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16. Abstract

This report briefly describes the major accomplishments of Research Project 388. Condition survey procedures used in the past to monitor the performance of rigid and overlaid pavements were improved and modified to accommodate the needs of the Texas State Department of Highways and Public Transportation (SDHPT). A micro computer was used during the field surveys to expedite the data entry procedure and eliminate the need for creating computer data files from field data forms.

Pavement evaluation procedures at network level, which were developed earlier, were modified to represent distress and priority indices on a scale of 0 to 100. A new method to evaluate pavements at project level was also developed, which uses a new index called Deflection Distress Index.

The application of the computer program PRP01 to predict future rehabilitation needs has been demonstrated using the existing data. Also the application of condition survey data to monitor the performance of pavements at network level has been illustrated by using the history of pavement conditions stored in the data bank.

A study of an experimental CRCP on IH610 frontage road in Houston was conducted in the past to investigate the effect of light weight aggregate on the pavement performance. A summary of the results of this study are also included in this report.

17. Key Words
rigid pavement, continuously reinforced concrete pavements (CRCP), jointed reinforced concrete pavements (JRCP and JCP), condition surveys, evaluation, prioritization at network level

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by

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W. R. Hudson

Research Report 388-5F

Condition Surveys and Performance Monitoring
of Existing and Overlaid Rigid Pavements
Research Project 3-8-84-388

conducted for

Texas State Department of Highways
and Public Transportation

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

by the

Center for Transportation Research
Bureau of Engineering Research
The University of Texas at Austin

November 1985

PREFACE

Research Report 388-5F, "Condition Surveys and Pavement Evaluation of Existing and Overlaid Rigid Pavements," is the 5th and final report for Research Project 388, "Condition Surveys and Performance Monitoring of Existing and Overlaid Rigid Pavements," which was conducted at the Center for Transportation Research (CTR), The University of Texas at Austin, as part of the Cooperative Highway Research Program sponsored by the Texas State Department of Highways and Public Transportation (SDHPT) and the Federal Highway Administration (FHWA).

The purpose of this final report is to summarize the findings that led to development and implementation of rigid pavement condition survey and evaluation procedures at the project and network levels to assist management authorities in the prioritization, scheduling, and budgeting of maintenance and rehabilitation of rigid pavements. Additionally, a description of the collection, processing, and storage of condition survey data is also provided. The use of condition survey data bank to monitor the highway system at network level by District and state engineers has been demonstrated.

We are indebted to all members of the CTR staff and to graduate students and professors of the Civil Engineering Department who participated in the various activities of Research Project 388. However, special acknowledgement is made to Dr. Muthu, who worked on the special study of light weight aggregate performance, Jim Long, who coordinated and conducted the field surveys, to Lyn Gabbert, who typed the manuscript, and Mike Hunt and Janis Cawthron for their computer program related activities. Thanks are extended to the Texas State Department of Highways and Public Transportation personnel for their cooperation, in particular Gerald B. Peck, Richard Rogers, and James Sassin.

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B. Frank McCullough

W. R. Hudson

LIST OF REPORTS

Report No. 388-1, "Development of a Deflection Distress Index for Project-Level Evaluation of CRC Pavements," by Victor Torres-Verdin and B. Frank McCullough, presents the derivation of a new approach for project-level evaluation of CRC pavements from condition survey data. The main features of computer program DDI1, which incorporates the principal findings from the study are discussed and an input guide for that program is provided along with a project-level condition survey manual.

Report No. 388-2, "Evaluation of the Effect of Survey Speed on Network-Level Collection of Rigid-Pavement Distress Data," by Victor Torres-Verdin, Chhote Saraf and B. Frank McCullough, describes work done in relation with an experiment performed to evaluate the effect of monitoring speed on the quality of rigid-pavement distress data collected at the network level.

Report No. 388-3, "Manual for Condition Survey of Continuously Reinforced Concrete Pavements and Jointed Concrete Pavements," by Chhote Saraf, Victor Torres-Verdin and B. Frank McCullough, presents the procedures for condition survey of CRC and JC pavements recommended for the Rigid Pavement Evaluation System.

Report No. 388-4, "Implementation of a Comprehensive Rigid Pavement Overlay Design System into a Condensed Overlay Design Manual," by Adrianus W. Viljoen and B. Frank McCullough, presents the development and application of a manual for the design of both rigid and flexible overlays for rigid pavements.

Report No. 388-5F, "Condition Surveys and Pavement Evaluation of Existing and Overlaid Rigid Pavements," by Chhote L. Saraf, B. Frank McCullough, and W. R. Hudson, summarizes the important findings of the study. The existing condition survey and pavement evaluation procedures were improved and used in the recent surveys during 1984. The data collected in the past was analyzed and its application in predicting future needs of rehabilitation has been illustrated. The data bank can be used by District and state engineers to monitor the highway network conditions at District as well as state level.

ABSTRACT

This report briefly describes the major accomplishments of Research Project 388. Condition survey procedures used in the past to monitor the performance of rigid and overlaid pavements were improved and modified to accommodate the needs of the Texas State Department of Highways and Public Transportation (SDHPT). A micro computer was used during the field surveys to expedite the data entry procedure and eliminate the need for creating computer data files from field data forms.

Pavement evaluation procedures at network level, which were developed earlier, were modified to represent distress and priority indices on a scale of 0 to 100. A new method to evaluate pavements at project level was also developed, which uses a new index called Deflection Distress Index.

The application of the computer program PRP01 to predict future rehabilitation needs has been demonstrated using the existing data. Also the application of condition survey data to monitor the performance of pavements at network level has been illustrated by using the history of pavement conditions stored in the data bank.

A study of an experimental CRCP on IH610 frontage road in Houston was conducted in the past to investigate the effect of light weight aggregate on the pavement performance. A summary of the results of this study are also included in this report.

KEYWORDS: Rigid Pavement, continuously reinforced concrete pavements (CRCP), jointed reinforced and concrete pavements (JRCP and JCP), condition surveys, rigid pavement evaluation at network and project level, rigid pavement, prioritization at network level.

SUMMARY

The major accomplishments of Research Project 388 are included in this final report. A condition survey manual was developed to describe the latest procedure used in the last condition surveys in 1984. This manual includes procedures for CRCP and JCP.

The development of pavement evaluation procedures is described. The existing evaluation procedure at network level was modified and a new method for use at project level has been developed and its application demonstrated.

The features of the condition survey data bank have been described and the use of computer program developed to retrieve the information and produce reports has been illustrated in this report. Also, the use of data bank to monitor the condition of highway network by District engineers as well as state engineers has been illustrated.

The application of a computer program PRP01 to predict the future needs of rehabilitation with any assumed budget constraints (or no constraints, if so desired) has been illustrated in this report.

IMPLEMENTATION STATEMENT

It is recommended that the pavement condition survey and evaluation procedures be implemented by the Texas State Department of Highways and Public Transportation wherever appropriate (network and/or project level). The computer program PRP01 can be used to study the effects of future budgets at different levels on the rehabilitation needs. The existing rigid pavement data bank which contains the pavement condition history for 10 years should be used to develop new performance prediction models and improve the existing ones. The PES data bank can be supplemented with this data of the past 10 years after developing a procedure to relate the section identifications used in both data banks.

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CHAPTER 1. INTRODUCTION

Condition surveys constitute the data feedback system based on periodic observations that are necessary to continue improvement and implementation of the Pavement Management System. Statewide condition surveys on rigid pavements have been conducted in 1974, 1978, 1980, 1982, and 1984, and they form the best data base in the United States. However, it is necessary that the condition surveys be carried out in the future so that design procedures involving prediction models can be verified. Monitoring of special-study pavement sections has provided a tremendous amount of useful information that has significantly contributed to the development of rigid pavement rehabilitation design systems, as well as criteria for prioritization and scheduling of overlays on rigid pavements at the network level.

The condition survey and performance monitoring of portland cement concrete pavement sections in Texas will permit proper planning of rehabilitation and maintenance and optimum expenditure of available funds. Additionally, actual performance of rigid pavements and overlays could be compared against the predicted performance, and recommendations could be made, if pertinent, to revise the design procedure. Likewise, improvements in the overlay design procedures could result from this feedback process.

BACKGROUND

In connection with Project 3-8-75-177, "Development and Implementation of the Design, Construction, and Rehabilitation of Rigid Pavements," and Project 3-8-79-249, "Implementation of Rigid Pavement Overlay and Design System," several major works were initiated that needed to be continued in the future. The first item was the continuation of the condition surveys of rigid and overlaid rigid pavements that have been conducted at periodic intervals, since 1974. This information was used in connection with the development of the revised design manuals for new concrete pavements and also for overlays. In addition, a detailed computer program PRP01 was developed that permits a prioritization of pavements in the state based on the damage. The program predicts the overlay requirements on pavements that need rehabilitation and also predicts the date of future failure and the subsequent rehabilitation needs. The program has a number of other features, such as investigating the results of fixed budgets, etc.

Also, in connection with these projects, overlay-design programs were developed for predicting the rehabilitation needs of a Portland cement concrete pavement, and the life cycle cost that will be incurred. This program has been used to design a number of overlays around the state by both CTR personnel and the Texas SDHPT personnel. The projects that have been designed and constructed should continue to be monitored in order that the predicted performance and actual performance may be compared. If different, the necessary revisions of the design method may be made.

OBJECTIVES OF THE STUDY

The primary objective of this study was to continue condition survey on the State's rigid pavements carried out in 1974, 1978, 1980, and 1982. This periodical monitoring has made possible the generation of the best data bank of its kind in the United States. Additionally, this objective also included the development of a Rigid Pavement Evaluation System similar to the Flexible Pavement Evaluation System currently in operation. A condition survey manual was to be provided to the Texas SDHPT in which the condition survey procedures will be explained in detail. Other objectives of the study are as follows:

(1) Include the overlaid rigid pavements in the data base. This will entail the following:

   (a) preparation of a condition survey form for rapid use, and
   (b) revision of the computer program PRP01 to accept overlaid pavement.

(2) Develop automated condition survey methods and programs which will be adaptable to overlay methods adjusting them to all pavement overlay method and PES and PMS methodology.

(3) Continue to monitor selected overlay projects. This will provide a better overall estimate of performance and will provide validation of overall design method RPRDS developed in Project 249.

(4) Maintain the overlay condition and performance data base developed to date until it can all be transferred to the Department.

SUMMARY OF ACCOMPLISHMENTS

Some of the results of this study have already been documented in the research reports 388-1 through 388-5. A summary of the contents of these report has been included in the List of Reports of this report and more details will be described in the later parts of this report. Additional work on the analysis of condition survey is included in Chapter 5 of this report.

SCOPE OF THE REPORT

This report summarizes the work accomplished in Project 388.

A discussion on the development of the condition survey procedures is included in Chapter 2. A computer program "QUIKSUR" was developed and used during the condition surveys of 1984 to record the field data directly on the computer disc of a portable micro computer "McIntosh".

Chapter 3 is devoted to the discussion of the pavement evaluation procedures which were developed in the past as well as under this study.

The details of data bank and its use are discussed in Chapter 4.

The application of condition survey data for network analysis is discussed in Chapter 5.

A summary of the results of a 20 year study of light weight aggregate performance are included in Chapter 6. The details of this study will be published in a research report on Project 472.

Chapter 7 presents the general conclusions and recommendations based on the findings of the study.

Three appendices at the end of this report include some details related to the text of this report.

CHAPTER 2. DEVELOPMENT OF CONDITION SURVEY PROCEDURES

INTRODUCTION

A large portion of the interstate highways in Texas is paved with Portland Cement Concrete pavements (about 30 percent of the total 3,000 miles). Some of these highways were constructed during the early phases of the interstate program and others at a later date. Thus, the pavement ages vary considerably and some portions require rehabilitation of some form.

In order to monitor the historical development of distress and various prominent distress types found in these pavements, a condition survey of these pavements was initiated in 1974. The procedures used in 1974 have been continuously modified to make the surveys more objective. To study the historical developments of these procedures it is recommended that the Research Reports 177-19, 177-20, 249-5, 388-2, and 388-3 (Refs 1 to 5) should be studied. The last report on the subject (Research Report 388-3) describes the condition survey procedure for CRCP and JCP, which were used in 1984 (Ref 5).

The following items were studied to develop the condition survey procedures:

(1) survey vehicle and speed,
(2) survey team,
(3) data recording forms and procedures, and
(4) distress descriptions.

SURVEY VEHICLE AND SPEED

Almost any passenger car (4 door sedan) may be used for this purpose, it was found that a van as shown in Fig 2.1 is more suitable for the job. A clear view of the pavement from front and sides makes the job much easier than the restricted side view of the pavements from a passenger car. Also,

Fig 2.1. Condition survey vehicle.

the proposed use of portable micro computer in future surveys will need the extra room available in the van (see Fig 2.2).

All the condition surveys between 1974 and 1982 were conducted at a travel speed of 2 - 5 mph. However, it was felt by the Texas SDHPT staff that the speed was too slow (specially for network level surveys). Therefore, an experiment was designed in early 1984 to study the effect of survey speed on the distress identifications in the field. The details of this study have been published in a Research Report 388-2 (Ref 4). The main features of this study are as follows:

(1) Test sections - 2 sections

- (a) 4-lane divided CRCP, 15.2 miles long; and
- (b) 4-lane divided JRCP, 15.6 miles long.

(2) Survey speeds - 3 different speeds

- (a) 25 mph,
- (b) 15 mph, and
- (c) 5 mph.

(3) Survey Teams - 3 different teams of 2 persons each

- (a) 2 teams had prior experience, and
- (b) 1 team had no prior experience.

(4) Distress manifestations included in the survey

- (a) CRCP - transverse cracks with severe spalling,
  - minor punchouts
  - severe punchouts
  - asphalt patches
  - concrete patches

Fig 2.2. Micro-computer placed inside the survey vehicle.

(b) JRCP - transverse cracks
- spalled joints and cracks
- corner breaks
- slabs with longitudinal cracking
- patches

Based on the results of this study, it was observed that the effect of the survey speed on the accuracy of the distress information collected is very significant for some distress manifestations in both CRC and JRC pavements. Transverse cracks with severe spalling and minor punchouts could not be accurately recorded when the average survey speed was increased from 5 to 15 or 25 mph, while inspecting the CRCP section. The effect of survey speed on the collection of distress data was more significant in the JRCP section than in the CRCP section, since only two distress manifestations could be adequately recorded; i.e., transverse cracks and corner breaks (for further details see Research Report 388-2, Ref 4). In general, however, it can be stated that as the speed increases, the number of distress manifestations that can be accurately recorded decreases. Therefore it was recommended that survey speed should be selected to allow recording of at least the most significant variables included in the computation of distress index of rigid pavements.

The condition surveys conducted in the summer of 1984 were performed at a vehicle speed of about 15 mph.

Also, the condition survey data for each project was recorded for a segment length of 0.2-mile during the 1974, 1978, 1980, and 1982 surveys. However, at the request of the Texas SDHPT staff, the segment length for 1984 condition surveys was changed to 0.4-mile.

Further validation of 1984 condition surveys data was performed in the summer of 1985. For this purpose, a limited number of previously surveyed sections were selected and surveyed again at a slow speed of 0-5 mph. The results of this survey are summarized in Table 2.1

It is clear from Table 2.1 that the data recorded in 1984 surveys at 15 mph compares reasonably well with the data collected in 1985. When ever a

TABLE 2.1. COMPARISON OF OBSERVED NUMBER OF FAILURES DURING 1982, 1984, AND 1985

		Survey Year					Survey Year		
Project	Milepost	1982	1984	1985	Project	Milepost	1982	1984	1985
W13006	679.4	9	8	7	W13017	643.0	7	0	6
(District 13)	679.0	22	5	3	(District 13)	642.6	2	2	6
	678.6	2	3	2		642.2	2	1	2
	678.2	18	4	4		641.8	3	1	5
	677.8	11	9	8		641.4	6	4	4
	677.4	1	4	10		641.0	7	8	15
	677.0	13	5	5		640.6	6	3	8
	676.6	4	35	4		640.2	2	1	3
	676.2	5	1	1		639.8	1	6	3
	675.8	24	14	15		639.4	1	10	10
	675.4	11	5	12		639.0	4	3	4
	675.0	3	3	3		638.6	2	2	1
						638.2	0	0	1
						637.8	8	1	4
W13016	656.6	7	4	6		637.4	0	0	1
(District 13)	656.2	4	1	1		637.0	3	1	3
	655.8	0	1	1		636.6	0	1	1
	655.4	4	1	2		636.2	1	0	1
	655.0	0	0	2		635.8	0	0	0
	654.6	2	0	0		635.4	0	0	0
	654.2	4	2	6		635.0	3	1	1
	653.8	8	5	9					
	653.4	9	3	6					

significant difference in the number of failures is observed between 1984 and 1985 data (see Eq 3.2 for a definition of failures), there may be other reasons besides the difficulty in observing the distresses at 15 mph. For example, several patches and punchouts may have been either combined or patched together to form a big patch (see mile post 676.6 on Project No. W13006). Also, if certain portions of the project were maintained just before the surveys, the number of failures would be considerably less than those observed during the previous surveys (see mile post 637.8 on Project W13017, etc.). In summary, the limited verification of data indicated that the data collected at 15 mph in 1984 was comparable to the previous data collected at 0-5 mph.

SURVEY TEAM

The condition survey manual (Ref 5) contains recommendations for a survey team of three persons which includes a driver of the vehicle and two passengers. Both passengers of the team participate in the surveys. The driver does not participate in the surveys except calling out the end of 0.4 mile distances. The passengers record the distresses selected for the survey.

The Texas SDHPT staff recommended a team of 3 persons so that the driver can be left alone for driving purposes only. These recommendations were implemented in the 1984 condition surveys.

The study conducted in 1984 (Ref 4) indicated that the "previous experience or training in conducting condition surveys in rigid pavements appeared to have a very important effect on the collection of data for certain distress manifestations. There was no consistency at all among the three teams when recording minor punchouts along the CRCP section. Training was even more important for recording properly JRCP distress data, because transverse cracks were the only distress manifestation whose average number per 0.4-mile segment did not change significantly with team number."

DATA RECORDING FORMS AND PROCEDURES

Condition survey data recording forms were developed and used in 1974 surveys. After these surveys, the forms were modified continuously to accommodate the changes which were found necessary. A set of data recording forms as used in 1982 and in previous surveys is included in Appendix A of Research Report 249-5 (Ref 3) along with the history of their development.

During the 1984 condition surveys, no data recording forms were used to record the data. Instead of the forms, a computer program "QUIKSUR" was developed and used to enter the data directly on a micro-computer (McIntosh) disc. The micro-computer was mounted inside the survey van and two key pads were used by the survey team to enter the data directly on the disc (see Fig 2.2).

DESCRIPTION OF DISTRESS

The appropriate definitions of various distresses observed in concrete pavements (CRCP, JRCP, and JCP) were developed and included in the condition survey manual (Ref 5). This manual contains the necessary information for conducting the condition surveys of rigid pavements. A description of computer program "QUIKSUR" is also included in this manual.

CHAPTER 3. DEVELOPMENT OF PAVEMENT EVALUATION PROCEDURES

A large network of highways, which includes rigid pavements, is maintained and rehabilitated every year by the Texas State Department of Highways and Public Transportation. Because of the large amount of money involved in these activities a systematic procedure of selecting the pavements is needed to use the funds effectively. An appropriate procedure of pavement evaluation provides a reasonable method of prioritizing the pavements for maintenance and rehabilitation purposes.

Rigid pavement evaluation procedures using the condition survey data were developed and reported in the Research Report 249-5 (Ref 3). The concept of distress index was used to develop the decision criteria for prioritizing a group of pavements. A brief description of this concept is included in the following paragraphs. For a detailed description of this concept, the readers are advised to read Reference 3.

DISTRESS INDEX

Distress index is the combination of distress manifestations to ascertain with a single number the amount of pavement deterioration (Ref 3). A simple form of an equation used to combine the various distress manifestations into a distress index (DI) is as follows:

$$DI = A_o + \sum_{i}^{n} A_i m_i \tag{3.1}$$

where

A_o = constant,

A_i = constant associated with the distress manifestation, i, and

m_i = amount of distress manifestation, i.

Distress condition survey data collected during the surveys of 1974 and 1978 were used to develop distress index equations for rigid pavements. A statistical technique called "discriminate analysis" was used to analyze the data and develop the following equations (Ref 3).

DI Equation for Continuously Reinforced Concrete Pavements (CRCP)

Distress index equation for continuously reinforced concrete pavements (CRCP) is as follows:

$$DI = 1.0 - 0.065FF - 0.009SS \qquad (3.2)$$

where

FF = number of failures per mile, and

SS = percentage of cracks with severe spalling.

Further details of this equation are included in Appendix A. A proposed method of tranforming DI values to a scale of 0-100 is also discussed in Appendix A.

DI Equation for Jointed Concrete Pavements (JCP)

Distress index equation for jointed concrete pavements (JCP) is as follows:

$$DI = 1.0 - 0.005CM - 0.006PS \qquad (3.3)$$

where

$$PS = \frac{\text{number of spalled cracks and joints/mile}}{\text{total number of discontinuities/mile}} \times 100$$

CM = number of transverse cracks/mile + number of patches/mile + 1/3 (number of corner breaks and punchouts/mile) + $\frac{\text{joint spacing (ft)}}{12}$ (number of slabs with longitudinal cracks).

The total number of discontinuities used in the factor PS can be estimated by adding the number of transverse cracks and number of joints together. The interpretation of DI values is the same as Eq 3.2, therefore a similar scheme as proposed in Appendix A can be used to tranform these values of DI to a scale of 0-100.

PRIORITIZING THE PAVEMENTS USING DISTRESS INDEX

The pavements are prioritized by using the distress index (DI) with other factors, such as age, traffic, rainfall, etc., in an equation of the following form (Ref 7):

$$Y = 5.26 + 0.46\ RF + 0.396\ FTF + 0.601\ TF + 0.749\ PSF + 1.66\ DF \tag{3.4}$$

where

Y = priority value (range 1.394 to 9.126) with highest number representing the pavement of lowest priority for rehabilitation,

RF = rainfall factor,

FTF = traffic factor,

PSF = PSI factor, and

DF = distress factor.

An explanation of various factors used in Eq 3.4 is included in Appendix B. As indicated above, the estimated values of Y range between 1.394 and 9.126. Also, the factors used in Eq 3.4 assume values between -1 and + 1. Therefore, it was decided to modify Eq 3.4 in such a manner so that the values of each factor can be used directly as they are recorded (for example, rainfall in inches, traffic in ADT, PSI in actual numbers, etc.). The resulting equation for the priority index is as follows:

$$PI = 13.5 - 0.40\ (\text{Rainfall, in.}) - 0.23\ (\text{Freeze-thaw cycles/year}) - 0.71 \times 10^{-3}\ (\text{ADT}) + 12.9\ \text{PSI} + 0.43\ \text{DI} \qquad (3.5)$$

An explanation of each term used in Eq 3.5 is included in Appendix B.

APPLICATION OF PAVEMENT EVALUATION MODEL AT NETWORK LEVEL

A computer program PRP01 was developed to analyze the rigid pavements (CRCP, JRCP, JCP) at network level for scheduling their rehabilitation using a similar pavement evaluation models as described earlier. This model includes only the distress index, traffic and PSI value. The model does not include rainfall and freeze-thaw considerations. The details of this program are fully described in Reference 3. A typical output of this program includes the following items:

(1) A prioritized list of pavement sections according to their distress condition at the time of the condition survey.

(2) A multi-period rehabilitation schedule of the pavement sections without considering budget constraints. The selection of candidates for each year is made on the basis of the magnitude of the distress index.

(3) A multi-period rehabilitation schedule of the pavement sections accounting for budget restrictions. The selection for each year depends on the magnitude of the distress index and the budget availability.

Figure 3.1 is a simplified flowchart of the computer program. Information on the distress condition of each project is required as an input. The program starts by calculating the distress index for each section. The sections are prioritized according to the magnitude of their distress indices. At this stage, a check is made of the design period. If the design period is set equal to zero, the program prints the priority list and stops, but, if the design period is larger than zero, the program continues. Next, a check is made for budget restrictions and two different criteria are followed, depending on the existence of budget constraints. If no budget constraints are imposed by the user, the rule for selecting the rehabilitation candidates is very simple: all the pavements which have reached terminal condition are included in the list for that year. If budget constraints are present, the selection of candidates is made on the basis of budget availability. The already prioritized sections are considered one by one and the rehabilitation cost of each is calculated and accumulated until the budget is satisfied. A list of candidate projects is printed for each year of the design period. The program checks to see if the design period has been covered, in which case it exits; otherwise, conditions are predicted for the next year and the program returns to the step in which the distress indices are calculated.

The possibility exists of optimizing the average condition of the sections using budget restrictions; however, it was thought this would complicate the program unnecessarily. A better objective function for optimization would consider user and maintenance costs, which, at this time, are not available in terms of distress.

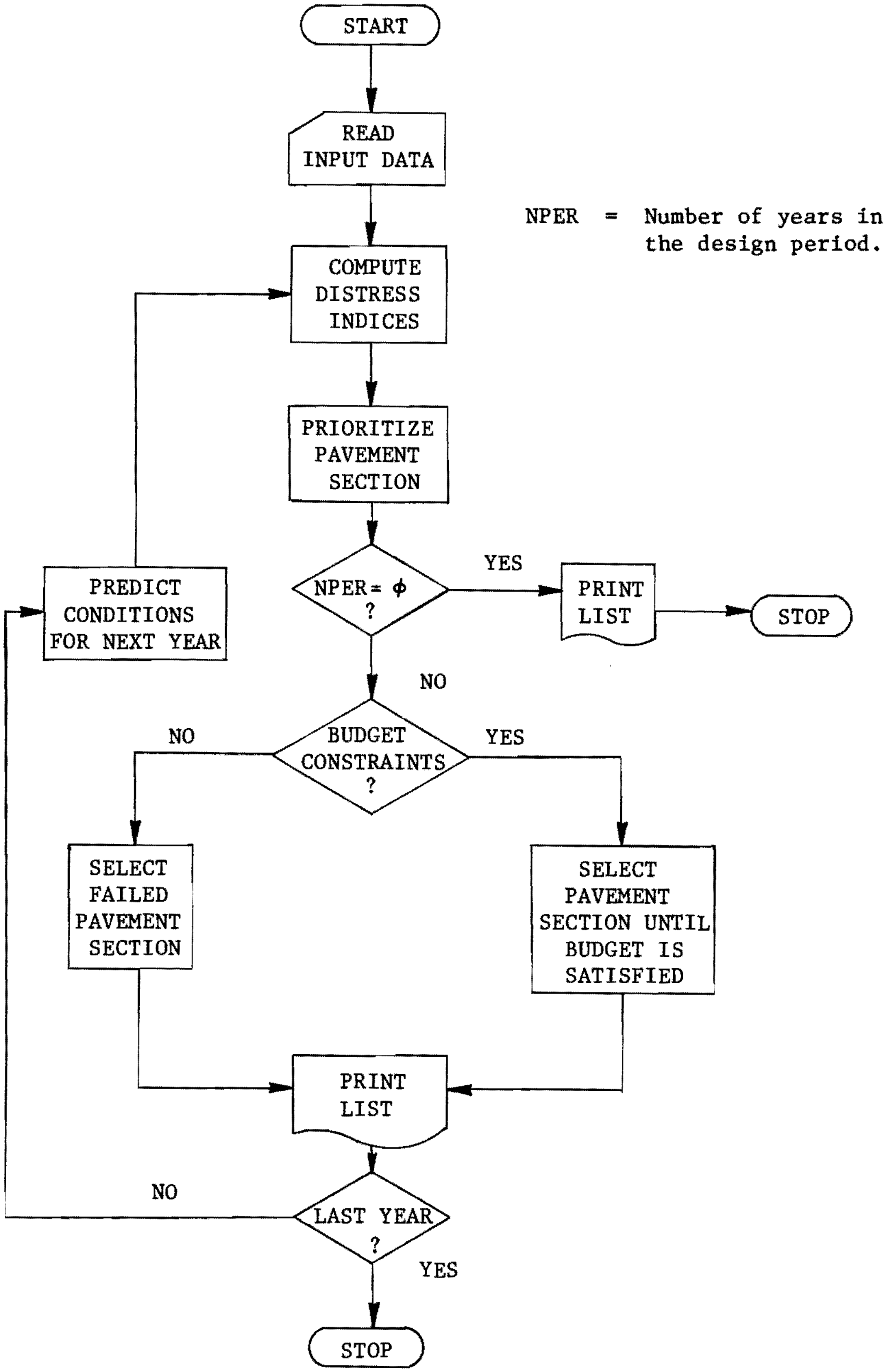

Fig 3.1. Simplified flowchart of the computer program (PRPØ1) to prioritize and schedule rehabilitation.

PAVEMENT EVALUATION AT PROJECT LEVEL

A concept of Deflection Distress Index (DDI) was developed to evaluate rigid pavements at project level. The details of this procedure are available in Research Report 388-1 (Ref 8). A brief summary of this method is described in the following paragraphs :

The term "Deflection Distress Index" or DDI was specially used in this study to represent the condition of the pavement at any time. The DDI for any given condition of the pavement is estimated by the following formula as explained in Reference 8:

$$DDI = A + B \cdot W_{2.5} \tag{3.6}$$

where

A, B = constants depending upon the shoulder type (flexible or rigid), and

$W_{2.5}$ = the number of unweighted axle load applications at which p = 2.5 (p is the present serviceability index).

In turn, the value of $W_{2.5}$ is determined by the following relationship:

$$\log W_{2.5} = 0.74 - 3.15 \log de \tag{3.7}$$

where

log de = the logarithm of the static edge deflection, in. (9,000 pound wheel load).

In order to develop a relationship between DDI and $W_{2.5}$, two extreme conditions were assumed. These conditions are illustrated in Fig 3.2 along with the linear relationship between DDI and $W_{2.5}$ using these extreme conditions as the two ends of the scale (DDI = 0 and DDI = 100).

A computer program DDI1 was developed to analyze any rigid pavement section by dividing it into elements bounded by cracks as illustrated in Fig 3.3. Considering a variety of rigid pavement distresses as illustrated in the figure, the edge deflection and hence DDI value for a known condition of the pavement element (determined from condition survey data at project level) can be determined. Using these values of DDI, a plot of the entire project between DDI and element number can be prepared as shown in Fig 3.4. Using this plot, the condition of the project can be evaluated as shown in this figure. For further details of this method of evaluating the pavements at project level, please refer to Research Report 388-1 (Ref 8).

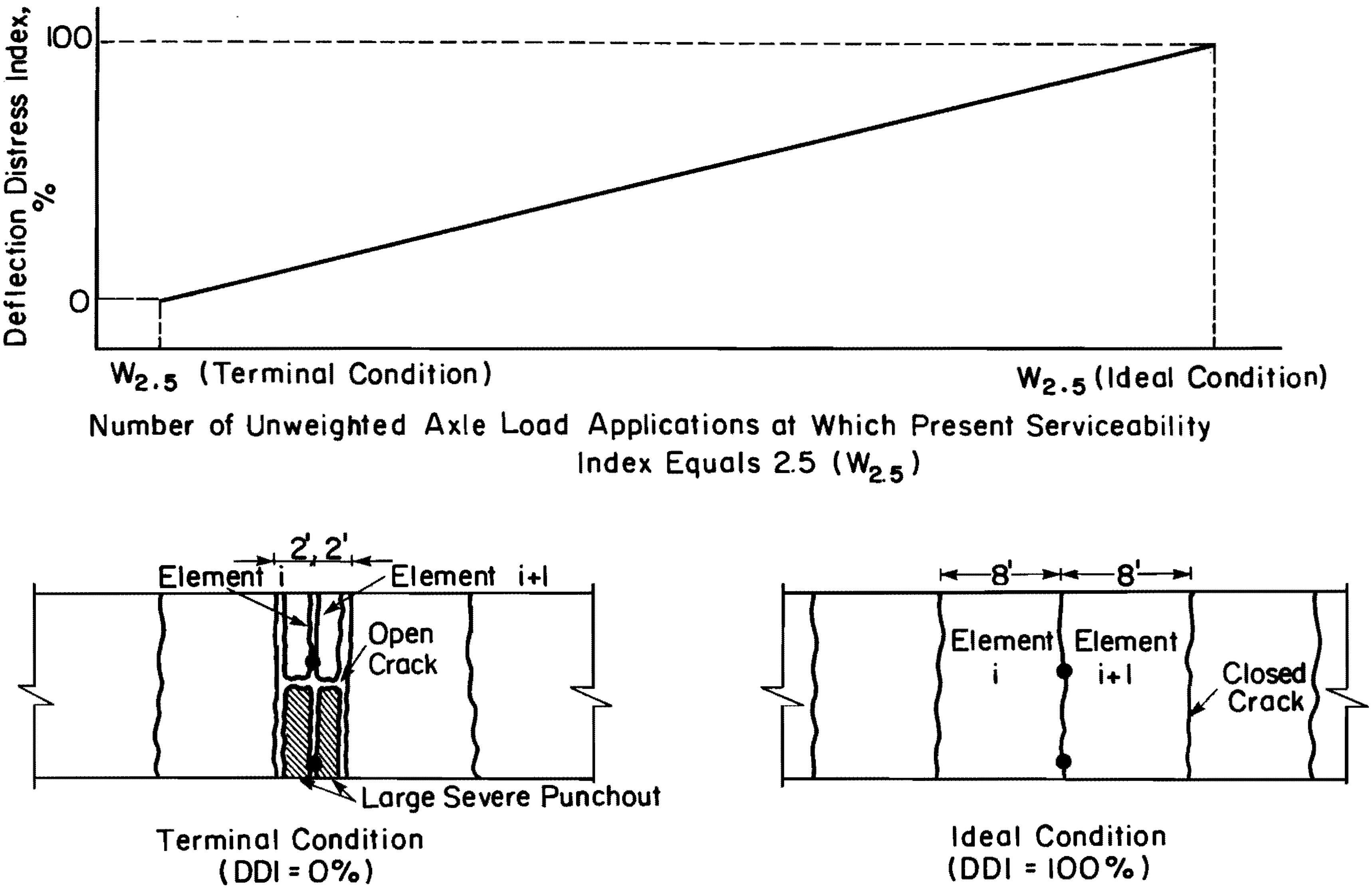

Fig 3.2. Computation of deflection distress index.

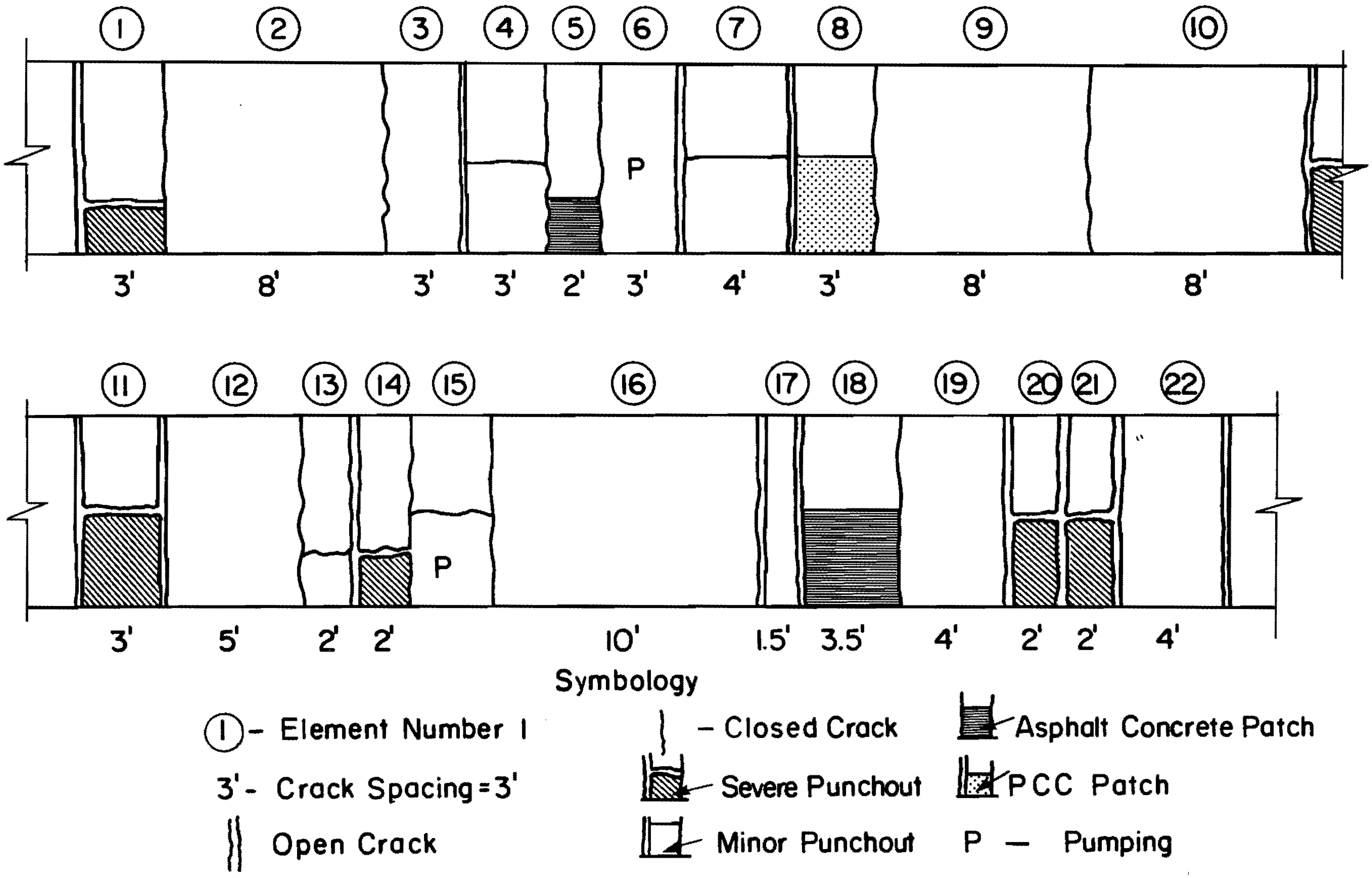

Fig 3.3. Hypothetical CRCP section analyzed by computer program DDI1.

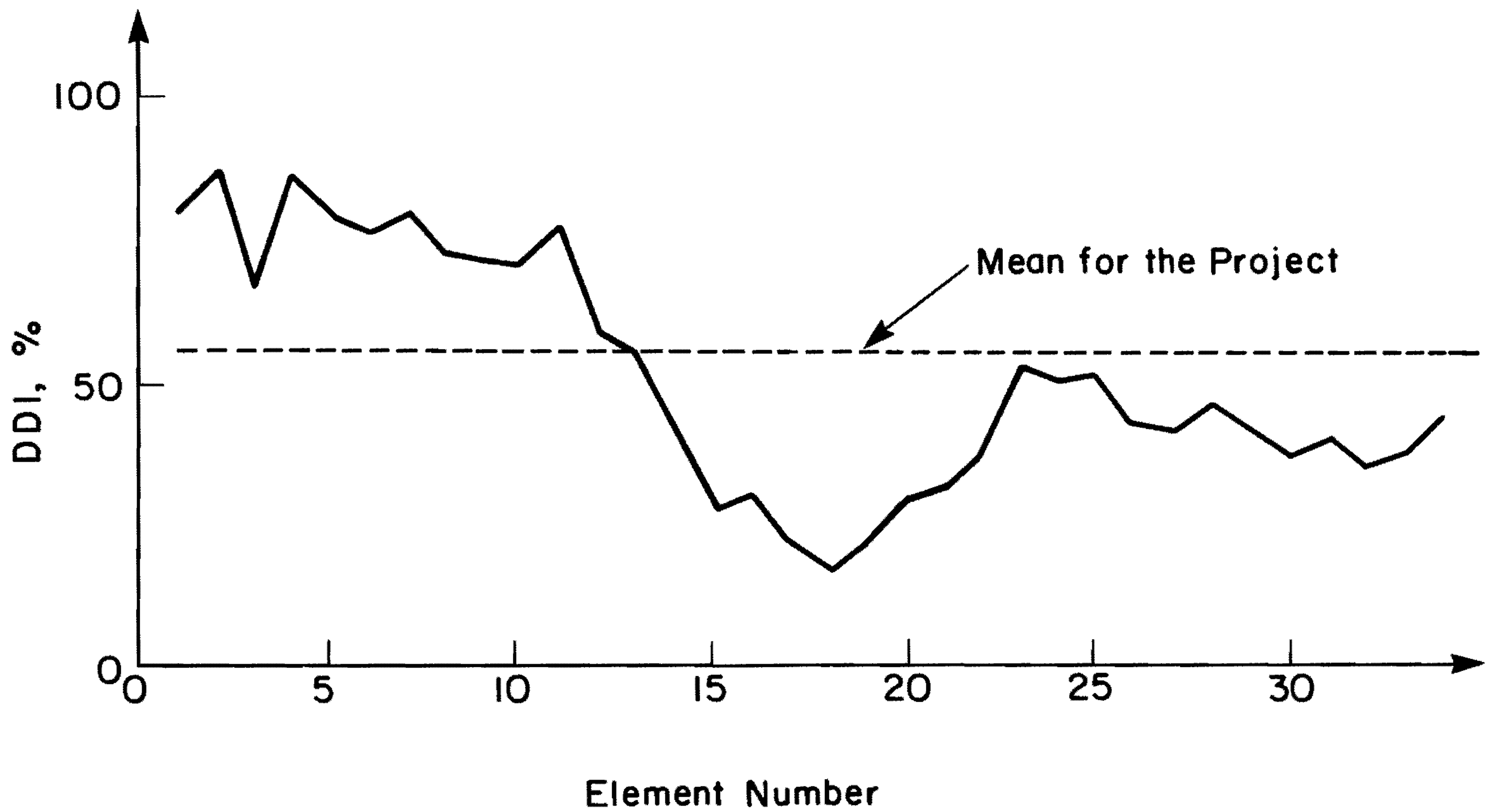

Fig 3.4. Conceptual illustration of the DDI within-project variation.

CHAPTER 4. DATA BANK

It was pointed out in Chapter 1 that the Center for Transportation Research (CTR) at The University of Texas at Austin started rigid pavement condition surveys in 1974. These surveys included all of the rigid pavements in the Interstate system within the state of Texas and some selected rigid pavements of the U.S. and state highways. Both, continuously reinforced (CRCP) and jointed (JCP and JRCP) pavements were included in the surveys. The data bank does not include any overlaid sections at the present time. A summary of mileage surveyed in each District is listed in Table 4.1. The current data bank contains the condition survey data for a total of about 3,052 miles (see Table 4.1).

DATA ITEMS INCLUDED IN THE DATA BANK

The current data bank resides on the magnetic computer tapes which can be read by the UT computers (CYBER system) and data can be processed for analysis and reporting purposes. The following data items are included in the data bank.

Common Data Items

There are several items which are common to all rigid pavements. These items are as follows:

(1) District number;
(2) control number;
(3) section number;
(4) highway number;
(5) age of pavement, years;
(6) direction (NS, EW, etc.);
(7) county;

TABLE 4.1. CURRENT STATUS OF RIGID PAVEMENT CONDITION SURVEY DATA BANK

District Number	Total Miles Surveyed by Pavement Type			Total Miles
	CRCP	JRCP	JCP	
1	70.4	--	70.6	141.0
2	419.6	--	41.0	460.6
3	129.6	--	97.6	227.2
4	144.0	--	--	144.0
5	90.0	--	--	90.0
9	85.8	--	17.2	103.0
10	22.4	--	23.4	45.8
11	--	--	3.2	3.2
12	15.6	173.8	47.6	237.0
13	184.0	--	36.2	220.2
15	46.8	--	--	46.8
16	--	--	22.6	22.6
17	240.8	--	11.0	251.8
18	116.2	--	311.8	428.0
19	127.8	--	67.2	195.0
20	10.2	33.4	141.0	184.6
24	127.8	--	--	127.8
25	62.0	--	61.3	123.3
Total	1893.0	207.2	951.7	3051.9

(8) job number;
(9) CFHR number;
(10) date of survey;
(11) location (from mile post to next mile post);
(12) raters' name;
(13) total length of each project and the length overlaid; and
(14) riding quality (not all sections).

CRC Pavement Related Data Items

(1) Percent spalling (minor and severe number of cracks);
(2) pumping (percent slab, minor and severe);
(3) punchouts (minor $<$ 20 feet; severe $>$ 20 feet); and
(4) patches (asphalt, PC concrete).

JC Pavement Related Items

(1) Transverse cracks (total, spalled, and faulted);
(2) patches in slab (asphalt, cement);
(3) edge pumping (feet);
(4) spalled joints (number);
(5) faulted joints (number);
(6) cracking at joints (number);
(7) patches at joint (asphalt, cement);
(8) bad joint sealant (number); and
(9) joint pumping (number).

ACP Overlay Related Items

(1) Overlay thickness,
(2) percentage of steel,
(3) concrete placement temperature,
(4) transition (yes or no),
(5) reflection cracks,

(6) patches,
(7) failures,
(8) bond failures, and
(9) rut depth.

<u>Data Retrieval and Reports</u>

Condition survey data collected since 1974 surveys have been stored on the computer tapes. Therefore, the desired data can be retrieved from these tapes. For this purpose, a number of computer programs were developed to retrieve and print the desired information. Figure 4.1 shows the sequence of steps to process the condition survey data. Four different reports produced for each district are identified in Fig 4.1. Typical examples of these reports are shown in Tables 4.2 to 4.5. Further details of condition survey data processing are available in Research Report 249-8F (Ref 6, Appendix A).

APPLICATIONS OF CONDITION SURVEY DATA

The condition survey data collected in the past and stored in the Data Bank can be used by the District and state highway engineers to monitor the rigid pavement network . Some examples of this application are illustrated in the following paragraphs.

<u>Monitoring of Pavement Conditions by District Engineer</u>

The condition survey data for all the projects within a District are collected for each project and summarized in a tabular form (see Table 4.4) for every 0.4-mile of the project. A plot of this data can be used by a District engineer to monitor the condition of any project as illustrated in Fig 4.2. This figure can easily identify one or more sections within a project which require special attention (see Fig 4.2).

Pavement performance records of various projects within a District can be plotted as illustrated in Fig 4.3. This plot can be used to compare various projects of a district and identify project(s) which shows unusual

TABLE 4.2. COMPUTER GENERATED REPORT 1

PROJECT IDENTIFICATION INFORMATION
DISTRICT 25

CFTR NO.	HWY	COUNTY	CTRL	SEC	JOB	LENGTH	CONST DATE
25003	WB IH-40	WHEELER	275	12	31	1.6	1973
	(SHAMROCK(JCT US-83) TO 1 MI W OF FW &D R.R.)						
25003	EB IH-40	WHEELER	275	12	31	2.4	1973
	(1.0MI W OF FW AND D R.R. TO SHAMROCK(JUNCTION US-83))						
25004	EB IH-40	WHEELER	275	13	29	1.6	1973
	(SHAMROCK(JCT. US-83) TO 1.0 MI EAST OF SHAMROCK)						
25004	WB IH-40	WHEELER	275	13	29	1.6	1973
	(1 MI E OF SHAMROCK TO SHAMROCK (JCT US-83))						
25005	EB IH-40	WHEELER	275	12	32	.8	1975
	(MILE POST 176- TO OKLAHOMA STATE LINE)						
25005	WB IH-40	WHEELER	275	12	32	.8	1975
	(TEXAS STATE LINE TO MILE POST 176)						
25002	EB IH-40	WHEELER	275	13	24	12.4	1970
	(1.0 MI EAST OF SHAMROCK TO OKLAHOMA STATE LINE)						
25002	WB IH-40	WHEELER	275	13	24	12.4	1970
	(OKLAHOMA STATE LINE TO 1 MI E OF SHAMROCK)						
25001	EB IH-40	WHEELER	275	12	20	14.0	1968
	(GRAY COUNTY LINE TO .9 MI W OF FW AND D RR)						
25001	WB IH-40	WHEELER	275	12	20	14.4	1968
	(.9 MI W OF FW AND D RR TO GRAY COUNTY LINE)						

TABLE 4.3. COMPUTER GENERATED REPORT 2

FAILURE SUMMARY FOR DISTRICT 25

CFTR NUMBER	CONST. DATE	SURVEY DATE	LENGTH TOTAL	LENGTH UNOVL	SPALLING (PER MILE) MINOR	SPALLING (PER MILE) SEVERE	PATCHES (PER MILE) AC	PATCHES (PER MILE) PCC	PATCHES (PER MILE) FLD	PUNCHOUTS (PER MILE)	FAILURES PER MILE	FAILURES TOTAL
25003WB	1973	1984	1.6	1.6	0	2.5	0	1.3	0	.6	0	0
		1982	1.8	1.8	168.9	.6	0	.6	0	0	0	0
		1978	1.8	1.8	146.1	.6	0	0	0	0	0	0
		1974	1.8	1.8	0	0	0	0	0	0	0	0
25003EB	1973	1984	2.4	2.4	0	8.7	.8	.4	0	0	1.3	3.0
		1982	2.8	2.8	211.8	.7	.4	.4	0	0	.7	2.0
		1978	2.8	2.8	211.8	.7	0	0	0	.7	.7	2.0
		1974	2.8	2.8	0	0	0	0	0	0	0	0
25004EB	1973	1984	1.6	1.6	0	7.5	1.3	1.3	0	0	2.5	4.0
		1982	1.6	1.6	156.3	.6	0	.6	0	.6	1.3	2.0
		1978	1.6	1.6	156.3	.6	0	0	0	.6	.6	1.0
		1974	1.6	1.6	0	0	0	0	0	0	0	0
25004WB	1973	1984	1.6	1.6	0	6.3	.6	.6	.6	1.3	3.1	5.0
		1982	1.6	1.6	130.0	.6	0	.6	0	0	.6	1.0
		1978	1.6	1.6	130.0	.6	0	.6	0	0	.6	1.0
		1974	1.6	1.6	0	0	0	0	0	0	0	0
25005EB	1975	1984	.8	.8	0	0	0	0	1.3	0	1.2	1.0
		1982	.9	.9	188.9	0	0	0	0	0	0	0
		1978	1.0	1.0	67.0	0	0	0	0	0	0	0
25005WB	1975	1984	.8	.8	0	2.5	0	0	1.3	0	1.2	1.0
		1982	1.0	1.0	130.0	0	0	0	0	0	0	0
		1978	1.0	1.0	86.0	0	0	0	0	0	0	0

(continued)

TABLE 4.3. (CONTINUED)

FAILURE SUMMARY FOR DISTRICT 25
(CONTINUED)

CFTR NUMBER	CONST. DATE	SURVEY DATE	LENGTH TOTAL	LENGTH UNOVL	SPALLING (PER MILE) MINOR	SPALLING (PER MILE) SEVERE	PATCHES (PER MILE) AC	PATCHES (PER MILE) PCC	PATCHES (PER MILE) FLD	PUNCHOUTS (PER MILE)	FAILURES PER MILE	FAILURES TOTAL
25002EB	1970	1984	12.4	12.4	0	1.2	.2	.2	.1	.2	.6	7.0
		1982	12.2	12.2	175.0	1.1	0	.2	0	0	.2	2.0
		1978	12.2	12.2	175.0	1.1	0	0	0	.1	.1	1.0
		1974	12.0	12.0	0	0	0	0	0	0	0	0
25002WB	1970	1984	12.4	12.4	0	.9	.5	.2	.1	.2	.9	11.0
		1982	12.4	12.4	190.4	.7	.2	.2	0	.1	.5	6.0
		1978	12.4	12.4	190.4	.7	0	.1	0	0	.1	1.0
		1974	12.4	12.4	0	0	0	0	0	0	0	0
25001EB	1968	1984	14.0	14.0	0	5.9	2.2	1.1	.1	.3	3.6	51.0
		1982	14.0	14.0	253.0	2.7	.9	.7	0	.4	2.0	28.0
		1978	14.0	14.0	253.0	2.7	0	0	0	0	0	0
		1974	14.0	14.0	0	0	0	0	0	0	0	0
25001WB	1968	1984	14.4	14.4	0	3.6	.4	1.1	.1	.2	1.9	27.0
		1982	15.0	15.0	252.0	1.3	.1	.7	0	2.2	3.1	46.0
		1978	14.8	14.8	254.1	1.4	0	0	0	.3	.3	4.0
		1974	14.8	14.8	0	0	0	0	0	.1	.1	1.0

DISTRICT MEANS (EXCLUDING TOTALLY OVERLAYED PROJECTS):

SURVEY DATE	LENGTH TOTAL	LENGTH UNOVL	SPALLING MINOR	SPALLING SEVERE	PATCHES AC	PATCHES PCC	PATCHES FLD	PUNCHOUTS	FAILURES PER MILE	FAILURES TOTAL
1984	6.2	6.2	0	3.9	.6	.6	.3	.3	1.6	*******
1982	6.3	6.3	185.6	.8	.2	.4	0	.3	.8	*******
1978	6.3	6.3	167.0	.8	0	.1	0	.2	.2	*******
1974	7.6	7.6	0	0	0	0	0	.0	.0	*******

TABLE 4.4. COMPUTER GENERATED REPORT 3

PROJECT SUMMARY SHEET
DISTRICT 25

****

CFTR NO.25002 HIGHWAY IH-40 EB 1984 SURVEY

****

MILE POST:	164.2	166.2	168.2	170.2
MILE POINT:	-0	-0	-0	-0

****

LENGTH (MILES):	2.0	2.0	2.0
LENGTH OVERLAYED:	0	0	0
SERVICEABILITY INDEX ( ):	-	-	-
CRACK SPACING (FEET)			
MEAN:	-	-	-
STANDARD DEVIATION:	-	-	-
PERCENT SPALLING			
MINOR:	-	-	-
SEVERE:	-	-	-
PUMPING			
MINOR:	NO	NO	NO
SEVERE:	NO	NO	NO
NUMBER OF SPALLING CRACKS			
MINOR:	0	0	0
SEVERE:	5	4	4
NUMBER OF PUNCHOUTS			
MINOR - L.T. 20 FT:	0	0	0
- G.T. 20 FT:	0	0	0
SEVERE - L.T. 20 FT:	0	0	0
- G.T. 20 FT:	1	1	0
A.C. REPAIR PATCHES:	0	0	1
P.C.C. REPAIR PATCHES:	0	0	0
FAILED REPAIR PATCHES:	0	0	0

****

(continued)

TABLE 4.4. (CONTINUED)

PROJECT SUMMARY SHEET
DISTRICT 25

CFTR NO.25002 HIGHWAY IH-40 EB (CONTINUED) 1984 SURVEY				
MILE POST:	170.2	172.2	174.2	176.2
MILE POINT:	-0	-0	-0	-0
LENGTH (MILES):	2.0	2.0	2.0	
LENGTH OVERLAYED:	0	0	0	
SERVICEABILITY INDEX ( ):	-	-	-	
CRACK SPACING (FEET)				
MEAN:	-	-	-	
STANDARD DEVIATION:	-	-	-	
PERCENT SPALLING				
MINOR:	-	-	-	
SEVERE:	-	-	-	
PUMPING				
MINOR:	NO	NO	NO	
SEVERE:	NO	NO	NO	
NUMBER OF SPALLING CRACKS				
MINOR:	0	0	0	
SEVERE:	2	0	0	
NUMBER OF PUNCHOUTS				
MINOR - L.T. 20 FT:	0	0	0	
- G.T. 20 FT:	0	0	0	
SEVERE - L.T. 20 FT:	0	0	0	
- G.T. 20 FT:	0	0	0	
A.C. REPAIR PATCHES:	1	0	0	
P.C.C. REPAIR PATCHES:	2	0	0	
FAILED REPAIR PATCHES:	0	0	0	

(continued)

TABLE 4.4. (CONTINUED)

PROJECT SUMMARY SHEET
DISTRICT 25

****

CFTR NO.25002 HIGHWAY IH-40 EB (CONTINUED) 1984 SURVEY

****

MILE POST:	176.2	176.6
MILE POINT:	-0	.400

****

LENGTH (MILES):	.4
LENGTH OVERLAYED:	0
SERVICEABILITY INDEX ( ):	-
CRACK SPACING (FEET)	
MEAN:	-
STANDARD DEVIATION:	-
PERCENT SPALLING	
MINOR:	-
SEVERE:	-
PUMPING	
MINOR:	NO
SEVERE:	NO
NUMBER OF SPALLING CRACKS	
MINOR:	0
SEVERE:	0
NUMBER OF PUNCHOUTS	
MINOR - L.T. 20 FT:	0
- G.T. 20 FT:	0
SEVERE - L.T. 20 FT:	0
- G.T. 20 FT:	0
A.C. REPAIR PATCHES:	0
P.C.C. REPAIR PATCHES:	0
FAILED REPAIR PATCHES:	0

****

TABLE 4.5. COMPUTER GENERATED REPORT 4

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                 ******************************

                         PROGRAM PRP01
                       CTR - UT AUSTIN
                      VERSION MAR 10,1982

                 ******************************


CRCP DISTRICT-25 SECTIONS FOR 1984 SURVEY
NOTE: NOT ALL SECTIONS SURVEYED IN 1984


ANALYSIS PERIOD=10

NO BUDGET CONSTRAINTS ARE TO BE CONSIDERED

UNIT COST OF OVERLAYING= 2.000 DLLS./IN.PER SQ.FT.
```

(continued)

TABLE 4.5. (CONTINUED)

PROGRAM PRP01 PAGE 2

CRCP DISTRICT-25 SECTIONS FOR 1984 SURVEY
NOTE: NOT ALL SECTIONS SURVEYED IN 1984

ACCORDING TO YOU INPUT INFORMATION
THE FOLLOWING DATA SET WAS READ

FROM COL. TO COL.	
1 - 7	SECTION IDENTIFICATION
8 - 14	DISTRESS TYPE 1
15 - 21	DISTRESS TYPE 2
22 - 28	DISTRESS TYPE 3
29 - 35	AGE OF PAVT AT CS
36 - 42	CUMULATIVE AXLE LOADS AT CS
43 - 49	ESAL GROWTH RATE
50 - 56	SECTION LENGTH
57 - 63	NUMBER OF LANES

25003WB	1.90	0	.10	11.00	0	0	1.60	0
25003EB	1.30	0	.50	11.00	0	0	2.40	0
25004EB	2.50	0	.40	11.00	0	0	1.60	0
25004WB	3.10	0	.40	11.00	0	0	1.60	0
25005EB	1.30	0	0	8.80	0	0	.80	0
25005WB	1.30	0	.10	8.80	0	0	.80	0
25002EB	.60	0	.10	14.10	0	0	12.40	0
25002WB	.90	0	.10	14.10	0	0	12.40	0
25001EB	3.60	0	.30	16.00	0	0	14.00	0
25001WB	1.90	0	.20	16.00	0	0	14.40	0

SUMMARY OF SECTIONS CONSIDERED IN THE ANALYSIS

SECTION TYPE	NO. OF SECTIONS	MILES
1	-0	0
2	10	62.00
	10	62.00

(continued)

TABLE 4.5. (CONTINUED)

PROGRAM PRP01 PAGE 3

CRCP DISTRICT-25 SECTIONS FOR 1984 SURVEY
NOTE: NOT ALL SECTIONS SURVEYED IN 1984

LIST OF PRIORITIZED SECTIONS AT TIME OF CS

SECTION ID	DISTRESS INDEX	CUMULATIVE ESAL (MILLIONS)	RANK
25001E	.763	0	1
25004W	.794	0	2
25004E	.833	0	3
25001W	.875	0	4
25003W	.875	0	5
25003E	.911	0	6
25005W	.915	0	7
25005E	.916	0	8
25002W	.940	0	9
25002E	.960	0	10

(continued)

TABLE 4.5. (CONTINUED)

PROGRAM PRP01 PAGE 4

CRCP DISTRICT-25 SECTIONS FOR 1984 SURVEY
NOTE: NOT ALL SECTIONS SURVEYED IN 1984

LIST OF PAVEMENT SECTIONS REQUIRING OVERLAY
YEARS AFTER CONDITION SURVEY= 1

SECTION ID	DISTRESS INDEX	CUMULATIVE ESAL (MILLIONS)	SECTION LENGTH (MILES)	OVERLAY COST (DLLS)	RANK
25001E	.655	N/A	14.00	N/A	1
25004W	.680	N/A	1.60	N/A	2
25004E	.728	N/A	1.60	N/A	3
25003W	.778	N/A	1.60	N/A	4
25001W	.783	N/A	14.40	N/A	5
25003E	.820	N/A	2.40	N/A	6
25005W	.821	N/A	.80	N/A	7
25005E	.822	N/A	.80	N/A	8
25002W	.856	N/A	12.40	N/A	9
25002E	.878	N/A	12.40	N/A	10
	.782		0	0	

(continued)

TABLE 4.5. (CONTINUED)

PROGRAM PRP01 PAGE 13

CRCP DISTRICT-25 SECTIONS FOR 1984 SURVEY
NOTE: NOT ALL SECTIONS SURVEYED IN 1984

LIST OF PAVEMENT SECTIONS REQUIRING OVERLAY
YEARS AFTER CONDITION SURVEY= 10

SECTION ID	DISTRESS INDEX	CUMULATIVE ESAL (MILLIONS)	SECTION LENGTH (MILES)	OVERLAY COST (DLLS)	RANK
25003W	-.010	0	1.60	1352535.	1
25005W	.084	N/A	.80	N/A	2
25005E	.085	N/A	.80	N/A	3
25001W	.143	N/A	14.40	N/A	4
25003E	.164	N/A	2.40	N/A	5
25002W	.308	N/A	12.40	N/A	6
25002E	.358	N/A	12.40	N/A	7
25004E	1.000	N/A	1.60	N/A	8
25001E	1.000	N/A	14.00	N/A	9
25004W	1.000	N/A	1.60	N/A	10
	.413		1.60	1352535.	

(continued)

TABLE 4.5. (CONTINUED)

PROGRAM PRPO1 PAGE 14

CRCP DISTRICT-25 SECTIONS FOR 1984 SURVEY
NOTE: NOT ALL SECTIONS SURVEYED IN 1984

SUMMARY TABLE

YEAR	AVG. DI	LENGTH (MILES)	BUDGET (DLLS)
1	.782	0	0
2	.688	0	0
3	.596	0	0
4	.508	0	0
5	.422	0	0
6	.338	0	0
7	.256	1.60	1378108.
8	.293	15.60	13472906.
9	.455	0	0
10	.413	1.60	1352535.
	.475	18.80	16203550.

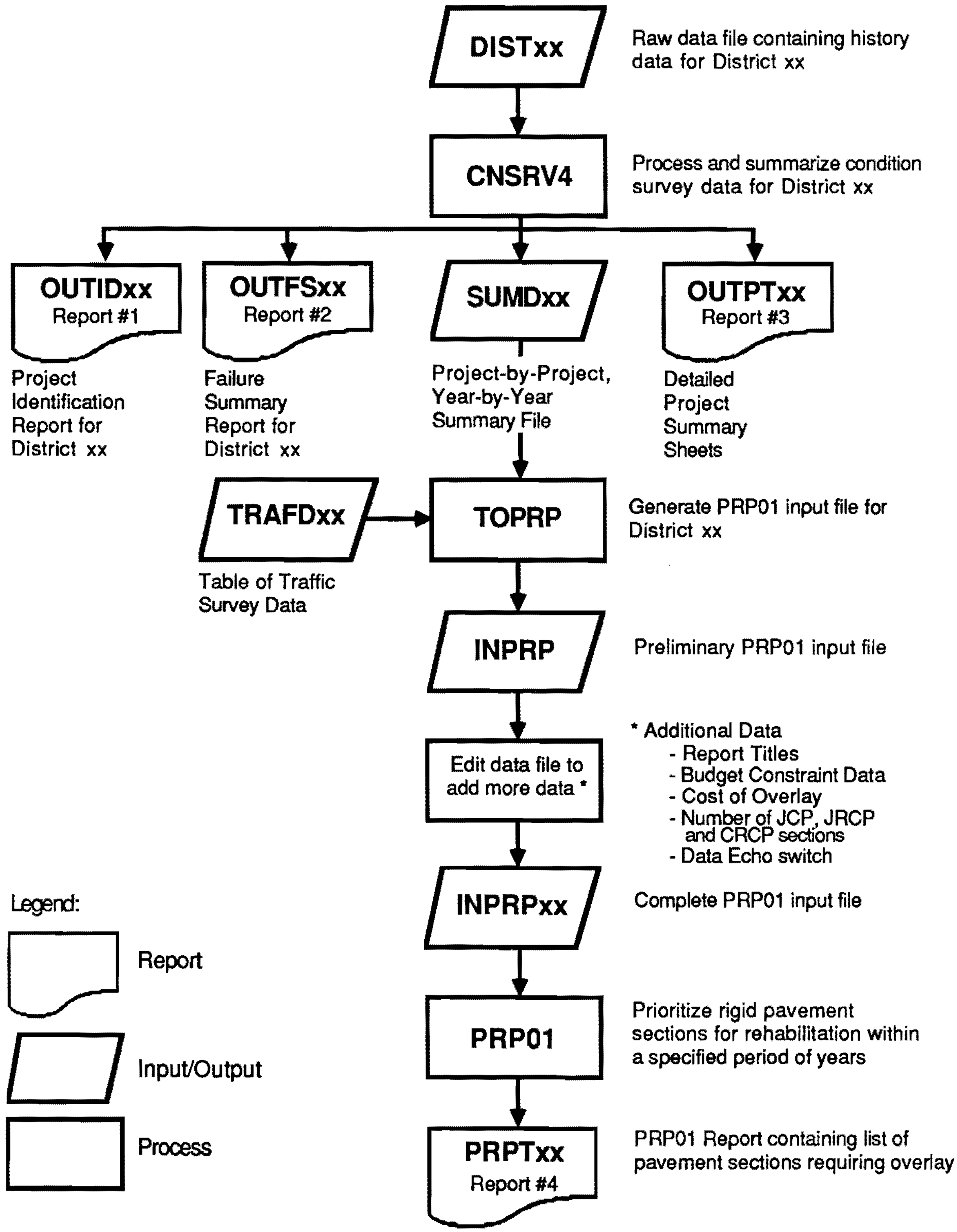

Fig 4.1. Sequence of programs, files and reports involved in the processing of District xx CRCP survey data.

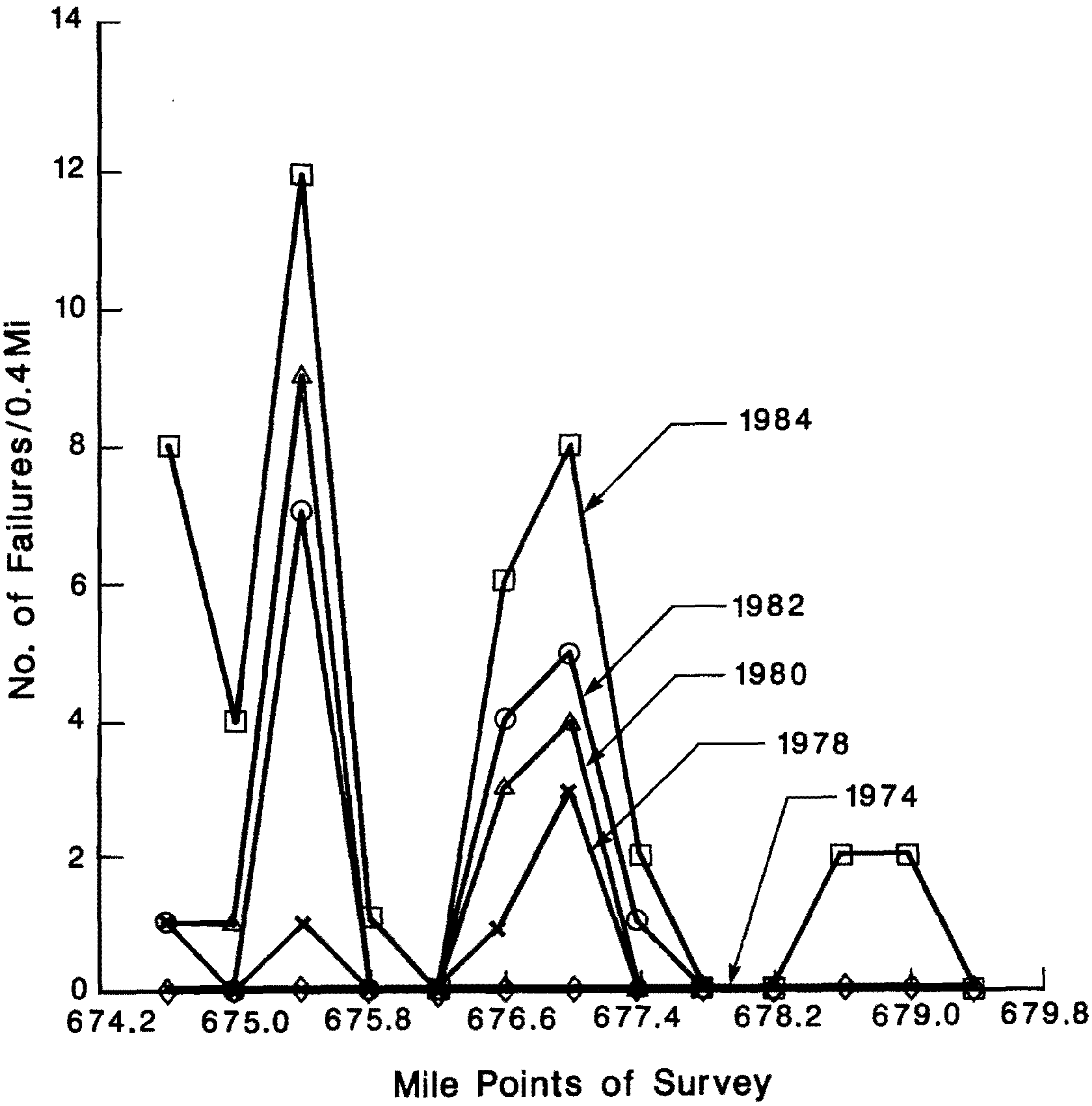

Fig 4.2. History of pavement condition Project 13006E.

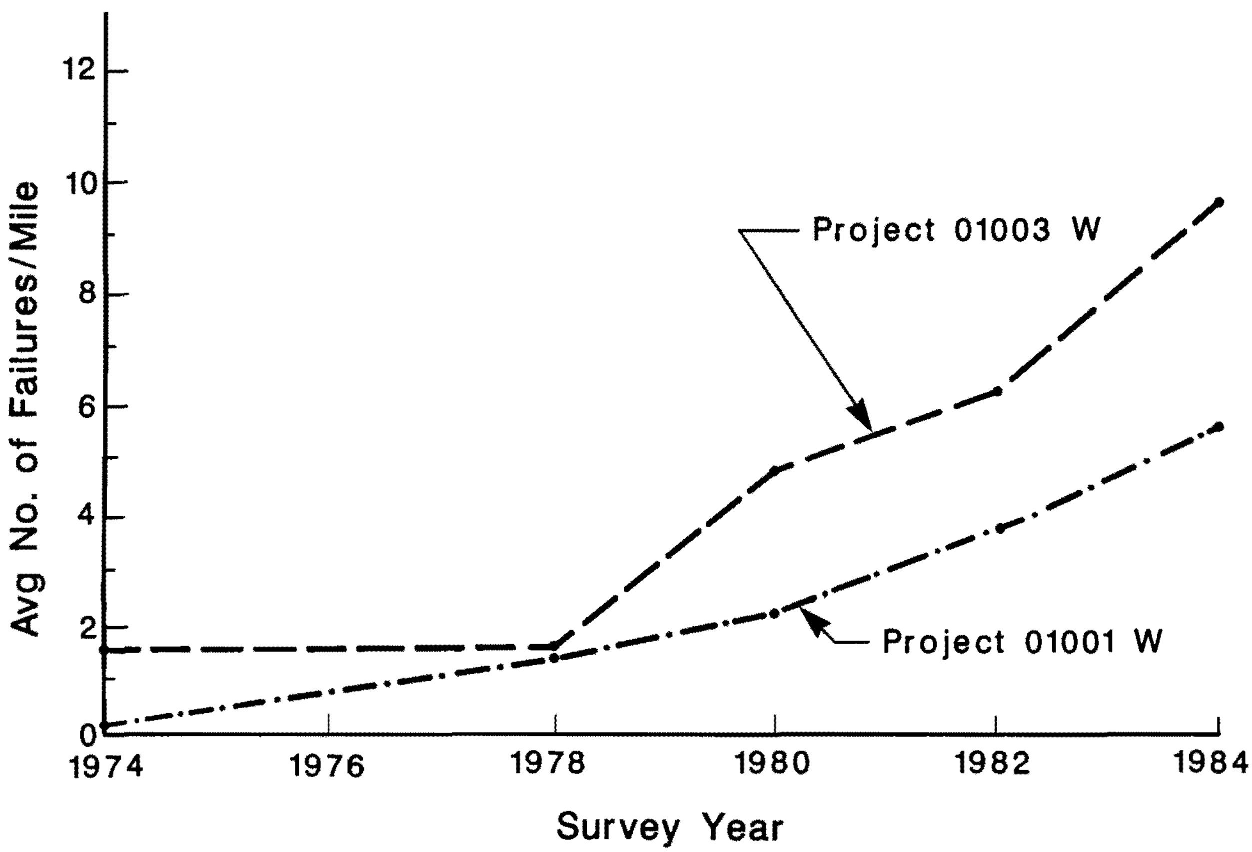

Fig 4.3. Pavement performance history for Projects 01003W and 01001W.

rate of deterioration between the two condition survey periods. For example, the rate of deterioration of project 01003W during 1978 and 1980 was observed to be very high as compared to previous survey period. Therefore, some portion of this project was overlaid between 1980 and 1982 and the rate of deterioration decreased. However, 1984 condition surveys indicate that this project is again deteriorating at a fast rate. Therefore this project needs special attention to keep the rate of deterioration low. One the other hand, it is evident that project 01001W does not show any signs of unusual deterioration.

Further application of condition survey data by District engineer is illustrated in Figs 4.4 and 4.5.

The development of failures in two projects of District 13 was studied as shown in Fig 4.4. Although both projects were built for the same design life, one of the project deteriorated at the faster rate than the other. An investigation of the site conditions of both project indicated that the foundation materials for these projects were different. The project (13017W) built on granular material developed failures at a slower rate than the project (13006W) built on clay material. This example illustrates the use of condition survey data in improving the standard design procedures. If the existing design procedures did not include considerations for the soil in the foundation, the pavement may not perform as expected.

The effect of rainfall on the pavement performance is illustrated in Fig 4.5. Two projects from Districts 4 and 10 were selected for this purpose. The effect of rainfall on both projects was insignificant for a period of about 9-12 years. After this period the rate of failures in the pavements located in high rainfall zone was observed to be (42 inch/year) higher than the rate of failure in the pavement in low rainfall zone (18 inch/year). Again this example illustrates the use of condition survey data in improving the existing design procedures.

Monitoring of Network Condition by State Engineers

The state engineers can monitor the condition of state network in the same manner as the District engineer monitors the district network.

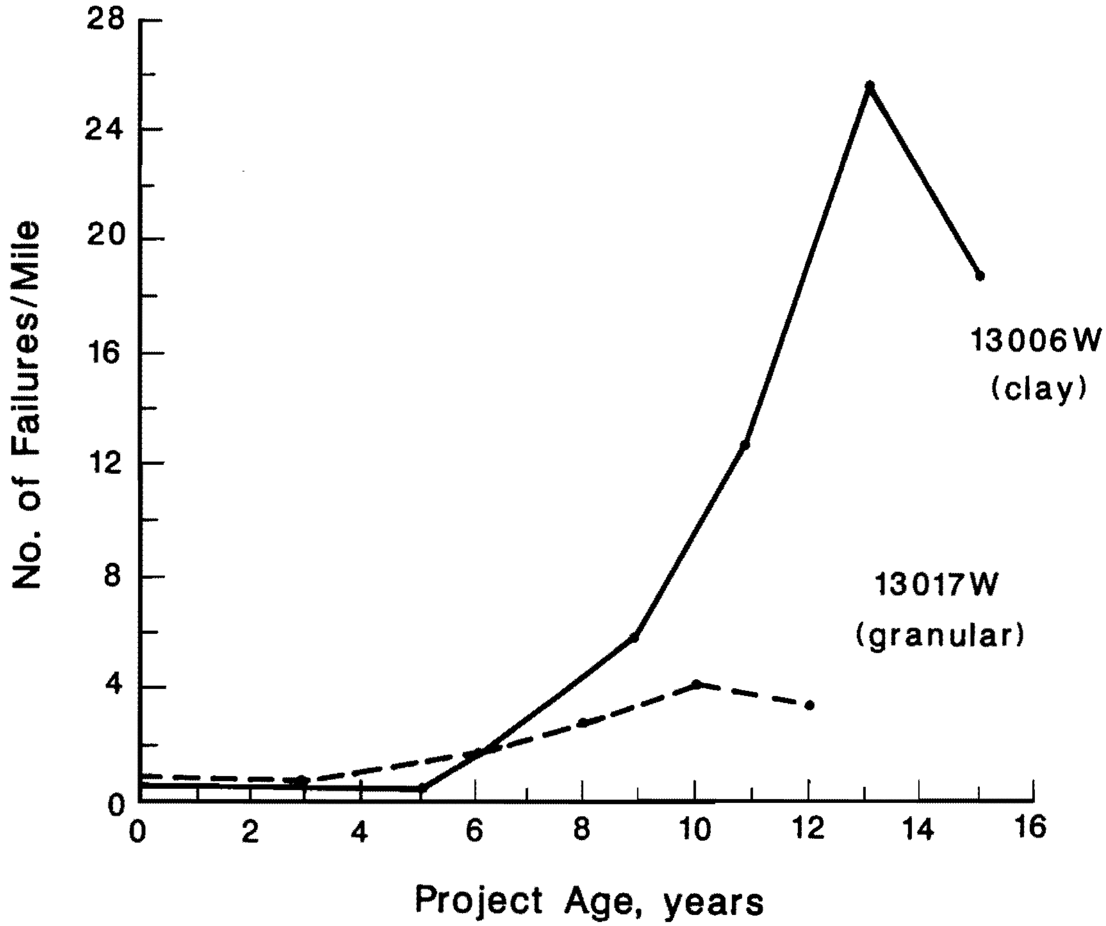

Fig 4.4. History of failures developed in Projects 13006W and 13017W.

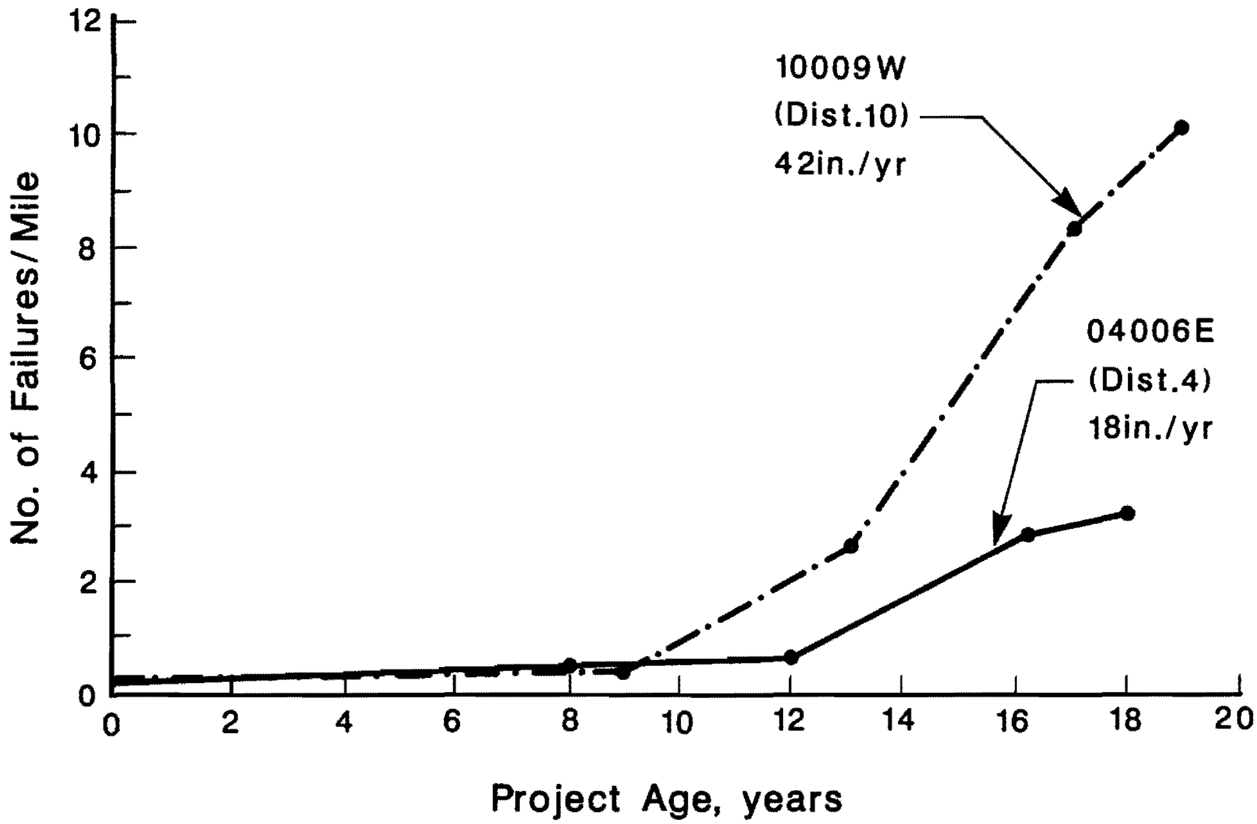

Fig 4.5. Effect of rainfall on pavement performance.

Additionally, the state engineer can study the average condition of pavements maintained by each district as illustrated in Fig 4.6. In this example, the figure clearly shows that the pavements in Districts 19 and 20 deteriorate at a faster rate than the pavements in other Districts (This figure was prepared for illustrative purposes only, therefore other districts were not included in this figure). The figure also indicates that the corrective measures taken by District 19 between 1980 and 1982 improved the network condition of the district considerably, as 1984 condition survey data showed that the rate of deterioration slowed down considerably. On the other hand, the corrective measures taken by District 20 between the same period did not sustain the condition very long because the 1984 condition surveys indicated that the average network condition in 1984 was worst than in 1980.

It is worth while to note that effectiveness of various maintenance and rehabilitation actions can be assessed from a simple plot similar to Fig 4.6. The actions taken by District 19 seems to be more effective in maintaining the pavement conditions to a lower level of failure than the actions taken by District 20. Although a detailed study of each district's action is required before arriving at a final conclusion in this regard, the value of this graph is obvious.

There are many other uses for utilizing the condition survey data either in it present form or slightly modified form. The utilization of this information, to a great extent, depends upon the ingenuity of the individual as well as its availability in time.

Efforts are underway to develop a rigid pavement condition survey data base (Project 472). It is expected that adequate consideration will be given to develop a data base management system which will allow easy access to this information.

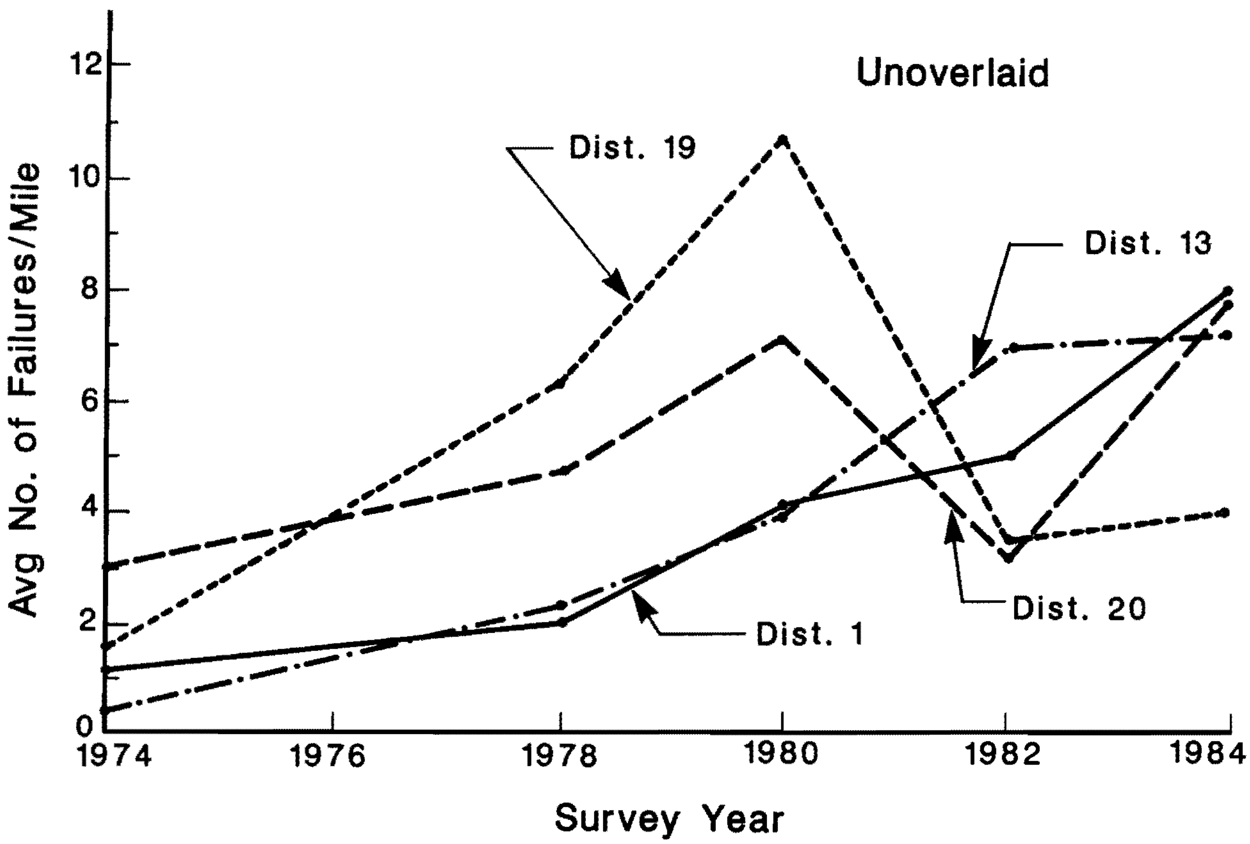

Fig 4.6. Pavement conditions of each District.

CHAPTER 5. ANALYSIS OF CONDITION SURVEY DATA AT NETWORK LEVEL

This chapter summarizes the results of the condition survey data analysis which can be used at network level. A computer program "PRP01", which was developed earlier to estimate the needs of pavement rehabilitation, was used in this analysis. A brief description of this program has been included in Chapter 3 of this report.

The condition survey data of Districts 1, 9, 13, and 17 were selected for the purpose of this analysis. The output of the program includes a summary of projects recommended for rehabilitation and their estimated distress index after a specified period (this period starts with the year the condition surveys were performed). An example of this summary is shown in Table 4.5. Since the last condition surveys were performed in 1984, therefore the actual values of distress index (DI) for projects within any district are generally available for the years 1974, 1978, 1980, 1982, and 1984. These actual values of DI were used to plot a graph between the actual and the estimated values of DI obtained from the output of PRP01. Figures 5.1 to 5.15 show these plots.

The computer program PRP01 utilizes the actual condition survey data to estimate the DI of each project for the survey year. Then these actual values of DI are used to predict estimated DI values for future years. Thus, the first year of survey, i.e., 1974 was used to estimate DI values of future years, e.g., 1978, 1980, 1982, and 1984. The earliest value of actual DI which can be used for this purpose is 1978. Similarly, the last value of actual DI is for the year 1984.

The plots of the four districts show a consistent pattern in the general relationship between the actual and predicted distress indexes as follows.

The 1978 actual DI values were used to compare the predicted DI values based on 1974 condition survey data as shown in Figs 5.1 to 5.3. These correlations show a general trend to be closely aligned and parallel to the ideal correlation reference line. This indicates that the predicted distress indices are significantly close to the actual values.

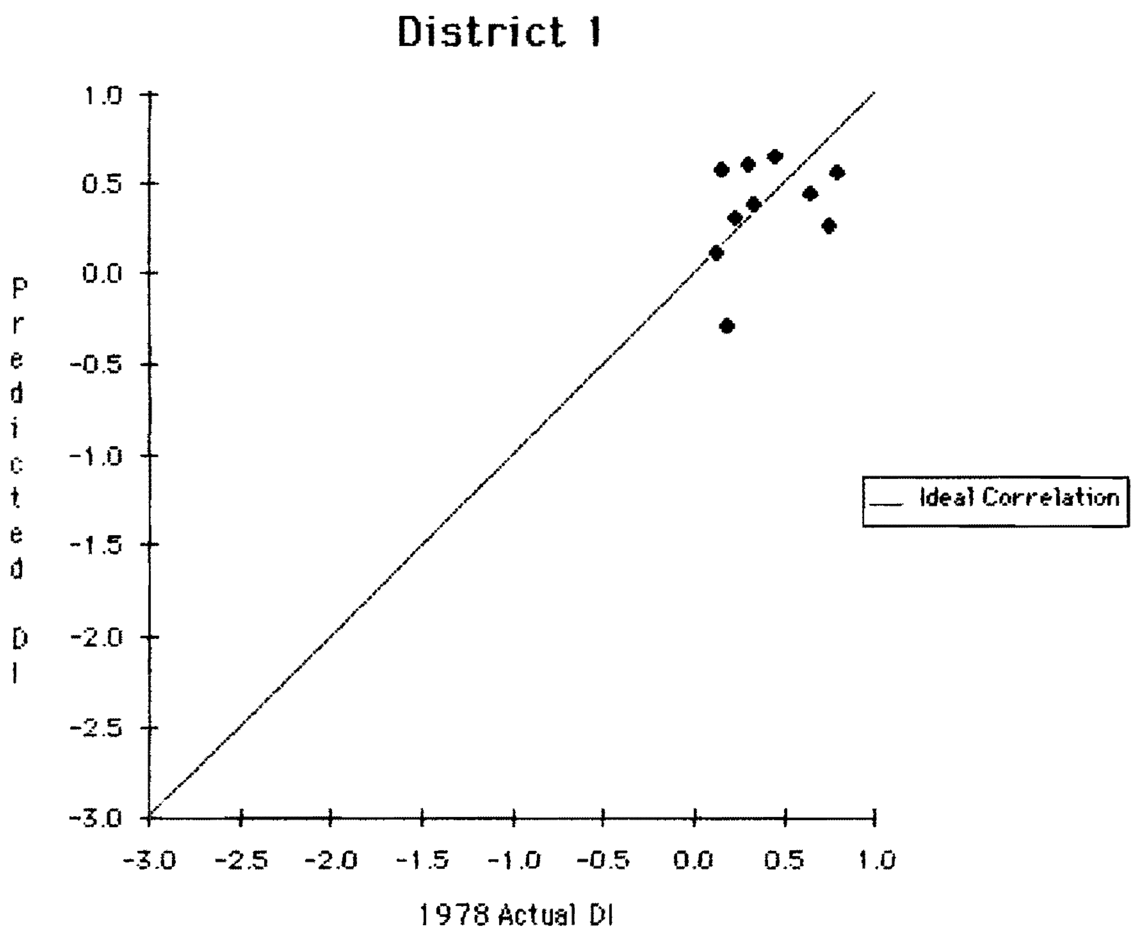

Fig 5.1. 1978 actual DI_S compared with predicted DI_S based on 1974 condition survey data.

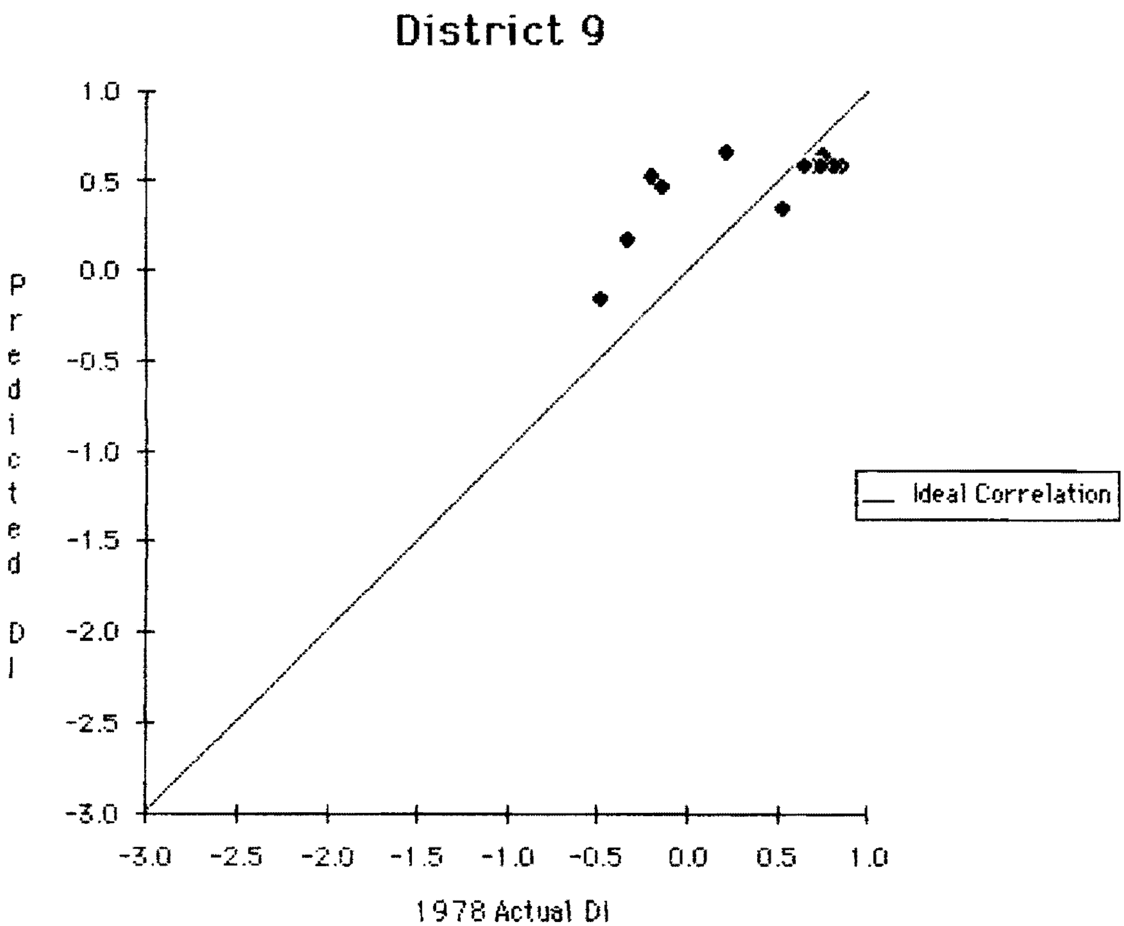

Fig 5.2. 1978 actual DI_S compared with predicted DI_S based on 1974 condition survey data.

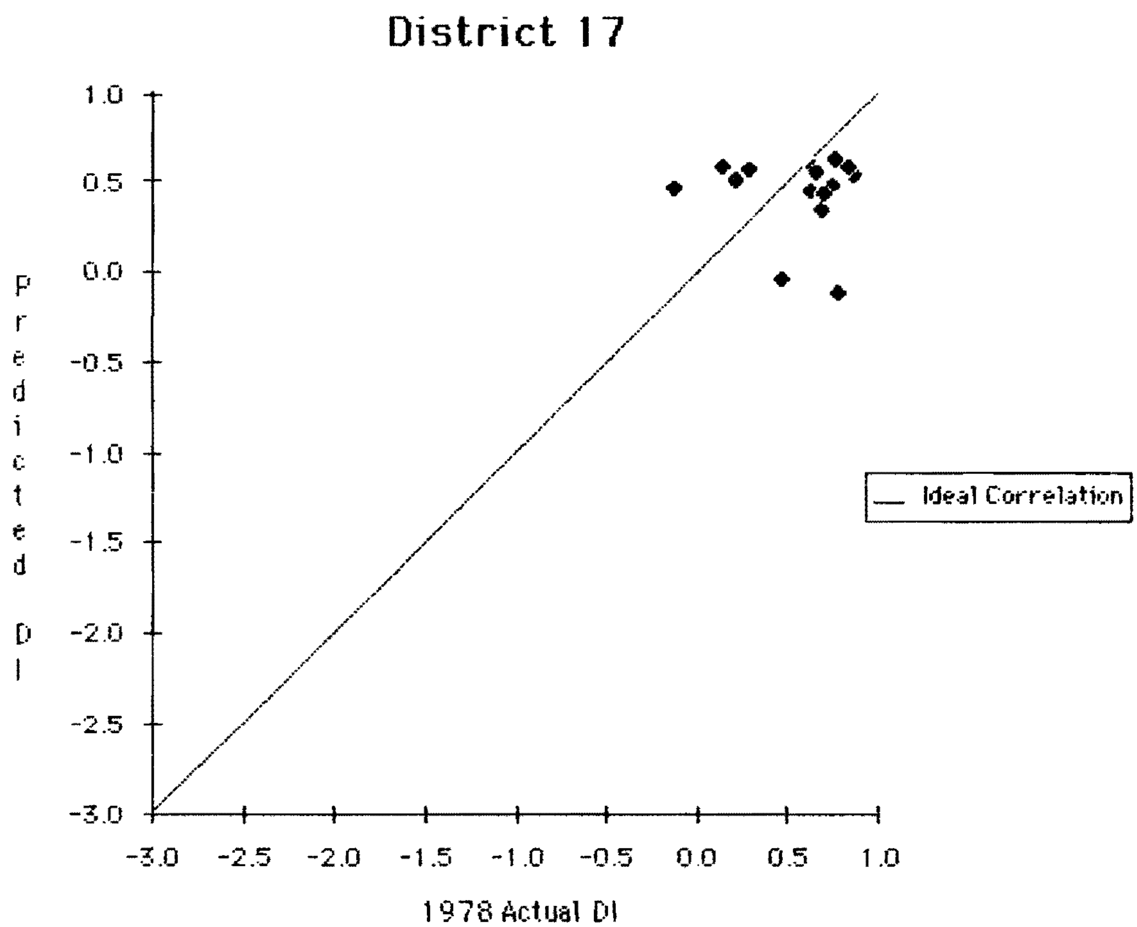

Fig 5.3. 1978 actual DI_S compared with predicted DI_S based on 1974 condition survey data.

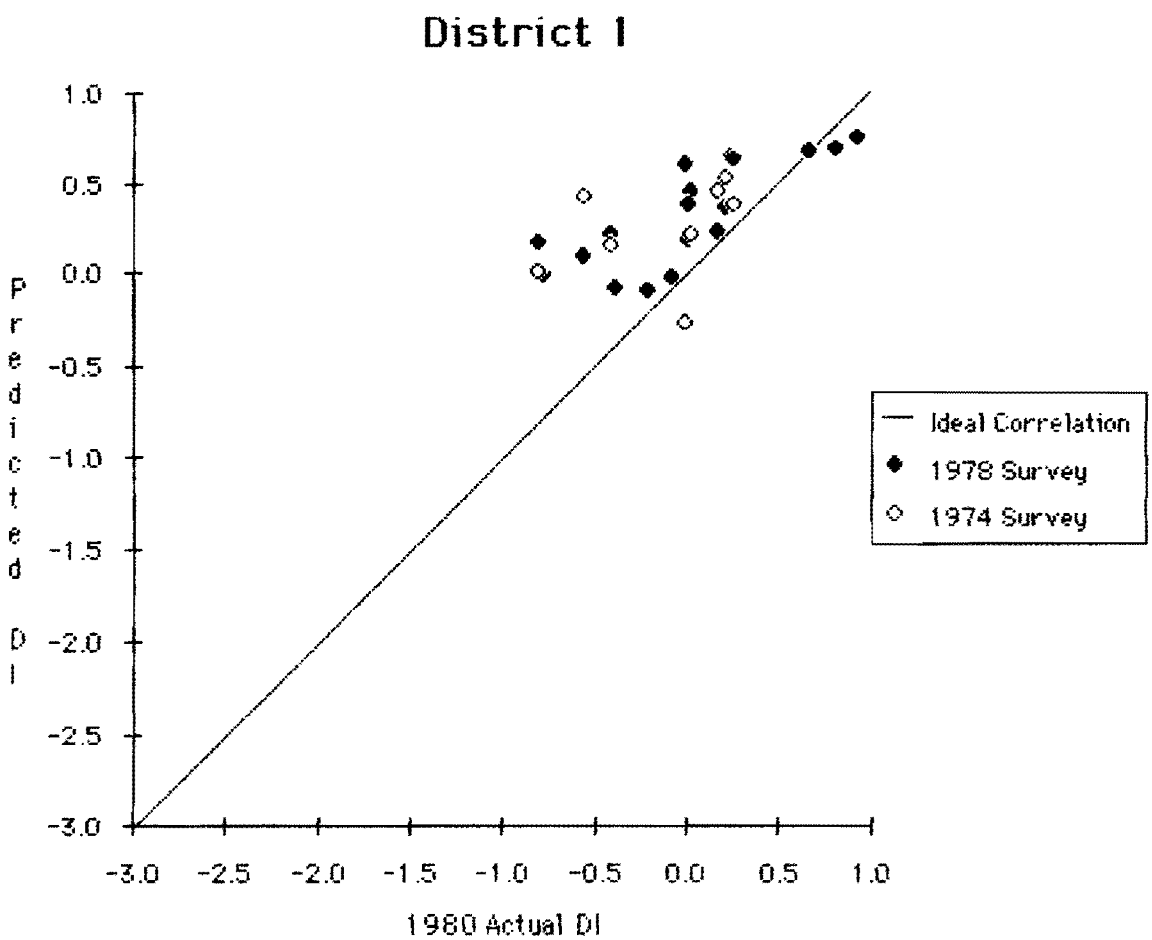

Fig 5.4. 1980 actual DI_S compared with predicted DI_S based on 1974 and 1978 condition survey data.

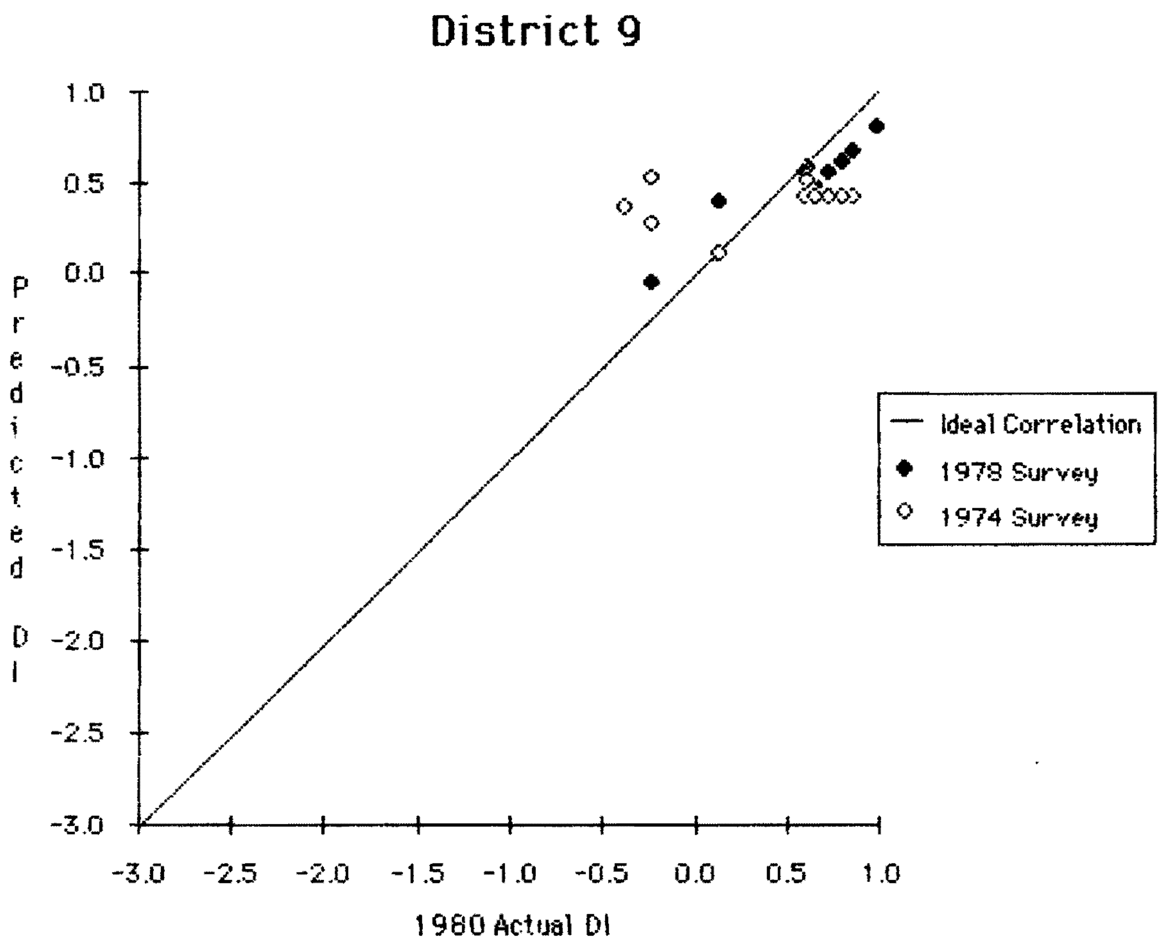

Fig 5.5. 1980 actual DI_S compared with predicted DI_S based on 1974 and 1978 condition survey data.

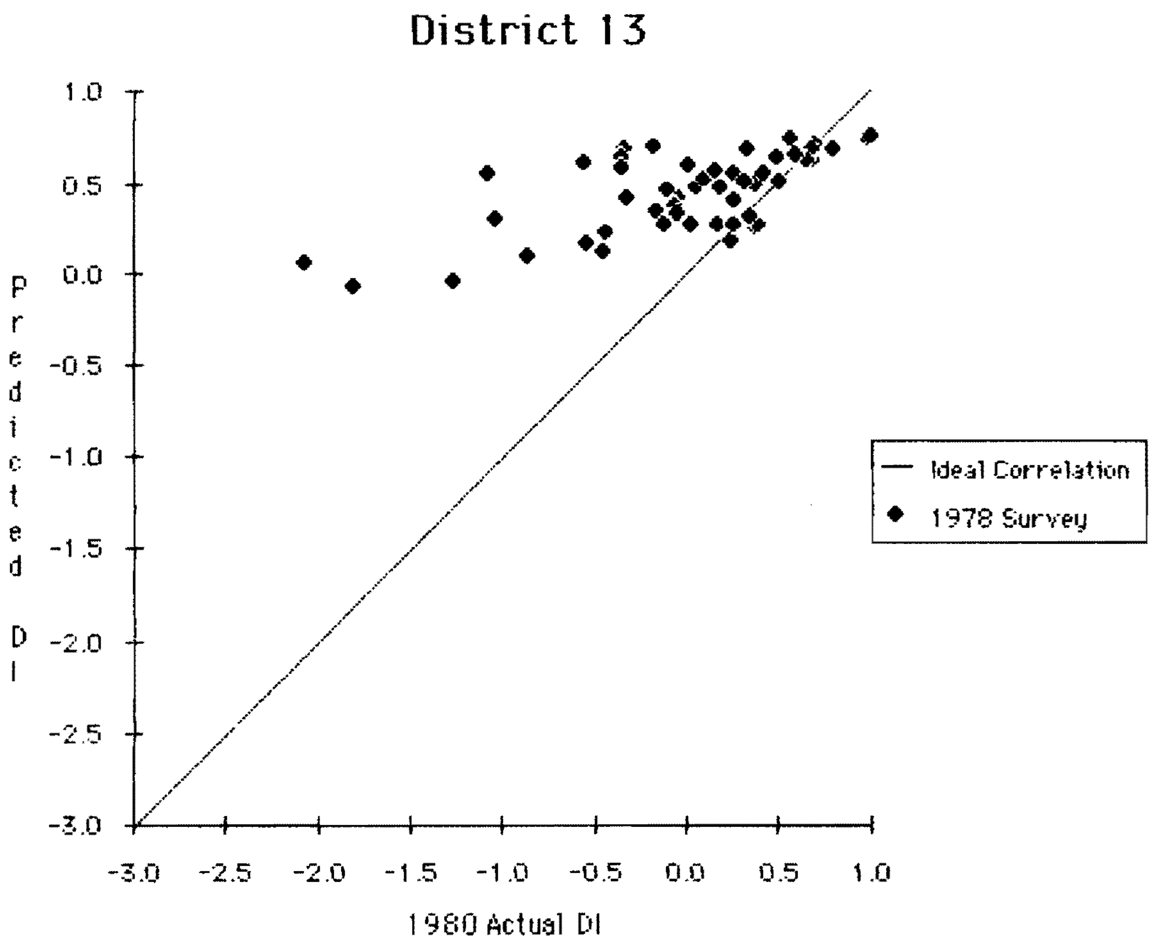

Fig 5.6. 1980 actual DI_S compared with predicted DI_S based on 1978 condition survey data.

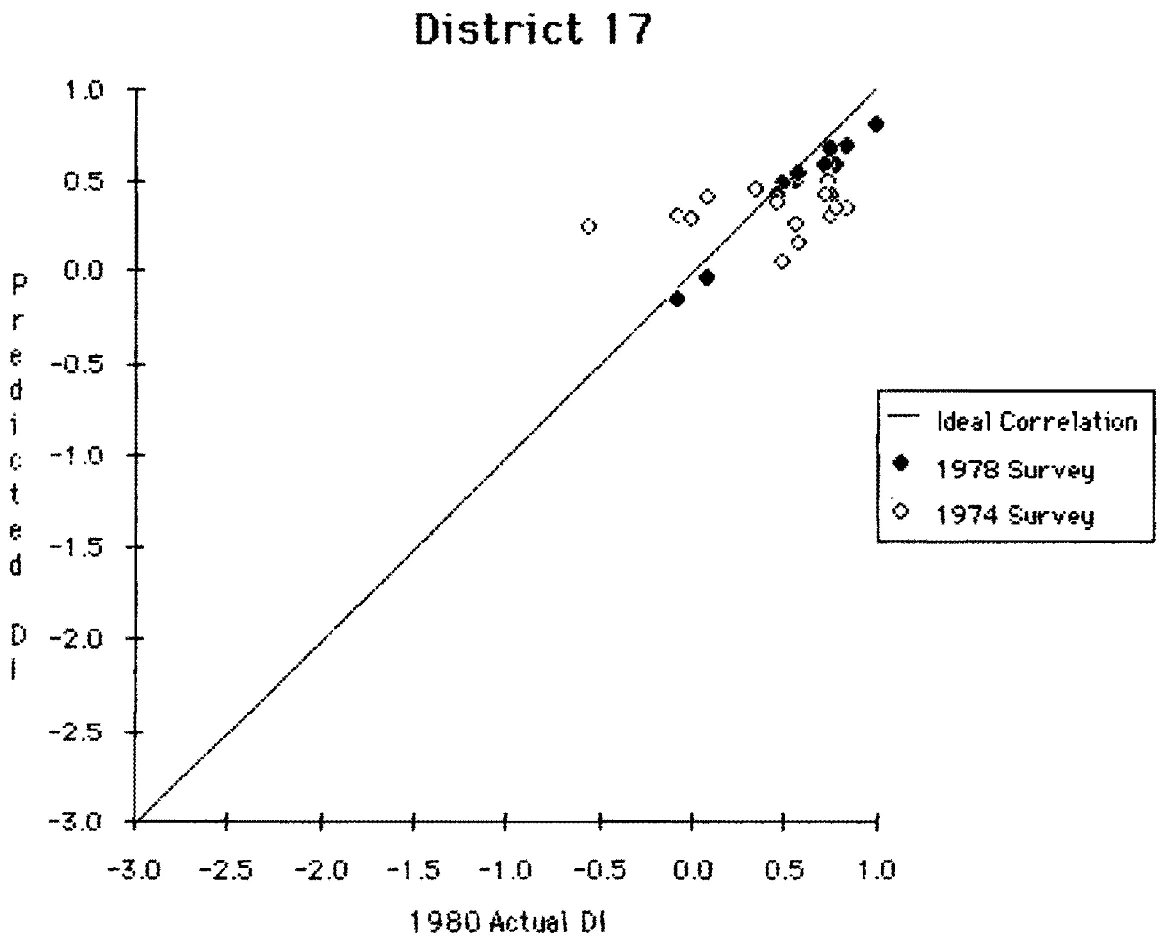

Fig 5.7. 1980 actual DI_S compared with predicted DI_S based on 1974 and 1978 condition survey data.

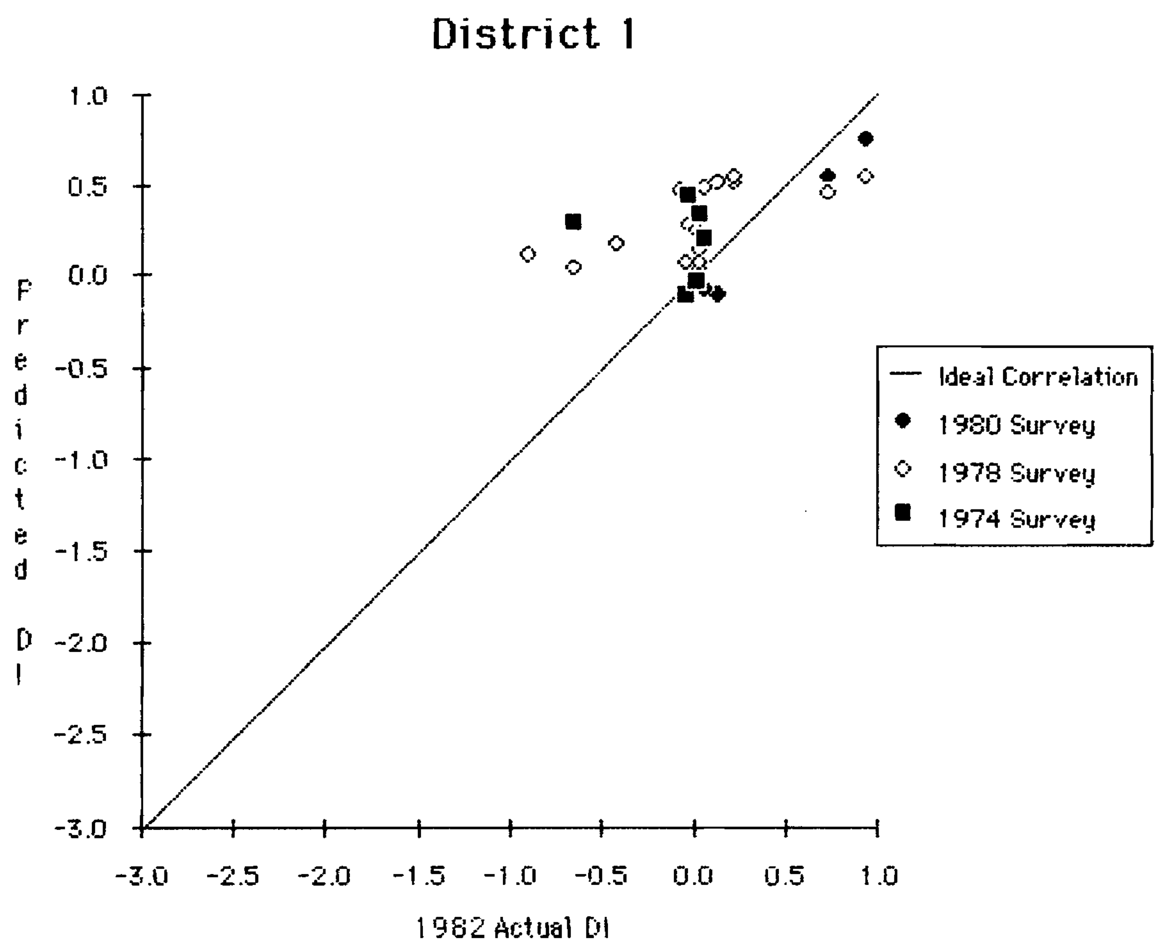

Fig 5.8. 1982 actual DI_S compared with predicted DI_S based on 1974, 1978, and 1980 condition survey data.

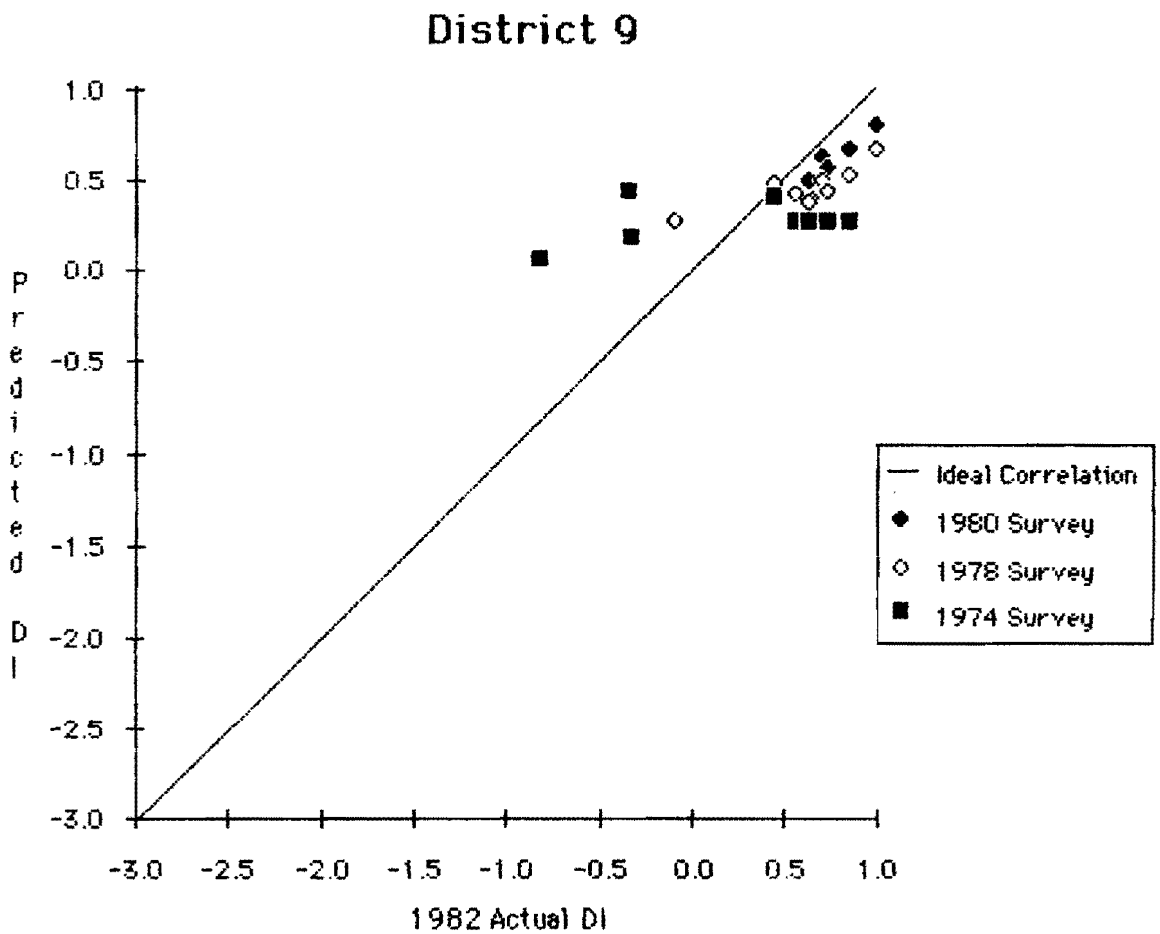

Fig 5.9. 1982 actual DI_S compared with predicted DI_S based on 1974, 1978, and 1980 condition survey data.

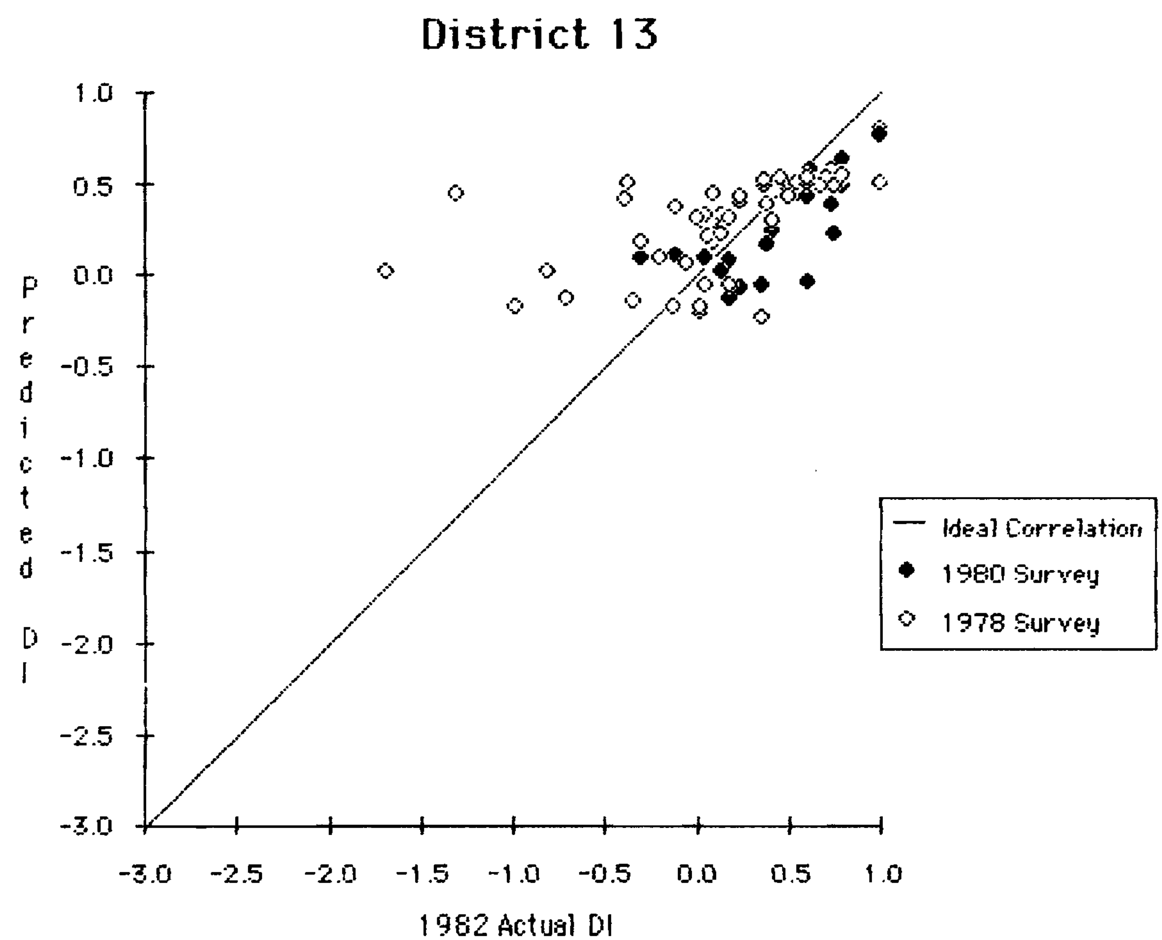

Fig 5.10. 1982 actual DI_S compared with predicted DI_S based on 1974, 1978, and 1980 condition survey data.

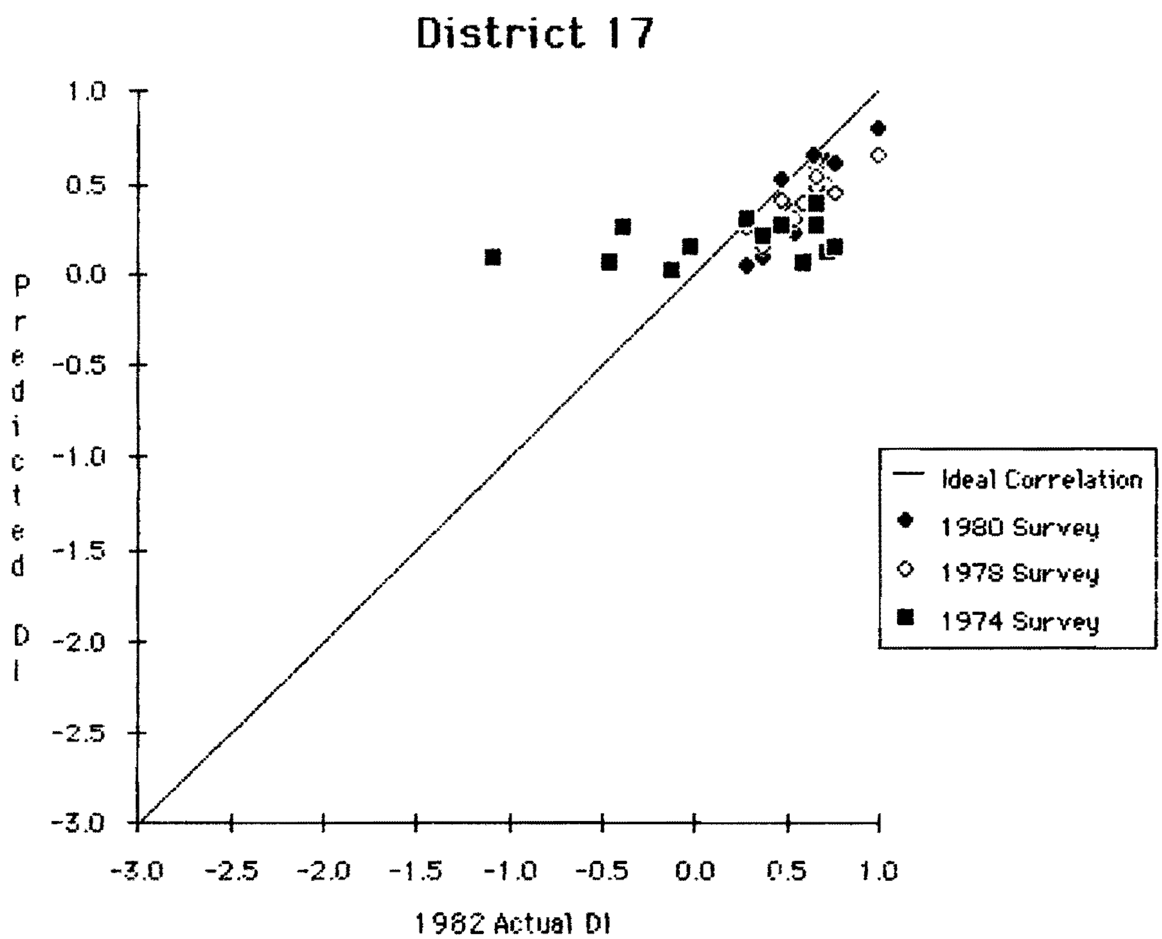

Fig 5.11. 1982 actual DI_S compared with predicted DI_S based on 1974, 1978, and 1980 condition survey data.

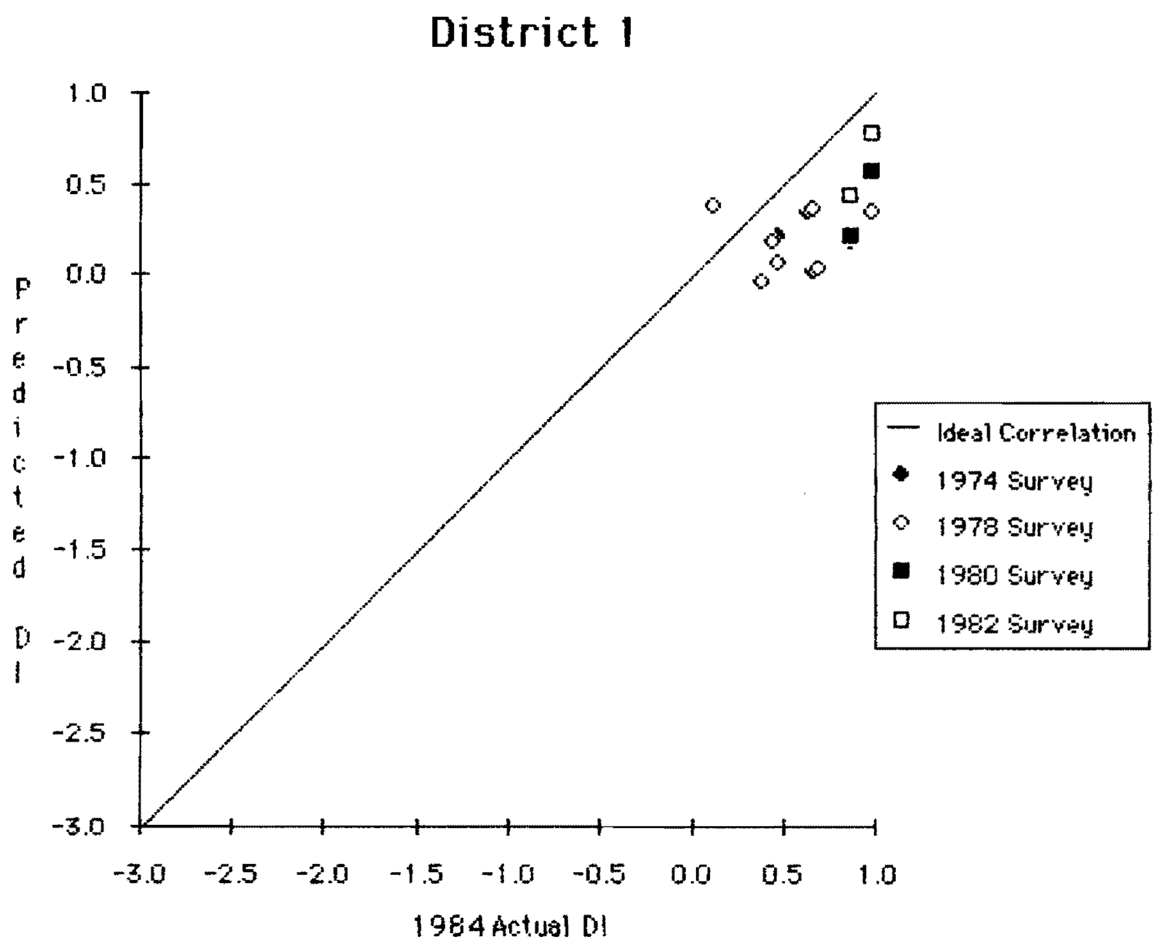

Fig 5.12. 1984 actual DI_S compared with predicted DI_S based on 1974, 1978, 1980, and 1982 condition survey data.

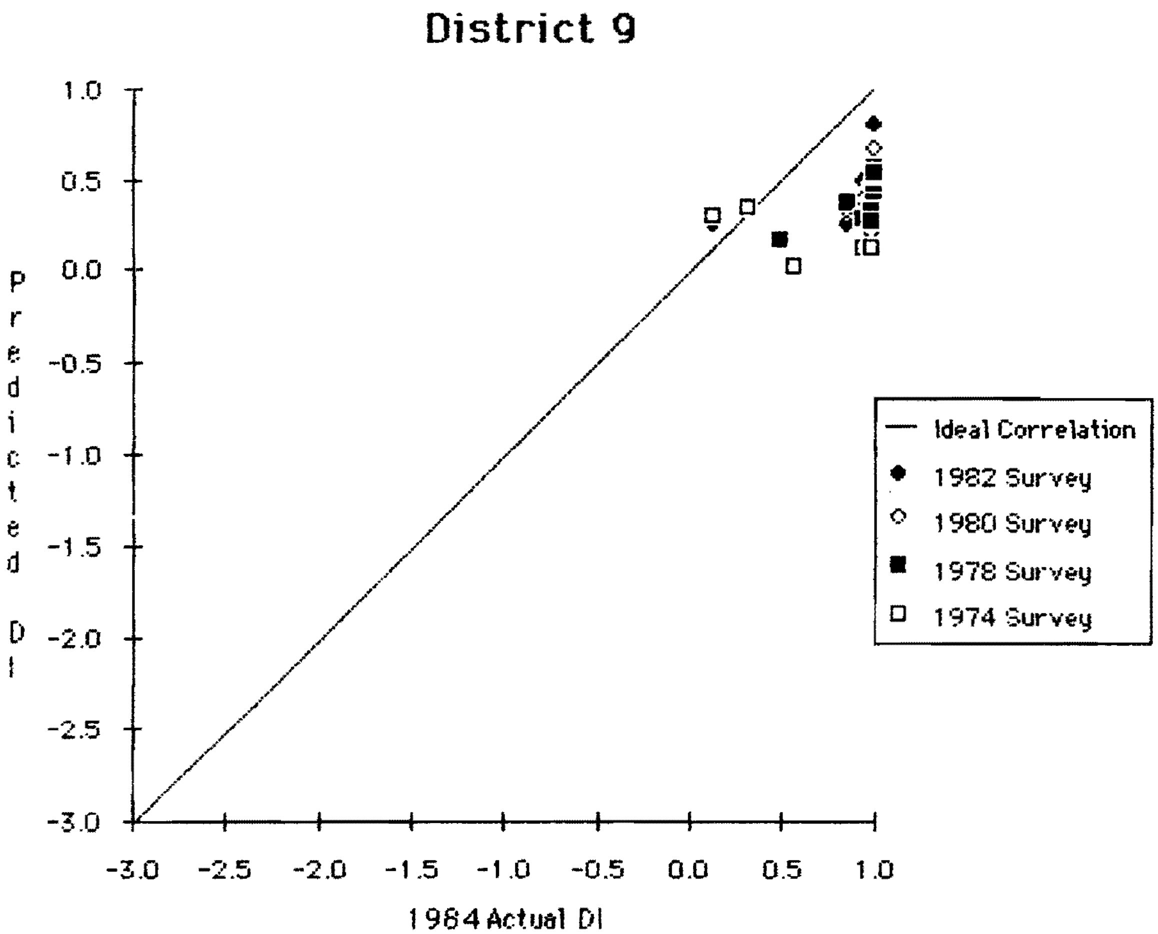

Fig 5.13. 1984 actual DI_S compared with predicted DI_S based on 1974, 1978, 1980, and 1982 condition survey data.

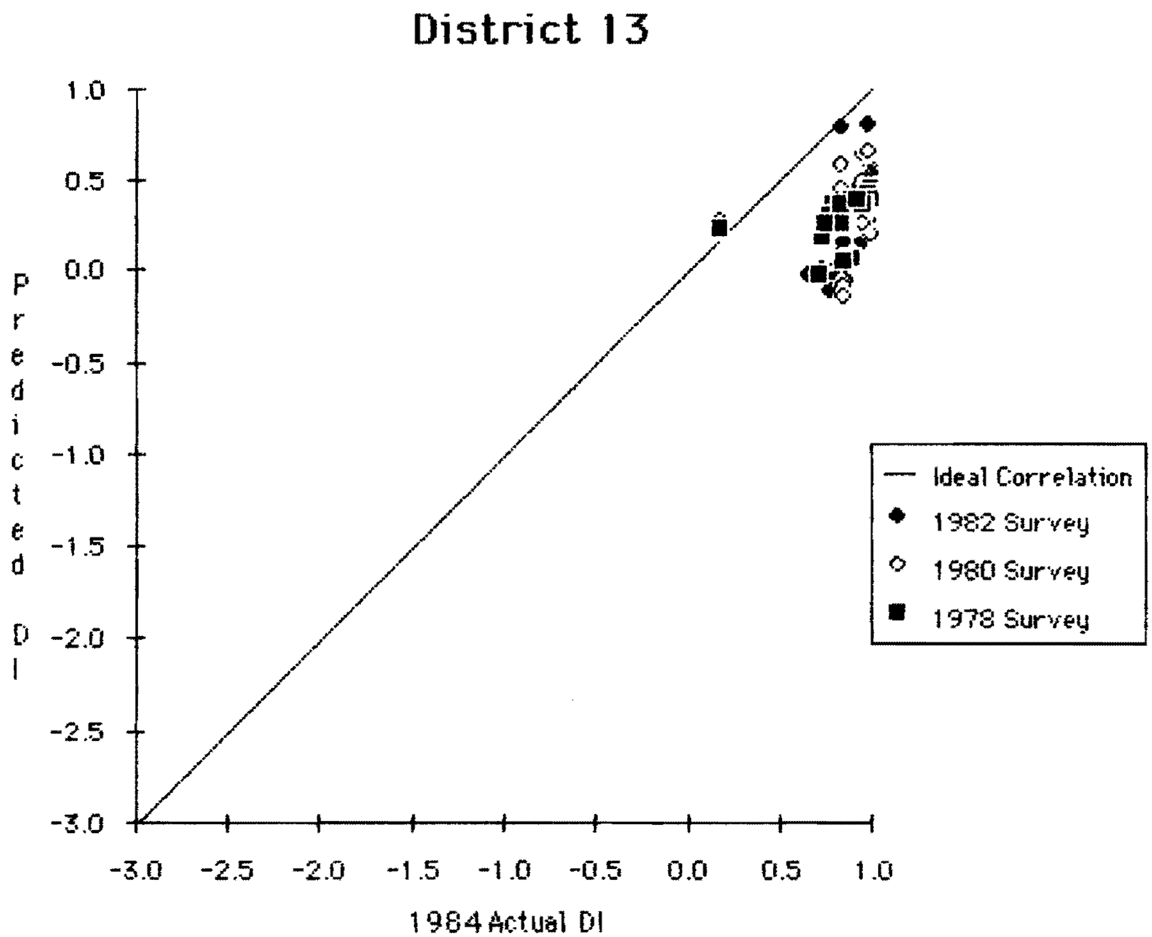

Fig 5.14. 1984 actual DI_S compared with predicted DI_S based on 1974, 1978, 1980, and 1982 condition survey data.

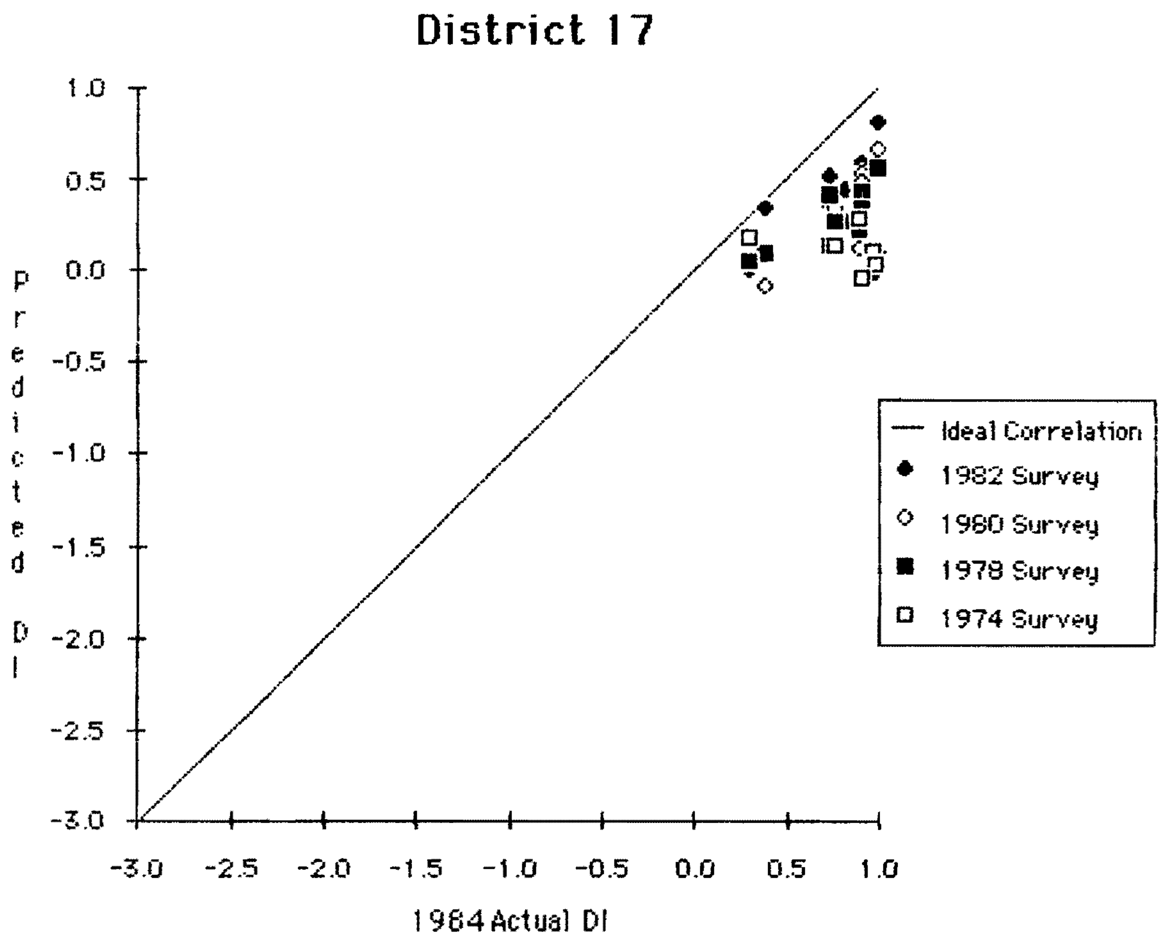

Fig 5.15. 1984 actual DI_S compared with predicted DI_S based on 1974, 1978, 1980, and 1982 condition survey data.

Figures 5.4 to 5.7 show the correlation between 1980 actual DI values and the estimated DI values based on 1974 and 1978 condition surveys. These correlations reflect a more horizontal trend which crosses the ideal correlation reference line. This represents a shift from the 1978 versus 1974 correlation, where there was a better correlation between actual and predicted distress indices, toward a pattern where the actual distress indices tend to be lower than predicted.

Figures 5.8 to 5.11 show the correlation between 1982 actual DI values and the estimated DI values based on 1980, 1978, and 1974 surveys. These correlations reflect the same general trend as the above (1980 versus 1978 and 1974 data) correlations.

Figures 5.12 to 5.15 show the correlation between 1984 actual DI values and the estimated values of DI based on 1982, 1980, 1978, and 1974 surveys. These correlations tend to show a trend opposite to that of the 1982 and 1980 sets. The position and slope of the 1984 set indicates that the actual distress index values are better than was predicted by the previous years' data analysis.

If we first work with the basic assumption that the PRP01 program generates reliable results, then we are forced to look for other factors which may have caused the variation in trends over the period of time analyzed.

One possible explanation may be found if we look at the amount and increase in relative weight of truck traffic on the roads during the period of analysis. The 1978 data set shows a relatively high correlation between actual and predicted distress indices. We may wish to refer to this period of time as a period of "normal usage". The 1980 and 1982 sets reflect prediction that are higher than actual distress indices. This may be a result of increased truck traffic on the highways beginning in the 1980's, which the PRP01 program was not designed to account for. Since the roads would have deteriorated quicker under the heavy truck usage than under "normal usage" we could expect the predicted distress index to be higher than the actual value (higher distress index represents less damage of pavement). To justify almost an exact reversal of the 1982 and 1980 set conditions in the 1984 set in which the actual value was higher than the predicted value we might consider that we had an influx of highway funds that was able to overlay many more sections of highway than were predicted to be overlayed. A previous consideration to keep in mind when looking at this correlation study is that there will not be a significant correlation in the data until the Texas SDHPT starts using the computer program predictions to help them determine which sections are in need of being overlayed.

This type of analysis of the PRP01 outputs has brought to our attention that further development of this program is needed in order to include a "wear-out" equation that could simulate the deterioration of pavement after it is predicted to be overlayed. Further development is also needed to incorporate automatic correlation analysis as has been preformed here in order to verify reliability. At this point, the program outputs a distress index of 0.996 for the first year after overlay and each year thereafter the distress index is reported as 1.000. With respect to the correlation plots of current interest this means that we can only extract data from projects which are either targeted for overlay or which have not yet been targeted for overlay within the specific year. The projects, therefore, may only be traced from the year of the condition survey until they are targeted for overlay, then they are lost due to the lack of a "wear-out" function after that point.

A direct attempt was also made to correlate the actual individual sections within a project that were overlayed with respect to sections that were predicted to be overlayed. This turned out to be a unproductive task possibly due to the factors concerning SDHPT's process for selecting sections to be overlayed, as mentioned above. Another factor which may have hindered this type of analysis is the limited amount of data that was available for analysis since there is no integration of the PRP01 program into the decision making process at the present time.

CHAPTER 6. SPECIAL ANALYSIS - PERFORMANCE OF LIGHT WEIGHT AGGREGATE

Two experimental sections were constructed in 1963-64 to study the possibility of reducing the percentage of steel in continuously reinforced concrete pavements (CRCP). For this purpose, preformed cracks at regular intervals were provided in these sections. A detailed report of this study will be published in a Research Report on Project 472. This chapter includes a brief summary of this study as it relates to the special analysis of the condition survey data.

SALIENT FEATURES OF THE EXPERIMENTAL SECTIONS

Location - Frontage roads to I-610 in Houston, Texas

Section Layout - 11 section as shown in Fig 6.1.

Materials of Construction -

(1) Cement concrete using
   - (a) standard aggregates (river gravel);
   - (b) light weight aggregate (crushed lime stone);

(2) reinforcing steel
   - (a) longitudinal steel in standard CRCP, 0.3, 0.4, and 0.5 percent;
   - (b) longitudinal steel in light weight CRCP, 0.3 and 0.4 percent;
   - (c) transverse steel in both cases - 1/2-inch bars at 32-inch centers.

Preformed Crack Spacing

(1) standard aggregate CRCP - 5 and 8 feet;

(2) light weight aggregate CRCP - 8 and 20 feet.

CONDITION SURVEY DATA

The condition survey data of these experimental sections included the following items:

(1) Transverse crack spacing and crack opening,

(2) minor and severe spalling of cracks, and

(3) deflection data using Benkelman Beam and/or Dynaflect.

The test sections' data was collected immediately after construction in 1963-64. After about 10 years (1974), a second set of data was collected to study the performance of the experimental sections. In 1984, the condition survey data was again collected to update the results of study reported in 1974. The results of the 20 year data analysis are summarized in the following paragraph of this report.

RESULTS OF THE STUDY

Analyses based on deflection, cracking and condition survey data of the experimental sections are presented in a research report to be published as Research Report 472-1. This section presents a brief summary of the results of the study.

Each type of aggregate is discussed individually to point out the effects of reinforcement and preformed crack spacing. The effects considered are deflection and mean crack spacing at different times and in terms of the rates of change over a long period of time.

EFFECT OF PREFORMED CRACK SPACING

Of sections built using the standard aggregate, those with 8-foot preformed crack spacing had fewer cracks in the early years, until 1968 in the case of sections with 0.4 percent and 0.5 percent steel. As sections with 8-foot preformed crack spacing continue to crack, they seem to behave relatively poorly in the long run. Thus, the selection between 5-foot and 8-foot preformed crack spacing depends on the desired design life and the percentage of longitudinal steel. If deflection rather than mean crack spacing is taken as the criterion, 5 feet of preformed crack spacing is clearly the better of the two alternatives.

In the case of lightweight aggregate sections, two values were tried for preformed crack spacing: 8 feet and 20 feet. The sections with 20-foot preformed crack spacing developed enough cracks to bring the mean crack spacing to about 8 feet, even during the first year of operation. All but one of these sections have maintained a mean crack spacing of about 8 feet for nearly twenty years. Hence, it appears that 8 feet is a natural crack spacing for sections using lightweight aggregate and 0.3 percent or 0.4 percent longitudinal steel.

EFFECT OF REINFORCING STEEL PERCENTAGE

In the case of standard aggregate CRCP sections, 0.3 percent longitudinal steel has resulted in less cracks than the other two steel percents considered. An interaction between steel percentage and preformed crack spacing is indicated from the data. Also, a combination of 0.3 percent steel and 5 feet preformed crack spacing is best among the combinations considered, from the point of view of minimizing transverse cracks. From the point of view of deflection over the long term, also, 0.3 percent seems to work better.

In the case of lightweight aggregate sections, no conclusion emerged from the data analysis, except that an interaction between steel percent and preformed crack was indicated in this case.

EFFECT OF TYPE OF AGGREGATE

The analyses lead to the conclusion that the use of lightweight aggregates in CRCP construction results in less cracks in both short term and long term. However, if deflection is considered, standard aggregate sections seem to maintain their structural quality better in the long term.

VERIFICATION OF MECHANISTIC MODELS

Chapter 5 of the research report (to be published as Research Report 472-1) includes a comparison of observed crack spacing with theoretical predictions made using computer program CRCP-3, developed at CTR. This program incorporates state-of-the-art mechanistic models to predict mean crack width, crack spacing, steel stress, and concrete stress.

The mechanistic predictions were in general agreement with observed crack spacing with some exceptions. The exceptions were standard aggregate sections 5 and 6 and light weight aggregate sections 8 and 9. The mechanistic model under-predicted the mean crack spacing of these sections, which are at the beginning of the set of experimental sections as the traffic approaches. These sections also had the curing temperature above 84' F. At this time it is not possible to draw any valid conclusions on this finding: the mechanistic model may need enhancement to simulate the effects of position on cracks and/or there may be a need to improve the prediction of curing temperature effect; or there could be other variables whose effect is not considered in the mechanistic model. More research is needed to find a definite answer.

CHAPTER 7. CONCLUSIONS AND RECOMMENDATIONS

The major conclusions and recommendations based on the results of this research project are outlined below.

CONCLUSIONS

(1) The development of condition survey procedures is a continuing process. As the needs of the Texas State Department of Highways and Public Transportation (SDHPT) in this regard change, so does the procedure. Condition surveys in urban areas require special considerations due to high traffic volumes and absence of adequate shoulder widths for driving the survey vans.

(2) It was discovered that surveying at 2-5 mph in rural areas created no safety hazards for a team of 2 persons, a driver and a passenger. However, surveying at a speed of about 15 mph will need full attention of the driver in driving the survey van. Therefore an additional person will be needed for this job.

(3) Direct entry of condition survey data on a micro-computer disc speeded the data recording process and eliminated the need for transferring the data on computer files from field data recording forms (used in early surveys until 1982).

(4) It is sometimes unsafe to conduct condition surveys of rigid pavements in urban areas with the current speed of 15 mph due to high traffic volumes in these locations.

(5) The error of personal judgement in recording the pavement distresses can be reduced by providing adequate training to the team members.

(6) Visual identification of desired pavement distresses becomes less reliable at survey speeds of greater than 15 mph.

(7) Distress index derived from pavement condition survey data can be used to prioritize projects at network level for rehabilitation purposes.

(8) Deflection distress index using the detailed condition survey data at project level can be used to prioritize sections of a project for rehabilitation purposes.

(9) Several applications of condition survey data have been illustrated in this report. These applications can be used by the District and state highway engineers. An easy access to this data by the Districts and state personnel will make it more usable by these groups.

(10) The use of rational models for prioritizing pavements at different levels provides a dependable tool to highway engineers in estimating their need of future rehabilitation and prepare budget requests.

(11) The consequences of inadequate funds spent in rehabilitating the critical projects or pavements can be estimated in advance with the help of pavement evaluation models described in this report as illustrated in Chapter 5 of this report.

(12) Transverse crack spacing can be increased in both standard and light weight concrete CRCP by preforming the cracks. However, the results of this limited study should be investigated further to determine any additional maintenance cost consequences.

(13) Some reduction in longitudinal steel was indicated in standard concrete pavements by preforming the cracks. However, no such trends were indicated in light weight concrete pavements.

(14) The use of light weight aggregates in pavements resulted in less transverse cracking but standard aggregate pavements maintained their structural quality (measured by surface deflections) better in long term.

RECOMMENDATIONS

(1) The possibilities of automating the condition surveys should be explored by using the modern techniques of image processing. This will allow to increase the speed of surveying, conduct condition surveys in areas of high traffic volume, and reduce subjectivity in identifying the pavement distresses.

(2) The model recommended for prioritizing the project at network level should be verified and improved if needed.

(3) The deflection distress index model developed for project-level prioritization should be verified and improved to accommodate the site specific needs.

(4) The existing rigid pavement condition survey data bank is a valuable resource available to researchers and other PMS activities related groups of the Texas SDHPT. It is recommended that these surveys should be continued for the life of the pavement.

(5) In order to derive full benefit of condition survey data, it is recommended that its access to various groups of the Texas SDHPT should be easy. For this purpose, development of a suitable rigid pavement condition survey data base management system should be seriously considered by the Texas SDHPT.

(6) In order to avoid subjectivity in prioritizing the pavements at project and network levels, the use of rational models by the concerned groups should be encouraged.

(7) The results of light weight aggregate study should be verified by constructing pilot study test sections.

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APPENDIX A

DISTRESS INDEX (DI) EQUATION FOR CRCP

APPENDIX A. DISTRESS INDEX (DI) EQUATION FOR CRCP

The following equation has been developed to estimate the DI of CRCP:

$$DI = 1.0 - 0.065FF - 0.009SS \tag{A.1}$$

where

FF = number of failures per mile, and

SS = percentage of cracks with severe spalling.

Further, FF (number of failures/mile) is defined as the sum of the following four distress manifestations:

$$FF = ACP + PCCP + SPO + MPO$$

where

ACP = average number of asphaltic concrete patches per mile,

PCCP = average number of Portland cement concrete patches per mile,

SPO = average number of severe punchouts per mile, and

MPO = average number of minor punchouts per mile.

Also, the condition surveys of CRCP conducted in various Districts indicate that the average transverse crack spacing ranges between 2.9 feet and 8.7 feet. Since the current survey procedures do not allow for the actual measurements of the crack spacing, an average value of about 5.0 feet can be used for calculating the percentage of cracks with severe spalling (SS) as follows:

$$SS\ (\%) = \frac{\text{number of cracks with severe spalling/mile}}{5280/5} \times 100$$

$$= \frac{\text{number of cracks with severe spalling/mile}}{10.56} \qquad (A.2)$$

Ranking of CRCP Using DI

The estimated value of DI (see Eq A.1) can be used to rank the pavements. For this purpose, the pavements can be divided into two categories. In the first category, there are pavements which do not require any overlay, but the distress condition varies from no failures (FF = 0) to maximum number of failures possible under this category. For conditions in Texas this number has been observed to be 16 (FF = 16). Using these two limiting values for FF and assuming SS = 0, the value of DI would be between 1.0 and 0.0 (Eq A.1). In this case DI = 1 represents pavements with no apparent distress and DI = 0 represents pavements with a total of 16 failures/mile. Therefore any value between 0 and 1 represents the intensity of failures as observed on any given pavement.

In the second category of pavements are those CRCPs which are considered for overlaying, because the number of failures are greater than 16. Since the value of DI estimated for this case is always less than zero, a smaller value of DI which is far away from zero represents worst condition than the value which is closer to zero. The lowest possible value of DI expected under this category is assumed to be -8.0. This represents the worst possible condition of the pavement and hence is ranked at the top in the list of the pavements designated for overlaying jobs.

Conversion of DI to a Scale of 0-100 to Match with the SDHPT Ranking Scale

The current practice of the Texas SDHPT is to rank the pavements on a scale of 0-100. In this scale, rank = 0 represents the worst condition of the pavement and rank = 100 represents the perfect condition. Also, depending upon the functional classification of the road, ranking below a certain level (say rank = 35) is considered to be bad enough so that an overlay will be required under this condition. Since this point on the scale varies with the functional classification of the road, it is represented by a variable point A in Fig A.1.

Using the three limiting values of DI, as described above, and matching them with the limiting values used on the ranking scale, the following relationships are developed to estimate the Texas SDHPT ranking. Figure A.1 illustrates the two scales used in these calculations.

Category I - Pavement Requiring No Overlays. In this case

$$DI \geq 0.0.$$

$$\text{Ranking} = A + (100 - A) * DI \qquad (A.3)$$

Category II - Pavements Requiring Overlays. In this case

$$DI \leq 0.0 \text{ (but not less than } -8.0)$$

$$\text{Ranking} = A + \left(\frac{DI * A}{8} \right) \qquad (A.4)$$

Note: If the estimated DI $\leq$ -8.0, assume DI = -8.0.

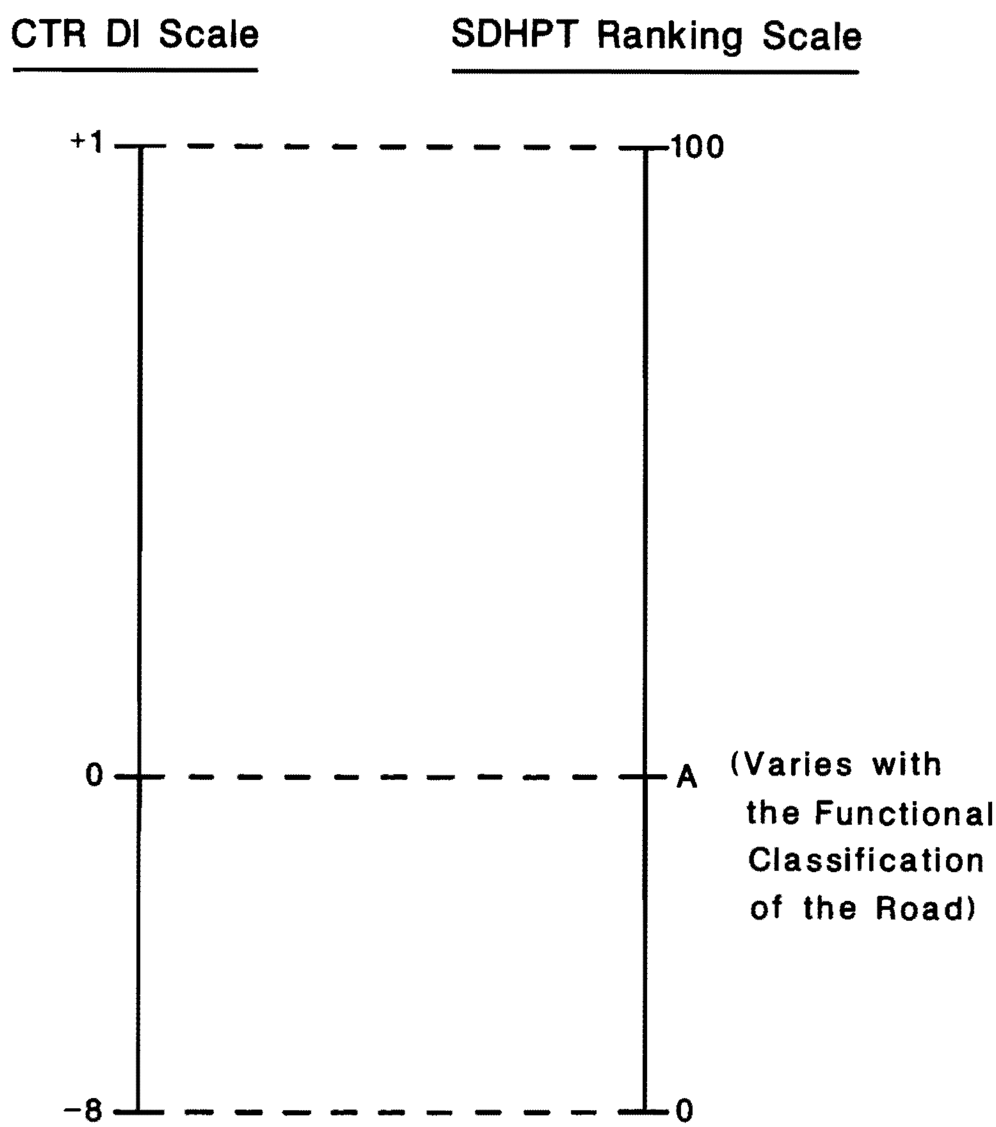

Fig A.1. Center for Transportation Research CI scale and the Texas State Department of Transportation and Public Highways ranking scale.

Examples

The following examples illustrate the use of Eqs A.3 and A.4 to estimate the rankings of pavements. The data as well as the estimated values are shown in Table A.1.

Solution to Example 1.

$$FF/1.8 \text{ mile} = 7 + 0 + 0 + 4 = 11$$

$$FF/1.0 \text{ mile} = 11/1.8 = 6.1$$

$$\text{number of cracks with severe spalling/mile} = \frac{38}{1.8} = 21$$

$$SS\ (\%) = \frac{21}{10.56} = 2\%.$$

Using Eq A.1, the value of DI is

$$DI = 1.0 - 0.065\ (6.1) - 0.009\ (2) = 0.5855$$

Since DI > 0.00 in this case, therefore using Eq A.3, we get

$$\text{Ranking} = 35 + (100 - 35) * 0.5855 = 73.06 \approx \underline{73}$$

Solution to Example 2.

$$FF/1.8 \text{ mile} = 24 + 15 + 9 + 0 = 48$$

$$FF/1.0 \text{ mile} = 48/1.8 = 26.67$$

$$\text{Number of cracks/with severe spalling/mile} = \frac{191}{1.8} = 106$$

$$SS\ (\%) = \frac{106}{10.56} = 10\%$$

TABLE A.1. DATA USED IN EXAMPLES 1 AND 2 AND THE ESTIMATED DISTRESS INDICES

	Observations							Results	
Example No.	ACP	PCCP	SPO	MPO	SS	Segment Length (Mile)	A	DI	Ranking
1	7	0	0	4	38	1.8	35	0.5855	73
2	24	15	9	0	191	1.8	35	0.8236	31

Using Eq A.1, we get

$$DI = 1.0 - 0.065\ (26.67) - 0.009\ (10)$$
$$DI = -0.8236$$

Since DI < 0.0 in this case, we will use Eq A.4 to estimate ranking as follows:

$$\text{Ranking} = 35 + \left(\frac{-0.8236 * 35}{8} \right)$$

$$= 31.4 \approx \underline{31}.$$

APPENDIX B

PRIORITIZATION EQUATION FOR RIGID PAVEMENTS

APPENDIX B. PRIORITIZATION EQUATION FOR RIGID PAVEMENTS

The prioritization equation for rigid pavements is as follows:

$$Y = 5.26 + 0.46\ RF + 0.396\ FTF + 0.601\ TF + 0.749\ PSF + 1.66\ DF \tag{B.1}$$

where

Y = priority value,

RF = rainfall factor,

FTF = freeze-thaw factor,

TF = traffic factor,

PSF = PSI factor, and

DF = distress factor.

There are five factors which have been used in the estimate of priority value (Y). These factors are related to measured quantities/estimated values as shown in Table B.1. The values of these factors range between -1 and +1.

Using the two extreme values of all five factors, the value of Y for perfect pavement (requiring no overlay) is 9.126. The value of Y for a pavement in worst possible condition (very high in priority for overlaying) is 1.394. Since it is inconvenient to determine the values of five factors from Table 3.1, it was decided to modify Eq B.1 such that the direct measurements of all five factors could be used in the equation. Also, it was considered important to limit the value of Y to a whole number, say, between 0 and 100. Therefore, the following modified equation was obtained:

$$PI = 13.5 - 0.40\ (\text{Rainfall, in.}) - 0.23\ (\text{Freeze-thaw cycles/year}) - 0.71 \times 10^{-3}\ (\text{ADT}) + 12.9\ \text{PSI} + 0.43\ (\text{DI}) \tag{B.2}$$

TABLE B.1. SUGGESTED CATEGORIES OF THE VARIABLES IN EQ B.1

A. Rainfall - inches/year

Categories	Num erical Value
10	+ 1.0
10 but 20	0.5
20 but 30	0.0
30 but 40	- 0.5
40	-1.0

B. Freeze-thaw - cycles/year

Categories	Num erical Value
15	+ 1.0
15 but 30	0.05
30 but 45	0.0
45 but 60	- 0.5
60	- 1.0

C. Traffic, ADT

Categories	Num erical Value
1,000	+ 1.0
1,000 but 8,000	0.5
8,000 but 15,000	0.0
15,000 but 23,000	- 0.5
23,000	- 1.0

D. Present Serviceability Index

Categories	Num erical Value
2.5	- 1.0
2.5 but 3.0	- 0.5
3.0 but 3.5	0.0
3.5 but 4.0	+ 0.5
4.0	+ 1.0

(continued)

TABLE B.1. (CONTINUED)

E. Distress

Categories	Num erical Value
(1) Rigid Pavements	
(a) Minimal Distress - 5 or fewer failures per mile, some minor spalling, little or no pumping at edges and longitudinal joints	+ 1.0
(b) Moderate Distress - 6 to 13 failures per mile, fair percentages of minor spalling in pavement section, some severe spalling, moderate pumping at edges and longitudinal joints	0.0
(c) Significant Distress - 14 or more mailures per mile, fair to substantial amounts of severe spalling, moderate to extensive pumping at edges and longitudinal joints	- 1.0
(2) Flexible Pavements	
(a) Minimal Distress - slight cracking, little or no rutting and slight alligatoring in a few areas	+ 1.0
(b) Moderate Distress - intermittent moderate cracking with some spalling, frequent slight cracking, and intermittent slight or moderate alligatoring and rutting	0.0
(c) Significant Distress - extensive moderate cracking and rutting, frequent moderate alligatoring	- 1.0

where

PI = priority index (range 0-100),

Rainfall, in. = amount of annual rainfall per year, inches with the following limits:

(a) Rainfall < 10" = 10"

(b) Rainfall > 40" = 40",

Freeze-thaw/year = number of freeze-thaw cycles at the site/year with the following limits:

(a) freeze-thaw cycles < 15 = 15

(b) freeze-thaw cycles > 60 = 60,

ADT = average daily traffic with the following limits:

ADT < 1,000 = 1,000

ADT > 23,000 = 23,000,

PSI = present serviceability index, with the following limits:

PSI > 4.0 = 4.0

PSI < 2.5 = 2.5, and

DI = distress index as obtained from Eqs A.3 and A.4 (0-100).

Examples

The following examples illustrate the use of Eq B.2. Table B.2 summarizes the data and results of calculation for estimating the priority index of various pavements included in the table.

Example No. 1.

(1) Rainfall < 10", therefore use a value of 10" in the equation.

(2) Freeze-thaw cycles/year < 15, therefore use a value of 15 for calculations.

(3) ADT < 1,000, therefore use a value of 1,000 in the calculations.

(4) PSI > 4.0, therefore use a value of 4.0 in the calculations.

(5) DI = 100 is used in the equation.

Substituting the above values in Eq B.2, the estimated PI = 99.8, or approximately = 100. This represents a pavement which does not require any

TABLE B.2. DATA USED IN EXAMPLES 1, 2, AND 3 AND THE ESTIMATED PRIORITY INDICES

Example No.	Rainfall Per Year	Freeze-thaw Cycles/Year	ADT Vehicle/Day	PSI	Distress Index	Estimated Priority Index	
1	8"	10	500	4.2	100	99.8	100
2	50	70	25,000	2.0	0	-0.38	0
3	20	40	10,000	3.5	55	58	

overlay because the pavement shows no visual distress (DI = 100) and is located in a dry area with very small chances of freeze-thaw cycles and very light traffic.

On the other hand, the pavement shown in Example No. 2 is exactly opposite of Example No. 1. High rainfall with large number of freeze-thaw cycles/year, high traffic, low PSI, and low DI (= 0), represents the worst possible situation for this pavement. Therefore the estimated priority index (PI) is approximately zero for this case.

A pavement between the two extreme conditions is represented by Example No. 3. It's PI value is 58.