress.

Mathematical Expression of the PCI

The degree of pavement deterioration is a function of:

1. Types of distress

2. Severity of distress, such as spalling of cracks or depth of ruts

3. Amount or density of distress, which can be expressed as a percentage of the total pavement area.

Each of these distress characteristics has a significant effect on how the overall amount of physical pavement deterioration is determined. If any of these three characteristics is ignored, developing a meaningful condition index will be difficult.

Because there are several types of distress, several possible degrees of severity for each type, and a wide range of amount or density for each type, combining the effects of these three characteristics into one index is the major problem in deriving a condition index. After evaluating current methods,[8-12] a model for expressing PCI was developed. The model is based on

---

[8] M. Y. Shahin and F. M. Rozanski, *Automated Pavement Maintenance and Repair Management System*, Technical Information Pamphlet C-79/ADA042582 (CERL, June 1977).

[9] M. Y. Shahin, M. I. Darter, and S. D. Kohn, *Development of a Pavement Maintenance Management System, Vol I, Airfield Pavement Condition Rating*, Report Number AFCEC-TR-76-27 (AFCEC, November 1976).

[10] M. Y. Shahin, M. I. Darter, and S. D. Kohn, *Development of a Pavement Maintenance Management System, Vol II, Airfield Pavement Distress Identification Manual*, Report No. AFCEC-TR-76-27 (AFCEC, November 1976).

[11] D. A. Voss, R. L. Terrel, F. Finn, and D. Hovey, *A Pavement Evaluation System for Maintenance Management*, a paper prepared for presentation at the Western Summer Meeting, Highway Research Board, Olympia, Washington (August 1973).

[12] R. V. LeClerc and T. R. Marshall, *A Pavement Condition Rating System and Its Use*, Symposium on Pavement Evaluation, AAPT Proceedings (1969).

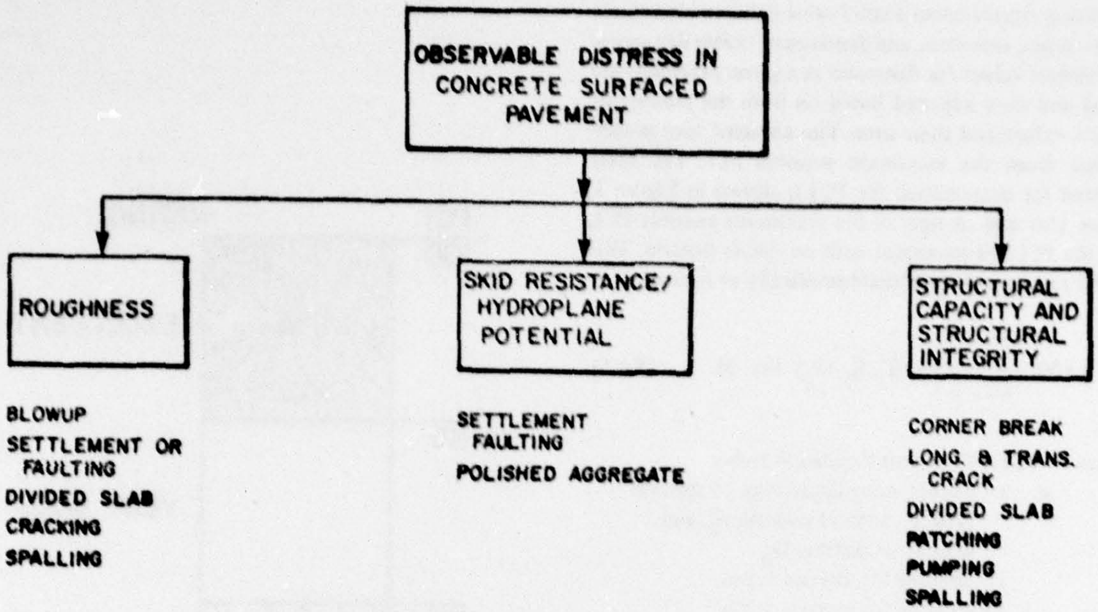


Figure 1. Relationship of observable distress on concrete pavement condition indicators.

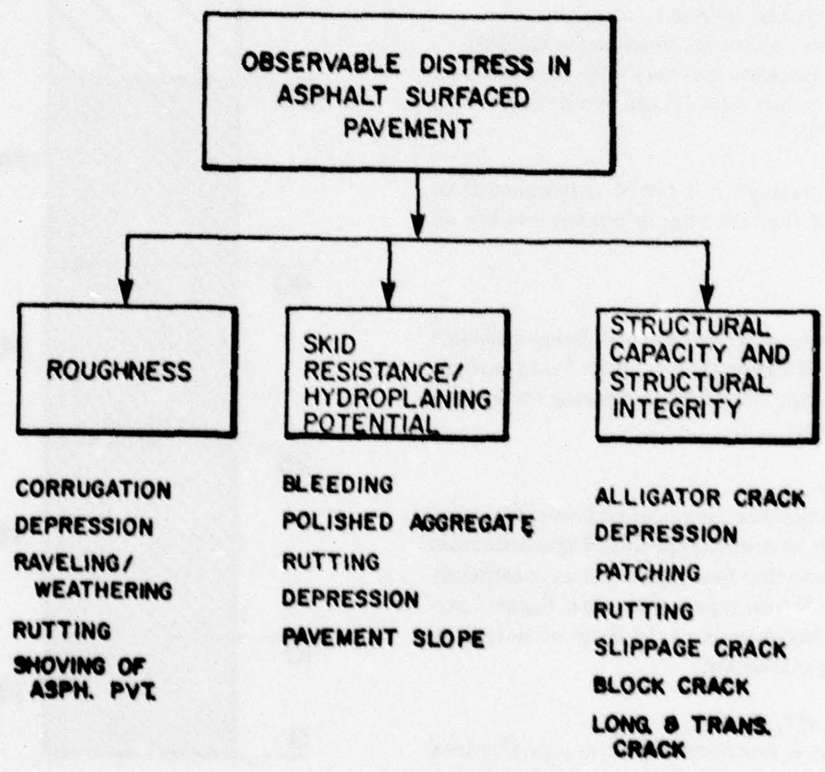


Figure 2. Relationship of observable distress in asphalt-surfaced pavements to pavement condition indicators.

weighting values (called deduct values) that are functions of the types, severities, and densities of visible distresses. The deduct values for distresses in a given pavement are added and then adjusted based on both the number of deduct values and their sum. The adjusted sum is subtracted from the maximum possible PCI. The scale selected for determining the PCI is shown in Figure 3, where 100 was chosen as the maximum possible PCI, i.e., the PCI of a pavement with no visible distress. This model can be expressed mathematically as follows:

$$PCI = 100 - \sum_{i=1}^{p} \sum_{j=1}^{m_i} a(T_i, S_j, D_{ij})\ F(t, d) \qquad \text{[Eq 1]}$$

where PCI = Pavement Condition Index

a( ) = deduct value depending on distress type T_i, level of severity S_j, and density of distress D_{ij}

i = counter for distress types

j = counter for severity levels

p = total number of distress types for pavement type under consideration

m_i = number of severity levels for the i^{th} type of distress

F(t,d) = an adjustment function for multiple distresses that vary with total summed deduct value (t) and number of deducts (d).

A pavement section's PCI can be determined from Eq 1 only when the following information is known (Figure 4).

Distress Types

Each distress type in the pavement being evaluated must be identified and described. Figure 5 is an example description of alligator or fatigue cracking for asphalt-surfaced pavements.

Distress Severity

Most distress types occur in various levels of severity, which must each be defined explicitly. These definitions must be written so that field engineers can consistently identify a given distress type and severity. Figure 5 provides example descriptions of the levels of severity of alligator or fatigue cracking.

Deduct Values—$a(T_i, S_j, D_{ij})$

Deduct values as functions of distress type (T_i), level of severity (S_j), and density (D_{ij}) must be determined, as illustrated in the following example. (Chapter 3 provides a detailed description.) A major structural distress

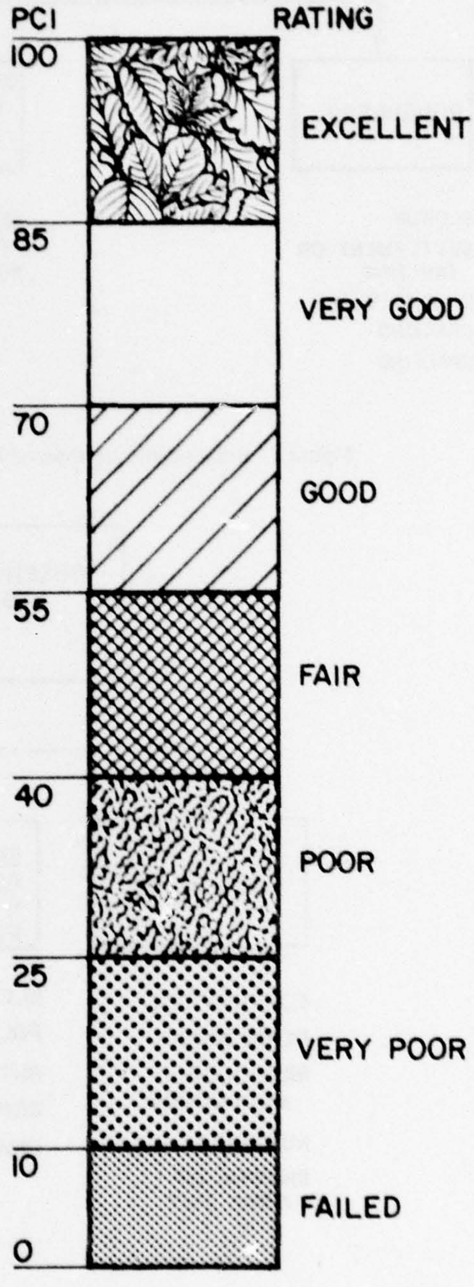


Figure 3. Scale used for Pavement Condition Index (PCI).

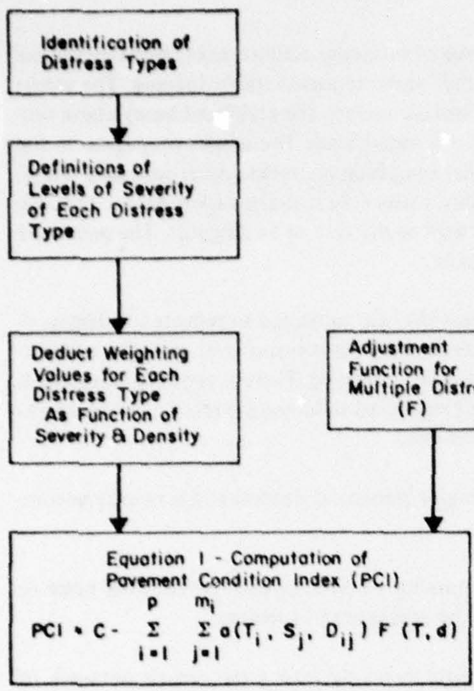


Figure 4. Information needed to determine the Pavement Condition Index using Eq 1.

of asphalt-surfaced pavement is alligator or fatigue cracking (Figure 5). Deduct values must be determined over a range of density (i.e., percent area) of distress. The deduct values must be based on some selected rating scale, such as a scale ranging from 0 to 100, with 0 deduct indicating the distress has no impact on pavement condition and 100 deduct indicating an extremely serious distress which causes the pavement to fail. Deduct values can then be assigned to a given density and level of severity based on the impact of the distress on pavement condition (see Chapter 3). Figure 6 gives example deduct curves for alligator cracking for three levels of severity (low, medium, and high), and densities ranging from 0.1 to 100 percent of total pavement areas. A pavement section having 1 percent of high-severity alligator cracking would have a deduct value of 23, and the PCI would be:

$$PCI = 100 - 23 = 77$$

Curves like those shown in Figure 6 must be derived for each distress type and severity level. These curves are based on the assumption that only one distress type at a given level of severity exists in the pavement section; the curves are based on a scale of 0 to 100.

Adjustment Function for Multiple Distress Types—(F)

An adjustment function must be developed so that pavement sections having more than one distress can be evaluated using the curves described above. The deduct values are not linearly additive, because as additional distress types and/or severity levels occur in a given pavement section, the resulting impact of those distresses become smaller. Development of this function is presented in Chapter 3.

3 DEVELOPMENT

This chapter describes the development of the preliminary procedure for determining the pavement condition index (PCI) for roads and streets.

Development of Distress Definitions

Definitions of pavement distresses, including high-, medium-, and low-severity levels for each type of distress, were developed a few years ago.[13] In the process of developing the PCI for airfield pavement,[14,15] valuable experience was gained toward improving the distress definitions for roads and streets. Based on this experience, the distress/severity definitions were improved for use in calculating the PCI for roads. Figure 5 provides a definition for alligator or fatigue cracking in asphalt pavement.

Development of Deduct Values

Deduct values are numbers that represent the effects that distresses have on a pavement's structural integrity and surface operational condition. A deduct value is a function of the type, severity, and density of a distress.

Deduct values were developed by evaluating hypothetical "sample units" of pavement. Sample unit sizes

---

[13] M. Y. Shahin, M. I. Darter, F. M. Rozanski, and R. Stark, *Development of an Installation Surfaced Area Maintenance and Repair Management System*, Technical Infomation Pamphlet C-49/ADA017328 (CERL, September 1975).

[14] M. Y. Shahin and F. M. Rozanski, *Automated Pavement Maintenance and Repair Management System*, Technical Information Pamphlet C-79/ADA042582 (CERL, June 1977).

[15] M. Y. Shahin, M. I. Darter, and S. D. Kohn, *Development of a Pavement Maintenance Management System, Vol I, Airfield Pavement Condition Rating*, Report Number AFCEC-TR-76-27 (AFCEC, November 1976).

Name of Distress: Alligator Cracking

Description: Alligator or fatigue cracking is a series of interconnecting cracks caused by fatigue failure of the asphalt concrete surface under repeated traffic loading. The cracking initiates at the bottom of the asphalt surface (or stabilized base) where tensile stress and strain is highest under a wheel load. The cracks propagate to the surface initially as a series of parallel longitudinal cracks. After repeated traffic loading, the cracks connect, forming many-sided, sharp-angled pieces that develop a pattern resembling chicken wire or the skin of an alligator. The pieces are less than 2 ft (.6 m) on the longest side.

Alligator cracking occurs only in areas that are subjected to repeated traffic loadings, such as wheel paths. Therefore, it would not occur over an entire area unless the entire area was subjected to traffic loading. Pattern-type cracking which occurs over an entire area that is not subjected to loading is rated as block cracking, which is not a load-associated distress.

Alligator cracking is considered a major structural distress and is usually accompanied by rutting.

Severity Levels:

L* – Fine, longitudinal hairline cracks running parallel to each other with none or only a few interconnecting cracks. The cracks are not spalled.

M – Further development of light alligator cracking into a pattern or network of cracks that may be lightly spalled.

H – Network or pattern cracking has progressed so that the pieces are well defined and spalled at the edges; some of the pieces rock under traffic.

Note: Spalling of the cracks is a breakdown of the material along the sides of the crack.

How to Measure: Alligator cracking is measured in square feet of surface area. The major difficulty in measuring this type of distress is that two or three levels of severity often exist within one distressed area. If these portions can be distinguished easily from each other, they should be measured and recorded separately. However, if the different levels of severity cannot be divided easily, the entire area should be rated at the highest severity level present.

*L – Low severity level
M – Medium severity level
H – High severity level

Figure 5. Example description of a distress and definition of its severity levels.

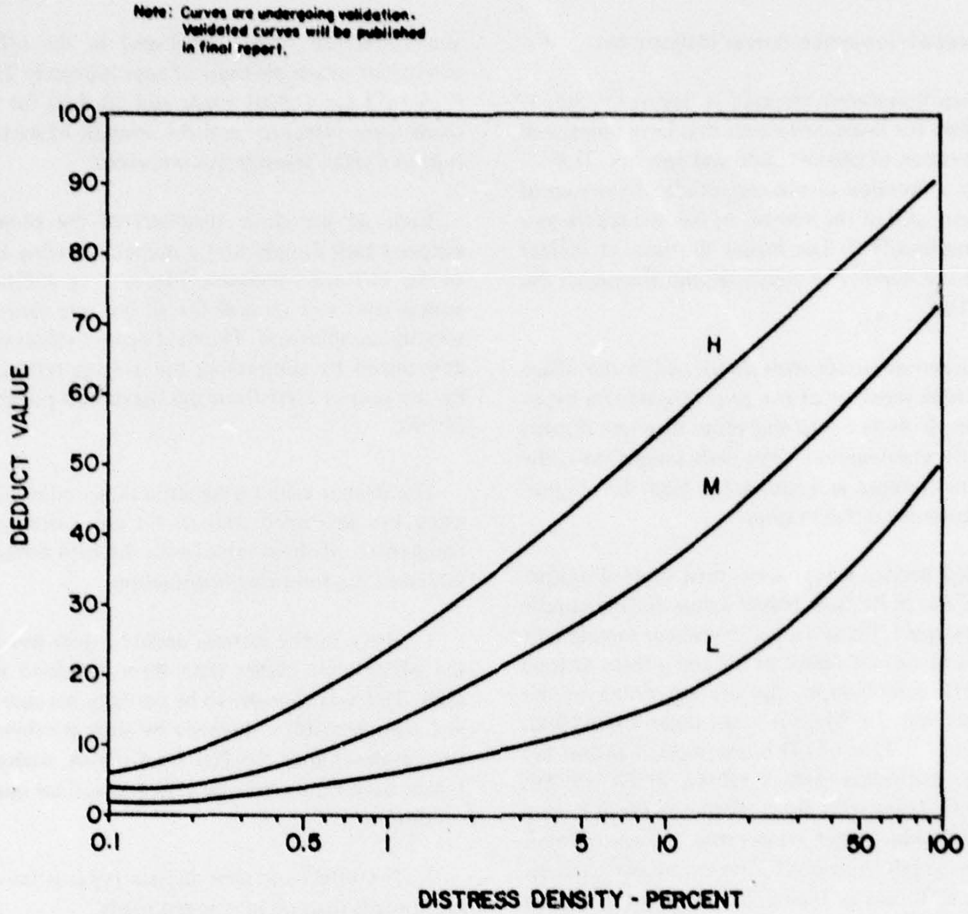


Figure 6. Deduct value curves for alligator cracking.

of 2500 sq ft (225 m^2) for asphalt and 20 slabs for jointed concrete (a slab length of 30 ft [9 m] or less was assumed) were chosen based on experience in developing the PCI for airfields. Each hypothetical sample unit contained one distress at a particular severity level and at one of five density levels.*

Each member of the project staff evaluated each sample unit and independently assigned the sample units numerical ratings according to the PCI scale (Figure 3).

The ratings were averaged for each sample unit and subtracted from 100 to produce the deduct values for each distress/severity/density combination. For example, for medium-severity block cracking at 30 percent density, the average of the sample unit ratings was 76 (very good). The deduct value was, therefore, 100 − 76 = 24.

For each severity level of each distress, the deduct values were plotted against the corresponding densities, and smooth curves were drawn through the points to produce the deduct curves.

Figure 6 shows the deduct curves for alligator cracking for asphalt-surfaced pavements.

*The densities of concrete distress were computed by dividing the number of slabs containing the distress by the total number of slabs in the sample unit. The densities of most asphalt distresses were computed by dividing the surface area of distress by the sample unit area. Edge cracking and longitudinal/transverse cracking densities were expressed in ft/100 sq ft (9 m^2) potholes in number of potholes/100 sq ft (9 m^2).

Development of Correction Curves (Adjustment Function)

The correction curves are used to adjust the sum of deduct values for those pavements that have more than one combination of distress type and severity. The adjustment is a function of the magnitude of the sum of deduct values and of the number of distress type/severity combinations.[16,17] The higher the sum of deduct values and the number of combinations, the higher the adjustment is.

The correction curves were developed in the office by having each member of the project staff rate hypothetical sample units containing more than one distress type/severity combination. For each sample unit, the ratings were averaged and subtracted from 100 to produce the corrected deduct values.

Corrected deduct values were then plotted against the sum of the individual deduct values for the sample unit. For example, for an asphalt pavement sample unit with a sum of deduct values of 80 and a three distress type/severity combination, the average rating of the project staff was 32. The corrected deduct value was, therefore, 100 − 32 = 68. This was plotted against the sum of the individual deduct values, which was 80. Other sample units with three distresses (each having an individual deduct value greater than 5*) were plotted on the same graph. A smooth curve was drawn through the points, as shown in Figure 7. The extent of correction increases as the sum of deduct values increases.

Similar "correction curves" were developed for q (the number of distresses with deduct values greater than 5) equal to 2, 4, 6, and 8.

Initial Field Test

Portions of some local city streets were surveyed to initially verify the distress definitions, deduct curves, and correction curves developed in the office. The conditions of sample units of approximately 2500 sq ft (225 m^2) for asphalt roads and 20 slabs for concrete roads were surveyed, and the amount of each distress type at a given severity was measured.

Each of the three members of the project staff assigned each sample unit a numerical rating according to the PCI scale shown in Figure 3. In addition, each sample unit was rerated for all but one distress type/severity combination. The field deduct values were then determined by subtracting the average rating assigned by the project staff from the maximum possible score of 100.

The deduct values were also calculated in the office, using the developed deduct and correction curves. A comparison of these values with the field deduct values indicated the following information.

1. Many of the distress deduct values developed in the office were higher than those obtained from the field. This was thought to be partially because the project staff was still influenced by their previous experience in developing the PCI for airfields, where the distresses have a more adverse effect on surface operational condition.

2. The effect of some distress types is less on low-speed roads than on high-speed roads.

It was also found through the field survey that some definitions of distress severity levels did not reflect field conditions accurately.

All data obtained from this field test were used to revise the distress definitions, deduct curves, and correction curves. Figures A1, A2, B1, and B2 in Appendices A and B provide the distress definitions and curves for jointed concrete and asphalt surfaced pavements, respectively. The PCI is a valid technique for comparing pavements in terms of structural integrity and surface operational condition against a common standard. It can be used by the pavement engineer as an effective tool to communicate pavement condition to management and as an aid in determining the need for M&R. It should be emphasized, however, that more field tests, revisions, and improvements are necessary before the pavement condition rating procedure is finalized for implementation.

---

[16] M. Y. Shahin and F. M. Rozanski, *Automated Pavement Maintenance and Repair Management System*, Technical Information Pamphlet C-79/ADA042582 (CERL, June 1977).

[17] M. Y. Shahin, M. I. Darter, and S. D. Kohn, *Development of a Pavement Maintenance Management System, Vol I, Airfield Pavement Condition Rating*, Report Number AFCEC-TR-76-27 (AFCEC, November 1976).

*Previous experience had shown that distresses with deduct values of less than 5 had little effect on pavement condition. Counting them would distort the adjustment function.

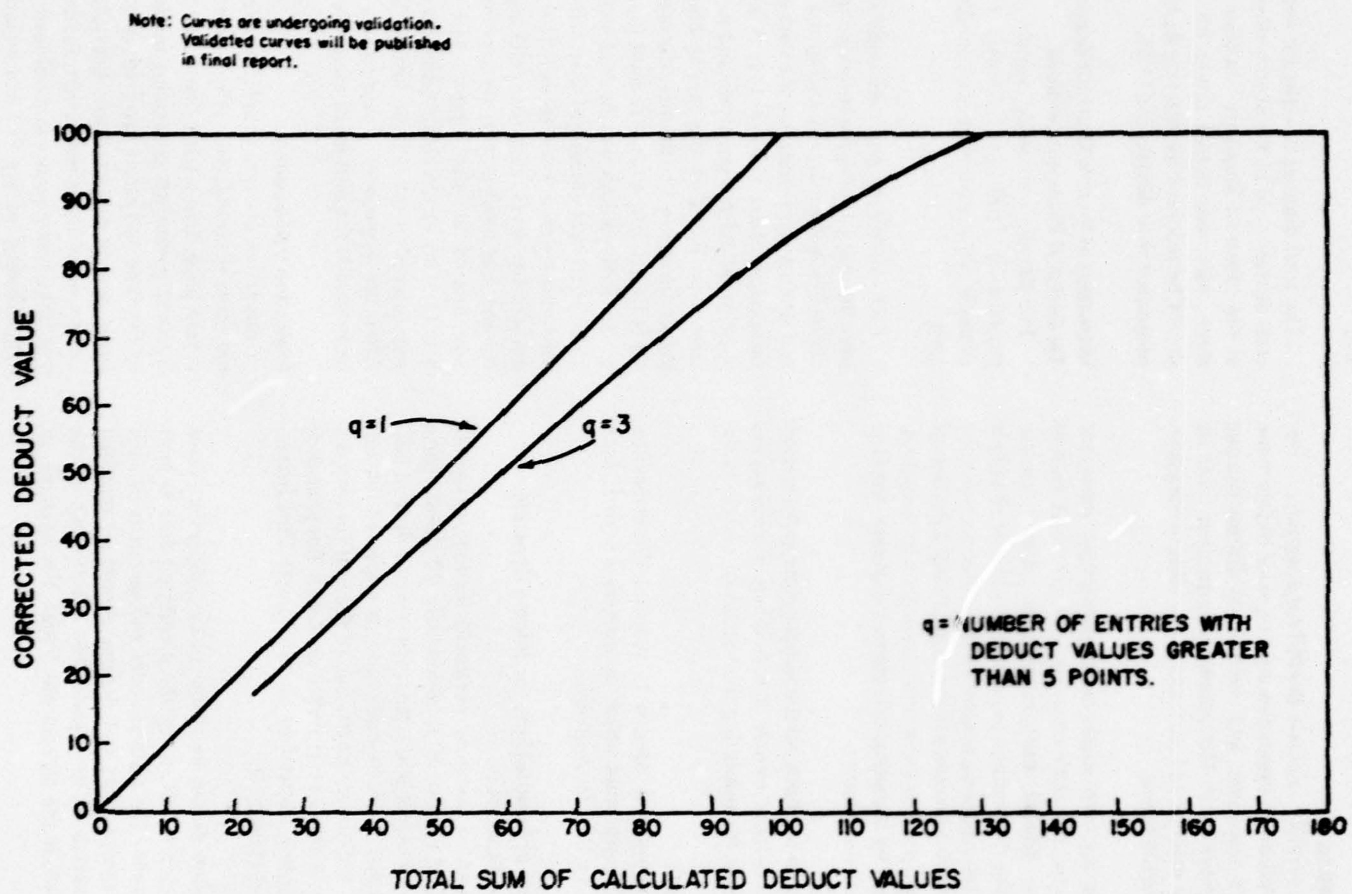


Figure 7. Corrected deduct value for jointed concrete pavements (q = 3).

4 INSPECTION PROCEDURE

Introduction

To accurately calculate the PCI for a section of pavement, a thorough inspection must be made to determine the types, quantities, and severities of distress existing *in the pavement.** The pavement inspection must be carefully planned and performed according to the guidelines presented here.

There are two methods of performing pavement inspections; for both methods, the pavement section must be divided into subsections called "sample units." The first method requires inspection of all sample units in the section (inspection of the entire section); the second method requires inspection of only a portion of the sample units in the section (inspection by sampling). Inspection by sampling is explained in greater detail at the end of this chapter.

For both methods, all the sample units in the section must be assigned sample unit numbers. Following are instructions for inspecting the individual sample units.

Equipment

The equipment needed to perform the inspection includes a measuring wheel (odometer), a 6- or 12-inch ruler, and a 10-ft straightedge.

Inspection of Sample Units for Jointed Concrete Pavement Sections

For jointed concrete pavement sections, a sample unit should consist of approximately 20 slabs. Figure 8 shows an example of a pavement section divided into sample units. Each "sample unit" is inspected individually by walking over each slab of the unit (or over the shoulder or sidewalk if traffic control is not provided) and recording distress(es) on the Sample Unit Inspection Sheet (Figure 9).

A sketch should be made on the inspection sheet of the sample unit, using the preprinted dots as joint intersections. The distress codes and severities of each distress except joint seal damage should be recorded on the sketch in the square that corresponds to the slab in which the distress was found. For example, in Figure 9, the notation "22M" indicates that medium-severity level linear cracking was found in the first slab.

The total number of slabs for each severity level of each distress type in the sketch should be summarized in the "Distress Summary" portion of the inspection sheet. Also, the overall rating for joint seal damage should be recorded by entering L, M, or H on the line preprinted with distress code "25."

Inspection of Sample Units for Asphalt- and Tar-Surfaced Pavement Sections

For flexible pavements, sample units should be approximately 2500 sq ft (255 m^2). Figure 10 shows an example of a pavement section divided into sample units.

Each sample is inspected individually by walking over the unit (or over the shoulder or sidewalk if traffic control is not provided), measuring each distress type and severity, and recording the data on the Sample Unit Inspection Sheet (Figure 11). A separate column is used to record the quantities and severities of each distress type found in the sample unit. In the example shown in Figure 11, the first distress encountered was 10 ft (3 m) of low-severity level longitudinal cracking, so the first column was headed with distress code 8, and "10L" was entered in that column. The next distress encountered was a 16 sq ft (1.4 m^2) area of medium-severity level alligator cracking, so the second column was headed with distress code 1, and "16M" was entered in that column. The next distress was 5 ft (1.5 m) of low-level transverse cracking, so "5L" was entered in the column headed by distress code 8. After the inspection is completed, quantities should be totaled at the bottom of each column.

Inspection by Sampling

Inspection of every sample unit in a pavement section may require considerable effort, especially if the section is very large. This is particularly true for asphalt- or tar-surfaced pavements containing much distress. Because of the time and effort involved, frequent surveys of an entire section subjected to a heavy traffic volume may be beyond available manpower, funds, and time. Therefore, a sampling plan was developed to allow adequate determination of the PCI and maintenance and repair needs by inspecting only a portion of the sample units in a pavement section. Use of the statistical sampling plan described in this section will reduce inspection time considerably without significant loss of accuracy. Use of the sampling plan presented is optional. In fact,

---

*The inspection procedure has been presented as an appendix in *Automated Pavement Maintenance and Repair Management System*, by M. Y. Shahin and F. M. Rozanski, Interim Report C-79/ADA042582, CERL, June 1977; however, it is presented here for the user's convenience.

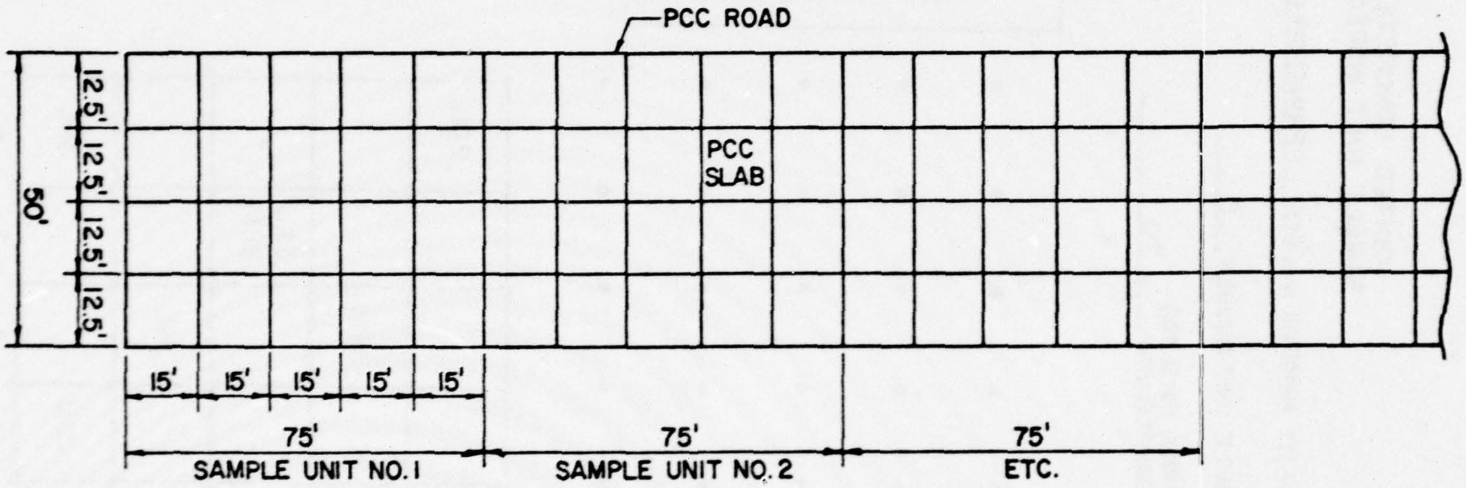


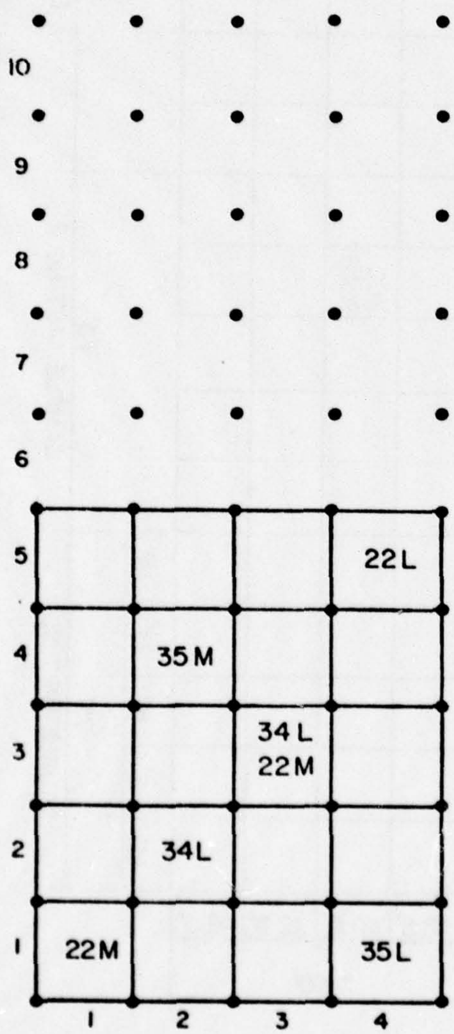
Figure 8. Illustration of division of a pavement section into sample units of 20 slabs.

JOINTED CONCRETE PAVEMENT
SAMPLE UNIT INSPECTION SHEET

FACILITY NAME OR NUMBER SPRINGFIELD SECTION NUMBER 1

SAMPLE UNIT NUMBER 2 RANDOM ☑ ADDITIONAL ☐

NUMBER OF SLABS
IN SAMPLE UNIT 20



DISTRESS TYPES AND CODES

21. BLOW UP
22. LINEAR CR (Long, Trans, and Diag)
23. DURABILITY CR
24. FAULTING
25. JOINT SEAL DAM
26. PATCH/UTIL CUT
27. POLISHED AGG
28. POPOUTS
29. PUMPING
30. RR CROSSING
31. SCALING
32. DIVIDED SLAB
33. JOINT SPALLING
34. CORNER SPALLING
35. CORNER BREAK
36. SMALL PATCH (Less than 5 Sq. Ft.)
37. SHRINKAGE CR
38. DEPRESSION
39. SHOULDER DROP
40. OVERALL DETER
41. OTHER

DISTRESS SUMMARY

DIST. CODE	SEV	TOTAL NMBR OF SLABS
25	M	[illegible]
22	L	1
22	M	2
34	L	2
35	L	1
35	M	1

Figure 9. Jointed concrete pavement Sample Unit Inspection Sheet.

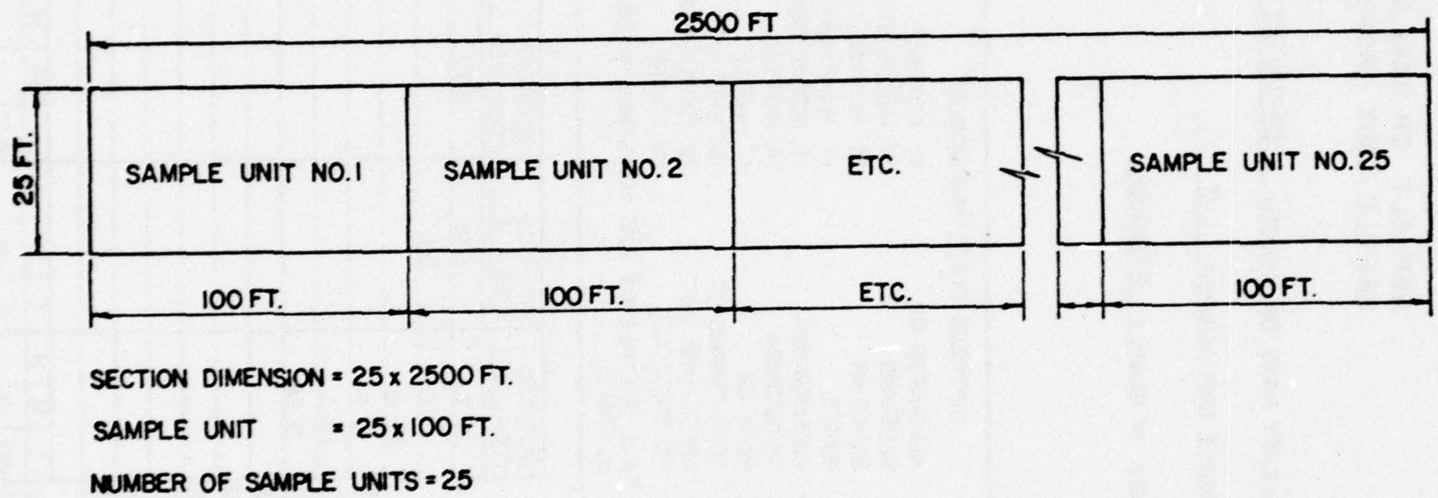


Figure 10. Example division of asphalt- or tar-surfaced pavement section into sample units.

ASPHALT OR TAR SURFACED PAVEMENT
SAMPLE UNIT INSPECTION SHEET

FACILITY NAME OR NUMBER GREEN ST SECTION NUMBER 5

SAMPLE UNIT NUMBER 7 RANDOM ADDITIONAL

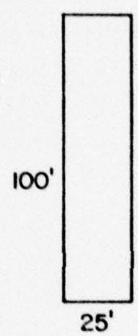
AREA OF SAMPLE 2500 SF

DISTRESS TYPES AND CODES*

1. ALLIGATOR CR
2. BLEEDING
3. BLOCK CR
4. BUMPS
5. CORRUGATION
6. DEPRESSION
7. EDGE CR
8. LONG/TRANS CR
9. PATCH/UTIL CUT
10. POLISHED AGG
11. POTHOLE
12. R.R. CROSSING
13. SLIPPAGE CR
14. WEATHER/RAVEL
15. REFLECTION CR
16. RUTTING
17. SWELL
18. SHOVING
19. OVERALL DETER
20. OTHER

*ALL DISTRESSES ARE MEASURED IN SQ FT EXCEPT 7, 8, AND 15.

SKETCH:



	DISTRESS CODE 8	DISTRESS CODE 1	DISTRESS CODE 16	DISTRESS CODE	DISTRESS CODE	DISTRESS CODE
QUANTITIES & SEVERITIES	10 L	16 M	50 L			
	5 L	6 L				
	15 L					
	5 M					
	10 L					
	5 M					

TOTAL	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H
	40	10		6	16		50											

Figure 11. Asphalt- or tar-surfaced pavement Sample Unit Inspection Sheet.

inspection of the entire section may be necessary if exact quantities of distress must be known for contractual maintenance work.

Determining the Number of Samples

The minimum number of sample units to be inspected should be determined from Figures 12 and 13 for jointed concrete and asphalt- or tar-surfaced pavements, respectively. The numbers obtained from these figures will insure adequate accuracy in determining the pavement section condition.

Selection of Samples

Determining which sample units to inspect is as important as determining the minimum number of samples. Samples must be selected randomly to insure an unbiased result. Random selection can be accomplished by using a random number table. If the number of sample units in a section exceeds 10, stratifying the section is recommended. Stratifying the section involves dividing it into a number of parts called strata. An equal number of sample units is then randomly selected from each stratum, as illustrated in the following example.

Figure 10 shows the section to be inspected; it contains a total of 25 sample units numbered from 1 to 25. The required minimum number of sample units is determined to be 10 (from Figure 13). The section can be divided into five strata of five sample units each.

Stratum 1	Sample units 1 through 5
Stratum 2	Sample units 6 through 10
Stratum 3	Sample units 11 through 15
Stratum 4	Sample units 16 through 20
Stratum 5	Sample units 21 through 25

Two sample units are selected at random from each stratum using a random number table, such as shown in Table 1. Units can be selected for this example by starting with any two digits in the table. The starting point in this example is at columns 5 and 6 of row 10 where the two-digit number "17" is located. To select two sample units for Stratum 1, two random numbers between 01 and 05 must be selected. Proceeding down columns 5 and 6 from the starting point, the first two random numbers encountered that fall between 01 and 05 are 03 (row 16) and 01 (row 25); therefore, sample units 01 and 03 will be inspected. The process would then be repeated for the other four strata. If the required units have not been obtained when the bottom of the column is reached, they can be obtained by proceeding as before from any other row-column combination; in this example, row 00 and columns 20 and 21 were selected. The numbers selected using this procedure are circled in Table 1.

Strata	Sample Units Selected
Stratum 1 (1-5)	01, 03
Stratum 2 (6-10)	09, 10
Stratum 3 (11-15)	12, 13
Stratum 4 (16-20)	16, 17
Stratum 5 (21-25)	21, 23

Therefore, sample units numbered 01, 03, 09, 10, 12, 13, 16, 17, 21, and 23 must be inspected.

Inspecting Additional Samples

The inspection data obtained will be used in PAVER[18] to extrapolate the quantities and densities of each distress over the entire pavement section. The extrapolation process, however will produce erroneous results for certain distresses which are not typical of the behavior of the entire pavement section. A special procedure should be followed for potholes, blow-ups, railroad crossings, and other distresses that are obviously not uniformly distributed along the pavement section.

Case 1—Nontypical distress falls within a random sample:

The sample should be identified as "additional" on the field inspection sheet, and another sample should be selected at random to replace it. For example, if a pothole is found in random sample 17, sample 17 should be completely inspected and identified on the field inspection sheet as "additional." Another sample should then be chosen randomly and included in the inspection.

Case 2—Nontypical distress occurs in a sample that was not randomly selected:

The sample containing the nontypical distress and all other samples containing the same distress should be inspected and recorded as additional samples.

[18] M. Y. Shahin, M. I. Darter, and F. M. Rozanski, *Pavement Inspection Reference Manual*, Technical Information Pamphlet C-48/ADA017329 (CERL, September 1975).

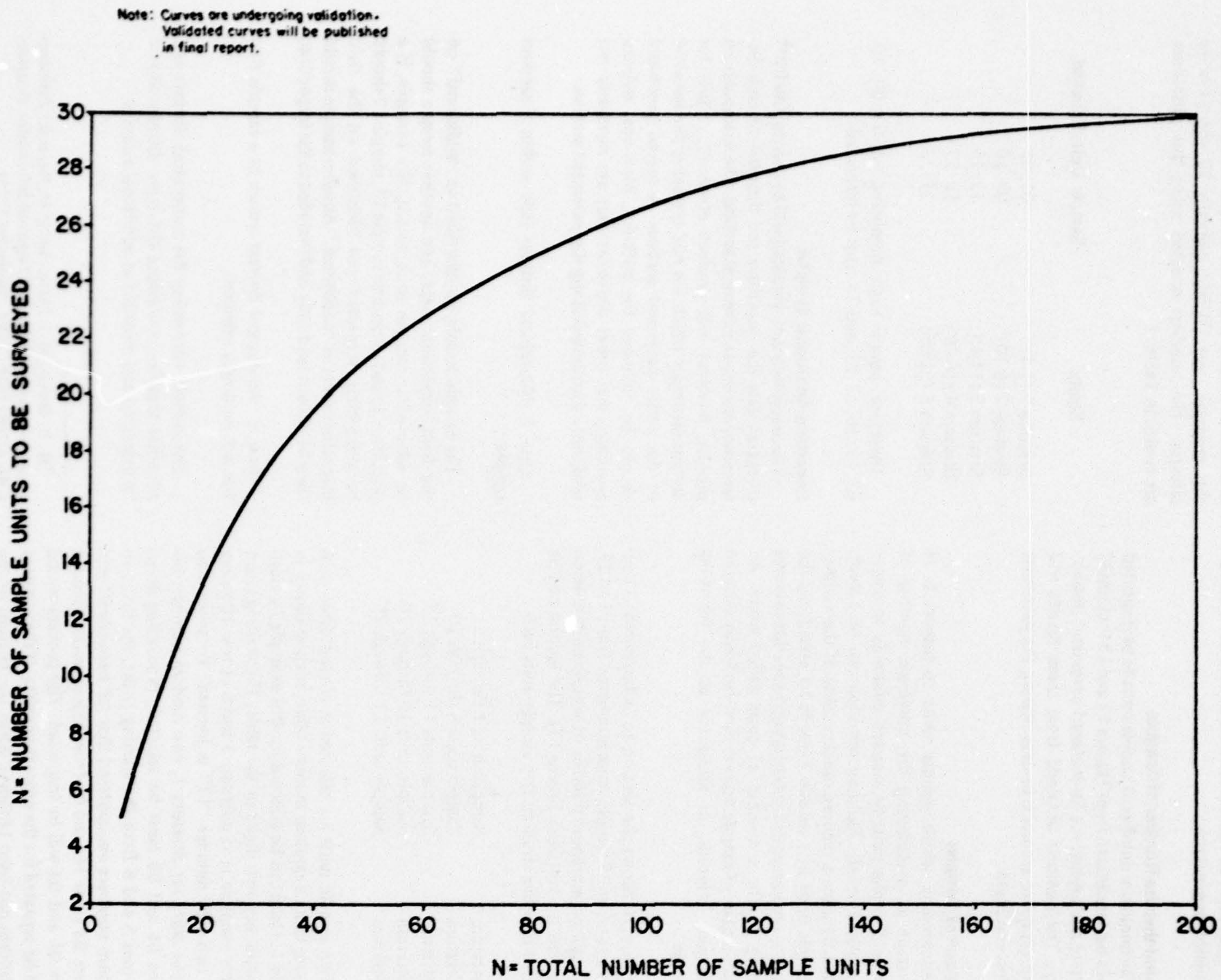


Figure 12. Plot for determining number of sample units required for jointed concrete pavement.

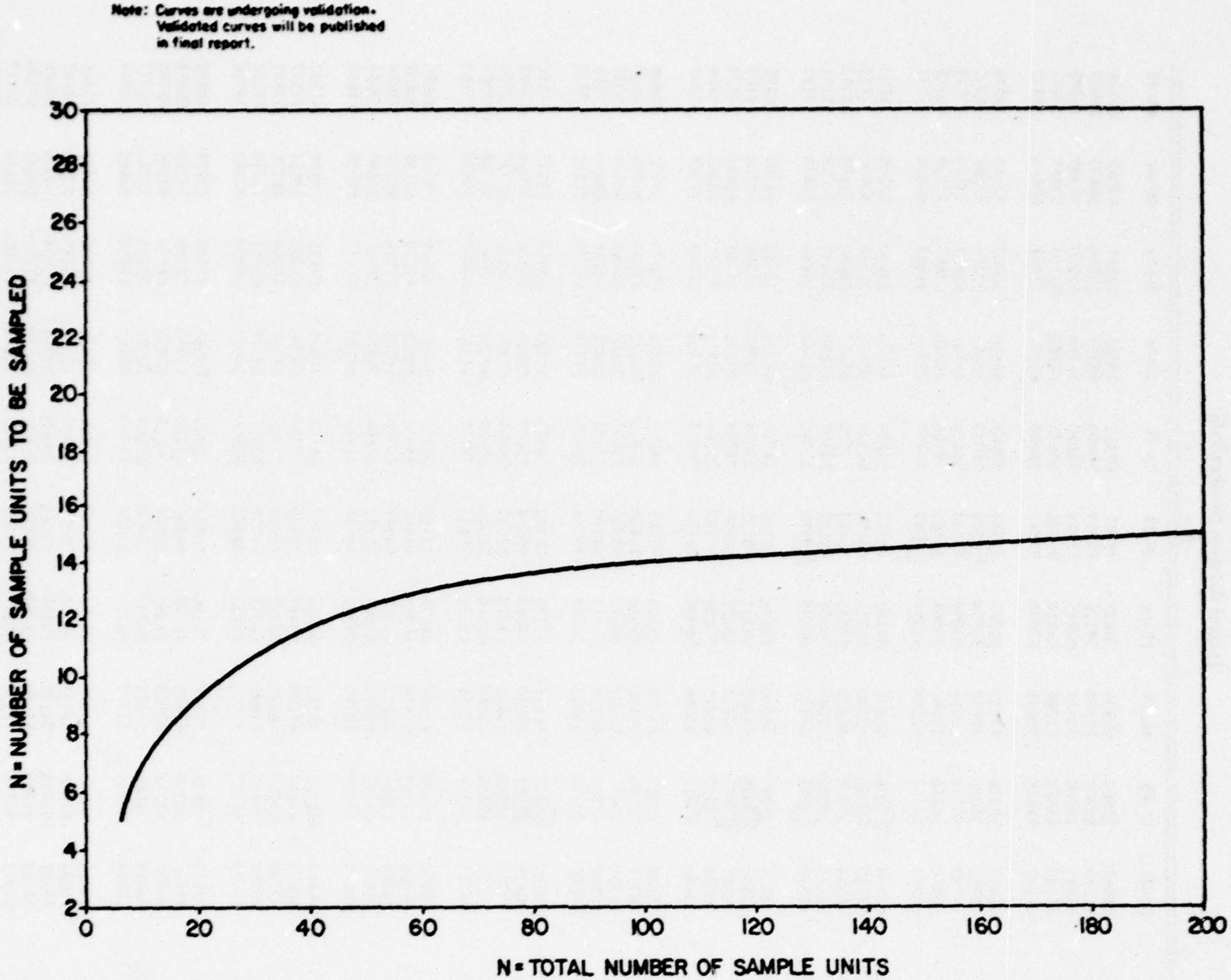


Figure 13. Plot for determining number of sample units required for asphalt- or tar-surfaced pavements.

Table 1
Typical Random Number Table

	00-04	05-09	10-14	15-19	20-24	25-29	30-34	35-39	40-44	45-49
00	54463	22662	65905	70639	79365	67382	29085	69831	47058	08186
01	15389	85205	18850	39226	42249	90669	96325	23248	60933	26927
02	85941	40756	82414	02015	13858	78030	16269	65978	01385	15345
03	61149	69440	11286	88218	58925	03638	52862	62733	33451	77455
04	05219	81619	10651	67079	92511	59888	84502	72095	83463	75577
05	41417	98326	87719	92294	46614	50948	64886	20002	97365	30976
06	28357	94070	20652	35774	16249	75019	21145	05217	47286	76305
07	17783	00015	10806	83091	91530	36466	39981	62481	49177	75779
08	40950	84820	29881	85966	62800	70326	84740	62660	77379	90279
09	82995	64157	66164	41180	10089	41757	78258	96488	88629	37231
10	96754	17676	55659	44105	47361	34833	86679	23930	53249	27083
11	34357	88040	53364	71726	45690	66334	60332	22554	90600	71113
12	06318	37403	49927	57715	50423	67372	63116	48888	21505	80182
13	62111	52820	07243	79931	89292	84767	85693	73947	22278	11551
14	47534	09243	67879	00544	23410	12740	02540	54440	32949	13491
15	98614	75993	84460	62846	59844	14922	48730	73443	48167	34770
16	24867	03648	44898	09351	98795	18644	39765	71058	90368	44104
17	96887	12479	80621	66223	86085	78285	02432	53342	42846	94771
18	90801	21472	42815	77408	37390	76766	52615	32141	30268	18106
19	55165	77312	83666	36028	28420	70219	81369	41943	47366	41067
20	75884	12952	84318	95108	72305	64620	91381	89872	45375	85436
21	16777	37116	58550	42958	21460	43910	01175	87894	81378	10620
22	46230	43877	80207	88877	89380	32992	91380	03164	98656	59337
23	42902	66892	46134	01432	94710	23474	20423	60137	60609	13119
24	81007	00333	39693	28039	10154	95425	39220	19774	31782	49037
25	68089	01122	51111	72373	06902	74373	96199	97017	41273	21546
26	20411	67081	89950	16944	93054	87687	96693	87236	77054	33848
27	58212	13160	06468	15718	82627	76999	05999	58680	96739	63700
28	70577	42866	24969	61210	76046	67699	42054	12696	93758	03283
29	94522	74358	71659	62038	79643	79169	44741	05437	39038	13163
30	42626	86819	85651	88678	17401	03252	99547	32404	17918	62880
31	16051	33763	57194	16752	54450	19031	58580	47629	54132	60631
32	08244	27647	33851	44705	94211	46716	11738	55784	95374	72655
33	59497	04392	09419	89964	51211	04894	72882	17805	21896	83864
34	97155	13428	40293	09985	58434	01412	69124	82171	59058	82859
35	98409	66162	95763	47420	20792	61527	20441	39435	11859	41567
36	45476	84882	65109	96597	25930	66790	65706	61203	53634	22557
37	89300	69700	50741	30329	11658	23166	05400	66669	48708	03887
38	50051	95137	91631	66315	91428	12275	24816	68091	71710	33258
39	31753	85178	31310	89642	98364	02306	24617	09609	83942	23716
40	79152	53829	77250	20190	56535	18760	69942	77448	33278	48805
41	44560	38750	83635	56540	64900	42912	13953	79149	18710	68618
42	68328	83378	63369	71381	39564	05615	42451	64559	97501	65747
43	46939	38689	58625	08342	30459	85863	20781	09284	26333	91777
44	83544	86141	15707	96256	23068	13782	08467	89469	93842	55349
45	91621	00881	04900	54224	46177	55309	17852	27491	89415	23466
46	91896	67126	04151	03795	59077	11848	12630	98375	52068	60142
47	55751	62515	21108	80830	02263	29303	37204	96926	30506	09808
48	85156	87689	95493	88842	00664	55017	55539	17771	69448	87530
49	07521	56898	12236	60277	39102	62315	12239	07105	11844	01117

5 CALCULATION OF PCI FROM INSPECTION RESULTS

Introduction

Chapter 4 presented the two methods of inspecting a pavement section. The data collected for each sample unit in the section were used to calculate the PCI. This chapter will explain how to calculate the PCI for a particular sample unit, and how to calculate the PCI for the entire pavement section.

Calculating PCI for a Sample Unit

Calculating the PCI for an individual sample unit is a relatively simple procedure which involves six basic steps (see Figure 14).

Step 1. Each sample unit is inspected and distress data recorded as explained in Chapter 4.

Step 2. The deduct values are determined from the deduct value curves for each distress type and severity.

Step 3. A total deduct value (TDV) is computed by summing all deduct values.

Step 4. Once the TDV is computed, the corrected deduct value (CDV) can be determined from the correction curves.

Step 5. The PCI can now be computed as PCI = 100 − CDV.

Step 6. The condition rating can be determined by using the scale shown in Figure 14.

Calculating the PCI for a Pavement Section

If all sample units in the feature are surveyed, the PCI of the section is computed by averaging the PCIs of all sample units. Inspection by sampling, however, requires a different method. If all surveyed sample units are selected randomly, the PCI of the pavement section is determined by averaging the PCI of the sample units. If any additional sample units are inspected, a weighted average must be used. The weighted average can be computed by using the following equation:

$$PCI_s = \frac{N-C}{N} PCI_1 + \frac{C}{N} PCI_2 \qquad \text{[Eq 2]}$$

where

PCI_s = PCI of pavement section
PCI_1 = average PCI of random samples
PCI_2 = average PCI of additional samples
N = total number of samples in feature
C = number of addition samples inspected.

Example Calculations of PCI for a Sample Unit

Referring to the field data sheets presented in Chapter 4 (Figures 9 and 11), the calculation of the PCI for each sample unit is presented below:

1. Jointed concrete sample unit. The first step after inspection is calculating the density of distress by dividing the number of slabs containing a particular distress and severity level by the total number of slabs in the sample unit. For example, two slabs contained linear cracking at medium severity, so the density is therefore calculated as 2/20 or 10 percent. The deduct values are then determined for each distress combination, from Appendix A, Figure A1, and the PCI is calculated as shown in Table 2.

2. Asphalt pavement sample unit. The difference in the procedure for calculating a PCI for an asphalt sample unit and that for a concrete sample unit is in the calculation of the distress density. Distress density in the asphalt sample unit is calculated by dividing the distress area by the sample unit area and multiplying the result by 100, with the following exceptions:

a. Edge cracking, linear cracking, joint reflection cracking, and bumps:

$$\text{Density} = \frac{\text{distress amount in linear feet}}{\text{sample unit area in square feet}} \times 100$$

b. Potholes

$$\text{Density} = \frac{\text{number of potholes}}{\text{sample unit area in square feet}} \times 100$$

After the distress density for each distress type/severity combination is calculated, the deduct values are determined from Appendix B, Figure B1.

Table 3 shows the PCI calculation for the asphalt pavement sample unit.

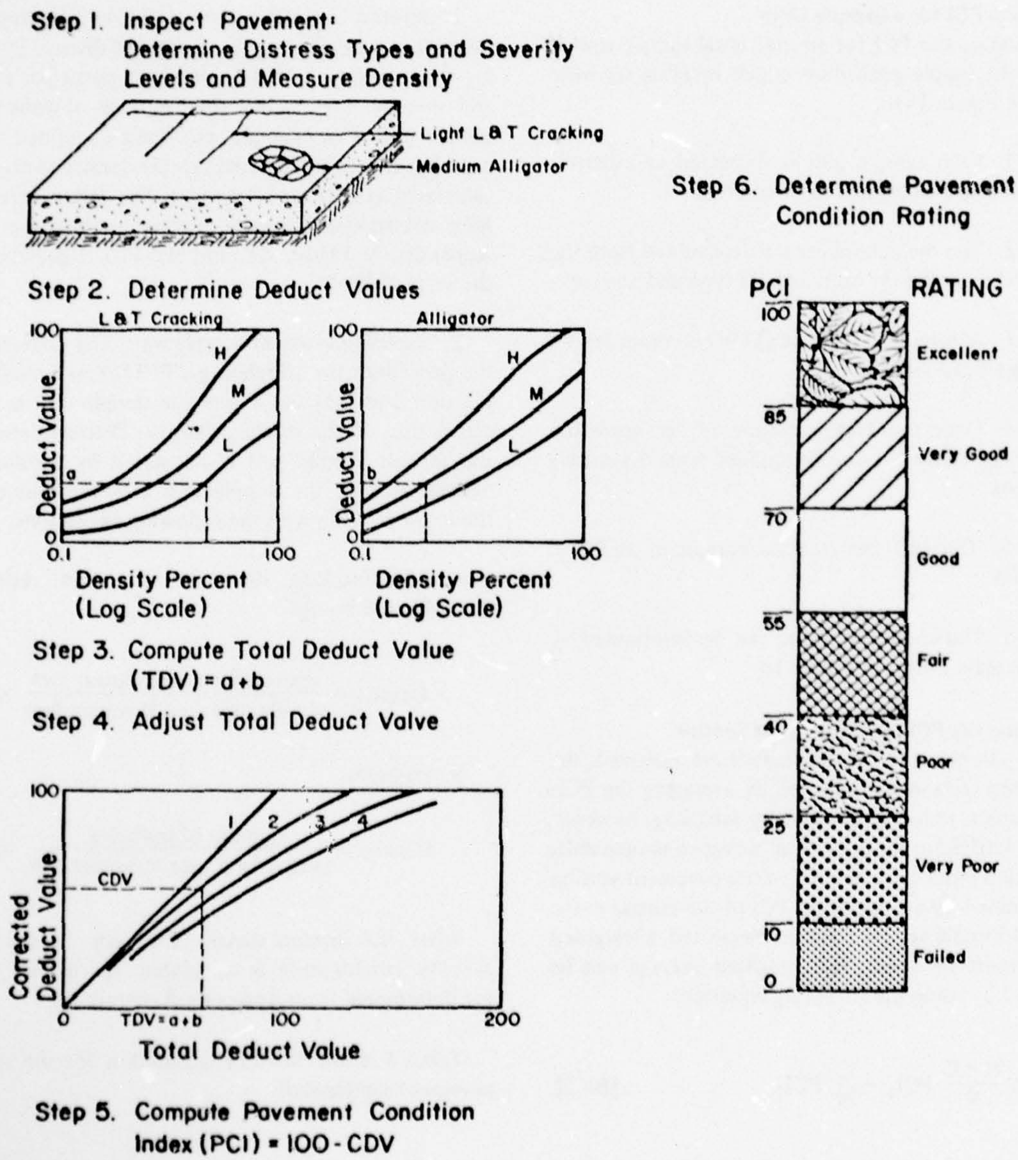


Figure 14. Steps for calculating pavement condition index.

Table 2
Example Calculation of the PCI for a Concrete Sample Unit
Total Number of Slabs in Sample 20

Distress Type	Severity Level	Quantity Slabs	Density %	Deduct* Value
Joint Seal Damage	M	20	100	4
Linear Crack	L	1	5	3
Linear Crack	M	2	10	9
Corner Spall	L	2	10	3
Corner Break	L	1	5	5
Corner Break	M	1	5	9
			TDV	33
			q**	2
			CDV†	33

PCI = 100 – CDV
= 100 – 33
PCI = 67

*The deduct values and CDV are obtained from Appendix A, Figures A1 and A2, respectively.

**q is the number of individual deduct values exceeding five points.

†If CDV is less than any of the individual distress deduct values, then CDV = highest individual deduct value.

Table 3
Example of PCI Calculation for an Asphalt Sample Unit
Area of Sample Unit 2500 sq ft (225 m²)

Distress Type	Severity Level	Quantity sq ft	Density %	Deduct* Value
Alligator Crk	L	6	0.24	2
Alligator Crk	M	16	0.64	10
Long/Trans Crk	L	40	1.6	2
Long/Trans Crk	M	10	0.4	1
Rutting	L	50	2.0	12
			TDV	27
			q**	2
			CDV†	20

PCI = 100 – CDV
= 100 – 20
PCI = 80

*The deduct values and CDV are obtained from Appendix B, Figures B1 and B2, respectively.

**q is the number of individual deduct values exceeding five points.

†If CDV is less than any of the individual distress deduct values, then CDV = highest individual deduct value.

6 SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

A preliminary procedure has been developed for determining a pavement condition index (PCI) for roads and streets. The PCI, which is expressed as a numerical rating ranging from 0 to 100, provides a measure of the pavement structural integrity and surface operational condition. The PCI is calculated based on pavement distress types, severities, and densities measured during an inspection of the pavement.

The procedure for rating a pavement section includes the following steps:

1. Dividing it into sample units (a sample unit is approximately 20 slabs for jointed concrete pavements and 2500 sq ft (225 m^2) for asphalt surface pavements)

2. Inspecting either each sample unit in the pavement section or only the number of sample units determined using the sampling techniques described in Chapter 4

3. Calculating the PCI for each sample unit surveyed (Figure 14)

4. Averaging the PCIs of the sample units to obtain the overall PCI of the pavement section.

Conclusions

The PCI is a valid technique for comparing pavements (against a common standard) in terms of structural integrity and surface operational condition. It can be used by the pavement engineer as an effective tool to communicate pavement condition to management and as an aid in determining the need for M&R. The PCI of pavement sections can be determined easily in the field.

Trained personnel can perform the pavement inspection with a measuring wheel (odometer), measuring scale, and a 10-ft straightedge.

The PCI does not directly measure load-carrying capacity and skid resistance. These items can only be measured by specialized teams and equipment.

Recommendations

The procedure for calculating the PCI (including distress definitions, deduct curves, and correction curves) has only been field-tested and revised once. It is recommended that the procedure be further field-tested a minimum of three times before it is made available to field personnel for implementation. The field tests should be performed at Army installations from different commands, and should include the participation of experienced field pavement engineers. During the field test the procedure should also be extended to be applicable to surfaced parking lots, storage areas, and hardstands.

After the PCI procedure is field-tested and verified, it is recommended that the finalized distress definitions be incorporated into the *Pavement Inspection Reference Manual*[19] and that the entire procedure be accepted for Army-wide implementation.

---

[19] M. Y. Shahin, M. I. Darter, and F. M. Rozanski, *Pavement Inspection Reference Manual*, Technical Information Pamphlet C-48/ADA017329 (CERL, September 1975).

REFERENCES

LeClerc, R. V., and T. R. Marshall, *A Pavement Condition Rating System and Its Use*, Symposium on Pavement Evaluation, AAPT Proceedings (1969).

Rand, D. W., *Pavement Evaluation III* (Maine Department of Transportation, Materials and Research Division, August 1973), pp 73-78.

Shahin, M. Y., M. I. Darter, F. M. Rozanski, and R. Stark, *Development of an Installation Surfaced Area Maintenance and Repair Management System*, Technical Information Pamphlet C-49/ADA017328 (Construction Engineering Research Laboratory [CERL], September 1975).

Shahin, M. Y., M. I. Darter, and F. M. Rozanski, *Pavement Inspection Reference Manual*, Technical Information Pamphlet C-48/ADA017329 (CERL, September 1975).

Shahin, M. Y., and F. M. Rozanski, *Automated Pavement Maintenance and Repair Management System*, Technical Information Pamphlet C-79/ADA-042582 (CERL, June 1977).

Shahin, M. Y., M. I. Darter, and S. D. Kohn, *Development of a Pavement Maintenance Management System, Vol I, Airfield Pavement Condition Rating*, Report Number AFCEC-TR-76-27 (Air Force Civil Engineering Center [AFCEC], November 1976).

Shahin, M. Y., M. I. Darter, and S. D. Kohn, *Development of a Pavement Maintenance Management System, Vol II, Airfield Pavement Distress Identification Manual*, Report No. AFCEC-TR-76-27 (AFCEC, November 1976).

Voss, D. A., R. L. Terrel, F. Finn, and D. Hovey, *A Pavement Evaluation System for Maintenance Management*, a paper prepared for presentation at the Western Summer Meeting, Highway Research Board, Olympia, Washington (August 1973).

APPENDIX A:
JOINTED CONCRETE PAVEMENT
DISTRESS DEFINITIONS, DEDUCT
CURVES, AND CORRECTION CURVES

PRECEDING PAGE BLANK

DISTRESSES ON PLAIN JOINTED CONCRETE PAVEMENTS (JOINT SPACING—30 ft [9 m])

Name of Distress:		Blow-up
Description:		Blow-ups occur in hot weather, usually at a transverse crack or joint that is not wide enough to permit expansion of the concrete slabs. The insufficient width is usually caused by infiltration of incompressible materials into the joint space. When expansion cannot relieve enough pressure, a localized upward movement of the slab edges (buckling) or shattering will occur in the vicinity of the joint. Blow-ups can also occur at utility cuts and drainage inlets.
Severity Levels:	L –	Buckling or shattering has not rendered the pavement inoperative, and only a slight amount of roughness exists.
	M –	Buckling or shattering has not rendered the pavement inoperative, and a significant amount of roughness exists.
	H –	Buckling or shattering has rendered the pavement inoperative.
How to Count:		A blow-up usually occurs at a transverse crack or joint. At a crack, it is counted as being in one slab; at a joint, two slabs are affected and the distress should be recorded as occurring in two slabs.

Name of Distress: Linear Cracking (Longitudinal, Transverse, and Diagonal Cracks)

Description: These cracks, which divide the slab into two or three pieces, are usually caused by a combination of traffic load repetition, thermal gradient curling, and moisture load repetition. (Slabs divided into four or more pieces are considered shattered.) Low-severity cracks are usually warping- or friction-related and are not considered major structural distresses. Medium- or high-severity cracks are usually working cracks and are considered major structural distresses.

NOTE: Hairline cracks that are only a few feet long and do not extend across the entire slab are rated as shrinkage cracks.

Severity Levels:

L – Crack has no spalling or minor spalling. If nonfilled, it is less than 1/8 in. (.32 cm) wide; or a filled crack can be of any width, but its filler material must be in satisfactory condition.

M – One of the following conditions exists: (1) a filled or nonfilled crack is moderately spalled; (2) a nonfilled crack has a mean width between 1/8 and 1 in. (.32 to 2.59 cm); (3) a filled crack has no spalling or minor spalling, but the filler is in unsatisfactory condition; or (4) the slab is divided into three pieces by low-severity cracks.

H – One of the following conditions exists: (1) a filled or nonfilled crack is severely spalled; (2) a nonfilled crack has a mean width approximately greater than 1 in. (2.59 cm); or (3) the slab is divided into three pieces by two or more cracks, one of which is at least medium severity.

How to Count: Once the severity has been identified, the distress is recorded as one slab.

Name of Distress: Durability ("D") Cracking

Description: Durability cracking is caused by freeze-thaw expansion of the large aggregate which, over time, gradually breaks down the concrete. It usually appears as a pattern of cracks running parallel to a joint or linear crack. Since the concrete becomes saturated near the joints and cracks, a dark-colored deposit can usually be seen around the fine durability cracks. This type of cracking may eventually lead to disintegration of the concrete within 1 to 2 ft (.3 to .6 m) of the joint or crack.

Severity Levels:

L – Pieces are defined by light cracks and cannot be removed.

M – "D" cracks are well-defined; pieces have been displaced but cover only a small part of the slab area.

H – "D" cracking has developed over a considerable amount of slab area and a significant number of pieces are removed. The "D" cracking has resulted in significant roughness.

How to Count: When distress is located and rated at one severity level, it is counted as one slab. If more than one severity level is found, the slab is counted as having the higher severity distress. For example, if light and medium durability cracking are located on one slab, the slab is counted as having medium only.

Name of Distress:	Faulting
Description:	Faulting is the difference in elevation across a joint or crack. Faulting may result from settlement of the slab due to a soft subgrade, an upward curling of the slab at the joints due to the moisture and temperature gradient, or, in heavily trafficked areas, from the pumping of material beneath the leading slab to beneath the trailing slab.
Severity Levels:	Severity levels are defined by the difference in elevation across the joint or crack.
L –	0.05-0.15 in. (.13 to .39 cm)
M –	0.15-0.25 in. (.39 to .65 cm)
H –	0.25 in. (.65 cm)
How to Count:	Faulting across a joint is counted as one slab. If only one or two joints are faulted in the sample unit, they should be measured separately in the outer wheel path at about 2 ft (.6 m) from the slab edge. Only the slabs affected are counted. If faulting is relatively constant throughout the sample unit, five or more joints should be measured and the mean fault computed and used for determining severity levels over the entire sample unit.

Name of Distress: Joint Seal Damage

Description:

Joint seal damage is any condition which enables soil or rocks to accumulate in the joints or allows significant infiltration of water. Accumulation of incompressible materials prevents the slabs from expanding and may result in buckling, shattering, or spalling. A pliable joint filler bonded to the edges of the slabs protects the joints from accumulation of materials and also prevents water from seeping down and softening the foundation supporting the slab.

Typical types of joint seal damage are: (1) stripping of joint sealant, (2) extrusion of joint sealant, (3) weed growth, (4) hardening of the filler (oxidation), (5) loss of bond to the slab edges, and (6) lack of sealant in the joint.

Severity Levels:

L – Joint sealer is in generally good condition throughout the section. Sealant is performing well; only a minor amount of any of the above types of damage is present.

M – Joint sealer is in generally fair condition over the entire surveyed section, with one or more of the above types of damage occurring to a moderate degree. Sealant needs replacement within 2 years.

H – Joint sealer is in generally poor condition over the entire surveyed section, with one or more of the above types of damage occurring to a severe degree. Sealant needs immediate replacement.

How to Count:

Joint seal damage is not counted on a slab-by-slab basis, but is rated based on the overall condition of the sealant over the entire section.

Name of Distress: Patching, Large (More than 5 Sq Ft [45 m^2]) and Utility Cut

Description: A patch is an area where the original pavement has been removed and replaced by a filler material. A utility cut is a patch that has replaced the original pavement because of placement of underground utilities. The severity levels of a utility cut are the same as those for regular patching.

Severity Levels:

L – Patch is functioning well with very little or no deterioration.

M – Patch has deteriorated and/or moderate spalling can be seen around the edges. Patch material can be dislodged with considerable effort.

H – Patch has deteriorated to a state which causes considerable roughness. The extent of the deterioration warrants replacement of the patch.

How to Count: The criteria are the same as for small patches.

Name of Distress:	**Polished Aggregate**
Description:	**Some aggregate types in the surface of a pavement become polished quickly under traffic. Others, such as certain types of gravel, are naturally polished. If these are used in a pavement surface without first being crushed, the pavement will become extremely slippery when wet.**
Severity Levels:	**No degrees of severity are defined. However, polished aggregate must be easily identifiable through visual inspection (including touching with hand) before it is counted as a distress.**
How to Count:	**An individual slab having polished aggregate over approximately 25 percent or more of its area should be counted.**

Name of Distress:	Popouts
Description:	A popout is a small piece of pavement that breaks loose from the surface due to freeze-thaw action in combination with expansive aggregates. Popouts usually range from approximately 1 to 4 in. (2.54 to 10.16 cm) in diameter and from 1/2 to 2 in. (1.27 to 3.08 cm) deep.
Severity Levels:	No degrees of severity are defined for popouts. However, popouts must be extensive before they are counted as a distress; i.e., average popout density must exceed approximately three popouts per square yard over the entire slab area.
How to Count:	The density of the distress must be measured. If there is any doubt about the average being greater than three popouts per square yard, at least three random 1-sq-yd (.8 m^2) areas should be checked. When the average is greater than this density, the slab should be counted.

Name of Distress:	Pumping
Description:	Pumping is the ejection of material by water through joints or cracks, caused by deflection of the slab under passing loads. Pumping can occur along the slab edge, causing loss of support. In additon, as a load moves across the joint between the slabs, water is first forced under the leading slab, and then forced back under the trailing slab. This action causes the erosion and eventual removal of soil particles. The result is a progressive loss of pavement support. Surface staining and base or subgrade material on the pavement close to joints or cracks are evidence of pumping. Pumping near joints indicates poor joint sealer and loss of support which will lead to cracking under repeated loads.
Severity Levels:	No degrees of severity are defined. It is sufficient to indicate that the pumping exists.
How to Count:	One pumping joint between two slabs is counted as two slabs. However, if the remaining joints around the slab are also pumping, one slab is added per additional pumping joint.

Name of Distress: Railroad Crossing

Description: Railroad crossing defects occur in the form of depressions or bumps around the tracks.

Severity Levels:

L – Ride quality* is rated as low severity.

M – Ride quality is rated as medium severity.

H – Ride quality is rated as high severity.

How to Count: The slabs crossed by the railroad track are counted.

*See page 51 for definition of ride quality.

Name of Distress: Scaling, Map Cracking, and Crazing

Description: Map cracking or crazing refers to a network of shallow, fine, or hairline cracks which extend only through the upper surface of the concrete. The cracks tend to intersect at angles of 120 degrees. Map cracking or crazing is usally caused by overfinishing the concrete, and may lead to scaling of the surface, which is the breakdown of the slab surface to a depth of approximately 1/4 to 1/2 in. (.63 to 1.26 cm). Scaling may also be caused by deicing salts, improper construction, freeze-thaw cycles, and poor aggregate. The type of scaling defined here is not that caused by "D" cracking. If there is scaling caused by "D" cracking, it should be counted under that distress only.

Severity Levels:

L – Crazing or map cracking exists over most of the slab area; the surface is in good condition with no scaling.

NOTE: The low-severity level is an indicator that scaling may develop in the future.

M – Slab is scaled, causing a low-severity ride quality.*

H – Slab is scaled, causing a medium- or high-severity ride quality.

How to count: Each slab having scaling is rated according to ride quality.

*See page 51 for definition of ride quality.

Name of Distress:		Divided Slab
Description:		A divided slab is broken into four or more pieces due to overloading and/or inadequate support. *If all pieces or cracks are contained within a corner break,* the distress is categorized as a severe corner break.
Severity Levels:	L –	Slab is broken into four or five pieces, with all cracks of low severity.
	M –	(1) Slab is broken into four or five pieces, with some or all cracks of medium severity (no high severity cracks); or (2) slab is broken into six or more pieces with all cracks of low severity.
	H –	One of the following conditions exists: (1) slab is broken into four or five pieces, with some or all cracks of high severity; (2) slab is broken into six or more pieces, with some or all cracks of medium or high severity.
How to Count:		If the slab is medium or high severity, no other distress is counted.

Name of Distress: Spalling (Transverse and Longitudinal Joint)

Description: Joint spalling is the breakdown of the slab edges within 2 ft (.6 m) of the joint. A joint spall usually does not extend vertically through the slab, but intersects the joint at an angle. Spalling results from excessive stresses at the joint caused by infiltration of incompressible materials or traffic load. Weak concrete at the joint (caused by overworking) combined with traffic loads is another cause of spalling.

Severity levels:

	Length of Spall	
Pieces of Spall	**2 ft (.6 m)**	**2 ft (.6 m)**
Tight–Cannot be easily removed (may be a few missing)	L	L
Loose–Can be removed and some are missing	L	M
Missing–Most have been removed	M	H

The following joint spall conditions are considered to be insignificant and should not be counted:

(1) A frayed joint where the concrete has been worn away somewhat.

(2) A small spall with tight pieces less than 2 ft (.6 m) long and 3 in. (7.52 cm) wide.

How to Count: If the joint spall is located along the edge of one slab, it is counted as one slab with joint spalling. If spalling is located on more than one edge of the same slab, the edge having the highest severity is counted and recorded as one slab. Joint spalling can also occur along the edges of two adjacent slabs. If this is the case, each slab is counted as having joint spalling.

Name of Distress: Spalling (Corner)

Description: Corner spalling is the breakdown of the slab within approximately 2 ft (.6 m) of the corner. A corner spall differs from a corner break in that the spall usually angles downward to intersect the joint, while a break extends vertically through the slab corner.

Severity Levels:

Pieces of Spall	Area of Spall, sq in.* 8-25	25-50	50
Tight–Cannot be removed easily (may be a few pieces missing)	L	L	L
Loose–Can be removed and some (50 percent) are missing	L	M	M
Missing–Most or all have been removed	M	M	H

*Metric Conversion Factor: 1 sq in. = 6.45 cm^2

Corner spalling having an area less than 8 sq in. (51.6 cm^2) is not counted.

How to Count: If one or more corner spalls having the same severity level are located in a slab, the slab is counted as one slab with corner spalling. If more than one severity level occurs, it is counted as one slab having the higher severity level.

Name of Distress: Corner Break

Description: A corner break is a crack that intersects the joints at a distance less than or equal to one-half the slab length on both sides, measured from the corner of the slab. For example, a slab with dimensions of 12 by 20 ft (4 by 6 m) that has a crack of 5 ft on one side and 12 ft (5.1 m) on the other side is not considered a corner break; it is a diagonal crack. However, a crack that intersects 4 ft (1.2 m) on one side and 8 ft (2.4 m) on the other is considered a corner break. A corner break differs from a corner spall in that the crack extends vertically through the entire slab thickness, while a corner spall intersects the joint at an angle. Load repetition combined with loss of support and curling stresses usually causes corner breaks.

Severity Levels:

L – Crack has either no spalling or minor spalling. If nonfilled, it has a mean width less than approximately 1/8 in. (.32 cm); a filled crack can be of any width, but the filler material must be in satisfactory condition. The area between the corner break and the joints is not cracked.

M – One of the following conditions exists: (1) filled or nonfilled crack is moderately spalled; (2) a nonfilled crack has a mean width between 1/8 and 1 in. (.32 to 2.54 cm), (3) a filled crack is not spalled or only lightly spalled, but the filler is in unsatisfactory condition; (4) the area between the corner break and the joints is lightly cracked.

H – One of the following conditions exists: (1) filled or nonfilled crack is severely spalled; (2) a nonfilled crack has a mean width greater than approximately 1 in. (2.54 cm); (3) the area between the corner break and the joints is severely cracked.

How to Count: A distressed slab is recorded as one slab if it (1) contains a single corner break; (2) contains more than one break of a particular severity; or (3) contains two or more breaks of different severities. For two or more breaks, the highest level of severity should be recorded. For example, a slab containing both light- and medium-severity corner breaks should be counted as one slab with a medium corner break.

Name of Distress: Patching, Small (Less Than 5 Sq Ft [.45 m^2])

Description: A patch is an area where the original pavement has been removed and replaced by a filler material. For condition evaluation, patching is divided into two types: small (less than 5 sq ft [.45 m^2]) and large (more than 5 sq ft [.45 m^2]).

Severity Levels:

L – Patch is functioning well with little or no deterioration.

M – Patch has deteriorated, and/or moderate spalling can be seen around the edges. Patch material can be dislodged with considerable effort.

H – Patch has deteriorated, either by spalling around the patch or cracking within the patch, to a state which warrants replacement.

How to Measure: If one or more small patches having the same severity level are located in a slab, they are counted as one slab containing that distress. If more than one severity level occurs, it is counted as one slab with the high severity level.

Name of Distress:	Shrinkage Cracks
Description:	Shrinkage cracks are hairline cracks that are usually only a few feet long and do not extend across the entire slab. They are formed during the setting and curing of concrete and usually do not extend through the depth of the slab.
Severity Levels:	No degrees of severity are defined. It is sufficient to indicate that shrinkage cracks exist.
How to Count:	If one or more shrinkage cracks exist on one particular slab, the slab is counted as one slab with shrinkage cracks.

Name of Distress: Depression/Settlement

Description: Depressions or settlements of the pavement surface are areas of the pavement which are lower than the surrounding pavement grades. These areas cause roughness and also allow the ponding of water. They are a cause for potential hydroplaning. They are also a contributing factor in weakening subgrade support, which allows water to seep down through the joints and cracks rather than running off.

Severity Levels:

L – Ride quality* is low severity

M – Ride quality is medium severity

H – Ride quality is high severity

How to Count: The slabs contained within the depression are counted.

*See page 51 for definition of ride quality.

Name of Distress: Lane/Shoulder Drop Off

Description: Lane/shoulder drop off is the differential settlement or erosion of the shoulder with respect to the pavement travel lane edge. This settlement causes a difference in elevation which can be a safety hazard. The settlement also increases water infiltration into the pavement.

Severity Levels:

L – The difference in elevation between the pavement edge and shoulder is 1/4 to 3/4 in. (.63 to 1.89 cm).

M – The difference in elevation is 3/4 to 1-1/2 in. (1.89 to 3.81 cm)

H – The difference in elevation is greater than 1-1/2 in. (3.81 cm)

How to Count: The slabs affected by the lane/shoulder drop-off are counted. The difference in elevation is the average of three different measurements along the side of the slab.

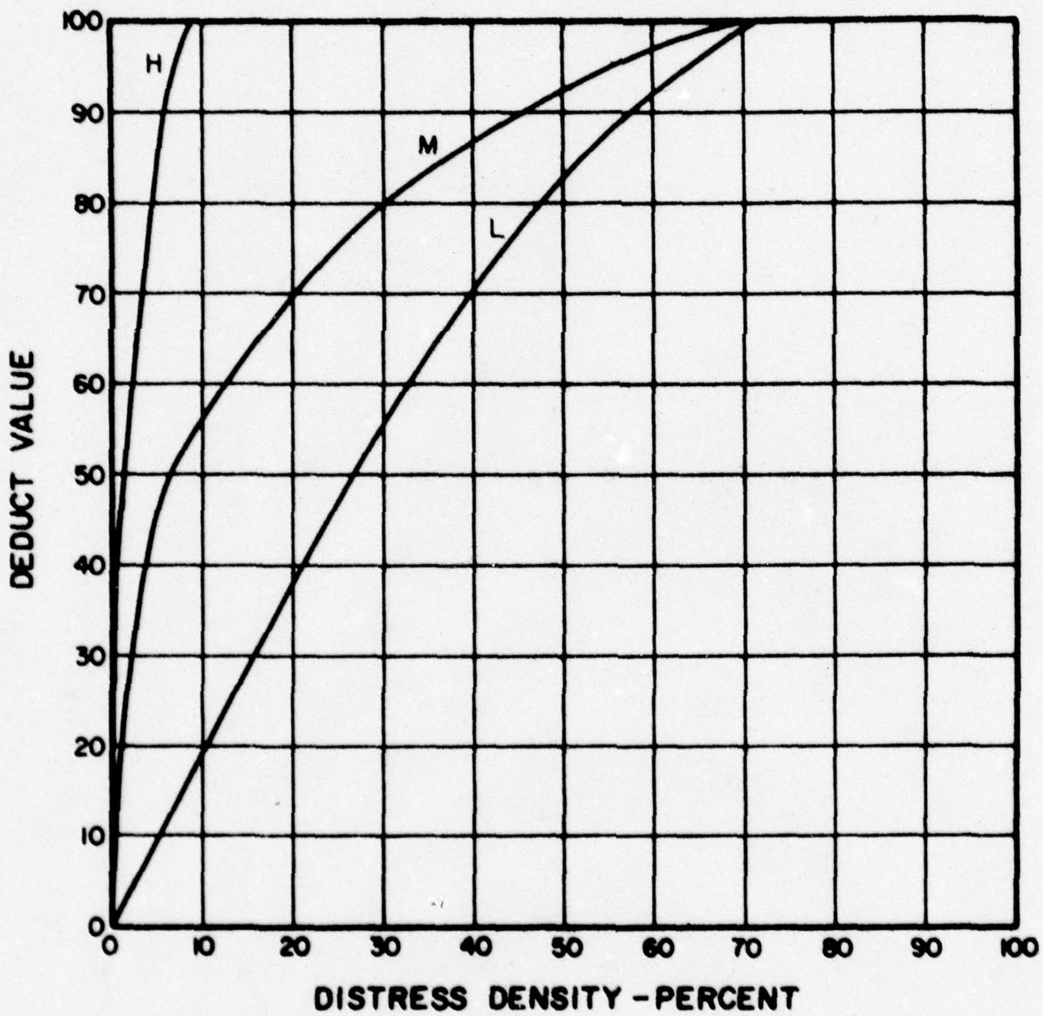
Ride quality is determined by riding in a *standard-size automobile* over the pavement section at the posted speed limit. Pavement sections located near stop signs should be rated at the normal deceleration speed used when approaching the sign. Ride quality is rated according to the following guidelines:

L – (1) Vibrations of the vehicle (i.e. from corrugations) are noticeable, but no reduction in speed is necessary for comfort or safety, and/or (2) individual bumps or settlements cause some bounce of the vehicle which creates no discomfort.

M – (1) Vibrations of the vehicle are significant and some reduction in speed is necessary for safety and comfort, and/or (2) individual bumps or settlements cause significant bounce of the vehicle, which creates some discomfort.

H – (1) Vibrations are so excessive that considerable reduction in speed is necessary for safety and comfort, and/or (2) individual bumps or settlements cause excessive bounce of the automobile, which creates substantial discomfort, and/or a safety hazard, and/or vehicle damage.

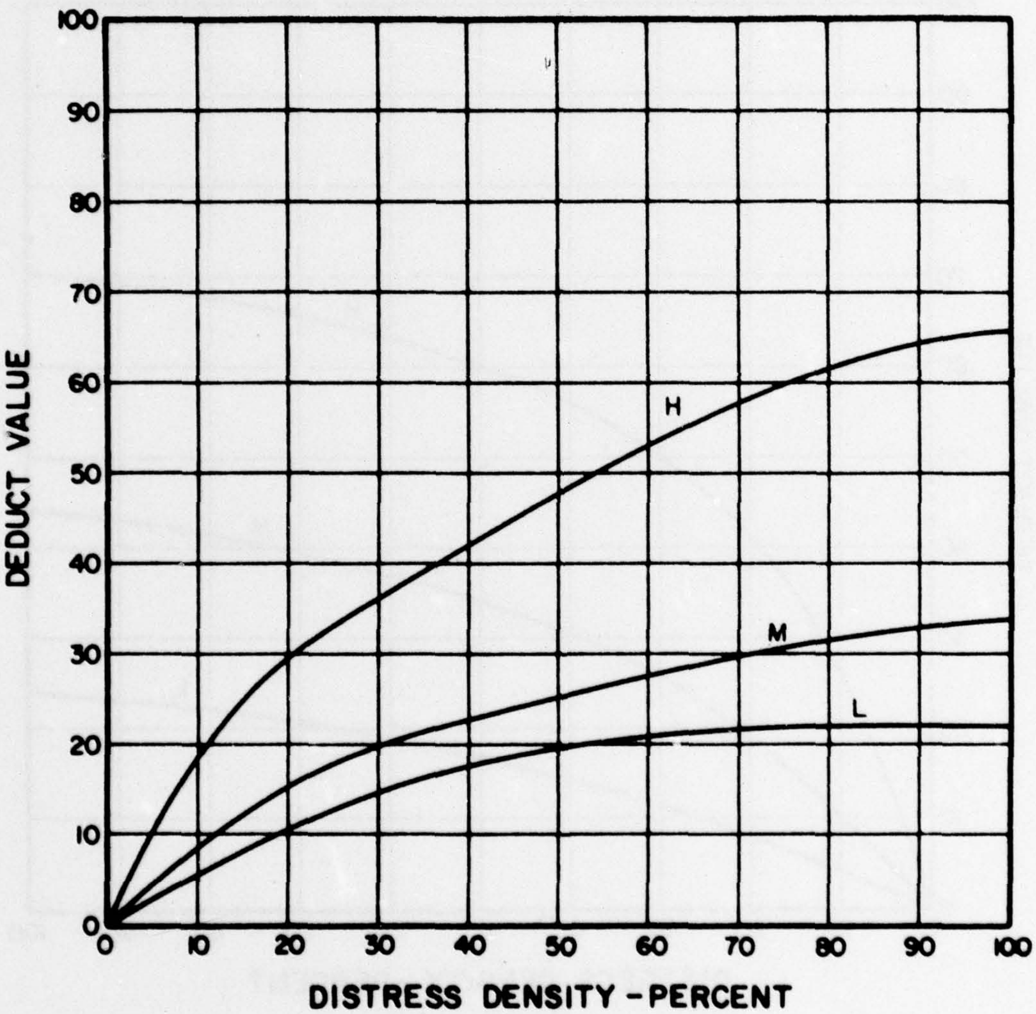
Note: Curves are undergoing validation. Validated curves will be published in final report.



1. Blow-ups

Figure A1. Jointed concrete pavement deduct curves.

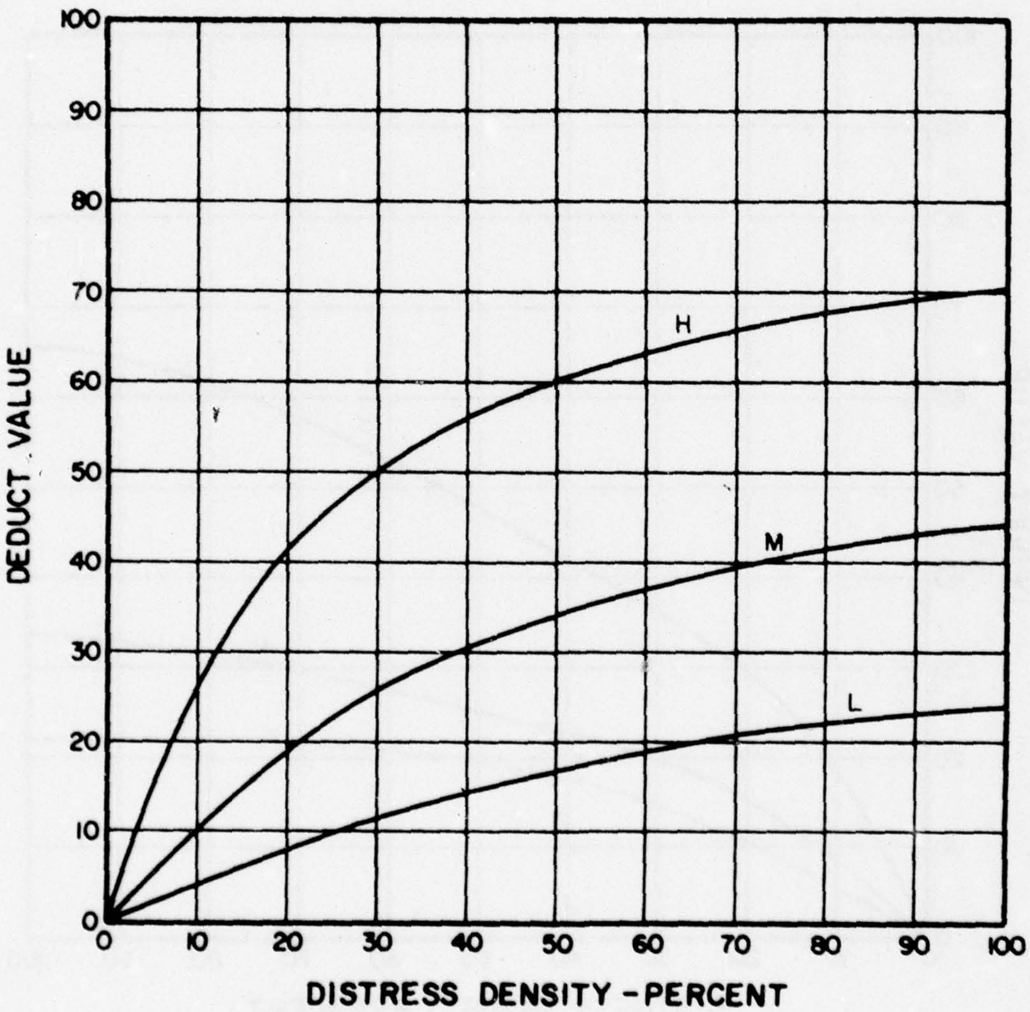
Note: Curves are undergoing validation. Validated curves will be published in final report.



2. Linear cracking

Figure A1 (cont'd)

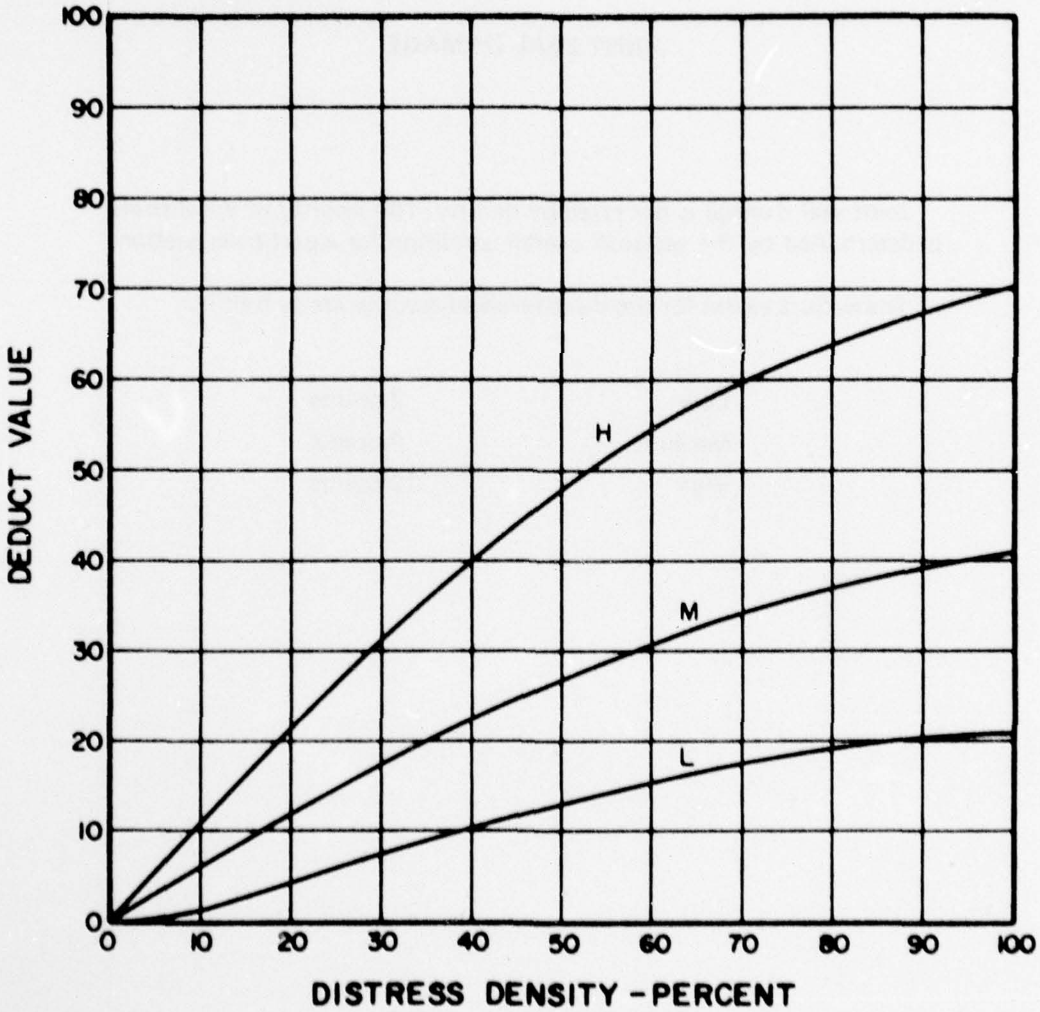
Note: Curves are undergoing validation. Validated curves will be published in final report.



3. Durability cracking

Figure A1 (cont'd)

Note: Curves are undergoing validation. Validated curves will be published in final report.



4. Faulting
Figure A1 (cont'd)

JOINT SEAL DAMAGE

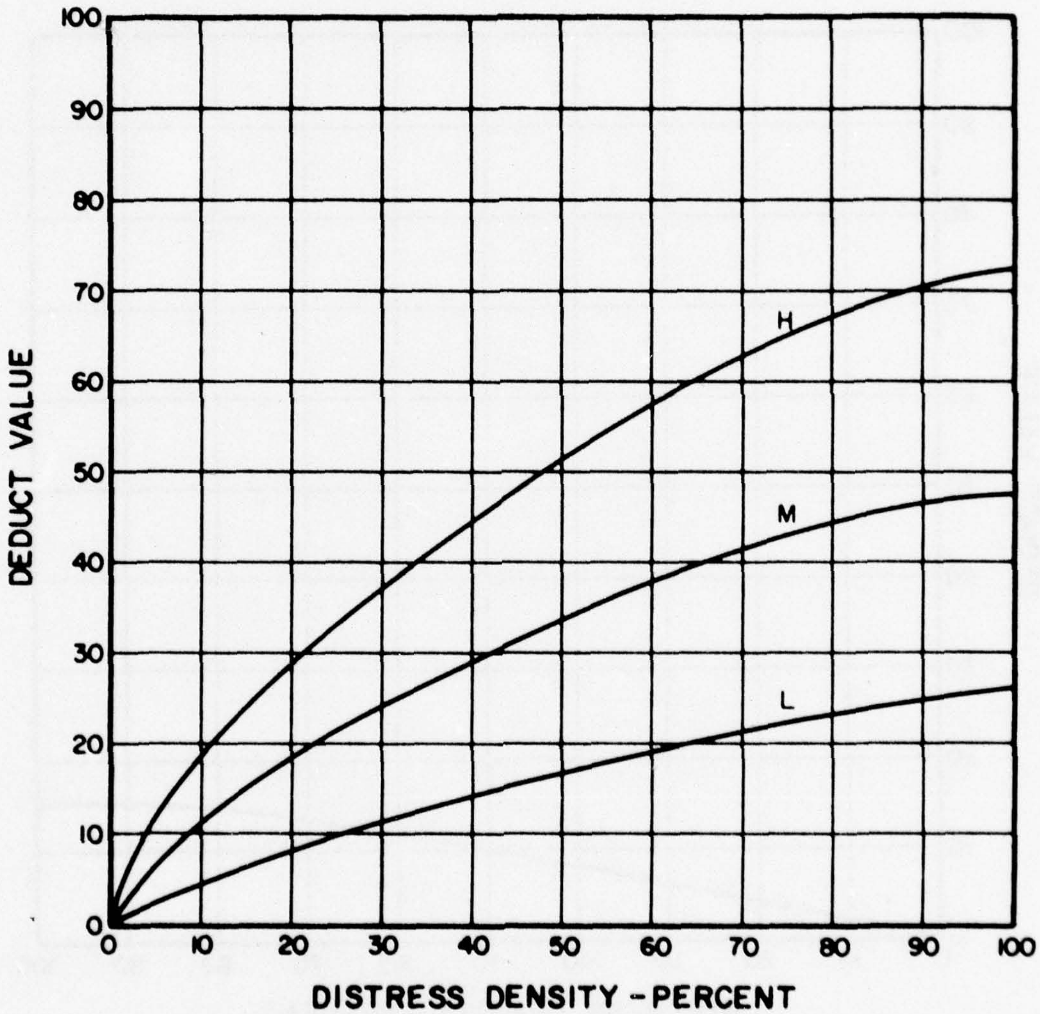
Joint seal damage is not rated by density. The severity of the distress is determined by the sealant's overall condition for a particular section.

The deduct values for the three levels of severity are as follows:

Low	2 points
Medium	4 points
High	10 points

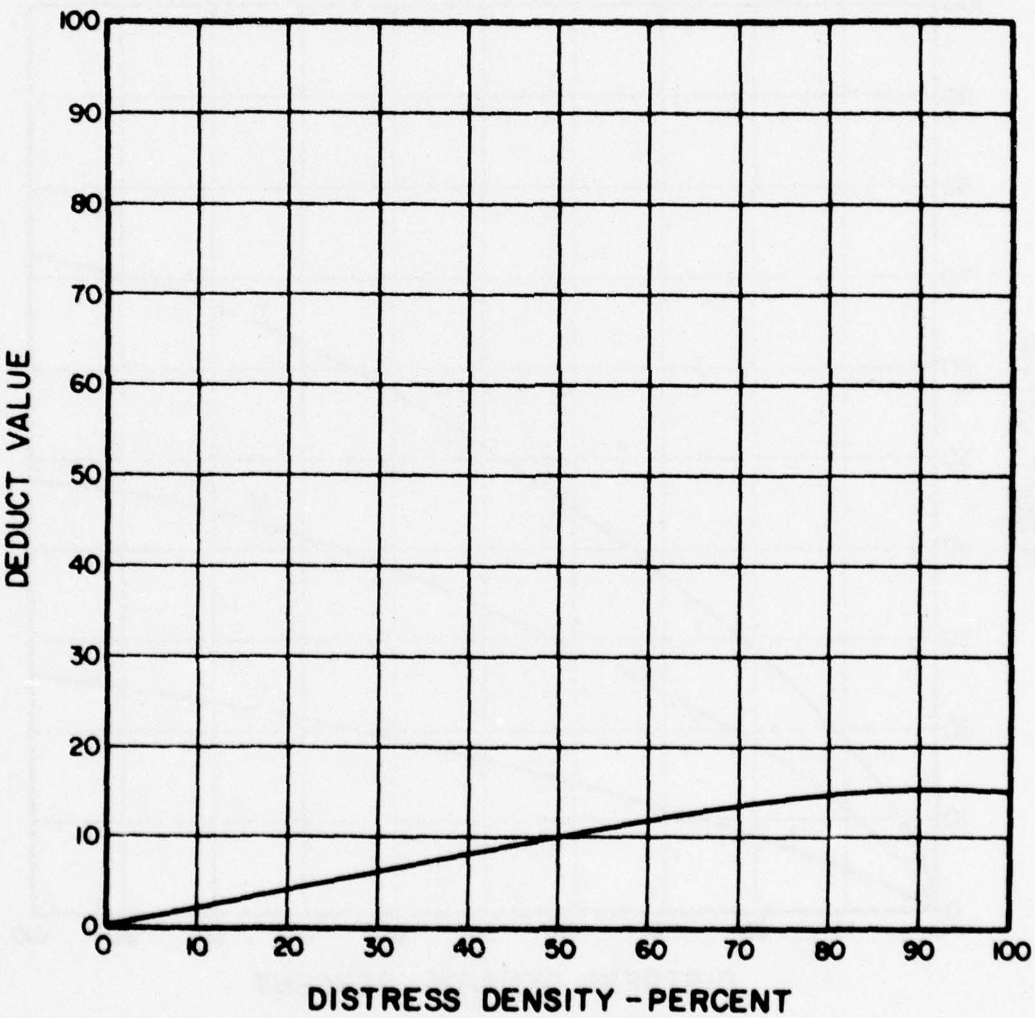
5. Joint seal damage
Figure A1 (cont'd)

Note: Curves are undergoing validation. Validated curves will be published in final report.



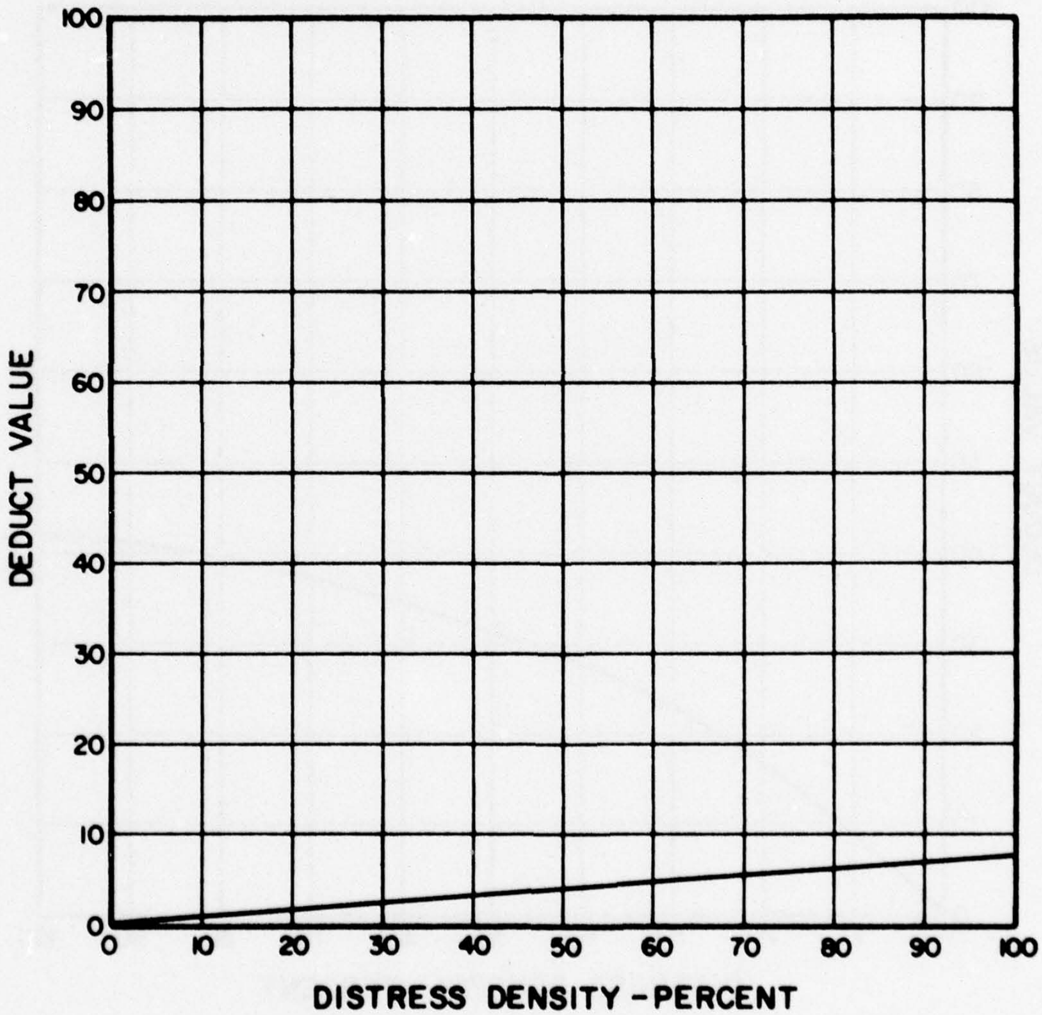
6. Patch/utility cut (>5 sq ft)
Figure A1 (cont'd)

Note: Curves are undergoing validation. Validated curves will be published in final report.



7. Polished aggregate
Figure A1 (cont'd)

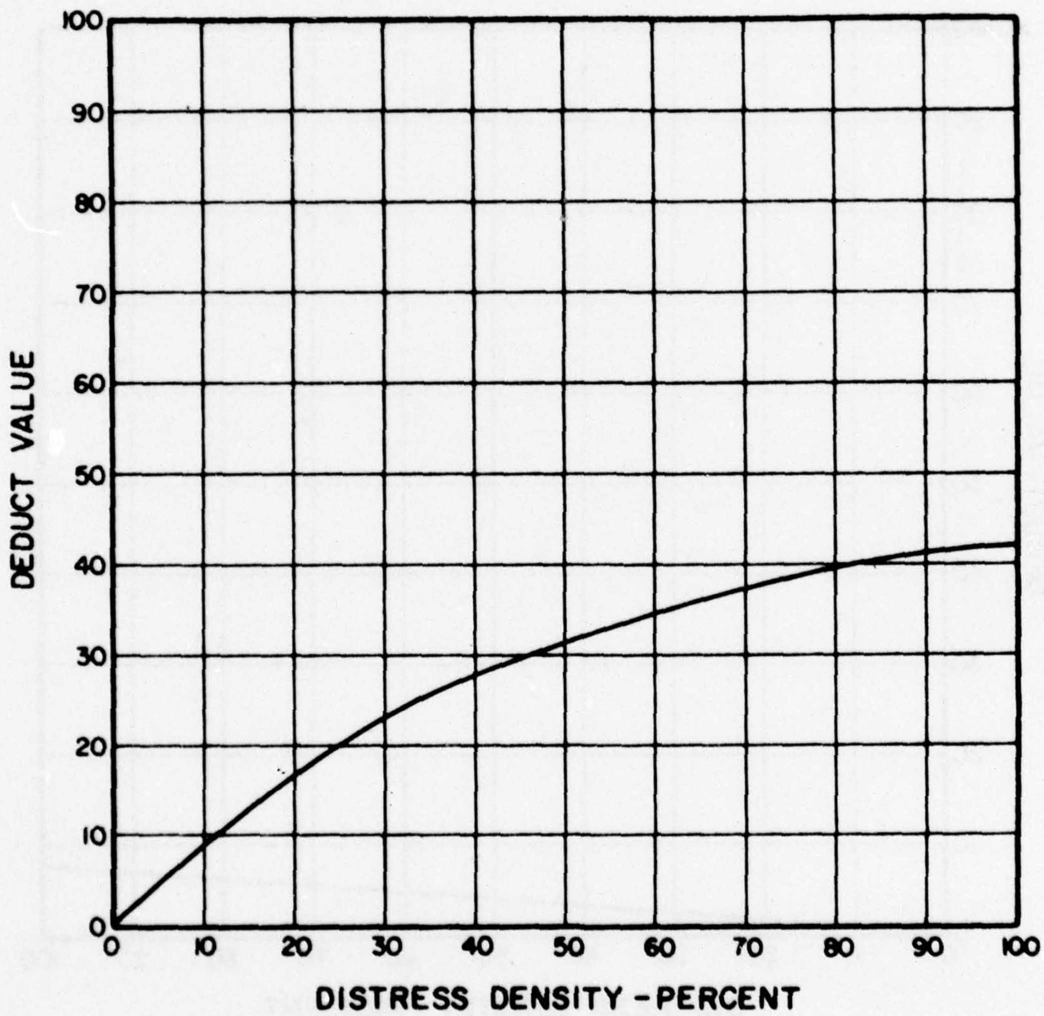
Note: Curves are undergoing validation.
Validated curves will be published
in final report.



8. Popouts

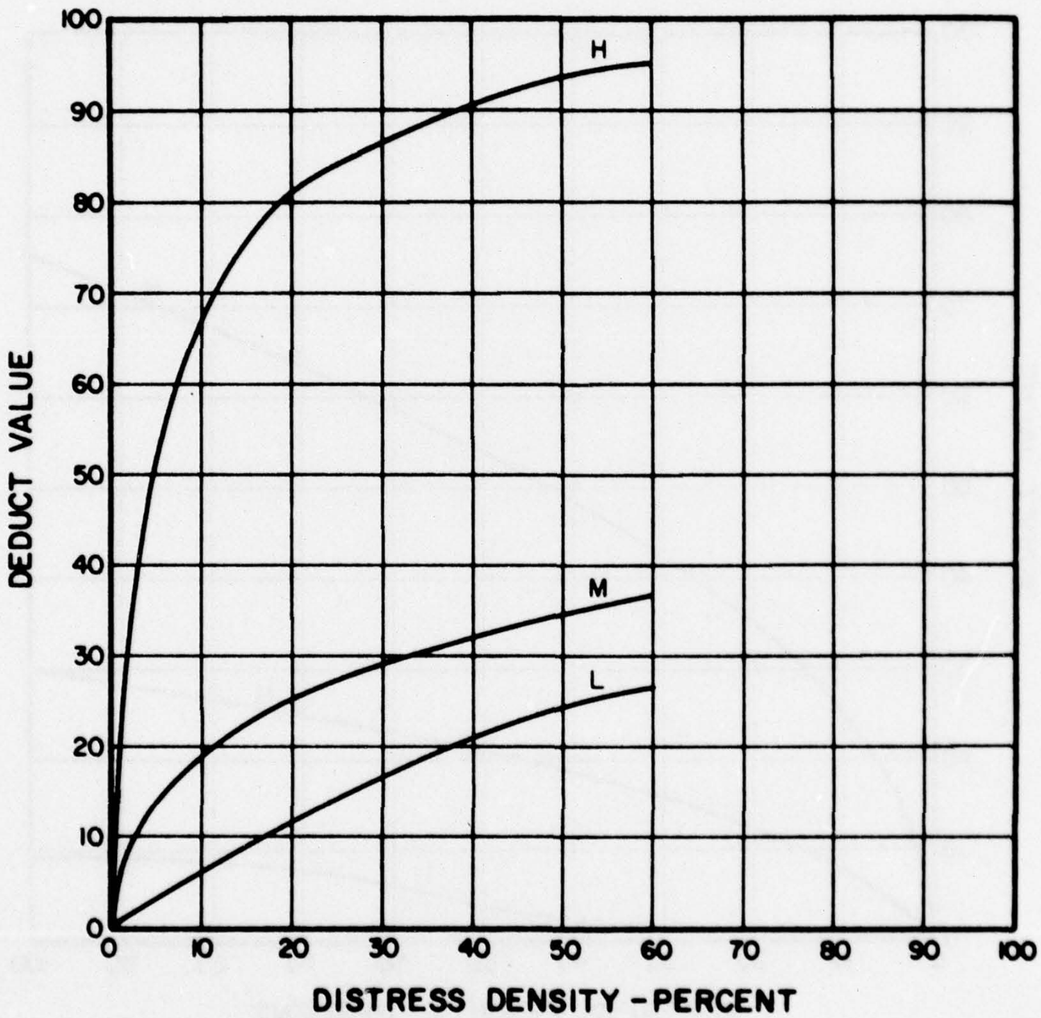
Figure A1 (cont'd)

Note: Curves are undergoing validation.
Validated curves will be published
in final report.



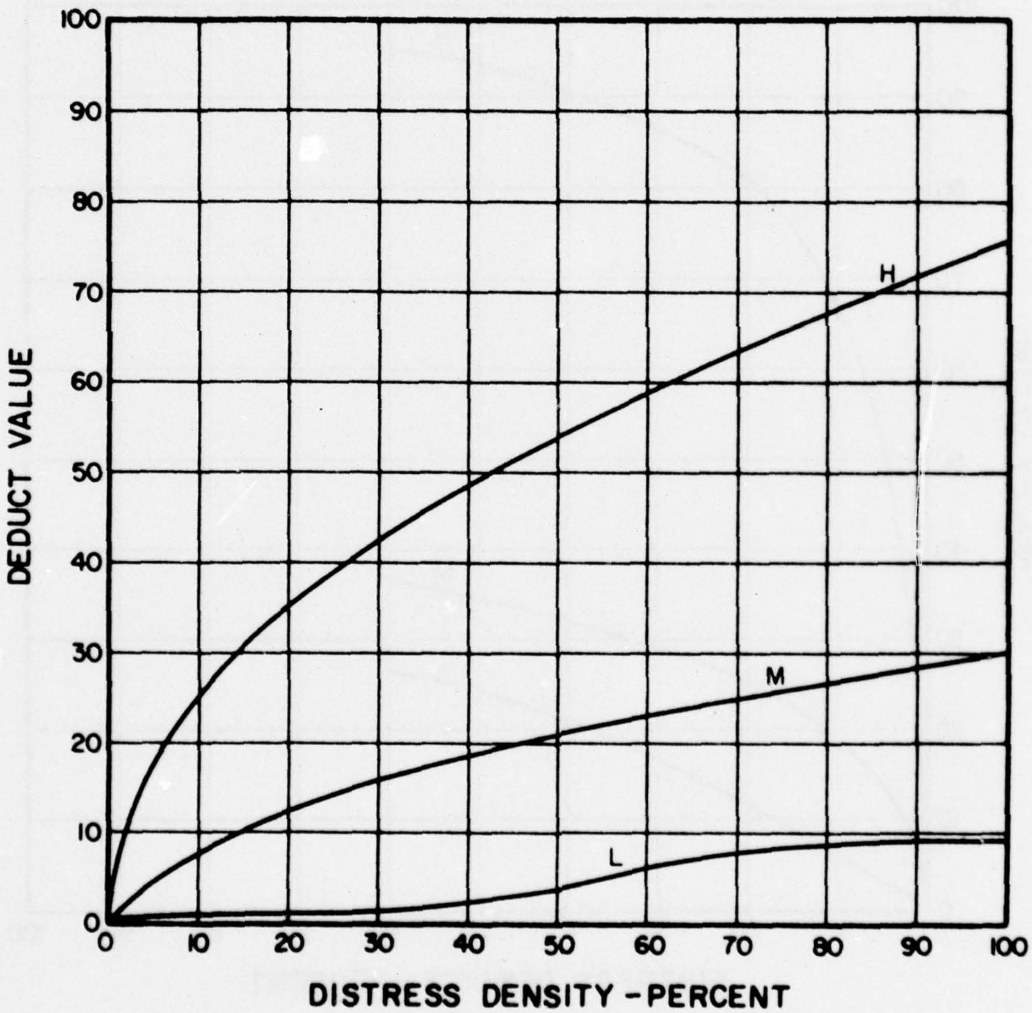
9. Pumping
Figure A1 (cont'd)

Note: Curves are undergoing validation. Validated curves will be published in final report.



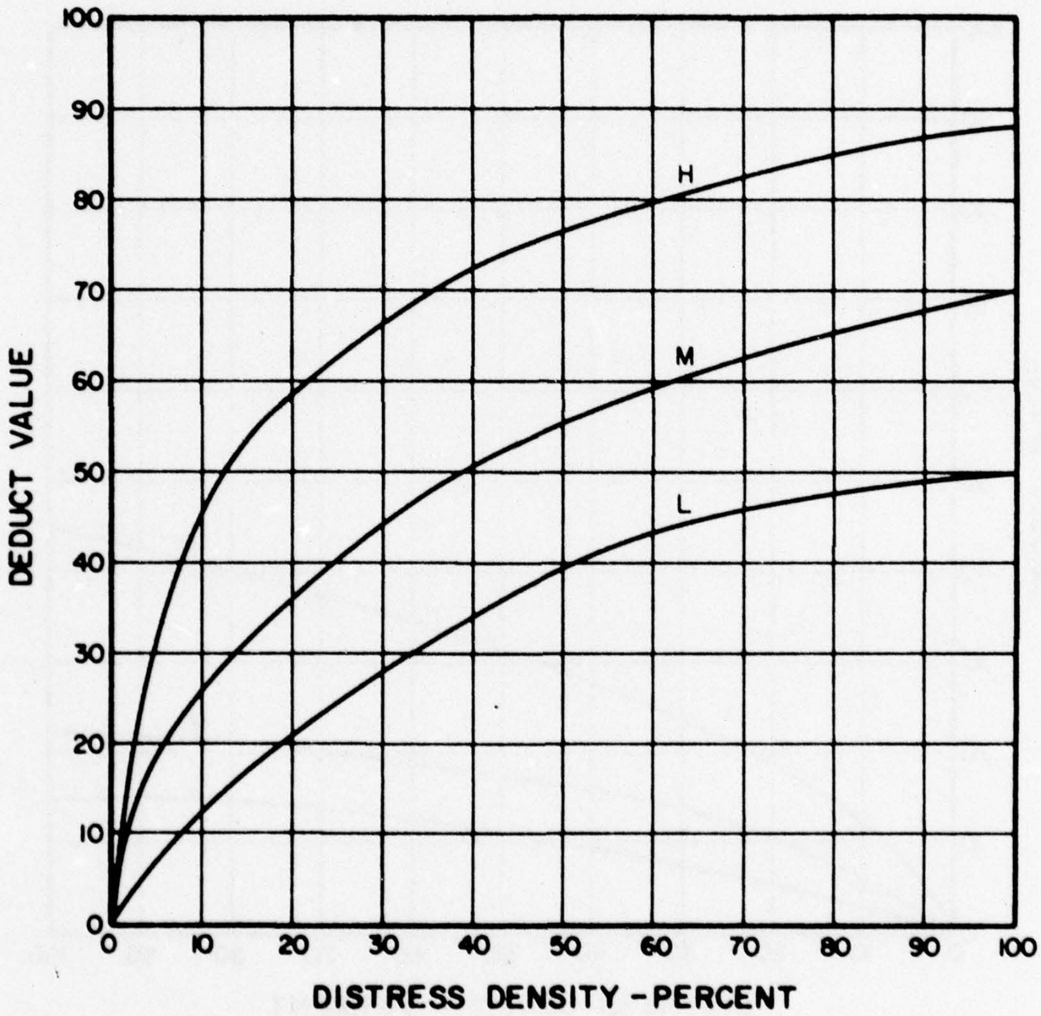
10. Railroad crossing
Figure A1 (cont'd)

Note: Curves are undergoing validation.
Validated curves will be published
in final report.



11. Scaling
Figure A1 (cont'd)

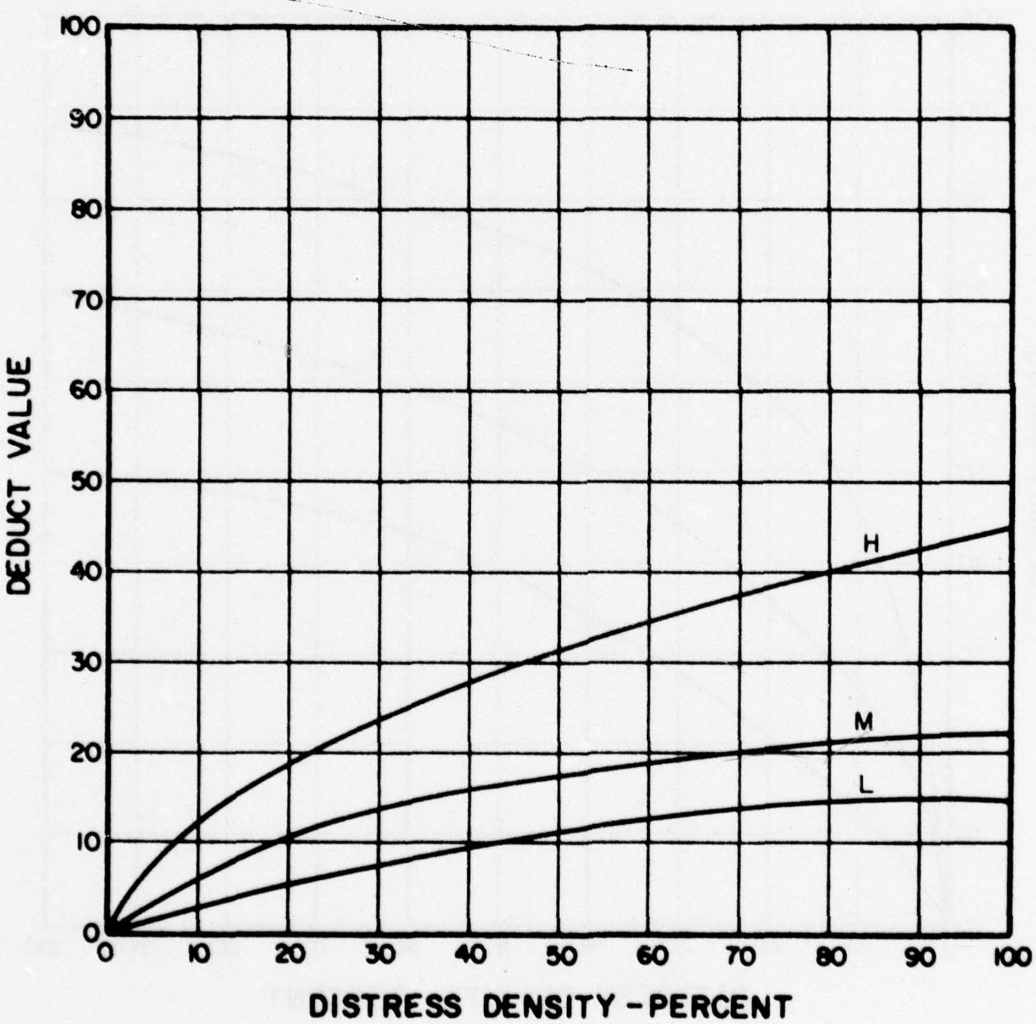
Note: Curves are undergoing validation. Validated curves will be published in final report.



12. Divided slab

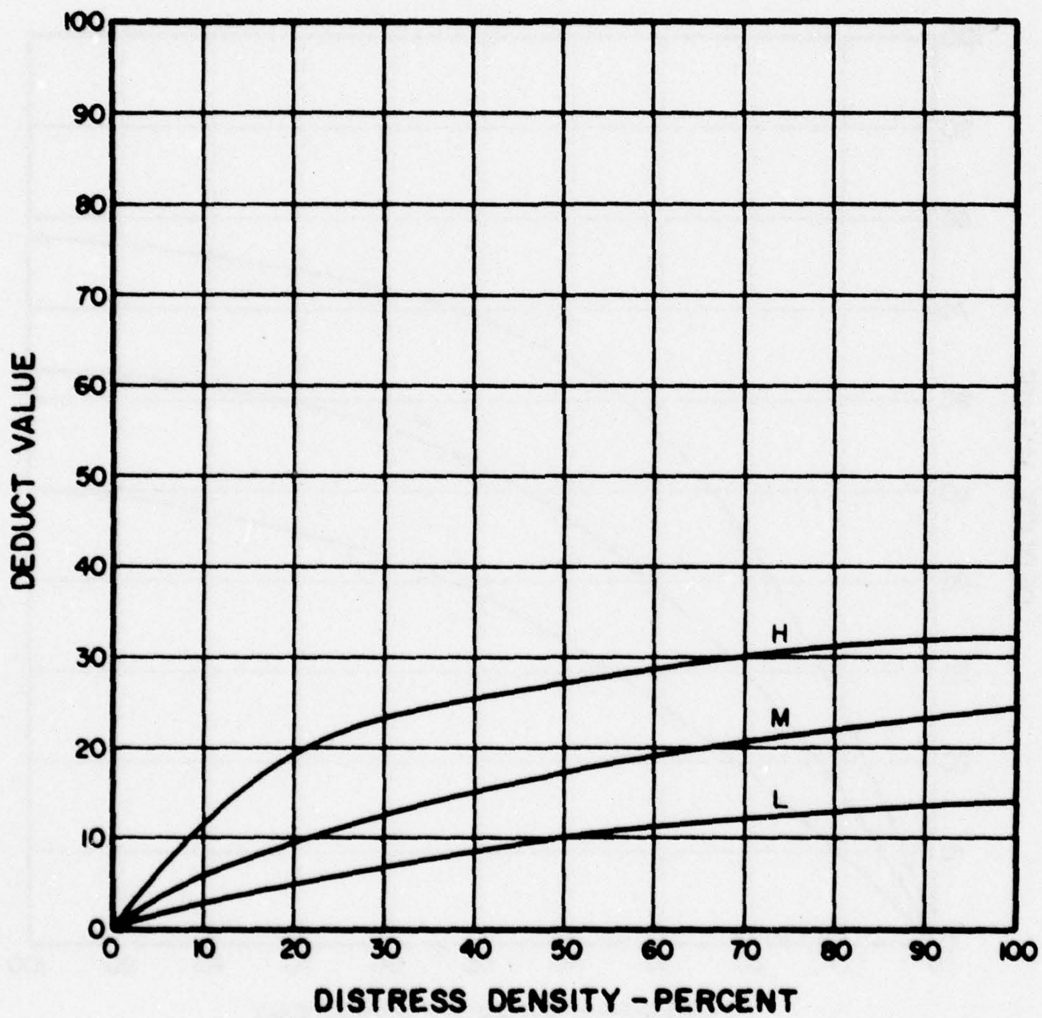
Figure A1 (cont'd)

Note: Curves are undergoing validation. Validated curves will be published in final report.



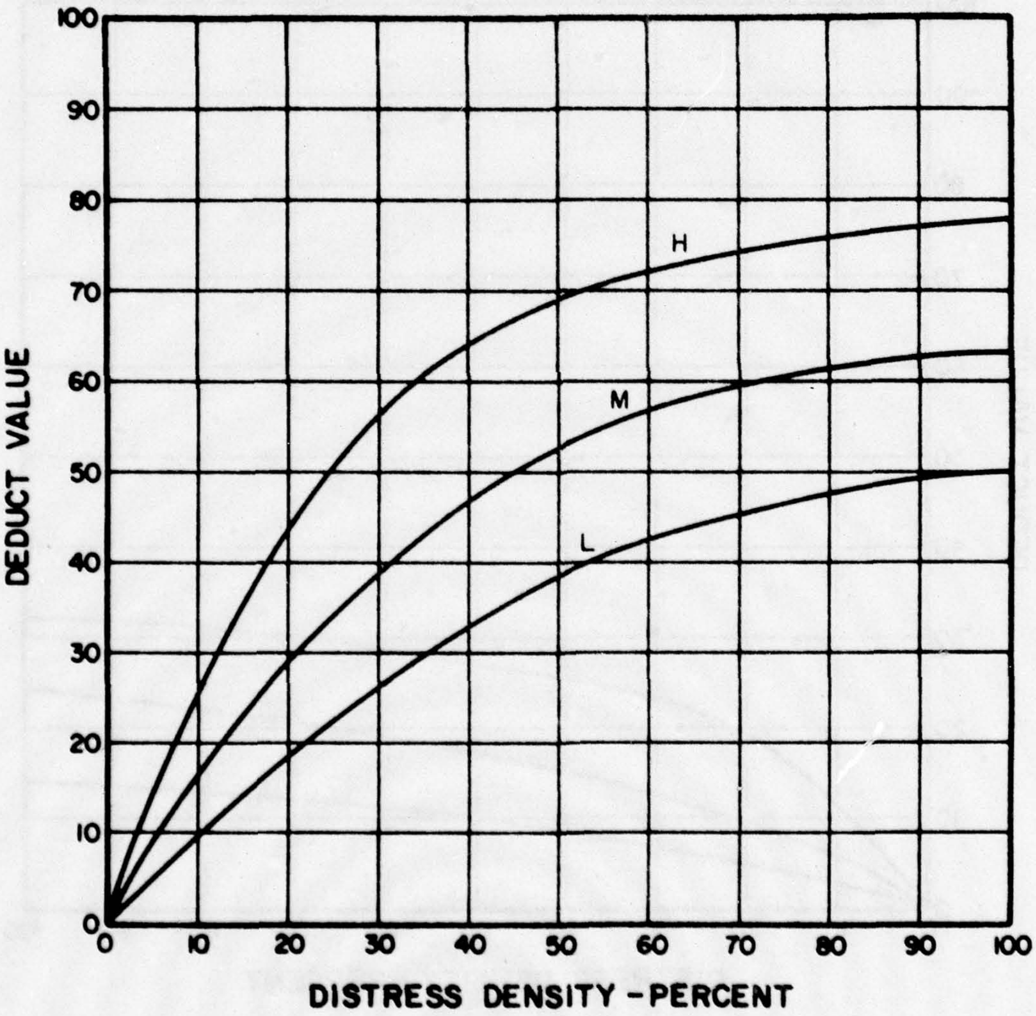
13. Joint spall
Figure A1 (cont'd)

Note: Curves are undergoing validation. Validated curves will be published in final report.



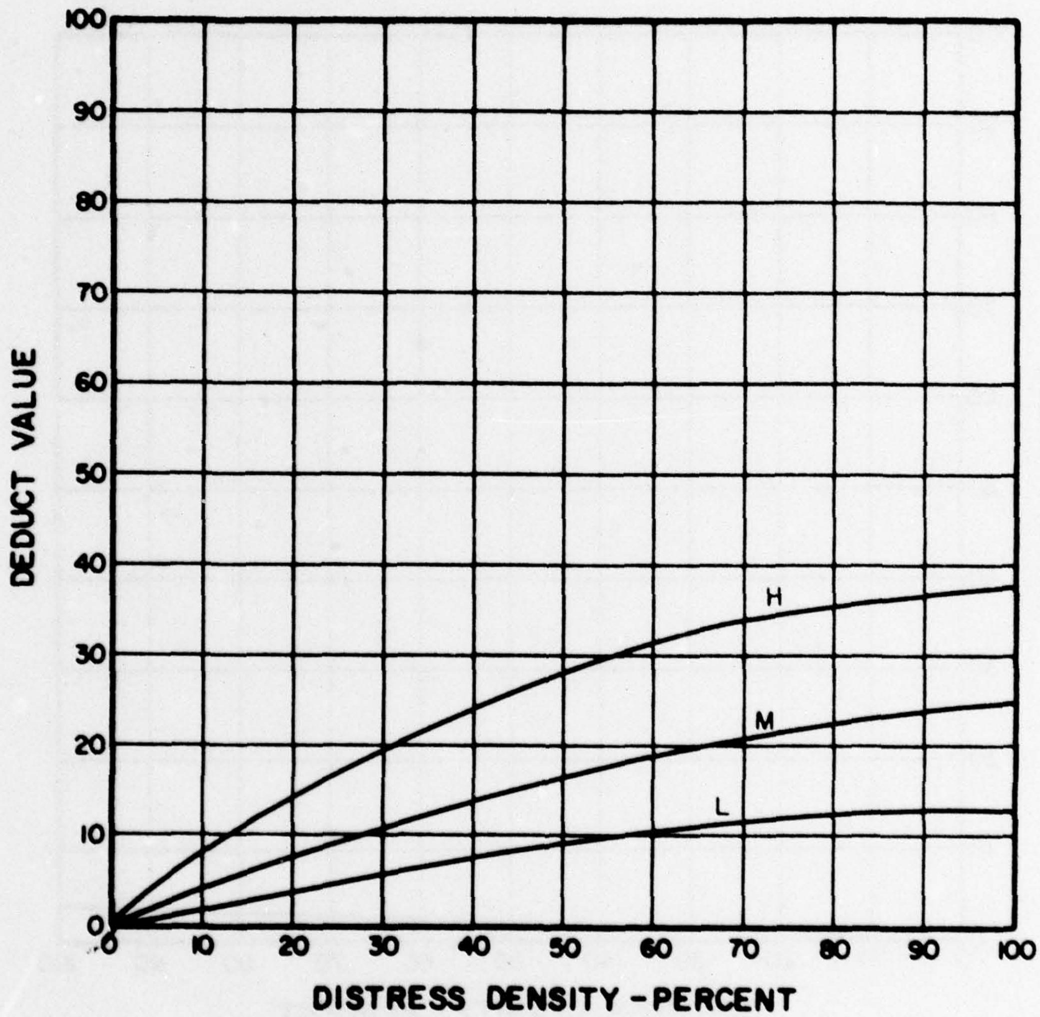
14. Corner spall
Figure A1 (cont'd)

Note: Curves are undergoing validation. Validated curves will be published in final report.



15. Corner break
Figure A1 (cont'd)

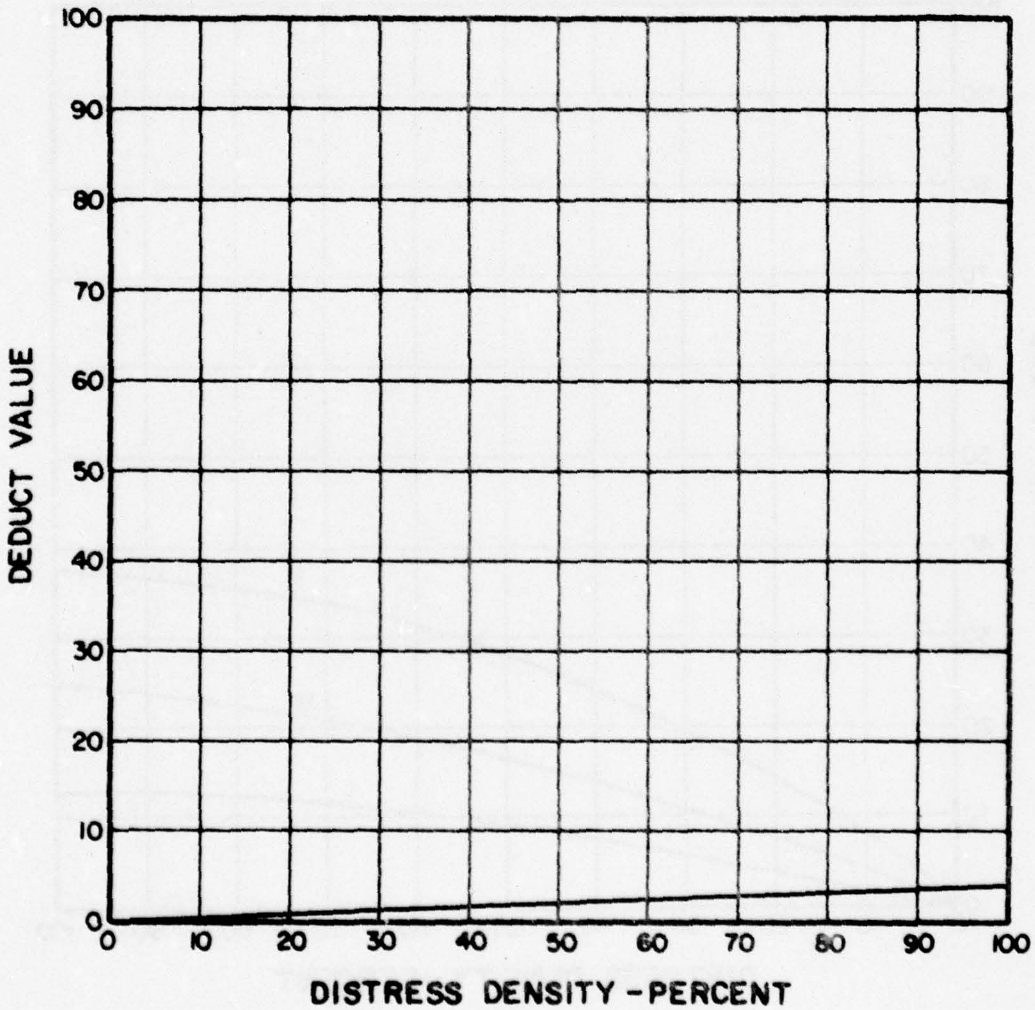
Note: Curves are undergoing validation. Validated curves will be published in final report.



16. Small patches

Figure A1 (cont'd)

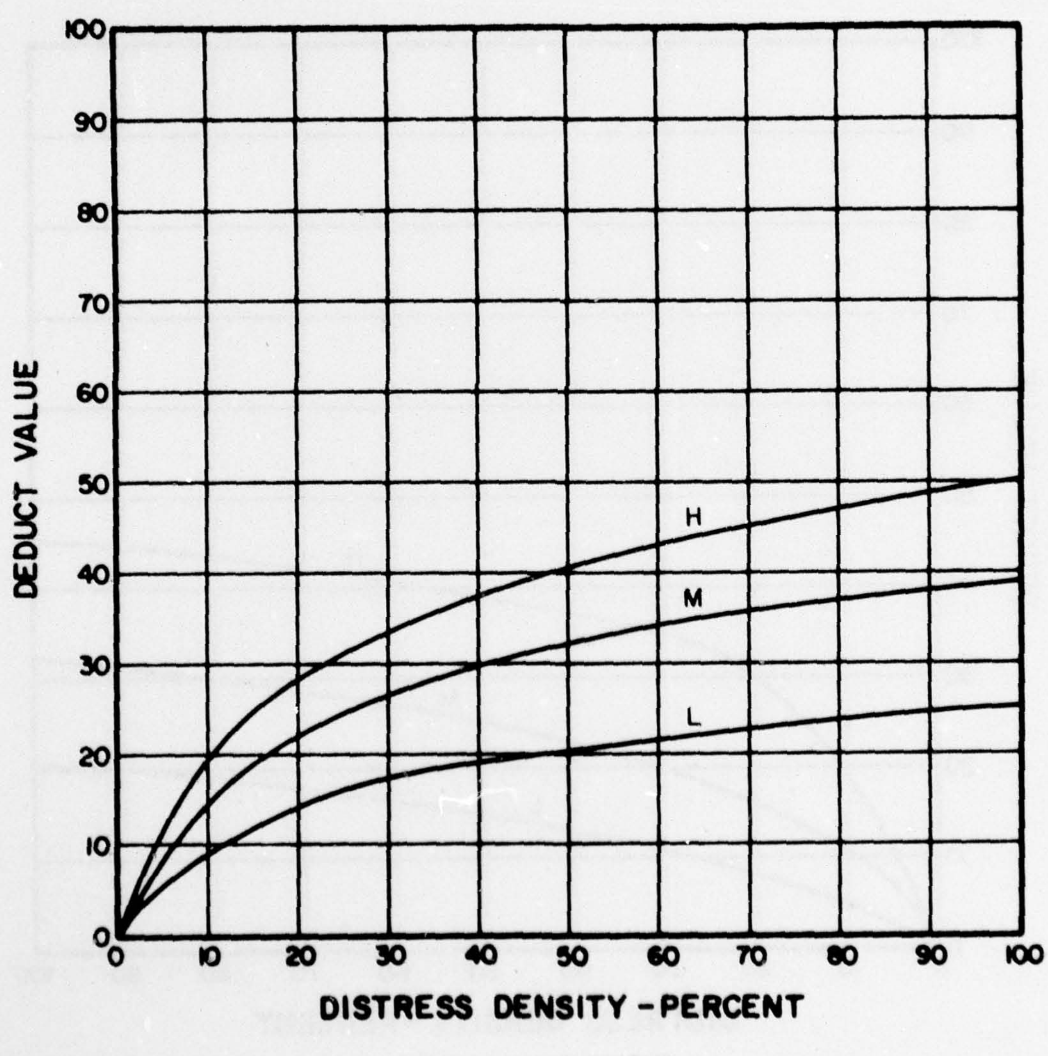
Note: Curves are undergoing validation.
Validated curves will be published
in final report.



17. Shrinkage cracks

Figure A1 (cont'd)

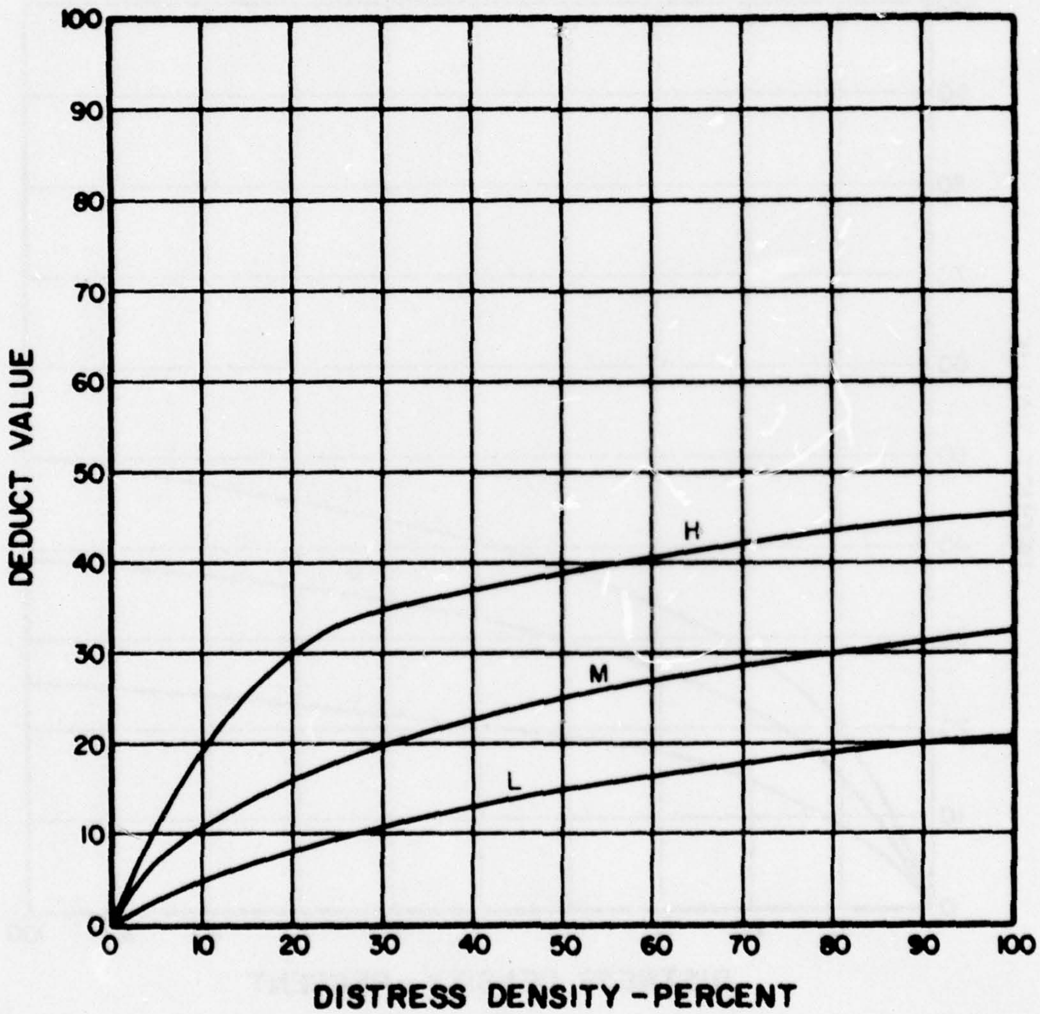
Note: Curves are undergoing validation. Validated curves will be published in final report.



18. Depression

Figure A1 (cont'd)

Note: Curves are undergoing validation. Validated curves will be published in final report.



19. Shoulder drop-off
Figure A1 (cont'd)

Note: Curves are undergoing validation.
Validated curves will be published
in final report.

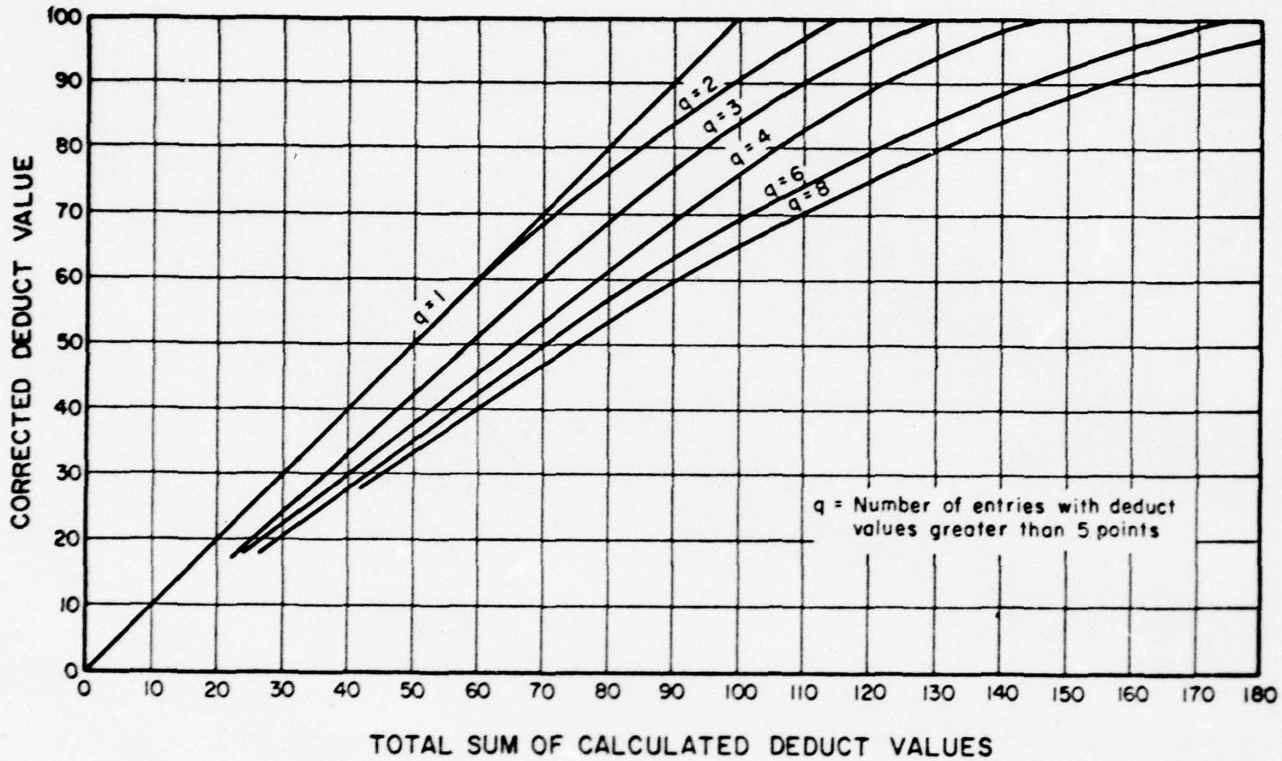


Figure A2. Corrected deduct values for jointed concrete pavements.

APPENDIX B:
ASPHALT- OR TAR-SURFACED PAVEMENT DISTRESS DEFINITIONS, DEDUCT CURVES, AND CORRECTION CURVES

PRECEDING PAGE BLANK

DISTRESS IN ASPHALT-SURFACED PAVEMENTS

Name of Distress: Alligator Cracking

Description:

Alligator or fatigure cracking is a series of interconnecting cracks caused by fatigue failure of the asphalt concrete surface under repeated traffic loading. The cracking initiates at the bottom of the asphalt surface (or stabilized base) where tensile stress and strain is highest under a wheel load. The cracks propagate to the surface initially as a series of parallel longitudinal cracks. After repeated traffic loading, the cracks connect, forming many-sided, sharp-angled pieces that develop a pattern resembling chicken wire or the skin of an alligator. The pieces are less than 2 ft (.6 m) on the longest side.

Alligator cracking occurs only in areas that are subjected to repeated traffic loadings, such as wheel paths. Therefore, it would not occur over an entire area unless the entire area were subjected to traffic loading. Pattern-type cracking which occurs over an entire area that is not subjected to loading is rated as block cracking, which is not a load-associated distress.

Alligator cracking is considered a major structural distress and is usually accompanied by rutting.

Severity Levels:

L – Fine, longitudinal hairline cracks running parallel to each other with no or only a few interconnecting cracks. The cracks are not spalled.

M – Further development of light alligator cracking into a pattern or network of cracks that may be lightly spalled.

H – Network or pattern cracking has progressed so that the pieces are well-defined and spalled at the edges; some of the pieces may rock under traffic.

NOTE: Spalling of the cracks is a breakdown of the material along the sides of the crack.

How to Measure:

Alligator cracking is measured in square feet of surface area. The major difficulty in measuring this type of distress is that two or three levels of severity often exist within one distressed area. If these portions can be easily distinguished from each other, they should be measured and recorded separately. However, if the different levels of severity cannot be divided easily, the entire area should be rated at the highest severity level present.

Name of Distress:		Bleeding
Description:		Bleeding is a film of bituminous material on the pavement surface which creates a shiny, grasslike, reflecting surface that usually becomes quite sticky. Bleeding is caused by excessive amounts of asphalt cement or tars in the mix and/or low air void content or excess application of a bituminous sealant. It occurs when asphalt fills the voids of the mix during hot weather and then expands onto the pavement surface. Since the bleeding process is not reversible during cold weather, asphalt or tar will accumulate on the surface.
Severity Levels:	L –	Bleeding has only occurred to a very slight degree and it is noticeable only during a few days of the year. Asphalt does not pick up on shoes or vehicles.
	M –	Bleeding has occurred to the extent that asphalt picks up on shoes and vehicles only during a few weeks in the year.
	H –	Bleeding has occurred extensively and considerable asphalt pickup on shoes and vehicles occurs during at least several weeks of the year.
How to Measure:		Bleeding is measured in square feet of surface area.

Name of Distress:	Block Cracking
Description:	Block cracks are interconnected cracks that divide the pavement into approximately rectangular pieces. The blocks may range in size from approximately 1 by 1 ft. (.3 by .3 m) to 10 by 10 ft (3 by 3 m). Block cracking is caused mainly by shrinkage of the asphalt concrete and daily temperature cycling (which results in daily stress/strain cycling). It is not load-associated. The occurrence of block cracking usually indicates that the asphalt has hardened significantly. Block cracking normally occurs over a large proportion of pavement area, but sometimes will occur only in nontraffic areas. This type of distress differs from alligator cracking in that alligator cracks form smaller, many-sided pieces with sharp angles. Also, unlike block cracks, alligator cracks are caused by repeated traffic loadings, and are therefore located only in traffic areas (i.e., wheel paths).
Severity Levels:	L – Blocks are defined by cracks that are nonspalled (sides of the crack are vertical) or only lightly spalled. Nonfilled cracks have 1/4 in. (.65 cm) or less mean width, and filled cracks have a filler in satisfactory condition.
	M – Blocks are defined by either (1) filled or nonfilled cracks that are moderately spalled; (2) nonfilled cracks that are not spalled or have only minor spalling but have a mean width greater than approximately 1/4 in. (.63 cm); or (3) filled cracks that are not spalled or have only minor spalling, but have filler in unsatisfactory condition.
	H – Blocks are well-defined by cracks that are severely spalled.
How to Measure:	Block cracking is measured in square feet of surface area. It usually occurs at one severity level in a given pavement section; however, any areas of the pavement section having distinctly different levels of severity should be measured and recorded separately.

Name of Distress: Bumps

Description: Bumps are localized upward displacements of the pavement surface. Bumps can be caused by several factors. Some of the common causes are:

1. Buckling or bulging of underlying PCC slabs (AC overlay)

2. Frost leave (ice lens growth)

3. Infiltration and buildup of material in a crack in combination with traffic loading (sometimes called "tenting)

Distortion and displacement can also take place over large areas of the pavement surface, causing large and/or long dips in the pavement. This condition is described under swelling.

Severity Levels:

L – Bump causes low-severity ride quality.*

M – Bump causes medium-severity ride quality.

H – Bump causes high-severity ride quality.

How to Measure: Bumps are measured in units of length (linear feet). If bumps occur in a pattern perpendicular to traffic flow and are spaced at $\leqslant$ 10 ft (3 m), the distress is counted as corrugation. If the bump is located in combination with a crack, the crack is also recorded.

*See page 51 for definition.

Name of Distress:		Corrugation
Description:		Corrugation is a series of closely spaced ridges and valleys (ripples) occurring at fairly regular intervals (usually less than 10 ft [3 m]) along the pavement. The ridges are perpendicular to the traffic direction. Traffic action combined with an unstable pavement surface or base usually causes this type of distress. If bumps occur in a series of less than 10 ft (3 m), no matter what the cause is the distress is considered corrugation.
Severity Levels:	L –	Corrugations cause low-severity ride quality.*
	M –	Corrugations cause medium-severity ride quality.
	H –	Corrugations have a high-severity ride quality.
How to Measure:		Corrugation is measured in square feet of surface area.

*See page 51 for definition.

Name of Distress: Depression

Description:

Depressions are localized pavement surface areas having elevations slightly lower than those of the surrounding pavement. In many instances, light depressions are not noticeable until after a rain, when ponding water creates "birdbath" areas; but the depressions can also be located without rain because of stains created by ponding of water. Depressions can be created by settlement of the foundation soil or can be "built up" during construction. Depressions cause roughness and, when filled with water of sufficient depth, could cause hydroplaning.

Severity Levels:

Maximum Depth of Depression

Severity	**High Speed** (> 40 mph)	**Low Speed** (< 40 mph)
L	1/8 – 1/2 in. (.32 – 1.27 cm)	1/2 – 1 in. (1.27 – 2.54 cm)
M	> 1/2 – 1 in. (1.27 – 2.54 cm)	> 1 – 2 in. (2.54 to 5.08 cm)
H	> 1 in. (2.54 cm)	> 2 in. (5.08 cm)

How to Measure:

Depressions are measured in square feet of surface area. The depth can be measured by placing a 10-foot straightedge across the depressed area and measuring the maximum depth in inches.

Name of Distress:		Edge Cracking
Description:		Edge cracks are parallel to and usually within 1 ft (.3 m) of the outer edge of the pavement. This distress can be caused by front-weakened base or subgrade near the edge of the pavement accelerated by traffic loadings. If the area between the crack and pavement edge breaks up (sometimes to the extent that pieces are removed), it is said to be raveled.
Severity Levels:	L –	Light cracks with no breakup or raveling.
	M –	Medium cracks with some breakup and raveling.
	H –	Considerable breakup or raveling along the edge.
How to Measure:		Edge cracking is measured in linear feet.

Name of Distress: Longitudinal and Transverse Cracking (non-PCC Slab Joint Reflective)

Description: Longitudinal cracks are parallel to the pavement's centerline or laydown direction. They may be caused by (1) a poorly constructed paving lane joint; (2) shrinkage of the AC surface due to low temperatures or hardening of the asphalt; or (3) a reflective crack caused by cracks beneath the surface course, including cracks in PCC slabs (but not at PCC joints). Transverse cracks extend across the pavement at approximately right angles to the pavement centerline or direction of laydown. They may be caused by items 2 or 3 above. These types of cracks are not usually load-associated. If the pavement is fragmented along a crack, the crack is said to be spalled.

Severity Levels:

L – Cracks have either minor spalling or no spalling. The cracks can be filled or nonfilled. Nonfilled cracks have a mean width of 1/4 in. (.63 cm) or less; filled cracks are of any width, but their filler material is in satisfactory condition.

M – One of the following conditions exists: (1) cracks are moderately spalled and can be either filled or nonfilled and of any width; (2) filled cracks are not spalled or are only lightly spalled, but the filler is in unsatisfactory condition; (3) nonfilled cracks are not spalled or are only lightly spalled, but mean crack width is greater than 1/4 in. (.63 cm); or (4) light random cracking exists near the crack or at the corners of intersecting cracks.

H – Cracks are severely spalled. They can be filled or nonfilled of any width.

How to Measure: Longitudinal and transverse cracks are measured in linear feet. The length and severity of each crack should be identified and recorded. If the crack does not have the same severity level along its entire length, each portion of the crack having a different severity level should be recorded separately. If a bump occurs at the crack, it is also recorded.

Name of Distress: Patching and Utility Cut Patch

Description: A patch is considered a defect, no matter how well it is performing. If a large amount of the pavement has been repaved or overlaid, it should not be recorded as a patch.

Severity Levels:

L – Patch is in good condition and is performing satisfactorily. Ride quality*is rated as low severity or better.

M – Patch is somewhat deteriorated and/or ride quality is rated as medium severity.

H – Patch is badly deteriorated and/or ride quality is rated as high severity. Patch needs replacement soon.

How to Measure: Patching is measured in square feet of surface area. However, if a single patch has areas of differing severity levels, these areas should be measured and recorded separately. For example, a 25-sq ft (2.25 m^2) patch may have 10 sq ft (.9 m^2) of medium severity and 15 sq ft (1.35 m^2) of low severity. These areas would be recorded separately. No other distresses are recorded within a patch (i.e., if patch material is shoving, it should not be counted as shoving.)

*See page 51 for definition.

Name of Distress:	Polished Aggregate
Description:	Aggregate polishing is caused by repeated traffic applications. Polished aggregate is present when close examination of a pavement reveals that the portion of aggregate extending above the asphalt is either very small, or that there are no rough or angular aggregate particles to provide good skid resistance. This type of distress is also indicated when the number on a skid resistance rating test is low or has dropped significantly from previous ratings.
Severity Levels:	No degrees of severity are defined. However, the degree of polishing should be significant before it is included in the condition survey and rated as a defect.
How to Measure:	Polished aggregate is measured in square feet of surface area.

Name of Distress: Potholes

Description: Potholes are small (usually less than 3 ft [.9m] in diameter), bowl-shaped depressions in the pavement surface. They generally have sharp edges and vertical sides near the top of the hole. Potholes are produced when traffic abrades small pieces of the pavement surface. These spots disintegrate because of poor surface mixtures, weak spots in the base or subgrade, or because they have reached a condition of high-severity alligator cracking. Free moisture collection in the hole accelerates its development. Potholes are generally structurally related distress and should not be confused with raveling and weathering. Thus, when holes are created from high-severity alligator cracking, they should be identified as potholes and not as weathering.

Severity Levels: Levels of severity are determined based on both the diameter and the depth of the pothole according to the table below.

Maximum Depth of Pothole	Average Diameter (inches [cm]) <6 in. (15.24 cm)	6 to 18 in. (15.24 to 45.72 cm)	>18 in. (45.72 cm)
1/2 to 1 in. (1.27 to 2.54 cm)	L	L	M
1 to 2 in. (2.54 to 5.08 cm)	L	M	H
>2 in. (5.08 cm)	M	H	H

How to Measure: Potholes are measured by counting the number that are of low, medium, and high severity and recording them separately.

Name of Distress:		Railroad Crossing
Description:		Railroad crossing defects occur in the form of depressions or bumps around the tracks.
Severity Levels:	L –	Ride quality* is slightly affected and vehicles do not slow down to cross.
	M –	Ride quality is moderately affected and vehicles normally slow down to cross.
	H –	Ride quality is affected to a great extent, and vehicles must cross very slowly.
How to Count:		The number of rails crossed by the railroad tracks are counted. Any large bump created by the tracks should be counted as part of the crossing.

*See page 51 for definition.

Name of Distress:	Slippage Cracking
Description:	Slippage cracks are crescent- or half-moon-shaped cracks having two ends pointed away from the direction of traffic. They are produced when braking or turning wheels cause the pavement surface to slide and deform. This usually occurs when there is a low-strength surface mix or a poor bond between the surface and the next layer of pavement structure.
Severity Levels:	No degrees of severity are defined. It is sufficient to indicate that a slippage crack exists.
How to Measure:	Slippage cracking is measured in square feet of surface area.

Name of Distress:	Weathering and Raveling
Description:	Weathering and raveling are the wearing away of the pavement surface caused by the loss of asphalt or tar binder and dislodging of aggregate particles. They may indicate that the asphalt binder has hardened significantly or that a poor-quality mixture exists.
Severity Levels:	L – Aggregate or binder has started to wear away.
	M – Aggregate and/or binder has worn away. The surface texture is moderately rough and pitted.
	H – Aggregate and/or binder has worn away to a considerable extent. The surface texture is severely rough and pitted.
How to Measure:	Weathering and raveling are measured in square feet of surface area.

Name of Distress: Joint Reflection Cracking from PCC Slabs (Longitudinal and Transverse)

Description: This distress occurs only on pavements having an asphalt surface over a portland cement concrete (PCC) slab. This category does not include reflection cracking from any other type of base (i.e., cement-stabilized, lime-stabilized); such cracks are listed as longitudinal and transverse cracks. Joint reflection cracking is caused mainly by movement of the PCC slab beneath the asphalt concrete (AC) surface because of thermal and moisture changes; it is not load related. However, traffic loading may cause a breakdown of the AC near the crack, resulting in spalling and foreign object damage (FOD) potential. If the pavement is fragmented along a crack, the crack is said to be spalled. A knowledge of slab dimensions beneath the AC surface will help to identify these cracks.

Severity Levels:

L – Cracks have only light spalling or no spalling, and can be filled or nonfilled. If nonfilled, the cracks have a mean width of 1/4 in. (.63 cm) or less; filled cracks are of any width, but their filler material is in satisfactory condition.

M – One of the following conditions exists: (1) cracks are moderately spalled and can be either filled or nonfilled and of any width; (2) filled cracks are not spalled or are only lightly spalled, but the filler is in satisfactory condition; (3) nonfilled cracks are not spalled or are only lightly spalled, but the mean crack width is greater than 1/4 in. (.63 cm); or (4) light random cracking exists near the crack or at the corners of intersecting cracks.

H – Cracks are severely spalled and can be either filled or nonfilled of any width.

How to Measure: Joint reflection cracking is measured in linear feet. The length and severity level of each crack should be identified and recorded. If the crack does not have the same severity level along its entire length, each portion should be recorded separately. For example, a crack that is 50 ft (15 m) long may have 10 ft (3 m) of high severity, 20 ft (6 m) of medium severity, and 20 ft (6 m) of light severity; these would all be recorded separately. If a bump occurs at the reflection crack, it is also recorded.

Name of Distress: **Rutting**

Description: A rut is a surface depression in the wheel paths. Pavement uplift may occur along the sides of the rut; however, in many instances, ruts are noticeable only after a rainfall, when the wheel paths are filled with water. Rutting stems from a permanent deformation in any of the pavement layers or subgrade, usually caused by consolidation or lateral movement of the materials due to traffic loads. Significant rutting can lead to major structural failure of the pavement.

Severity Levels:

Mean Rut Depth Criteria

Severity	**<40 mph**	**≥40 mph**
L	1/4 to 1/2 in. (.63 to 1.27 cm)	1/8 to 1/4 in. (.32 to .63 cm)
M	1/2 to 1 in. (1.27 to 2.54 cm)	1/4 to 1/2 in. (.63 to 1.27 cm)
H	1 in. (2.54 cm)	1/2 in. (1.27 cm)

How to Measure: Rutting is measured in square feet of surface area, and its severity is determined by the mean depth of the rut. To determine the mean rut depth, a straightedge should be laid across the rut and the depth measured. The mean depth in inches should be computed from measurements taken along the length of the rut.

Name of Distress:	Swell
Description:	Swell is characterized by an upward bulge in the pavement's surface. A swell occurs as a long gradual wave of more than 10 ft (3 m) in length. Swelling can be accompanied by surface cracking. A swell is usually caused by frost action in the subgrade or by swelling soil.
Severity Levels:	L – Swell causes low-severity ride quality.* Low-severity swells may not always be observable, but their existence can be confirmed by driving a vehicle over the section at the speed limit. An upward acceleration will occur if the swell is present.
	M – Swell causes medium-severity ride quality.
	H – Swell causes high-severity ride quality.
How to Measure:	The surface area of the swell is measured in square feet.

*See page 51 for definition.

Name of Distress: Shoving

Description: Shoving occurs when the pavement surface permanently displaces in a longitudinal direction in a localized area due to traffic loading. Shoving produces a short, abrupt wave because of pushing of the surface by traffic. This distress normally occurs only in liquid asphalt (cutback and emulsions) mix pavements due to instability. Shoves occurring in patches are considered in rating the patch, and not separately as shoves.

Severity Levels:

L – Shove causes low-severity ride quality.*

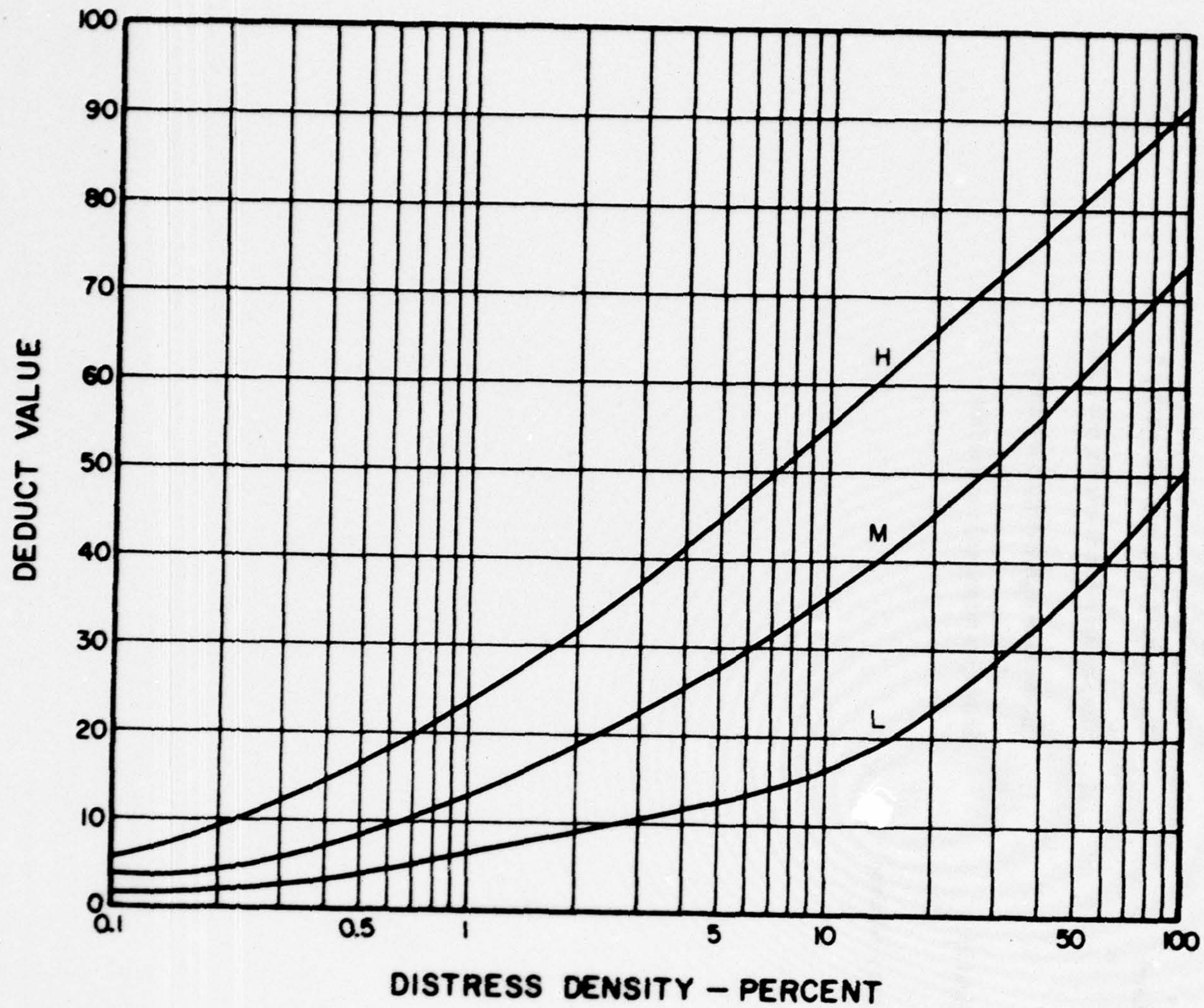
M – Shove causes medium-severity ride quality.

H – Shove causes high-severity ride quality.

How to Measure: Shoves are measured in square feet.

*See page 51 for definition.

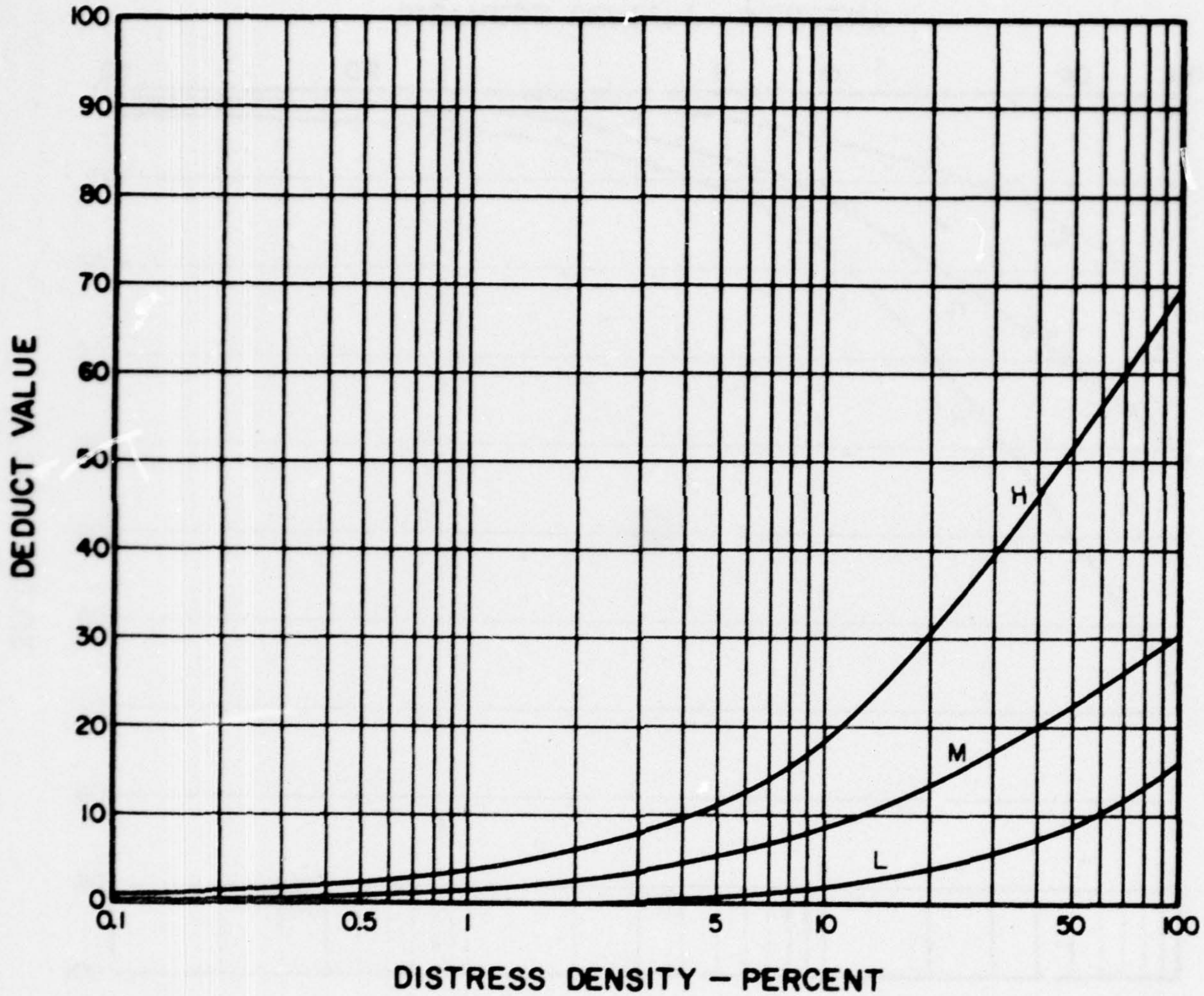
Note: Curves are undergoing validation. Validated curves will be published in final report.



1. Alligator cracking

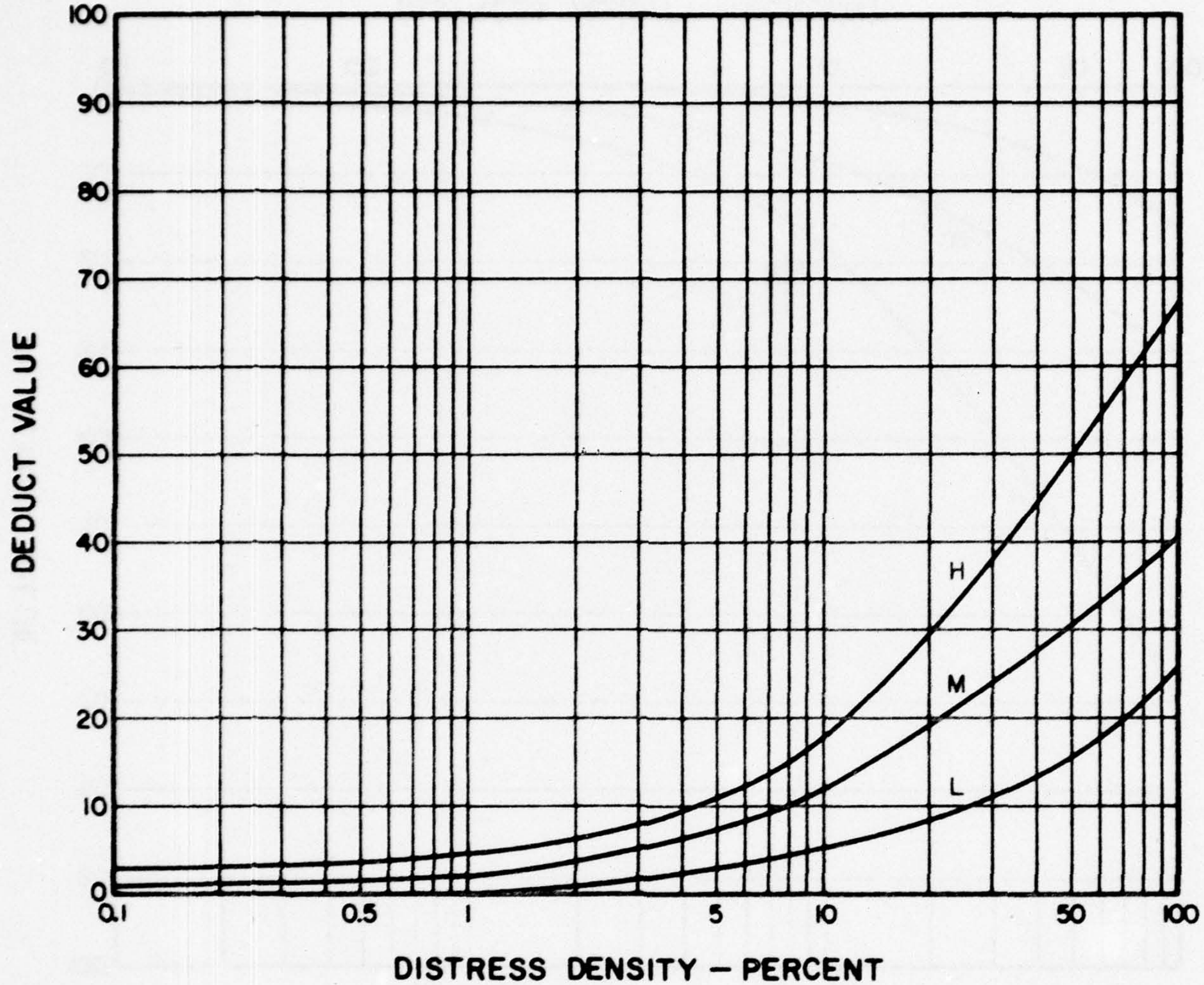
Figure B1. Asphalt- or tar-surfaced pavement deduct curves.

Note: Curves are undergoing validation. Validated curves will be published in final report.



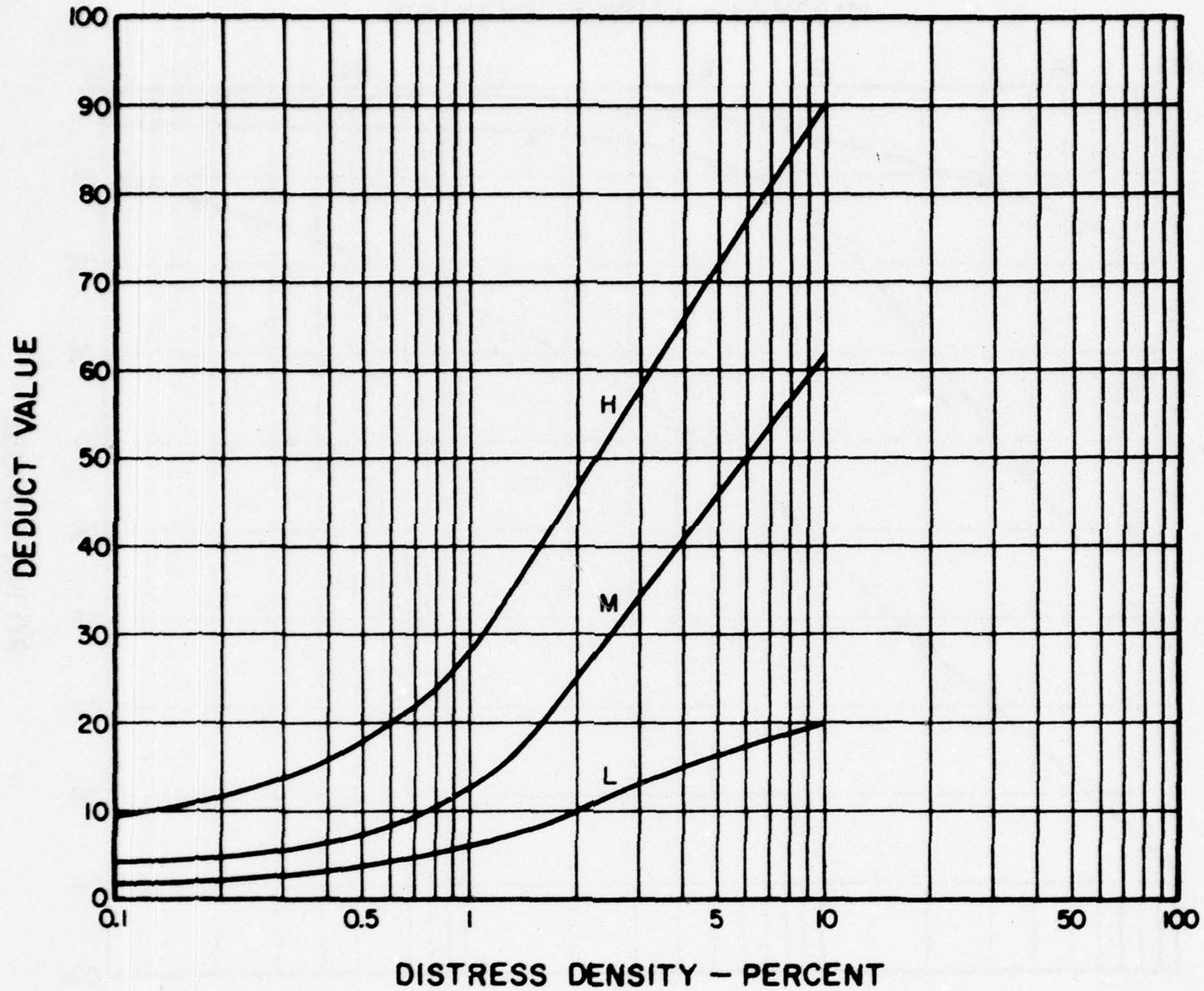
2. Bleeding
Figure B1 (cont'd)

Note: Curves are undergoing validation. Validated curves will be published in final report.



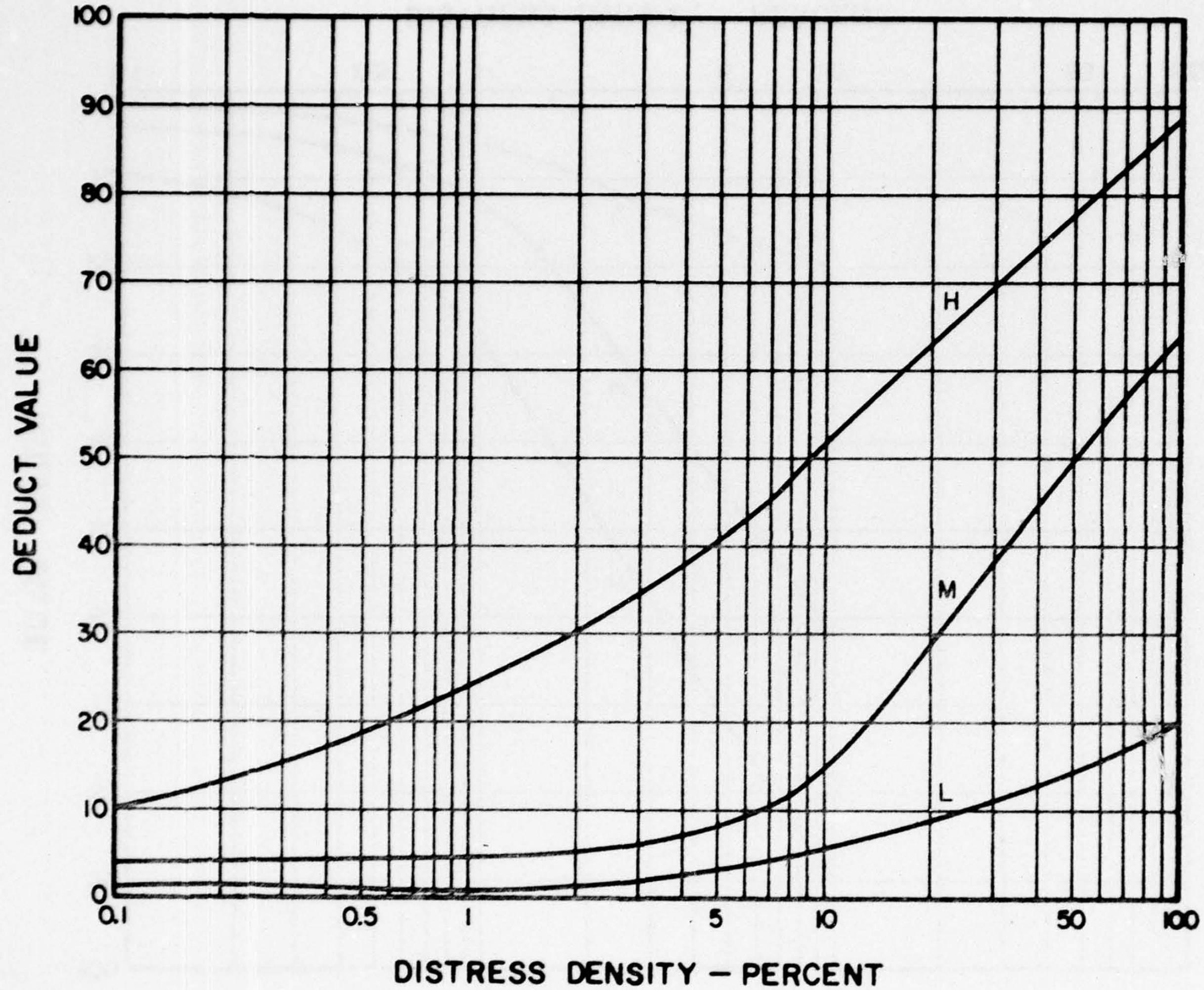
3. Block cracking
Figure B1 (cont'd)

Note: Curves are undergoing validation. Validated curves will be published in final report.



4. Bumps
Figure B1 (cont'd)

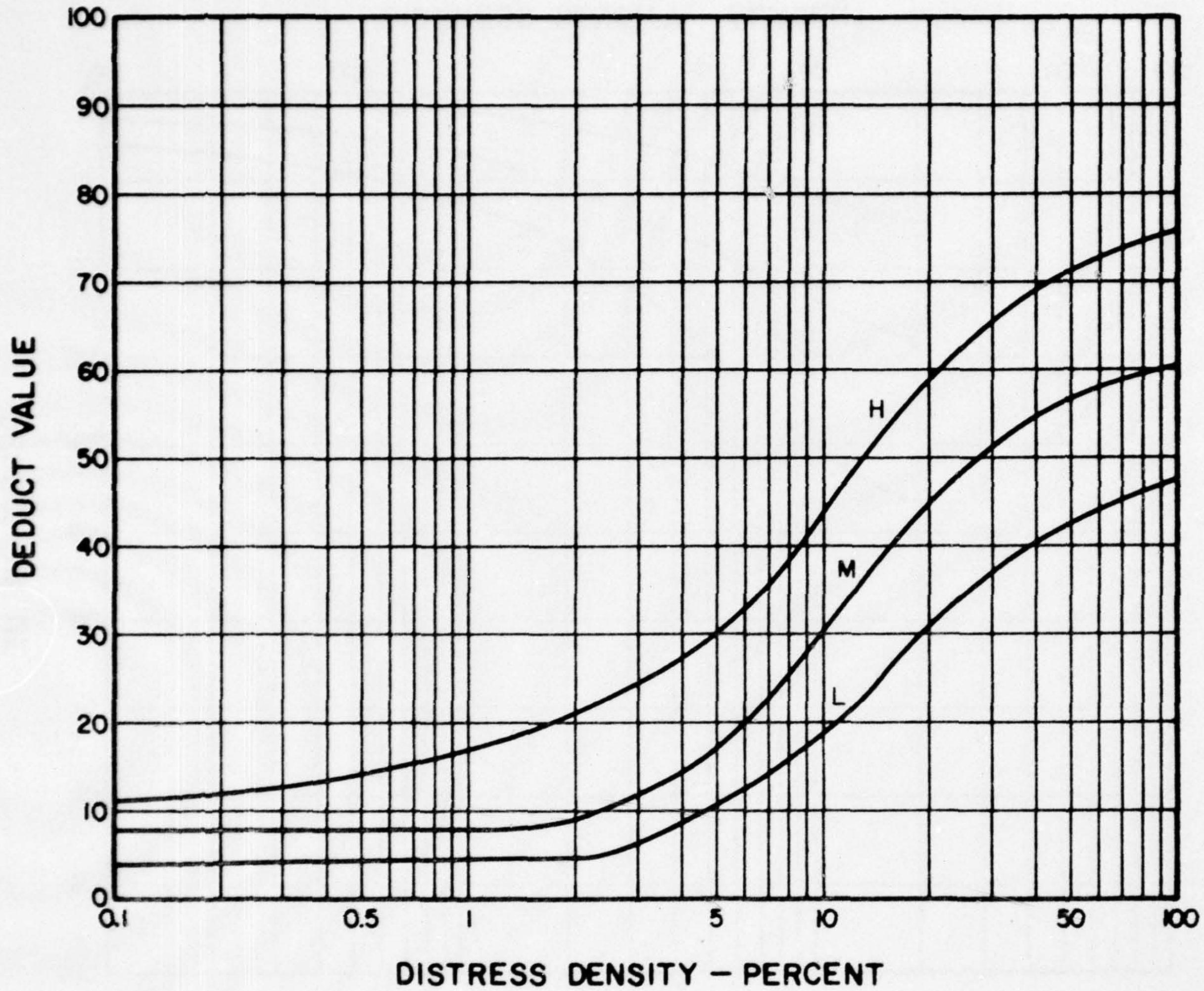
Note: Curves are undergoing validation. Validated curves will be published in final report.



5. Corrugation

Figure B1 (cont'd)

Note: Curves are undergoing validation.
Validated curves will be published
in final report.

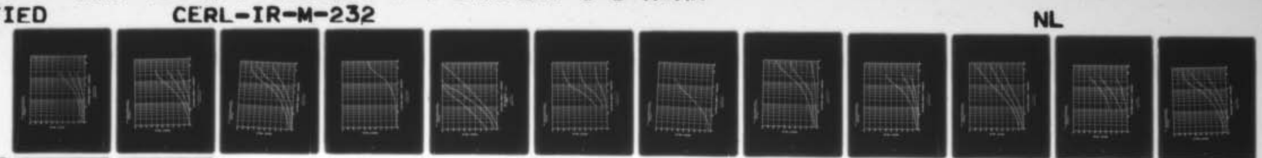


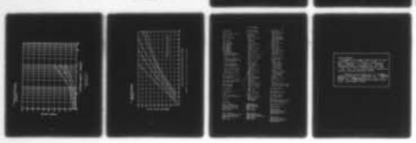
6. Depression
Figure B1 (cont'd)

AD-A057 148 CONSTRUCTION ENGINEERING RESEARCH LAB (ARMY) CHAMPAI--ETC F/G 13/2
DEVELOPMENT OF A PAVEMENT CONDITION INDEX FOR ROADS AND STREETS--ETC(U)
MAY 78 M Y SHAHIN, M I DARTER, S D KOHN

UNCLASSIFIED CERL-IR-M-232 NL

2 OF 3
AD
A057 148

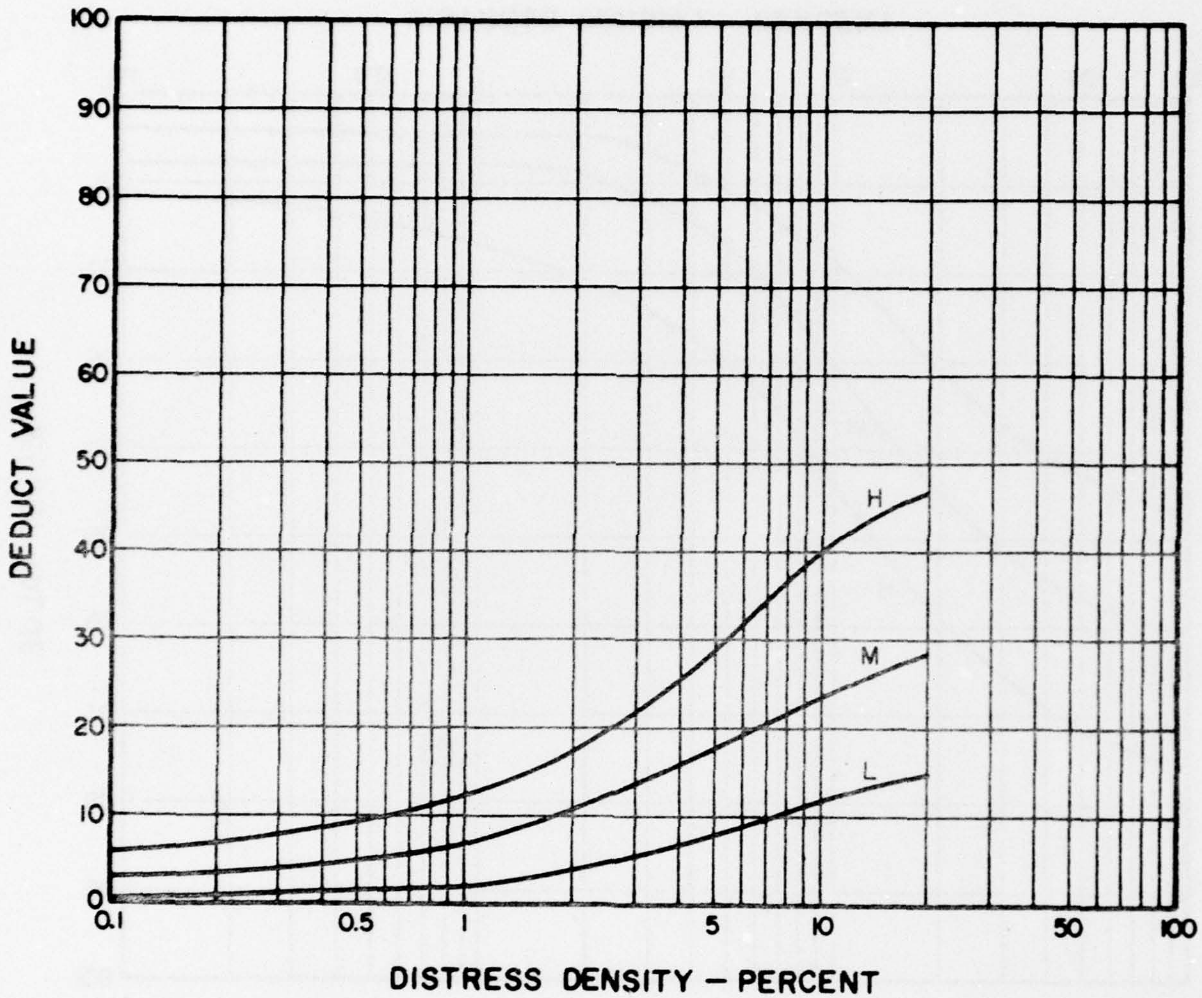




~~END~~
DATE
FILMED
9-78
DDC

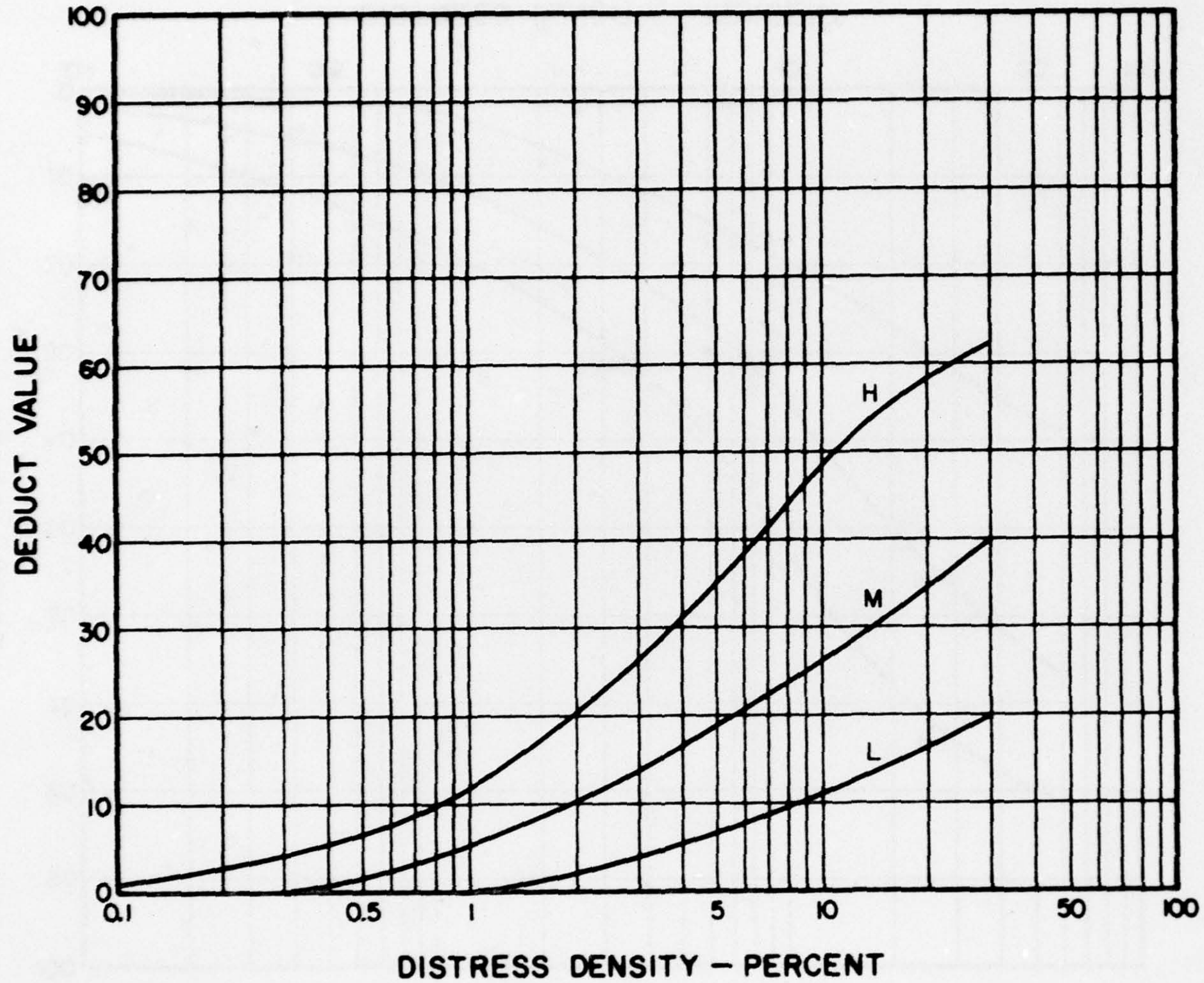
CONT.

Note: Curves are undergoing validation. Validated curves will be published in final report.



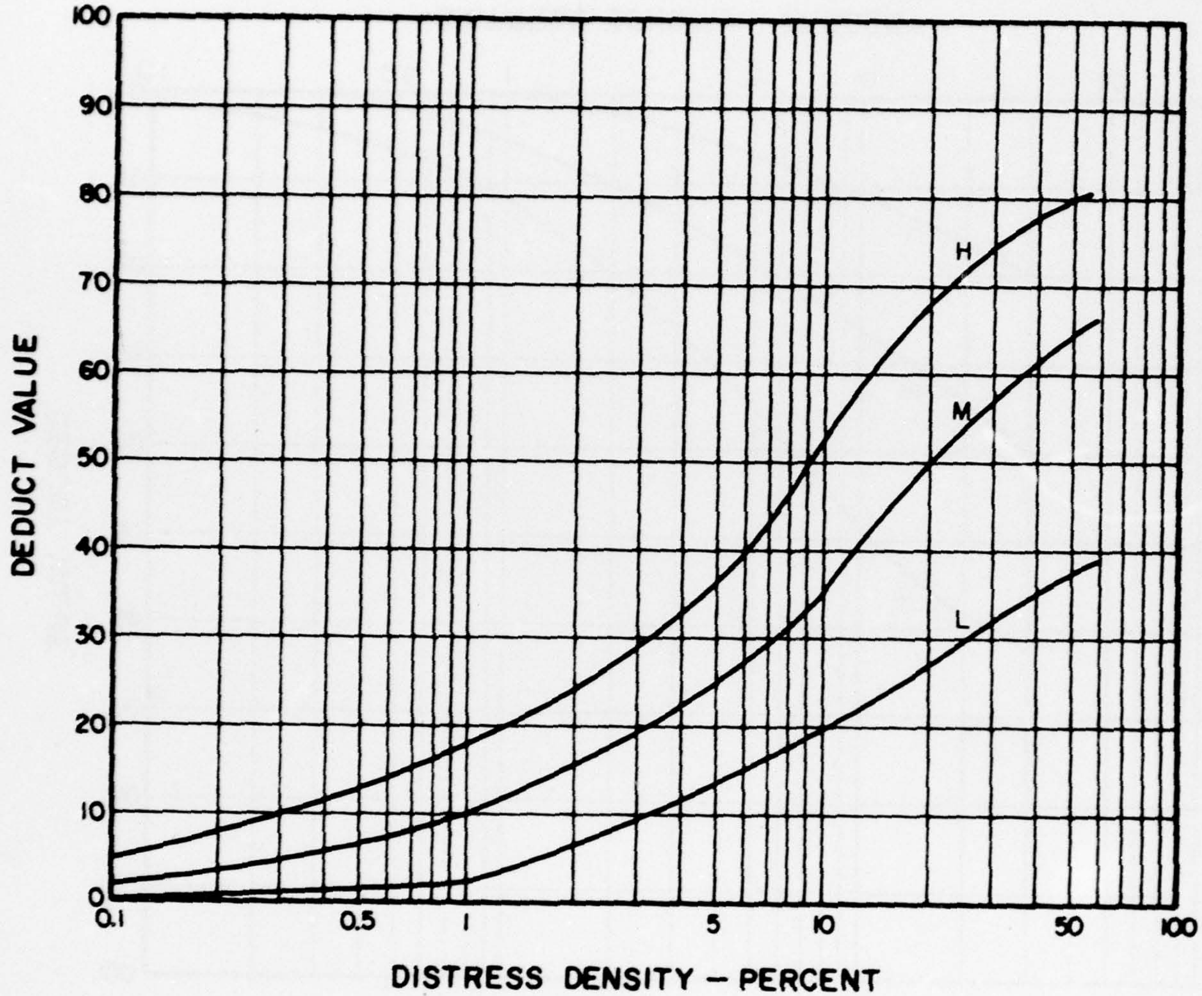
7. Edge cracking
Figure B1 (cont'd)

Note: Curves are undergoing validation. Validated curves will be published in final report.

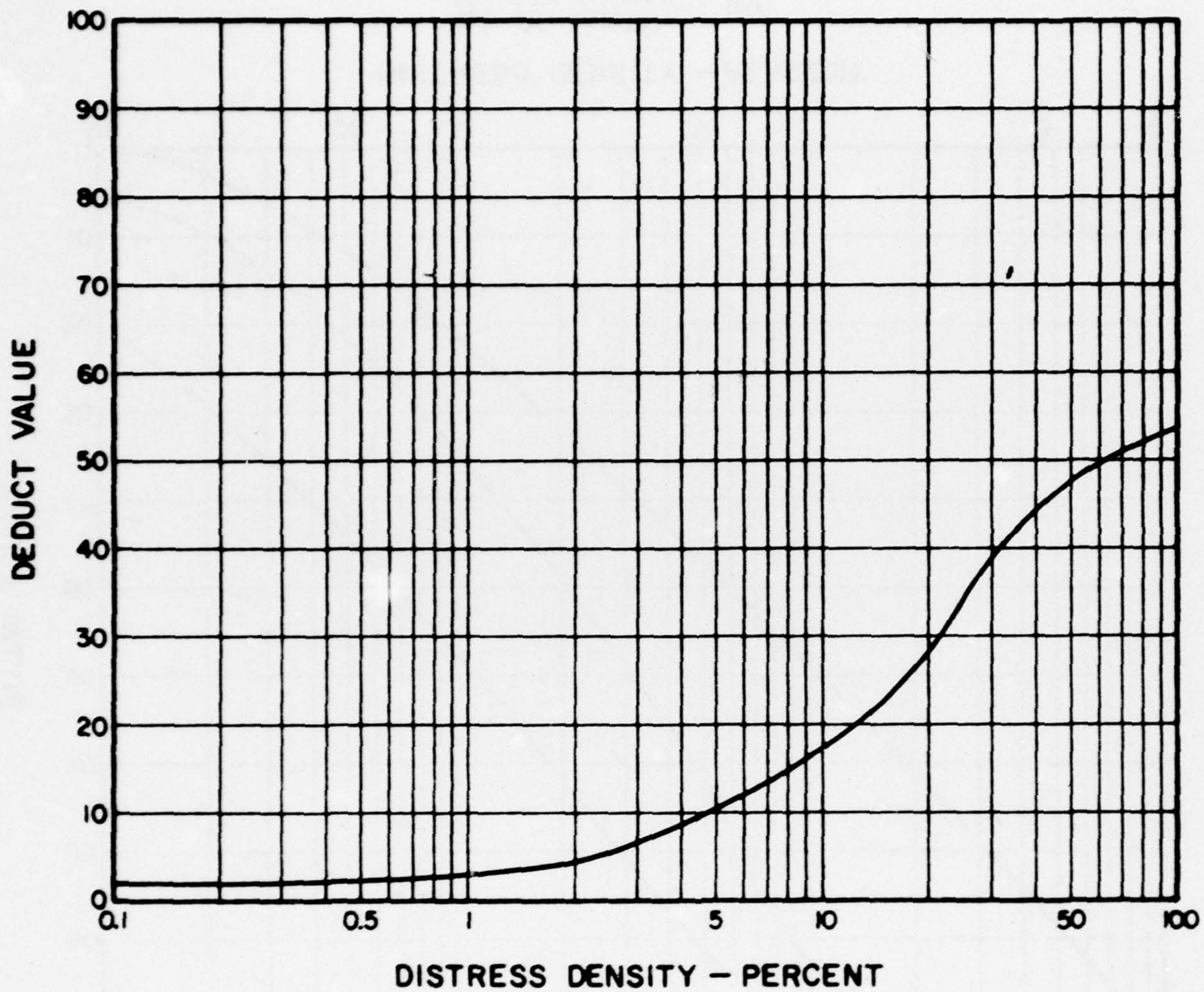


8. Longitudinal and transverse cracking
Figure B1 (cont'd)

Note: Curves are undergoing validation. Validated curves will be published in final report.

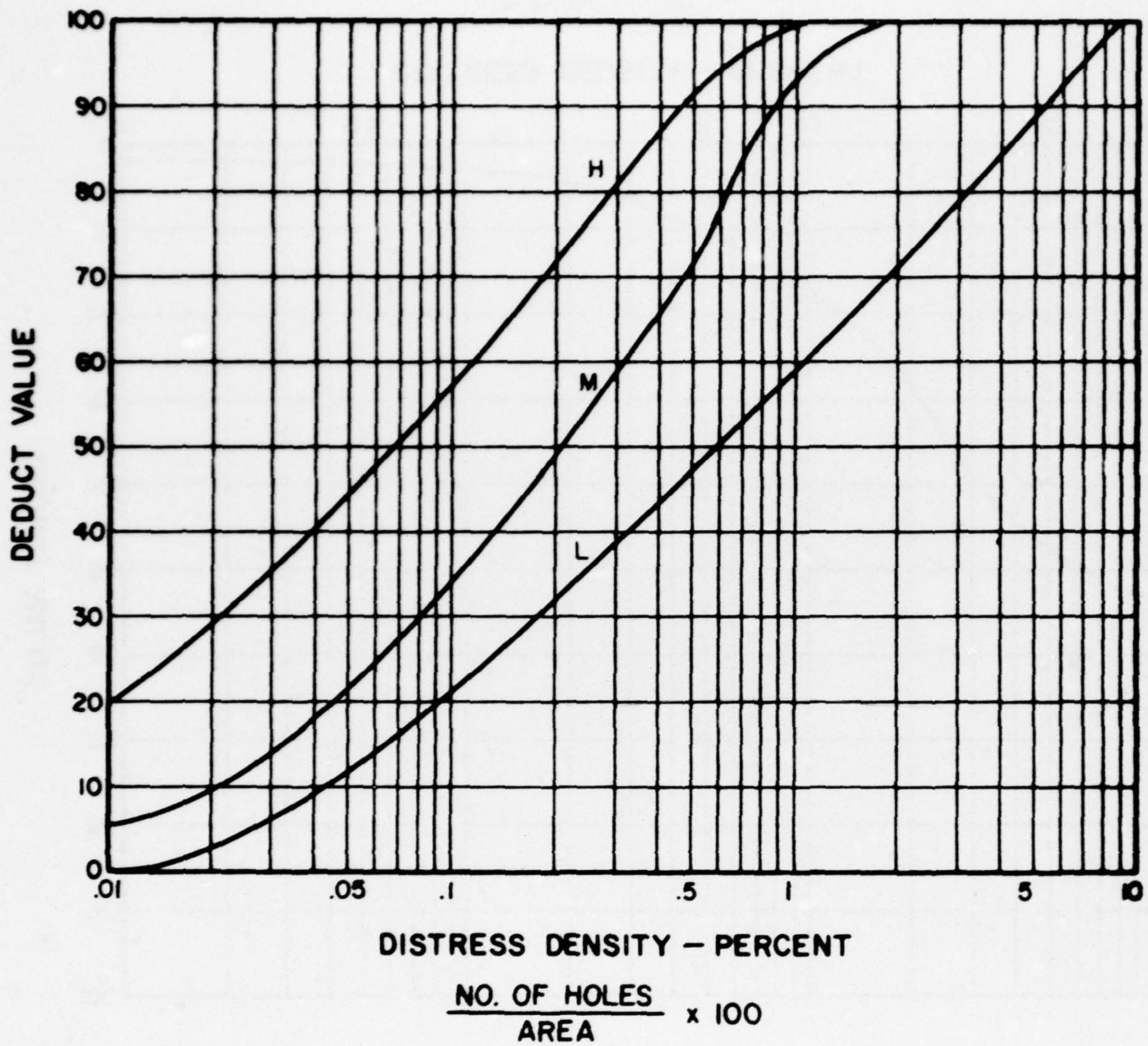


9. Patch utility cut
Figure B1 (cont'd)



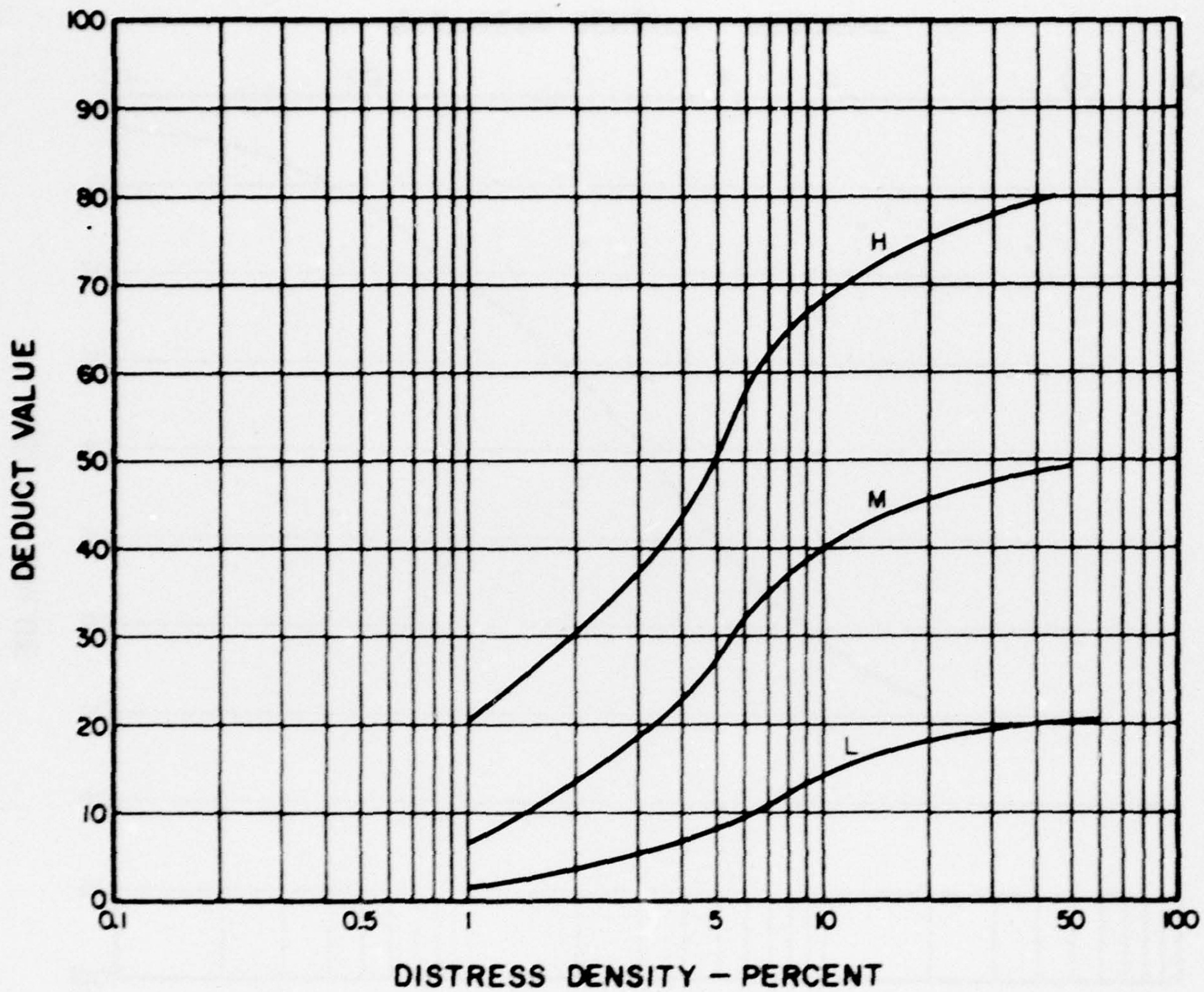
10. Polished aggregate
Figure B1 (cont'd)

Note: Curves are undergoing validation. Validated curves will be published in final report.



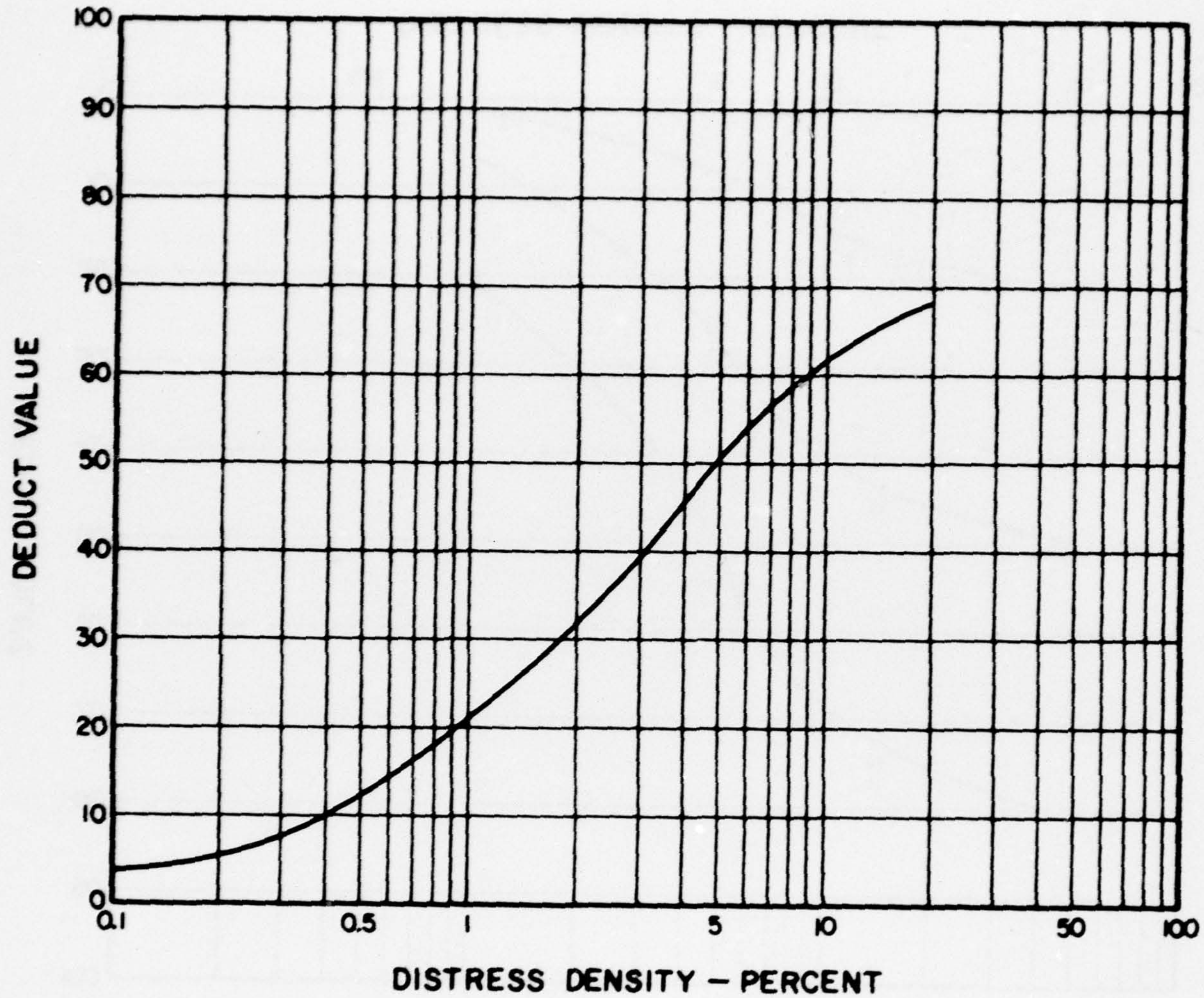
11. Potholes
Figure B1 (cont'd)

Note: Curves are undergoing validation. Validated curves will be published in final report.



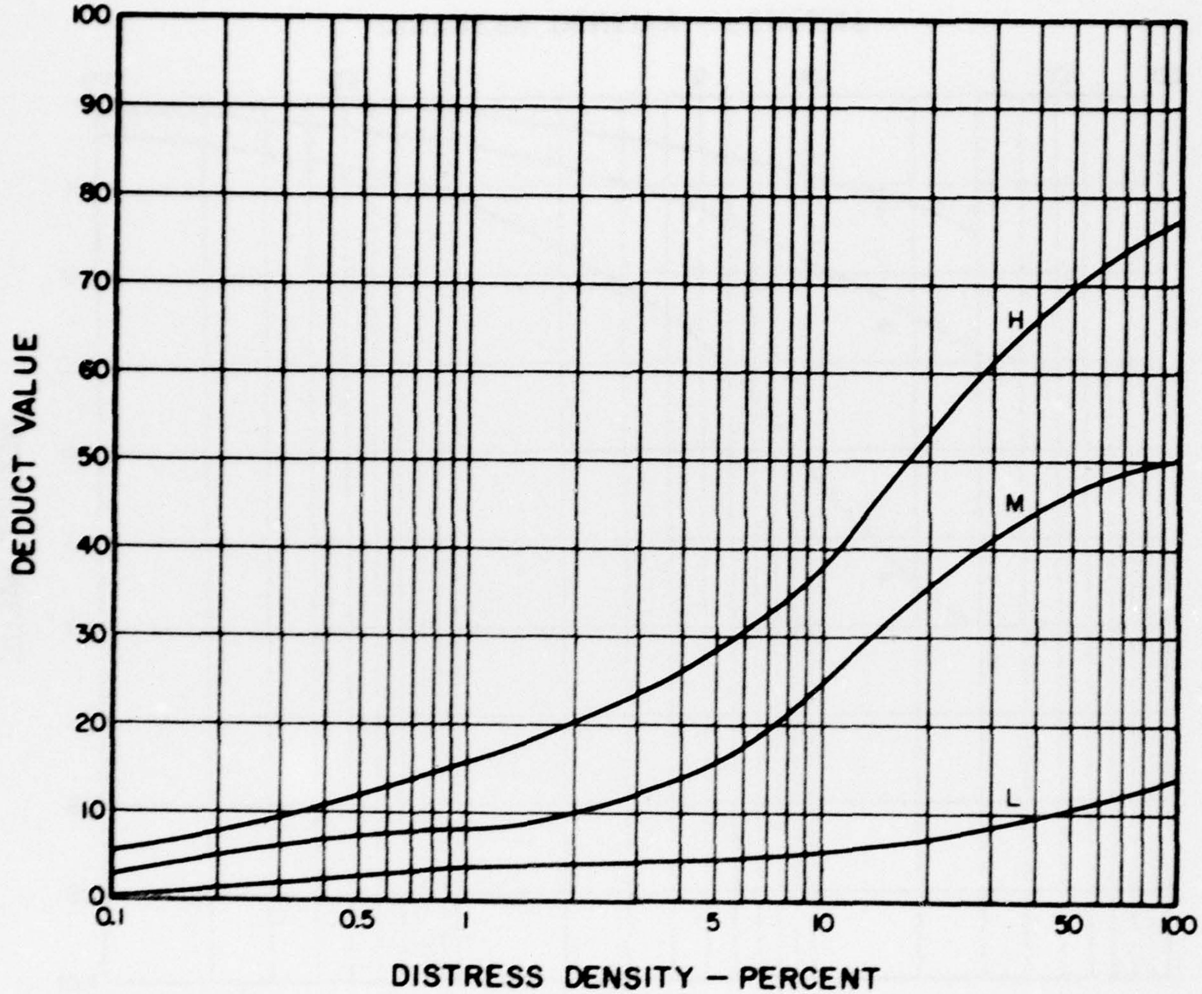
12. Railroad crossing
Figure B1 (cont'd)

Note: Curves are undergoing validation. Validated curves will be published in final report.



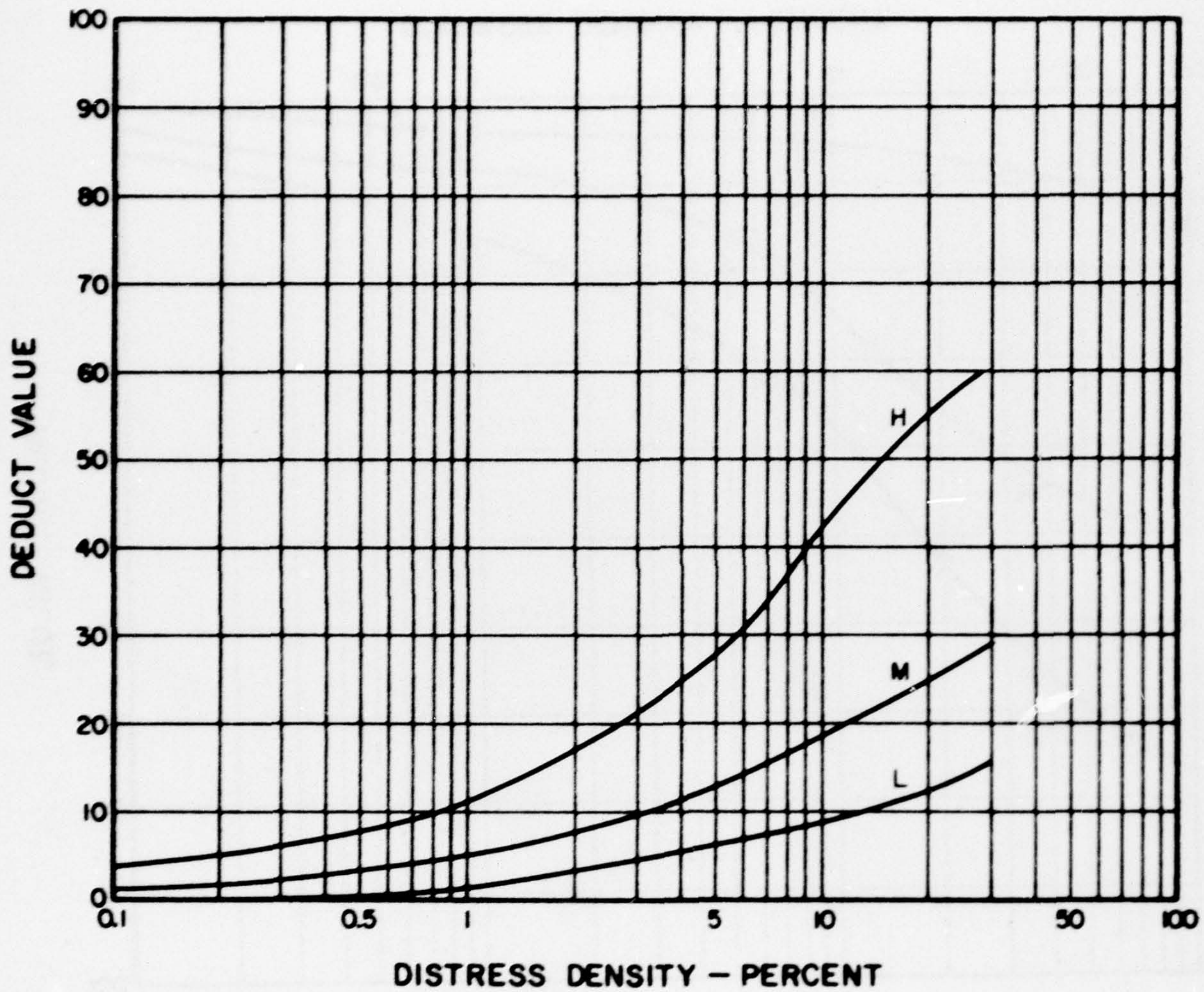
13. Slippage cracks
Figure B1 (cont'd)

Note: Curves are undergoing validation. Validated curves will be published in final report.



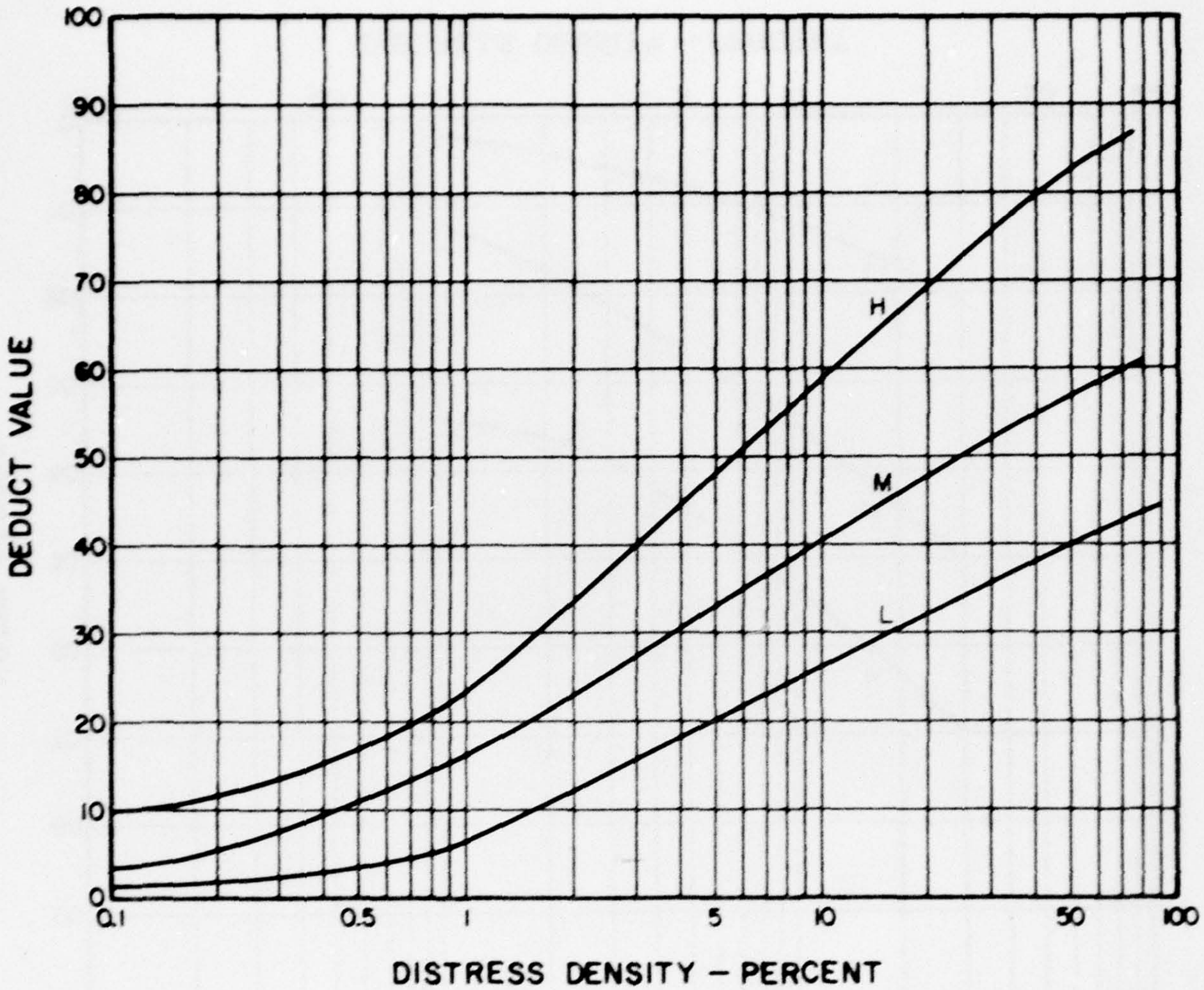
14. Weathering/raveling
Figure B1 (cont'd)

Note: Curves are undergoing validation.
Validated curves will be published
in final report.



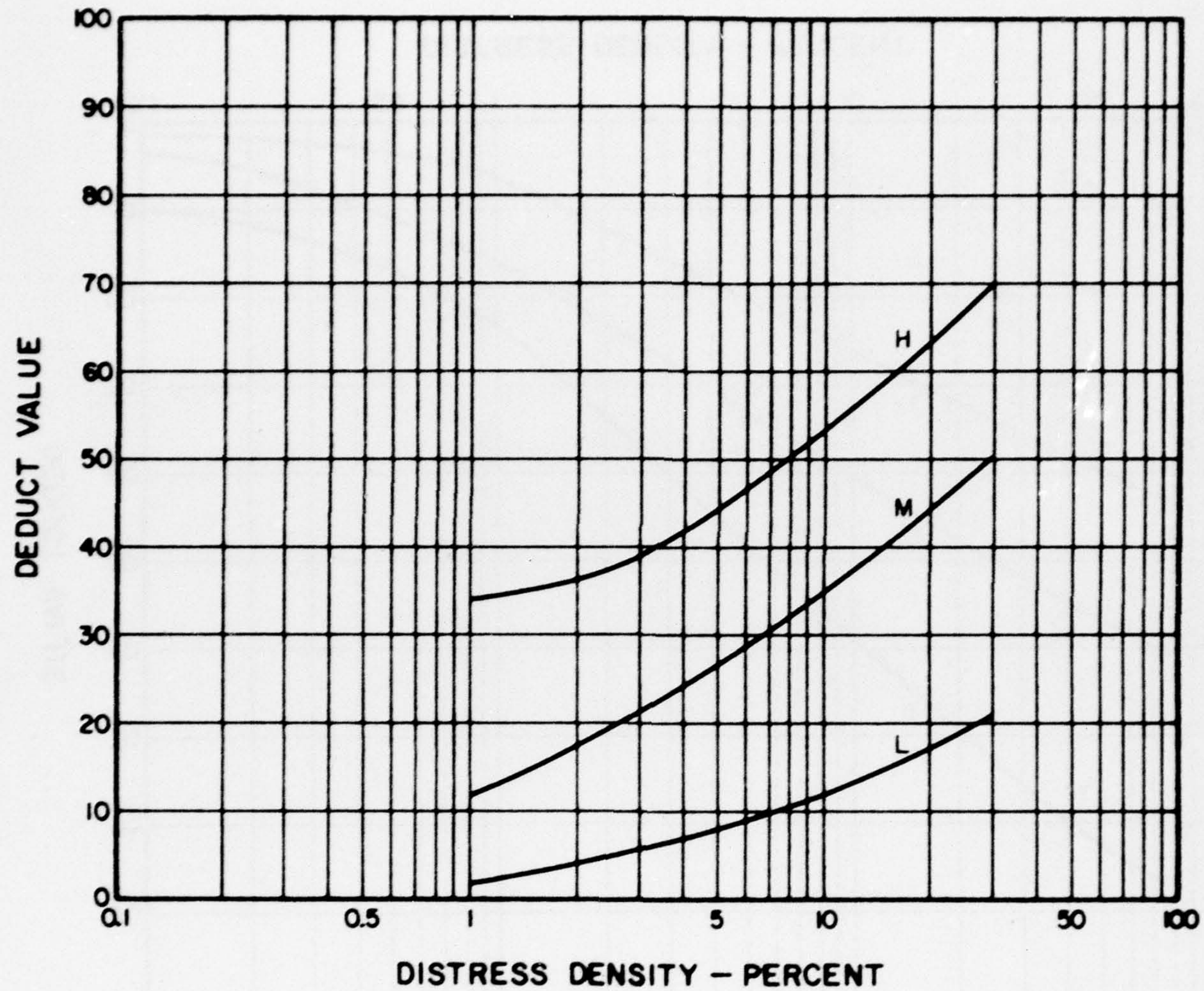
15. Joint reflective
Figure B1 (cont'd)

Note: Curves are undergoing validation.
Validated curves will be published
in final report.



16. Rutting
Figure B1 (cont'd)

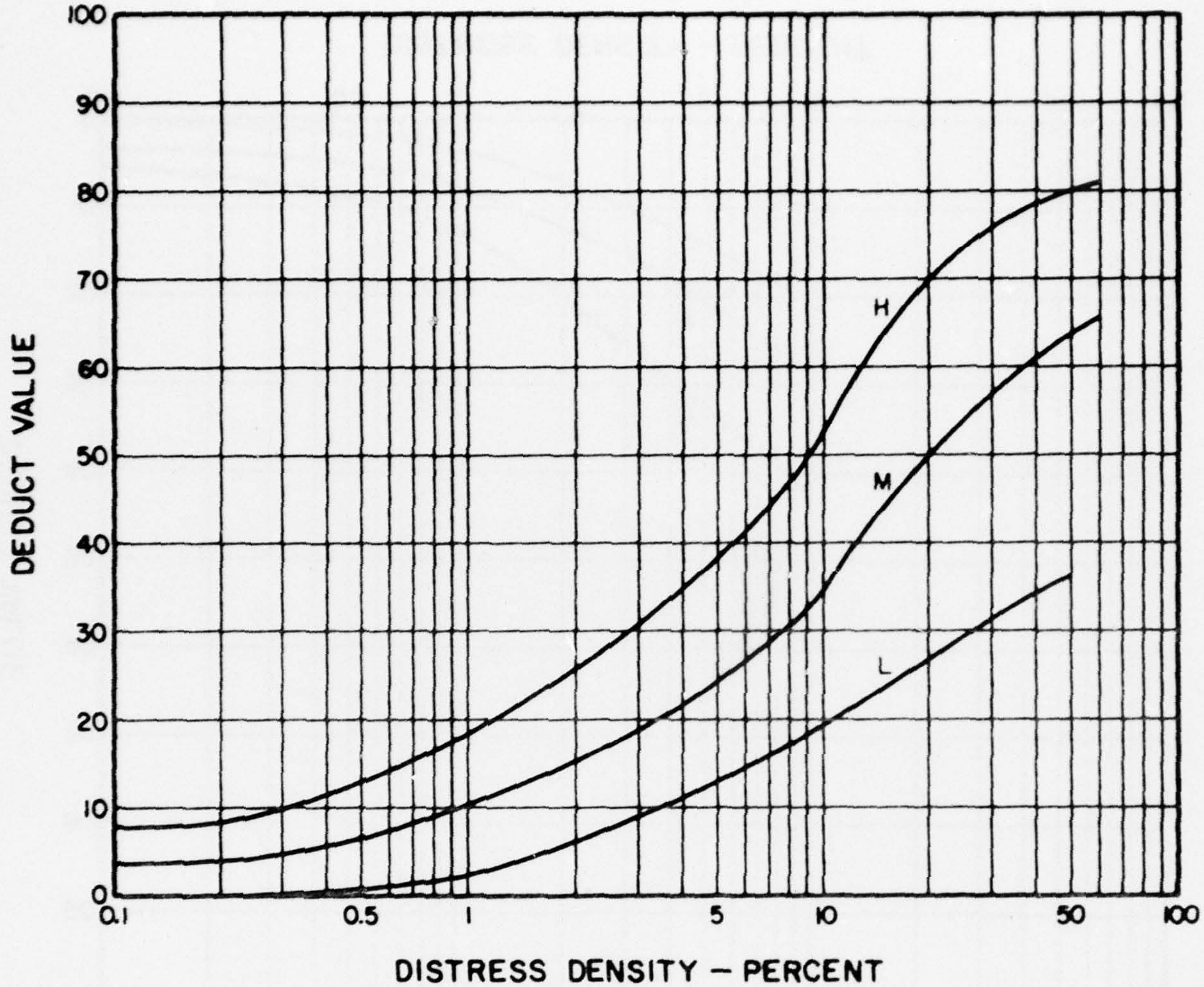
Note: Curves are undergoing validation.
Validated curves will be published
in final report.



17. Swell

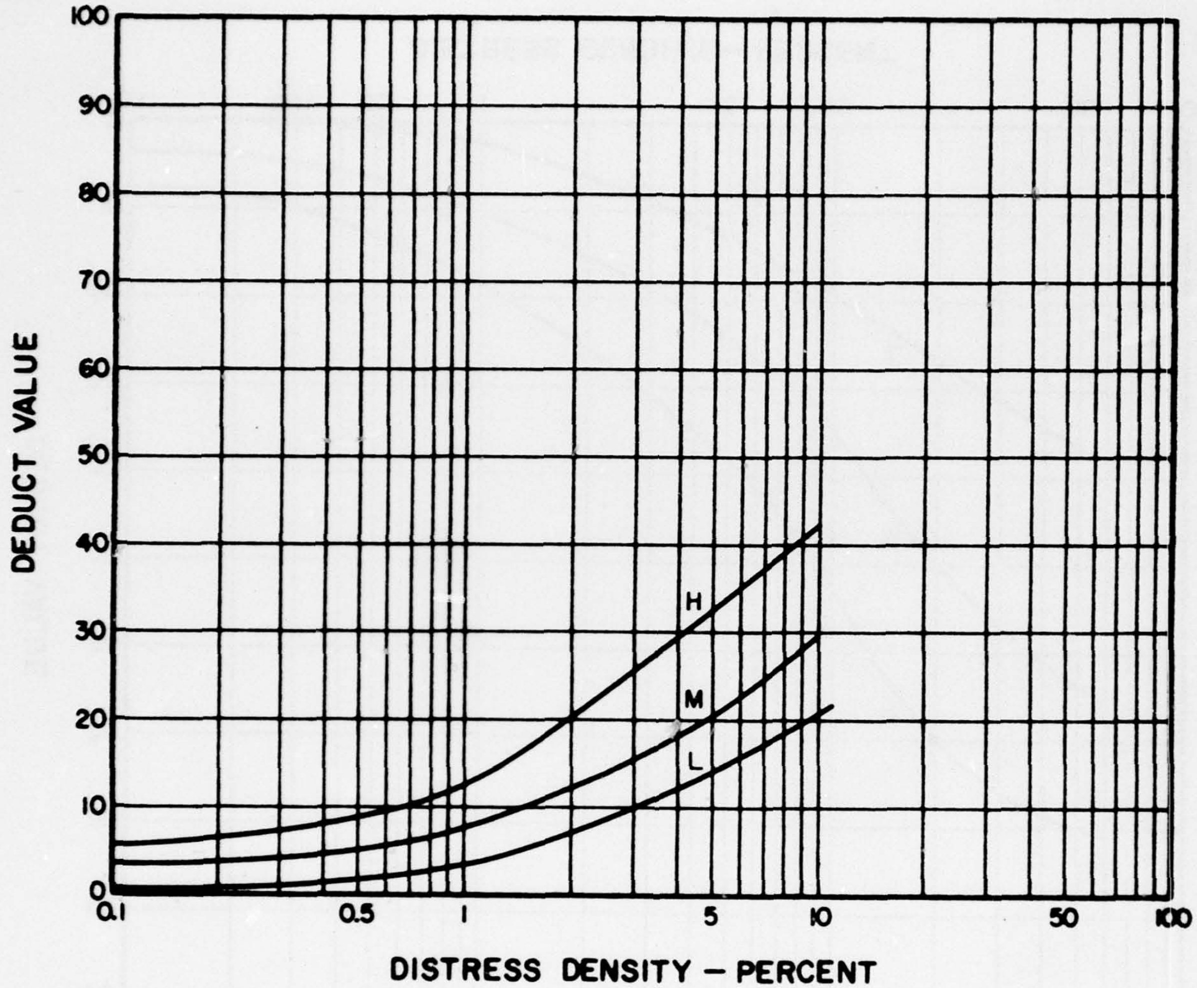
Figure B1 (cont'd)

Note: Curves are undergoing validation. Validated curves will be published in final report.



18. Shoving
Figure B1 (cont'd)

Note: Curves are undergoing validation. Validated curves will be published in final report.



19. Lane shoulder drop-off
Figure B1 (cont'd)

Note: Curves are undergoing validation. Validated curves will be published in final report.

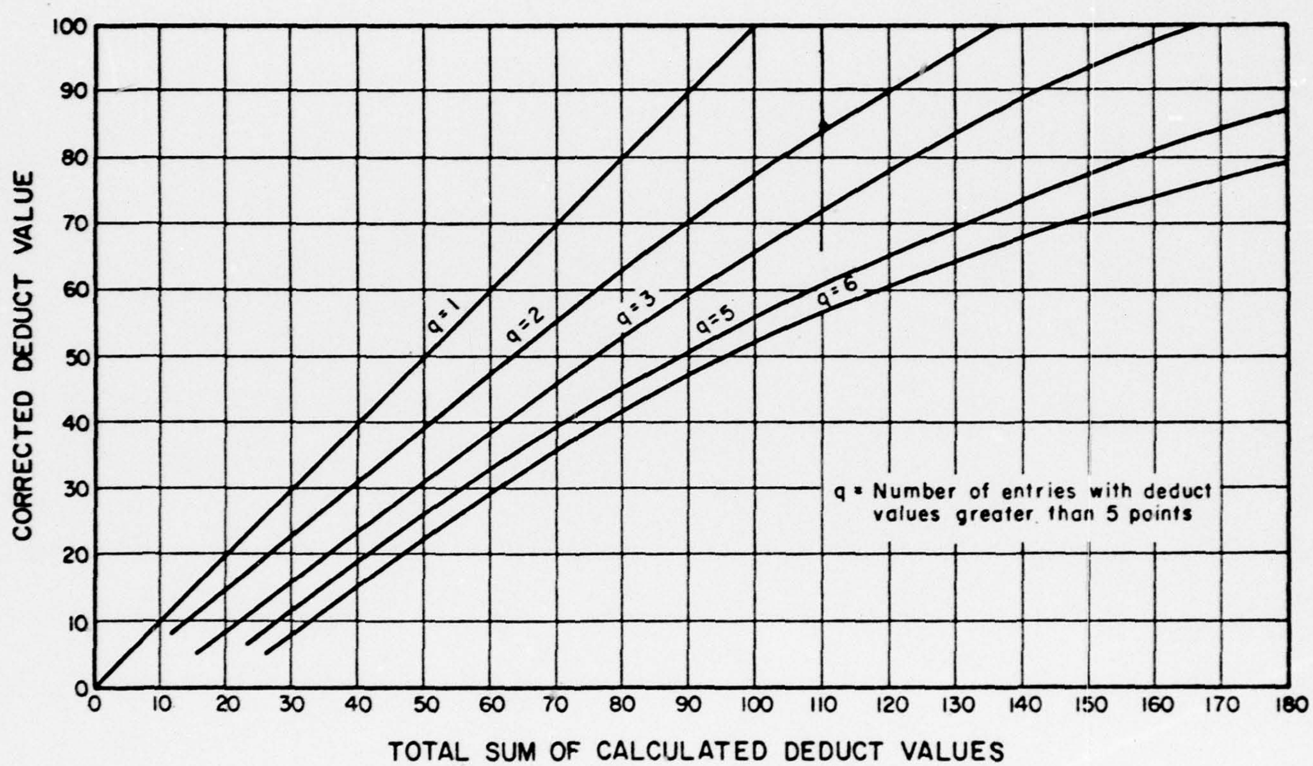


Figure B2. Corrected deduct values for asphalt- or tar-surfaced pavements.

FOM

CERL DISTRIBUTION

US Army, Europe
ATTN: AEAEN (4)

Director of Facilities Engineering
APO New York 09827

West Point, NY 10017
ATTN: Dept of Mechanics
ATTN: Library

HQDA (SGRD-EDE)

Chief of Engineers
ATTN: Tech Monitor
ATTN: DAEN-ASI-L (2)
ATTN: DAEN-FEE
ATTN: DAEN-FEE-A
ATTN: DAEN-FEP
ATTN: DAEN-FEZ-A
ATTN: DAEN-RDL
ATTN: DAEN-ZCP
ATTN: DAEN-PMS (11)
for forwarding to
National Defense Headquarters
Director General of Construction
Ottawa, Ontario K1A0K2
Canada

Canadian Forces Liaison Officer (4)
US Army Mobility Equipment
Research and Development Command
Ft Belvoir, VA 22060

British Liaison Officer (5)
US Army Mobility Equipment
Research and Development Center
Ft Belvoir, VA 22060

Airports and Const. Services Dir.
Technical Information Reference
Centre
KAOL, Transport Canada Building
Place de Ville
Ottawa, Ontario Canada k1A0N8

Ft Belvoir, VA 22060
ATTN: Learning Resources Center
ATTN: ATSE-TD-TL (2)
ATTN: Kingman Building, Library

US Army Foreign Science & Tech Center
ATTN: Charlottesville, VA 22901
ATTN: Far East Office

Ft Monroe, VA 23651
ATTN: ATEN-AD (3)
ATTN: ATEN-FE-ME

Ft Lee, VA 23801
ATTN: DRXMC-D (2)

Ft McPherson, GA 30330
ATTN: AFEN-FEB

USA-WES
ATTN: Concrete Laboratory
ATTN: Soils and Pavements Laboratory
ATTN: Library

USA-CRREL

6th US Army
ATTN: AFKC-EN

SCHEFFEY, Charles F.
Director, Office of Research
Federal Highway Admin - DOT
Office Research & Development
Rm 5124 Transpoint
WASH DC 20590

PASKO, Jr., Thomas J.
Chief, Paving & Struct Matls Group
Federal Highway Admin - DOT
Fairbank Highway Research Sta
HRS-22
WASH DC 20590

I Corps (ROK/US)Group
APO San Francisco 96358

US Army Engineer District
Saudi Arabia
ATTN: Library
New York
ATTN: Chief, Design Br
Buffalo
ATTN: Library
Pittsburgh
ATTN: Library
Norfolk
ATTN: Library
ATTN: Chief, NAOEN-M
Huntington
ATTN: Library
Wilmington
ATTN: Chief, SAWEN-D
Savannah
ATTN: Library
ATTN: Chief, SASAS-L
Mobile
ATTN: Library
ATTN: Chief, SAMEN
Vicksburg
ATTN: Chief, Engr Div
Louisville
ATTN: Chief, Engr Div
Detroit
ATTN: Library
St. Paul
ATTN: Chief, ED-D
Rock Island
ATTN: Library
ATTN: Chief, Engr Div
St. Louis
ATTN: Chief, ED-D
Kansas City
ATTN: Library (2)
ATTN: Chief, Engr Div
Omaha
ATTN: Chief, Engr Div
New Orleans
ATTN: Library
Fort Worth
ATTN: Library
ATTN: Chief, SWFED-D
ATTN: Chief, SWFED-F
Albuquerque
ATTN: Library
San Francisco
ATTN: Chief, Engr Div
Sacramento
ATTN: Library, Room 8307
ATTN: Chief, SPKED-D
Far East
ATTN: Chief, Engr Div
Japan
ATTN: Library
Alaska
ATTN: Library
ATTN: Chief, NPADE-R

US Army Engineer Division
Europe
ATTN: Technical Library
New England
ATTN: Chief, NEDED-T
Middle East (Rear)
ATTN: MEDED-T

MCCOMB, Richard A.
Highway Research Engr
Federal Highway Admin
HRS-14
DOT 400 7th St SW
WASH DC 20590

KENIS, William J.
Highway Research Engineer
Federal Highway Admin - DOT
HRS-14 Struct & Applied Mech Div
400 7th St SW
WASH DC 20590

US Army Engineer Division
South Atlantic
ATTN: Laboratory
ATTN: Chief, SADEN-TS
ATTN: Library
Huntsville
ATTN: Library (2)
ATTN: Chief, HNDED-M
ATTN: Chief, HNDED-SR
Lower Mississippi Valley
ATTN: Library
Ohio River
ATTN: Library
ATTN: Chief, Engr Div
North Central
ATTN: Library
Missouri River
ATTN: Library (2)
Southwestern
ATTN: Library
ATTN: Chief, SWDED-MA
Pacific Ocean
ATTN: Chief, Engr Div
ATTN: FM&S Branch
North Pacific
ATTN: Chief, Engr Div

Facilities Engineers
Carlisle Barracks, PA 17013
Ft Campbell, KY 42223
Ft Hood, TX 76544
TRADOC
Ft Dix, NJ 08640
Ft Belvoir, VA 22060
Ft Monroe, VA 23651
Ft Lee, VA 23801
Ft Knox, KY 40121
Ft Chaffee, AR 72905
Ft Sill, OK 73503
Ft Bliss, TX 79916
FORSCOM
Ft George G. Meade, MD 20755
Ft McPherson, GA 30330
Ft Sam Houston, TX 78234
Ft Carson, CO 80913
Ft Lewis, WA 98433
USAIC (2)
Ft Benning, GA 31905
CAC&FL (2)
Ft Leavenworth, KS 66027
AMC
Dugway, UT 84022
USACC
Ft Huachuca, AZ 85613
HQ, 1st Inf Div & Ft Riley, KS 66442
HQ, 5th Inf Div & Ft Polk, LA 71459
HQ, 7th Inf Div & Ft Ord, CA 93941

AF Civil Engr Center/XRL
Tyndall AFB, FL 32401

Little Rock AFB
ATTN: 314/DEEE (Mr. Gillham)
Jacksonville, AR 72076

Port Hueneme, CA 93043
ATTN: Library (Code L08A)
ATTN: Morrell Library

Washington, DC
ATTN: Building Research Advisory Board
ATTN: Library of Congress (2)
ATTN: Dept of Transportation Library

Defense Documentation Center (12)

Engineering Societies Library
New York, NY 10017

SPAIN, Lawrence F.
Engineer of Design
Transportation Research Board
2101 Constitution Ave NW
WASH DC 20418

CLARY, Adrian G.
Engineer of Maintenance
Transportation Research Board
2101 Constitution Ave NW
WASH DC 20418

Shahin, Mohamed Y
Development of a pavement condition index for roads and streets / by M. Y. Shahin, M. I. Darter, S. D. Kohn -- Champaign, Ill. : Construction Engineering Research Laboratory ; Springfield, Va. : available from National Technical Information Service , 1978.
111p. : ill. ; 27 cm. (Interim report - Construction Engineering Research Laboratory ; M-232)

1. Pavements, asphalt-evaluation. 2. Pavements, concrete-evaluation. 3. Roads-evaluation. I. Darter, Michael I. II. Kohn, Starr D. III. Title. IV. Series: U.S. Construction Engineering Research Laboratory. Interim report ; M-232.

AD-A057 148 CONSTRUCTION ENGINEERING RESEARCH LAB (ARMY) CHAMPAI--ETC F/G 13/2
DEVELOPMENT OF A PAVEMENT CONDITION INDEX FOR ROADS AND STREETS--ETC(U).
MAY 78 M Y SHAHIN, M I DARTER, S D KOHN

UNCLASSIFIED CERL-IR-M-232 NL

3 OF 3
AD
AO 57148

SUPPLEMENTARY
INFORMATION

END
DATE
FILMED
12-78
DDC

SUPPLEMENTARY

INFORMATION

ERRATA SHEET for Interim Report M-232

Please substitute the following footnotes for the ones printed in the report.

[1]M. Y. Shahin, M. I. Darter, F. M. Rozanski, and R. Stark, *Development of an Installation Surfaced Area Maintenance and Repair Management System*, Technical Information Pamphlet C-49/ADA017328 (Construction Engineering Research Laboratory [CERL], September 1975).

[2]M. Y. Shahin, M. I. Darter, and F. M. Rozanski, *Pavement Inspection Manual*, Technical Information Pamphlet C-48/ADA017329 (CERL, September 1975).

[3]M. Y. Shahin and F. M. Rozanski, *Automated Pavement Maintenance and Repair Management System*, Interim Report C-79/ADA042582 (CERL, June 1977).

[4]M. Y. Shahin, M. I. Darter, and S. D. Kohn, *Development of a Pavement Maintenance Management Management System, Vol I, Airfield Pavement Condition Rating*, Report No. AFCEC-TR-76-27 (Air Force Civil Engineering Center [AFCEC], November 1976).

[5]M. Y. Shahin, M. I. Darter, and S. D. Kohn, *Development of a Pavement Maintenance Management System, Vol II, Airfield Pavement Distress Identification Manual*, Report No. AFCEC-TR-76-27 (AFCEC, November 1976).

[6]M. Y. Shahin, M. I. Darter, and S. D. Kohn, *Development of a Pavement Maintenance System, Vol III, Maintenance and Repair Guidelines for Airfield Pavements*, Report No. AFCEC-TR-76-27 (AFCEC, September 1977).

[7]M. Y. Shahin, M. I. Darter, and S. D. Kohn, *Development of a Pavement Maintenance Management System, Volume V, Proposed Revision of Chapter 3, AFR 93-5*, Report No. AFCEC-TR-76-27 (AFCEC, 1978).

[8]M. Y. Shahin, M. I. Darter, and S. D. Kohn, *Development of a Pavement Maintenance Management System, Vol I, Airfield Pavement Condition Rating*, Report No. AFCEC-TR-76-27 (AFCEC, November 1976).

[9]M. Y. Shahin, M. I. Darter, and S. D. Kohn, *Development of a Pavement Maintenance Management System, Vol II, Airfield Pavement Distress Identification Manual*, Report No. AFCEC-TR-76-27 (AFCEC, November 1976).

[10]D. A. Voss, R. L. Terrel, F. Finn, and D. Hovey, *A Pavement Evaluation System for Maintenance Management*, a paper prepared for presentation at the Western Summer Meeting, Highway Research Board, Olympia, Washington (August 1973).

[11]R. V. LeClerc and T. R. Marshall, *A Pavement Condition Rating System and Its Use*, Symposium on Pavement Evaluation, AAPT Proceedings (1969).

[12]D. W. Rand, *Pavement Evaluation III*, Maine Department of Transportation, Materials and Research Division, August 1973), pp 73-78.

[13]M. Y. Shahin, M. I. Darter, and F. M. Rozanski, *Pavement Inspection Reference Manual*, Technical Information Pamphlet C-48/ADA017329 (CERL, September 1975).

[14]M. Y. Shahin, M. I. Darter, and S. D. Kohn, *Development of a Pavement Maintenance Management System, Vol I, Airfield Pavement Condition Rating*, Report No. AFCEC-TR-76-27 (AFCEC, November 1976).

[15]M. Y. Shahin, M. I. Darter, and S. D. Kohn, *Development of a Pavement Maintenance Management System, Vol II, Airfield Pavement Distress Identification Manual*, Report No. AFCEC-TR-76-27 (AFCEC, November 1976).

[16]M. Y. Shahin, M. I. Darter, and S. D. Kohn, *Development of a Pavement Maintenance Management System, Vol I, Airfield Pavement Condition Rating*, Report No. AFCEC-TR-76-27 (AFCEC, November 1976).

[17]M. Y. Shahin, M. I. Darter, and S. D. Kohn, *Development of a Pavement Maintenance Management System, Vol II, Airfield Pavement Distress Identification Manual*, Report No. AFCEC-TR-76-27 (AFCEC, November 1976).

[18]M. Y. Shahin and F. M. Rozanski, *Automated Pavement Maintenance and Repair Management System*, Interim Report C-79/ADA042582 (CERL, June 1977).