TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA/TX-79/44+177-20		

4. Title and Subtitle	5. Report Date
SUMMARY REPORT FOR 1978 CRCP CONDITION SURVEY IN TEXAS	January 1981
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
Manuel Gutierrez de Velasco and B. Frank McCullough	Research Report 177-20
9. Performing Organization Name and Address	10. Work Unit No.
Center for Transportation Research The University of Texas at Austin Austin, Texas 78712	11. Contract or Grant No. Research Study 3-8-75-177
12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
Texas State Department of Highways and Public Transportation; Transportation Planning Division P. O. Box 5051 Austin, Texas 78763	Interim
	14. Sponsoring Agency Code

15. Supplementary Notes

Study conducted in cooperation with the U. S. Department of Transportation, Federal Highway Administration. Research Study Title: "Development and Implementation of the Design, Construction and Rehabilitation of Rigid Pavements"

16. Abstract

With the objective of obtaining historical performance data for design, maintenance, and research, the Texas SDHPT initiated a series of condition surveys of CRCP in 1974. A follow-up survey was conducted in 1978. Using condition survey data for CRCP from 1974 and 1978 in the State, a qualitative analysis of the distress condition of these pavements was performed as described below.

(1) The primary objective was to make a summary analysis of the 1978 condition survey data and compare it with the 1974 condition survey data. The results are presented in a summary form with only minimal statistical analysis; therefore, only the obvious observations or conclusions are emphasized.

(2) The values predicted by the computer program, CRCP-2, are compared to the measured crack spacing data. The results indicate that the program is a viable tool that may be used to design the reinforcement for a given set of conditions.

(3) In addition, preliminary criteria have been developed for major rehabilitation. Using discriminant analysis, an equation was obtained to weight the different distress manifestations and assign a score to each CRCP section. The magnitude of score is related to the distress condition of the pavement and can be used to decide if a pavement should be overlayed.

17. Key Words	18. Distribution Statement
continuously reinforced concrete pavement (CRCP), condition survey, distress, rehabilitation, discriminant analysis, utility functions	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	144	

Form DOT F 1700.7 (8-69)

SUMMARY REPORT FOR 1978 CRCP CONDITION SURVEY IN TEXAS

by

Manuel Gutierrez de Velasco
B. Frank McCullough

Research Report Number 177-20

Development and Implementation of the Design, Construction
and Rehabilitation of Rigid Pavements

Research Project 3-8-75-177

conducted for

Texas State Department of Highways and Transportation

in cooperation with the
U. S. Department of Transportation
Federal Highway Administration

by the

CENTER FOR TRANSPORTATION RESEARCH

BUREAU OF ENGINEERING RESEARCH

THE UNIVERSITY OF TEXAS AT AUSTIN

January 1981

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

PREFACE

Texas has about 30 percent of the 10,000 miles of CRCP in the United States. These pavements are located throughout the State, with the environmental conditions and the traffic loading differing considerably from place to place, thus making Texas unique for the study of CRCP.

This report presents a qualitative analysis of the distress condition of CRCP in the State. We have attempted to take advantage of the field data collected since 1974 concerning the conditon of CRCP, to analyze it in a general form without getting involved with statistics. By doing this, we have emphasized the obvious factors and developed evidence to support further analysis. Nevertheless, statistical analysis has been used in developing criteria for major rehabilitation, and a later report will present performance algorithms based on a thorough statistical analysis of the data.

With this analysis, assessment of the merits can be made of the different environmental and loading conditions. Potential areas of failure can be identified for future maintenance planning using these findings.

Manuel Gutierrez de Velasco
B. F. McCullough

LIST OF REPORTS

Report No. 177-1, "Drying Shrinkage and Temperature Drop Stresses in Jointed Reinforced Concrete Pavement," by Felipe R. Vallejo, B. Frank McCullough, and W. Ronald Hudson, describes the development of a computerized system capable of analysis and design of a concrete pavement slab for drying shrinkage and temperature drop. August 1975.

Report No. 177-2, "A Sensitivity Analysis of Continuously Reinforced Concrete Pavement Model CRCP-1 for Highways," by Chypin Chiang, B. Frank McCullough, and W. Ronald Hudson, describes the overall importance of this model, the relative importance of the input variables of the model and recommendations for efficient use of the computer program. August 1975.

Report No. 177-3, "A Study of the Performance of the Mays Ride Meter," by Yi Chin Hu, Hugh J. Williamson, B. Frank McCullough, and W. Ronald Hudson, discusses the accuracy of measurements made by the Mays Ride Meter and their relationship to roughness measurements made with the Surface Dynamics Profilometer. January 1977.

Report No. 177-4, "Laboratory Study of the Effect of Non-Uniform Foundation Support on CRC Pavements," by Enrique Jiminez, B. Frank McCullough, and W. Ronald Hudson, describes the laboratory tests of CRC slab models with voids beneath them. Deflection, crack width, load transfer, spalling, and cracking are considered. Also used is the SLAB 49 computer program that models the CRC laboratory slab as a theoretical approach. The physical laboratory results and the theoretical solutions are compared and analyzed, and the accuracy is determined. August 1977.

Report No. 177-6, "Sixteenth Year Progress Report on Experimental Continuously Reinforced Concrete Pavement in Walker County," by Thomas P. Chesney, and B. Frank McCullough, presents a summary of data collection and analysis over a 16-year period. During that period, numerous findings resulted in changes in specifications and design standards. These data will be valuable for shaping guidelines and for future construction. April 1976.

Report No. 177-7, "Continuously Reinforced Concrete Pavement: Structural Performance and Design/Construction Variables," by Pieter J. Strauss, B. Frank McCullough, and W. Ronald Hudson, describes a detailed analysis of design, construction, and environmental variables that may have an effect on the structural performance of a CRCP. May 1977.

Report No. 177-9, "CRCP-2, An Improved Computer Program for the Analysis of Continuously Reinforced Concrete Pavements," by James Ma and B. Frank McCullough, describes the modification of a computerized system capable of analysis of a continuously reinforced concrete pavement based on drying shrinkage and temperature drop. August 1977.

Report No. 177-10, "Development of Photographic Techniques for Performance Condition Surveys," by Pieter J. Strauss, James Long, and B. Frank McCullough, discusses the development of a technique for surveying heavily trafficked highways without interrupting the flow of traffic. May 1977.

Report No. 177-11, "A Sensitivity Analysis of Rigid Pavement-Overlay Design Procedure," by B. C. Nayak, B. Frank McCullough, and W. Ronald Hudson, gives a sensitivity analysis of input variables of Federal Highway Administration computer-based overlay design procedure RPOD1. June 1977.

Report No. 177-12, "A Study of CRCP Performance: New Construction versus Overlay," by James I. Daniel, B. Frank McCullough, and W. Ronald Hudson, documents the performance of several continuously reinforced concrete pavements (CRCP) in Texas. April 1978.

Report No. 177-13, "A Rigid Pavement Overlay Design Procedure for Texas SDHPT," by Otto Schnitter, B. Frank McCullough, and W. Ronald Hudson, describes a procedure recommended for use by the Texas SDHPT for designing both rigid and flexible overlays on existing rigid pavements. The procedure incorporates the results of condition surveys to predict the existing pavement remaining life, field and lab testing to determine material properties, and elastic layer theory to predict the critical stresses in the pavement structure. May 1978.

Report No. 177-14, "A Methodology to Determine an Optimum Time to Overlay," by James I. Daniel, B. Frank McCullough, and W. Ronald Hudson, describes the development of a mathematical model for predicting the optimum time to overlay an existing rigid pavement (being prepared for submission).

Report No. 177-15, "Precast Repair of Continuously Reinforced Concrete Pavement," by Gary E. Elkins, B. Frank McCullough, and W. Ronald Hudson, describes an investigation into the applicability of using precast slabs to repair CRCP, presents alternate repair strategies, and makes new recommendations on installation and field testing procedures. May 1979.

Report No. 177-16, "Nomographs for the Design of CRCP Steel Reinforcement," by C. S. Noble, B. F.McCullough, and J. C. M. Ma, presents the results of an analytical study undertaken to develop regression equations and nomographs for use as a supplementary tool in the design of steel reinforcement in continuously reinforced concrete pavement by the Texas State Department of Highways and Public Transportation. August 1979.

Report No. 177-17, "Limiting Criteria for the Design of CRCP," by B. Frank McCullough, J. C. M. Ma, and C. S. Noble, presents a set of criteria which limits values of a set of variables to be used in the design of CRCP. These criteria are to be used in conjunction with Report No. 177-16. August 1979.

Report No. 177-18, "Detection of Voids Underneath Continuously Reinforced Concrete Pavements," by John Birkhoff and B. Frank McCullough, presents the results of an investigation in which three methods for detecting voids underneath CRC pavements (deflection, pumping and vibration) are evaluated with respect to reliability of successful void detection. August 1979.

Report No. 177-19, "Manual for Condition Survey of Continuously Reinforced Concrete Pavement," by Arthur Taute and B. Frank McCullough, presents the condition survey method used during the 1978 statewide CRCP condition survey. In addition, proposals for a condition survey procedure for jointed concrete pavement are presented. December 1979.

Report No. 177-20, "Summary Report for 1978 CRCP Condition Survey in Texas," by Manuel Gutierrez de Velasco and B. Frank McCullough, presents a qualitative analysis of the distress condition of CRCP in the State of Texas using field data collected in 1974 and 1978. Also, criteria are developed in order to weight the different distress manifestations in deciding when to overlay a CRCP. March 1981.

ABSTRACT

With the objective of obtaining historical performance data for design, maintenance, and research, the Texas SDHPT initiated a series of condition surveys of CRCP in 1974. A follow-up survey was conducted in 1978.

Using condition survey data for CRCP from 1974 and 1978 in the State, a qualitative analysis of the distress condition of these pavements was performed as described below.

(1) The primary objective was to make a summary analysis of the 1978 condition survey data and compare it with the 1974 condition survey data. The results are presented in a summary form with only minimal statistical analysis; therefore, only the obvious observations or conclusions are emphasized.

The analytical approach consisted of isolating each of the different variables involved (age, traffic, environmental conditions, material type, etc.) and defining qualitatively its effects on the distress of the pavement (failures, crack spacing, and spalling of cracks). An extensive number of graphs and tables were used in the analysis. Basically, the data indicate the life of 8-inch CRCP in Texas for 1 to 6×10^6 equivalent 18-kip single-axle applications, and the changing performance across the State implies thicker pavements are required in the eastern part of the State than the western for the same traffic.

(2) The values predicted by the computer program, CRCP-2, are compared to the measured crack spacing data. The results indicate that the program is a viable tool that may be used to design the reinforcement for a given set of conditions.

(3) In addition, preliminary criterion has been developed for major rehabilitation. Using discriminant analysis, an equation was obtained to weight the different distress manifestations and assign a score to each CRCP section. The magnitude of score is related to the distress condition of the pavement and can be used to decide if a pavement should be overlayed.

KEY WORDS: continuously reinforced concrete pavement (CRCP), condition survey, distress, rehabilitation, discriminant analysis, utility functions.

SUMMARY

In this report, an attempt is made to analyze the distress condition of CRCP in ten of the Texas SDHPT Districts.

First, a summary of the distress of the various districts is given; this includes failures per mile (punchouts and patches), cracking and spalling of the pavement under study. Next, each of the distress types is related to the different variables assumed to affect the distress condition of the pavement (age, traffic, environmental conditions, etc.). The crack spacing data computed by the program CRCP-2 are compared to the crack spacing data collected in the field. Finally, data for sections that were overlayed between the 1974 and 1978 condition surveys are used to determine a criterion for deciding when to overlay in terms of distress condition of the pavement.

The results are discussed from the standpoint of original design intent and, in the last section, conclusions and recommendations are given. In the appendices, the data used for the analysis are presented and some of the topics are discussed in more detail.

IMPLEMENTATION STATEMENT

Analysis of the 1974 and 1978 condition survey data along with comparison of previous design and construction practices and recent design developments led to the following statements:

(1) Thickness of CRCP must be related to the equivalent 18-kip axle-load applications expected, the soil support, and the concrete type employed; the practice of using 8-inch pavements with improved subbase did not give adequate results.

   (a) Thicker pavements must be used as the projected design traffic increases.

   (b) For equal traffic conditions, a thicker pavement should be used in the eastern part than in the western part of the State.

   (c) In general, CRCP constructed with coarse aggregate of crushed limestone has a better performance history than the silicious river gravel, and thus, changes should be made in the specifications and design standards to recognize this.

(2) The equations presented in Chapter 8, developed from the field data characterizing the reasons leading to overlay of CRCP, are useful as a criteria in deciding future overlays.

TABLE OF CONTENTS

PREFACE iii

LIST OF REPORTS v

ABSTRACT ix

SUMMARY xi

IMPLEMENTATION STATEMENT xiii

CHAPTER 1. INTRODUCTION 1

Background on 1974 Condition Survey 1
Description of 1978 Condition Survey 1
Objectives 3
Scope of the Report 3

CHAPTER 2. SUMMARY OF STATEWIDE DISTRESS CONDITION

Failures 5
Cracking 9
Spalling 9
Observations by Districts 9

CHAPTER 3. DISCUSSION OF ANALYTICAL APPROACH 13

CHAPTER 4. ANALYSIS OF FAILURE DATA

Effect of Age 15
Effect of Traffic 15
Effect of Geographical Location 21

CHAPTER 5. ANALYSIS OF CRACK SPACING

Effect of Age 27
Effect of Traffic 27
Effect of Geographical Location and Concrete Properties . . 30

CHAPTER 6. COMPARISON OF MEASURED AND PREDICTED CRACK SPACING . . 31

CHAPTER 7. ANALYSIS OF SPALLING

Effect of Age 35
Effect of Traffic 35
Effect of Geographical Location 35
Effect of Crack Spacing 39
Effect of Concrete Type 39

CHAPTER 8. ANALYSIS OF OVERLAYED SECTIONS

Failures and Spalling before Overlaying 41
Criterion to Overlay 44
Discriminant Equation 44
Utility Function 47
Criterion for Major Rehabilitation 48

CHAPTER 9. DISCUSSION OF RESULTS

Discussion of Distress Manifestations 49
Crack Spacing 50
Discriminant Analysis Technique 51

CHAPTER 10. CONCLUSIONS

Distress Manifestations 53
Average Crack Spacing 53

CHAPTER 11. RECOMMENDATIONS 55

REFERENCES 57

APPENDICES

Appendix A. Summary of Failures in Each District 59
Appendix B. Summary of Cracking and Spalling in Each District 89
Appendix C. Theoretical Prediction of Crack Spacing . . . 107
Appendix D. Use of Discriminant Analysis to Evaluate the Distress Condition of CRCP 115

THE AUTHORS 127

CHAPTER 1. INTRODUCTION

With the objective of obtaining historical performance data for design, maintenance and research, the Texas State Highway Department of Public Transportation (SDHPT) initiated a condition survey of CRCP in 1974. Ten of the SDHPT Districts were considered in this first round of surveys, shown in Fig 1. In 1976, the CRCP in the more urban districts, i.e., Districts 2, 12, 15, and 18 were surveyed,using photographic techniques. In 1978, a follow-up survey was conducted.

Background of 1974 Condition Survey

In order to obtain performance information, a comprehensive survey of all continuously reinforced pavements in the State of Texas was carried out in 1974. The intention was to quantify distress in the CRCP in use throughout the state, from which the general condition of CRCP could be verified, unique design and performance problems could be established, and limited, and detailed performance studies could be set up for research on the establishment of new design criteria (Ref 1).

A survey technique was developed (Refs 1 and 2). Each road was surveyed by two persons in one vehicle, traveling on the shoulder at approximately 5 miles per hour. Sections of 0.2 miles were rated considering the distress condition, and the riding quality of the facility. The distress manifestations recorded were: transverse and localized cracks, spalling, pumping, punchouts, and repair patches. These data, after being collected in the field, were stored, processed, and reported by a computer. The reports were distributed to the districts and the SDHPT.

Description of 1978 Condition Survey

During the second half of 1978, the CRCP in the state were surveyed again, to follow up the objectives set in 1974 and to help in planning

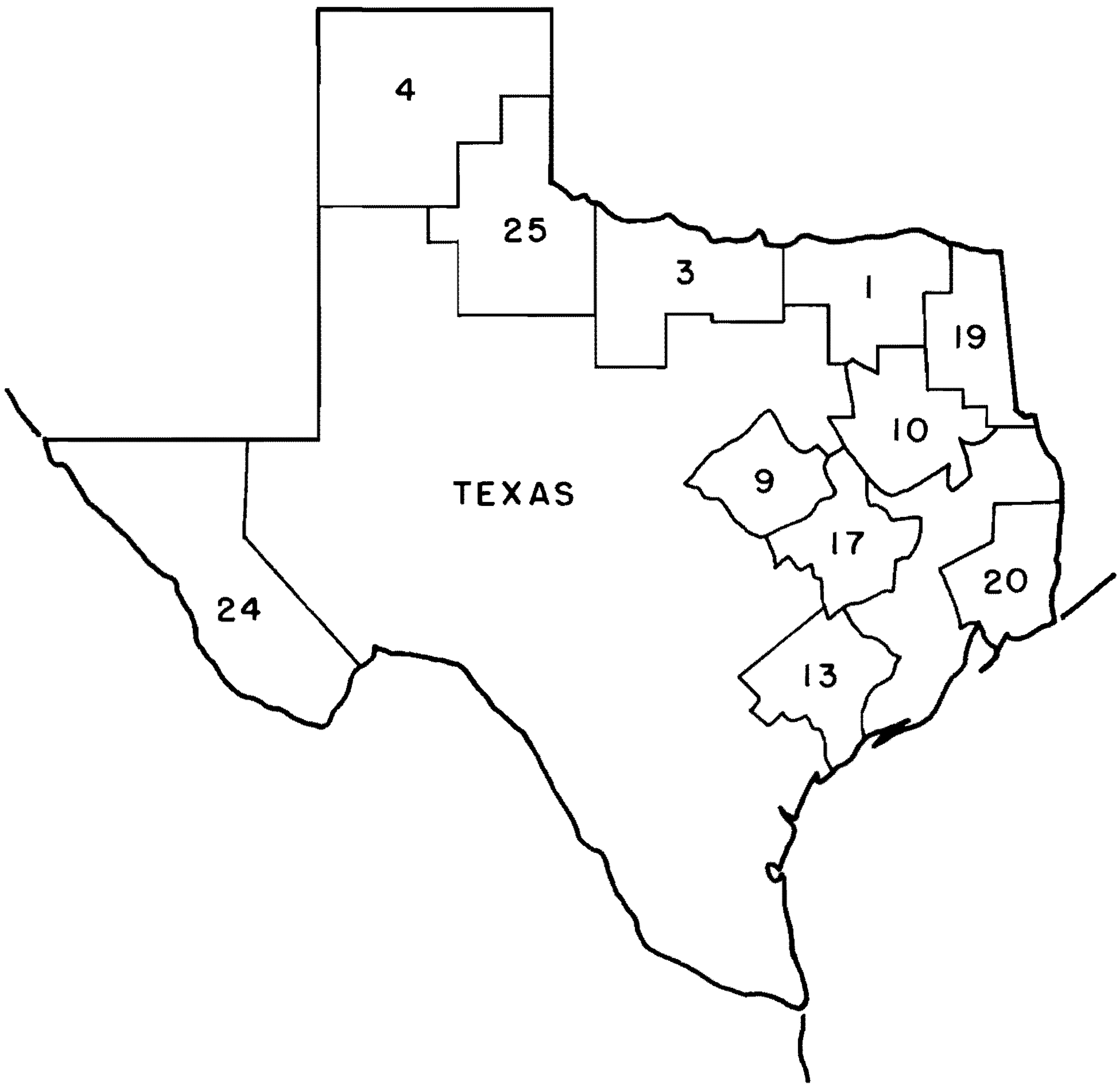


Fig 1. Location of districts surveyed in 1974 and 1978.

and scheduling of maintenance and rehabilitation activities. The same survey technique was used, but the records and the reporting procedures were modified.

The results of the 1978 condition survey of CRCP in the State of Texas are reported in a series of four reports: the first one encompasses a computer summary of the condition survey for each specific district; the second report documents the procedure for the surveys and contains a description of the storage of the data as a permanent record; the third report covers the overall 1978 condition survey and compares it with the 1974 data; the last report is a detailed analysis of the condition survey results.

The first report was circulated to the Districts in an unpublished form. This report is the third in the series and the others will follow at later dates.

Objectives

The primary objective of this report is to make an analysis of the 1978 condition survey and compare it with the 1974 condition survey data.

Thus, results are presented in a summary form with only a minimal statistical analysis. Only the obvious observations or conclusions are emphasized, such as more distress in certain areas of the state, the effect of traffic, etc. The capabilities of a reinforcement design program, CRCP-2, are tested by comparing its results to the field data collected. In addition, preliminary criteria have been developed for major rehabilitation, taking into account the pavements overlayed since 1974.

Scope of the Report

In the next section, a summary of the distress conditions in the various districts in the state is given; this summary includes failures per mile and cracking and spalling of the pavements studied. Next, an analysis of the data is attempted; the parameters involved are age, climatic conditions, traffic, construction methods, and geometrical and mechanical properties of the materials. The conclusions obtained are summarized in the last part of the report. Appendices A and B contain the data considered in the analysis. Appendix C presents the background material for predicting the crack spacing to be compared with measured values. An analysis of the overlayed sections is performed, and from it a criterion for deciding when to overlay is developed; Appendix D is a detailed description of the procedure followed. A more detailed summary of the data is the scope of another report.

CHAPTER 2. SUMMARY OF STATEWIDE DISTRESS CONDITION

The distress manifestations recorded during the 1978 condition survey were spalling, pumping, punchouts, and patches (see Reference 1 for a detailed explanation of these terms). In addition, the average crack spacing for each project was determined. For discussion purposes in this report, the distress manifestations are considered as failures, cracking, and spalling.

In this section, each of the distress manifestations is examined relative to state-wide historical trends between 1974 and 1978. In addition, general comments are made relative to each of the districts.

Failures

In accordance with the Highway Design Division's request, failures are considered as the sum of punchouts and repaired patches observed on the pavement. A punchout is defined as closely spaced transverse cracks linked by longitudinal cracks to form rectangular shaped blocks. Patches may be either portland cement concrete or asphalt concrete. During the survey, the condition of the repair patch was not determined; only the number of repairs were counted. In Fig 2, the mean numbers of failures per mile in each district are shown for 1974 and 1978. The number of failures in each district would be expected to increase from 1974 to 1978; in some cases this is not true because the highly distressed sections have been overlayed, reducing the observable number of failures per mile.

The number of failures per mile in some districts is larger than in others, but the reason is not apparent from the data, and that will be the subject of subsequent reports. In Table 1, further information for each district is given: the length reported, the length overlayed since 1974, the age range, failures per mile, and the mean riding quality. The mean riding quality was not obtained for each District in 1978, so only limited observations can be made regarding this term. To assist the reader in making relative comparisons, the survey data is summarized in Table 2 in terms of length, age, mean failures, maximum failures, and riding quality.

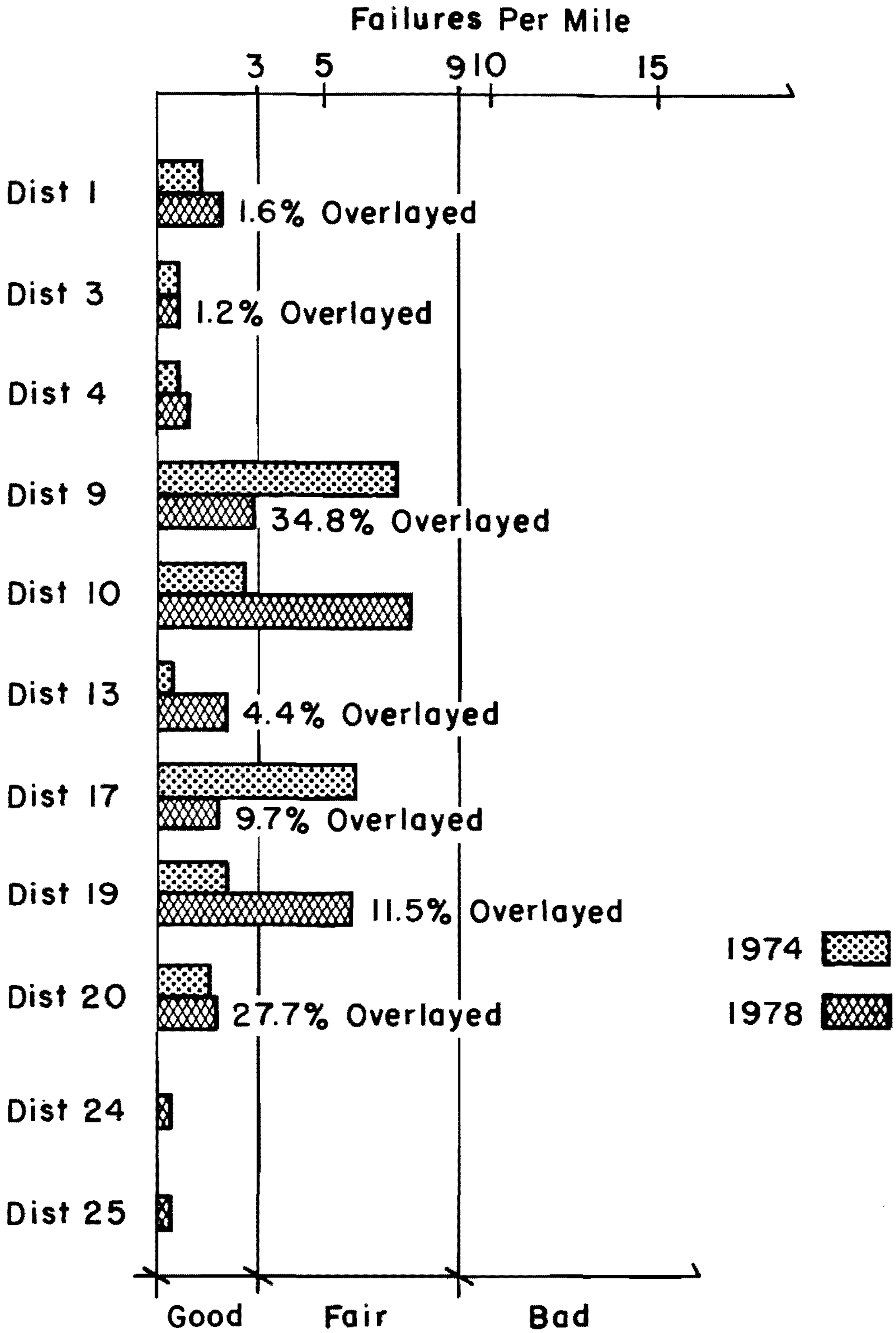


Fig 2. Mean failures per mile in each district.

TABLE 1. SUMMARY OF FAILURES FOR THE CRCP 1978 SURVEY

District	Length Reported (miles)	Length Overlayed Since 1974 (miles)	Age Range (years)	Mean Failures Per Mile		Maximum Number of Failures Per Mile	Mean Riding Quality	
				1974	1978		1974	1978
1	89.2	1.6	3.5 to 14.5	1.2	1.9	7.8	3.2	-
3	115.0	1.4	5.0 to 14.0	0.4	0.4	1.7	3.2	-
4	81.2	0	6.2 to 13.8	0.4	0.9	6.1	3.3	-
9	46.6	16.2	7.9 to 18.5	7.1	2.9	19.0	2.8	3.1
10	167.3	0	11.3 to 15.2	2.6	7.4	22.4	3.2	-
13	292.6	13.0	4.3 to 16.1	0.3	2.0	26.7	3.5	-
17	238.2	23.0	6.2 to 17.4	5.9	1.7	6.6	3.6	3.6
19	216.5	24.8	6.5 to 13.8	2.0	5.9	45.0	3.5	-
20	77.2	21.4	6.4 to 15.4	1.5	1.7	28.9	3.1	-
24	99.0	0	3.0 to 8.9	0	0.2	0.7	-	-
25	61.2	0	3.0 to 10.2	0	0.3	0.8	3.9	-

TABLE 2. TENTATIVE PAVEMENT CONDITION SCALE

Failures Per Mile	Condition
0 - 3	Excellent
3 - 9	Fair
9 - 27	Poor
27 (+)	Very poor

Cracking

All continuously reinforced concrete pavements have transverse cracking, but, if the average spacing over a distance is less than two feet, the probability of punchouts is increased. Thus, transverse cracking, i.e., spacing of less than two feet, was considered as a distress manifestation. In 1974, the length of pavement within the section surveyed having close transverse cracking was added; and, the accumulated length as a percentage of the section length was reported. In 1978, 300-foot samples, one in each project, were chosen at random and the spacing between cracks was measured. The average crack spacing was then computed and considered as a representative value for the project.

Spalling

Spalling is defined as the widening of existing cracks through secondary cracking or breaking of the crack edge. A minor spall is defined as edge cracking where the loss of material has formed a spall of one-half-inch wide or less. Severe spalling defines the case where the spalling has widened so much that smoothness of ride is affected.

The criterion for measuring spalled cracks in 1978 was changed from the criterion followed in 1974. In 1974, an estimate of the percentage of cracks that showed minor and severe spalling was made. In 1978, the actual number of spalled cracks in every section was determined; the percentage of spalling was then derived from this figure and the average crack spacing.

Only spalling data for 1978 are presented due to the limitations already mentioned. In Table 3, a summary of cracking and spalling in the districts considered is given; further details may be found in Appendix B.

Observations by Districts

Using the data in Tables 1 and 3, general observations can be made relative to each District.

District 1. The number of failures per mile encountered is, in general small; the maximum number of failures is 7.8. No major differences exist

TABLE 3. STATEWIDE SUMMARY OF CRACK SPACING AND SPALLED CRACKS

District	Mean Crack Spacing (feet)	Percent Spalled Cracks	
		Minor	Severe
1	6.9	26.9	0.6
3	6.3	20.5	0.1
4	3.2	18.9	0.2
9	8.7	44.2	1.1
10	6.8	54.7	2.1
13	5.1	18.6	3.8
17	4.0	11.8	0.9
19	3.7	18.5	6.5
20	4.2	13.3	8.2
24	5.0	28.6	0.4
25	2.9	13.4	0.1

between the 1974 and the 1978 data, and no sections were overlayed during the four year interval.

District 3. The condition of the CRCP is good according to the survey. Even the maximum number of failures per mile is small.

District 4. The CRCP condition in this district is also good. The largest number of failures per mile is 6.1, which is in the "fair" category.

District 9. Various projects in this district are within the "poor" range of failures per mile. This district contains some of the oldest CRCP in the state. The mean riding quality in the district was improved from 1974 to 1978 due to overlaying several of the projects. It appears that the main criteria for overlaying was the number of failures per mile rather than the riding quality. Nevertheless, most of the projects have a riding quality of less than 3.0.

District 10. District 10 has a large number of failures per mile. A number of the projects are in the "poor" condition category.

District 13. In general, the CRCP condition in this district is good.

District 17. In general, the condition is "fair". Several projects have been overlayed; it is apparent that the number of failures was the main criteria to overlay since the mean riding quality, i.e., PSI, was above 3.0.

District 19. In this district, several of the sections are ranked as "poor". The maximum number of failures per mile may be misleading, since it was calculated over a very short section. Almost 25 miles have been overlayed in the district; the criteria for overlaying are not clear from the data.

District 20. Although the mean number of failures per mile is not large, a few of the individual sections have numerous failures; this leads to a large maximum number of failures. From the data, it is not apparent what the primary criteria to overlay are.

District 24. The numbers of failures in the different sections are small. The riding quality was not recorded in the 1974 survey.

District 25. Most of the projects in this district are fairly new, and the number of failures is small.

CHAPTER 3. DISCUSSION OF ANALYTICAL APPROACH

The data can be analyzed from a number of levels, but our approach consists of isolating each of the different parameters, with the help of graphs, charts, maps, etc., to define qualitatively the effect of each variable parameter on the performance of the highway.

The first step is to select the parameters which will be observed and which may have an important influence on the process of deterioration of the highway. The distress condition can be hypothesized to be a function of the age of the pavement, traffic, climatic conditions, construction procedures, and geometric and mechanic properties of the materials in the pavement structure.

Past experience and the available data constrain our analysis to the following parameters:

(1) age,

(2) traffic conditions,

(3) geographical location: this encompasses climate and soil type,

(4) construction procedures,

(5) material type: limestone vs. river gravel concrete, and

(6) material property: strength of concrete.

At this stage, it is important to mention that a true isolation of the variables is not possible due to the interactions among them; that is, we could choose observations under the same conditions and draw some conclusions regarding the variable being studied, but the conclusions might not be valid for a different combination of the fixed conditions. Thus, any conclusions will be, of necessity, generalizations supporting the obvious factors.

A more detailed analysis, taking into account the effects of all variables at different levels, will be considered in another report where statistical analysis will be performed in detail.

CHAPTER 4. ANALYSIS OF FAILURE DATA

In this section, the effects of various parameters in the occurrence of failures are studies. It was previously stated that punchouts and repaired patches in a section were combined and considered as failures.

Generally, in a CRC pavement, the longitudinal stresses are large compared with the transverse stresses unless the spacing between cracks becomes so small that the transverse stresses are significant, leading to the formation of punchouts.

Effect of Age

Age per se is not a cause of failure occurrence, but it interacts with other factors, i.e., traffic, temperature, moisture, etc., to produce or increase the number of failures.

It is obvious that the number of failures per mile should increase with age. However, in Table 4, the number of failures suddenly drops for pavements older than fourteen years; the reason is that most of the pavements above this age have been overlayed, as may be noted in Fig 3.

In Table 5, the number of failures per mile for different ages in the various districts surveyed is shown. In general, it can be observed that, in any district, the number of failures increases with time.

If we compare across districts by age, the large variability in performance can be noted, which implies that other factors are influencing the results.

Effect of Traffic

From Fig 4 and Table 6, it is apparent thatt an increase in axle load applications leads to a larger number of failures. It is important to note that the percentage of overlayed sections increases with traffic load applications for pavement with traffic between 5 and 6 million 18K-EAL. Where

TABLE 4. EFFECT OF AGE IN CRCP FAILURES

Age (years)	Length Reported	Length Overlayed (miles)	Percent Length Overlayed	Number of Failures* per mile	
				1978	1974
0 to 2	-	-	-	-	0.0
2 to 4	15.6	-	0.0	0.5	0.2
4 to 6	84.6	5.0	5.9	0.4	0.4
6 to 8	365.9	9.0	2.5	1.1	2.2
8 to 10	244.4	1.4	0.6	1.4	2.6
10 to 12	315.0	54.2	17.2	4.4	2.3
12 to 14	232.2	7.8	3.4	6.2	37.8
14 to 16	180.3	21.4	11.9	5.6	25.3
> 16	37.7	33.0	87.5	0.4	-

Rating Score

See next page.

TABLE 5. NUMBER OF FAILURES PER MILE* FOR DIFFERENT AGES IN VARIOUS DISTRICTS

	District										
Age (years)	1	3	4	9	10	13	17	19	20	24	25
0 to 2	-	-	-	-	-	-	-	-	-	-	-
2 to 4	0	-	-	-	-	-	-	-	-	1.2	0
4 to 6	-	0.5	-	-	-	0	-	-	-	0.4	0.6
6 to 8	0.2	0.3	0.5	0.2	-	0.8	2.7	0.8	0.9	0.2	-
8 to 10	0.4	0.5	1.6	-	-	2.9	1.0	-	0.3	0.2	0.1
10 to 12	4.4	0.9	1.5	9.5	3.3	1.9	3.1	9.7	1.4	-	0.1
12 to 14	1.2	0	0	5.2	8.4	-	-	6.6	12.5	-	-
14 to 16	3.8	0.4	-	-	10.0	7.6	0.9	-	0.1	-	-
>16	-	-	0.4	0	-	-	0	-	-	-	-

*Relative Score

0-3 good

3-9 fair

9(+) bad

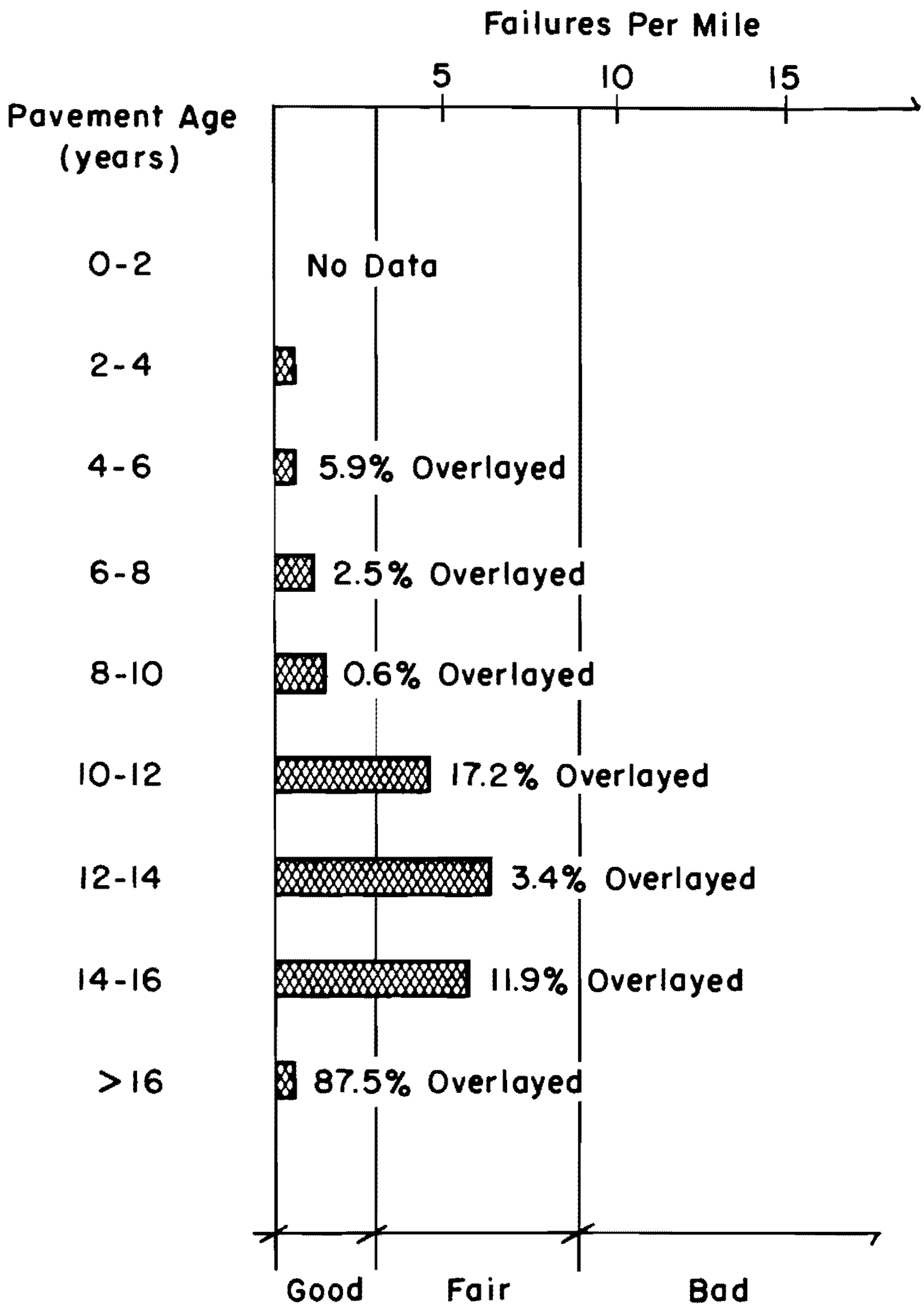
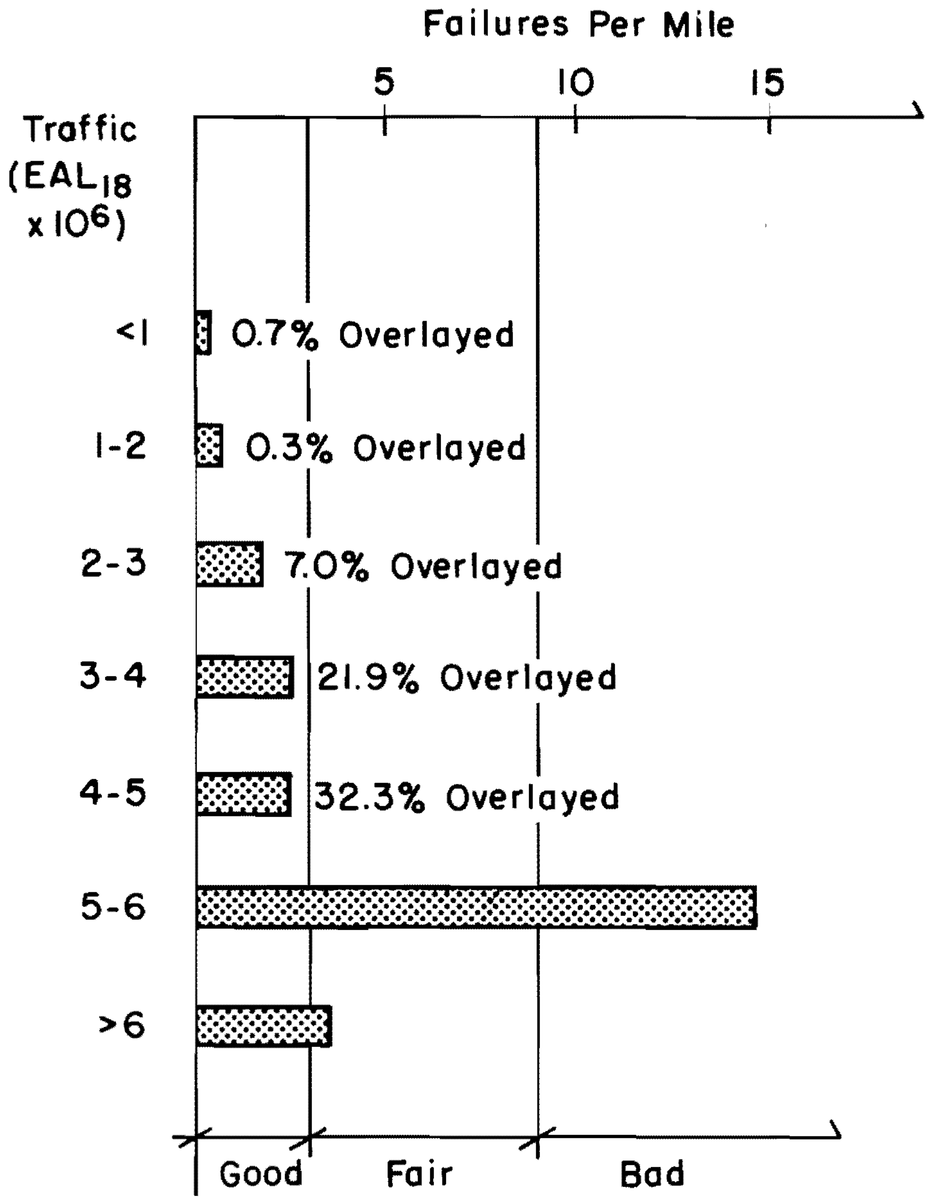


Fig 3. Effect of age on CRCP failures (1978 data).



Note: This chart includes only sections that have not been overlayed. The percentage of overlayed pavements has been annotated to the right of the bar chart.

Fig 4. Effect of traffic on CRCP failures.

TABLE 6. EFFECT OF TRAFFIC ON CRCP FAILURES (1978)

Traffic ($EAL_{18} \times 10^6$)	Length Reported	Length Overlayed	Percent Length Overlayed	Number Failures Per Mile*
< 1	28.2	0.2	0.7	0.3
1 to 2	74.2	0.2	0.3	0.6
2 to 3	235.0	17.4	7.0	1.6
3 to 4	193.8	42.4	21.9	2.5
4 to 5	78.6	25.4	32.3	2.4
5 to 6	51.9	-	-	14.7
> 6	10.2	-	-	3.3

*Overlayed sections not considered

no overlayed sections were recorded, the number of failures falls out of the trend shown by the rest of the data (Fig 4).

In Table 7, the number of failures per mile for different traffic conditions in the various districts surveyed is shown. The increment of failures with load applications is not obvious because overlayed sections within districts have not been considered.

Effect of Geographical Location

Geographical location is a broad term used here to encompass temperature, moisture, and soil type. The eastern part of the state is more humid and has more ground water (Fig 5); the lowest temperatures are recorded in the north; expansive clays are more frequently found in the east (Fig 6).

From the plots in Fig 7, where the influence of geographical location on the number of failures per mile for a constant age is shown, it may be seen that the districts located in the eastern part of Texas have a larger number of failures. For instance, for pavement between 10 and 12 years old, the Districts that show more failures are 9, 17, and 19, while the Districts with the least failures are 3, 4, and 25, which are located in the west.

In order to see if the latter effect was due to traffic, a bar chart was plotted (Fig 8) for the influence of geographical location in terms of the number of failures per mile at constant traffic applications. Districts 9, 17, and 19 still show the largest number of failures for a fixed value of applications, and Districts 3, 4, and 25 still show a smaller number of failures per mile.

It may be concluded that there is a definite influence of the geographical location, i.e., of temperature, humidity, ground water, and soil type, in the distress condition of a CRC pavement; the worst conditions are in the eastern districts.

TABLE 7. NUMBER FAILURES PER MILE FOR DIFFERENT TRAFFIC CONDITONS IN THE VARIOUS DISTRICTS

Traffic ($EAL_{18} \times 10^6$)	District 1	3	4	9	10	13	17	19	20	24	25
< 1	0.2	0.5	-	-	-	-	-	-	-	-	-
1 to 2	1.2	0.5	-	-	-	-	-	-	-	-	0.5
2 to 3	-	0.9	0.8	12.0	-	-	3.7	0.7	-	-	0.1
3 to 4	2.0	-	-	5.3	-	-	1.8	4.2	-	-	-
4 to 5	2.8	-	5.4	3.1	-	-	0.9	-	-	-	-
5 to 6	-	-	0	-	-	-	-	15.8	-	-	-
> 6	-	-	0	-	-	-	-	4.4	-	-	-

Rating Scale

0-3 Excellent

3-9 Fair

9-27 Poor

27+ Very Poor

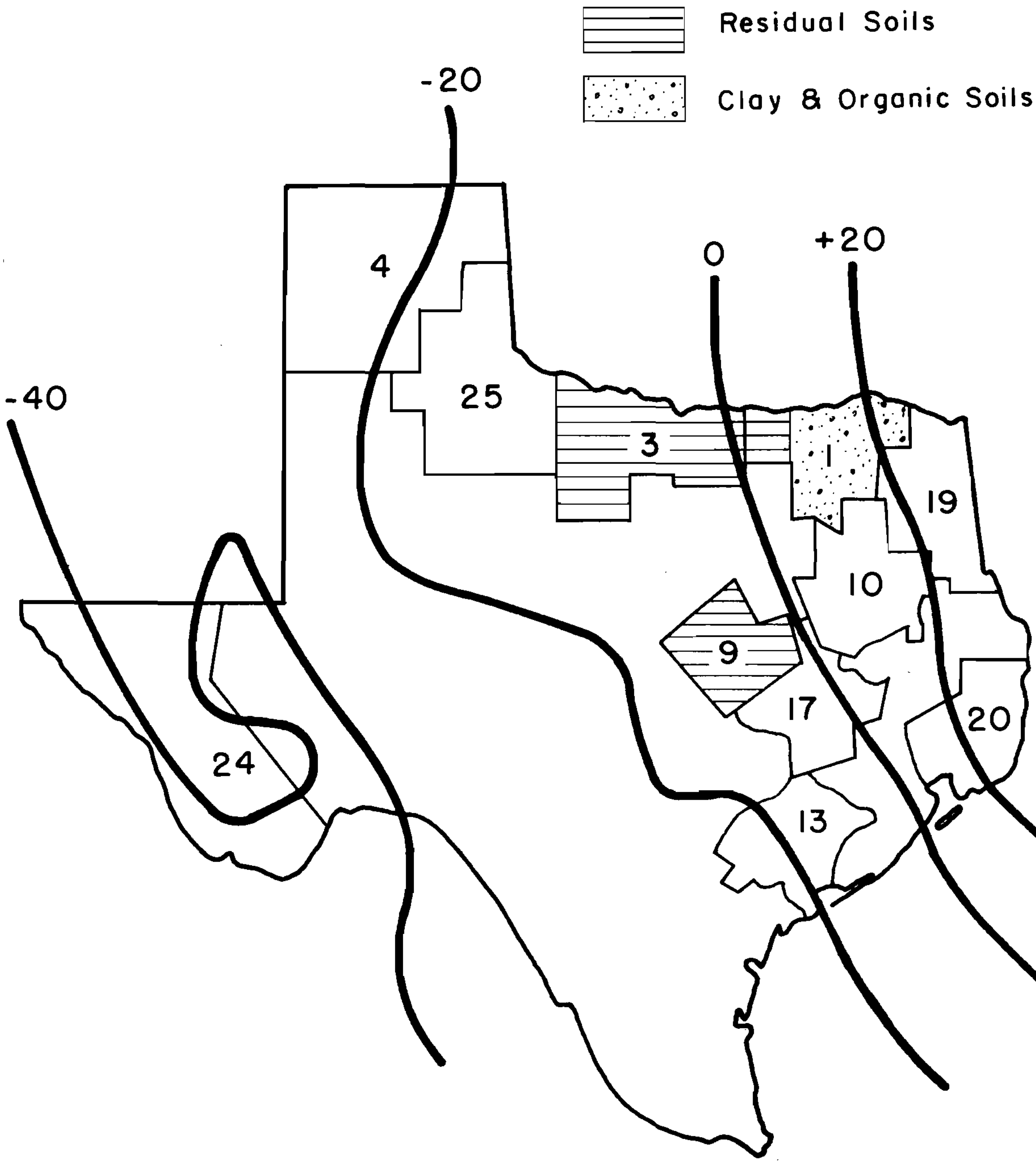


Fig 5. Contours of Thornthwaite moisture index for Texas.

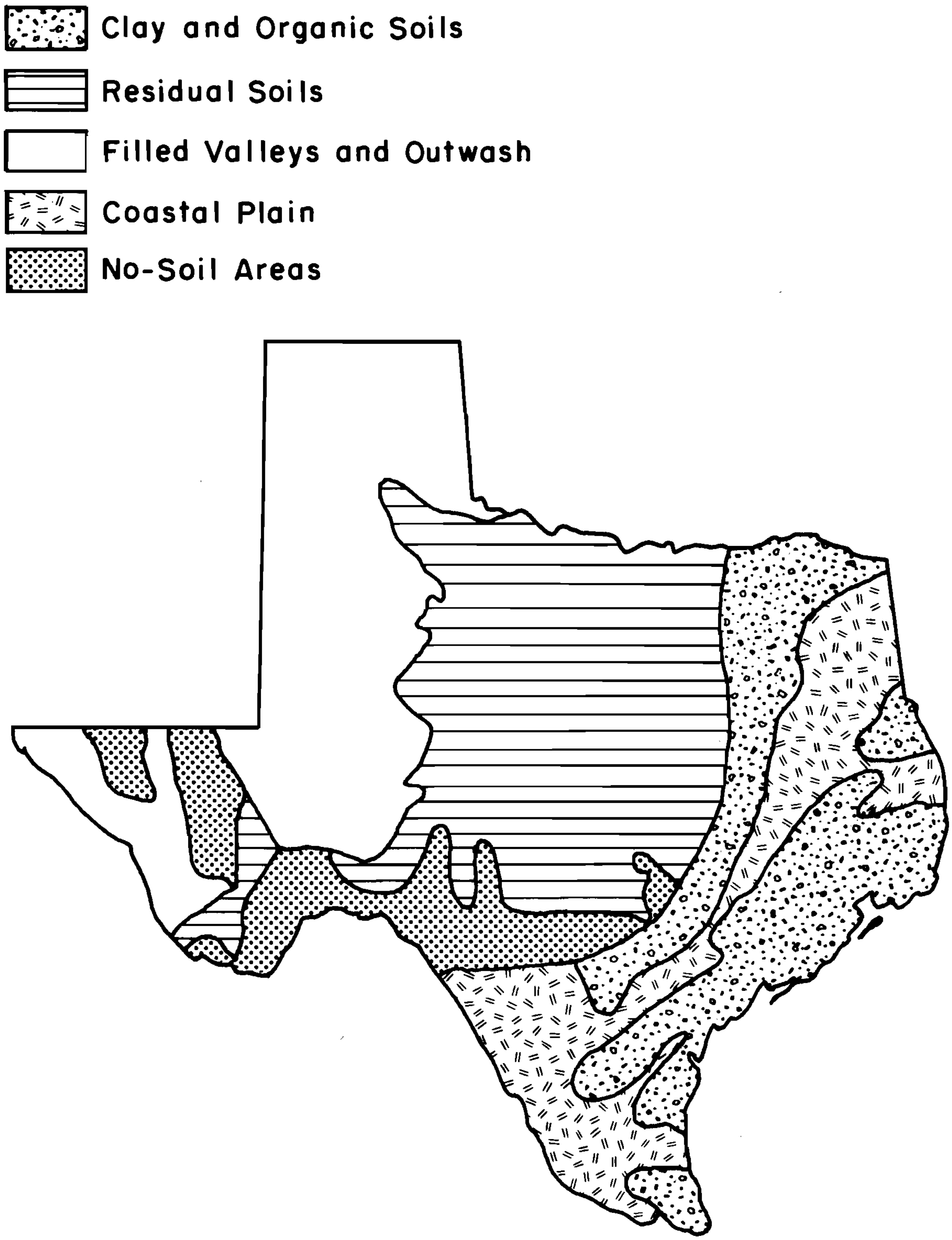


Fig 6. Different soil types in Texas (after Belcher, Gregg, Jenkins, and Woods).

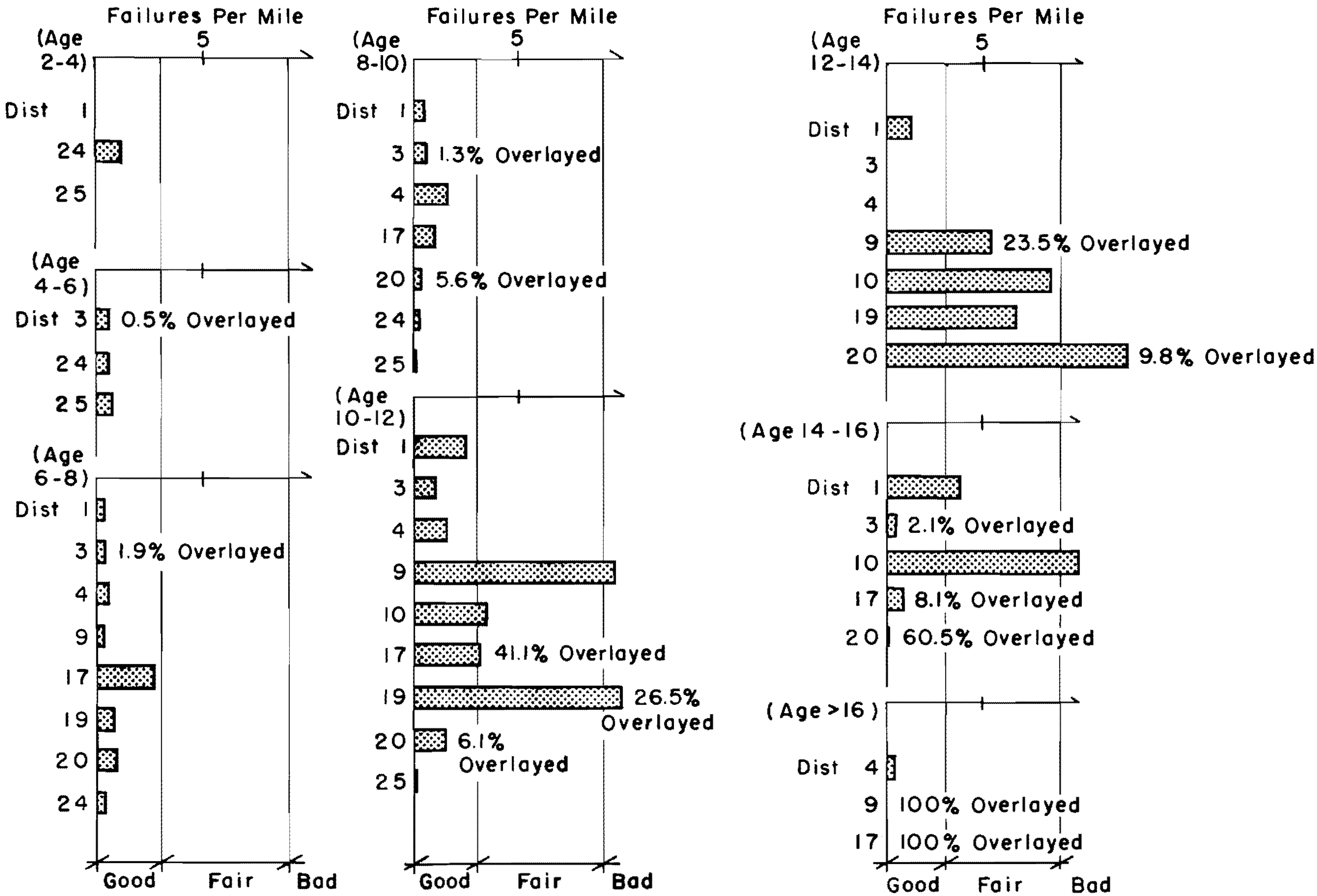


Fig 7. Influence of location on number of failures per mile (constant age, years).

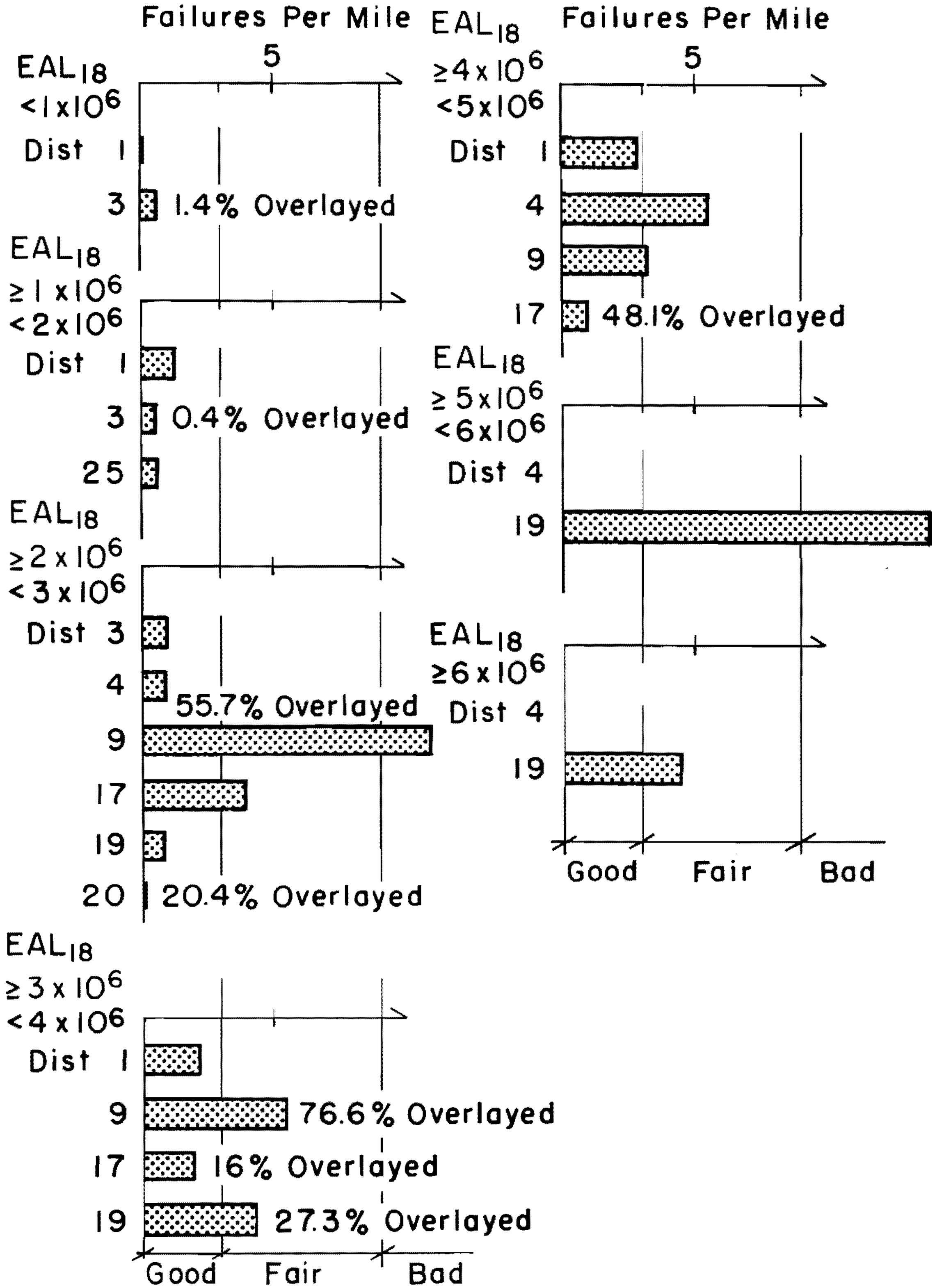


Fig 8. Influence of loaction on number of failures per mile (constant traffic).

CHAPTER 5. ANALYSIS OF CRACK SPACING

One of the most important responses of a continuously reinforced concrete pavement to the action of traffic and environment is its crack pattern. The design methods for CRCP are based on the precept of keeping the crack pattern within certain limits in order to avoid distress leading to the failure of the pavement.

The mechanism of cracking is very complex since it is affected by a large number of interacting variables. Cracking in CRCP starts with the first year. Several variables affect the spacing of the cracks; the most important being age, traffic, moisture, temperature, reinforcement, and concrete properties. In this section, the effects of age, traffic, and geographical location on crack spacing are examined.

Effect of Age

In Table 8, the crack spacing for different ages in the various districts surveyed has been summarized. From these data, it appears that crack spacing is independent of the age of the pavement in a gross analysis. Studies done by McCullough and Chesney on specific projects showed that the crack pattern develops quickly in the first months and only a slight decrease in the average crack spacing is to be seen in the following years (Ref 4). These data show the average crack spacing only for ages in excess of one year; therefore, the age effect is not present. Furthermore, the other variables affecting crack spacing are more dominant; hence, the small changes expected after one year may not be detected.

Effect of Traffic

The influence of the number of load applications is not apparent from Table 9. Theoretically for a certain number of applications the material should fail in fatigue and the crack spacing become smaller to relieve the stress. This concept can not be ascertained from our data. An increase in the number

TABLE 8. AVERAGE CRACK SPACING (FT) FOR CRCP IN 1978 CONSIDERED IN TERMS OF AGE AND LOCATION i.e., DISTRICTS

	District										
Age (years)	1	3	4	9	10	13	17	19	20	24	25
0 to 2	-	-	-	-	-	-	-	-	-	-	-
2 to 4	7.2	-	-	-	-	-	-	-	-	4.9	-
4 to 6	-	7.7	-	-	-	3.0	-	-	-	4.6	3.1
6 to 8	3.8	4.9	4.5	-	-	6.2	4.8	3.5	2.6	5.6	-
8 to 10	5.1	7.2	2.9	-	-	4.3	2.9	-	4.2	5.9	3.3
10 to 12	8.0	4.8	3.3	7.0	-	3.0	3.1	4.6	4.6	-	2.9
12 to 14	6.2	6.1	3.6	9.6	6.9	-	-	2.9	3.8	-	-
14 to 16	8.3	5.9	-	-	6.8	4.1	4.3	-	4.6	-	-
> 16	-	-	-	-	-	-	-	-	-	-	-

TABLE 9. EFFECT OF TRAFFIC ON CRACK SPACING FOR EACH DISTRICT

Traffic ($EAL_{18} \times 10^6$)	District										
	1	3	4	9	10	13	17	19	20	24	25
< 1	3.33	7.03	-	-	-	-	-	-	-	-	-
1 to 2	-	5.73	-	-	-	-	-	-	-	-	3.00
2 to 3	-	4.80	3.27	-	-	-	4.70	3.51	-	-	3.08
3 to 4	8.15	-	-	7.00	-	-	3.03	4.33	-	-	-
4 to 5	7.45	-	3.40	-	-	-	4.25	-	-	-	-
5 to 6	-	-	4.00	-	-	-	-	4.20	-	-	-
> 6	-	-	3.70	-	-	-	-	-	-	-	-

of loads should produce closer crack spacing. In order to demonstrate this point the crack spacings in 1978 should be compared to those in 1974, but these data were not taken in 1974.

In conclusion, the effect of traffic upon crack spacing of CRC pavements cannot be assessed from these data without a second set of observations.

Effect of Geographical Location and Concrete Properties

Districts 3, 4, and 25, which are located in the northern part of the state, have the coldest temperatures, and aggregates of two types, gravel and limestone, have been used in the concrete mixtures. Along the Gulf Coast, in Districts 13 and 20, minimum temperatures of about 10 degrees Fahrenheit have been recorded, and most of the concretes poured in these districts are gravel concretes.

In Appendix B, crack spacings from some of the projects surveyed are given. The aggregate type used in the concrete mix was obtained from Ref 3. The temperature and humidity data are from Ref 5.

From a visual imspection of the data, it may be observed that:

(1) In areas with similar temperatures, limestone concrete pavements show larger crack spacing than gravel concrete pavements.

(2) In colder areas, crack spacings appear to be smaller for both types of aggregate.

(3) For districts with similar conditions of temperature, crack spacings appear to be similar for equal concrete types.

CHAPTER 6. COMPARISON OF MEASURED AND PREDICTED CRACK SPACING

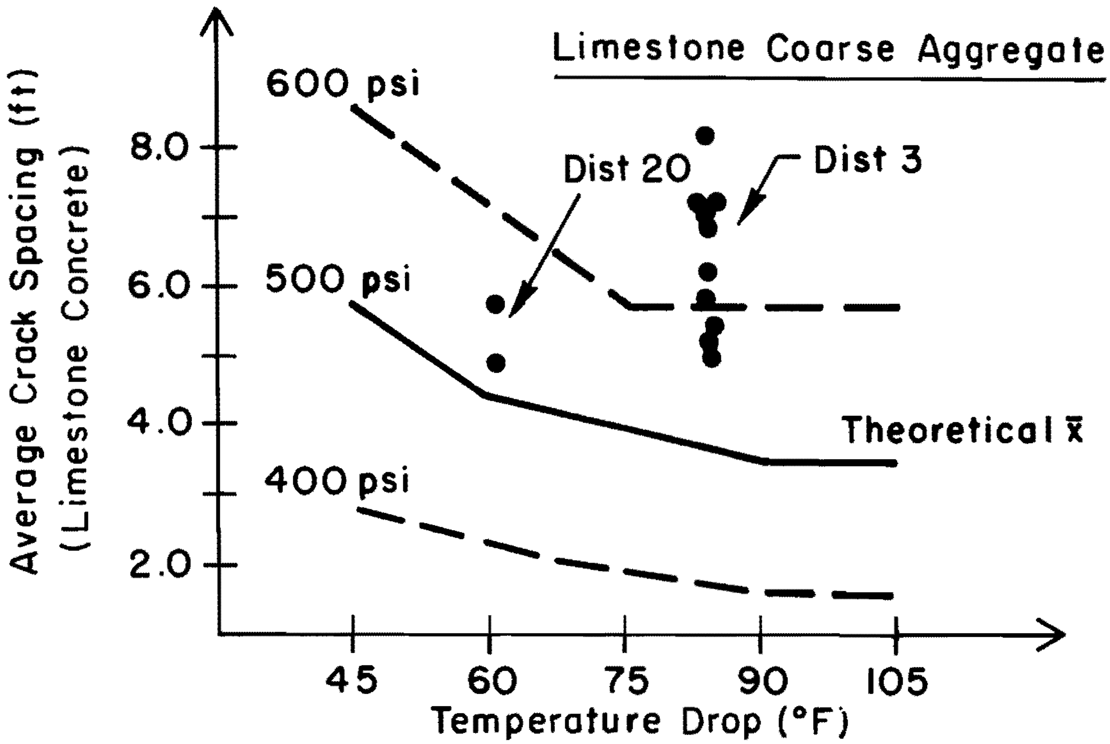
The purpose of this section is to compare crack spacing data obtained in the field with the values predicted by Computer Program CRCP-2. This program was developed for the Texas SDHPT by the CTR (Refs 9 and 10) to design CRCP for specific environmental conditions and material properties.

For comparison purposes, consideration is given to the effects of geographical location (environmental condition) and concrete properties. The temperatures selected for this study represent the conditions found in different parts of the State of Texas. The concrete properties analyzed are those influenced by the aggregate type used in the concrete mix; also, different concrete tensile strengths were considered. Appendix C presents the development of the theoretical crack spacing for comparison with field data.

Figure 9 was developed to compare the values obtained from the computer against the data obtained from the field. A value of tensile strength of concrete of 500 psi was selected as the average value. The curing temperature was selected to be 75 degrees F as an average value, and so the temperature drop was calculated as the difference between the average value and the lowest temperature recorded in the area.

In Fig 9, it is observed that the predicted value of crack spacing for limestone concrete is slightly lower than the values observed in the field. This may be due to several causes: higher tensile strength of concrete than that specified, thermal coefficient of the concrete lower than the assumed value, percent steel larger than the assumed value, different concrete shrinkage, and lower curing temperature (temperature drop). The most likely reasons are: (1) the tensile strength of the limestone concrete is greater than used, and (2) the assumed values for thermal coefficient and temperature drop. The unavailability of specific project input data limits our deductions.

The predicted values for the silicious gravel concrete agree well with the measured data. The crack spacing shows a tendency to reduce with the temperature drop. This may be due to an actual thermal coefficient different than assumed.



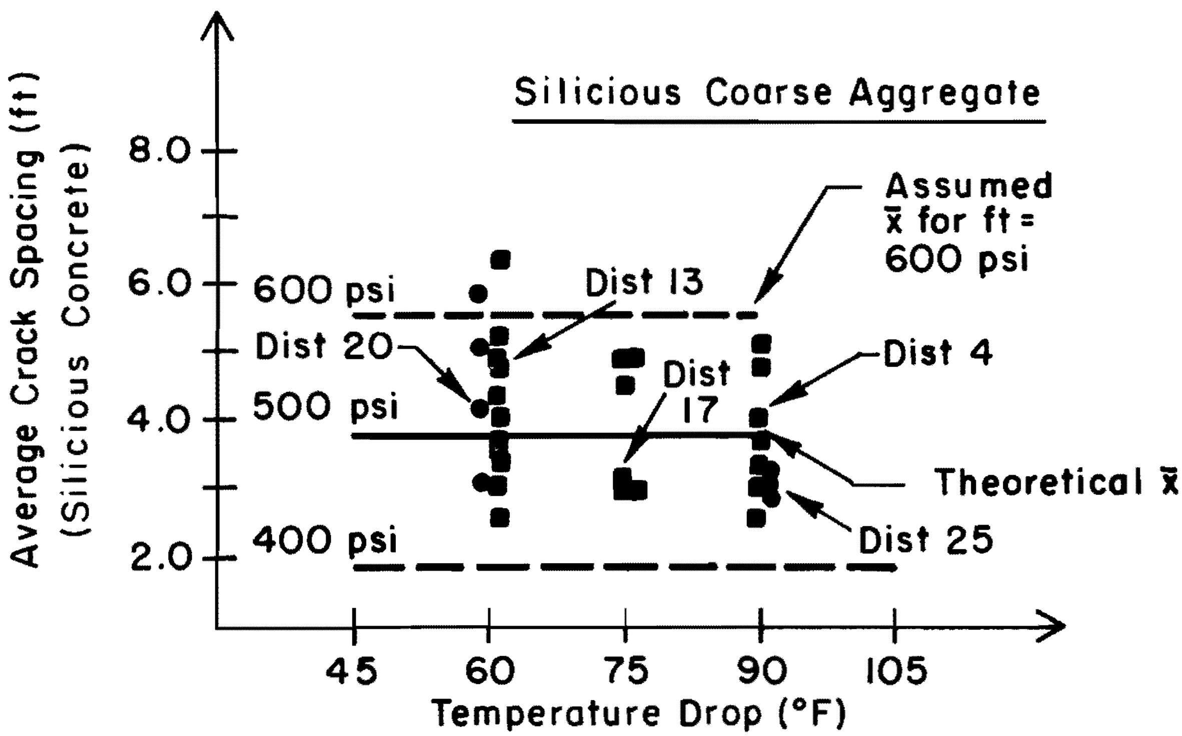


Fig 9. Comparison of theoretical and actual crack spacing values.

The general conclusions derived from the field data corroborate the computer results. That is, limestone concrete pavements show larger crack spacing than silicious gravel concrete pavement; the larger the temperature drop the smaller the crack spacing; and, the temperature effects are reduced as the thermal coefficient of concrete tends to equal that of the steel.

CHAPTER 7. ANALYSIS OF SPALLING

Most of the following analysis is limited to minor spalling. It is important to distinguish between minor and severe spalling since initially it was felt that severe spalling was a secondary phase. Recent studies (Ref 1) indicate the latter is usually produced as a result of the construction operations and shows less variability with age, traffic, location, etc.

Effect of Age

Table 10 summarizes the spalling condition of CRC pavements for different ages. A statewide trend may be observed; the spalling increases with time, and this trend is more apparent in Table 12, which considers the data on a District basis.

Keep in mind that the overlayed sections are not considered; also, some of the figures correspond to small projects which are not representative. Comparison of 1974 and 1978 data is somewhat difficult because during 1974 the spalled condition was subjectively determined.

Effect of Traffic

In Table 11, spalling is compared with the number of 18k-EAL applications. This summary shows that spalling increases as the number of applications increases.

Table 13 presents the percentage of spalling for different traffic applications in the various districts surveyed. The increase of spalling with traffic is not readily apparent in the table. The available traffic data are not sufficient to draw a definitive conclusion.

Effect of Geographical Locations

Previously, the correlation of crack spacing and spalling was analyzed. It was mentioned that crack spacing is largely dependent in the geographical location of the pavement due to the temperature and moisture conditions.

TABLE 10. SUMMARY OF CRACK SPACING AND SPALLING FOR DIFFERENT CRC PAVEMENT AGES

Age(years)	Crack Spacing(feet)	Percent Spalling
< 4	6.1	12.45
6	5.2	18.01
8	5.0	18.10
10	4.7	17.71
12	4.3	18.58
14	5.0	30.68
16	5.7	28.00

TABLE 11. SUMMARY OF CRACK SPACING AND SPALLING FOR DIFFERENT TRAFFIC APPLICATIONS

Traffic (EAL_{18} x 10^6)	Crack Spacing(feet)	Percent Spalling
< 1	5.2	9.86
1 to 2	5.2	16.11
2 to 3	3.8	16.59
3 to 4	4.8	18.22
4 to 5	5.0	22.5
5 to 6	4.1	31.33
> 6	3.7	16.55

TABLE 12. AVERAGE PERCENT MINOR SPALLING FOR CRCP IN 1978 CONSIDERED IN TERMS OF AGE AND GEOGRAPHICAL LOCATION

	District										
Age (yrs)	1	3	4	9	10	13	17	19	20	24	25
< 4	1.6									23.3	
4 to 6	21.4									26.3	10.1
6 to 8	6.5	12.4	17.2	-	-	20.2	13.6	10.2	5.4	50.9	-
8 to 10	11.7	20.4	18.0	-	-	17.6	10.7	-	12.6	22.0	13.5
10 to 12	17.3	17.1	21.6	9.4	-	13.8	8.7	25.6	13.8	-	18.3
12 to 14	44.4	25.0	16.8	61.6	52.0	-	-	19.6	15.1	-	-
> 14	35.4	19.6	-	-	57.4	18.2	13.5	-	11.1	-	-

TABLE 13. AVERAGE PERCENT MINOR SPALLING FOR CRCP IN 1978 CONSIDERED IN TERMS OF TRAFFIC APPLICATIONS AND GEOGRAPHICAL LOCATION

Traffic	District										
($EAL_{18} \times 10^6$)	1	3	4	9	10	13	17	19	20	24	25
< 1	6.70	16.30	-	-	-	-	-	-	-	-	-
1 to 2	-	17.50									10.55
2 to 3	-	17.10	21.83	-	-	-	14.35	12.60	-	-	15.90
3 to 4	35.35	-	-	9.40	-	-	9.33	16.30	-	-	-
4 to 5	3.79	-	14.75	-	-	-	13.50	-	-	-	-
5 to 6	-	-	18.00	-	-	-	-	36.66	-	-	-
> 6	-	-	16.55	-	-	-	-	-	-	-	-

As geographical location affects the crack spacing, it also affects the percentage spalling. This may be noted in Table 12. The percentage of spalling is different for each district, with the warmer districts having the lowest percentages in most of the cases.

Effect of Crack Spacing

In Fig 10, data from Table 3 has been plotted in order to detect correlation between crack spacing and spalling. It is apparent from the figure that there is a trend for percent spalling to increase with larger crack spacings.

In Table 3, it is also noted that severe spalling shows no correlation to crack spacing or minor spalling. The origin of the severe spalls usually is poor construction practices, e.g., excess vibration of the concrete.

Effect of Concrete Type

It was noted that concretes made with limestone coarse aggregates show less spalling, for a similar crack spacing, than silicious gravel concretes. Similar results were observed by McCullough et al (Ref 9) when studying the effect of design variables on spalling and cracking. The explanation for the better performance of limestone coarse aggregate concrete has to do with its lower modulus of elasticity and better bonding characteristics as compared to those of gravel. Another possible course is the indication of higher concrete strengths found in the limestone coarse aggregate concretes placed in Texas (Fig 9).

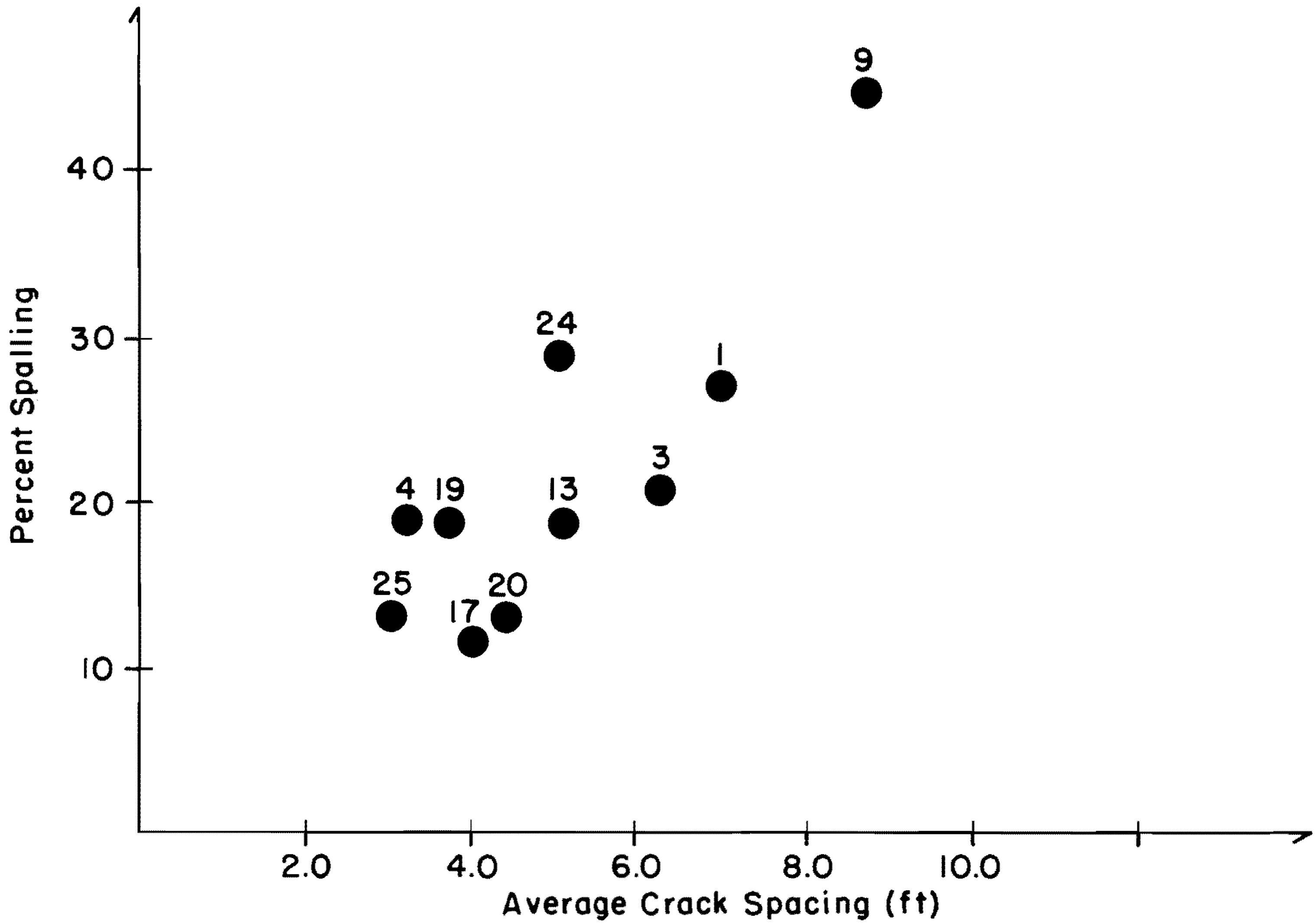


Fig 10. Correlation between crack spacing and percent spalling (minor).

CHAPTER 8. ANALYSIS OF OVERLAYED SECTIONS

During the 1978 condition survey various sections were found to have been overlayed since 1974. The purpose of this section is to determine the causes leading to this major rehabilitation for use as critera for future overlays.

Failures and Spalling before Overlaying

In the earlier sections of this report several points were observed:

(1) In Table 1 it was noted that the western districts (3, 4, 24, and 25) have less overlayed sections than the eastern districts (See also Fig 2).

(2) District 10, which is located in the eastern part of the state, has no overlayed sections, but a more detailed analysis shows that, during the 1978 condition survey, this district showed the largest number of failures per mile and the largest percentage of spalled cracks.

(3) The percentage of overlayed sections is larger for older pavements, as may be seen in Table 4 and Fig 3.

(4) In Table 6 and Fig 4 it is observed that the percentage of overlayed sections increases with the number of traffic applications up to a point. The number of expected EAL_{18} applications determined from AASHTO interim guides may be helpful in explaining the percentage of overlayed sections, or the level of distress, found during the condition survey. Table 14 is a factorial illustrating the number of EAL_{18} to a terminal serviceability of 2.5. Note that for modulus of rupture values of 600 psi, the number of applications falls in the range of 5 to 6 million EAL_{18}. For this range, large increases in the number of failures and the area of overlay can be seen in Fig 4.

In Table 15, a summary of the 1974 distress conditions of several highway sections which were found to be overlayed in 1978 is given. The following may be observed.

TABLE 14. FACTORIAL FOR AN 8-INCH CRCP ILLUSTRATING THE NUMBER OF EAL_{18} APPLICATIONS ($x\ 10^6$) - FROM AASHTO INTERIM GUIDES

S_c (psi)	400		600		800	
E_c (psi) / K(pci)	4.5×10^6	6×10^6	4.5×10^6	6×10^6	4.5×10^6	6×10^6
300	1500	1000	5000	4000	15 000	10 000
400	1500	1500	5500	5000	20 000	15 000
500	2000	1500	8000	5500	25 000	20 000

S_c = Concrete flexural strength.

E_c = Concrete modulus of elasticity.

K = Composite soil support value.

TABLE 15. DISTRESS CONDITION BEFORE OVERLAYING (1974)

CFHR Section Number†	Minor Spalling (percent)*	Failures Per Mile	PSI	Length Overlayed (miles)
101 EB	0	2.5	2.9	0.4
WB	20	0	2.9	0.6
103 EB	5	15.0	3.0	0.2
	20	5.0	3.0	0.2
WB	0	0	2.5	0.2
322 SB	0	0	3.6	1.4
314 NB	0	0	3.1	0.6
SB	0	0	2.7	1.0
301 SB	5	0	2.9	0.2
901 NB **	50	26	2.7	2.0
SB **	50	28.3	2.8	1.8
902 BN **	50	8.3	2.7	4.0
SB **	50	20.5	2.6	4.0
903 NB **	20	7.5	2.8	2.0
SB **	20	36.5	2.6	2.0
1701 NB	5	50.3	3.1	11.4
SB	20	49.4	3.2	11.2
1702 NB	20	12.5	3.4	0.8
SB	20	1.7	3.5	1.2
1705 NB	20	7.9	3.4	12.6
SB	5	13.1	3.3	7.4
1910 EB	5	1.0	3.3	5.4
WB	5	0.4	3.2	5.6
1911 EB	5	5.7	3.3	1.4
WB	5	3.0	3.3	2.0
1914 EB	5	3.0	3.4	5.0
WB	5	2.9	3.4	5.2
2015 SB	-	7.5	2.9	0.4
2004 EB	5	11.8	3.0	9.0
WB	5	-	3.0	9.0
2021 EB	-	1.6	3.1	0.2

* Subjectively determined ** Active clays.

† The first digits are district numbers.

(1) During the 1974 survey, the overlayed sections in District 9 showed a high percentage of spalled cracks and an average of 22.7 failures per mile, and active clays were detected in the subgrade. This district had the largest number of failures per mile in 1974 and it had the highest percentage of overlayed sections in 1978.

(2) District 17 showed a large number of failures per mile; 29.9 is the average.

(3) A trend is not apparent from Table 15 concerning District 19, although it may be observed in Fig 2 that the number of failures per mile in the district increased rapidly from 1974 to 1978; thus the distress condition may have changed sharply after 1974 for the sections considered.

(4) In District 20, a large number of failures per mile existed.

From the visual analysis of the 1974 distress data, it may be concluded that the overlayed sections had a large number of failures per mile and/or a high percentage of spalled cracks.

Criterion to Overlay

The data collected may be used to determine analytically the reasons leading to overlay; that is, having data on several variables from two groups, overlayed and non-overlayed pavements, we can describe the ways in which the groups differ on these variables. Appendix D is a detailed description of the statistical technique followed to develop criterion for major rehabilitation or overlays on CRCP.

Discriminant Equation

The equation developed to discriminate between overlayed and non-overlayed pavements is of the form

$$z = 0.8 + \sum_{i=1}^{n} a_i z_i \qquad i = 1, 2, \ldots, n$$

where

z = discriminant score,

a_i = weighting coefficient,

z_i = standarized values of the n discriminating variables used in the analysis. These standarized values are calculated as follows:

$$z_i = \frac{x_i - \bar{x}_i}{\sigma_{x_i}}$$

where

x_i = value of the distress manifestation i for the case being classified,

$\bar{x}_i$ = mean value of the distress manifestation i ,

σ_{x_i} = standard deviation for $\bar{x}_i$.

Table 16 summarizes the parameters to be used with the equations presented above. If these data are used with the general equation, then a specific equation for Texas conditions is obtained as follows:

$$Z = 2.07 - 0.14X_1 - 0.03X_2 - 0.02X_2 + 0.007$$

where

X_1 = average failures per mile section

X_2 = minor spalling measured as percent of cracks experiencing spalling

X_3 = severe spalling measured as percent of cracks experiencing spalling

X_4 = pumping as percent of total length

TABLE 16. PARAMETERS TO BE USED WITH DISCRIMINATING EQUATIONS

i	Distress Manifestation	a_i	$\bar{x}_i$	σ_i
1	Failures per mile	-1.13	3.99	8.14
2	Minor spalling (percent)	-0.49	21.36	15.17
3	Severe spalling (percent)	-0.12	3.07	6.08
4	Pumping (percent)	0.04	3.78	5.91

Thus, if any pavement is evaluated by using the equations presented, a discriminant score, or zeta value, is obtained. This zeta value tells us if pavements with similar scores have or have not been overlayed. If z is smaller than zero then there is a larger probability that the pavement under evaluation is a good candidate to overlay. Similarly, a pavement with z value larger than zero has a larger probability of being in good shape.

Utility Function

The z value described above can be more easily interpreted if it is transformed to a Utility Function. This function ranges from zero to one depending on the degree of distress of the facility.

The utility value is the probability associated with each z value that a given pavement belongs to the non-overlayed pavements group. If a pavement has a probability close to one of belonging to the non-overlayed pavements, then it is in good condition and its utility is equal to that probability. Conversely, if the pavement has a low probability of being in the non-overlayed group, its utility will probably be low.

An approximate equation that relates z to this probability (from Ref 13) is

For $z \geq 0$

$$U(z) = 1.0 - f(z)\,(b_1 t + b_2 t^2 + b_3 t^3 + b_4 t^4 + b_5 t^5)$$

where

$U(z)$ = utility assigned to a pavement for a combination of distress modes with a discriminant score z

$$f(z) = \frac{1}{\sqrt{2\pi}} \exp\left[-\frac{z^2}{2}\right]$$

$$t = \frac{1}{1 + 0.23164(z)}$$

$$b_1 = 0.31938$$

$$b_2 = -0.35656$$

$$b_3 = 1.78148$$

$$b_4 = -1.82126$$

$$b_5 = 1.33027$$

for $z < 0$

$$U(z) = f(z)\ (b_1 t + b_2 t^2 + b_3 t^3 + b_4 t^4 + b_5 t^5)$$

where

$$t = \frac{1}{1 - 0.23164(z)}$$

Criterion for Major Rehabilitation

The criterion proposed for deciding when to overlay is to compare the utility of a given pavement with the utility of the mean case for the group of overlayed pavements. This mean case is obtained by substituting the mean distress values for the overlayed pavements into the equations above. From this, any pavement with utility $U(z) < 0.12$ should be overlayed.

CHAPTER 9. DISCUSSION OF RESULTS

In the previous sections, the condition survey data obtained in 1978 have been analyzed in detail relative to age, traffic, and geographical location. In addition, comparisons have been made to the 1974 condition survey where relevant. Thus, in this section, an attempt will be made to summarize these or the data relative to their effect on design construction and maintenance. The results will be discussed from the standpoint of distress manifestations and then of crack spacing.

Discussion of Distress Manifestations

After analyzing the data from several different approaches, it is apparent that the number of failures and the spalling percentage increase with pavement age. The trend is even more apparent when the accumulative 18-kip equivalent axle applications are substituted for age. This trend justifies the fatigue approach that has been used with CRCP pavement. In the original stages of design development for CRCP, fatigue criteria were not available, and thus the results from jointed pavements, i.e., the AASHO Road Test were applied. These data may be used with further analysis to develop actual fatigue criteria for CRCP. One factor that may apparently be deduced from the data analysis is the thicker pavements must be used as the projected design traffic increases.

Failures and spalling were also influenced by the geographical location. Generally, there were considerably more failures in the eastern part of the state than the western part of the state. This may be attributed to moisture conditions and soils. Generally, the eastern part of the state experiences considerably more moisture, thus reducing the soil support value, and the soils are generally poorer in the eastern part of the state. It appears from the data analysis that for equal traffic conditions, a thicker pavement should be used in the eastern part of the state than in the western part of the state.

Another pertinent observation noted in the data analysis is that CRCP constructed with siliceous river gravel coarse aggregate generally experiences greater failures and spalling for equal traffic and geographical conditions. In general, it may be stated that CRCP constructed with coarse aggregate limestone has a better performance history.

During the design and construction phases for most of the CRCP considered in this study, the basic concept was to use an 8-inch CRCP and then improve the subbase support conditions as greater traffic was experienced. It is apparent from this study that this practice was not adequate. It is also apparent that the thickness of the CRCP must be related to projected equivalent 18-kip single-axle applications and the soil support conditions. Projects with poor soil conditions and high projected traffic should be considerably thicker than those with a lower projected traffic and better soil conditions. The present practice of permitting the use of crushed limestone coarse aggregates or siliceous river gravel coarse aggregates as a contractor's option without changing the thickness is not supported by performance. In general, thicker pavements should be used if siliceous river gravels are permitted. This would require a substantial change in the present specifications and construction procedures.

Crack Spacing

Crack spacing data obtained in the field have been compared with the values predicted by Program CRCP2. The variables used were tensile strength of concrete, coarse aggregate type, and temperature drop to simulate the environmental conditions and the concrete properties of the pavements in Texas.

The data imply that Program CRCP2 may be an invaluable tool in predicting crack spacing. The calculated values showed a large influence on the changes in the variables chosen, which were corrobated by the field observations. For the cases studied, the tensile strength of concrete showed the largest influence on crack spacing. The effect of the aggregate type is more

The data imply that Program CRCP2 may be an invaluable tool in predicting crack spacing. The calculated values showed a large influence on the changes in variables chosen, which were corrobated by the field pronounced in ther thermal coefficient of the concrete, and as the thermal coefficient tends to be equal to the coefficient of the steel the effects of temperature drop are minimized. This may be seen by comparing Fig 9 (a) and 9 (b) where, for $\alpha_c/\alpha_s = 1.0$, the curve becomes a horizontal line. The influence of temperature drop is evident in the figures shown.

The values of shrinkage are difficult to define and difficult to model; therefore, they were not taken into account and fixed values were selected. The effects of ambient humidity were also neglected. Nevertheless, the prediction values obtained agree well with the field data.

Discriminant Analysis Technique

Discriminant Analysis techniques were applied to evaluate the distress condition of CRCP with the purpose of defining the terminal point for major rehabilitation.

The equations developed weigh the different distress manifestations and assign a score to each pavement. Such a score can be used to decide if a pavement should be overlayed.

It is believed that this approach is a step further in the rationalization of the evaluation of the distress condition of a pavement.

CHAPTER 10. CONCLUSIONS

An analysis of the condition survey data obtained during the 1974 and 1978 surveys leads to the following conclusions in terms of distress manifestations and crack spacing.

Distress Manifestations

(1) The number of failures per mile increases with the age of the pavement. In some cases the data are confounded because the highly distress sections observed in 1974 were overlayed before the 1978 survey.

(2) Increased failures correlate with an increase in axle load applications until a value of 5 to 6 x 10^6 EAL_{18} is reached. At that point, there appears to be a significant increase in failures with overlays thereafter.

(3) Geographical location (temperature, moisture, and soil type) has a definitive influence. Districts located in the eastern part of Texas have a larger number of failures per mile.

(4) Minor spalling increases with age and EAL_{18}.

(5) Major spalling, however, appears to be more related to construction practices.

(6) CRCP with crushed limestone coarse aggregate experiences less spalling than CRCP with siliceous gravel aggregate.

(7) Overlayed sections had a large number of failures per mile and/or a high percentage of spalled cracks before being rehabilitated. Overlays were generally produced when the failures reached a level of 20 per mile or 50 percent of the cracks experiences spalling.

Average Crack Spacing

(1) Age did not appear to significantly influence crack spacing in pavements older than one year, but this observation is tempered by the fact that other variables may have masked this effect.

(2) In areas with similar temperatures, CRCP with limestone coarse aggregates show larger crack spacing than siliceous gravel concretes.

(3) In the colder areas of the state, crack spacing appears to be smaller for both types of aggregate.

(4) For districts with similar conditions of temperature, crack spacings are similar for equal concrete types.

(5) A comparison of crack spacing data obtained in the field with the values predicted by Program CRCP2 support the program as a viable design tool.

(6) For the cases studied in predicting crack spacing, it was found that the tensile strength of concrete had a large influence on the crack spacing. The higher the tensile strength, the greater the crack spacing.

(7) The percentage of spalled cracks tends to increase with crack spacing.

CHAPTER 11. RECOMMENDATIONS

Analysis of the 1974 and 1978 condition survey data along with a comparison of previous design and construction practices and recent design developments leads to the following recommendations:

(1) CRCP should be designed for the specific conditions of soil and equivalent 18-kip axle applications projected on a specific project. The application of a constant thickness, i.e., 8 inches, with adjustments in the subbase support has proven to be inadequate. In general, thicker pavements should be used for high projected traffic loads and poor soil conditions.

(2) The comparison of measured crack spacings and those predicted with CRCP2 indicates that the computer program is a viable design tool that can be used to design the reinforcement for a given set of conditions.

(3) The utility function derived to assess the distress condition of the pavement is believed to represent a step ahead in the rationalization of the evaluation of the distress condition of a pavement.

(4) The 1978 data should be reanalyzed in a more detailed manner using more sophisticated techniques to develop a fatigue failure criteria for CRCP.

(5) The condition surveys of CRCP should be continued. It is apparent that the data will provide new and improved design procedures as well as providing criteria for the allocation of maintenance funds for pavement repair.

REFERENCES

1. McCullough, B. F., and P. J. Strauss, "A Performance Survey of Continuously Reinforced Concrete Pavements in Texas," Center for Highway Research, Research Report 21-1F, The University of Texas at Austin, 1974.

2. McCullough, B. F., and P. J. Strauss, "Development of Photographic Techniques for Performing Condition Surveys," Center for Highway Research, Research Report 177-10, The University of Texas at Austin, 1977.

3. Machado, J. P., et al, "CRCP: Prediction of Distress Quantities," Center for Highway Research, Research Report 177-8, The University of Texas, Austin, Texas, 1977.

4. McCullough, B. F., and T. P. Chesney, "Sixteenth Year Progress Report on Experimental CRCP in Walker County," Center for Highway Research, Research Report 177-6, The University of Texas at Austin, 1976.

5. National Oceanic and Atmospheric Administration, "Annual Summary of Local Climatological Data," National Climatic Center, Asheville, North Carolina, 1977.

6. Truman, J. R., and T. J. Hirsch, "The Physical Properties of Concrete at Early Ages," Texas Transportation Institute, Texas A&M University, College Station, Texas, 1961.

7. Gutierrez de Velasco, M., "Prediction of Crack Spacing in CRCP in Texas," Term project submitted in class CE 391P, The University of Texas at Austin, Spring 1979.

8. Witkoski, F. C., and R. K. Shaffer, "CRCP in Pennsylvania," HRB Bulletin 238, 1960.

9. McCullough, B. F., A. Abou-Ayyash, W. R. Hudson, and J. P. Randall, "Design of CRCP for Highways," Center for Highway Research, Research Project NCHRP 1-15, Final Report, The University of Texas at Austin, 1975.

10. Ma, J., and B. F. McCullough, "CRCP2, An Improved Computer Program for the Analysis of CRCP," Center for Highway Research, Research Report 177-9, The University of Texas at Austin, 1977.

11. Thorndike, R. M., Correlational Procedures for Research, Gardner Press, Inc., New York, 1978.

12. Nie, N. H., et al, Statistical Package for the Social Sciences (2nd Edition), McGraw-Hill, 1970.

13. Abramowitz and Stegun, Handbook of Mathematical Functions, National Bureau of Standards, 1968.

14. Gutierrez de Velasco, M., and B. F. McCullough, "Use of Discriminant Analysis to Evaluate the Distress Condition of CRCP," Technical Memorandum 177-70, Center for Highway Research, The University of Texas, Austin, Texas, 1979.

APPENDIX A

SUMMARY OF FAILURES IN EACH DISTRICT

FAILURE SUMMARY FOR DISTRICT 1

CFHR NO.		AGE	LENGTH	REPAIR PATCHES (NO./MILE) A.C. 1974/1978	REPAIR PATCHES (NO./MILE) P.C.C. 1974/1978	PUNCHOUTS (NO./MILE) 1974/1978	FAILURES (NO./MILE) 1974/1978	FAILURES (TOTAL) 1974/1978
101	EB *	14.5	6.2	1.8 / 3.1	.3 / .3	1.6 / 1.2	3.7 / 4.7	23 / 27
101	WB *	14.5	6.2	.2 / 1.1	0.0 / 0.0	0.0 / .4	.2 / 1.4	1 / 8
102	EB	14.5	1.8	1.4 / 4.4	1.4 / 0.0	0.0 / 1.7	2.9 / 6.1	4 / 11
102	WB	14.5	1.8	6.0 / 7.2	.5 / 0.0	2.5 / .6	9.0 / 7.8	18 / 14
103	EB *	13.3	6.2	.6 / .7	.2 / 0.0	0.0 / .2	.8 / .9	5 / 5
103	WB *	13.3	6.2	1.2 / 1.3	.5 / .3	0.0 / 0.0	1.7 / 1.7	10 / 10
104	EB	13.2	5.4	1.0 / .9	1.0 / .4	0.0 / 0.0	1.9 / 1.3	10 / 7
104	WB	13.2	5.4	.2 / .9	0.0 / 0.0	0.0 / .2	.2 / 1.1	1 / 6
105	EB	13.0	5.2	.6 / 1.0	0.0 / 0.0	0.0 / .2	.6 / 1.2	3 / 6
105	WB	13.0	5.2	1.2 / 1.2	0.0 / 0.0	0.0 / 0.0	1.2 / 1.2	6 / 6
108	NB	11.3	9.0	.2 / 1.0	0.0 / 0.0	0.0 / 1.2	.2 / 2.2	2 / 20
108	SB	11.3	9.0	1.2 / 4.2	0.0 / 0.0	.1 / 2.3	1.3 / 6.6	12 / 59
111	NB	9.0	.4	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
111	SB	9.0	.4	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
112	NB	9.0	2.0	0.0 / 0.0	0.0 / 0.0	0.0 / .5	0.0 / .5	0 / 1

(Continued)

FAILURE SUMMARY FOR DISTRICT 1
(CONTINUED)

CFHR NO.		AGE	LENGTH	REPAIR PATCHES (NO./MILE) A.C. 1974/1978	REPAIR PATCHES (NO./MILE) P.C.C. 1974/1978	PUNCHOUTS (NO./MILE) 1974/1978	FAILURES (NO./MILE) 1974/1978	FAILURES (TOTAL) 1974/1978
113	NB	7.5	10.0	0.0 / 0.0	0.0 / 0.0	0.0 / .1	0.0 / .1	0 / 1
113	SB	7.5	1.6	0.0 / 0.0	0.0 / 0.0	0.0 / .6	0.0 / .6	0 / 1
115	EB	3.5	3.6	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
115	WB	3.5	3.6	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
DISTRICT MEANS:				.8 / 1.4	.2 / .1	.2 / .5	1.2 / 2.0	5.0 / 9.6

NOTES: AVERAGE SIZE OF A.C. PATCH = 32.8 SQ.FT.
AVERAGE SIZE OF P.C.C. PATCH = 29.1 SQ.FT.
AVERAGE SIZE OF PUNCHOUT = 2.3 SQ.FT.

* = INDICATES SECTION CONTAINS OVERLAY(S).

FAILURE SUMMARY FOR DISTRICT 3

CFHR NO.		AGE	LENGTH	REPAIR PATCHES (NO./MILE) A.C. 1974/1978	REPAIR PATCHES (NO./MILE) P.C.C. 1974/1978	PUNCHOUTS (NO./MILE) 1974/1978	FAILURES (NO./MILE) 1974/1978	FAILURES (TOTAL) 1974/1978
318	NB	6.0	8.0	0.0 / 0.0	0.0 / .1	0.0 / 0.0	0.0 / .1	0 / 1
318	SB	6.0	8.0	0.0 / .1	0.0 / 0.0	0.0 / 0.0	0.0 / .1	0 / 1
317	NB	6.0	.8	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
317	SB	6.0	.6	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
320	NB	6.0	2.8	0.0 / .4	0.0 / 0.0	0.0 / 0.0	0.0 / .4	0 / 1
320	SB	6.0	9.8	0.0 / .9	0.0 / 0.0	0.0 / .3	0.0 / 1.2	0 / 12
319	NB	6.0	.4	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
319	SB	6.0	.6	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
308	EB	11.0	1.2	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
308	WB	11.0	1.2	2.5 / 1.7	0.0 / 0.0	0.0 / 0.0	2.5 / 1.7	3 / 2
307	EB	11.0	1.2	0.0 / .8	0.0 / 0.0	1.7 / 0.0	1.7 / .8	2 / 1
307	WB	11.0	1.0	0.0 / 0.0	0.0 / 0.0	0.0 / 2.0	0.0 / 2.0	0 / 2
306	EB	11.0	2.8	.4 / 0.0	0.0 / .7	0.0 / 0.0	.4 / .7	1 / 2
306	WB	11.0	3.0	.3 / 0.0	0.0 / .3	5.0 / .3	5.3 / .7	16 / 2
316	NB	8.0	6.9	.2 / .1	0.0 / 0.0	0.0 / .1	.2 / .3	1 / 2

(Continued)

FAILURE SUMMARY FOR DISTRICT 3
(CONTINUED)

CFHR NO.		AGE	LENGTH	REPAIR PATCHES (NO./MILE) A.C. 1974/1978	REPAIR PATCHES (NO./MILE) P.C.C. 1974/1978	PUNCHOUTS (NO./MILE) 1974/1978	FAILURES (NO./MILE) 1974/1978	FAILURES (TOTAL) 1974/1978
316	SB *	8.0	3.6	.3 / 0.0	0.0 / 0.0	0.0 / .3	.3 / .3	1 / 1
310	NB	10.0	9.3	.2 / .3	0.0 / 0.0	.2 / .2	.4 / .5	4 / 5
310	SB	10.0	9.0	.4 / .1	.1 / 0.0	.1 / 0.0	.7 / .1	6 / 1
311	NB	10.0	1.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
311	SB *	10.0	1.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
322	NB	5.0	10.4	0.0 / 0.0	0.0 / .1	0.0 / .3	0.0 / .4	0 / 4
322	SB *	5.0	.2	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
314	NB *	9.0	.2	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
314	SB *	9.0	.2	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
312	NB	10.0	3.5	0.0 / 1.4	0.0 / 0.0	0.0 / .3	0.0 / 1.7	0 / 6
312	SB	10.0	3.7	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
301	NB	14.3	3.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
301	SB *	14.3	2.8	.3 / 1.2	0.0 / 0.0	0.0 / 0.0	.3 / 1.2	1 / 3
303	BW	14.3	1.8	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
303	SB	14.3	2.0	1.0 / .5	0.0 / 0.0	0.0 / 0.0	1.0 / .5	2 / 1

(Continued)

FAILURE SUMMARY FOR DISTRICT 3
(CONTINUED)

CFHR NO.		AGE	LENGTH	REPAIR PATCHES (NO./MILE) A.C. 1974/1978	REPAIR PATCHES (NO./MILE) P.C.C. 1974/1978	PUNCHOUTS (NO./MILE) 1974/1978	FAILURES (NO./MILE) 1974/1978	FAILURES (TOTAL) 1974/1978
305	NB	14.0	1.6	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
305	SB	14.0	1.4	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
304	NB	14.0	5.2	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
304	SB	14.0	5.2	.2 / 0.0	0.0 / 0.0	0.0 / 0.0	.2 / 0.0	1 / 0
315	EB	9.0	1.2	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
315	WB	9.0	1.4	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
DISTRICT MEANS:				.2 / .2	.0 / .0	.2 / .1	.4 / .4	1.1 / 1.3

NOTES: AVERAGE SIZE OF A.C. PATCH = 42.6 SQ.FT.
AVERAGE SIZE OF P.C.C. PATCH = 7.5 SQ.FT.
AVERAGE SIZE OF PUNCHOUT = 6.5 SQ.FT.

* - INDICATES SECTION CONTAINS OVERLAY(S).

FAILURE SUMMARY FOR DISTRICT 4

CFHR NO.		AGE	LENGTH	REPAIR PATCHES (NO./MILE) A.C. 1974/1978	REPAIR PATCHES (NO./MILE) P.C.C. 1974/1978	PUNCHOUTS (NO./MILE) 1974/1978	FAILURES (NO./MILE) 1974/1978	FAILURES (TOTAL) 1974/1978
406	WB	11.8	5.8	0.0 / 0.0	0.0 / 0.0	.7 / .3	.7 / .3	4 / 2
406	EB	11.8	5.4	0.0 / 0.0	0.0 / .6	.4 / 0.0	.4 / .6	2 / 3
405	WB	11.8	7.6	0.0 / .1	0.0 / .7	0.0 / .3	0.0 / 1.1	0 / 8
405	EB	11.8	8.1	.2 / 0.0	2.4 / 0.0	.4 / 0.0	3.0 / 0.0	25 / 0
404	EB	12.0	1.8	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
404	WB	12.0	1.8	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
402	WB	13.8	2.2	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
402	EB	13.8	2.2	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
410	WB	9.7	4.4	0.0 / 0.0	0.0 / .0	0.0 / 0.0	0.0 / .0	0 / 1
410	EB	9.7	4.4	.2 / 0.0	0.0 / 2.0	0.0 / 0.0	.2 / 2.0	1 / 9
407	EB	9.7	5.6	1.6 / 0.0	.5 / 4.5	0.0 / .2	2.1 / 4.6	12 / 26
407	WB	11.7	6.2	.2 / .5	0.0 / 4.2	0.0 / 1.5	.2 / 6.1	1 / 38
403	EB	12.8	1.2	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
403	WB	12.8	1.2	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
409	WB	9.8	4.2	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0

(Continued)

FAILURE SUMMARY FOR DISTRICT 4
(CONTINUED)

CFHR NO.		AGE	LENGTH	REPAIR PATCHES (NO./MILE) A.C. 1974/1978	REPAIR PATCHES (NO./MILE) P.C.C. 1974/1978	PUNCHOUTS (NO./MILE) 1974/1978	FAILURES (NO./MILE) 1974/1978	FAILURES (TOTAL) 1974/1978
409	EB	9.8	4.6	0.0 / .2	0.0 / 0.0	0.0 / 0.0	0.0 / .2	0 / 1
411	WB	6.2	7.2	0.0 / .1	.1 / 0.0	0.0 / .4	.1 / .6	1 / 4
411	EB	6.2	7.4	0.0 / .1	0.0 / .1	.1 / .1	.1 / .4	1 / 3
408	EB	9.8	.6	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
408	WB	9.8	.8	1.3 / 0.0	0.0 / 2.5	0.0 / 0.0	1.3 / 2.5	1 / 2
412	WB	16.1	2.4	0.0 / 0.0	0.0 / 0.0	0.0 / .4	0.0 / .4	0 / 1
412	EB	16.1	2.3	0.0 / 0.0	.4 / .4	0.0 / 0.0	.4 / .4	1 / 1
DISTRICT MEANS:				.2 / .1	.2 / .7	.1 / .1	.4 / .9	2.2 / 4.5

NOTES: AVERAGE SIZE OF A.C. PATCH = 23.9 SQ.FT.
AVERAGE SIZE OF P.C.C. PATCH = 59.3 SQ.FT.
AVERAGE SIZE OF PUNCHOUT = 3.2 SQ.FT.

* - INDICATES SECTION CONTAINS OVERLAY(S).

FAILURE SUMMARY FOR DISTRICT 9

CFHR NO.		AGE	LENGTH	REPAIR PATCHES (NO./MILE) A.C. 1974/1978	REPAIR PATCHES (NO./MILE) P.C.C. 1974/1978	PUNCHOUTS (NO./MILE) 1974/1978	FAILURES (NO./MILE) 1974/1978	FAILURES (TOTAL) 1974/1978
901	NB *	18.0	2.0	1.5 / 0.0	22.0 / 0.0	2.0 / 0.0	25.5 / 0.0	51 / 0
901	SB *	18.0	1.8	.6 / 0.0	26.1 / 0.0	1.7 / 0.0	28.3 / 0.0	51 / 0
902	NB *	18.0	4.0	0.0 / 0.0	7.8 / 0.0	.8 / 0.0	8.5 / 0.0	34 / 0
902	SB *	18.0	4.0	.5 / 0.0	18.5 / 0.0	1.5 / 0.0	20.5 / 0.0	82 / 0
904	NB	13.5	1.9	1.1 / 2.1	0.0 / 3.2	0.0 / 1.6	1.1 / 6.8	2 / 13
904	SB	13.5	1.8	3.3 / 0.0	2.2 /16.1	0.0 / 0.0	5.6 /16.1	10 / 29
905	NB	14.0	.8	0.0 / 3.7	0.0 / 1.2	0.0 / 0.0	0.0 / 5.0	0 / 4
905	SB	14.0	.8	0.0 / 0.0	2.5 / 1.2	0.0 / 0.0	2.5 / 1.2	2 / 1
907	NB	11.8	1.0	0.0 / 0.0	5.0 /17.0	0.0 / 2.0	5.0 /19.0	5 / 19
907	SB	11.8	1.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
908	NB	7.9	.8	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
908	SB	7.9	.8	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
909	NB	7.9	1.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
909	SB	7.9	1.0	0.0 / 1.0	0.0 / 0.0	0.0 / 0.0	0.0 / 1.0	0 / 1
910	NB	7.9	1.4	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0

(Continued)

FAILURE SUMMARY FOR DISTRICT 9
(CONTINUED)

CFHR NO.	AGE	LENGTH	REPAIR PATCHES (NO./MILE) A.C. 1974/1978	REPAIR PATCHES (NO./MILE) P.C.C. 1974/1978	PUNCHOUTS (NO./MILE) 1974/1978	FAILURES (NO./MILE) 1974/1978	FAILURES (TOTAL) 1974/1978
910 SB	7.9	1.5	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
903 NB *	14.0	2.2	0.0 / 0.0	6.4 / 0.0	.5 / 0.0	6.8 / 0.0	15 / 0
903 SB *	14.0	2.2	0.0 / 0.0	32.3 / 0.0	.5 / 0.0	32.7 / 0.0	72 / 0
906 NB	12.5	7.6	.3 / .3	.4 / 1.1	.1 / 1.1	.8 / 2.4	6 / 18
906 SB	12.3	7.6	0.0 / 1.4	2.6 / 3.4	.3 / .3	2.8 / 5.1	22 / 39
DISTRICT MEANS:			.4 / .4	6.3 / 2.2	.4 / .2	7.0 / 2.8	17.6 / 6.2

NOTES: AVERAGE SIZE OF A.C. PATCH = 37.8 SQ.FT.
AVERAGE SIZE OF P.C.C. PATCH = 84.5 SQ.FT.
AVERAGE SIZE OF PUNCHOUT = 2.6 SQ.FT.

* - INDICATES SECTION CONTAINS OVERLAY(S).

FAILURE SUMMARY FOR DISTRICT 10

CFHR NO.	AGE	LENGTH	REPAIR PATCHES (NO./MILE) A.C. 1974/1978	REPAIR PATCHES (NO./MILE) P.C.C. 1974/1978	PUNCHOUTS (NO./MILE) 1974/1978	FAILURES (NO./MILE) 1974/1978	FAILURES (TOTAL) 1974/1978
1006 EB	12.9	5.2	3.5 / 6.2	.2 / 1.7	.4 / .6	4.0 / 8.5	21 / 44
1007 EB	12.9	4.8	4.8 / 6.3	1.0 / 4.8	1.0 / .4	6.9 /11.5	33 / 55
1001 EB	15.2	4.0	3.0 / .8	1.3 /10.3	.8 / .5	5.0 /11.5	26 / 46
1005 EB	13.8	8.2	1.2 / .6	.1 / .6	.1 / .1	1.5 / 1.3	12 / 11
1004 EB	14.6	8.0	1.6 /15.4	.6 / 2.0	.2 / 1.0	2.4 /18.4	20 / 147
1002 EB	15.0	6.6	0.0 / 1.7	.5 / .8	0.0 / .2	.5 / 2.6	3 / 17
1003 EB	14.6	6.2	1.5 / 3.9	2.1 / 3.9	0.0 / 1.9	3.5 / 9.7	22 / 60
1009 EB	12.5	7.8	.6 / .8	.4 / .8	0.0 / 3.7	1.0 / 5.3	8 / 41
1010 EB	12.3	7.4	3.5 / .3	2.3 / 3.2	.8 / 7.3	6.6 /10.8	49 / 80
1014 EB	12.4	8.2	5.1 / 1.2	1.8 / 5.2	1.0 /16.0	7.9 /22.4	66 / 184
1008 EB	12.8	4.8	3.3 / 2.9	.8 / 4.0	1.0 / 9.6	5.2 /16.5	25 / 79
1011 EB	11.9	4.0	.3 / 1.5	.3 / 1.0	0.0 / 1.3	.5 / 3.8	2 / 15
1012 EB	11.3	6.4	.3 / .6	.3 / .8	.5 / 1.2	1.1 / 2.7	7 / 17
1013 EB	11.3	1.8	0.0 / 0.0	0.0 / 0.0	0.0 / .6	0.0 / .6	0 / 1
1012 WB	11.3	6.4	.9 / 1.1	.4 / 1.6	.5 / 1.2	1.8 / 3.9	10 / 25

(Continued)

FAILURE SUMMARY FOR DISTRICT 10
(CONTINUED)

CFHR NO.	AGE	LENGTH	REPAIR PATCHES (NO./MILE) A.C. 1974/1978	REPAIR PATCHES (NO./MILE) P.C.C. 1974/1978	PUNCHOUTS (NO./MILE) 1974/1978	FAILURES (NO./MILE) 1974/1978	FAILURES (TOTAL) 1974/1978
1011 WB	11.9	4.0	1.0 / 2.8	0.0 / 1.5	.3 / 1.5	1.3 / 5.8	5 / 23
1008 WB	12.8	4.8	0.0 / .4	.2 / 0.0	0.0 / 1.3	.2 / 1.7	1 / 8
1014 WB	12.4	8.4	1.8 / .8	.7 / 2.4	.6 / 7.7	3.1 /11.0	26 / 92
1013 WB	11.3	1.8	0.0 / 0.0	.6 / 0.0	0.0 / 0.0	.6 / 0.0	1 / 0
1010 WB	12.3	7.4	2.3 / .1	1.1 / 3.2	.3 / 5.7	3.6 / 9.1	27 / 67
1009 WB	12.5	7.8	.1 / .3	.1 / .1	0.0 / 2.2	.3 / 2.6	2 / 20
1003 WB	14.6	6.2	.5 / 1.8	.3 / .5	0.0 / 1.6	.8 / 3.9	5 / 24
1002 WB	15.0	6.6	.3 / 1.1	.2 / .6	0.0 / 0.0	.5 / 1.7	3 / 11
1004 WB	14.6	8.1	2.7 /12.5	1.5 / 4.8	.5 / 1.5	4.6 /18.8	38 / 152
1005 WB	13.8	8.4	.2 / 1.0	0.0 / .6	.1 / .1	.4 / 1.7	3 / 14
1001 WB	15.2	4.0	.5 / 2.5	.5 / 2.0	0.0 / 0.0	1.0 / 4.5	4 / 18
1007 WB	12.9	4.8	4.0 / 3.5	1.5 / 6.3	.8 / 1.3	6.2 /11.0	30 / 53
1006 WB	12.9	5.2	3.1 / 2.5	0.0 / 2.5	.4 / 1.2	3.5 / 6.2	19 / 32

(Continued)

FAILURE SUMMARY FOR DISTRICT 1∅
(Continued)

```
**************************************************************************************

DISTRICT MEANS:                  1.6 / 2.6     .7 / 2.3       .3 / 2.5    2.6 / 7.4   16.5 /47.7

NOTES:   AVERAGE SIZE OF A.C. PATCH      =  26.0 SQ.FT.
         AVERAGE SIZE OF P.C.C. PATCH    =  52.2 SQ.FT.
         AVERAGE SIZE OF PUNCHOUT        =   3.4 SQ.FT.

         * - INDICATES SECTION CONTAINS OVERLAY(S).
```

FAILURE SUMMARY FOR DISTRICT 13

CFHR NO.	AGE	LENGTH	REPAIR PATCHES (NO./MILE) A.C. 1974/1978	REPAIR PATCHES (NO./MILE) P.C.C. 1974/1978	PUNCHOUTS (NO./MILE) 1974/1978	FAILURES (NO./MILE) 1974/1978	FAILURES (TOTAL) 1974/1978
1317 EB	6.6	8.5	.1 / 0.0	0.0 / .8	0.0 / .2	.1 / 1.1	1 / 9
1317 WB	6.6	8.3	.2 / .5	0.0 / .8	.1 / .4	.4 / 1.7	3 / 14
1320 EB	6.5	2.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
1320 WB	6.5	2.2	0.0 / .5	0.0 / 1.8	0.0 / .9	0.0 / 3.2	0 / 7
1321 EB	6.5	8.0	0.0 / 0.0	0.0 / .3	0.0 / .1	0.0 / .4	0 / 3
1321 WB	6.5	8.0	0.0 / 0.0	0.0 / 1.1	0.0 / .3	0.0 / 1.4	0 / 11
1316 EB	7.0	3.6	0.0 / 0.0	0.0 / 0.0	0.0 / .6	0.0 / .8	0 / 3
1316 WB	7.0	3.8	0.0 / .3	0.0 / .8	0.0 / .3	0.0 / 1.3	0 / 5
1315 EB	7.0	5.6	.2 / 0.0	.2 / .9	0.0 / .2	.4 / 1.1	2 / 6
1315 WB	7.0	5.6	.2 / 0.0	0.0 / 1.8	.6 / .2	.7 / 2.0	4 / 11
1313 EB	8.3	5.6	0.0 / 0.0	0.0 / .9	0.0 / .2	0.0 / 1.1	0 / 6
1313 WB	8.3	5.8	0.0 / .5	0.0 / 6.0	.2 / .5	.2 / 7.1	1 / 41
1314 EB	8.3	.4	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
1314 WB	8.3	.2	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
1311 EB	9.2	6.2	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0

(Continued)

FAILURE SUMMARY FOR DISTRICT 13
(CONTINUED)

CFHR NO.	AGE	LENGTH	REPAIR PATCHES (NO./MILE) A.C. 1974/1978	REPAIR PATCHES (NO./MILE) P.C.C. 1974/1978	PUNCHOUTS (NO./MILE) 1974/1978	FAILURES (NO./MILE) 1974/1978	FAILURES (TOTAL) 1974/1978
1311 WB	9.2	6.2	0.0 / .2	.2 / 1.0	.2 / 0.0	.3 / 1.1	2 / 7
1306 EB	9.6	5.0	0.0 / 0.0	0.0 / 1.2	0.0 / 0.0	0.0 / 1.2	0 / 6
1306 WB	9.6	5.0	0.0 / .2	0.0 / 6.2	.2 / .2	.2 / 6.6	1 / 33
1307 EB	9.6	10.2	0.0 / .6	.1 / .2	.3 / 1.2	.4 / 2.0	4 / 20
1307 WB	9.6	10.2	.2 / 2.0	1.0 / 2.2	.8 / 1.6	2.0 / 5.7	20 / 58
1302 EB	14.5	7.4	.7 / 0.0	0.0 / .4	.1 / 5.1	.8 / 5.5	6 / 41
1302 WB	14.5	7.4	0.0 / .7	.5 / 2.7	.1 / 3.1	.7 / 6.5	5 / 48
1301 EB	16.1	2.4	0.0 / 1.2	1.2 / 1.7	0.0 / 5.0	1.2 / 7.9	3 / 19
1301 WB	16.1	2.4	1.7 / 4.2	.4 / 4.2	.4 / 1.2	2.5 / 9.6	6 / 23
1303 EB	15.1	12.3	0.0 / .4	.2 / 1.8	0.0 / 2.5	.2 / 4.7	2 / 58
1303 WB	15.1	12.2	.2 / 2.1	1.1 / 6.0	.2 / 3.7	1.6 /11.8	19 / 144
1312 SB	9.2	3.8	0.0 / 0.0	0.0 / .3	0.0 / 0.0	0.0 / .3	0 / 1
1312 NB	9.2	6.6	2.1 / .2	0.0 / 5.9	0.0 / 1.1	2.1 / 7.1	14 / 47
1325 SB	6.8	.6	0.0 / 0.0	0.0 / 0.0	0.0 /26.7	0.0 /26.7	0 / 16
1325 NB	6.8	.6	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0

(Continued)

FAILURE SUMMARY FOR DISTRICT 13
(CONTINUED)

CFHR NO.	AGE	LENGTH	REPAIR PATCHES (NO./MILE) A.C. 1974/1978	REPAIR PATCHES (NO./MILE) P.C.C. 1974/1978	PUNCHOUTS (NO./MILE) 1974/1978	FAILURES (NO./MILE) 1974/1978	FAILURES (TOTAL) 1974/1978
1326 SB	6.6	3.2	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
1326 NB	6.6	3.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
1327 SB	6.6	.6	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
1327 NB	6.6	.6	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
1328 SB	6.6	3.2	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
1328 NB	6.6	3.2	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
1324 SB	5.3	6.0	0.0 / 0.0	0.0 / 0.0	0.0 / .2	0.0 / .2	0 / 1
1324 NB	5.3	1.4	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
1323 SB	5.3	5.2	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
1323 NB	5.3	5.0	0.0 / .2	0.0 / 0.0	0.0 / .4	0.0 / .6	0 / 3
1322 SB	5.3	3.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
1322 NB	5.3	2.4	.5 / .4	0.0 / 0.0	0.0 / 0.0	.5 / .4	1 / 1
1329 SB	4.3	5.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
1329 NB *	4.3	4.8	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
1330 SB	6.4	2.4	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0

(Continued)

FAILURE SUMMARY FOR DISTRICT 13
(CONTINUED)

CFHR NO.	AGE	LENGTH	REPAIR PATCHES (NO./MILE) A.C. 1974/1978	REPAIR PATCHES (NO./MILE) P.C.C. 1974/1978	PUNCHOUTS (NO./MILE) 1974/1978	FAILURES (NO./MILE) 1974/1978	FAILURES (TOTAL) 1974/1978
1330 NB	6.4	2.2	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
1331 SB *	6.6	1.8	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
1331 NB	6.6	1.9	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
1332 SB	6.1	5.4	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
1332 NB	6.1	5.1	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
1333 SB	6.1	3.1	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
1333 NB	6.1	2.4	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
1319 SB	6.6	5.8	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
1319 NB *	6.6	4.8	0.0 / .2	0.0 / 0.0	0.0 / .9	0.0 / 1.1	0 / 5
1318 SB	6.6	8.2	0.0 / .2	0.0 / 0.0	0.0 / .9	0.0 / 1.1	0 / 9
1318 NB *	6.6	8.0	0.0 / 0.0	0.0 / 0.0	0.0 / .5	0.0 / .8	0 / 2
1305 SB	10.1	8.8	1.1 / .6	0.0 / .2	0.0 / 1.5	1.1 / 2.3	10 / 20
1305 NB	10.1	8.8	0.0 / .3	0.0 / .2	.3 / .9	.3 / 1.5	3 / 13
1308 SB	9.2	3.2	0.0 / 0.0	0.0 / 0.0	0.0 / .9	0.0 / .9	0 / 3
1308 NB	9.2	3.4	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0

(Continued)

FAILURE SUMMARY FOR DISTRICT 13
(CONTINUED)

CFHR NO.	AGE	LENGTH	REPAIR PATCHES (NO./MILE) A.C. 1974/1978	REPAIR PATCHES (NO./MILE) P.C.C. 1974/1978	PUNCHOUTS (NO./MILE) 1974/1978	FAILURES (NO./MILE) 1974/1978	FAILURES (TOTAL) 1974/1978
1310 SB	9.2	1.4	.7 / .7	0.0 / 0.0	0.0 / 0.0	.7 / .7	1 / 1
1310 NB	9.2	1.6	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
1309 SB *	9.2	1.2	1.7 / 0.0	0.0 / 0.0	0.0 / 0.0	1.7 / 0.0	1 / 0
1309 NB	9.2	1.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
DISTRICT MEANS:			.2 / .3	.1 / .8	.1 / 1.0	.3 / 2.0	1.7 /10.9

NOTES: AVERAGE SIZE OF A.C. PATCH = 23.9 SQ.FT.
AVERAGE SIZE OF P.C.C. PATCH = 59.3 SQ.FT.
AVERAGE SIZE OF PUNCHOUT = 3.2 SQ.FT.

* = INDICATES SECTION CONTAINS OVERLAY(S).

FAILURE SUMMARY FOR DISTRICT 17

CFHR NO.		AGE	LENGTH	REPAIR PATCHES (NO./MILE) A.C. 1974/1978	REPAIR PATCHES (NO./MILE) P.C.C. 1974/1978	PUNCHOUTS (NO./MILE) 1974/1978	FAILURES (NO./MILE) 1974/1978	FAILURES (TOTAL) 1974/1978
1701 NB	*	17.4	11.6	23.8 / 0.0	17.9 / 0.0	9.3 / 0.0	51.0 / 0.0	571 / 0
1701 SB	*	17.4	11.4	20.8 / 0.0	17.8 / 0.0	9.0 / 0.0	48.5 / 0.0	553 / 0
1702 NB	*	14.9	14.8	1.1 / .2	.1 / .1	.5 / .1	1.7 / .4	26 / 6
1702 SB	*	14.9	15.0	.6 / 1.0	.1 / .1	.3 / .3	1.1 / 1.3	16 / 18
1705 NB	*	11.0	12.8	.5 / 0.0	4.1 / 0.0	3.1 / 0.0	7.8 / 0.0	100 / 0
1705 SB	*	11.0	13.2	.4 / 0.0	6.5 / 0.0	3.1 / 0.0	10.0 / 0.0	132 / 0
1703 NB		11.0	12.8	.5 / 0.0	.2 / .2	.5 / .6	1.2 / .9	15 / 11
1703 SB		11.0	12.8	1.2 / 1.5	.1 / 1.1	.9 / 2.4	2.1 / 5.0	27 / 64
1704 NB		11.0	6.1	.8 / 0.0	0.0 / 0.0	0.0 / .3	.8 / .3	5 / 2
1704 SB		11.0	5.6	0.0 / .2	.2 / 5.0	.5 / 1.4	.7 / 6.6	4 / 37
1707 NB		9.0	16.2	.1 / 0.0	0.0 / 0.0	.1 / .2	.2 / .2	3 / 4
1707 SB		9.0	16.0	.5 / 0.0	.1 / .1	.1 / .9	.7 / 1.0	11 / 16
1710 NB		7.0	17.2	1.0 / .3	.5 / .1	.1 / 2.4	1.6 / 2.8	27 / 49
1710 SB		7.0	17.2	.5 / 1.5	.1 / .3	.1 / 3.5	.6 / 5.3	10 / 92
1709 NB		7.0	.6	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0

(Continued)

FAILURE SUMMARY FOR DISTRICT 17
(CONTINUED)

CFHR NO.	AGE	LENGTH	REPAIR PATCHES (NO./MILE) A.C. 1974/1978	REPAIR PATCHES (NO./MILE) P.C.C. 1974/1978	PUNCHOUTS (NO./MILE) 1974/1978	FAILURES (NO./MILE) 1974/1978	FAILURES (TOTAL) 1974/1978
1709 SB	7.0	.8	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
1708 NB	7.5	12.2	0.0 / .7	.1 / .3	.1 / .7	.2 / 1.7	2 / 21
1708 SB	7.5	12.0	.5 / 1.2	0.0 / .4	.1 / 3.3	.6 / 4.9	7 / 59
1706 NB	10.0	2.4	.8 / 1.7	0.0 / 0.0	0.0 / 1.3	.8 / 2.9	2 / 7
1706 SB	10.0	2.3	1.3 / .4	0.0 / .9	0.0 / 3.5	1.3 / 4.8	3 / 11
1711 NB	6.2	12.8	0.0 / 0.0	0.0 / 0.0	0.0 / .1	0.0 / .1	0 / 1
1711 SB	6.2	12.4	0.0 / 0.0	0.0 / .2	0.0 / .4	0.0 / .6	0 / 7
DISTRICT MEANS:			2.5 / .4	2.2 / .4	1.3 / 1.2	5.9 / 1.8	68.8 /18.4

NOTES: AVERAGE SIZE OF A.C. PATCH = 17.8 SQ.FT.
AVERAGE SIZE OF P.C.C. PATCH = 36.4 SQ.FT.
AVERAGE SIZE OF PUNCHOUT = 2.6 SQ.FT.

* = INDICATES SECTION CONTAINS OVERLAY(S).

FAILURE SUMMARY FOR DISTRICT 19

CFHR NO.	AGE	LENGTH	REPAIR PATCHES (NO./MILE) A.C. 1974/1978	REPAIR PATCHES (NO./MILE) P.C.C. 1974/1978	PUNCHOUTS (NO./MILE) 1974/1978	FAILURES (NO./MILE) 1974/1978	FAILURES (TOTAL) 1974/1978
1901 EB	13.8	7.0	.1 / .3	.4 / .4	0.0 / 3.3	.6 / 4.0	4 / 28
1902 EB	13.2	5.6	0.0 / .5	5.0 /11.3	0.0 / 4.3	5.0 /16.1	28 / 90
1903 EB	13.2	.4	0.0 / 0.0	7.5 / 7.5	0.0 / 0.0	7.5 / 7.5	3 / 3
1904 EB	12.8	8.2	.1 / 1.3	1.3 / 2.9	0.0 / 2.9	1.4 / 7.2	11 / 59
1905 EB	11.8	9.6	0.0 / .1	.3 / .3	0.0 / 0.0	.3 / .4	3 / 4
1906 EB	11.8	7.0	1.9 / 4.9	2.0 /12.3	1.3 / 3.4	5.1 /20.6	36 / 144
1907 EB	11.8	.3	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
1908 EB	11.7	7.6	1.6 / 9.1	9.0 /18.8	.6 / 1.7	11.2 /29.6	110 / 225
1909 EB	11.6	7.1	0.0 / .7	1.0 / 3.1	.1 / 0.0	1.1 / 3.8	8 / 27
1910 EB *	11.2	5.6	0.0 / 0.0	.9 / 0.0	0.0 / 0.0	.9 / 0.0	5 / 0
1911 EB *	11.2	6.0	0.0 / 0.0	1.7 / .7	0.0 / .2	1.7 / .9	10 / 4
1914 EB *	10.9	7.8	0.0 / 0.0	1.9 / 0.0	0.0 / .4	1.9 / .4	15 / 1
1915 EB	10.7	3.4	0.0 / 2.4	0.0 / 1.2	.9 / .9	.9 / 4.4	3 / 15
1917 EB	7.9	7.0	.1 / 0.0	0.0 / .1	0.0 / .3	.1 / .4	1 / 3
1918 EB	6.8	7.0	.4 / .1	.1 / .7	.1 / .1	.7 / 1.0	5 / 7

(Continued)

FAILURE SUMMARY FOR DISTRICT 19
(CONTINUED)

CFHR NO.	AGE	LENGTH	REPAIR PATCHES (NO./MILE) A.C. 1974/1978	REPAIR PATCHES (NO./MILE) P.C.C. 1974/1978	PUNCHOUTS (NO./MILE) 1974/1978	FAILURES (NO./MILE) 1974/1978	FAILURES (TOTAL) 1974/1978
1919 EB	7.2	10.0	.1 / 0.0	.1 / .5	0.0 / .2	.2 / .7	2 / 7
1920 EB	6.5	7.8	.1 / .3	.1 / .3	.1 / .3	.4 / .8	3 / 6
1901 WB	13.8	7.1	0.0 / .1	.2 / .6	.3 / 1.5	.5 / 2.3	3 / 16
1902 WB	13.2	5.6	.9 / .4	.7 / 6.6	0.0 / 2.0	1.6 / 8.9	9 / 50
1903 WB	13.2	.4	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
1904 WB	12.8	8.2	.2 / .2	.4 / 1.5	.1 / 2.4	.7 / 4.1	6 / 34
1905 WB	11.8	9.4	0.0 / .3	.1 / .3	.6 / 2.0	.7 / .6	7 / 6
1906 WB	11.8	6.8	1.6 / 2.4	3.7 /10.0	.3 / 2.8	5.6 /15.1	39 / 103
1907 WB	11.8	.2	0.0 / 0.0	10.0 /20.0	5.0 /25.0	15.0 /45.0	3 / 9
1908 WB	11.7	10.0	.1 / .5	2.0 /12.4	0.0 / 5.8	2.1 /18.7	21 / 187
1909 WB	11.6	7.0	0.0 / 0.0	0.0 / .7	0.0 / .3	0.0 / 1.0	0 / 7
1910 WB *	11.2	5.6	0.0 / 0.0	.4 / 0.0	0.0 / 0.0	.4 / 0.0	2 / 0
1911 WB *	11.2	6.0	0.0 / 0.0	1.5 / 1.7	0.0 / 0.0	1.5 / 1.7	9 / 7
1914 WB *	10.9	7.8	0.0 / 0.0	1.9 / 0.0	0.0 / 0.0	1.9 / 0.0	15 / 0
1915 WB	10.7	3.4	0.0 / .9	0.0 / .3	0.0 / .9	0.0 / 2.1	0 / 7

(Continued)

FAILURE SUMMARY FOR DISTRICT 19
(CONTINUED)

CFHR NO.	AGE	LENGTH	REPAIR PATCHES (NO./MILE) A.C. 1974/1978	REPAIR PATCHES (NO./MILE) P.C.C. 1974/1978	PUNCHOUTS (NO./MILE) 1974/1978	FAILURES (NO./MILE) 1974/1978	FAILURES (TOTAL) 1974/1978
1917 WB	7.9	7.0	0.0 / .1	0.0 / 0.0	0.0 / .6	0.0 / .7	0 / 5
1918 WB	6.8	7.0	.1 / .3	0.0 / .4	0.0 / .1	.1 / .9	1 / 6
1919 WB	7.2	10.0	0.0 / 0.0	0.0 / .5	.1 / [illegible]	.1 / .5	1 / 5
1920 WB	6.5	7.6	.1 / .1	0.0 / .5	0.0 / .9	.1 / 1.6	1 / 12
DISTRICT MEANS:			.2 / .7	1.5 / 3.4	.3 / 1.6	2.0 / 5.9	10.7 /31.7

NOTES: AVERAGE SIZE OF A.C. PATCH = 22.6 SQ.FT.
AVERAGE SIZE OF P.C.C. PATCH = 59.3 SQ.FT.
AVERAGE SIZE OF PUNCHOUT = 3.2 SQ.FT.

* - INDICATES SECTION CONTAINS OVERLAY(S).

FAILURE SUMMARY FOR DISTRICT 20

CFHR NO.	AGE	LENGTH	REPAIR PATCHES (NO./MILE) A.C. 1974/1978	REPAIR PATCHES (NO./MILE) P.C.C. 1974/1978	PUNCHOUTS (NO./MILE) 1974/1978	FAILURES (NO./MILE) 1974/1978	FAILURES (TOTAL) 1974/1978
2002 NB	15.3	1.4	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
2005 NB	15.0	1.6	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
2006 NB	14.2	.9	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
2012 NB	13.3	1.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
2022 NB	9.1	1.2	.8 / .8	0.0 / 0.0	0.0 / 0.0	.8 / .8	1 / 1
2023 NB	7.2	1.2	0.0 / 0.0	0.0 / 0.0	0.0 / .8	0.0 / .8	0 / 1
2002 SB	15.3	1.4	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
2005 SB	15.0	1.6	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
2006 SB	14.2	.9	3.0 / 0.0	0.0 / 0.0	0.0 / 0.0	3.0 / 0.0	3 / 0
2011 SB	13.5	3.2	3.1 / 0.0	0.0 / 0.0	0.0 / 0.0	3.1 / 0.0	10 / 0
2012 SB	13.3	1.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
2013 SB	13.3	.4	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
2014 SB	12.8	2.8	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
2015 SB *	11.8	2.8	2.9 / 0.0	.4 / 5.5	1.1 / 0.0	4.3 / 5.5	12 / 12
2016 SB	11.8	.6	3.3 / 0.0	0.0 / 0.0	0.0 / 0.0	3.3 / 0.0	2 / 0

(Continued)

FAILURE SUMMARY FOR DISTRICT 20
(CONTINUED)

CFHR NO.	AGE	LENGTH	REPAIR PATCHES (NO./MILE) A.C. 1974/1978	REPAIR PATCHES (NO./MILE) P.C.C. 1974/1978	PUNCHOUTS (NO./MILE) 1974/1978	FAILURES (NO./MILE) 1974/1978	FAILURES (TOTAL) 1974/1978
2022 SB	9.1	1.2	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
2023 SB	7.2	2.2	.4 / 0.0	0.0 / .5	0.0 / .9	.4 / 1.4	1 / 3
2004 EB *	15.1	9.4	6.1 / 0.0	7.0 / 0.0	2.8 / 0.0	15.9 / 0.0	127 / 0
2009 EB	13.7	8.0	.6 / 7.9	1.1 / 4.4	1.1 / .5	2.9 /12.8	23 / 102
2017 EB	11.1	.7	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
2018 EB	11.1	2.8	.4 / 0.0	0.0 / .4	.4 / 0.0	.7 / .4	2 / 1
2021 EB *	9.0	4.8	0.0 / 0.0	0.0 / 0.0	0.0 / .2	0.0 / .2	0 / 1
2026 EB	6.4	.6	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
2001 WB	15.4	.5	0.0 / 0.0	0.0 / 0.0	1.7 / 0.0	1.7 / 0.0	1 / 0
2003 WB	15.2	4.0	0.0 / 0.0	0.0 / 0.0	0.0 / .3	0.0 / .3	0 / 1
2004 WB *	15.1	9.4	1.0 / 0.0	.3 / 0.0	1.8 / 0.0	3.2 / 0.0	29 / 0
2009 WB *	13.7	8.0	0.0 / 3.3	2.1 /23.8	1.9 / 1.9	4.0 /28.9	32 / 185
2019 WB	10.8	2.4	0.0 / 0.0	0.0 / 0.0	.4 / 0.0	.4 / 0.0	1 / 0
2020 WB	10.8	.6	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0

(Continued)

FAILURE SUMMARY FOR DISTRICT 2Ø
(Continued)

2Ø26 WB	6.4	.6	Ø.Ø / Ø.Ø	Ø.Ø / Ø.Ø	Ø.Ø / Ø.Ø	Ø.Ø / Ø.Ø	Ø / Ø
**							
DISTRICT MEANS:			.7 / .4	.4 / 1.1	.4 / .2	1.5 / 1.7	8.1 /1Ø.2

NOTES: AVERAGE SIZE OF A.C. PATCH = 32.8 SQ.FT.
AVERAGE SIZE OF P.C.C. PATCH = 7Ø.3 SQ.FT.
AVERAGE SIZE OF PUNCHOUT = 5.7 SQ.FT.

* = INDICATES SECTION CONTAINS OVERLAY(S).

FAILURE SUMMARY FOR DISTRICT 24

CFHR NO.	AGE	LENGTH	REPAIR PATCHES (NO./MILE) A.C. 1974/1978	REPAIR PATCHES (NO./MILE) P.C.C. 1974/1978	PUNCHOUTS (NO./MILE) 1974/1978	FAILURES (NO./MILE) 1974/1978	FAILURES (TOTAL) 1974/1978
2422 EB	3.0	2.2	0.0 / .5	0.0 / 0.0	0.0 / 0.0	0.0 / .5	0 / 1
2423 EB	3.0	1.4	0.0 / .7	0.0 / 0.0	0.0 / 0.0	0.0 / .7	0 / 1
2420 EB	4.2	11.4	0.0 / .4	0.0 / 0.0	0.0 / 0.0	0.0 / .4	0 / 4
2415 EB	6.5	.4	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
2414 EB	6.5	12.0	0.0 / .1	0.0 / 0.0	0.0 / 0.0	0.0 / .1	0 / 1
2412 EB	8.3	1.2	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
2411 EB	8.3	9.8	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
2409 EB	8.9	2.8	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
2410 EB	8.9	7.0	0.0 / .1	0.0 / .1	0.0 / 0.0	0.0 / .3	0 / 2
2410 WB	8.9	7.0	0.0 / .6	0.0 / 0.0	0.0 / 0.0	0.0 / .6	0 / 4
2409 WB	8.9	2.8	.4 / 0.0	0.0 / 0.0	0.0 / 0.0	.4 / 0.0	1 / 0
2411 WB	8.3	9.8	0.0 / .1	0.0 / .1	0.0 / 0.0	0.0 / .2	0 / 2
2412 WB	8.3	1.2	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
2414 WB	6.5	12.0	.3 / .2	0.0 / .2	0.0 / .1	.3 / .4	3 / 5
2415 WB	6.5	.4	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0

(Continued)

FAILURE SUMMARY FOR DISTRICT 24
(CONTINUED)

CFHR NO.	AGE	LENGTH	REPAIR PATCHES (NO./MILE) A.C. 1974/1978	REPAIR PATCHES (NO./MILE) P.C.C. 1974/1978	PUNCHOUTS (NO./MILE) 1974/1978	FAILURES (NO./MILE) 1974/1978	FAILURES (TOTAL) 1974/1978
2420 WB	4.2	14.8	0.0 / .4	0.0 / 0.0	0.0 / 0.0	0.0 / .4	0 / 6
2423 WB	3.0	1.2	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
2422 WB	3.0	2.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
DISTRICT MEANS:			.0 / .2	0.0 / .0	0.0 / .0	.0 / .2	.2 / 1.4

NOTES: AVERAGE SIZE OF A.C. PATCH = 22.6 SQ.FT.
AVERAGE SIZE OF P.C.C. PATCH = 59.3 SQ.FT.
AVERAGE SIZE OF PUNCHOUT = 3.2 SQ.FT.

* = INDICATES SECTION CONTAINS OVERLAY(S).

FAILURE SUMMARY FOR DISTRICT 25

CFHR NO.	AGE	LENGTH	REPAIR PATCHES (NO./MILE) A.C. 1974/1978	REPAIR PATCHES (NO./MILE) P.C.C. 1974/1978	PUNCHOUTS (NO./MILE) 1974/1978	FAILURES (NO./MILE) 1974/1978	FAILURES (TOTAL) 1974/1978
2503 WB	5.2	1.6	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
2503 EB	5.2	2.6	0.0 / 0.0	0.0 / 0.0	0.0 / .8	0.0 / .8	0 / 2
2504 EB	5.2	1.4	0.0 / 0.0	0.0 / 0.0	0.0 / .7	0.0 / .7	0 / 1
2504 WB	5.2	1.4	0.0 / 0.0	0.0 / .7	0.0 / 0.0	0.0 / .7	0 / 1
2505 EB	3.0	.8	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
2505 WB	3.0	.8	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
2502 EB	8.3	12.0	0.0 / 0.0	0.0 / 0.0	0.0 / .1	0.0 / .1	0 / 1
2502 WB	8.3	12.2	0.0 / 0.0	0.0 / .1	0.0 / 0.0	0.0 / .1	0 / 1
2501 EB	10.2	13.8	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0 / 0
2501 WB	10.2	14.6	0.0 / 0.0	0.0 / 0.0	.1 / .3	.1 / .3	1 / 4
DISTRICT MEANS:			0.0 / 0.0	0.0 / .1	.0 / .2	.0 / .3	.1 / 1.0

NOTES: AVERAGE SIZE OF A.C. PATCH = 23.9 SQ.FT.
AVERAGE SIZE OF P.C.C. PATCH = 59.3 SQ.FT.
AVERAGE SIZE OF PUNCHOUT = 3.2 SQ.FT.

* - INDICATES SECTION CONTAINS OVERLAY(S).

APPENDIX B

SUMMARY OF CRACKING AND SPALLING IN EACH DISTRICT

DIST1		CRACKS		SPALLS(%)	
CFHR	NO.	SPACE	STD.DEV.	MINOR	SEVERE
101	EB	7.8	5.5	33.2	0.7
	WB	7.1	3.3	42.6	0.5
102	EB	10.3,7.7	5.2,4.3	38.4,34.7	0.0,0.2
	WB	9.1,9.5	5.7,5.6	28.0,30.3	0.3,0.0
103	EB	6.2	3.2	43.7	1.4
	WB	6.2	3.3	53.0	0.2
104	EB	-	-	-	-
	WB	-	-	-	-
105	EB	5.6	3.0	25.4	0.9
	WB	6.7	3.3	55.3	0.3
108	NB	8.8	4.4	17.1	0.0
	SB	7.2	3.9	17.4	0.4
111	NB	-	-	-	-
	SB	7.8	4.0	16.2	0.0
112	NB	2.4	1.2	7.1	2.2
-		-	-	-	-
113	NB	3.5	1.7	5.3	2.4
	SB	4.1	2.1	7.7	0.5
115	EB	-	-	-	-
	WB	7.2	3.5	1.6	0.2
		6.9		26.9	0.6

DIST3		CRACKS		SPALLS(%)	
CFHR	NO.	SPACE	STD.DEV.	MINOR	SEVERE
301	NB	5.9	3.5	17.8	0.0
	SB	5.1	2.7	20.2	0.0
303	NB	6.7	3.2	13.2	0.0
	SB	5.9	3.1	27.1	0.1
304	NB	6.0	3.4	11.3	0.0
	SB	8.9,5.1	4.0,3.1	50.5,29.5	0.0,0.0
305	NB	5.4	2.6	17.6	0.0
	SB	6.0	3.3	31.0	0.6
306	EB	4.4	2.1	35.4	0.0
	WB	5.6	2.7	12.0	0.1
307	EB	5.2	2.3	37.8	0.0
	WB	5.6	2.4	0.0	0.0
308	EB	2.6	1.3	7.3	0.0
	WB	5.4	2.1	10.1	0.1
310	NB	5.0	3.0	18.8	0.3
	SB	5.4	2.9	12.9	0.6
311	NB	10.0	4.8	42.2	0.0
	SB	8.6	3.4	27.8	0.0
312		-	-	-	-
		-	-	-	-
314		-	-	-	-
		-	-	-	-
315	EB	6.8	3.8	77.2	0.5
	WB	7.2	4.9	13.5	0.3
316	NB	4.3,5.4	2.4,3.8	6.8,18.0	0.3,0.3
	SB	-	-	-	-

(Continued)

(Continued)

317	NB	.	.	.	.
	SB	.	.	.	.
318	NB	9.5	4.4	14.8	0.2
	SB	6.9	3.3	24.8	0.0
319	NB	.	.	.	.
	SB	7.1	2.1	17.6	0.0
320	NB	.	.	.	.
	SB	.	.	.	.
322	NB	7.1	4.1	28.2	0.0
	SB	.	.	.	.
		6.3		20.5	0.1

DIST4		CRACKS		SPALLS(%)	
CFHR	NO.	SPACE	STD.DEV.	MINOR	SEVERE
402	EB	3.4	2.2	14.2	1.2
	WB	3.4	2.2	20.0	0.2
403	EB	3.6	1.4	14.8	0.3
	WB	3.8	2.0	18.3	0.0
404	EB	4.4	2.2	14.3	0.0
	WB	3.6	1.7	21.7	0.8
405	EB	2.9	1.1	35.0	0.1
	WB	2.6	1.1	19.1	0.0
406	EB	3.2	1.5	25.9	0.1
	WB	3.1	1.3	27.6	0.0
407	EB	3.5	1.8	13.8	0.7
	WB	3.3	1.8	15.7	0.9
408	EB	-	-	-	-
	WB	2.6	1.3	24.5	0.1
409	EB	2.8,2.4	1.1,2.4	8.8,7.3	0.0,0.0
	WB	2.8	1.5	21.7	0.0
410	EB	2.8	1.5	14.4	0.1
	WB	3.1	1.4	25.5	0.2
411	EB	5.4	2.7	22.7	0.0
	WB	3.5	1.6	11.6	0.1
412	EB	-	-	-	-
	WB	-	-	-	-
		3.2		18.9	0.2

DIST9		CRACKS		SPALLS(%)	
CFHR	NO.	SPACE	STD.DEV.	MINOR	SEVERE
901	NB	-	-	-	-
	SB	-	-	-	-
902	NB	-	-	-	-
	SB	-	-	-	-
903	NB	-	-	-	-
	SB	-	-	-	-
904	NB	-	-	-	-
	SB	-	-	-	-
905	NB	-	-	-	-
	SB	-	-	-	-
906	NB	9.6	2.9	68.2	0.9
	SB	9.6	2.9	55.0	1.6
907	NB	7.0	2.5	9.4	0.7
	SB	-	-	-	-
908	NB	-	-	-	-
	SB	-	-	-	-
909	NB	-	-	-	-
	SB	-	-	-	-
910	NB	-	-	-	-
	SB	-	-	-	-
		8.7		44.2	1.1

DIST10		CRACKS		SPALLS(%)	
CFHR	NO.	SPACE	STD.DEV.	MINOR	SEVERE
1001	EB	-	-	-	-
	WB	-	-	-	-
1002	EB	9.3	3.9	62.6	0.5
	WB	7.3	4.1	54.3	0.1
1003	EB	6.5	4.1	62.2	1.6
	WB	4.7	3.7	49.2	1.4
1004	EB	6.2	3.5	52.0	8.9
	WB	6.5	4.8	64.3	4.6
1005	EB	-	-	-	-
	WB	-	-	-	-
1006	EB	-	-	-	-
	WB	-	-	-	-
1007	EB	-	-	-	-
	WB	-	-	-	-
1008	EB	-	-	-	-
	WB	-	-	-	-
1009	EB	9.1	5.6	49.1	0.7
	WB	8.4	4.2	58.2	0.3
1010	EB	6.5	3.5	45.7	2.4
	WB	5.9	3.2	55.8	0.8
1011	EB	-	-	-	-
	WB	-	-	-	-
1012	EB	-	-	-	-
	WB	-	-	-	-
1013	EB	-	-	-	-
	WB	-	-	-	-
1014	EB	5.7	2.2	35.6	1.8
	WB	6.0	3.6	67.8	1.5
		6.8		54.7	2.1

DIST13		CRACKS		SPALLS(↓)	
CFHR	NO.	SPACE	STD.DEV.	MINOR	SEVERE
1301	EB	3.4	1.9	7.1	2.9
	WB	3.5	2.4	21.8	123.5
1302	EB	4.0	2.2	5.5	12.8
	WB	4.1	2.7	32.6	10.9
1309	EB	4.7	2.8	25.8	1.7
	WB	4.8	2.6	16.6	3.4
1305	NB	3.2	1.7	16.6	16.3
	SB	2.9	1.5	10.9	3.9
1306	EB	2.3	1.0	1.7	0.5
	WB	3.4	1.5	6.7	0.6
1307	EB	2.8	1.5	3.7	0.8
	WB	2.5	1.2	4.1	1.2
1308	NB	8.5	3.3	45.3	13.1
	SB	5.9	4.0	35.4	78.9
1309	NB	4.3	3.3	21.5	11.2
	SB	3.2	2.1	13.4	1.23
1310	NB	5.8	4.5	39.7	13.4
	SB	4.5	3.3	21.1	7.0
1311	EB	3.4	1.6	14.0	0.0
	WB	3.7	2.1	13.3	0.1
1312	NB	4.4	2.9	7.1	6.0
	SB	5.1	2.9	19.3	6.4
1313	EB	3.6	2.1	8.4	0.3
	WB	5.0	2.7	26.4	0.4
1314	EB	-	-	-	-
	WB	-	-	-	-

(Continued)

(Continued)

1315	EB	6.5	3.3	16.4	0.0
	WB	6.2	2.3	11.9	0.4
1316	EB	5.7	2.1	11.0	0.1
	WB	5.5	2.1	13.1	0.3
1317	EB	7.8	2.9	8.3	0.0
	WB	8.7	3.8	26.6	1.1
1318	NB	3.5	2.3	11.1	0.9
	SB	4.4	2.2	22.1	5.9
1319	NB	3.6	2.1	21.3	1.1
	SB	4.6	2.6	43.4	1.1
1320	EB	9.3	4.3	16.5	0.0
	WB	11.1	5.8	19.5	0.2
1321	EB	10.5	3.7	20.5	0.2
	WB	12.4	4.3	51.1	0.0
1322	NB	4.7,5.9	3.1,2.4	6.9,25.7	1.4,9.9
	SB	5.4	3.6	19.4	2.0
1323	NB	4.9	3.1	19.9	1.2
	SB	-	-	-	-
1324	NB	-	-	-	-
	SB	5.4	3.1	18.9	0.9
1325	NB	-	-	-	-
	SB	-	-	-	-
1326	NB	-	-	-	-
	SB	-	-	-	-
1327	NB	-	-	-	-
	SB	-	-	-	-
1328	NB	-	-	-	-
	SB	-	-	-	-

(Continued)

(Continued)

1329	NB	-	-	-	-
	SB	3.0	1.5	11.7	0.3
1330	NB	-	-	-	-
	SB	3.1	1.7	10.0	0.3
1331	NB	-	-	-	-
	SB	-	-	-	-
1332	NB	5.3	2.8	14.0	8.2
	SB	4.7	2.7	35.8	8.3
1333	NB	4.3	2.9	5.4	2.6
	SB	5.7	2.8	31.9	4.9
		5.1		18.6	3.8

DIST17		CRACKS		SPALLS(%)	
CFHR	NO.	SPACE	STD.DEV.	MINOR	SEVERE
1701	NB	-	-	-	-
	SB	-	-	-	-
1702	NB	4.4	2.6	11.4	0.0
	SB	4.1	2.2	15.6	0.2
1703	NB	2.9	1.3	7.7	0.0
	SB	3.5	1.5	9.9	0.1
1704	NB	2.9	1.3	9.9	0.8
	SB	3.0	1.3	7.1	3.3
1705	NB	-	-	-	-
	SB	-	-	-	-
1706	NB	-	-	-	-
	SB	-	-	-	-
1707	NB	3.0	1.5	10.7	0.0
	SB	2.9	1.2	10.7	0.1
1708	NB	3.1	1.6	5.5	0.0
	SB	6.1	3.6	20.7	0.2
1709	NB	-	-	-	-
	SB	-	-	-	-
1710	NB	4.6	1.7	14.9	0.2
	SB	5.0	1.8	16.3	0.1
1711	NB	5.0	3.5	13.9	5.0
	SB	4.9	4.0	10.4	0.9
		4.0		11.8	0.9

DIST19		CRACKS		SPALLS(%)	
CFHR	NO.	SPACE	STD.DEV.	MINOR	SEVERE
1901	EB	2.2	1.1	18.0	0.7
	WB	1.9	1.0	16.4	2.7
1902	EB	3.6	2.3	12.9	22.7
	WB	3.4	2.4	18.7	13.4
1903	EB	2.7	1.6	12.8	2.4
	WB	2.1	1.1	4.1	1.9
1904	EB	3.2	1.7	37.6	1.6
	WB	3.8	2.0	36.4	0.3
1905	EB	8.0	4.2	33.0	0.0
	WB	5.3	3.0	17.2	0.5
1906	EB	3.4	1.8	41.8	1.5
	WB	6.6	6.0	29.9	0.5
1907	EB	-	-	-	-
	WB	-	-	-	-
1908	EB	-	-	-	-
	WB	3.8	2.2	37.6	11.2
1909	EB	-	-	-	-
	WB	-	-	-	-
1910	EB	-	-	-	-
	WB	-	-	-	-
1911	EB	2.6,2.5	1.2,1.1	5.1,4.6	33.9,24.6
	WB	3.1	1.3	10.9	42.7
1914	EB	-	-	-	-
	WB	3.4	1.5	19.1	11.0
1915	EB	4.8	2.8	35.2	0.6
	WB	5.1	2.3	26.1	09.1

(Continued)

(Continued)

1917	EB	4.6	2.7	10,0	0.1
	WB	4.6	3.2	11.4	0.0
1918	EB	3.9	1.9	19,6	0,1
	WB	2.6	1.4	5.1	0.1
1919	EB	2.8	1.0	12.5	0,3
	WB	2.7	1.2	10.5	0.4
1920	EB	2.6	1.2	5.9	0,1
	WB	- 3.2	- 1.6	- 6.7	- 0.1
		3.7		18.5	6.5

DIST20		CRACKS		SPALLS(%)	
CFHR	NO.	SPACE	STD.DEV.	MINOR	SEVERE
2001	WB	-	-	-	-
2002	NB	-	-	-	-
	SB	-	-	-	-
2003	WB	5.8	4.0	12.5	21.2
2004	EB	-	-	-	-
	WB	-	-	-	-
2005	NB	3.3	2.3	15.1	5.3
	SB	5.3	3.6	9.4	3.2
2006	NB	4.3	2.4	5.5	1.9
	SB	4.5	2.9	13.0	5.5
2009	EB	5.4	3.1	31.2	0.1
	WB	5.9	3.7	29.5	0.1
2011	SB	4.7	3.2	22.0	2.4
2012	NB	2.8	3.3	8.5	2.7
	SB	2.6	1.9	4.2	1.5
2013	SB	-	-	-	-
2014	SB	3.2	1.6	11.5	14.7
2015	SB	5.0	2.8	29.9	14.3
2016	SB	4.1	2.1	28.3	14.7
2017	EB	3.0	2.1	2.8	27.5
2018	EB	3.9	2.2	5.6	30.3
2019	WB	7.2	3.6	2.2	0.1

(Continued)

(Continued)

2020	WB	-	-	-	-
2021	EB	4.2	3.4	16.9	10.0
2022	NB	4.0	2.2	8.9	10.6
	SB	4.4	2.7	12.1	5.0
2023	NB	2.6	0.9	6.7	1.3
	SB	2.6	0.9	4.0	0.5
2026	EB	-	-	-	-
	WB	-	-	-	-
		4.2		13.3	8.2

DIST24		CRACKS		SPALLS(%)	
CFHR	NO.	SPACE	STD.DEV.	MINOR	SEVERE
2409	WB	6.8	3.1	23.5	0.1
	EB	6.0	2.4	5.4	0.3
2410	EB	7.1	2.9	20.8	0.5
	WB	7.2	3.5	13.0	0.1
2411	EB	5.6	3.0	28.4	0.0
	WB	4.6	1.5	30.3	0.2
2412	EB	4.0	1.8	25.1	0.2
	WB	5.6	2.2	29.3	0.1
2414	EB	6.6	2.1	63.6	0.4
	WB	5.6	2.3	44.6	0.8
2415	EB	-	-	-	-
	WB	4.6	2.5	44.5	0.0
2420	EB	3.7,6.1	2.3,2.5	13.0,39.9	0.1,0.9
	WB	4.4,4.1	2.2,2.8	17.8,34.3	0.0,0.8
2422	EB	-	-	-	-
2423	EB	4.9	2.7	23.3	0.0
	WB	-	-	-	-
		5.0		28.6	0.4

DIST25		CRACKS		SPALLS(%)	
CFHR NO.		SPACE	STD.DEV.	MINOR	SEVERE
2501	EB	3.1	1.6	18.3	0.1
	WB	2.7	1.1	18.3	0.0
2502	EB	3.0	1.3	12.6	0.2
	WB	3.5	1.8	14.4	0.0
2503	EB	2.9	1.2	8.8	0.1
	WB	3.1	1.6	12.3	0.0
2504	EB	3.4	1.2	9.3	0.0
	WB	-	-	-	-
2505	EB	-	-	-	-
	WB	-	-	-	-
		2.9		13.4	0.1

APPENDIX C

THEORETICAL PREDICTION OF CRACK SPACING

APPENDIX C. THEORETICAL PREDICTION OF CRACK SPACING

The Computer Program CRCP

The computer program CRCP2 is a useful tool for the analysis of wheel load, temperature, and shrinkage effects on continuously reinforced concrete pavements. Crack spacing is one of the outputs of the program.

The crack spacing is determined by comparing concrete strength with concrete stress at a given time interval.

Selection of Input for CRCP2

The criterion followed to choose the input data for the computer runs was to simulate the environmental conditions and type of aggregate used in the concrete mix. A justification of the values used may be found in Ref 7.

Aggregate Type

Two aggregates are considered in this study: gravel and limestone, which are the most commonly used in Texas. In Ref 6, it was concluded that the aggregate type has no discernible influence on the concrete strength, but it was found to have a significant effect in the following properties:

(1) thermal coefficient,
(2) drying shrinkage, and
(3) tensile-flexural strength ratio of concrete.

Environmental conditions

In Table C.1, some climatological data from Texas are shown. Although the average temperatures are about the same in all the state, lower temperatures are recorded in the northwestern and west stations. Humidity is somewhat higher along the coast. In Refs 3 and 5 more detail is given on the climatic conditions.

TABLE C. 1. CLIMATOLOGICAL DATA IN TEXAS (Ref 5)

Station	Temperature				Average Relative Humidity
	Normal		Extremes		
	Maximum	Minimum	High	Low	
Amarillo	70.8	43.9	108	-14	54
Dallas-Ft. Worth	76.5	54.4	109	4	67
El Paso	77.2	49.5	109	- 8	39
Galveston	74.5	65.0	101	8	78
Houston	79.8	58.0	101	18	77
Lubbock	73.6	45.8	107	-16	56
Port Arthur	78.3	58.6	107	14	79
Victoria	79.7	60.5	107	16	74
Waco	77.8	56.4	112	- 5	67
Wichita Falls	77.0	51.2	113	- 5	64

Computer Results

In Table C.2, the crack spacing output data from Program CRCP2 is shown. From that table we may conclude that:

(1) In general, limestone concrete produces larger crack spacing than gravel concrete.

(2) The tensile strength of the concrete is an important factor in determining crack spacing. The larger the tensile strength, the larger the crack spacing (Fig C. 1).

(3) Note that gravel shows the same crack spacing for changes in temperature, while limestone concrete shows different values for changes in temperature. The explanation is that temperature differences become significant only when the thermal coefficients of the steel and the concrete are different. In this study, the thermal coefficient of gravel concrete was chosen to be equal to that of steel. In Fig C.3, the effect of the thermal coefficient is shown.

(4) When the thermal coefficients of concrete and steel are different, the crack spacing is smaller for larger temperature drops. Fig C.2 shows the effect of temperature drop in crack spacing.

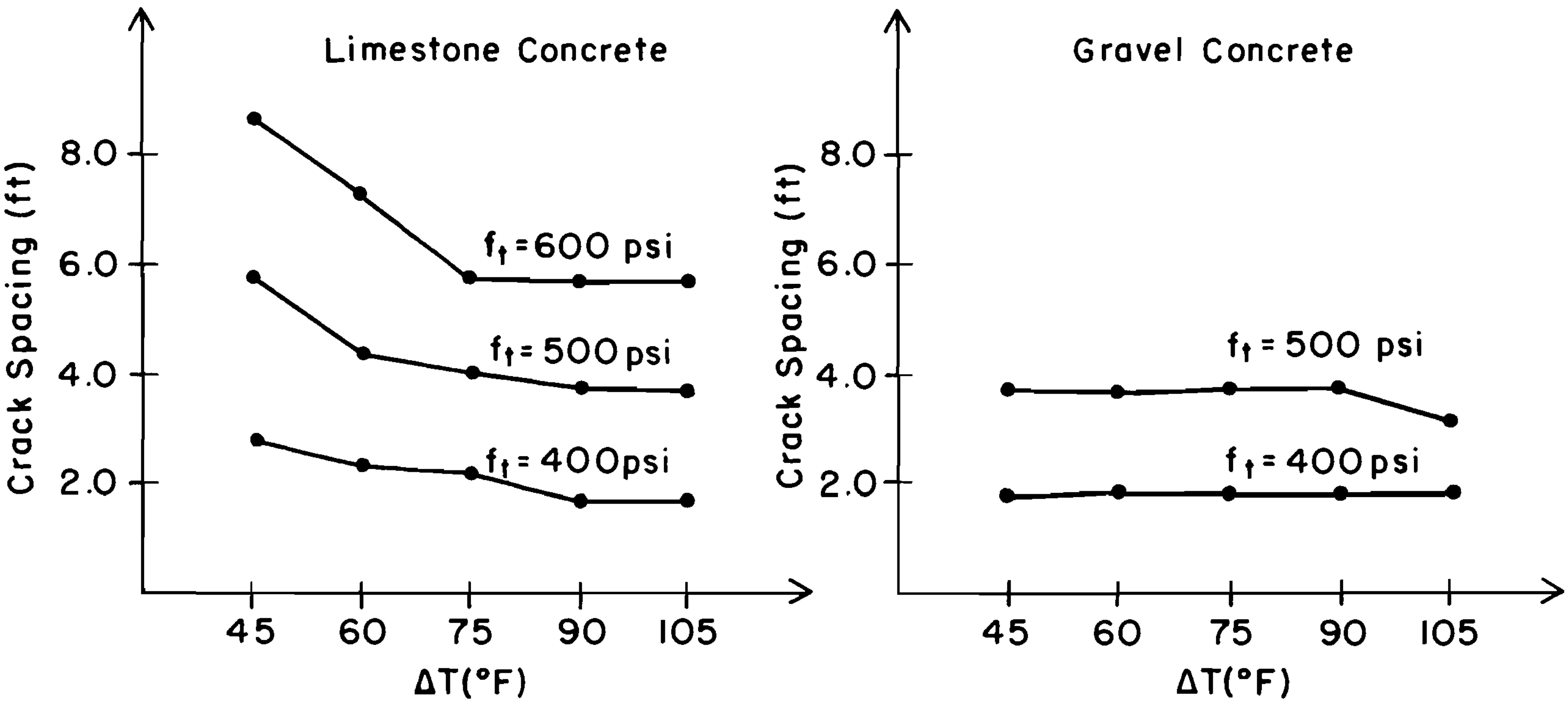
(5) For equal temperature drops and tensile strengths, curing temperature and lowest temperature have no effect on the results. Temperature drop is the difference between the curing temperature and the lowest temperature recorded.

TABLE C.2. CRACK SPACING OBTAINED FROM CRCP2 COMPUTER PROGRAM

		Concrete					
		f_t = 400		f_t = 500		f_t = 600	
Curing Temperature ($^{\circ}$F)	Lowest Temperature ($^{\circ}$F)	Gravel	Limestone	Gravel	Limestone	Gravel	Limestone
60	-15	1.891	2.171	3.777	4.337	*	5.776
	0	1.891	2.171	3.777	4.337		7.220
	15	1.891	2.895	3.777	5.782		8.663
75	-15	1.891	1.628	3.777	3.614	*	5.776
	0	1.891	2.171	3.777	4.337		5.776
	15	1.891	2.171	3.777	4.337		7.220
90	-15	1.891	1.628	2.832	3.614	*	5.776
	0	1.891	1.628	3.777	3.614		5.776
	15	1.891	2.171	3.777	3.614		5.776

* Execution aborted by the program

f_t = tensile strength of concrete, psi.



(a) Limestone coarse aggregate concrete.

(b) Silicious river gravel coarse aggregate concrete.

Fig C.1. Effect of tensile strength of concrete in crack spacing.

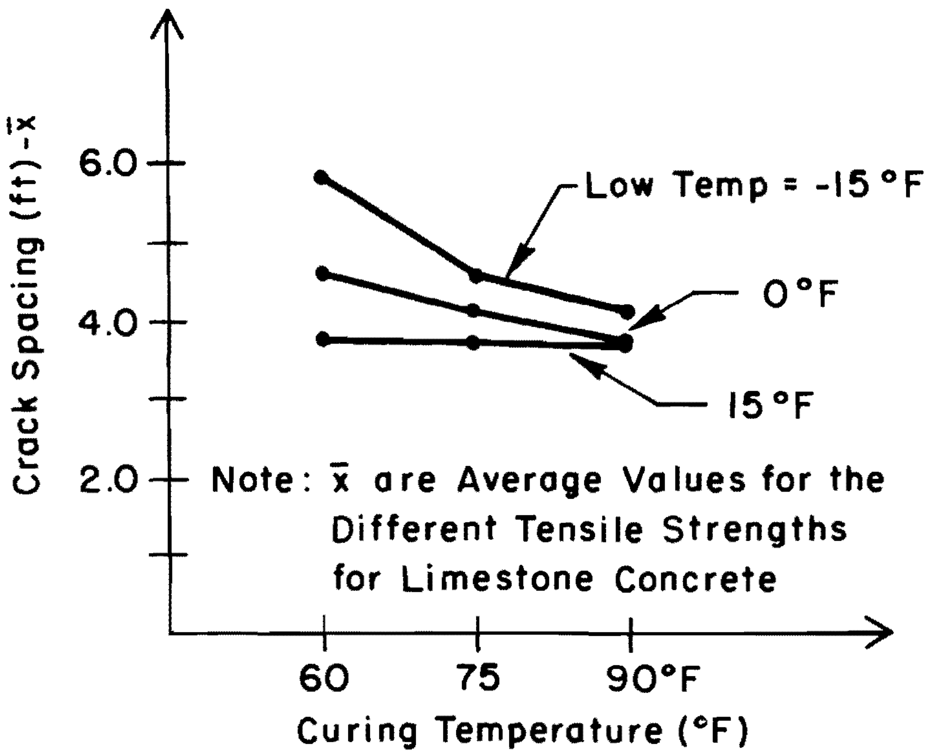


Fig C.2. Effect of temperature drop in crack spacing.

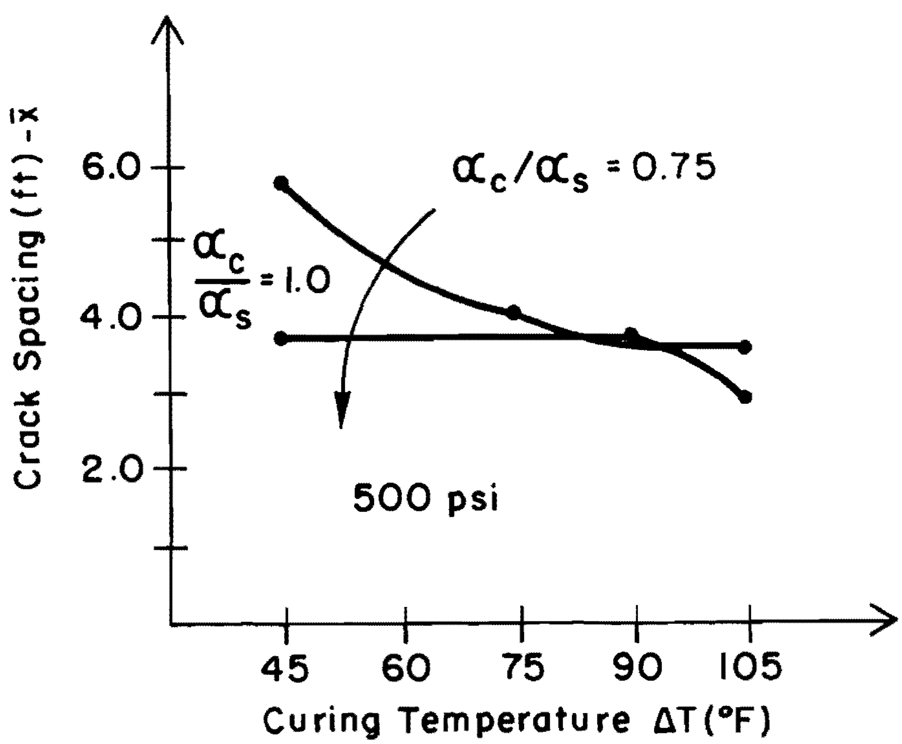


Fig C.3. Effect of thermal coefficients ratio in crack spacing.

APPENDIX D

USE OF DISCRIMINANT ANALYSIS TO EVALUATE THE DISTRESS CONDITION OF CRCP

APPENDIX D. USE OF DISCRIMINANT ANALYSIS TO EVALUATE THE DISTRESS CONDTION OF CRCP

INTRODUCTION

This Appendix describes the application of discriminant analysis technique to the evaluation of the distress condition of CRCP for the purpose of defining the terminal point for major rehabiliation. The specific objectives considered in this evaluation are

(1) the development of a utility function to assess a quality score to the pavement and

(2) the definition of a criterion for major rehabilitation or overlays on CRCP.

DISCRIMINANT ANALYSIS

Some of the pavements surveyed during 1974 were overlayed prior to the survey in 1978. The distress data recorded during the 1974 and 1978 Condition Surveys can be used to determine the reason leading to overlay; that is, having data on several variables from two groups, overlayed and nonoverlayed pavements, it is necessary to describe the difference between the groups.

One method for attacking the problem is to examine the group means and variances directly and describe the differences between the groups on each variable in turn. However, it may also be desirable to seek one or more composites of the variables such that the composites show maximum differences among means of composite scores and minimum overlap in the distributions of these scores. An approach such as this is called a discriminant function analysis.

The discriminant analysis is a statistical technique used to classify data into groups; its objective is to construct a boundary, that is, a discriminant equation, such that the elements of each group can be separated. Once the equation is defined, any new element can be assigned into one of the predetermined groups.

In the development of the disriminant function, a subprogram called "discriminant" of the statistical package SPSS was used (Ref 12).

RESULTS FROM THE ANALYSIS

The equation developed to discriminate is of the form

$$z = \sum_{i=1}^{n} a_i z_i \; ; \quad (i = 1, \ldots , n) \tag{1}$$

where

z = discriminant score,

a_i = weighting coefficients, and

z_i = standarized values of the n discriminating variables used in the analysis.

The standarized values z_i are calculated as follows:

$$z_i = \frac{x_i - \bar{x}_i}{\sigma x_i} \tag{2}$$

where

x_i = value of the distress manifestation i for the case being classified,

$\bar{x}_i$ = mean value of the distress manifestation i , and

σ_{x_i} = standard deviation for $\bar{x}_i$.

Table D.1 summarizes the parameters to be used with the equation presented above.

Therefore, if any pavement is evaluated by using the equations presented, a discriminant score, or zeta value, is obtained. This zeta value indicates if pavements with similar scores have or have not been overlayed. If z is smaller than -0.8 then there is a larger probability that the pavement under evaluation is a good candidate to overlay. Similarly, a pavement with z value larger than -0.8 has a larger probability of being in good condition.

TABLE D. 1. CONSTANTS TO BE USED WITH EQUATIONS (1) and (2)

i	Distress Manifestation	a_i	$\bar{x}_i$	σ_{xi}
1	Failures per mile	- 1.13	3.99	8.14
2	Minor spalling (percent)	- 0.49	21.36	15.17
3	Severe spalling (percent)	- 0.12	3.07	6.08
4	Pumping (percent)	0.04	3.78	5.91

TABLE D. 2. MEAN VALUES FOR OVERLAYED PAVEMENTS

Distress Mode	Mean
Failures per mile	15.567
Minor spalling (percent)	32.121
Severe spalling (percent)	4.962
Pumping (percent)	5.797

TABLE D. 3. NUMBER OF CASES CORRECTLY PREDICTED BY THE DISCRIMINANT EQUATION

Group	Number of Cases	Number of Correct Predictions	Percent
Overlayed	34	22	64.7
Nonoverlayed	199	185	93.0
Total	233	207	88.8

In order to simplify the interpretation of Eq 1, the z value can be modified so that is is compared to zero rather than to -0.8 by using the equation

$$z = 0.8 + \sum_{i=1}^{n} a_i z_i \qquad (3)$$

DEVELOPMENT OF A UTILITY FUNCTION

Once the discriminant function has been developed, it can be used to assign a utility value to any CRCP under evaluation. Several options can be followed:

(1) Use of z function as it is. The z values not only discriminate between overlayed and nonoverlayed sections when compared to the boundary value, but, depending on the magnitude of z, they indicate how good or how bad the distress in the CRCP is. The higher z, the better, and vice versa.

(2) Ignoring the sign of the z function. If the sign is ignored, each weighting coefficient a_i represents the relative contribution of its associated type of distress to the discriminant function. This weighting coefficient can be used in combination with utility curves of each type of distress.

The average utility can be obtained from an equation of the form

$$avu = u_f^a \times u_{ms}^b \times u_{ss}^c \times u_p^d \qquad (4)$$

where

avu = average visual utility,

u_f = utility assigned to a certain number of failures per mile, obtained from given curves,

u_{ms} = utility assigned to certain percent of minor spalling,

u_{ss} = utility assigned to certain percent of severe spalling, and

u_p = utility assigned to certain percent of pumping.

The exponents for Eq 4 can be defined as follows:

$$a = a_1/\Sigma|a_i|;$$

$$b = a_2/\Sigma|a_i|; \text{ etc.}$$

The remainder of the symbols are defined similarly.

(3) Utility developed from the z equation. There is a probability associated with each z value that can be used as a utility value for a CRCP facility. It is the probability that a given pavement belongs to the nonoverlyed pavement group; that is, if a pavement has probability close to one of belonging to the nonoverlayed pavement, then it is in good condition and its utility is equal to that probability. Conversely, if the pavement has a low probability of being in the nonoverlyed group, then its utility will be low.

In this appendix, only the third option is investigated further because it was felt to be the best approach for the following reasons: it may be obtained easier than the second approach because of boundary value problems, interpretation is easier than the first approach, and it may be derived directly from the discriminant analysis.

UTILITY FUNCTION DEVELOPED FROM THE Z EQUATION

Figure D. 1 is a plot of z value against the probability of belonging to the nonoverlayed group for any distress modes combination. An approximate equation that relates z to this probability is as follows:

For $z \geq 0$

$$u(z) = 1.0 - f(z)(b_1t + b_2t^2 + b_3t^3 + b_4t^4 + b_5t^5)$$

where

$u(z)$ = utility assigned to a pavement for a combination of distress modes with a discriminant score z .

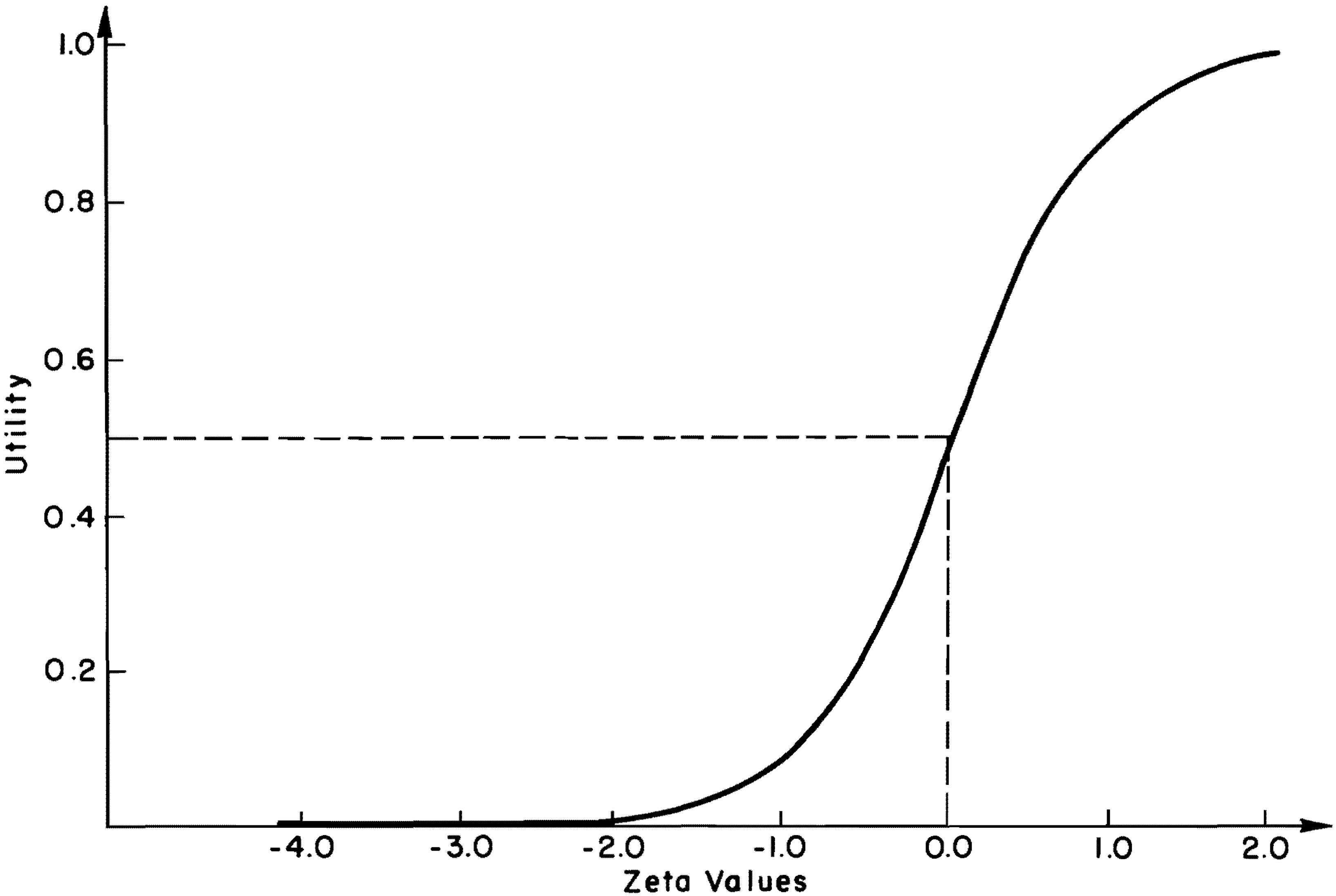


Fig D.1. Utility versus zeta values.

$$f(z) = \frac{1}{\sqrt{2\pi}} \exp \{- \frac{1}{2} (z)^2\}$$

$$t = \frac{1}{1 + 0.23164(z)}$$

$$b_1 = 0.31938$$

$$b_2 = - 0.35656$$

$$b_3 = 1.78148$$

$$b_4 = - 1.82126$$

$$b_5 = 1.33027$$

In the case of $z < 0$

$$u(z) = f(z)(f_1 t + b_2 t^2 + b_3 t^3 + b_4 t^4 + b_5 t^5)$$

where

$$t = \frac{1}{1 - 0.23164(z)} \quad \text{(Ref 13)}$$

Then, if the corresponding equation is applied to find the probability associated with a given z, the utility of a pavement with such z is determined. This utility value ranges from zero to one; the closer the utility is to one, the better the condition of the CRCP.

CRITERION FOR MAJOR REHABILITATION

According to the discriminant function we have already developed, if z is smaller than zero, the pavement would be classified as a candidate to be overlayed. Nevertheless, if we refer to Fig D.1, we may find that a smaller value of z could be adopted as criterion for deciding when to overlay.

Figure D.2 is an oversimplification of the distribution of the overlayed and nonoverlayed pavements. Pavements located in the "zone of conflict" are pavements that are not in a bad condition that may or may not have been overlayed. The derived z boundary value has been shifted to the right

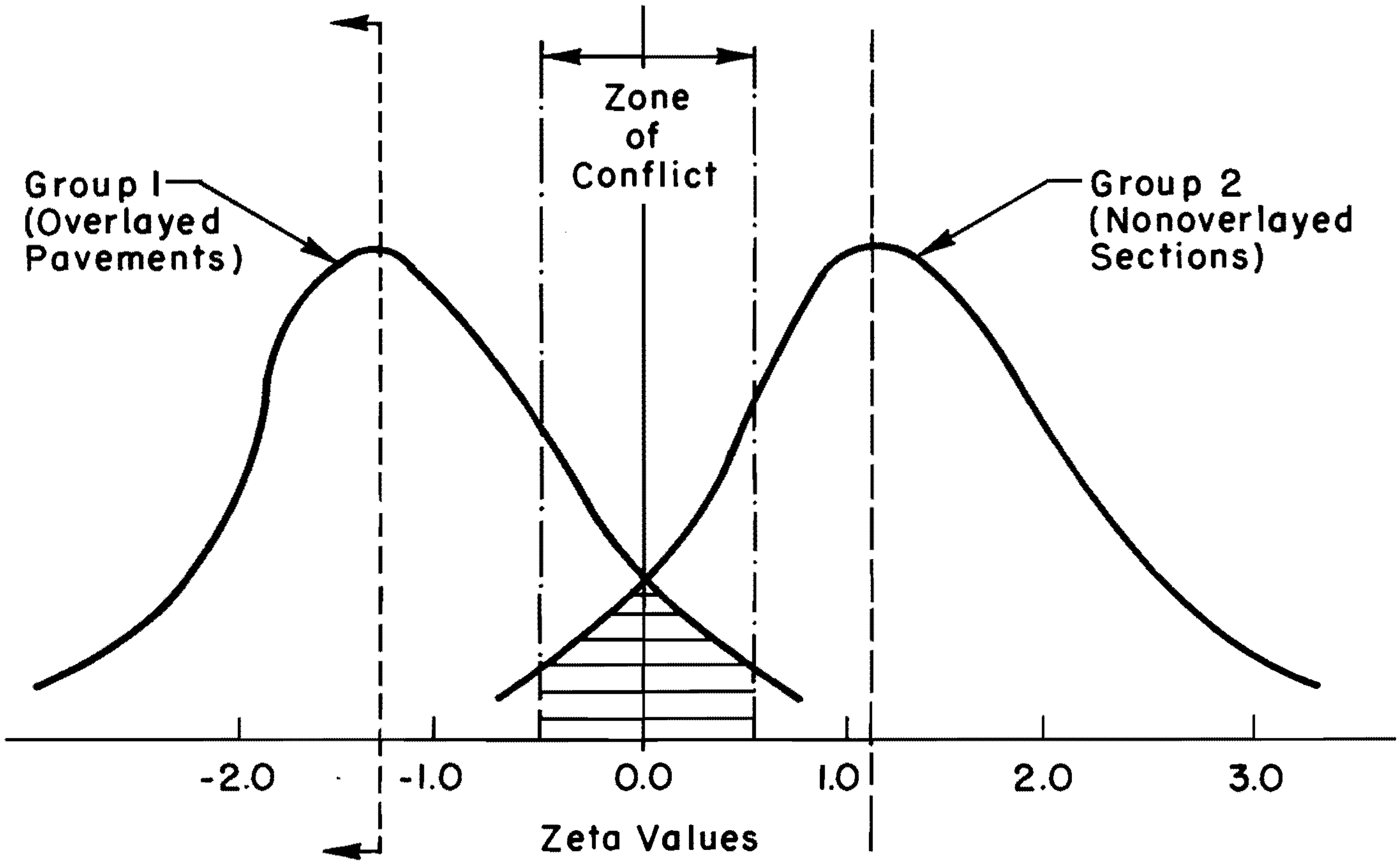


Fig D.2. Graphic representation of the distribution of data for the development of a criterion to overlay.

because of the existence of sections with negligible distress that have been overlayed. For these pavements, the criterion followed to overlay apparently was not a combination of the distress modes considered.

After further consideration, it was felt that a better criterion for deciding when to overlay is the mean z value for the group of overlayed pavements. This mean z value is calculated by substituting the mean distress. values calculated for this group into the discriminant equation. These mean distress values are summarized in Table D.2.

From the discriminant function

$$\begin{aligned} z &= (\Sigma a_i z_i) + 0.8 \\ &= - 1.13\ z_i - 0.49\ z_2 - 0.12\ z_3 + 0.04\ z_4 = 0.8 \\ &= - 1.98 + 0.8 \\ &= - 1.18 \end{aligned}$$

where

$$z_1 = \frac{15.56 - 3.99}{8.14} = 1.42$$

$$z_2 = \frac{32.12 - 21.36}{15.16} = 0.71$$

$$z_3 = \frac{4.96 - 3.06}{6.08} = 0.31$$

$$z_4 = \frac{5.80 - 3.78}{5.90} = 0.34$$

In terms of degree of utility, this z value becomes

$$a < 0$$

Therefore,

$$5 = \frac{1}{1 - 0.23\ (-1.17)} = 0.79$$

$$f(z) = \frac{1}{\sqrt{2\ \pi}} \exp\{- \tfrac{1}{2}\ (1.18)^2\} = 0.20$$

$$u(z) = 0.12$$

The criterion proposed for deciding when to overlay are

(1) Any pavement with utility $u(z) \leq 0.12$ should be overlayed.

(2) If the cost of repairing a pavement is larger than the cost of overlaying, that pavement should be overlayed.

REMARKS

At this stage, it is important to mention some points inherent to the approach that has been followed and that might invalidate the results:

(1) The discriminant function obtained is linear, this might not be the case. This situation arises from the fact that the mathematics involved in the discrimant analysis are based on the assumption that the distributions of the groups are equivalent (variances and covariances should be the same in both groups).

(2) The variables have been assumed to be normally distributed.

(3) The subjective decision of overlaying the sections that was used in the analysis has been assumed to be the correct decision criteria.

(4) The data points used are not comprehensive. That is, for distress values outside the range of the data, the z equation derived is not applicable.

(5) Not all the distress types have been included. The criterion followed for deciding whether or not to overlay some of the sections used in our analysis could have been different than the combination of the distress types used here.

In spite of the restrictions mentioned above, the prediction results obtained from the z score are encouraging. In Table D.3, the cases correctly classified by the z equation are summarized; the points used to test the prediction capability of the discriminant function are the same as the ones used to develop the equation.

Also, it is believed that this approach is a step further in the rationalization of the evaluation of the distress condition of a pavement.

THE AUTHORS

Manuel Gutierrez de Velasco received his B.Sc. in Civil Engineering at the University of Guadalajara, Mexico, in 1974; he obtained a M.S. degree from the University of Mexico (UNAM) in 1976. He has worked in the area of concrete structures in several consulting firms in Mexico; he also worked for the Mexican Institute of Cement and Concrete (IMCYC). He joined the Center for Transportation Research in 1978 as a research assistant and currently is pursuing a Ph.D. degree at The University of Texas at Austin with research in the field of concrete pavements.

B. Frank McCullough is a Professor of Civil Engineering at The University of Texas at Austin, and is Director of the Center for Transportation Research. He has strong interests in pavements and pavement design and has developed design methods for continuously reinforced concrete pavements currently used by the State Department of Highways and Public Transportation, U.S. Steel Corporation, and others. He has also developed overlay design methods now being used by the FAA, U.S. Air Force, and FHWA. During nine years with the State Department of Highways and Public Transportation he was active in a variety of research and design activities. He worked for two years with Materials Research and Development, Inc., in Oakland, California, and for the past nine years for The University of Texas at Austin. He participates in many national committees and is the author of over 100 publications that have appeared nationally.