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PAVER Update

Pavement Maintenance Management for Roads and Streets Using the PAVER System

by
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The PAVER and Micro PAVER Pavement Maintenance Management Systems are designed to optimize the use of funds allocated for pavement maintenance and rehabilitation (M&R). PAVER, a field-tested, validated mainframe computer system, and Micro PAVER, a microcomputer version of the PAVER system, can be used to manage roads, streets, parking lots, and airfield pavements. This report combines information from several previous publications to provide a single, convenient reference for the field. In addition, enhancements to the systems since 1981 are described.

PAVER and Micro PAVER use the Pavement Condition Index (PCI) condition survey and rating procedure developed at the U.S. Army Construction Engineering Research Laboratory (USACERL). This report outlines the procedures for dividing the pavement network into management units, performing the PCI condition survey and determining a PCI, determining M&R needs and priorities, and selecting the most cost-effective M&R alternative. Newly developed technologies, including pavement deterioration prediction techniques which are being incorporated into the PAVER and Micro PAVER Systems, are discussed as are new reporting capabilities, the preparation of annual and long-range work plans, and project development.

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The PAVER and Micro PAVER Pavement Maintenance Management Systems are designed to optimize the use of funds allocated for pavement maintenance and rehabilitation (M&R). PAVER, a field-tested, validated mainframe computer system, and Micro PAVER, a microcomputer version of the PAVER system, can be used to manage roads, streets, parking lots, and airfield pavements. This report combines information from several previous publications to provide a single, convenient reference for the field. In addition, enhancements to the systems since 1981 are described.

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FOREWORD

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The work was performed by the Engineering and Materials Division (EM), U.S. Army Construction Engineering Research Laboratory (USACERL). Dr. R. Quattrone is Chief, USACERL-EM.

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PAVEMENT MAINTENANCE MANAGEMENT FOR ROADS AND STREETS USING THE PAVER SYSTEM

1 INTRODUCTION

Background

The U.S. Army is responsible for maintaining more than 560 million square yards of pavement. Managing a pavement network that large requires a systematic, objective method of determining maintenance and rehabilitation (M&R) needs and priorities to ensure efficient allocation of resources. Both engineering and economic factors must be taken into consideration in determining cost-effective M&R strategies. In 1968, the U.S. Army Construction Engineering Research Laboratory (USACERL) began developing the Pavement Maintenance Management System, now known as PAVER, to assist as a tool in making standard, practical decisions.

PAVER was developed under the auspices of Headquarters, U.S. Army Corps of Engineers (HQUSACE) through funding from the Army and Air Force. It was originally designed to be operated on a mainframe computer at military installations, but also has far-reaching application among municipalities, airports, and counties. PAVER was field-tested and validated at Fort Eustis, VA, through a full-scale demonstration monitored by 21 pavement engineers. PAVER has been (or will be) used at more than 60 military installations, including the full-scale, centrally funded implementation of all U.S. Army Forces Command (FORSCOM) installations which began in FY85.

One of the primary functions of a Pavement Management System (PMS) is predicting pavement condition into the future. To make this type of projection, there must be an objective, repeatable scale for determining the present pavement condition. PAVER uses the Pavement Condition Index (PCI)--a numerical index from 0 to 100 that gives an indication of a pavement's structural integrity and operational condition. Developed at USACERL, the PCI is based on the types, severity, and quantity of pavement distress identified during a condition survey.

Acceptance of the PCI and the PAVER System as a basis for determining project funding requirements and allocations has been increasing in recent years. The Federal Aviation Administration (FAA) has issued an Advisory Circular[1] detailing the procedures and guidelines for PCI airfield condition surveys on AC and PCC pavements, and repair methods for the maintenance of airfield pavements. In recent action by the FAA, Federal funding was made available for performing PCI surveys. The U.S. Air Force, a cosponsor of the PCI's development, has mandated its use on all airfields and uses it for evaluation and prioritization of M&R projects.

In 1984, USACERL began developing a microcomputer version of PAVER called "Micro PAVER." This project was initially sponsored by the FAA, with additional capabilities funded by the Army and Air Force. Micro PAVER maintains most of the capabilities of mainframe PAVER, while taking advantage of the more user-friendly features of a microcomputer. Micro PAVER offers an economical solution to small data base users seeking the advantages provided by a PMS. The American Public Works Association (APWA) has adopted Micro PAVER as the best available PMS, and has assisted

[1] *Guidelines and Procedures for Maintenance of Airport Pavements*, Federal Aviation Administration Advisory Circular 150/5380-6 (December 1982).

in its implementation at more than 45 municipalities. In this report, "PAVER" and "PAVER System" are used to denote both mainframe PAVER and Micro PAVER unless "mainframe" or "Micro" is specified.

Many other technological advancements and capabilities have been added to PAVER. New techniques in modeling pavement condition deterioration have led to better prediction methods, resulting in better budget forecasts. Lessons learned from the implementation of PAVER at military installations have triggered development of better tools for project planning as well as short- and long-range planning.

Procedures for maintenance management of an installation's roads and streets using the PAVER System have been documented in earlier USACERL Technical Reports.[2] However, the system has been enhanced in several ways since then and the previous information requires updating. In addition, the large volume of information in previous reports needs to be condensed for easy access to the most pertinent aspects of PAVER.

Objective

The twofold objective of this report is to (1) document the new technologies that have been incorporated into PAVER since its completion in 1981, including the newly developed pavement condition prediction techniques, and (2) condense previous information on the systems, highlighting only those areas of interest to persons wishing an overview of the current capabilities.

Approach

Portions of previously published reports and manuals documenting the PCI procedure and the PAVER System were extracted and condensed for presentation in this report. Also, the newer technologies incorporated into the system were documented. Examples were developed to illustrate how these applications can be implemented.

Report Organization

Chapter 2 provides an overview of the maintenance management concepts used in the PAVER System, procedures and guidelines for dividing a pavement network into manageable components are in Chapter 3, and the procedures required for performing a PCI condition survey are in Chapter 4. Next, Chapter 5 discusses techniques for pavement condition prediction. Chapter 6 introduces the computerized PAVER and Micro PAVER programs. Details as to how these programs can be used for network- and project-level management decisions are discussed in Chapters 7 and 8. Finally, Chapters 9 and 10 present methods for developing annual and long-range work plans and project justification.

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[2] M. Y. Shahin and S. D. Kohn, *Pavement Maintenance Management for Roads and Parking Lots,* Technical Report M-294/ADA110296 (U.S. Army Construction Engineering Research Laboratory [USACERL], 1981); D. R. Uzarski and R. C. Soule, *The Practical Use of PAVER in Planning, Programming, and Developing Projects for Pavement Maintenance and Repair,* Technical Report M-86/04/ADA167312 (USACERL, March 1986).

Mode of Technology Transfer

The PAVER and Micro PAVER programs have demonstrated application in the military community and are being used at some 60 installations. Military users interested in implementing either of the programs should contact the U.S. Army Engineering and Housing Support Center (CEHSC-FB). Pavement management short courses, cosponsored by the University of Illinois Department of Civil Engineering, USACERL, and CEHSC, are provided four times each year. Military use of the PAVER System is being directed through the revision of the Army Regulation (AR) 420-72, *Surfaced Areas, Railroads, and Associated Structures,* and Technical Manual (TM) 5-623, *Pavement Maintenance Management.*

The PAVER and Micro PAVER programs are available to nonmilitary users through the APWA. Micro PAVER can also be obtained through the University of Illinois Department of Continuing Education. Points of contact are given in Chapter 6.

2 MAINTENANCE MANAGEMENT CONCEPTS AND COMPONENTS

Overview

In past years, when maintenance funds were easier to obtain, pavement maintenance was typically performed as the need was brought to the engineer's attention. Past experience tended to dictate the selection of short-term repair techniques with little regard given to the long-term effects of the selected remedy. In today's economic environment, as pavement deterioration rates exceed the availability of M&R funds, a more systematic approach to determining M&R needs and priorities is required. Pavement networks must now be managed, not simply maintained.

The recent emergence of PMS products has provided engineers with the tools needed to manage their pavements economically. A PMS provides a systematic, consistent method for selecting M&R needs and priorities and determining the optimal time of repair by predicting future pavement condition. The importance of early detection and repair of pavement distress cannot be overstated; the consequences of neglect are graphed in Figure 1. If repairs are performed during the early stages of deterioration preceding the sharp decline in pavement condition, repair costs of 80 percent can be saved. In addition to money savings, less shutdown time would be required, making neglect a costly alternative. A PMS can be used to alert the manager to this point in a pavement's life cycle.

Pavement management consists of two levels of analysis: (1) the network level, in which the agency's entire pavement network is considered for budgeting, planning, scheduling, and selection of potential M&R projects and (2) the project level, in which potential projects are evaluated in more detail to identify feasible alternatives that address the site-specific conditions. The final step in project-level analysis is to perform life-cycle costing for selection of the most cost-effective M&R alternative.

The concepts and components comprising maintenance management are introduced in this chapter. Various approaches to determining M&R needs, differences in network- and project-level management, and the components used to perform pavement management are also discussed.

Approaches To Determining M&R Needs

Various organizations in the United States use different approaches to determine the necessary maintenance and rehabilitation for a given pavement section. Brief descriptions of the three most common approaches, which are shown in Figure 2, follow.

Habitual Approach

Many agencies use the "habitual" or ad hoc approach, in which the staff applies the M&R alternatives that experience indicates is the best solution. Evaluation suggests that this approach results in the seemingly habitual application of a selected few alternatives. A major drawback to this approach is that because of the limited set of alternatives, the best or most economical option for the pavement being considered may not be selected.

Present Condition Approach

In the "present condition" approach, the pavement is first evaluated using various condition indicators. Based on an analysis of these indicators, an M&R alternative is selected to correct the condition; however, no life-cycle cost comparisons of the alternatives are considered. A major

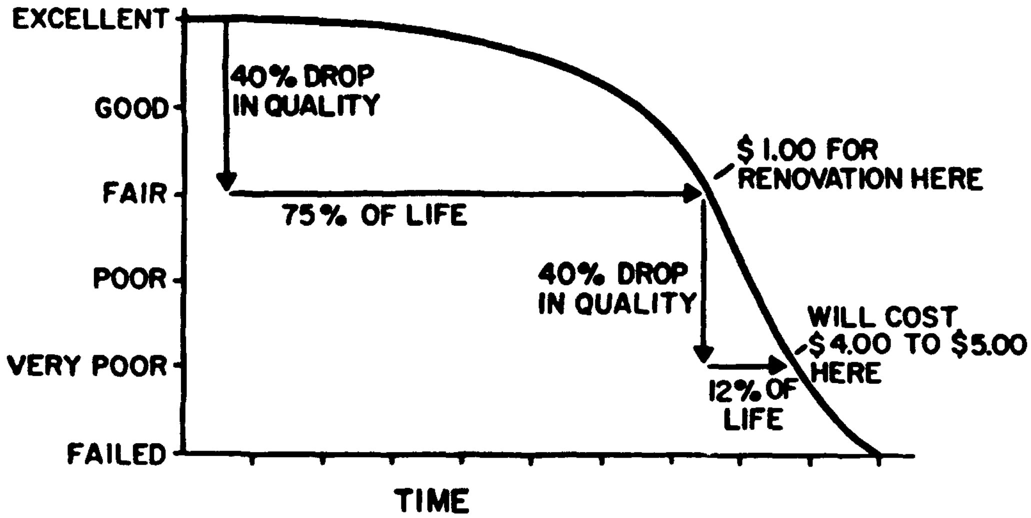

Figure 1. Typical pavement condition life cycle.

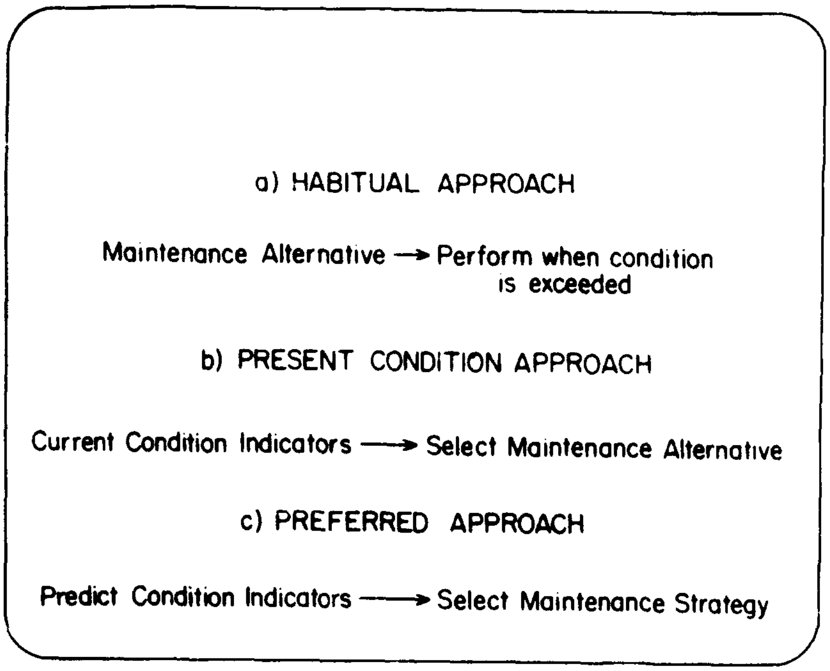

Figure 2. Approaches to determining maintenance needs.

advantage of this approach is that the prescribed M&R alternative addresses the deficiencies found in the pavement. The disadvantage is that the choice may not be the most cost-effective method.

Strategy Approach

The "Strategy" approach requires not only an in-depth evaluation of the pavement under consideration, but also prediction of its future condition. This process ensures selection of the most economical M&R strategy, as determined on a life-cycle cost basis. Projection of future condition requires the ability to measure condition on an objective, repeatable scale, such as the PCI shown in Figure 3 and discussed in more detail in Chapter 4.

By projecting rate of change on an objective condition scale, a meaningful life-cycle cost analysis can be performed to compare the various M&R alternatives and the future maintenance costs associated with each. Not only is the best M&R alternative selected, but the optimal time of application is also determined. As discussed earlier, such a decision is critical in order to avoid the higher M&R costs caused by excessive deterioration.

Project- vs. Network-Level Management

The individual selection of the best M&R alternative for each project being considered is known as "project-level management." Each project is analyzed in detail and the most feasible alternative is selected on a case-by-case basis. Little or no consideration is given to the resource requirements of other projects being evaluated. Engineers have been trained to work at the project level, which may be acceptable as long as money is abundant.

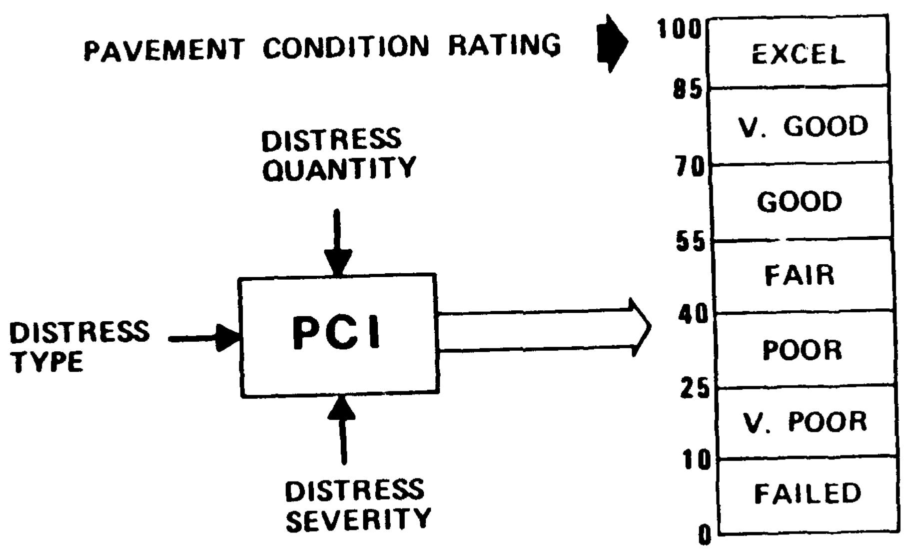

Figure 3. Pavement Condition Index (PCI) concept.

However, this is currently not the case. Top management is now demanding budget projections for each fiscal year (FY) that consider their agency's entire network. This process is not possible within current resources if there must be an in-depth evaluation for each project to arrive at required budgets. Instead, the pavement network must be inspected in less detail and at a faster rate to identify a list of potential projects. When the needs of the entire network are considered, the process is referred to as "network-level management." When a pavement section is selected as a potential project, only then is it scheduled for in-depth evaluation and selection of a specific M&R strategy at the project level.

In general, network-level management considers the agency's short- and long-range budget needs, present and future overall network condition, and the identification and prioritization of potential projects to be considered at the project level. At the project level, the primary objective is to select the most cost-effective M&R strategies within existing management constraints.

Components of Maintenance Management Systems

The generic maintenance management concepts described in this chapter were developed for use in the PAVER System. These same components, as shown in Figure 4, are now being used to develop maintenance management systems for built-up roofing, railroads, and other civil works structures. Each component is discussed below.

Network Inventory

The first step in maintenance management is to determine what needs to be managed. The PAVER System can inventory both surfaced and unsurfaced roads and streets, parking lots, and airfield pavements. Each agency has the option of inventorying all or a portion of its pavement network, depending on the level and method of implementation. Several factors must be considered when implementing these options, including available funds; type, amount, and condition of the pavement network; availability of trained personnel to implement and maintain PAVER; and access to and level of computer support.

Once the question of which pavements to include is answered, the network must be divided into smaller units called "branches" and "sections." Pavement sections represent the management unit for which all major M&R decisions are made. A section typically has consistent characteristics such as pavement structure, construction history, traffic, and condition throughout the entire length or area. The guidelines and procedures for dividing a pavement network are discussed in Chapter 3.

The network inventory should be used to store the physical characteristics of each pavement section. Information such as the section dimensions, surface type, and a functional classification should be included in the inventory, but most importantly, condition information for each section in the network should be present. Although the network inventory is one of the most tedious demands in initiating a maintenance management system, it is the crucial step in establishing the foundation for the rest of the system. Once the network inventory is prepared correctly, it need not be repeated.

Database

Without an efficient filing system, massive data collection can lead only to confusion and waste of resources. For a small network, a manual filing system could probably be established. With the current advances in technology, computerized data bases for easy data storage and access are within the reach of every agency. When storing data, every effort should be made to ensure the high quality

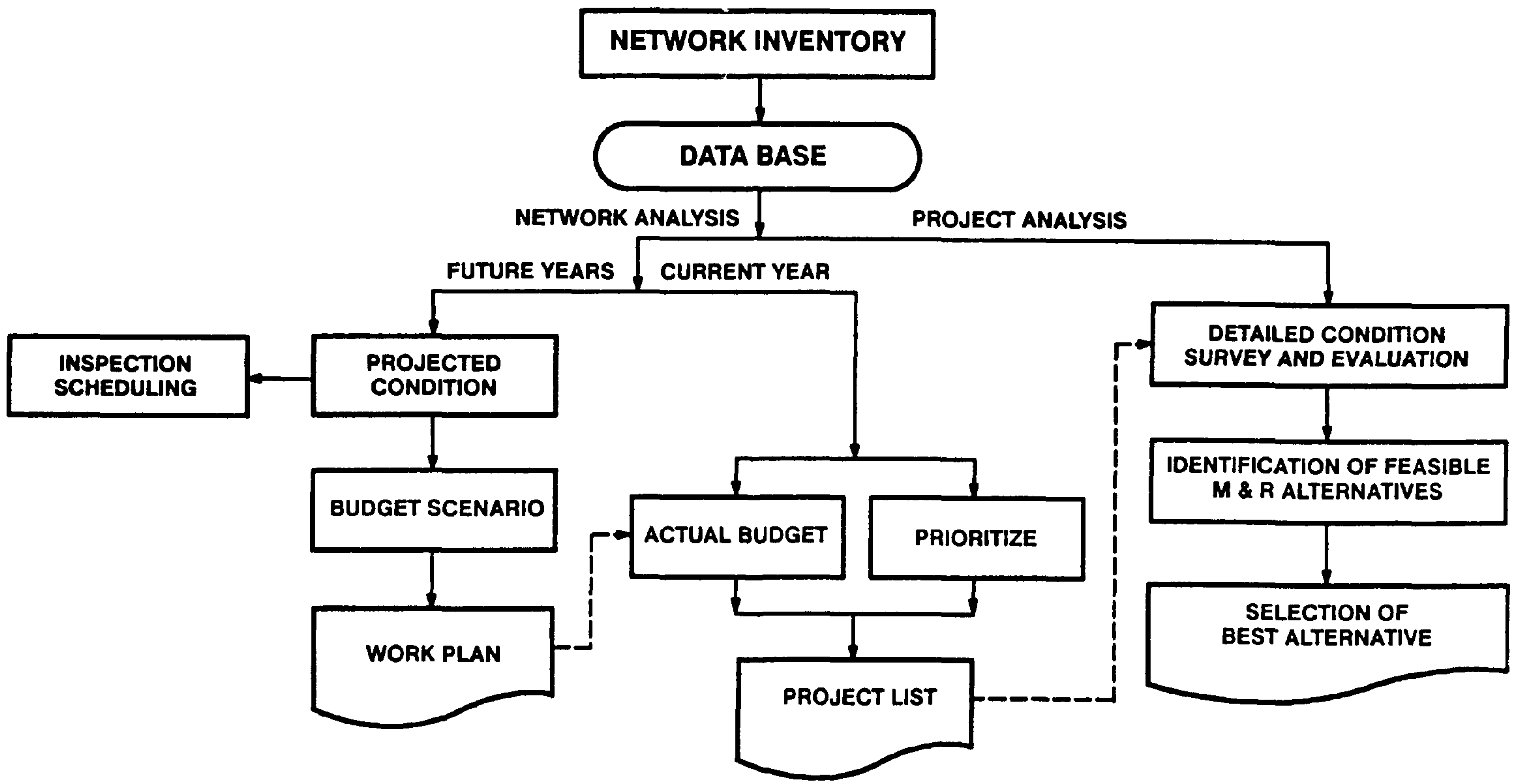

Figure 4. Components of maintenance management systems.

of data being stored. Information should be reviewed and screened before being entered into the data base, and checked again after its entry to ensure data integrity.

Network inventory and data base establishment represent the major efforts required to initiate a maintenance management system. The remaining components represent the payoff that results from these efforts.

Network-Level Management in a PMS

In network-level management, current and future M&R requirements are determined by considering the needs of the entire pavement network. The most important step in analyzing network needs accurately is to project the future condition of each section. This projection provided the input needed to perform two tasks: (1) scheduling future condition inspections and (2) identifying sections that will require major M&R in future years for budget estimating.

Pavement sections are flagged for inspection when their projected condition falls below a user-specified minimum allowable condition level. Optimally, this will be the point at which the pavement begins the sharp decline in condition and at which M&R should be performed. Also, based on the section's rate of deterioration, or loss of PCI points per year, reinspections are scheduled, allowing pavements with a high rate of deterioration to be inspected more often than those with a lower rate.

One method of selecting candidate sections for future major M&R work is based on establishing minimum acceptable condition levels for each pavement use and rank being considered (i.e., primary roadways or secondary parking lots). Unit cost of repairs for each surface type being considered can be entered for various PCI ranges, supplying all information needed for preparing a 5-year budget estimate. A more sophisticated budgeting tool now being developed uses optimization techniques which ensure that either least cost or maximum benefit/cost ratio for the agency is met while meeting any managerial minimum condition constraints.

The forecasted budget requirements forming the budget planning report should then be compared with the actual amount of money allocated for M&R in the program year. When the forecasted budget requirements exceed the actual amount of dollars available, as is usually the case, a prioritization scheme should be developed to provide a method of determining which pavement sections will be repaired first. By comparing the prioritized projects with the actual budget, a list of potential projects which are candidates for M&R in the current program year is produced. This potential project list provides the link with project-level management.

Project-Level Management in a PMS

In project-level management, each section identified in the network analysis as a candidate for M&R in the current year should be subjected to a detailed condition survey. This assessment should include both destructive and nondestructive testing as discussed in Chapter 8. The results of these detailed surveys are then used to identify feasible alternatives that can correct existing deficiencies and prevent their recurrence. The various alternatives identified, including "no action," should be compared on a life-cycle cost basis. In addition, the economic feasibility of combining adjacent sections into one large project should be investigated. The results, combined with any budget and/or management constraints, produce the final M&R project list for the current program year.

A more sophisticated analysis for the current year's projects would include consideration of the benefits associated with each feasible alternative for each section. An analysis of both benefits and life-cycle costs produces M&R alternatives that ensure maximum return on investment for the agency.

Benefits of a PMS

Implementation of a PMS benefits the user in several ways. With an objective, consistent method of evaluating pavement condition, M&R needs and priorities can be determined on a systematic, documentable engineering basis. Necessary budget requirements can be identified for maintaining pavements at various levels of serviceability, and the effects on the pavement network of delaying the necessary repairs can be shown. Finally, a PMS can be used to ensure selection of the most cost-effective M&R strategy by performing a life-cycle cost analysis on all feasible M&R alternatives. It is important to remember that a PMS does not replace good engineering judgment. It serves only as a tool to assist the engineer in the decision-making process.

3 NETWORK DIVISION AND DATA COLLECTION

Before the PAVER System can be used as a tool to manage an agency's pavements, the network to be managed must be defined. This network could encompass all paved or unpaved roads and streets, parking areas, or airfield pavements. In general terms, PAVER is capable of inventorying all surfaced areas that provide an accessway for ground and/or air traffic. Depending on the management demands on the system and the scale of implementation, the inventory could consist of a limited amount of data (including pavement identification, results from one pavement condition survey, date of construction and/or last major repair, and surface type) or a wide range of information built on historical data and various destructive and/or nondestructive test results. Guidelines as to the type and amount of data to be collected are presented under **Data Collection Requirements** below.

Once the network is identified, it must be broken into smaller components to manage the inventoried pavements. Fairly specific guidelines have been established dividing the network for use with the PAVER System. Some flexibility has been built into the procedure to accommodate unusual situations or specific agency constraints; however, it is strongly suggested that, without the guidance of someone experienced in PAVER implementations, the guidelines and recommendations for work division be followed closely. Errors or misjudgments in network division have proven to be very costly if discovered after data have been entered into the data base. By following the guidelines presented in this chapter for roads and streets and Air Force Regulation (AFR) 93-5[3] or FAA Advisory Circular 150/5380-6 for airfield pavements, and using good engineering judgment, all costly errors can be avoided the first time through, resulting in an effective data base for the agency.

Network Division

As a means of managing a large data base more effectively, PAVER requires that the network be divided into smaller, more manageable components. Using the data available on pavement use, surface type, structure, and traffic patterns, the network is divided into the following elements:

- Zone
- Branch
- Section
- Sample unit.

The following guidelines for network division are applicable for roads, streets, and parking lots. Guidance on network division for airfield pavements can be found in AFR 93-5 or FAA Advisory Circular 150/5380-6.

Zone

The decision to divide an agency's network into zones can be made at the agency's discretion. Typically zones are used to group geographic portions of a large network based on a characteristic common to the subset. Zones can be used in any way that would prove useful to the agency implementing the system. Zones have been used effectively to designate remote areas, funding sources for M&R work, snow removal priority zones, and snow routes. Army installations can choose to use zones to distinguish between family and nonfamily housing. Use of zones is completely optional to the agency. No capabilities are lost by omitting it. However, if zones allow network management

[3]Air Force Regulation (AFR) 93-5, *Airfield Pavement Evaluation Program* (Department of the Air Force, 1981).

activities to be performed faster or more effectively or efficiently, it may be to the agency's advantage to use them.

A zone is represented in the PAVER System by a four-character, alphanumeric code. The name may consist of any combination of letters and numbers chosen by the agency, or may be designated to correspond to an existing numbering scheme. For example, an installation can be divided into zones that correspond to the existing Integrated Facilities System (IFS) numbering scheme being used for facilities management. The zones are identified by a four-digit code, where the first character is either a P for Post or R for Reserve Center, the second character R for Roadway or P for Parking area, and the last two characters represent the first two numbers of the block number. For example, Zone PR86 consists of Post Roadways in the block beginning with the numbers 86.

Branch

A branch, a mandatory component of a pavement network, is defined as any identifiable part of the pavement network which is a single entity and has a distinct function. For example, an individual street and a parking lot would each be considered a separate branch of the pavement network. Similarly, airfield features such as runways and taxiways would each be considered separate branches.

The easiest way to identify the branches comprising the pavement network is to use the existing name identification system used on the agency's maps. Each street on the network could be isolated and identified as a separate and distinct branch. The process also could be used on parking lots; however, depending on their size and location, many smaller lots could be combined to form one branch if necessary. This arrangement will be illustrated in an example later in this section.

Figure 5 shows a portion of an installation map that contains several streets and parking areas. Each street shown on the map can be identified as being a single entity with a distinct function and should be defined as a separate branch. Marshall Street is an example of a branch, as is the parking lot shown adjacent to the post office.

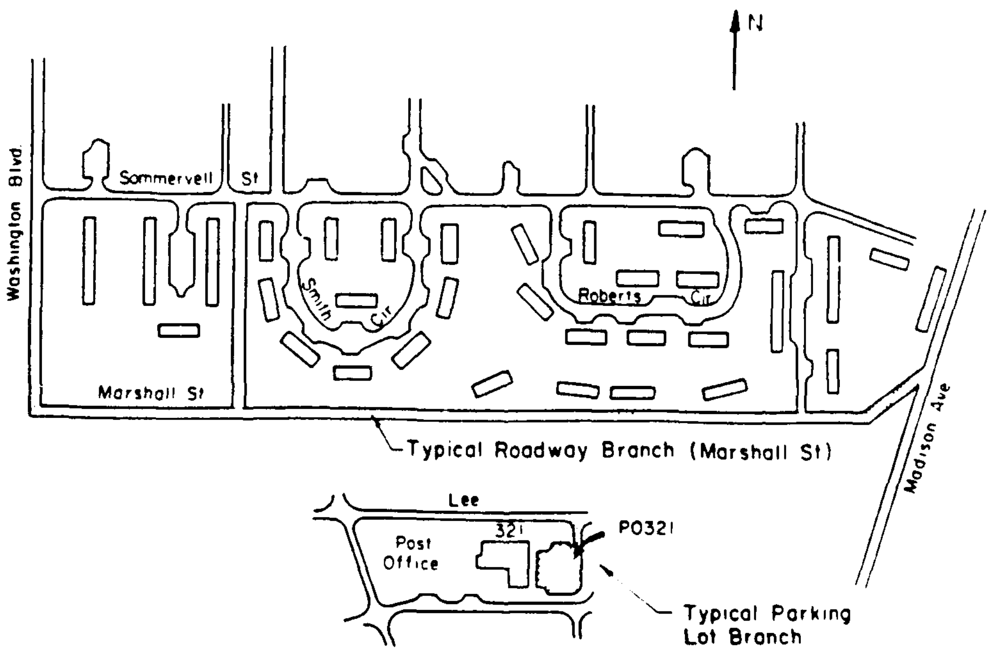

Figure 5. Installation map showing typical pavement branches.

Each branch identified is represented in two ways in the PAVER System: (1) by an alphanumeric descriptive name up to 25 characters (maximum) called the BRANCH NAME and (2) by a five-character (maximum) alphanumeric code called the BRANCH NUMBER. Existing street names, such as "Marshall Street" in the previous example, are typically used as branch names. Areas such as parking lots and storage areas that do not already have assigned names can be given descriptive names to associate them with their area as was done with the post office parking lot.

The branch number is a unique code, assigned to each branch, which is used to help store and retrieve data from the PAVER files. The agency's selection of the code to be used as the branch number should consider several factors, including:

1. Are there existing codes at the agency that could be used to ensure compatibility? For example, IFS facility codes may be used where the roadways have been identified using the network basis.

2. For ease of identification or for sorting purposes, it may be advantageous to have the first character of the branch number be a letter that identifies a group of branches as shown in Table 1. For example, all branch numbers for roads and streets on an installation may start with the letter "I" for installation road.

3. PAVER reports often list the branch number and not the branch name. For this reason, abbreviating the branch name as a branch number may make reports easier to read.

4. Branch codes cannot be duplicated; each code must be unique.

Table 1

Branch Codes

Type of Branch	First Letter in Branch Code
Installation road	I
Parking lot	P
Motor pool	M
Storage/hardstands	S
Runway	R
Taxiway	T
Helicopter pad	H
Apron	A
Other	X

Section

Because a branch is typically a large unit of the pavement network, it does not always have consistent characteristics throughout its entire area or length. For this reason, branches are subdivided into smaller components called "sections" for management purposes. A section should be viewed as a segment of the branch which a manager would treat in a uniform way when considering issues such as the application and selection of M&R treatments. Each branch must consist of at least one section, but may consist of more if characteristics vary throughout the branch. Points to consider when dividing branches into sections are:

1. Pavement structure
2. Traffic
3. Construction history
4. Pavement rank
5. Drainage facilities and shoulders
6. Condition.

Guidance for each point is summarized below.

Pavement Structure. The pavement structure is one of the most important criteria for dividing a branch into sections. The structural composition (thickness and materials) should be consistent throughout the entire section. Because information on structure is not always readily available, construction records should be searched or a network-level combination NDT and coring program developed to provide or verify all information on structural composition.

Traffic. The volume and load intensity of traffic should be consistent within each individual section. For airfield pavements, a section should be defined by traffic channelization. For roads and streets, primary consideration should be given to truck traffic. An intersection could be treated as a separate section if it has a much higher volume of traffic than the surrounding pavement.

Construction History. All pavements within a given section should have a consistent construction history. Any pavements constructed during different time periods, by different contractors, or using different materials and/or techniques should be considered separate sections. Areas that have received major repair work should also be divided into separate sections.

Pavement Rank. If a branch changes along its length from primary to secondary, or secondary to tertiary, a section division should be made. On a road, if a branch becomes a divided roadway along its length, a separate section should be defined for each direction of traffic. For airfield pavements, it may be more appropriate to ensure that a section be confined to a single pavement use. For example, a taxiway that passes through an apron is identified as a section, separate and distinct from the apron pavement.

Drainage Facilities and Shoulder. It is recommended that drainage facilities and shoulder type be consistent throughout a section.

Condition. After each section is initially inspected, pavement condition within the section could be used to subdivide it into other sections if a considerable variation in condition exists. For example, if a section of a roadway has one portion in a different condition than another portion, section divisions should be made.

Other Considerations. It is important to remember that the items discussed above are only *guidelines*. Each agency must take into account its own unique situation in defining sections. The way an agency interprets these guidelines will influence data base effectiveness and some of the related costs. Defining very short sections to ensure common pavement structure requires a high sampling rate to obtain a section PCI with the level of accuracy needed for project-level decision making. The higher the sampling rate, the higher the costs associated with inspections. In addition, the sections may be too small to schedule individual M&R work productively. If they are too large, the characteristics may not be consistent across the entire area. This situation could result in PCI values that are not truly representative of the section as a whole. The outcome could be incorrect design and budget decisions.

At present, a section is represented in the mainframe PAVER program by a two-character alphanumeric code; in Micro PAVER, up to a three-character alphanumeric code may be used. (Modifications to the mainframe program to allow for the additional character are expected to be completed in the future.) This code is referred to as the SECTION NUMBER and is used for storage and retrieval of all section information residing in the data base. Sections are typically numbered in increasing order from the north or west end of the branch. (Each section should be identified on the agency's network map and/or street map, with arrows indicating the beginning and the ending points.) An example of a network divided into sections and the corresponding section numbers are shown in Figure 6.

Section identification sketches, such as the one shown in Figure 7, should be prepared and kept on file for each section in the network. These records should include not only a detailed sketch of the section, but also information such as surface type, pavement structure, and section area to serve as a reference for M&R project planning. Some agencies feel it is also necessary to mark the beginning and ending points of each section on the pavement itself. Plain brass disks embedded in the curbs, and nails with washers pounded into the pavement have all been used as methods of marking pavements. These markings, however, should never be relied on as the *only* method of section identification because each technique provides only a temporary mark.

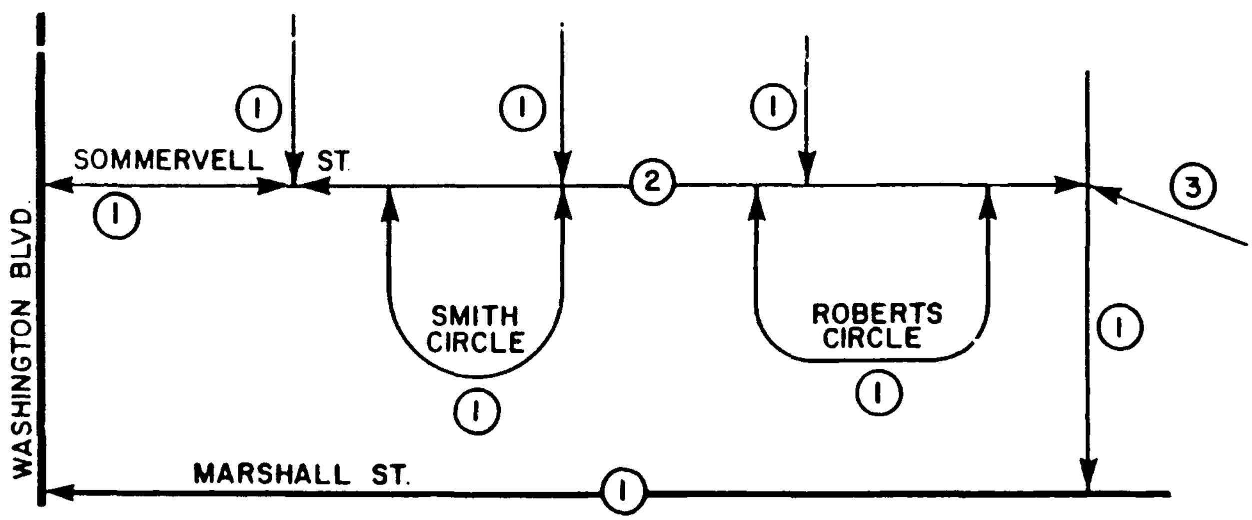

Figure 6. Sections identified on an installation.

Installation Name	Date	Branch Name/Branch No.	Section No.	Zone	Length	Width	Area
FORT BRAGG	10/01/87	BAXTER STREET / BAXTR	03	H	983 ft.	19 ft.	2150 Sy.

Branch Use	Section Cat.	Pavement Rank	Surface Type	Slab	Last Const. Date
(Roadway) Runway Helipad Parking Taxiway Motorpool Other Apron Storage	A B C (D) E F G I J K Y N	P S (T) X N A B C D E	(AC) PCC APC GR ST X	Width ____ ft. Length ____ ft. Total No. ____ slabs	04 / 04 / 63 mm dd yy

Section Begins SIXTH STREET Section Ends FIFTH STREET Total No. Sample Units 10

On sketch: note any subsurface drainage structures (type, location) and secondary structures, such as manholes, water shutoffs, etc.

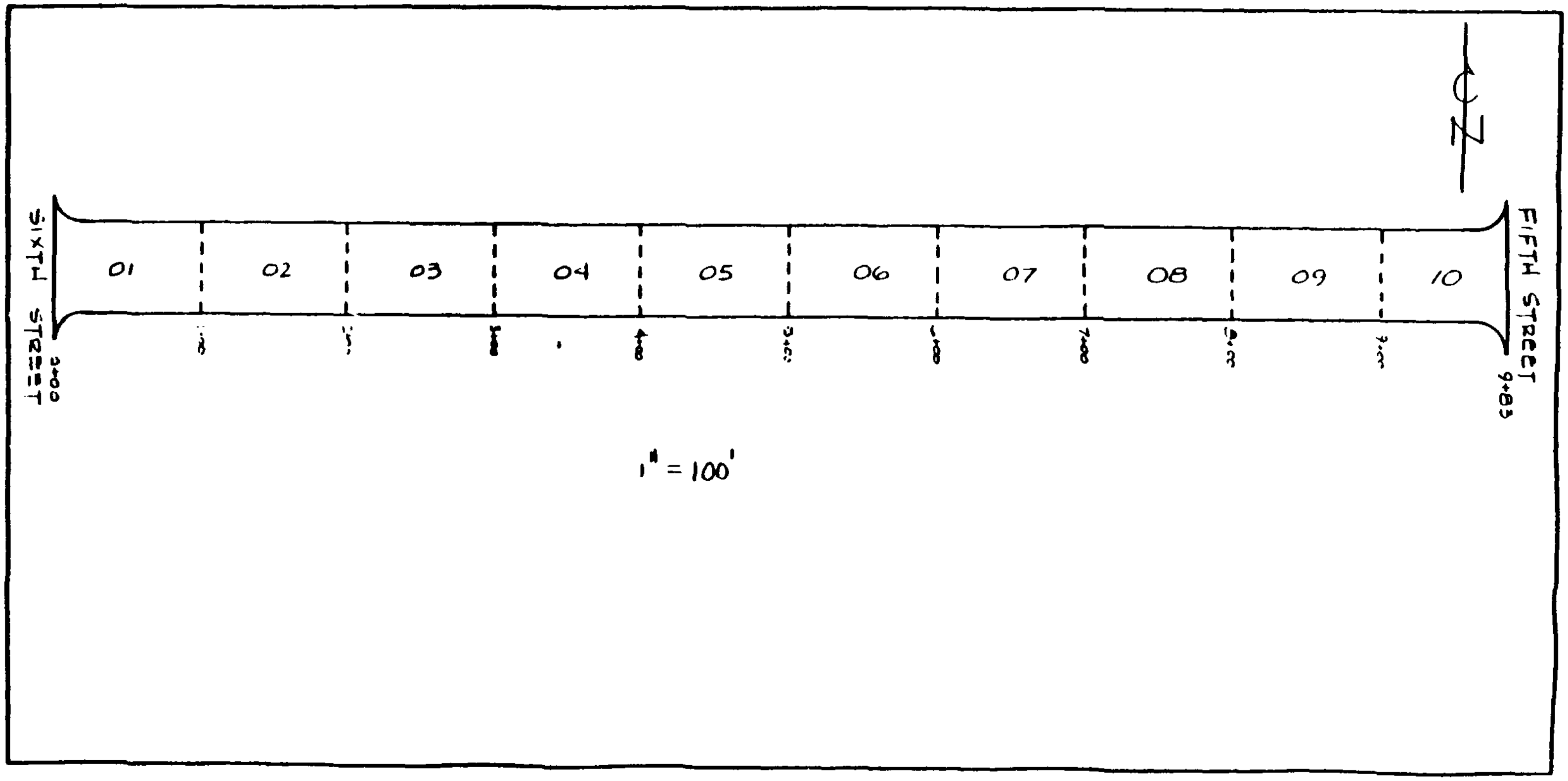

Figure 7. Section identification sketch for new roadway. (Source: TM 5-623, *Pavement Maintenance Management* [HQDA, November 1982].)

The same guidelines for dividing roads and streets into sections can also be used to divide parking lots and storage areas into smaller components. Typically, parking lots are defined as a branch consisting of only one section. In special cases, such as very large or very small lots, an agency may choose to manage them differently. In the case of very small parking lots (designed for fewer than 10 vehicles), a section may be composed of several small lots located relatively close to each other and with similar characteristics. For example, Figure 8 shows a group of small parking lots around Smith Circle. Because of their size and nearness to each other, these lots can be considered as a branch with only one section. The parking lots on Summervell Street, however, are relatively large and do not have consistent characteristics. Therefore, they have been defined as one branch (Parking Lots on Summervell Street), but each lot is considered to be one section.

In the case of a very large parking area in which driving routes can be defined, individual sections can be defined based on traffic patterns and use. Field observations of these areas during use will help show how to divide the lot into sections. An example of a large parking area divided into five sections is shown in Figure 9.

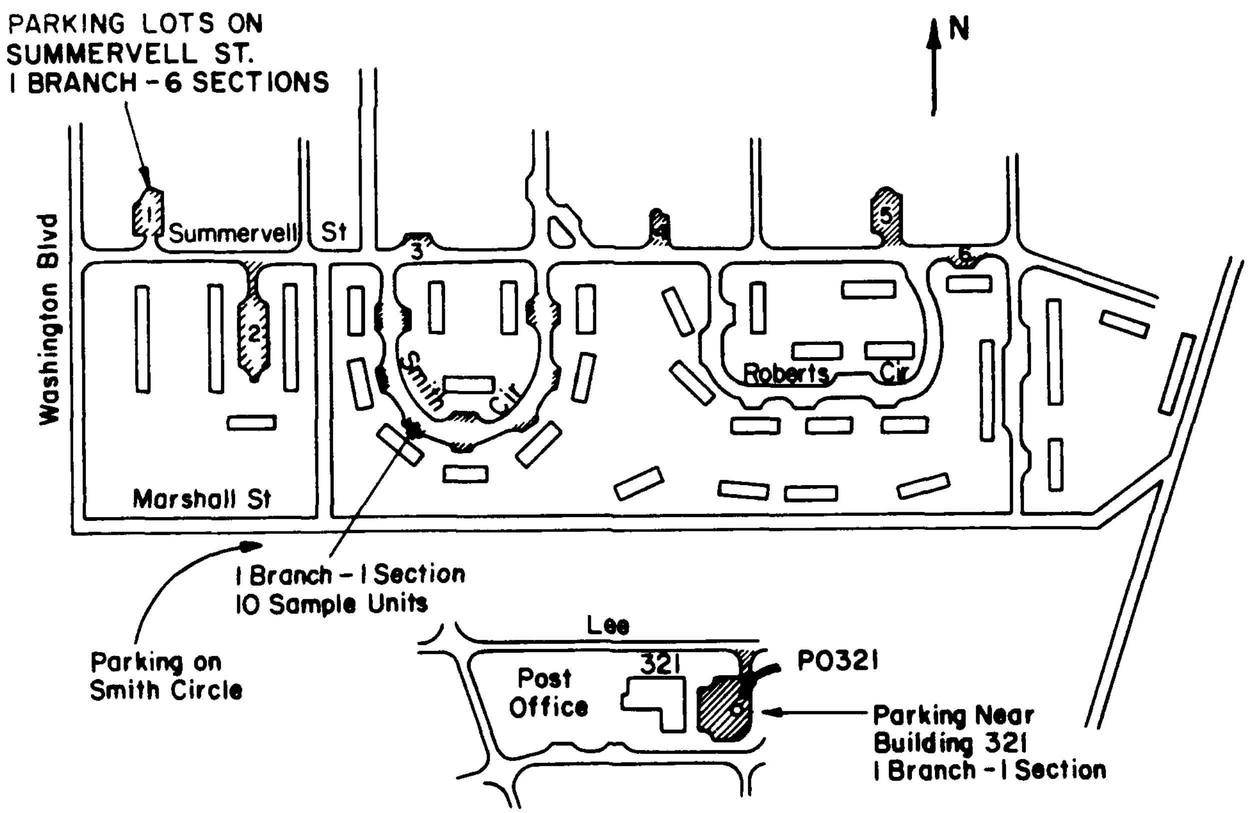

Figure 8. Installation map showing various methods of identifying parking area branches.

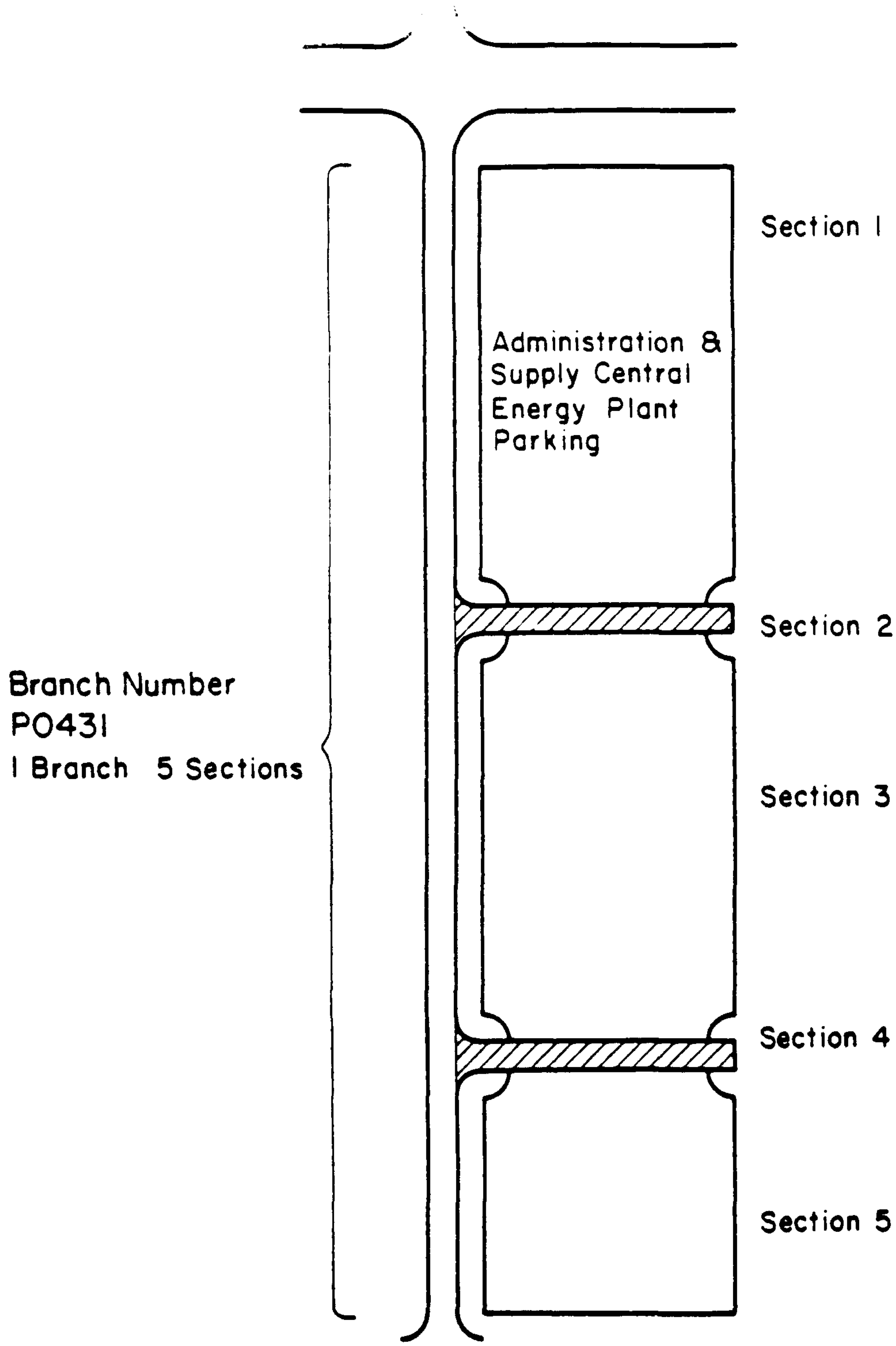

Figure 9. Large parking area divided into several sections.

Sample Units

The smallest component of the pavement network is the sample unit. A sample unit is defined as any easily identified, convenient area of pavement section which is designated only for the purpose of pavement inspection. For asphalt- or tar-surfaced roads (including asphalt overlay over concrete), a sample unit is defined as an area 2500 ± 1000 ft. For concrete roads with joint spacings less than or equal to 30 ft, the recommended sample unit size is 20 ± 8 slabs. For slabs with joint spacings greater than 30 ft, imaginary joints less than 30 ft apart and in perfect condition should be assumed. For example, if slabs have a joint spacing of 50 ft, imaginary joints may be assumed at 25 ft. Thus each slab would be counted as two slabs for the purpose of pavement inspection. It should be noted that sample unit sizes close to the recommended mean (i.e., 2500 sq ft, or 20 slabs) are preferred for accuracy.

The most significant criterion in identifying a sample unit is convenience. For example, Figure 10 shows an asphalt pavement section 22 ft wide by 4720 ft long. It can be divided into sample units that are 22 ft wide by 100 ft long, for a total sample unit size of 2200 sq ft. Because of the length of the section, some of the sample units may have to be of a different length than the others. Not all sample units have to be the same size. They do, however, have to fit within the guidelines established for recommended sample unit size to ensure a statistically valid PCI. In the example shown, the section is divided into 46 units that are each 100 ft long plus one unit that is 120 ft long. Therefore, the last sample unit has an area of 22 ft by 120 ft or 2640 sq ft.

It is strongly recommended that, on the section identification sketches kept for each section, the size and location of sample units be shown. These sketches can be used to relocate sample units for future inspections. Guidance on the number of sample units to inspect is covered in the next chapter.

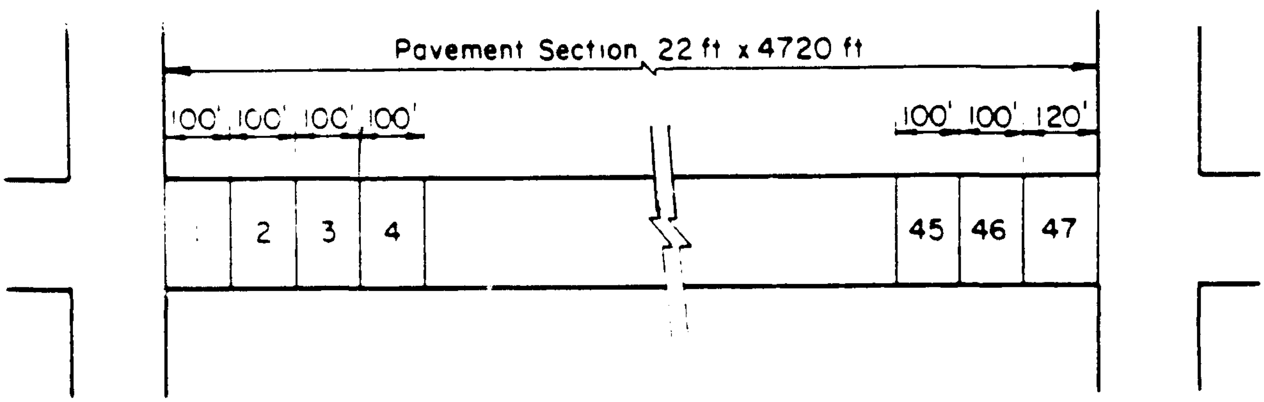

Figure 10. Example of asphalt section divided into sample units.

Data Collection Requirements

When fully implemented, the PAVER System can provide a wealth of information for use by an agency in managing its pavement network. Decisions at both the network and project levels can be made quickly and reliably based on the information stored in the automated data base, as long as the data are accurate and up to date. PAVER can be used successfully, however, with only a portion of the data entered into the system. Most network-level decisions can be made with general information about the pavement sections. Managing only at the network level temporarily postpones the need for collecting in-depth details about a pavement section which may require extensive coring or nondestructive testing. Project-level information can be added later, when the agency feels comfortable with the concepts and capabilities of PAVER.

At the simplest level of implementation, four items of information must be provided to obtain any benefit at the network level. These items include:

1. Network definition: an inventory of the branches and sections as defined by the agency. The minimum data required for branch definition are the branch number and branch use. The minimum data required for section definition are section number, pavement rank, and surface type.

2. Pavement Condition Index (PCI): each pavement section stored in the data base must have the results of a PCI inspection entered so that a current condition rating is available. The survey is performed as described in the next chapter.

3. Last Construction Date (LCD): to predict pavement condition accurately, the last date when the pavement was considered to have been in perfect condition must be stored. In general, this date is typically the date of the last major M&R work (overlay, etc.) or the date of initial construction. If the last construction date is not known, a "best guess" should be made based on old construction records, interviews with senior employees, or good judgment. The effect of assigning a random date on pavement condition prediction is shown in Figure 11. In the first case, a random date of 1965 was chosen as the last construction date. Using the actual PCI which was determined from a condition inspection, a PCI of 60 was predicted 5 years into the future. In the second case, the actual last construction date of 1974 was used. This choice resulted in a predicted PCI of 43--substantially different than the previous case.

4. Maintenance policy and priority scheme: to use PAVER for effective network-level management, at least one maintenance policy and priority scheme should be developed. PAVER generates a report that applies the distress maintenance policy to the distresses identified in the latest condition survey in order to develop a distress M&R plan. For major repair, the agency's prioritization scheme is used to identify which of the pavements flagged for M&R work should receive the highest priority. The development of a priority scheme is covered in more detail in Chapter 7.

As additional funds become available, or as the need arises, additional data can be collected and added to the data base. As in other decision-making processes, the more data available, the better the engineer can make informed decisions for maintaining the agency's pavements.

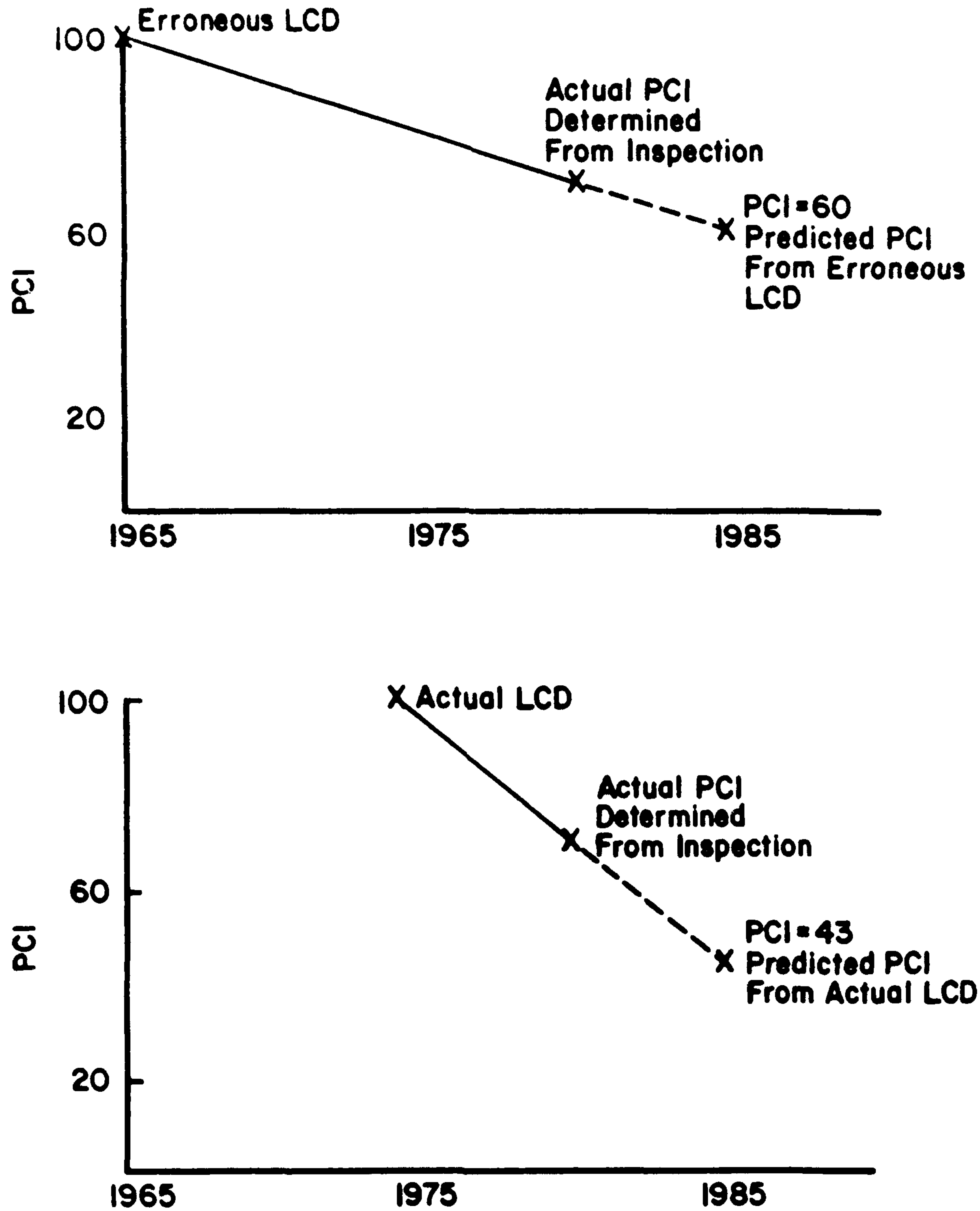

Figure 11. Effect of inaccurate Last Construction Date (LCD) on the predicted PCI.

4 PAVEMENT CONDITION SURVEY AND RATING PROCEDURE

Overview

The most useful feature of an effective PMS is the ability to both determine the current condition of a pavement network and predict pavement condition sometime into the future. To predict condition reliably, an objective, repeatable rating system for identifying the pavement's present condition must be used. The PAVER System uses the PCI, a numerical index ranging from 0 for a failed pavement to 100 for a pavement in perfect condition, as its pavement condition rating.

The PCI is calculated based on the results of a visual condition survey in which distress type, severity, and quantity are identified. Field verification of the PCI inspection method has shown that the index gives a good indication of a pavement's structural integrity and operational condition.[4] It has also been shown that, at the network level, the observation of existing distress in the pavement provides a useful index of both the current condition and an indication of future performance under existing traffic conditions, without requiring comprehensive testing programs such as roughness, skid resistance, and structural capacity. As a result, large savings can be realized in term of both time and money.

The degree of pavement deterioration is a function of distress type, distress severity, and amount or density of distress. Because of the large number of possible combinations, producing one index that would take into account all three factors was one of the major problems in developing the PCI. To overcome this problem, "deduct values" were introduced as a type of weighing factor to indicate the size of the effect that each particular distress type, severity level, and distress density combination has on pavement condition. Based on input from field-testing and evaluating the procedure, accurate descriptions of distress types and severity levels, and the corresponding deduct values, were derived so that a composite distress index (the PCI) could be determined. Additional information on development of the PCI can be found elsewhere.[5]

Figure 12 presents an overview of the steps involved in determining the PCI of a pavement section. Step 1, dividing the section into sample units, was covered in Chapter 3. The pavement inspection techniques comprising the second step are discussed in this chapter. Included are the methods for determining the number of sample units to inspect, and which sample units to inspect, as well as the survey procedures used for asphalt concrete (AC) and Portland cement concrete (PCC) pavements. The last section of this chapter covers steps 3 through 7, manual calculation of the PCI for each sample unit inspected and extrapolation of the date to determine the average PCI of the pavement section.

Pavement Inspection Sampling Techniques

The inspection of every sample unit in a pavement section may require considerable effort, especially if the section is large. In an effort to limit the amount of resources required, a sampling plan was developed so that a reasonable estimate of the PCI could be determined by inspecting only a portion of the sample units in the pavement section. Table 2 lists recommended sampling rates for random samples.

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

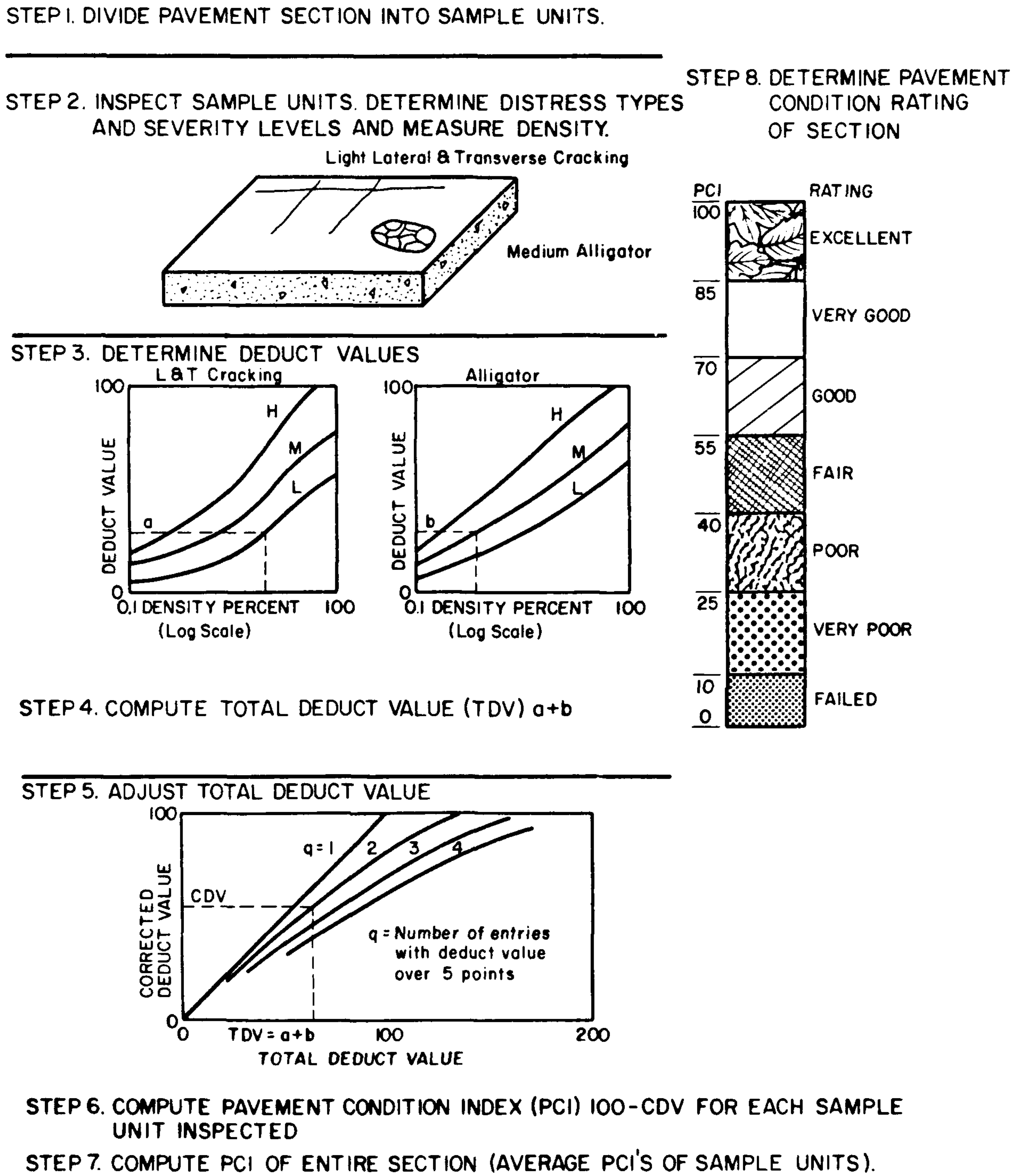


Figure 12. Steps for determining PCI of a pavement section.

The number and location of sample units to be inspected depends entirely on the purpose of the inspection. If the objective is to make network-level decisions based on the overall condition of the pavement in the network, then a survey of some of the sample units per section as shown in Table 2 may be sufficient. The sample units selected should be chosen to be representative of the overall condition of the section.

If, however, the purpose of the inspection is to select or analyze various M&R alternatives for a pavement section at the project level, then more sampling should be performed. The sampling procedures for this level of decision-making are described below.

Determining the Number of Sample Units To Be Inspected

The first step in performing inspection by sampling is to determine the minimum number of sample units (n) that must be surveyed to obtain an adequate estimate of the section's PCI. This number is determined by using the curves shown in Figure 13. Using this number, a reasonable estimate of the true mean PCI of the section will be provided. The estimate is within +5 points of the true mean PCI 95 percent of the time. The curves were constructed using Equation 1:

$$n = [N \cdot \sigma^2]/[e^2/4(N-1) + \sigma^2] \qquad \text{[Eq 1]}$$

where:

N = total number of sample units in pavement section

e = allowable error in the estimate of the section PCI (e was set equal to 5 when constructing the curves in Figure 13)

σ = standard deviation of the PCI between sample units in the section.

Table 2

Recommended Sampling Rates for Random Samples, Network-Level

No. of Sample Units in Section	No. of Units To Be Inspected
1-4	1
5-10	2
11-20	3
21-40	5
more than 40	10 percent (round up to next whole sample unit)

The curves in Figure 13 can be used based on the PCI standard deviation among sample units or PCI range (i.e., lowest sample unit PCI subtracted from the highest sample unit PCI). When performing the initial inspection, the PCI standard deviation for a pavement section is assumed to be 10 for AC surfaced pavements (or PCI range of 25) and 14 for PCC surfaced pavements (or PCI range of 35). These values are based on actual data obtained from many surveys. For subsequent inspections, the actual PCI standard deviation or range (determined from the previous inspection) is used to determine the minimum number of sample units to be surveyed. As Figure 13 shows, when the total number of samples within the section is less than 5, every sample unit should be surveyed. If N is greater than 5, at least five sample units should be surveyed.

Selecting the Sample Units To Inspect

Deciding which sample units to inspect is just as important as determining the minimum number of sample units to survey. It is recommended that the sample units to be inspected be spaced equally throughout the section and that the first sample unit be chosen at random. This technique, known as "systematic sampling," is illustrated in Figure 14 and described briefly below:

1. The sampling interval (i) is determined by i = N/n, where N = total number of available sample units and n = minimum number of sample units to be surveyed: i is rounded off to the smaller whole number (e.g., 3.6 is rounded to 3).

2. The random start (s) is selected at random between 1 and the sampling interval (i). For example, if i = 3, the random start would be a number from 1 to 3.

3. The sample units to be surveyed are identified as s, s + i, s + 2i, etc. If the selected start is 3, then the samples to be surveyed are 6, 9, 12, etc.

Selecting "Additional" Sample Units

One of the major objections to systematic sampling is that sample units in exceptionally good condition that may exist in the section are not necessarily included in the survey. In other cases, sample units that have atypical distresses, such as railroad crossings, may be selected at random as being representative of the section.

To overcome these problems, the inspector should identify any unusual sample units and inspect them as "additional" units rather than randomly selected sample units. When "additional" sample units are included in the survey, the calculation of the PCI is slightly altered to prevent extrapolation of the unusual conditions across the entire section. This procedure is discussed in more detail later in this chapter under **Calculating the PCI.**

Detailed Condition Survey Procedures

The procedures used to perform a PCI condition survey will vary depending on the surface type of the pavement being inspected. In any case, the pavement section must first be divided into sample units of which either all or a portion are selected for inspection as described in the previous section. This section describes the inspection procedures used for both rigid and flexible pavements. In addition, newly developed techniques for performing an unsurfaced road condition survey are presented. The distress definitions in Appendix A must be followed when performing pavement inspections so an accurate PCI can be determined.

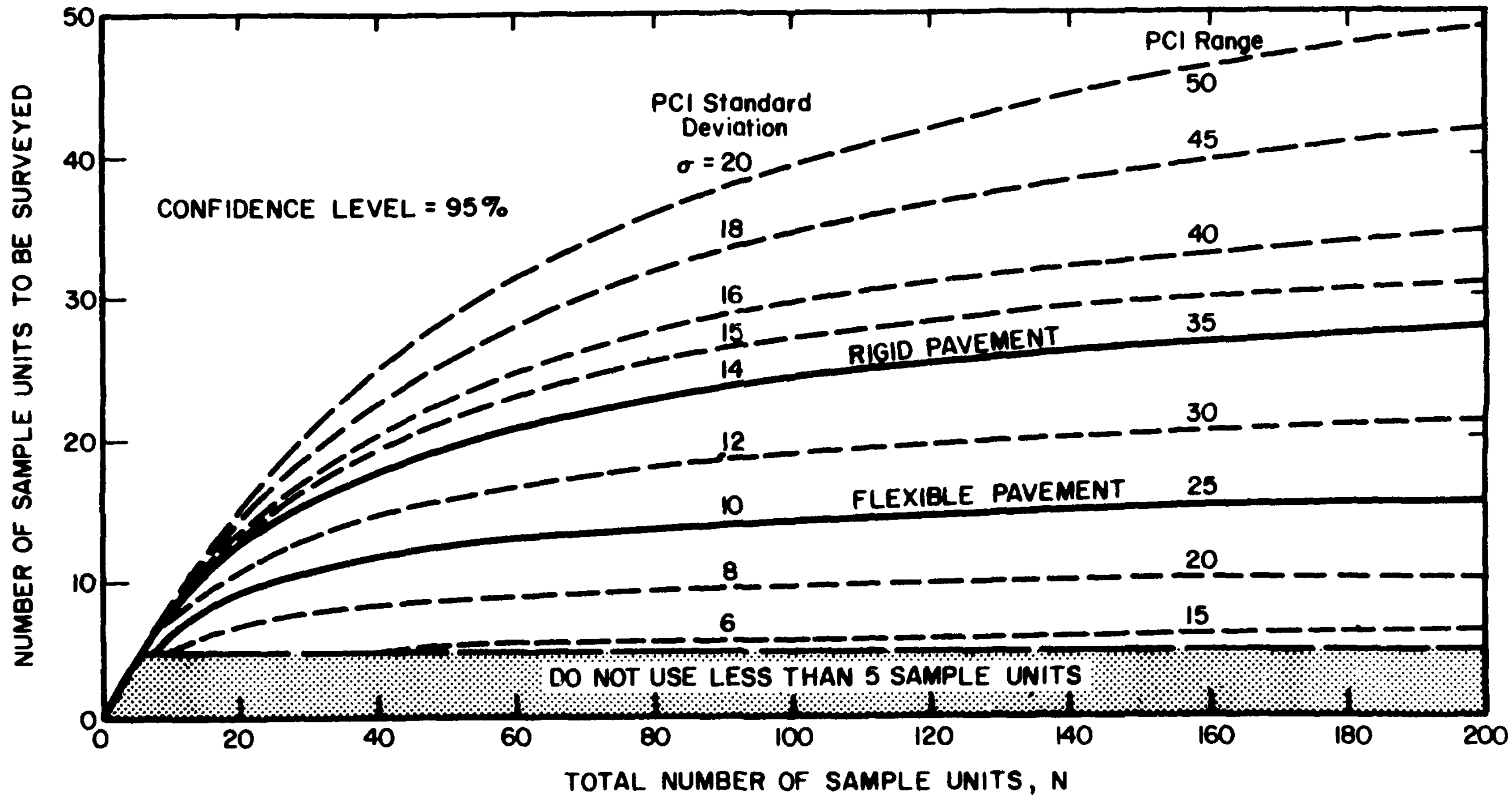


Figure 13. Selection of minimum number of sample units. (Source: AFR 93-5, *Airfield Pavement Evaluation Program* [USAF, 1981].)

Total Number of Sample Units In Section (N) = 47

Minimum Number of Units To Be Surveyed (n) = 13

Interval (i) = $\frac{N}{n} = \frac{47}{13} = 3.6$ = 3

Random Start (S) = 3

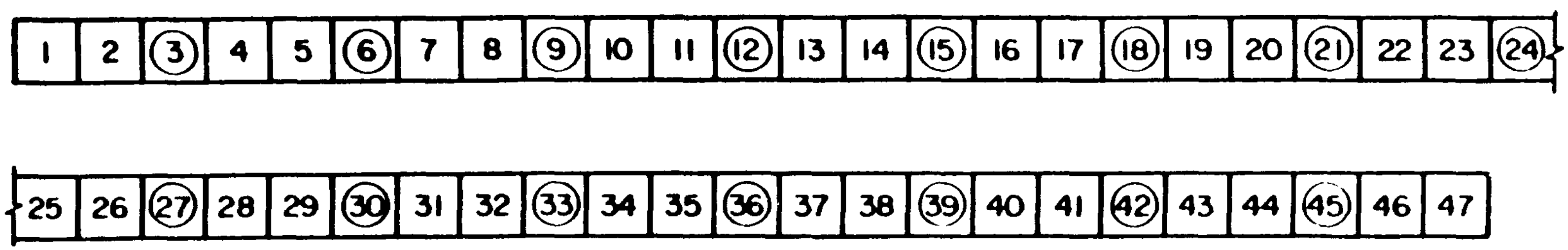


Figure 14. Example selection of sample units to be surveyed.

Rigid Pavements

The following procedures should be used to inspect PCC pavements.

Equipment. Inspectors will need a hand odometer for measuring slab size, a straight-edge and ruler for measuring faulting and lane/shoulder drop-off, and the PCI distress guide (Appendix A).

Procedure. All sample units in a section, those selected using Table 2, or those selected by the statistical sampling procedure are inspected. The actual inspection is performed by walking over each slab of the sample unit being surveyed and recording distress existing in the slab on the concrete pavement inspection data sheet, an example of which is shown in Figure 15. One data sheet is used for each sample unit. The sample unit is sketched using the dots as joint intersections. The appropriate number code for each distress found in the slab is entered in the square representing the slab. These number codes correlate with the distress identification provided in PAVER to store the distress information. The letter L (low), M (medium), or H (high) is included along with the distress number code to indicate the severity level of the distress. For example, 28L indicates that a slab has low-severity linear cracking. Refer to Appendix A for help in identifying distresses and their severity levels. Follow these guidelines very closely.

Space is provided on the concrete pavement inspection data sheet for summarizing the distresses and calculating the PCI for the sample unit. Remember to record the overall severity level of the joint sealant (i.e., L, M, or H). Calculation of the PCI is discussed later in this chapter.

Flexible Pavements

The following procedures should be used on all asphalt, tar-surfaced, and asphalt-over-concrete pavements.

Equipment. Inspectors require a hand odometer to measure distress lengths and areas, a straight-edge, a ruler to measure the depth of ruts or depressions, and the PCI distress guide (Appendix A).

Procedure. All sample units in a section, those selected using Table 2, or those selected by the sampling procedure are inspected. The distress inspection is conducted by walking over the sample unit, measuring the distress type and severity according to Appendix A, and recording the data on the flexible pavement survey sheet, which is shown in Figure 16. One data sheet is used for each sample unit. The distress codes provided on this data sheet correlate with the distress identification provided in PAVER to store this distress information. Each column on the data sheet is used to represent a distress type, and the amount and severity of each distress found are listed in the column. For example, in Figure 17, distress number 6 (depression) is recorded as 6 x 4L, which indicates that the depression is a 6 ft by 4 ft area of low severity. Distress number 10 (longitudinal and transverse cracking) is measured in linear feet, so 10L indicates 10 ft of low severity cracking, and 5M indicates 5 ft of medium cracking. The total distress data are used to compute the PCI of the sample unit as discussed later in this chapter.

Unsurfaced Roads

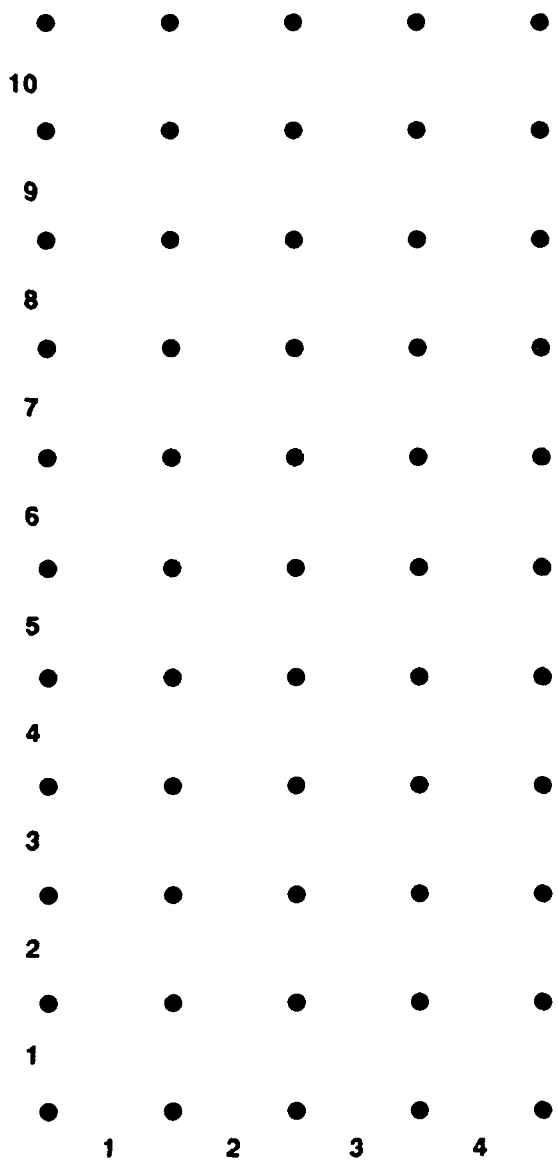
A procedure for inspecting and rating unsurfaced low-volume roads was recently developed by the U.S. Army Cold Regions Research and Engineering Laboratory (USACRREL) under the Federal Highway Administration Rural Technical Assistance Program Project No. 29 "Revising the PAVER

CONCRETE PAVEMENT INSPECTION SHEET

Branch ______________________ Section ______________________

Date ______________________ Sample Unit ______________________

Surveyed by ______________________ Slab Size ______________________



Distress Types

21. Blow-Up Buckling/Shattering
22. Corner Break
23. Divided Slab
24. Durability ("D") Cracking
25. Faulting
26. Joint Seal Damage
27. Lane/Shldr Drop Off
28. Linear Cracking
29. Patching, Large & Util Cuts
30. Patching, Small
31. Polished Aggregate
32. Popouts
33. Pumping
34. Punchout
35. Railroad Crossing
36. Scaling/Map Cracking/Crazing
37. Shrinkage Cracks
38. Spalling, Corner
39. Spalling, U Joint

Dist. Type	Sev.	No Slabs	% Slabs	Deduct Value
26#				
Deduct Total		q =		
Corrected Deduct Value (CDV)				

PCI = 100 - CDV = ____________

Rating = ____________

* All Distresses Are Counted On A Slab-By-Slab Basis Except Distress 26, Which Is Rated for the Entire Sample Unit.

Figure 15. Blank jointed concrete sample unit inspection sheet.

ASPHALT PAVEMENT INSPECTION SHEET

Branch ____________________ Section ____________________

Date ____________________ Sample Unit ____________________

Surveyed by ____________________ Area of Sample ____________________

Distress Types		Sketch:
1. Alligator Cracking	11. Patching & Util Cut Patching	
2. Bleeding	12. Polished Aggregate	
3. Block Cracking	*13. Potholes	
*4. Bumps and Sags	14. Railroad Crossing	
5. Corrugation	15. Rutting	
6. Depression	16. Shoving	
*7. Edge Cracking	17. Slippage Cracking	
*8. Jt Reflection Cracking	18. Swell	
*9. Lane/Shldr Drop Off	19. Weathering and Raveling	
*10. Long & Trans Cracking		

	Existing Distress Types					
Total Severity L						
Total Severity M						
Total Severity H						

PCI Calculation				
Distress Type	Density	Severity	Deduct Value	
				PCI = 100 - CDV =
				Rating =
Deduct Total		q =		
Corrected Deduct Value (CDV)				

* All Distresses Are Measured in Square Feet Except Distresses 4, 7, 8, 9, and 10 Which Are Measured in Linear Feet; Distress 13 Is Measured in Number of Potholes.

Figure 16. Blank asphalt-surfaced pavement sample unit inspection sheet.

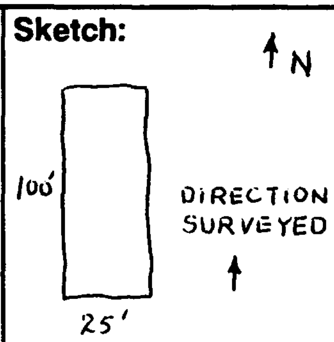
ASPHALT PAVEMENT INSPECTION SHEET

Branch	GREEN ST.	**Section**	001
Date	10/21/87	**Sample Unit**	1
Surveyed by	SLK	**Area of Sample**	2500 SQ FT

Distress Types

1. Alligator Cracking
2. Bleeding
3. Block Cracking
*4. Bumps and Sags
5. Corrugation
6. Depression
*7. Edge Cracking
*8. Jt Reflection Cracking
*9. Lane/Shldr Drop Off
*10. Long & Trans Cracking
11. Patching & Util Cut Patching
12. Polished Aggregate
*13. Potholes
14. Railroad Crossing
15. Rutting
16. Shoving
17. Slippage Cracking
18. Swell
19. Weathering and Raveling

Sketch:



Existing Distress Types

	10	1	15	6	13	
	10 L	1x6 L	2x25 L	6x4 L	1 L	
	5 L	2x8 M				
	15 L					
	5 M					
	10 L					
	5 M					
Total Severity L	40	6	50	24	1	
Total Severity M	10	16				
Total Severity H						

PCI Calculation

Distress Type	Density	Severity	Deduct Value
1	0.24	L	4
1	0.64	M	17
6	0.96	L	4
10	1.60	L	4
10	0.40	M	3
13	0.04	L	11
15	2.00	L	13
Deduct Total		q = 3	56
Corrected Deduct Value (CDV)			35

PCI = 100 - CDV = 65

Rating = GOOD

*** All Distresses Are Measured In Square Feet Except Distresses 4, 7, 8, 9, and 10 Which Are Measured In Linear Feet; Distress 13 Is Measured In Number of Potholes.**

Figure 17. Asphalt-surfaced pavement sample unit inspection sheet showing distress data and PCI calculations.

PMS for Use on Unpaved Roads." The inspection procedure, described in a USACRREL Special Report,[6] rates unsurfaced roads in terms of an Unsurfaced Road Condition Index (URCI). Recent modifications to PAVER have provided for storage of unsurfaced road inspection results and automated calculation of the URCI. This additional capability allows an agency to systematically manage its unsurfaced roads as well as surfaced pavements.

Calculating the PCI

Once the PCI condition survey has been completed for every sample unit, the results are used to calculate the PCI. This index can be calculated either manually or automatically by entering the distress information into the PAVER data base. The PCI calculation is based on the deduct values already mentioned--weighting factors ranging from 0 to 100 which indicate the impact each distress has on pavement condition. A deduct value of 0 indicates that a distress has no effect on pavement performance whereas a value of 100 indicates an extremely serious distress.

Referring to Figure 12, calculation of the PCI for a sample unit is outlined in Steps 1 through 6. Step 7 is used to compute the PCI for the entire section. Step 1, dividing the pavement section into sample units was described in Chapter 3. The beginning of this chapter has described how to perform the PCI condition survey (Step 2). The rest of this chapter discusses steps 3 through 7 for determining the deduct values and the PCI for each sample unit and for the entire section.

Manual Calculation of PCI for a Sample Unit

The results of the survey must be summarized by distress type and severity level for each sample unit inspected. For each concrete sample unit, the total number of slabs in which each distress type/severity level combination occurred is counted and entered in the space provided on the inspection sheet. This total number is then divided by the total number of slabs in the sample unit to obtain the percentage density. For asphalt pavements, the amount of distress found in the entire sample unit, in either square feet, linear feet, or number of occurrences in the case of potholes, is summed for each distress type/severity level combination. This quantity is then divided by the area of the sample unit to obtain the percentage density. Allowances have been built into the system to account for situations in which distress quantities in linear feet and the number of occurrences are divided by areas in square feet. No adjustments are needed. These procedures are to be repeated for each distress type/severity level combination identified in the survey.

Distresses measured in metric units (linear meters or number of occurrences) would have to be converted to English units to use the same deduct value curves. For this reason, deduct value curves are given in metric units in Appendix B for the following distresses: edge cracking, joint reflection cracking, lane/shoulder drop-off, longitudinal and transverse cracking, and potholes.

The deduct values for each distress type and severity are determined using the deduct value curves found in Appendix B. Individual curves have been developed for each of the defined distress types. In the example shown in Figure 17, 0.24 percent low-severity alligator cracking was identified in the condition survey. Entering the appropriate curve at a distress density of 0.24 percent, the low-severity curve results in a deduct value of 33 as shown in Figure 18. This procedure is repeated until deduct values have been determined for each distress type/severity level combination identified. All individual deduct values are summed and a final total deduct value (TDV) is computed.

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[6] R. A. Eaton, S. Gerard, and D. W. Cate, *Rating Unsurfaced Roads, A Field Manual for Measuring Maintenance Problems*, Special Report 87-15 (U.S. Army Cold Regions Research and Engineering Laboratory [USACRREL], August 1987).

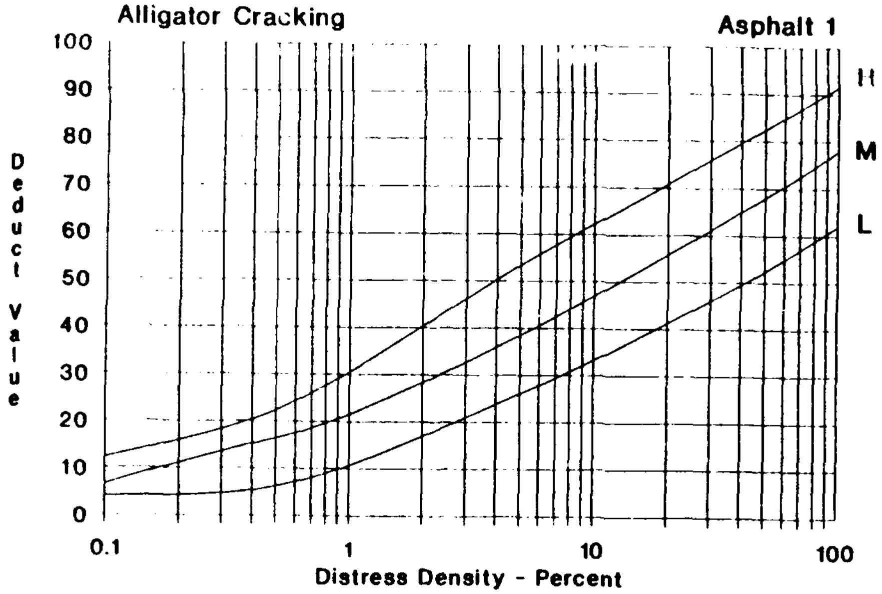


Figure 18. Deduct value curve for alligator cracking.

Once the TDV is computed, a corrected deduct value (CDV) is determined from the correction curves. The purpose of the CDV is to take into account the effects of multiple distresses in a sample unit. When determining the CDV, if any individual deduct value is higher than the CDV, the CDV is set equal to the highest individual deduct value. For example, assume that two distresses were found in an asphalt pavement, one with a deduct value of 50 and the other with a deduct value of 10. Using Figure B20 of Appendix B, the CDV for q = 2 (q = number of individual deduct values greater than 5) is 44 since 44; is lower than 50, the CDV is set equal to 50.

In Step 5, the PCI is computed using the equation PCI = 100 - CDV. Examples of PCI calculation for AC and PCC pavements can be found in Figures 17 and 19, respectively.

Calculating PCI for a Section

If all sample units in a section are surveyed, the PCI of the section is computed by averaging the PCIs of all sample units. Inspection by sampling, however, requires a different approach. If all surveyed sample units are selected randomly, the PCI of the pavement section is determined by averaging the PCI of the sample units inspected. If any additional sample units are inspected, a weighted average must be used. The weighted average is computed by using Equation 2:

$$PCI_S = \frac{(N-A)\ PCI_1 + A \cdot PCI_2}{N} \qquad \text{[Eq 2]}$$

where: PCI_S = PCI of pavement section

PCI_1 = average PCI of random samples

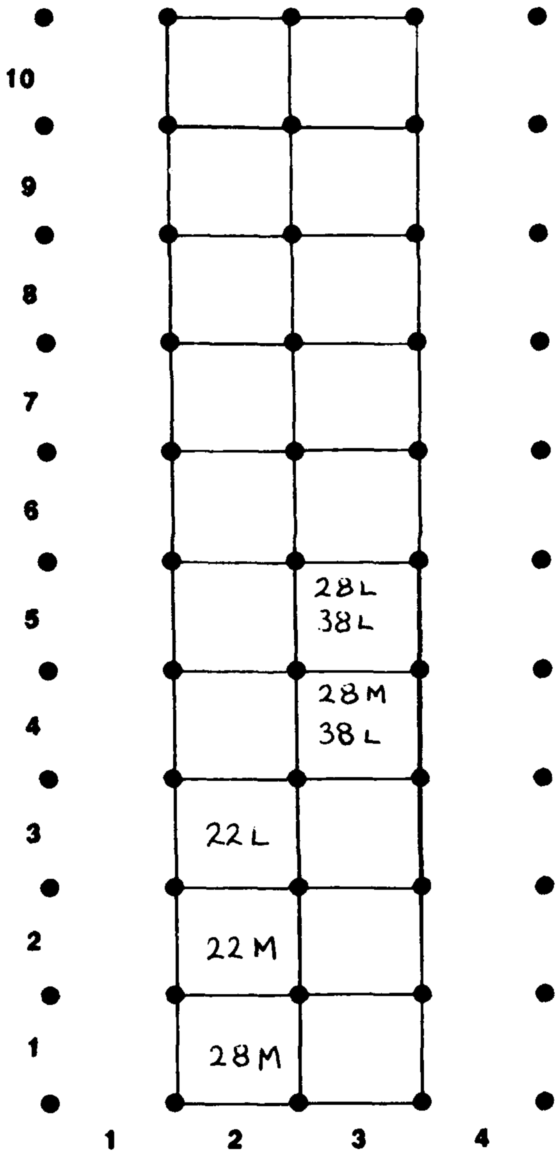
PCI_2 = average PCI of additional samples

N = total number of samples in the section

A = number of "additional" samples inspected.

CONCRETE PAVEMENT INSPECTION SHEET

Branch MARSHALL AVE. **Section** 001
Date 10/3/87 **Sample Unit** 1
Surveyed by SLK **Slab Size** 15 x 20



Distress Types

21. Blow-Up Buckling/Shattering
22. Corner Break
23. Divided Slab
24. Durability ("D") Cracking
25. Faulting
26. Joint Seal Damage
27. Lane/Shldr Drop Off
28. Linear Cracking
29. Patching, Large & Util Cuts
30. Patching, Small
31. Polished Aggregate
32. Popouts
33. Pumping
34. Punchout
35. Railroad Crossing
36. Scaling/Map Cracking/Crazing
37. Shrinkage Cracks
38. Spalling, Corner
39. Spalling, U Joint

Dist. Type	Sev.	No Slabs	% Slabs	Deduct Value
26*	M			4
22	L	1	5	4
22	M	1	5	8
28	L	1	5	3
28	M	2	10	9
38	L	2	10	1
Deduct Total		q = 2		29
Corrected Deduct Value (CDV)				24

PCI = 100 - CDV = 76

Rating = VERY GOOD

* All Distresses Are Counted On A Slab-By-Slab Basis Except Distress 26, Which Is Rated for the Entire Sample Unit.

Figure 19. Jointed concrete sample unit inspection sheet showing distress information and PCI calculation.

For example, if in a section with 13 sample units, five random sample units out of 12 were inspected and determined to have PCIs of 56, 72, 65, 69, and 61, and two additional sample units with PCIs of 42 and 39 were included, the PCI of the section would be:

$$PCIs = \frac{(13-2)\ (65) + 2\ (41)}{13}$$

Determining Distress Quantities for a Pavement Section

When a pavement has been inspected by sampling, it is necessary to extrapolate the quantities and densities of distress over the entire pavement section to determine total quantities for the section. If all sample units surveyed were selected at random, the extrapolated quantity of a given distress at a given severity level would be determined as shown in the following example for medium-severity alligator cracking.

Section Information

Surface type: Asphalt concrete
Area: 24,500 sq ft

Total number of sample units in the section: 10 five-sample units were surveyed at random, and the amount of medium-severity alligator cracking was determined as follows:

	Sample Unit ID Number	Sample Unit Area, sq ft	Medium-Severity Alligator Cracking, sq ft
	02	2500	100
	04	2500	200
	06	2500	150
	08	2500	50
	10	2000	100
Total Random		12,000	600

The average density for medium-severity alligator cracking is, therefore 600/12,000 = 0.05. The extrapolated quantity is determined by multiplying the density by section area, i.e., 0.05 x 24,500 = 1225 sq ft.

If "additional" sample units were included in the survey, the extrapolation process would be slightly different. In the example given above, assume that sample unit number 01 was surveyed as an additional unit and that the amount of medium-severity alligator cracking was measured as follows:

Additional Sample Unit ID	Sample Unit Area, sq ft	Medium-Severity Alligator Cracking, sq ft
01	2500	1000
Total Additional	2500	1000

Since 2500 sq ft were surveyed as additional, the section's randomly surveyed area was therefore 24,500 - 2500 = 22,000 sq ft. The extrapolated distress quantity is obtained by multiplying the distress density by the section's randomly surveyed area and then adding the amount of additional distress. In this example:

$$\text{Extrapolated Distress Quantity} = 0.05 \times 22{,}000 + 1000 = 2100 \text{ sq ft}$$

Automated PCI Calculation

Computing the PCI manually is a simple operation for a single sample unit; however, the volume of data generated from a survey is generally quite large and calculations involving these data are time-consuming. Once distress information has been entered into the PAVER data base, the program can automatically calculate the PCI of each sample unit surveyed and determine an overall PCI for a section, as well as extrapolated distress quantities (Figure 20). The program can also determine the percentage of deduct values based on distress mechanism (load, climate/durability, other) for a section. The percentage deduct values attributed to each distress mechanism are the basis for determining the primary cause(s) of pavement deterioration. This feature is discussed in more detail in Chapter 8 on project-level management. Refer to the user's guide for PAVER[7] or Micro PAVER[8] for assistance in loading inspection results into the data base.

[7] M. Y. Shahin, *Pavement Management, the PAVER System: User's Guide*, ADP Manual 356-1 (Facilities Engineering Support Agency, 1985).

[8] M. Y. Shahin, *Micro PAVER Version 2.1 User's Guide* (University of Illinois Continuing Education, 1986).

DATE SURVEYED = OCT/30/1982 BRANCH/SECTION NUMBER = A2 /AC

SECTION SIZE = 1746 SLABS

TOTAL NUMBER OF SAMPLE UNITS = 68

ALLOWABLE ERROR WITH 95% CONFIDENCE = 5

SAMPLE UNIT ID = 18
SIZE OF SAMPLE = 16 SLABS

DISTRESS-TYPE	SEVERITY	QUANTITY	DENSITY %	DEDUCT VALUE
63 LINEAR CR	LOW	2	12.50	10.1
65 JT SEAL DMG	MEDIUM	16	100.00	7.0
66 SMALL PATCH	LOW	2	12.50	1.5
69 PUMPING	N/A	7	43.75	34.8
73 SHRINKAGE CR	N/A	2	12.50	1.8
75 CORNER SPALL	LOW	1	6.25	2.3

PCI = 57

SAMPLE UNIT ID = 41
SIZE OF SAMPLE = 24 SLABS

DISTRESS-TYPE	SEVERITY	QUANTITY	DENSITY %	DEDUCT VALUE
65 JT SEAL DMG	MEDIUM	24	100.00	7.0
71 FAULTING	LOW	1	4.17	3.9
74 JOINT SPALL	LOW	2	8.33	3.0
75 CORNER SPALL	LOW	1	4.17	1.5

PCI = 84

SAMPLE UNIT ID = 63
SIZE OF SAMPLE = 21 SLABS

DISTRESS-TYPE	SEVERITY	QUANTITY	DENSITY %	DEDUCT VALUE
63 LINEAR CR	LOW	1	4.76	4.6
65 JT SEAL DMG	MEDIUM	21	100.00	7.0
69 PUMPING	N/A	6	28.57	24.5
74 JOINT SPALL	MEDIUM	1	4.76	4.2

PCI = 66

SAMPLE UNIT ID = 78
SIZE OF SAMPLE = 24 SLABS

DISTRESS-TYPE	SEVERITY	QUANTITY	DENSITY %	DEDUCT VALUE
65 JT SEAL DMG	HIGH	24	100.00	12.0
71 FAULTING	LOW	1	4.17	3.9
74 JOINT SPALL	LOW	3	12.50	4.1
75 CORNER SPALL	LOW	3	12.50	4.6

PCI = 75

Figure 20. PAVER automatic PCI calculation.

NUMBER OF RANDOM SAMPLE UNITS SURVEYED = 4

NUMBER OF ADDITIONAL SAMPLE UNITS SURVEYED = 0

PCI OF SECTION = 70 RATING = GOOD

RECOMMENDED MINIMUM OF 31 RANDOM SAMPLE UNITS TO BE SURVEYED.

STANDARD DEVIATION OF PCI BETWEEN RANDOM UNITS SURVEYED = 11.6%

EXTRAPOLATED DISTRESS QUANTITIES FOR SECTION

DISTRESS-TYPE	SEVERITY	QUANTITY	DENSITY %	DEDUCT VALUE
63 LINEAR CR	LOW	62	3.55	3.5
65 JT SEAL DMG	MEDIUM	1253	71.76	7.0
65 JT SEAL DMG	HIGH	493	28.24	12.0
66 SMALL PATCH	LOW	41	2.35	.4
69 PUMPING	N/A	267	15.29	14.2
71 FAULTING	LOW	41	2.35	2.6
73 SHRINKAGE CR	N/A	41	2.35	.8
74 JOINT SPALL	LOW	103	5.90	2.4
74 JOINT SPALL	MEDIUM	21	1.20	1.6
75 CORNER SPALL	LOW	103	5.90	2.2

*** PERCENT OF DEDUCT VALUES BASED ON DISTRESS MECHANISM ***

LOAD RELATED DISTRESSES = 7.49 PERCENT DEDUCT VALUES.

CLIMATE/DURABILITY RELATED DISTRESSES = 40.67 PERCENT DEDUCT VALUES.

OTHER RELATED DISTRESSES = 51.84 PERCENT DEDUCT VALUES.

Figure 20 (Cont'd)

5 NEW TECHNIQUES FOR PAVEMENT CONDITION PREDICTION

Overview

The ability to predict pavement deterioration accurately is critical to the success of a PMS. An accurate pavement condition prediction technique provides a fundamental tool to aid in the planning and cost allocation of M&R activities. At the project level, this ability allows for improved life-cycle costing of various M&R alternatives.

At present, PCI prediction is based on a straight-line extrapolation of the last two PCI-versus-age points. For example, in Figure 21 the PCI of the pavement in 5 years is predicted to be 18.

While this method of predicting deterioration is accurate enough for a short period of time, it is not accurate over a long period or for predicting the rate of deterioration of relatively new pavements. An example pavement deterioration curve is shown in Figure 22. The rate of deterioration changes rapidly as the pavement begins to fail. A straight-line extrapolation would not predict this change in rate.

A more reliable pavement condition prediction model has been developed.[9] This model uses mathematical techniques to fit a curve to the data. This chapter describes this method of pavement condition prediction. Although this method was developed for incorporation into the PAVER System, it can be used effectively by other management systems that require historical condition data.

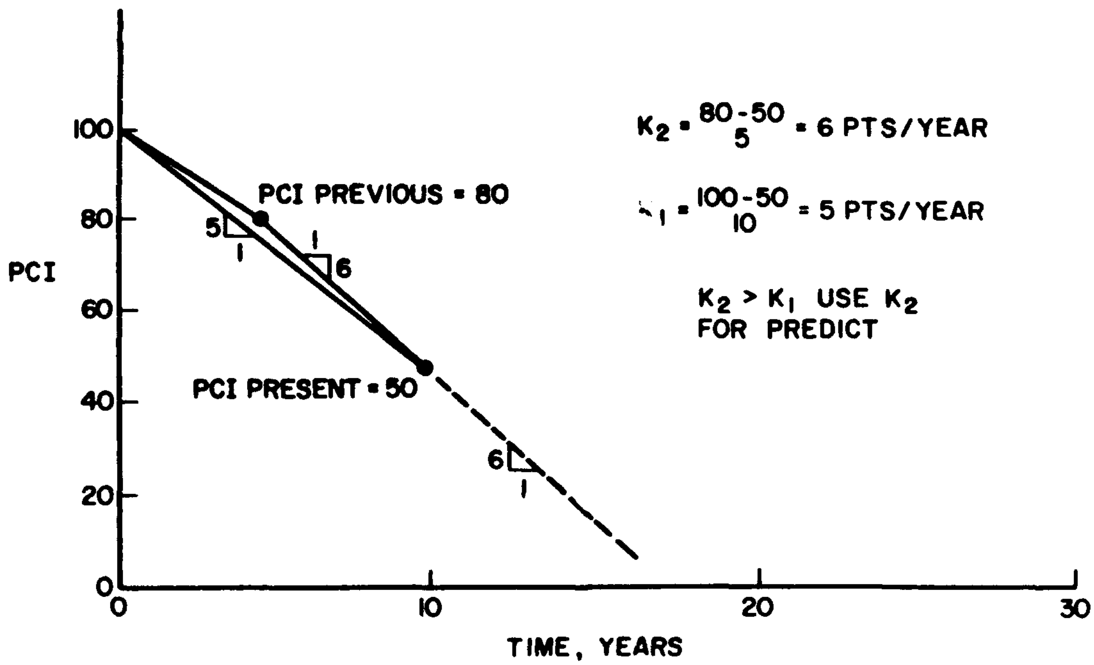


Figure 21. Sample PCI slope/determination for condition prediction.

[9]M. Y. Shahin, et al., *New Techniques for Modeling Pavement Deterioration* (Transportation Research Board Record 1123, January 1987).

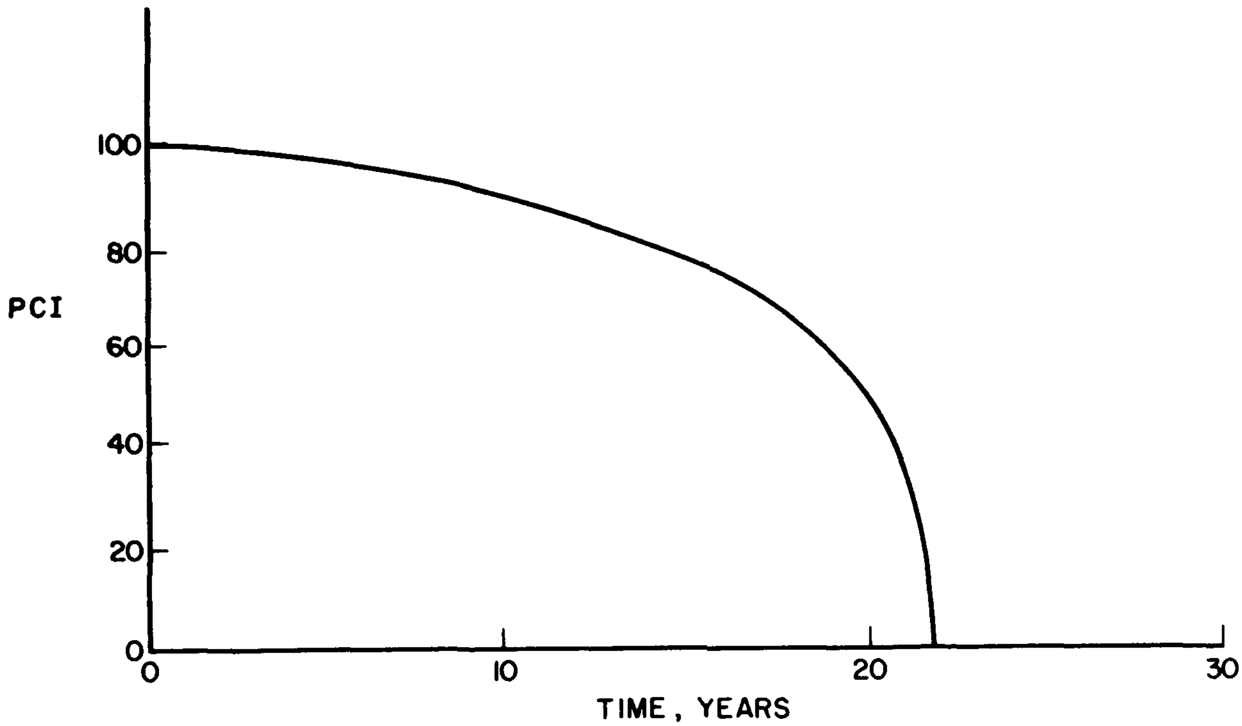


Figure 22. Example pavement deterioration curve.

Pavement Family Grouping

Data can be retrieved in the PAVER System with an automatic extraction program that selects information about any family of pavement sections. This information is retrieved based on the user-specified definition of a pavement family. A pavement family is defined as a group of pavement sections with similar deterioration characteristics. The choice for pavement family selection, shown in Table 3, includes Branch Use, Pavement Rank, Surface Type, Zone, Section Category, Last Construction Date, and PCI. The user's ability to set family definitions that may be unique for his/her particular location permits models to be developed specifically for that location. Information extracted for each family includes pavement identification, age, and PCI.

Filter Procedure

After data are received, it is necessary to filter out all that are inaccurate. Filtering is done using a specially developed computer program. In this procedure, the data are first sorted by pavement section identification number, age, and PCI. When the same section is listed more than once, sequential cases of the same section are compared. If the PCI increases with age and the increase is greater than 20 points, the case with the higher PCI is moved to the "errors" file. This action indicates that either an error is present in one of the records or that major rehabilitation has been performed between condition surveys which would place this section in a different family of pavements. If a pavement section of the same age is listed more than once and the PCIs are the same, only one pavement section is retained. If the PCIs are different for the same section and age, all cases are removed to the "errors" file.

Table 3

Pavement Family Selection Criteria

Branch Use	Pavement Rank	Surface Type
MT - Motorpool	A - Principal	AC - Asphalt Concrete
ST - Storage	B - Arterial	PCC - Portland Cement Concrete
RO - Roadway	C - Collector	BR - Brick
PA - Parking	D - Industrial	GR - Gravel
RV - Runway	E - Residential	ST - Stone
AP - Apron	P - Primary	X - Other
HE - Helipad	S - Secondary	AAC - Asphalt Concrete Overlay on AC
TA - Taxiway	T - Tertiary	APC - Asphalt Concrete Overlay on PCC
		ABR - Asphalt Concrete Overlay on BR

A further check on spurious data is done using a set of boundaries defined by a maximum and a minimum envelope expected over the life of the pavements. The program includes a default envelope; however, the user can easily modify these values. If a record falls outside either the upper or lower boundary, the record is moved to the "errors" file. Figure 23 shows example output from the filter procedure.

Outlier Analysis

The data-filtering procedure is used to remove obvious errors in the data as described above. Further examination of the data for statistical removal of extreme points is performed in the outlier analysis. This step is important because cases with unusual performance can have a substantial impact on the way family behavior is modeled.

A program has been written to calculate residuals, which are the differences between the observed and predicted PCI values. The residuals were found to have a normal frequency distribution which allowed a confidence interval to be set. For example, an interval of three standard deviations in both directions contains 99.8 percent of the observed PCIs. Figure 24 shows example output from the outlier procedure. Sections that were detected as outliers based on the confidence intervals are circled.

Family Condition Prediction

A best-fit curve applies to the remaining data using a constrained least squares method. This curve is constrained in that it is not allowed to have a positive slope since the PCI cannot increase with age.

This best-fit curve for the family analysis extends only as far as the available data. To predict future conditions, the curve is extrapolated by extending a tangent of the same slope as that of the curve at the last deterioration behavior zone. This approach is depicted in Figure 25.

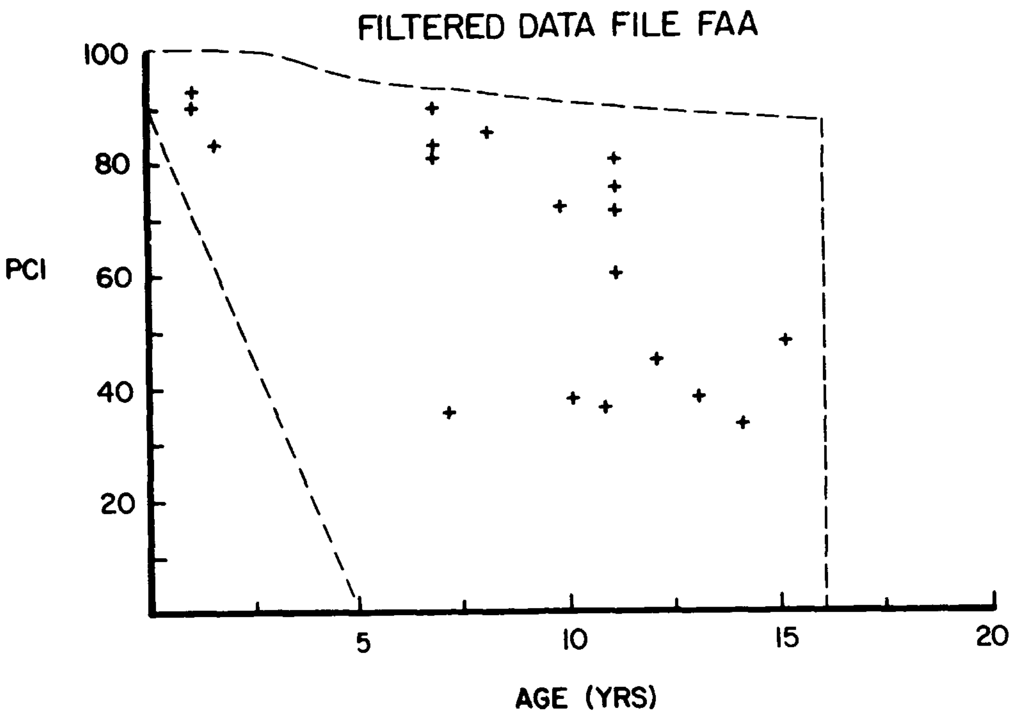


Figure 23. Sample output from the filter procedure.

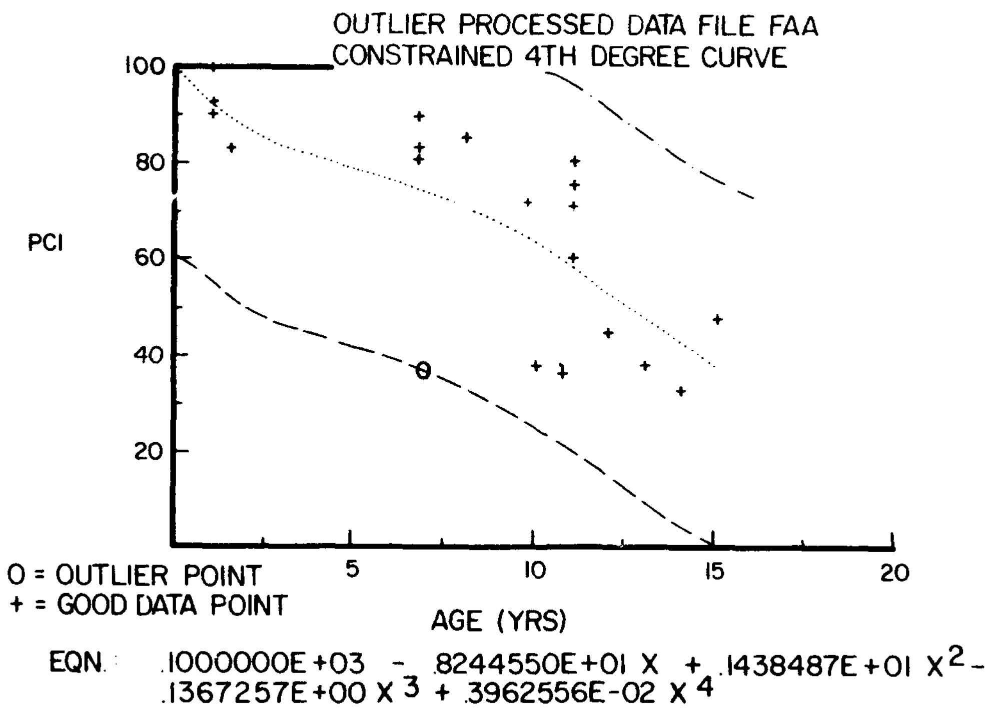
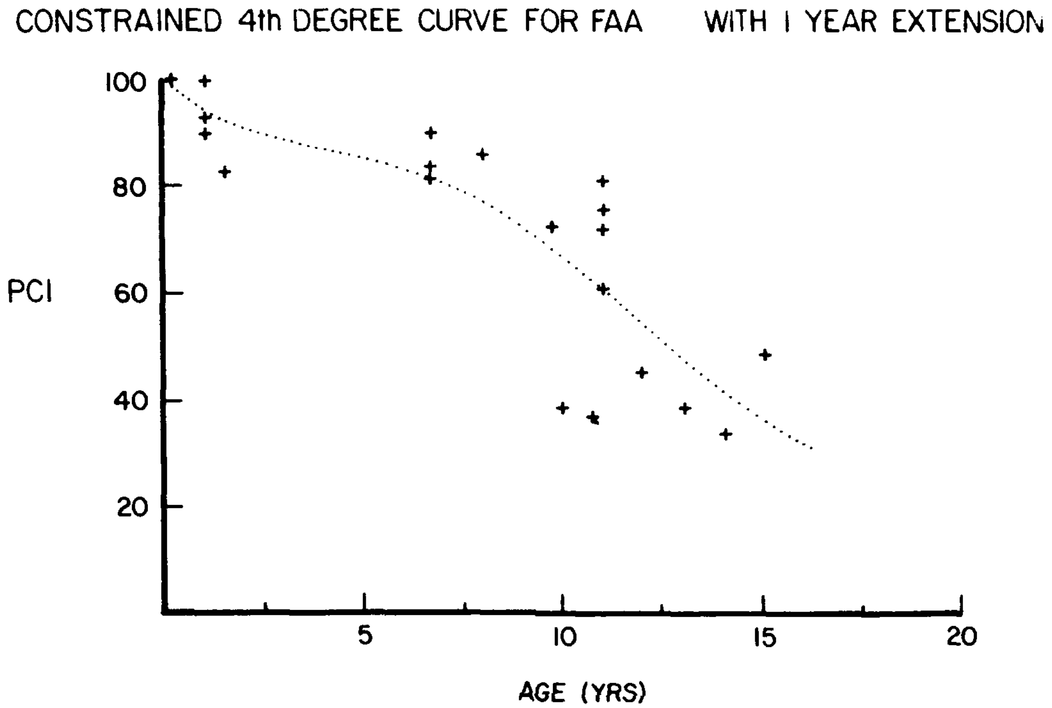


Figure 24. Sample output from the outlier procedure.



PCI = .1000000E+03 - .6391411E +01 X + .1368907E +01 X ^{2} -
.1516525E +0X 3 + .4647153E -02 X 4

Figure 25. Pavement family condition curve extrapolated 1 year.

Pavement Section Condition Prediction

PCI prediction at the section level uses the pavement family prediction model curve. The prediction function for a pavement family represents the average behavior of all the sections of that family. The prediction for each section is done by taking its position relative to the family prediction curve. It is assumed that the deterioration of all pavements in a family is similar and is a function of only their present condition, regardless of age. A section prediction curve is drawn through the latest PCI/age point for the pavement section being investigated, parallel to the family prediction curve as shown in Figure 26. The predicted PCI can then be determined at the desired future age.

Benefits of the New Procedures

These procedures proved to be a complete method to model and predict pavement family and pavement section behavior. They were developed in such a way that when more data are incorporated into the data base, the model will be improved.

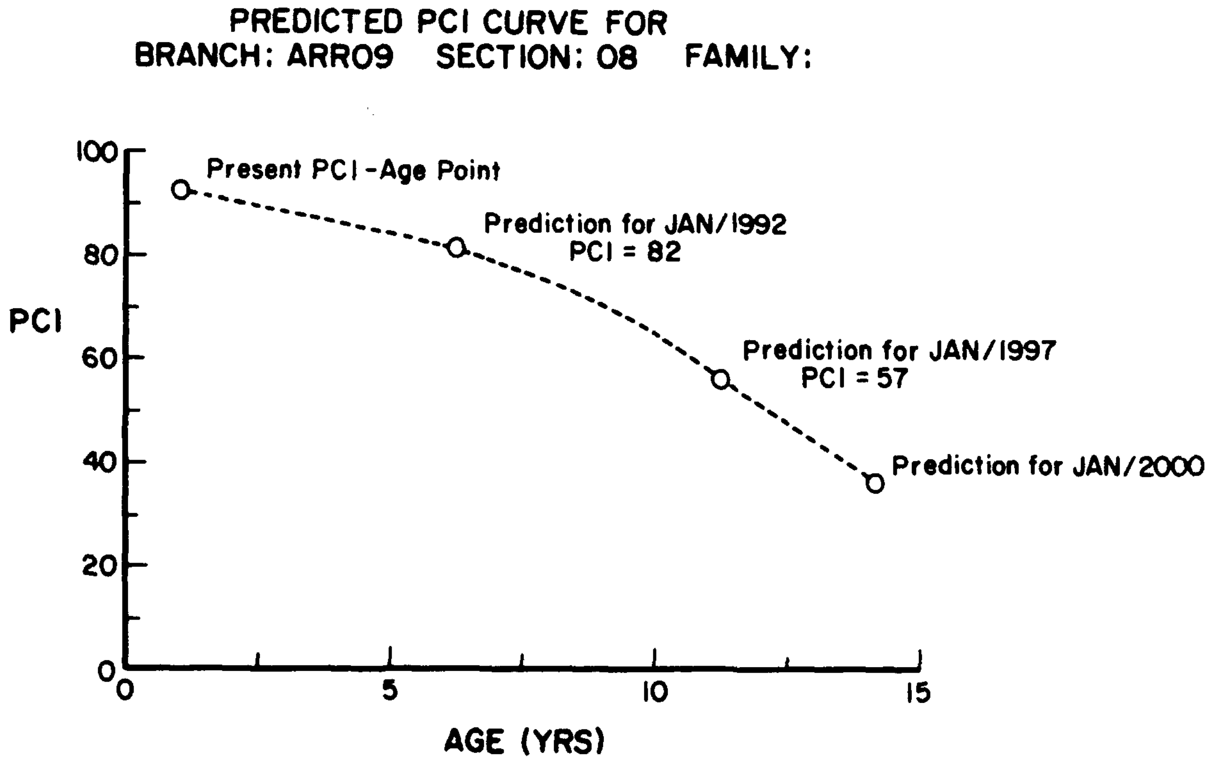


Figure 26. Pavement condition prediction based on prediction curve.

6 MAINFRAME PAVER AND MICRO PAVER COMPUTERIZED SYSTEMS

Overview

Mainframe PAVER and Micro PAVER are computerized systems that provide the pavement manager with the data and procedures necessary for practical decision-making to identify cost-effective M&R spending for roads, streets, parking lots, and airfields. The development of these systems was described briefly in Chapter 1.

The PAVER System provides the user with many important capabilities: data storage and retrieval, data base administration, pavement network definition, pavement condition rating, project prioritization, inspection scheduling, determination of present and future network condition, identification of M&R needs, performance of economic analyses, budget planning, and report generation. The system enables the user to identify the effects of performing no major repairs on the pavement network, determine life-cycle costs for various M&R alternatives, and determine a rational, objective basis for evaluating pavement condition and M&R needs and priorities. The use of these capabilities for network- and project-level management is discussed in Chapters 7 and 8.

Hardware Requirements and Availability

While mainframe PAVER and Micro PAVER have similar capabilities, their means of operating are quite different. The mainframe PAVER data bases, programs, and procedures are stored on the Power Computing Company (PCC) mainframe timesharing computer system. The system is accessed through a terminal via a telephone connection. The hardware needed is a personal computer (PC) or dummy terminal, modem, and a dedicated telephone line. Each user is provided an individual account that allows access to the system. The PC can be used on its own, without being connected to PCC, to prepare data entry files.

The Micro PAVER system operates on an IBM (registered trademark of International Business Machines)-compatible PC. A hard disk drive, with a recommended 20-MB or higher storage capacity, is strongly recommended. To operate the system, 640 K random access memory (RAM) is necessary. Version 2.0 or higher of MS-DOS is the operating system required. Figure 27 compares the time to generate a report for five different PCs.

When manipulating a large data base, mainframe PAVER is much faster at generating reports than Micro PAVER. However, the timesharing costs for mainframe PAVER are often prohibitive for the small-scale user. One advantage of Micro PAVER is that it does not require a telephone connection. Interference on a telephone line can cause data and reports to become garbled or lost.

Installations interested in implementing either of the programs should contact the U.S. Army Engineering and Housing Support Center. For nonmilitary users, mainframe PAVER is contracted through the APWA. The two distribution centers for Micro PAVER are the APWA and the University of Illinois Office of Continuing Education (Urbana campus). Each center is responsible for establishing individual fees for distribution and providing users with program updates as they become available. These fees will vary according to the service provided to the user (e.g., training,

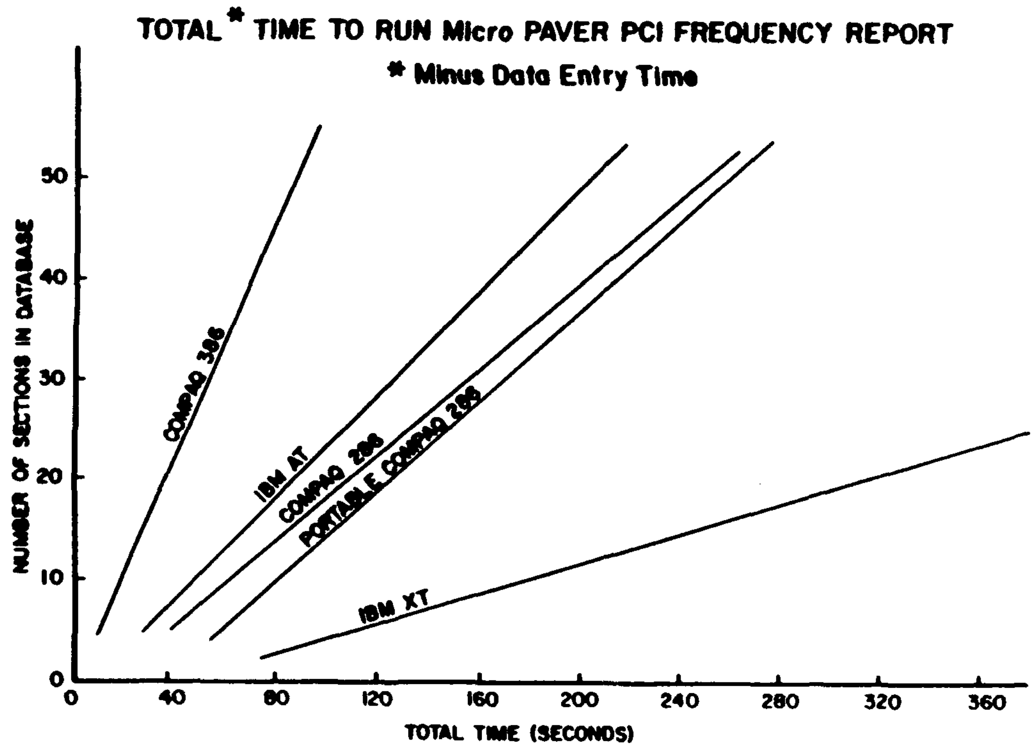


Figure 27. PCI Frequency Report generation times.

implementation assistance, user's group membership). Users are advised to investigate which distributor will best serve their needs. The two distribution centers are:

American Public Works Association (APWA)
1313 East 60th Street
Chicago, IL 60637
(312) 667-2200

Pilot Strategic Support Center
University of Illinois Office of Continuing Education
302 East John
Champaign, IL 61820
(217) 333-2882

Other professional organizations that can act as distribution centers to their members are the National Association of State Airport Operators (NASAO) and the American Association of Airport Executives (AAAE).

Report Capabilities

The following reports are among those available on both PAVER and Micro PAVER. Details on the use of these systems can be found in the *PAVER System User's Guide* and the *Micro PAVER User's Guide*.

1. LIST, List Report - This lists the branch number, branch name, and number of sections in each branch requested by the user.

2. INV, Inventory Report - This report provides inventory information, such as branch number, use, name, and area, as well as section number, category, zone, and surface type, for the pavement section stored in the data base. The user is given overall inventory information.

3. PCI, PCI Report - This report gives concise information from the last inspections performed. It can be used to rank M&R projects based on the user's prioritization policy.

4. FREQ, PCI Frequency Report - This report provides the user with an overall frequency of condition, based on PCI, for the years requested. This projected condition can be used to help plan future M&R and to inform management of network condition. Since the PCI extrapolation used assumes no major repairs have occurred between the last inspection and prediction dates, the user can see the impact of performing no major repairs.

5. BUDPLAN, Budget Planning Report - This report is useful for providing the user with a 5-year budget plan estimating the annual rehabilitation dollars required to maintain pavements above a user-specified condition level.

6. SCHED, Inspection Schedule Report - This report is useful for preparing a 5-year plan of pavement sections to be surveyed each year.

7. CNDHIST, Condition History Report - This reports helps the user determine M&R needs of a pavement section by plotting PCI over time for a given section.

8. MRG, M&R Report - Using maintenance guidelines for specific distress types, users can input a repair policy for their data base. This repair policy is then used in the M&R Report to estimate the type and cost of routine repair to specific sections. It can also be used to compute the cost of an overlay after distress repair.

9. Network Maintenance Report - Similar to the M&R Report which allows the user to apply a maintenance policy to a particular section, the Network Maintenance Report allows a maintenance policy to be applied to all or a portion of the pavement network. This report can be used to estimate the type and cost of routine repair across the entire network.

10. ECON1, Economic Analysis Report - For any given pavement section, several repair alternatives may be considered feasible. The Economic Analysis Report can be used to help select the most appropriate alternative. The user inputs initial costs, periodic maintenance costs, and one-time future maintenance costs. The report provides the user with the initial cost and equivalent uniform

annual cost per square yard. This program allows the user to vary interest rates, repair costs, and timing so that their effect on alternatives can be analyzed.

A valuable feature of Micro PAVER is that it allows more flexibility in customizing reports than mainframe PAVER. The user can select which pavements to include in each report. For example, with the Inventory Report, the selection criteria include branch number, section number, branch use, surface type, pavement rank, zone, section category, and section area. One or more of these criteria can be chosen. When generating the PCI Report, a manager can use the selection criteria to list the sections in alphabetical order or by ascending or descending PCI.

Planned Enhancements and Future Updates

Both mainframe and Micro PAVER are being revised and improved. In October, 1988, several improvements were released for Micro PAVER. New data entry fields include traffic, material properties, and work history information. A program was added to allow key fields to be changed. This enhancement allows the user to change data such as the last inspection date, branch number, and section number. A Family Analysis program was added to both mainframe and Micro PAVER to improve predictions of future PCIs based on the behavior of the entire pavement family. A new report called the Budget Frequency Report allows the user to predict future PCI frequency for different budgets. Also, a program was released for importing data from mainframe PAVER and exporting it to Micro PAVER. This feature allows the data to be manipulated on Micro PAVER, which is more user-friendly.

Version 2.1 of Micro PAVER was released in October 1989. This version included the ability to scroll reports sent to the terminal, improved report output, and improved graphics. The Budget Condition Forecasting Report was modified to allow the user to choose the start date for the analysis period. A new report called the Preventive Maintenance Report was added. This report uses the flowchart shown in Figure 28 to select global preventive maintenance options.

Mainframe PAVER is currently under revision for distributive processing using Micro PAVER as an example, thus taking advantage of the user-friendly attributes of Micro PAVER and the speed of mainframe PAVER. This revision will be released in June 1990; optimization techniques are being researched and will be added at some future date, as well as graphics capabilities, and the ability to combine data bases.

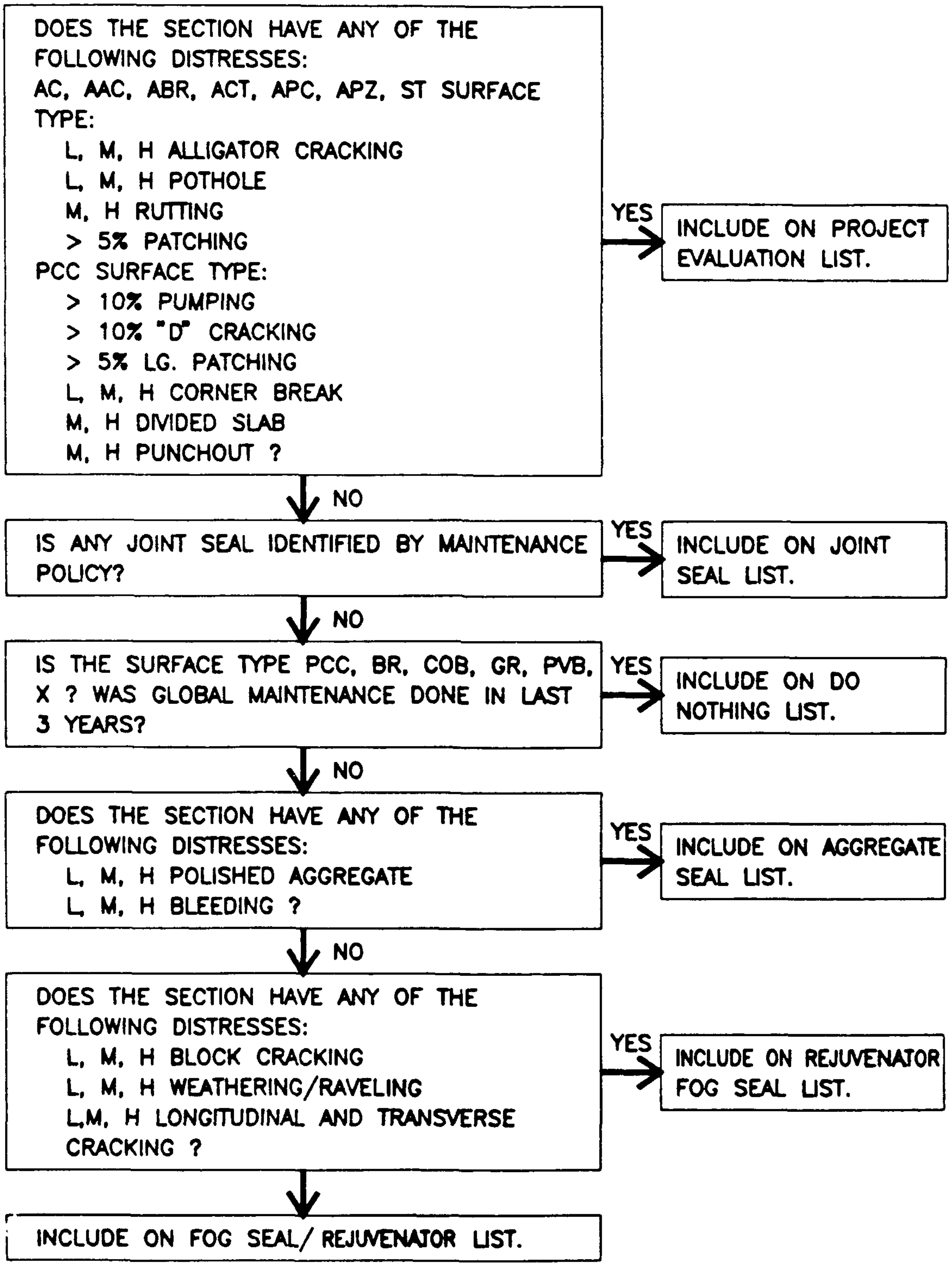


Figure 28. Decision tree for preventive maintenance report.

7 NETWORK-LEVEL MANAGEMENT

Overview

Once a data base has been established, the PAVER system can be used to assist in making pavement management decisions. Managing a pavement network effectively requires decisions at two levels: (1) a network level at which global decisions are made regarding the management of a group of common pavement sections or the entire pavement network and (2) a project level at which decisions are made as to the most cost-effective M&R alternative for a section identified as a candidate for repair. PAVER programs can be used to automate many management functions at both the network and project levels. This chapter presents the concepts involved in network-level management and the ways PAVER can help managers make effective network decisions.

Network-level management involves decisions about inspection scheduling, identification of candidate sections for repair, budget forecasting (including both long-range budget estimation and building scenarios), prioritization of candidate sections, identification of routine maintenance projects, prediction of future conditions, and evaluation of current conditions. In addition to providing an automated inventory of the pavements being managed, PAVER has a series of programs that access the data base and produce customized reports to aid in the decision-making process.

Fundamental to the decision-making process is the prediction of future conditions as shown in Figure 29. Condition prediction is used as the basis for developing inspection schedules and identifying sections requiring routine maintenance or major repair work. Once sections requiring future work and/or inspections have been identified, a potential budget for the current year and up to 5 years into the future can be developed. By using the agency's prioritization scheme and comparing the potential budget with the actual dollars available for the current year, a list of potential projects is produced. This list becomes the link with project-level management, which is covered in Chapter 8.

Because network-level management is used for producing global budget estimates, building and contrasting various fiscal scenarios, and answering "what if" questions, average costs can be taken with no loss of accuracy. Budgets are estimated based on average repair costs for various PCI ranges for each surface type. Questions related to funding cuts, future pavement conditions if no major repair is performed, or investigating the effect of a high inflation rate on budget estimates can be addressed reasonably using these average costs. To ensure that the decisions are reasonable, the engineer needs to make sure that the maintenance policy and M&R costs used reflect current conditions in the area, and that the agency's prioritization scheme is representative of its decision-making process. In addition, any assumptions used should be identified and evaluated. Chapter 8 discusses more fully the selection of feasible M&R alternatives.

PAVER can assist in the network-level decision-making process by generating several standard reports. The use of each report in network-level management is discussed in detail below. Sample output from each report is included. Examples of using these reports for developing annual and 5-year plans are presented in Chapter 9.

PAVER Report Usage

Inventory Report

One of the immediate payoffs to using an automated pavement management system is the inventory information stored on all pavements in the pavement network. A listing of pavement section

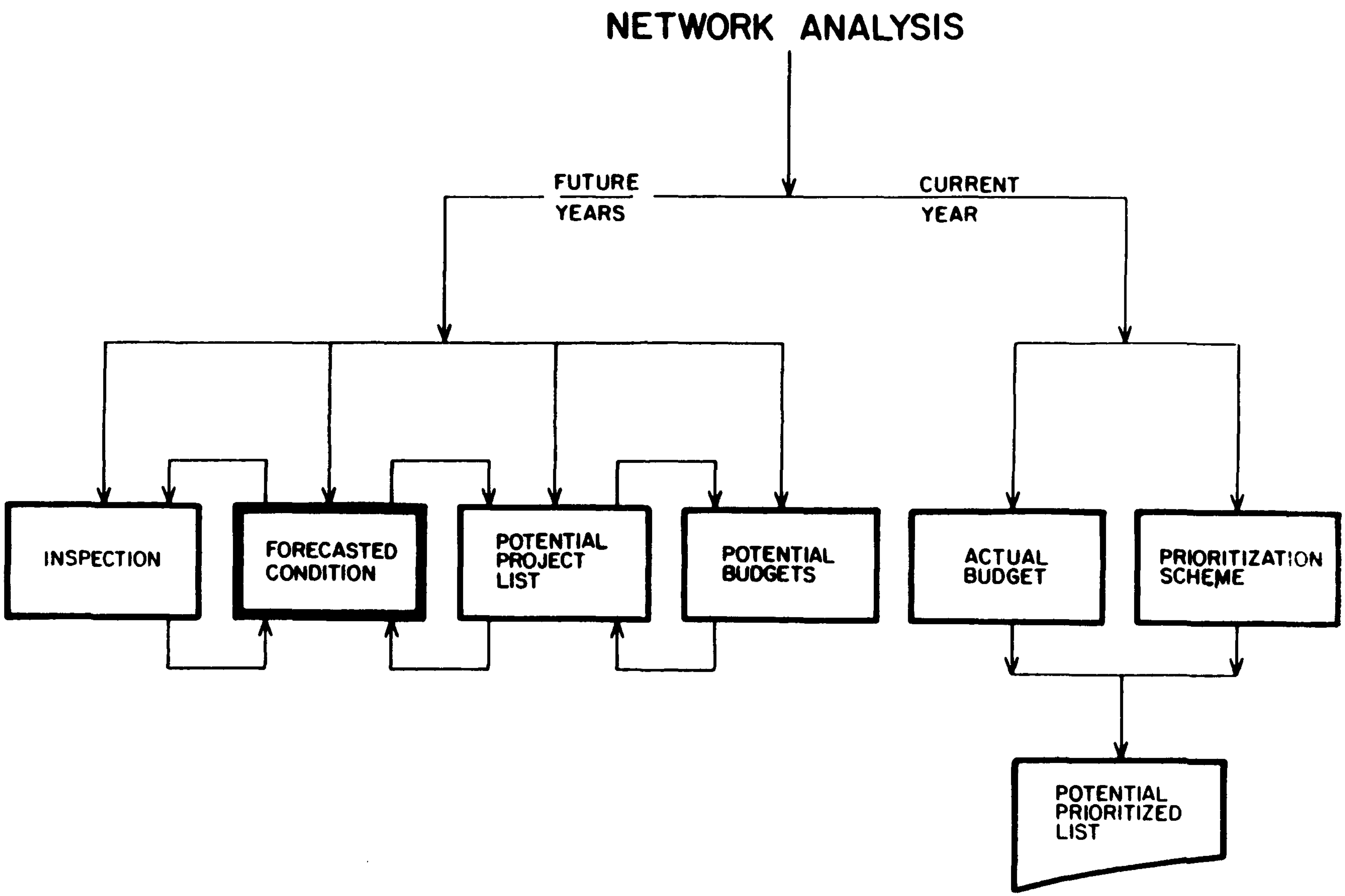


Figure 29. Network-level management.

information stored in the data base can be obtained by running the Inventory Report. As seen in Figure 30, this report provides information on each of the sections defined for the branches requested. This information includes section number, section category, zone, pavement rank, surface type, beginning and end points, and section area. This report can be useful in providing (1) quantities of pavement with a particular surface type or pavement rank, (2) beginning and end points for M&R projects, and (3) total pavement areas which can be used for estimating work quantities.

Inspection Scheduling Report

Because pavements deteriorate at different rates, condition inspections should be scheduled according to time intervals that take into account these differences. The Inspection Schedule Report allows the user to schedule inspections for the next 5 years based on a minimum "trigger" PCI value and the recommended number of years between inspections for four different rates of deterioration (loss of PCI points/year). Each of these values is selected by the user so that the effects of varying conditions can be evaluated. A minimum "trigger" PCI value is required for each branch use (RUNWAY, ROADWAY, PARKING, etc.)/pavement rank (PRIMARY, SECONDARY, etc.) combination to be included in the report. Any section that deteriorates to the minimum PCI within the 5-year period addressed in the report is flagged for inspection in the year it deteriorates to that condition. The section's deterioration rate is also checked to flag sections for inspection even if they have not reached the user-specified minimum PCI value. In addition, the Inspection Schedule Report can be used to identify sections with high rates of deterioration that may require major repair work. Chapter 8 discusses the selection of a trigger deterioration rate and target minimum PCI value. Figure 31 shows sample output from the Inspection Schedule Report.

PCI Frequency Report

A valuable tool to any manager is the ability to quickly display the current condition of the agency's pavement network. In addition, being able to determine the impact on the network of deferring major repair work now or in the future allows the manager to model "what if" scenarios with potential budget cuts to M&R dollars.

The PCI Frequency Report provides the user with a plot of pavement condition distribution for the current year or any future year. Future condition distributions simulate the consequences to the network of performing no major repair, as shown in Figure 32. In this figure, plots were developed for a sample agency for January 1989 and January 1993. Presuming no major repair has occurred between the last inspection and prediction dates, the anticipated network deterioration can be seen. During the 1989 to 1993 time period, the network average fell from 76 to 64 and the number of sections in the poor, very poor, and failed conditions went from 1 to 7 out of 39.

Future conditions are predicted based on a straight-line extrapolation method as discussed in Chapter 5. If only two data points are stored in the data base, the slope of the straight line is used to predict pavement condition. If three or more points are present, the maximum slope between inspections or from the last construction/overlay date to an inspection date is used to represent the rate of deterioration.

USACERL has developed a method of predicting pavement deterioration based on "family" deterioration curves which will represent true pavement deterioration patterns more accurately than previously possible. This method was described in detail in Chapter 5. The Family Analysis Report allows the user to develop a deterioration curve. The Section Prediction Report will do section condition predictions using curves that have been stored. Future plans are to include the family analysis method as part of the PCI Frequency Report and others such as the Budget Planning Report, which is discussed below.

INVENTORY REPORT

AGENCY NUMBER:

REPORT DATE: MAR/09/1988

Branch Number: 1SMOT

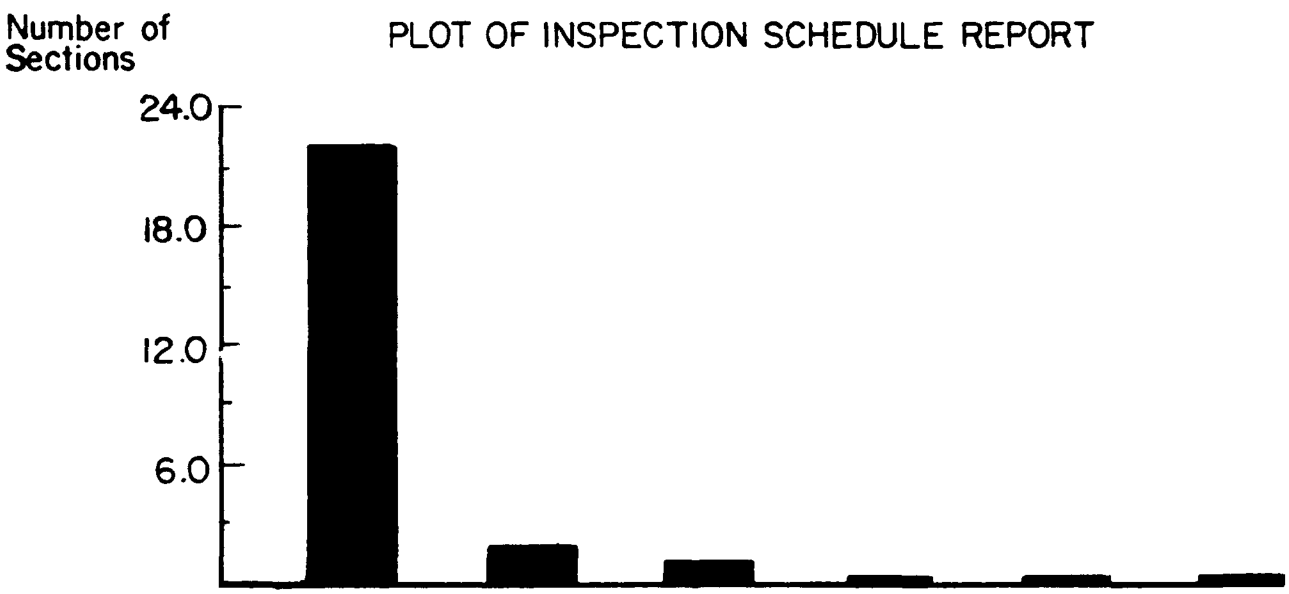
BRANCH NUMBER/USE/ NAME		SECTION NUMBER	SECTION CATEGORY	ZONE	PAVEMENT RANK	SURFACE TYPE	AREA (SF)
1SMOT / ROADWAY/		01	N	PR19	SECONDARY	AC	11700
	FROM:		E EDGE S "	TO:		W EDGE PAR	
SOUTH MOTO		02	N	PR18	SECONDARY	AC	11700
	FROM:		E EDGE PAR	TO:		W EDGE S "	
		03	N	PR17	SECONDARY	AC	25803
	FROM:		E EDGE S F	TO:		W 132FT E	
		04	N	PR16	SECONDARY	AC	18918
	FROM:		W 132FT E	TO:		W EDGE S J	
		05	N	PR15	SECONDARY	AC	37944
	FROM:		E EDGE S O	TO:		PARKING LO	
		06	N	PR12	SECONDARY	AC	5103
	FROM:		PARKING LO	TO:		PARKING LO	
		07	N	PR11	SECONDARY	AC	7623
	FROM:		PARKING LO	TO:		W EDGE S 9	
			TOTAL AREA OF SELECTED SECTIONS:				118791

Figure 30. Example Inventory Report.

Budget Condition Forecasting

With effective budget forecasting tools, a manager can estimate the dollars necessary for long-term M&R work. The Budget Condition Forecasting allows the user to produce 5-year projections of major rehabilitation requirements to meet a particular condition level. Figure 33 is an example report. The user is required to enter three types of input to run this report: (1) minimum "target" PCI values for each branch use/pavement rank to be considered in the report, (2) average unit repair costs based on surface type and PCI ranges, and (3) the expected inflation rate during the analysis period. Each agency is responsible for determining these inputs, since they vary with geographical location, time, and agency goals. As sections deteriorate to the "target" PCI values, repair costs are calculated for each of the 5 years in the analysis period based on the user-entered unit costs. By varying the "target" PCI values and the inflation rate, various economic scenarios can be investigated. The program also allows the user to vary the minimum PCIs each year during the analysis period to investigate the cost of gradually building up the network condition as opposed to a budget requiring a large initial outlay of dollars.

In addition to estimating the costs of long-range major rehabilitation requirements, the Budget Condition Forecasting can be used to approximate the dollars required for performing the current-year routine maintenance needs. This projection can be done by: (1) forcing every pavement section to be flagged for maintenance and (2) using localized maintenance unit costs rather than major rehabilitation costs. To ensure that each section is flagged, the target PCI is set at 99. All but the



Year to Inspect	1990	1991	1992	1993	1994	1995
Number of Sections	22	2	1	0	0	0
Total Sections	25					

Figure 31. Example Inspection Schedule Report.

INSPECTION SCHEDULE REPORT

Agency Name: FORT STEWART, AC PRIMARY ROADS >55
Agency Number: 01 Report Date: APR/27/1990

Branch Use : All
Pavement Rank : All
Surface Type : All
Zone : All
Section Category : All
Last Construction Date: All
PCI : All

Summary of Data for the Inspection Schedule Report

Minimum PCI Table

Branch Use	Pavement Rank	Min PCI
ROADWAY	P	50

Number of Years between Inspections Table

Rate of Deterioration (pts/yr)	Years between Inspections
> 9	1
6 - 9	2
2 - 5	3
< 2	3

Table of Inspection Schedule Report

Pavement Rank	Year to Inspect 1990	1991	1992	1993	1994	1995
Primary	22	2	1	0	0	0
Total Sections to Inspect	22	2	1	0	0	0

Total Number of Sections to Inspect : 25
Total Number of Sections Not Needing Inspection: 0
Total Number of Missing Values : 0

Figure 31. (Cont'd).

INSPECTION SCHEDULE REPORT

Agency Name: FORT STEWART, AC PRIMARY ROADS >55
Agency Number: 01   Report Date: APR/27/1990

Branch Use : All
Pavement Rank : All
Surface Type : All
Zone : All
Section Category : All
Last Construction Date: All
PCI : All

Section List of Inspection Schedule Report

Year to Inspect	Branch Num	Branch Name	Use	Section Num	Rank	Surf	Area(SF)
1990	IGA47	GEORGIA RTE. 47	ROADWAY	01	P	AC	256797.00
1990	IGULA	GULICK AVENUE	ROADWAY	01	P	AC	48663.00
1990	IGULA	GULICK AVENUE	ROADWAY	02	P	AC	131238.00
1990	IHERR	HERO ROAD	ROADWAY	01	P	AC	32733.00
1990	IHERR	HERO ROAD	ROADWAY	02	P	AC	12600.00
1990	IHERR	HERO ROAD	ROADWAY	03	P	AC	12942.00
1990	IHERR	HERO ROAD	ROADWAY	04	P	AC	270162.00
1990	IMEMD	MEMORIAL DRIVE	ROADWAY	01	P	AC	9783.00
1990	IMEMD	MEMORIAL DRIVE	ROADWAY	02	P	AC	13959.00
1990	IUTIS	UTILITY STREET	ROADWAY	01	P	AC	41850.00
1990	IWILN	WILSON AVENUE (NORTH)	ROADWAY	01	P	AC	42624.00
1990	IWILN	WILSON AVENUE (NORTH)	ROADWAY	02	P	AC	31185.00
1990	IWILN	WILSON AVENUE (NORTH)	ROADWAY	03	P	AC	22653.00
1990	IWILS	WILSON AVENUE (SOUTH)	ROADWAY	02	P	AC	4995.00
1990	IWILS	WILSON AVENUE (SOUTH)	ROADWAY	03	P	AC	37098.00
1990	IWILS	WILSON AVENUE (SOUTH)	ROADWAY	04	P	AC	82575.00
1990	IWILS	WILSON AVENUE (SOUTH)	ROADWAY	05	P	AC	164898.00
1990	IWILS	WILSON AVENUE (SOUTH)	ROADWAY	06	P	AC	42498.00
1990	IWILS	WILSON AVENUE (SOUTH)	ROADWAY	07	P	AC	6507.00
1990	IWRIR	ROAD TO WRIGHT FIELD	ROADWAY	01	P	AC	34362.00
1990	IWRIR	ROAD TO WRIGHT FIELD	ROADWAY	02	P	AC	36405.00
1990	IWRIR	ROAD TO WRIGHT FIELD	ROADWAY	03	P	AC	164169.00
1991	IUTIS	UTILITY STREET	ROADWAY	02	P	AC	26154.00
1991	IUTIS	UTILITY STREET	ROADWAY	03	P	AC	14715.00
1992	IWILS	WILSON AVENUE (SOUTH)	ROADWAY	01	P	AC	39996.00

Total Number of Sections to Inspect : 25
Total Number of Sections Not Needing Inspection: 0
Total Number of Missing Values : 0

Figure 31. (Cont'd).

PCI FREQUENCY REPORT

Agency Name:
Agency Number:

Report Date: NOV/04/1988

Branch Use : All
Pavement Rank : All
Surface Type : All
Zone : All
Section Category : All
Last Construction Date: All
PCI : All

TABLE OF PCI FREQUENCY REPORT

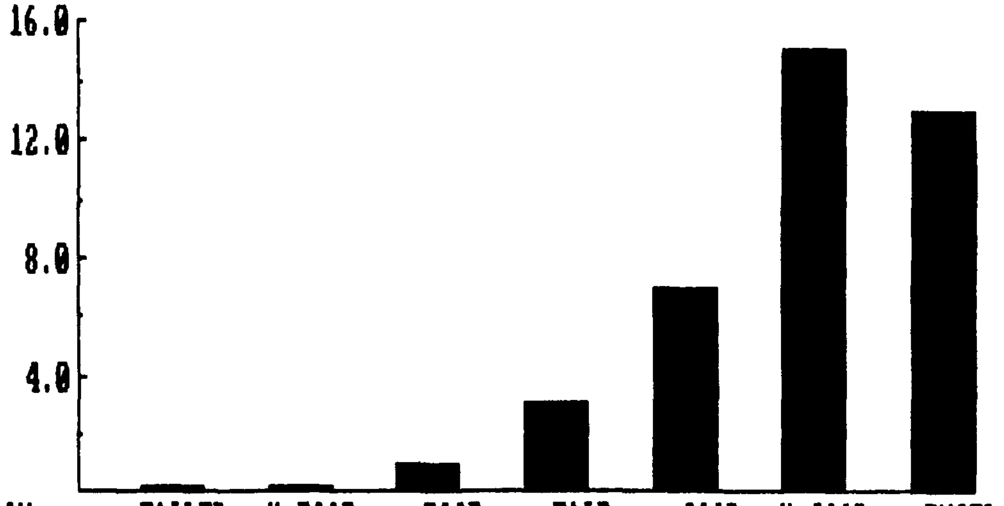
YEAR: JAN 1993

CONDITION	PCI RANGE	NO. OF SECTIONS	% OF SECTIONS	TOTAL AREA	% OF AREA
FAILED	0 - 10	0	.00	.00	.00
VERY POOR	11 - 25	1	2.56	41958.00	1.92
POOR	26 - 40	6	15.38	406647.00	19.64
FAIR	41 - 55	5	12.82	324270.00	14.86
GOOD	56 - 70	12	30.77	519552.00	23.81
VERY GOOD	71 - 85	11	28.21	734958.00	33.69
EXCELLENT	86 - 100	4	10.26	154413.00	7.08

TOTAL NUMBER OF SECTIONS: 39
AVERAGE PCI : 64
TOTAL SECTION AREA : 2181798.00
NUMBER OF MISSING VALUES: 0

NO. OF SECTIONS

PLOT OF PCI FREQUENCY REPORT
YEAR: JAN 1989



CONDITION	FAILED	V.POOR	POOR	FAIR	GOOD	V.GOOD	EXCEL
	.00%	.00%	2.56%	7.69%	17.95%	38.46%	33.33%
NO. SEC.	0	0	1	3	7	15	13
TOTAL SEC.	39						

Figure 32. Example PCI Frequency Report.

SECTION LIST OF PCI FREQUENCY REPORT

YEAR: JAN 1989

NUMBER/ BRANCH USE / NAME	SECTION NUM/RANK/SURF/	AREA	LAST INSPECTION	LAST PCI	PRED PCI
ANDRS / ROADWAY/ ANDERSON STREET	.01 /S /AC /	51840.00	JAN/30/1987	64	60
CASBL / ROADWAY/ CASA BLANCA ROAD	02 /S /AC /	41157.00	JAN/27/1987	76	73
CASBL / ROADWAY/ CASA BLANCA ROAD	01 /S /AC /	41859.00	JAN/29/1987	55	50
CUTLR / ROADWAY/ CUTLER STREET	01 /S /AC /	85293.00	DEC/01/1987	84	73
HUGHS / ROADWAY/ HUGHES STREET	01 /S /AC /	127008.00	DEC/01/1987	89	81
HVHLE / ROADWAY/ HOOVER HILL ROAD	01 /S /AC /	93600.00	DEC/01/1987	84	73
IAPDR / ROADWAY/ APACHE DR	01 /S /AC /	57897.00	OCT/18/1986	94	88
ICENT / ROADWAY/ CENTRAL DR	03 /S /AC /	48177.00	OCT/22/1986	86	83
ICENT / ROADWAY/ CENTRAL DR	02 /S /AC /	23058.00	OCT/22/1986	93	92
ICENT / ROADWAY/ CENTRAL DR	01 /S /AC /	73593.00	OCT/22/1986	87	84
ICOMA / ROADWAY/ COMANCHE AVE	01 /S /AC /	78012.00	OCT/17/1986	96	92
IDAKO / ROADWAY/ DAKOTA ST	01 /S /AC /	27720.00	OCT/17/1986	96	92
ILAGU / ROADWAY/ LAGUNA DR	01 /S /AC /	118917.00	OCT/19/1986	96	92
IMART / ROADWAY/ MARTIN DR	02 /S /AC /	12078.00	OCT/22/1986	92	90
IMART / ROADWAY/ MARTIN DR	01 /S /AC /	39420.00	OCT/21/1986	91	89
IMART / ROADWAY/ MARTIN DR	03 /S /AC /	5463.00	OCT/22/1986	80	76
IMUSK / ROADWAY/ MUSKOGEE STREET	01 /S /AC /	153000.00	OCT/21/1986	100	93
INAVA / ROADWAY/ NAVAJO CT	01 /S /AC /	125820.00	OCT/21/1986	96	92
IOVNA / ROADWAY/ OVNARD BLVD	02 /S /AC /	79857.00	OCT/24/1986	97	94
IWICH / ROADWAY/ WICHITA DR	01 /S /AC /	7146.00	OCT/18/1986	96	92
IWICH / ROADWAY/ WICHITA DR	03 /S /AC /	38853.00	OCT/18/1986	96	92
IWICH / ROADWAY/ WICHITA DR	02 /S /AC /	5823.00	OCT/18/1986	96	92
LKRDG / ROADWAY/ LOCKRIDGE LOO	01 /S /AC /	66969.00	JAN/20/1987	79	73
LKRDG / ROADWAY/ LOCKRIDGE LOO	02 /S /AC /	41958.00	DEC/01/1987	81	68
MCCUL / ROADWAY/ MCCULLY STREET	01 /S /AC /	30420.00	JAN/22/1987	76	71
MINUE / ROADWAY/ MINUE STREET	01 /S /AC /	95364.00	FEB/03/1987	47	41
PATTN / ROADWAY/ PATTON DRIVE	01 /S /AC /	67077.00	JAN/22/1987	68	62
SADOW / ROADWAY/ SADOWSKI ROAD	01 /S /AC /	98208.00	JAN/30/1987	68	64
SAFIE / ROADWAY/ SAFI ROAD	01 /S /AC /	52173.00	JAN/27/1987	76	73
SMITH / ROADWAY/ SMITH ROAD	01 /S /AC /	44532.00	JAN/30/1987	45	39
ST24E / ROADWAY/ 24TH STREET	01 /S /AC /	52632.00	JAN/22/1987	73	68
ST31E / ROADWAY/ 31ST STREET	02 /S /AC /	23436.00	FEB/02/1987	68	64
ST31E / ROADWAY/ 31ST STREET	01 /S /AC /	9513.00	FEB/03/1987	76	73
STRCK / ROADWAY/ STORCK ROAD	01 /S /AC /	4887.00	JAN/30/1987	66	62
STRCK / ROADWAY/ STORCK ROAD	02 /S /AC /	45999.00	JAN/30/1987	56	51
VNABL / ROADWAY/ VENABLE ROAD	01 /S /AC /	56709.00	DEC/01/1987	91	85
WALES / ROADWAY/ WALES STREET	01 /S /AC /	73458.00	DEC/01/1987	89	81
WNRTE / ROADWAY/ WAINRIGHT DRIVE	01 /S /AC /	34182.00	JAN/23/1987	78	74
WNRTE / ROADWAY/ WAINRIGHT DRIVE	03 /S /AC /	48690.00	FEB/14/1987	81	77

Figure 32. (Cont'd).

BUDGET CONDITION FORECASTING REPORT

Agency Name: FORT STEWART, AC PRIMARY ROADS >55
Agency Number: 01 Report Date: APR/27/1990

Branch Use : All
Pavement Rank : All
Surface Type : All
Zone : All
Section Category : All
Last Construction Date: All
Last Inspection PCI : All
Projected PCI : All
Inflation Rate : .00 %

Section List of Budget Condition Forecasting Report
(Costs in thousands of dollars)

Date to Repair	Branch Num / Use	Section Num / Rank / Surf	Pred PCI	$/SF	Section Area(SF)	Cost ($1000's)
MAY/1990	IGULA / ROADWAY	01 / P / AC	55	1.31	48663.00	63.87
MAY/1990	IHERR / ROADWAY	01 / P / AC	35	2.25	32733.00	73.65
MAY/1990	IWILS / ROADWAY	07 / P / AC	52	1.42	6507.00	9.27
MAY/1990	IWRIR / ROADWAY	01 / P / AC	54	1.35	34362.00	46.39
MAY/1991	IMEMD / ROADWAY	01 / P / AC	51	1.46	9783.00	14.31
MAY/1992	IMEMD / ROADWAY	02 / P / AC	54	1.35	13959.00	18.84
MAY/1992	IWILS / ROADWAY	03 / P / AC	55	1.31	37098.00	48.69
MAY/1992	IWRIR / ROADWAY	03 / P / AC	55	1.31	164169.00	215.47
MAY/1993	IWILS / ROADWAY	04 / P / AC	54	1.35	82575.00	111.48
MAY/1993	IWRIR / ROADWAY	02 / P / AC	55	1.31	36405.00	47.78
MAY/1994	IGULA / ROADWAY	02 / P / AC	53	1.39	131238.00	182.09
MAY/1994	IWILN / ROADWAY	02 / P / AC	55	1.31	31185.00	40.93

Total Number of Sections Repaired : 12
Total Number of Sections Not Needing Repair: 13
Total Number of Missing Values : 0

Figure 33. Example Budget Condition Forecasting Report.

BUDGET CONDITION FORECASTING REPORT

Agency Name: FORT STEWART, AC PRIMARY ROADS >55
Agency Number: 01 Report Date: APR/27/1990

Branch Use : All
Pavement Rank : All
Surface Type : All
Zone : All
Section Category : All
Last Construction Date: All
Last Inspection PCI : All
Projected PCI : All
Inflation Rate : .00 %

Summary of Data for the Budget Condition Forecasting Report

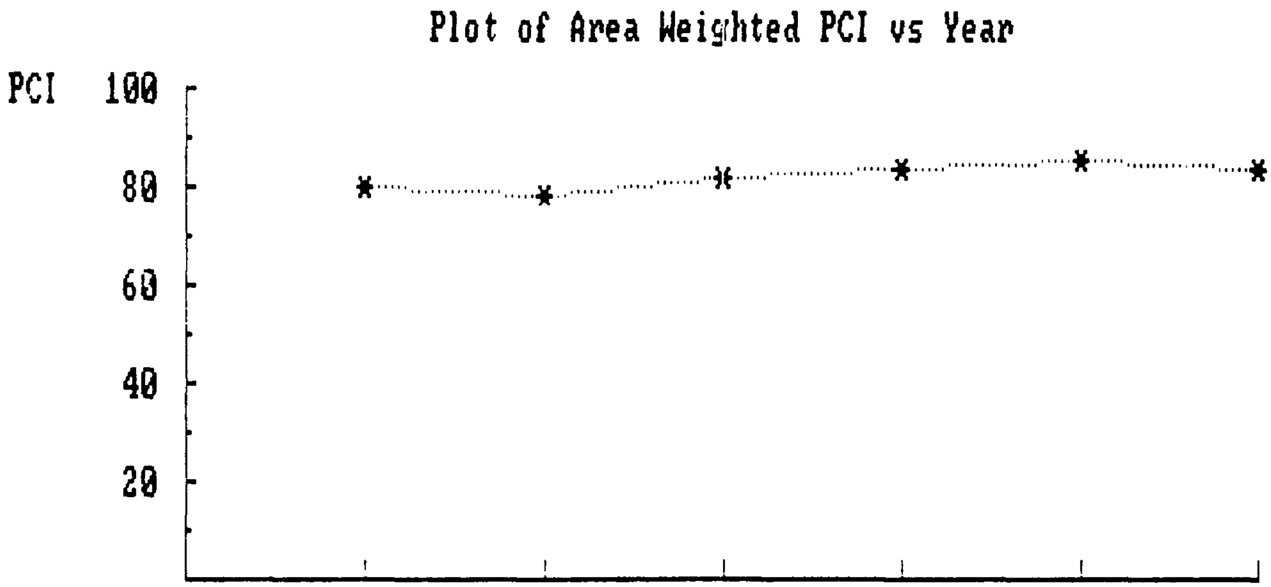
Minimum PCI Table

Branch Use	Pavement Rank	Year of Repair 1990	1991	1992	1993	1994	1995
ROADWAY	P	55	55	55	55	55	55

Unit Repair Cost Table
(Cost in $/SF)

Surface Type	0-20	21-40	41-60	61-80	81-100
AC	3.00	2.50	1.50	.75	.50

Figure 33. (Cont'd).



Year:	1990	1991	1992	1993	1994	1995
Average Section PCI:	82	81	84	85	86	83
Area Weighted PCI:	80	79	82	84	86	84
Budget Amt:	193.18	14.31	283.01	159.26	223.02	.00

[Press Any Key]

Figure 33. (Cont'd).

pavements in perfect condition will be addressed in their current condition. By using localized maintenance unit costs for each surface type in various PCI ranges, the current year's localized maintenance requirements can be estimated.

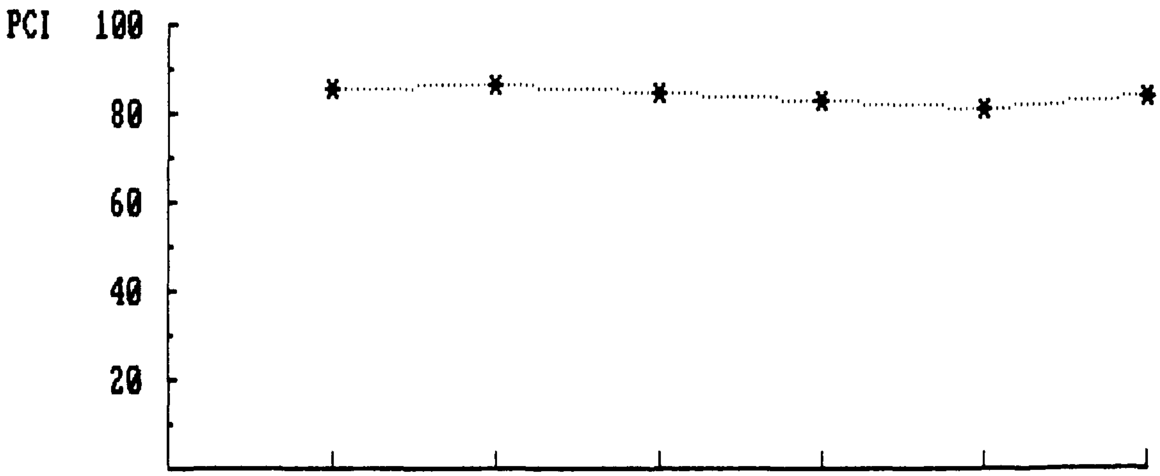
In addition, the BCF Report projects the system condition in each year, assuming all of the necessary repairs are made. The inputs for this report are the same as for the Budget Condition Forecasting. Future section condition is predicted based on a straight-line extrapolation. A section which is repaired is assumed to have a PCI of 100 with a deterioration rate of 3 PCI points per year.

The output from the BCF Report includes a plot of the average PCI for the system in each year along with the required budget. An example of this plot is shown in Figure 34. In this example, the minimum PCI input was 60 for primary and secondary roads, 55 for tertiary roads, and 50 for parking lots. The average PCI of the system ranges from 81 to 87 over the 5-year period.

Minimum PCI Table

Branch Use	Pavement Rank	1990	1991	1992	1993	1994	1995
		Year of Repair					
ROADWAY	P	60	60	60	60	60	60
ROADWAY	S	60	60	60	60	60	60
ROADWAY	T	55	55	55	55	55	55
ROADWAY	X	50	50	50	50	50	50

Plot of Area Weighted PCI vs Year



Year:	1990	1991	1992	1993	1994	1995
Average Section PCI:	87	89	86	85	82	85
Area Weighted PCI:	86	87	85	83	81	84
Budget Amt:	432.08	150.08	.00	36.25	.00	268.59

Figure 34. Plot of average system PCI for a 5-year period from the BCF Report.

PCI Report

Ideally, an agency has the dollars required to perform all M&R work needed to maintain the network in good condition; realistically, this is rarely the case. Agencies need to prioritize projects so that the most important work is funded first. The PCI can be used as one objective measurement of prioritization; however, it should not be relied upon as the only indicator. Other factors that should be considered are pavement rank and branch use.

The PCI Report can be used to rank pavement sections by condition within various sorting options to help prioritize projects. For example, if primary roadways with PCIs greater than 70 are given highest priority, all primary roadways can be sorted (or grouped) together by ascending or descending PCI. This tool can greatly assist the engineer in identifying pavement sections in each of the prioritization categories. Figure 35 shows a sample PCI Report.

Network Maintenance Report

Frequently, routine maintenance (crack filling or patching) is the only work necessary over much of the pavement network. The Network Maintenance Report uses the agency's local maintenance policies, which were stored during data entry, and applies them to the distresses identified in the latest condition survey for each analyzed section. Table 4 shows an example local maintenance policy.

This report calculates the cost for each pavement section by maintenance type. As shown in Figure 36, two types of outputs are available as the result of running this report. The first is a section detail report which is produced for each section being analyzed. This report lists the distress types and severities of all distresses identified in the latest condition survey, along with work type, quantity, and cost of maintenance as outlined in the maintenance policy being used. A second output, the Work Type Summary, is a table listing each type of work required, the branches and sections in which it is required, the amount of work, and total cost of performing that activity.

Summary

The PAVER system enables managers to quickly assess network condition now and in the future, develop annual work plans, estimate 5-year budget requirements, prioritize M&R projects and play "what if" games with various economic scenarios. However, managers must ensure that the data base is current and that the policies and costs used are representative of the local environment in order to obtain reports that will be realistic estimations. Use of the PAVER system in developing annual and 5-year plans is discussed in more detail in Chapter 9.

PCI REPORT

REPORT DATE: MAR/09/1988

AGENCY NUMBER:

BRANCH NUMBER/USE/ NAME	SECTION NUM/RANK/SURF/AREA(SF)		LAST CONSTRUCT DATE	LAST INSPECTION DATE	PCI
ICTYH / ROADWAY	01 / S / AC / 82782		JUN/06/1942	APR/30/1986	62
COUNTY ROA	CAT: N	ZONE: PR00	AGE (YRS): 43.9		
IEPST / ROADWAY	01 / S / AC / 16785		JUN/06/1942	APR/30/1986	58
EAST "P" S	CAT: N	ZONE: PR07	AGE (YRS): 43.9		
IEPST / ROADWAY	02 / S / AC / 13194		JUN/06/1942	APR/30/1986	62
EAST "P" S	CAT: N	ZONE: PR07	AGE (YRS): 43.9		
ISMOT / ROADWAY	01 / S / AC / 11700		JUN/06/1982	APR/30/1986	80
SOUTH MOTO	CAT: N	ZONE: PR19	AGE (YRS): 3.9		
ISMOT / ROADWAY	02 / S / AC / 11700		JUN/06/1982	APR/30/1986	83
SOUTH MOTO	CAT: N	ZONE: PR18	AGE (YRS): 3.9		
ISMOT / ROADWAY	03 / S / AC / 25803		JUN/06/1982	APR/30/1986	57
SOUTH MOTO	CAT: N	ZONE: PR17	AGE (YRS): 3.9		
ISMOT / ROADWAY	04 / S / AC / 18918		JUN/06/1982	APR/30/1986	49
SOUTH MOTO	CAT: N	ZONE: PR16	AGE (YRS): 3.9		
ISMOT / ROADWAY	05 / S / AC / 37944		JUN/06/1982	APR/30/1986	56
SOUTH MOTO	CAT: N	ZONE: PR15	AGE (YRS): 3.9		
ISMOT / ROADWAY	06 / S / AC / 5103		JUN/06/1942	APR/30/1986	30
SOUTH MOTO	CAT: N	ZONE: PR12	AGE (YRS): 43.9		
ISMOT / ROADWAY	07 / S / AC / 7623		JUN/06/1982	APR/30/1986	88
SOUTH MOTO	CAT: N	ZONE: PR11	AGE (YRS): 3.9		
ST / ROADWAY	1 / T / AC / 2000		SEP/22/1987	SEP/22/1987	100
stone road	CAT:	ZONE:	AGE (YRS): .0		

Figure 35. Example PCI Report.

Table 4

Example Local Maintenance Policy

Distress	Sev	Work Type & Description		Cost	Unit
41 ALLIGATOR CR	M	PA-AS	Patching - AC Shallow	6.00	sq ft
41 ALLIGATOR CR	H	PA-AS	Patching - AC Shallow	6.00	sq ft
41 ALLIGATOR CR	L	DO-NO	No Appropriate Loc Maint Actvt	.00	ft
42 BLEEDING		DO-NO	No Appropriate Loc Maint Actvt	.00	ft
43 BLOCK CR	M	DO-NO	No Appropriate Loc Maint Actvt	.00	ft
43 BLOCK CR	H	DO-NO	No Appropriate Loc Maint Actvt	.00	ft
43 BLOCK CR	L	DO-NO	No Appropriate Loc Maint Actvt	.00	ft
44 CORRUGATION	L	DO-NO	No Appropriate Loc Maint Actvt	.00	ft
44 CORRUGATION	H	PA-AL	Patching - AC Leveling	5.50	sq ft
44 CORRUGATION	M	PA-AL	Patching - AC Leveling	5.50	sq ft
45 DEPRESSION	M	PA-AL	Patching - AC Leveling	5.50	sq ft
45 DEPRESSION	L	DO-NO	No Appropriate Loc Maint Actvt	.00	ft
45 DEPRESSION	H	PA-AL	Patching - AC Leveling	5.50	sq ft
46 JET BLAST		DO-NO	No Appropriate Loc Maint Actvt	.00	ft
47 JT REF. CR	M	CS-AC	Crack Sealing - AC	1.00	ft
47 JT REF. CR	L	DO-NO	No Appropriate Loc Maint Actvt	.00	ft
47 JT REF. CR	H	CS-AC	Crack Sealing - AC	1.00	ft
48 L & T CR	L	DO-NO	No Appropriate Loc Maint Actvt	.00	ft
48 L & T CR	H	CS-AC	Crack Sealing - AC	1.00	ft
48 L & T CR	M	CS-AC	Crack Sealing - AC	1.00	ft
49 OIL SPILLAGE		DO-NO	No Appropriate Loc Maint Actvt	.00	ft
50 PATCHING	L	DO-NO	No Appropriate Loc Maint Actvt	.00	ft
50 PATCHING	H	PA-AD	Patching - AC Deep	6.00	sq ft
50 PATCHING	M	PA-AD	Patching - AC Deep	6.00	sq ft
51 POLISHED AG		DO-NO	No Appropriate Loc Maint Actvt	.00	ft
52 WEATH/RAVEL	L	DO-NO	No Appropriate Loc Maint Actvt	.00	ft
52 WEATH/RAVEL	H	DO-NO	No Appropriate Loc Maint Actvt	.00	ft
52 WEATH/RAVEL	M	DO-NO	No Appropriate Loc Maint Actvt	.00	ft
53 RUTTING	M	PA-AL	Patching - AC Leveling	5.50	sq ft
53 RUTTING	H	PA-AL	Patching - AC Leveling	5.50	sq ft
53 RUTTING	L	DO-NO	No Appropriate Loc Maint Actvt	.00	ft
54 SHOVING	L	DO-NO	No Appropriate Loc Maint Actvt	.00	ft
54 SHOVING	H	DO-NO	No Appropriate Loc Maint Actvt	.00	ft
54 SHOVING	M	DO-NO	No Appropriate Loc Maint Actvt	.00	ft
55 SLIPPAGE CR		PA-AS	Patching - AC Shallow	6.00	sq ft
56 SWELLING	L	DO-NO	No Appropriate Loc Maint Actvt	.00	ft
56 SWELLING	H	DO-NO	No Appropriate Loc Maint Actvt	.00	ft
56 SWELLING	M	DO-NO	No Appropriate Loc Maint Actvt	.00	ft
61 BLOW-UP	L	PA-PF	Patching - PCC Full Depth	6.00	sq ft
61 BLOW-UP	M	SL-RP	Slab Replacement	6.50	sq ft

```
                     Network Maintenance Report

Agency Name -
Report Date - MAR/09/1988

Branch Use              : All
Zone                    : All
Section Category        : All
Last Construction Date: All
PCI                     : All


Branch Name      -                WEST "N" S     Section Length  -       890 LF
Branch Number    - IWNST                         Section Width   -        36 LF
Section Number   - 02                            Section Area    -     32040 SF

Inspection Date - APR/30/1986                    Section PCI     -        37

                   Dis    Dist-Qty   Work                                Total
Distress Type      Sev    Work-Qty   Type                                Cost ($)
-------------------------------------------------------------------------------
10 L & T CR        M      1654 LF
                          1654 LF    Crack Sealing - AC                     1654
-------------------------------------------------------------------------------
                                                         Total              1654
```

Figure 36. Example section detail and work-type summary table from the Network Maintenance Report.

Network Maintenance Report

Agency Name -
Report Date - MAR/09/1988

Branch Use : All
Zone : All
Section Category : All
Last Construction Date: All
PCI : All

Work Type Summary Table

Work Type	Branch/ Section		Work-Qty	Cost ($)
Crack Sealing - AC	IE13A	01	192 LF	192
	IE13A	03	214 LF	214
	IE14A	02	3416 LF	3416
	IPOST	01	474 LF	474
	IS08A	01	163 LF	163
	IS09A	01	155 LF	155
	IS09A	03	136 LF	136
	IS10A	01	2942 LF	2942
	IS10A	05	135 LF	135
	IS10R	01	26 LF	26
	ISAST	01	1658 LF	1658
	ISAST	02	1027 LF	1027
	ISBST	01	707 LF	707
	ISBST	02	151 LF	151
	ISJRD	04	389 LF	389
	ISJST	02	3449 LF	3449
	ISSST	01	337 LF	337
	IW14A	04	642 LF	642
	IWNST	02	1654 LF	1654
		Total:	17867 LF	17867

Total cost of all work ($): 17867

Figure 36. (Cont'd).

8 PROJECT-LEVEL MANAGEMENT

This chapter provides guidelines for conducting project-level investigations and selecting the best M&R alternative for a project. Pavement design procedures are not included.

Project-level evaluations should be performed prior to preparation of plans and specifications for a given M&R project. The quantities obtained from the project-level evaluation will be used in the design process.

Background Data Collection

Construction and Maintenance History

Knowledge of construction and maintenance history is of great importance to project development. Construction and maintenance historical data to be gathered should include the following:

- Pavement structure and date of original construction
- Dates and thicknesses of any subsequent overlays
- Available maintenance history including patching, joint sealing, crack sealing, and seal coats
- Available properties of materials used in each construction phase.

The construction and maintenance historical information is necessary for the proper design of rehabilitation alternatives and for providing valuable feedback on what did and did not work for that specific site. Following are examples of such feedback:

1. A pavement was originally constructed in 1940. It received an AC overlay after 20 years, a second overlay after 10 years, and a third overlay after 5 years. It has become obvious that a fourth overlay may not be cost-effective.

2. A slurry seal was applied 6 months ago; however, it has been sheared off in many places. Slurry seals should be avoided in future rehabilitation of this facility.

3. Cracks and joints on some pavements were never maintained. The life of these pavements is relatively low compared to others where this type of maintenance was applied. Joint and crack sealing should be a major consideration in any future rehabilitation.

Work history can be stored in the PAVER system. The work history should be updated as M&R work is performed. PAVER will automatically update the Last Construction Date when items such as overlay and reconstruction are entered in the work history.

Traffic Record

The traffic record includes both traffic history and projected future traffic. An accurate traffic record is essential for assessing past damage and to determine an effective rehabilitative design that takes into consideration future traffic. The PAVER system stores traffic records.

Project-Level Inspection

Since the results of a project-level inspection will be used in detailed analysis of the section, distress types, severity, and amount must be accurate. The number of samples that must be surveyed for this accuracy is calculated by the PAVER inspection report. However, since the quantity of distresses is also used for preparing plans and specifications at the contract level, a 100 percent survey may be desirable.

Drainage

The condition of the drainage structures and the pavement section's overall ability to drain must be investigated during the detailed distress survey. The drainage condition should be coded for input into the data base, and a brief description of the deficiencies noted on the "comments" portion of the inspection. Specific items that should be looked for in the field are:

- Is the storm sewer system performing as designed?
- Are inlets and culverts clear and set at proper elevations?
- Is water standing on the pavement?
- Where appropriate, are ditch lines clear and free of standing water? Inspectors should always be aware of moisture-induced distresses that can worsen moisture damage.

Nondestructive Deflection Testing (NDT)

NDT provides valuable information for project analysis. Many types of NDT equipment are available and can be classified as static load, vibrating steady-state force, or impulse load.

The Benkelman Beam is used to do static load NDT. When using this equipment, the pavement is deflected under an actual wheel load. As the vehicle moves slowly away, the rebound deflection is measured. This test procedure, while the equipment is relatively inexpensive, is very slow so that the amount of testing that can be done is limited.

Vibrating steady-state force NDT devices apply a sinusoidal load to the pavement. Geophones measure the maximum deflection and the deflection basin. The most common types of vibrating steady-state force devices are the Dynaflect and the Road Rater. The Dynaflect can only apply a 1000-lb load, whereas the Road Rater, depending on the model, can apply loads up to 8000 lb. With thick pavement sections, caution must always be exercised when using low loads to ensure that a true structural response is obtained.

Impulse loading drops a given mass a known distance onto a loading plate. The maximum and basin deflections are then measured. This type of equipment can generate loads from 3000 to 50,000-lb force, depending on the mass and the drop height. This type of device is known as a "falling weight deflectometer" (FWD) and best simulates the pavement response under a moving wheel load.

PAVER allows the user to store NDT results. Experienced engineering judgment must be used to interpret and use NDT data properly. NDT results are used to determine the following information:

1. Asphalt pavements--

- Elastic modulus of each of the structural layers, which are in turn used for load fatigue analysis

- Overlay thickness design

- Deflection profile for both trafficked and nontrafficked areas. The profile is used to identify failed areas or those with a potential for failure. Higher deflection of trafficked compared with nontrafficked areas indicates a structural inadequacy or potential failure, assuming the pavement has the same construction history in both areas.

2. Concrete pavements--

- Load transfer across joints

- Void detection

- Concrete elastic modulus and subgrade modulus of reaction, which are used (along with load transfer) to determine critical stresses and perform a fatigue analysis

- Overlay thickness design.

NDT offers several advantages over destructive testing, including the ability to test hundreds of locations in the same amount of time it takes to perform only a few tests of the field California Bearing Ratio (CBR) or subgrade modulus (k) destructive tests. Also, the results obtained from NDT are true *in situ* values in contrast to destructive testing results for which undisturbed samples are difficult to obtain. However, destructive testing may be necessary in some cases as discussed below.

Destructive Testing

Destructive testing can be used to supplement NDT results or to provide necessary information by itself without NDT. With the current state-of-the-art technology in pavement analysis, combining destructive and NDT would yield better results than using either method alone. For accurate back-calculation of the layer properties, it is strongly recommended that exact layer thicknesses be determined by coring in locations where NDT results are going to be used for that purpose. As a supplement for NDT, the following destructive tests can be used:

1. Coring for exact layer thickness determination

2. Unified subgrade soil classification in a few representative locations

3. Visual classification of the base and subbase materials and their conditions in a few representative locations

4. For asphalt pavements, Marshall stability testing on a few asphalt concrete cores as well as penetration and viscosity (and/or softening point) on extracted asphalt

5. For concrete pavements, indirect tensile strength and/or compressive strength on a few representative samples.

If no NDT is performed, then a much more extensive destructive testing program is recommended. In addition to performing the tests listed above on a frequent basis, the following tests are also recommended:

1. Field CBR on the subgrade and granular layers for asphalt pavements

2. Field subgrade modulus (k) for concrete pavements

3. Modulus of resilience tests on base and subbase materials.

Destructive testing may also be necessary to investigate special problems such as "D" cracking in concrete pavements or reflection cracking in asphalt pavements. Table 5 lists the common destructive tests along with their ASTM designations. The PAVER System allows the user to store material test results.

Roughness and Skid Resistance

Roughness and skid resistance measurements are not necessary for every project-level evaluation. Roughness measurement is most valuable when the pavement is in very good condition with little or no distress. This would detect long wave roughness which would effect driving at high speeds but is not visible. If reconstruction is imminent, roughness measurements of the existing pavement may not be of any value. To assess skid resistance, accident records can indicate locations with little resistance. However, for pavements such as runways, skid resistance should be measured on a regular basis to ensure safety.

Selection of M&R Alternatives

M&R can be classified into routine/preventive maintenance and major repair. Routine/preventive maintenance is generally more economical for pavements in very good or excellent condition. As a pavement deteriorates below the very good condition (PCI less than 70), the agency should assess the economics of major repair. Past experience has shown that the level of major rehabilitation and the unit cost associated with the work increase as the PCI decreases, as shown in Figure 37.

Pavement Evaluation

The selection of feasible M&R alternatives should be based on the results of evaluation. Figure 38 shows a stepwise procedure that is recommended for summarizing the results of an evaluation. This procedure provides a rational basis for identifying feasible alternatives. Following is a description of each of the steps in this procedure and how they should be completed.

Step 1: Overall Condition. The mean section PCI is determined by computing the average of all sample units inspected within the section (adjusted if "additional" nonrandom sample units are included --see Chapter 4).

Table 5

Destructive Tests by ASTM Number

Property Tested	ASTM Test
Asphalt Concrete Samples	
Marshall stability and flow	D 1559-82
Bulk specific gravity and density of compacted asphalt concrete	D 2726-83
Theoretical maximum specific gravity of asphalt concrete	D 2041-78
Percent air voids	D 3203-83
Asphalt by weight of aggregates/mix	D 2172
Asphalt recovery from solution	D 1856-79
Penetration of asphalt	D 5-83
Softening point	(AASHTO:T53-81)
Specific gravity of bitumen	D 70-82
Concrete Samples	
Splitting tensile strength of cylindrical concrete specimens	C 496-71
Soil Samples	
Particle size analysis of soils	D 422-63 (1972)
Liquid limit, plastic limit	D 4318-83
Classification of soils for engineering purposes	D 2487-83
Moisture density regulations of soils and soil-aggregate mixtures	D 1557-78
California Bearing Ratio (CBR)	D 1883-73 (1978)
Specific gravity of course aggregates	C 127-81
Specific gravity of fine aggregates	C 128-79

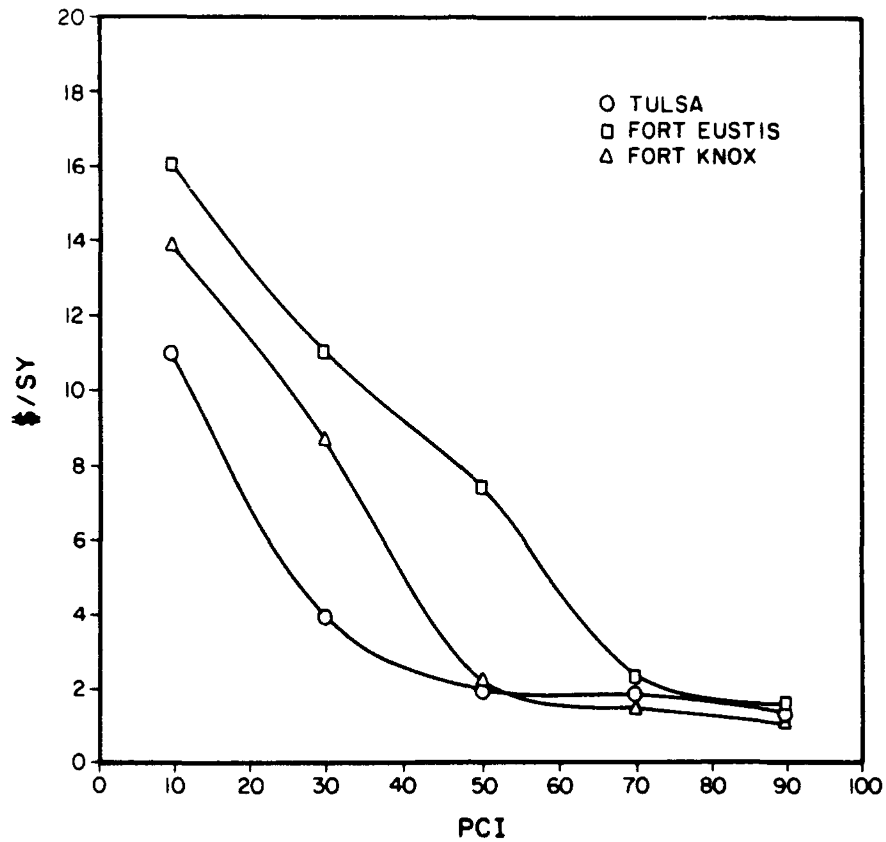


Figure 37. Average rehabilitation cost for asphalt concrete roads.

Step 2: Variation of PCI. Variations of materials, construction, subgrade, and/or traffic loadings may cause certain portions of a given section to show a significantly different condition than the average of the overall section. Areas having a poorer condition are of major concern. Variation within a section occurs on both a localized random basis and a systematic basis. Systematic variation occurs when a large concentrated area of the section has a significantly different condition from the rest. For example, if traffic is channelized into a certain portion of the section, that portion may show much more distress than the rest of the area. When a significant amount of systematic variability exists within a section, strong consideration should be given to dividing it into two or more sections. A localized random variation might point to a localized problem, such as a soft subgrade spot or poor compaction around a culvert, which should be corrected.

Step 3: Rate of Deterioration. The long-term rate of deterioration is determined through a comparison with the deterioration rate of other pavements in the same family. A family of pavements is defined as those with the same surface type (AC, PCC, etc.), pavement use (RUNWAY, ROADWAY, etc.), pavement rank (primary, secondary, etc.), level of traffic (trafficked, nontrafficked), and other factors that might affect pavement performance.

A family's rate of deterioration can be analyzed using the Family Analysis Report. This report plots PCI vs. age, as shown by the example in Figure 25. The figure shows an envelope covering the majority of data (one standard deviation above and below the best fit curve). Pavement sections located within that envelope are classified as normal rate of deterioration, above the envelope as low, and below the envelope as high.

1. **Overall Condition Rating - PCI**

Rating -	Failed,	Very Poor,	Poor,	Fair,	Good,	Very Good,	Excellent
PCI	0-10	11-25	26-40	41-55	56-70	71-85	86-100

2. Variation of Condition Within Section - PCI
   a. Localized Random Variation — Yes, No
   b. Systematic Variation — Yes, No
3. Rate of Deterioration of Condition - PCI
   a. Long-term period, since construction or last overall repair — Low, Normal, High
   b. Short-term period, 1 year — Low, Normal, High
4. Distress Evaluation
   a. Cause
      Load Associated Distress — ___ percent deduct value
      Climate/Durability Associated — ___ percent deduct value
      Other Associated Distress — ___ percent deduct value
   b. Moisture, Drainage, Effect on Distress — Minor, Moderate, Major
5. Deficiency of Load-Carrying Capacity — No, Yes
6. Surface Roughness — Minor, Moderate, Major
7. Skid Resistance/Hydroplaning Potential — Minor, Moderate, Major
8. Previous Maintenance — Low, Normal, High
9. Comments: ____________________

____

____

____

____

____

Figure 38. Stepwise procedure for section evaluation summary.

The pavement's rate of deterioration must also be estimated based on a short-term or yearly loss of PCI. When the mean PCI of a section (assuming that only routine maintenance is applied) decreases by seven or more PCI points, the rate of deterioration should be considered high. If the loss in PCI is four to six points, the short-term rate of deterioration should be considered normal or average. The Micro PAVER Condition History Report (see Figure 39) provides a PCI time curve for a specific section, including a 5-year projection, which will aid in determining the rate of deterioration. Engineering judgment should be exercised carefully when evaluating the short-term rate of deterioration because of errors in repeatability of the PCI.

Step 4: Pavement Distress Evaluation. Examination of specific distress types, severities, and quantities provides a valuable aid in determining the cause of pavement deterioration, its condition, and eventually its M&R needs. Figures 40 and 41 generally classify distress types for concrete- and asphalt-surfaced pavements according to cause and effect on condition. Conditions at each pavement will dictate which distresses will be placed into each group.

In the PAVER System, distresses have been classified into three groups based on cause: (1) load-associated, (2) climate-associated, (3) caused by other factors. Tables 6 and 7 list distress classification as used in PAVER for paved roads and airfields, respectively. Unsurfaced roads are not classified by PAVER. The following steps (a through d below) comprise a procedure for manually determining the primary cause(s) of pavement condition deterioration for a given section.

a. The total deduct values attributable to load, climate, and other causes are determined separately. For example, the following distresses were measured on an asphalt section and the deduct values determined from the curves provided in Appendix B:

Distress Type	Severity	Overall Density For Section	Deduct Value
Alligator Cracking	Medium	6.4	50
Transverse Cracking	Low	2.0	8
Rutting	Low	2.7	20

The total deduct value attributable to load is 70, and that attributable to climate is 8. There is no distress classified as "other."

b. The percentage of deducts attributable to load, climate, and other causes is computed. For the above example, the calculation is as follows:

$$\text{Load} = 70/78 \times 100 = 90 \text{ percent}$$

$$\text{Climate} = 8/78 \times 100 = 10 \text{ percent}$$

$$\text{Total} = 100 \text{ percent}$$

c. The percentage of deduct values attributed to each cause is the basis for determining the primary cause(s) of pavement deterioration. In this example, distresses caused primarily by load have resulted in 90 percent of the total deducts, whereas all other causes have produced only 10 percent. Thus, traffic load is by far the major cause of deterioration for this pavement section. PAVER automatically calculates the total deduct values attributable to load, climate, and other associated distresses for a section when the PCI is calculated.

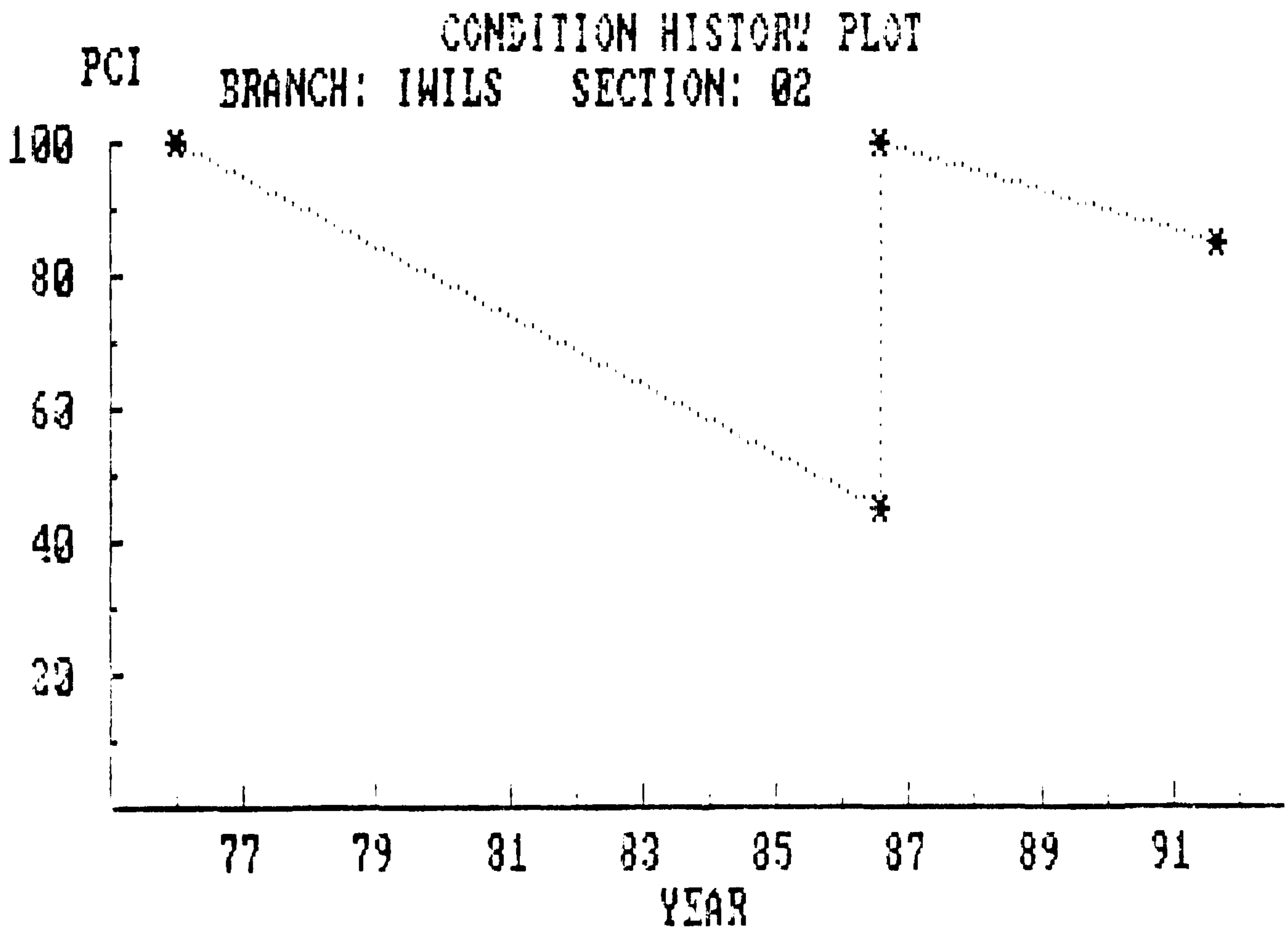


Figure 39. Example PCI/time curve . om the Condition History Report.

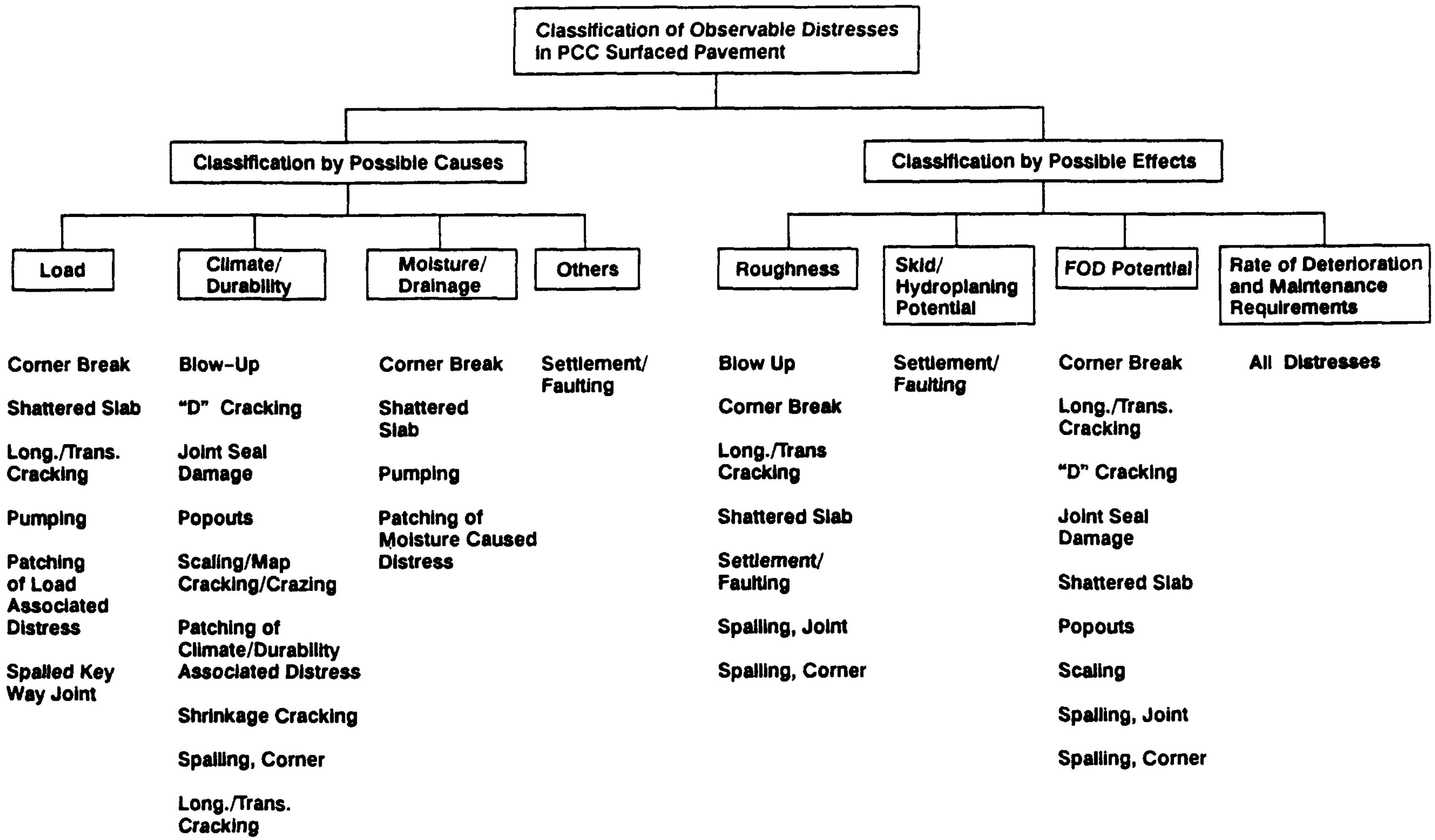


Figure 40. General classification of concrete distress types based on causes and effects on conditions.

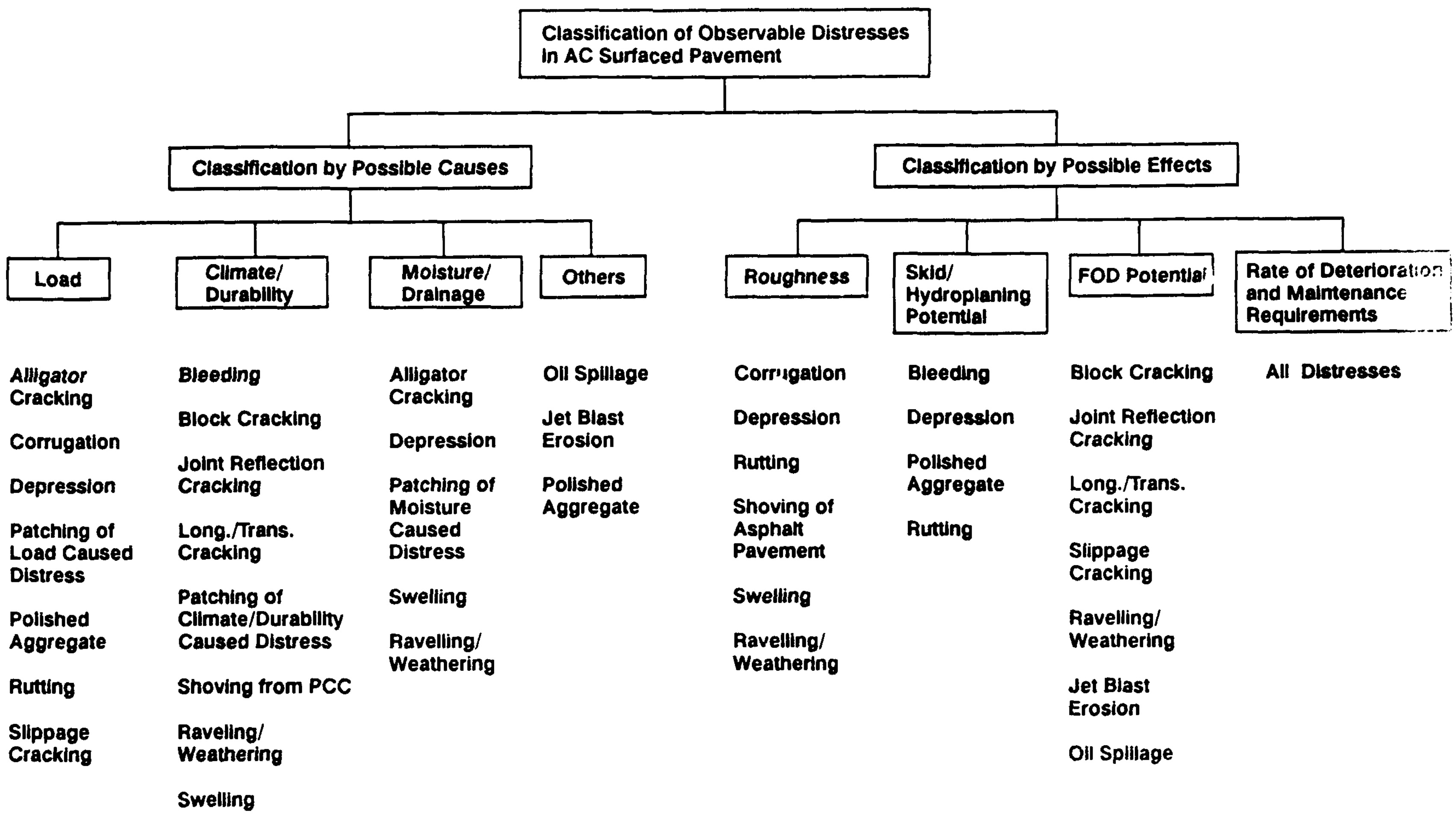


Figure 41. General classification of asphalt distress types based on causes and effects on conditions.

Table 6

PAVER Distress Classification for Roads and Parking Areas

Code	Distress	Cause
Asphalt-Surfaced Road & Parking Areas		
01	Alligator Cracking	Load
02	Bleeding	Other
03	Block Cracking	Climate
04	Bumps and Sags	Other
05	Corrugation	Other
06	Depression	Other
07	Edge Cracking	Load
08	Joint Reflection	Climate
09	Lane/Shoulder Drop-Off	Other
10	Longitudinal and Traverse Cracking	Climate
11	Patching and Utility Cut Patching	Other
12	Polished Aggregate	Other
13	Potholes	Load
14	Railroad Crossing	Other
15	Rutting	Load
16	Shoving	Load
17	Slippage Cracking	Other
18	Swell	Other
19	Weathering and Raveling	Climate
Portland Cement Concrete Roads & Parking Areas		
21	Blowup/Buckling	Load
22	Corner Break	Climate
23	Divided Slab	Other
24	Durability ("D" Cracking)	Climate
25	Faulting	Other
26	Joint Seal Damage	Load
27	Lane/Shoulder Drop-Off	Other
28	Linear Cracking	Other
29	Patching, Large	Other
30	Patching, Small	Other
31	Polished Aggregate	Other
32	Popouts	Load
33	Pumping	Other
34	Punchout	Other
35	Railroad Crossing	Climate
36	Scaling/Map Cracking/Crazing	Climate
37	Shrinkage Cracks	Climate
38	Spalling, Corner	Climate
39	Spalling, Joint	Load

Table 7

PAVER Distress Classification for Airfields

Code	Distress	Cause
Asphalt-Surfaced Airfields		
41	Alligator Cracking	Load
42	Bleeding	Other
43	Block Cracking	Climate
44	Corrugation	Other
45	Depression	Other
46	Jet Blast	Other
47	Joint Reflection/Cracking	Climate
48	Longitudinal/Transverse Cracking	Climate
49	Oil Spillage	Other
50	Patching	Other
51	Polished Aggregate	Other
52	Weathering/Raveling	Climate
53	Rutting	Load
54	Shoving	Other
55	Slippage Cracking	Other
56	Swelling	Other
Concrete-Surfaced Airfields		
61	Blowup	Climate
62	Corner Break	Climate
63	Linear cracking	Other
64	Durability Cracking	Other
65	Joint Seal Damage	Other
66	Small Patch	Other
67	Large Patch/Utility Cut	Other
68	Popouts	Other
69	Pumping	Load
70	Scaling/Crazing	Other
71	Faulting	Other
72	Shattered Slab	Other
73	Shrinkage Cracking	Climate
74	Joint Spalling	Load
75	Corner Spalling	Load

d. The pavement drainage situation should be evaluated. If moisture is accelerating deterioration of the pavement, the engineer must determine how it is happening and why (e.g., groundwater table, infiltration of surface water, ponding water on the pavement). If moisture is contributing significantly to the rate of pavement condition deterioration, ways must be found to prevent or minimize this problem.

Step 5: Load-Carrying Capacity Evaluation. The objective of this evaluation is to determine if the existing pavement structure is deficient based on current or expected future traffic. The distress evaluation procedure presented above can be used to determine the pavement structural adequacy with respect to current traffic. Structural analysis for overlay design or analysis for a change in mission can only be done using the results from NDT and destructive testing.

Step 6: Surface Roughness. There are three ways to evaluate surface roughness. First, user complaints are considered to be subjective but highly reliable sources of qualitative roughness information. Second, certain distress types contained in the PCI may be correlated with localized roughness. Third, the roughness can be measured quantitatively using special equipment.[10]

Step 7: Skid Resistance and Hydroplaning Potential. Skid resistance can be measured using special equipment.[11] Also, skid problems can be identified by reviewing accident records.

Step 8: Previous M&R applied. A pavement section can be kept in operating condition almost indefinitely if extensive M&R is applied continually. However, there are major drawbacks to this maintenance strategy, such as overall cost, downtime of pavement, increase in roughness caused by excessive patching, and limitations of manpower and equipment. The amount and types of previous M&R applied to a pavement section are important factors in deciding what type of M&R is needed. PAVER allows the agency to store records of M&R that has been performed on pavement sections. A pavement for which a large portion has been patched or replaced must have had many previous distress problems which are likely to continue in the future.

Permanent patching of asphalt pavements and large areas of patching (more than 5 sq ft) and/or slab replacement of concrete pavement can be used as criteria for evaluating previous maintenance. Patching or slab replacement ranging between 1.5 and 3.5 percent (based on surface area for asphalt and number of slabs for concrete) is considered normal; more than 3.5 percent is considered high, and less than 1.5 percent is considered low. Some pavement sections may have received an excessive amount of M&R other than patching. If the engineer finds that a section should be evaluated as having high previous maintenance, then this decision should take precedence over evaluation criteria based on only patching and slab replacement.

Step 9: Comments. Any constraints in choosing an M&R alternative should be identified in the comments section.

Identification of Feasible M&R Alternatives

The selection of feasible M&R alternatives should be based on results of the pavement evaluation discussed above. A set of 14 general M&R alternatives is found in Table 8. To further assist in

[10] J. A. Crovetti and M. Y. Shahin, *Long-Term Pavement Performance Equipment Selection*, Strategic Highway Research Program (SHRP) (1986).

[11] Federal Aviation Administration (FAA) Advisory Circular 150/5345-1, *Approved Airport Equipment* (July 1988); A. H. Joseph and R. A. Andreas, *Literature Review of Skid-Measuring Equipment and Techniques*, Misc. Paper 5-73-28 (U.S. Army Engineer Waterways Experiment Station, 1972).

Table 8

Maintenance and Repair Alternatives

1. Reconstruction	
2. Structural overlay (asphalt-concrete)	8. Surface treatment
3. Leveling overlay (asphalt-overlay)-- 2 in. nominal	9. Slab jacking
	10. Surface recycling
4. PCC overlay	11. Structure recycling
5. Grooving	12. Redefine section
6. Grinding	13. Drainage modification
7. Porous friction course	14. Routine maintenance

identifying various repair alternatives, Figure 42 presents common overall M&R alternatives for both concrete- and asphalt-surfaced pavements.

Once a list of feasible M&R alternatives has been developed, life-cycle cost must be analyzed in order to select the most cost-effective solution. This step is discussed in Chapter 10, **USE OF THE PAVER SYSTEM FOR PROJECT JUSTIFICATION.**

Jointed-Concrete-Surfaced Pavements

1. Overlay with unbonded, partially bonded, or fully bonded Portland cement concrete (rigid overlay).

2. Overlay with all-bituminous or flexible overlay (nonrigid overlay).

3. Portland cement concrete pavement recycling--process by which an existing Portland cement concrete pavement is processed into aggregate and sand sizes, then used in place of, or in some instances with addition of, conventional aggregates and sand, into a new mix and placed as a new Portland cement concrete pavement.

4. Pulverize existing surface in place, compact with heavy rollers, place aggregate on top, and overlay.

5. Replace keel section, i.e., remove central portion of pavement feature (subjected to much higher percentage of traffic coverage than rest of pavement width) and replace with new pavement structure.

6. Reconstruct by removing existing pavement structure and replacing old one.

7. Grind off thin layer of surface if predominant distress is scaling or other surface stresses; overlay may or may not be applied.

Groove surface if poor skid resistance/hydroplaning potential is the main reason for overall M&R.

Asphalt- or Tar-Surfaced Pavement

1. Overlay with all-bituminous or flexible overlay.

2. Overlay with Portland cement concrete (rigid overlay).

3. Hot-mix asphalt pavement recycling--one of several methods in which the major portion of the existing pavement structure (including, in some cases, the underlying untreated base material) is removed, sized, and mixed hot with added asphalt cement at a central plant. The process may also include the addition of new aggregate and/or softening agent. The finished product is a hot-mix asphalt base, binder, or surface course.

4. Cold-mix asphalt pavement recycling--one of several methods in which the entire existing pavement structure (including, in some cases, the underlying untreated base material) is processed in place or removed and processed at a central plant. The materials are mixed cold and can be reused as an aggregate base, or asphalt and/or other materials can be added during mixing to provide a higher strength base. This process requires use of an asphalt surface course or surface seal coat.

5. Asphalt pavement surface recycling--one of several methods in which the surface of an existing asphalt pavement is planed, milled, or heated in place. In the latter case, the pavement may be scarified, remixed, relaid, and rolled. In addition, asphalts, softening agents, minimal amounts of new asphalt hot mix, aggregates, or combinations of these may be added to obtain desirable mixture and surface characteristics. The finished product may be used as the final surface, or may, in some instances, be overlaid with an asphalt surface course.

6. Apply a porous friction course to restore skid resistance and eliminate hydroplaning potential.

7. Replace keel section, i.e., remove central portion of pavement feature (subjected to much higher percentage of traffic coverage than rest of pavement width) and replace with new pavement structure.

8. Reconstruct by removing existing pavement structure and replacing with a new one.

Figure 42. Types of overall repair.

9 DEVELOPMENT OF INPUT TO ANNUAL AND LONG-RANGE PAVEMENT WORK PLANS USING PAVER

Once the inspection and construction history data have been entered into the data base, the PAVER system can be used to develop annual and long-range work plans. PAVER does not specifically generate these plans, but serves as a decision-making tool that provides pavement managers with the information needed to produce these plans.

Annual Work Plan

An Annual Work Plan (AWP) consists of the Annual Recurring Requirements (ARR) and Programmed Year Projects (PYP). The following PAVER reports are used to develop them.

- The PCI Report lists the pavement section numbers and the area, age, and PCI from the latest inspection.

- The Family Analysis Report and Section Prediction Report provide a best-fit curve for predicting future PCI based on pavement age and grouping by homogeneous families of structure and use.

- The Budget Condition Forecasting Report estimates future annual budgets to maintain the pavement above a minimum PCI.

- The Network Maintenance Report estimates M&R costs based on a previously defined distress maintenance policy.

- The Preventive Maintenance Report provides (1) a summary of the localized and global preventive maintenance requirements and (2) a list of pavements with structural distress having a PCI above a specified minimum PCI.

Annual Recurring Requirements

The ARR consists of activities classified as either preventive or safety M&R. Preventive M&R consists of both localized maintenance (e.g., crack sealing and patching) and global maintenance (e.g., surface sealing). Safety M&R involves pothole patching and lane shoulder drop-off leveling. These tasks should be fully funded in accordance with AR 420-72.

Preventive M&R

Preventive M&R consists of localized and global maintenance activities that slow the deterioration rate to preserve the pavement investment. Localized preventive maintenance includes crack sealing and various patching techniques, as shown in Figure 43. Global preventive maintenance includes various methods of surface sealing for asphalt pavements and joint sealing for concrete pavements, as shown in Figure 44.

An example of a PAVER localized preventive maintenance policy for asphalt surfaced roads is shown in Figure 45. The policy addresses only localized maintenance for each distress type/severity combination and should be applied only to pavements above the Critical PCI. The Critical PCI is defined as the PCI value below which the pavement shows a significant increase in both the rate of deterioration and preventive maintenance cost. Figure 46 is a schematic diagram of a typical deterioration curve showing the recommended range of the Critical PCI value. The Critical PCI is usually between 55 and 70. Selection of the Critical PCI value depends on the pavement network and family of pavements under consideration. A value of 55 is most likely to be selected unless an unreasonable preventive maintenance cost is determined at or near the 55 level. If so, a higher value should be used. The Family Analysis Report and the Network Maintenance Report are used in identifying the Critical PCI value as described later in this chapter.

The selection criteria of the Preventive Maintenance Report allow the user to specify which maintenance policy to apply to pavement sections above the Critical PCI. This report is very useful in identifying both localized and global preventive maintenance needs.

Global preventive maintenance is recommended for those asphalt pavement sections having a PCI above the Critical value and showing no structural distress. The specific type of maintenance depends on the age of the pavement, its use, and existing distresses. For example, a pavement with weathering and raveling will benefit from a fog seal or a rejuvenator. A pavement with a smooth surface or skid problem should not be treated with a rejuvenator but should be considered for a chip or slurry seal or should be programmed for a thin overlay (see the section on Programmed Year Projects). Global preventive maintenance for Portland cement concrete (PCC) pavements usually consists of joint sealing.

Safety M&R

Safety M&R consists of localized repairs needed to keep the pavement safe. An example of a localized safety M&R policy for asphalt surfaced roads is shown in Figure 47. The complete policy would address localized M&R for each distress type/severity combination. Localized safety should be applied only to those pavement sections not selected for preventive maintenance. For example, if all sections with a PCI over 60 receive preventive maintenance, all sections at or below 60 should receive safety M&R. The localized safety policy is actually a small portion of the preventive maintenance policy.

Although major repair may be scheduled for some pavement sections, the time needed to plan and complete the repair may leave the sections unsafe for some time. Safety M&R is intended to ensure that the pavement is usable and safe in the interim before major repair.

The localized safety maintenance requirements are easily generated using the Network Maintenance Report. The selection criteria of the report allow the user to apply a specific safety policy to pavements below the Critical PCI. It should be noted that applying the preventive maintenance policy to pavement sections below the Critical PCI value is exorbitantly expensive and not cost effective in most cases. The lower the PCI, the higher the cost. It may be cheaper to reconstruct pavements with a PCI below the Critical value than to try to perform preventive maintenance.

Programmed Year Projects

PYP includes all pavement sections at or below the Critical PCI as well as all sections above the Critical PCI that are beginning to show structural distress. Sections above the Critical PCI and approaching the Critical PCI should be funded along with the ARR.

If the budget permitted, performing the most cost-effective M&R on all the PYP sections would be desirable. However, this is not usually the situation. Therefore, it is important to prioritize the PYP sections to ensure the highest return on investment and to meet managerial constraints and preferences.

The number one priority should undoubtedly be given to pavement sections above the Critical PCI level that show structural distress. These sections are beginning to deteriorate rapidly, but the deterioration can be arrested and the pavement restored to good condition at a low cost if the rehabilitation is done promptly.

Other pavement sections can be prioritized according to the pavement condition and rank (functional classification). Figure 48 is a recommended priority scheme for the PYP sections.

The Budget Condition Forecasting Report, which is based on average repair costs for a given PCI, provides a quick tool for developing the PYP. This report is a combination of the Budget Planning Report and the PCI Frequency Report. It provides a 5-year budget plan estimating the annual rehabilitation cost required to maintain the pavement condition above a minimum standard. It also allows the user to project what effect varying this minimum standard has on the budget and gives an overall frequency of condition based on this minimum. Information in this report can be used to define the pavement network's condition, plan future M&R, and predict the impact of not performing any major repairs.

Procedure Summary

The following is a step-by-step summary of the PAVER procedure for developing the AWP.

1. Determine the Critical PCI:

1.1. Use the PAVER Family Analysis Report to visually establish a range of possible Critical PCI values.

1.2. Select or establish preventive and safety maintenance policies for localized distress.

1.3. Apply the preventive maintenance policy to pavement sections in the identified Critical PCI range using the Network Maintenance Report. The Critical PCI value is the PCI at which the preventive maintenance costs begin to increase rapidly.

2. Develop AWP above the Critical PCI (Figure 49):

2.1. Use the Preventive Maintenance Report to identify the localized and global preventive maintenance needs.

2.2. The Preventive Maintenance Report also identifies those pavement sections beginning to show structural distress and recommends them for project evaluation instead of global preventive maintenance. These sections should be reinspected to make sure the PCI is current (within last 6 months). The following analysis should be conducted:

a. Review distress data to verify the existence of structural distress. If structural distress does not exist or is very localized and the PCI is relatively high, the section should be removed from the project evaluation list.

b. Evaluate the rate of deterioration through the use of the Condition History Report. If an adequate budget is not available to perform M&R on all the sections, the sections with the highest rate of deterioration should be repaired first. For sections of approximately the same rate of deterioration, those with a lower PCI should be repaired first.

c. To obtain the estimated repair cost, run the BCF Report with a minimum PCI equal to 100 for all sections. Sort the output by branch number and section number.

3. Develop AWP at or Below the Critical PCI (Figure 50):

3.1 Using the Network Maintenance Report, apply the localized safety M&R policy to all pavement sections below the Critical PCI to identify the localized safety needs.

3.2 Determine major M&R for sections approaching the Critical PCI at the programmed year by running the BCF Report for all sections above the Critical PCI beginning with the programmed year. The selected minimum PCI should be equal to the Critical PCI. Sort the report output by year to repair, branch number, and section number. Examine the list of sections in the programmed year and make sure to subtract sections already identified in step 2.2.

It is recommended that the sections approaching the Critical PCI be verified using the Section Prediction Report. This is needed since the current version of the BCF Report uses the straight line condition projection procedure rather than the family curve concept. If the results from the BCF and Section Prediction Report do not agree, the Section Prediction Report results should be used.

3.3 Determine major M&R for sections below the Critical PCI by running the BCF Report for all pavement sections below the Critical PCI beginning with the programmed year. The selected minimum PCI should be equal to or greater than the Critical PCI. Since all sections are below the Critical PCI, all sections will show under the programmed year. Examine the list of sections and subtract sections already identified in item 2.2 above.

4. Develop ARR and PYP (Figure 51):

4.1 Add the results of Step 2.1 (localized and global preventive maintenance) and Step 3.1 (localized safety maintenance) to calculate the ARR.

4.2 Add the results from Step 2.2 (the major repairs above the Critical PCI), Step 3.2 (sections approaching the Critical PCI), and Step 3.3 (sections below the Critical PCI).

AWP Example

The following example illustrates the development of an AWP for a small network of asphalt concrete, family housing roads from an Army installation consisting of eight pavement sections (Figure 52). These pavement sections received a PCI inspection in the fall of 1986.

Step 1.1. The Family Analysis Report deterioration curve was generated for the network (Figure 53). The range for the Critical PCI is 55 to 70.

Step 1.2. The selected preventive and safety policies for the network were generated (Figures 54 and 55, respectively).

Step 1.3. The Network Maintenance Report was generated for pavement sections in the 55 to 70 PCI range using the preventive maintenance policy. The report output is shown in Figure 56. Two sections, 4 and 5, are in that range. The estimated cost of M&R for both sections is not high; therefore, the Critical PCI value of 55 was selected. To demonstrate how preventive maintenance costs increase below the Critical PCI, the preventive policy was applied to these pavements. The results are shown in Figure 57. The M&R costs were high, ranging from to $22,204 to $66,792 per section, with a total estimated cost of $141,131. This finding confirmed the correct selection of the Critical PCI.

Step 2.1. The Preventive Maintenance Report is run for all pavement sections above the Critical PCI of 55 to identify the localized and global preventive maintenance requirements. The total cost of localized preventive maintenance, shown in Figure 58, is $840. The Network Maintenance Report can be used to generate section details with the work type identified for each distress. The global maintenance, shown in Figure 59, indicates that sections 4, 6, 7, and 8 should receive a rejuvenator or fog seal at a total cost of $6,331. (A rejuvenator is the preferred option but a fog seal would be better than nothing.)

Step 2.2. The highest PYP priority is assigned to section 5, which has a PCI of 69. Although *this section has a PCI above the Critical value*, it was identified by the Preventive Maintenance Report for project evaluation because it has medium severity alligator cracking which is a load-related distress. The BCF Report was used to estimate the cost of repair at $7,250 as shown in Figure 60.

Step 3.1. The application of the safety policy to pavement sections below the Critical PCI of 55 is shown in Figure 61. The total cost of safety M&R is $27.

Step 3.2. The BCF Report output for the sections approaching the critical PCI is shown in Figure 62. The cost in year 1 for the annual work plan is 0.

Step 3.3. Priorities for the PYP sections below PCI 55 were assigned using Figure 48. All the sections were classified as priority 10 because they all ranked tertiary and had PCIs below 40. The Budget Planning Report output for the priority 10 classification is shown in Figure 63.

Step 4.1. The total budget for the ARR program was calculated by adding the costs from steps 2.1 and 3.1 for a total of $7,198.

Step 4.2. The total budget for the PYP was calculated by adding the costs from steps 2.2, 3.2, and 3.3 for a total of $89,880.

Figure 64 shows a summary of the AWP work classification for the network. The total AWP is the sum of the ARR and PYP: $97,078. The AWP example has been limited to a small data base for the purpose of demonstration, but the same steps can be easily applied to any size data base. Moreover, this procedure does not preclude the use of engineering judgment; rather, it is intended to facilitate and encourage the use of engineering experience and principles.

Long Range Work Plan Procedure Summary

Although development of long range plans is much simpler than development of annual plans, PAVER can greatly facilitate the process. The long range plan should address the same M&R types addressed in the annual plan.

1. Determine Localized Preventive Maintenance Cost.

The ideal way to project future localized preventive maintenance is to predict the condition of each pavement section and estimate the future needs based on a preestablished PCI vs. localized maintenance cost relationship, as shown in Figure 65. The pavement section condition prediction should take into account the scheduled global preventive major M&R. Because this procedure is not automated, the calculations can be tedious. It is acceptable to use the estimated localized preventive maintenance from the annual plan and repeat the value annually.

2. Determine Global Preventive Maintenance Cost.

Global preventive maintenance should be applied every 2 to 5 years to pavements predicted to remain above the Critical PCI. This application should be subject to both engineering and administrative conditions. For example, a rejuvenator should not be used if the pavement has received a slurry seal, and an aggregate seal should not be applied on heavily traveled primary pavements.

Since most PAVER data bases do not include historical global preventive maintenance records, it would be acceptable to use the same estimated dollar value from the annual plan every 3 years until the end of the long range plan period. Once historical records are available, a better estimate would be an average of several past global maintenance costs.

3. Determine Localized Safety Maintenance Cost.

Use the value from the annual work plan and repeat annually. As the network condition improves, this value should decrease and optimally should be close to zero.

4. Determine the Cost of Pavement Sections Reaching the Critical PCI.

The BCF Report output generated in Step 3.2 is used here. The list of sections in each of the years beyond the programmed year should be examined and those sections already identified by the annual work plan for major M&R should be eliminated.

All sections with structural distress and those below the Critical PCI were identified by the annual work plan. No new sections are identified in this area, but if all of the work cannot be completed in year 1 due to budget constraints, the remaining work will move to year 2 and so on.

LWP Example

Step 1. The Localized Preventive Maintenance cost in the AWP is $840 (Figure 58). This cost is repeated annually as shown in Figure 64.

Step 2. The Global Preventive Maintenance cost in the AWP is $6,331 (Figure 59). Global maintenance will be repeated every 3 years so this cost will be incurred in year 4 as shown in Figure 64.

Step 3. The Localized Safety Maintenance cost of $27 (Figure 61) will be repeated in each year as shown in Figure 64.

Step 4. The BCF Report generated in Step 3.2 is used to determine the cost of pavement sections reaching the Critical PCI. Figure 62 shows that in 1993, section 7 is predicted to have a PCI of 51. The cost to repair this section is $16,320.

Figure 64 shows the summary of the annual and long range work plans.

It should be noted that both the annual work plan and the long range work plan should be updated after performing work or conducting inspections.

- CRACK SEALING
- PATCHING, AC LEVELING
- PATCHING, SURFACE COURSE
- PATCHING, FULL DEPTH

Figure 43. Typical asphalt pavement localized preventive maintenance.

- NONAGGREGATE SURFACE TREATMENTS
  — FOG SEAL
  — COAL-TAR SEAL
  — REJUVENATING SEAL

- AGGREGATE SURFACE TREATMENTS
  — SAND SEAL
  — SLURRY SEAL
  — AGGREGATE SURFACE TREATMENT

Figure 44. Typical asphalt pavement global preventive maintenance.

DIST	SEV	MAINT	COST/$	UNIT
ALLIGATOR CRACKING	M & H	PATCHING FULL DEPTH	5.0	SY
BLOCK CRACKING	M & H	CRACK SEALING	0.6	LF
•				
•				
•				
•				
•				

Figure 45. Example localized preventive maintenance policy.

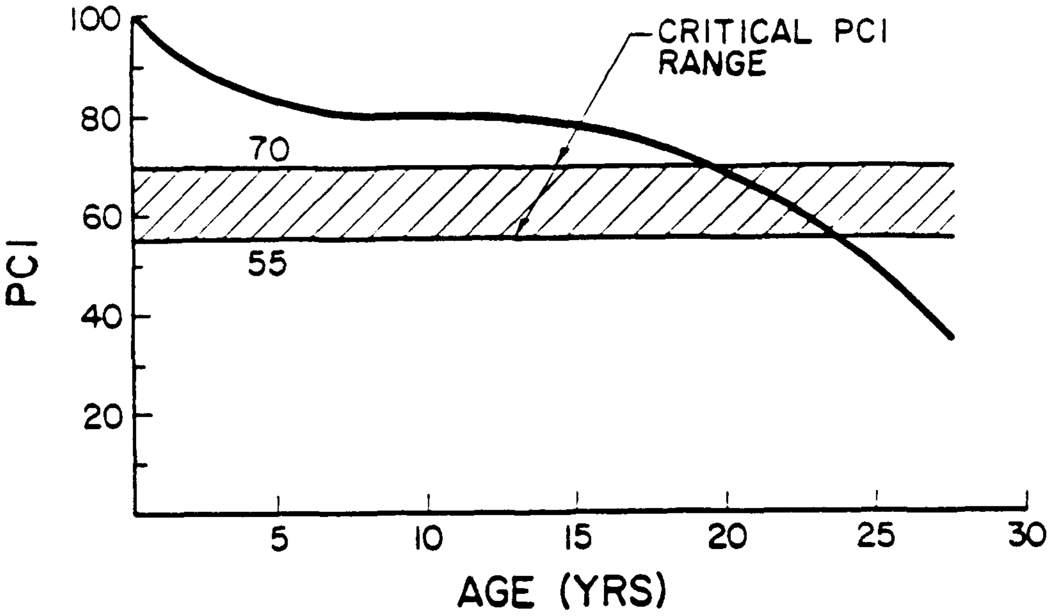


Figure 46. Critical PCI range.

DIST	SEV	MAINT	COST/$	UNIT
BUMPS	H	PATCHING, SURFACE	18.0	SY
POTHOLE	M & H	PATCHING, FULL DEPTH	45.0	SY

Figure 47. Example localized safety maintenance policy.

PCI RANGE	PAVEMENT RANK		
	P	S	T
56 TO CRITICAL PCI	2	4	7
41 TO 55	3	6	9
LESS THAN 41	5	8	10

Figure 48. Prioritization scheme for Programmed Year Projects.

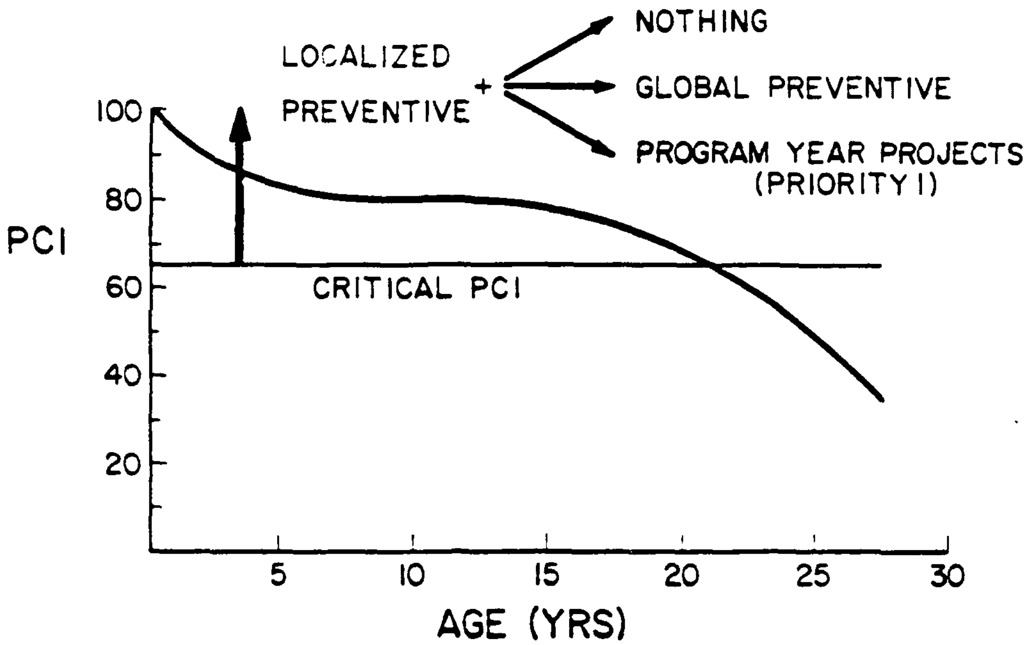


Figure 49. Annual Work Plan, PCI greater than Critical PCI.

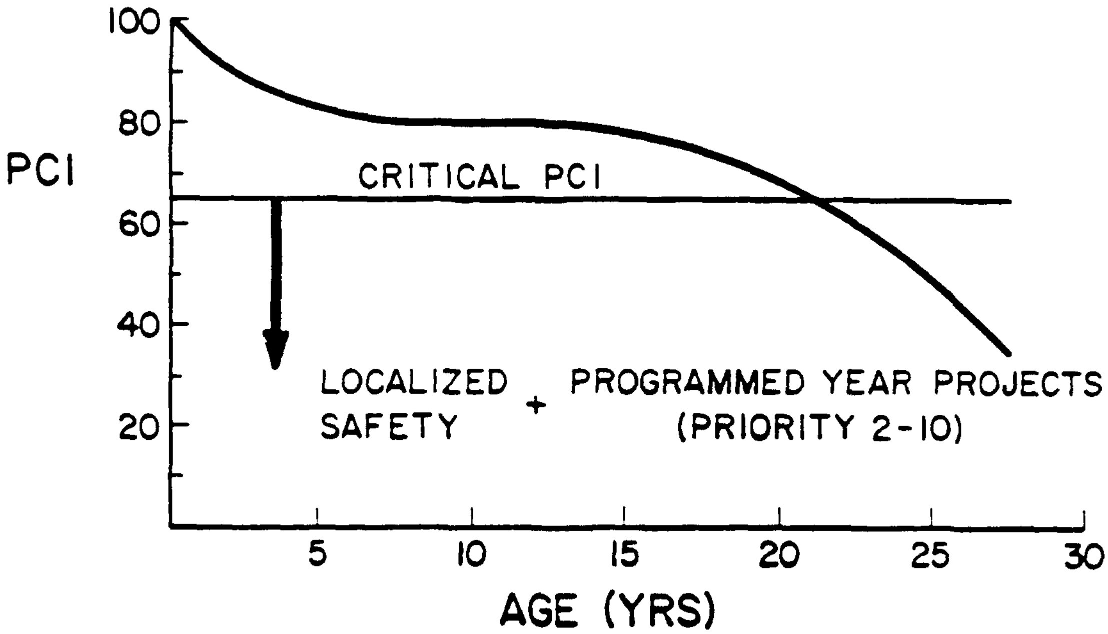


Figure 50. Annual Work Plan, PCI less than Critical PCI.

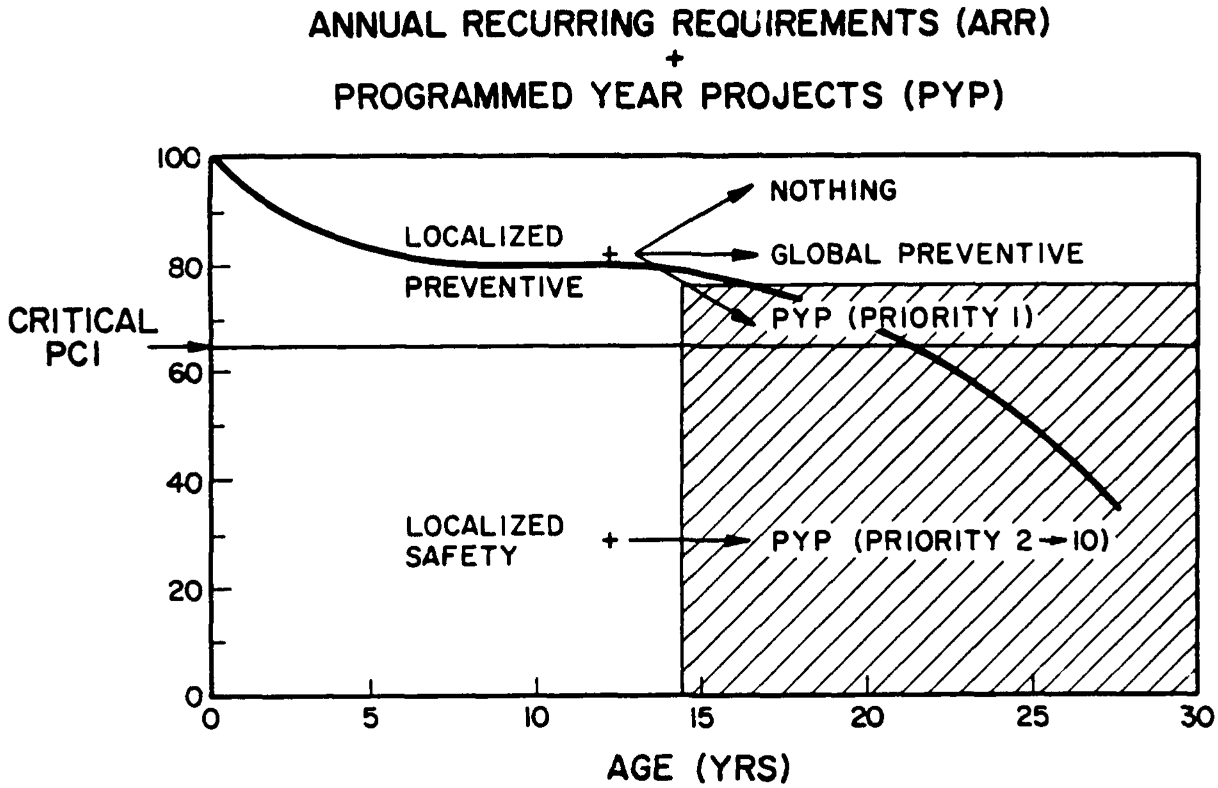


Figure 51. Summary of Annual Work Plan.

SECTION	AGE	PCI
1	27	30
2	27	37
3	27	39
4	21	59
5	21	69
6	2	84
7	2	89
8	2	98

Figure 52. Example PCI Report.

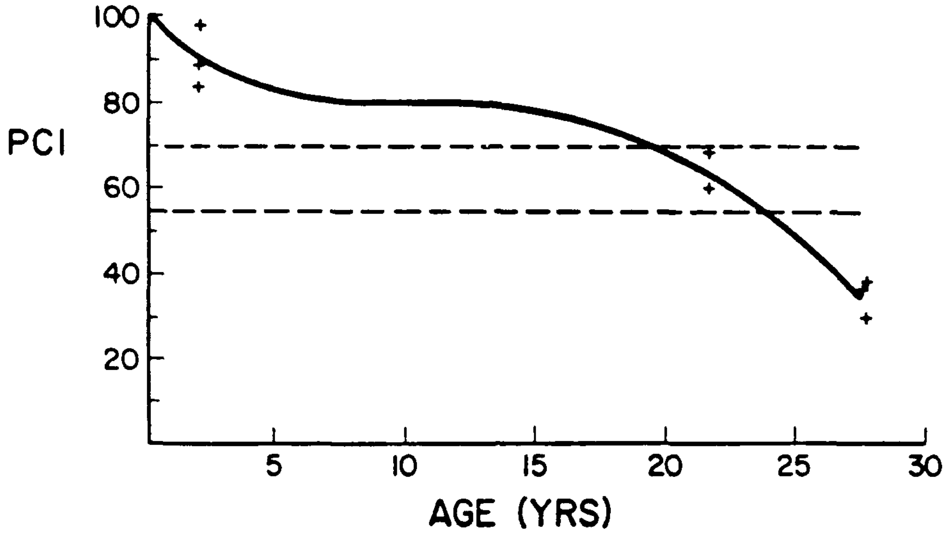


Figure 53. Example Family Analysis Report.

Policy Number: 2	Policy Description: PREVENTIVE , ROADS

Distress	Sev	Work Type & Description	Cost	Unit
1 ALLIGATOR CR	H	PA-AD Patching - AC Deep	5.00	sq. ft.
1 ALLIGATOR CR	M	PA-AD Patching - AC Deep	5.00	sq. ft.
3 BLOCK CR	M	CS-AC Crack Sealing - AC	.60	ft.
3 BLOCK CR	H	CS-AC Crack Sealing - AC	.60	ft.
4 BUMPS/SAGS	M	PA-AS Patching - AC Shallow	2.00	sq. ft.
4 BUMPS/SAGS	H	PA-AS Patching - AC Shallow	2.00	sq. ft.
5 CORRUGATION	M	PA-AL Patching - AC Leveling	1.00	sq. ft.
5 CORRUGATION	H	PA-AD Patching - AC Deep	5.00	sq. ft.
6 DEPRESSION	M	PA-AD Patching - AC Deep	5.00	sq. ft.
6 DEPRESSION	H	PA-AD Patching - AC Deep	5.00	sq. ft.

Distress	Sev	Work Type & Description	Cost	Unit
7 EDGE CR	M	CS-AC Crack Sealing - AC	.60	ft.
7 EDGE CR	H	PA-AD Patching - AC Deep	5.00	sq. ft.
8 JT REF. CR	M	CS-AC Crack Sealing - AC	.60	ft.
8 JT REF. CR	H	CS-AC Crack Sealing - AC	.60	ft.
9 LANE SH DROP	M	PA-AL Patching - AC Leveling	1.00	sq. ft.
9 LANE SH DROP	H	PA-AL Patching - AC Leveling	1.00	sq. ft.
10 L & T CR	M	CS-AC Crack Sealing - AC	.60	ft.
10 L & T CR	H	CS-AC Crack Sealing - AC	.60	ft.
11 PATCH/UT CUT	H	PA-AD Patching - AC Deep	5.00	sq. ft.
13 POTHOLE	M	PA-AD Patching - AC Deep	5.00	sq. ft.

Distress	Sev	Work Type & Description	Cost	Unit
13 POTHOLE	H	PA-AD Patching - AC Deep	5.00	sq. ft.
13 POTHOLE	L	PA-AD Patching - AC Deep	5.00	sq. ft.
15 RUTTING	M	PA-AD Patching - AC Deep	5.00	sq. ft.
15 RUTTING	H	PA-AD Patching - AC Deep	5.00	sq. ft.
16 SHOVING	M	PA-AS Patching - AC Shallow	2.00	sq. ft.
16 SHOVING	H	PA-AS Patching - AC Shallow	2.00	sq. ft.
17 SLIPPAGE CR	L	PA-AS Patching - AC Shallow	2.00	sq. ft.
17 SLIPPAGE CR	H	PA-AD Patching - AC Deep	5.00	sq. ft.
17 SLIPPAGE CR	M	PA-AD Patching - AC Deep	5.00	sq. ft.

Figure 54. Preventive M&R policy.

Policy Number:	1	Policy Description: SAFETY M&R

Distress	Sev	Work Type & Description	Cost	Unit
4 BUMPS/SAGS	H	PA-AS Patching - AC Shallow	2.00	sq ft.
9 LANE SH DROP	H	PA-AL Patching - AC Leveling	1.00	sq. ft.
11 PATCH/UT CUT	H	PA-AD Patching - AC Deep	5.00	sq. ft.
13 POTHOLE	M	PA-AD Patching - AC Deep	5.00	sq. ft.
13 POTHOLE	H	PA-AD Patching - AC Deep	5.00	sq. ft.

Figure 55. Safety M&R policy.

SECTION	PCI	DIST/SEV	REPAIR	COST $
4	59	LANE SH DROP/M	PATCHING- AC LEVELING	666
5	69	ALLIGATOR CRACKING/M	PATCHING- FULL DEPTH	174
				$840

Figure 56. Network maintenance report for a PCI range of 55 to 70.

SECTION	PCI	COST $
1	30	66,792
2	37	52,135
3	39	22,204
		$141,131

Figure 57. Network maintenance report for PCIs less than 55.

WORK TYPE	SECTION	QTY, SF	COST, $
PATCHING, AC LEVELING	4	665	666
PATCHING, FULL DEPTH	5	68	174
			$840

Figure 58. Localized preventive maintenance list.

WORK TYPE	SECTION	AREA (SF)	COST ($)
REJUVENATOR	4	7218	481
	6	30411	2027
	7	28476	1898
	8	28881	1925

PROJECT EVALUATION LIST

SECTION	AREA	PCI	REASON FOR PROJ. EVALUATION
5	16,866	69	ALLIGATOR CR (M)

Figure 59. Global preventive maintenance and project evaluation lists.

YEAR TO REPAIR	SECTION	PRED PCI	AREA (SF)	COST ($)
1990	1	20	31374	40160
1990	2	28	27909	29470
1990	3	31	13329	13000
1990	4	53	7821	3500
1990	5	64	16866	7250
1990	6	53	30411	14750
1990	7	68	28881	11680
1990	8	94	28476	11550

COST TO REPAIR SECTION ON PROJECT EVALUATION LIST

Figure 60. Cost of major repair for sections on project evaluation list.

WORK TYPE	SECTION	QTY, SF	COST, $
PATCHING, FULL DEPTH	1	9	27
			$27

Figure 61. Localized safety maintenance.

YEAR TO REPAIR	SECTION	PRED PCI	AREA (SF)	COST ($)
YEAR 4 (1993)	7	51	28,476	16,320

Figure 62. Cost of major repair for sections approaching critical PCI.

YEAR TO REPAIR	SECTION	PRED PCI	AREA (SF)	COST ($)
1990	1	20	31,374	40,160
1990	2	28	27,909	29,470
1990	3	31	13,329	13,000
				82,630

Figure 63. Cost of major repair for sections below critical PCI.

TYPE / YR	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6
LOCALIZED PREV MAINT	840	840	840	840	840	840
GLOBAL PREV MAINT	6,331			6,331		
LOCALIZED SAFETY MAIN	27	27	27	27	27	27
MAJOR M&R ABOVE C PCI	7,250					
MAJOR M&R AT C PCI				16,320		
MAJOR M&R BELOW C PCI	82,630					
TOTAL BUDGET	$97,078	$867	$867	$23,518	$867	$867

Figure 64. Summary of annual and long range work plans.

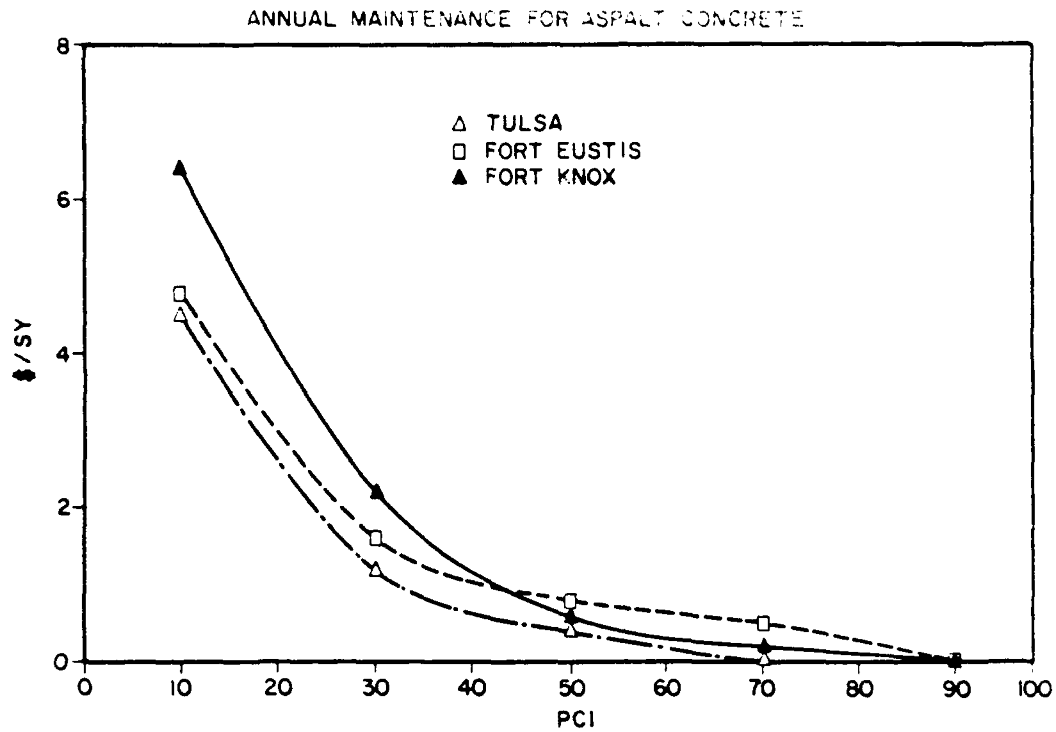


Figure 65. Example PCI vs. localized maintenance cost relationship.

10 USE OF THE PAVER SYSTEM FOR PROJECT JUSTIFICATION

A project-level evaluation should be completed prior to the preparation of plans and specifications to select the feasible repair alternatives. An economic analysis is then performed on the alternatives to justify the one(s) chosen. A detailed pavement evaluation at the project level was covered in Chapter 8.

Much of the information required for a project-level evaluation can be obtained from the reports generated by PAVER. A Surfaced Area Facility Evaluation Form (Appendix C) has been developed to help the user evaluate different repair alternatives. This form can be adjusted to suit the user's needs. This chapter explains how PAVER's reports can be used for project justification.

Project Identification

Data are needed to identify the project and provide information for determining M&R alternatives. These data can be obtained from the PAVER Inventory Report (Figure 66). This information should include the branch and section numbers and a description of the project's location. A project might consist of several branches and sections. The location description is helpful in identifying the beginning and end points in the project to someone unfamiliar with the branch and section numbering system.

The branch use, pavement rank, and surface type are needed to help determine feasible alternatives. The branch use can mandate the length of time available for the project. A runway, for example, cannot be closed for a long period of time. If complete reconstruction is necessary, the fact that the pavement is a runway could justify paying the contractor for working around the clock. The pavement rank can also provide justification for alternatives. For example, a primary pavement carries more traffic at a higher speed than a tertiary pavement so it must be maintained in better condition. The surface type will determine what type of maintenance policies can be applied to the pavement.

The final piece of information needed from the Inventory Report is the project dimensions. The project area is needed for a cost analysis of the various repair alternatives.

Project Evaluation

Pavement age and PCI can be obtained from the PAVER PCI Report as shown in Figure 67. The PCI for a project evaluation should be from a more detailed condition survey than at the network level. Project-level inspections require that the PCI be within +5 points of the true PCI. Although the number of sample units to be inspected for this degree of accuracy can be obtained from the Inspection Report, a 100 percent survey may be desirable for accurate repair quantity estimation. The Inspection Report will also generate distress information. An example of this report is shown in Figure 68.

The PCI Report lists the year of last overlay or reconstruction as well as the date of the last inspection and pavement age. By looking at these data, the user can determine the deterioration rate, which is useful in justifying a repair alternative. For example, if the last overlay applied lasted for only half of its design life, then the reason should be investigated and other alternatives considered for the current project. The Inspection Report will calculate the PCI of a section and the percentage of load- and climate-related distresses. If a significant percentage of load-related distresses (more than 5 percent) is found in a section, a structural repair should be considered. If most of the distresses are climate-related, a surface treatment might be the best alternative.

INVENTORY REPORT

AGENCY NUMBER:

REPORT DATE: FEB/17/1988

BRANCH NUMBER/USE/ NAME		SECTION NUMBER	SECTION CATEGORY	ZONE	PAVEMENT RANK	SURFACE TYPE	AREA (SF)
I2204 / ROADWAY/		01			TERTIARY	AC	1167
ROAD 13	FROM: S EDGE CNTY DETOUR			TO: BLDG 2204			
			TOTAL AREA OF SELECTED SECTIONS:				1167
I5030 / ROADWAY/		01			TERTIARY	AC	720
ROAD 14	FROM: W EDGE W 14TH AVE			TO: BLDG 5031			
			TOTAL AREA OF SELECTED SECTIONS:				720
IBRIG / ROADWAY/		01			TERTIARY	AC	1873
ROAD 15	FROM: W EDGE WISCONSIN			TO: E EDGE MIDDLE ST			
			TOTAL AREA OF SELECTED SECTIONS:				1873
IE13A / ROADWAY/		03			PRIMARY	AC	1838
road 1	FROM: W EDGE E "J" ST			TO: W EDGE "K" ST			
			TOTAL AREA OF SELECTED SECTIONS:				1838
IEHST / ROADWAY/		01			SECONDARY	AC	1837
ROAD 6	FROM: E EDGE E 12TH ST			TO: W EDGE E 13TH ST			
			TOTAL AREA OF SELECTED SECTIONS:				1837
IEKRD / ROADWAY/		01			SECONDARY	AC	6028
ROAD 9	FROM: E EDGE E 14TH AVE			TO: TANK TRAIL			
			TOTAL AREA OF SELECTED SECTIONS:				6028
IEKST / ROADWAY/		01			SECONDARY	AC	3375
ROAD 8	FROM: W EDGE E 12TH AVE			TO: E EDGE E 14TH AVE			
			TOTAL AREA OF SELECTED SECTIONS:				3375

Figure 66. Example Inventory Report.

PCI REPORT

REPORT DATE: FEB/17/1988

AGENCY NUMBER:

Surface Type: AC
Last Construction Date: >= JAN/01/1965

BRANCH NUMBER/USE/ NAME	SECTION NUM/RANK/SURF/AREA(SF)	LAST CONSTRUCT DATE	LAST INSPECTION DATE	PCI
I2204 / ROADWAY	01 / T / AC / 1167	SEP/30/1974	SEP/30/1987	35
ROAD 13	CAT: ZONE:	AGE (YRS): 13.0		
IE13A / ROADWAY	03 / P / AC / 1838	SEP/30/1966	SEP/30/1987	79
road 1	CAT: ZONE:	AGE (YRS): 21.0		
IEKST / ROADWAY	01 / S / AC / 3375	SEP/30/1977	SEP/30/1987	69
ROAD 8	CAT: ZONE:	AGE (YRS): 10.0		
IS09A / ROADWAY	02 / P / AC / 5662	SEP/30/1972	SEP/30/1987	56
ROAD 2	CAT: ZONE:	AGE (YRS): 15.0		
ISEST / ROADWAY	02 / S / AC / 1837	SEP/30/1980	SEP/30/1987	86
ROAD 7	CAT: ZONE:	AGE (YRS): 7.0		
ISMOT / ROADWAY	04 / S / AC / 2102	SEP/30/1983	SEP/30/1987	48
ROAD 12	CAT: ZONE:	AGE (YRS): 4.0		
IW14A / ROADWAY	01 / P / AC / 663	SEP/30/1981	SEP/30/1987	94
ROAD 4	CAT: ZONE:	AGE (YRS): 6.0		
P015I / PARKING	01 / X / AC / 1486	SEP/30/1981	SEP/30/1987	25
PARKING LOT 3	CAT: ZONE:	AGE (YRS): 6.0		

Figure 67. Example PCI Report.

DATE SURVEYED = JUL/12/1984   BRANCH/SECTION NUMBER = ARR09/01

SECTION SIZE = 220000 SF

TOTAL NUMBER OF SAMPLE UNITS = 44

ALLOWABLE ERROR WITH 95% CONFIDENCE = 5

SAMPLE UNIT ID = 1
SIZE OF SAMPLE = 5000 SF

DISTRESS-TYPE	SEVERITY	QUANTITY	DENSITY %	DEDUCT VALUE
48 L & T CR	LOW	50	1.00	4.9

PCI = 95

NUMBER OF RANDOM SAMPLE UNITS SURVEYED = 5

NUMBER OF ADDITIONAL SAMPLE UNITS SURVEYED = 0

PCI OF SECTION = 93   RATING = EXCELLENT

RECOMMENDED MINIMUM OF 5 RANDOM SAMPLE UNITS TO BE SURVEYED.

STANDARD DEVIATION OF PCI BETWEEN RANDOM UNITS SURVEYED = 2.0%

EXTRAPOLATED DISTRESS QUANTITIES FOR SECTION

DISTRESS-TYPE	SEVERITY	QUANTITY	DENSITY %	DEDUCT VALUE
41 ALLIGATOR CR	LOW	9	.00	7.0
48 L & T CR	LOW	2024	.92	4.8
48 L & T CR	MEDIUM	176	.08	4.0

*** PERCENT OF DEDUCT VALUES BASED ON DISTRESS MECHANISM ***

LOAD RELATED DISTRESSES = 44.35 PERCENT DEDUCT VALUES.

CLIMATE/DURABILITY RELATED DISTRESSES = 55.65 PERCENT DEDUCT VALUES.

OTHER RELATED DISTRESSES = .00 PERCENT DEDUCT VALUES.

Figure 68. Example Field Inspection Report.

The Inspection Report will also list the distresses present in a pavement section. Examination of these distresses can provide valuable input as to the cause of pavement failure. Repair alternatives should be selected to eliminate the cause of failure. For example, if pumping occurred in a jointed PCC pavement, then drainage, voids, load transfer, and joint seal should all be considered in selecting the M&R alternatives.

M&R Alternatives

Once all of the above information is available, the project manager can develop feasible M&R alternatives. A tentative strategy was developed at the network level as discussed in Chapter 9. This strategy should be used as a starting point. Several repair or maintenance alternatives can be applied for any given section. Whatever alternative is chosen should repair the pavement adequately to eliminate or reduce the factors that led to its deterioration.

Several alternatives are plausible for any given project; however, some may not be feasible. Therefore, the engineer should first consider each alternative from a feasibility perspective. Although an option may be feasible and incorporate sound engineering judgment and analysis, external factors may preclude its being practical. For example, although recycling is common in some parts of the country and its merits have been proven, it is still not practiced commonly in certain geographical areas. If local contractors do not have the specialized equipment or expertise required to do recycling and are unwilling to spend the capital, then recycling is not a practical alternative.

Life-cycle cost analysis must be performed on each feasible alternative. Figures that should be considered in this analysis are initial construction costs and future M&R.

Construction costs are determined using standard estimating procedures. The first step is to determine the quantities of all items pertinent to the project, such as relocation of secondary structures, shoulders, and drainage improvements. Some of these estimates might be approximate, but as long as the numbers are reasonable, the analysis will be valid. After amounts have been estimated, unit prices are used to project the construction costs.

M&R cost prior to an overlay can be estimated using the PAVER M&R Report. The report uses a maintenance policy, input by the user, to calculate M&R costs. The information needed includes a policy for each distress type and a unit cost. For example, the policy to repair high severity alligator cracking might be to deep patch. The policy for low severity alligator cracking might be to do nothing. The program will use this policy to calculate M&R costs for some or all of the distresses present in a section using the distress quantities from the field inspection. Example M&R alternatives are listed in Tables 9 and 10 for AC and PCC, respectively.

Future M&R costs must be estimated by making a reasonable projection in terms of today's dollars. The life-cycle cost analysis procedures will use inflation and interest factors to adjust current costs for the future. The engineer must make an assumption about the type and frequency of work.

For example, if an overlay is to be applied initially, a seal coat might be applied in 5 years and a seal coat and patching might be done in 10 years.

Salvage value of the pavement after the analysis period is often ignored. If the various alternatives will leave the pavement in approximately the same condition, then the salvage values of the pavements will cancel each other. However, if one alternative allows the pavement to completely deteriorate so as to require complete reconstruction while another alternative would only require an overlay, the latter should be assigned a salvage value.

Table 9

Asphalt Concrete Pavement Distress Types and M&R Alternatives

Distress Type	Do Nothing	Crack Seal	Partial Depth Patch	Full Depth Patch	Skin Patch	Pothole Filling	Apply Heat & Roll Sand	Apply Seal	Surface Emulsion	Apply Rejuvenation	Apply Aggregate Seal Coat	Notes
Alligator Cracking			M,H	M,H				L		L		
Bleeding	L						L,M,H					
Block Cracking	L	L,M,H								L	L,M	
Bumps and Sags	L		M,H	M,H	M,H							
Corrugations	L		M,H	M,H								
Depression	L		M,H	M,H	M,H							
Edge Cracking	L	L,M	M,H	M,H								If predominant, apply shoulder seal, e.g., aggregate seal coat
Joint Reflective Cracking	I	L,M,H	H									
Lane Shoulder Drop-Off	L											If predominant, level shoulder and apply aggregate seal coat
Longitudinal Transverse Cracking	L	L,M,H	H					L		L	L,M	
Patching and Utility Cut	L	M	H**	H**								
Polished Aggregate	A5										A	
Potholes			L	L,M,H		L,M,H						
Railroad Crossing	L				L,M,H							
Rutting	L		L,M,H	M,H	L,M,H							
Shoving	L		M,H									
Slippage Cracking	L	L	M,H									
Swell	L			M,H								
Weathering and Raveling	L		M					L,M		L	M,H	

*Note: L = low severity; M = medium severity; H = high severity; A = has only on e severity level.
**Replace patch.

Table 10

Jointed Concrete Pavement Distress Types and M&R Alternatives*

Distress Type	Do Nothing	Crack Sealing	Joint Sealing	Partial Depth Patch (Bonded)	Full Depth Patch	Slab Replacement	Under-Sealing	Grinding Slab	Slab Jack-Grout	Notes
Blow-ups				L[a],H[a]	H[a]	H[a]				[a]Must provide expansion joint
Corner Break	L	L,M,H			M,H	H				
Divided Slab		L,M				M,H				
"D" Cracking	L	L[b]	L[b]	M,H	M,H	H				[b]If "D" cracks exist, seal all joints and cracks
Faulting	L					H		M,H	M,H	
Joint Seal Damage	L		M[c],H							[c]Joint seal local areas
Lane/Shoulder Drop-Off	L									If predominant, level shoulder, apply aggregate seal coat
Linear Cracking	L	L,M,H		H[d]	H	H				[d]Replace patch
Polished Aggregate	A									If predominant, apply major or overall repair, e.g., overlay grooving
Popouts	A									
Pumping		A	A				A			
Punchouts	L	L,M			M,H	H				
Railroad Crossing	L									If M or H, level surface
Scaling/Map Cracks/ Crazing	L			M,H	H					
Shrinkage Cracks	A									
Corner Spalling	L			L,M,H						
Joint Spalling	L		L	M,H	M,H[e]					[e]If caused by keyway failure, provide load transfer

*Note: L = low severity; M = medium severity; H = high severity; A = has only one severity level.

Economic Analysis

Once the life cycle and cost of each alternative have been estimated, an economic analysis can be done to compare the alternatives. The ECON1 Report in the PAVER System can be used to perform the economic analysis. Data that must be entered to run the report include the interest rate, inflation rate, analysis period, fiscal year to start analysis, and M&R activity date and cost.

The report calculates the present worth (PW), the equivalent uniform annual cost (EUAC), and the equivalent uniform annual cost per square yard of each alternative as follows:

$$PW = \frac{C\ (1 + INF)^{n}}{(1 + INT)^{n}} \qquad \text{[Eq 3]}$$

where: C = expenditure in today's cost

INF = inflation rate

INT = interest rate

n = number of years until expenditure.

The following equation can be used to calculate the EUAC from the present worth:

$$EUAC = PW \left[\frac{INT}{1 - (1 + INT)^{-n}} \right] \qquad \text{[Eq 4]}$$

Using the life-cycle cost analysis procedures described above, the most economical alternative can be chosen from the list of feasible alternatives. The M&R alternative with the lowest life-cycle cost should be used. This method is consistent with the network-level goal of performing the maximum number of repairs while minimizing the overall cost.

11 CONCLUSION

This report has reviewed the state of the art in pavement maintenance management using the PAVER System. This system is available as a mainframe program called PAVER and as a microcomputer version called Micro PAVER. The systems use the Pavement Condition Index (PCI) as a method of establishing M&R priorities and justifying pavement M&R projects.

PAVER can be used for both network- and project-level management. At the network level, the system can be used for developing annual- and long-range plans. The PAVER System will also produce reports that can be used to determine the budget required to maintain the pavement network and to show the effect of different budgets on the network. At the project level, the system can be used to calculate the costs of various M&R alternatives and help the user choose the most cost-effective solution.

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APPENDIX A:

DISTRESS IDENTIFICATION GUIDE

Distress in Asphalt Pavements

During the field condition surveys and validation of the PCI, several questions were commonly asked regarding the identification and measurement of some of the distresses. The answers to these questions are included under the section titled "How to Measure" for each distress. For convenience, however, items that are referenced frequently are listed below:

1. If alligator cracking and rutting occur in the same area, each is recorded separately at its respective severity level.

2. If bleeding is counted, polished aggregate is not counted in the same area.

3. Bumps and sags are measured in units of linear feet.

4. If a crack occurs at the ridge or edge of a bump, the crack and bumps are recorded separately.

5. If any distress (including cracking and potholes) is found in a patched area, it is not recorded; its effect on the patch, however, is considered in determining the severity level of the patch.

6. A significant amount of polished aggregate should be present before it is counted.

7. Potholes are measured by the number of holes having a certain diameter, not in units of square feet.

The above is not intended to be a complete list. To properly measure each distress type, the inspector must be familiar with its individual measurement criteria.

Nineteen distress types for asphalt-surfaced pavements are listed alphabetically in this appendix. Figure A1 shows pavement condition based on PCI rating.

Ride Quality

Ride quality must be evaluated in order to establish a severity level for the following distress types:

1. Bumps
2. Corrugation
3. Railroad crossings
4. Shoving
5. Swells.

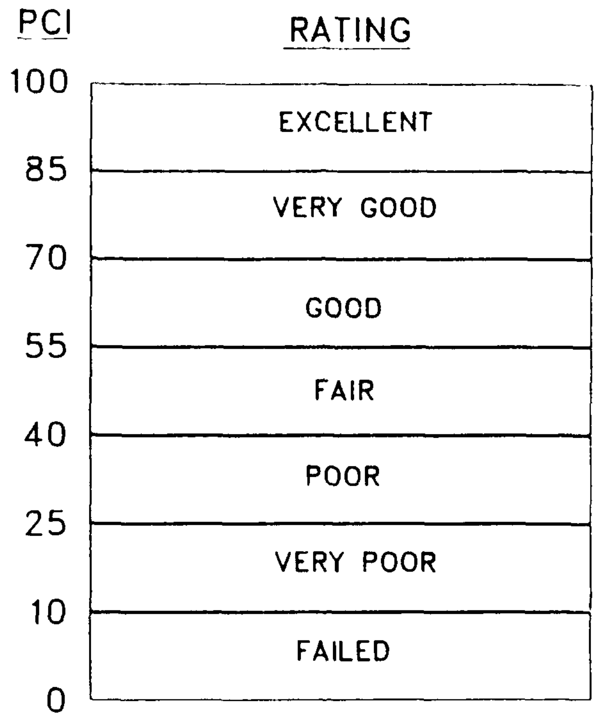

Figure A1. Pavement Condition Index.

To determine the effect these distresses have on ride quality, the inspector should use the following severity-level definitions of ride quality:

1. L (low). Vehicle vibrations (e.g., from corrugation) are noticeable, but no reduction in speed is necessary for comfort or safety, and/or individual bumps or settlements cause the vehicle to bounce slightly, but create little discomfort.

2. M (medium). Vehicle vibrations are significant and some reduction in speed is necessary for safety and comfort, and/or individual bumps or settlements cause the vehicle to bounce significantly, creating some discomfort.

3. H (high). Vehicle vibrations are so excessive that speed must be reduced considerably for safety and comfort, and/or individual bumps or settlements cause the vehicle to bounce excessively, creating substantial discomfort, and/or a safety hazard and/or high potential vehicle damage.

Ride quality is determined by riding in a standard-sized automobile over the pavement section at the posted speed limit. Pavement sections near stop signs should be rated at the normal deceleration speed used when approaching the sign.

Definitions of Repair Options for Asphalt Pavements

1. Cold Milling - Carbide teeth cutting bits are used to chip off the surface of the pavement to remove material.

2. Heater Scarify - 3/4 inch of the pavement is heated and scarified to provide a smooth, crack-free surface. Can be used before overlaying to slow reflective cracking.

3. Overlay - An application of asphalt concrete over the existing surface to correct surface deficiencies and/or increase the load carrying capacity of the pavement.

4. Patching:

Shallow - A stable, compacted leveling course is placed in depressions to level off the surface.

Partial depth - the deteriorated area of the asphalt surface course is removed and replaced.

Full depth - the deteriorated area of the asphalt surface course and the base course are removed and replaced. The subgrade is recompacted.

5. Reconstruction - complete replacement of the pavement.

6. Recycle - the reworking of a pavement structure or its component material to improve their performance and correct noted deficiencies.

7. Seal Cracks - cracks are often routed to remove debris before sealing.

8. Surface Seal - an application of bituminous spray, such as for seals and rejuvenators.

9. Surface Treatment - an application of bituminous binder with aggregate, such as sand seals, slurry seals, and chip seals.

ALPHABETICAL LIST OF DISTRESS TYPES: ASPHALT PAVEMENTS

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. Cracking begins at the bottom of the asphalt surface (or stabilized base) where tensile stress and strain are 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 generally less than 2 ft (0.6 m) on the longest side.

Alligator cracking occurs only in areas subjected to repeated traffic loading, 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 that occurs over an entire area not subjected to loading is called "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 interconnecting cracks. The cracks are not spalled* (Figure A2).

M - Further development of light alligator cracks into a pattern or network of cracks that may be lightly spalled (Figure A3).

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 (Figure A4).

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 present.

Options for Repair:

L - Do nothing; Surface seal; Overlay

M - Partial or full depth patch; Overlay; Reconstruct.

H - Partial or full depth patch; Overlay; Reconstruct.

*Crack spalling is a breakdown of the material along the sides of the crack.

Figure A2. Examples of low-severity alligator cracking.

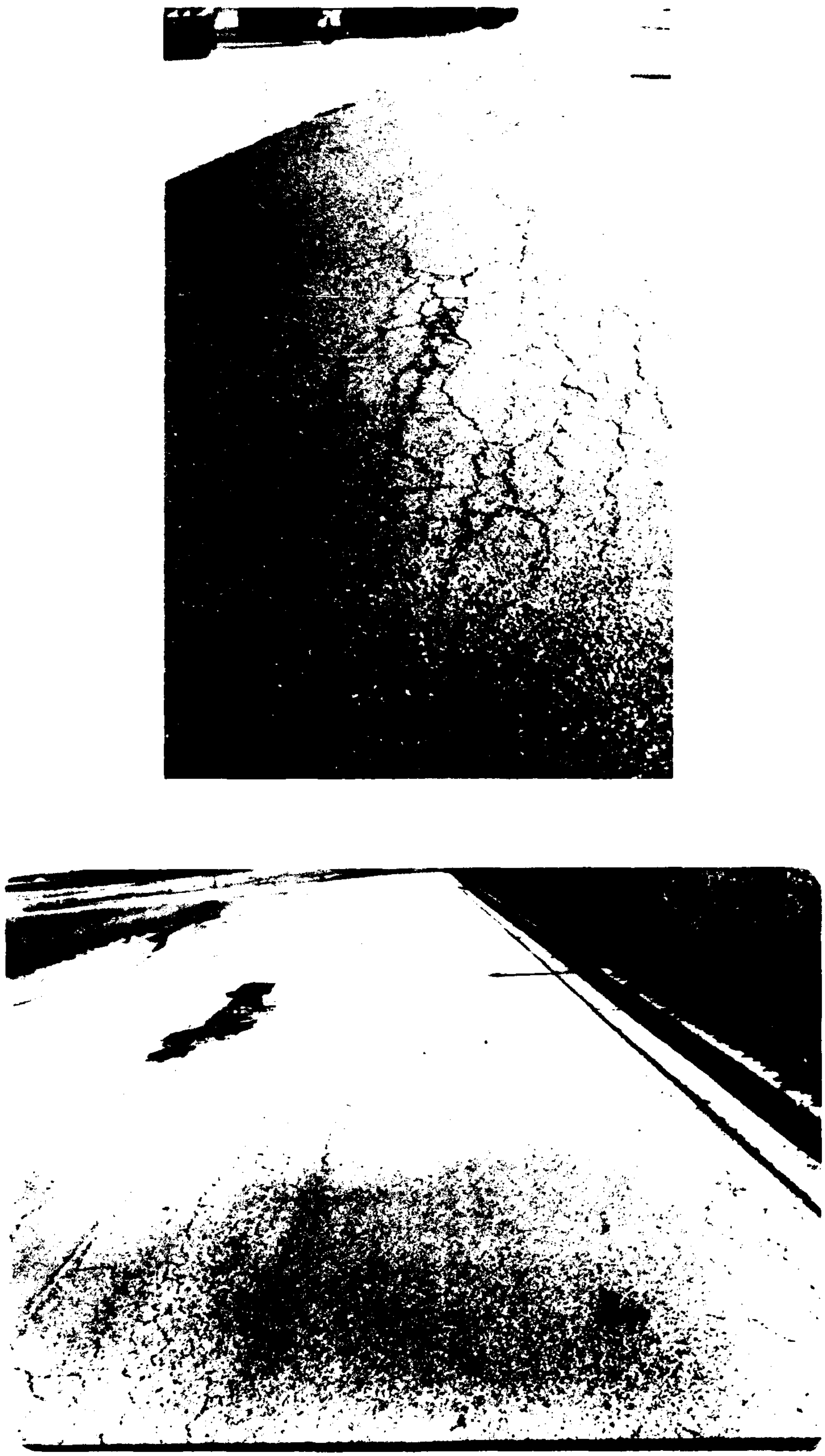

Figure A3. Examples of medium-severity alligator cracking.

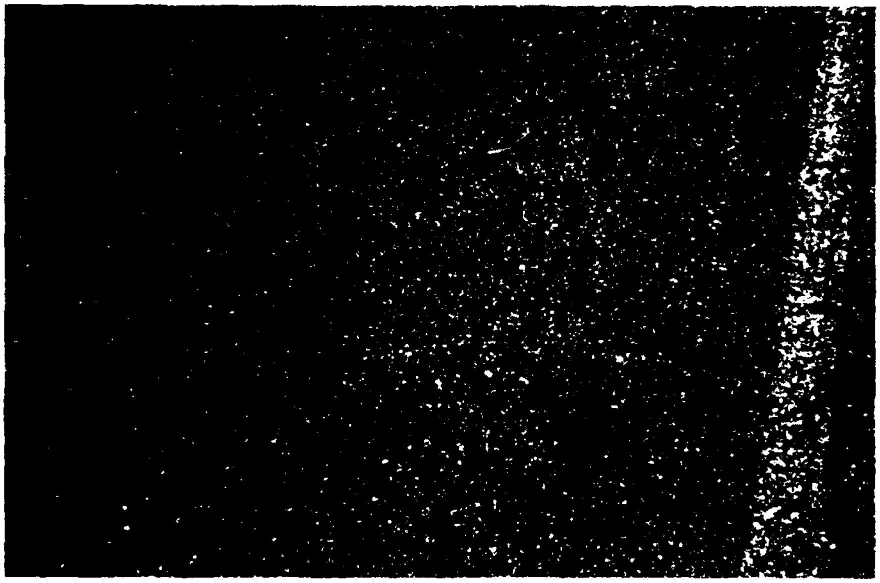

Figure A3. (Cont'd).

Figure A4. Examples of high-severity alligator cracking.

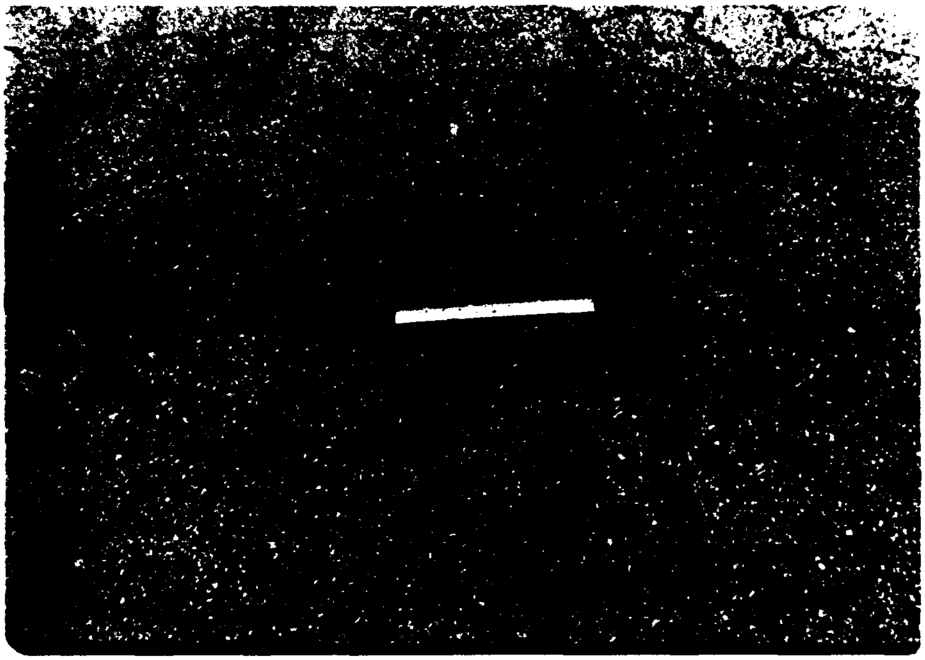

Figure A4. (Cont'd).

Bleeding

Description: Bleeding is a film of bituminous material on the pavement surface that creates a shiny, glasslike, reflecting surface that usually becomes quite sticky. bleeding is caused by excessive asphalt cement or tars in the mix, excess application of a bituminous sealant, and/or low air void content. It occurs when asphalt fills the voids of the mix during hot weather and then expands onto the pavement surface. Since the bleeding process in 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 is noticeable only during a few days of the year. Asphalt does not stick to shoes or vehicles (Figure A5).

M - Bleeding has occurred to the extent that asphalt sticks to shoes and vehicles during only a few weeks of the year (Figure A6).

H - Bleeding has occurred extensively and considerable asphalt sticks to shoes and vehicles during at least several weeks of the year (Figure A7).

How to Measure: Bleeding is measured in square feet of surface area. If bleeding is counted, polished aggregate should not be counted.

Options for Repair:

L - Do nothing.

M* - Apply sand/aggregate and roll.

H* - Apply sand/aggregate and roll.

*Preheat if necessary.

Figure A5. Low-severity bleeding.

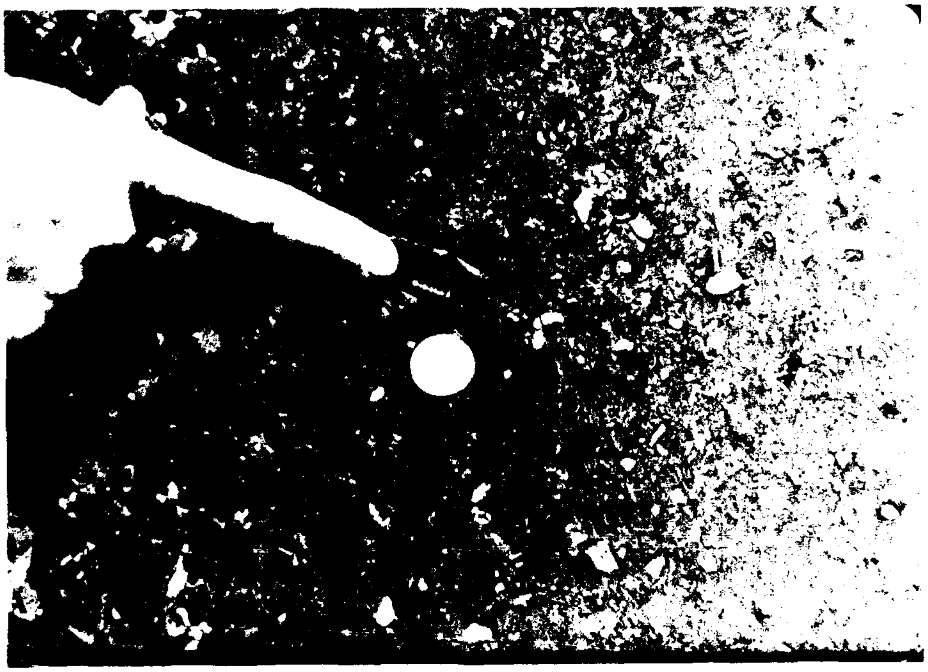

Figure A6. Medium-severity bleeding.

Figure A7. High-severity bleeding.

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 (0.3 by 0.3 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. Block cracking usually indicates that the asphalt has hardened significantly. Block cracking normally occurs over a large portion of the 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, alligator cracks are caused by repeated traffic loadings, and are therefore found only in traffic areas (i.e., wheel paths).

Severity Levels:

L - Blocks are defined by low-severity* cracks (Figure A8).

M - Blocks are defined by medium-severity* cracks (Figure A9).

H - Blocks are defined by high-severity cracks (Figure A10).

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.

Options for Repair:

L - Seal cracks over 1/8 in.; Surface seal.

M - Seal cracks; Recycle surface; Heater scarify and overlay.

H - Seal cracks; Recycle surface; Heater scarify and overlay.

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*See definitions of longitudinal transverse cracking.

Figure A8. Low-severity block cracking.

Figure A9. Examples of medium-severity block cracking.

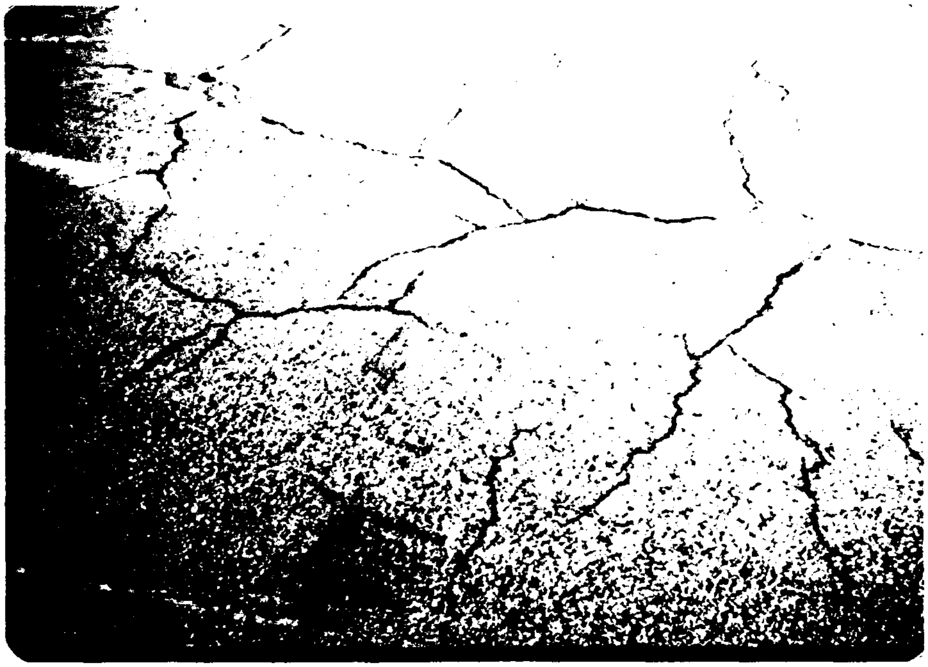


Figure A9. (Cont'd).

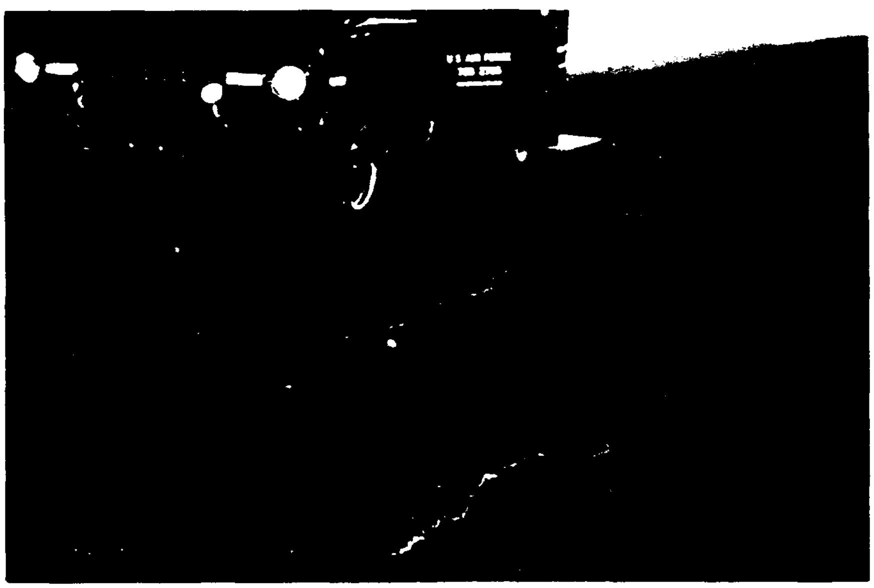


Figure A10. High-severity block cracking. (A few inches around the crack are severely broken.)

Bumps and Sags

Description: Bumps are small, localized, upward displacements of the pavement surface. They are different from shoves in that shoves are caused by unstable pavement. Bumps, on the other hand, can be caused by several factors, including:

1. Buckling or bulging of underlying PCC slabs in AC overlay over PCC pavement.

2. Frost heave (ice, lens growth).

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

Sags are small, abrupt, downward displacements of the pavement surface.

Distortion and displacement that occur over large areas of the pavement surface, causing large and/or long dips in the pavement are called "swelling."

Severity Levels:

L - Bump or sag causes low-severity ride quality (Figure A11).

M - Bump or sag causes medium-severity ride quality (Figure A12).

H - Bump or sag causes high-severity ride quality (Figure A13).

How to Measure: Bumps or sags are measured in linear feet. If bumps appear in a pattern perpendicular to traffic flow and are spaced at less than 10 ft (3 m), the distress is called corrugation. If the bump occurs in combination with a crack, the crack is also recorded.

Options for Repair:

L - Do nothing.

M - Cold mill; Shallow, partial or full depth patch.

H - Cold mill; Shallow, partial or full depth patch; Overlay.

Figure A11. Low-severity bumps and sags.

Figure A12. Examples of medium-severity bumps and sags.

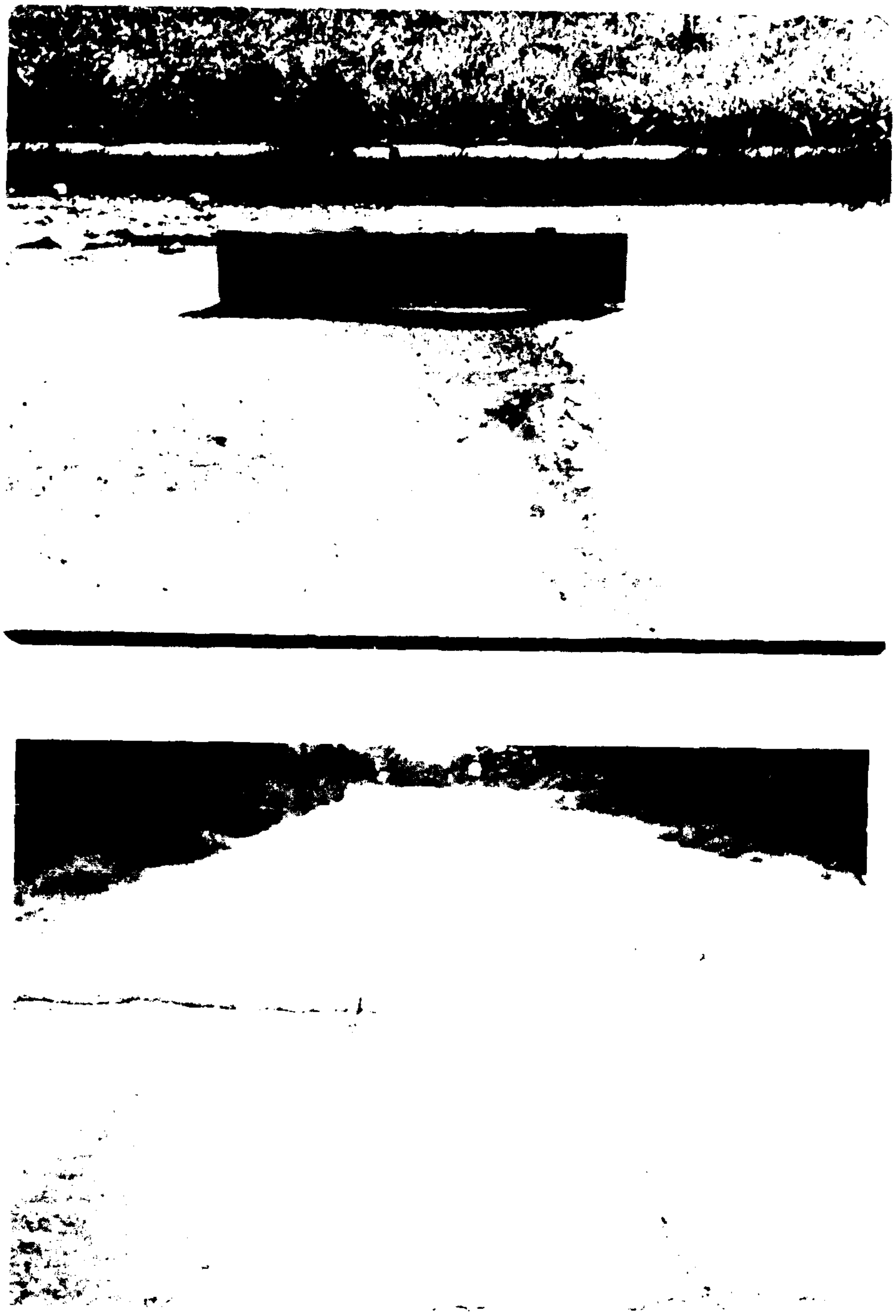


Figure A12. (Cont'd).

Figure A13. High-severity bumps and sags.

Corrugation

Description: Corrugation (also known as "washboarding") 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. This type of distress is usually caused by traffic action combined with an unstable pavement surface or base. If bumps occur in a series of less than 10 ft (3 m), due to any cause, the distress is considered corrugation.

Severity Levels:

L - Corrugation produces low-severity ride quality (Figure A14).

M - Corrugation produces medium-severity ride quality (Figure A15).

H - Corrugation produces high-severity ride quality (Figure A16).

How to Measure: Corrugation is measured in square feet of surface area.

Options for Repair:

L - Do nothing.

M - Reconstruct.

H - Reconstruct.

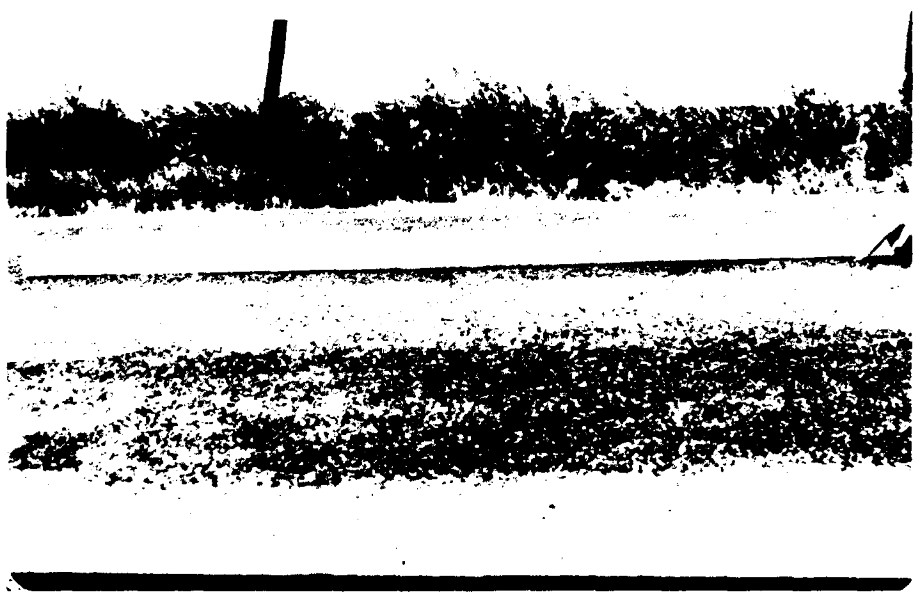


Figure A14. Low-severity corrugation.

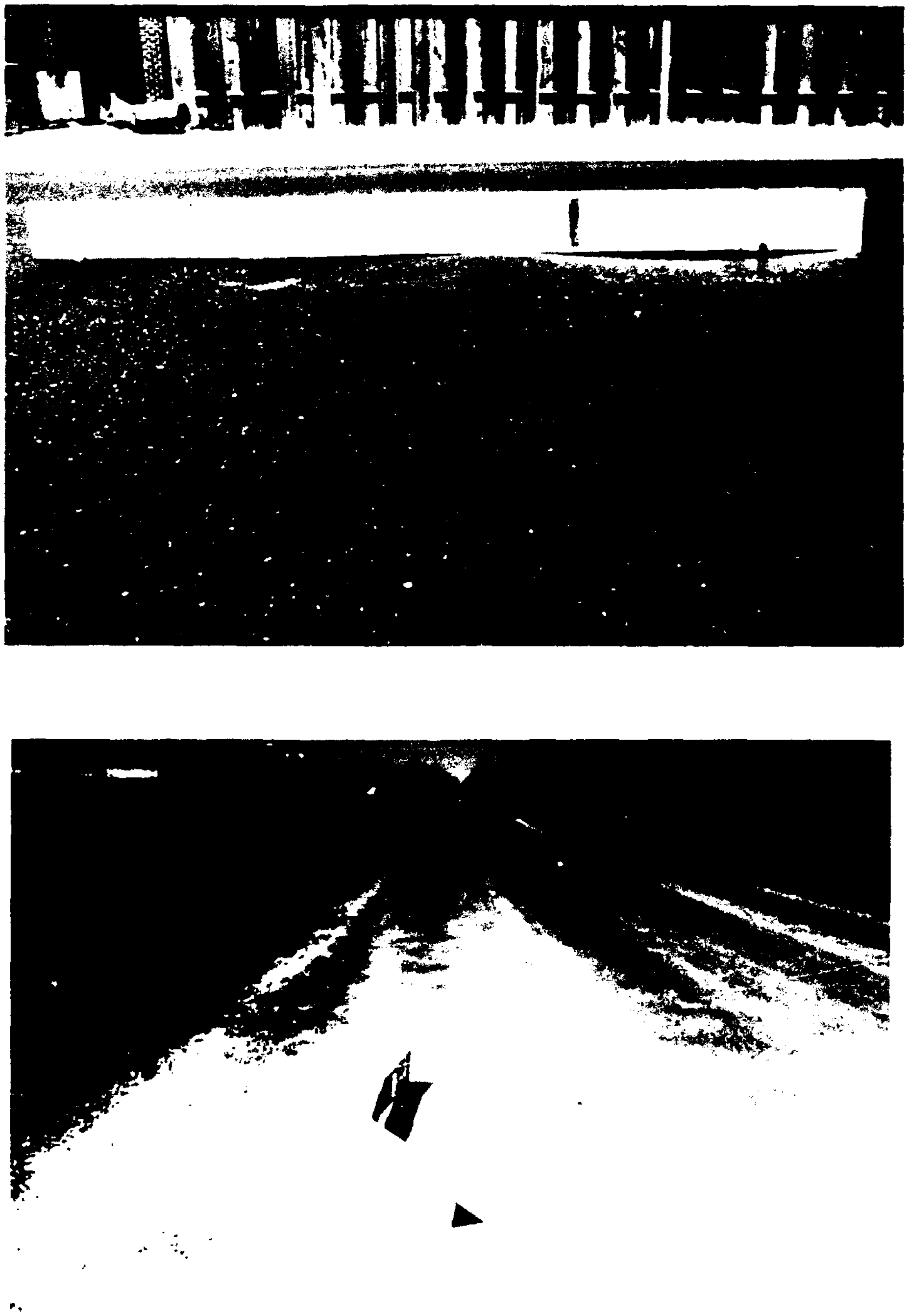


Figure A15. Examples of medium-severity corrugation.

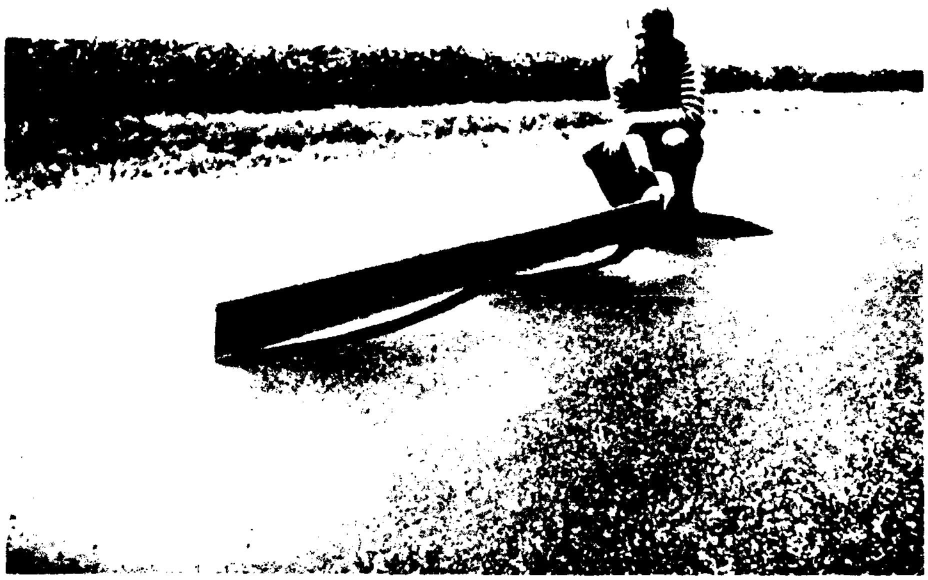


Figure A16. High-severity corrugation.

Depression

Description: Depressions are localized pavement surface areas with 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 a "birdbath" area; on dry pavement, depressions can be spotted by looking for stains caused by ponding water. Depressions are created by settlement of the foundation soil or are a result of improper construction. Depressions cause some roughness, and when deep enough or filled with water, can cause hydroplaning.

Sags, unlike depressions, are abrupt drops in elevation.

Severity Levels: Maximum Depth of Depression

L - 1/2 to 1 in. (13 to 25 mm) (Figure A17).

M - 1 to 2 in. (25 to 51 mm) (Figure A18).

H - more than 2 in. (51 mm) (Figure A19).

How to Measure: Depressions are measured in square feet of surface area.

Options for Repair: L - Do nothing.

M - Shallow, partial, or full depth patch.

H - Shallow, partial, or full depth patch.

Figure A17. Low-severity depression.

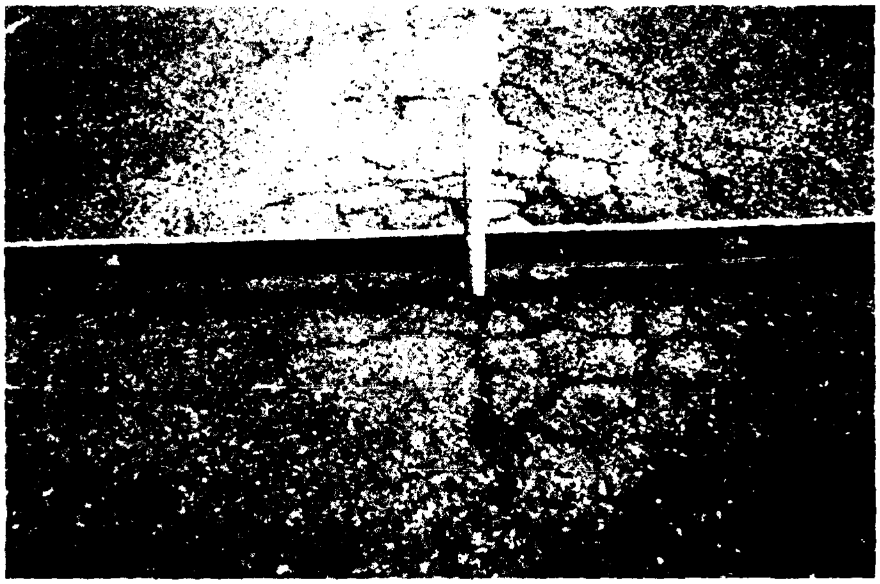


Figure A18. Medium-severity depression.

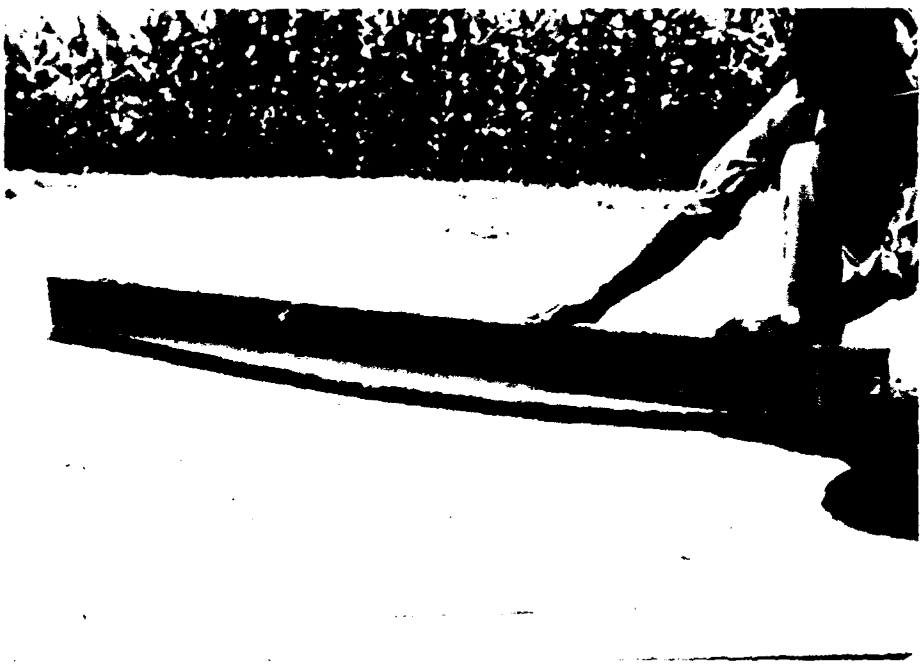


Figure A19. High-severity depression.

Edge Cracking

Description: Edge cracks are parallel to and usually within 1 to 2 ft (0.3 to 0.6 m) of the outer edge of the pavement. This distress is accelerated by traffic loading and can be caused by frost-weakened base or subgrade near the edge of the pavement. The area between the crack and pavement edge is classified as raveled if it breaks up (sometimes to the extent that pieces are removed).

Severity Levels:

L - Low or medium cracking with no breakup or raveling (Figure A20).

M - Medium cracks with some breakup and raveling (Figure A21).

H - Considerable breakup or raveling along the edge (Figure A22).

How to Measure: Edge cracking is measure in linear feet.

Options for Repair:

L - Do nothing; Seal cracks over 1/8 in. (3 mm).

M - Seal cracks; Partial depth patch.

H - Partial depth patch.

Figure A20. Low-severity edge cracking.

Figure A21. Medium-severity edge cracking.

Figure A22. Examples of high-severity edge cracking.

Figure A22. (Cont'd).

Joint Reflection Cracking (From Longitudinal and Transverse PCC Slabs)

Description: This distress occurs only on asphalt-surfaced pavements that have been laid over a PCC slab. It does not include reflection cracks from any other type of base (i.e., cement- or lime-stabilized); these cracks are caused mainly by thermal- or moisture-induced movement of the PCC slab beneath the AC surface. This distress is not load-related; however, traffic loading may cause a breakdown of the AC surface near the crack. If the pavement is fragmented along a crack, the crack is said to be spalled. A knowledge of slab dimension beneath the AC surface will help to identify these distresses.

Severity Levels: L - One of the following conditions exists (Figure A23):

1. Nonfilled crack width is less than 3/8 in. (10 mm), or
2. Filled crack of any width (filler in satisfactory condition).

M - One of the following conditions exists (Figure A24):

1. Nonfilled crack width is 3/8 to 3 in. (10 to 76 mm).
2. Nonfilled crack of any width up to 3 in. (76 mm) surrounded by light random cracking (Figure A24).
3. Filled crack of any width surrounded by light random cracking.

H - One of the following conditions exists (Figure A25):

1. Any crack filled or nonfilled surrounded by medium or high severity random cracking.
2. Nonfilled cracks over 3 in. (76 mm).
3. A crack of any width where a few inches of pavement around the crack are severely broken. (Crack is severely broken.)

How to Measure: Joint reflection cracking is measured in linear feet. The length and severity level of each crack should be recorded separately. For example, a crack that is 50 ft (15 m) long may have 10 ft (3 m) of high severity cracks; these would all be recorded separately. If a bump occurs at the reflection crack, it is also recorded.

Options for Repair: L - Seal cracks over 1/8 in. (3 mm).

M - Seal cracks; Partial depth patch.

H - Partial depth patch; Reconstruct joint.

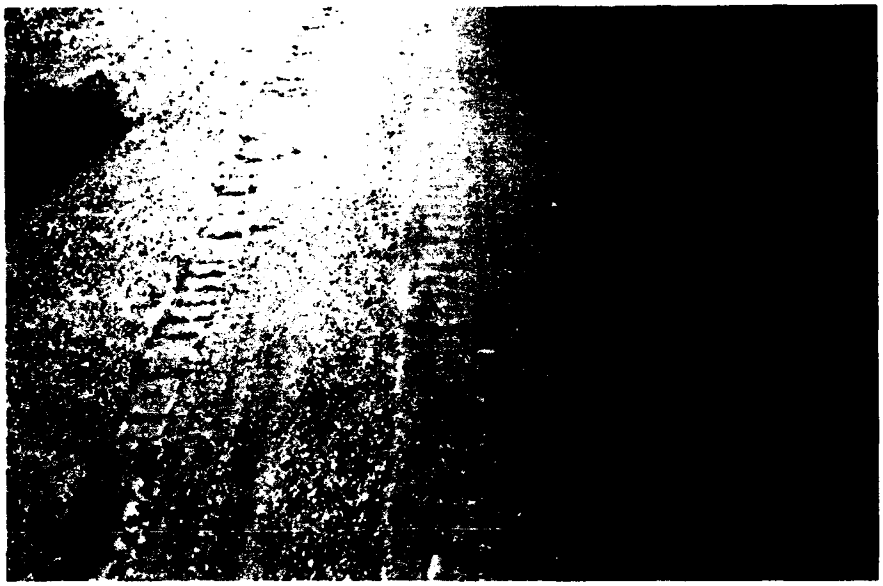


Figure A23. Low-severity joint reflection cracking.

Figure A24. Medium-severity joint reflection cracking.

Figure A25. High severity joint reflection cracking.

Lane/Shoulder Drop-Off

Description: Lane/shoulder drop-off is a difference in elevation between the pavement edge and the shoulder. This distress is caused by shoulder erosion, shoulder settlement, or by building up the roadway without adjusting the shoulder level.

Severity Levels:

L - The difference in elevation between the pavement edge and shoulder is 1 to 2 in. (25 to 51 mm) (Figure A26).

M - The difference in elevation is more than 2 to 4 in. (51 to 102 mm) (Figure A27).

H - The difference in elevation is greater than 4 in. (102 mm) (Figure A28).

How to Measure: Lane/shoulder drop-off is measured in linear feet.

Options for Repair: L, M, H - Regrade and fill shoulders to match lane height.

Figure A26. Low-severity lane/shoulder drop-off.

Figure A27. Medium-severity lane/shoulder drop-off.

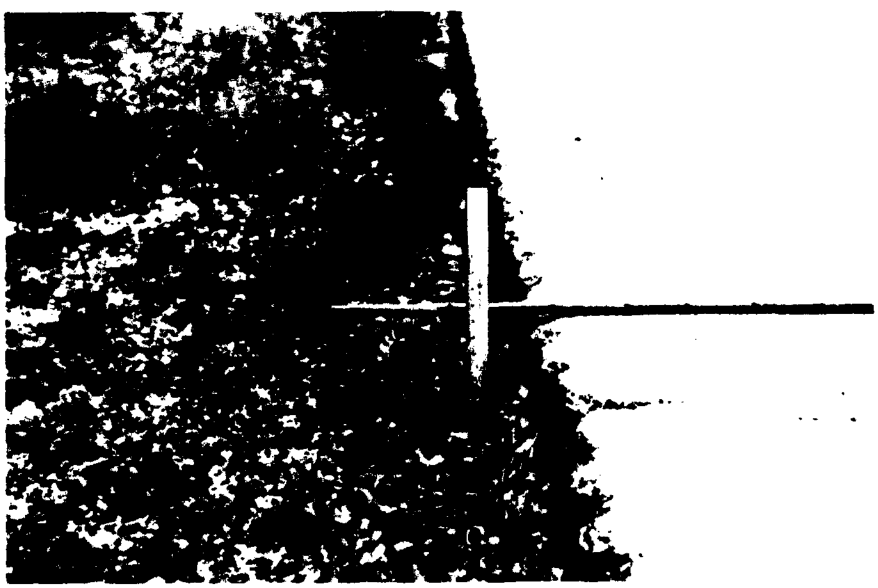


Figure A28. Examples of high-severity lane/shoulder drop-off.

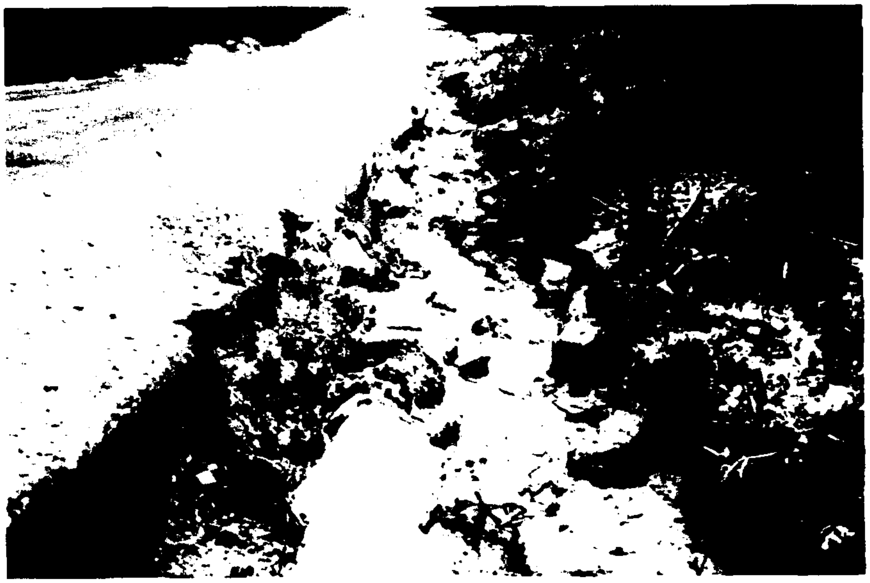


Figure A28. (Cont'd).

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 and/or daily temperature cycling.

3. A reflective crack caused by cracking beneath the surface course, including cracks in PCC slabs (but not PCC joints).

Transverse cracks extend across the pavement at approximately right angles to the pavement centerline or direction of laydown. These types of cracks are not usually load-associated.

Severity Levels: L - One of the following conditions exists (Figure A29):

1. Nonfilled crack width is less than 3/8 in. (10 mm), or

2. Filled crack of any width (filler in satisfactory condition).

M - One of the following conditions exists (Figure A30):

1. Nonfilled crack width is 3/8 to 3 in. (10 to 76 mm).

2. Nonfilled crack is any width up to 3 in. (76 mm) surrounded by light and random cracking.

3. Filled crack is of any width surrounded by light random cracking.

H - One of the following conditions exists (Figure A31):

1. Any crack filled or nonfilled surrounded by medium- or high-severity random cracking.

2. Nonfilled crack over 3 in. (76 mm).

3. A crack of any width where a few inches of pavement around the crack is severely broken.

How to Measure: Longitudinal and transverse cracks are measured in linear feet. The length and severity of each crack should be recorded after identification. 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 or sag occurs at the crack, it is also recorded.

Options for Repair:

L - Do nothing; Seal cracks more than 1/8 in. wide.

M - Seal cracks.

H - Seal cracks; Partial depth patch.

Figure A29. Low-severity longitudinal and transverse cracking.

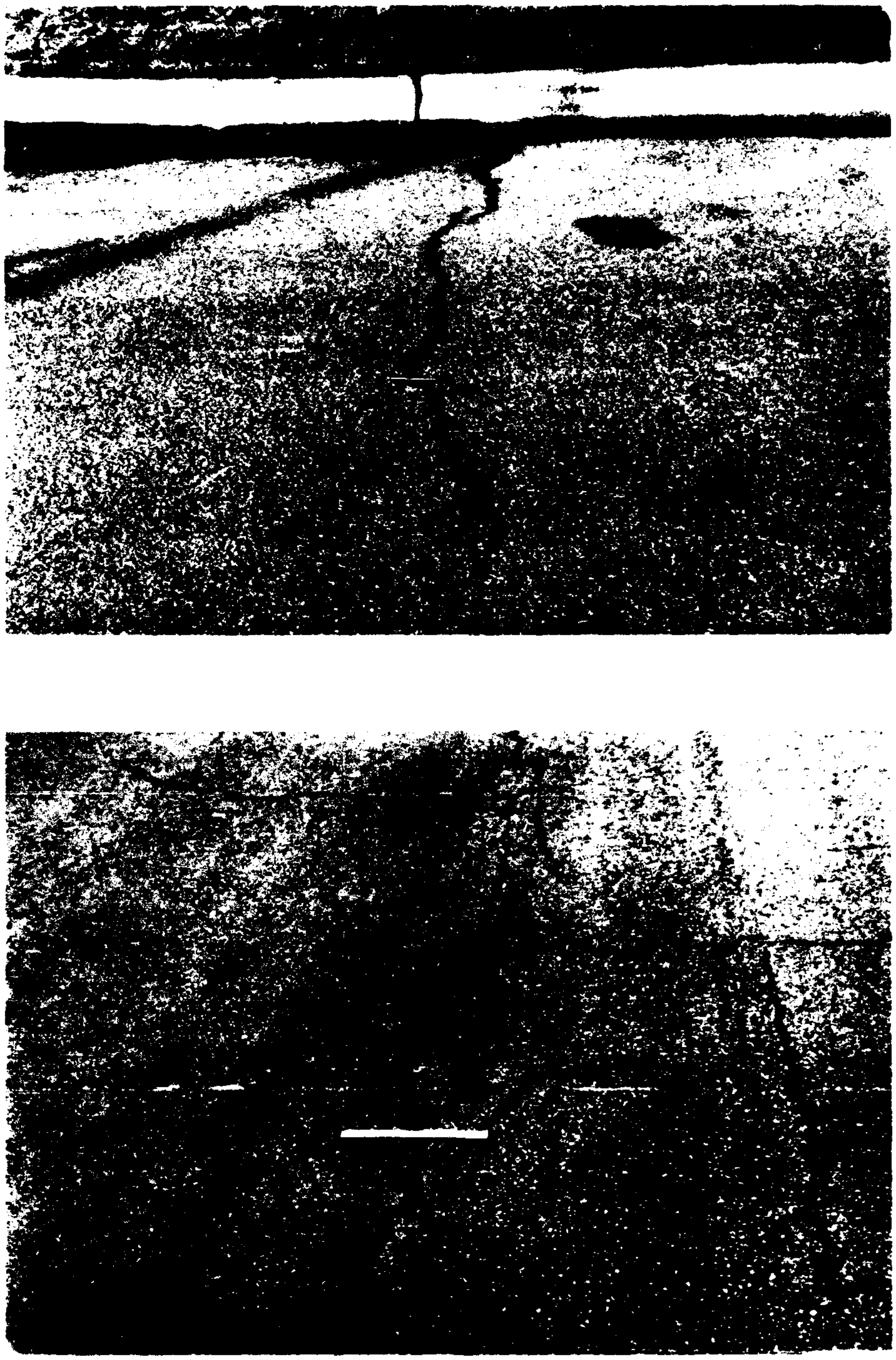


Figure A30. Examples of medium-severity longitudinal and transverse cracking.

Figure A31. High-severity longitudinal and transverse cracking.

Patching and Utility Cut Patching

Description: A patch is an area of pavement that has been replaced with new material to repair the existing pavement. A patch is considered a defect no matter how well it is performing (a patched area or adjacent area usually does not perform as well as an original pavement section). Generally, some roughness is associated with this distress.

Severity Levels:

L - Patch is in good condition and satisfactory. Ride quality is rated as low severity or better (Figure A32).

M - Patch is moderately deteriorated and/or ride quality is rated as medium severity (Figure A33).

H - Patch is badly deteriorated and/or ride quality is rated as high severity. Needs replacement soon (Figure A34).

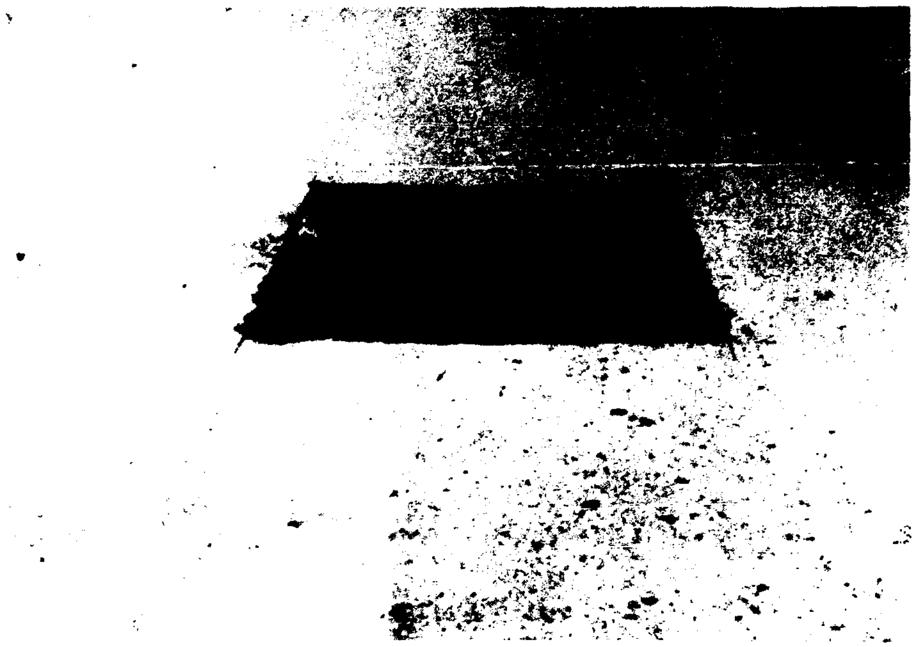
How to Measure: Patching is rated in square feet of surface area. However, if a single patch has areas of differing severity, these areas should be measured and recorded separately. For example, a 25 sq ft (2.32 m^2) patch may have 10 sq ft (0.9 m^2) of medium severity and 15 sq ft (1.35 m^2) of low severity. These areas would be recorded separately. No other distresses (e.g., shoving and cracking) are recorded within a patch; even if the patch material is shoving or cracking, the area is rated only as a patch. If a large amount of pavement has been replaced, it should not be recorded as a patch, but considered as new pavement (e.g., replacement of a complete intersection).

Options for Repair:

L - Do nothing.

M - Do nothing; Replace patch.

H - Replace patch.



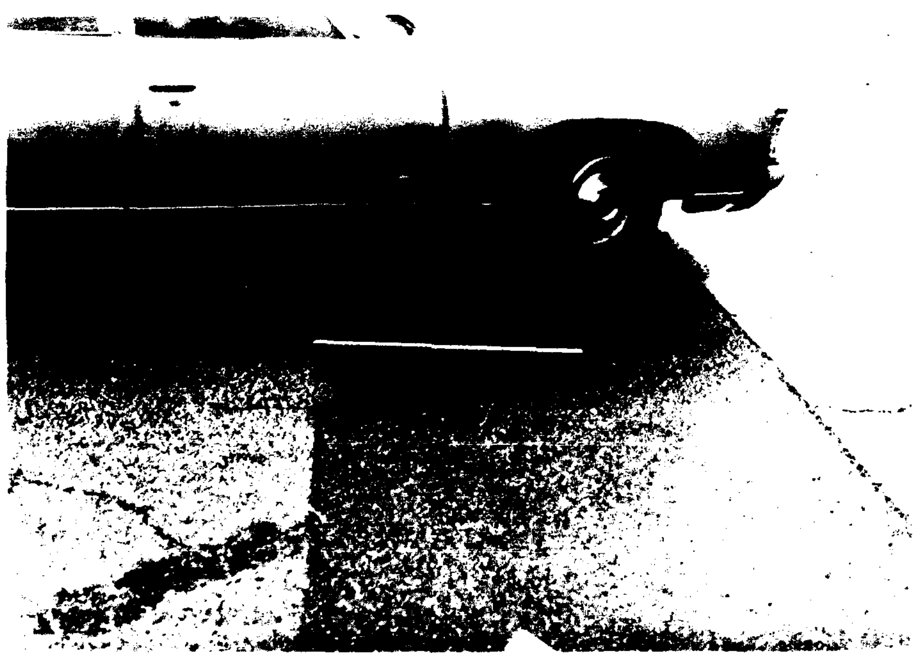


Figure A32. Examples of low-severity patching and utility cut patching.

Figure A32. (Cont'd).

Figure A33. Medium-severity patching.

Figure A34. High-severity utility cut patching.

Polished Aggregate

Description: This distress is caused by repeated traffic applications. When the aggregate in the surface becomes smooth to the touch, adhesion with vehicle tires is considerably reduced. When the portion of aggregate extending above the surface is small, the pavement texture does not significantly contribute to reducing vehicle speed. Polished aggregate should be counted when close examination reveals that the aggregate extending above the asphalt is negligible, and the surface aggregate is smooth to the touch. This type of distress is indicated when the number on a skid resistance test is low or has dropped significantly from a previous rating.

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 (Figure A35).

How to Measure: Polished aggregate is measured in square feet of surface area. If bleeding is counted, polished aggregate should not be counted.

Options for Repair: L, M, H - Do nothing; Surface treatment; Overlay; Mill and overlay.

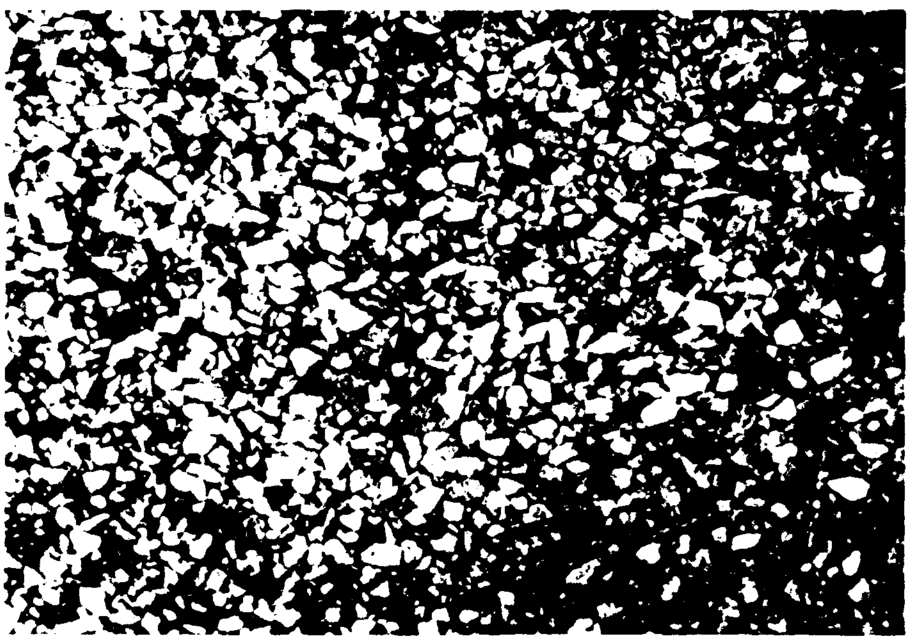


Figure A35. Polished aggregate.

Potholes

Description: Potholes are small--usually less than 3 ft (0.9 m) in diameter--bowl-shaped depressions in the pavement surface. They generally have sharp edges and vertical sides near the top of the hole. Their growth is accelerated by free moisture collection inside the hole. Potholes are produced when traffic abrades small pieces of the pavement surface. The pavement then continues to disintegrate because of poor surface mixtures, weak spots in the base or subgrade, or because it has reached a condition of high-severity alligator cracking. Potholes most often are structurally related distresses and should not be confused with raveling and weathering. When holes are created by high-severity alligator cracking, they should be identified as potholes, not as weathering.

Severity Levels: The levels of severity for potholes less than 30 in. (762 mm) in diameter are based on both the diameter and the depth of the pothole, according to Table A1.

If the pothole is more than 30 in. (76 mm) in diameter, the area should be determined in square feet and divided by 5 sq ft (0.47 m^2) to find the equivalent number of holes. If the depth is 1 in. (25 mm) or less, the holes are considered medium severity. If the depth is more than 1 in. (25 mm), they are considered high severity (Figures A36 through A38).

Table A1

Levels of Severity for Potholes

Maximum Depth of Pothole	**Average Diameter (in.) (mm)**		
	4 to 8 in. (102 to 203 mm)	**8 to 18 in. (203 to 457 mm)**	**18 to 30 in. (457 to 762 mm)**
1/2 to 1 in. (12.7 to 25.4 mm)	L	L	M
>1 to 2 in. (25.4 to 50.8 mm)	L	M	H
>2 in. (50.8 mm)	M	M	H

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

Options for
Repair:

L - Do nothing; Partial or full depth patch.

M - Partial or full depth patch.

H - Full depth patch.

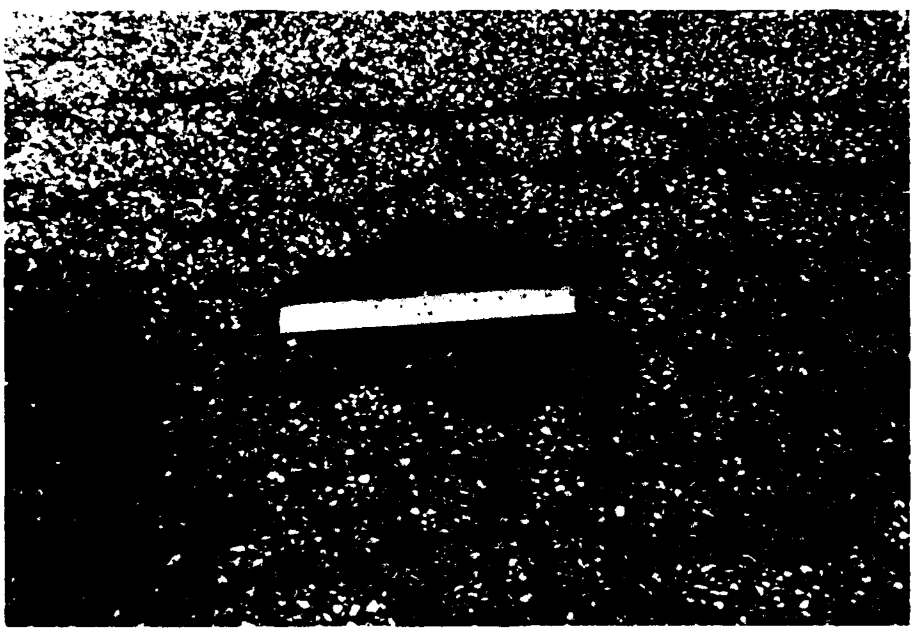


Figure A36. Low-severity potholes.

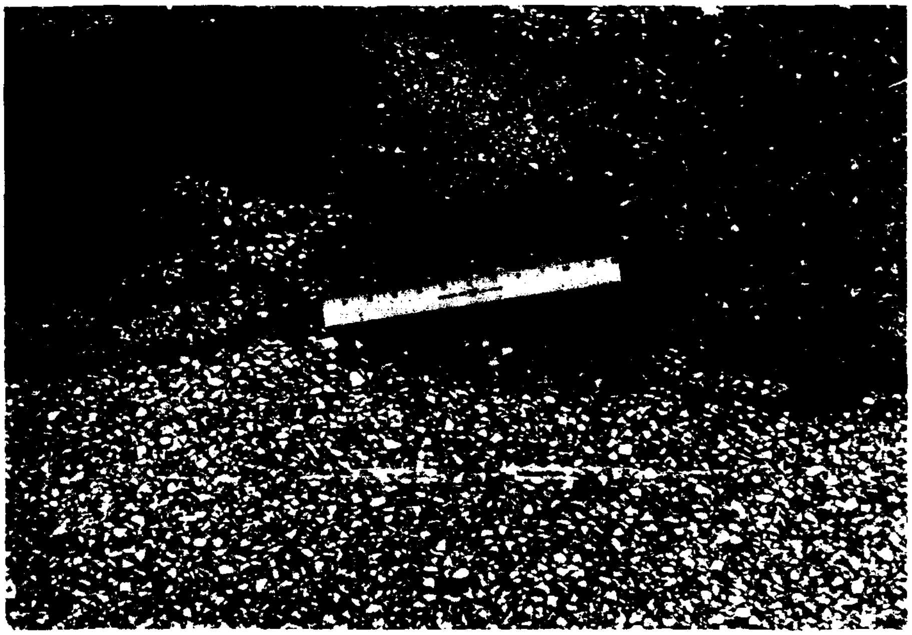


Figure A36. (Cont'd).

Figure A37. Medium-severity pothole.

Figure A38. High-severity potholes.

Railroad Crossing

Description: Railroad crossing defects are depressions or bumps around and/or between tracks.

Severity Levels:

L - Railroad crossing causes low-severity ride quality (Figure A39).

M - Railroad crossing causes medium-severity ride quality (Figure A40).

H - Railroad crossing causes high-severity ride quality (Figure A41).

How to Measure: The area of the crossing is measured in square feet of surface area. If the crossing does not affect ride quality, it should not be counted. Any large bump created by the tracks should be counted as part of the crossing.

Options for Repair:

L - Do nothing.

M - Shallow or partial depth patch approach; Reconstruct crossing.

H - Shallow or partial depth patch approach; Reconstruct crossing.

Figure A39. Low-severity railroad crossing.

Figure A40. Medium-severity railroad crossing.

Figure A41. High-severity railroad crossing.

Rutting

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

Severity Levels: Mean Rut Depth

L - 1/4 to 1/2 in. (6 to 13 mm) (Figure A42).

M - >1/2 to 1 in. (>13 to 25 mm) (Figure A43).

H - >1 in. (>25 mm) (Figure A44).

How to Measure: Rutting is measured in square feet of surface area and its severity is determined by the mean depth of the rut (see above). The mean rut depth is calculated by laying a straightedge across the rut, measuring its depth, then using measurements taken along the length of the rut to compute its mean depth in inches.

Options for Repair: L - Do nothing; Mill and overlay.

M - Shallow, partial, or full depth patch; Mill and overlay.

H - Shallow, partial, or full depth patch; Mill and overlay.

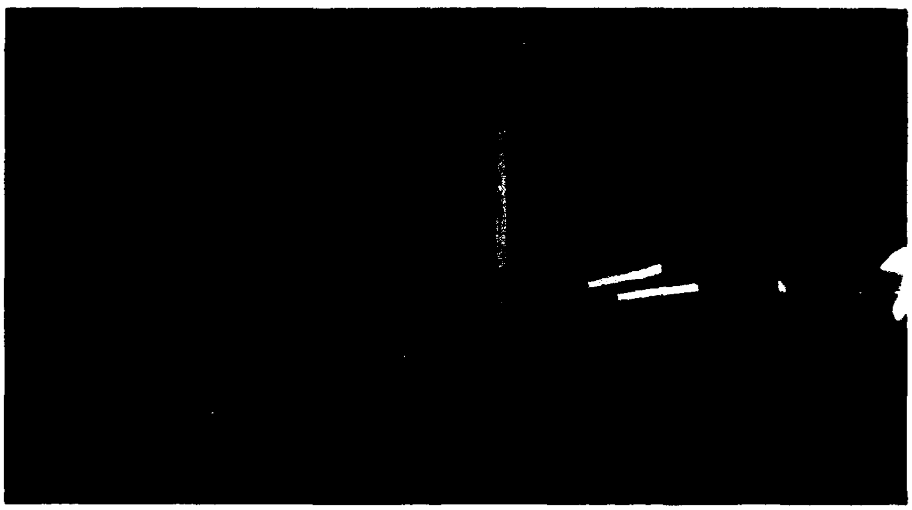


Figure A42. Examples of low-severity rutting.

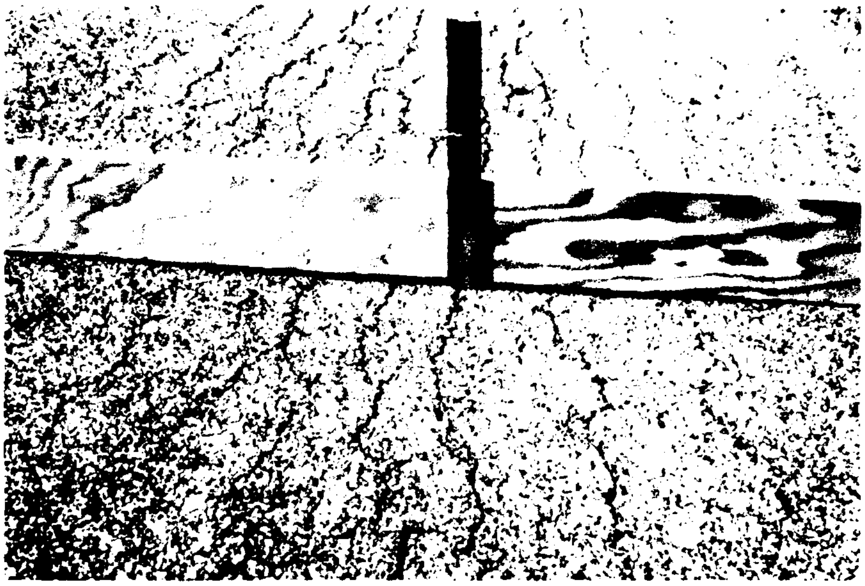


Figure A42. (Cont'd).

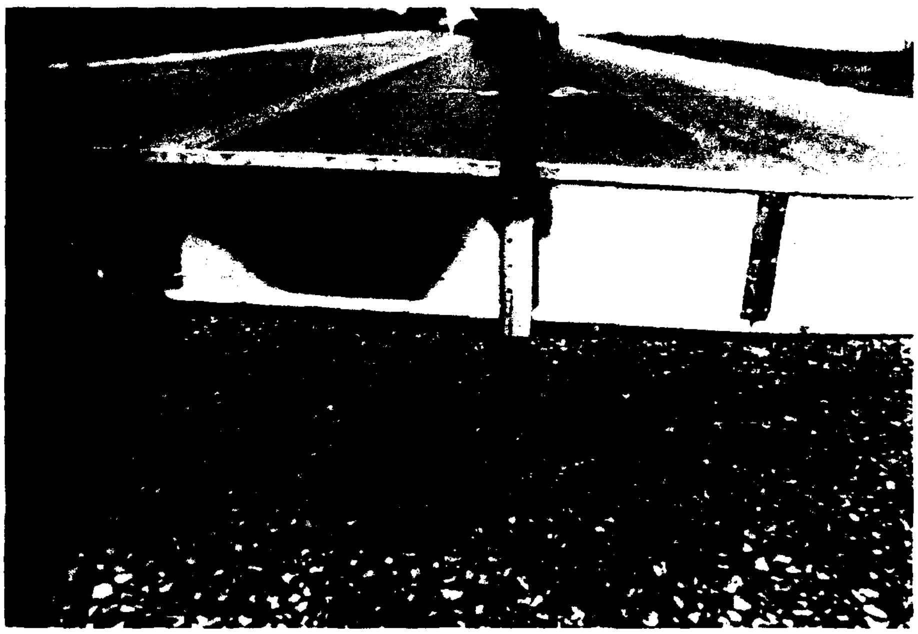


Figure A43. Medium-severity rutting.

Figure A44. High-severity rutting.

Shoving

Description: Shoving is a permanent, longitudinal displacement of a localized area of the pavement surface caused by traffic loading. When traffic pushes against the pavement, it produces a short, abrupt wave in the pavement surface. This distress normally occurs only in unstable liquid asphalt mix (cutback or emulsion) pavements.

Shoves also occur where asphalt pavements abut PCC pavements; the PCC pavements increase in length and push the asphalt pavement, causing the shoving.

Severity Levels:

L - Shove causes low-severity ride quality (Figure A45).

M - Shove causes medium-severity ride quality (Figure A46).

H - Shove causes high-severity ride quality (Figure A47).

How to Measure: Shoves are measured in square feet of surface area. Shoves occurring in patches are considered in rating the patch, not as a separate distress.

Options for Repair:

L - Do nothing; Mill.

M - Mill; Partial or full depth patch.

H - Mill; Partial or full depth patch.

Figure A45. Low-severity shoving.

Figure A46. Medium-severity shoving approaching high severity.

Figure A47. High-severity shoving.

Slippage Cracking

Description: Slippage cracks are crescent or half-moon shaped cracks. They are produced when braking or turning wheels cause the pavement surface to slide or deform. This distress usually occurs when there is a low-strength surface mix or poor bond between the surface and the next layer of the pavement structure.

Severity Level:

L - Average crack width is less than 3/8 in. (10 mm) (Figure A48).

M - One of the following conditions exists (Figure A49):

1. Average crack width is between 3/8 and 1-1/2 in. (10 and 38 mm)
2. The area around the crack is broken into tight-fitting pieces.

H - One of the following conditions exists (Figure A50).

1. The average crack width is greater than 1-1/2 in. (38 mm)
2. The area around the crack is broken into easily removed pieces.

How to Measure: The area associated with a given slippage crack is measured in square feet and rated according to the highest level of severity in the area.

Options for Repair:

L - Do nothing; Partial depth patch.

M - Partial depth patch.

H - Partial depth patch.

Figure A48. Low-severity slippage cracking.

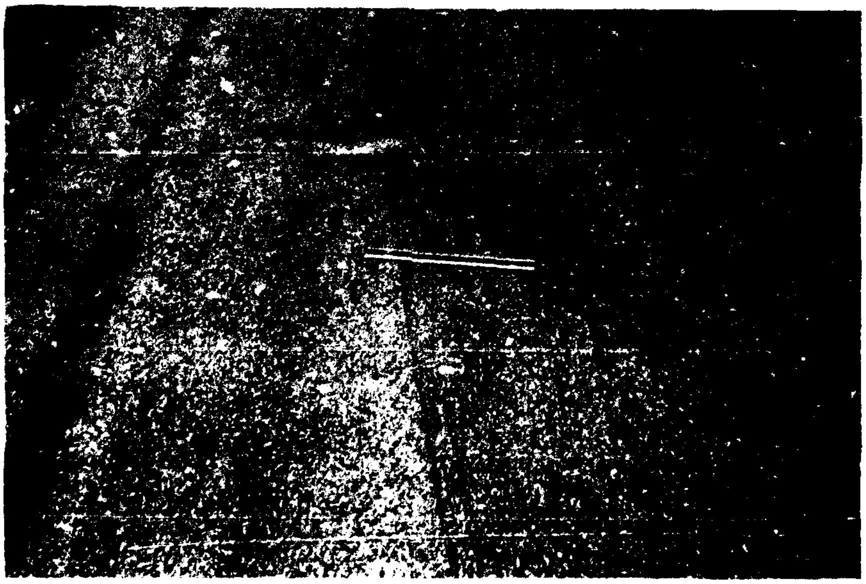


Figure A49. Medium-severity slippage cracking.

Figure A50. High-severity slippage cracking.

Swell

Description: Swell is characterized by an upward bulge in the pavement's surface--a long, gradual wave more than 10 ft (3 m) long (Figure A51). Swelling can be accompanied by surface cracking. This distress is usually caused by frost action in the subgrade or by swelling soil.

Severity Level:

L - Swell causes low-severity ride quality. Low-severity swells are not always easy to see, but can be detected by driving at the speed limit over the pavement section. An upward motion will occur at the swell if it 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.

Options for Repair:

L - Do nothing.

M - Do nothing; Reconstruct.

H - Reconstruct.

Figure A51. Example of a swell. Severity is based on ride quality.

Weathering and Raveling

Description: Weathering and raveling are the wearing away of the pavement surface due to a loss of asphalt or tar binder and dislodged aggregate particles. These distresses indicate that either the asphalt binder has hardened appreciably or that a poor-quality mixture is present. In addition, raveling may be caused by certain types of traffic, e.g., tracked vehicles. Softening of the surface and dislodging of the aggregates due to oil spillage are also included under raveling.

Severity Levels:

L - Aggregate or binder has started to wear away. In some areas, the surface is starting to pit (Figure A52). In the case of oil spillage, the oil stain can be seen, but the surface is hard and cannot be penetrated with a coin.

M - Aggregate or binder has worn away. The surface texture is moderately rough and pitted (Figure A53). In the case of oil spillage, the surface is soft and can be penetrated with a coin.

H - Aggregate or binder has been worn away considerably. The surface texture is very rough and severely pitted. The pitted areas are less than 4 in. (10 mm) in diameter and less than 1/2 in. (13 mm) deep (Figure A54); pitted areas larger than this are counted as potholes. In the case of oil spillage, the asphalt binder has lost its binding effect and the aggregate has become loose.

How to Measure: Weathering and raveling are measured in square feet of surface area.

Options for Repair:

L - Do nothing; Surface seal; Surface treatment.

M* - Surface seal; Surface treatment; Overlay.

H* - Surface treatment; Overlay; Recycle; Reconstruct.

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*If localized, i.e., due to oil spillage, then partial depth patch.

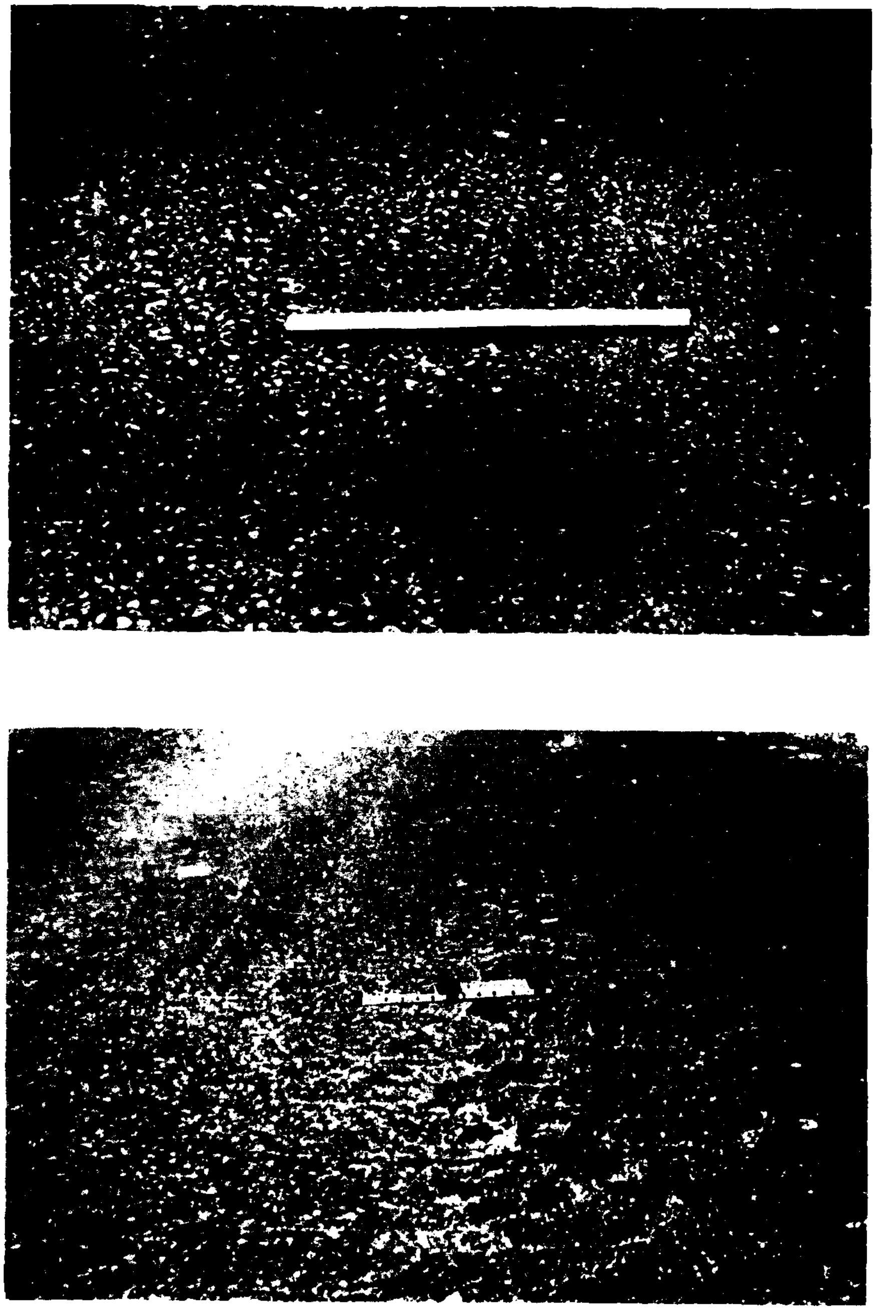

Figure A52. Examples of low-severity weathering and raveling.

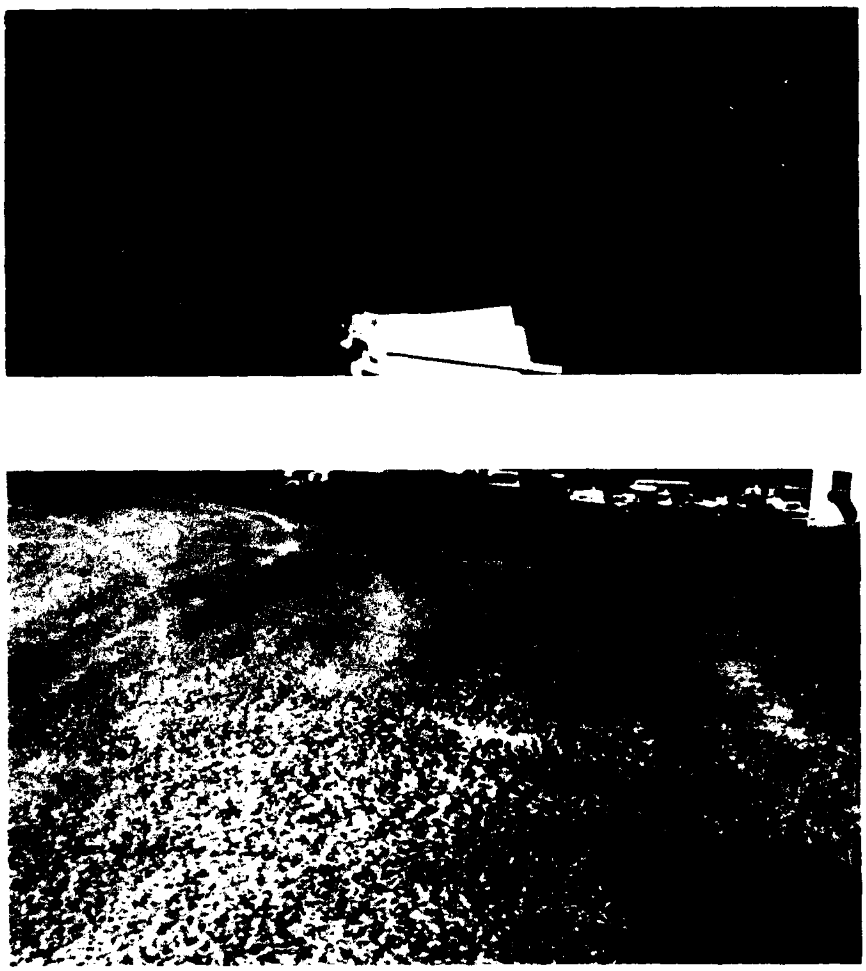

Figure A53. Examples of medium-severity weathering and raveling.

Figure A54. High-severity weathering and raveling.

Distress in Jointed Concrete Pavements

This section lists alphabetically 19 distress types for jointed concrete pavements. Distress definitions apply to both plain and reinforced jointed concrete pavements, with the exception of linear cracking distress, which is defined separately for plain and reinforced jointed concrete.

During the field condition surveys and validation of the PCI, several questions were often asked regarding the identification and counted method of some of the distresses. Answers to these questions are included under the section titled "How to Count" for each distress. For convenience, however, the items referenced most frequently are listed below:

1. Faulting is counted only at joints. Faulting associated with cracks is not counted separately since it is incorporated into the severity-level definitions of cracks. Crack definitions are also used in defining corner breaks and divided slabs.

2. Joint seal damage is not counted on a slab-by-slab basis. Instead, a severity level is assigned based on the overall condition of the joint seal in the area.

3. Cracks in reinforced concrete slabs that are less than 1/8 in. wide are counted as shrinkage cracks. Shrinkage cracks should not be counted to determine if the slab is broken into four or more pieces.

4. If the original distress of a patch is more severe than the patch, the original distress is the distress type recorded. For example, although patch material is present on the scaled area of the slab illustrated in Figure A55, only the scaling is counted.

5. Low-severity scaling (i.e., crazing) should only be counted if there is evidence that future scaling is likely to occur.

6. The severity levels of blowup and railroad distress in jointed concrete pavements are rated according to the distress' effect on ride quality.

The above list is not intended to be complete. To measure each distress type properly, the inspector must be familiar with the individual criteria.

Definition of Repair Options for Concrete Pavement

1. Grinding - Closely spaced diamond blades are used to remove material and provide a smooth surface.

2. Grooving - Patterns are cut into the concrete to reduce hydoplaning and provide skid resistance.

3. Joint Reconstruction - The joint is replaced by resawing it after one or both sides of the joint have been patched and/or doweled to provide load transfer.

4. Patching - *Partial Depth* - When the distress affects only the top few inches of the slab, the weakened concrete is removed down to sound concrete and the area patched. *Full Depth* - When the distress extends through the slab, the affected area is saw cut and removed down to the base. The base should be recompacted.

5. Seal Cracks - Cracks should be routed to remove any incompressible before sealing.

6. Underseal - Undersealant, such as cement grout, is inserted by pressure beneath the slab to fill voids and resist future pumping action. It is recommended that load transfer be provided if needed to extend the life of the pavement.

Figure A55. Distress in jointed concrete pavements.

ALPHABETICAL LIST OF DISTRESS TYPES: JOINTED CONCRETE PAVEMENTS

Blowup/Buckling

Description: Blowups or buckles occur in hot weather, usually at a transverse crack or joint that is not wide enough to permit slab expansion. 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. Blowups can also occur at utility cuts and drainage inlets.

Severity Levels:

L - Buckling or shattering causes low-severity ride quality (Figure A56).

M - Buckling or shattering causes medium-severity ride quality (Figure A57).

H - Buckling or shattering causes high-severity ride quality (Figure A58).

How to Count: At a crack, a blowup is counted as being in one slab. However, if the blowup occurs at a joint and affects two slabs, the distress should be recorded as occurring in two slabs. When a blowup renders the pavement inoperable, it should be repaired immediately.

Options for Repair:

L* - Do nothing; Partial or full depth patch.

M* - Full depth patch; Slab replacement.

H* - Full depth patch; Slab replacement.

Figure A56. Low-severity blowup/buckling.

*Must provide expansion joints if patched.

Figure A57. Examples of medium-severity blowup/buckling.

Figure A58. High-severity blowup/buckling approaching inoperable condition.

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 (3.7 by 6.1 m) that has a crack 5 ft (1.5 m) on one side and 12 ft (3.7 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, whereas a corner spall intersects the joint at an angle. Load repetition combined with loss of support and curling stresses usually cause corner breaks.

Severity Levels:

L - Break is defined by a low-severity crack* and the area between the break and the joints is not cracked or may be lightly cracked (Figure A59).

M - Break is defined by a medium-severity crack* and/or the area between the break and the joints has a medium crack (Figure A60).

H - Break is defined by a high-severity crack* and/or the area between the break and the joints is highly cracked (Figure A61).

How to Count: 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.

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 low- and medium-severity corner breaks should be counted as one slab with a medium corner break.

Options for Repair:

L** - Do nothing; Seal cracks over 1/8 in. (3 mm).

M** - Seal cracks; Full depth patch.

H** - Full depth patch.

*See **Linear Cracking** for a definition of low-, medium-, and high-severity cracks.

**Should check for loss of foundation support or voids under corners. If this condition exists, should consider subsealing and installing load transfer devices.

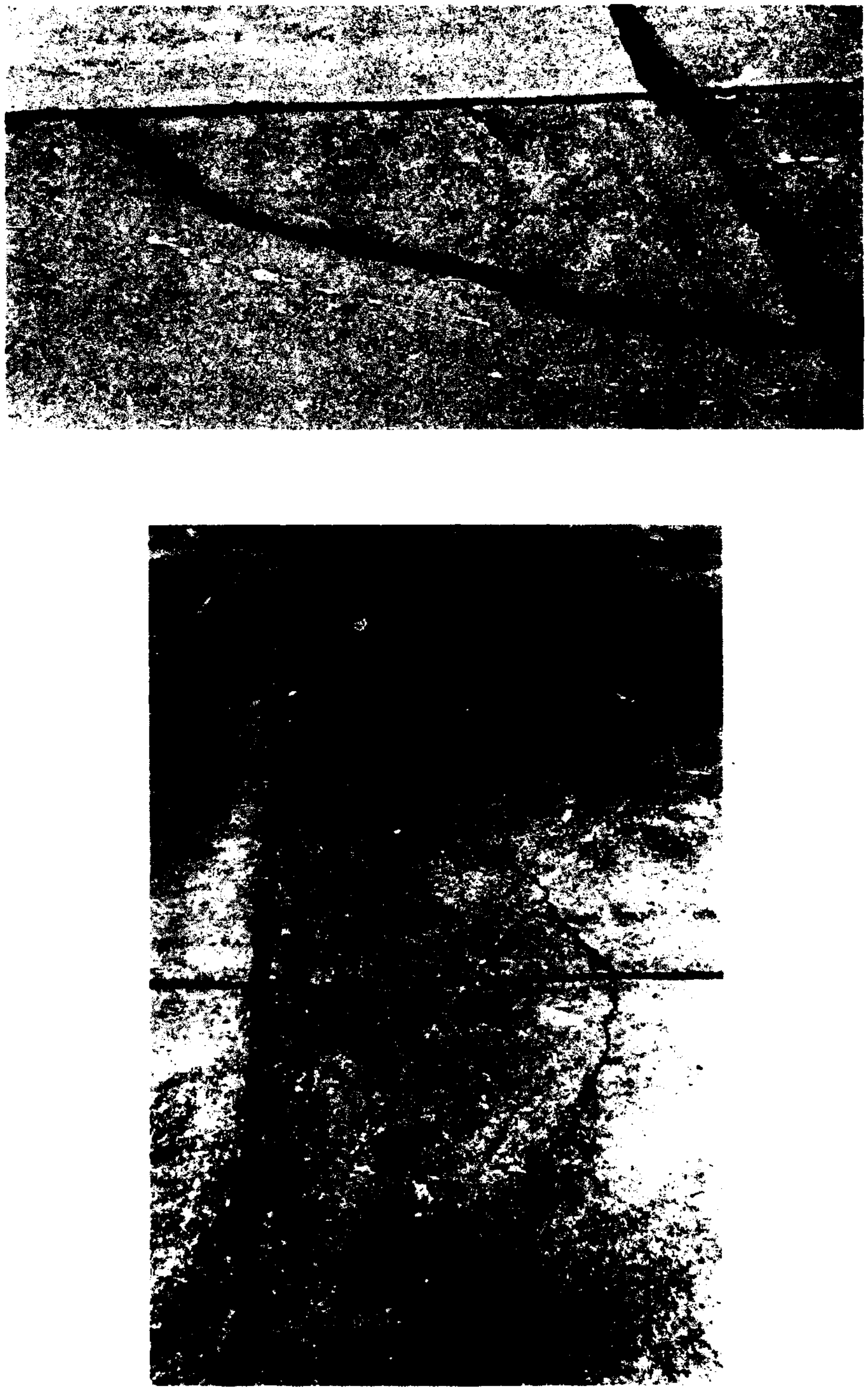

Figure A59. Examples of low-severity corner breaks.

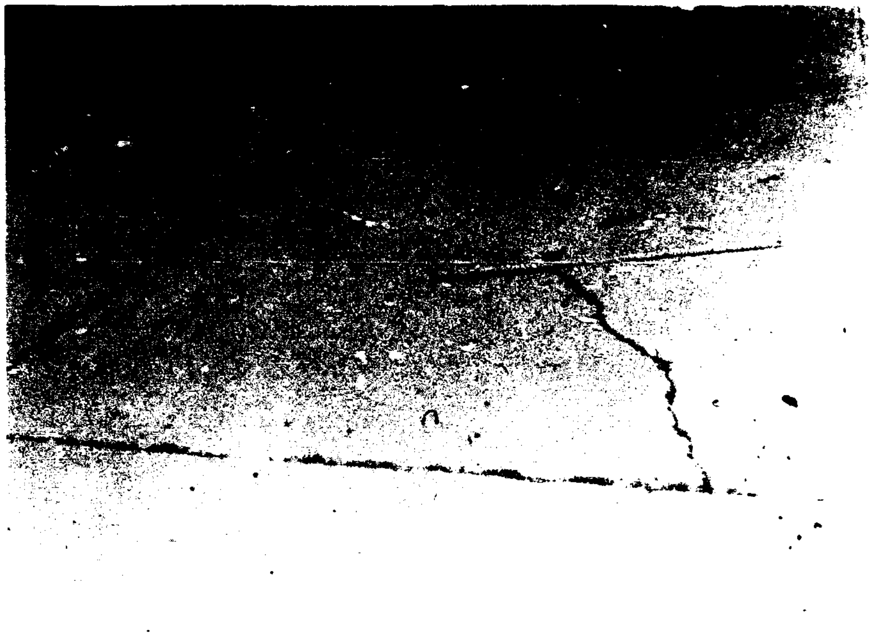

Figure A60. Medium-severity corner break defined by a medium-severity crack.

Figure A61. High-severity corner break.

Divided Slab

Description: Slab is divided by cracks 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: Table A2 lists severity levels for divided slabs. Examples are shown in Figures A62 through A65.

Table A2

Levels of Severity for Divided Slabs

Severity of Majority of Cracks	**Number of Pieces in Cracked Slab**		
	4 to 5	**6 to 8**	**More than 8**
L	L	L	M
M	M	M	H
H	H	H	H

How to Count: If the divided slab is medium- or high-severity, no other distress is counted.

Options for Repair:

L - Do nothing; Seal cracks more than 1/8 in. wide.

M - Replace slab.

H - Replace slab.

Figure A62. Low-severity divided slab. Most cracks are low-severity (less than 1/2 in. [13 mm] wide and no faulting).

Figure A63. Medium-severity divided slab.

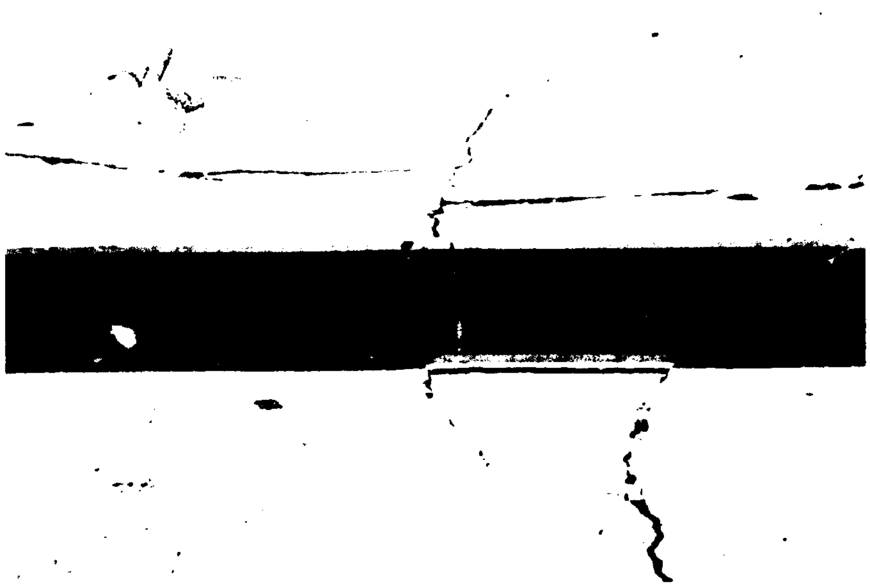

Figure A64. High-severity divided slab caused by high-severity cracks.

Figure A65. More examples of high-severity divided slabs.

Figure A65. (Cont'd).

Durability ("D") Cracking

Description: "D" Cracking is caused by freeze-thaw expansion of the large aggregate which, over time, gradually breaks down the concrete. This distress usually appears as a pattern of cracks running parallel and close to a joint or linear crack. Since the concrete becomes saturated near joints and cracks, a dark-colored deposit can usually be found around fine "D" cracks. This type of distress may eventually lead to disintegration of the entire slab.

Severity Levels:

L - "D" Cracks cover less than 15 percent of slab area. Most of the cracks are tight, but a few pieces may have popped out (Figure A66).

M - One of the following conditions exists (Figure A67):

1. "D" cracks cover less than 15 percent of the area and most of the pieces have popped out or could be removed easily.
2. "D" Cracks cover more than 15 percent of the area. Most of the cracks are tight, but a few pieces may have popped out or could be removed easily.

H - "D" cracks cover more than 15 percent of the area and most of the pieces have come out or could be removed easily (see Figure A68).

How to Count: When the distress is located and rated at one severity, it is counted as one slab. If more than one severity level exists, the slab is counted as having the higher severity distress. For example, if low and medium "D" cracking are on the same slab, the slab is counted as medium-severity cracking only.

Options for Repair:

L - Do nothing.

M* - Full depth patch; Reconstruct joints.

H* - Full depth patch; Reconstruct joints; Slab replacement.

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*Complete pavement reconstruction may be considered based on economics.

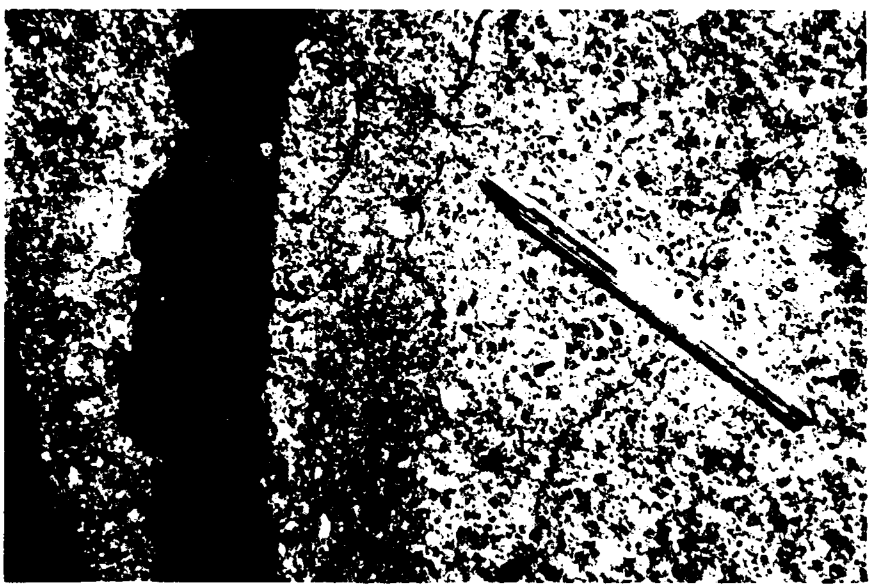


Figure A66. Examples of low-severity durability cracking.

Figure A67. Medium-severity durability cracking.

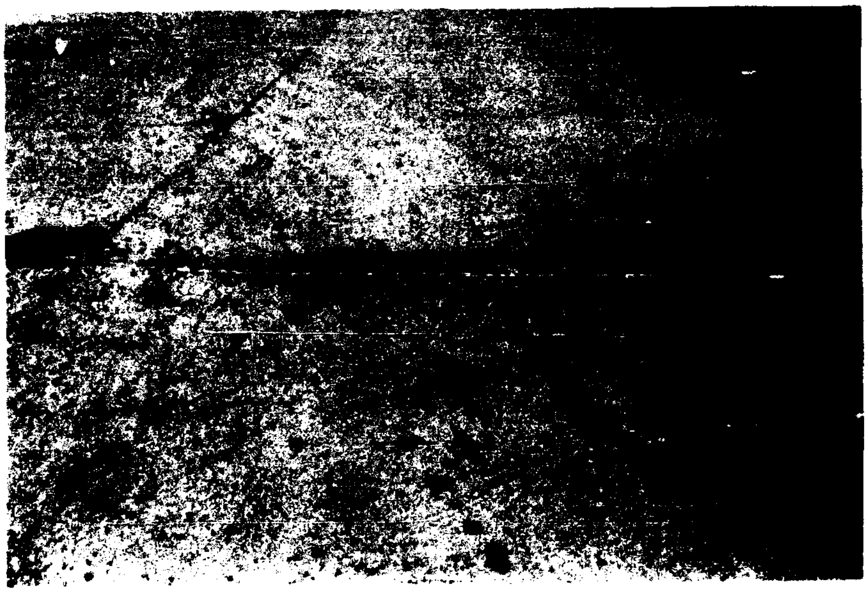


Figure A68. Examples of high-severity durability cracking.

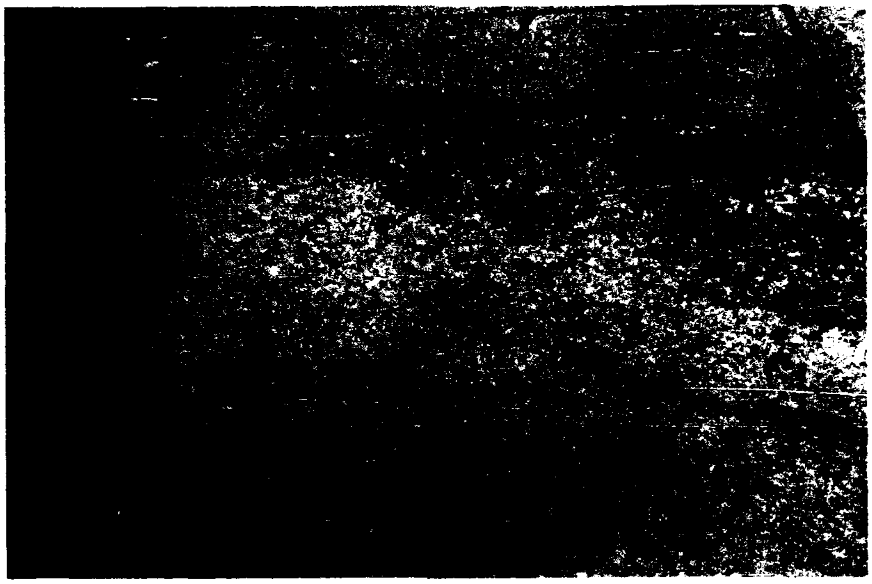


Figure A68. (Cont'd).

Faulting

Description: Faulting is the difference in elevation across a joint. Some common causes of faulting are:

1. Settlement because of soft foundation.

2. Pumping or eroding of material from under the slab.

3. Curling of the slab edges due to temperature and moisture changes.

Severity Levels: Severity levels are defined by the difference in elevation across the crack or joint as indicated in Table A3. Figures A69 through A71 show examples of the different severity levels.

Table A3

Levels of Severity for Faulting

Severity Level	Difference in Elevation
L	1/8 to 3/8 in. (3 to 10 mm)
M	>3/8 to 3/4 in. (10 to 19 mm)
H	>3/4 in. (>19 mm)

How to Count: Faulting across a joint is counted as one slab. Only affected slabs are counted.

Faults across a crack are not counted as distress, but are considered when defining crack severity.

Options for Repair: L* - Do nothing; Grind

M* - Grind.

H* - Grind.

*If faulting is caused by settlement or loss of support, then subsealing and installing load-transfer devices should be considered.

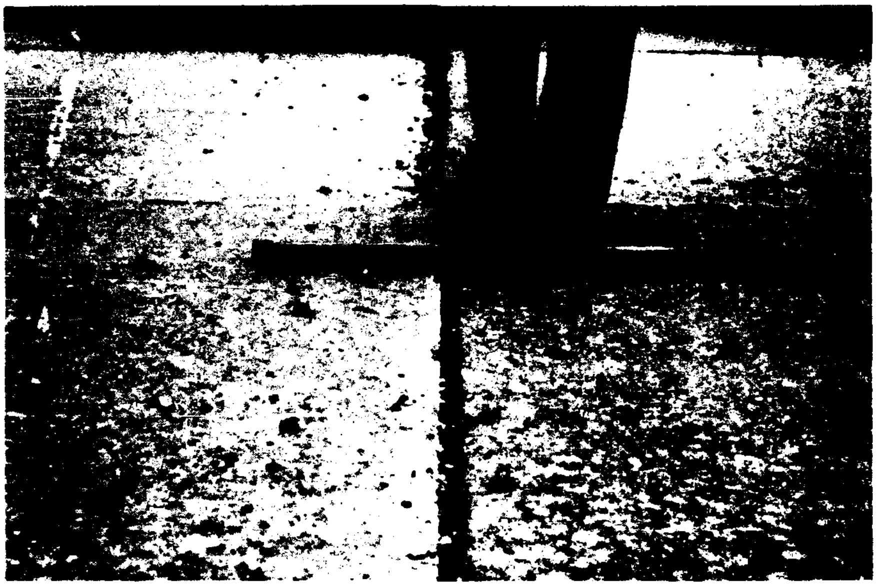


Figure A69. Low-severity faulting.

Figure A70. Examples of medium-severity faulting.

Figure A71. High-severity faulting.

Joint Seal Damage

Description: Joint seal damage is any condition that enables soil or rocks to accumulate in the joints or allows significant water infiltration. Accumulation of incompressible materials prevents the slab 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 material accumulation and 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.
6. Lack or absence of sealant in the joint.

Severity Levels:

L - Joint sealant is in generally good condition throughout section (Figure A72). Sealant is performing well, with only minor damage (see above).

M - Joint sealant is in generally fair condition over the entire section, with one or more of the above types of damage occurring to a moderate degree. Sealant needs replacement within 2 years (Figure A73).

H - Joint sealant is in generally poor condition over the entire section, with one or more of the above types of damage occurring to a severe degree. Sealant needs immediate replacement (Figure A74).

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 area.

Option for Repair:

L - Do nothing.

M - Reseal joints.

H - Reseal joints.

Figure A72. Low-severity joint seal damage.

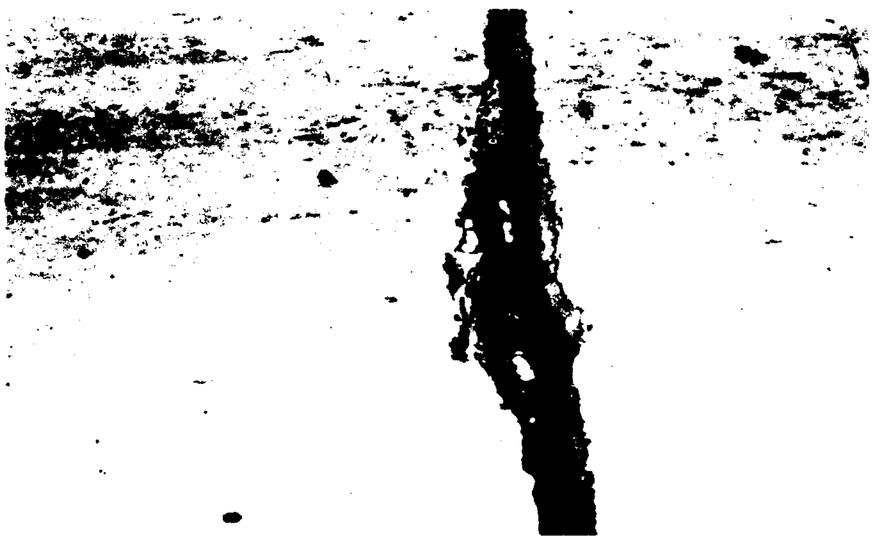


Figure A73. Medium-severity joint seal damage.

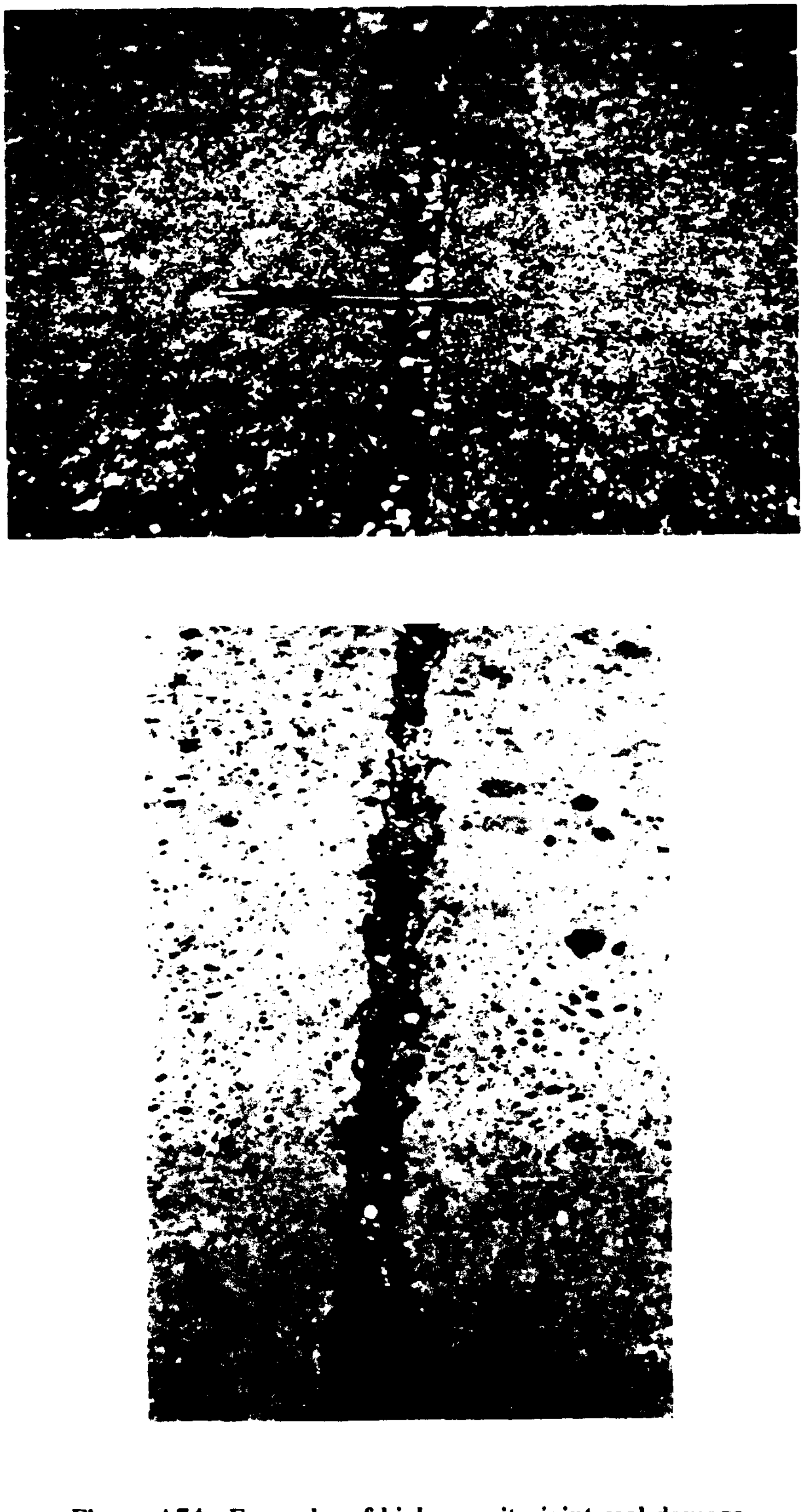


Figure A74. Examples of high-severity joint seal damage.

Lane/Shoulder Drop-Off

Description: Lane/shoulder drop-off is the difference between the settlement or erosion of the shoulder and the pavement travel-lane edge. The elevation difference can be a safety hazard; it can also cause increased water infiltration.

Severity Levels:

L - The difference between the pavement edge and shoulder is 1 to 2 in. (25 to 51 mm) (Figure A75).

M - The difference in elevation is 2 to 4 in. (51 to 102 mm) (Figure A76).

H - The difference in elevation is greater than 4 in. (102 mm) (Figure A77).

How to Count: The mean lane/shoulder drop-off is computed by averaging the maximum and minimum drop along the slab. Each slab exhibiting distress is measured separately and counted as one slab with the appropriate severity level.

Options for Repair: L, M, H - Regrade and fill shoulders to match lane height.

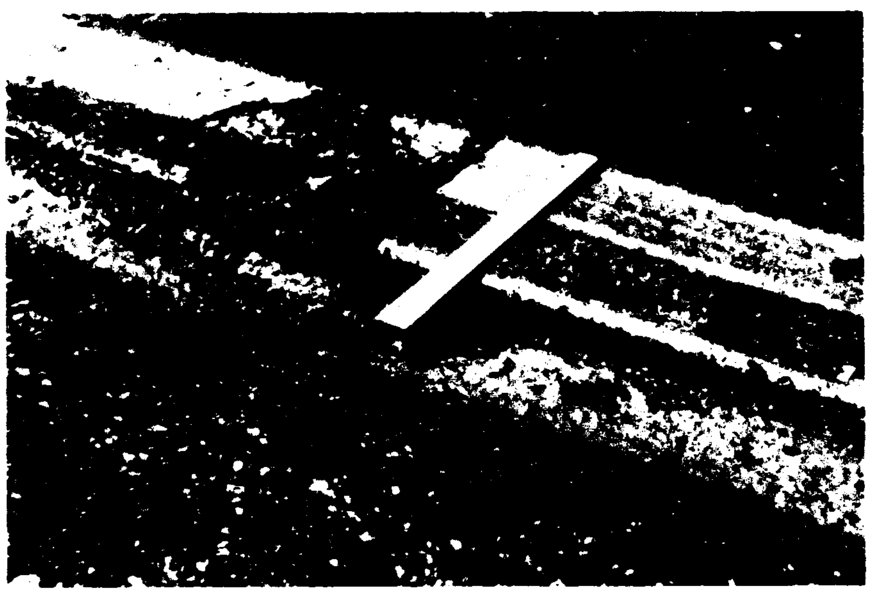


Figure A75. Low-severity lane/shoulder drop-off.

Figure A76. Medium-severity lane/shoulder drop-off.

Figure A77. High-severity lane/shoulder drop-off.

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 repeated traffic loading, thermal gradient curling, and repeated moisture loading. (Slabs divided into four or more pieces are counted as divided slabs.) Low-severity cracks are usually related to warp or friction and are not considered major structural distresses. Medium- or high-severity cracks are usually working cracks and are considered major structural distresses (Figure A78 through A80).

Hairline cracks that are only a few f et long and do not extend across the entire slab are counted as shrinkage cracks.

Severity Levels: Nonreinforced Slabs

L - Nonfilled* cracks less than or equal to 1/2 in. (12 mm) or filled cracks of any width with the filler in satisfactory condition. No faulting exists.

M - One of the following conditions exists:

1. Nonfilled crack with a width between 1/2 and 2 in. (12 and 51 mm).
2. Nonfilled crack of any width up to 2 in. (51 mm) with faulting of less than 3/8 in. (10 mm).
3. Filled crack of any width with faulting less than 3/8 in. (10 mm).

H - One of the following conditions exists:

1. Nonfilled crack with a width greater than 2 in. (51 mm).
2. Filled or nonfilled crack of any width with faulting greater than 3/8 in. (10 mm).

Reinforced Slabs

L - Nonfilled cracks 1/8 to 1 in. (3 to 25 mm) wide; filled crack of any width with the filler in satisfactory condition. No faulting exists.

M - One of the following conditions exists:

1. Nonfilled cracks with a width between 1 and 3 in. (25 and 76 mm) and no faulting.
2. Nonfilled crack of any width up to 3 in. (76 mm) with up to 3/8 in. (10 mm) of faulting.
3. Filled crack of any width with up to 3/8 in. (10 mm) faulting.

---

*Filled cracks for which filler is unsatisfactory are treated an nonfilled.

H - Once of the following conditions exists:

1. Nonfilled crack more than 3 in. (76 mm) wide.

2. Filled or nonfilled crack of any width with faulting over 3/8 in. (10 mm).

How to Count:

One the severity has been identified, the distress is recorded as one slab. If two medium-severity cracks are within one slab, the slab is counted as having one high-severity crack. Slabs divided into four or more pieces are counted as divided slabs. In reinforced slabs, cracks less than 1/8 in. (3 mm) wide are counted as shrinkage cracks.

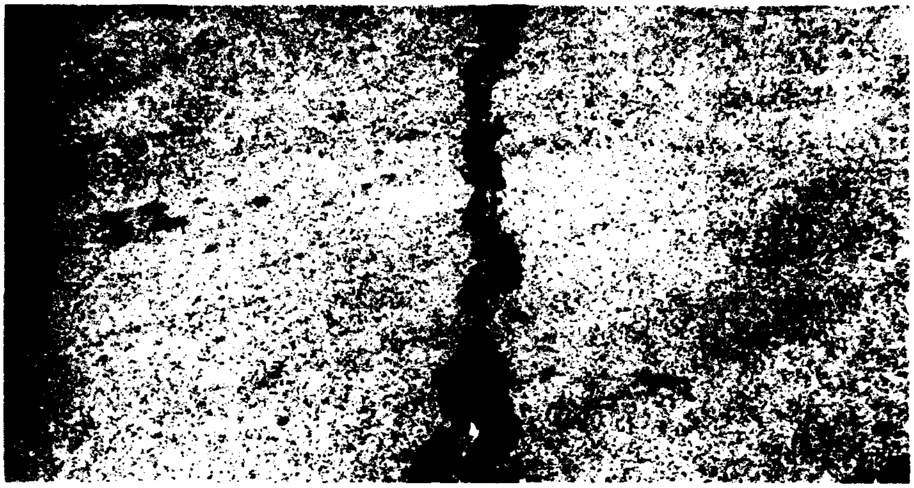
Slabs longer than 30 ft (9.1 m) are divided into approximately equal length "slabs" having imaginary joints assumed to be in perfect condition.

Options for Repair:

L - Do nothing; Seal cracks over 1/8 in.

M - Seal cracks.

H - Seal cracks; Full depth patch; Slab replacement.



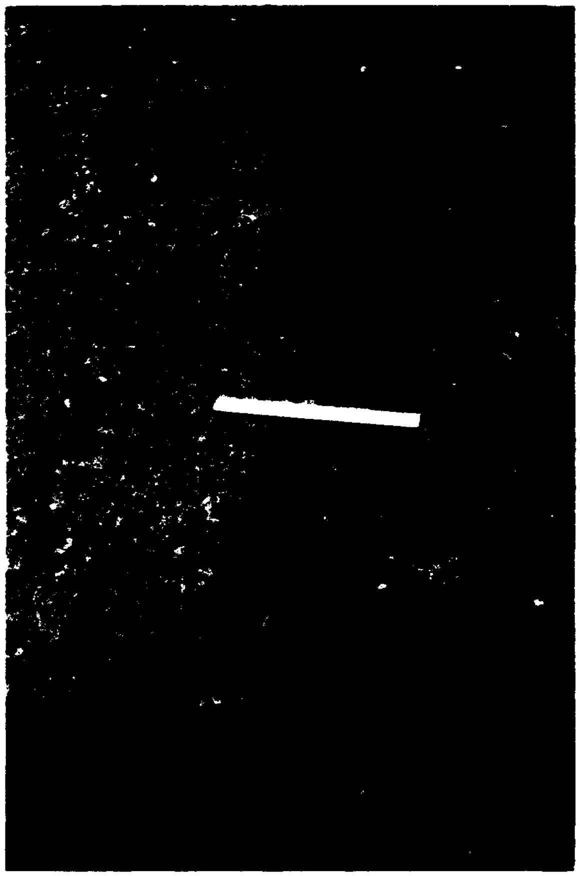


Figure A78. Examples of low-severity linear cracking in nonreinforced concrete slab.

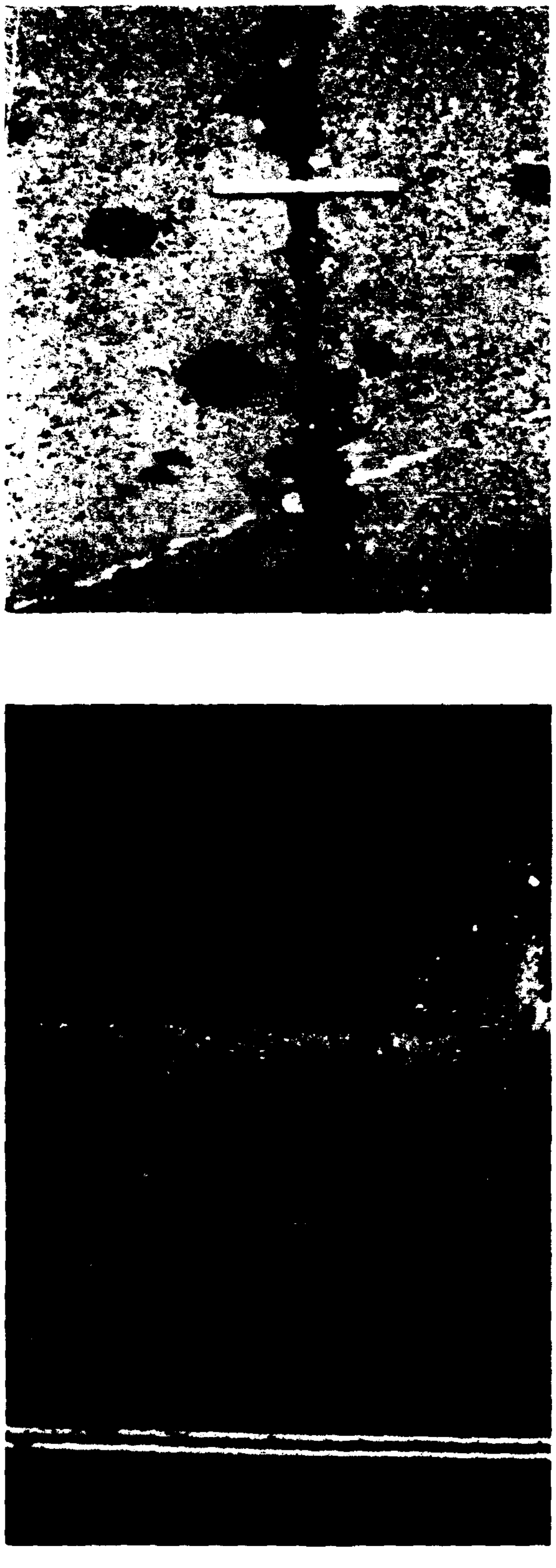


Figure A79. Examples of medium-severity linear cracking in reinforced concrete slab.

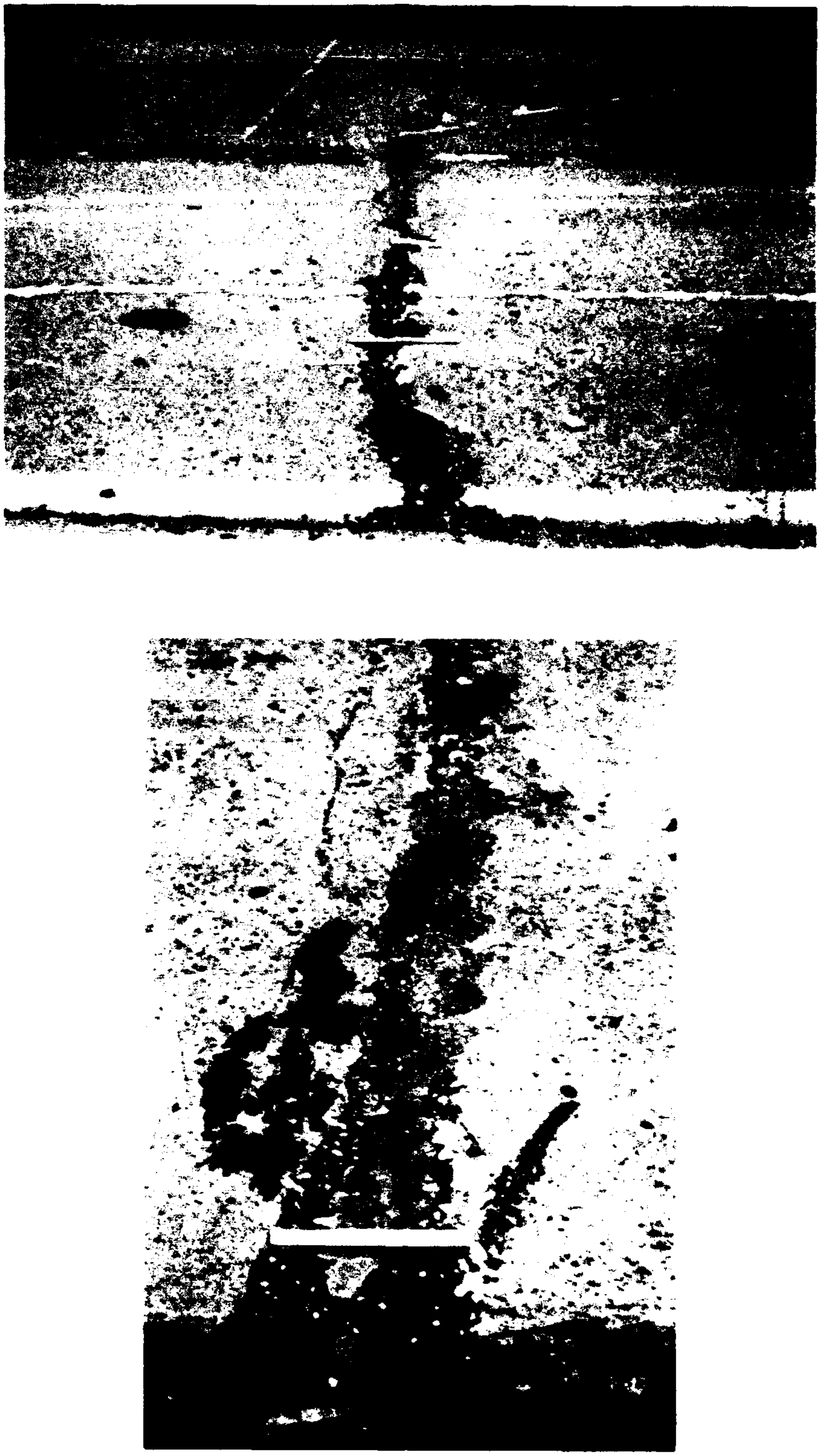


Figure A80. Examples of high-severity linear cracking in nonreinforced concrete slab.

Patching, Large (More Than 5 sq ft [0.45 m^2]) and Utility Cuts

Description: A patch is an area where the original pavement has been removed and replaced by filler material. A utility cut is a patch that has replaced the original pavement to allow the installation or maintenance 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 little or no deterioration (Figure A81).

M - Patch is moderately deteriorated and/or moderate spalling can be seen around the edges. Patch material can be dislodged with considerable effort (Figures A82 and A83).

H - Patch is badly deteriorated. The extent of the deterioration warrants replacement (Figure A84).

How to Count: If a single slab has one or more patches with the same severity level, it is counted as one slab containing that distress. If a single slab has more than one severity level, it is counted as one slab with the higher severity level.

If the cause of the patch is more severe, only the original distress is counted.

Options for Repair:

L - Do nothing.

M - Seal cracks; Replace patch.

H - Replace patch.

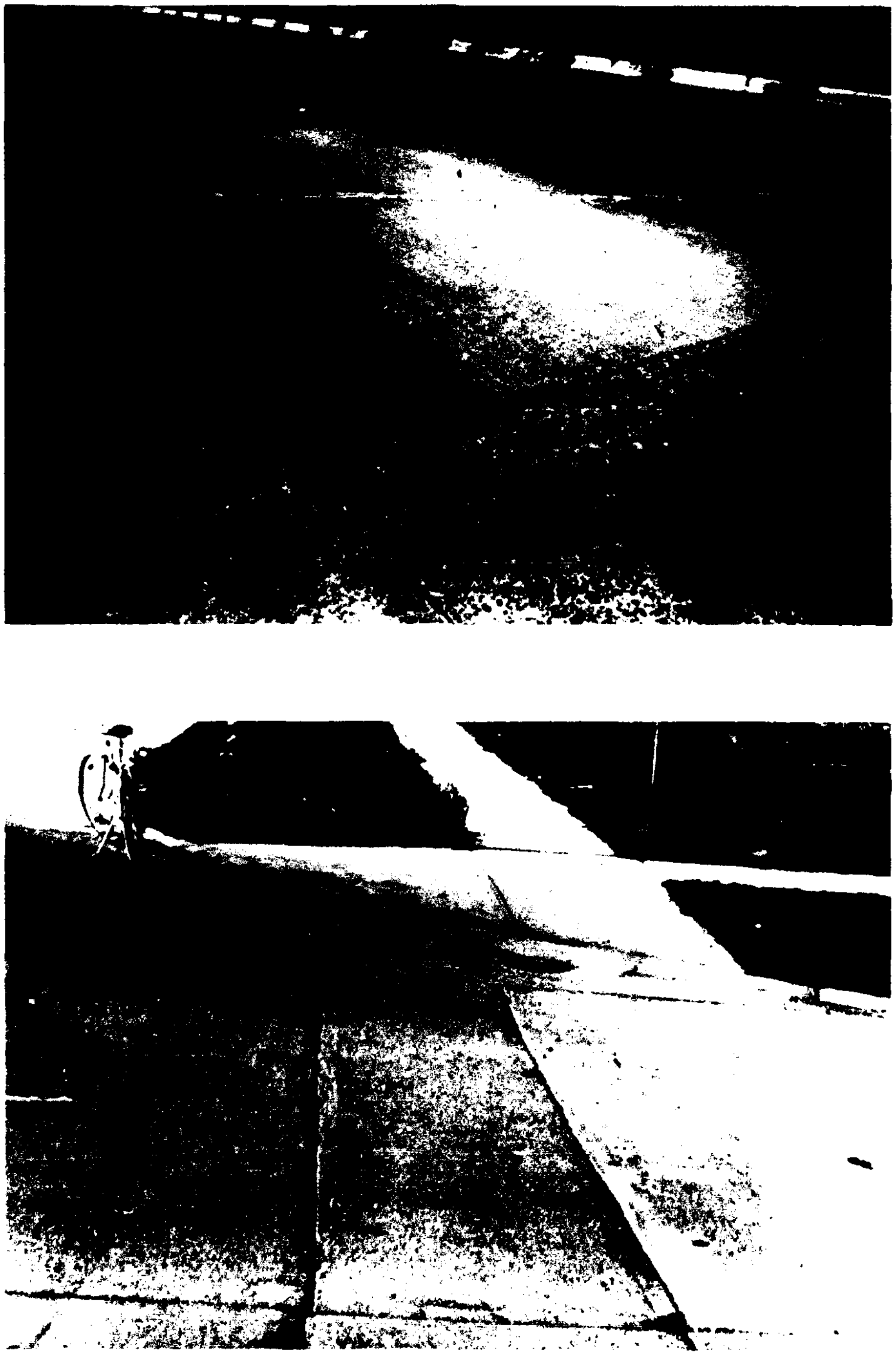


Figure A81. Examples of low-severity patching (large, utility cuts).

Figure A82. Examples of medium-severity patching (large).

Figure A83. Medium-severity patching (large, utility cuts).

Figure A84. High-severity patching (large).

Patching, Small (Less than 5 sq ft [0.45 m^2])

Description: A patch is an area where the original pavement has been removed and replaced by a filler material.

Severity Levels:

L - Patch is functioning well with little or no deterioration (Figure A85).

M - Patch is moderately deteriorated. Patch material can be dislodged with considerable effort (Figure A86).

H - Patch is badly deteriorated. The extent of deterioration warrants replacement (Figure A87).

How to Count: If a single slab has one or more patches with the same severity level, it is counted as one slab containing that distress. If a single slab has more than one severity level, it is counted as one slab with the higher severity level.

If the cause of the patch is more severe, only the original distress is counted.

Options for Repair:

L - Do nothing.

M - Do nothing; Replace patch.

H - Replace patch.

Figure A85. Low-severity patching (small).

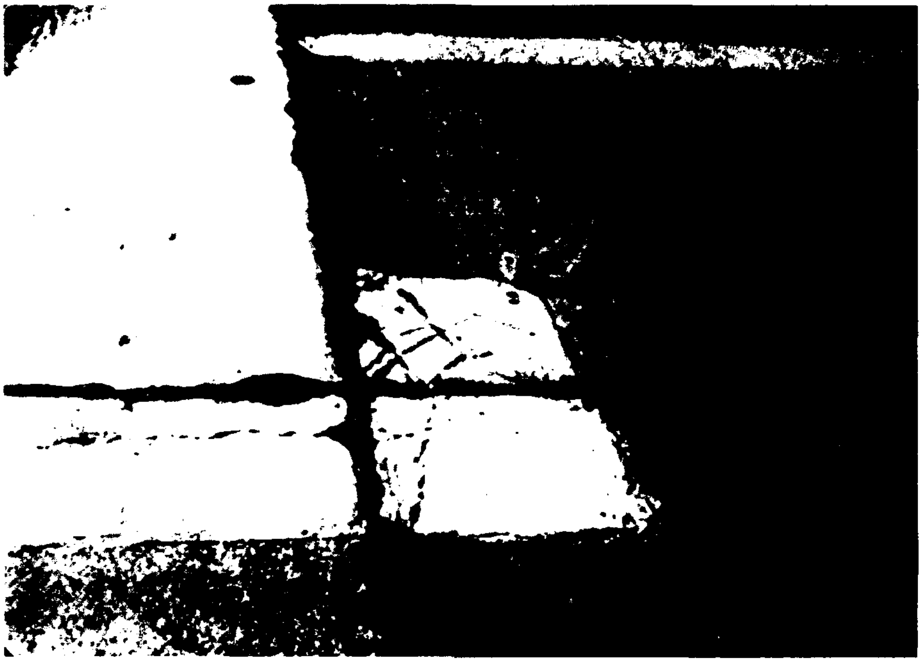


Figure A86. Medium-severity patching (small).

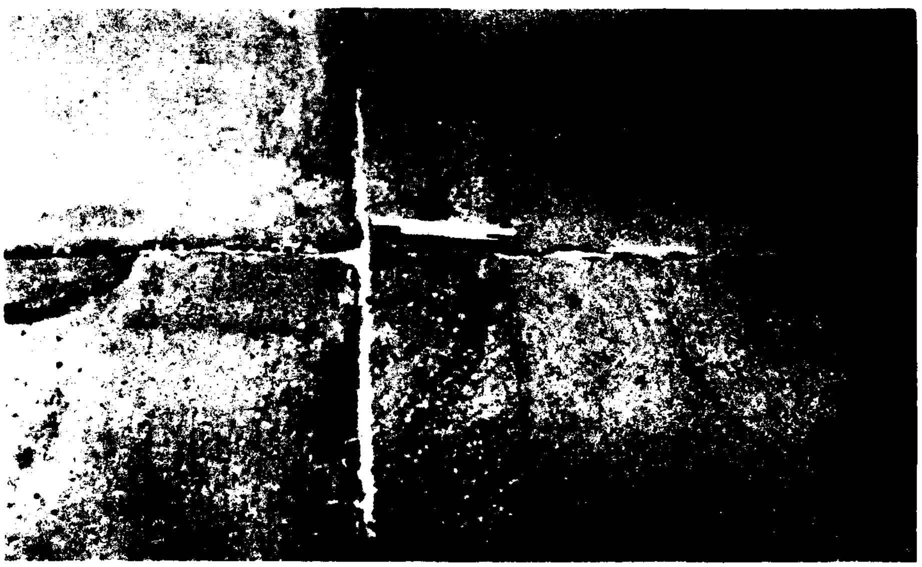


Figure A87. High-severity patching (small).

Polished Aggregate

Description: This distress is caused by repeated traffic applications. When the aggregate in the surface becomes smooth to the touch, adhesion with vehicle tires is considerably reduced. When the portion of aggregate extending above the surface is small, the pavement texture does not significantly contribute to reducing vehicle speed. Polished aggregate extending above the concrete is negligible, and the surface aggregate is smooth to the touch. This type of distress is indicated when the number on a skid resistance 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 (Figure A88).

How to Count: A slab with polished aggregate is counted as one slab.

Options for Repair: L, M, H - Groove surface; Overlay.

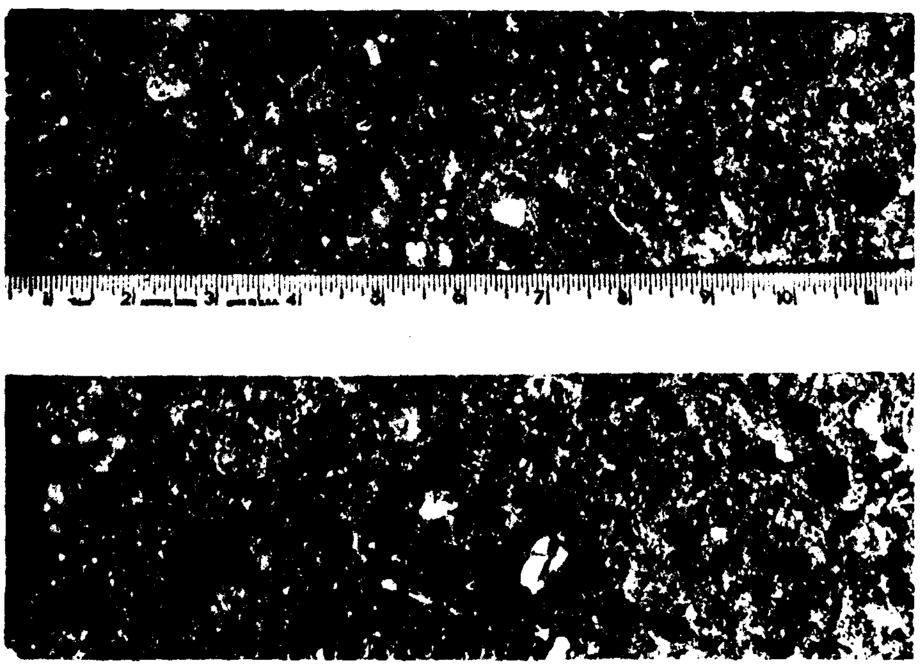


Figure A88. Polished aggregate on a concrete pavement.

Popouts

Description: A popout is a small piece of pavement that freeze-thaw action, combined with aggregate expansion, causes to break loose from the surface. Popouts usually range in diameter from approximately 1 to 4 in. (25 to 102 mm) and in depth from 1/2 to 2 in. (13 to 51 mm).

Severity Levels: No degrees of severity are defined for popouts. However, popouts must be extensive before they are counted as a distress. Average popout density must exceed approximately three popouts per square yard over the entire slab area (Figure A89).

How to Count: The density of the distress must be measured. If there is any doubt that the average is greater than three popouts per square yard, at least three random 1 sq yd (0.84 m^2) areas should be checked. When the average is greater than this density, the slab should be counted.

Options for Repair: L, M, H - Do nothing.

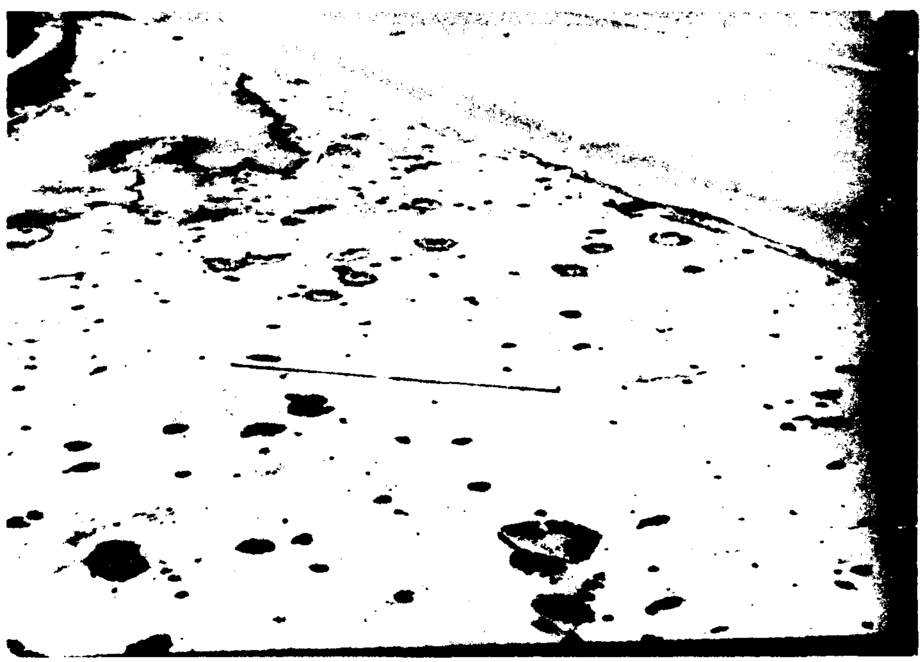


Figure A89. Popouts.

Pumping

Description: Pumping is the ejection of material from the slab foundation through joints or cracks. This is caused by deflection of the slab with passing loads. 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 erodes and eventually removes soil particles, resulting in progressive loss of pavement support. Pumping can be identified by surface stains and evidence of base or subgrade material on the pavement close to joints or cracks. Pumping near joints is caused by poor joint sealer and indicates loss of support; repeated loading will eventually produce cracks. Pumping can also occur along the slab edge, causing loss of support.

Severity Levels: No degrees of severity are defined. It is enough to indicate that pumping exists (Figure A90).

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.

Options for Repair: L, M, H - Underseal; Joint and crack seal; Restore load transfer.

Figure A90. Examples of pumping.

Figure A90. (Cont'd).

Punchout

Description: This distress is a localized area of the slab that is broken into pieces. The punchout can take many different shapes and forms, but it is usually defined by a crack and a joint, or two closely spaced cracks (usually 5 ft [1.52 m] wide). This distress is caused by heavy repeated loads, inadequate slab thickness, loss of foundation support, and/or a localized concrete construction deficiency (e.g., honeycombing).

Severity Levels: Table A4 lists the severity levels for punchouts, and Figures A91 through A93 show examples.

Table A4

Levels of Severity for Punchouts

Severity of Majority of Cracks	Number of Pieces		
	2 to 3	4 to 5	>5
L	L	L	M
M	L	M	H
H	M	H	H

How to Count: If a slab contains one or more punchouts, it is counted as containing a punchout at the severity level of the most severe punchout.

Options for Repair:

L - Do nothing; Seal cracks

M - Full depth patch.

H - Full depth patch.

Figure A91. Low-severity punchout.

Figure A92. Medium-severity punchout.

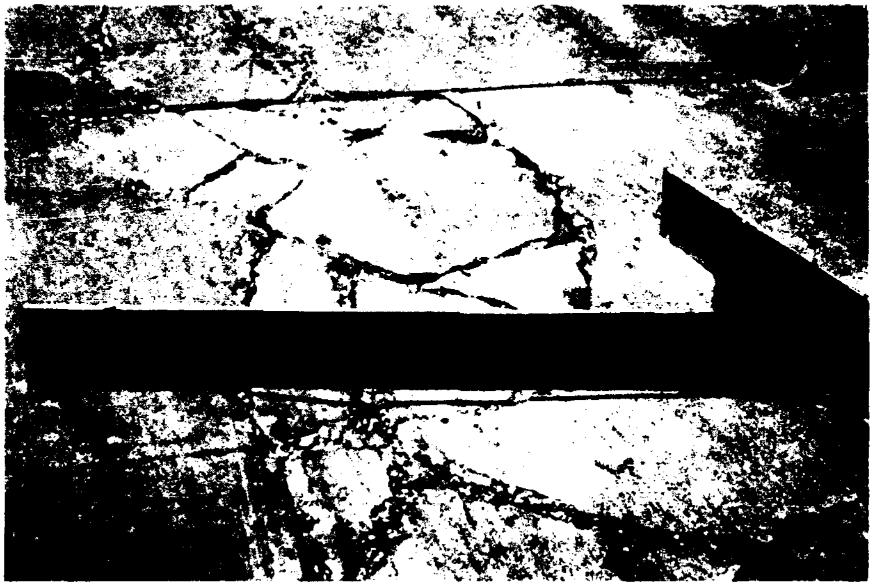


Figure A93. High-severity punchout.

Railroad Crossing

Description: Railroad crossing distress is characterized by depressions or bumps around the tracks.

Severity Levels:

L - Railroad crossing causes low-severity ride quality (Figure A94).

M - Railroad crossing causes medium-severity ride quality (Figure A95).

H - Railroad crossing causes high-severity ride quality (Figure A96).

How to Count: The number of slabs crossed by the railroad tracks is counted. Any large bump created by the tracks should be counted as part of the crossing.

Options for Repair:

L - Do nothing.

M - Partial depth patch approach; Reconstruct crossing.

H - Partial depth patch approach; Reconstruct crossing.

Figure A94. Low-severity railroad crossing.

Figure A95. Medium-severity railroad crossing.

Figure A96. High-severity railroad crossing.

Scaling/Map Cracking/Crazing

Description: Map cracking or crazing refers to a network of shallow, fine, or hairline cracks that extend only through the upper surface of the concrete. The cracks tend to intersect at angles of 120 degrees. Map cracking or crazing is usually caused by concrete overfinishing, and may lead to surface scaling, which is the breakdown of the slab surface to a depth of approximately 1/4 to 1/2 in. (6 to 13 mm). Scaling may also be caused by deicing salts, improper construction, freeze-thaw cycles, and poor aggregate. The type of scaling defined here is not caused by "D" cracking. If scaling is 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 only minor scaling present (Figure A97).

M - Slab is scaled, but less than 15 percent of the slab is affected (Figure A98).

H - Slab is scaled over more than 15 percent of its area (Figure A99).

How to Count: A scaled slab is counted as one slab. Low-severity crazing should only be counted if the potential for scaling appears to be imminent, or a few small pieces come out.

Options for Repair:

L - Do nothing.

M - Do nothing; Slab replacement.

H - Partial or full depth patch; Slab replacement; Overlay.

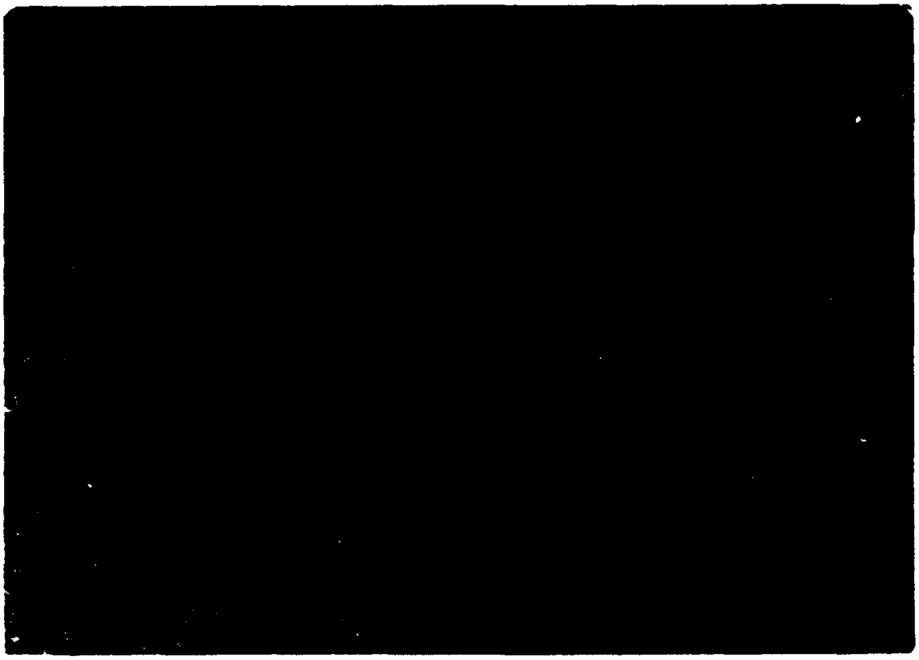


Figure A97. Low-severity scaling/map cracking/crazing.

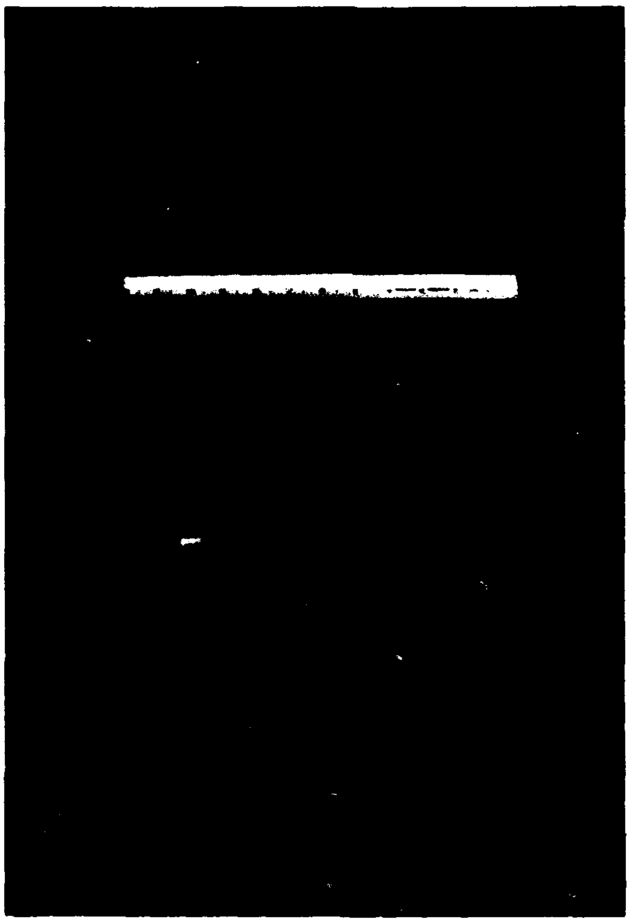


Figure A98. Medium-severity scaling/map cracking/crazing.

Figure A99. Examples of high-severity scaling/map cracking/crazing.

Figure A99. (Cont'd).

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 the concrete and usually do not extend through the depth of the slab.

Severity Levels: No degrees of severity are defined. It is enough to indicate that shrinkage cracks are present (Figure A100).

How to Count: If one or more shrinkage cracks exist on a particular slab, the slab is counted as one slab with shrinkage cracks.

Options for Repair: L, M, H - Do nothing.

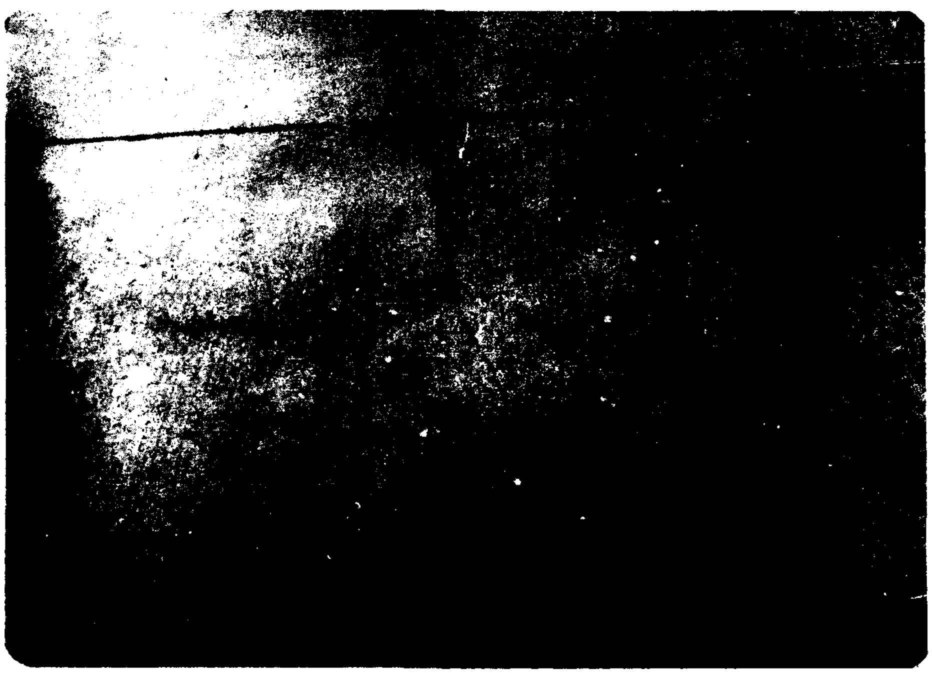


Figure A100. Shrinkage crack.

Spalling, Corner

Description: Corner spalling is the breakdown of the slab within approximately 2 ft (0.6 m) of the corner. A corner spall differs from a corner break in that the spall usually angles downward to intersect the joint, whereas a break extends vertically through the slab corner. Spalls less than 5 in. (127 mm) from the crack to the corner on both sides should not be counted.

Severity Levels: Table A5 lists the levels of severity for corner spalling. Figures A101 through A103 show examples. Corner spalling with an area of less than 10 sq in. (6452 mm^2) from the crack to the corner on both sides should not be counted.

Table A5

Levels of Severity for Corner Spalling

	Dimensions of Sides of Spall	
Depth of Spall	**5 x 5 in. to 12 x 12 in. (127 x 127 mm) to (305 x 305 mm)**	**>12 x 12 (305 x 305 mm)**
<1 in. (25 mm)	L	L
>1 to 2 in. (>25 to 51 mm)	L	M
>2 in. (51 mm)	M	H

How to Count: If one or more corner spalls with the same severity level are 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 with the highest severity level.

Options for Repair:

L - Do nothing.

M - Partial depth patch.

H - Partial depth patch.

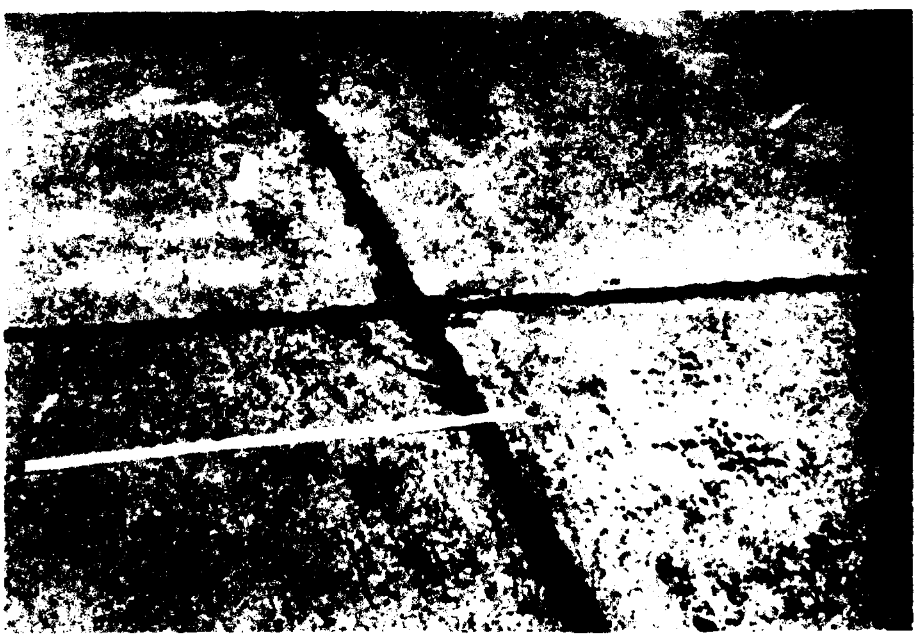


Figure A101. Examples of low-severity corner spalling.

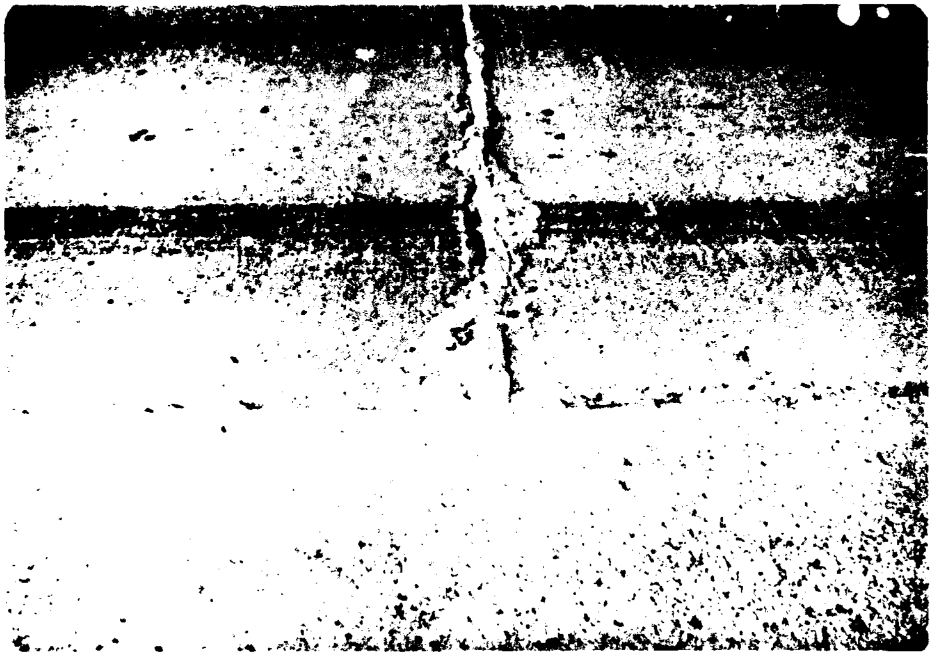


Figure A102. Medium-severity corner spalling.

Figure A103. High-severity corner spalling.

Spalling, Joint

Description: Joint spalling is the breakdown of the slab edges within 2 ft (0.6 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:

1. Excessive stresses at the joint caused by traffic loading or by infiltration of incompressible materials.

2. Weak concrete at the joint caused by overworking.

3. Water accumulation in the joint and freeze-thaw action.

Severity Levels: Table A6 and Figures A104 through A106 show the severity levels of joint spalling. A frayed joint where the concrete has been worn away along the entire joint is rated as low-severity.

Table A6

Levels of Severity for Joint Spalling

Spall Pieces	**Width of Spall**	**Length of Spall**	
		<2 ft (0.6 m)	**>2 ft (0.6 m)**
Tight--cannot be easily removed (may be a few pieces missing)	<4 in. (102 mm)	L	L
	>4 in. (102 mm)	L	L
Loose--can be removed and some pieces are missing; if most or all pieces are missing, spall is shallow, less than 1 in. (25 mm)	<4 in.	L	M
	>4 in.	L	M
Missing--most or all pieces have been removed	<4 in.	L	M
	>4 in.	M	H

How to Count: If spall is along the edge of one slab, it is counted as one slab with joint spalling. If spalling is 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.

Options for Repair:

L - Do nothing.

M - Partial depth patch.

H - Partial depth patch; Reconstruct joint.

Figure A104. Low-severity joint spalling.

Figure A105. Medium-severity joint spalling.

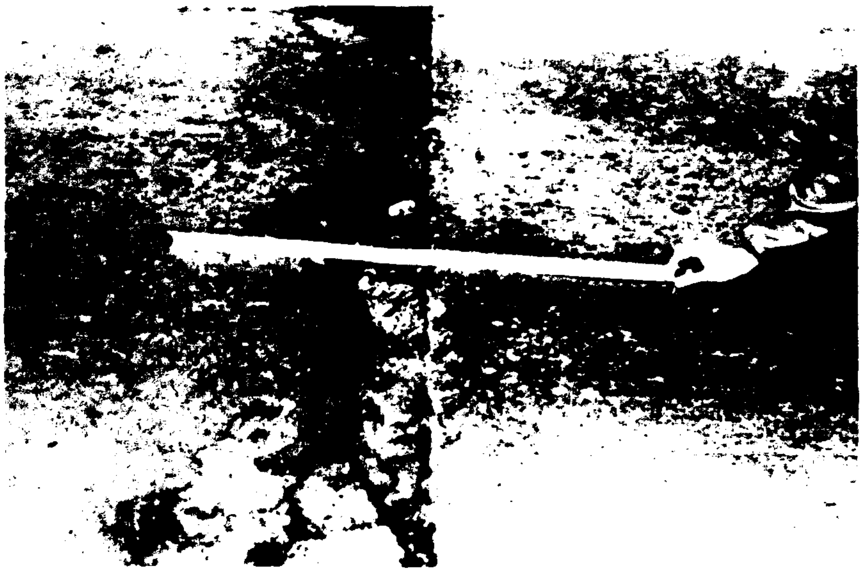


Figure A106. High-severity joint spalling.

APPENDIX B:

DEDUCT VALUE CURVES

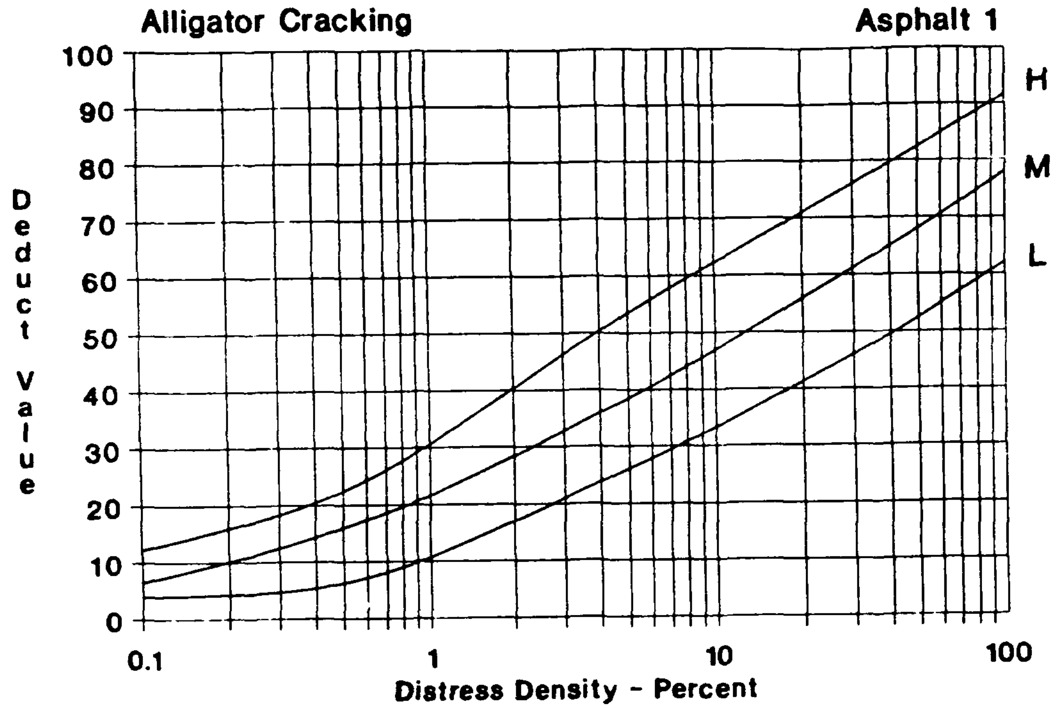


Figure B1. Alligator cracking.

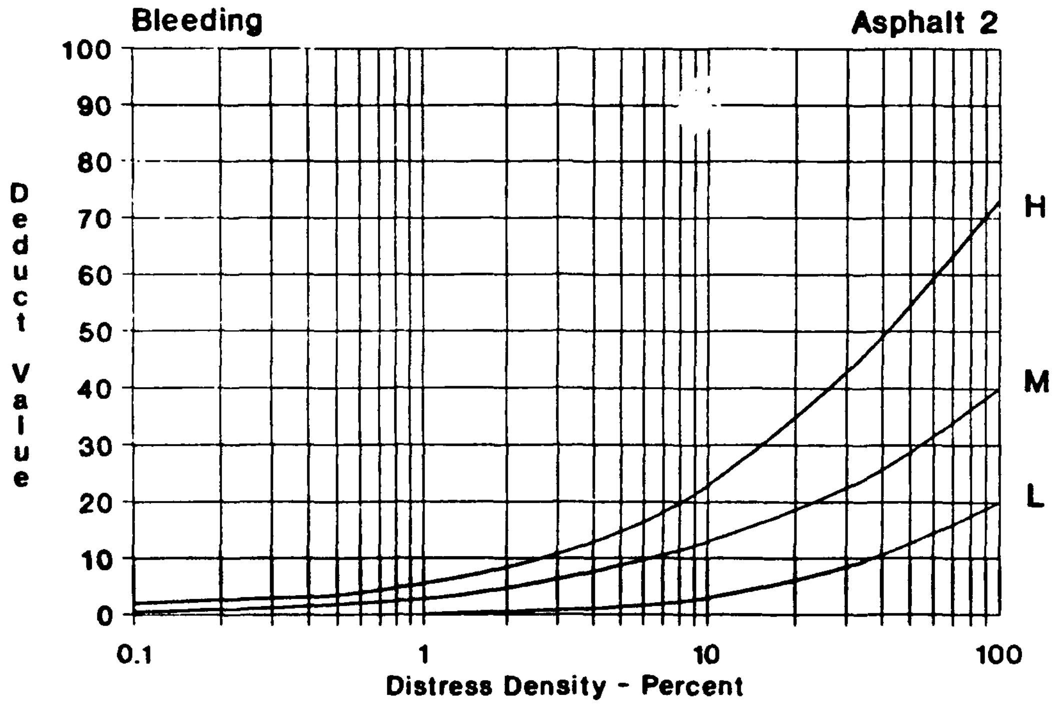


Figure B2. Bleeding.

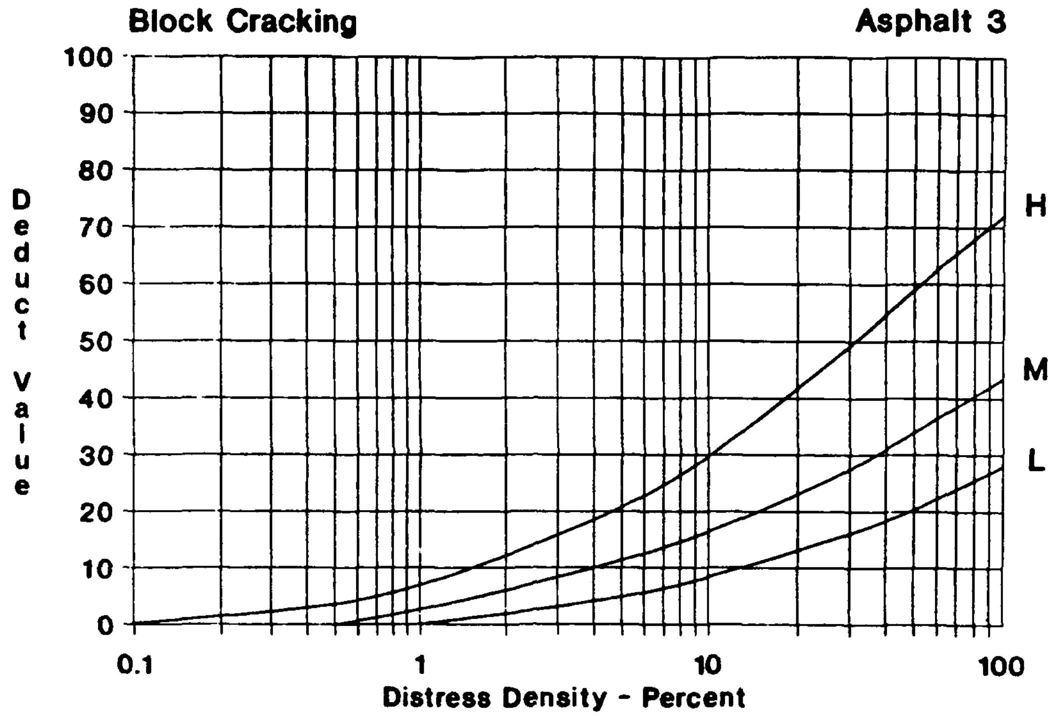


Figure B3. Block cracking.

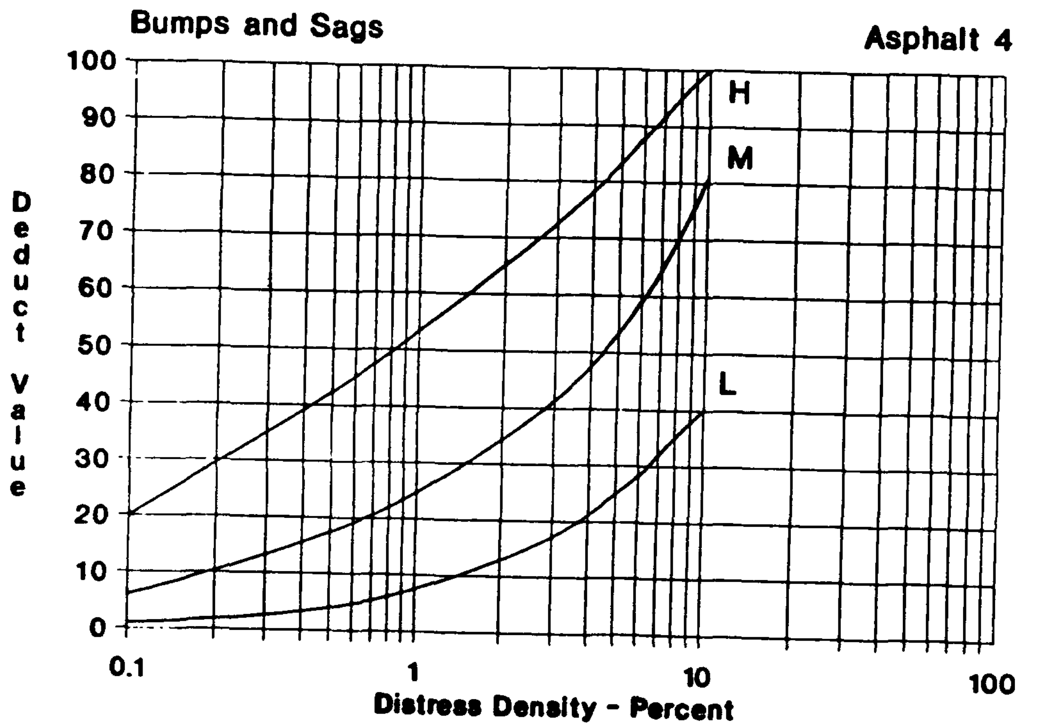


Figure B4. Bumps and sags.

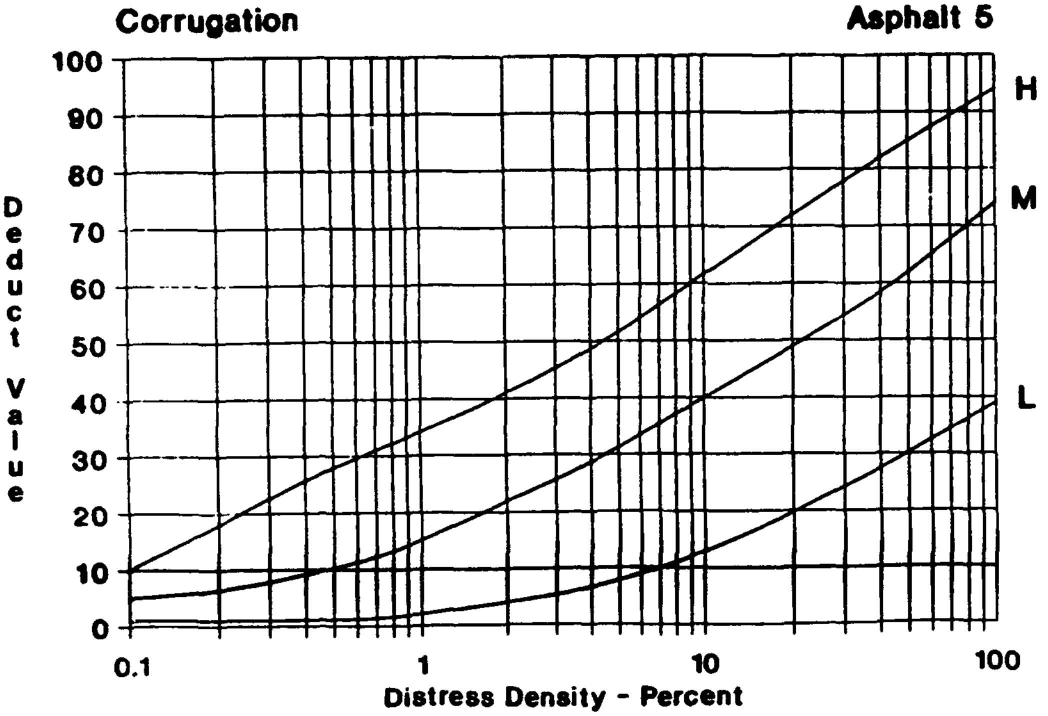


Figure B5. Corrugation.

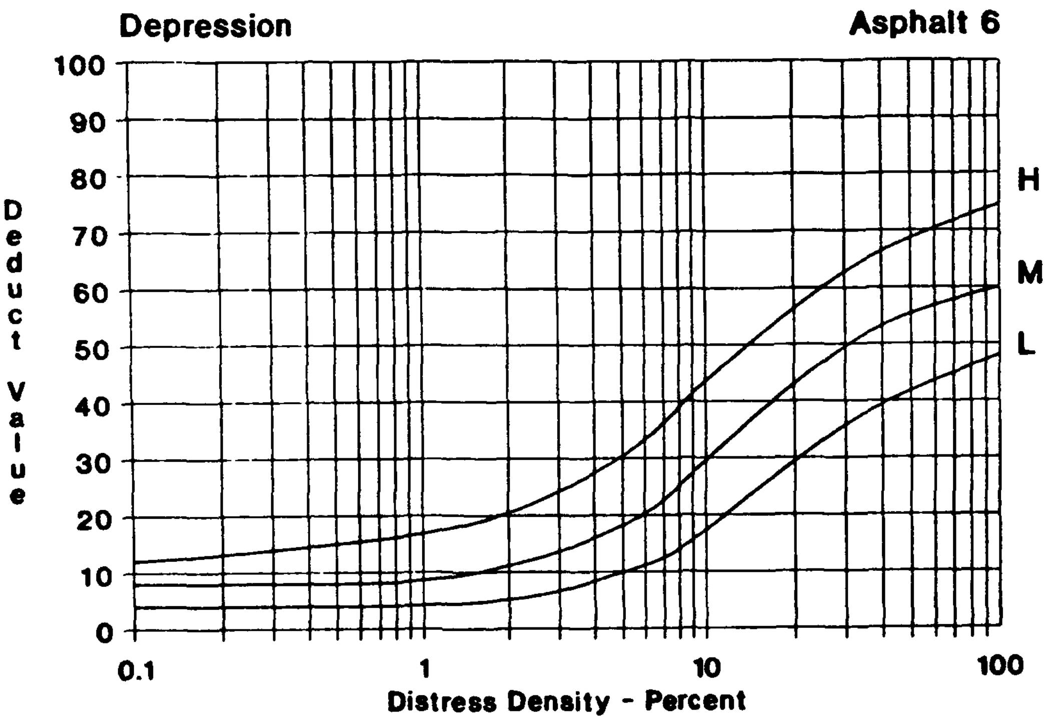


Figure B6. Depression.

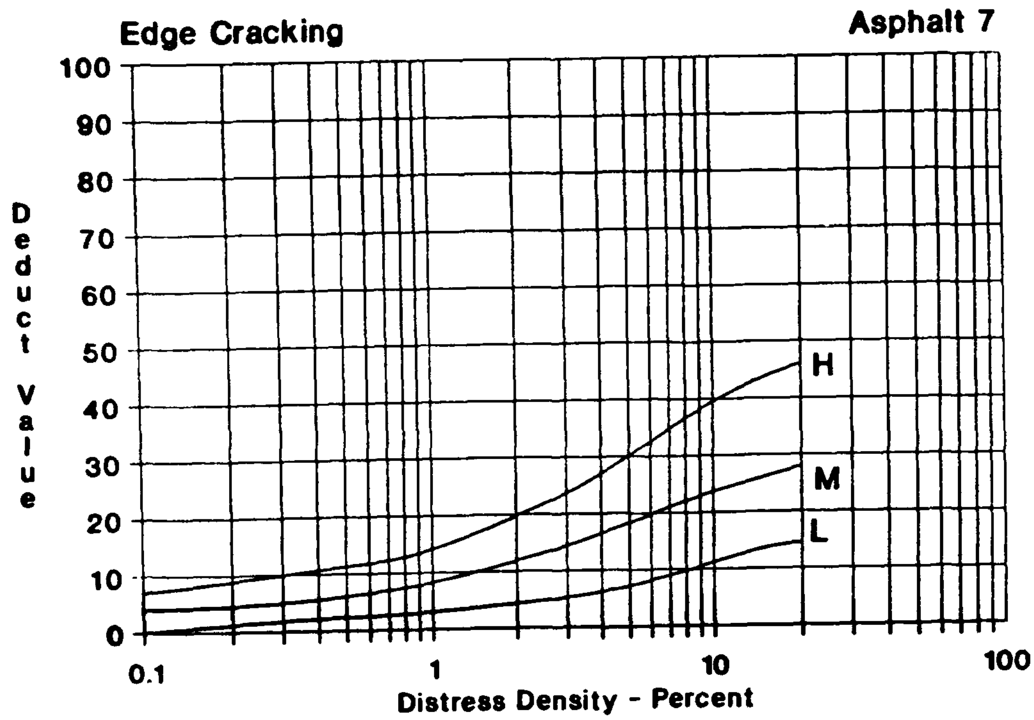


Figure B7a. Edge cracking (English units).

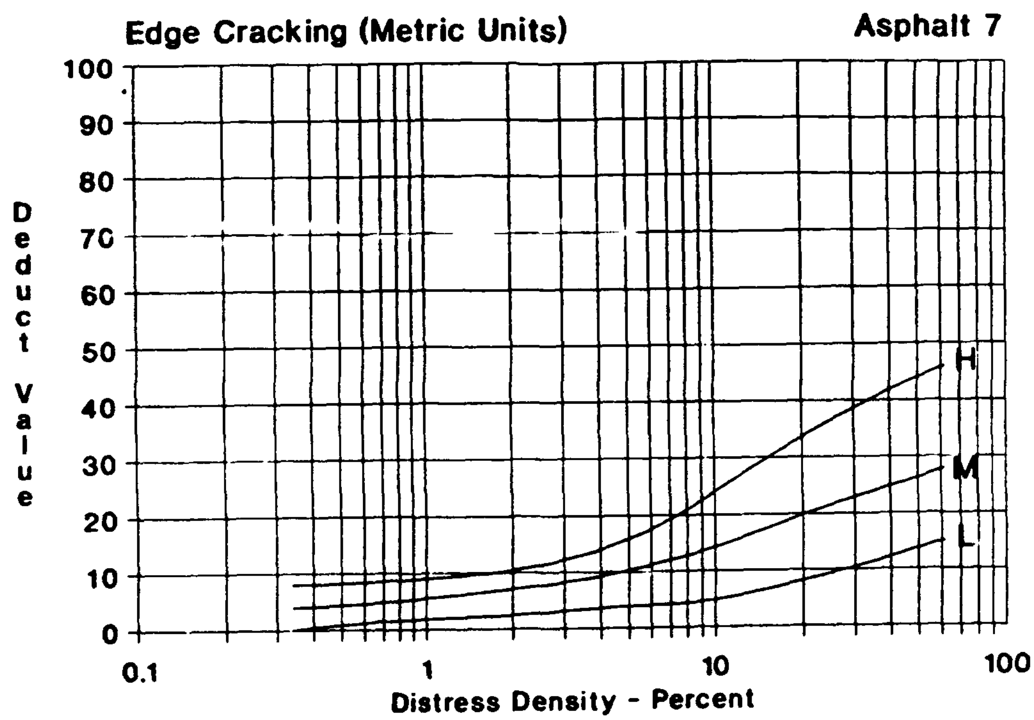


Figure B7b. Edge cracking (metric units).

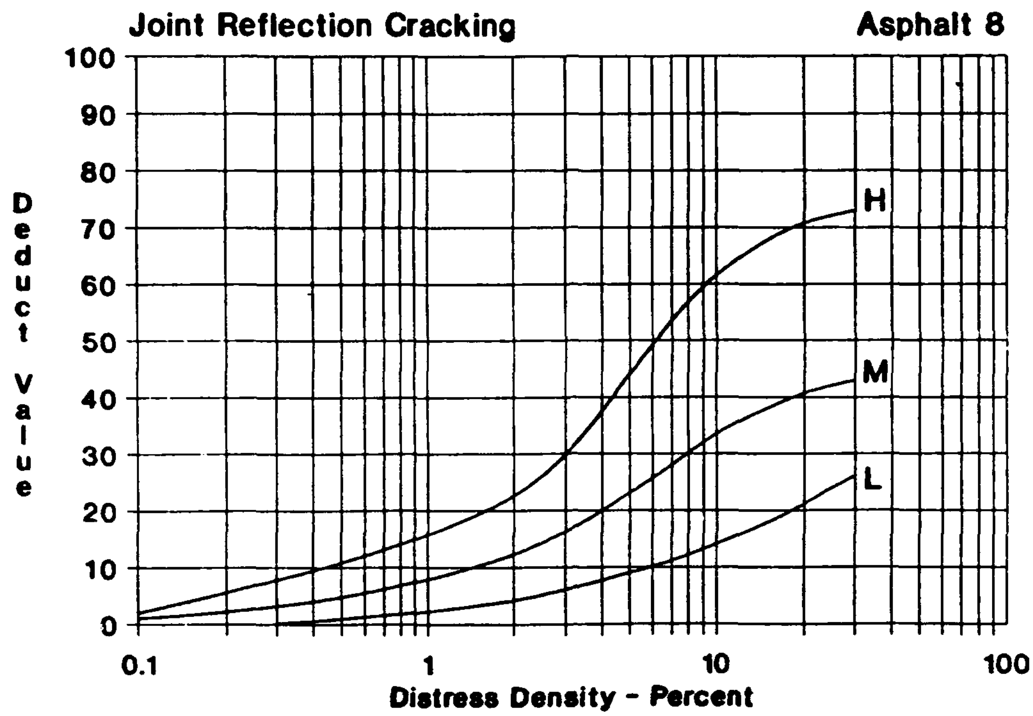


Figure B8a. Joint reflection cracking (English units).

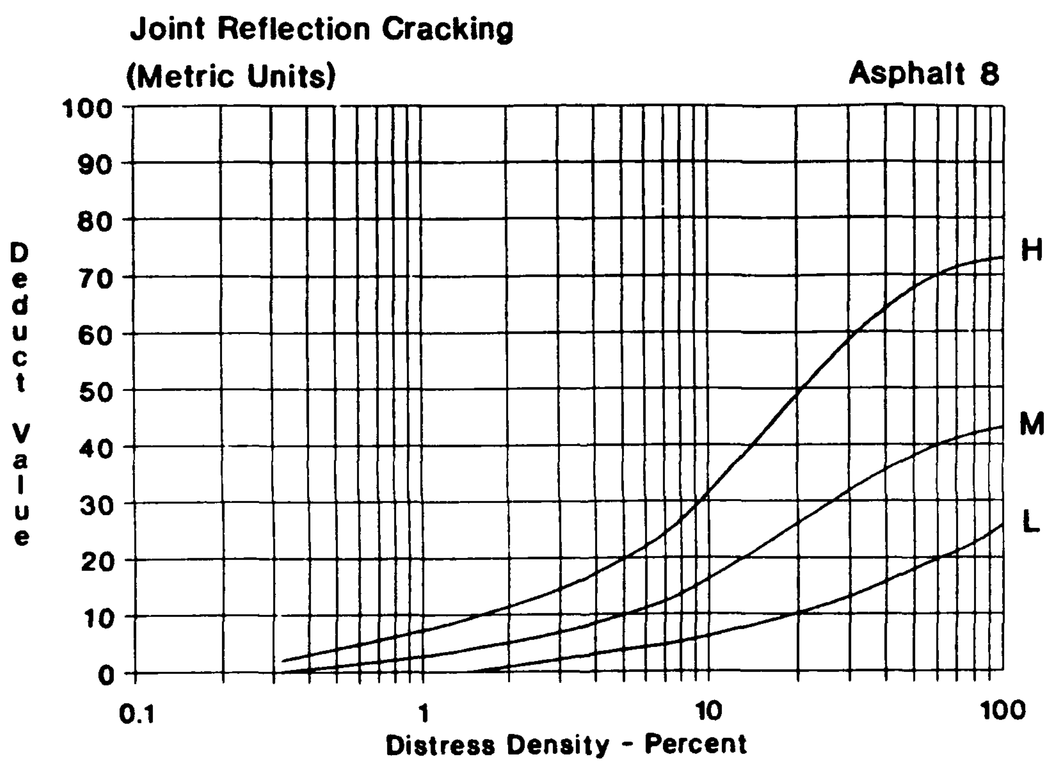


Figure B8b. Joint reflection cracking (metric units).

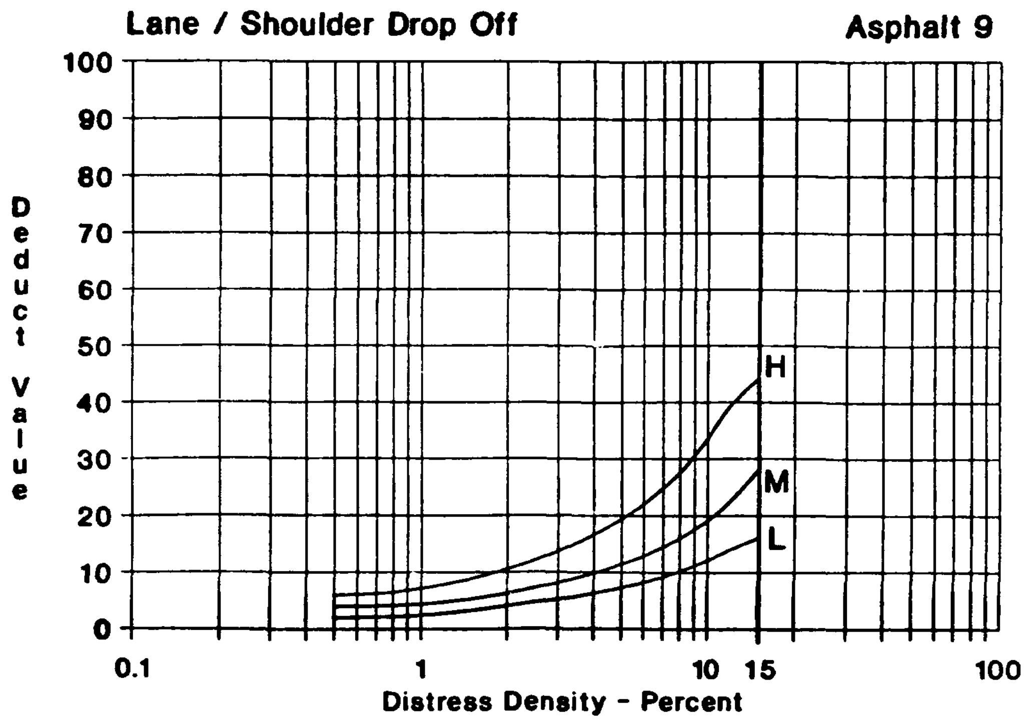


Figure B9a. Lane/shoulder drop-off (English units).

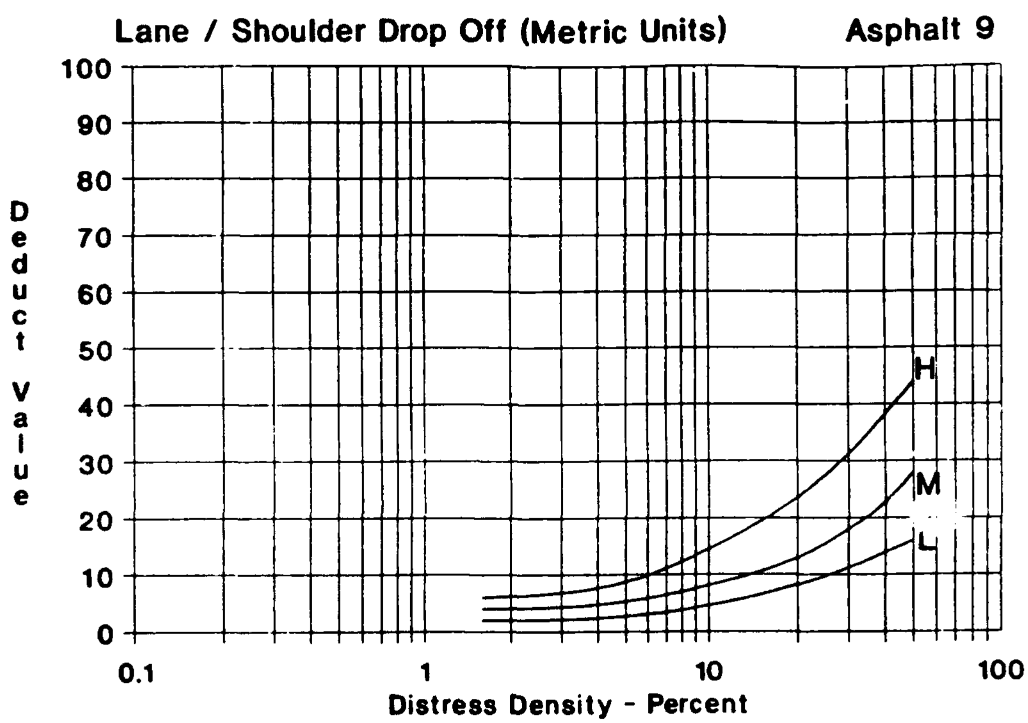


Figure B9b. Lane/shoulder drop-off (metric units).

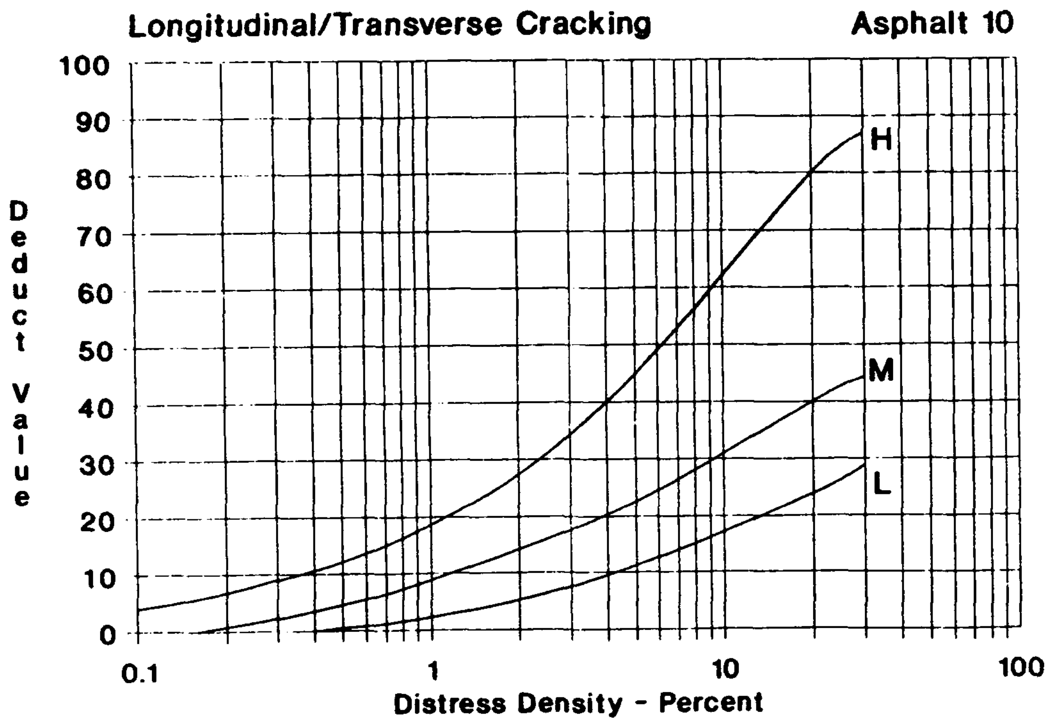


Figure B10a. Longitudinal and transverse cracking (English units).

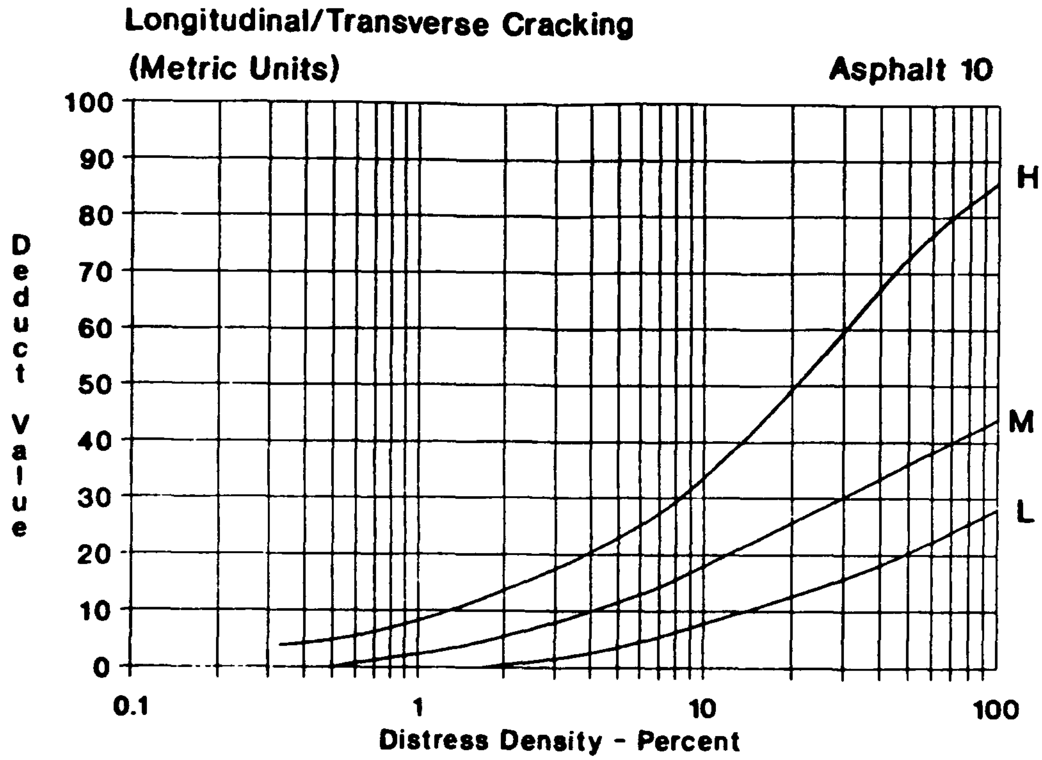


Figure B10b. Longitudinal and transverse cracking (metric units).

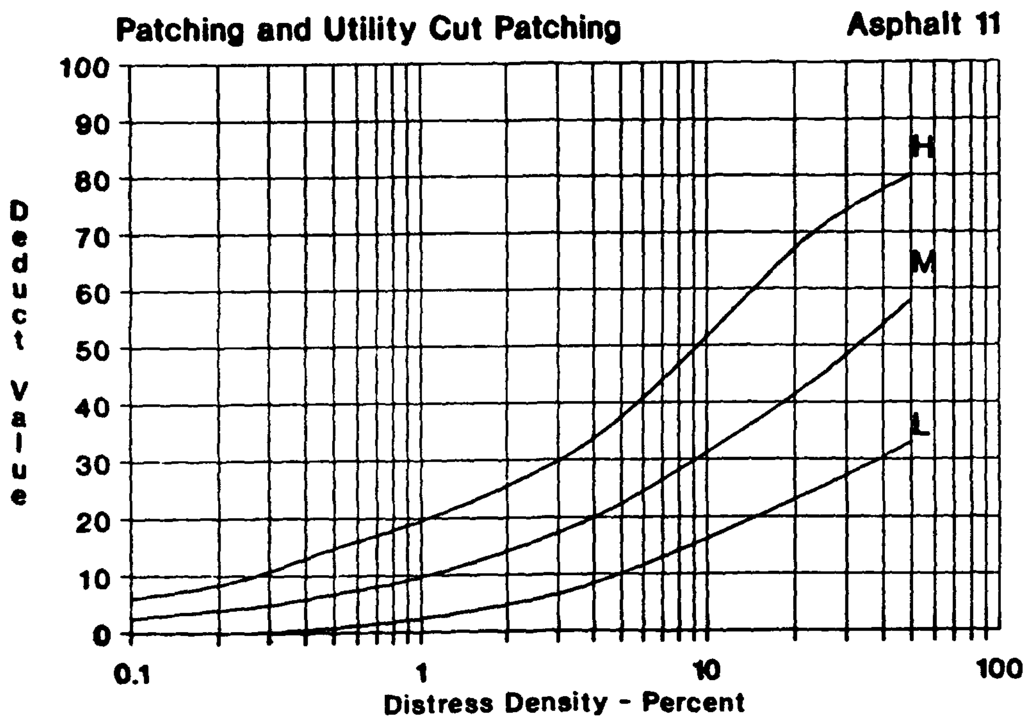


Figure B11. Patching and utility cut patching.

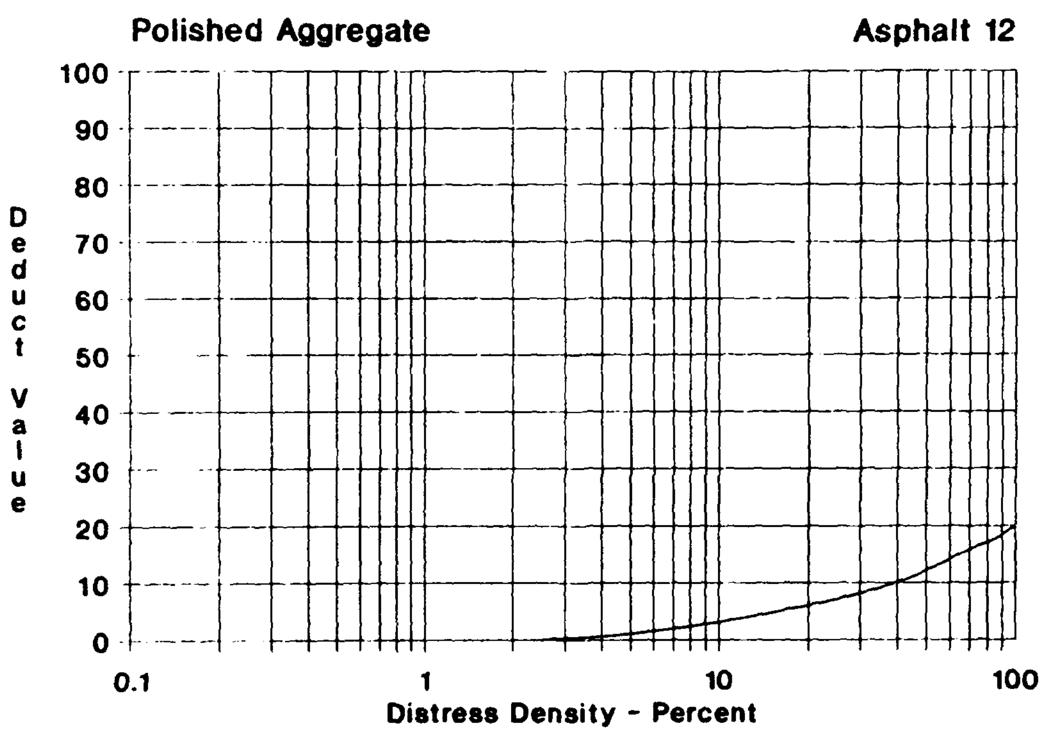


Figure B12. Polished aggregate.

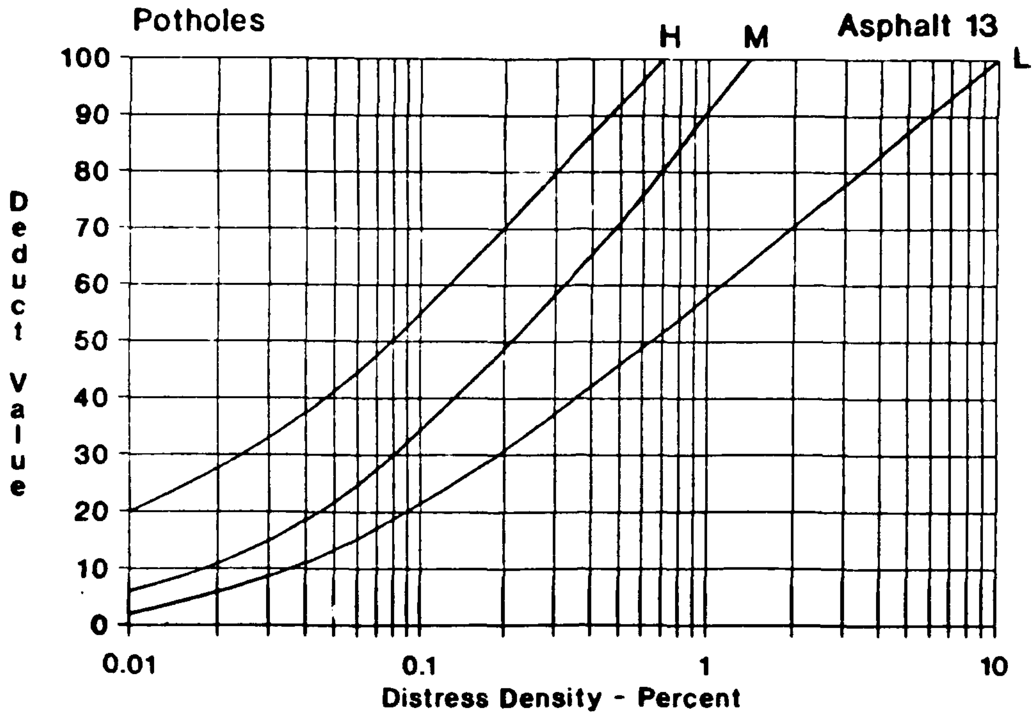


Figure B13a. Potholes (English units).

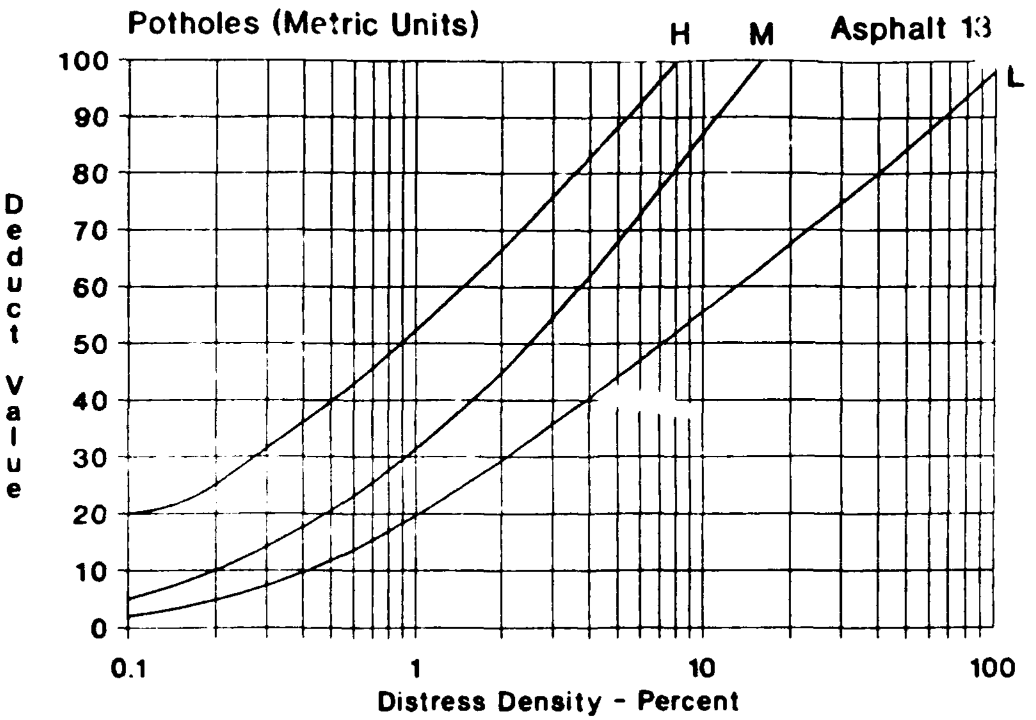


Figure B13b. Potholes (metric units).

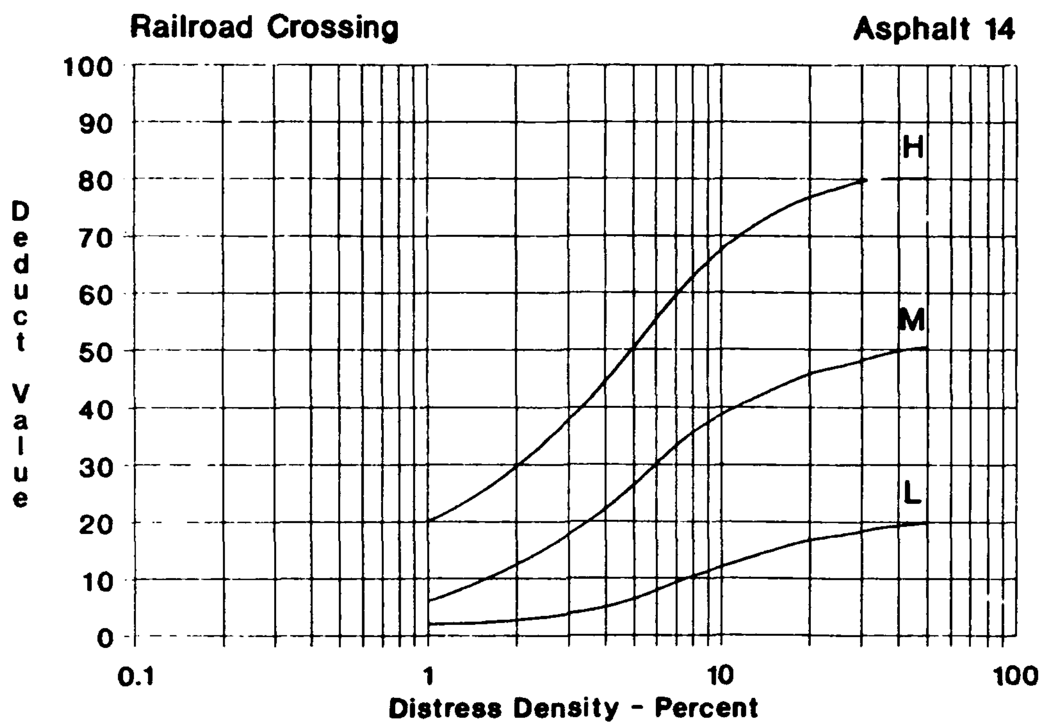


Figure B14. Railroad crossing (asphalt).

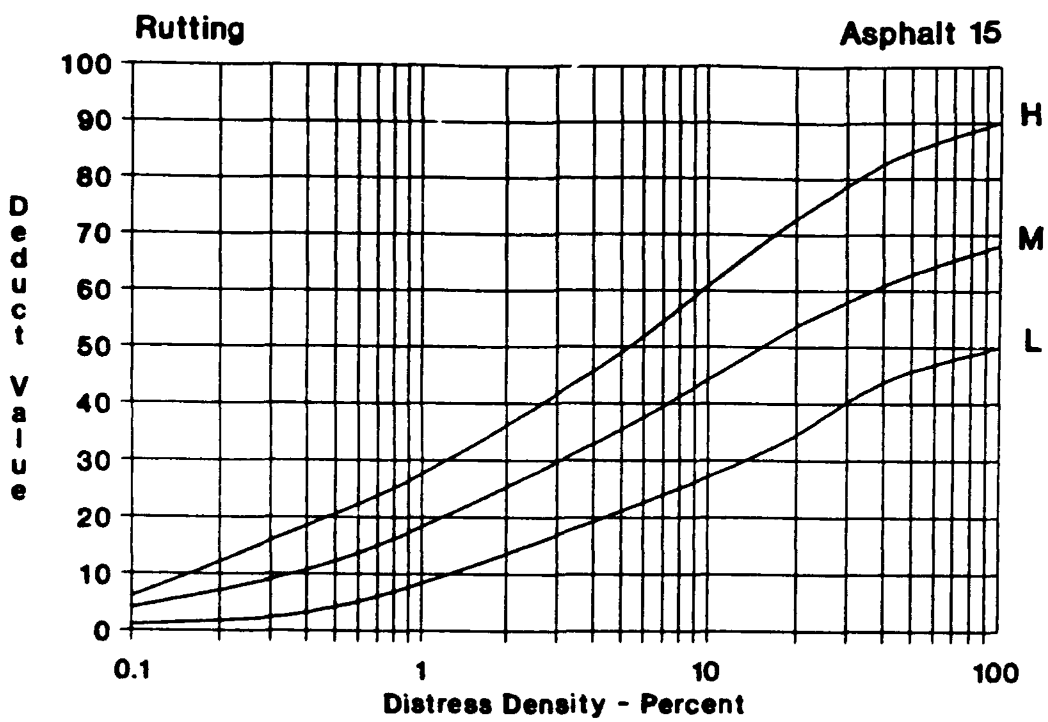


Figure B15. Rutting.

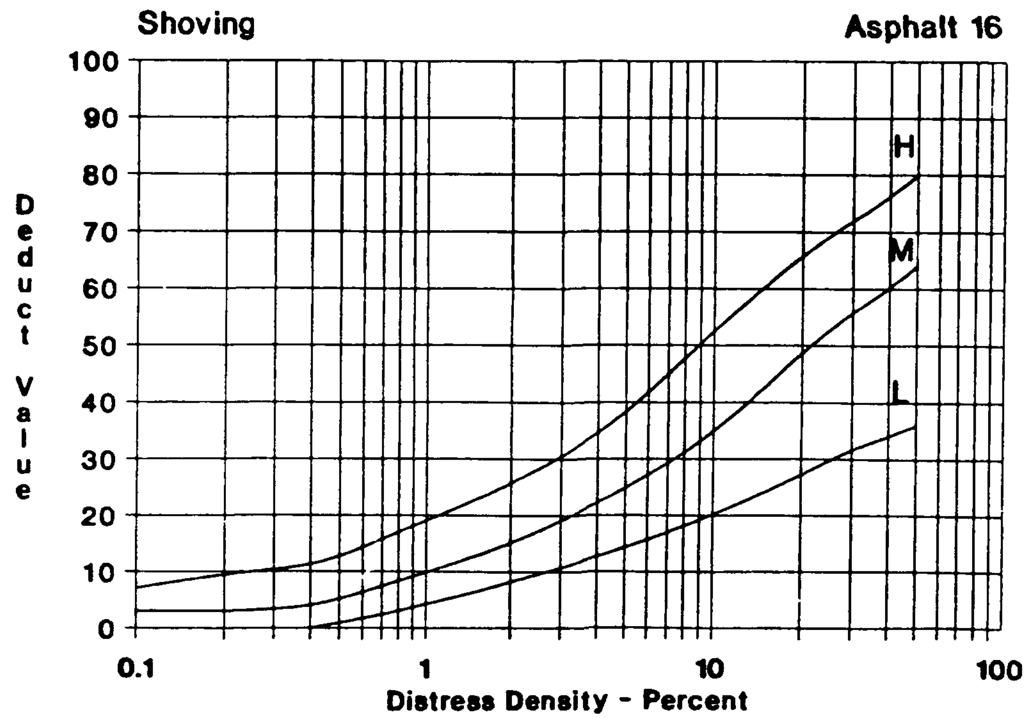


Figure B16. Shoving.

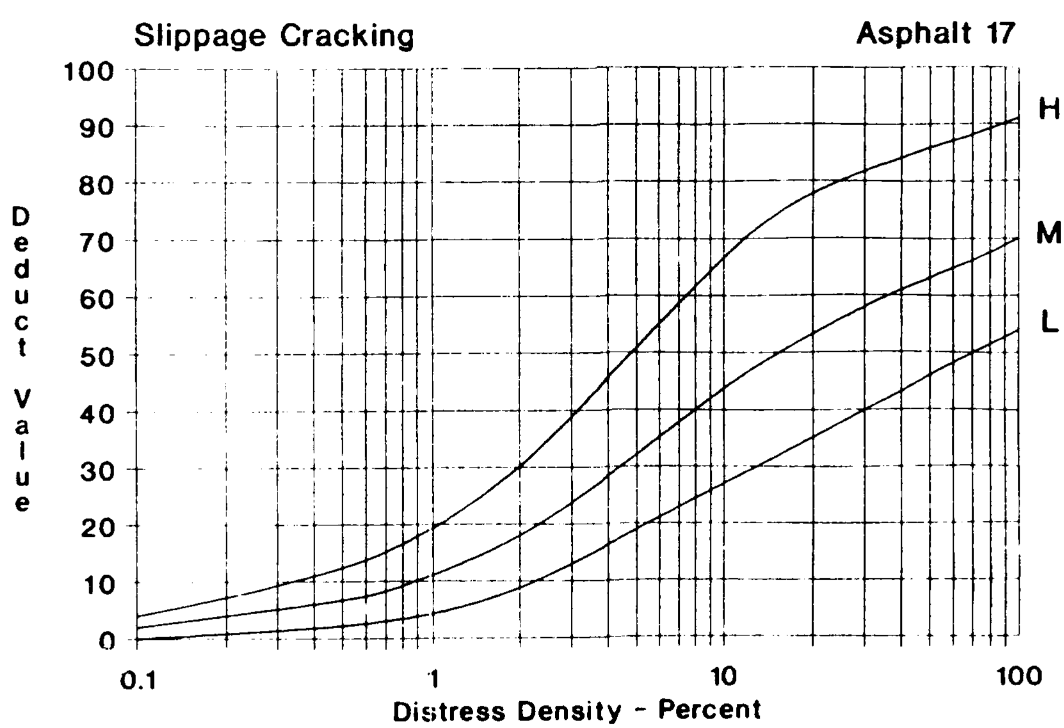


Figure B17. Slippage cracking.

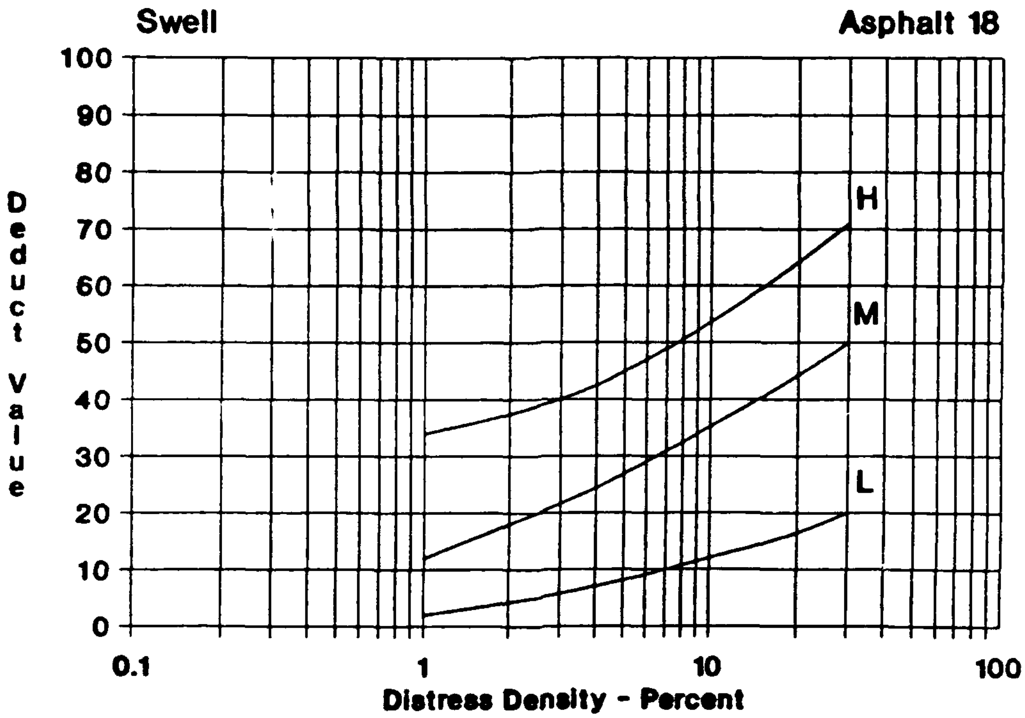


Figure B18. Swell.

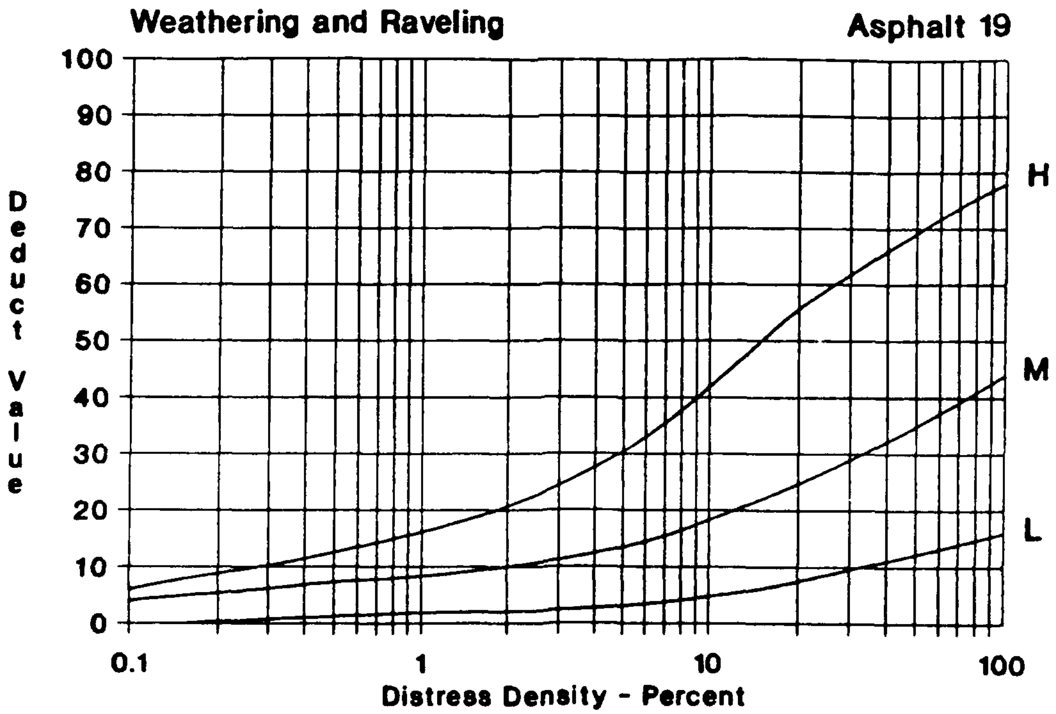


Figure B19. Weathering and raveling.

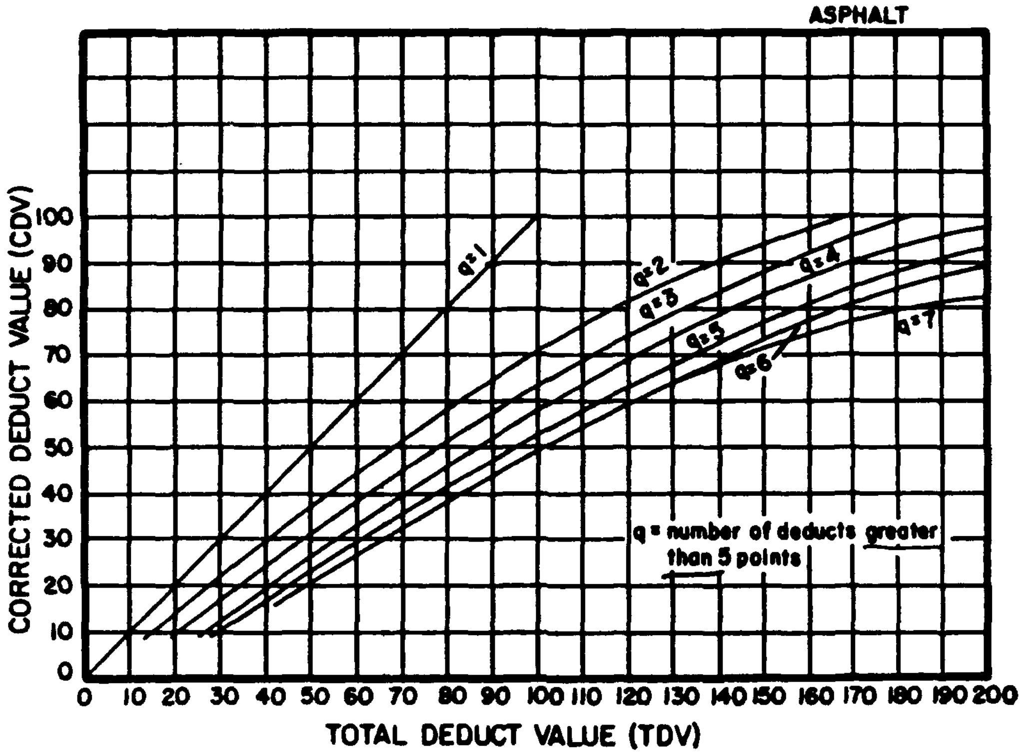


Figure B20. Corrected deduct value curves for asphalt-surfaced pavements.

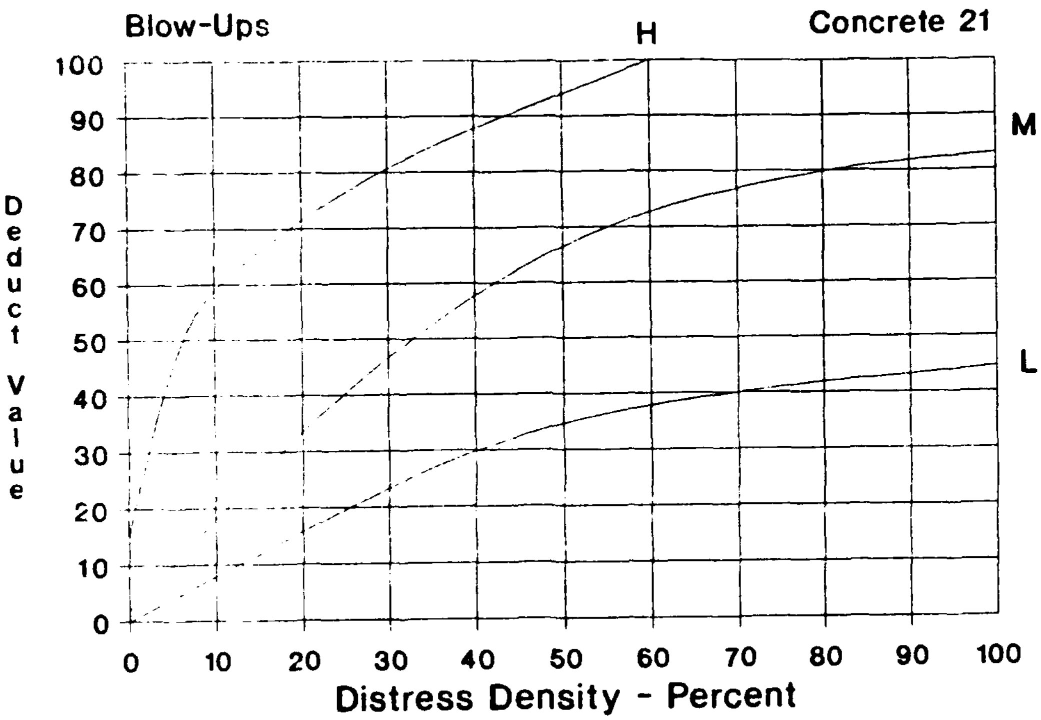


Figure B21. Blowups.

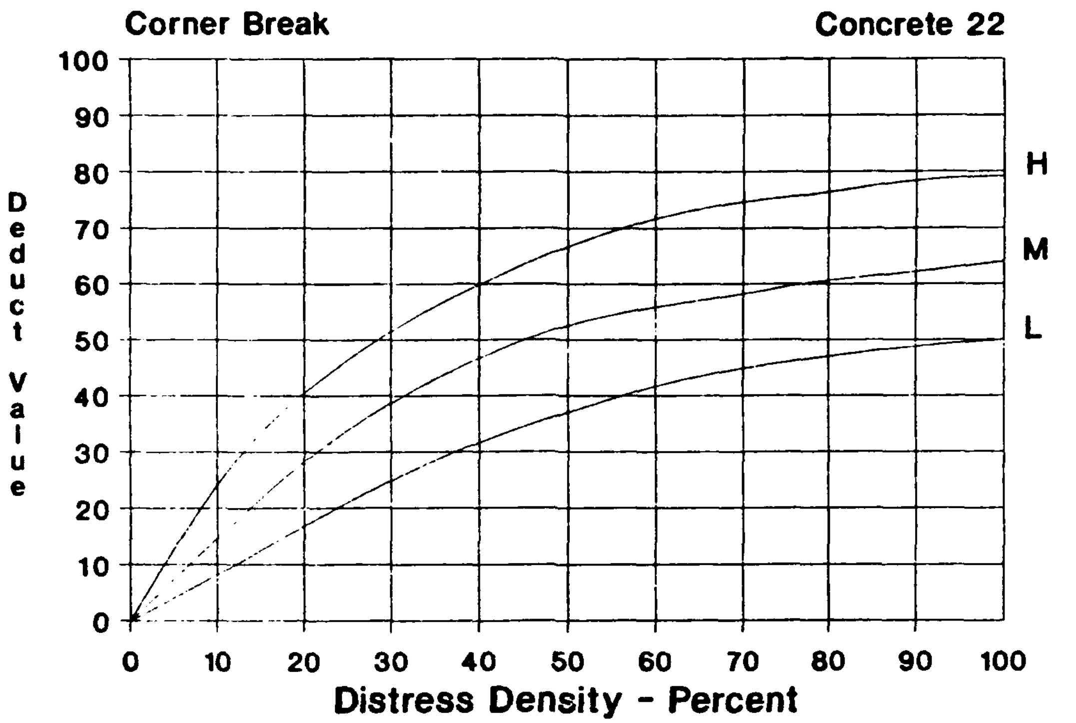


Figure B22. Corner break.

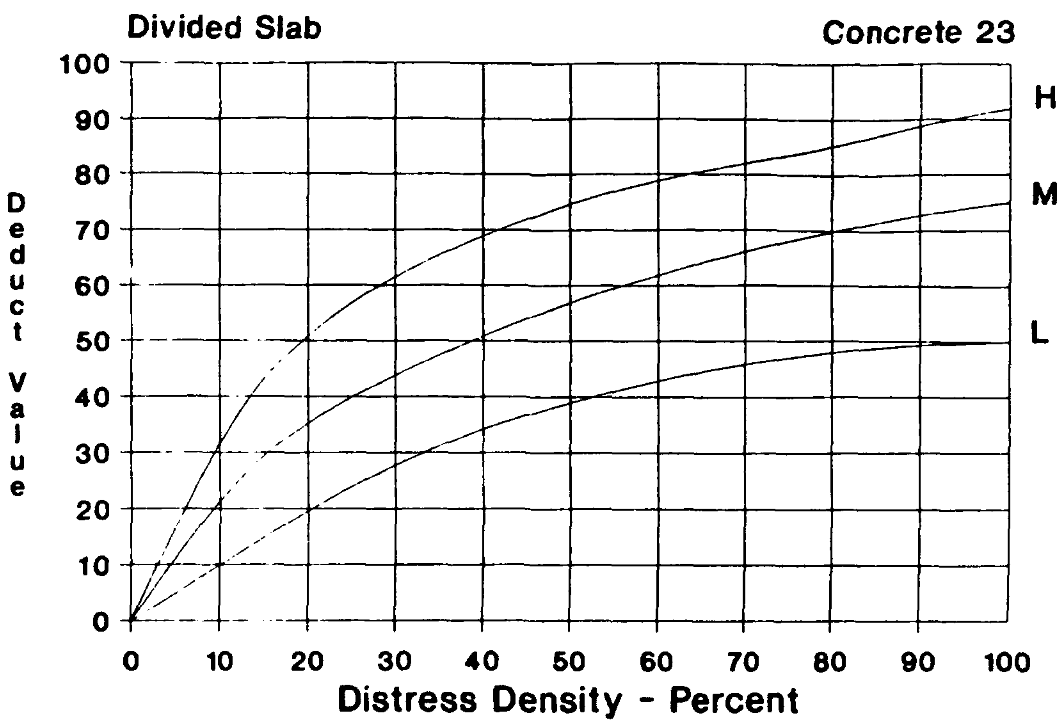


Figure B23. Divided slab.

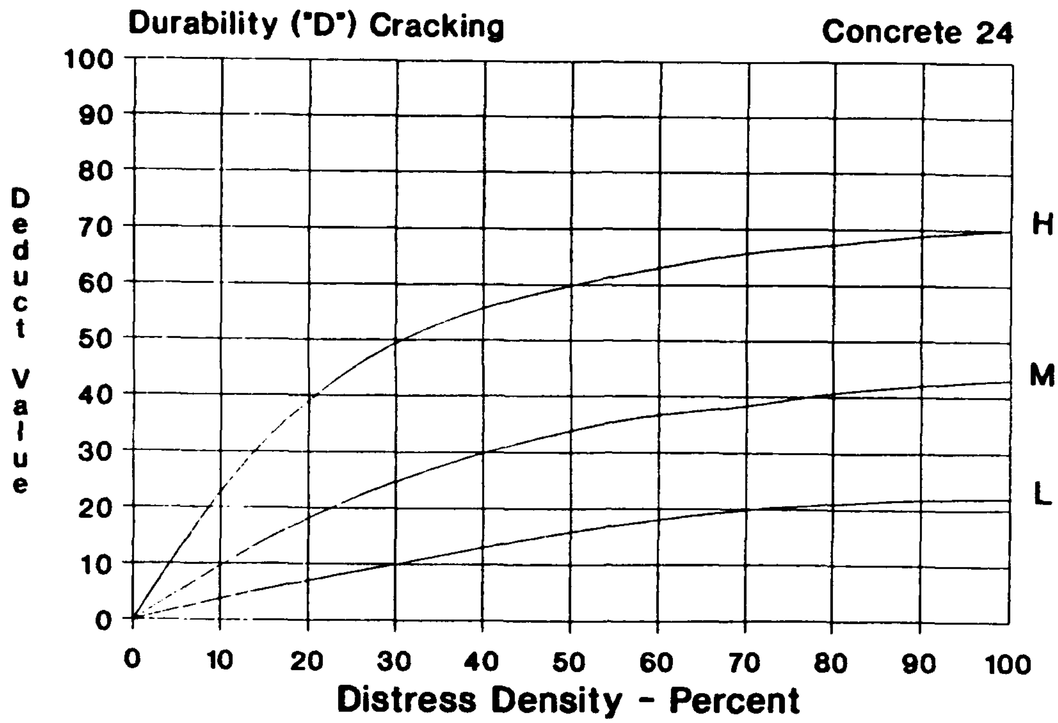


Figure B24. Durability ("D") cracking.

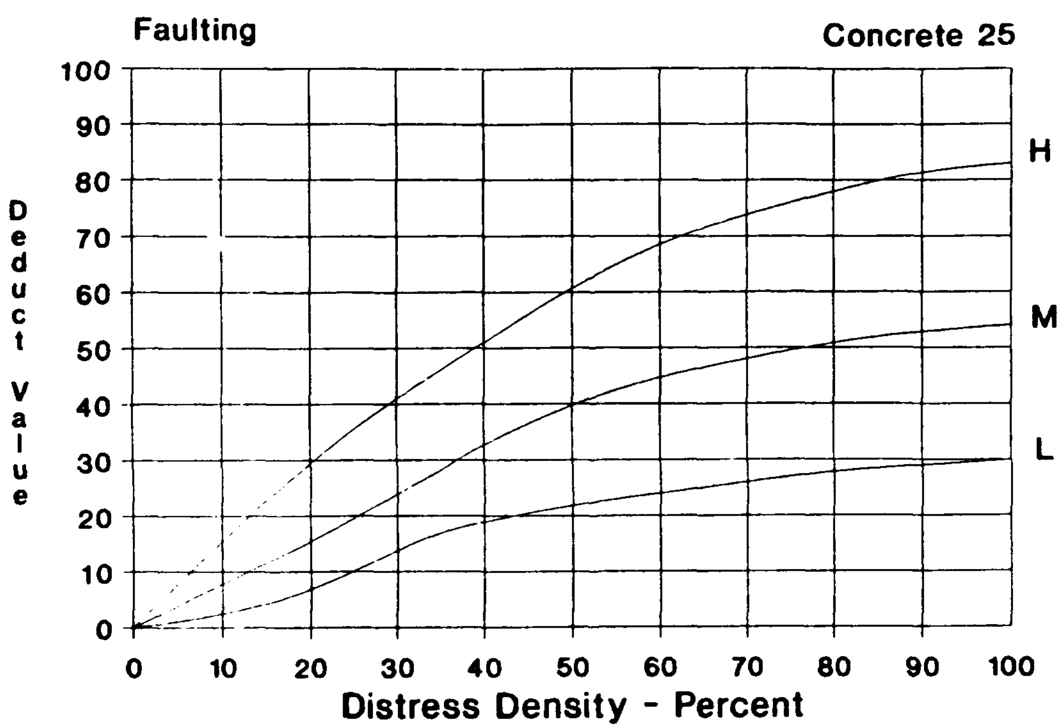


Figure B25. Faulting.

Joint Seal Damage Concrete 26

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

The deduct values for the three levels of severity are:

LOW	2 points
MEDIUM	4 points
HIGH	8 points

Figure B26. Joint seal damage.

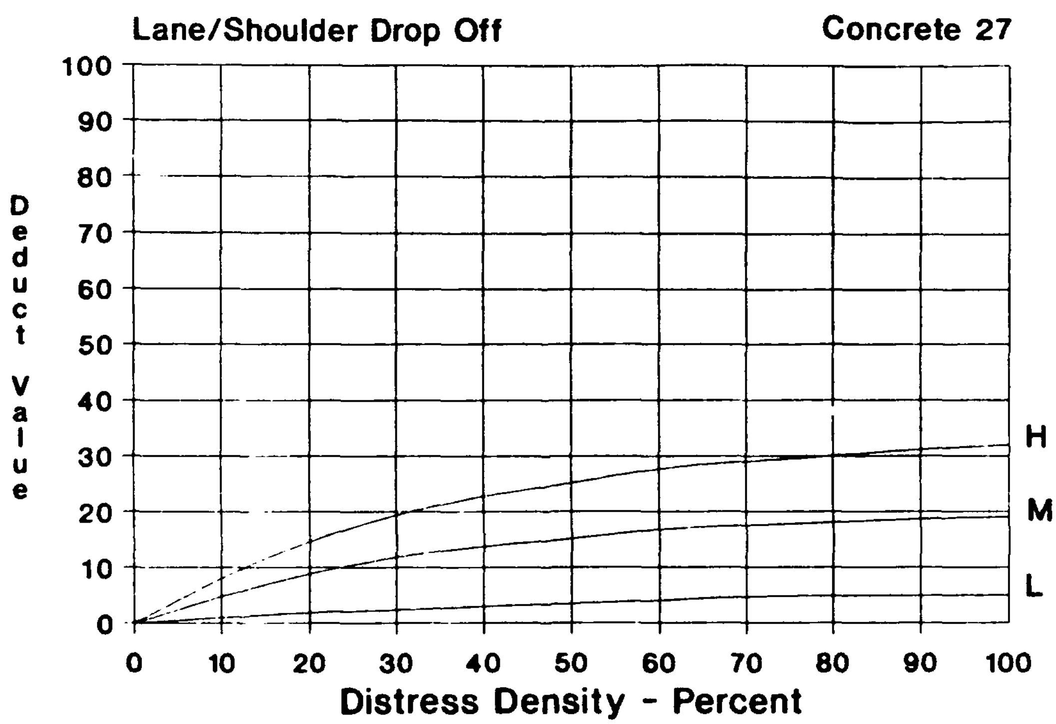


Figure B27. Lane/shoulder drop-off.

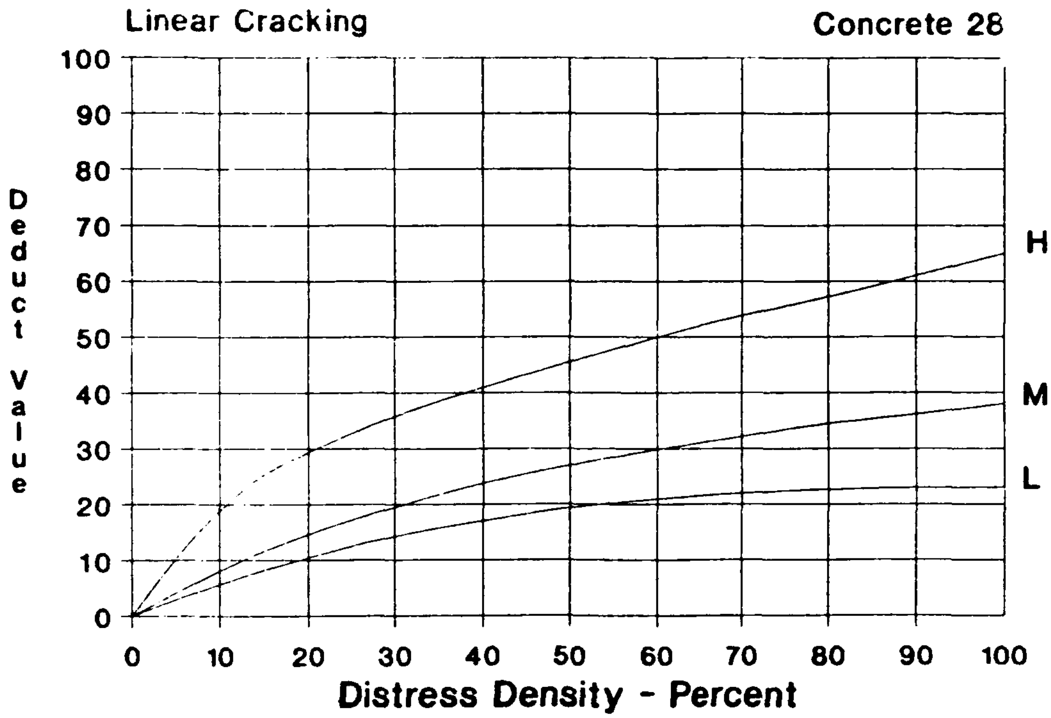


Figure B28. Linear cracking.

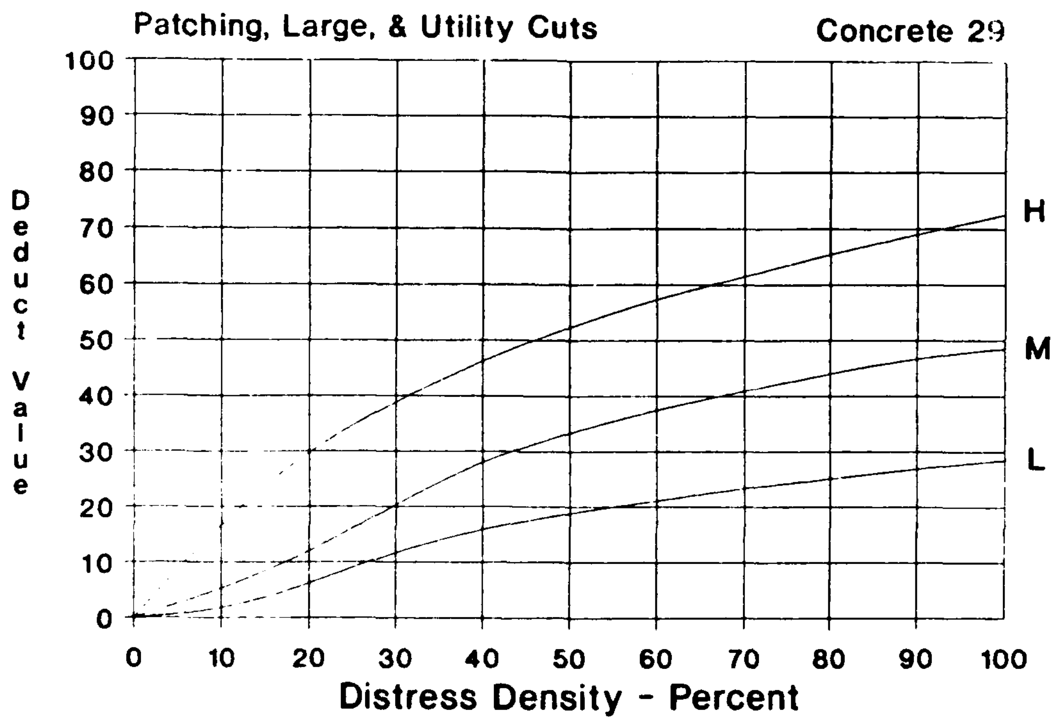


Figure B29. Patching (large, utility cuts).

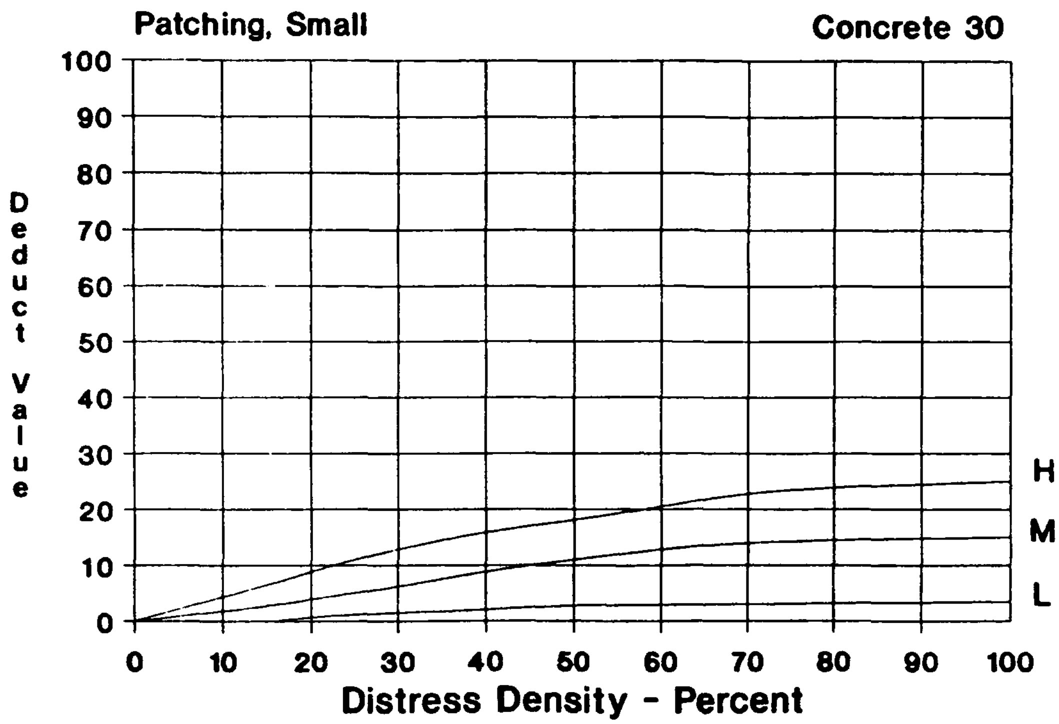


Figure B30. Patching (small).

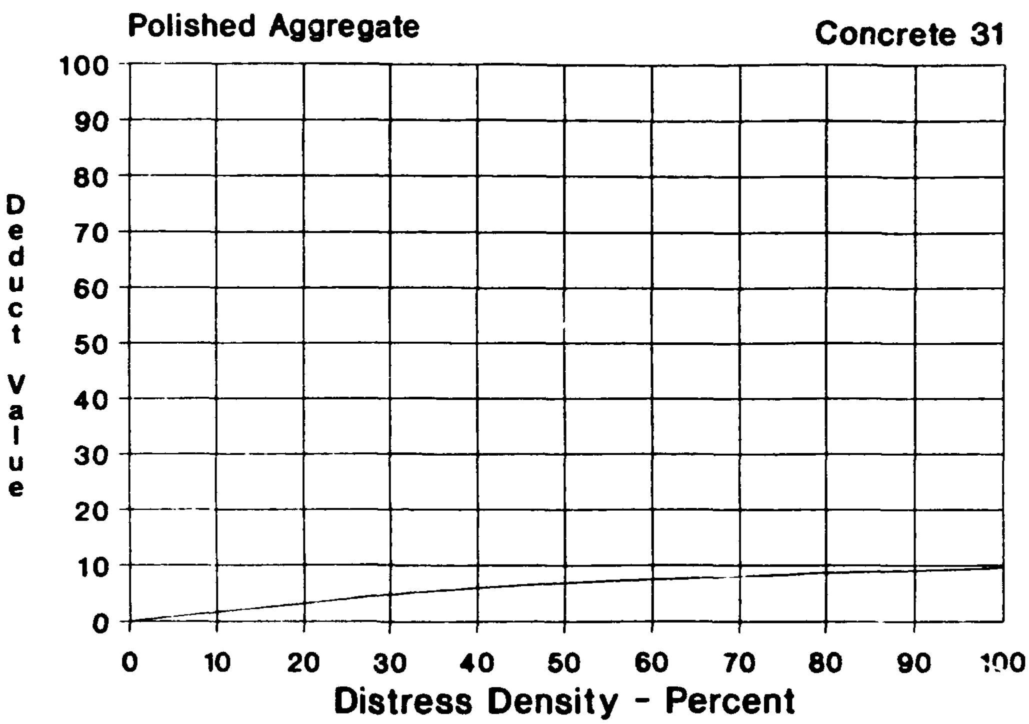


Figure B31. Polished aggregate.

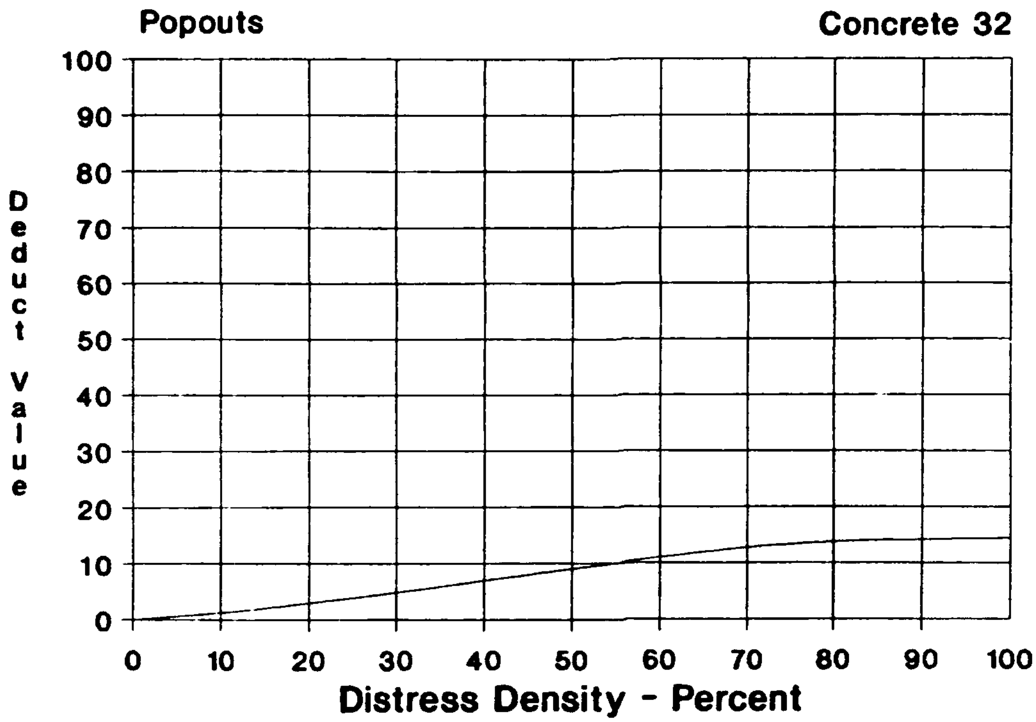


Figure B32. Popouts.

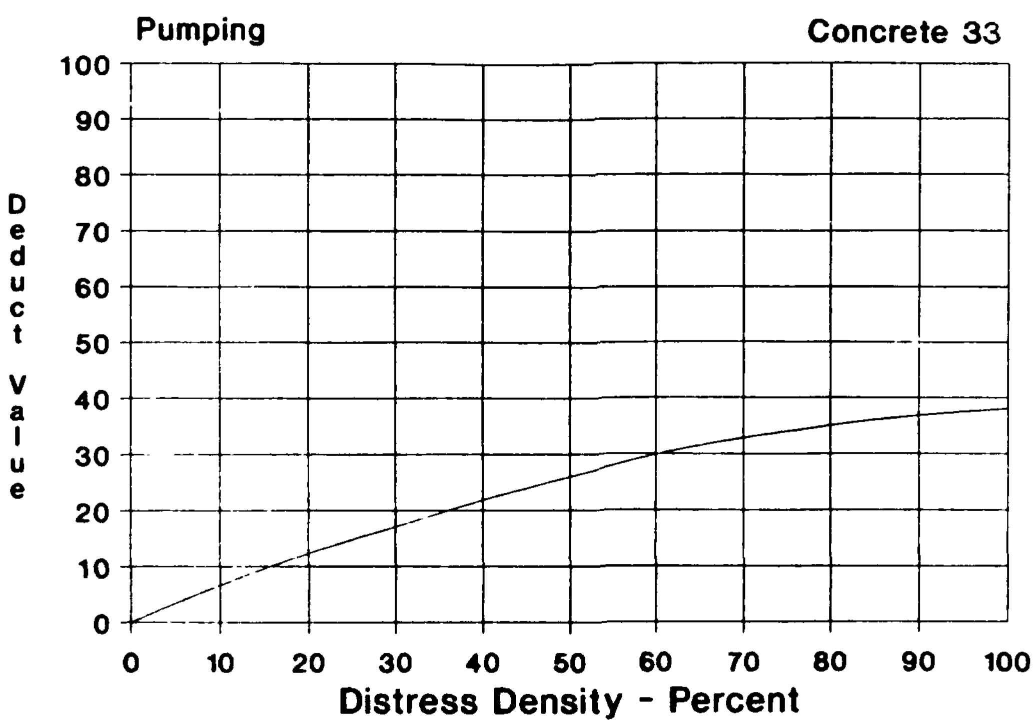


Figure B33. Pumping.

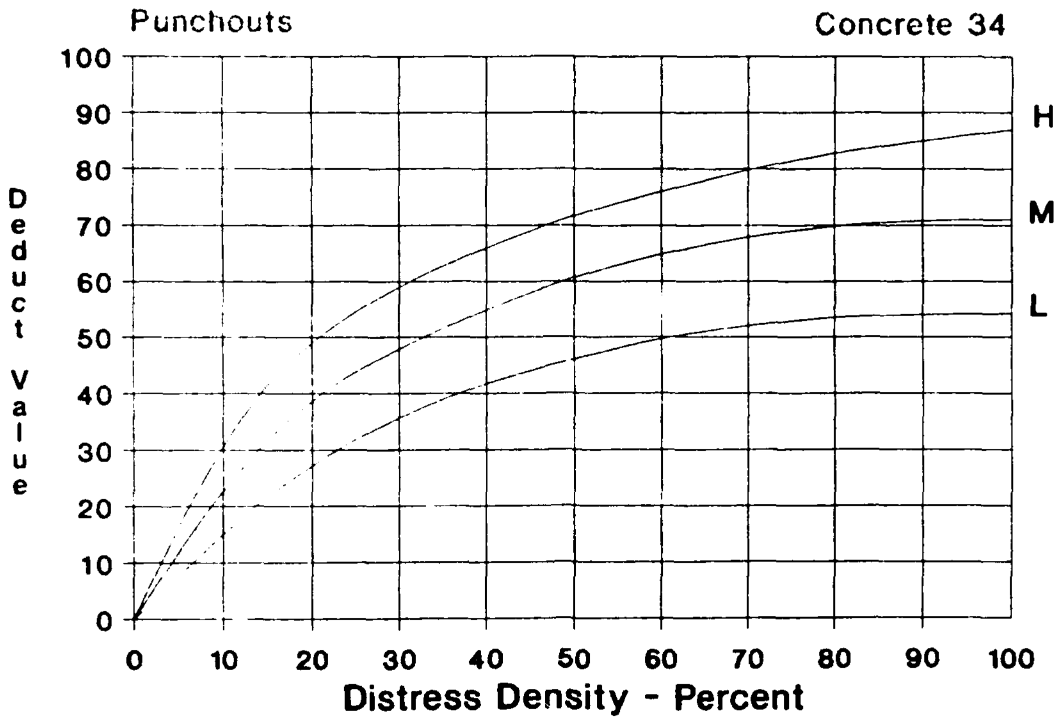


Figure B34. Punchouts.

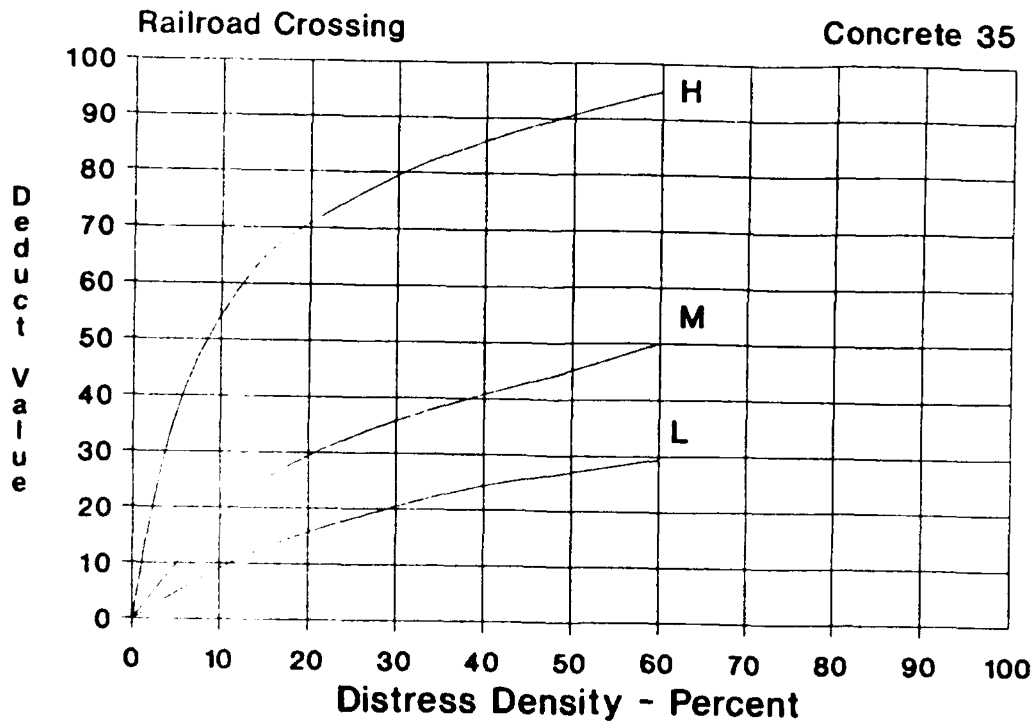


Figure B35. Railroad crossing (concrete).

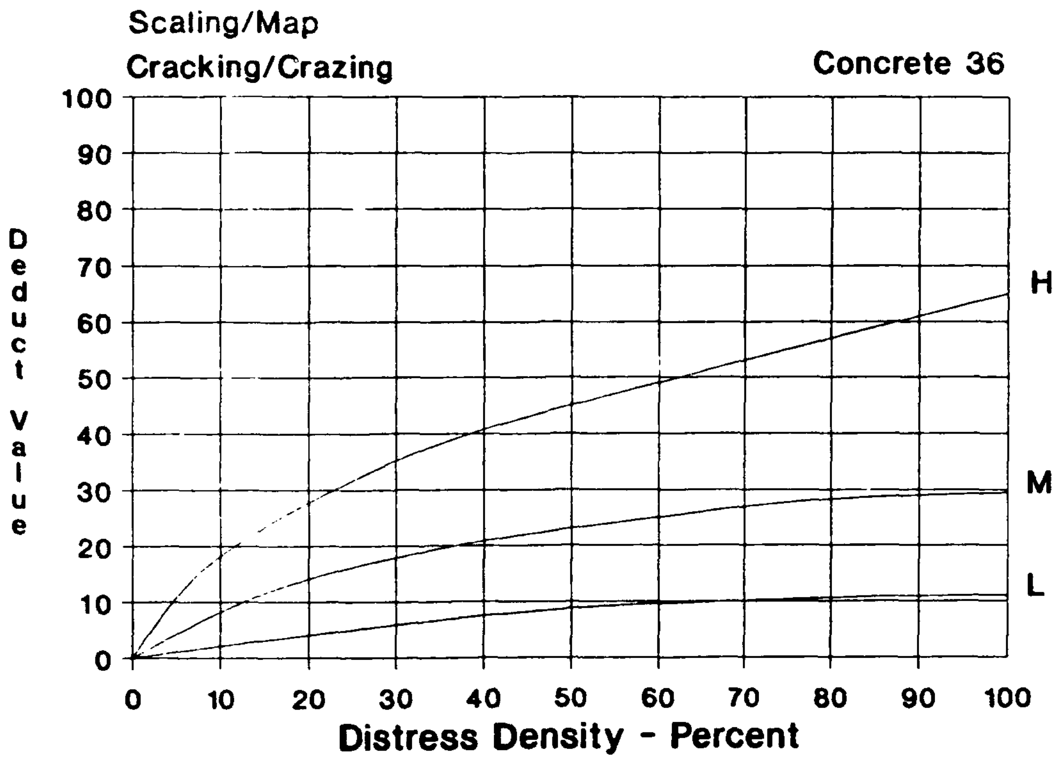


Figure B36. Scaling/map cracking/crazing.

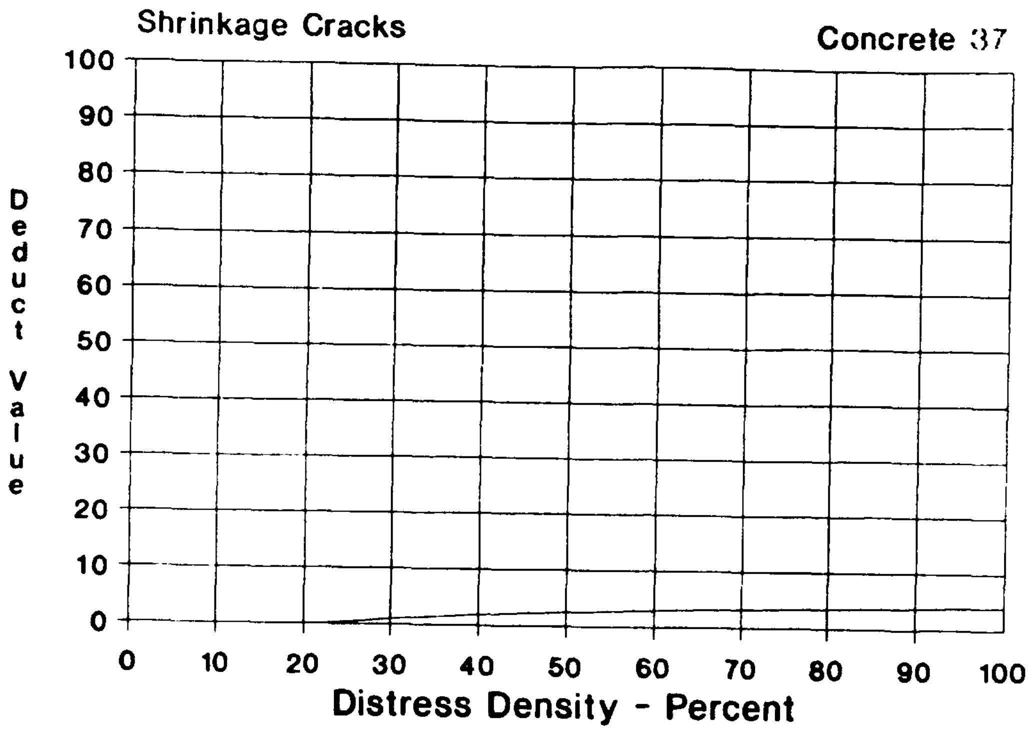


Figure B37. Shrinkage cracks.

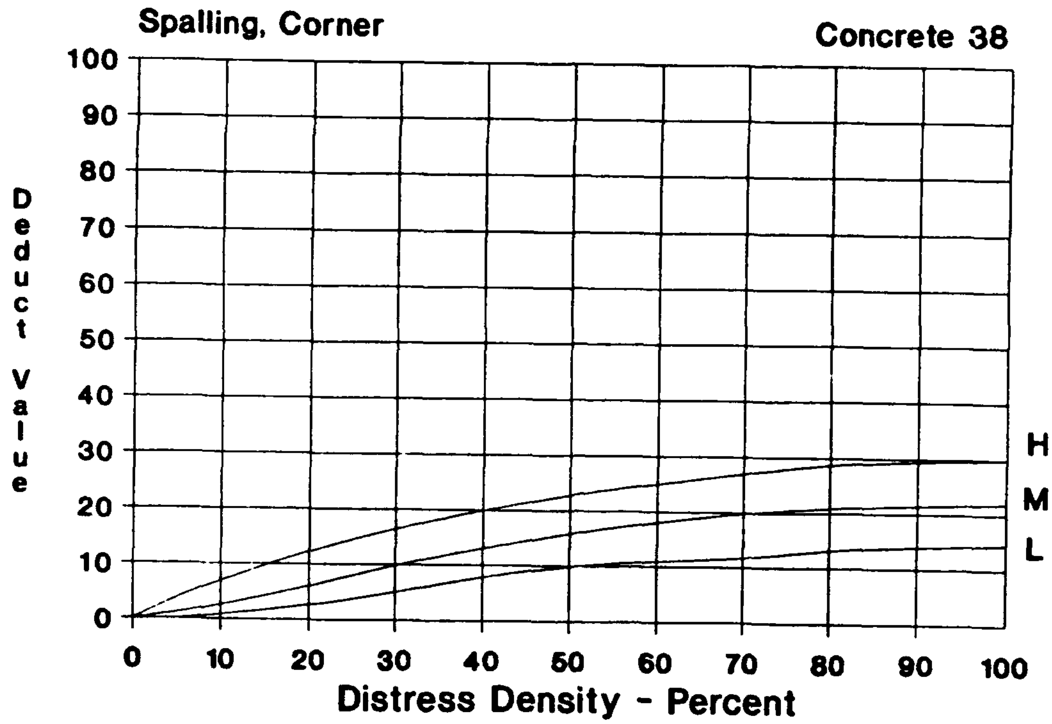


Figure B38. Corner spalling.

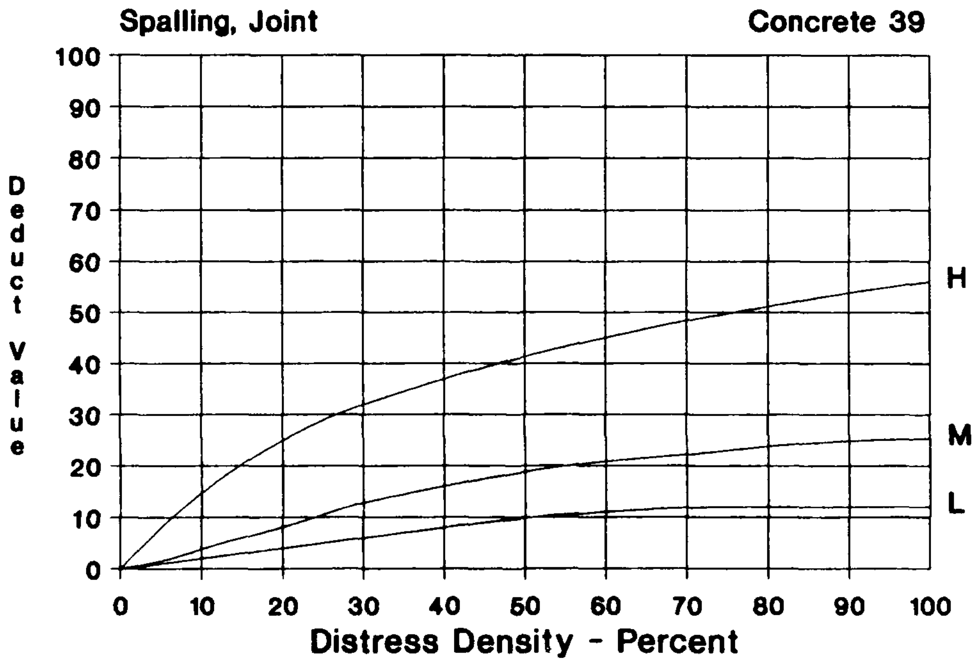


Figure B39. Joint Spalling.

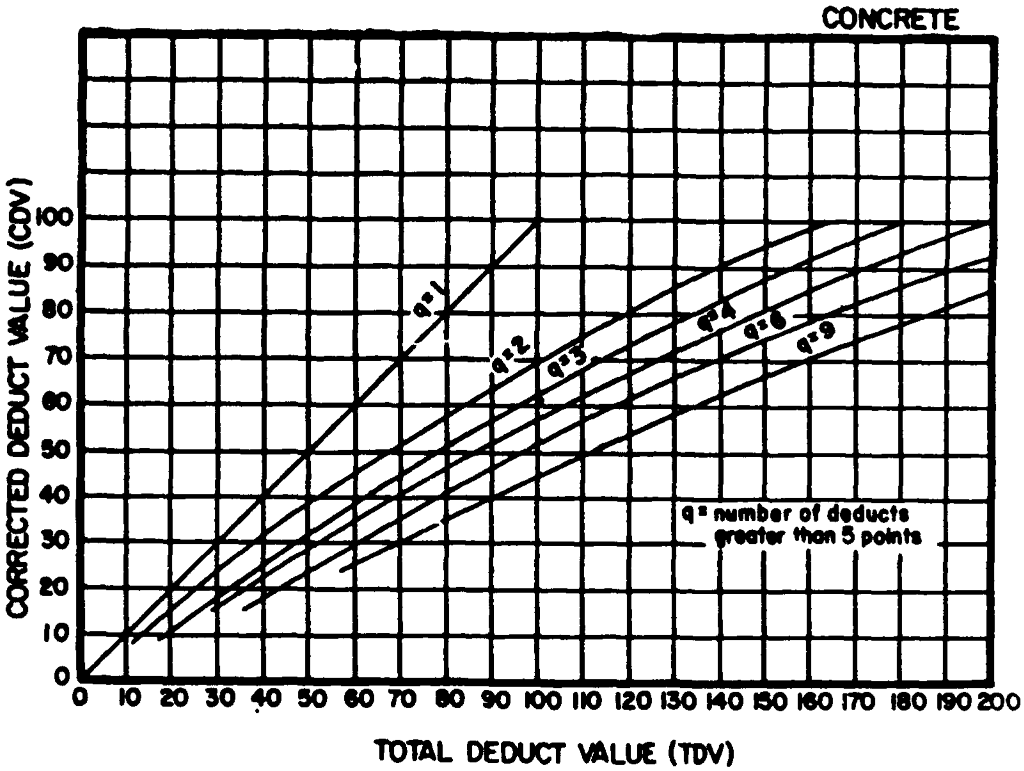


Figure B40. Corrected deduct values for jointed concrete pavement.

APPENDIX C:

SURFACED AREA FACILITY EVALUATION FORM

Project Number: ________________

Project Description: ____

____

1.0 Facility Data

1.1 Facility Number/Branch Number: ______________________

1.2 Project Location (street name, beginning and end points, etc.):

1.3 Category Code (5-digit code, refer to AR 415.28): ____________

1.4 Facility/Branch Use (choose one): ______________________________

Roads/Street
- a. Roadway
- b. Tank trail
- c. Other

Parking
- d. Incidental parking
- e. Organizational vehicle parking
- f. Non-organizational vehicle parking

Airfields
- g. Runway
- h. Taxiway
- i. Apron
- j. Helipad
- k. Other

Other
- l. Open storage
- m. Other surface area

1.5 Surface Type (choose one): ____________________

AC	(Asphalt Concrete)
AAC	(Asphalt Overlay over Asphalt Concrete)
APC	(Asphalt Overlay over Portland Cement Concrete)
ABR	(Asphalt over Brick)
PCC	(Portland Cement Concrete)
ST	(Surface Treatment)
GR	(Gravel)
BR	(Brick)
CO	(Cobblestone)
CPB	(Concrete Paving Block)
X	(Other)

1.6 Pavement Rank (choose one): ___________

P	(Primary)	T	(Tertiary)
S	(Secondary)	X	(Other)

(Refer to TM5-822-2 for definitions)

1.7 Pavement Dimensions:

Average Length (feet): _________

Average Width (feet): __________

Actual Area (square yards (sy=sf/9)): _________

2.0 Project Evaluation

2.1 Pavement Age:

Year of original construction: _________________
Year of last overlay or reconstruction: _________
Number of years since last overlay or reconstruction
(Present year - year of last overlay or reconstruction): _______

2.2 Pavement Condition Index (PCI): ___________

(The PCI is determined as a result of a visual survey. If the automated PAVER program is available, the PCI will automatically be calculated as a result of entering the distress information identified from the survey. For manual calculation of the PCI, refer to U.S. Army Technical Manual [TM] 5 - 623.)

2.3 Pavement Distress:

Percent Load Related (% of Total Deduct Value): _______

(If the automated PAVER program is available, the percent deducts will be automatically calculated as a result of entering the distress information identified from the survey. For manual calculation, use the following equation for load related distress mechanisms:

$$\% \text{ Load Deduct Value} = \frac{\text{Total \# of load related deducts}}{\text{Total of all deduct values}} \times 100$$

The following distress types are identified in the automated PAVER program as being causes of load related distress:

Asphalt Concrete		Portland Cement Concrete	
Alligator Cracking	Rutting	Corner Break	Punchout
Edge Cracking	Shoving	Divided Slab	
Potholes		Linear Cracking	

2.4 Surface Roughness (choose one): _________

None
Minor
Moderate
Major

(Surface roughness can be determined by riding over the pavement section at its speed limit and observing the relative ride quality.)

2.5 Are safety hazards present? __________

If yes, choose overall severity: _________

Low
Medium
High

Describe: ____

2.6 Feasible M&R Strategies:

An M&R Strategy may consist of various M&R alternatives over the life of the pavement. The overall life of any selected strategy should be at least 10 years. Table C1 lists example M&R alternatives to be used in formulating the selected strategies for economic analysis.

Strategy 1 Description: ____

____

Estimated Overall Life of Strategy 1: _________ years

Strategy 2 Description: ____

____

Estimated Overall Life of Strategy 2: _________ years

Strategy 3 Description: ____

____

Estimated Overall Life of Strategy 3: _________ years

3.0 Life-Cycle Costs

Complete the Life-Cycle Cost Analysis for each feasible strategy identified in section 2.6. Life-cycle costing determines an average annual expenditure over the life of an M&R strategy for the comparison of options with unequal economic lives. If the effectiveness of each strategy is equal, then the strategy with the lowest equivalent uniform annual cost (EUAC) is the most cost-effective solution.

If the automated PAVER program is available, the ECON1 report can be used to determine the EUAC. For manual calculation, use the Life-Cycle Cost Analysis table for each feasible strategy determined in section 2.6.

If there are a number of sections that have the same, or some of the same, suggested feasible alternatives after the condition survey stage, it may be desirable to combine all of these sections into one project. In this case, the life-cycle cost analysis should be performed using the total area of all of the project sections in the calculation of the EUAC for each feasible strategy.

If it is desired to combine a number of sections into one project (for example, all of the sections in a branch), even though the sections have different suggested feasible strategies, the feasible strategies for the project should be those considered most economical for the entire project. The life-cycle cost analysis should then be performed for these strategies using the total area to be repaired of all of the sections in the project.

LIFE CYCLE COST ANALYSIS

3.1 M & R Strategy (section 2.6): ______________________________________

3.2 Life of M & R Strategy (section 2.6): __________

(1) ACTIVITY YEAR	(2) ACTIVITY YEAR -CURRENT YEAR	(3) M & R WORK DESCRIPTION (LIST ALL ACTIVITIES ASSOCIATED WITH THE M & R ALTERNATIVE)	(4) WORK QUANTITY (UNITS)	(5) $ PER WORK UNIT	(6)=(4)x(5) TOTAL COST ($)	(7) f_i	(8)=(6)x(7) PRESENT WORTH (TOTAL COST x f_i)
						TOTAL	

f2 = _________ (see Table 3, use value from 3.2 above)

3.3 EUAC = Present Worth x f2 = _______ x _______ = $__________

3.4 EUAC/sy = EUAC / Area (sy) = ______ / _______ = $__________

Summary of Surfaced Area Facility Evaluation

Project Number: _________

Project Description: ____

____

Project Area (sy): ____________ (section 1.7)

Pavement Condition Index (PCI): __________ (section 2.2)

M & R Strategy Selected: ____

____

Life of M & R Strategy Selected: _________

Equivalent Uniform Annual Cost (EUAC in $/sy): __________ (section 3.4)

Comments:

Table C1

Possible M&R Alternatives

Local (spot) M&R activities (e.g., crack filling, patching, joint repair, slab replacement, etc.)
Surface treatment rejuvenation (and localized M&R as described above)
Functional asphalt concrete (AC) overlay (usually less than 2 in.)
Structural AC overlay (usually greater than 2 in.)
AC overlay with fabric
AC overlay with heater scarification
Reconstruction: surface only
Reconstruction: entire structure (surface, base course, subbase, etc.)

TABLE C2	
YEAR	f1
Activity Year - Current Year	
0	1.000
1	0.954
2	0.867
3	0.788
4	0.717
5	0.652
6	0.592
7	0.538
8	0.489
9	0.445
10	0.405
11	0.368
12	0.334
13	0.304
14	0.276
15	0.251
16	0.228
17	0.208
18	0.189
19	0.172
20	0.156
21	0.142
22	0.129
23	0.117
24	0.107
25	0.097
26	0.088
27	0.080
28	0.073
29	0.066
30	0.060

TABLE C3	
Life of M&R Strategy	f2
(use value from B in Table 11)	
0	1.0000
1	1.0488
2	0.5491
3	0.3833
4	0.3007
5	0.2514
6	0.2188
7	0.1958
8	0.1787
9	0.1655
10	0.1551
11	0.1467
12	0.1399
13	0.1342
14	0.1294
15	0.1253
16	0.1218
17	0.1188
18	0.1162
19	0.1139
20	0.1119
21	0.1102
22	0.1087
23	0.1073
24	0.1061
25	0.1050
26	0.1040
27	0.1032
28	0.1024
29	0.1017
30	0.1011

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