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16. Abstract

The structural performance of continuously reinforced concrete pavements in the State of Texas has become a matter of great importance to administrators since about 3000 miles of 24-foot wide pavement of this type have been built in the last fourteen years. This report concerns itself with the condition survey and the analysis of the data in the wide field of possible strategies.

The survey form developed made a survey from an automobile, travelling on the shoulder of the pavement, possible. A two-man team was used to cover around 12 miles per day. A statistical analysis, based on the rating of three teams on single pavement sections, allows control of the quality of rating.

Several ways of analysis of the data are discussed, some of which are plots of distress as surveyed by the teams, a summary statistic in the form of a histogram and the possibility of calculating a single figure depicting distress by assigning weights to each category of distress. This figure is defined as distress index in this report.

Research into the relative importance of each type of distress is started on in the report. This will assist in compiling the distress index as well as in the assessment of important distress manifestations in the pavement from a maintenance point of view since an early prevention of distress may prevent subsequent failures.

It is concluded that the survey form serves a useful purpose and that the survey results are useful in design, maintenance, and research.

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A PERFORMANCE SURVEY OF CONTINUOUSLY REINFORCED CONCRETE PAVEMENTS IN TEXAS

by

B. Frank McCullough
Pieter J. Strauss

Research Report 21-1F

Pragmatic Application of Rigid Pavement Research

Research Project 3-8-74-21

conducted for

The Texas Highway Department

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

by the

CENTER FOR HIGHWAY RESEARCH
THE UNIVERSITY OF TEXAS AT AUSTIN

November 1974

PREFACE

A proposal, submitted in March 1973, discussed the probability of strengthening current pavement design techniques as well as special attention to difficult problems encountered in pavement design and maintenance. The aims and methods changed as the research developed to encompass a proper condition survey of all continuously reinforced concrete pavements (CRCP) which could serve a threefold purpose, namely the determination of the present structural condition of CRCP in Texas for planning purposes, to assist in the location of problem sections which need attention and to aid in a data feedback system as a part of the pavement management system presently being developed in the state of Texas.

This is the first and last report of work done under this project and it entails the background that led to the research as well as the scope of the study. The development of a survey form that fits the need of all concerned, is elaborated on. This was the main concern since the whole study depended on the successful survey of the condition of continuously reinforce concrete pavements.

Once the success of an objective survey was ensured, attention could be paid to analysis of the data to fulfill the needs of design, planning, maintenance and research.

The results of the study as a whole, contributes to a better understanding of the performance of continuously reinforced pavements and can be used in the data feedback system which forms part of the rigid pavement management system.

This project is supported by the Texas Highway Department in cooperation with the Federal Highway Administration, Department of Transportation. Their sponsorship and support are gratefull acknowledged.

B. Frank McCullough
Pieter Strauss

November 1974

ABSTRACT

The structural performance of continuously reinforced concrete pavements in the State of Texas has become a matter of great importance to administrators since about 3000 miles of 24-foot wide pavement of this type have been built in the last fourteen years. This report concerns itself with the condition survey and the analysis of the data in the wide field of possible strategies.

The survey form developed made a survey from an automobile, travelling on the shoulder of the pavement, possible. A two-man team was used to cover around 12 miles per day. A statistical analysis, based on the rating of three teams on single pavement sections, allows control of the quality of rating.

Several ways of analysis of the data are discussed, some of which are plots of distress as surveyed by the teams, a summary statistic in the form of a histogram and the possibility of calculating a single figure depicting distress by assigning weights to each category of distress. This figure is defined as distress index in this report.

Research into the relative importance of each type of distress is started on in the report. This will assist in compiling the distress index as well as in the assessment of important distress manifestations in the pavement from a maintenance point of view since an early prevention of distress may prevent subsequent failures.

It is concluded that the survey form serves a useful purpose and that the survey results are useful in design, maintenance, and research.

KEY WORDS: performance, CRCP, structural, condition, analysis, statistical, distress.

SUMMARY

A method for surveying the condition of continuously reinforced concrete pavements in the State of Texas is developed. The different types of distress are defined and documented in a manual. An easy way to survey the distress quantitatively is discussed. The form used in the survey allows the survey to be done from an automobile traveling on the shoulder of the pavement at about five miles per hour.

Different teams are used to do the survey and the apparent differences between teams are analyzed statistically. It was found that the differences are insignificant so that the sample checking by two outside teams have been abandoned.

The survey form is drawn up in a sequence of increase in distress to the final stage of total failure. This sequence is confirmed by the results of the survey and it paves the way to the development of a distress index which depicts the present condition of a pavement from a maintenance point of view. This index is also useful to designers.

Results of the survey in different districts are presented in the form of histograms.

IMPLEMENTATION STATEMENT

Many of the results of the survey have been implemented by the different districts. The results give an objective view of existing repair patches as well as the size and distribution of failures. This enables the maintenance man to plan future activity in the form of manpower and finance.

Results of the survey are utilized in a present study to establish immediate changes in design procedures. This study has as its purpose the evaluation of the different types of distress in terms of design parameters which can be controlled at the time of design construction. Implementation of the results into design procedure, therefore, is not so obvious at this stage. However, it is possible to start implementing the concept of preventative maintenance since the sequence of distress formation has been established and early signs of future distress can be located. The distribution of failures throughout the State is also known to design engineers who can work towards a change in methods of design to improve performance.

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CHAPTER 1. INTRODUCTION

Continuously reinforced concrete pavements (CRCP) have been in use since 1938 and have rendered good service under diverse climatic conditions in several states, including Indiana, Illinois, Texas, California, Mississippi, New Jersey, Michigan, Maryland, and Pennsylvania. Texas alone has close to 3000 miles of 24-foot-wide CRCP, and the oldest pavements, which are around 15 years old, are still in service on heavily trafficked interstate highways.

Texas has employed the pavement management system to a great extent (Ref 1). A very important part of this system is the prediction of future performance with a knowledge of present day design parameters and the behavior of pavements in use. Furthermore, the feedback data system has become indispensable for proper management, not only from a design point of view but, even more important, for the maintenance of existing pavements.

The need to predict performance and thus maintenance strategy has stressed the importance of developing a systematic procedure of surveillance. Different methods to achieve this goal have been investigated and some have been put into use. This report deals with the survey of CRCP in mainly rural Texas.

Background

Several research studies in rigid pavement design have been completed in recent years. Although the findings have made a significant impact on present day pavement design procedure, the performance of pavements frequently is different than expected or predicted. The need to define the extent of this difference and to outline the probable reasons for it has been apparent for a long time. Since the Texas Highway Department (THD) has invested extensively in the construction of continuously reinforced concrete pavements, a research project was initiated in which a systematic objective approach to surveying the existing CRCP could be developed.

The understanding of the behavior of rigid pavement and specifically CRCP was greatly improved by the results of research studies such as the performance of CRCP (1-8-63-66), the subbase design project (3-8-66-98), the design manual revisions project (3-8-71-502), and the system analysis program project (1-8-69-123). The implementation of most of this knowledge is being carried out in present day design procedures. However, as a result of the above mentioned research, the need to predict the performance of CRCP more accurately was recognized. The goal was to discover the contributions of all the different elements to the general performance and the relative sensitivity of each element. Texas has the unique opportunity to pursue this investigation since a vast number of experimental projects have been incorporated in the highway system, in the planning or in the process of constructing CRCP. Some of these experimental pavements have turned out to be "headaches" to maintenance engineers, but a considerable amount of data that has been collected through the years can be analyzed, processed, and used for improving design, construction, and maintenance procedures.

Everyday designs of CRCP, however, have not escaped failure and in some instances special problem areas were encountered. A question, therefore, arises: "How many problem areas exist and what is the general condition of CRCP in Texas?" Since CRCP has been constructed in virtually every type of environmental condition that exists in Texas, the need to compare supports the idea of a proper and systematic survey of the condition of CRCP in Texas.

Around 1700 miles of 24-foot-wide CRCP pavements have been constructed in rural Texas since 1958. Very little of this has been overlayed and virtually all of it is still exposed to traffic and climate. Since the CRCP is used in every possible climatic and traffic condition in Texas, it provides an excellent opportunity to study the contribution of all factors in the performance. Unfortunately, there has been no common yardstick to measure structural performance, and the validity of certain claims, such as the one that the performance of CRCP under certain conditions is superior, has not been established thus far.

Experimental pavements were built in the period 1958 - 1964 with an accurate monitoring of behavior at that time. Several reports were written on this subject as well as on their performance. This practice has, however, been discontinued since then, and it may be considered a timely action to assess the performance of old test sections after a period of more than 12 years of satisfactory use. Furthermore, the introduction of the systems analysis of rigid pavements has precipitated the need to predict future performance, using existing design criteria and a knowledge of present behavior. One way to do this is to assess structural performance and correlate that with serviceability and maintenance.

Generally, therefore, the time was ripe to initiate a systematic and objective way of assessing the present condition of CRCP in Texas. This survey can be used in numerous ways to assist present design, maintenance, and research procedures.

Objectives of the Study

Initially, the proposal for this study aimed at the analysis of unique problems and a limited performance study: "to assist the Texas Highway Department design personnel in solving unique design and performance problems, setting up field studies and analyzing the data obtained; and to conduct a limited performance study made of concrete pavements in the Gulf Coast Area in order to establish immediate design criteria."

This objective was extended to include a comprehensive survey of all continuously reinforced pavements in the state of Texas in order to test the applicability of rigid pavement research done so far. 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 but detailed performance studies could be set up for research on the establishment of new design criteria.

Scope of Study

There are numerous problems in the design and performance of CRCP that need specialized analysis outside the routine design procedure. Since numerous failures have occurred in recent years on some projects, the question of the qualitative distribution of similar potential and existing failures in Texas arose. These could not be determined at the time and a systematic survey was needed to achieve the goal. Furthermore, a need to know the general condition of CRCP in Texas was felt, to be used to estimate general performance and as a predictor of future maintenance.

In pursuit of the common goal, namely a quantitative measure of distress, a survey form was developed. An accompanying manual on the definitions of the different types of distress provided the means to train different teams to do the survey. The greatest amount of time was spent on accumulation of data from the survey of pavements, especially in rural Texas. However, as part of the research program, several experimental sections as well as sections where excessive failures were experienced were surveyed in detail. Special studies were initiated as a result of special design problems in an Urban District. These design studies mainly covered comparative analyses of flexible and rigid pavements utilizing different design approaches.

During the period of survey and research, regular communication between the Highway Design Division of THD and the CFHR at The University of Texas was maintained and was indispensable for the common good of the project.

Scope of the Report

Since December 1973, the time when the project began, a survey form and a manual of instructions for using the form have been developed. Generally, due to a lack of time and funds, only rural areas of Texas have been surveyed so far, except for a few experimental surveys in one urban district. Although this report covers only the sections surveyed, it is felt that the results can be applied generally throughout Texas, since all possible climatic conditions have been covered as well as many sections under severe traffic conditions.

Previous research has given a good feel for the possible types of distress that can be encountered (Ref 2). A survey form and an accompanying manual were compiled, which include only six distress types. This enabled the survey to be done by different teams with a regular check by an outside agency to establish a common standard of survey. The development of this form as well as the survey itself is discussed in Chapter 2.

The results were analyzed and plotted by a computer; a statistical analysis on the condition of every section, in the form of a histogram to illustrate the percentage of occurrence of every distress, was added; and the resulting reports were sent to the different districts via the Highway Design Division of THD.* The analysis of the results and compilation by computer of

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*These reports are available in District offices, D-8 of THD, and CFHR.

a detailed printout of the quantitative distribution of distress are elaborated on in Chapter 3.

Certain problem and experimental areas are further analyzed in Chapter 4 to determine reasons for untimely failures. An effort was made to isolate predictors of poor performance, from which future performance could be established. This type of analysis required the quantitative assessment of distress, which also lends itself to the determinations of a single numerical value of performance, percent failure or a distress index, which can be used to compare different sections or for any other purpose associated with performance or serviceability.

The survey thus enabled engineers to determine problem areas, areas of failure or potential failure, for maintenance planning and gave an idea of the present day condition of CRCP.

CHAPTER 2. DEVELOPMENT OF SURVEY FORMS

The background and requirements of the proposed survey of CRCP have been discussed in the previous chapter. The development of the survey form itself, the definitions of the types of distress under investigation, and the quantitative analysis of the survey will be discussed in this chapter.

Requirements of the Survey

Experience gained in previous research (Ref 2) led to the belief that distress in CRCP could be divided into a few distinct groups. Furthermore, a survey form had to be implemented for this project which allowed the survey to be done from an automobile traveling at approximately 5 mph in order to complete a statewide survey in a reasonable time. Definite guidelines had to be established which would permit different teams to do the survey, with an adjustment calculated from a statistical analysis on a sample section surveyed by three or more teams to give all surveys a common standard.

Six distinct patterns of distress were distinguished from the surveys under project NCHRP 1-15, Design of Continuously Reinforced Concrete Pavements for Highways, namely, transverse cracking, radial cracking, longitudinal cracking, spalling, pumping, and punch outs. This project has as its purpose the survey of distress due to factors other than those caused by design or construction practices, such as longitudinal cracking due to subgrade subsidence or poor joint construction and regularly spaced transverse cracking due to specific design procedures. Repair patches were included as a final indication of structural failure and to assist the THD in assessing past maintenance expenditures and to predict a possible future area for more maintenance.

Sequence of Distress

The CRCP can be designed for a particular initial crack spacing by varying factors such as concrete properties, steel reinforcement, and subbase friction (Ref 3). Further distress occurs as a result of traffic induced loads and environmental conditions. To assist in the analysis, the survey form was arranged to reflect the increasing order of distress formation. It was believed that an undesirable set of circumstances could lead to a condition in which the spacing of transverse cracks would be reduced under traffic and environmental conditions until a spacing of 18 inches to 30 inches was reached. This progress of cracking could result in the entry of surface water into subgrade layers and in the reduction of slab stiffness. Excessive moisture could result in pumping and with the reduced slab stiffness, increase deflection of the slab with consequential spalling of the cracks as well as longitudinal cracks between closely spaced transverse cracking. This secondary longitudinal cracking, with spalling and pumping, frequently leads to punch outs. This primary stage of slab longitudinal cracking was therefore defined as "minor" punch outs. Whenever these blocks moved excessively and became loose the condition was defined as "severe" punch outs. Factors which may not be traffic related but may affect future performance, such as surface spalling and localized cracking, were also included.

Generally, the distress was classified into the six categories. A qualitative difference within every category was distinguished by defining the "minor" and "severe" case. This sequence of distress in the field is reflected in the survey form, Fig 1. A detailed definition, using photographs as well as a more detailed discussion of every distress type, is included in Appendix A.

Quantity of Distress. The speed of surveying made it impossible to measure the quantity of every type of distress properly. A system of quantification had to be developed, and, for this purpose, an estimation of percentage was found to be convenient. Since the maintenance engineer is most interested in the extent of structural failures, the actual size of punch outs and repair patches had to be estimated.

Transverse and localized cracking lends itself to a quantitative definition of percentage of pavement area that is distressed in this way. The percentage of cracks that had spalling forced the surveyor to investigate every crack for spalling. Pumping was measured where it occurred in the longitudinal joint between the pavement edge and the shoulder. Pumping of the edge was surveyed to avoid mistaking the staining of the transverse cracking

CRCP

PERFORMANCE SURVEY

District	Control	Section	Highway	County	Leave Blank	Date Mo. Day Yr.
17	274	4	IH 45 NB	Sterling		01-14-73

Leave Blank	Location From	To	Raters
	Darling	2.5 mi. North of Silver	J. Jones & F. Smith

Mile Post	Mile Point	Transverse Cracks % M 1-5	M 5-20	M 20-50	M 50-100	S 1-5	S 5-20	S 20-50	S 50-100	Localized Cracks % M 1-5	M 5-20	M 20-50	M 50-100	S 1-5	S 5-20	S 20-50	S 50-100
314.0	31.231	1								1							
314.2	31.431		1											1			
314.4	31.631						1			1							
314.6	31.831					1				1							
314.8	32.031						1			1							
315.0	32.231						1				1						
315.2	32.431																

Mile Post	Spalling % M 1-5	M 5-20	M 20-50	M 50-100	S 1-5	S 5-20	S 20-50	S 50-100	Pumping % M 1-5	M 5-20	M 20-50	M 50-100	S 1-5	S 5-20	S 20-50	S 50-100
314.0		1							1							
314.2	1					1							1			
314.4	1									1						
314.6		1			1											
314.8					1				1							
315.0						1			1							
315.2																

Mile Post	Punch Outs in feet M 1-3	M 4-9	M 10-19	M > 20	S 1-3	S 4-9	S 10-19	S > 20	Repair Patches Square feet A.C. 1-15	A.C. 16-120	A.C. 121-240	A.C. >241	P.C.C. 1-15	P.C.C. 16-120	P.C.C. 121-240	P.C.C. >241	Ride
314.0																	3.3
314.2		2			1				3					1			3.0
314.4	1														1		3.2
314.6										2							3.1
314.8	1																3.4
315.0	2		1											1			3.2
315.2																	

M - Minor S - Severe A.C. - Asphalt P.C.C. - Portland Cement

Condition of Shoulder Good surface, Side Joint Open, Repair not successful, Long. cracking

General Comments Condition fair, Drainage good except at mile 314.3, Longitudinal cracking at 314.6, Survey done on wet pavement, Construction Joint Bad 314.1

Fig 1. Performance survey sheet.

for pumping of these cracks and to have a common definition for pumping irrespective of climatic conditions at the time of the survey.

The lengths of punch outs and the size of repair patches were estimated and the count was listed under the appropriate column. The procedure is described in detail in Appendix A of this report.

The quantitative scales for transverse cracking, localized cracking, spalling, and pumping were reduced to percentage scales whereas punch outs and repair patches were quantified in four convenient size categories as shown in Fig 1. Four categories were chosen, to facilitate the estimation of size or length. Distress measured in percentage was also classified in four categories. The limits were chosen so that five categories of quantity could be established for statistical reasons. Thus, the two outside limits of 0 and 100 were established. However, a quantity of less than one percent was deemed as insignificant and hard to define in any case. The limits then reduced to one and 100 with four categories to be established. The estimation of plus or minus 50 percent of distress can be made fairly accurately. Therefore, 50 percent was established as one limit which left the last 50 percent to be subdivided into three categories. This was done by two limits, at 20 percent and 5 percent, which form a regular spacing on a log plot, with 5 percent five times the first limit of one percent, 20 percent four times the 5 percent limit, 50 percent about three times the 20 percent limit, and 100 percent two times the 50 percent limit. Figure 1 is an example of the proposed survey form. At the top, lines are included to meet the need for defining the exact position of the survey itself. Rideability was included to provide a team rating of the general serviceability of the sections. Two lines at the bottom of the sheet provide space for comments on distress other than those surveyed.

The Survey. A decision to survey the road from an automobile traveling at approximately 5 mph was made in the early stages of the project. This decision had a big influence on the simplicity of the form as well as the technique of the survey. The most reliable method of survey was found to be a two-man team, which allowed the division of responsibility for the six items on the survey sheet. Experimental surveys of 0.1, 0.2, 0.5, and 1.0-mile sections proved the survey of 0.2-mile sections to be the best, especially since a two-man team had to do it. The method of survey is discussed in detail in Appendix A.

An average of four teams per district were trained in the survey method with the aid of color slides, a manual, and the experimental survey of a short section. These teams did the bulk of the survey while teams from the Research Section of the Planning Design Division and the Center for Highway Research monitored 10 percent of the total length for statistical comparison and uniformity.

Statistical Comparison of Texas. All the CRCP that was surveyed in every district was surveyed by the district personnel themselves. Ten percent of the road length was additionally surveyed by teams from THD (D-10) and CFHR as a means of determining the variation amongst teams and to be used as a factor of adjustment to bring all ratings to the same standard.

Since a decision based on an ordinary calculation of standard deviation and the associated coefficient of variance or a confidence interval within which all team ratings should fall for acceptance was not practical in this case, an engineering approach was chosen, namely, the use of a control chart. The average of the three team ratings was taken as the correct rating. From this, two limits could be established using the unbiased estimator of the actual mean rating and the unbiased estimator of the actual standard deviation. The control limits were established as plus or minus one quantitative rating higher or lower than the correct rating. Thus, it could be determined whether a team's rating was within control or not. An example of a chart is shown in Fig 2 and a detailed discussion of the procedure of analysis is included in Appendix B.

A visual comparison of the different ratings led to the same conclusion since, for example, one team might have estimated 19 percent spalling whereas the average was 21 percent. This would have had ratings in two different categories, but essentially both are the same estimation of 20 percent.

The results of the statistical analyses indicated a high standard of survey on the side of the district teams. Initial differences could be traced to the method of schooling, but an increase in the number of slides and examples of estimation improved the standard to such an extent that the rating of the third team on a 10 percent sample basis was abandoned for the last three district surveys. The control was not seriously affected since it was found that the team rating from the CFHR nearly always coincided with the average of the three teams.

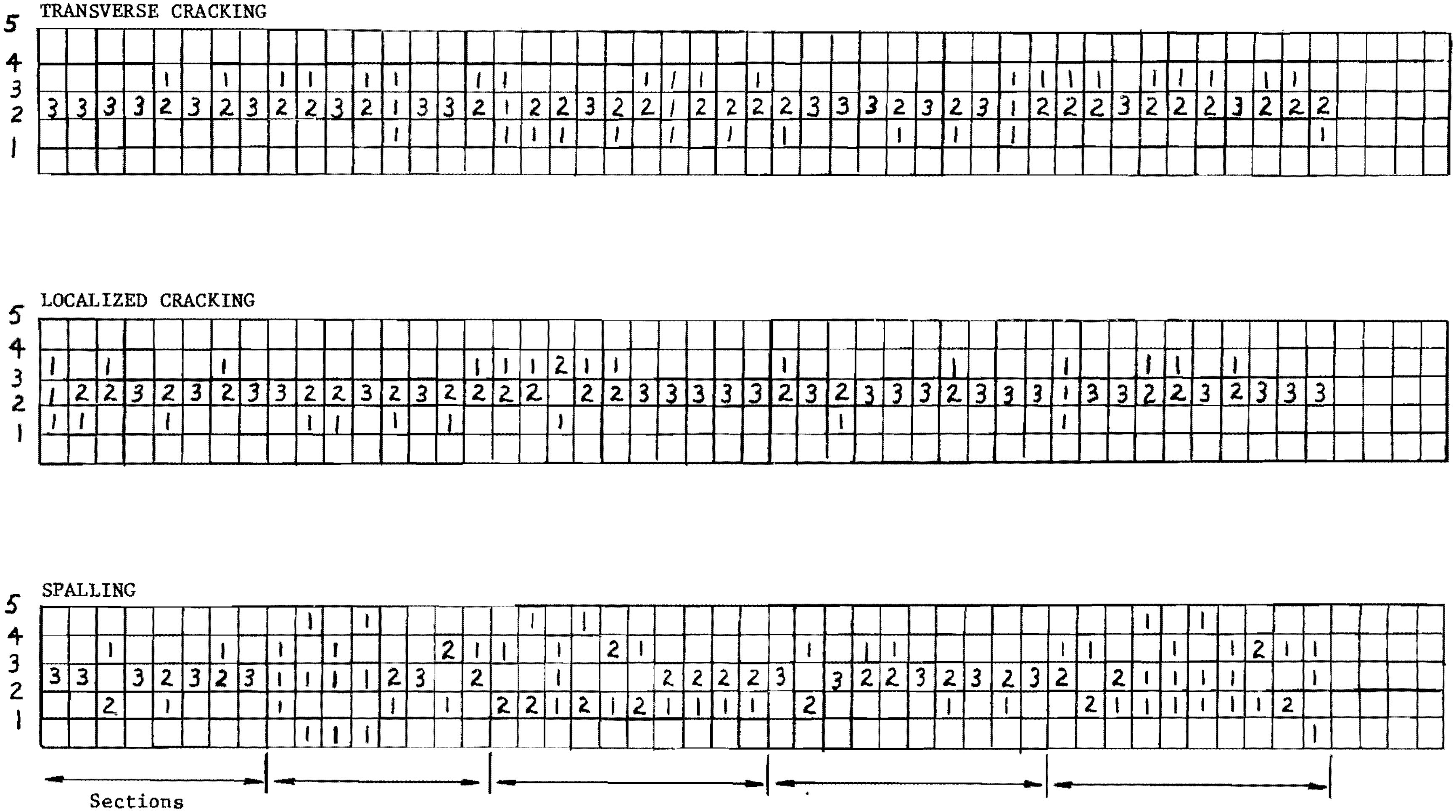

Fig 2. Summary of control survey.

In general, it can be concluded that the surveys were done satisfactorily and only minor changes woulc be necessary to bring the comparison up to a common standard throughout the state. The survey form itself proved to be successful and the procedure of survey holds promise for the future.

CHAPTER 3. RESULTS

The vast amount of data collected in the field was available only on survey sheets, and these had to be processed and reported in a way which was useful to the THD districts as well as design divisions. The first reports were compiled on the conditions of CRCP in every district itself without any effort to analyze the data. The reason for this was to provide the data in a handy format for analysis and comparison within every district itself. Adjustments to surveys so that all studies would reflect information based on the same common standard will come after the circumstances that led to minor discrepancies are researched.

Data Storage

Efficient use of the available survey data was possible only if storage was properly done. Since the data on the survey sheets could easily be transferred onto computer cards, the computer was utilized for storage as well as reporting in the form of graphs.

The different sections of highways surveyed are stored under road number, control and section number, lane surveyed, and date of survey. A plot of the amount of distress against milepoint readings was obtained by using the computer. This plot facilitated the comparison of sections and the development of distress. Figure 3 illustrates this point; two types of distress, namely spalling, minor and severe, and pumping, minor and severe, are shown. The extent of the two types of distress as well as the severity can easily be detected. The close relationship between the two distress types is obvious in this particular section, and this is of great assistance in maintenance planning and research.

Milepoints were used instead of mileposts at the request of the Highway Design Division. The milepoint refers to a figure on the road inventory log, which means that it will be a fixed point as long as the road exists. The same cannot be said of the mileposts since they may change in the future.

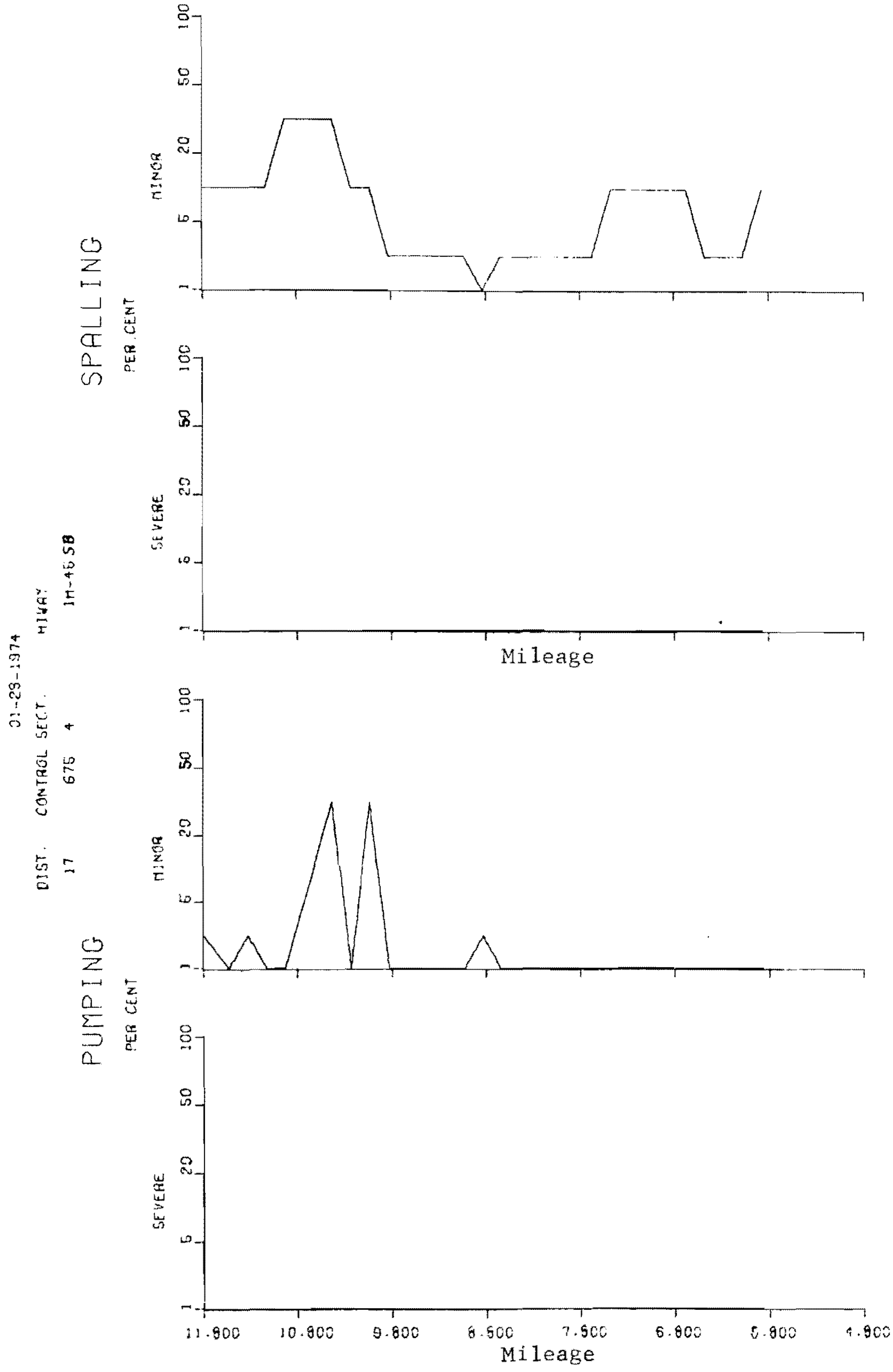

Fig 3. Typical diagram of distress versus distance.

Summary Statistic

A further aid in the analytical process was the construction of histograms on which the frequency of the occurrence of a particular quantity of distress is displayed. This is illustrated in Fig 4, a histogram of the relative distribution of the different types of distress in rural Texas. A detailed discussion of the compilation of histograms as well as the summary statistic for each district is contained in Appendix C. Here it is sufficient to say that a figure of 24 percent of 5 to 20 percent minor transverse cracking means that 24 percent of all sections surveyed in rural Texas in the case of Fig 4 have between 5 and 20 percent minor transverse cracking. This type of summary statistic provides an opportunity to determine the extent of certain types of failures and is useful in comparing sections.

As mentioned above, a histogram for each district is included in Appendix C. Certain general conclusions can be drawn from a study of these histograms:

(1) Districts in the relatively colder, north, part of Texas had more localized cracking.

(2) The eastern districts of the state, where wetter conditions are experienced, show more transverse cracking.

(3) Districts with highways that carry relatively heavy loads of traffic and which are located in the wetter parts experience more pumping.

These histograms have been adjusted so that by using the control surveys they reflect the relative performance for comparison. A general histogram for all the CRCP that has been surveyed in Texas is included in Fig 4 of this report.

Another way of comparing sections is illustrated in Fig 5. The figure depicts spalling and pumping on a four-lane highway built with exactly the same materials and using the same specification. One lane leads from a major part and the other lane feeds traffic towards the part. Since no other external factor but a difference in traffic could cause the damage, it is obvious what the effect of traffic load is.

Although the above exercise gives a fairly good representation of the existing condition and provides a tool for comparison between districts, a need still exists for one figure depicting distress. A conceptual method of deriving a distress index by giving relative weighting factors to each type of

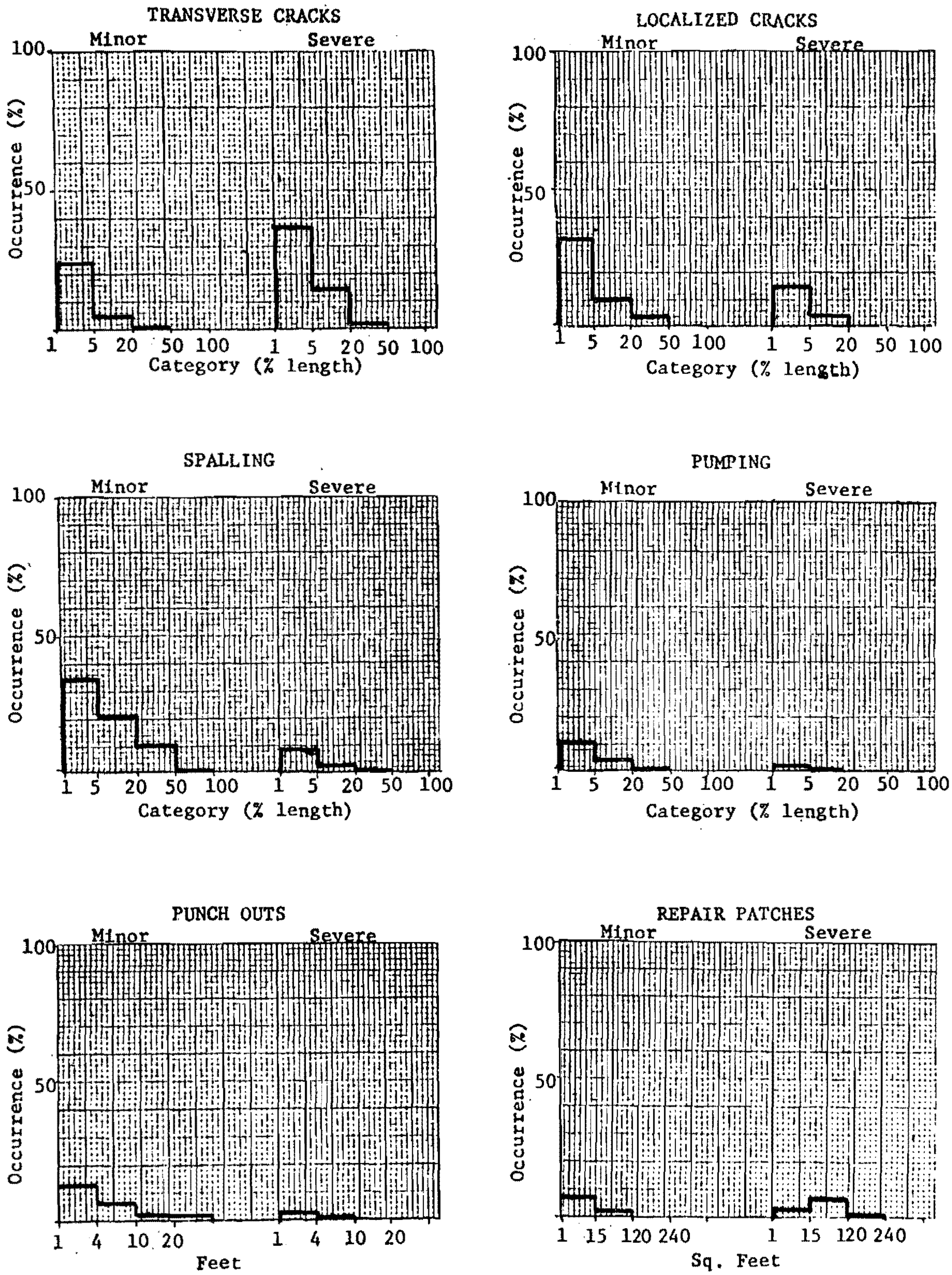

Fig 4. Distribution of distress in rural Texas.

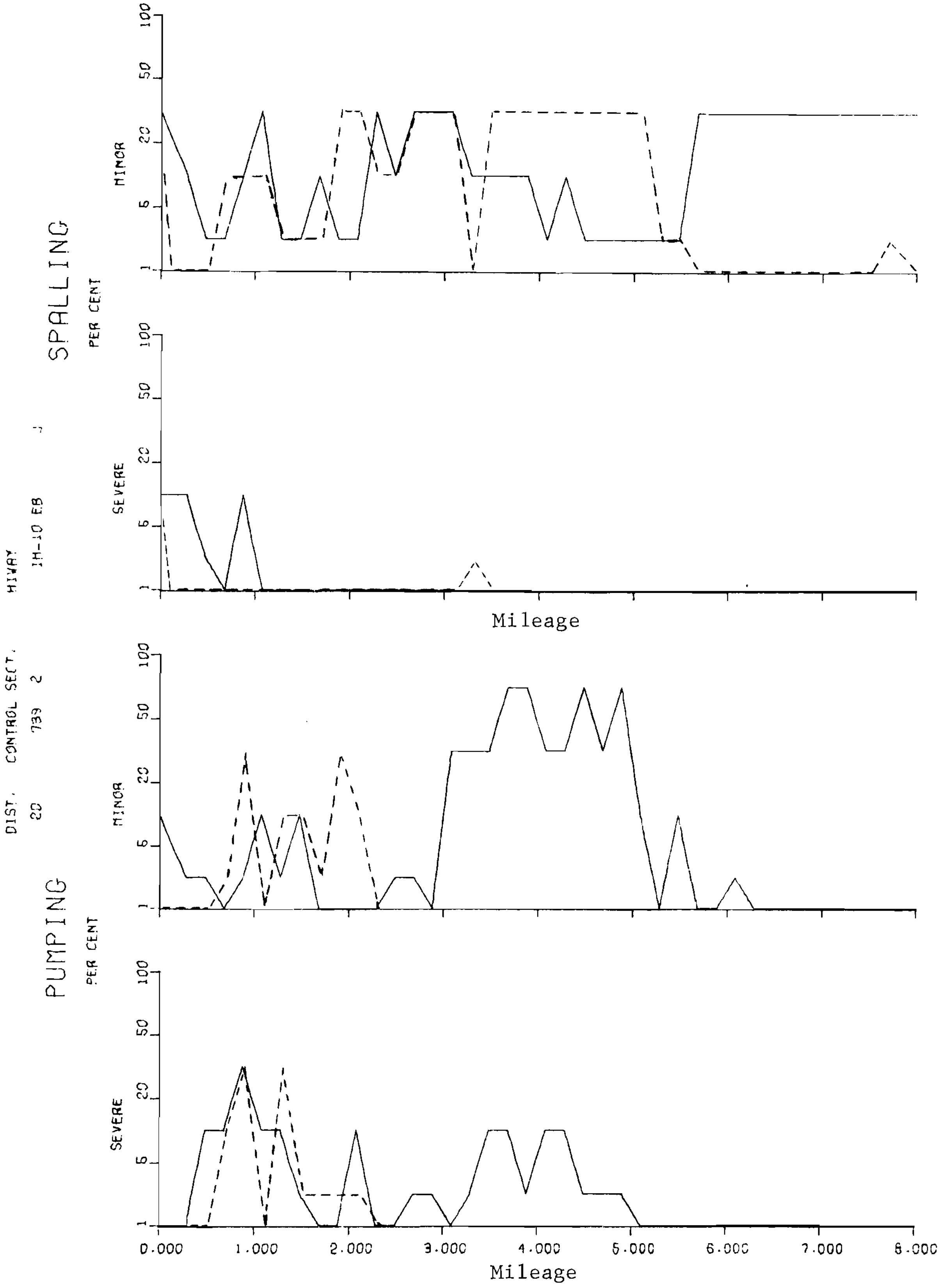

Fig 5. Difference in distress between two lanes.

distress is utilized in the next chapter to determine the influence of early types of distress on the final performance.

CHAPTER 4. MANIFESTATION OF FAILURE

Basic reporting techniques such as plots and histograms for each control/section in every district were utilized in the first reports to the districts.* This report contains, in Appendix C, adjusted summary statistics for each district in the form of a histogram that depicts the current status fairly accurately. These methods, however, do not relate distress or failure closely enough in that quality and quantity of distress are not combined into one figure that depicts percentage failure or a distress index. Such a figure will be most convenient in comparative studies of sections of road under different environmental conditions.

An effort is made in the following sections to develop and illustrate the usage of such a common yardstick and its usage in research or to predict future distress from a knowledge of the existing conditions.

Distress Index

The need to express total distress of a pavement in one single figure has led to the development of an index that depicts the total distress on a section of pavement relative to the maximum distress that can practically be tolerated on any pavement. Another way to look at it is to define the most distressed CRCP pavement ever found as in a state of 100 percent failure or with a distress index (D.I.) of 100. The pavement that shows no crack at all, which may be true only in theory, has a D.I. of zero. Other pavements can be classified between these two extremes and the D.I. of a pavement can be plotted as indicated in Fig 6. The D.I. as plotted here was derived by assigning a relative weight to each category of distress. The one figure for the D.I., therefore, was computed by summation of the products of these weighting factors and the quantity of the particular distress. Serviceability is defined as the ability of a section of pavement to serve present day

*These reports are available in the district offices, D-8 of THD, and CFHR.

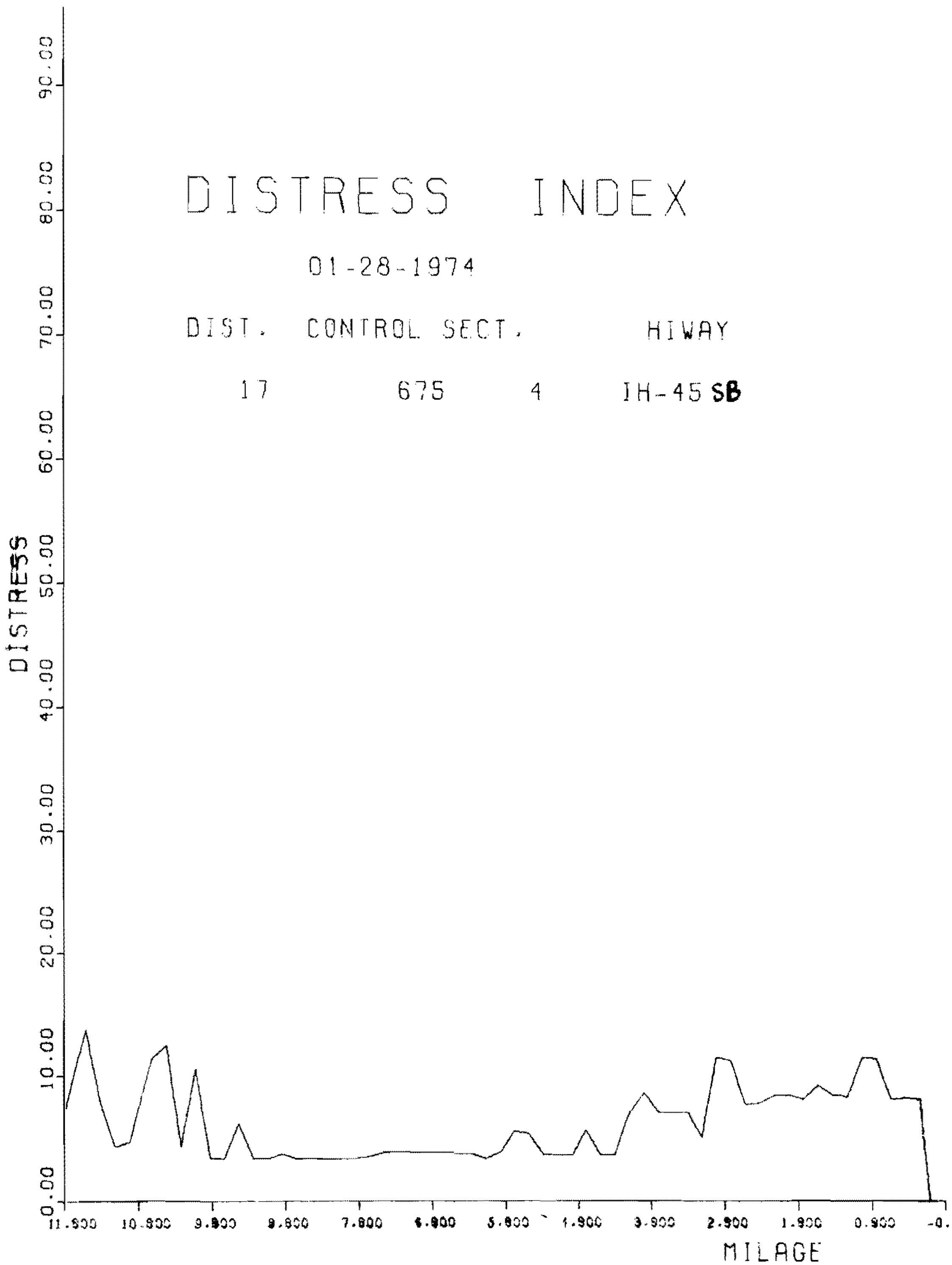

Fig 6. Example of distress index versus distance.

traffic in its existing condition and it can be related to a rideability rating. Mays meter rideability is plotted against the D.I. in Fig 7 to illustrate the relationship between the D.I. and rideability. The same weighting factors were used for the different distresses to calculate D.I. for both sections shown in the figure. The relative differences in the two lines may therefore be attributed to a difference in initial rideability or they may be due to the influence of warping. The conclusion that can be drawn from this plot is that the distress index gives a good indication of rideability and therefore of the serviceability rating. It is also clear that rideability improves with a lower D.I. or less distress while the opposite is true with increased D.I.

The relative contribution of traffic induced loading is illustrated in Fig 8. The weighting factors used above were used in this analysis. Although Section A was opened to traffic about five years before Section B, Section B now shows much more distress than A, which is understandable if the distress index is plotted against the total traffic load, as in Fig 8.

The derivation of a distress index by assigning weighting factors to the different categories seems to give a justified and useful figure that correlates with the general concept of loss in rideability or serviceability indexes as used in the pavement management system. The weighting factor is important in that it gives an indication of the relative contribution of early distress to failure. This is a very useful concept in the management of maintenance procedures as well as in the prediction of future performance. A more detailed investigation into this concept is presented in the next few pages.

Transverse Cracks

In a previous study (Ref 3), it was found that the spacing between cracks in a CRCP depends primarily on factors such as drop in temperature during curing, shrinkage of the concrete, and friction between subbase and concrete slab. It is clear that the concrete properties as well as the subbase characteristics are of importance in predicting crack spacing. This change in crack spacing with time, as a result of temperature change and shrinkage, is illustrated in Fig 9, the result of an experiment in Houston. The same graph also illustrates the effect of a change in concrete properties where the traffic was the same, plots B and C. However, it will be noticed that the crack

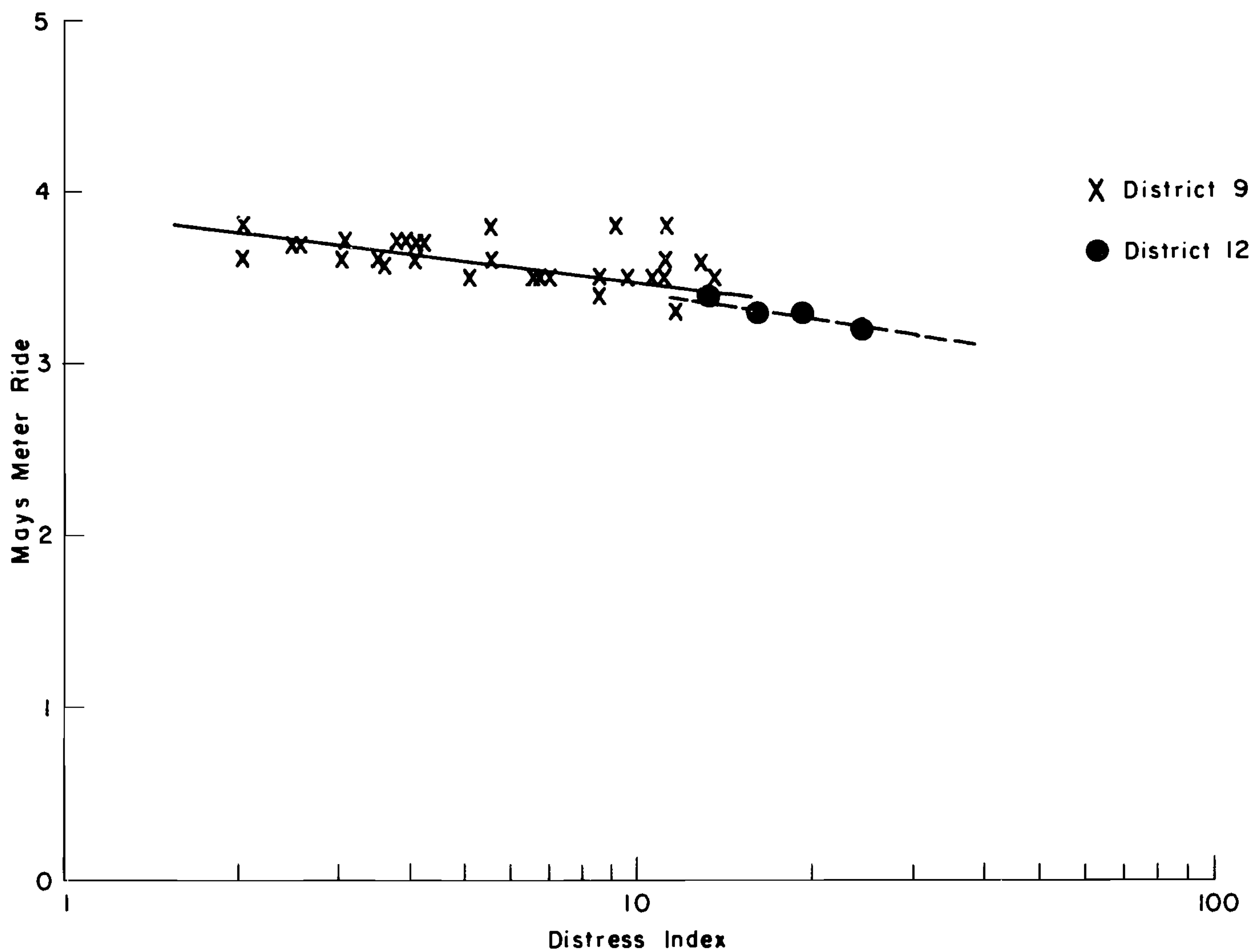

Fig 7. Distress index versus Mays Meter rideability.

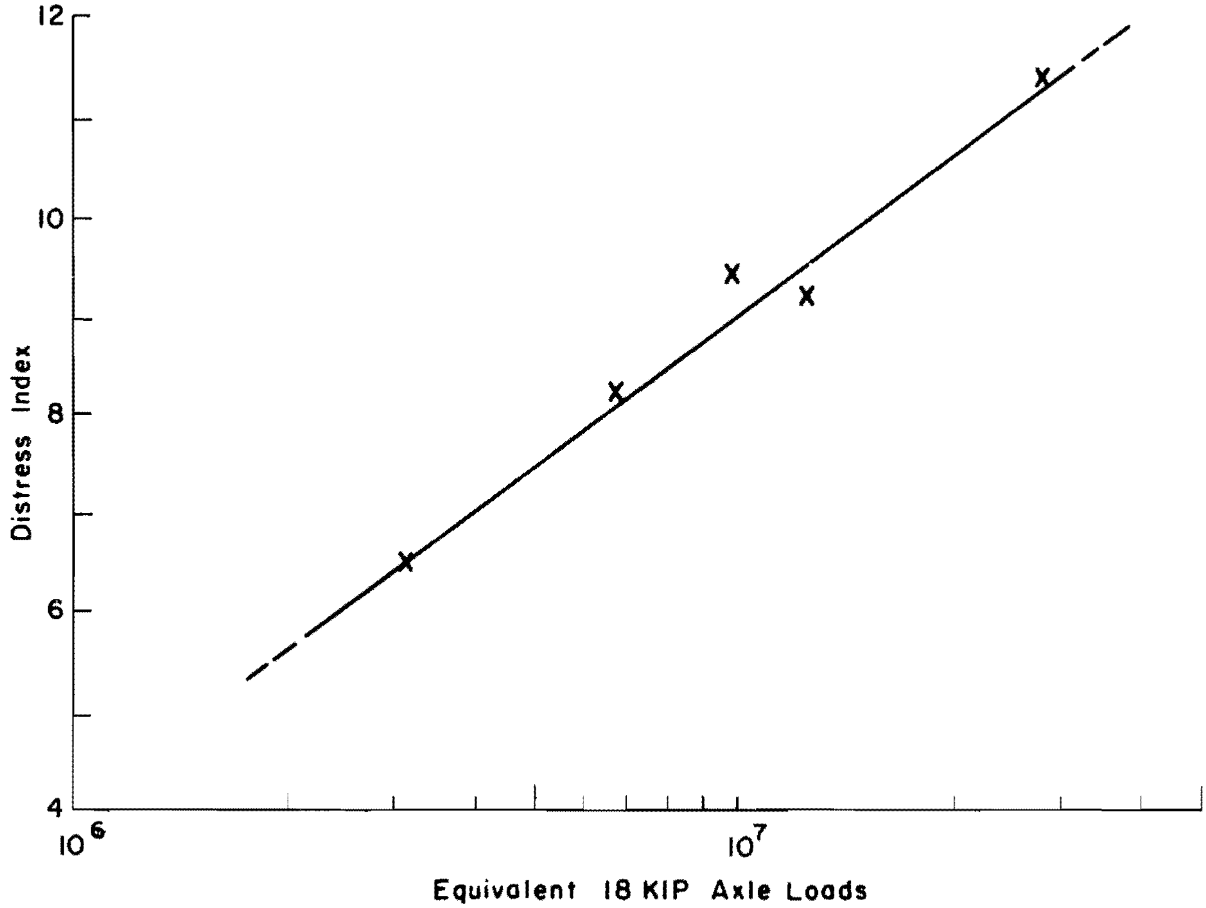

Fig 8. Change of distress index with increase in traffic load.

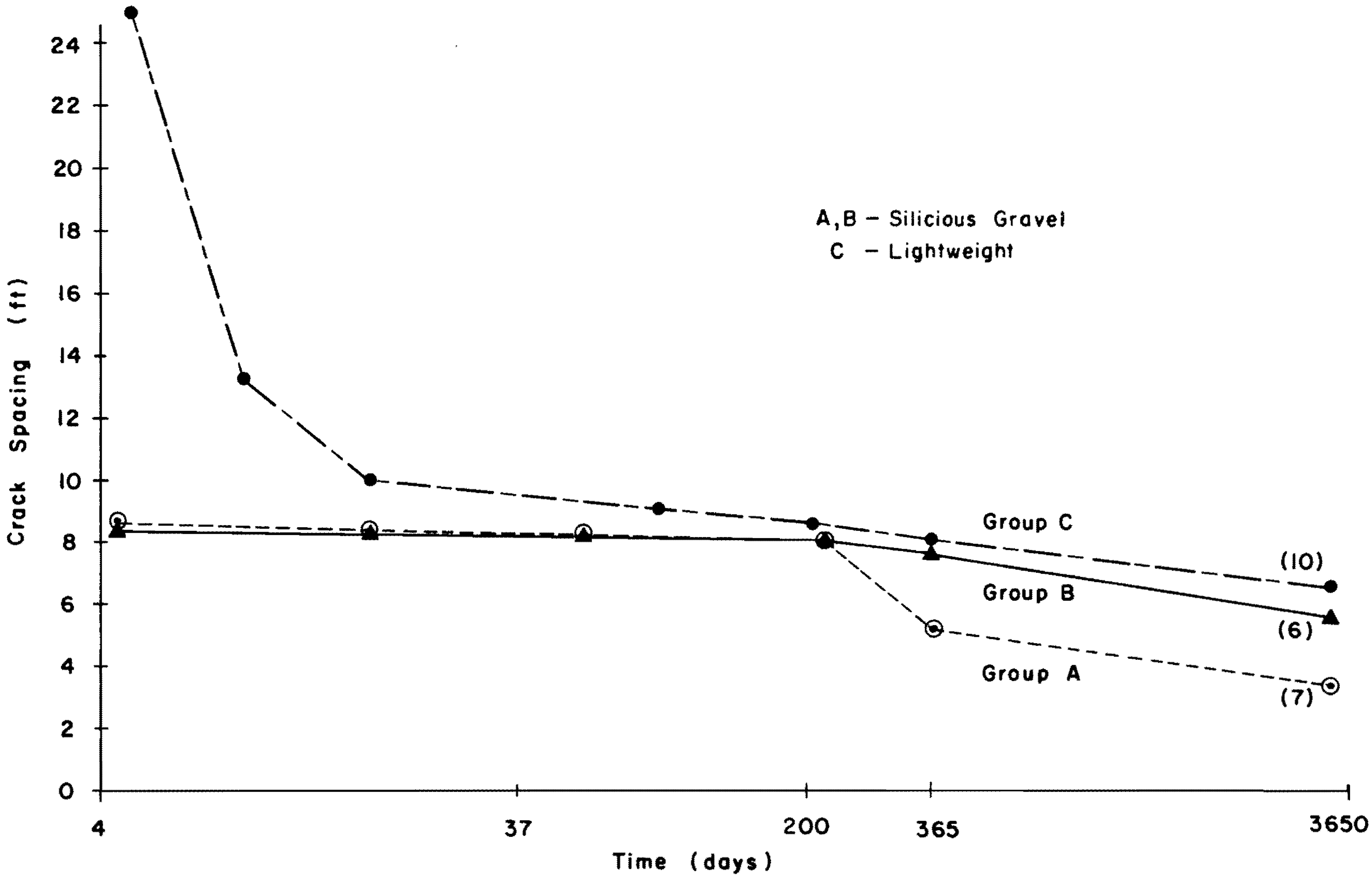

Fig 9. Change in crack spacing with time.

spacing was considerably reduced in plot A after approximately one year although plots B and A represent the same quality and type of concrete. This difference can be attributed to a higher traffic load on A as compared to B or C.

A further decrease in the spacing of transverse cracks seems to be a function of the traffic load. More loading may lead to radial or localized cracking if further cracking occurs. This, however, needs to be further investigated.

Spalling

Since the pavement is subjected to external loads such as traffic loads, changing temperatures, and rain, cracking tends to widen with a consequential ingress of surface water to the sublayers.

Figure 10 depicts the influence of crack width on minor spalling, where minor spalling is defined as spalling into the concrete itself. (See Appendix A.) Figure 11 indicates the relationship between the Texas Triaxial subsoil classification and percentage of minor spalling on IH-35 in the Falls-McLennan Counties. Since minor spalling may be associated with excessive vertical movement of the slab under traffic loads, the contribution of a poor subgrade and wide cracks can be explained. The conclusion can therefore be made that more vertical movement under traffic can be expected where a poorer subsoil is encountered or where water stands a chance to enter the pavement through wider cracks. This phenomenon is elaborated on in the next section.

The second type of spalling encountered on CRCP, defined as severe spalling in this survey, evidently shows no relation to subgrade soil type, crack width, or any other phenomenon discussed so far. However, a strength analysis, as shown in Fig 12, is revealing in the sense that on Houston highways it was found that cracks that showed severe spalling also had low strength in the top two inches. This indicates that severe spalling is a function of the concrete properties.

It can be concluded that minor, or deep, spalling is affected by the crack width in the CRCP and that everything that is related to it, such as percentage steel, friction, and shrinkage, and by the deflection of the pavement and everything associated with it, such as poor subgrade, loss of support, and pumping. Severe of surface spalling, on the other hand, relates purely to the concrete properties and probable techniques utilized in the

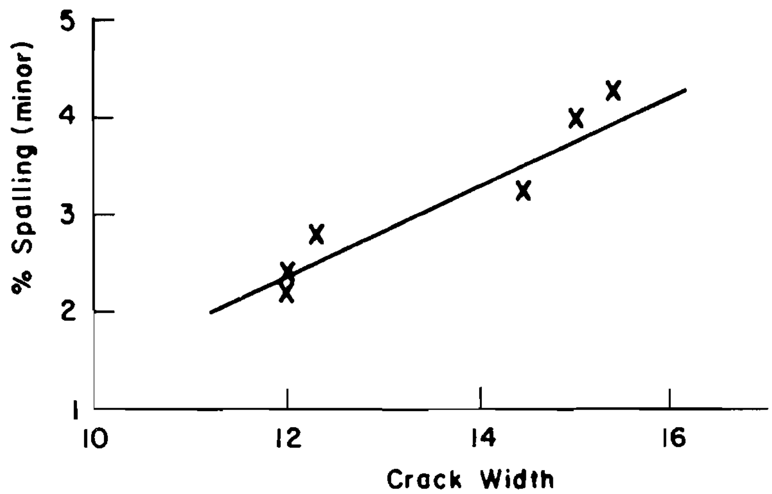

Fig 10. Influence of crack width on minor spalling.

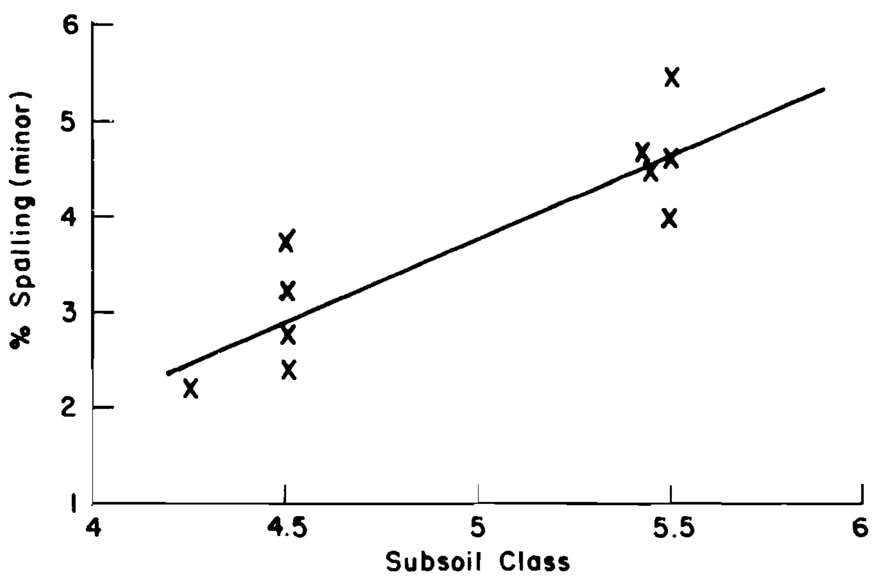

Fig 11. Influence of subsoil on minor spalling.

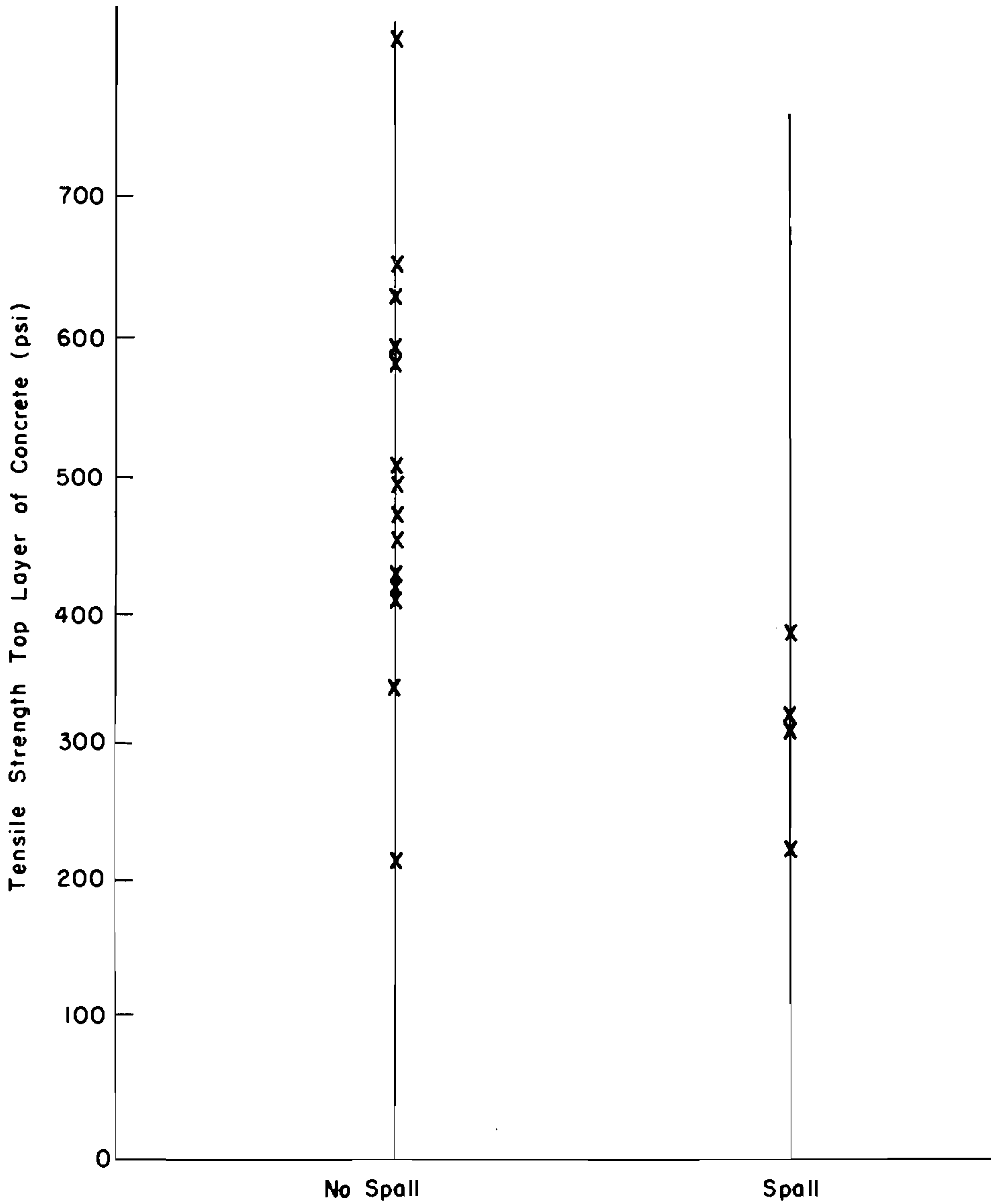

Fig 12. Effect of concrete strength
on severe spalling.

construction, since the position of the spall relative to the crack in the pavement depends on the direction of paving during construction.

Pumping and Punch Outs

A study on IH-35 in Falls-McLennan Counties offered an excellent opportunity to investigate the effect of pumping on punch outs. The pavement was built in 1959 and follow-up studies with photographs revealed that initial loss of subgrade materials may result in pumping because of wide cracks and poor subsoil as discussed in the previous section. Appendix D contains a full report on this investigation and it will suffice to summarize the conclusions here, especially with reference to Fig 13 of this report.

Figure 13(a) is a picture taken in the early days of the pavement, namely 1964. The failure at that stage occurred close to a construction joint and was due to poor vibration at this spot. As a result of an open side joint, cracking, and therefore the entrance of surface water, minor pumping occurred farther down the road. Note the progress of failures in Fig 13(b), taken in 1974, as well as more pumping farther down the road. Evidently the trouble has not been solved yet at the joint either, and pumping, with minor spalling, still occurs at this spot. It can be concluded, therefore, that stains of materials loss from the subbase are an indication of later failure. It is important not only to repair the failed slab but also to prevent a further loss of subgrade support through pumping or whatever causes exist. Closely related to the above point is the fact that the size of the first repair should be big enough to encompass adjoining pavement that shows signs of distress that may lead to failure. Traffic plays a big role in pumping; more pumping occurred where heavy trucks travelled close to the pavement edges, such as at the inside of curves and on uphill sections. The most important factor, however, is to provide proper drainage or to prevent water from accumulating under the pavement. This stresses the point made earlier that preventative maintenance becomes increasingly important.

This chapter illustrates the importance of early predictors, such as closely spaced transverse cracking and loss of subgrade material, to indicate failure areas. It has been illustrated that the sequence of distress indeed follows some pattern close to that illustrated by the sequence on the survey form, Fig 1. Furthermore, it is possible to derive a figure depicting

(a) 1964

(b) 1974

Fig 13. Effect of early pumping on later failures.

distress, in this case called distress index, which will be useful in comparing sections and predicting future maintenance problems and may even be useful in predicting future maintenance cost. The contribution to a management system is significant since it is possible to predict performance from behavior by using the concept. This provides a means of pavement management since a change of distress index with traffic load, Fig 8, and therefore of time is possible.

CHAPTER 5. DISCUSSION OF RESULTS

The survey procedure was devised so as to provide maximum utilization of the results by all agencies concerned. A common standard can be assured by adjustment of the remaining discrepancies using the statistical analysis already discussed. This will provide a common yardstick for planning, maintenance, design, and research purposes. Generally, the whole rigid pavement management system will profit from this exercise in that the transition from primary to secondary response will be better understood. At the same time, a tool is available to predict performance from a knowledge of behavior at the early stages of the pavement life.

The District

The method of survey as well as the guidelines established in the manual caused the rater to make an objective assessment of distress. This experience may prove to be useful within the districts since important distress areas that may require major maintenance can be recognized in the initial stages of development.

The survey form was developed so as to provide maximum information on quantity of distress, especially to the maintenance man. This may facilitate the planning and financing of maintenance operations. Preventive maintenance may play a bigger role in the future since the survey as well as follow-up surveys will indicate areas of potential failure which need this kind of maintenance procedure.

Figure 14 illustrates this point by giving a pictorial view of the possible change of distress index with time, or increase in cumulative traffic load. Just after construction, the D.I. will increase due to shrinkage cracking in weaker sections. With an increase in traffic, D.I. will stay more or less constant until further cracking occurs due to fatigue, etc. From this time on, X_2 , water will enter the pavement with a subsequent loss of subgrade support by soaking or pumping, increase in spalling, and, from time X_3 onwards, occurrence of punch outs. At a time X_4 the rideability

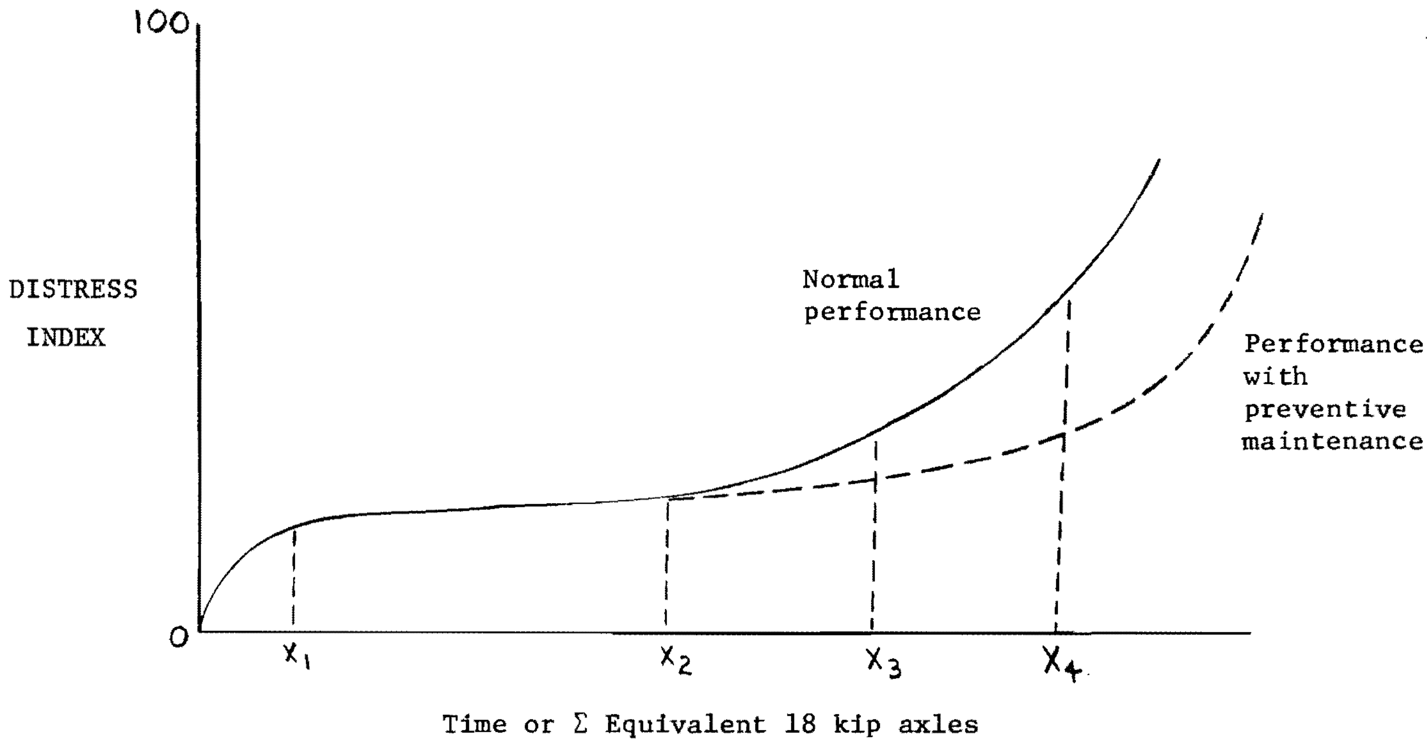

Fig 14, Hypothetical distress index with time.

may be low enough to consider overlaying the pavement. The effect of preventive maintenance is illustrated on the same figure by a dotted line. It is evident from the above discussion that different techniques or strategies of maintenance are possible. This will allow the maintenance engineer to predict areas of future maintenance as well as provide the means to decide on the maintenance strategy, whether it be preventing pumping, entrance of water, or other distress.

The educational value for the district can not be overlooked since a manual in which the orderly and logical sequence of distress formation is described was established to be used in maintenance and planning procedures and finally in designs.

Design

Texas experiences a significant difference in environmental conditions from district to district. Conditions in the Panhandle differ considerably with those in South Texas. Similarly the performance of rigid pavements in West Texas is bound to be different from those in East Texas because of climate, materials being used, and subsoil conditions. Quantifying the differences in terms of distress has always been a matter of concern, especially since the traffic conditions as well as the age of pavements may be different.

The results of the survey in hand are a first step in the acquisition of a common yardstick to measure relative structural performance and to compare CRCP in the Panhandle with that in Houston, for example. The histograms included in this report provide a fairly good means of comparing the relative performance of CRCP in different districts in Texas. The plots provided in the first reports give an indication of the extent of distress for maintenance planning as well as a more detailed picture of the distribution of distress within every district. The relative performance of different designs can be compared using the histograms as well as a knowledge of the traffic experienced on the particular sections.

This survey is a useful first step in deriving a figure of relative structural performance for maintenance purposes as well as a possible assessment of the merit of different design procedures under different climatic and loading conditions.

Research

Previous research and experience had led to the assumption of the sequence of distress as well as the six main categories. Analyses of the three team ratings and the survey itself have led to evidence of more than two subdivisions in some categories, as previously anticipated. This phenomenon stresses the point that follow-up studies in greater detail are necessary as are further general surveys within the next two or three years.

Environmental changes as well as different construction techniques apparently contribute considerably to distress formation. Transverse cracking, for example, can be closely spaced under certain circumstances and localized cracks can be formed with no regard to the traffic load, as occurred in colder regions of the Panhandle. Three different types of spalling instead of two could be distinguished; these were severe or surface spalling due to concrete properties, minor or deep spalling due to slab deflection and vertical movement, and "crack spalling" which may be due to horizontal movement of the slab as well as dirt being washed into these cracks. However, within a district very little change could be found in type and classification (definitions) within any category of distress, and the difference may be reflected only in the final detailed research into the contribution of each type of distress to the distress index. Research, however, is needed to substantiate the above mentioned phenomena.

Thus far, information existed only on detailed experimental sections in Texas. No means were in hand to assess the relative performance of each or the existence of important problem areas. A summary of the types of distress under different conditions, in the form of histograms or plots, now facilitates the selection of road sections with particular problems that need further investigation and research.

The major task of research, however, is to define the weighting factors to derive a distress index. As can be gathered from the discussion so far, a single figure depicting distress is still lacking. However, the existing survey is a powerful tool in isolating the contribution of each type of distress to a final performance index.

Management

The whole exercise may be summarized as the aim to fulfill the requirements as established in the rigid pavement design system (RPS). Figure 15 depicts a flow diagram of RPS and it is easy to distinguish the importance of this survey in building a bridge between the limiting responses and performance with time, i.e., the establishing of a performance production model.

The development of the weighting factors in determining distress index is aimed at fulfilling this important goal. As already discussed, distress index relates closely to rideability and therefore to serviceability index. Future research aims at determining the relative importance of each type of distress in the distress index and, thereby, to the derivation of the serviceability index.

Past research (Ref 4) has in part fulfilled the goal of establishing the link between primary and limiting response. This survey will be useful in carrying on with research on the relationship between limiting response and performance with time.

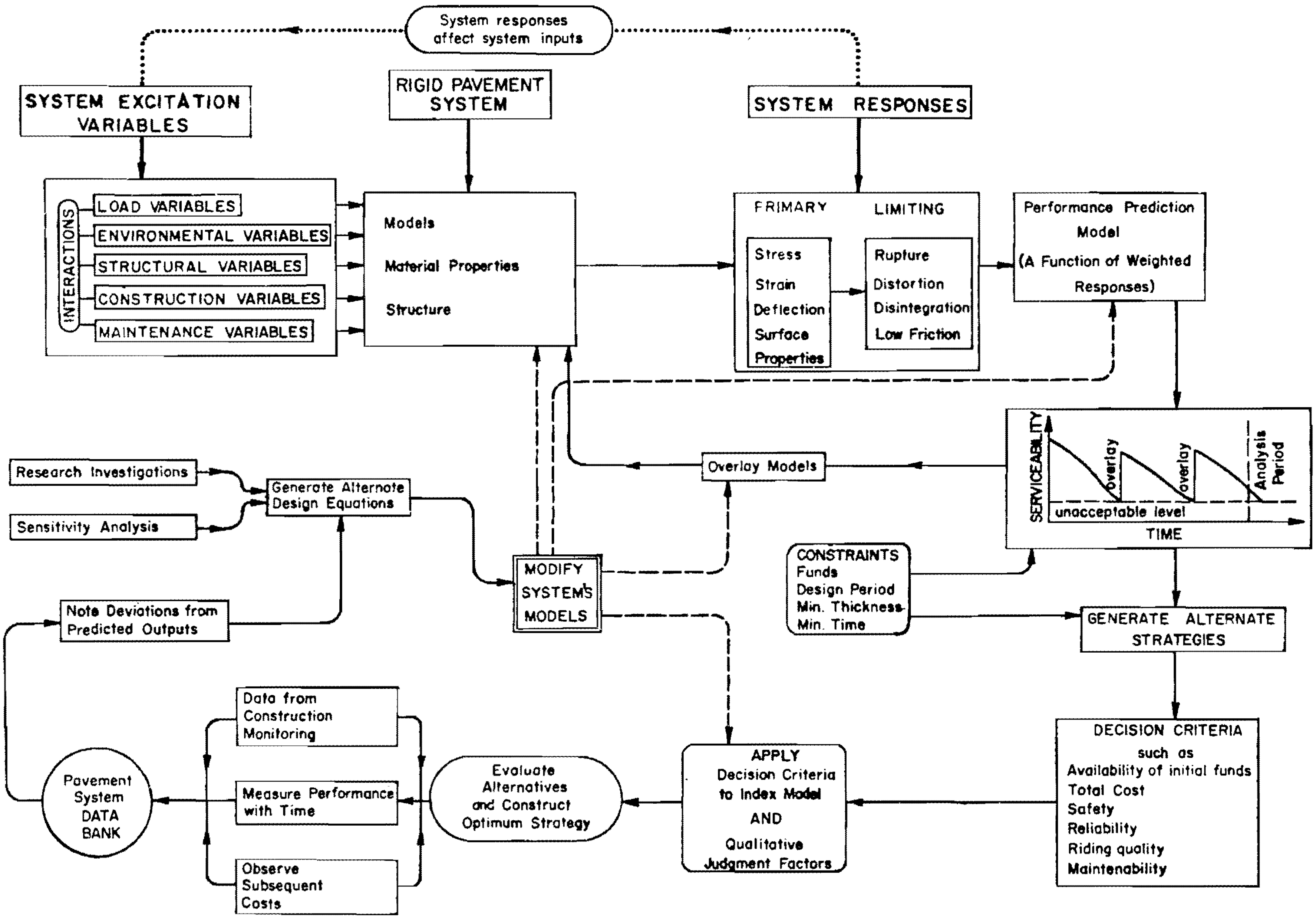

Fig 15. Conceptual rigid pavement design system.

CHAPTER 6. CONCLUSIONS

Rigid pavements in Texas have presented an excellent opportunity to develop a useful system of surveying and categorizing the different types of distress. Apart from a major contribution to research prospects, the survey also provides useful data on the existing condition of pavements. This information has become important in assessing the relative performance of different designs, the potential areas of failure for maintenance planning, and, more directly, information on areas that need immediate attention.

The vast amount of data gathered presents an excellent opportunity to develop models lacking in the rigid pavement system. Thus, relationships between limiting response and performance as well as the relative importance of different design aspects, responses, and environmental conditions on the performance curve can be established.

More direct conclusions from the survey need to be mentioned:

(1) A definite relationship exists between the different types of distress, to such an extent that the influence of one type on the next can be established.

(2) Type of distress, therefore, can be arranged in the growing order of occurrence from which prediction of future failure is possible.

(3) This knowledge presents an excellent opportunity for sound maintenance and design management.

(4) The survey can be done accurately and objectively enough by different teams to be used for research and planning purposes. If any differences exist, adjustments can be made on the basis of a sample survey by an outside team.

(5) Reporting of the data in the form of histograms and plots facilitates comparison between sections as well as being useful for maintenance planning.

(6) Research is needed to establish the quantitative relationship between distress and structural performance to provide one figure that depicts a distress index, which relates to serviceability.

(7) A survey, with an analysis the form of plots and histograms, will be very useful in preventive maintenance. The relative importance of each type of distress which deserves early attention can be established by determination of the weighting factor.

Generally, the survey made a major contribution to rigid pavement management. Follow-up surveys in due time will establish new guidelines for changes in the system or to confirm existing management practice.

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APPENDIX A

APPENDIX A. A COMPARISON OF THE RATINGS OF THREE AGENCIES IN ONE DISTRICT

Introduction

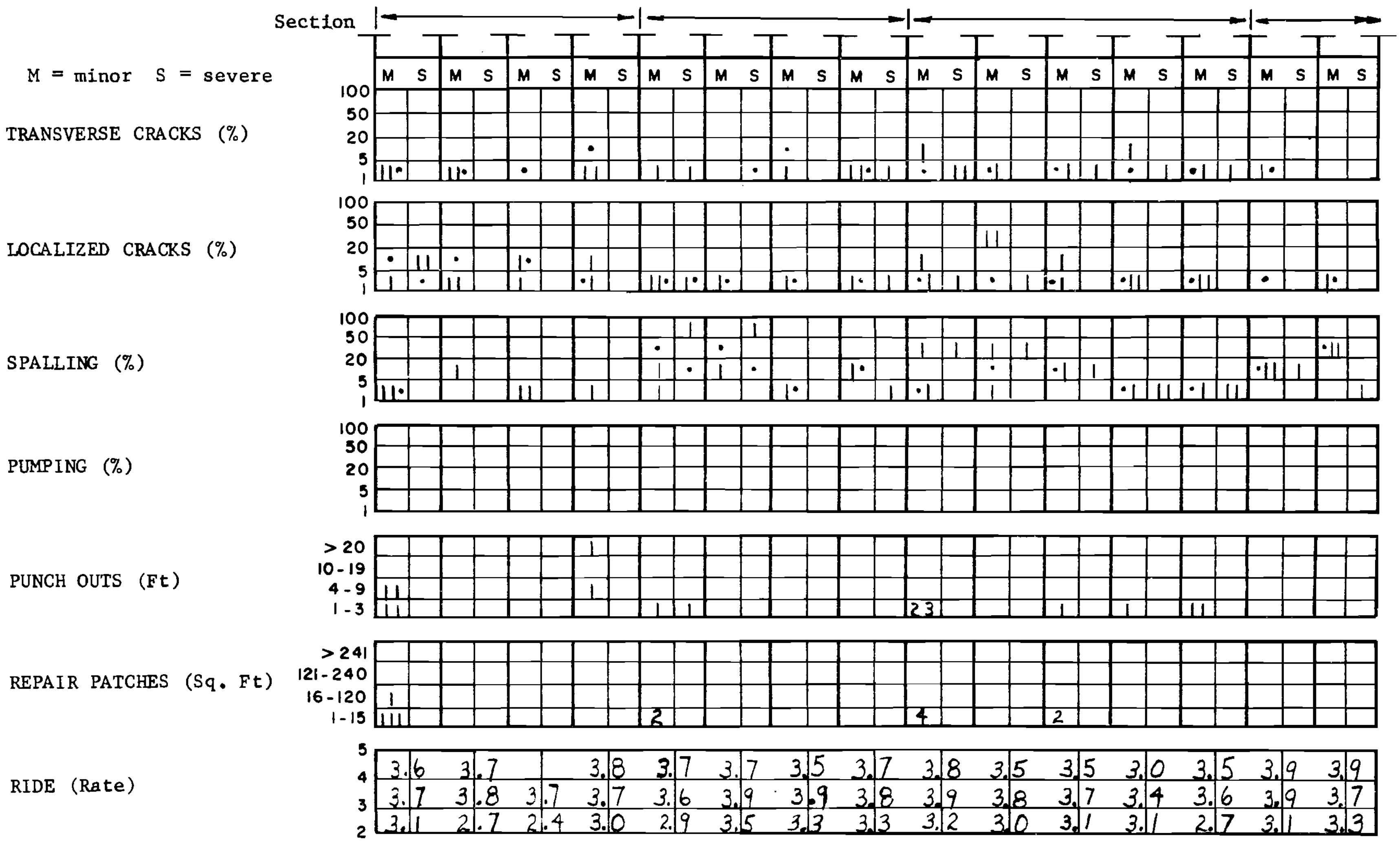
All the continuously reinforced concrete pavements surveyed in the district are surveyed by the personnel themselves. In addition, 10 percent of the road length is surveyed by a team from the Texas Highway Department (D-10) and the same 10 percent is surveyed by a team from the Center for Highway Research as a means of determining the variation amongst teams and to be used as a factor to adjust the rating within a district for comparison of the condition of CRCP in one district with that in another district.

A visual comparison as well as a statistical analysis is made in this study. Both methods seem to be satisfactory and the conclusion is made that the survey is done within the practical limits of accuracy that the survey form provides.

Data Available

The three different surveys are summarized on survey sheets, Fig A.1. The survey done by the team from CFHR is marked with a dot. Although the data are compiled in two sheets, five different sections, which were several miles apart, were surveyed. There is, therefore, no relationship between sections as reported by the district survey, that is, more than one team was involved in the district survey.

Table A.1 is a summary extraction from Fig A.1 with the middle line of Table A.1 taken as the correct value of the survey, as represented by the average rating of the three teams. The average of the three teams was calculated by numbering the lines on the survey sheets. This was done to eliminate the qualitative differences in distress between sections on the road. By this method, all sections have the same quantity of distress, as defined by the box between lines 2 and 3, and only the variation between teams is taken into consideration.



(continued)

Fig A.1. Team ratings.

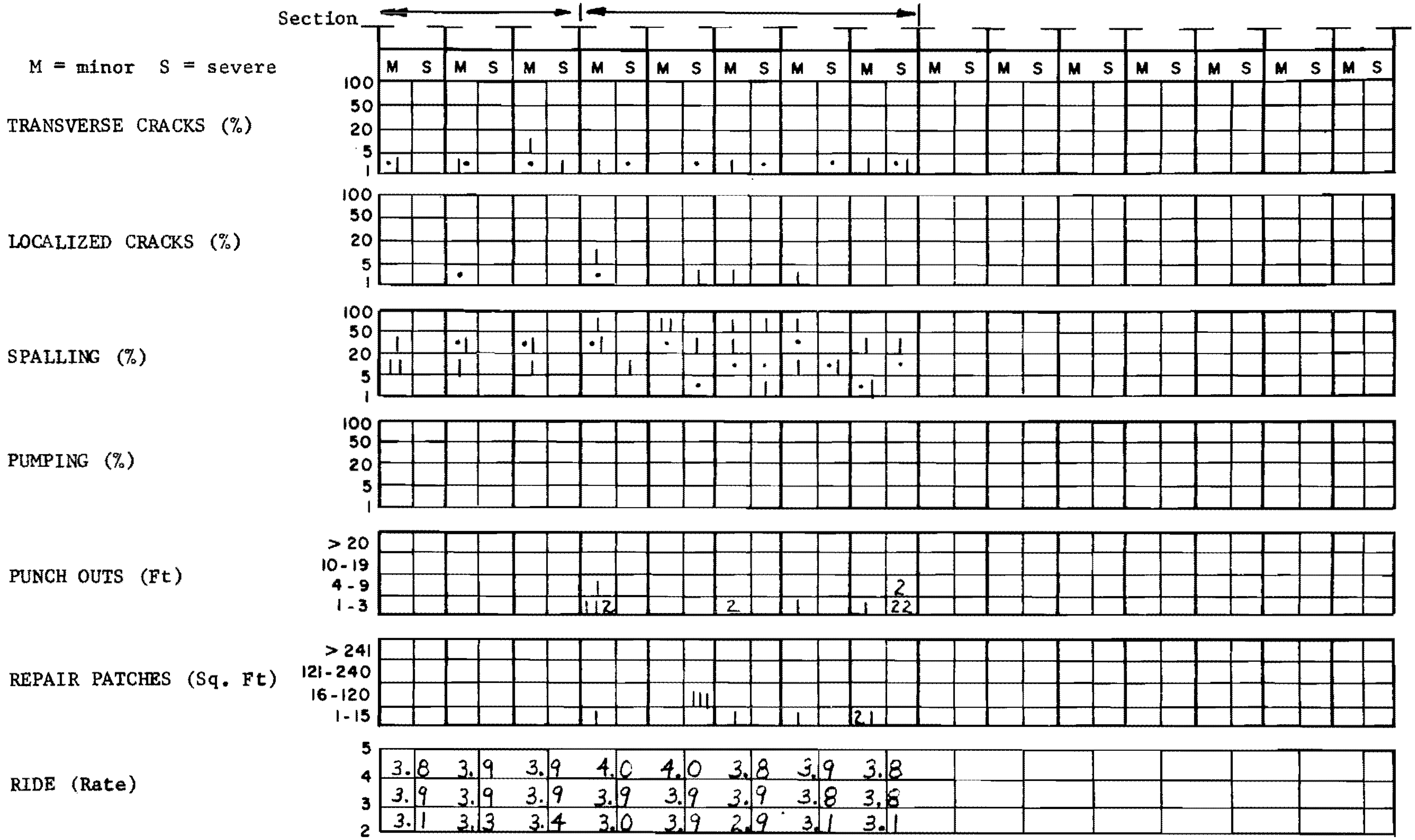
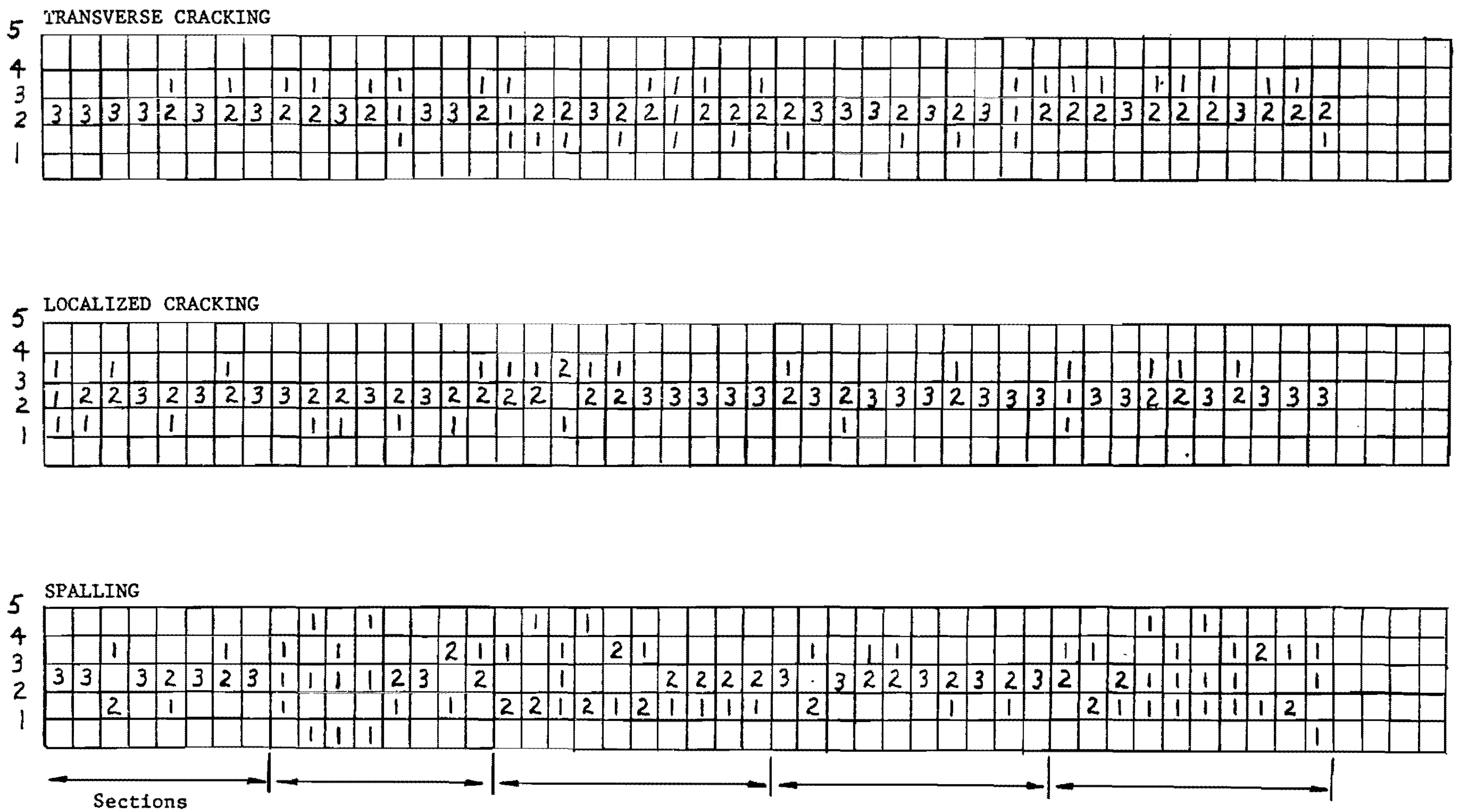


Fig A.1 (continued). Team ratings.

TABLE A.1. SUMMARY OF CONTROL SURVEY.



Statistical Analysis

The results as summarized in Table A.1 were used for statistical analysis. The lines were numbered 1 to 5 and the box between lines 2 and 3 represents the average of the three ratings, defined as the correct rating. Two sample sizes are under consideration, namely, the "three" teams (this also plays the role of a random sample) and the number of sections surveyed. Since a decision based on an ordinary calculation of standard deviation and the associated coefficient of variance or a confidence interval is not practical in this case (the interval in the case of spalling, for example, will include the whole range of possible ratings at a 90 percent level of confidence), an engineering approach was chosen, namely, the drawing up of a control chart.(1) This enables the analyst to determine the sections where the survey has gone out of control and possible reasons for it.

Transverse Cracking. The average or mean $\bar{\bar{x}}$ is determined:

$$\bar{\bar{x}} = \frac{\bar{x}_1 + \bar{x}_2 + \bar{x}_3 \quad . \; . \; . \quad \bar{x}_k}{k}$$

where $\bar{x}_1$, $\bar{x}_2$, $\bar{x}_3$ . . . $\bar{x}_k$ are the means of every subgroup and $\bar{\bar{x}}$ is the mean of the means of k subgroups.

For transverse cracking $\bar{\bar{x}} = 2.562$, which is also an unbiased estimator of the actual mean rating. On a similar basis, the standard deviation is defined as

$$\bar{S} = \frac{S_1 + S_2 + S_3 \quad . \; . \; . \quad S_k}{k}$$

where S_1 , S_2 , . . . S_k are the standard deviations of the subgroup.

An unbiased estimator of the actual standard deviation S_1 is given by $\bar{S} / C_2$ where C_2 depends on the size of the subgroups, or $C_2 = 0.7236$ for a sample size of 3 . $\bar{S}$ for transverse cracks = 0.330 .

The limits within which all ratings must lie for the survey to be within control are

$$\bar{\bar{x}} \pm (2.576\ \bar{S}\ /\ 0.7236\ n)$$

for a 99 percent confidence level (2.576) and $n = 3$ (subgroup size). Therefore, the limits 2.562 ± 0.605 apply when the actual average is 2.562 . The control limits are, therefore, 1.957 and 3.167 .

The conclusion that can be drawn from this is that ratings between lines 1 and 4 are considered correct and the survey is under control.

Localized Cracking. Using the same theory as above, with the standard deviation $\bar{S}$ for localized cracking being 0.265 , the limits of control are 2.539 ± 0.548 , or 1.991 and 3.087 , where the average rating is 2.539 . Thus, all ratings fall within the limits again and the rating is under control.

Spalling. The standard deviation of $\bar{S}$ of spalling is 0.680 . The limits within which the rating should be to be under control are 2.457 ± 1.400 , which is 1.057 and 3.857 .

Ratings between lines 1 and 4 are defined as indicating that the process is under control. However, 10 team ratings are outside these limits and the rating of spalling can be defined as not being under control in this particular district.

Other Distress. Since no pumping was recorded and since punch outs and repair patches cannot be analyzed by other than visual comparison, no statistical analysis was performed here.

Visual Comparison

The quantitative measurement of distress on the survey form is done by marking in one of four boxes. Therefore, it is quite possible that one team considers there to be 19 percent of a particular distress while the other two teams define it as just over 20 percent, which represents two different boxes on the survey sheet. Both can be deemed correct since both are around 20 percent. Whenever distress was quantified in two adjacent boxes, it can therefore be accepted as correct.

The question arises as to which two teams are correct when three consecutive boxes were marked, i.e., boxes 1.5, 2.5, and 3.5, for example. The correct value may be on line 2, i.e., 5 percent distress, or on line 3 or 20 percent distress, for example. Both will have to be accepted since no definition of the correct rating can be given here.

All ratings outside the middle three boxes, as defined in Table 1, will have to be defined as wrong ratings. This is the same conclusion that was made under the statistical analysis.

One last comment on this aspect must however be made and that is the case where two teams have rated in box 1.5 and one team in box 3.5, for example. The average, and therefore the correct rating as defined before, is the rating in box 2.5. It can be argued that the majority of teams have rated closer to line 1 than to line 3 and that the team in box 3.5 is wrong. Looking at the statistical analysis of this case for spalling, for example, the average $\bar{\bar{x}}$ is 2.167 . The control limits for this isolated case will be 2.167 ± 1.400 or 0.767 and 3.567 which will rule the rating in box 3.5 right. However, when the general rating of localized cracks is considered and a case like this is assumed to occur there, the limits will be 2.167 ± 0.545 which will rule the rating in box 3.5 wrong.

Comparing the ratings of different teams for punch outs, it can be noticed in Fig A.1 that all the ratings were grouped within two blocks every time except for one case at the end of section 1. Where the ratings were closely spaced, the same argument holds as for the other distress manifestations as previously discussed, namely, that it is only a question of estimation of size or quantity around the borderline between blocks. The one case mentioned can be explained by the possibility that one team did not see the punch out; the second team saw it and estimated it to be 4 to 9 feet long. The third team saw the punch out, estimated the length at maybe 4 to 9 feet but got out of the automobile and noticed that a fine crack had actually developed farther, thus making it more than 20 feet long, which was their entry in the survey form.

All three teams rated similarly with repair patches except that one team counted a few asphaltic repair patches size 1 to 45 square feet where other teams may have considered them as less than one square foot or as patches of severe spalling.

The rating of ride of the two teams from D-10 and CFHR differed considerably from the Mays Meter readings (the last in the line of three readings). The general trend was 0.6 lower for the Mays Meter than those for the two teams, which were close together and which were done separately.

Conclusions

The rating of transverse cracking and localized cracking was found to be acceptable under both statistical analysis and visual inspection. Spalling, however, seems to be out of control in 10 cases. An analysis of the different teams indicates that the teams from the district were out in six cases, all within two sections and rated by the same team. CFHR was out in no cases and D-10 in four instances. This can be explained by the fact that it was the first opportunity of rating for the district team and the second for D-10, and CFHR has defined the distress in the manual and compiled the form. A further conclusion that can be drawn is that spalling was not properly defined and explained during the schooling of the specific district team.

The other distress manifestations, punchouts, and repair patches did not give any trouble except that minor punch outs were seen in one case where other teams did not notice it.

The technique of schooling teams was changed since these results came to light and no similar trouble has been encountered since. Teams are given much more individual attention and several sections are rated under supervision. To ensure uniformity, the teams are encouraged to use the same type of vehicle and not to survey on foot.

In general it can be concluded that the rating is done satisfactorily and a high standard is achieved.

APPENDIX B

APPENDIX B. PERFORMANCE SURVEY OF CONTINUOUSLY REINFORCED CONCRETE PAVEMENTS

OBJECTIVE

A need to assess the performance of continuously reinforced concrete roads in Texas has led to the development of a performance survey procedure as described in this manual.

Since speed is of prime importance at this stage, accuracy had to be sacrificed to a certain extent. However, provided the survey is done as prescribed, it will be a powerful tool in the hands of the maintenance as well as the design engineer. A more detailed investigation can be carried out at the trouble spots if deemed necessary.

PROCEDURE OF SURVEY

The road is surveyed by two persons in one vehicle, travelling on the shoulder at approximately five miles per hour. The driver, while noting the condition of the shoulder to comment on it later, must assess the section length that is subjected to pumping, count the punch outs and determine the size of the repair patches.

The passenger, who sits on the back seat behind the driver to get a better view of the road, quantifies transverse and localized cracking and makes a note of the spalling encountered.

The road is surveyed in sections of 0.2 miles and at the end of every section, the driver informs the passenger of his findings. This, with his own assessment, is entered in one column of the survey sheet. Therefore, only one survey sheet is used between the two raters.

At the end of every three miles, when a sheet of the survey form must have been completed, the condition of the shoulder is discussed and commented on. Other obvious distress phenomena or interesting facts about the road are also noted under general comments. A few things to look out for, will be discussed later on.

After a section of road has been completed, the rideability is rated by travelling on the lane that has been rated, at a speed of fifty miles per hour. This too will be discussed in a following paragraph.

Since the survey is done at varying speeds, depending on the amount of distress on the pavement, it is recommended that a vehicle with an automatic transmission be used. It is advisable to use a flashing warning light on the roof of the vehicle as well as a "Go Slow" triangle at the rear of the car for safety.

THE SURVEY FORM

A copy of the survey form is included for your reference.

At the top of the sheet, a few details must be given to define the position of the section. Space is provided for the control number, section number, the highway number, the number of the district and the county in which this section is located. The exact location of the section must be described to facilitate reference to or a detailed survey of the section at a later stage.

The names of both raters must be listed as well as the date of survey. This form will be processed by computer; it is therefore important to write in the blocks provided and to start writing from the last block as shown on the attached survey sheet.

It is imperative to tie the sections in with the mileposts alongside the road. The trip recorder of the vehicle may be used to facilitate the subdivision of section lengths into 0.2 mile sections. The milepost readings, however, must be entered in the space provided.

The sheet is divided into nine main columns of which five are subdivided into two columns each, designated by "M" and "S" which stands for "Minor" and "Severe". This is to describe the severity of the different distress phenomena. Distress on the other hand is quantified by estimating length, area, or by counting the spots of distress. The appropriate column for transverse cracks, localized punch outs and repair patches that falls under the same category are counted and entered in the column provided. The figure that represents your rating of ride is written in, as shown. This will be discussed under the appropriate heading later on. However, it is necessary to draw the attention to the fact that the amount of distress is divided into four categories which make it unnecessary to determine the exact quantity. A good estimate will be sufficient for the purpose of this survey.

DISTRESS DESCRIPTIONS

Transverse Cracking

All continuously reinforced concrete roads will show transverse cracking to a certain extent. However, for the purpose of this survey, only cracks that change from the regular crack pattern and generally at a spacing closer than eighteen inches, will be considered.

The different lengths of road, within the section surveyed, that experience transverse cracking as defined above, are added up and the accumulated length of road as a percentage of the section length, 0.2 miles or 1000 feet in this case, is entered in the survey sheet.

Say for example that the average transverse crack spacing is 20 feet but every 100 feet a cluster of transverse cracks, spaced at 18 inches, 6 feet long is experienced. This means that 60 feet out of 1000 feet has transverse cracking as defined above which will be 6 percent. Therefore, the block 5-20 percent transverse cracking on the survey sheet must be marked.

The difference between minor and severe transverse cracking is illustrated in Fig B.1 and Fig B.2.

Minor transverse cracks are defined as cracks which are newly formed, narrow or not easy to see, Fig B.1, and severe transverse cracks as big, well-defined openings, Fig B.2.

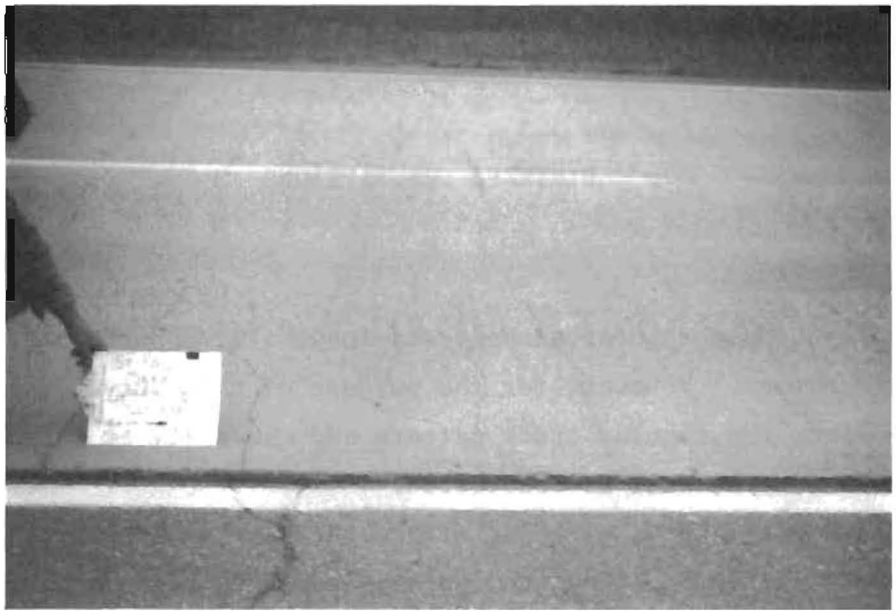


Fig B.1. Minor transverse cracking.

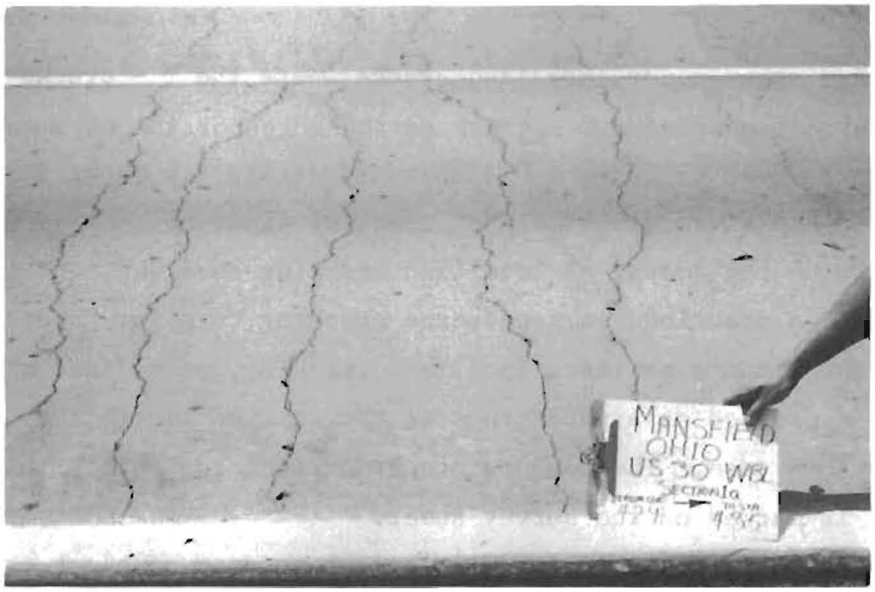
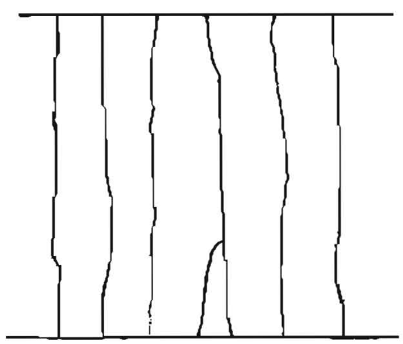


Fig B.2. Severe transverse cracking.



Localized Cracking

When the closely spaced transverse cracks start to deteriorate by the formation of Y - cracks that link the transverse cracks, it is called localized cracking. See Fig B.3.

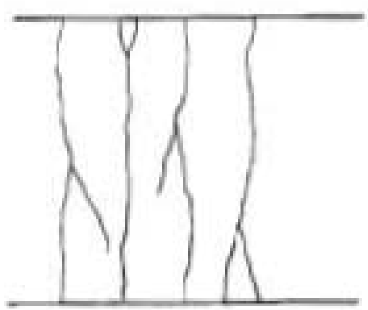
Figure B.3 shows minor localized cracks where the Y - cracks start to form with an occasional completed Y - crack on the edges of the pavement.

Severe localized cracking is illustrated in Fig B.4 where Y - cracking has been completed and a radial pattern of cracking shows up.

To determine the amount of localized cracking on a section, the same method is used as described in transverse cracking, namely: the different lengths of road that experience localized cracking, as defined above, are added up and expressed as a percentage of the section length, 0.2 miles or 1000 feet in this case. The appropriate block that represents this estimate the closest, is marked on the survey sheet.

The attention is drawn to the distress phenomenon of block cracking where transverse cracks are linked by a longitudinal type of crack. This is not defined as localized cracking but will be defined as a punch out later on.

Fig B.3.   Minor localized cracking.



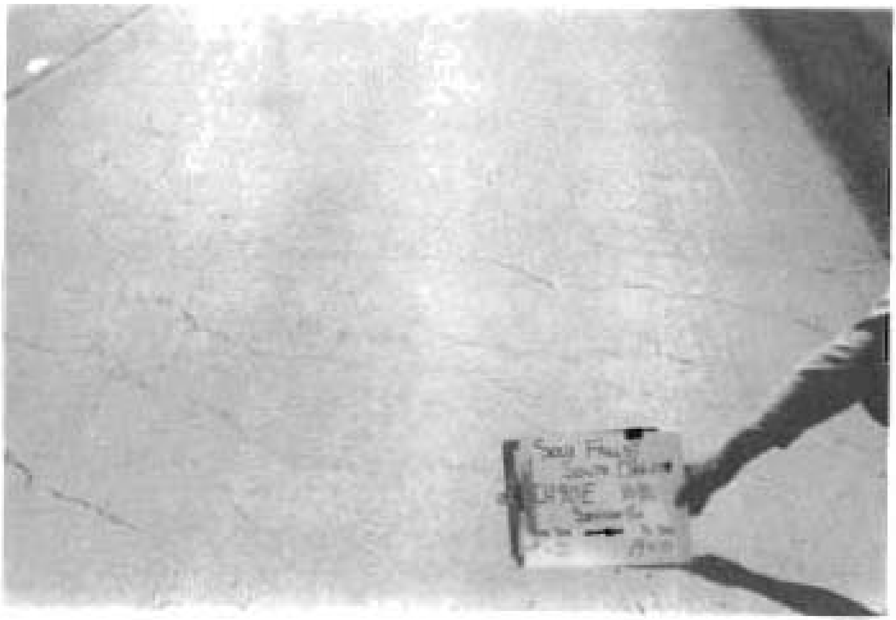
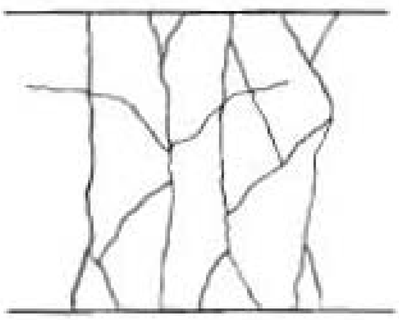


Fig B.4. Severe localized cracking.



Spalling

Spalling is defined as the widening of existing cracks through secondary cracking or breaking of the crack edges. The depth of a spall is generally less than one inch but it can be very wide.

This provides a suitable method of defining the difference between minor and severe spalling since almost every crack experiences secondary cracking in some or other way.

Minor spalling is defined as a condition of edge cracking where the loss of material has formed a spall of one half-inch wide as indicated in Fig B.5.

Severe spalling defines the case where the cracks have been widened to such an extent that the smoothness of ride is affected by the spall, Fig B.6.

In measuring the quantity of spalling, every crack is important. The whole crack is defined by the most severe condition of spalling that exists in that crack. Therefore, if a crack shows secondary cracking over the whole length but one potential place of spalling, like the wheel path, shows an opening of 1/2 inch where concrete has been lost, the crack is defined to show minor spalling. The same applies when a crack shows a severe spall of say 3 inches by 12 inches. This crack is spalling severely although the rest of the crack may show minor spalling.

An estimate of the percentage of cracks that show minor and severe spalling is made and entered into the two columns that are provided. Again, it is not necessary to have the exact percentage since only four categories are provided for estimating the quantity.

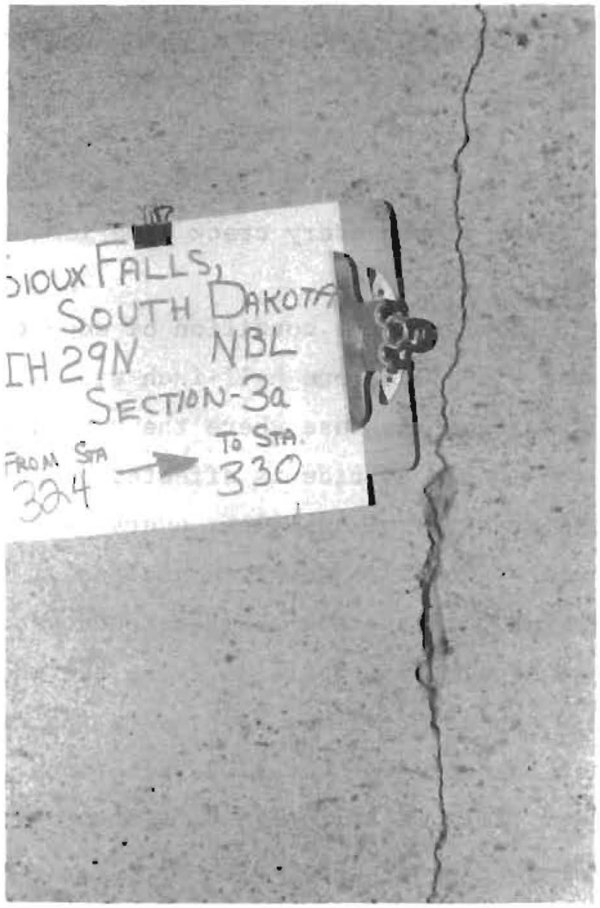


Fig B.5. Minor spalling.

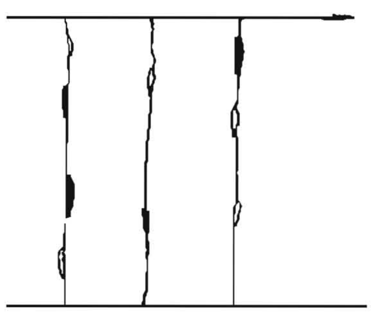
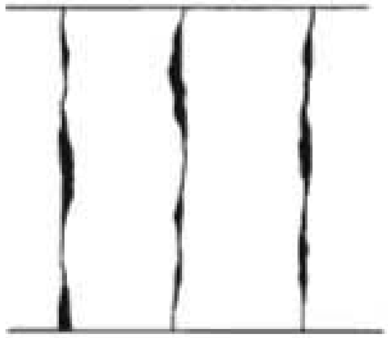


Fig B.6. Severe spalling.



Pumping

Water penetrates through cracks and openings in the pavement and when a load, such as a heavy vehicle passing over a crack, is applied, water is pressed out again taking fine material of the sublayers with it. This is defined as pumping.

Pumping may occur at construction joints that have opened up longitudinal cracks or transverse cracks. However, for the purpose of this survey, only pumping at the edge of the pavement will be recorded. The edge in this case is the joint where the pavement and the shoulder meets.

Minor pumping is defined as water being pumped out leaving streaks of fines on the surface of the shoulder or pavement as shown in Fig B.7.

Severe pumping is an indication of a severe loss of fines from the sublayers and it will also be associated with vertical movement of the pavement where pumping occurs. Figure B.8 gives an indication of severe pumping.

The percentage of section length that is subjected to pumping is recorded. The worst condition of pumping again defines the quality of pumping at that section, although some minor pumping may be experienced within the section. If a few distinct spots of pumping are found, say 300 feet apart, they are handled as separate sections subjected to pumping and are assessed as minor or severe separately. The minor sections are added separately from the severe sections and recorded on the sheet in the appropriate column.

Fig B.7. Minor pumping.

Fig B.8. Severe pumping.

Punch Outs

When closely spaced transverse cracks are linked by longitudinal cracks to form blocks, it is defined as a punch out. This must not be confused with longitudinal cracking as shown in Fig B.9, which are not recorded on the sheet save under general comments.

A minor punch out is defined as a condition where longitudinal cracks have started to form as shown in Fig B.10. The cracks need not to have linked with transverse cracking in all cases.

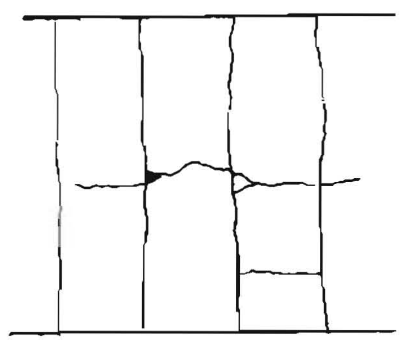
A severe condition of punch out is shown in Fig B.11 where a parallel series of longitudinal cracks have formed a block which moves under traffic.

Again the extent of a punch out condition is defined as the length of road that is subjected to this form of distress.

The survey sheet is divided into four categories of punch out lengths namely 1 - 3, 4 - 9, 10 - 19, and above 20. The number of punch outs with the same length are recorded in the appropriate column as shown. Figure B.11, for instance, will be defined as one punch out length 1 - 3 feet although there are 3 blocks that move under traffic and although the total length of longitudinal cracking is approximately 4 feet.

Fig B.9. Longitudinal cracking not to be rated.

Fig B.10. Minor punch out.



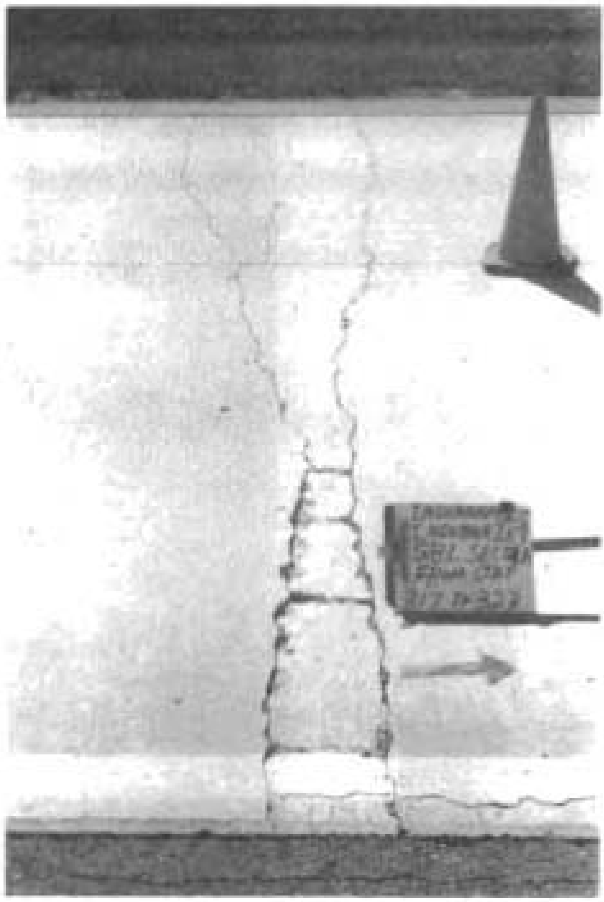
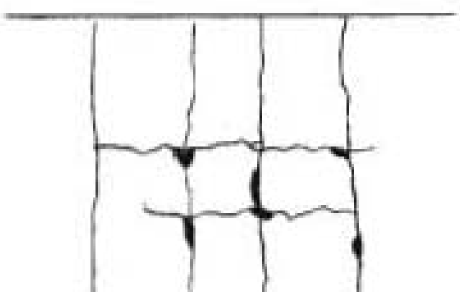


Fig B.11. Severe punch out.



Repair Patches

The pavement needs to be repaired in the final stages of distress. Repairs can be made either with Portland Cement concrete or asphalt cement concrete. The condition of the repair patch will not be determined. Columns are provided to record whether the patch is made in asphaltic or Portland Cement concrete, Figs B.12 and B.13.

To determine the amount of patching that is involved, a scale is provided for in square feet of patch work. The scale is divided in four categories, namely 1 - 15, 16 - 120, 121 - 240, and greater than 241 square feet patches. It is determined under which category every patch falls and the number of patches for every category is counted and the figure entered on the survey sheet.

It is important to note that repair work that is done over the full depth of concrete thickness is classified as a repair patch. Patching of spalling and overlaying part of the concrete pavement are not classified as patch work. The former is defined as spalling and the latter is commented on under General Comments.

Fig B.12. Asphaltic concrete patch defined as minor.

Fig B.13. Portland cement concrete patch defined as severe.

Ride

Ride is an indication of the smoothness of the pavement and should be measured with a Mays Meter or a similar device. However, it is quite possible to do it fairly accurately if the rater has had some experience.

The road is rated by travelling at a speed of 50 miles per hour across it. No attention is paid to any distress since it has already been commented on. The rating of rideability solely depends on the smoothness of the road. Usually a road is not allowed to have a rideability of below 2.0 before it is overlayed and about the maximum that can be obtained on any surface is a rating of 4.5.

Condition of Shoulder

A line of comment is provided to note any distress on the shoulder itself like the joint between the pavement and the shoulder; whether it has opened up, been repaired and any failure in the area as shown in Fig B.14. Also comment on the surface of the shoulder whether it has been repaired, shows any signs of scuffing or a great difference in level between the shoulder and the pavement. See Fig B.15.

The condition of the shoulder usually gives a good indication of any subsurface drainage problems. Note any occurrence of crocodile cracking and shoving on the shoulder. Also comment on the existence of grass that grows in the cracks or in the side joint.

Fig B.14. Shoulder distress, open joint with cracking.

Fig B.15. Shoulder distress, scuffing of surface.

General Comments

A comment must be made about the general condition of the section. Take special notice of drainage conditions or lack of drainage, marked differences in distress or adjacent lanes which are not surveyed, any peculiarities such as bad construction joints, cracks that have opened up to a great extent, and to excessive longitudinal cracking. Figure B.16 is a picture of subsurface drains that were installed and Fig B.17 shows steel that has been placed too close to the surface.

Other comments that may assist in the analysis of the results such as the weather conditions at the time of the survey (cracks show up better in wet weather) and an elaboration on the figures in the sheet itself can be made here.

The general appearance of the pavement such as the existence of waves in areas with swelling clay, and the condition and position of overlays if any, are also of importance.

If the space provided for general comments is not big enough, the back of the form may be used.

CONCLUSION

It is important to do the survey as quickly as possible, however, if bad sections are encountered, it may be advisable to slow down so as to make the best use of the opportunity. The survey form is drawn up to make estimates of quantity easy wherever possible and an elaborate estimation of quantity is unnecessary.

Fig B.16. Subsurface drain installed.

Fig B.17. Steel reinforcement too close to surface.

CRCP

PERFORMANCE SURVEY

District	Control	Section	Highway	County	Leave Blank	Date Mo. - Day - Yr.
						- -

Leave Blank	Location From	To	Raters

Mile Post	Mile Point	Transverse Cracks %								Localized Cracks %								Spalling %								Pumping %								Punch Outs in feet								Repair Patches Square feet								Ride
		M				S				M				S				M				S				M				S				M				S				A.C.				P.C.C.				
		1–5	5–20	20–50	50–100	1–5	5–20	20–50	50–100	1–5	5–20	20–50	50–100	1–5	5–20	20–50	50–100	1–5	5–20	20–50	50–100	1–5	5–20	20–50	50–100	1–5	5–20	20–50	50–100	1–5	5–20	20–50	50–100	1–3	4–9	10–19	> 20	1–3	4–9	10–19	> 20	1–15	16–120	121–240	>241	1–15	16–120	121–240	>241	

5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80

M - Minor S - Severe A.C. - Asphalt P.C.C. - Portland Cement

Condition of Shoulder ______________________________

General Comments ______________________________

____

APPENDIX C

APPENDIX C. ANALYSIS OF THE SURVEY IN THE FORM OF HISTOGRAMS

Continuously reinforced pavements (CRCP) in rural Texas have been surveyed. Analysis of the data is limited to a few processes at this stage since there is a lack of knowledge on the relative contribution of each type of distress of the total distress per section. However, a summary statistic in the form of a histogram may serve a useful purpose in that it presents an indication of the distribution of distress.

BACKGROUND

There is no generally accepted and objective method to evaluate the structural performance of CRCP which also compares the performance of one section against the other. This survey provides the first step toward developing such a method in that a common yardstick to measure distress has been established by definition of the qualitative and quantitative occurrence of distress.

The next step is to establish a method to evaluate these results by an objective, and, if possible, by an accepted statistical, method. It is recognized that a comparison of sections simply by visual inspection of the survey results is not a practical solution. A plot of the results considerably assists in this type of analysis and a summary statistic in the form of a histogram may further increase the capability of the administrator to make comparisons.

SUMMARY STATISTIC

A histogram can be compiled of each section of road surveyed. This type of analysis depicts the frequency of occurrence of each type of distress as a percentage of the total possible occurrence. The same principle can be used to compile a histogram for each district which includes all sections within that district.

The method for calculating frequency of occurrence for the first type of distress, namely transverse cracking, was also utilized for localized cracking, spalling, and pumping. This method can best be illustrated by an example: a 10-mile section of road is surveyed in 0.2-mile subsections. Twenty of the subsections display severe transverse cracking in the category 1 - 5 percent, i.e., 1 - 5 percent of each of the 20 subsections has severe transverse cracks. Therefore, 20 of 50 subsections or 40 percent of the subsections surveyed had 1 - 5 percent severe cracking.

A somewhat different approach is used to calculate the frequency of occurrence of punch outs and repair patches. In this case, the frequency of occurrence of any quantitative category is calculated. For example, say 2 of the 50 subsections surveyed had 10 punch outs each of the 1 - 4 foot size; and five other sections had one punch out each in the same category. This means that seven subsections or 14 percent had one or more punch outs that were between one and four feet long. However, the fact that some sections had more punch outs in the same category was not taken into account in this analysis, and this is a limitation of the method and penalizes the sections with more punch outs. However, a reasonable comparison between districts is possible since all bad sections experience the same restriction. This method had to be followed; otherwise, a three-dimensional histogram would have to be constructed to reflect the true results.

DISCUSSION

Histograms from all rural districts surveyed are included in this appendix. The CRCP surveyed included sections in all climates that can be expected in Texas except for the most western parts. Bearing in mind that there is no differentiation between new and older sections, certain aspects can be pointed out:

(1) A knowledge of the definition of minor transverse cracks makes it possible to distinguish between districts with relatively old and new CRCP.

(2) Districts with severe transverse cracking usually have the more minor spalling.

(3) Districts located in the north, had more localized cracking.

(4) Districts experiencing more minor spalling also had more failures in the form of punch outs and repair patches.

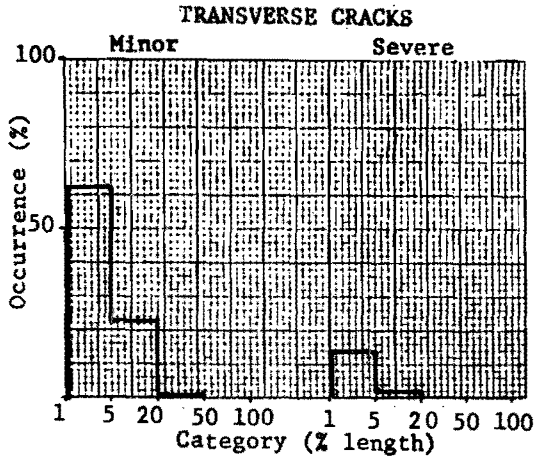
(5) The eastern districts, with wetter climates (poorer subgrades), show more cracking than the relative drier climates.

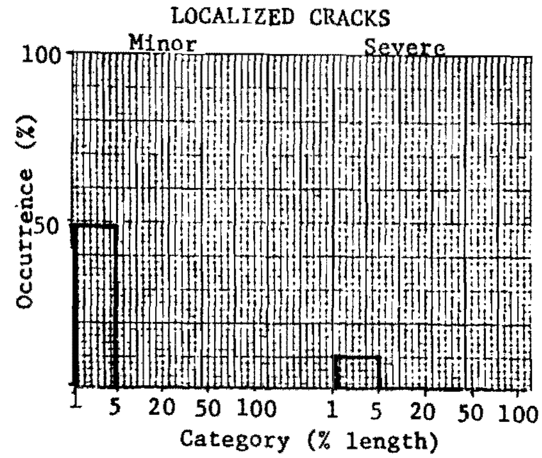
(6) Districts with predominantly heavier traffic and wetter climates show more pumping.

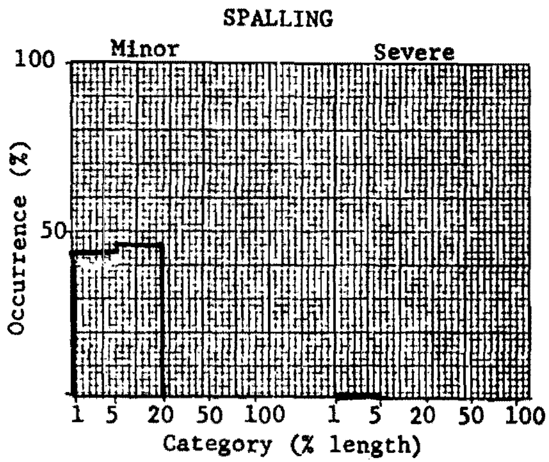
The histogram that summarizes the conditionof all the CRCP in Texas, Fig 6 in the report, clearly shows that minor spalling, minor localized cracking and severe transverse cracking are the more frequent types of distress.

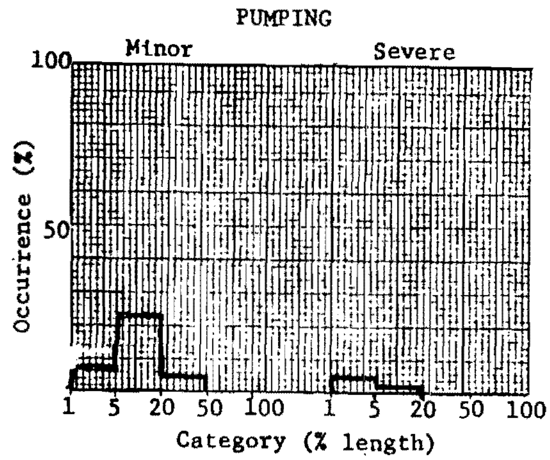
CONCLUSIONS

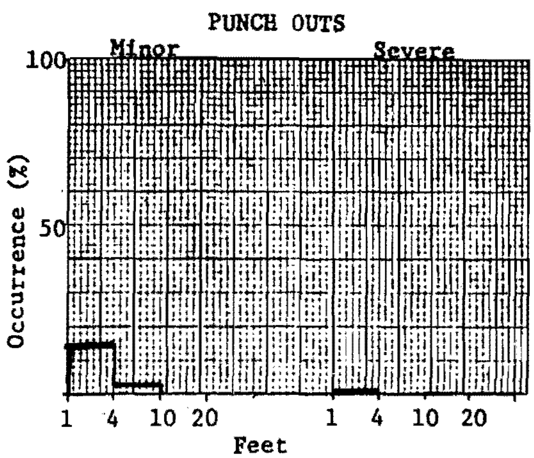
Lack of a proper method of comparing the structural performance of different sections is clearly illustrated in the effort to compare the CRCP in different districts by using histograms. Not until the relative importance of every type of distress has been established can a fair and objective comparison be made. However, a summary-statistic in the form of a histogram provides a useful tool for relative assessment and gives an indication of the districts with particular problems and the types of distress that are predominant. A follow-up study in a year or two on a similar basis may prove to be very useful in tracking down the relative growth of each type of distress and thereby establish its relative importance under those particular circumstances.

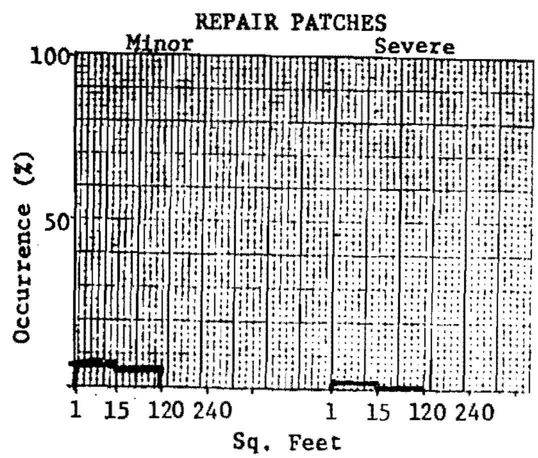












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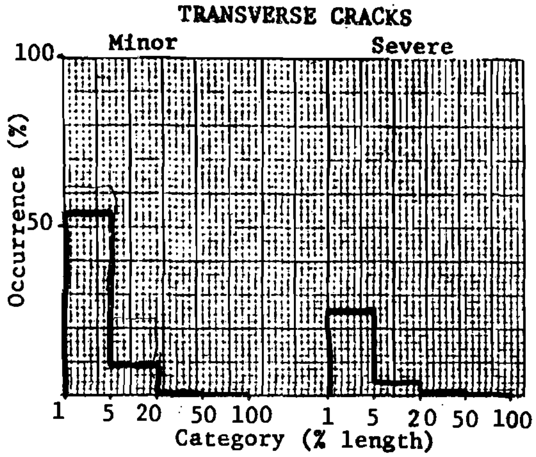

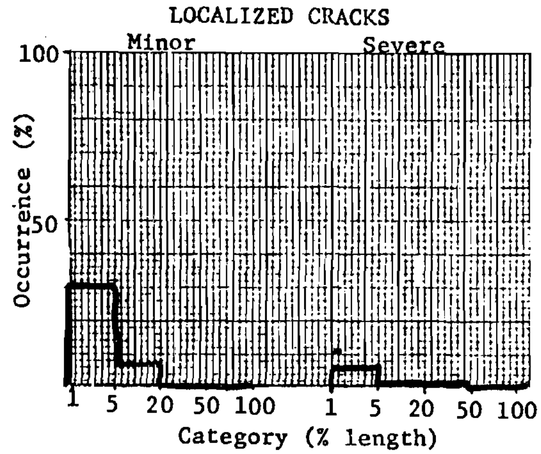

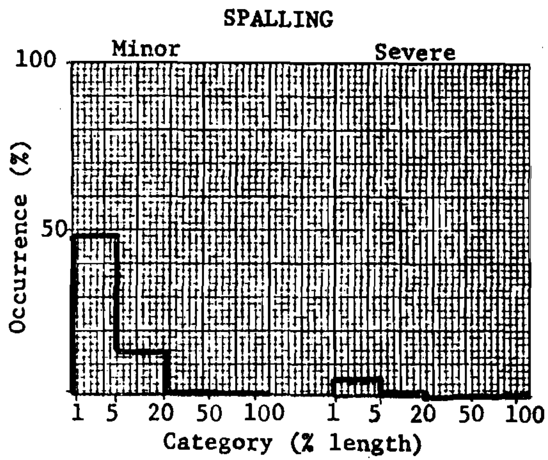

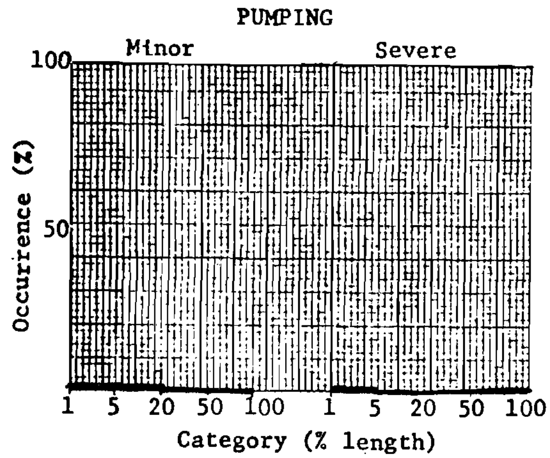

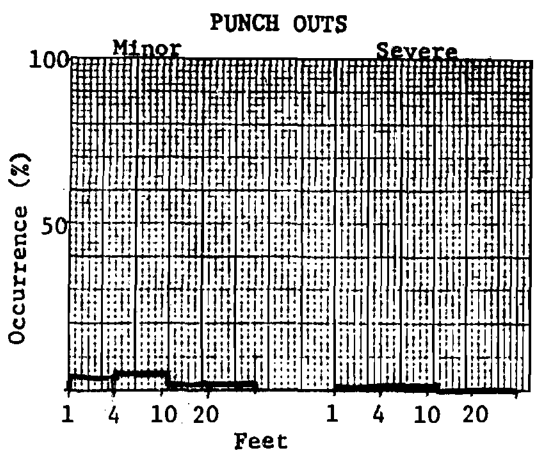

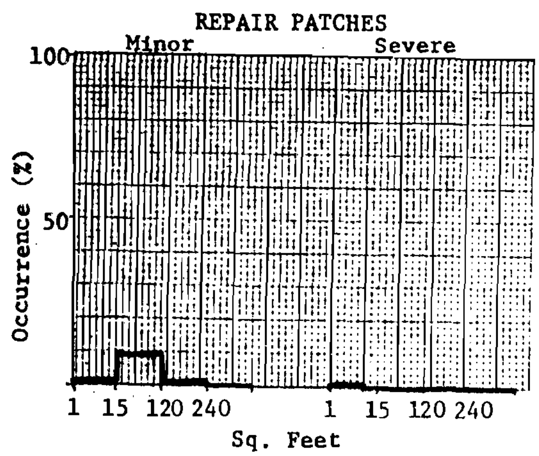

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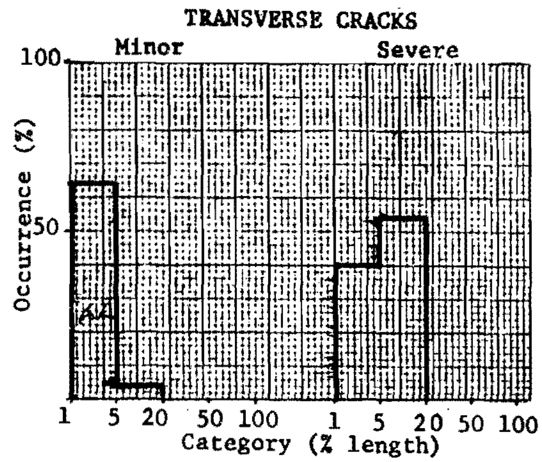
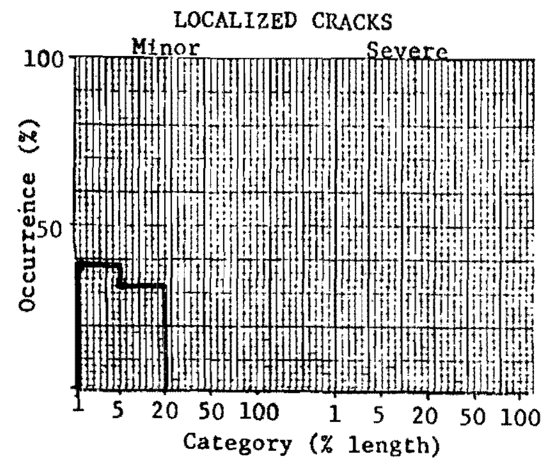
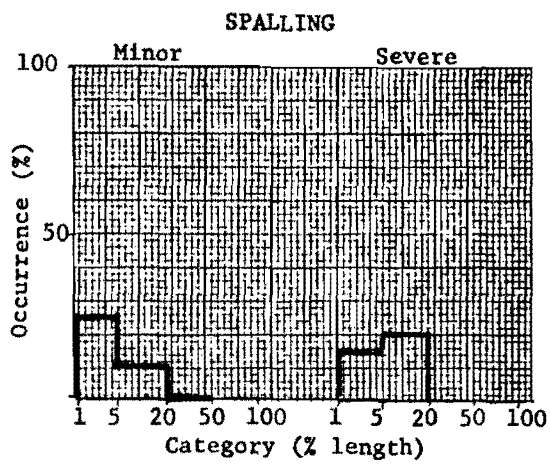
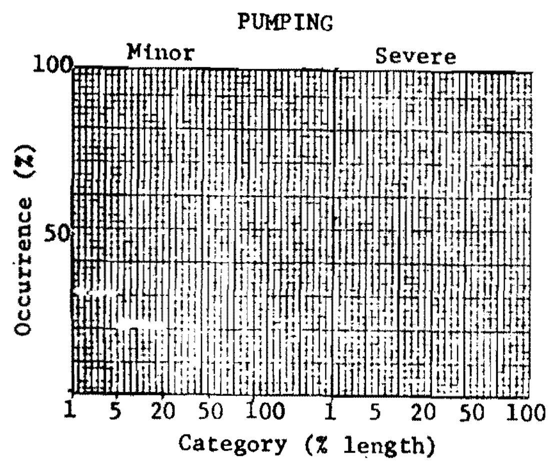
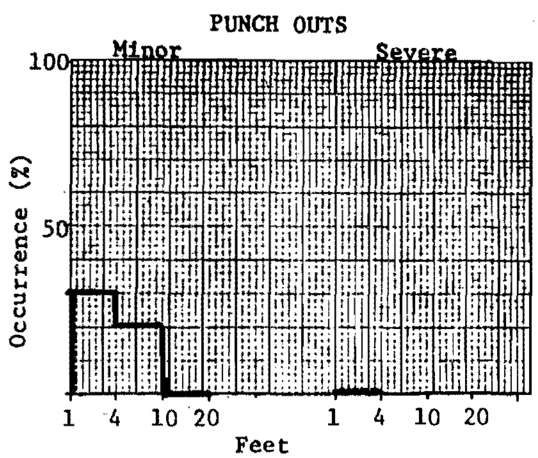
District	Control	Section	Highway	County	Date

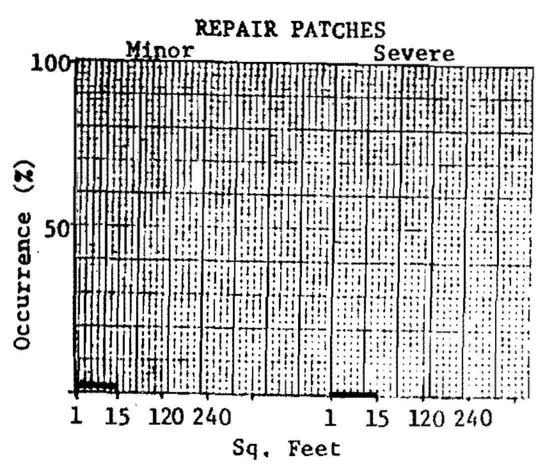












4 District | All Control | All Section | All Highway | All County | 5/74 Date

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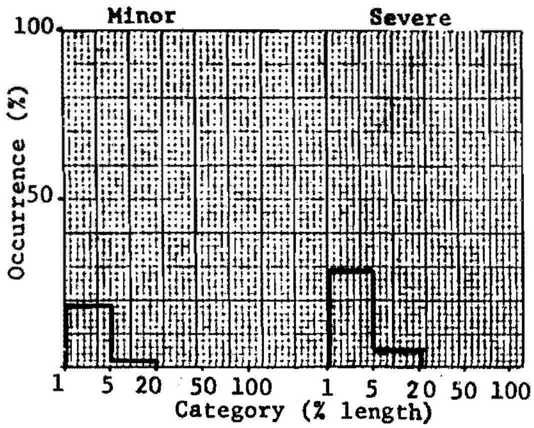

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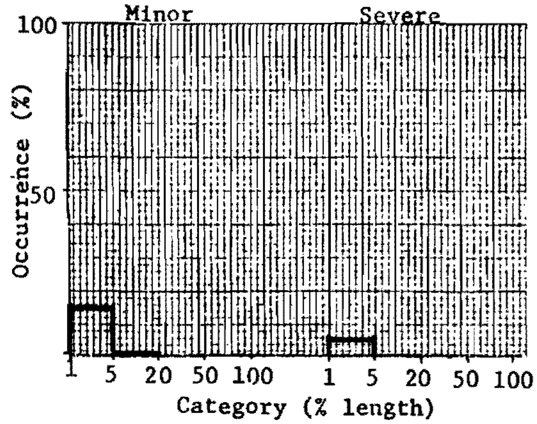

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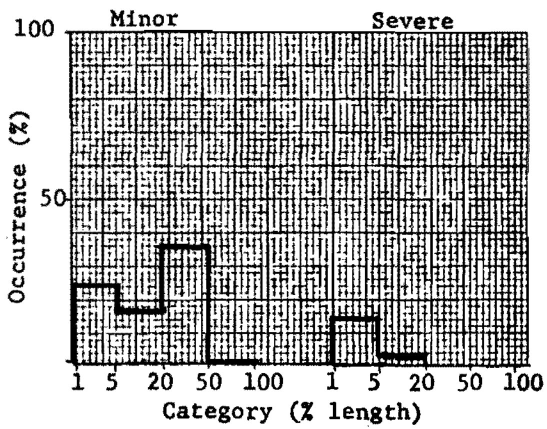

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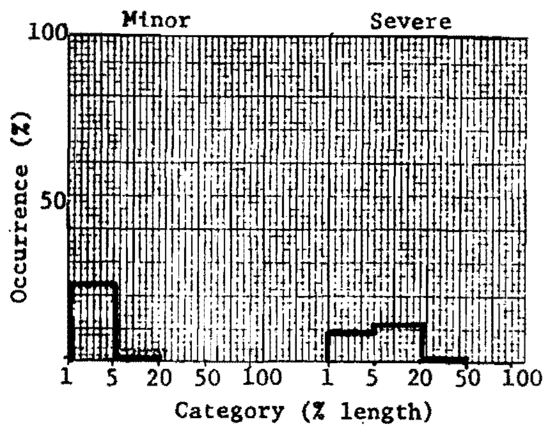

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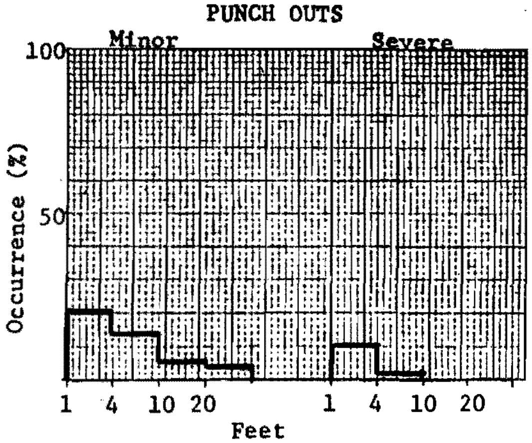

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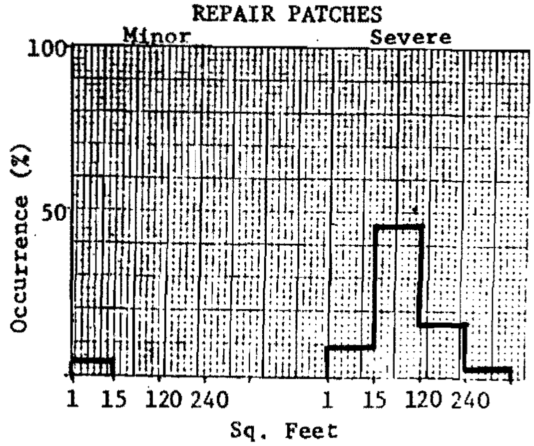

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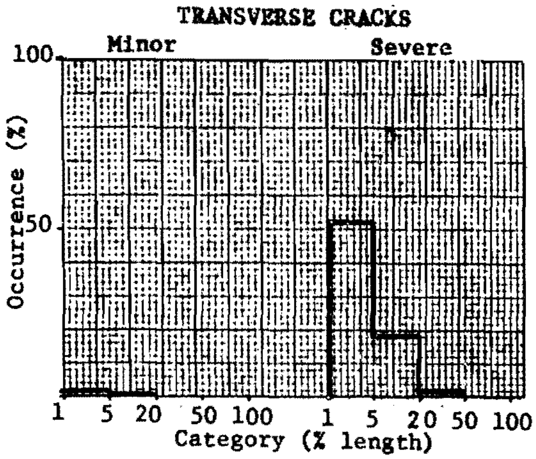
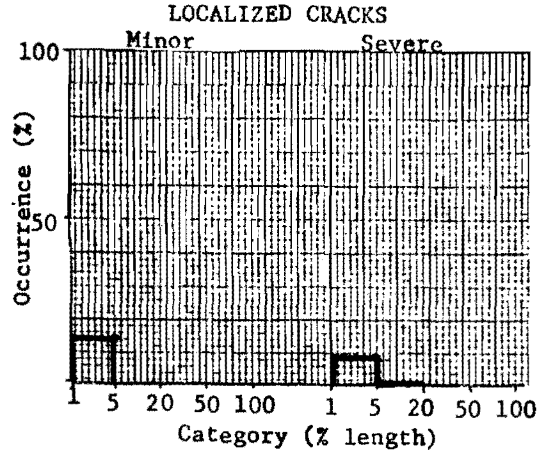
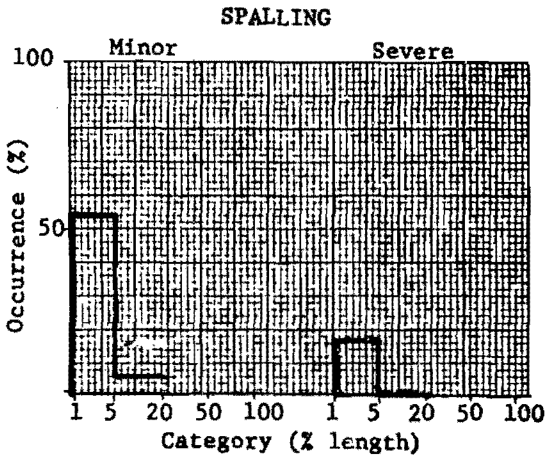
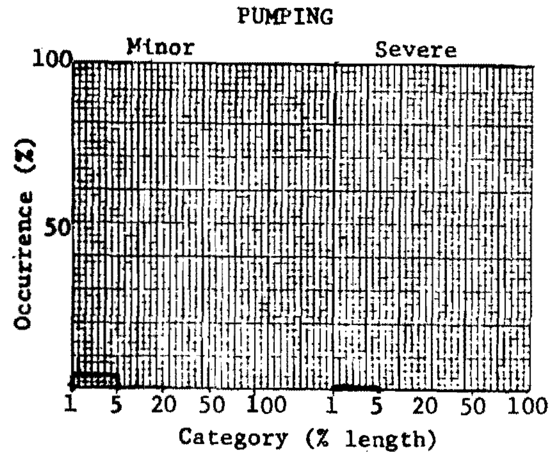
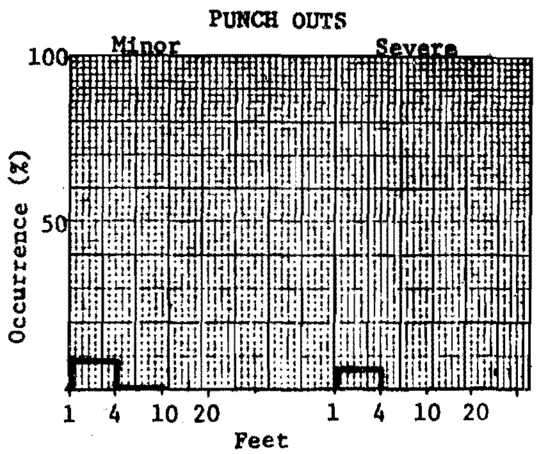
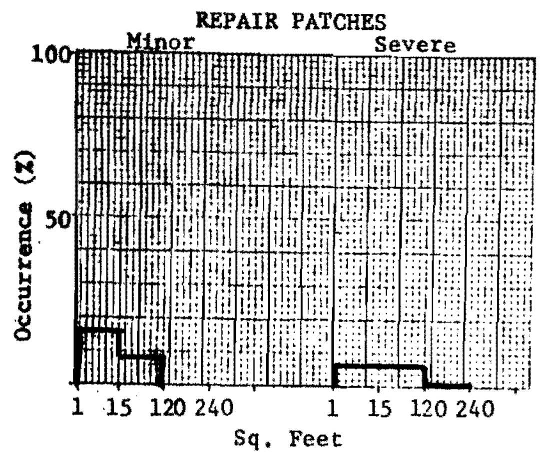




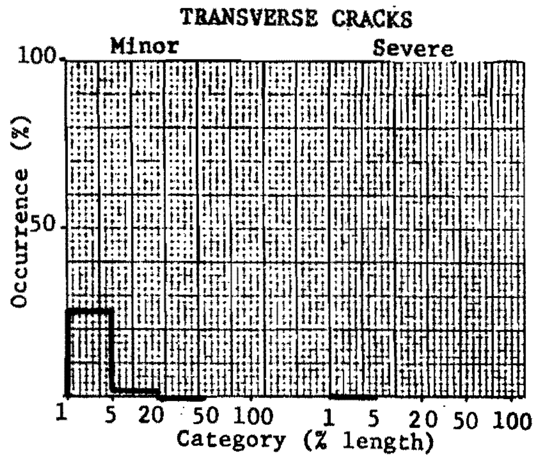


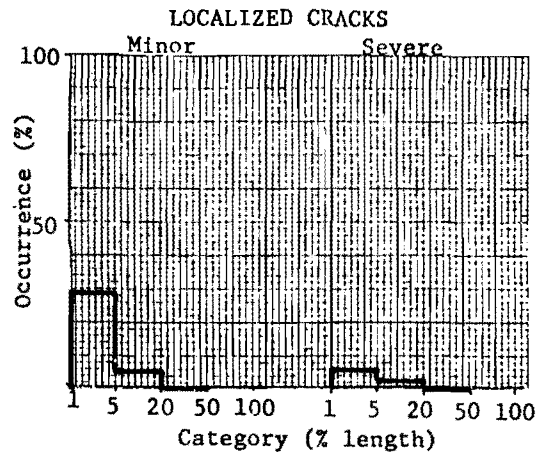


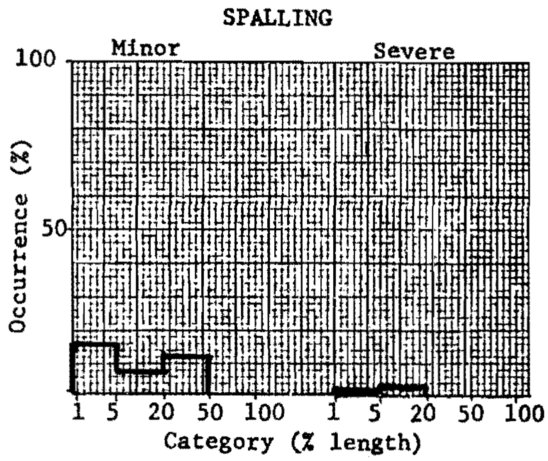


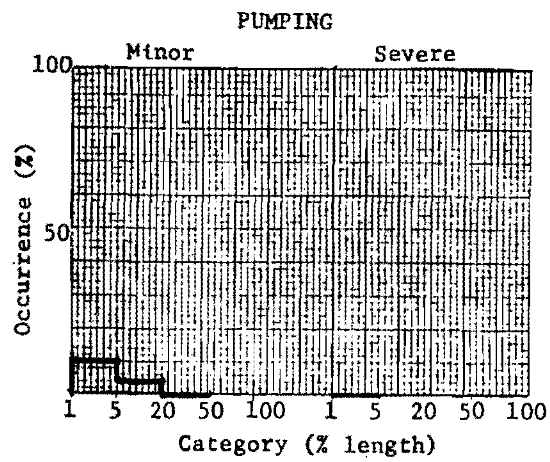


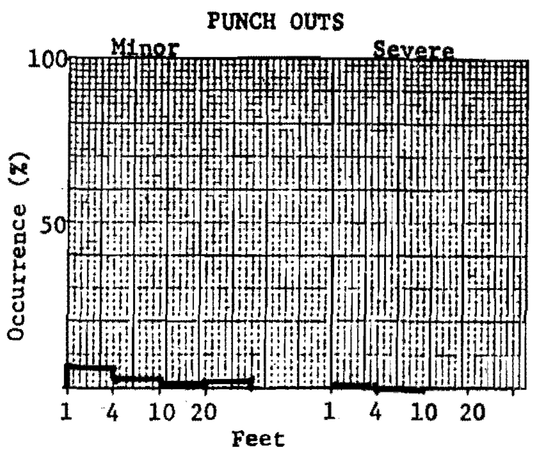
10	All	All			4/74
District	Control	Section	Highway	County	Date

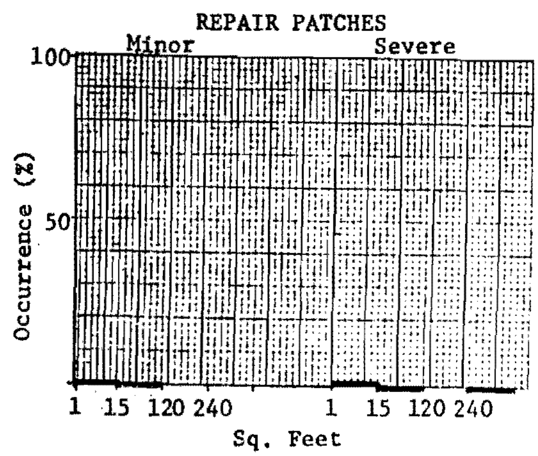




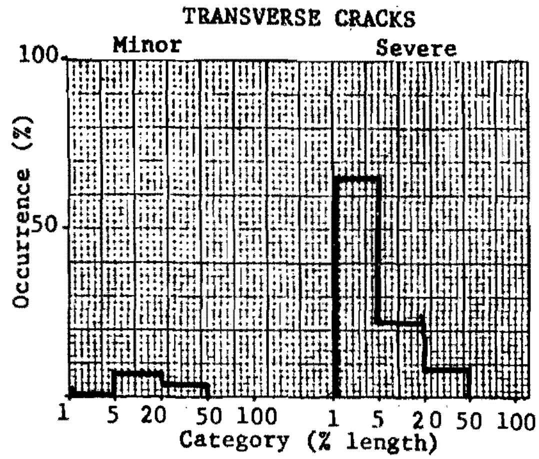


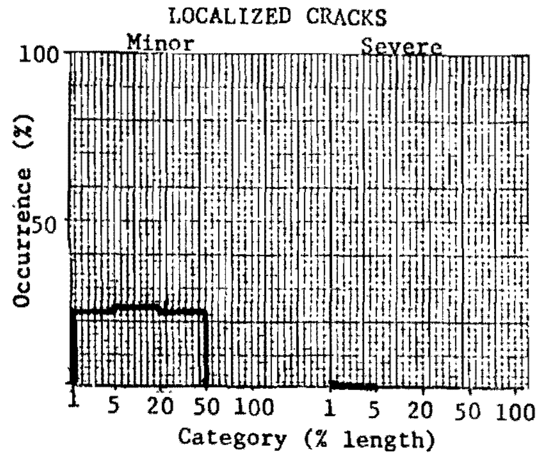


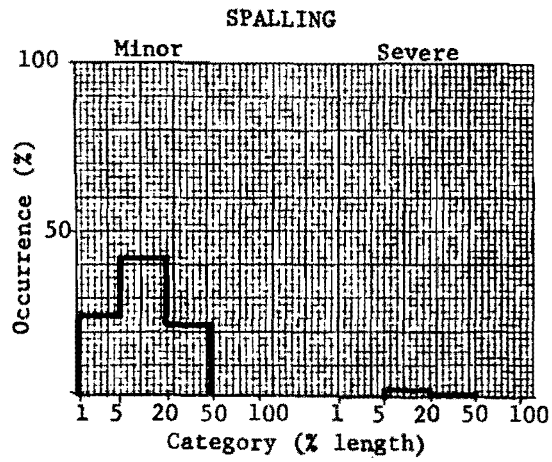


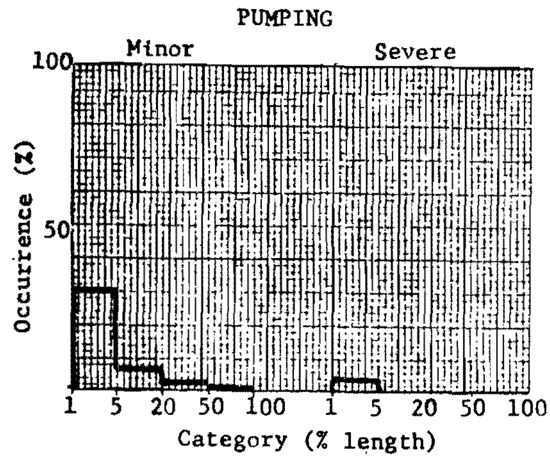


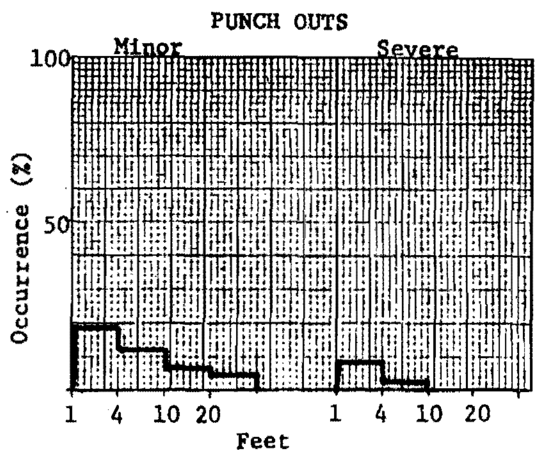
13	ALL	ALL	ALL		
District	Control	Section	Highway	County	Date

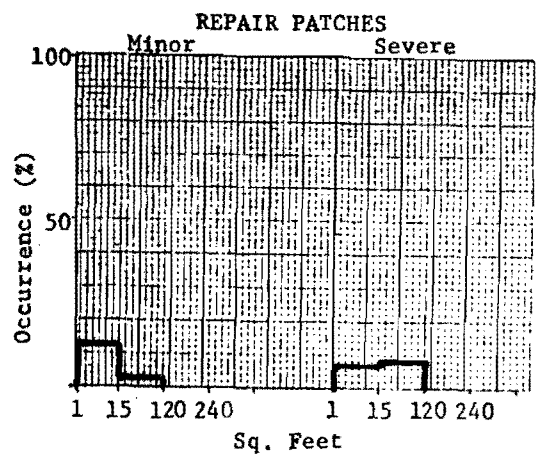




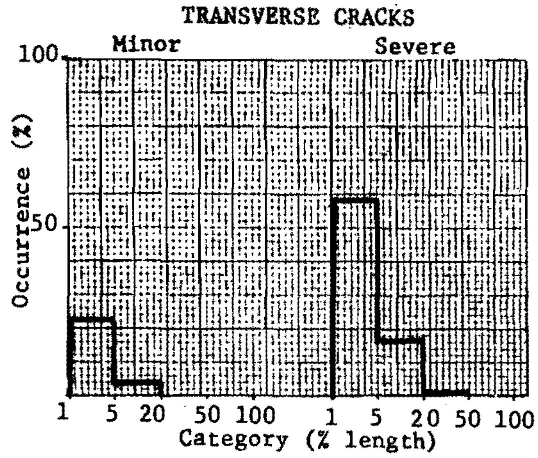


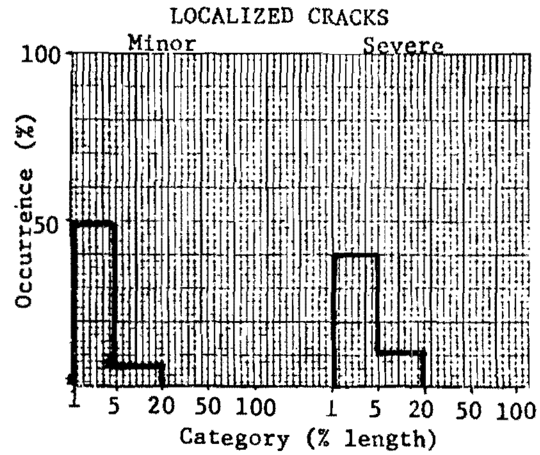


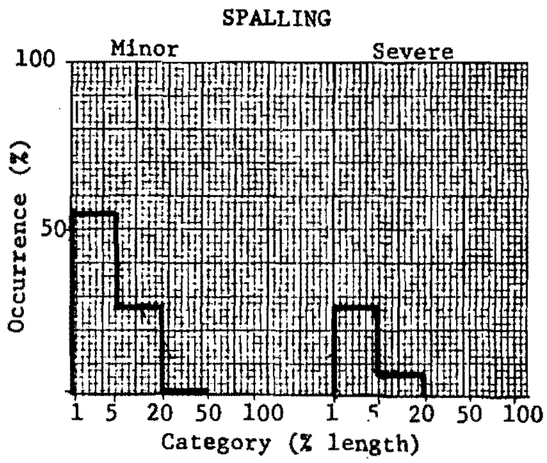


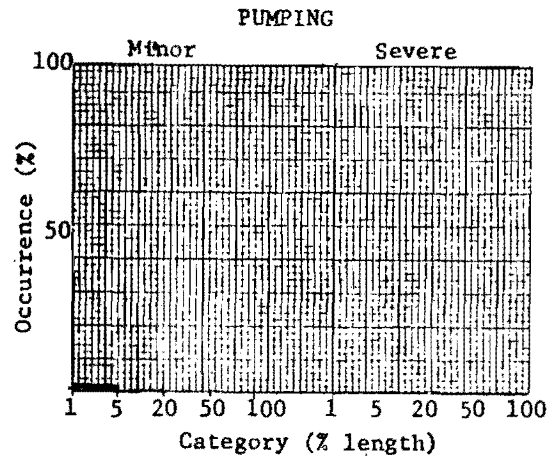


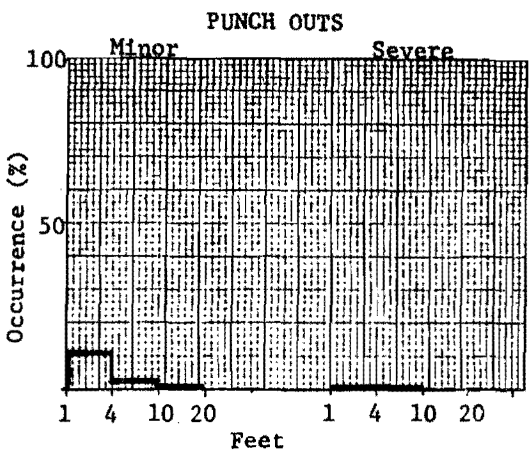
17	All	All	All	All	2/74
District	Control	Section	Highway	County	Date

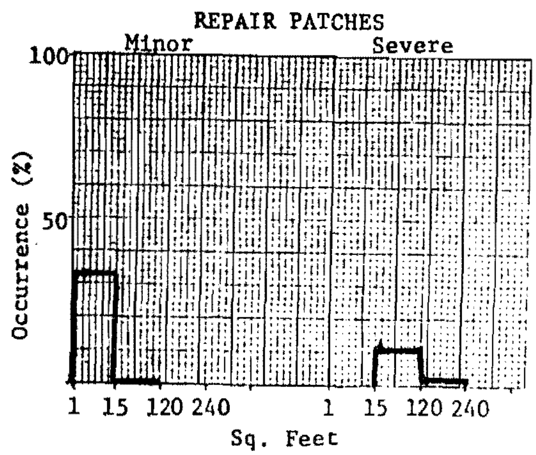




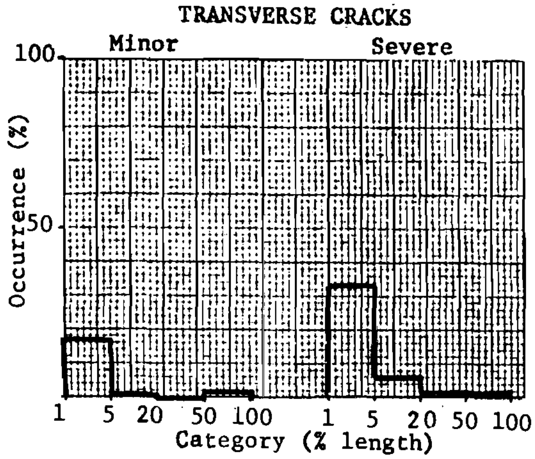


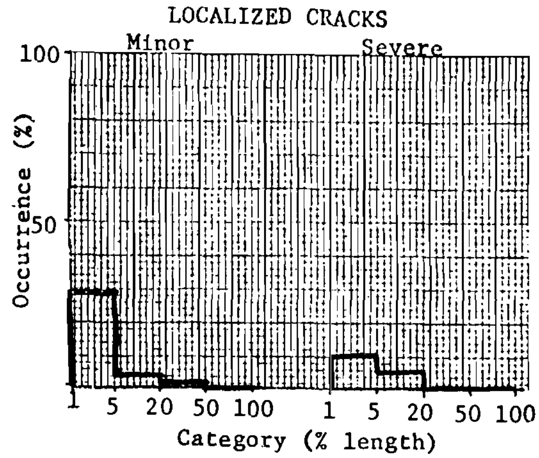


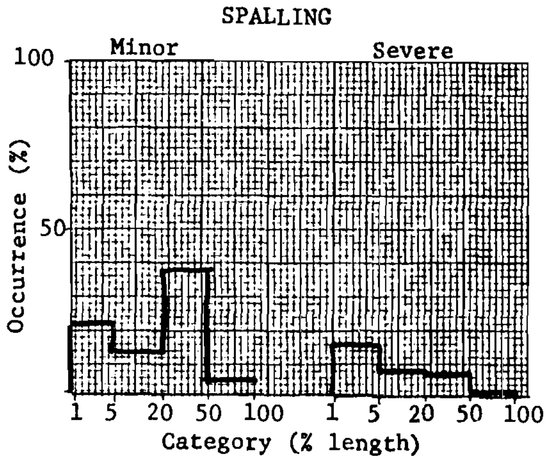


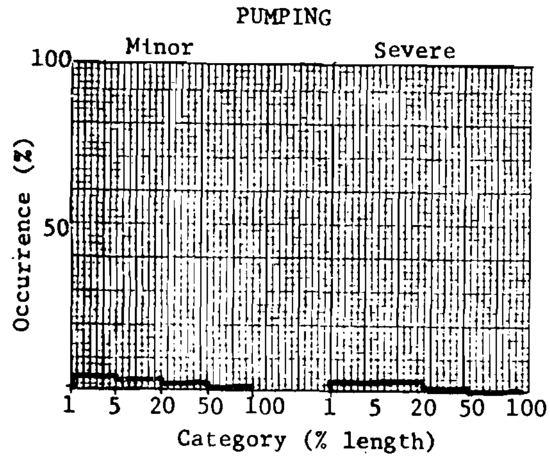


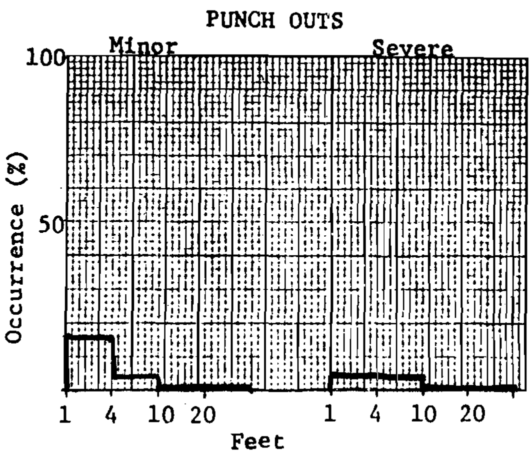
19	All	All	All	All	5/74
District	Control	Section	Highway	County	Date

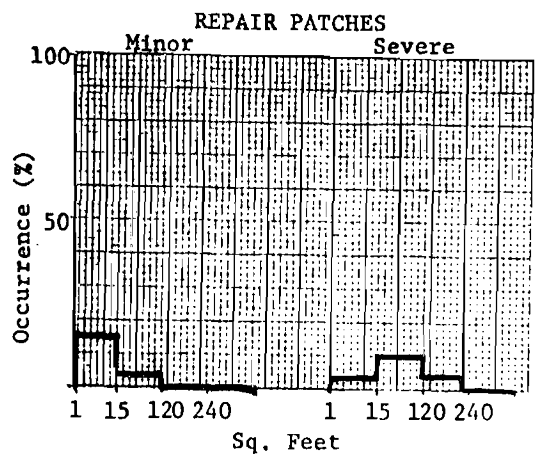




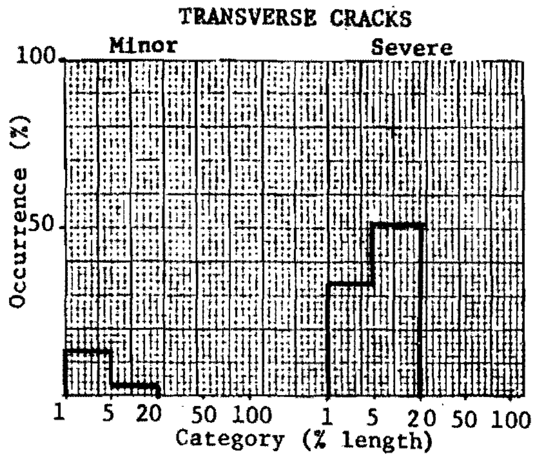


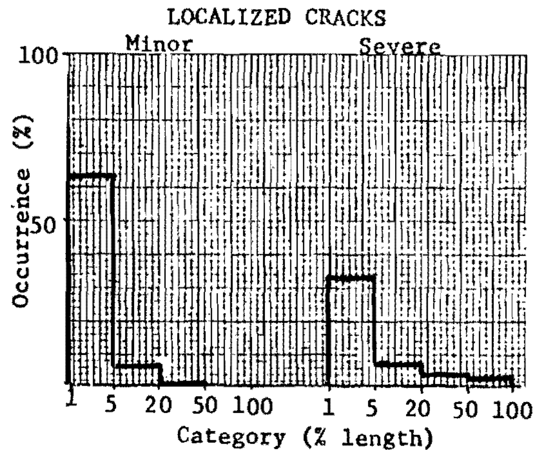


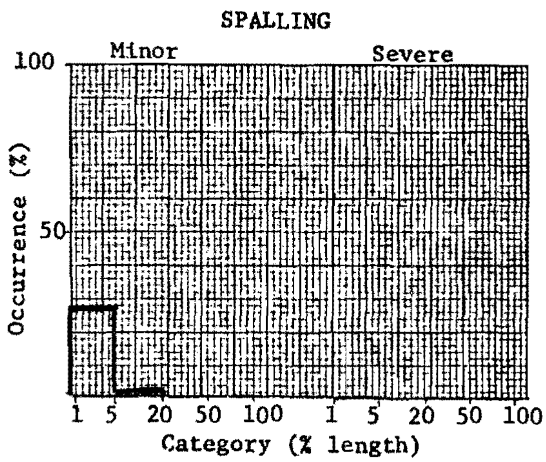


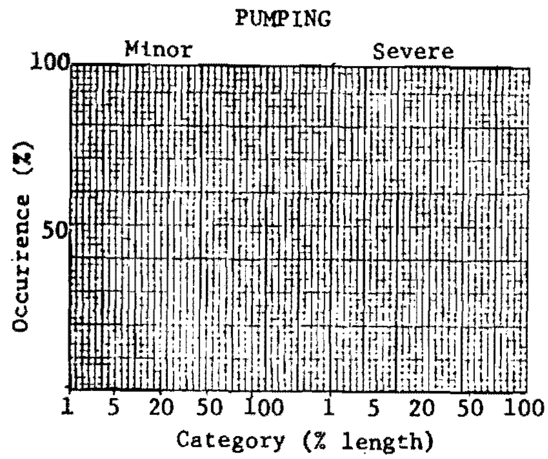


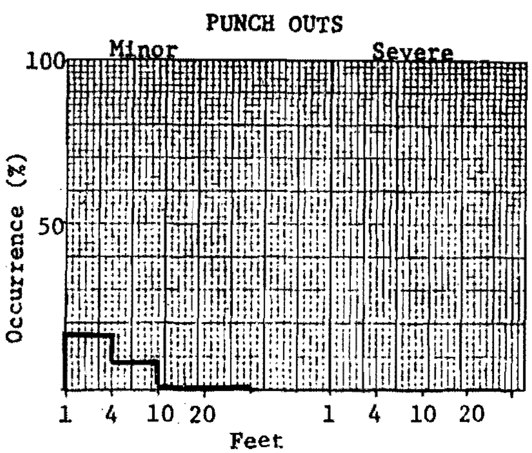
20	All	All	—	—	—
District	Control	Section	Highway	County	Date

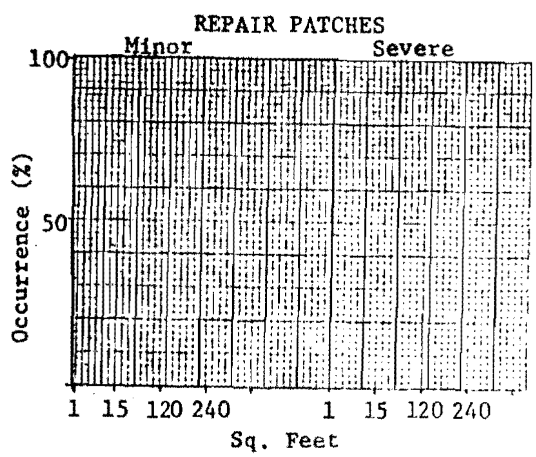












25	All	All	IH 40	—	—
District	Control	Section	Highway	County	Date

APPENDIX D

APPENDIX D. THE EFFECT OF PUMPING ON FAILURES

PROBLEM STATEMENT

The particular continuously reinforced concrete pavement (CRCP) was constructed in 1957 to 1958. The first repairs were made in October 1959 and from that time on repairs were frequently made. The failures at first occurred at or near construction points sith subsequent progress into sound concrete from the old repairs. During the last few years, repairs were made all along the pavement length. This investigation has as its goal the analysis of the different types of distress and their contribution to the general structural failure of the pavement. Particular attention is focused on the effect of pumping and the factors that lead to pumping.

DATA AVAILABLE

Seventeen reports of surveys that cover the period of 1958 to 1964 are available. The main concern of those reports was the program of failure itself and the investigation into the reasons for failure at particular spots. The surveys were made by visual inspection during repair operations and the major findings were:

(1) The failures were not due to a design problem but reflected a construction error.

(2) Honeycombing at the failure areas was a result of poor vibration techniques.

(3) Bar laps in the reinforcement did not contribute to the failures.

(4) Future repairs should be in excess of two feet wide to insure slab continuity after repair.

Five areas subjected to pumping were discovered in the period of 1961 to 1964. Photographs were taken of these areas and the repairs made at that time were reported on. A condition survey was performed in March 1974 during which the extent of different distresses was quantified using a form that was developed for the Texas Highway Department and lends itself to a thorough detailed survey. Appendix D.1 shows the general field survey of the sections.

Apart from surveys of failure areas, a series of photographs were taken and followed up in 1974. They indicate that frequent maintenance was required on each repair patch throughout the life of the pavement.

ANALYSIS

The history in photographs proved to be a very valuable tool in the analysis of failure throughout the years. The supplementary condition survey provides a means to research into the reasons for the failures.

Photographs

Photographs of pumping and early failures were taken as far back as 1960; distress at Station 3+00 southbound lane (SBL), for example, began as pumping and eventually repairs were required several times. Pumping of this section occurred in 1961, as shown in Fig D.1a. Figure D.1b was taken in 1964 and D.1c in 1974. Note the width of the side joint in D.1b and subsequent repairs on the pavement as well as failure on the shoulder in D.1c.

Figure D.2 depicts the extent of failure at a construction joint and the subsequent repairs. The first indications of failure were observed in 1961 followed by spalling in 1962 (Figs D.2a and D.2b, respectively). Initial failure was due to insufficient vibration of the concrete at the time of construction. It is quite evident that the repair patch is failing again, as illustrated in Fig D.3b, a general view of the area. A picture was taken from the same position in 1964 (Fig D.3a). Comparing the last two pictures, it seems that the failure is repeated in exactly the same position as before. Note the pumping in D.3a farther along the road, top right corner of the picture, and compare it with the patch in D.3b adjacent to the previous pumping.

The second area of failure occurred at Station 22+00 northbound lane (NBL). Figures D.4a and D.4b illustrate the punch out that occurred in 1962, D.4a being taken in February and D.4b in May. A repair was made in October 1962 (Fig D.4c), but it failed in April 1963 (Fig D.4d). This failure was

CRCP

PERFORMANCE SURVEY

CONTROL ______ SECTION ______ LOCATION: From ______ To ______

HIGHWAY IH 35 SB DISTRICT 9 COUNTY McLennan RATER Jim, Pieter DATE 3/7/74

MILE POSTS

M = minor S = severe

MILE POSTS	TRANSVERSE CRACKS (%) M	TRANSVERSE CRACKS (%) S	LOCALIZED CRACKS (%) M	LOCALIZED CRACKS (%) S	SPALLING (%) M	SPALLING (%) S	PUMPING (%) M	PUMPING (%) S	PUNCH OUTS (Ft) M	PUNCH OUTS (Ft) S	REPAIR PATCHES (Sq. Ft) M	REPAIR PATCHES (Sq. Ft) S	RIDE (Rate from 0 to 5)
.6 – .4		X (1–5)			X (20–50)				4-9: 1			16-120: 1	3.9
.4 – .2			X (1–5)		X (20–50)			X (1–5)				16-120: 2	4.0
.2 – 319.					X (20–50)			X (5–20)				121-240: 2; 16-120: 3	3.6
319. – .8	X (1–5)				X (20–50)		X (1–5)		4-9: 1; 1-3: 1			16-120: 1	3.7
.8 – .6					X (20–50)		X (1–5)	X (5–20)				16-120: 1; 1-15: 1	3.7
.6 – .4					X (20–50)		X (1–5)	X (20–50)				121-240: 1; 16-120: 4	3.6
.4 – .2		X (1–5)		X (1–5)	X (5–20)		X (1–5)		>20: 1; 1-3: 1	1-3: 1		121-240: 3; 16-120: 5	3.5
.2 – 318.		X (1–5)			X (20–50)		X (1–5)	X (1–5)	4-9: 3	4-9: 1; 1-3: 1	1-15: 1	121-240: 1; 16-120: 14; 1-15: 1	3.4
318. – .8		X (1–5)	X (5–20)		X (20–50)				4-9: 1; 1-3: 1				3.5
.8 – .6		X (5–20)			X (5–20)				>20: 2; 4-9: 1; 1-3: 1			121-240: 1; 16-120: 2; 1-15: 1	3.6
.6 – .4			X (1–5)		X (20–50)		X (1–5)		4-9: 1; 1-3: 11			>241: 1; 121-240: 1; 16-120: 1	3.5
.4 – .2				X (1–5)	X (20–50)		X (1–5)		4-9: 11; 1-3: 1			>241: 1; 1-15: 1	3.6
.2 – [illegible]			X (1–5)		X (20–50)			X (5–20)	4-9: 1			>241: 1; 16-120: 1	3.6
[illegible] – .8													3.7
.8 – .6													3.6

CONDITION OF SHOULDER ______

GENERAL COMMENTS ______

CRCP
PERFORMANCE SURVEY

CONTROL ______ SECTION ______ LOCATION: From ______ To ______

HIGHWAY IH 35 SB DISTRICT 9 COUNTY McLennan RATER Jim Pieter DATE 3/7/74

MILE POSTS: 317. .8 .6 .4 .2 316. .8 .6 .4 .2 315. .8 .6 .4 .2 314.

M = minor S = severe

TRANSVERSE CRACKS (%)

	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S
100–50																														
50–20																														
20–5																														
5–1		X				X		X		X								X		X						X				

LOCALIZED CRACKS (%)

	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S
100–50																														
50–20																														
20–5																														
5–1											X		X										X			X	X			

SPALLING (%)

	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S
100–50													X		X															
50–20	X		X		X		X		X		X						X		X		X		X			o	X		X	
20–5																									X					o
5–1		X																								X		oX		

PUMPING (%)

	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S
100–50																														
50–20																														
20–5		X						X		X						X		X		X										
5–1	X		X		X	X	X		X						X		X		X			X								

PUNCH OUTS (Ft)

	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S
> 20	1						1																							
10-19			1												1		1				1									
4-9			1				1				1				2		1		1				1							
1-3			1	1	2							1	1	2	1		1		1			1		1						

REPAIR PATCHES (Sq. Ft)

	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S
> 241																														
121-240		2		1				1		1				1		3		4												
16-120		1		2		2		1		3		1		2		3		12		8		4		2						4
1-15								2		1								1	1											

RIDE (Rate from 0 to 5): 3.6 | 3.7 | 3.7 | 3.6 | 3.7 | 3.8 | 3.5 | 3.4 | 3.6 | 3.7 | 3.8 | 3.8 | 3.7 | 3.8 | 3.8

CONDITION OF SHOULDER ______

GENERAL COMMENTS ______

CRCP

PERFORMANCE SURVEY

CONTROL ____________ SECTION ____________ LOCATION: From ____________ To ____________

HIGHWAY IH 35 SB DISTRICT 9 COUNTY Mclennan RATER Jim, Pieter DATE 3/7/74

M = minor S = severe

	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S
MILE POSTS	314.		.8		.6																									
TRANSVERSE CRACKS (%) 50–100																														
TRANSVERSE CRACKS (%) 20–50																														
TRANSVERSE CRACKS (%) 5–20																														
TRANSVERSE CRACKS (%) 1–5																														
LOCALIZED CRACKS (%) 50–100																														
LOCALIZED CRACKS (%) 20–50																														
LOCALIZED CRACKS (%) 5–20																														
LOCALIZED CRACKS (%) 1–5																														
SPALLING (%) 50–100																														
SPALLING (%) 20–50	X			o																										
SPALLING (%) 5–20																														
SPALLING (%) 1–5		o																												
PUMPING (%) 50–100																														
PUMPING (%) 20–50																														
PUMPING (%) 5–20																														
PUMPING (%) 1–5																														
PUNCH OUTS (Ft) > 20																														
PUNCH OUTS (Ft) 10-19																														
PUNCH OUTS (Ft) 4-9																														
PUNCH OUTS (Ft) 1-3			1	1																										
REPAIR PATCHES (Sq. Ft) > 241																														
REPAIR PATCHES (Sq. Ft) 121-240				2																										
REPAIR PATCHES (Sq. Ft) 16-120				4																										
REPAIR PATCHES (Sq. Ft) 1-15																														
RIDE (Rate from 0 to 5)	3.8		3.5																											

CONDITION OF SHOULDER ____________

GENERAL COMMENTS ____________

CRCP
PERFORMANCE SURVEY

CONTROL ________ SECTION ________ LOCATION: From ________ To ________

HIGHWAY IH 35 NB DISTRICT 9 COUNTY Falls RATER Jim, Pieter DATE 3/7/74

MILE POSTS

M = minor S = severe

MILE POSTS	.6–.8		.8–314.		314.–.2		.2–.4		.4–.6		.6–.8		.8–315.		315.–.2		.2–.4		.4–.6		.6–.8		.8–316.		316.–.2		.2–.4		.4–.6	
	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S
TRANSVERSE CRACKS (%) 100																														
50																														
20		X																										X		
5												X																		X
1																														
LOCALIZED CRACKS (%) 100																														
50																														
20																														
5											X										X				X				X	
1																														
SPALLING (%) 100		o		o		o		o		o		o		o																
50	X		X		X		X		X		X		X		X	o	X		X				X		X		X			
20																		o											X	X
5		X		X		X		X		X		X		X														X		
1																														
PUMPING (%) 100																														
50		X																												
20				X		X																								
5	X							X								X		X		X										
1																														
PUNCH OUTS (Ft) > 20																														
10-19																														
4-9					1											1														
1-3			3		1		2							1	1	2	1									1				
REPAIR PATCHES (Sq. Ft) > 241																														
121-240																1												2		
16-120		3		5		2		1		12		2		4		3		4		7		1				1		3.		4
1-15									1	1			1		1	1								1						
RIDE (Rate from 0 to 5)	3.6		3.8		3.8		3.8		3.3		3.5		3.5		3.5		3.5		3.5		3.7		3.8		3.7		3.6		3.5	

CONDITION OF SHOULDER ________

GENERAL COMMENTS ________

CRCP
PERFORMANCE SURVEY

CONTROL ______ SECTION ______ LOCATION: From ______ To ______

HIGHWAY IH 35 NB DISTRICT 9 COUNTY Falls RATER Jim, Pieter DATE 3/7/74

MILE POSTS

M = minor S = severe

		.6–.8		.8–317.		317.–.2		.2–.4		.4–.6		.6–.8		.8–318.		318.–.2		.2–.4		.4–.6		.6–.8		.8–319.		319.–.2		.2–.4		.4–.6	
		M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S
TRANSVERSE CRACKS (%)	100																														
	50																														
	20																														
	5		X		X																										
	1																														X
LOCALIZED CRACKS (%)	100																														
	50																														
	20																														
	5																														
	1	X		X										X						X											
SPALLING (%)	100																														
	50																														
	20	X						X		X		X		X		X		X		X		X		X		X		X		X	
	5			X	X	X	X								o		o		o		o		o				o				o
	1		X						X								X								o				o		
PUMPING (%)	100																														
	50																														
	20																														
	5																														
	1									X												X									
PUNCH OUTS (Ft)	> 20																											1			
	10-19																									1					
	4-9							1																							
	1-3																		1	1					1						
REPAIR PATCHES (Sq. Ft)	> 241																														
	121-240		1																												
	16-120		2		1		3		3						6				1								1		1		
	1-15																														

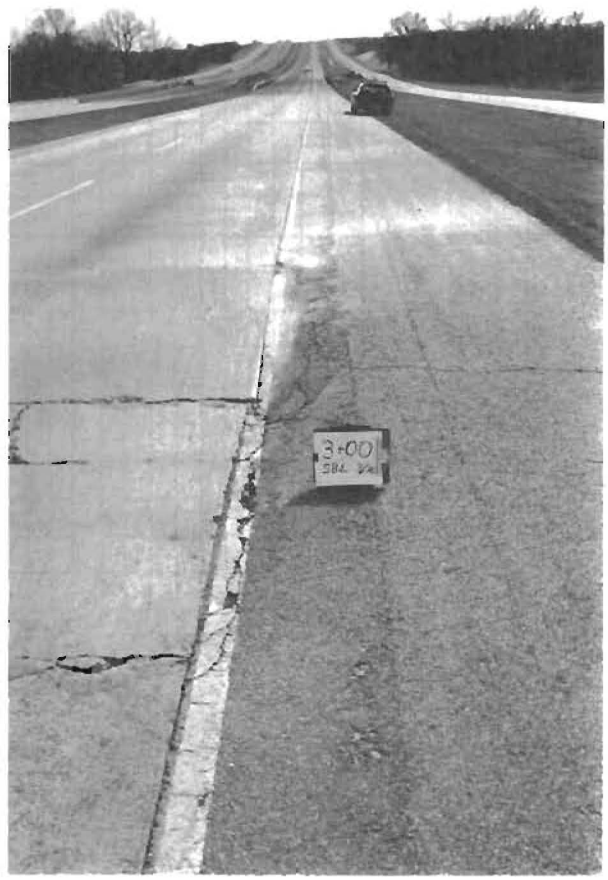
	.6–.8	.8–317.	317.–.2	.2–.4	.4–.6	.6–.8	.8–318.	318.–.2	.2–.4	.4–.6	.6–.8	.8–319.	319.–.2	.2–.4	.4–.6
RIDE (Rate from 0 to 5)	3.5	3.4	3.5	3.6	3.6	3.5	3.4	3.6	3.5	3.6	3.5	3.6	3.6	3.5	3.6

CONDITION OF SHOULDER ______

GENERAL COMMENTS ______

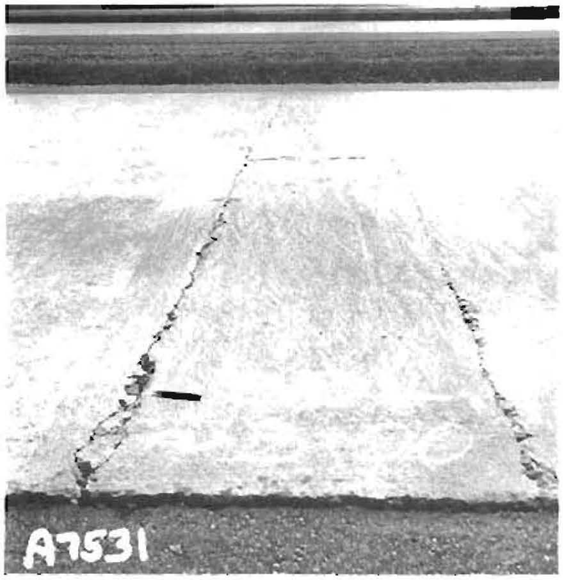
(a) April 1961

(b) March 1964



(c) March 1974

Fig D.1.



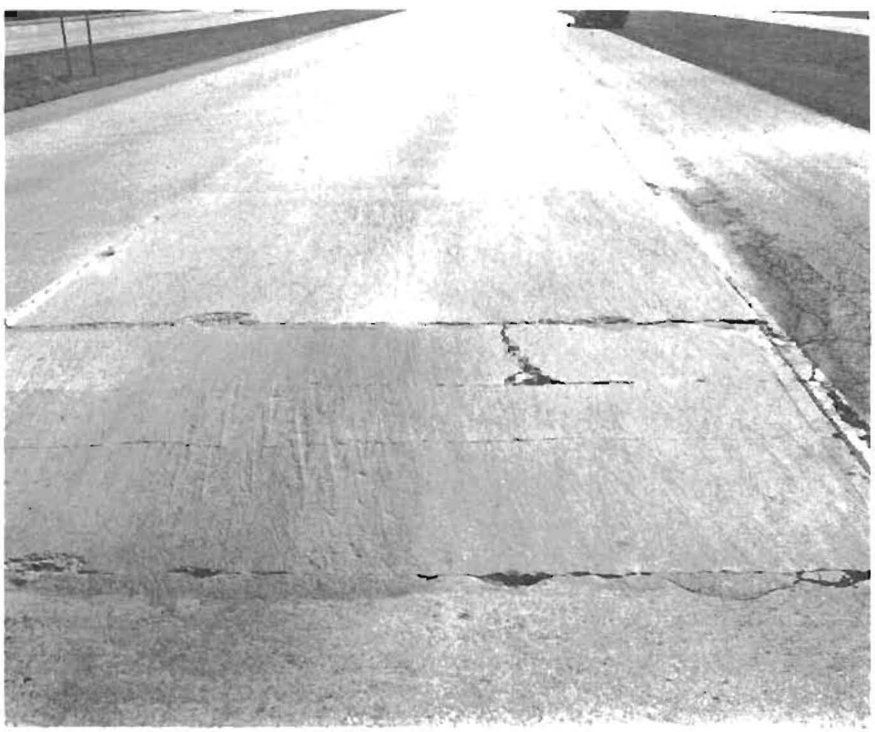
(a) October 1961

(b) May 1962

(c) March 1974

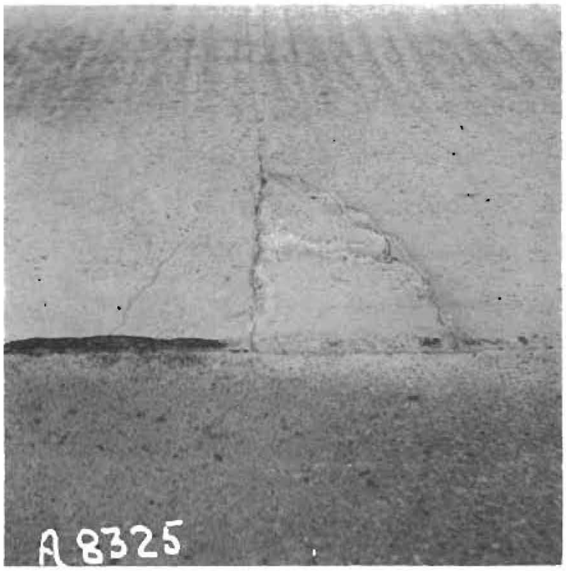
Fig D.2.

(a) 1964

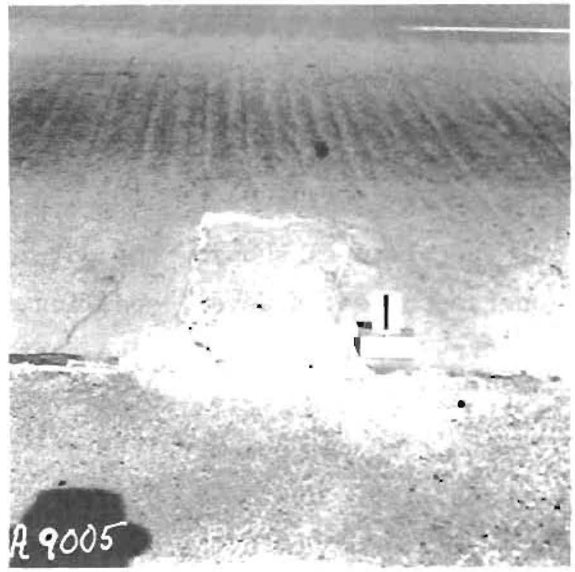


(b) 1974

Fig D.3.

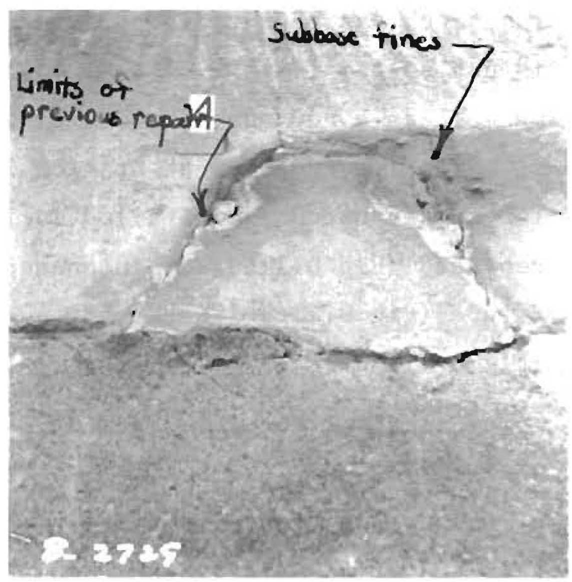


(a) February 1962



(b) May 1962

(c) October 1962



(d) April 1963

Fig D.4.

associated with severe pumping, as illustrated in all the pictures. The existing repair patch is shown in Fig D.5. Again, note the punch out forming and the severe pumping with failure on the shoulder.

A reference crack was photographed every time a survey was conducted. Figures D.6a, D.6b, D.6c, D.7a, and D.7b illustrate the decay of 1960, 1962, 1963, and 1974. The crack occurred on an on-ramp with the far side of the pictures showing the outside lane and the near side showing the on-ramp on which severe spalling finally developed. No visible failure occurred on the outside lane apart from a small minor spall that appeared between 1963 and 1974; compare Figs D.7a and D.7b. Severe spalling occurred in the ramp between May 1962 and October 1962 (Figs D.6b and D.6c) and was patched after 1963 (Fig D.7a).

A severe punch out developed at Station 141+50 SBL as a result of pumping previously reported as "streaks of material occurring on the shoulder." This punch out (Figs D.8a and D.8b) was repaired in 1961 (Fig D.8c). The patch lasted well through 1962 and 1963 (Figs D.9a and D.9b) but heavy pumping caused severe spalling on the edge in 1964 (Fig D.9b). The patch has been replaced several times since then and still the problem is not solved (Figs D.9c and D.10). Note the three large patches in Fig D.10 as well as a new punch out forming at the bottom of the picture.

Pumping reported at Station 176 SBL quickly resulted in a failure. The repair patch again failed in 1964 (Fig D.11a) and was extended and replaced (Fig D.11b). Maintenance will again be required in the near future (Fig D.11c). Note that a subsurface drain was installed at one time (Fig D.11b).

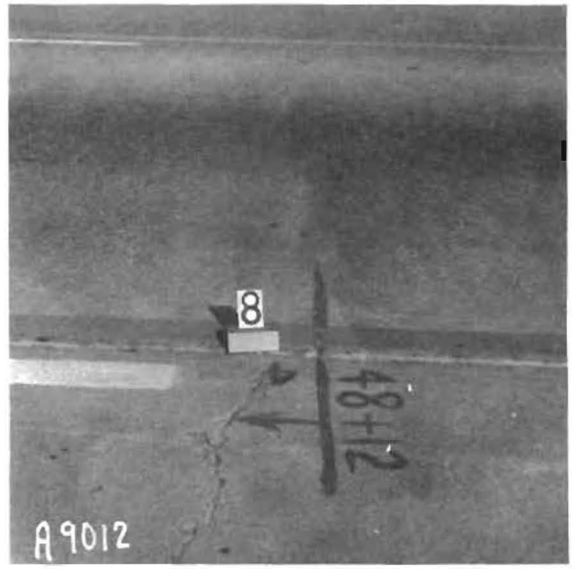
Performance Survey

Unfortunately no performance survey was made prior to 1974 except a report on five areas that indicated pumping. The 1974 survey was performed using the survey sheet included in this appendix. The results were combined and are plotted in Figs D.12 and D.13, Fig D.12 being the NBL and Fig D.13 the SBL. Punch outs were combined with repair patches to form one graph since both depict one hundred percent structural failure of the pavement. Only the general trend is of importance and therefore the weighing factors

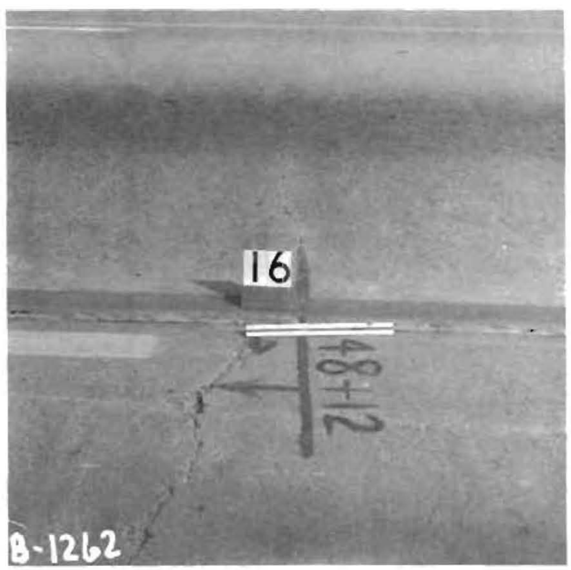
March 1974

Fig D.5.

(a) October 1960



(b) May 1962



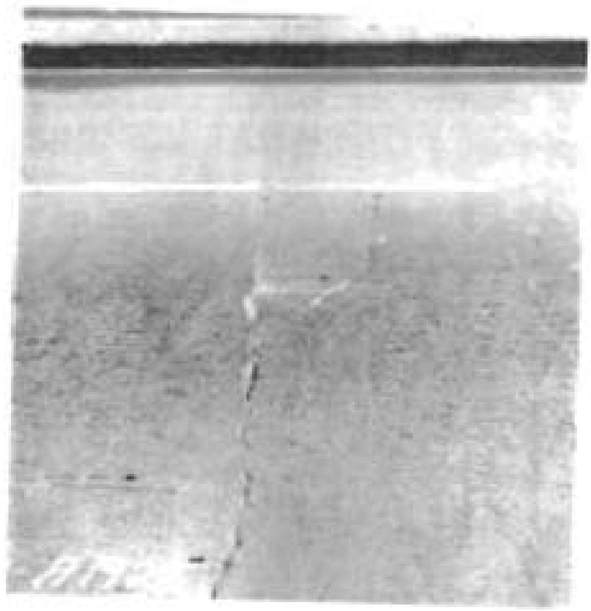
(c) October 1962

Fig D.6.

(a) April 1963

(b) March 1974

Fig D.7.

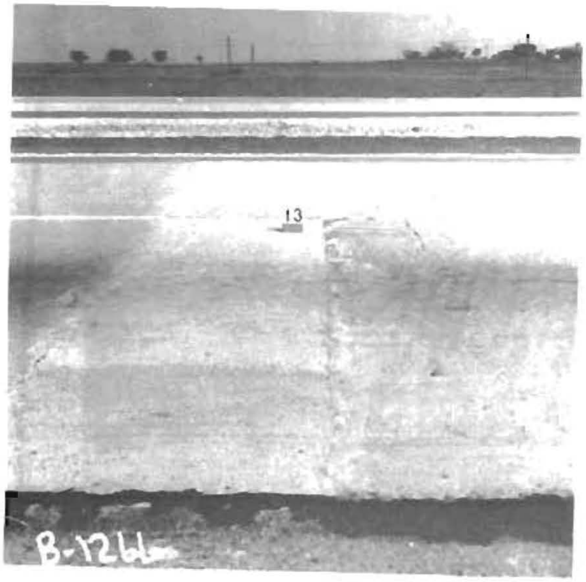


(a) May 1960

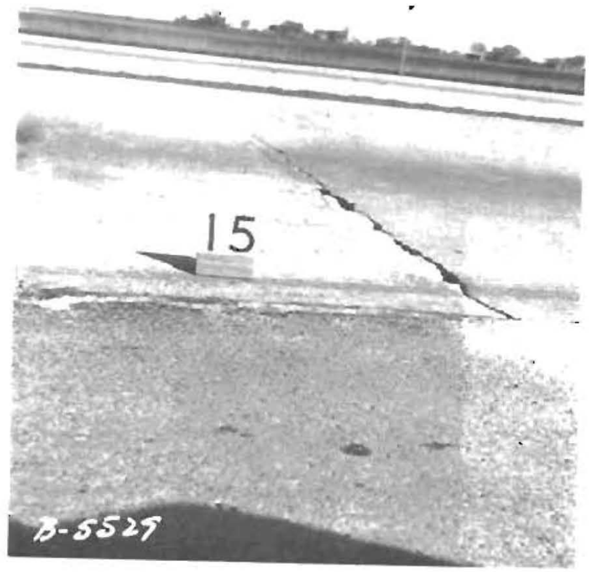
(b) January 1961

(c) April 1961

Fig D.8.



(a) October 1962



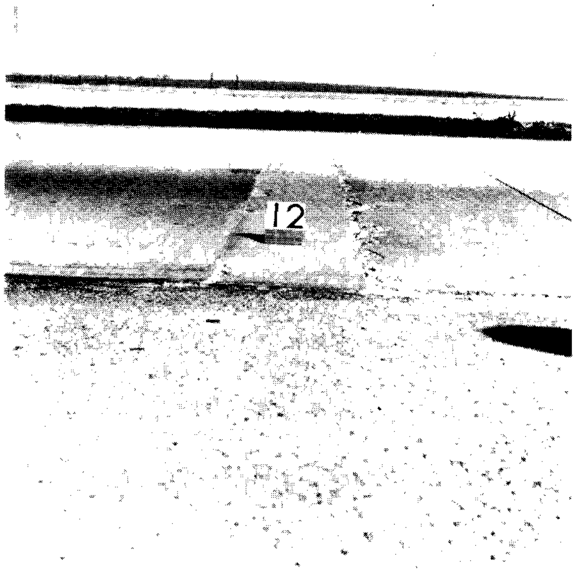
(b) March 1964

(c) March 1974

Fig D.9.

March 1974

Fig D.10.



(a) March 1964

(b) March 1974

(c) March 1974

Fig D.11.

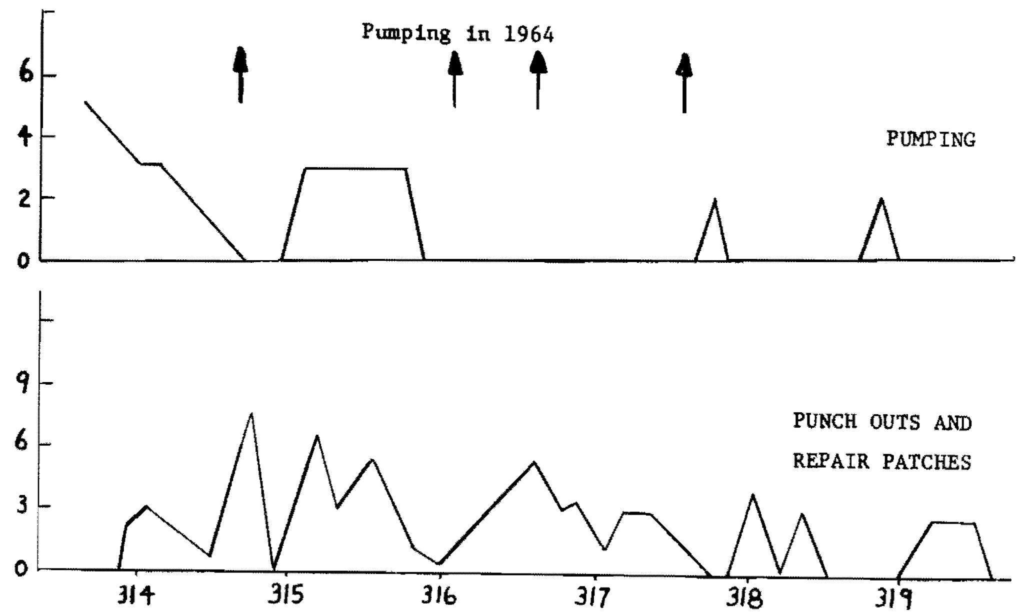


Fig D.12. North bound lane: relative distress with distance.

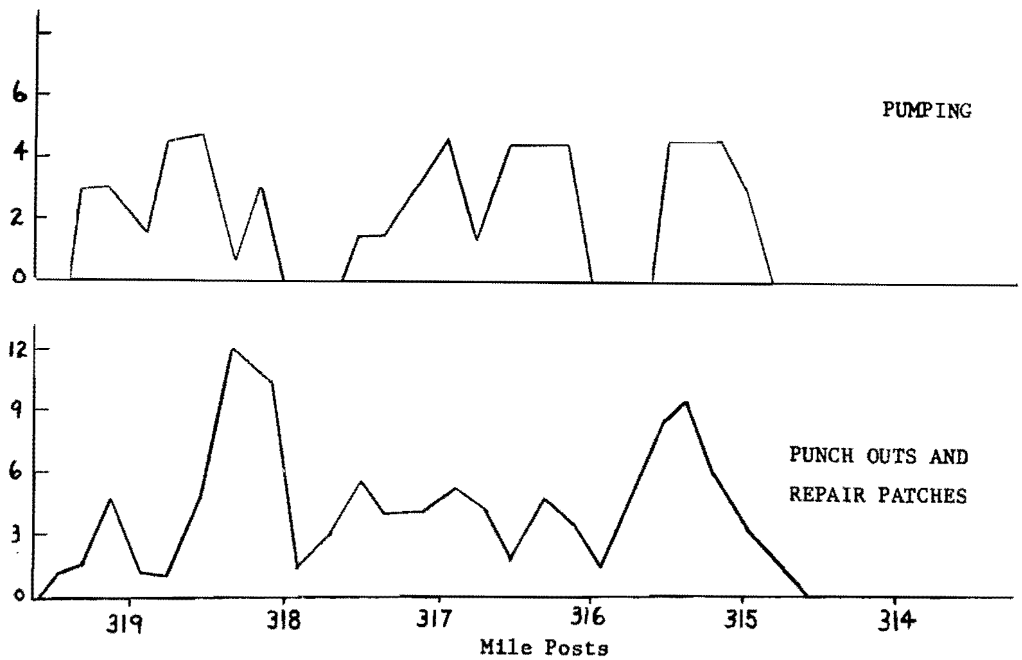


Fig D.13. South bond lane: relative distress with distance.

to combine the two are not reported on. Areas that were pumping in 1962 are marked with arrows in Fig D.13 on the plot of repair patches and punch outs combined.

DISCUSSION

The pictures provided reliable information to compare the performance of a CRCP over a period of time. It is evident that punch outs were initiated by edge pumping in all cases that were investigated. Evidently no repair patch was a success, probably due to the fact that pumping still occurred after the patch work has been completed. Pumping as well as structural failure on the CRCP went hand in hand with failure on the first 12 inches of the shoulder width next to the pavement. In most cases, a punch out formed in exactly the same position every time, although the repair patch extended over a big area.

Basically, the same evidence can be derived from the results of the condition survey. Very little pumping occurred in the NBL, which was built on a fill in most of the section length. The SBL was built in a small side cut and therefore was at or below natural ground level all the time. Most of the pumping was experienced on the SBL (compare Figs D.12 and D.13). The early areas of pumping resulted in crests in the plot of punch outs and repair patches combined. It also seems as if the trend of pumping in 1974 follows the trend of punch outs and repair patches (compare the two graphs in Fig D.13). This cannot be said of the NBL (Fig D.12) since very little pumping and punch outs/repairs occurred on this section.

CONCLUSIONS

Several general conclusions can be drawn from the study. Research on the exact weight factors may lead to more specific conclusions but, for the moment, the following will have to suffice:

(1) Assuming that both lanes carried the same amount of traffic, it can be concluded that pumping is a big source of failure.

(2) It is no good to repair a punch out if the source of the punch out, in most cases pumping, has not been fixed.

(3) Pumping generally occurs where the pavement is at or below natural ground level.

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