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16. Abstract

This report represents the development of a pavement evaluation system, distress and decision criteria indices, and an experimental design for a long-term monitoring system of CRC pavement network. The indices are intended to provide the Texas State Department of Highways and Public Transportation (SDHPT) with guidelines for generating decisions for the management of roadway maintenance. The experimental condition survey was designed to collect data for the evaluation and modification of the current CRCP design procedures and develop the performance prediction models.

The distress and decision criteria indices were developed on the basis of ten years of observed condition survey data using Discriminant Analysis. The distress index is a weighted combination of various distress manifestations occurring in a pavement section. The decision criteria index is a selected limiting value of distress index below which pavement rehabilitation, such as overlay, is recommended.

In order to analyze the significance of the influence of the variables on pavement performance, a factorial experiment was designed. Random sampling technique was used in this study to select test projects from a set of experimental factorials. The visual experimental condition survey was conducted in the summer, 1987. Preliminary data analysis was performed and the results of the analysis indicated that the updated pavement design procedure and performance prediction models can be developed from further data analysis.

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DEVELOPMENT OF A LONG-TERM MONITORING SYSTEM FOR TEXAS CRC PAVEMENT NETWORK

by

Chia-pei J. Chou
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Research Report Number 472-2

Research Project 3-8-86-472
Rigid Pavement Data Base

conducted for

Texas State Department of Highways and Public Transportation

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October 1988

PREFACE

This is the second in a series of reports that describe the work done on Project 472, "Rigid Pavement Data Base." The study is being conducted at the Center for Transportation Research (CTR), The University of Texas at Austin, as part of a cooperative research program sponsored by the Texas State Department of Highways and Public Transportation and the Federal Highway Administration.

This report presents the development of an experimental design for a long-term monitoring system for the Texas CRCP network and the development of distress and decision criteria indices for determining the current pavement distress condition and the time when a pavement has reached its terminal condition.

Many people have contributed their help towards the completion of this report. Thanks are extended to all the CTR personnel and especially to Ken Hankins, and Lyn Gabbert. Valuable comments were provided by Jim Brown, Richard Rogers, and Jerry F. Daleiden from the Texas State Department of Highways and Public Transportation.

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LIST OF REPORTS

Report No. 472-1, "Evaluation of Proposed Texas SDHPT Design Standards for CRCP," by Mooncheol Won, B. Frank McCullough, and W. R. Hudson, presents the results of an evaluation of proposed CRCP Design Standard for various coarse aggregates, describes the theoretical models used in the study, and discusses several important design parameters for CRCP. April 1988.

Report No. 472-2, "Development of a Long-Term Monitoring System for Texas CRC Pavement Network," by Chia-pei J. Chou, B. Frank McCullough, W. R. Hudson, and C. L. Saraf, presents the application of an experimental design method to develop a long-term monitoring system in Texas. Development of a distress index and a decision criteria index for determining the present and terminal conditions of pavements is also discussed. October 1988.

ABSTRACT

This report represents the development of a pavement evaluation system, distress and decision criteria indices, and an experimental design for a long-term monitoring system of CRC pavement network. The indices are intended to provide the Texas State Department of Highways and Public Transportation (SDHPT) with guidelines for generating decisions for the management of roadway maintenance. The experimental condition survey was designed to collect data for the evaluation and modification of the current CRCP design procedures and develop the performance prediction models.

The distress and decision criteria indices were developed on the basis of ten years of observed condition survey data using Discriminant Analysis. The distress index is a weighted combination of various distress manifestations occurring in a pavement section. The decision criteria index is a selected limiting value of distress index below which pavement rehabilitation, such as overlay, is recommended.

In order to analyze the significance of the influence of the variables on pavement performance, a factorial experiment was designed. Random sampling technique was used in this study to select test projects from a set of experimental factorials. The visual experimental condition survey was conducted in the summer, 1987. Preliminary data analysis was performed and the results of the analysis indicated that the updated pavement design procedure and performance prediction models can be developed from further data analysis.

KEYWORDS: CRCP, condition survey, Distress Index, Decision Criteria Index, rehabilitation, Discriminant Analysis, experimental design, long-term monitoring system, performance prediction model.

SUMMARY

The primary objective of this research was to develop an experimental design for the network level condition survey in order to evaluate CRC pavement performance in Texas. In addition to the experiment design, other major contributions have been made, such as development of the distress and rehabilitation criteria indices for determining the current pavement distress condition and the time when a pavement has reached its terminal condition. The distress index was developed, using discriminant analysis, from the condition survey data from 1974 to 1984. It is a weighted combination of several major distress manifestations occurring in a pavement section. For major rehabilitation, a pavement is classified as a candidate for overlay if its distress index is smaller than zero. Once the current pavement distress condition can be expressed as a single number, i.e., as a Zeta-score, its future condition can be predicted through the relationship between the Zeta-score and some independent variables considered to have influence on pavement deterioration.

The approach adopted for determining the relationship was the monitoring of existing in-service roads. A factorial experiment permitting maximum use of data collected on a limited number of study test sections was designed. A set of independent variables was selected as the experimental factors, based on the study of the AASHTO equations, field data analysis, and mechanistic models. These selected variables are design and construction parameters, environmental parameters, and pavement age. Each experimental factor possesses several levels which cover a wide range of conditions existing in Texas. Since no information regarding these selected experimental factors is available in the existing distress data bank, data were collected from various sources for the entire CRCP network.

Several experimental factorials were established based on the different levels of experimental factors. From a total of 355 projects in the CRCP network, 112 projects were selected. Definitions and methods for measurement of surveyed variables are presented in this study. A pilot study and training session were scheduled prior to the network experimental condition survey in order to investigate the feasibility of the proposed measurement methods and survey forms. It was found that no change was necessary for either one.

Fourteen Districts were included in the experimental condition survey. A total of 425 test sections were selected from the 112 pavement projects. More than 40 percent of the test sections are located in Districts 2, 13, and 18. The distress condition of each test section was calculated using the distress index equation. It was observed that most of the Districts had a lower average Zeta-score in 1987 than in 1984. The difference in the Zeta-scores for these two years varies from District to District because of the different levels of the experimental factors. The effects of some design experimental factors on the Zeta-score and pavement mean crack spacing were observed through the preliminary data analysis. These significant effects imply that an applicable performance prediction model, in which distress is a function of the various experimental factors, should be developed from future data analysis.

IMPLEMENTATION STATEMENT

A scheme for evaluating the current pavement performance condition and designing a long-term experimental condition survey was developed. Applying the distress and decision criteria indices, the pavement performance condition for the CRCP network can be estimated and a list of rehabilitation candidates can be generated. These rehabilitation candidates can be prioritized on the basis of their distress index values, Zeta-scores. Furthermore, the experimental design developed for the statewide condition survey furnishes valuable information for updating the pavement design procedure and the development of a pavement performance prediction model.

It is recommended that the experimental condition survey be carried out periodically, so that the network of CRC pavements can be monitored continuously and the accuracy of the performance prediction model can be evaluated.

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CHAPTER 1. INTRODUCTION

BACKGROUND

The Texas State Department of Highways and Public Transportation (SDHPT) currently has about 5,600 lane-miles of continuously reinforced concrete pavement (CRCP) in service, and present activities are focussed on their maintenance and rehabilitation. The expenditures required to maintain and rehabilitate pavements in Texas were estimated by the FHWA to exceed $400 million per year in 1986 (Ref 1). Because of the large amount of money involved, any improvement in the management and technology for maintenance and rehabilitation could result in significant savings. Therefore, the development of a reliable design procedure for new roadways is considered to be one of the most important tasks at the present time. In order to support this activity, it is necessary to collect periodically condition and performance data for the CRCP in Texas. These data can be used to evaluate the pavement performance and develop performance prediction models. Also, current design procedures can be evaluated and improved with the help of historical condition and performance survey data. The data usually recorded for pavement evaluation consist of measurements of structural capacity, riding quality, skid resistance, and distress.

A network level pavement condition survey to collect the distress information on the CRCP in Texas has been conducted since 1974. From the recorded data, it has been observed that, while riding quality remains at an acceptable level from the user's point of view, the rigid pavement sections are sometimes approaching the end of their lives from the structural viewpoint. Therefore, the use of distress condition is considered to be a more realistic way to evaluate the performance of rigid pavement.

Although a data bank of CRCP distress information was established 14 years ago by the Center for Transportation Research (CTR) of The University of Texas at Austin, it does not contain sufficient information regarding design and construction variables, environmental condition, and traffic for each CRCP section. Nevertheless, a distress index for CRCP was developed based on the condition survey data for 1974 and 1978, and distress prediction models were established, based on some simplified prediction equations, i.e., distress as a function of time (Ref 2). It was found that both the distress index and the distress prediction models provided a very good quantitative analysis of current pavement condition and estimated future deterioration. However, no precise prediction should be expected from these prediction equations because only a few independent variables were included in the model. Also, no prediction can be made for those pavement projects which were not included in the survey network.

It is generally recognized that pavement distress manifestations are affected by a number of factors besides pavement age, but it is not possible to collect information on all of them. Thus, the most important factors should be included in the distress data bank for use in predicting the performance of the pavement structure. These factors, including design and construction variables, environmental variables, and traffic data, are called the pavement fundamental variables in order to distinguish them from the distress manifestation data in the data bank. Selecting these factors becomes one of the most important tasks. A performance prediction model can be obtained through the development of the relationship between pavement distress condition and the pavement fundamental variables. Since there are more than 350 pavement projects in the CRCP network in Texas, an experiment design for the network level condition survey, with some of the fundamental variables as the experimental factors and the distress manifestations as the experimental measurements, is thought to be the most appropriate and economical method for establishing the relationship.

OBJECTIVES

The basic hypothesis of the research reported here is that the most practical pavement performance prediction models are those which are developed from systematically collected field data and also that certain fundamental parameters can be effectively used in such model development. The primary objective of this study is to design the experiment for the development of CRCP design equation. This can be achieved by completing the following supporting objectives:

(1) develop the distress index and decision criteria index for CRC pavement based on the periodical condition survey data from 1974 to 1984. These indices should be a combination of all major distress manifestations which have strong effects on pavement performance;
(2) establish the experimental factors and variables to be measured in the experimental condition survey;
(3) collect the information on experimental factors developed above for the entire CRCP network in Texas;
(4) develop the experimental factorial and select pavement projects for the condition survey;
(5) establish measurement methods and survey procedures;
(6) conduct the condition survey and collect the desired information; and
(7) analyze the relationship between the collected distress data and the experimental factors.

RESEARCH APPROACH

The approach adopted for determining pavement performance and the prediction model was to monitor existing in-service roads. Figure 1.1 is a flow chart showing the research approach used in this study. In general, the concepts of this research study can be divided into three subdivisions:

developing the distress index, designing the decision criteria index, and developing the performance prediction model.

Distress Index

The Distress Index is a function of various types of distress manifestations occurring in a pavement section. It can be used for determining the current pavement distress condition. Equation 1.1 shows the general format of this index function:

$$DI = f\{ D_1, ..., D_i, ..., D_m \} \tag{1.1}$$

where

DI = distress index, and

D_i = distress manifestation, e.g., spalling, punchouts, etc.

Decision Criteria Index

The Decision Criteria Index (DCI) is defined as the selected limiting value (LV) of the Distress Index. When the DI of any specific pavement section reaches the predetermined DCI value, this pavement section is considered to have reached its terminal condition and major maintenance, such as overlay or rehabilitation, is required immediately. Thus, DCI can be written as

$$DCI = DI_{\text{limiting value (LV)}}$$

Performance Prediction Model

Although the DI properly indicates the present distress condition of a pavement project, it is also desirable to know its future deterioration condition. Therefore, development of an accurate performance prediction model is considered to be a very important task in this research study. The purpose of the performance prediction model is to establish the relationship between the DI and all the possible variables which have significant influence on pavement performance. This relationship can be written as

$$DI(t) = f\{ X_1, ..., X_i, ..., X_n(t) \} \tag{1.2}$$

where

X_i = pavement fundamental parameters, e.g., slab thickness, material properties, traffic, etc.; and

t = time, or pavement age, in months.

Figure 1.2 conceptually illustrates the relationships between DI, DCI, and the performance prediction model [DI (t)]. For a given pavement project at a given time, t_k, the DI_k is calculated from the actual condition survey data. However, the required time, Dt, that a pavement's DI value decreases from DI_k to the critical DI_{LV} should be obtained from the performance prediction model. The intersection of the DI_{LV} dash line and the DI (t) curve is considered as the failure point, which indicates that the pavement has reached its terminal condition.

Since several fundamental parameters of the prediction model are functions of time, it is realized that a well-planned condition survey should be conducted periodically for several years in order to obtain enough information for the development of this prediction model. Therefore, in this study, an experiment permitting maximum use of data collected on a limited number of study tests was designed for this purpose.

In this study, a distress index and a decision criteria index were developed first, through the study of historical condition survey data. A set of independent variables considered to have significant effects on pavement performance

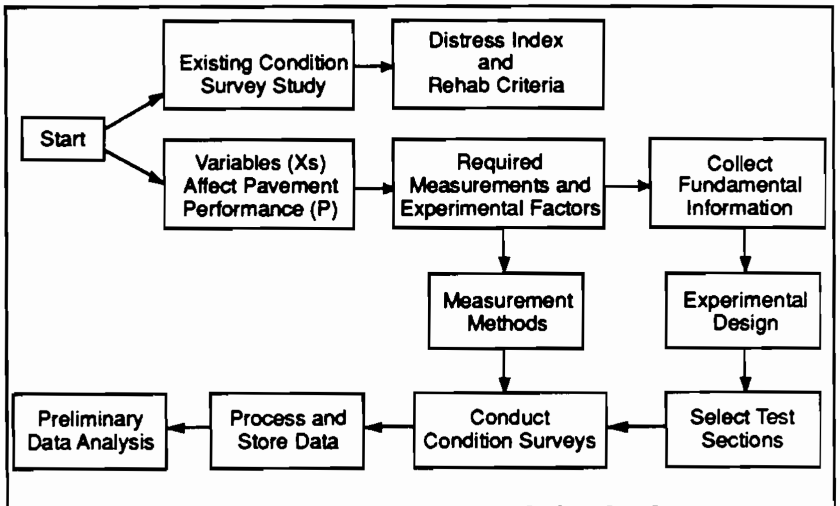


Fig 1.1. Flow chart of the experiment design development.

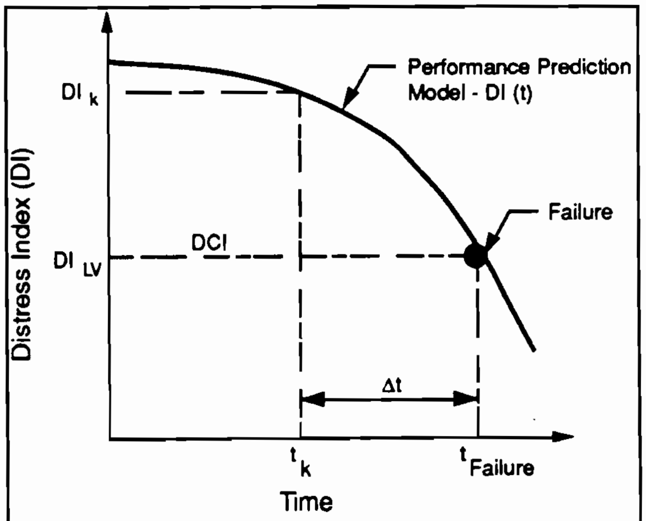


Fig 1.2. Failure criterion for continuously reinforced concrete pavement.

was selected based on the studies on both mechanistic models as well as empirical equations. For these independent variables, levels were selected which covered a wide range of conditions existing in Texas. These are shown in the top part of the flowchart in Fig 1.1. Test projects and test sections were chosen from a set of experimental factorials. A total of 425 test sections from 112 pavement projects were surveyed in this study.

A preliminary data analysis was performed to investigate the general relationship between the independent variables and pavement performance. This relationship can be used in further studies to develop the most applicable pavement performance prediction model.

SCOPE AND ORGANIZATION

The first chapter of the report presents the background, objectives of the research, and the basic research approach.

Chapters 2 and 3 involve the development of the distress index and the decision criteria index. Chapter 2 describes the evolution of previous condition survey procedures and the established data reduction program CONSRV. Development of the distress index and the rehabilitation criteria index is presented in Chapter 3. These indices were developed using discriminant analysis based on the network condition survey data from 1974 to 1984.

Chapter 4 describes the selection of a set of independent variables to be used as the experimental factors. Each variable was considered to have significant influence on pavement performance from either the theoretical or the empirical point of view. The selection of variables to be included in the experiment design is also presented in this chapter.

In Chapter 5, the definitions, data collection, and storage of the independent variables for pavement projects for the experiment design are discussed.

Chapter 6 presents the procedure for developing the experiment design and the criteria for test section selection. The random sampling technique was used to select the appropriate pavement projects from the experimental factorials for the condition survey.

The definitions and measurement methods for variables surveyed in both the general condition survey and the diagnostic study are presented in Chapter 7. The design survey forms and a pilot study are also presented in this chapter.

Chapter 8 describes the field survey procedure and the conducting of the condition survey, and findings and problems that occurred during the condition survey are presented.

A historical summary of the statewide distress condition and a preliminary data analysis of the effects of experimental factors on distress index and crack spacing are presented in Chapter 9.

Finally, Chapter 10 summarizes the major conclusions of the research and presents several recommendations for future development.

CHAPTER 2. REVIEW OF THE EXISTING CONDITION SURVEY PROCEDURES OF CRCP IN TEXAS

INTRODUCTION

A large portion of the Interstate highway network of Texas is continuously reinforced concrete pavement (CRCP). Some of these highways were constructed in the early 1950's and the design procedures, construction techniques, and pavement ages vary considerably. Therefore, the highway segments require major maintenance, such as overlays and rehabilitation, at different times.

A periodical condition survey program was initiated in 1974 to monitor the historical development of various distress types and evaluate the performance of the CRCP network of Texas. The research study was conducted by the Center for Transportation (CTR), The University of Texas at Austin, in conjunction with the personnel from the SDHPT Highway Design Division (Ref 3). Subsequently, statewide condition surveys were conducted in 1978, 1980, 1981, 1982, and 1984. At first, the condition surveys were conducted mainly on rural Texas highways. The urban highways, in Districts 2, 12, 15, and 18, were included in the survey network after 1980. The condition survey procedure has been continuously modified in order to make the survey more objective.

Analysis of the results provides objective information which may improve the overall CRCP management system in Texas. A very important part of this system is the prediction of future performance based on present design parameters and the behavior of pavements in use. Furthermore, the feedback data have become indispensable for proper management, not only from a design point of view but, even more importantly, for the maintenance of existing pavements.

PURPOSE OF CONDITION SURVEY

Development of a suitable condition survey data base will create an important source of valuable information for planning, design, construction, maintenance, and rehabilitation purposes. Various condition survey procedures exist, each with its own advantages and disadvantages. The survey procedures used for the historical condition survey of CRCP in Texas were designed to meet the following purposes.

(1) ***Evaluating the Design Predictions.*** The feedback data collected from the condition survey should provide accurate and useful information for checking the design predictions. For instance, the designed crack spacing of the CRCP at selected ages could be verified by the condition survey data.

(2) ***Optimizing Maintenance and Rehabilitation Schedules.*** A scheme which uses only the serviceability index does not seem applicable to the CRCP in Texas since this parameter does not indicate when a pavement receiving routine maintenance will reach its terminal condition. Routine maintenance is carried out over the life of the pavement as deemed necessary by the pavement manager, but the pavement needs overlay when the riding quality or structural quality of the pavement reaches a terminal condition. Thus, condition surveys should provide information which can be used for optimizing the maintenance and rehabilitation schedules.

(3) ***Evaluating The Design of Overlays.*** An overlay design procedure for the Texas SDHPT was developed in 1978 (Ref 4). This program has been used experimentally to design a number of overlays around the state by both CTR personnel and Texas SDHPT personnel. The condition survey and performance monitoring data of the overlaid projects can be used to compare the predicted performance, and recommendations can be made to revise the design procedures.

(4) ***Efficiency of Data Collection, Storage and Manipulation.*** It would be impractical to collect observations and measurements of all the distress manifestations which may occur in a pavement. Considering the level of research study, one could survey a small sample in great detail (project level), or a larger sample in less detail (network level), or some combination of the two extremes. No matter which level the condition survey data are recorded in, they should be readily usable and should be suited for easy computer storage and manipulation.

EVOLUTION OF THE SURVEY PROCEDURES

CRCP condition survey procedures have evolved over a number of years and were used in the historical condition survey. With time, improvements have been made so that the procedures fit the circumstances and requirements of each time period. Initially, the various distress manifestations which occur in CRCP were ascertained. Most of these distress manifestations were subjectively recorded with regard to severity and extent in the first survey year, 1974. In the next survey year, 1978, these distress manifestations were recorded in as objective a manner as possible. There were also a few changes of measured items in the 1980 survey. Some urban districts were included in the statewide condition survey in 1981 and 1982, but no major changes in survey procedures were made during those years. Finally, major changes in survey speed, section length, and certain recording procedures were made in 1984. A microcomputer was installed in the condition survey van so that the field data could be entered directly onto a computer disk during surveys.

Distress Manifestations

A explanation of the development of typical CRCP distress manifestations will be useful for understanding the evolution of the survey procedures. Transverse cracks appear in a pavement soon after its construction. They are mainly due to the large stresses caused by drying shrinkage and temperature drops. When two transverse cracks are fairly close together (roughly 2 to 3 feet), the portion of the slab between the cracks acts as a beam in the transverse direction, and longitudinal cracks occur. When two closely spaced transverse cracks are linked by a longitudinal crack, a punchout is formed. Concurrently, the slab is flexed under load and the upper edges of the cracks may break off, or spall. Spalling may also result from material ingress into a crack and subsequent elongation of the slab due to increased temperatures. Water passes through cracks and openings in the pavement and penetrates the sublayers. When a load is applied, the water is pressed out of the crack, taking fine material of the sublayers with it. This is defined as pumping. Under this condition, voids under the slab may result, causing increased deflections and stresses within the slab.

1974 Survey Procedure

Six distress manifestations were observed during the 1974 statewide condition survey: transverse cracks, localized cracks, spalling, pumping, punchouts, and patches. A decision to survey the road from a van travelling at approximately 5 mph was made. A two-man team was formed to allow for the division of responsibility for the six items on the survey sheets. Experimental surveys of 0.1, 0.2, 0.5, and 1.0-mile sections proved that the survey of 0.2-mile sections was the best (Ref 3). It was also felt that that was roughly the maximum length of road to which similar subgrade properties would apply. Only the distress in the outer lane was recorded, as this is the lane with the heaviest traffic. In addition to the various distress manifestations, the subjective Present Serviceability Rating (PSR) was collected for every 0.2-mile section. It was decided to apply the condition survey utilizing the above procedure to all the rural CRCP in Texas.

A brief description of each type of distress and what was to be gained by its measurement is given below:

(1) ***Transverse Cracks.*** All CRCP exhibit transverse cracking, but cracks which were closer than 18 inches were considered. The extent of the cracking was recorded as a percent of the pavement length which exhibited such cracking (Ref 3). The cracking was classed as minor or severe. Minor transverse cracks were defined as cracks which were newly found, narrow, or not easy to see, and severe transverse cracks, as wide, well-defined openings.

(2) ***Localized Cracks.*** When closely spaced transverse cracks start to deteriorate by the formation of circular cracks that link transverse cracks, the result is called localized cracking. The extent and severity were recorded similarly to those for the transverse cracking. This distress also provided an indication of the amount of fatigue in the pavement.

(3) ***Spalling.*** Spalling was 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. Spalling was also classed as minor and severe, depending upon the width of the spall. An estimate of the percentage of cracks that showed minor and severe spalling was made and entered into the survey form as the measured quantity of spalling. The presence of more spalled cracks indicates less load transfer and more fatigued pavement.

(4) ***Pumping.*** Pumping, as defined earlier, may occur at construction joints, at cracks, and between cracks. However, only pumping at the joint where the pavement and the shoulder meet was recorded. The severity of the pumping was determined by the amount and size of material carried out by the water. The percentage of section length that was subjected to either minor or severe pumping was recorded.

(5) ***Punchouts.*** The formation of a punchout has been described earlier. A minor punchout was defined as a condition in which the block formed by transverse and longitudinal cracks does not move under traffic and the surrounding cracks are narrow and in good condition. A severe condition of punchout is when the block moves under traffic and the surrounding cracks are wide open and spalled. The extent of the punchouts was defined by grouping the punchouts according to size and counting the number of punchouts occurring along a fixed length of road.

(6) ***Patches.*** Punchouts may be repaired with either asphalt concrete or portland cement concrete. The number of repaired patches of a specified type which fall into a specific size category were counted per 0.2 mile of the road. The condition of a repaired patch was not recorded. The patches provided an indication of the portion of the roadway which had reached the terminal condition and needed rehabilitation.

In addition to the above visual survey procedures, the possibility of utilizing photographic techniques was investigated in order to develop procedures for conducting the condition survey on heavily trafficked urban highways. In 1976, photographic techniques were used in some urban areas. A detailed description is given in Ref 5.

1978 Survey Procedure

The 1978 survey procedure was developed by modifying the 1974 procedure, which demonstrated the need for more objectivity. The 1974 survey speed was retained while the recording and observation of the various distress manifestations were changed as described below. In addition to the various distress manifestations, the subjective Present Serviceability Rating (PSR) was recorded for every 0.2-mile section.

(1) ***Transverse and Localized Cracking.*** Transverse cracking was omitted in the 1978 survey because it was felt that the changes would not be significant in four years. Localized cracking was left out of the survey also. It was believed that localized cracking was associated with problems due to construction in the earlier years of CRCP and it was practically nonexistent in the CRCP constructed in the 1960's and 1970's. Instead, the crack spacing along a 300-foot sample of the roadway within each construction job was recorded.

(2) ***Spalling.*** In order to obtain a more objective measurement, the number of spalled cracks per 0.2-mile section was counted and recorded . The concept of severity as defined in the 1974 survey procedure was retained. An estimate of the percentage of spalled cracks was obtained by combining the number of spalled cracks with the measured crack spacing.

(3) ***Pumping.*** No change was made in this distress item in 1978.

(4) ***Punchouts.*** Since most punchouts recorded in the 1974 survey were small, it was decided to simplify the size category into two groups, shorter or longer than 20 feet. The number of punchouts per 0.2 mile was recorded.

(5) ***Patches.*** One or more severe punchouts can be repaired by a patch. Both the size category and the condition of the patch were omitted in the 1978 survey; only the number of patches per 0.2 mile of asphalt cement type or portland cement concrete type was recorded.

The method for obtaining data for every 0.2-mile section proved successful in 1974 and again in 1978 and it was only applied to all the rural CRCP in Texas. The photographic techniques used in the survey of urban highways was terminated, because the analysis of photographs was an extremely time consuming task.

1980 Survey Procedure

There was very little change between the surveys of 1978 and 1980. The survey speed and the survey section length of 0.2 mile were retained. However, the recording of transverse crack spacing and PSR was omitted, because it was felt that the changes in crack spacing would not be significant in the two-year period and the measurement of PSR was very subjective. The recording of pumping was changed also. Since the measurement of pumping was not objective and most of the percentage of section length that was subjected to either minor or severe pumping was small, the recording of pumping was changed to note only its presence. Thus, instead of recording the percentage of either minor or severe pumping or the section length, a yes or no was used to indicate the occurrence or non-occurrence of both types of pumping. Only rural CRCP were surveyed in 1980.

1981 Survey Procedure

Some urban highways were again included in the condition survey in 1981. It was decided to return to the visual survey. The procedure adopted was similar to the 1980 rural condition survey. Only District 2 (Fort Worth) and District 18 (Dallas) were surveyed during this year.

1982 Survey Procedure

No change of survey procedure was made for this year. The survey procedure of 1980 was retained. However, two additional urban districts were included into the statewide CRCP condition survey: District 12 (Houston) and District 15 (San Antonio).

1984 Survey Procedure

In order to maximize the number of pavement sections surveyed by a given team in a given time, the Center for Transportation Research (CTR) of The University of Texas at Austin was asked to evaluate the effect of survey speed on the accuracy of condition survey data by the Texas SDHPT. It was considered necessary to increase the previous average survey speed of 5 mph as much as possible without changing the accuracy of the information gathered significantly. It was also suggested that the data should be collected for 0.4-mile sections instead of 0.2-mile.

An experiment was conducted in early 1984 regarding the analysis of survey speed (Ref 6). Based on the results of that experiment, it was decided to conduct the condition survey at a speed of 15 mph. Therefore, the recording procedure and observation of various distress manifestations had to be modified. In addition, a computer program, QUICKSUR, was developed to enter field data directly onto a microcomputer disc (Ref 7). Since two recorders were necessary, a crew of three persons, instead of two, was suggested by SDHPT, to allow the driver to concentrate on driving. A microcomputer equipped with an extra key pad was used instead of the traditional mechanical counters. This allowed both recorders to enter data simultaneously.

The distress types included in the 1984 survey procedure were severe spalling, severe punchouts, and asphalt and portland cement concrete patches. Distress of pumping was left out because of the fast surveying speed. A brief description of each distress type is as follows:

(1) ***Severe Spalling.*** The definition and severity of spalling were the same as described earlier. However, minor spalling had to be omitted because of the increased survey speed. Only transverse cracks showing signs of severe spalling were counted.

(2) ***Severe Punchout.*** For the same reason minor spalling was omitted, minor punchouts were not included in the condition survey. Minor and severe punchouts were defined in the same manner as for the previous survey years.

When the longitudinal crack of a punchout extended across several transverse cracks, it was decided that only one punchout should be recorded, and the size category was not used in the procedure. Therefore, only the number of severe punchouts per 0.4-mile section were recorded.

(3) ***Patches.*** A patch was defined as a repaired section of the pavement where the repair work had been carried out to the full depth of the concrete. The size and condition of the patch were not recorded. Asphalt cement patches and portland cement concrete patches were counted separately for each 0.4-mile section.

It was found that the 1984 condition survey was more efficient than the previous survey years since fewer distress types were recorded, the survey speed was faster, and field data were input directly. Both rural districts and urban districts were surveyed.

DATA REDUCTION: PROGRAM "CONSRV"

Field data have been collected for ten years since 1974. A computer program, CONSRV, was developed to process and summarize condition survey data collected in various highway districts in Texas. This program has been modified several times in order to bring it up to date. The latest updated version is named CONSRV4 and produces the following reports:

(1) project identification information, including the CTR number, length, construction data, and location of each project within a district;

(2) a failure summary, including the total and non-overlaid lengths, total and per-mile numbers of failures, and per-mile counts of spalling, patches, and punchouts for each project in each year surveyed;

(3) detailed project summary sheets which itemize all the survey data recorded in the latest survey for each project, broken down into one-mile segments, including mile posts, mile points, total and overlaid project lengths, serviceability indices, means and standard deviations of crack spacing, minor and severe spalling, minor and severe pumping, the number of minor and severe spalled cracks, the number of minor and severe punchouts greater than and less than 20 feet, and the number of AC and PCC repair patches.

In addition, CONSRV4 produces a project-by-project and year-by-year summary file of historical condition survey data suitable for analysis by other programs.

Each of the reports produced by the program is written in its own output file, which can be printed separately. A flowchart of the different reports and files produced by the program is given in Fig 2.1. The program produces all these summaries from the condition survey files, each of which contains data for one district; these condition survey files are stored as permanent files in the CDC mainframe system of The University of Texas at Austin.

SUMMARY

This chapter presents the history of the condition survey of CRCP in Texas. The condition surveys have been carried out in rural and urban districts; the rural districts were surveyed in 1974, 1978, 1980, 1982, and 1984, and the urban districts were surveyed in 1976, 1981, 1982, and 1984.

Also presented are a description of and an examination of the development of various distress manifestations in CRCP in order to present the evolution of survey procedures adopted for the condition surveys. The major distress types recorded in the surveys were transverse cracks, localized cracks, crack spacing, spalling, pumping, punchouts, and patches. The original survey procedure was developed over a number of years. However, improvements have been made with time so that the procedures fit the circumstances and requirements of each time period. Therefore, in some cases, different criteria were followed in measuring the same distress manifestation.

A visual survey was applied to the rural districts during the initial survey in 1974 and was carried out through 1984. Because of extremely heavy traffic, the condition surveys of urban highways were difficult at speeds of less than 30 mph. Therefore, photographic techniques were developed and used in the 1976 condition surveys of urban districts. Al-

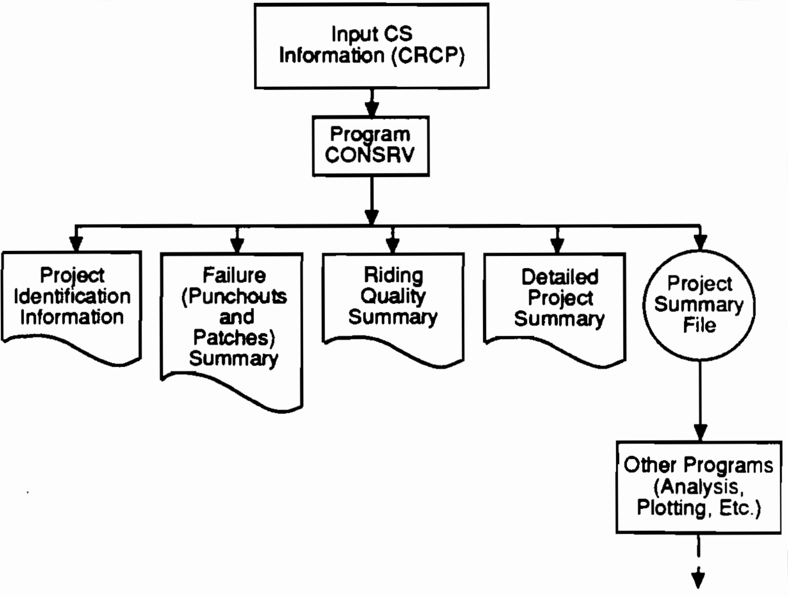


Fig 2.1. Reports and files produced by program CONSRV to process and summarize CRCP

though pictures provided an excellent record of pavement condition, the analysis of the photographs was a time consuming task, and, in 1981, it was decided to return to the visual survey for the urban districts.

Finally, the data reduction program, CONSRV, which has been used to summarize and report the condition survey data, is presented and discussed. The program can generate three independent reports and a summary file from the condition survey files, each of which contains data sorted by district. Copies of the generated reports and summary file of each district are kept at the Texas SDHPT for each survey year. The condition survey files are stored as permanent files in the CDC mainframe system of The University of Texas at Austin.

CHAPTER 3. DEVELOPMENT OF DISTRESS INDEX AND REHABILITATION CRITERIA INDEX

INTRODUCTION

This chapter presents the use of distress concepts in the Pavement Management System (PMS) for CRC pavements. Special emphasis is focused on the application of discriminant analysis techniques (Refs 8, 9, and 10) to the evaluation of the distress condition of CRCP in order to define the level of pavement performance and determine a criteria for major rehabilitation. This scheme is intended to help the Texas SDHPT in the management of its highway network.

The concepts of indices, the results of some previous studies regarding the development of distress index and rehabilitation criteria index, and reduction of data from the original survey data and the discriminant analysis method are also presented.

BACKGROUND

By reviewing existing schemes for maintenance and rehabilitation management, it was found that the pavement serviceability index (PSI) was used nationwide for deciding whether or not a major rehabilitation or an overlay was necessary. The PSI concept was developed by Carey and Irick in 1960 and used at the AASHO Road Test (Ref 11). They showed that the serviceability of a pavement is largely a function of its roughness.

A study of a sample of the different degrees of complexity of the existing network level maintenance and rehabilitation prioritization methods was made (Ref 2). It was concluded that a scheme which used only the serviceability index is not applicable to CRC pavements in Texas. The serviceability history of a pavement with heavy maintenance does not appear to change with time or traffic, while the distress condition changes significantly (Figs 3.1 and 3.2). Each point in the figures represents a surveyed section of CRCP in Texas (Refs 12 and 13). The number of failures (punchouts and patches) per mile was obtained from the records of the CRCP condition surveys performed in Texas in 1974 and 1978. The most likely reason for the consistency over time of the serviceability index is the continuous repair of the highway sections by SDHPT maintenance personnel. This routine maintenance provided tremendous improvements in pavement roughness which plays a relatively important role in the serviceability index. Therefore, it is not uncommon for a pavement section to be approaching the end of its life from the structural or economical point of view while the riding quality remains unchanged. Thus, the use of distress measures may be a more realistic way to evaluate a pavement's terminal condition. The development of a distress index to indicate the present pavement condition, therefore, is important.

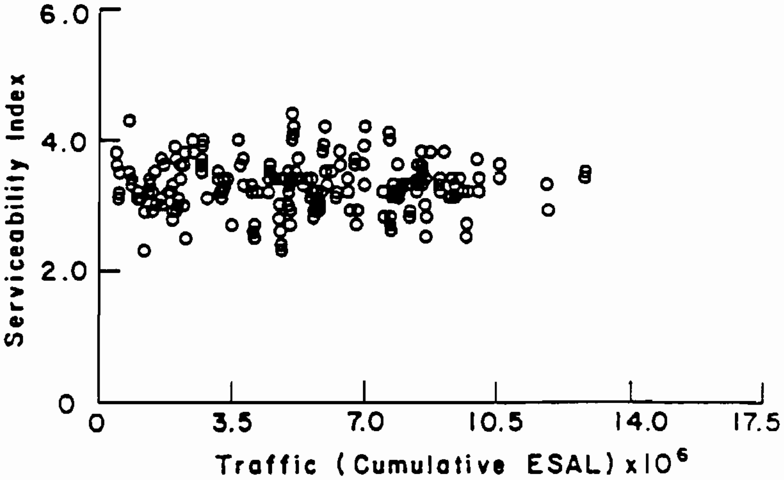


Fig 3.1. Serviceability index versus traffic applications (both directions) for Texas CRCP sections surveyed in 1974 and 1978 (Ref 2).

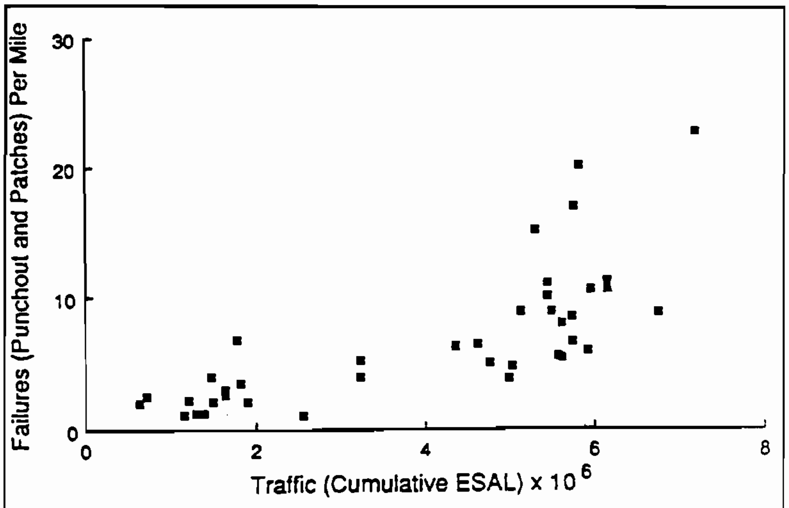


Fig 3.2. Number of failures per mile (punchouts and patches) versus traffic applications (both directions) for Texas CRCP sections surveyed in 1974 and 1978.

DEFINITION OF THE INDICES

In this section, the definitions of distress and decision criteria indices are presented in a simplified form. A more detailed description is given in Ref 14.

Distress Index (DI)

Distress is the visible consequence of carrying to a limit the response of the pavement to load, environment, and other inputs. A distress index (DI) based on a combination of distress manifestations and shows with a single number the amount of pavement deterioration (Ref 14).

A simple form of an equation can be used to combine the various distress manifestations into a distress index:

$$DI = A_o + \sum_{i=1}^{n} \frac{d_i}{D_i} \tag{3.1}$$

where

d_i = amount of distress manifestation i,
D_i = terminal condition of a pavement section if distress type i is an isolated occurrence,
A_o = constant, and
n = number of distress types.

Another way of presenting the same equation is to substitute $1/D_i$ with A_i, a constant, to obtain

$$DI = A_o + \sum_{i=1}^{n} A_i d_i \tag{3.2}$$

It should be noted that the distress index equation is not necessarily linear. Most of the time, a non-linear model can explain the deterioration type of variables more properly, especially when the deterioration rate is a function of time. However, a non-linear model can be transformed into the above linear type if this is required by a certain statistical technique.

Decision Criteria Index (DCI)

A decision criteria index is the selected limiting value of DI which is considered to indicate the failure condition of a pavement section associated with age, traffic, and pavement structure (Ref 14). That is, when the pavement's DI drops to the DCI, the pavement section is considered to have reached its terminal condition.

Theoretically, the decision criteria should include riding quality, safety, and economics, but in this study only the implications of distress are considered.

LITERATURE REVIEW

The existing equations which are used to estimate distress and decision criteria indices were developed by using the pavement condition data collected in 1974 and 1978 (Refs 2 and 15). The discriminant analysis method was selected for those studies after various methods were reviewed. The various methods reviewed at that time were

(1) subjective parameters (Ref 16),
(2) regression analysis (Ref 17),
(3) factor analysis (Ref 18), and
(4) discriminant analysis (Refs 8, 9, and 10).

The equations derived from the subjective parameters method are those in which the coefficients, i.e., the relative weights of the variables in Eq 3.2, are assigned using only experience and engineering judgement. The other three types of equations involve some form of correlational procedure: regression, factor, or discriminant analysis. A detailed description of each of the above methods is given in Ref 2. Distress data for jointed concrete pavements and CRC pavements were used to further investigate and compare the various methods. It was concluded that discriminant analysis appeared to be the most appropriate technique for the data available and its results were encouraging. About 92 percent of the cases for jointed pavements and 88 percent of those for CRCP were correctly classified by this analysis. Therefore, the discriminant analysis technique was adopted to develop a distress index and a decision criteria index.

Discriminant Analysis

Discriminant analysis is a statistical technique which is used to classify data into groups by maximizing the differences between group means. To distinguish the groups, discriminant variables that measure characteristics on which the groups are expected to differ are selected. The objective of discriminant analysis is to weigh and combine linearly the discriminant variables in some fashion so that the groups are forced to be as statistically distinct as possible. Further details of this technique are presented in the following sections.

In Gutierrez de Valesco's and Noble's studies (Refs 2 and 15), only the distress data collected in the 1974 and 1978 condition surveys were used. Several distress manifestations were recorded, namely, patches and punchouts per mile, percent of minor spalling, percent of severe spalling, and percent of pumping. Some of the pavements surveyed during 1974 were overlaid prior to the survey in 1978. This information was used to determine the reasons leading to the decision for overlaying. Data on several variables from two groups (overlaid and non-overlaid pavements) were used for this purpose.

Using the statistical package SPSS, a discriminant equation was obtained, as described in the following sections. After some data transformations were made, the following equation was developed (Refs 2 and 15):

$$Z = 1.0 - 0.065\,FF - 0.015\,MS - 0.009\,SS \tag{3.3}$$

where

Z = discriminant score (Zeta score),

FF = number of failures (punchouts and patches) per mile,
MS = percent minor spalling, and
SS = percent severe spalling.

The percent of pumping was initially included in the analysis and a positive coefficient was obtained. It was then decided to exclude the pumping term from the analysis, because its counter intuitive sign was misleading. A possible explanation for the positive sign is the high correlation between failures and pumping.

Interpretation of Discriminant Score

If "Zeta score" for all the pavements in the historical data set are calculated, then the mean Zeta score for each group can be calculated. It is believed that the individual Zeta score will tend to be distributed normally about these means. A frequency distribution for each of the two groups is plotted (against Zeta score) on one continuous horizontal axis (Fig 3.3). The discriminant score can be interpreted as follows: if the score is positive for a given pavement project, then the project is in good condition; if the score is smaller than zero the project is considered to have failed and needs rehabilitation or overlay. The pavements located in the "zone of conflict" are pavements whose classification is uncertain within the reliability of the analysis.

Noble (Ref 15) suggested that a lower value of Zeta score should be adopted as the criterion to decide when to overlay. He also stated that the distribution of the overlaid and non-overlaid pavements shown in Fig 3.3 was an oversimplification. Pavements located in the zone of conflict are pavements that are not in an excessively bad condition. With the above considerations, it was felt that a better criterion to use when deciding whether or not to overlay, was the mean Zeta score for the group of overlaid pavements. This means that the Zeta score is calculated by substituting the mean distress values calculated for this group in Eq 3.3. The criterion proposed to decide when to overlay then is that, any pavement with a Zeta score smaller than -1.16 should be overlaid (Fig 3.4).

It should be mentioned that several assumptions were made in both studies. These assumptions, which might invalidate the results if not satisfied, are

(1) The discriminant function obtained is linear.
(2) The variables are normally distributed.
(3) The subjective decisions for overlaying the sections are correct.
(4) The data points used are not comprehensive.
(5) Not all distress types have been included.
(6) The Zeta scores of both overlaid and non-overlaid groups are normally distributed.

Further studies on items (1), (5), and (6) have been made and are discussed in the following sections. Furthermore, it was concluded in both studies that 88.8 percent of the data were correctly classified by the Zeta equation (Eq 3.3), which is summarized in Table 3.1. It was noted that 88.8 percent is the average percent of correct prediction of the total data. There existed a large difference of the correct prediction percentage between the overlaid and non-overlaid groups. A modification is made to reduce the difference as much as possible. Detailed description of the procedure is given in the later sections.

DATA REDUCTION

In order to modify the existing distress and decision criteria indices and make the discriminant analysis study more comprehensive, the distress data of the ten years condition surveys were reviewed and included in this study. As described in Chapter 2, data were recorded as the cumu-

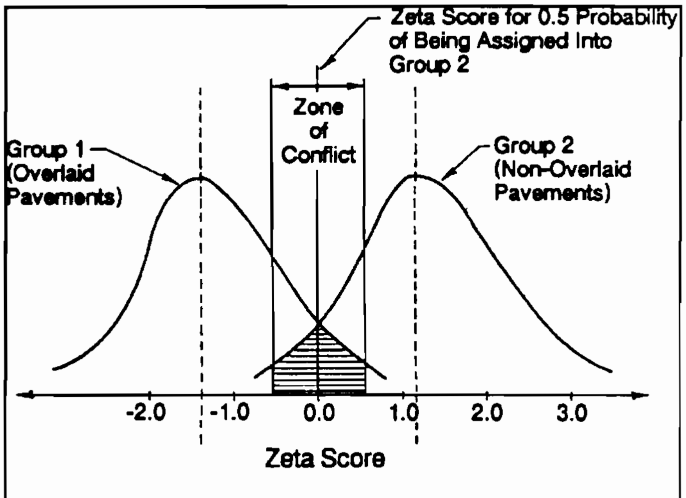


Fig 3.3. Modified distribution of Zeta scores for data set used in discriminant analysis (Ref 2).

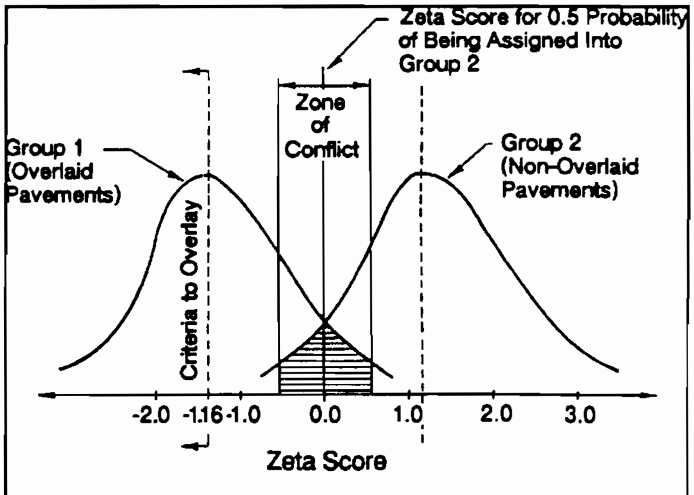


Fig 3.4. Distribution of Zeta scores for two group data sets used in discriminant analysis of Ref 15.

lative amount of various distress manifestations for every 0.2 mile in the survey years from 1974 to 1982 and for every 0.4 mile in 1984 of each survey project. Project lengths generally varied from a fraction of a mile to more than 15 miles. After the condition survey data were collected and stored, the data were reduced for use in the statistical analysis. The data reduction procedure is briefly described in the following paragraph.

First, the condition survey raw data for each pavement project for each survey year were examined in order to separate the data for overlaid category from that for non-overlaid category. Overlaid category is defined as the group having projects that are ready for overlay. This step had to be done manually because some pavement projects were only partially overlaid; this is believed to be the most efficient way to isolate the overlaid data by examining the raw data. It was found that some surveyed projects were overlaid between two successive survey years. Projects that were surveyed prior to the years of overlay are grouped into the overlaid category. This is because that in general, data collected before the overlay represent the worst condition of the pavement. The distress data can, therefore, be used to determine the condition leading to the decision for overlaying. For example, if a pavement project was overlaid in 1981, the distress data collected in 1980, just before the overlay, represent the condition of the pavement as an "overlaid" project. On the other hand, distress data for the project collected in 1974 and 1978 represent the condition of the pavement as "non-overlaid" project. Therefore, the projects of each survey year were grouped into either overlaid or non-overlaid category based on the above criteria. The average distress manifestation per mile of every overlaid and non-overlaid project was then calculated. This was done either by modifying the summary file SUMD, produced from the program CONSRV, for the non-overlaid projects or by directly calculating from the raw data for the overlaid projects. This reduced the original survey data of the 10-year period to 1365 data points. Each datum, representing a pavement project for a certain year, is composed of five numbers; each number represents the mean value of a distress manifestation: minor spalling, severe spalling, minor punchouts, severe punchouts, and patches. Since no condition survey data can be collected after the overlay, several data points were removed from the data base because of the zero values. In addition, survey data of 1984 were not included, because subsequent data are not available to check which category the pavement projects of 1984 should be grouped into. Therefore, the final data base consisted of 882 data points, 826 non-overlaid and 56 overlaid. This data base was then edited to include a sixth number, 1 or 2, for each datum point. The number 1 means that the project is overlaid, and the number 2 means that it is non-overlaid. Finally, the data base was used for the discriminant analysis and the five distress manifestations were used as discriminant variables for the analysis.

TABLE 3.1. STATISTICAL PARAMETERS OF THE CRCP DATA USED FOR THE DISCRIMINANT ANALYSIS (REF 15)

Pavement Group	Number of Observations	Number of Correct Predictions	Percent Correct
Overlaid	34	22	64.7
Non-overlaid	199	185	93.0
Total	233	207	88.8

DISCRIMINANT ANALYSIS OF DATA

In this study, the historical data are separated into two groups, overlaid and non-overlaid pavements. Each data point of each group represents the distress condition of a specific section in a specific survey year. By using discriminant analysis, one or more composites, or discriminant functions of the distress variables, will be derived so that the composite(s) can construct a boundary, which minimizes the overlap in the distribution of the discriminant scores of the different groups. The discriminant score is the value of the composite function for a particular data set. Ideally, the discriminant scores for the cases within a particular group will be fairly similar. The maximum number of discriminant functions which can be derived is either one less than the number of groups or equal to the number of discriminant variables, if there are more groups than variables. Therefore, only one function is derived in this study.

The inputs of the discriminant analysis are the historical condition survey data, including various distress types and their corresponding groups. The outcomes of the analysis are the discriminant function, a mathematical equation, and the relative magnitude for each data point that can be used as a distress index. In addition, the percentages of analyzed data which were correctly classified into each groups are given. Once the equation is developed, data for any new project can be assigned to one of the predetermined groups by calculating its discriminant score and comparing it with the boundary between the groups.

In the development of the discriminant function, the "discriminant" subprogram of the statistical package SPSS was used (Ref 9).

At this stage, it is important to mention several assumptions inherent in the approach used in this study:

(1) The distress variables are normally distributed.
(2) The SDHPT District's decisions for overlaying the projects were correct and consistent.
(3) The total cost of overlaying a pavement when it should not be overlaid is equal to the total cost of not overlaying a pavement when it should be.

ANALYSIS, RESULT, AND COMPARISON

Analysis

The discriminant function (equation) developed in the analysis to discriminate between groups is

$$Z_i = \sum_{j=1}^{m} a_j z_{ij} \, ; (i = 1, \ldots, n; \text{and } j = 1, \ldots, m) \qquad (3.4)$$

where

Z_i = discriminant score of the i^{th} observation (pavement project),

a_j = weighting coefficient for the j^{th} discriminant variable,

z_{ij} = standardized value for the i^{th} observation and the j^{th} discriminant variable (distress measure) used in the analysis,

n = total number of observations, and

m = total number of the discriminant variables.

The standardized value, z_{ij}, is calculated as follows:

$$z_{ij} = \frac{x_{ij} - \bar{x}_{.j}}{\sigma_{x_{.j}}} \qquad (3.5)$$

where

x_{ij} = value of the j^{th} distress manifestation, for the i^{th} observation,

$\bar{x}_{.j}$ = mean value of $x_{.j}$, values of the j^{th} distress manifestation for all observations, and

$\sigma_{x_{.j}}$ = standard deviation of $x_{.j}$, which equals

$$\sqrt{\frac{\sum_{i=1}^{n} (x_{ij} - \bar{x}_{.j})^2}{n-1}}$$

As can be seen in Eq 3.4, the discriminant function is linear, but it may not produce a realistic situation. However, the statistical program requires a linear form and any non-linear transformation of the discriminating variables should be made before this program is used. Several transformation models were tested, including multiple linear, second degree polynomial, and natural logarithm. The logarithm model produced the best results. It is also the most commonly used transformation for "growth" type data, e.g., distress evolution, and cases in which the mean is proportional to the standard deviation, which is true in this study.

Based upon the findings of the above analysis, Eq 3.5 is modified to the following form, while Eq. 3.4 remains unchanged:

$$z_{ij} = \frac{\ln(x_{ij} + 1) - \bar{x}'_{.j}}{\sigma_{x'_{.j}}} \qquad (3.6)$$

where

x_{ij} = same as defined before;

$$\bar{x}'_{.j} = \frac{\sum_{i=1}^{n} \ln(x_{ij} + 1)}{n};$$

n = total number of observations, for both overlaid and non-overlaid groups; and

$\sigma_{x'_{.j}}$ = standard deviation of $[\ln(x_{.j} + 1)]$

Table 3.2 summarizes the parameters to be used in Eq 3.6. The variable "patch" is the sum of asphalt cement, portland cement concrete, and failure patches. It was decided that inclusion of the minor and severe spalling terms in the equation would be misleading because of their negative signs. In addition, the two terms have relatively small values of coefficients compared to the other three variables. Thus, another equation was developed without considering the terms of minor and severe spalling. Table 3.3 represents the coefficients, mean values, and standard deviations of analyzed discriminant variables used in the improved discriminant equation. This equation can be further simplified by introducing the total means and deviations of the distress variables in Eqs 3.4 and 3.6 to obtain Eq 3.7:

TABLE 3.2. CONSTANTS TO BE USED IN EQS 3.4 AND 3.6 (WITH MINOR SPALLING AND SEVERE SPALLING)

i	Distress Manifestation	a_j	$\bar{x}'_{.j}$	$\sigma_{x'_{.j}}$
1	Minor Spalling (MPS)	-0.04248	3.5580	2.5075
2	Severe Spalling (SSP)	-0.09866	1.4191	1.6301
3	Minor Punchout (MPUNT)	0.05373	1.0853	1.0502
4	Severe Punchout (SPUNT)	0.47223	0.3015	0.5044
5	Patch (PATCH)	0.72323	0.6313	0.8281

TABLE 3.3. STATISTICAL PARAMETERS OF THE CRCP DATA USED IN EQS 3.4 AND 3.6 (WITHOUT MINOR SPALLING AND SEVERE SPALLING)

i	Distress Manifestation	a_j	$\bar{x}'_{.j}$	$\sigma_{x'_{.j}}$
1	Minor Punchout (MPUNT)	0.01869	1.0853	1.5020
2	Severe Punchout (SPUNT)	0.44485	0.3015	0.5044
3	Patch (PATCH)	0.72391	0.6313	0.8281

$$Z = -1.02544 + 0.01872\,(\text{MPUNT}) + 1.04429\,(\text{SPUNT}) + 1.09347\,(\text{PATCH}) \quad (3.7)$$

where

Z = discriminant score or "Zeta score,"
MPUNT = ln (minor punchout per mile + 1),
SPUNT = ln (severe punchout per mile + 1),
PATCH = ln (total patches per mile + 1).

As is noted in Eq 3.7, the Zeta score has a minimum value of -1.02544 and it increases with the quantities of various distresses. Because it was always thought that pavements in good condition should have higher scores than those in poor condition, the signs of constant terms and coefficients are reversed and Eq 3.7 is rewritten as Eq 3.8, with the same variable definitions:

$$Z' = 1.02544 - 0.01872\,(\text{MPUNT}) - 1.04429\,(\text{SPUNT}) - 1.09347\,(\text{PATCH}) \quad (3.8)$$

The new Zeta scores for all the analyzed observations for both overlaid and non-overlaid groups are calculated and the mean scores of each group are also computed. Table 3.4 summarizes the mean scores of each group and the probability of correct prediction by the discriminant equation. The grand mean value, zero, is used as the dividing point to separate these two groups. Information for these calculations may be obtained from the computer output (Appendix A).

It should be emphasized that the individual Zeta score will not have the same distribution pattern about each group mean because of the different characteristics in nature. The historical distress record of any specific pavement project always starts from its best condition, i.e., no distress, and as the distress increases with time and traffic the project approaches an unacceptable condition, before overlay. Thus, there exists a high bound, the best condition, in the Zeta score distribution of the non-overlaid group, while the Zeta score of the overlaid group tends to be distributed normally. A frequency distribution for each of the two groups is plotted (against the Zeta score) on one continuous horizontal axis (Fig 3.5). The shadow area indicates the overlap of the two distributions. In the discriminant analysis, the grand mean of the groups will always be zero, which falls between the two group means but is not necessarily the average of these two means. A special case happens only when the groups have an equal amount of data and each has a normal distribution of the Zeta score. Overlapping of the Zeta scores between the two groups is unavoidable. This area, the zone of conflict, can be reduced by transforming the input data and/or by calculating a specific value of the Zeta score which will give a pavement a 50 percent probability of being assigned to the non-overlaid group when it should have been grouped in the overlaid group, and vice-versa (see Fig 3.3).

TABLE 3.4. GROUP MEANS OF DISCRIMINANT ZETA SCORE AND NUMBER OF CASES CORRECTLY PREDICTED BY THE DISCRIMINANT EQUATION (EQ 3.8)

Group	Mean	Number of Cases	Number of Correct Classifications	Percent
Overlaid	-3.1736	56	5.1	92.9
Non-Overlaid	0.2151	826	757	91.6
Total	0.0000	882	809	91.72

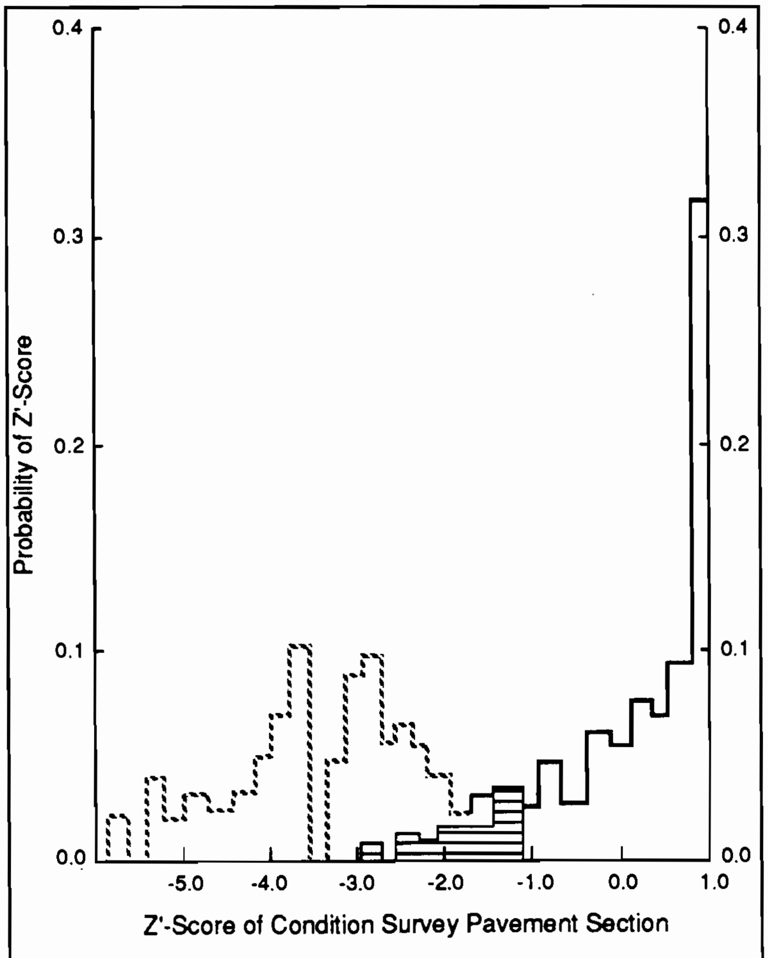


Fig 3.5. Frequency distribution of Zeta scores based on Eq 3.8 for the data set used in the discriminant analysis.

For the equation formed by using the data for the whole data base, the specific Zeta score was calculated as -1.60.

Therefore, if the Z′ of any pavement is less than -1.60, there is a strong probability that the pavement is a good candidate for an overlay. Similarly, a pavement with a Z′ value larger than -1.60 has a large probability of being in good condition so that no overlay is necessary. Under the above analysis, when Z′ has the value of -1.60, the overlap area is equally divided (Fig 3.6). The right half represents the probability (α) that a pavement which should be overlaid is misclassified into the non-overlaid group. Likewise, the left half indicates the probability (β) that a pavement is classified into the overlaid group while it is still above the acceptable level. It is believed that the ratio of α to β equals to the ratio of the total cost, including agency and user cost, of not overlaying a pavement when it should be to the total cost of overlaying a pavement when it should not. In order to simplify the decision making about which value the Z′ should be, an assumption was made. It was assumed that the total costs, of overlaying and not overlaying for above two conditions are equal. The Zeta score of -1.60 is, therefore, considered to be the appropriate value to separate the two groups evenly in this study. This decision results in α = β = possible minimum value = 7.4 percent. If the study of test analysis is made and the actual ratio of these two costs is obtained, a new Zeta score should be used to separate the overlaid and non-overlaid groups in order to make the ratio of α to β equal to the calculated cost ratio.

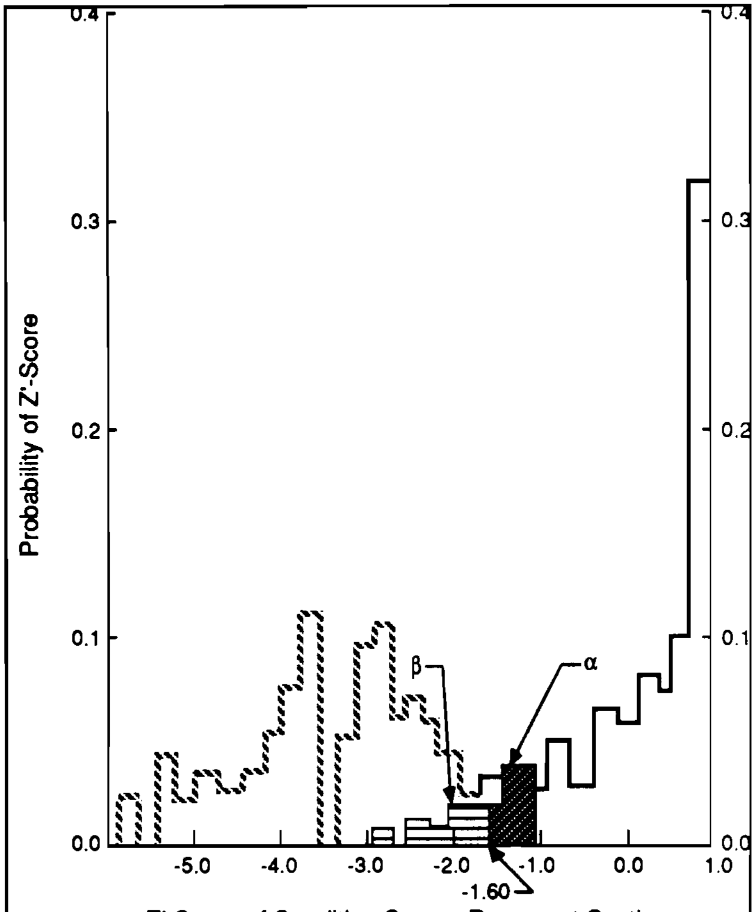


Fig 3.6. Frequency distribution of Zeta scores with -1.60 as the dividing point.

Results

Based on the above analysis, Eq 3.8 can then be modified so that the Zeta scores are compared to zero rather than to -1.60, by using

$$Z'' = Z' + 1.60$$

$$= 2.62544 - 0.01872\ (MPUNT) - 1.04429\ (SPUNT) - 1.09347\ (PATCH) \qquad (3.9)$$

and

$$Z'' = 1.0 - 0.0071\ (MPUNT) - 0.3978\ (SPUNT) - 0.4165\ (PATCH) \qquad (3.10)$$

A plot of the Z′′ frequency distributions of the two groups, based on Eq 3.10, is represented in Fig 3.7. Table 3.5 summarizes the probability of correct prediction for both groups using Eq 3.10.

In Eq 3.10 the most important variable that affects the Z′′ is patch (PATCH), followed by severe punchouts (SPUNT) and minor punchouts (MPUNT). It was noted that approximately 11 patches or 12 severe punchouts, per lane-mile calculated from Eq 3.10, will cause a pavement project to be overlaid when the other distress variables are all zeros. An example of the calculation is shown below:

If minor punchout = severe punchout = 0,

then

number of patches /lane-mile to cause overlay of a

$$\text{pavement} = e^{\left(\frac{1}{0.4165}\right)} = 11.$$

The final equation correctly classified 92.6 percent (1–α), out of 882 cases. The cases used to test the prediction capability of the discriminant equations were the same as the ones used to develop the equation.

Comparison with Previous Distress Index Model

Although the same discriminant analysis was used in the previous studies for developing the distress index for CRCP, several major differences in the input data, analysis, and results exist. These differences are briefly described as follows:

(1) Pumping was included in the previous studies but not in the current one. As it was defined earlier, pumping is the action in which water is squeezed out of a crack joint when a load is applied and carries out some fine material of the sublayer with it. It is obvious that pumping is easier to detect right after rain than after a long dry period. Therefore, it is difficult to have data collected for this item that are consistent. Besides, instead of recording the percentage of pumping, the presence or non-presence (yes or no) was used to indicate the occurrence of pumping in the 1980 survey. No consistent data are available for the discriminant analysis even if we wanted to include this item.

(2) The percentages of minor and severe spalling were included before, but the average numbers of spalling of either type are used in this study. The percentage of spalling is calculated as the number of spalled cracks divided by the total transverse cracks for a section length. It is possible for two pavement projects to have the same percentages of spalling but different numbers of spalled cracks because they have different numbers of transverse cracks too. Therefore, the actual number of spalled cracks is considered more correct than the percentage of spalling to represent the distress condition of a pavement project. Nevertheless, minor and severe spalling are excluded in the current study because of the negative sign of its coefficient.

(3) Numbers of minor and severe punchouts and patches were summed together as the variable "failure" in the previous studies. They are separated as three independent variables in this study. From Eq 3.10, it is found that their weights, or coefficients, are different. The weight of minor punchouts is considerably smaller than those of the other two variables. This finding indicates that separating the three variables may give a better discriminant analysis than combining them.

(4) Only 1974 and 1978 condition survey data were used in the previous studies, but ten years (1974-1984) of survey data were included in this study. This is due to the limitation of data available at that time. In addition, both rural and urban districts were included in the current study which makes the analysis more comprehensive.

(5) The non-linear model, the natural logarithm, was adopted in this study, while the simple linear model was used in the past. The logarithmic transformation is commonly used for type of data that grow with age, e.g., distress development, and it results in the best fit for data grouping.

(6) It was assumed in the past studies that both overlaid and non-overlaid groups are normally distributed along the continuous Zeta score axis (Figs 3.3 and 3.4). However, it was found that there is a high bound in the Zeta score distribution of the non-overlaid group which makes this group more like a Poisson's Distribution (Figs 3.5 and 3.6). Since the groups have neither

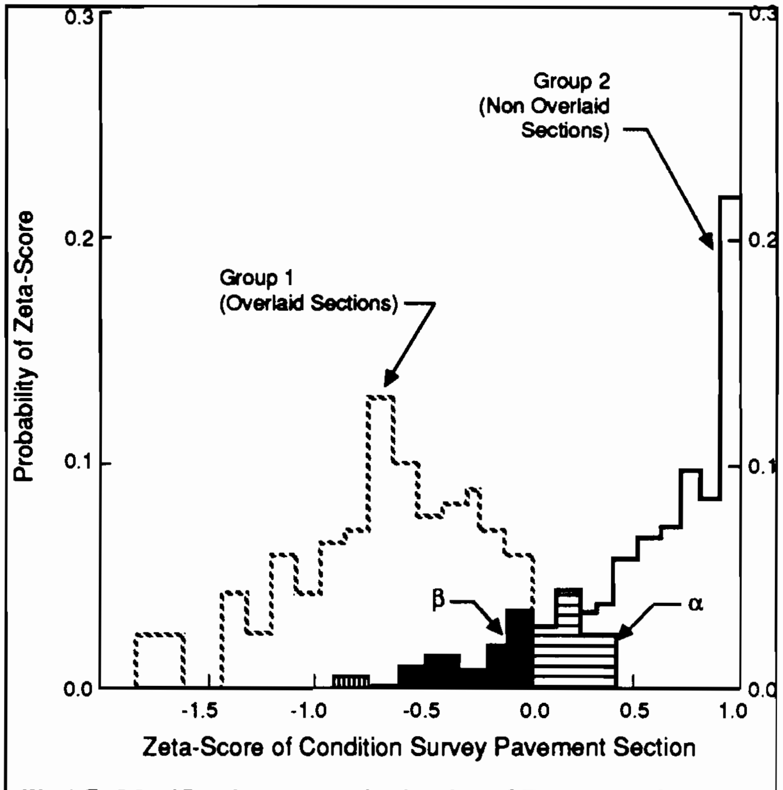


Fig 3.7. Modified frequency distribution of Zeta scores based on Eq 3.10 for the non-overlaid and overlaid groups.

TABLE 3.5. NUMBER OF CASES CORRECTLY PREDICTED BY THE DISCRIMINANT EQUATION

Group	Number of Cases	Number of Correct Classifications	Percent
Overlaid	56	52	92.9
Non-Overlaid	826	765	92.6
Total	882	817	92.6

normal distributions of Zeta scores nor equal amounts of data, using the average Zeta score of the two group means to represent the grand mean for the previous studies results in incorrect findings.

(7) The percentage of correct predictions of all data points has been improved from 88.8 to 92.6. A more important improvement is that the difference in correct prediction percentage between overlaid and non-overlaid groups has been reduced from 28.7 to 0.3. In the previous studies, the percentage of correct prediction for overlaid and non-overlaid groups were 64.7 and 93.0 respectively. This implies that the weighted 88.8 percent is not a good indicator of the general condition of both groups since the area of the conflict zone is not equally separated by the dividing Zeta score. In other words, the 92.6 percent of correct prediction resulting from this study is more accurate in presenting the overall condition because both the groups have equal percentages of correct predictions. Therefore, the dividing Zeta score selected in this study gives a better separation of the overlaid and non-overlaid pavements.

SUMMARY

This chapter focuses on the derivation of a distress index and a rehabilitation criteria index for the CRCP network in Texas. Some previous studies were reviewed and evaluated. Discriminant analysis was chosen out of several approximate methods aimed at developing a distress index because its technique is appropriate for the available data. A linear model developed in Gutierrez's and Noble's studies (Refs 2 and 15) was briefly described. Although several aspects of the input data and assumptions were improved in this study, it is believed that the previous model was the best using the limited data available at that time.

The historical condition survey data for the CRCP network were used in this study. The logarithmic transformation of the original distress data was performed before the discriminant technique was applied because that resulted in the best fit for data groups.

After several modifications, the final equation used to calculate the distress index, Zeta score, is

$$Z'' = 1.0 - 0.0071\,(MPUNT) - 0.3978\,(SPUNT) - 0.4165\,(PATCH) \qquad (3.10)$$

where

Z'' = distress index or Zeta score,
MPUNT = ln (minor punchouts per mile + 1),
SPUNT = ln (severe punchouts per mile + 1), and
PATCH = ln (total patches per mile + 1).

The criterion for major rehabilitation of a pavement is that its distress index, Z'', be less than or equal to zero.

Finally, a comparison of the previous and the current studies was presented. Several major differences in the input data, analysis, and results were listed and discussed.

CHAPTER 4. DEVELOPMENT OF THE EXPERIMENTAL FACTORS AND VARIABLES TO BE MEASURED

INTRODUCTION

Statewide condition surveys on CRC pavements have been conducted periodically since 1974. Monitoring of pavement sections has provided a tremendous amount of useful information that has significantly contributed to the development of CRCP rehabilitation design systems as well as criteria for prioritization and scheduling of overlays at the network level as described in Chapter 3. However, condition surveys need to be carried out so that design procedures involving prediction models which were developed from the existing survey data (Ref 2) can be verified. Furthermore, in order to evaluate the relationship between CRCP performance and the variables of design, construction materials, environment, and traffic, the development of an experimental design and a sampling method for the network of pavements in Texas is considered to be important and necessary. This chapter describes the evaluation of the effects of all possible input variables on pavement performance from the empirical as well as the theoretical point of view. The specific objectives considered in this evaluation are

(1) the development of a list of experimental factors and the variables in the experimental condition survey and
(2) the definitions of factor levels to be used in the experimental design.

As described in Chapter 3, the distress index was developed using the method of discriminant analysis . For any given pavement, data for each distress manifestation can be substituted into the discriminant equation to obtain the distress index, Zeta score, for that pavement.

Since the pavement distress condition is a function of structure design, construction variables, environmental factors, traffic, and age, it is desirable to obtain a relationship between the influential factors and the Zeta score. Therefore, an experiment was designed for this purpose (Fig 4.1). Variables which were considered to have significant influence on pavement performance were included as experimental factors. Each factor was assigned different levels to obtain a complete factorial experiment.

EVALUATION OF THE POSSIBLE VARIABLES

A list of the possible variables is shown in Fig 4.2. It includes variables of pavement design, construction, environment, traffic, and age. Evaluation of these variables from both empirical, AASHTO equations, and theoretical, mechanistic models, points of view was made in order to select the most significant variables out of the list. The empirical models usually involve statistical analysis to fit an equation to field data; that is, the data are used to generate the model. The theoretical models utilize established mechanical principles and variables to estimate a pavement response. An important difference between the two types of models is that mechanical models are limited by the hypotheses used in their derivation, while empirical models are limited by the ranges between the maximum and minimum values of parameters used in the analysis.

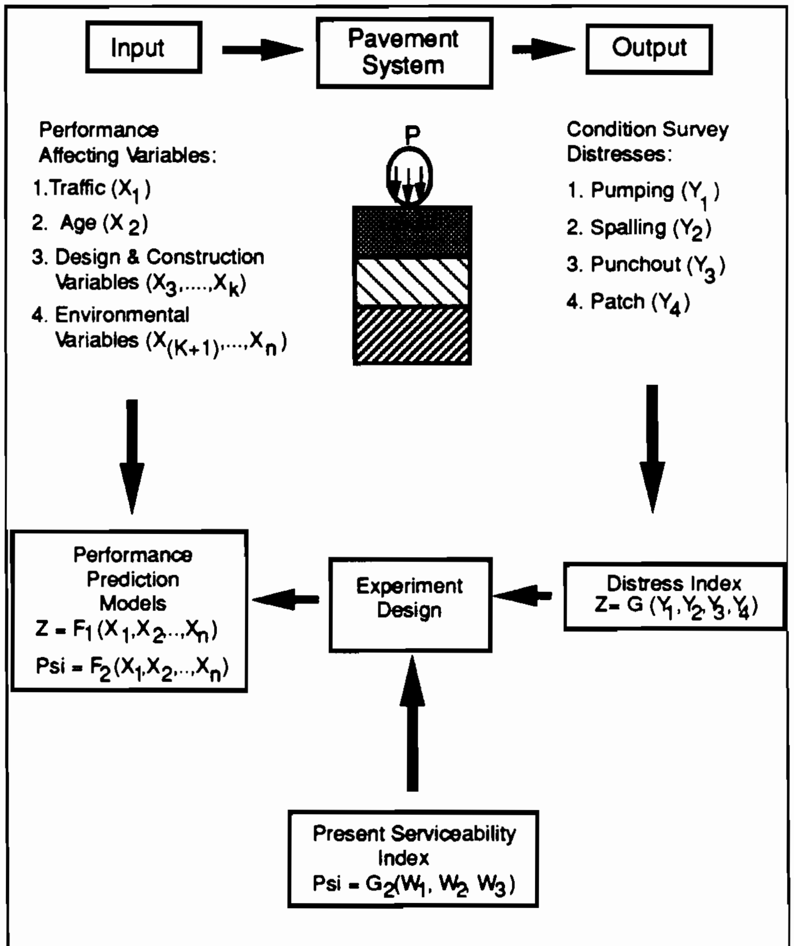


Fig 4.1. Layout of the relationship between the input variables and performance of pavement system.

I. Design/Construction Factors

- A. Concrete Layer Properties
  1. Concrete Aggregate Type,
  2. Type of the steel: bar mats or welded-wire fabric,
  3. Amount of transverse and longitudinal steel, and
  4. Thickness.
- B. Subbase Layer Properties
  1. Coarse aggregate type,
  2. Typeand amount of stabilization,if any,
  3. Surface coating if any, and
  4. Type of grading cut of fill.
- C. Roadbed Layer Properties
  1. Type of stabilization,if any,
  2. Stabilization thickness, and
  3. Type of grading cut or fill.
- D. Shoulder
  1. Surface layer,
     - a. Type of the material: concrete cement or asphalt cement,
     - b. Thickness, and
  2. Base layer,
     - a. Type of coarse aggregate,
     - b. Type of stabilization, if any, and
     - c. Thickness.

II. Environmental Factors

- A. Moisture
  1. Rainfall,
  2. Humidity,
  3. Evaporation,
  4. Transpiration, and
  5. Soil Suction.
- B. Temperature
  1. Solar radiation,
  2. Thermal fatigue; no. if annual freeze-thaw cycles,
  3. Annual lowest temperature, and
  4. Daily temperature drop.
- C. Clay activity: shrink shrink/swell charicteristics.

III. Traffic Volume

- A. Accumulated equivalent18 kip single axle loads,
- B. Annual Average Daily Traffic, and
- C. Directional Distibution Factor (D).

IV. Pavement Age Months

Fig 4.2. Variables considered in the significance analysis of pavement performance.

AASHTO Equations

The pavement design procedures described in *AASHO Interim Guide for the Design of Rigid and Flexible Pavements* (1962) were primarily based on the results of the AASHO Road Test, supplemented by existing design procedures and available theories. After the guide was used for a few years by the states, the AASHTO Design Committee, in 1972, issued *AASHTO Interim Guide for Design of Pavement Structures.* This updated guide incorporated experience that had accrued since the issue of the original guide. In 1981, the chapter on rigid pavement design was revised (Ref 19). In 1986, several modifications related to flexible and rigid pavement designs were included in the design guide (Refs 20 and 21). These are the major modifications made in the design procedures for rigid pavements:

(1) Reliability is introduced to permit the designer to use the concept of risk analysis for various classes of roadways.

(2) The environmental factors of moisture and temperature are objectively included so that environmental considerations can be rationally accounted for in the design procedure. This approach replaced the subjective regional factor term previously used.

(3) The design procedure is modified to include such factors as tied shoulders, subbase erosion, and lean subbase designs.

The final design equation used for rigid pavements in the guide is given in Eq 4.1.

$$\log W_{18} = Z_R * S_o + 7.35 \log(D+1) - 0.06 + \frac{\log\left(\frac{\Delta PSI}{4.5 - 1.5}\right)}{1 + \frac{1.624 \times 10^7}{(D+1)^{8.46}}}$$

$$+ (4.22 - 0.32P_t) \log\left[\left(\frac{S_c' \times C_d}{215.63 * J}\right)\left(\frac{D^{0.75} - 1.132}{D^{0.75} - \frac{18.42}{Z_c^{0.25}}}\right)\right] \tag{4.1}$$

where

W_{18} = predicted number of 18-kip equivalent single axle load applications to reach P_t;
Z_R = standard normal deviation;
S_o = combined standard error of the traffic prediction and performance prediction;
D = slab thickness, inches;
DPSI = difference between the initial design serviceability index, P_i, and the design terminal serviceability index, P_t;
P_t = serviceability at the end of time, t;
S_c' = modulus of rupture of PCC, psi;
J = load transfer coefficient (equals 3.2 for protected corner);
C_d = drainage coefficient;
Z_c = E_c / k;
E_c = modulus of elasticity for PCC; and
k = modulus of subgrade reaction, pci.

It is important to recognize that Eq 4.1 was derived from empirical information obtained at the AASHO Road Test and modified by mechanistic models. As such, this equation represents a best fit to observations at the road test. The solution represents the mean value of traffic which can be carried for given inputs.

From Eq 4.1, it is clear that the pavement life, or number of 18-kip load applications, is a function of several variables of design, construction materials, and environment, which can be presented as follows:

$$W_{18} = f\{\, DPSI, S_c', E_c, C_d, J, k, Z_R, S_o, D \,\} \qquad (4.2)$$

Each of the variables on the right side of Eq 4.2 can be further analyzed as follows.

ΔPSI: Loss of Serviceability During the Pavement Design Life. The serviceability of a pavement is defined as its ability to serve the type of traffic which uses the facility (Ref 11). The measure of serviceability is the Present Serviceability Index (PSI), which ranges from 0 (worst road) to 5 (perfect road). The initial PSI, P_i, is defined as the serviceability value of a new pavement. The P_i value observed at the AASHO Road Test was 4.5 for new rigid pavements. Terminal serviceability index, P_t, is defined as the lowest index that will be tolerated before rehabilitation, resurfacing, or reconstruction becomes necessary. Therefore, the PSI value at any time can be expressed as a function of pavement deterioration condition:

$$PSI = f\{\, \text{roughness, patches, cracks} \,\} \qquad (4.3)$$

S_c', E_c: Modulus of Rupture (Flexural Strength) and Elastic Modulus of PCC.. Both moduli represent the stiffness of portland cement concrete. The values of these two moduli are mainly a function of the coarse aggregate type, water-cement ratio and the cement content of the PCC. The modulus of rupture required by the design procedure is the mean value determined after 28 days using third point loading. Texas SDHPT currently specifies an average modulus of rupture of 650 psi, 7 days center point loading. Utilizing the appropriate correction factors, the specification can be equated with a value of 720 psi at 28 days for third point loading specified in the design procedure of 1986 AASHTO Guide for Design of Pavement Structures.

C_d: Drainage Coefficient. Drainage effects on pavement performance are considered in terms of the effects of moisture on subgrade strength and on base erodibility. The C_d value is dependent on the quality of drainage and the percent of time during the year the pavement structure would normally be exposed to moisture levels approaching saturation. The latter is dependent on the average yearly rainfall and the prevailing drainage condition.

$$C_d = f\{\, \text{quality of drainage, yearly rainfall} \,\} \qquad (4.4)$$

J: Load Transfer Coefficient. This factor is used in rigid pavement design to account for the ability of a concrete pavement structure to transfer load across discontinuities, such as joints and cracks. Load transfer devices, such as aggregate interlock and the presence of tied concrete shoulders, all have an effect on this value. As a general guide for the range of J-values, higher J's should be used with low k-values, high thermal coefficients, and large variations of temperature. The J value can be expressed as

$$J = f\{\, k, \text{aggregate types (thermal coefficients), temperature} \,\} \qquad (4.5)$$

k : Effective Modulus of Subgrade Reaction. For a specific design life, W_{18}, the slab thickness can not be determined unless an estimate of the slab support, the effective subgrade modulus, is provided. The effective k-value is dependent upon several different factors besides the roadbed soil resilient modulus. The first step in the development of effective modulus of subgrade reactions is to estimate the composite modulus of subgrade reaction (k_{comp}) by combining factors of subbase thickness (D_{SB}), subbase elastic modulus (E_{SB}), and roadbed soil resilient modulus (M_R). The roadbed soil resilient modulus can be obtained through the laboratory relationship between the resilient modulus and the moisture content. An alternative procedure is to back calculate the resilient modulus using deflection data measured on in-service pavements. Different types of subbases have different strengths or modulus values. The consideration of E_{SB} is actually an evaluation of different subbase types. The roadbed soil resilient modulus is very sensitive to seasonal changes. The seasonal resilient modulus is determined by the clay content, moisture, temperature, PI, etc.

$$k_{comp}(t, m) = f\{\, D_{SB}, \text{subbase type}, M_R(t, m, \text{soil}) \,\} \qquad (4.6)$$

where

$k_{comp}(t, m)$ = composite modulus of subgrade reaction, a function of temperature (t) and moisture (m);

M_R (t,m) = roadbed soil resilient modulus, a function of temperature (t), moisture (m), and soil properties.

The second step in the process is to calculate the design k value (k_{design}) from the k_{comp}, when there is a rigid foundation within a certain depth under the surface of the subgrade. The k_{design} increases when the depth of the rigid foundation from the surface of the subgrade decreases.

$$k_{design}(t,m) = f\{k_{comp}(t,m), M_R(t,m), D_{SG}\} \quad (4.7)$$

where

D_{SG} = the distance between the surface of the subgrade and the rigid foundation.

Since the k_{design} and the k_{comp} are functions of temperature and moisture, the final step in the development of effective modulus of subgrade reactions is to combine the seasonal k_{design} value using the relative damage by each season as the weighting factor.

Z_R, S_o: Standard Normal Deviation and Overall Standard Deviation. These two items are used in the reliability estimates which were introduced in the latest version of the AASHTO Guide. Basically, the "reliability" is a means of incorporating uncertainty into the design process to ensure that the various design alternatives will last the analysis period.

D : Designed Slab Thickness. The slab thickness can be determined from the rigid pavement design nomograph with the the estimated future traffic, W_{18}, and values of other variables in Eq 4.2.

By combining Eqs 4.2 to 4.7, variables considered to have significant effects on pavement design and performance are listed in Table 4.1. These variables are good candidates for experimental design and performance estimates of pavements as indicated.

Mechanistic Models

Several mechanistic models for predicting performance of rigid pavements are available. However, the Continuously Reinforced Concrete Pavement (CRCP) model (Refs 22 and 23) was selected to evaluate the effects of variables on pavement performance from the theoretical point of view. Although the CRCP model has been modified several times, the theoretical concept is unchanged. The equations used in the model are based on the behavior of pavements and their response to internal and external stresses. The internal stresses are associated with shrinkage and temperature and the externally induced stresses are due to wheel load and frictional resistance between a concrete slab and the supporting material.

All concrete elements and structures are subject to varying degrees of volume change, depending on the make-up, configuration, and environment of the concrete Uniform volume change will not produce cracking if the structure is relatively free to change volume in all directions. This is rarely the case because the concrete is usually restrained by internal and external restraints. The internal restraints are related to the following items:

(1) steel – its quantity, deformations, bar size, strength, modulus of elasticity, and thermal coefficient; and
(2) concrete – its thickness, strength, modulus of elasticity, thermal coefficient, and creep.

On the other hand, the external restraints are a function of the following items:

(1) friction developed between slab and subbase,
(2) bond to adjacent lane, and
(3) distance from the end or the edge of pavement.

These restraints lead to the development of tensile stresses in the concrete, and, whenever the induced forces exceed the tensile strength, transverse cracks form to relieve these stresses. As shrinkage and temperature drop increase with time, more transverse cracking develops and the crack pattern of the pavement is established.

The crack pattern, involving the crack spacing and crack width, is probably the most important physical aspect in the design of CRCP. The initial crack pattern is due primarily to internal forces, i.e., shrinkage and temperature drop. The further formation of crack pattern can be attributed to the externally induced stresses due to wheel loads. In the CRCP model, a series of equations were developed to predict the (1) crack spacing, (2) crack width, (3) stress in steel, and (4) stress in concrete (Fig 4.3) due to drying shrinkage, temperature change, and applied wheel loads. Each of the predicted values is expressed as a function of several design, material, and environmental variables (Ref 22). By combining the four prediction equations, the following relationship can be obtained:

$$(\bar{X}, \Delta X, s_s, s_{cm}) = f\{E_c, E_s, S_c', a_c, a_s, DT, DM, F, D_{slab}, W_{18}\} \quad (4.8)$$

TABLE 4.1. LIST OF DESIGN AND PERFORMANCE VARIABLES

Serial Number	Design Variables	Measurable Performance Variables
1	Rainfall	Roughness
2	Temperature	Patches
3	Coarse Aggregate Type	Cracks
4	Soil Type	Traffic (ESAL)
5	Subbase Type	
6	Slab Thickness	

where

$\overline{X}$ = mean crack spacing,
DX = crack width,
s_s = steel stress,
s_c = concrete stress,
E_c = modulus of elasticity of concrete,
E_s = modulus of elasticity of steel,
S_c' = modulus of rupture of concrete,
a_c = thermal coefficient of concrete,
a_s = thermal coefficient of steel,
DT = temperature drop (the difference between the concrete placement temperature and the lowest temperature that occurred).
DM = moisture change,
F = friction coefficient between pavement slab and subbase,
D_{slab} = slab thickness, and
W_{18} = number of 18-kip wheel load applications.

In Eq 4.8, the variables E_c, S_c', and α_c are properties of portland cement concrete which are mainly governed by water-cement ratio, cement factor, and aggregate type:

$$(E_c, S_c', a_c) = f\ \{\text{ water-cement ratio, cement factor, aggregate types }\} \qquad (4.9)$$

Similarly, the friction coefficient between pavement slab and subbase is a function of subbase type:

$$F = f\ \{\text{ subbase types}\} \qquad (4.10)$$

Combining Eqs 4.8 to 4.10 gives the possible variables which can be used as either experimental design factors or measured items in future condition surveys (Table 4.2).

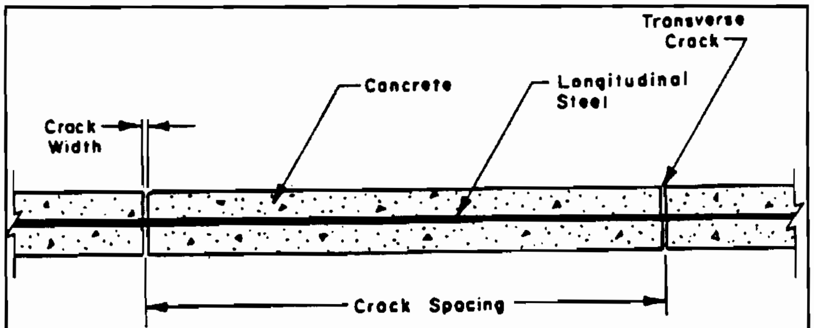
Field Survey Studies

The performance of most of the CRC pavements in Texas is generally satisfactory and thus they achieve in many cases the original objectives of providing good riding quality and low maintenance cost, compared to flexible pavements, and minimum traffic interruptions over the service life. However, as the total traffic and age of CRCP increases, distress manifestations become more prevalent. During 1972, the Rigid Pavement Design Committee of the Highway Research Board conducted a survey of the various state highway departments which use CRCP to ascertain the distress manifestations observed by these states (Ref 24). Table 4.3 is a summary of the results of this survey. These distress manifestations are listed by the ranking assigned by the states, which was based on the frequency of occurrence. The probable causes of the first four ranked distress manifestations are presented below.

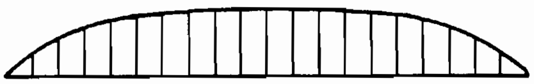
The first and second distress types, erratic crack pattern and uniform crack spacing, indicate the need to evaluate the crack spacing and crack width for various environmental conditions and design parameters experienced on a given project. The third ranked item, spalling, is associated primarily with excessive deflections, excessive crack width, and concrete material problems. The fourth ranked item, localized punchout, appears to be associated with inadequate thickness and inadequate vibration of slabs. Thus, the solution to these distress manifestations appears to be primarily the improvement in thickness design and construction techniques.

In addition to the above field study, an analysis associated with the influences of soil type, roadbed grading (cut or fill), shoulder condition (good or bad), and rainfall on pavement distress manifestations was studied by the CTR staff in 1986 (Ref 25). Three pavement projects with different roadbed soil types, 13006WB, 13016WB, and 13017WB, were selected in District 13. Each of the projects has various combinations of subgrade grading and shoulder conditions. Several conclusions were drawn from that study and are presented below:

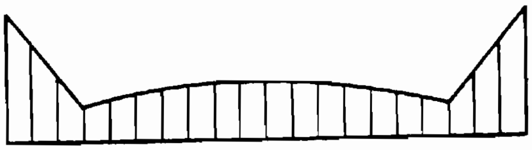
(1) Both cut and fill grading conditions have positive



(a) Continuously reinforced concrete pavement.



(b) Concrete stress distribution.



(c) Steel stress distribution.

Fig 4.3. Continuously reinforced concrete pavement model showing pavement responses due to volumetric changes.

TABLE 4.2. LIST OF DESIGN AND PERFORMANCE VARIABLES FROM THE MECHANISTIC MODEL

Serial Number	Design Variables	Measurable Performance Variables
1	Coarse Aggregate Type	Crack Spacing
2	Slab Thickness	Crack Width
3	Elasticity Modulus of Concrete	Traffic (ESAL)
4	Elasticity Modulus of Steel	
5	Subbase Type	
6	Temperature Drop	
7	Rainfall	

influence on the development of pavement distress manifestations. Cut affects the pavement performance more than fill. The increasing size of cut or fill increases the average failure number (punchouts and patches) per mile.

(2) Pavements having longitudinal cracks between the outside lane and the shoulder have more failures than those which have no cracks between the pavement and shoulders.

(3) The soil types have significant effect on the development of distresses in pavements. Of the three soil types, clay sections develop the most distresses. Mixtures of clay and sand are the intermediate and granular materials develop the least number of failures. Figure 4.4 shows the performance of two projects with clay and granular material, respectively, underneath the pavements.

Another important finding was that rainfall showed a strong influence on pavement performance. Figure 4.5 presents the effect of rainfall on pavement performance using the failure data of the years 1974, 1978, and 1982. This figure shows a direct relationship between mean failures per mile (MFPM) and normal annual precipitation. The number of failures suddenly drops for districts with normal annual rainfalls greater than 44 inches, because most of the pavements in these districts have been overlaid. A more meaningful relationship was obtained by plotting the average rate of the mean failures per mile per year (ARFPM) and normal annual rainfall. The ARFPM was calculated by the following relationship (Ref 26):

$$\text{ARFPM} = \frac{\text{MFPM in 1984} - \text{MFPM in 1974}}{10} \qquad (4.11)$$

A regression analysis was performed to determine the relationship between the ARFPM and the average annual rainfall, P, of the Districts of Texas. The following equation was obtained (Ref 26):

$$\log(\text{ARFPM}) = -4.05 + 2.35 \log(\text{P}) \qquad (4.12)$$

$$(R^2 = 0.94;\ S = 0.129)$$

This is a simple one-variable regression analysis. The value of R^2 indicates that there is a strong correlation between ARFPM and P. The ARFPM increases with the increase in P, as shown in Fig 4.6. It was observed that when the pavements start developing some initial damage, the MFPM in high rainfall areas increases at a higher rate than in lower rainfall areas, as shown in Fig 4.7.

The effects of roadbed soil on the performance of CRCP were further studied by combining it with the average rainfall. Figures 4.7 and 4.8 show the effects of rainfall on the performance of CRCP in two different roadbed soil types. Pavements built on subgrade soil containing 100 percent clay were selected for Fig 4.7. It is evident from this figure that the pavement built in the high rainfall area developed more failures per mile than the pavement built in the low rainfall area. On the other hand, if the clay content of roadbed soil is almost zero, then the effect of rainfall on the pavement performance is almost negligible, as shown in Fig 4.8.

From the findings of the above field survey studies, several possible variables were identified as candidates for experimental design factors and variables to be measured in the experimental condition surveys (Table 4.4).

EVALUATION OF RESULTS

In order to select appropriate factors for the design of the experiment and the variables to be measured in the experimental condition surveys, Tables 4.1, 4.2, and 4.4 were combined together and further analyzed and the variables

TABLE 4.3. CRCP DISTRESS MANIFESTATIONS AS REPORTED BY HRB COMMITTEE SURVEY (REF 24)

Ranking	Distress Manifestation	State Reporting*
1	Erratic Crack Pattern	20
2	Uniform Crack Spacing	18
3	Spalling	15
4	Localized Punchout	13
5	Construction Joints	13
6	Longitudinal Cracking	10
7	Open Cracking	11
8	Localized Radial	8
9	Open Crack with Pumping	6
10	Blowup	4
11	Transverse Fragmentation	1

* Twenty-nine out of the thirty-three states using CRCP reportedthe existance of distress manifestations. The other four did notrespond to the survey.

were reduced to a reasonable number. Since each design factor has two or more levels, the practical number of experimental design factor preferably is to be kept as small as possible so that the design factorial does not become too complex and large. Additional restrictions for factor selection on all pavement projects were imposed in order to maintain the quality and homogeneity of the information used. The initial quality control mechanism required that all data parameters selected for this study be common to all pavement projects so that the pavement sections not included in the experimental design could benefit from the findings of this study. Another restriction required that all experimental factors should be easily obtainable.

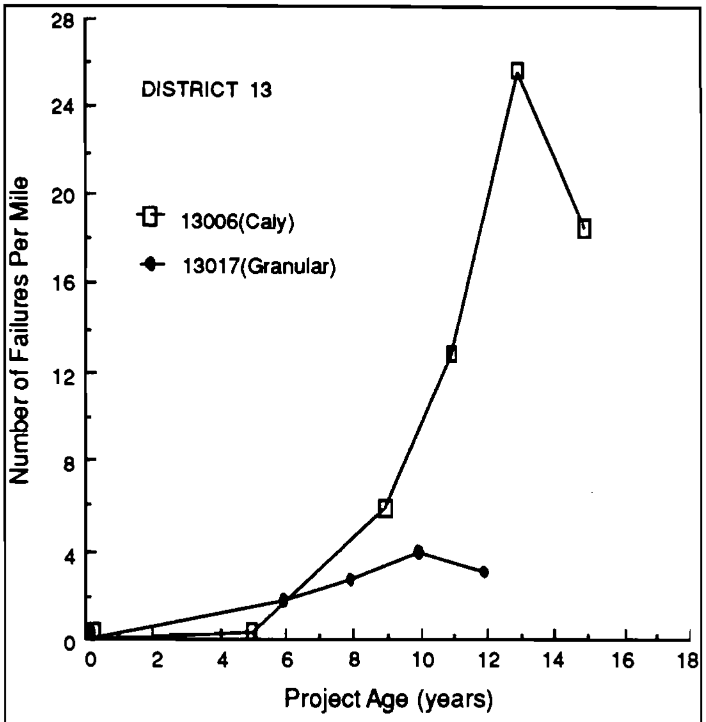


Fig 4.4. Pavement distress condition of various soil types.

The following paragraphs represent the final results of the study to select an experimental design and measurable performance variables based upon practical experience and judgement.

Experimental Design Variables

(1) *Slab Thickness* (D_{slab}). The thickness of the concrete slab is considered to have a direct and strong influence on pavement performance. It was selected as a candidate for the experimental design in all three tables.

(2) ***Coarse Aggregate Type (CAT).*** From the above analysis, there is no doubt that concrete properties definitely govern pavement behavior. Also, the type of coarse aggregate affects the concrete properties, because of its relatively high percentage in the mix. Therefore, this item was selected and two major types of aggregate siliceous river gravel (SRG) and limestone (LMS) are included in the design.

(3) ***Subbase Type (SBT).*** From Eq 4.6 and Eq 4.10, subbase type is shown to be important for pavement performance, from both empirical and theoretical points of view. This factor can be grouped into four categories, namely, portland cement treated, asphalt cement treated, lime treated, and crushed stone subbases.

(4) ***Roadbed Soil Type.*** The shrinkage/swell characteristic of the subgrade soil determines the potential for layer movement within the structure. Therefore, the prime surfacial soil characteristic is affected by the presence of swelling clay in the surface layer. Two categories of soil, swelling and non-swelling, were selected for the experimental design based on the Texas Land Resources Map (Ref 28).

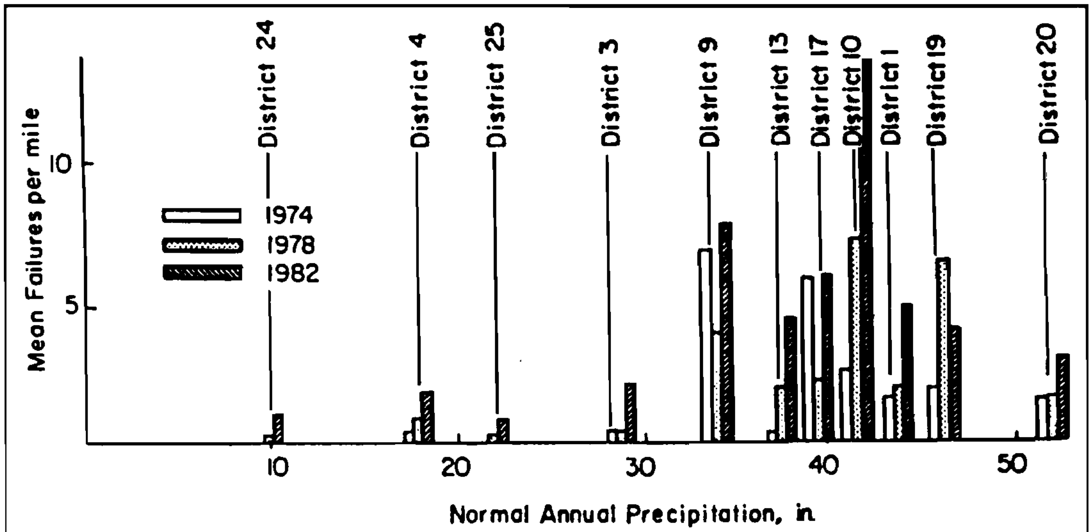


Fig 4.5. Mean failures per mile versus normal annual precipitation.

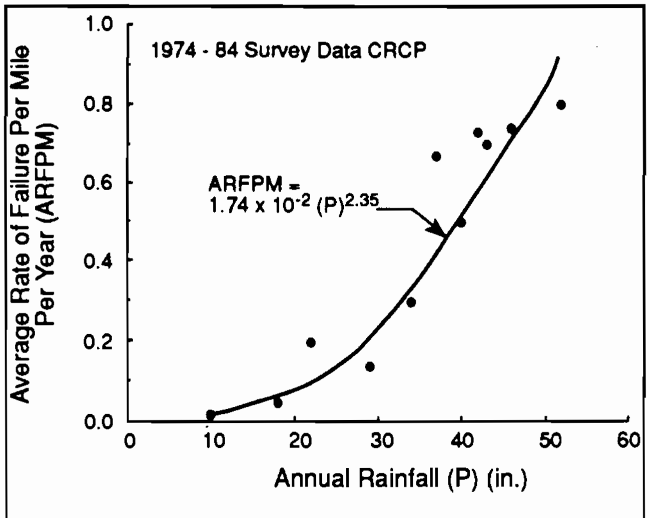


Fig 4.6. Effect of rainfall on the rate of failure per mile per year.

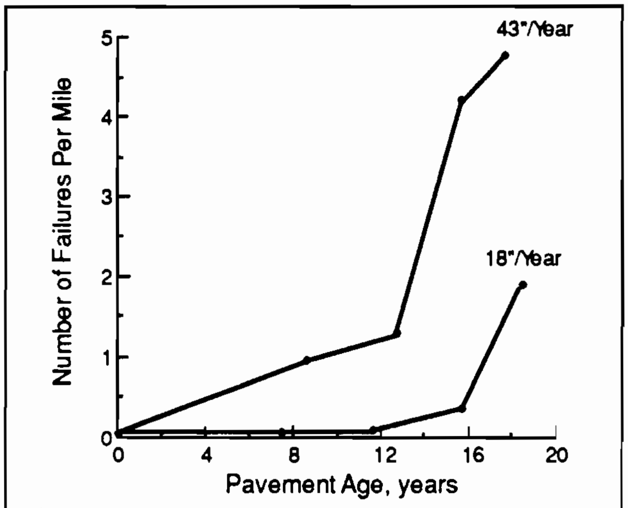


Fig 4.7. Effect of rainfall on pavement performance (subgrade - 100 percent clay).

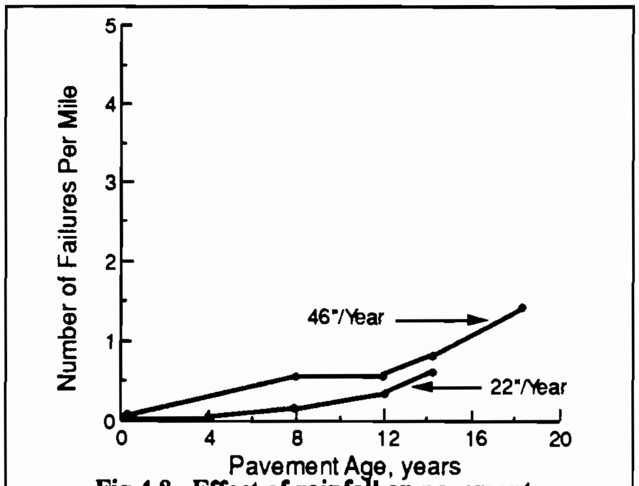


Fig 4.8. Effect of rainfall on pavement performance (subgrade - 0 percent clay).

(5) ***Average Annual Rainfall.*** From Tables 4.1, 4.2, and 4.4, it is evident that the average annual rainfall is one of the most important environmental factors, especially when it interacts with the swelling clay in the surface layer. Therefore, it was selected as a factor of the experimental design.

(6) ***Temperature.*** For reasons similar to those for the average annual rainfall, temperature was considered as an important environmental factor because of its influence on pavement performance. Since the transverse crack development and the crack width are highly related to temperature drop, rather than increase, average annual lowest temperature was selected.

(7) ***Age.*** Pavement age is another important factor that was included in the experimental design. It is not only an indication of traffic growth but also has strong interaction with the environmental factors.

(8) ***Roadbed Grading Type.*** From Eqs 4.6 and 4.7, it is obvious that the roadbed soil resilient modulus, M_R, plays an important role in the characterization of the effective modulus of subgrade reaction. It is known that the value of M_R is not only related to the calculated mean modulus of any specific material at any specific time but is also influenced by the type and size of roadbed grading (Ref 25). However, the roadbed grading type is hardly consistent throughout the entire pavement project. Thus it was chosen as a sub-factor in the experimental design and is described in detail in Chapter 6.

Measurable Performance Variables

From the above studies of rigid pavements regarding the effects of pavement design, construction, environment, and traffic variables on pavement performance, the following variables were selected for measurement in the field. The variables were generated by combining Tables 4.1, 4.2, and 4.4. A detailed description of each of the selected variables is given in Chapter 7.

(1) Crack Spacing,
(2) Crack Width,
(3) Punchouts,
(4) Patches,
(5) Surface Roughness,
(6) Deflections,
(7) Shoulder Condition, and
(8) Traffic (ESAL).

It should be recognized that the distress manifestations observed on overlaid and non-overlaid pavements are different. Therefore, a different set of variables is needed if the pavement section has been overlaid. A detailed description of the following variables is presented in Chapter 7:

(1) Reflected Cracks,
(2) Bond Failures,

(3) Failures,
(4) Patches,
(5) Rut Depth,
(6) Surface Roughness,
(7) Deflections,
(8) Shoulder Condition, and
(9) Traffic (ESAL).

Levels of Experimental Design Variables

Table 4.5 represents the selected levels of each variable as described earlier. The selection of these levels was primarily based on the pavement sections available in the network and the engineering judgement.

Since the subgrade grading type for any particular pavement is not likely to be consistent throughout the entire section, including this parameter as a subdivision factor will reduce the efforts of completing the factorial.

TABLE 4.4. LIST OF DESIGN AND PERFORMANCE VARIABLES FROM THE FIELD SURVEY STUDIES

Serial Number	Experimental Design Variables	Measurable Performance Variables
1	Concrete Materials Coarse Aggregate Type	Crack Spacing
2	Slab Thickness	Crack Width
3	Tempature	Spalling
4	Rainfall	Punchouts
5	Roadbed Soil Type	Shoulder Condition
6	Roadbed Gradng	Roughness
7		Deflection

SUMMARY

This chapter mainly describes the evaluation of all possible variables which have influence on pavement performance. The AASHTO equations, mechanistic models, and some field survey studies of rigid pavement were reviewed and analyzed in order to select the factors and their levels for the experimental design and the variables to be measured in the experimental condition survey.

The selected experimental parameters and their corresponding levels are summarized in Table 4.5.

Due to the different characteristics of the distress manifestations in the overlaid and non-overlaid pavements, two sets of variables were generated as the items for measurement in the experimental condition survey.

After the experimental design and measurable performance variables had been determined, the next step was to collect the information about these design variables for the entire CRCP network. Pavement sections having the same characteristics for any given combination of experimental factors were clustered together. Experimental sections were then randomly selected from the clusters to fill out the factorial. A detailed description of this procedure is presented in the following chapters.

TABLE 4.5. FACTORS AND LEVELS USED IN THE EXPERIMENT DESIGN

		Levels			
	Parameters	1	2	3	4
1	Slab Thickness	6"	8"	9"	13"
2	Coarse Aggregate Type	Siliceous River Gravel	Limestone	--	--
3	Subbase Type	Cement Treated	Asphalt Cement Treated	Crushed Stone	Lime Treated
4	Roadbed Soil	Swelling	Non-Swelling	-	--
5	Average Annual Rainfall	High	Medium	Low	--
6	Average Annual Lowest Temperature	High	Low	--	--
7	Age	≤15	≤15	--	--
8	Roadbed Grading Type	Cut	Fill	At Grade	Transition

CHAPTER 5. DEVELOPMENT OF THE DATA BASE FOR THE EXPERIMENTAL FACTORIAL DESIGN

An unlimited number of variables related to pavement distress manifestations can be utilized to predict the performance of a pavement structure. To insure the quality and homogeneity of the information actually used, an evaluation of all the possible variables was made in Chapter 4. Four types of variables were finally selected and utilized for the experimental design. They are design variables, environmental factors, traffic data, and pavement age. The variables chosen in each type reflect singular and interactive relationships with the various distress manifestations. Information on the variables for each pavement project was collected for the experimental factorial design. The definitions and the procedures of data collection and storage for each selected variable are presented as follows.

DESCRIPTION OF VARIABLES

Design Variables

Three out of seven experimental design factors are design variables. They are slab thickness, subbase type, and coarse aggregate type. In addition, the subgrade grading type is included as a subgroup and is also presented in this section.

(1) ***Slab Thickness.*** This is the topmost layer of the pavement structure and consists of portland cement concrete and reinforcing steel. In the rigid pavement design procedure, a nomograph is used for determining the slab thickness for each effective k-value and some other inputs, such as the estimated traffic, W_{18}, design serviceability loss, ΔPSI, etc. This item was not included in the previous studies because 82 percent of the CRC pavements have thicknesses of 8 inches (Ref 14), and therefore, CRC pavements were considered to have uniform thickness. However, this variable is included in this study and has four categories, 6, 8, 9, and 13 inches. Information on slab thickness can be easily found in the project construction plans which are stored primarily in the Equipment and Procurement Division (D-4), Record Management Section of the Texas SDHPT. For each highway section, it is necessary to know the county and the construction control-section-job number in order to find the corresponding construction plans. It should be mentioned that construction plans of projects (highway sections) which are under construction or newly completed may not yet have been sent to the proper storage location. In that case, the information can be obtained by contacting the highway district office in which the project is located.

(2) ***Subbase Type.*** The subbase is the transition zone between the subgrade and pavement layers. It is designed to provide a stronger and a more uniform base for the concrete layer than is possible from the subgrade alone. The CRCP subbase generally consists of one to three compacted layers of granular or stabilized material. The total effect of the multi-level subbase is a strong, impervious pavement layer capable of supporting a concrete layer. Subbase data utilized in this study included that for various materials stabilized with suitable admixtures. From the project construction plans mentioned above, the subbase type, i.e., asphalt treated, portland cement treated, lime treated, or natural crushed stone, and its thickness can be found.

(3) ***Coarse Aggregate Type (CAT).*** Based on the AASHTO guides (Refs 19 and 20) the mix design and material specifications for the portland cement concrete should be in accordance with or equivalent to the requirements of the AASHTO guides "Specifications for Highway Construction" and "Standard Specifications for Transportation Materials." No further requirements or information is concerning the type of coarse aggregate used in the concrete mix design. However, it is recognized that the coarse aggregate type has significant influence on pavement performance, as discussed in the previous chapter. It not only affects the load transfer coefficient, J, and the concrete strength, but also governs the thermal coefficient (a_c) of the concrete. Two typical types of coarse aggregates, limestone and siliceous river gravel, were included in this study. Compared to finding items (1) and (2), finding the coarse aggregate type requires more effort. It is recorded in the Materials Testing Reports, which are in Folder #5 of the Project Correspondence. However, the CAT actually used in the pavement slab is usually not reported in a single testing report. This is because the contractors usually submit more than one kind of coarse aggregate type to the Materials and Tests Division (D-9) for specifications examination before they start the field construction. Each of these examinations results in one "Aggregate Test Report." The contractors will finally choose one of the approved aggregate for use. A quick way to check the coarse aggregate finally used is to find the source(s) (company and pit) of the coarse aggregate from the "Core Test Report," match the source(s) with one of the "Aggregate Test Reports," and then read the coarse aggregate type from the latter. One thing that should be mentioned here is that the Materials Testing Reports and Project Correspondence are stored in three different ways, based upon the "closed" date of the construction files and records. If the closed date is about four or five years ago, the project could have been filed on microfilm. If the project was completed more recently, the records may still be stored as loose paper copies. However, if the project is under construction, the incomplete files of Materials Testing Reports are at the Materials and Tests Division (D-9), Camp Hubbard, Austin, Texas. For the first two cases, the microfilms and loose paper copies are both available in the D-4, Records Management Section of the SDHPT.

(4) ***Roadbed Grading Type.*** As described earlier, this item was included in this study as a subgroup factor. In other

words, it is not used as a factorial factor in the experimental design, as are slab thickness, subbase type, and coarse aggregate type. This is mainly because the roadbed grading type varies from place to place along a pavement project and also differs from project to project. Information on this item is difficult to obtain unless a field trip is taken. Therefore, the data base did not record this information before the proposed condition surveys. The definition used in this study for cut and fill is that a difference in height of 5 feet or more between the surface of the subgrade and the adjacent land, as shown in Fig 5.1, determines the existence of a cut or fill.

Environmental Factors

The environmental factors chosen for this study represent the various geographical conditions that may contribute to the deterioration of pavement performance. The following variables were included in this group.

(1) ***Average Annual Rainfall.*** The data collected for this parameter are the arithmetic means computed over a time period spanning three consecutive decades, 1951 - 1980. A contour map (Fig 5.2) showing the normal annual precipitation over the entire state can be obtained from the Weather and Climate Section, Texas Department of Water Resources. This map is based on data collected by the National Oceanic and Atmospheric Administration, U.S. Department of Commerce, for the period 1951-1980. The average annual rainfall for each pavement section can be obtained by roughly locating the pavement section on this map.

(2) ***Average Annual Lowest Temperature.*** The data for this parameter can be collected in the same manner as for item (1). These values are also the arithmetic means for the period 1951-1980. There are 160 temperature or temperature/precipitation stations in the state of Texas. Data collected from these stations were published in a report titled "Monthly Normals of Temperature, Precipitation, and Heating and Cooling Degree Days 1951-1980, Texas" (Ref 27). From this publication the average minimum monthly temperature (AMMT) of the coldest month for each station was read. It was found that the lowest AMMT for the 160 stations during 1951-1980 always happened in January. Therefore, it was assumed that the January data AMMT can be used to represent the average annual lowest temperature when there are no other data available. The stations and the temperature data are marked on a Texas Climatological Stations Map, and the average annual lowest temperature for a pavement section can be obtained, again by roughly locating the section on the map.

(3) ***Roadbed Soil Type (Swelling Characteristics).*** The surficial soil characteristic is indicated by the presence of active clay in the surface layer. The specific soil type is not important per se; the soil used as the subgrade is treated to virtually uniform specifications and possesses similar properties for all CRCP. The roadbed swelling characteristic can affect the rate of serviceability loss. Swelling refers to the localized volume changes that occur in expansive roadbed soils as they absorb moisture. A drainage system can be effective in minimizing roadbed swelling if it reduces the availability of moisture for absorption. However, these characteristics are more relevant to performance predictions than is the soil classification and are therefore more indicative of behavior characteristics. The swelling characteristic of roadbed soil underneath the pavement structure is obtained by approximately locating the pavement section on the Texas Land Resources Map (Ref 28). It is not surprising to find that there is more than one type of soil under a pavement section if it has a relatively long length. In order to simplify this situation, the major kind of soil that dominates the entire section was determined. In other words, the type of soil that occupies the largest portion of the section characterizes the swelling property for that pavement section. In this study, the swelling characteristic was divided into two categories, "low" and "high." A pavement section which contains "low to medium" swell potential soil is grouped into the low swell category, while one that contains "medium" and "medium to high" swell potential soil is grouped into the high swell category.

Traffic Data

The 18-kip equivalent single axle load (ESAL) is one of the most important factors in pavement design, maintenance, planning, and research. However, it is also the most difficult parameter to obtain because of the complexity involving the AADT, truck percentage, truck category distribution, and truck weight distribution. So far there is no

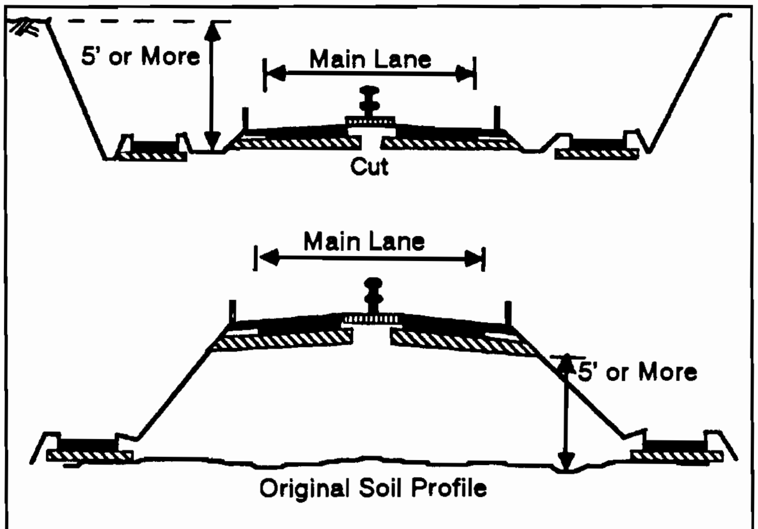


Fig 5.1. Layout of the subgrade grading type, cut and fill.

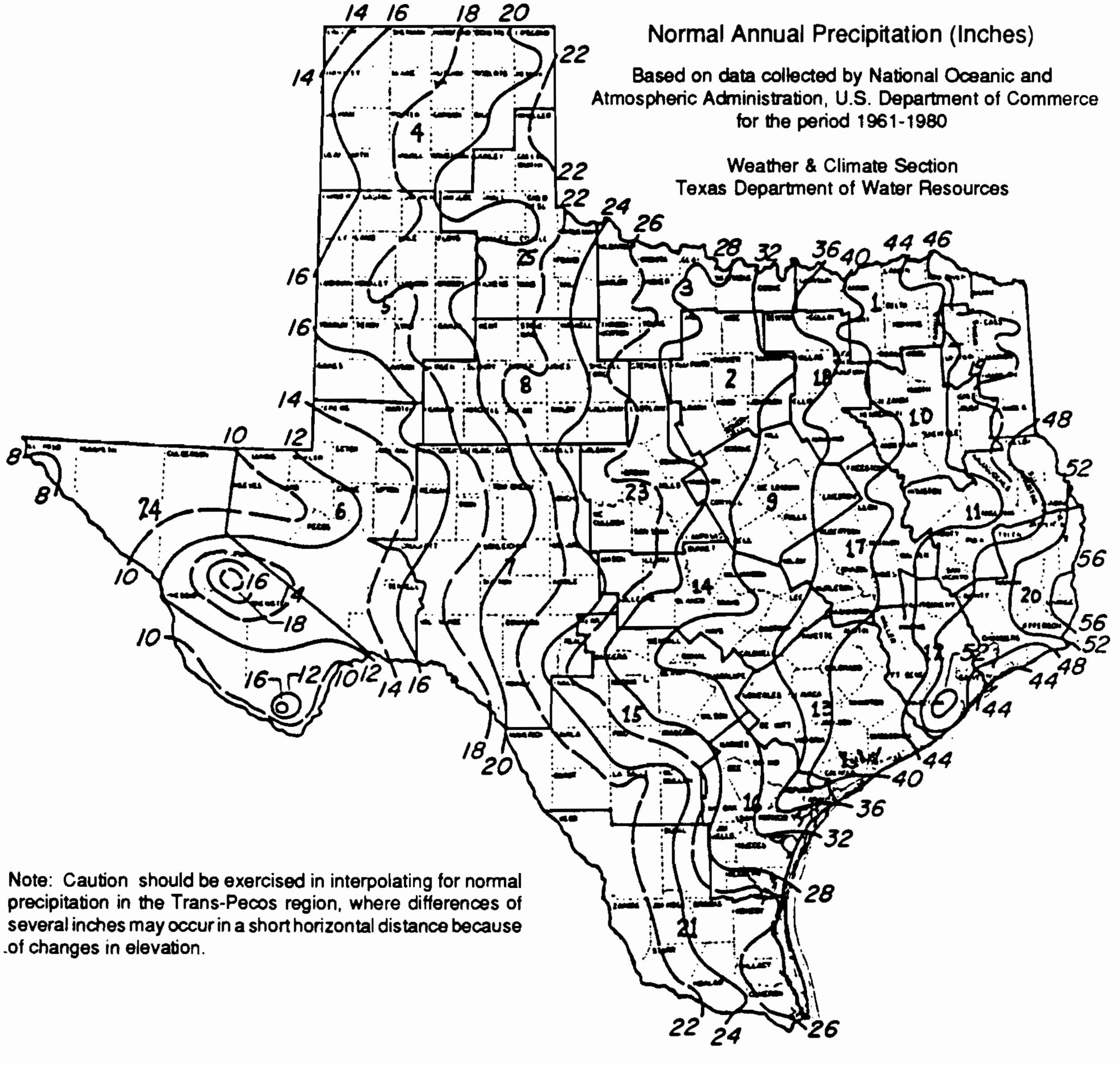
complete set of 18-kip ESAL data available for the Texas highway network. Therefore, the AADT was obtained and stored in the database for this study.

(1) ***Average Annual Daily Traffic (AADT).*** There is a set of district highway maps providing the AADT data for each highway, including the farm to market roads (FM). This set of maps is published by the Texas SDHPT each year. A historical record of the AADT can be obtained from a series of AADT maps for the years of interest. It should be mentioned that there are only 138 traffic counting stations in the State of Texas (Ref 29). In other words, only 138 highway sections have actual surveyed AADT data while others have estimated data. In this study, the AADT data for the year 1985 was included since the data for 1986 were not available at that time. This information should be updated and included in the data base from time to time. In addition, the average AADT growth rate is also included. Its description is given below.

(2) ***Average AADT Growth Rate.*** This parameter is the arithmetic mean of the yearly AADT percent variation computed over the time period of 1970 to 1985. Data for the AADT percent variation by years are provided in the "Traffic Annual Report, Table 4," published by the Texas SHDPT (Ref 30).

Pavement Age

This is the arithmetic subtraction of the completion year of project construction and the current year. In the data base, only the construction completion year is included. This information was obtained from the report of "Project Iden-



Normal Annual Precipitation (Inches)

Based on data collected by National Oceanic and Atmospheric Administration, U.S. Department of Commerce for the period 1961-1980

Weather & Climate Section
Texas Department of Water Resources

Note: Caution should be exercised in interpolating for normal precipitation in the Trans-Pecos region, where differences of several inches may occur in a short horizontal distance because of changes in elevation.

Fig 5.2. A contour map of the normal annual precipitation in Texas.

tification Information" generated by computer program "CONSRV," which is described in Chapter 2.

In addition to the above variables, the beginning and ending mileposts of each pavement project are also recorded in the data base. Data collected for this item were obtained from the report of "Project Summary Sheets" generated by "CONSRV."

It is not out of place to mention that the collection of data for most of the above items was very time consuming work. It also needed personal judgement from time to time when the desired information was not clear or readily available.

DATA STORAGE

Several computer data-base packages were considered in selecting an appropriate one for this study. The personal computer version of the Statistical Analysis System (SAS) (Ref 31) was finally chosen because it is convenient to use, has excellent data analysis functions, is a friendly operating system, and is easy to access.

Data were input using a free format, i.e., leaving blanks between the input values. Zero was used when the data were not available. Each pavement section takes two lines in this database. The first line includes, in order, highway number, the Center for Transportation Research (CFTR) number, county, control-section-job number, length, slab thickness, coarse aggregate type, subbase type, soil swelling characteristic, average annual rainfall, average annual lowest temperature, and construction completion year. The second line consists of the beginning and ending mileposts, 1985 AADT, and average AADT growth rate. All the data were stored as a SAS data set under the file name "CONDSUY.DAT."

Since the raw data were stored using a free format and sometimes in random order, i.e. data were not ordered by the CFTR number, data rearrangement is necessary in order to sort the data set in some definite order. Appendix B is the output of the total CRCP network data sorted by the District and CFTR numbers.

SUMMARY

This chapter primarily describes the procedures for data collection and storage for the experimental factorial design. Four types of variables, design variables, environmental factors, traffic data, and pavement age, were selected in this study. In addition, mileposts for both beginning and ending points of each project were included as supplementary information for project location identification. Sources for the information on each parameter are summarized in Table 5.1.

The PC version of the Statistical Analysis System was chosen for the data storage for this study. This is because it is convenient to use and it has an excellent data analysis function and a friendly operating system. A complete and reordered output of the entire CRCP network data of Texas is given in Appendix B.

TABLE 5.1. SOURCES OF THE PARAMETERS USED IN THE EXPERIMENTAL FACTORIAL DESIGN

Factorial Parameters	Sources
Slab Thickness	SDHPT Project Construction Plans
Subbase Type	SDHPT Project Construction Plans
Coarse Aggregate Type	Material Testing Reports -- Folder # 5 of Project Correspondence
Natural Soil Type	Weather and Climate Section, Texas Department of Water Resources
Average Annual Rainfall	Texas Land Resources
Average Annual Low Temperature	Weather and Climate Section, Texas Department of Water Resources
Average Annual Daily Traffic (1985)	Traffic Annual Report, Table 1 Texas SDHPT
Average AADT Growth Rate	Traffic Annual Report, Table 4 Texas SDHPT
Construction Completion Year	Report of Project Identification Information

CHAPTER 6. EXPERIMENTAL DESIGN AND SITE SELECTION CRITERIA

INTRODUCTION

This chapter describes the experiment designed to collect highway pavement data for developing a historical deterioration data base and performance prediction model. Data for the various experimental factors have been collected and stored as an SAS data set. However, since only limited levels of each factor were chosen for the experimental factorial, data reduction from the entire CRCP network became necessary in order to create the appropriate population for each factorial cell. A sampling procedure was adopted to select the pavement projects for the condition survey from each population.

A description of the criteria used to select the test sections is also included in this report. Proposed criteria (Ref 32) were presented to SDHPT personnel in a joint meeting with the CTR staff during a committee action meeting. Recommendations made by the committee members are presented in this chapter.

EXPERIMENTAL DESIGN

An experimental design is a plan for the orderly collection and analysis of data (Ref 33). Since a number of different factors affect pavement performance, a factorial experiment was developed so that the effects of various factors could be investigated simultaneously. The factorial approach is efficient and results in a considerable saving of time and resources, in comparison to the alternate procedure of conducting separate experiments, each of which deals with a single factor. Moreover, in a factorial experiment, the effects of each factor can be examined individually and interaction with other factors can be studied. Thus, a great deal of information is accumulated about the effects of the factors and about their interrelationships (Ref 34).

Candidate Test Sections: Existing Highway Projects vs. New Projects

Theoretically, highway projects involved in the experimental design are of two general types: (1) those test sections which are selected from existing highways and (2) those test sections which are selected from new pavements (Ref 35).

Generally, every section in the existing highway system can be regarded as a candidate test section, but one purpose of the selection guidelines is to suggest how essential information can be obtained through the study of relatively few sections and test sites. A major advantage of an existing pavement study is that a wide range of loads and performance can be studied at the outset, as opposed to the many years that may be required for the complete observation of new pavements.

There are several inherent difficulties associated with using only existing pavements. In the first place, it may be virtually impossible to find suitable pavement projects to represent variations that can be used either to support or to modify the performance relationships that were developed at the Road Test. For example, it might be desirable to find if the effect of surface thickness on performance is similar to that at the Road Test or not. However, if there is little or no variation in surface thickness in the whole system of pavements within the state, no such effect can be studied. It is clear that a number of relationships developed at the Road Test cannot be completely checked or translated by existing pavement studies, mainly because certain Road Test structural conditions do not exist in the local highway system.

It may also be quite difficult to obtain reliable traffic and load data for existing pavement sections. Since performance is defined in terms of accumulated ESAL, adequate load histories are essential to the study of pavement performance.

Another problem is the determination of initial serviceability and strength conditions for an existing pavement. Although laboratory tests of existing materials can indicate present and future strengths, there is no method for estimating the extent to which the initial strengths have changed.

Another difficulty is that any nominal condition of loading, environment, or structure is likely to be accompanied by a rather long list of variables (e. g., construction variations) whose separate effects cannot be identified. Thus a reliable analysis will require an average performance of a large number of sections having the same nominal characteristics.

Several obvious advantages are inherent in the study of new experimental pavements. The objectives for such a study can set out very specific relationships to be studied with the precision that is built into the experimental design and construction control for the test sections involved. Thus, it is likely that these experimental sections will be more adequately identified than existing pavement sections and that less extraneous variation will be connected with the study. As a result, it may be expected that, with fewer test sections, answers to specific questions will be more definitive than can be determined from existing pavement studies.

Another major advantage with new experimental test sections is that additional factors of interest not appearing in existing pavements can be introduced. Outstanding examples in structural design include the increasing practice of subbase stabilization and the interest in composite pavement design.

As with the AASHO Road Test itself, every experimental study has limitations. One disadvantage of a new pavement performance experiment is that several years of observations may be required to study the ultimate performance of test sections, especially for those sections that are designed with high reliability relative to their expected traffic and environmental exposure. If the structural variables of the experimental sections are all at high level and cover a very narrow range, the differential effects of experimental factors on performance may not be observable for ten years or more and, in fact, may not be of any practical significance. In all studies, however, it is possible to analyze section to section variations in strength.

In summary, it is assumed that there are good reasons, as well as disadvantages, for conducting studies of both existing pavements and new pavements, and that the first type of research will usually be used. Therefore, in this study only existing CRC pavements were considered. Suggestions and recommendations from this study are expected to result in guidelines for new pavement studies that should be made at a later date.

Data Reduction

Complete information on the experimental factors has been collected for the entire CRCP network of Texas. There were 355 CRCP projects in the network, but only 262 projects qualified for the experimental design because of their corresponding levels of parameters. Pavement projects which had slab thicknesses other than 6, 8, 9, or 13 inches or a coarse aggregate type different from limestone or siliceous river gravel were excluded from the experimental design. Nevertheless, all the 355 projects were stored in the data base. Owing to the policies of the FHWA regarding roadway construction during the period from 1950 to the 1970's, a very large portion of the CRCP sections in Texas have slabs 8 inches thick. Table 6.1 shows the distribution of slab thicknesses of the 262 pavement projects selected for this study.

Despite the unbalanced distribution, pavement thickness remains a design parameter in the factorial in order to evaluate its effects on pavement performance. It was noted that 34 out of the 262 pavement projects had been overlaid once or more during their service lives. In order to compare the pavement performance of overlaid and non-overlaid sections, the pavement projects were separated into two categories, overlaid and non-overlaid. Hence, two sets of factorials were formed and the overlaid set has only one-eighth of the data of the non-overlaid set. The emphasis was, therefore, placed on the non-overlaid factorial. A series of factorial tables are shown in Appendix C.

Experimental Factorial

It should be noted that the procedure for factorial design used in this study is different from the conventional design procedure. The latter uses the completely randomized design method, in which the experimental units are drawn from the populations and assigned to all treatment combinations of the levels of all the factors as randomly as possible. The method used in this study is more like stratified sampling.

The CRCP segments were first divided into groups of categories based upon the properties of the experimental design factors, and then independent samples within each group or stratum were selected into factorial cells (treatment combinations). Since each highway segment (experimental unit) has been built and opened to traffic for a known length of time, all the properties of the experimental design factors are fixed (i.e., coarse aggregate type, subbase type, geographic location, temperature, moisture and natural soil type, etc.). This realistic situation makes the setup of the factorial design different from that for the controlled experimental design, which randomly assigns untreated, uniform experimental units into all treatment combinations. Therefore, as many experimental units as are needed for the controlled experimental design can be prepared or produced in order to create a balanced factorial. In other words, there are always enough experimental units for each treatment combination to receive one or more units as desired and no cell is blank. However, since highway sections which had been in service were the only available experimental units in this study and it was impossible and not feasible to obtain hundreds of highway sections and randomly assign them to all treatment combinations (slab thickness, temperature, rainfall, etc.), unbalanced factorials were unavoidable.

Sampling Within Factorial Cells

Highway projects that incorporated as big a variety of construction materials and techniques as possible and were built over a long period of time had to be chosen. Since there was a desire to select highway projects from all over the state, it was assumed that a uniform maintenance program and technique was executed throughout the State. This eliminated the possibility of a variation in maintenance strategy, which has an influence on pavement performance. Other requirements were the inclusion of a wide variety of roadbed types, a variation in the geometry, and a change in terrain that could be associated with drainage characteristics.

As mentioned earlier, unbalanced factorials are unavoidable in this experimental design study, and some factorial cells have more than ten highway projects while others have only one, two, or even no experimental units. The first criterion of test projects selection is concerned with the number of projects that should be randomly selected

TABLE 6.1. DISTRIBUTION OF SLAB THICKNESSES OF THE 262 CRCP PROJECTS

Thickness (inches)	Overlaid	Non-Overlaid	Subtotal
6	1	23	24
8	25	190	215
9	8	10	18
13	0	5	5
Subtotal	34	228	$\boxed{262}$

from each factorial cell to represent that specific treatment combination. After consulting with a statistician, the following rules were determined:

(1) for factorial cells which have one to four highway projects, one project was selected;

(2) for factorial cells which have five or more highway projects, two projects were selected.

The sample project must be random and without replacement. There were 112 pavement projects selected for the factorial design, and they are presented in Appendix D. Tables 6.2 and 6.3 are summaries of the 112 pavement projects. The summaries show the distribution of overlaid and non-overlaid projects for each slab thickness category and the distribution of pavement projects for each district within the state of Texas.

SELECTION OF TEST SECTION LOCATIONS

The test sections to be investigated were selected with a regression analysis of data in mind. However, since the factorials are unbalanced, there is no guarantee of success in the regression analysis. Therefore, considering the possibility of a future analysis using other techniques, such as comparisons between sections, the layout had to be as versatile as possible.

A set of printouts for the selected highway projects is shown in Appendix E. Information listed in the printout for each selected project provides a detailed description of the environmental and construction variables of the selected projects. Furthermore, it furnishes the project starting and ending mileposts, the easiest way to identify the project location. The test sections selected from the projects are the survey units on which the condition surveys will be conducted in the future. The criteria for selecting these test sections are given in the following paragraphs.

(1) ***Length of Test Section.*** The unit length of sections for the condition survey was determined to be 1000 feet (0.2 mile) because that was considered to be the average length for uniform roadbed construction (cut, fill, or at-grade).

(2) ***Number of Test Section Selected from Each Project.*** The number of test sections from each project is dependent on the length of that specific project. If its length is shorter than or equal to 3.0 miles, one cut, one fill, one at-grade, and one transition between a cut and a fill should be selected. If the project is more than 3.0 miles long, two cut, two fill, one at-grade, and one transition should be selected. The definitions of cut and fill are given later. If it is impossible to find the required number of test sections in any specific project, a note should be made on the survey sheet. A test section with either cut, fill, at-grade, or transition can be in the tangent part, or the horizontal curve, of the highway section.

(3) ***Cut and Fill.*** A cut section is defined as a section which has a difference in height of 5 feet or more compared to the adjacent land. Likewise, a fill section is defined as a section which is 5 feet or more higher than the adjacent land. Figure 6.1 shows a typical longitudinal profile, which includes a cut, a fill, an at-grade, and a transition.

(4) ***Tips for Test Section Selection.***

   (a) Select the at-grade part of the project, if possiblwe. If it is necessary to select a hillside, do not pick the down-hill section, for the sake of safety.

   (b) Do not select any test section close to or on a bridge.

   (c) Do not select a test section close to a highway entrance, ramp, or exit.

It is believed that test sections can be selected successfully if the above criteria are followed. After the surveyors select the test section, they have to mark the section with spray paint. The marks should be made on the shoulder near the edge of the outside lane every 200 feet. A detailed

TABLE 6.2. DISTRIBUTION OF 112 OVERLAID AND NON-OVERLAID PAVEMENT PROJECTS SELECTED FOR THIS STUDY

Thickness (inches)	Overlaid	Non-Overlaid	Subtotal
6	1	11	12
8	14	74	88
9	3	5	8
13	0	4	4
Subtotal	18	94	112

TABLE 6.3. DISTRIBUTION OF 112 SELECTED PAVEMENT PROJECTS OVER THE DISTRICTS OF TEXAS

District	Overlaid	Non-Overlaid	Subtotal
1	4	2	7
2	3	16	19
3	0	10	10
4	3	5	8
5	0	4	4
9	2	1	3
12	0	2	2
13	4	11	15
15	4	1	5
17	3	3	6
18	4	14	18
19	4	0	4
20	1	4	5
24	4	3	7
			Total = 112

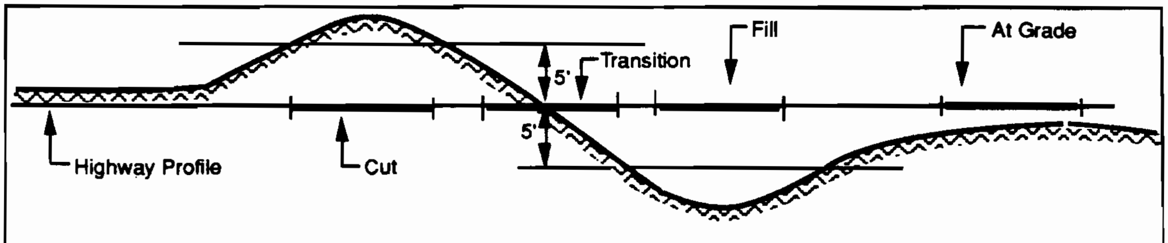


Fig 6.1. A highway project with cut, fill, flat, and transition sections.

description of the marking procedure is presented in Chapter 8.

SUMMARY

Information with respect to the experimental factors has been collected and stored as an SAS data set. The complete CRCP network consisted of 355 highway projects with various factor combinations. However, since only a limited number of levels of each factor were chosen for the experimental design, 262 out of 355 pavement projects were actually included in the design as the population of factorial cells (Appendix C). A sampling method was used to select the pavement projects for the condition survey from each factorial cell. For factorial cells which have one to four highway projects, one project is selected; for factorial cells which have five or more highway projects, two projects are selected.

Finally, two sets of factorials, overlaid and non-overlaid, were created in order to separate the highway sections into their corresponding categories (Appendix D). There were 112 pavement projects included in the two sets of factorials. A comparison of pavement performance for these two categories should be studied in the near future.

Owing to the realistic condition of this experimental design, the design procedure is different from that for a controlled experimental design and an unbalanced factorial is unavoidable.

Several assumptions and restrictions that influence the site selection were presented. They can be summarized as follows:

(1) A uniform maintenance program and technique were used throughout the Districts of Texas.

(2) The length of a survey unit was 1000 feet (0.2 mile).

(3) The number of survey units that should be randomly drawn from each selected section depend on the length of that specific section. It was concluded that (a) for highway projects which are shorter than or equal to 3.0 miles long, one cut, one fill, one transition, and one at-grade survey unit should be selected; (b) for highway projects which are more than 3.0 miles long, two cut, two fill, one transition, and one at-grade survey unit should be selected.

(4) The selection of survey units must be random and without sample replacement.

CHAPTER 7. ESTABLISHMENT OF MEASUREMENT METHODS AND DEVELOPMENT OF PILOT STUDY

INTRODUCTION

As described in Chapter 4, two categories of variables, non-overlaid and overlaid, are to be measured as a part of the experimental design. In each category, many variables are amenable to measurement, and for each variable there may be many alternative measurement procedures, each of which gives a certain amount of information about the variable being measured.

It was pointed out in the early chapters that an important aspect of this study is an investigation of the influence of variables, such as pavement design, construction materials, environmental factors, and traffic, on pavement performance. To do this investigation it will be necessary to include in the measurement program techniques for obtaining parameters required for the investigation.

Several previous studies were reviewed (Refs 3, 9, 21, 35, 36, and 37) and the measurement methods for previously measured variables were established. Survey forms were then developed for use in an experimental condition survey based on the requirements of the measurement techniques. Finally, a pilot study was scheduled prior to the network experimental condition survey since it could provide valuable information to modify the survey procedures and measurement methods, if necessary. A detailed description is presented in the following sections.

DEFINITIONS AND METHODS FOR MEASUREMENT OF DISTRESS MANIFESTATIONS

The field work consists of two separate items, a general condition survey and a diagnostic study. This section describes the definitions and methods developed and adopted for collecting the field measurements conducted in connection with the general condition survey and diagnostic study. The general condition survey is described first, because most of the items surveyed in this category need visual measurements only. The others may require some simple tools, such as a rolatape measuring wheel, a tape recorder, or a microscope. The diagnostic study will start after the completion of the general condition survey. The measurement program will be more extensive than the general condition survey. The physical measurements consist of Dynaflect deflections and surface profile measurements.

GENERAL CONDITION SURVEY

It was mentioned earlier that the distress manifestations observed on the non-overlaid and the overlaid pavements are different. The information and data collected for the non-overlaid pavements in the general condition survey are described below.

Non-Overlaid Pavements

(1) ***Crack Spacing.*** Crack spacing is the distance in feet between transverse cracks. Measurement of crack spacing is very simple and straightforward and only the outside lane of the roadway is measured. It was decided that the actual crack spacing of the first 200 feet of the test section will be measured to the nearest 0.1 foot. The cumulative distance from the starting point to each crack was recorded by using a rolatape and a tape recorder. For the remaining 800 feet of the test section, only the number of cracks was counted. Data were recorded as the number of cracks for every 200 feet. The mean crack spacing of the entire test section can be computed by dividing 1000 feet by the total number of cracks.

(2) ***Crack Width.*** Transverse crack width will be measured with a microscope with a graduated eyepiece capable of measuring to the nearest 0.001 inch. Since it is known that crack width varies with slab temperature (Ref 38), it is recommended that the crack width for some specific pavements be measured several times during the day so that the rate of change of crack width for various pavement temperatures can be obtained. Since this measurement procedure is time consuming, it is not feasible to measure all selected test sections. Most of the test sections will be measured for a certain time of the day only.

It has been found that there is no significant difference in crack width at different locations along any specific transverse crack (Ref 21). Thus, the measurement can be taken anywhere transversely across the crack. In this study, measurements of crack width will be taken every 200 feet at a location close to the edge of the outside lane. In an attempt to obtain measurements representative of the true crack width, the microscope should be focused some distance down in the crack, rather than on the surface. Usually, it is possible to register on the matching faces of a broken piece of aggregate. This method is believed to give fairly reliable results, although it may not be extremely accurate.

Since the measurement of crack width requires that the microscope be placed on the cracks, it is necessary to block traffic for safety reasons. Therefore, the crack width measurements will be taken during the diagnostic study, while the deflection and roughness measurements are recorded.

(3) ***Punchout.*** A punchout is defined as closely spaced transverse cracks linked by longitudinal cracks to form a block. A minor punchout is defined as a condition where, although a block has formed, no sign of movement under the traffic is apparent (Fig 7.1). The cracks surrounding the minor punchout are narrow and few signs of spalling are apparent. A severe punchout occurs when the block moves under the traffic. The surrounding cracks will be fairly wide and signs of pumping around the edge of the

block may be apparent (Fig 7.2). The numbers of minor and severe punchouts per 200 feet are recorded separately on the survey sheet.

(4) ***Repair Patches.*** Severe punchouts are repaired by patching the pavement. A repair patch is defined as a repaired section of the pavement where the repair work has been carried out to the full depth of the concrete slab. Asphalt concrete repair patches and portland cement concrete repair patches are recorded separately from each other. There are no notes to be made in regard to the condition of either repair. However, the size of the patch is recorded. A scale has been provided by dividing the sizes into three categories, namely, 1 through 50, 51 through 100, and greater than 100 square feet. The sizes and numbers of all patches per 200 feet are determined and the category is recorded on the survey sheet.

(5) ***Shoulder Condition.*** It is necessary to record whether there is any distress on the shoulder itself, such as at the joint between the pavement and the shoulder; whether it has opened up, or been repaired; and any failure in the area. Comment should also be made concerning the surface of the shoulder: whether it has been repaired, it shows any signs of scuffing, or there is a great difference in level between the shoulder and the pavement. Any occurrence of alligator cracking and shoving on the shoulder should be noted. This information usually gives a good indication of any subsurface drainage problems.

Overlaid Pavement

As a highway pavement reaches its terminal condition from either the user's point of view (i.e., serviceability rating or index) or the highway engineer's point of view (structural capacity), major rehabilitations are considered as necessary for restoring the riding quality and/or skid properties and prolonging the useful life of the highway pavement. Laying a new layer, or overlay, over the existing pavement, is the most common rehabilitation practice.

An overlay is classified as either flexible or rigid. Flexible overlays include those that are made up of asphaltic concrete or asphaltic concrete over a granular base. At the other end of the spectrum, rigid overlays may consist of plain, simply reinforced, or continuously reinforced concrete pavements.

Since most of the existing overlays on the CRC pavements of Texas are flexible, and the distress manifestations of rigid overlay are similar to those of CRC pavements (Refs 39 and 40), the emphasis in this section is on the distress types associated with asphalt concrete overlay.

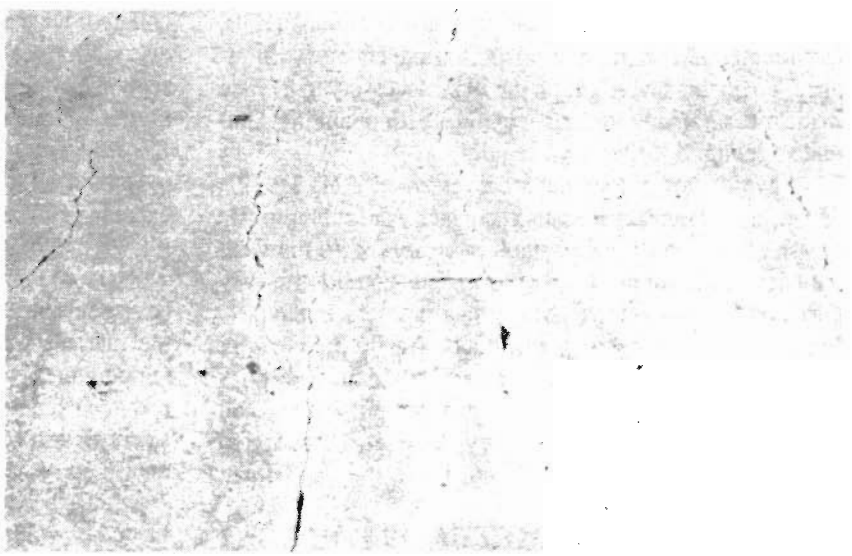


Fig 7.1. Minor punchouts.

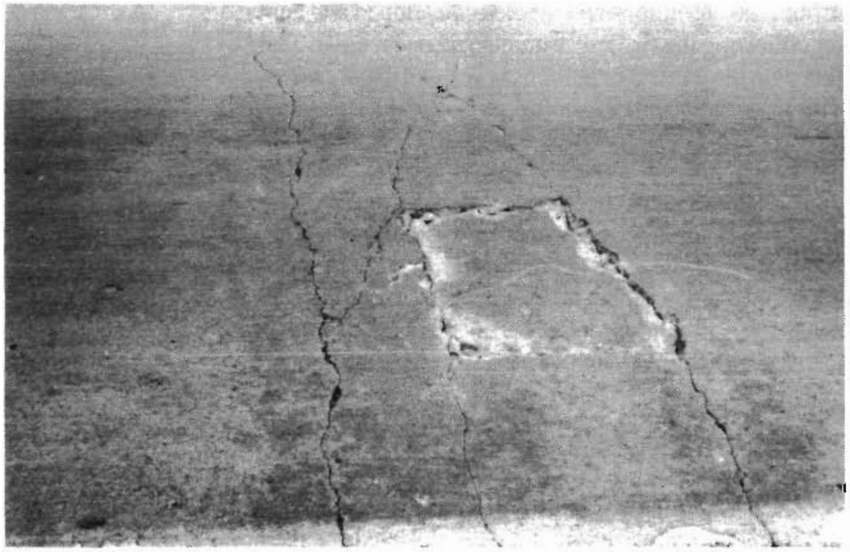


Fig 7.2. Severe punchouts.

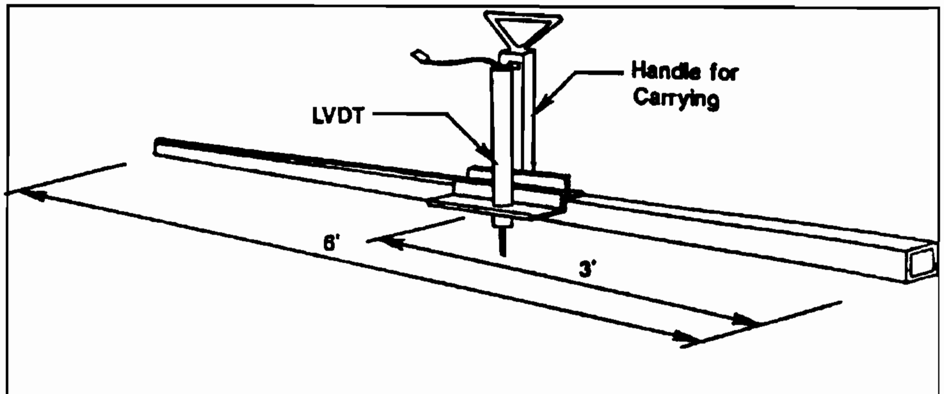


Fig 7.3. The rut depth measuring gauge.

(1) ***Reflected Cracks.*** Cracks and joints of the underlying pavement may reflect onto the upper overlaid layer. The condition before overlaying is recorded and if a crack appears in the same location after the overlay is placed, it is recorded as a reflected crack. The number of reflected cracks is recorded for every 200 feet of the test section.

(2) ***Bond Failures.*** A bond failure occurs when the overlay separates from the underlying layer of an area of the pavement, exposing the original pavement. The information recorded for this distress is the presence or absence of bond failure. Thus, "yes" (Y) or "no" (N) is recorded on the survey sheet.

(3) ***Failures.*** Punchouts and patches which have reflected through and which will soon require patching are called failures. The number of failures is entered in the survey sheet for every 200 feet.

(4) ***Patches.*** Repaired failures found in the overlay are recorded as patches. Similar to the recording of failures, the number of patches is recorded for every 200 feet of the test sections.

(5) ***Rut Depth.*** Rutting is a form of permanent deformation in the wheel path caused by consolidation of one or more of the paving layers. The device shown in Fig 7.3 is used to measure the rut depths of the ACP overlays. This rut depth gauge uses an LVDT to measure the rut depth in the wheel path (Ref 41). Measurements are taken at every 200 feet. Maximum rut depth is measured by moving the gauge transversely across the road within the wheel track area until a maximum reading is obtained. Data for the maximum rut depth for every 200 feet are recorded on the survey form. Since the measuring gauge must be placed on the traffic lane, it is necessary to block the traffic, and, therefore, the rut depth will be measured along with the diagnostic study.

(6) ***Shoulder Condition.*** This item will be measured similarly to that described for the non-overlaid pavements.

Diagnostic Study

After completion of the general condition survey, a diagnostic study will be carried out to obtain more valuable information about the condition of the pavement network. This study is scheduled to be conducted in the near future. All the pavement projects selected for the general condition survey are also the candidates for the diagnostic study. As described earlier, this study consists of surface deflection measurements using the Dynaflect or any other device, and surface profile measurements using the Mays Ride Meter or any other device. A general description of each of these measurements, including its device, functions, and operating characteristics, is given in the following paragraphs.

Deflection Study

One of the best methods for evaluating the condition of the pavement structure along the length of a road involves deflection measurements taken at fixed intervals along the road. Using this information, it is possible to divide the road into sections as well as to determine overlay thickness along the highway, if an overlay is necessary.

The Dynaflect has traditionally been used for structural evaluation of rigid pavements in Texas. The Dynaflect system and its operating characteristics are discussed in Refs 42, 43, 44, and 45. The Dynaflect is a trailer-mounted device which applies a sinusoidal force of relatively light magnitude on the pavement surface. Through the research studies, it has been found that the Dynaflect deflections are significantly influenced at the pavement edge and corner by temperature differentials in the slab (Ref 46). These factors and some unusual field results have suggested that special problems may exist in the evaluation of rigid pavements. The capability of the Falling Weight Deflectometer (FWD) to induce a transient pulse on the pavement surface similar to the load of a moving truck wheel and to vary the load amplitude suggest it is a reasonable choice for rigid pavement evaluation (Ref 47).

The FWD is a pavement loading device used to produce transient impulse forces. The load or equivalent analysis is applied to the pavement through a circular loading plate. The applied load, measured by a load cell above the loading plate, produces a corresponding deflection of the pavement structure. This deflection is measured by seismic deflection transducers placed at selected points to determine the deflection basin. Basically an FWD applies an impulse load by dropping a known mass from a predetermined height. The mass falls on a foot plate connected to a rigid base plate by rubber buffers, which act as springs. Figure 7.4 illustrates the FWD loading and deflection measuring layout.

Purpose and Use of Deflection Measurement

(1) ***Structure Evaluation.*** Monitoring pavements for structural adequacy is desirable before performing any major maintenance and rehabilitation work or for checking if a high level of distress is indicated by a condition survey. Structural monitoring is performed by making deflection measurements along the road. Subsequently the deflection data are analyzed to estimate the structural adequacy by using an empirical, allowable deflection approach or a mechanistic approach using layered theory computation.

(2) ***Materials Characterization.*** The FWD deflection basin measured on an existing pavement is also used to back-calculate Young's Moduli for the pavement layers. This approach reduces the need for characterization of the pavement materials by laboratory tests.

(3) ***Void Detection.*** The loss of soil support under rigid pavements associated with voids leads to increased load stresses and increased deflections. To study this problem, a deflection profile along the pavement edge may be compared with the corresponding deflections in the inside lane. For any rigid pavement, deflection surveys for the purpose of void detection should be considered as an integral part of the monitoring program.

(4) ***Load Transfer Evaluation.*** Deflection measurements taken across the transverse cracks and/or joints can be used to estimate the adequacy of load transfer. Deflection measurements can also be used with the results of general condition surveys for diagnostic checking of the condition of transverse cracks and joints.

Procedure for Data Collection

Since the deflection measurements in this study will be used for many purposes, the FWD sensors should be placed at more than one location. The placement of the deflection devices is described in this section.

1. All the geophones are calibrated every day prior to taking the FWD to the test section.
2. Deflection measurements are made every 200 feet, close to transverse cracks and between two adjacent cracks (spacing of 5 to 8 feet). The measurements are taken on the outside lane only.
3. Locations are selected one foot from the edge as well as in the wheel path in the outside travel lane.

Figure 7.5 shows the layout of selected test locations at 200-foot intervals. This procedure results in 15 readings for a 1000-foot test section.

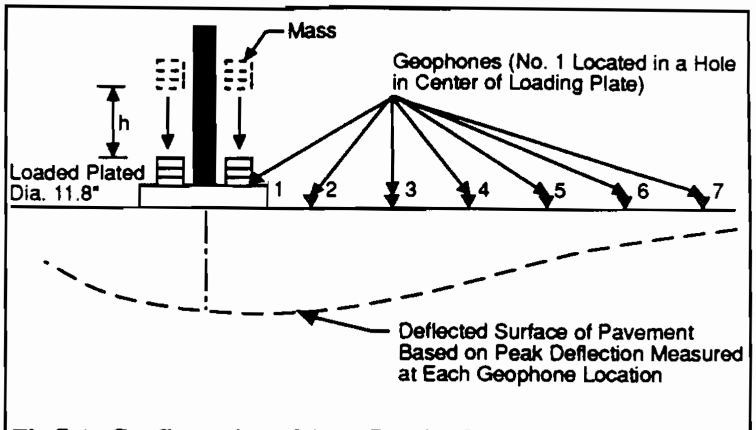


Fig 7.4. Configuration of Dynaflect load wheels and geophones in operating position.

Mays Ride Meter Study

In order to assure the quality of the road system and predict pavement performance, the Texas SDHPT began using the Surface Dynamics Profilometer (SDP) in early 1967. This system proved to be a good device for obtaining accurate road profile information, but, because of its high equipment and operating cost and the desirability of having a simple economical device available, it was decided to investigate the Mays Ride Meter (MRM). The primary advantages of the MRM are its ease of operation and the fact that it provides a roughness record concomitantly with the roughness measurements to give a permanent record of the locations of rough areas in a pavement. This device, however, unlike the SDP, is extremely sensitive to the characteristics of the vehicle in which it is installed as well as to environmental and other conditions. Therefore, to be useful for providing roughness measurements, these devices have to be calibrated to some standard and then continually monitored to insure accuracy. Several extensive studies regarding MRM calibration, operation, and measurements

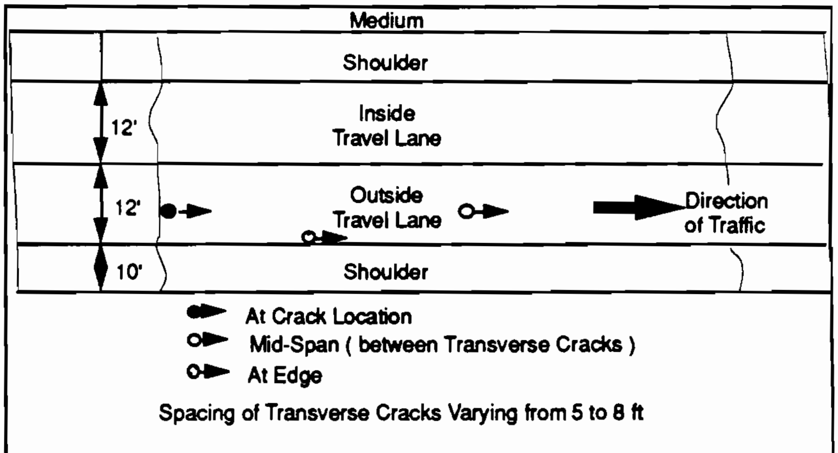


Fig 7.5. FWD test positions with respect to transverse cracks.

are reported in Refs 48, 49, and 50. Brief descriptions of the measuring technique, calibration, operation, and control procedure are given in this section.

Measuring Technique. The roughness measurements of MRM are proportional to the vertical changes between the vehicle body and its rear axle as the vehicle travels over a pavement. These vertical motions are accumulated and are recorded on an advancing paper tape or strip chart by a recording pen moving at a rate proportional to the movements of the vehicle body and its differential. Vehicle distance traveled is also indicated on this roughness chart by an automatic event marker connected to the speedometer drive system. By measuring the amount of chart movement per unit of road length traveled, a roughness measurement directly proportional to the total body-differential movement, in inches per mile, can be obtained. Rainhart Engineering Company has manufactured a commercial version of the recording device which replaces the original mechanical pulleys with a photocell sensing system. By using this device the MRM operator can record additional notes on the chart paper, i.e., general event marker, while the machine is in operation. Figure 7.6 depicts a typical paper tape measurement record of the Rainhart MRM.

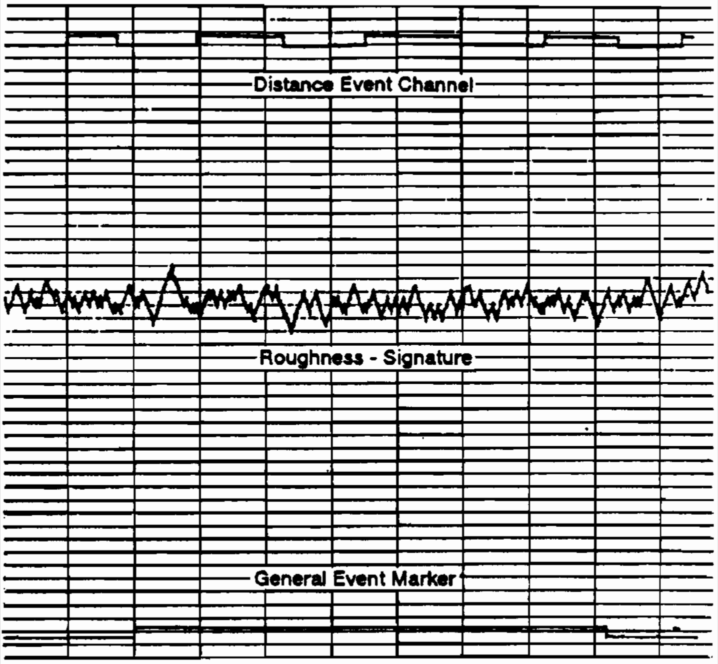


Fig 7.6. Typical Rainhart MRM measurement record.

Calibration. Since the MRM roughness measurements are dependent on all factors which affect a vehicle's suspension system, a standard roughness value which can be used for all instruments is needed. The standard value (serviceability index or SI) is a single number ranging from zero to five. It was introduced in Chapter 4. The SI values simply provide a means of correlating the roughness readings of a given section obtained by two different instruments. Calibration involves developing the necessary tables for converting MRM roughness readings, in inches per mile, to SI values. A detailed description is given in Refs 48 and 50.

MRM Operating Procedure. The operating procedures described below should be followed closely by the MRM operators in order to insure accurate readings.

(1) Measurements should be made only under normal driving conditions, particularly where weather is concerned. For example, measurements should not be made during heavy rain, snow, extremely cold weather, or gusty wind conditions. There is also the possibility that abnormal tire pressure variations will affect vehicle body movement. Measuring during any conditions which might directly or indirectly affect vehicle body movement should be avoided.

(2) For measuring during summer months, it is recommended that the Rainhart manufactured devices be installed in air-conditioned vehicles to help keep the MRM electronics cool.

(3) Before making a set of measurements, the MRM equipment should be visually inspected. The pens should be adjusted for proper marking and clearance before each measurement run.

(4) Two operators are necessary, one for driving the vehicle and the other for operating the MRM. The vehicle driver typically provides mileage information to the MRM operator and operates the event marker channel. The MRM operator monitors the roughness record, insuring proper operation, and makes any necessary event marks or comments on the strip chart during operations.

(5) The MRM device can be operated at a speed of 50 mph on the test section. However, this speed should be attained at least 0.2 mile before the beginning of the test section.

Measurement Control Procedures. Accurate measurements depend on proper usage and operation of the MRM. Proper operation of the equipment can be insured by development of a set of control procedures in which MRM results are continually monitored.

These control procedures provide a means of detecting MRM's out-of-calibration conditions and involve the use of replicate runs or measurements over a known test or control section. Twenty such sections are to be established immediately following the initial MRM calibration procedures, providing a large pool from which more than one control section can be selected for testing an out-of-calibration condition. Since these sections are to be used for roughness control, sections where changes in the pavement conditions are expected to be at a minimum should be selected so that the sections can be used as long as possible. The selection of the control sections is an important part of the control procedures, since they will be used for determining if the MRM is still in calibration. A detailed description of the establishment of control charts and control operations is presented in Ref 48 and is not repeated here.

THE SURVEY FORMS

A copy of the survey form used in the general condition survey is shown in Figs 7.7 and 7.8 for non-overlaid and overlaid sections, respectively. Figure 7.9 shows a copy of the field identification sheet, which is used for both non-overlaid and overlaid pavement sections. At the top of Fig 7.9, details of the position of the section are given. Space is provided for the district number, control-section-job number, highway number, CFTR number, direction, and county in which the section is located. The exact location or the mile posts at both ends of the section must be given to facilitate reference to the diagnostic study and future surveys of the section at a later date. The date of the survey, number of the lane, and the names of both raters should be noted on this sheet.

The Center for Transportation Research has developed an identification numbering system called CFTR for all the pavement projects included in the experiment design. It is a five-digit number.

The first two digits represent the district number itself. The remaining three digits represent the sequence number in which the pavements were built, 001 being the oldest pavement in the data base within a district. There is always more than one test section for each selected pavement project, so one space is provided after the hyphen in the CFTR number for the sequential number of the selected test section of that specific pavement project.

At the bottom of Fig 7.9, profile and plan view diagrams of the highway section are provided to illustrate the characteristics of the selected test section. The test section should be marked either as at-grade, cut, fill, or transition for its profile and either curvature or tangent for its horizontal alignment.

In the field, the only reference to location of a test section is the mile post. Further subdivision into 200-foot segments is facilitated by the measuring device, a rolatape. Distress is quantified by estimating length or area or by counting the spots of distress. In Fig 7.7 punchout is subdivided into two columns, minor and severe, to describe the severity of the distress phenomena. If distress manifestations are observed between, for example, 200 feet and 400 feet from the starting mile post, the data are filled into the same row as the preceding number, i.e., the 200-foot row.

Crack spacing is recorded for only the first 200 feet of each test section. The cumulative readings of the distance, from the rolatape, are input into the form. For the remaining 800 feet of the test section, the numbers of cracks are counted and input. At the bottom of Figs 7.7 and 7.8, space is provided for a brief description of the shoulder condition and general comments.

PILOT STUDY

The purpose of the pilot study was to investigate the feasibility of the proposed measurement methods and survey forms for the general condition survey, establish the proper survey procedure, and provide a training session for people who are going to participate in the condition survey but have little or no field experience. Therefore, the pilot study was scheduled prior to the network experimental condition survey.

The first step of this study was site selection. In order to investigate as many experimental factors as possible and complete the study within one working day, six pavement projects on Interstate Highway 10 in District 13 were selected. They are CFTR 13002 and 13007 in Colorado county, 13006 and 13015 in Fayette county, and 13016 and 13021 in Gonzales county. Although these six projects have similar environmental factors and traffic volumes, the coarse aggregate type, subbase type, soil type, and age vary from one to another. The field trip took place on June 30, 1987. Dr. B. Frank McCullough, Bill Ward, and six Civil Engineering graduate students participated. It was found that the survey forms and measurement methods were adequate for the condition survey and no change was necessary.

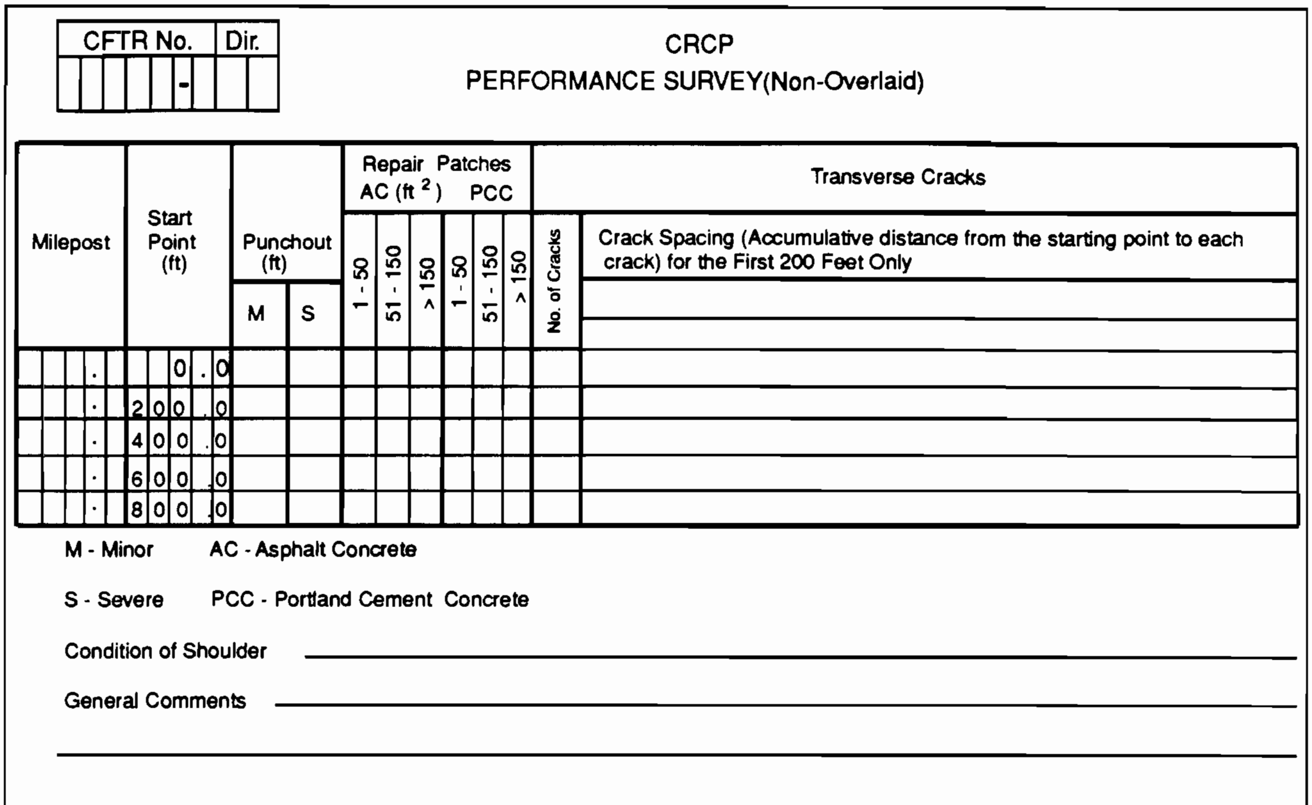
The survey procedures were reviewed by the researchers and finalized. A detailed description of these procedures is presented in Chapter 8. After this pilot study, the network condition survey was scheduled. It is also described in Chapter 8.

SUMMARY

The field surveys are divided into two parts, a general condition survey and a diagnostic study, based on the complexity of the required survey instruments. Definitions and methods for measuring distress manifestations of general condition survey are presented in this chapter. This includes crack spacing, crack width, punchouts, and repaired patches for non-overlaid pavements and reflected cracks, bond failures, failures, patches, and rut depth for overlaid pavements.

The FWD and the Mays Ride Meter have been used in the past for diagnostic study to collect data on pavement deflection and roughness. A general description of each of these measurements, including its device, functions, and operating characteristics, is given after the description of the general condition survey.

Copies of the survey forms used in the general condition survey are presented in Figs 7.7, 7.8, and 7.9. In addition to the data collected on distress manifestations, location identification, test section description, survey date, and rater's names are recorded on the forms, as shown in Fig 7.9. The major difference between the current survey forms and those



CFTR No.	Dir.
☐☐☐☐☐ - ☐☐	

CRCP

PERFORMANCE SURVEY(Non-Overlaid)

Milepost	Start Point (ft)	Punchout (ft)		Repair Patches AC (ft²)			PCC				Transverse Cracks
		M	S	1 - 50	51 - 150	> 150	1 - 50	51 - 150	> 150	No. of Cracks	Crack Spacing (Accumulative distance from the starting point to each crack) for the First 200 Feet Only
.	0.0										
.	200.0										
.	400.0										
.	600.0										
.	800.0										

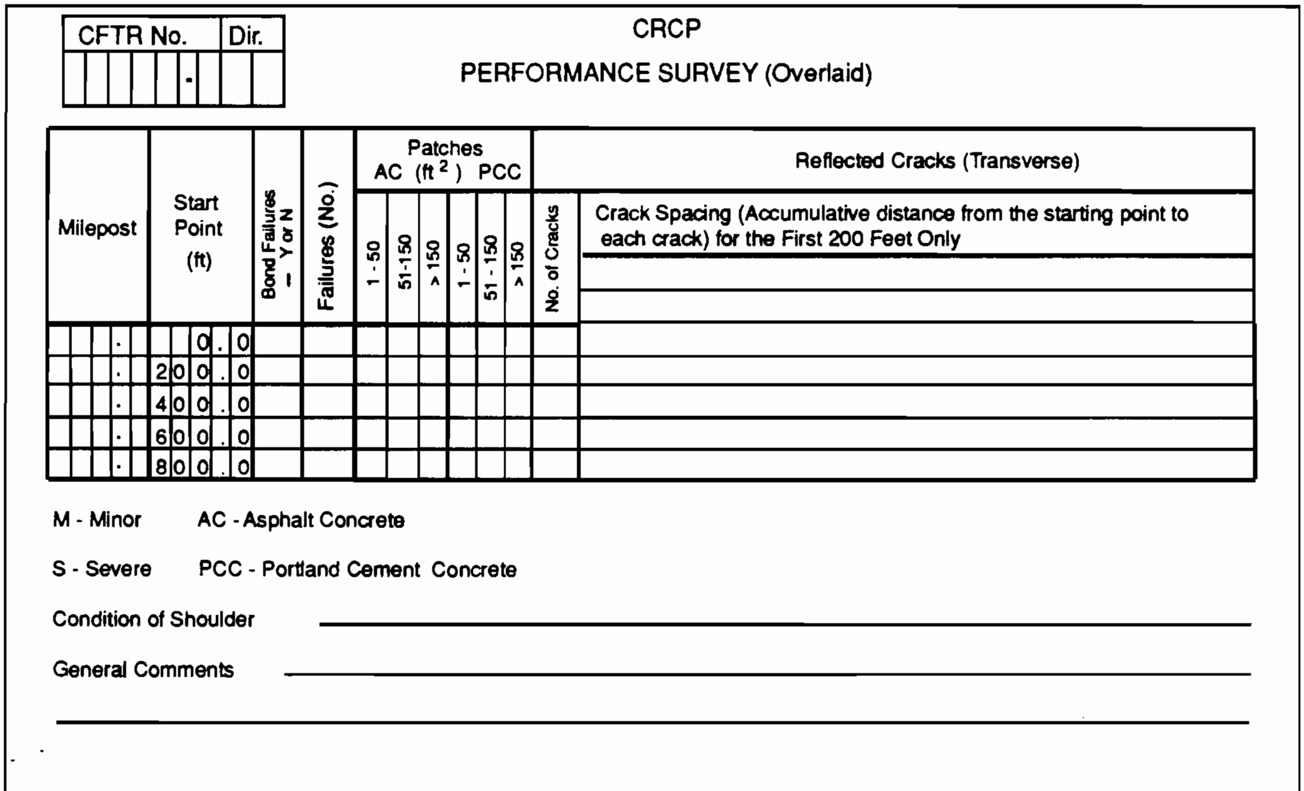
M - Minor AC - Asphalt Concrete

S - Severe PCC - Portland Cement Concrete

Condition of Shoulder ______________________

General Comments ______________________

Fig 7.7. Field sheet for recording distress manifestation of non-overlaid CRCP section.



CFTR No.	Dir.
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CRCP

PERFORMANCE SURVEY (Overlaid)

Milepost	Start Point (ft)	Bond Failures — Y or N	Failures (No.)	Patches AC (ft²)			PCC				Reflected Cracks (Transverse)
				1 - 50	51-150	> 150	1 - 50	51 - 150	> 150	No. of Cracks	Crack Spacing (Accumulative distance from the starting point to each crack) for the First 200 Feet Only
.	0.0										
.	200.0										
.	400.0										
.	600.0										
.	800.0										

M - Minor AC - Asphalt Concrete

S - Severe PCC - Portland Cement Concrete

Condition of Shoulder ______________________

General Comments ______________________

Fig 7.8. Field sheet for recording distress manifestations of overlaid CRCP section.

used in previous surveys is the inclusion of highway section diagrams. By marking the diagrams, the profile and horizontal alignment of the specific test section can be easily identified.

Finally, a brief description of the pilot study is presented. It was scheduled prior to the network condition survey since it could provide valuable information to modify the survey procedure and measurement methods, if necessary. Six pavement projects on Interstate Highway 10 in District 13 were selected for this study. It was concluded that no changes were required in the survey forms or measurement methods. In addition, the survey procedures were established during the pilot study and are presented in the following chapter.

District	Control - Section - Job	Highway	CFTR No.	Dir	County	Date Mo./Day/ Yr.
	– –		-			/ /
Location From		To			No. of Lane	Raters

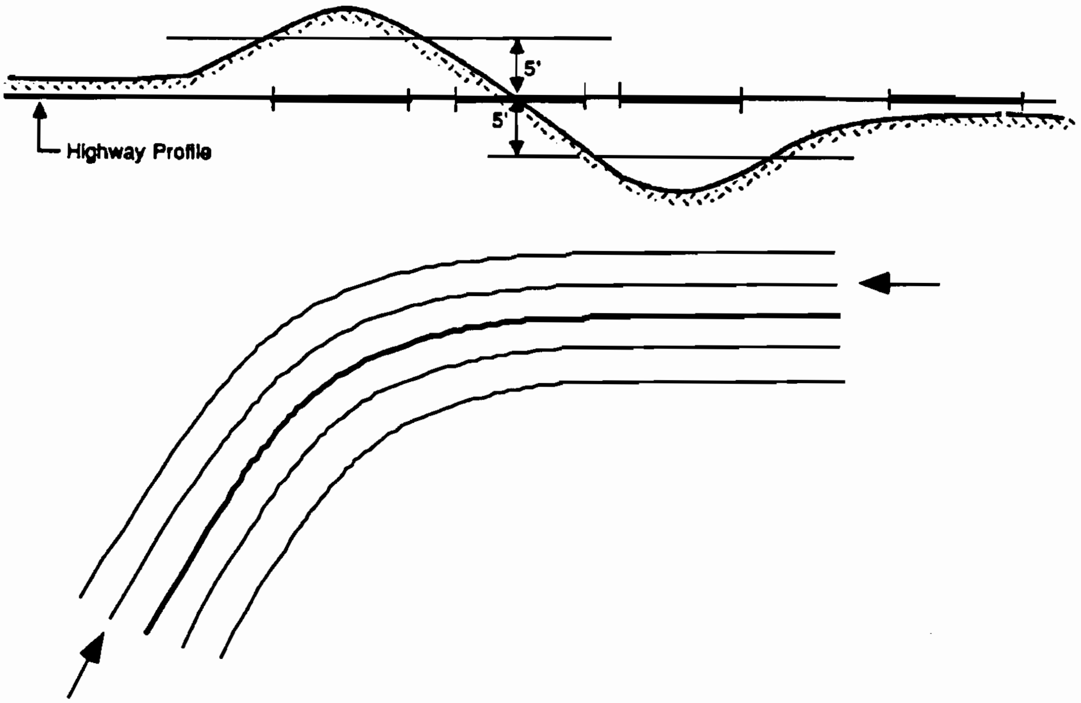

Fig 7.9. Identification form for the condition survey for both non-overlaid and overlaid sections.

CHAPTER 8. PAVEMENT CONDITION SURVEY

INTRODUCTION

This chapter describes the procedure and the scheme for a statewide field survey of in-service CRC pavements. Only the general condition survey is presented in this chapter. The diagnostic study is scheduled to be conducted later and will be described in the next report.

One hundred and twelve pavement projects were selected from the existing data base for the experimental condition survey. Appendix F shows the locations of these 112 projects. Most projects have four to six test sections, depending on the project length, but some of them have fewer and some section lengths are less than 1,000 feet long. A detailed description of the findings and problems that occurred during the condition survey is also presented in this chapter.

FIELD SURVEY PROCEDURE

The following items and pieces of equipment were prepared and used in the general condition survey:

(1) field survey forms, clipboards, and pencils,
(2) spray paint,
(3) rolatape, or distance measuring wheel,
(4) tape recorder,
(5) video camera and numbered pieces of cardboard or paper for picture identification,
(6) map for location of projects to survey and a list of the supporting information for the project (Appendices E and F), and
(7) safety vests and hats.

District control-section maps were used to identify the relative locations of the surveyed projects. However, the mileposts of the projects provided in the supporting information helped to precisely locate the projects.

Each survey team consisted of two persons. The surveyors checked the length of each selected project (Appendix E) and decided the number of test sections to be measured in that project, based on the criteria for the test section selection. When a selected test section was reached, the vehicle was parked on the shoulder close to the end point of the section with the hazard lights on. The team walked toward the starting point of that test section, which ensured that the surveyors always walked against the traffic, reducing the possibility of an accident. The information required on the first survey sheet (Fig 7.9) was recorded.

One person measured the distance and marked the pavement while the other counted the number of punchouts, repair patches, and transverse cracks for a non-overlaid section, and reflected cracks, failures, bond failure, and patches for an overlaid section. Data collected for each distress were recorded on the second survey sheet, Fig 7.7 for a non-overlaid section and Fig 7.8 for an overlaid section. Only the outside lane of the roadway was surveyed. The first point (ending point) was marked by spray painting a strip on the shoulder approximately one foot long extending from the pavement edge. The rolatape was set to zero and placed at the painted strip for starting the distance measurement. A strip was marked every 200 feet, and the cumulative distance from the starting point, not the first point, was written beside the strip. Since the distance measurement started backward from the end point and the total length is 1,000 feet, the strip at the first 200 feet was marked as 800. The following strips for every 200 feet were marked as 600, 400, and so on. The CFTR test section number was marked on both ends so the section could be located easily at a later date. Figure 8.1 represents an example of the marks for the test section.

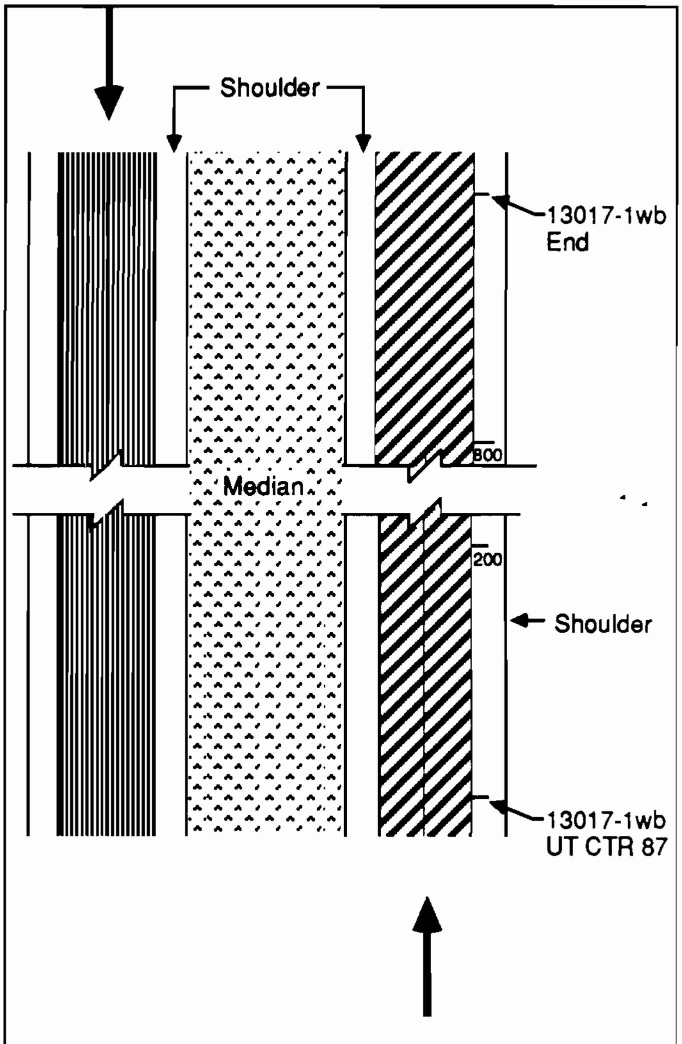

Fig 8.1. Example of the marks on a test section.

After completion of the distance measurement and marking, the cumulative distance from the starting point to each crack was recorded for the first 200 feet. A recorder and rolatape were used. Data for crack spacing were transcribed from the tape to the survey sheets.

A video image of the first 200 feet of the test section was recorded to give an overview of the section. A 5.5 x 8.5-inch paper or cardboard (one-half of letter size) with the CFTR test section number on it was placed on the pavement at the beginning point for the video records. The shoulder condition and any pertinent comments were recorded on the bottom of the second survey sheet.

SUMMARY OF FINDINGS AND PROBLEMS

As described in Chapter 6, it was planned that four test sections be selected if the project length was less than or equal to 3.0 miles and six test sections if it was more than 3.0 miles. Each test section was supposed to be 1,000 feet long. However, several unexpected situations during the condition survey affected the test section selection.

(1) Some of the selected non-overlaid projects had been overlaid since the last condition survey, 1984. Not many significant distress manifestations were observed in these pavement projects. In order to obtain the needed information regarding the pavement overlay construction, highway life files, which are stored in D-10, SHDPT, were reviewed for each CRC pavement project of the network. The existing data base was then modified and brought up to date. Some other non-overlaid projects were selected from the experimental factorial in order to replace those which are already overlaid.

(2) In the urban areas, Dallas, Fort Worth, Houston, and San Antonio, the surveys were not conducted for some projects because of the heavy traffic.

(3) Although it was planned that no test section selected for this study would be close to a highway entrance ramp, exit, or bridge for safety's sake, some selected test sections were surveyed under such circumstances because of other constraints.

(4) Some pavement projects had less than the required number of test sections, primarily due to their uniform geographic features.

(5) Some test sections were shorter than 1,000 feet because it was difficult to obtain full length for a cut or a fill section which has a height difference of 5 feet or more compared to the adjacent land. The shortest length of a test section was 500 feet. The survey procedures for the shorter test sections were the same as for the full 1,000-foot-long sections.

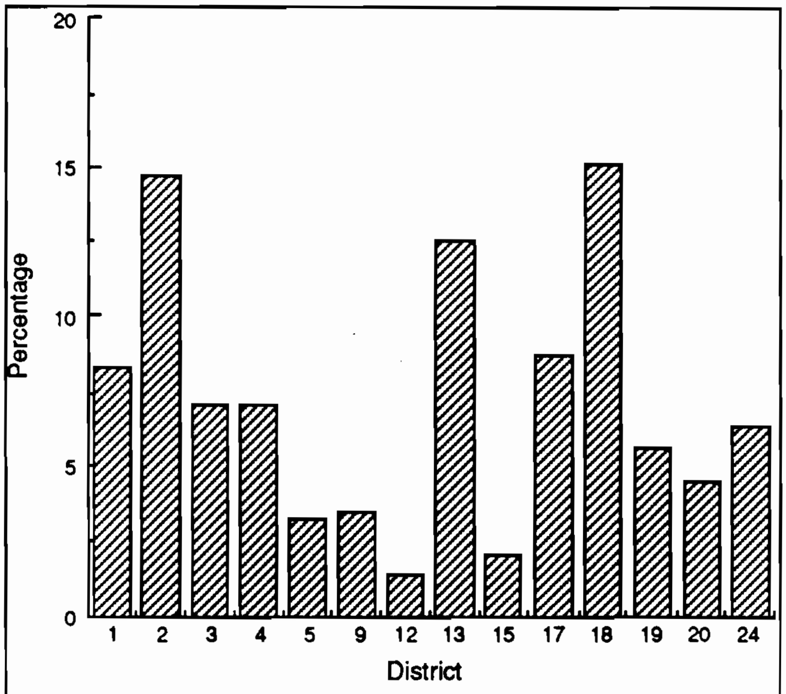

Fig 8.2. Distribution of 425 test sections over the districts.

Fig 8.3. Distribution of 425 test sections for the various highway categories.

(6) A few newly constructed CRC pavement projects were found during the condition survey. They were included in the data base after the completion of the survey work.

There were 425 test sections which were selected from the 112 pavement projects. Figures 8.2 and 8.3 show the percentage distribution of the test sections over the different districts and highway categories. In addition, Figs 8.4 and 8.5 show the distributions of section length and various grade constructions.

DATA STORAGE

Presently, the data are stored on the IBM 3081 in three SAS data sets: SDS.MASTER consists of background information common to each section, SDS.COND87 holds the 1987 condition survey data, and SDS.CRACK contains the crack spacing from the 1987 survey (Ref 51). Using separate files will make the total file size small by eliminating redundant information and will allow storage of data on a PC diskette. Also each file may be separately accessed when information contained in the other two files is not needed. Table 8.1 indicates the file names in which each variable can be found. A simple merge statement can combine two or more files using the same section ID number (CFTR) when necessary.

Figure 8.6 shows the creation sequence for the database (Ref 51). The master data set was created by typing in the raw data (MASTER.DATA) and processing it through an SAS program (CREATEM.SAS), resulting in the SAS data set SDS.MASTER. Additions, deletion, or changes can be easily made by editing the raw data and rerunning the program.

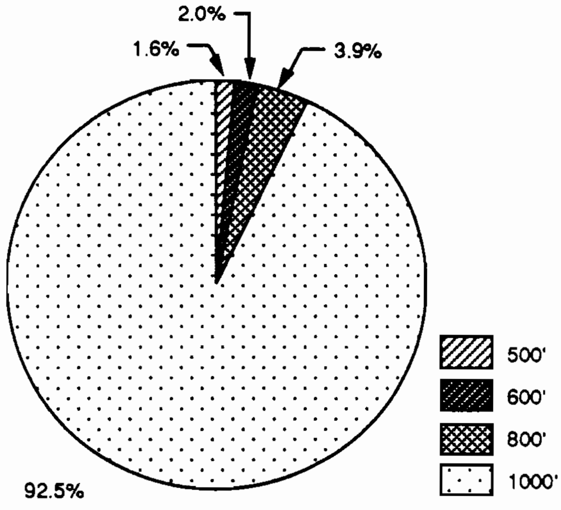

Fig 8.4. Distribution of 425 test sections for various section lengths.

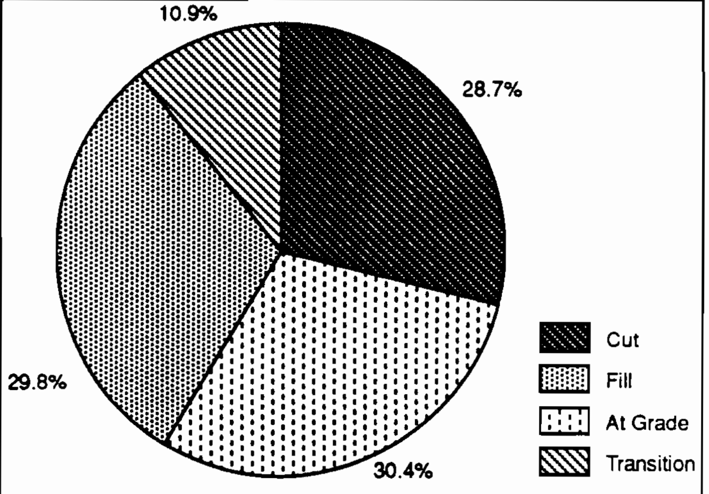

Fig 8.5. Distribution of 425 test sections for various subgrade grading types.

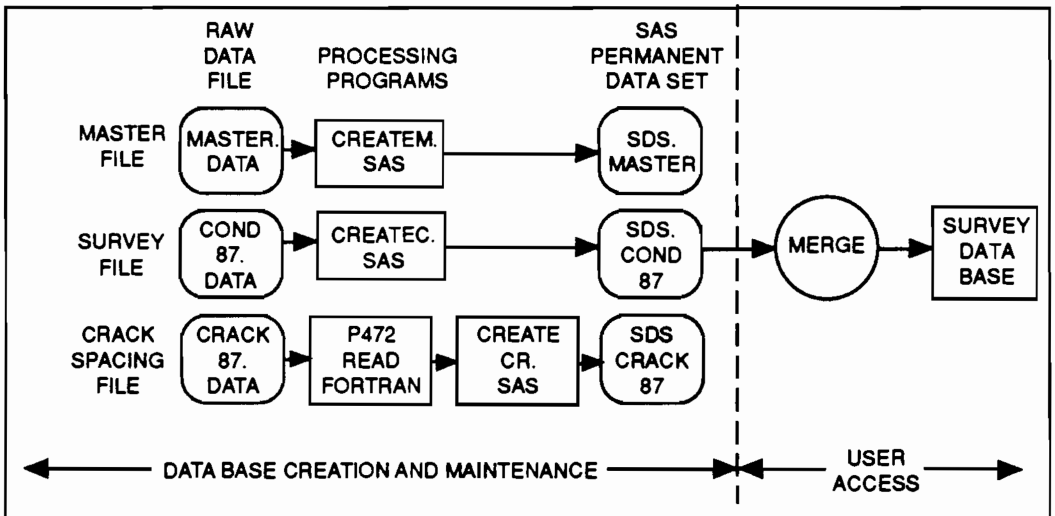

Fig 8.6. Database creation sequence.

Similarly, condition survey data were key entered from field survey forms into file COND87.DATA and then processed by CREATEC.SAS to produce the final SAS data set SDS.COND87. Crack spacing data were typed from the survey forms into CRCAK87.DATA. Two programs were used to process the data : first, a Fortran program (P472READ. FORTRAN) and then an SAS program (CREATECR.SAS), resulting in the final data set SDS.CRACK87. Modification of these files can be accomplished in a manner similar to that described for the master file above.

Appendix G shows a list of survey information resulting from a merge of data sets SDS.MASTER and SDS.COND87. This set of information includes a detailed description of selected test sections and the distress manifestations.

TABLE 8.1. DATABASE CONTENTS

Item	Description	Files*
CFTR	Section ID Number	M,S,C
SECT	Subsection Surveyed	S,C
DIR	Direction Surveyed	S,C
COUNTY	County Name	M
HWY	Highway Design	M
CTRL	SDHPT Control Number	M
SEC	SDHPT Section Number	M
JOB	SDHPT Construction Job Number	M
NJOB	SDHPT Subsequent Job Numbers	M
CDATE	Construction Date	M
OV1-0V4	Date of First Four Overlays	M
MP1	Beginning Milepost	M
MP2	Ending Milepost	M
L	Section Length (entire section, miles)	M
D	Pavement Thickness (inches)	M
CAT	Coarse Aggregate Type: 1-SRG; 2=LS; 3-1 & 2; 4=SLAG,; 5=1 & 4 or 2& 4	M
SBT	Subbase Type: 1 = Asphalt treated; 2=Cement Treated; 3=Lime treated; 4=Crushed Stone	M
SOIL	Y for Swelling Soil, or N if Not	M
TEMP	Yearly Temperature Range (°F)	M
RAIN	Average Annual Rainfall	M
ADT	Average Daily Traffic (estimated)	M
G	ADT Growth Rate (estimated)	M
LANE	Number of Lanes (each direction)	M
ST	Surface Type (AC, C& G, etc.)	M
MAIN	Y if Main Lane; N if Shoulder or Acc.	M
DATE	Date Surveyed	S
LANES	Number of Lanes	S
RATER	Rater Code	S
CFP	Cut/Fill Position	S
CURVE	Curve (Y or N)	S
OVR	Overlaid (Y or N)	S
LEN	Length Surveyed (feet)	S
FROM	Survey Section Start (text)	S
TO	Survey Section End (text)	S
ACP	Number of Asphalt Patches	S
PCCP	Portland Cement Patches	S
NCRK	Number of Cracks (1st 200 feet)	S
BF	Bonding Failures	S
NF	Number of Failures	S
MPO	Minor Punchouts	S
SPO	Severe Punchouts	S
CRK	Individual Crack Spacing	C

*Items designated M are present in master file; S in condition survey file; C in crack spacing file.

CHAPTER 9. PRELIMINARY DATA ANALYSIS

INTRODUCTION

The primary objective of this chapter is to summarize the results of the 1987 condition survey data analysis and compare them with the previous condition survey data. Although several distress manifestations and crack data were recorded, distress index (Zeta score - a weighted combination of punchouts and patches) and crack spacings are the only two items included in the analysis.

Results are presented in a summary form with only a minimal statistical analysis. Only the obvious observations or conclusions are emphasized, e.g., the Zeta score is lower in some areas of the state than in others, the effect of age, etc.

In the next section, a summary of the distress conditions in the various districts of the state is given. This summary includes the mean Zeta scores obtained from 1987 condition surveys and the state-wide historical trends observed between 1984 and 1987. Crack spacing distribution for pavements using limestone and silicious river gravel aggregates is also presented. Next, an analysis of the data is attempted; the parameters involved are age, climatic conditions, soil types, and profile characteristics. The conclusions obtained are summarized in the last part of this chapter.

SUMMARY OF STATE-WIDE DISTRESS CONDITION

The distress manifestations recorded during the 1987 condition survey were minor punchouts, severe punchouts, and patches. In addition, the crack spacing for the first 200 feet of each test section was also recorded. For discussion purposes, in this chapter the distress manifestations are combined as distress index (Zeta score). Discussion is focused on the examination of state-wide historical trends of Zeta scores and the general crack spacing distribution for pavement sections with different coarse aggregate types. In addition, general comments are made relative to each of the districts.

Zeta Score

The Zeta score or distress index is a weighted combination of the major distress manifestations: punchouts and patches. The Zeta score of each test section was calculated using Eq 3.10. Figure 9.1 presents the mean Zeta scores of the test sections in each district for the 1987 condition survey. The mean Zeta scores range from 0.98 to -.092. A detailed description of the distress condition of each district is given in the following section. In Fig 9.2, the mean Zeta scores for each district are shown for the years 1984 and 1987 for the same selected test sections. These test sections are not exactly the same as those presented in Fig 9.1 since not all test sections selected in 1987 were surveyed in 1984. Only the sections surveyed in both years were used for comparison in Fig 9.2.

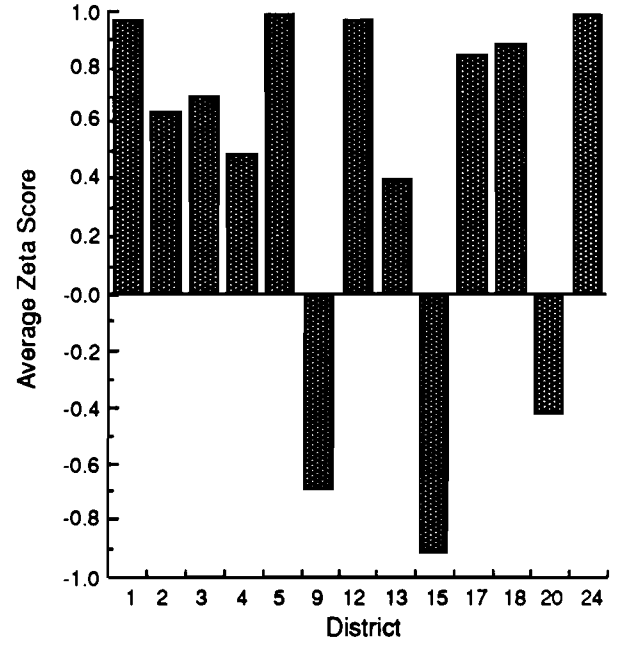

Fig 9.1. The mean Zeta score of 1987 survey.

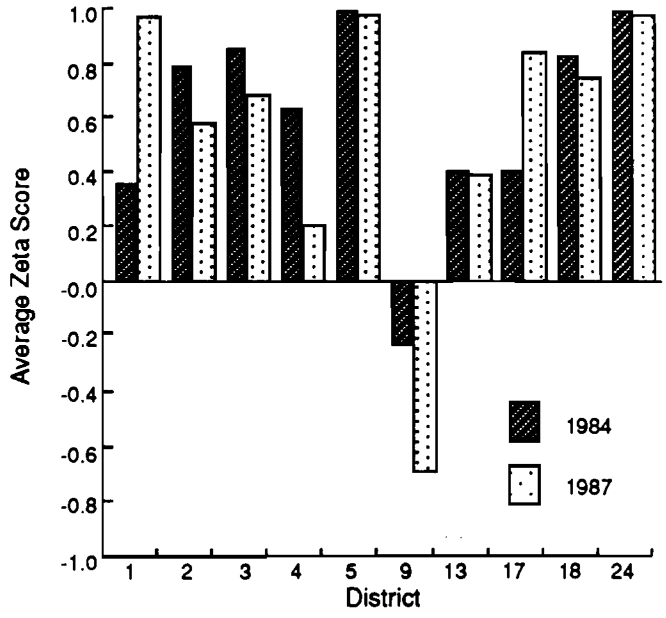

Fig 9.2. The average Zeta score for the same test sections for 1984 and 1987 surveys.

The Zeta scores for some districts are smaller than for others, but the reason is not apparent from the data. A preliminary data analysis is presented herein, but the complicated regression models will be the subject of subsequent studies. In Table 9.1, the historical Zeta scores for each district are given. The Zeta scores in each district would be expected to decrease from 1974 to 1987. However, in some cases this is not true because the highly distressed sections are generally overlaid, reducing the observable number of punchouts and patches. Furthermore, distress indices for the survey years 1974 to 1984 are the average values for each individual district, and the data for 1987 represent the mean values of selected test sections of each district only. Nevertheless, the general decreasing trend of Zeta scores is still apparent.

TABLE 9.1. THE HISTORICAL AVERAGE ZETA SCORE FOR EACH DISTRICT

District	1974	1978	1980	1982	1984	1987
1	0.639	0.431	0.257	0.141	-0.105	0.970
2	- -	- -	- -	0.657	0.597	0.634
3	0.888	0.886	- -	0.599	0.673	0.760
4	0.793	0.639	- -	0.369	0.660	0.536
5	- -	- -	- -	1.000	1.000	0.981
9	-0.048	0.194	-0.117	-0.177	-0.111	-0.682
10	0.386	-0.295	-0.490	-0.559	-0.020	- -
12	- -	- -	- -	1.000	- -	0.971
13	0.853	0.347	0.297	-0.160	-0.163	0.395
15	- -	- -	- -	0.856	0.853	-0.918
17	0.074	0.401	0.221	0.007	0.344	0.837
18	- -	- -	0.367	0.924	0.500	0.873
19	0.546	-0.133	-0.413	0.179	0.127	- -
20	0.247	0.134	-0.303	0.353	-0.249	-0.416
24	1.000	0.924	- -	0.924	0.960	0.975
25	0.962	0.962	- -	0.544	0.530	- -

Crack Spacing

All CRC pavements develop transverse cracks, but, as the crack spacing decreases, the probability of punchouts increases. Crack spacing information was not recorded in any previous condition survey, except 1978. In 1978, 300-foot samples, one in each project, were chosen at random and the spacing between cracks was measured. In 1987, the crack spacing for the first 200 feet of each 1000-foot test section was measured, and the number of transverse cracks for the remaining 800 feet was recorded. An overall distribution of crack spacing for two different coarse aggregate types, limestone (LMS) and silicious river gravel (SRG), for the entire state is given in Fig 9.3. It is obvious that the mean crack spacing for pavement using LMS is double that for pavement using SRG. This is primarily due to the smaller thermal coefficient of LMS. Some other factors, such as rainfall, temperature, etc., also influence the crack spacing. An analysis is given later in this chapter.

Observations by Districts

Based on Figs 9.1 and 9.2 and Table 9.1, general observations can be made relative to each district.

District 1. The Zeta score decreased consistently from 1974 to 1984. In 1984, the mean Zeta score was below zero, which indicated that many projects were in bad condition. It was found that two-thirds of the projects in this district were overlaid in 1986 and early 1987. The major maintenance of the highly distressed projects resulted in a high Zeta score for 1987.

District 2. District 2 had been surveyed only three times during the past 13 years. Zeta scores for this district had a small drop and then increased in 1987. One-fourth of the pavement projects were overlaid between 1984 and 1987.

District 3. Most of the surveyed sections are in good condition. More than 80 percent of the test sections had Zeta scores greater than 0.95; however, the lowest value was -0.08. The average value is 0.76.

District 4. The general CRCP condition in this district was fair according to the 1987 survey data. The Zeta scores range from 0.98 to -1.22; the latter means that pavement is in a very bad condition. No project had been overlaid during the past three years. Several pavement projects were predicted to need an overlay in the near future, based on the low Zeta scores.

District 5. There was no significant change in the pavement distress conditions during the past three years. The CRC pavements in this district are in very good condition (mean Zeta score = 0.98).

District 9. Several projects in this district are in very bad condition. Almost all the Zeta scores were smaller than zero. It is observed from Table 9.1 that the mean Zeta scores of this district have been decreasing since 1974 and are always close to or smaller than zero. This indicates that the poor condition should be improved by overlay or rehabilitation as soon as possible.

District 10. No test section was selected from this district in 1987. However, the mean Zeta scores decreased consistently from 1974 to 1982. Five out of fourteen projects were overlaid in 1985 and 1987.

District 12. This district was surveyed only in 1982 and 1987. The conditions of pavements remained unchanged. The conditions of the six selected test sections were very good, based on the survey data of 1987.

District 13. Similar to those for Districts 1, 9, and 10, the mean Zeta scores for this district decreased consistently from 1974 to 1984, and there was a negative value in 1984. Six out of twenty-three non-overlaid projects in 1984 were overlaid between 1984 and 1987. This resulted in an improved mean Zeta score of 0.395 in the condition survey of 1987.

District 15. The condition of test sections in this district was poor. However, the data represent only one specific selected project because the other selected projects were overlaid and no Zeta score was calculated from them. This non-overlaid project, CFTR 15901, was a relatively new project in the CRCP network and had never been surveyed; therefore, no comparison could be made.

District 17. In general, the CRCP condition in this district was good. Half of the projects have been overlaid since 1984, which resulted in the higher Zeta score in 1987.

District 18. In this district, most of the projects were considered to be in good condition. Only one project had a negative Zeta score, -0.02, which indicates that it should be overlaid as soon as possible.

District 19. No data were recorded in this district in 1987. Historically, the general condition of the district has been poor. Most projects have been overlaid once or more since 1980, which improved the distress condition.

District 20. The historical mean Zeta scores of this district have always been very low. Although a few projects have been overlaid since 1982, the general condition of CRC pavements was still very poor based on the 1987 survey data.

District 24. This district has always had a very high mean Zeta score for each survey year. No significant changes have been observed through these years.

District 25. No project in this district was chosen for 1987 surveys. Most projects were built in the early 70's, and no overlay has been made. The general condition of CRCP was considered to be good in 1984.

ANALYTICAL APPROACH

The data can be analyzed from a number of levels, but the approach used in this chapter consists of isolating each experimental factor and combining some of the factors, such as soil type and rainfall, to define qualitatively the effect of each variable parameter or of combined parameters on the performance of the highway pavements.

The first step was to select the parameters which may have an important influence on the deterioration of the pavement sections. The distress index, Zeta, can be hypothesized to be a function of the pavement age, climatic condition, grading construction type, mechanical properties of the design materials in the pavement structure, and traffic. Since the 18-kip ESAL data were not available, the effect of traffic is not considered in this analysis.

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

(1) pavement age;
(2) geographical location: this encompasses temperature, rainfall, and soil type;
(3) profile characteristics: cut, fill, at-grade, and transition; and
(4) material type: limestone and silicious river gravel.

It is apparent that a true isolation of the variables is not possible due to the interactions among them; thus, conclusions are drawn regarding the subject variable only from observations made under the same conditions. A more detailed analysis taking into account the effects of all variables at different levels should be considered in further studies.

ANALYSIS OF DISTRESS INDEX

In this section, the effects of various parameters on the distress index, Zeta, are discussed. As stated earlier, the distress index is a weighted combination of distress manifestations, punchouts, and patches.

Effect of Profile Characteristics

It is not surprising to see that the profile characteristics have a significant effect on the pavement performance, particularly when it interacts with other factors, i.e., rainfall, subbase drainage, and age. In Fig 9.4, the average Zeta scores for different profile characteristics and different age categories in two geographical locations, Districts 3 and 13, are shown. Pavement is defined as "young" if its age is equal to or less than 15 years and "old" if it is over 15 years.

It is obvious from Fig 9.4 that the pavement sections in the transition area, between cut and fill, have the lowest Zeta score. In other words, the performance in the transition area is the worst among the other grading types. Sections with cut grading type show the best performance and those at-grade type the next. Fill grading type has a Zeta score smaller than at-grade type, but greater than transition. This trend is true for pavements in different geographical locations and at different ages. In addition, if a comparison is made of the various types of grading by geographical location, a larger variability in performance can be noted in District 13 than in District 3, which implies that other factors, such as rainfall, will influence the results.

Effect of Climatic Condition and Pavement Age

Climatic condition encompasses temperature and rainfall. The eastern part of the state (Districts 19 and 20) has the highest annual rainfall and ground water level; the lowest temperatures are recorded in the north (Districts 4 and 25).

In Fig 9.5, the mean Zeta score of four typical climatic conditions, Districts 4, 13, 20, and 24, for different survey years are shown. It is noted that the distress condition is worst in the eastern part of Texas (District 20), while the district located in west Texas (District 24) has the best. Districts 4 (north) and 13 (southeast) have similar quantitative performances; the former has the lowest temperature but little annual rain, and the later has a higher temperature but more rainfall. A trade-off exists between these two environmental factors.

It is noted from Fig 9.4 that pavement age has an important influence on pavement performance. Old pavements always have a lower Zeta score than young pavements for the same grading type in the same district. It is also observed from Fig 9.5 that pavement distress condition deteriorates with age. The districts having higher moisture show a faster deterioration rate than districts in the dry area.

Effect of Rainfall and Soil Type

From the plots in Fig 9.6, where the influence of rainfall and soil type on the distress index is presented, it is seen that pavements, whether with swelling clay or non-swelling soil, have lower Zeta scores if they are located in the high rainfall regions. However, the drop of Zeta score is more rapid with increasing rainfall if pavement is built in a swelling clay area. The difference in the Zeta scores of the two soil types is not significant unless the moisture level is high.

ANALYSIS OF CRACK SPACING

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

Pavement cracks usually start right after the completion of construction, due to the temperature and moisture changes. Several other factors and their interactions affect the crack formation. In this section, some of the most important factors, i.e., coarse aggregate type, rainfall, temperature, and pavement age, are examined.

Effect of Coarse Aggregate Type

Two of the aggregate types most used in concrete slabs were selected for this analysis. The concrete properties, such as tensile strength and thermal coefficient, are highly influenced by the coarse aggregate type. As was previously stated, LMS concrete has larger crack spacing than SRG concrete. Both aggregate types have bell shaped distributions for crack spacing, on the natural log basis (Fig 9.3). The difference in mean crack spacing of these two aggregate types is very significant, since limestone has a much lower thermal coefficient than silicious river gravel aggregate.

Effect of Climatic Condition

From Fig 9.7, it is apparent that both temperature and rainfall have drastic effects on crack spacing for LMS and SRG concrete pavements. The average annual lowest temperature (AALT) (Ref 28) was used here with the assumption that all pavement sections were cured at the same temperature. Theoretically, crack spacing is a function of temperature drop, and temperature drop is defined as the difference between the curing temperature and the lowest temperature which the pavement experienced during the same year cycle. AALT was use in this analysis as a substitute for real temperature drop since the curing temperature is assumed to be the same for all pavement sections. The crack spacing shows a tendency to reduce with the reduction in AALT.

Pavement sections were divided into two groups, based on the rainfall. It was also noted from Fig 9.7 that pavements located in the high rainfall area (> 32 inches/year) have a crack spacing smaller than pavements located in the low rainfall area (< 32 inches/year). It was concluded that the SRG concrete pavements located in the cold, humid areas have the smallest crack spacing, 2.3 feet, if the other factors are kept constant.

Effect of Age

In Fig 9.8, the effect of pavement age on crack spacing for LMS and SRG concrete pavements is presented. In this figure, it is observed that age has more effect on crack spacing of SRG concrete than of LMS concrete. LMS concrete pavement crack spacing ranged from 5.5 feet to 6.3 feet, while the crack spacing of SRG concrete pavement decreased from 4.5 to 2.5 feet with age. However, data for this analysis are available only for ages from 10 to 24 years, and the crack spacing of either type of concrete is rather low at 10 years when compared to the original CRCP slab length, 100 to 150 feet. Studies by McCullough and Chesney on specific projects showed that the crack patterns develop quickly in the first months and only a slight decrease in the mean crack spacing is seen in the following years (Ref 52). Since there are no available data to show the process of the crack spacing decrease in the early stages of pavement life, no sound conclusion can be made regarding the effect of age on crack spacing here.

SUMMARY OF FINDINGS

An analysis of the historical condition survey data obtained during the 1974 to 1987 surveys leads to the following findings in terms of distress index and crack spacing.

Distress Index (Zeta Score)

(1) The Zeta score varies with different profile characteristics. A pavement section with cut grading type shows the best performance during its life. The distress index of the other grading types decreases in order of at-grade, fill, and transition between cut and fill.

(2) The Zeta score decreases with the age of the pavement. In some cases, the data are confounded because the highly distressed sections were overlaid between two adjacent surveys.

(3) Climatic conditions have a definitive influence. Districts located in the eastern part of Texas have the worst performance while Districts located in west Texas have the best. The distress conditions of north Texas (cold but dry) and southeast Texas (warm and humid) are in between the conditions of pavement located in east and west Texas.

(4) No major difference in the Zeta scores exists between pavements built on swelling clay and those on non-swelling soil in the dry regions. However, there is a significant difference in their performance when the rainfall is high.

Crack Spacing

(1) Coarse aggregate types play an important role in the cracking pattern. LMS concrete pavements have almost the double crack double spacing of SRG concrete pavements.

(2) In the humid areas of the state, crack spacing appears to be smaller for both types of aggregate. This is also true in the cold areas.

(3) Age has more effect on crack spacing for SRG concrete than for LMS concrete for pavements older than 10 years. Since the crack pattern develops quickly in the first month and only a slight decrease in the crack spacing is observed in the following years, no definite conclusion can be made regarding the effect of age on crack spacing for the entire pavement life.

CHAPTER 10. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

INTRODUCTION

This chapter presents a brief description of the derivation of the distress index (DI) and the decision criteria index (DCI) from the historical condition survey data and a summary of the procedure carried out to develop the experimental design for the network level condition survey of CRCP in Texas. The principal conclusions from this study are provided in the second section of this chapter, and recommendations for further research and possible extensions of the concepts of the performance prediction model and the experimental design are presented in the last part of the chapter.

SUMMARY

The primary objective of this research was to develop an experimental design for the network level condition survey in order to develop a long-term monitoring system for Texas CRC pavement. In addition to the experimental design, other major contributions have been made, such as developing the distress and decision criteria indices for determining the current pavement distress condition and the time when a pavement has reached its terminal condition. The distress index was developed using discriminant analysis from the condition survey data for 1974 to 1984. It is a weighted combination of several major distress manifestations occurring in a pavement section. For major rehabilitation, a pavement is classified as a candidate for overlay if its distress index is smaller than zero. Once the current pavement distress condition can be expressed as a single number, i.e., as a Zeta score, its future condition can be predicted through the relationship between the Zeta score and some independent variables considered to have an influence on pavement deterioration. However, this relationship can not be obtained unless sufficient distress information is available from a well-planned condition survey conducted periodically for years.

The approach adopted in this study for determining the relationship was to monitor the existing, in-service roads. A factorial experiment permitting maximum use of data collected on a limited number of study test sections was designed. A set of independent variables was selected as the experimental factors, based on the investigation of the AASHTO equations (Table 4.1), mechanistic models (Table 4.2), and field data analysis (Table 4.4). These variables include

(1) design and construction parameters: slab thickness, coarse aggregate type, subbase type, roadbed soil type, and roadbed profile characteristics;
(2) environmental parameters: average annual rainfall, and average annual lowest temperature; and
(3) pavement age.

The experimental factors possess control levels which cover a wide range of conditions existing in Texas. Since no information regarding these selected experimental factors is available in the existing distress data bank, data were collected from various sources for the entire CRCP network.

Eight experimental factorials were established based on the different levels of experimental factors and whether the pavement project was overlaid or not. From the 355 projects in the CRCP network, 112 projects were selected. Definitions and methods for measurement of surveyed variables are presented in this study. A pilot study and training session were scheduled prior to the network experimental condition survey in order to investigate the feasibility of the proposed measurement methods and survey forms. It was found that no changes, were necessary for either one.

Fourteen districts were included in the experimental condition survey. A total of 425 test sections were selected from the 112 pavement projects. More than forty percent of the test sections were located in Districts 2, 13, and 18. Some statistical analyses showed the distribution of test sections for various highway categories, section lengths, and subgrade grading types.

The distress condition of each test section was calculated using the distress index equation. It was observed that most of the districts had a lower average Zeta score in 1987 than in 1984. The difference in the Zeta scores for these two years varied from district to district because of their different values for experimental factors. It was found through the preliminary data analysis that most experimental design factors or their interactions, e.g., roadbed profile characteristics, rainfall and soil type, coarse aggregate type, etc., have significant influence on the Zeta score and pavement mean crack spacing. These significant effects imply that suitable performance prediction models, in which distress is a function of the various experimental factors, should be developed in future data analysis.

CONCLUSIONS

The principal conclusions concerning the development of the experimental design for the CRC pavement network and data collection for the pavement performance condition survey are summarized in this section. In the process of experimental design, distress and decision criteria Indices were developed and a data base for pavement fundamental information was formed. The conclusions regarding the development of these indices are presented below.

Three conclusions were drawn from the development of the distress and decision criteria Indices.

(1) It was found from the historical condition survey record that, for CRC pavements, distress gives a better indication of the pavement performance condition than riding quality. Therefore, it was recommended that the distress index should be used as the decision criterion for major maintenance, such as overlay and rehabilitation.

(2) The distress index was developed using 10 years of condition survey data with the discriminant analysis method (Eq 3.10). Punchouts and patches were the primary distress manifestations included in the distress index equation.

(3) The distress index equation provides a method for ranking of the rehabilitation needs for a network analysis and maintenance programming. Zeta scores ranged from +1.0 to -1.8 with zero as the decision criterion, with a confidence level of 92.6 percent.

In relation to the development of the experimental design and pavement performance condition survey, the following conclusions were derived:

(1) A set of independent variables was selected for the experimental factors, based on an investigation from both the empirical and the theoretical viewpoints. These variables were slab thickness, coarse aggregate type, subbase type, roadbed soil type, average annual rainfall, average annual lowest temperature, pavement age, and subgrade grading type. Levels of each variable were selected to cover a wide range of conditions existing in Texas.

(2) Information regarding the experimental factors for all the CRCP network projects was collected from various sources and stored in the existing distress data bank as fundamental pavement information. This made the data bank the most complete data base in the U. S.

(3) There were 112 pavement projects selected for the condition survey from a set of experimental factorials using the random sampling method. Most of them were 8-inch-thick pavements. Since the 1000-foot test section is the survey unit on which the condition survey will be conducted in the future, the criteria for selecting the test sections were developed and are listed in the report.

(4) The general performance condition survey was completed in the summer of 1987. A total of 425 test sections were selected and surveyed. Distress data and other information were processed and combined with the previous distress data and fundamental pavement information.

Through the preliminary data analysis, conclusions regarding the application of the distress manifestation data base formed from the condition survey are summarized below:

(1) the subgrade grading type has a significant influence on the distress index, the Zeta score. In general, a pavement section with cut grading shows the best performance during its life. The distress indexes of the other grading types decrease in the order of at-grade, fill, and transition between cut and fill.

(2) The Zeta score decreases with pavement age. In some cases, the data are confounded because the highly distressed sections were overlaid between two adjacent surveys.

(3) Climatic conditions have a definitive effect on distress deterioration. Districts located in east Texas, the highest rainfall area, show the worst distress condition, while Districts located in west Texas, the dry area, have the best performance.

(4) Pavements built on swelling clay have lower Zeta scores than those on non-swelling soil. The difference becomes more significant if they are located in the high rainfall regions.

(5) Coarse aggregate type plays an important role in the cracking pattern. Limestone concrete pavements have double the mean crack spacing of pavements with silicious river gravel.

(6) No sound conclusion can be made regarding the effect of age on crack spacing for either LMS or SRG concrete pavements.

RECOMMENDATIONS

Several recommendations for future research along with possible extensions of the concepts of the experiment design and the performance prediction model are presented below:

(1) The distress index can be improved by further study of the following assumptions used in developing the index.

   (a) It was assumed that each district has the same maintenance technique and scheme and that the district's decisions to overlay the projects are correct and consistent.

   (b) It was also assumed that the total costs, agent and user costs, of overlaying a pavement when it should not be overlaid are equal to the total costs of not overlaying a pavement when it should be.

(2) If the relationship between distress and performance is to include JRCP and/or flexible pavements, similar distress indices need to be developed for evaluating those pavement types. Different experimental factors and measurements should be studied and chosen for each type of pavement condition survey.

(3) Accurate traffic data for 18-kip ESAL should be collected and included in the experimental factorial as one of the factors, since traffic is known to have an extremely significant influence on pavement distress deterioration. Accurate traffic data should also be considered as one of the most important independent parameters in the performance prediction model.

(4) Design criteria adopted in the construction of CRCP sections should be modified based on the different performance levels of the cut, fill, at-grade, and transition grading types.

(5) The diagnostic study, which provides information on deflection and roughness, should be conducted as soon as possible. Material properties and the correlation of distress index and PSI should be investigated.

(6) A rigorous performance prediction model should be developed in the near future, taking into account the effects on the Zeta score of all experimental factors at different levels.

(7) By monitoring the present distress index of a CRCP section with time, the accuracy of the performance prediction model could be investigated in greater detail. It is suggested that the long-term monitoring of the experimental sections be carried out.

(8) In order to update the established data bank, it is recommended that the fundamental information and the distress condition of any newly constructed pavement section be included in the data bank.

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APPENDIX A. LISTING OF OUTPUT FOR THE DEVELOPMENT OF DISCRIMINANT EQUATIONS

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                                                                                  04 AUG 86
          ****************************************
          *         COMPUTATION CENTER           *
          *    UNIVERSITY OF TEXAS AT AUSTIN     *
          ****************************************

          S P S S - - STATISTICAL PACKAGE FOR THE SOCIAL SCIENCES

          CDC 6000/CYBER VERSION 9.0  -  LOCAL RELEASE 1.2

          376000 CM MAXIMUM FIELD LENGTH REQUEST



                     RUN NAME        DISCRIMINANT ANALYSIS OF CONDITION SURVEY DATA
                     VARIABLE LIST   MPOUT,SPOUT,PATCH,OVERLAY
                     N OF CASES      UNKNOWN
                     INPUT FORMAT    FIXED(20X,3F10.1,F5.1)


                    ACCORDING TO YOUR INPUT FORMAT, VARIABLES ARE TO BE READ AS FOLLOWS

                    VARIABLE  FORMAT  RECORD    COLUMNS

                    MPOUT     F10. 1       1     21-  30
                    SPOUT     F10. 1       1     31-  40
                    PATCH     F10. 1       1     41-  50
                    OVERLAY   F 5. 1       1     51-  55

 THE INPUT FORMAT PROVIDES FOR    4 VARIABLES.    4 WILL BE READ.
 IT PROVIDES FOR  1 RECORDS ('CARDS') PER CASE.
 A MAXIMUM OF    55 'COLUMNS' ARE USED ON A RECORD.

                     VALUE LABELS    OVERLAY(1.0)YES (2.0)NO.
                     VAR LABELS      MPOUT, MINOR PUNCHOUT PER MILE
                                     SPOUT, SEVERE PUNCHOUT PER MILE
                                     PATCH, NO. OF PATCH PER MILE
                                     OVERLAY, WHETHER THE SECTION HAD BEEN OVERLAID

 CPU TIME REQUIRED..       .031 SECONDS


                     DISCRIMINANT    GROUPS=OVERLAY(1.0,2.0)/
                                     VARIABLES=MPOUT,SPOUT,PATCH/
                                     ANALYSIS=MPOUT,SPOUT,PATCH/
                                     METHOD=DIRECT/
                     OPTIONS         5,6,8,11,12
                     STATISTICS      1,2,4,7,8

              00101300 CM REQUIRED FOR DISCRIMINANT ANALYSIS
              00101600 CM REQUIRED FOR DISCRIMINANT CLASSIFICATION

              OPTION - 1
              IGNORE MISSING VALUE INDICATORS
              (NO MISSING VALUES DEFINED...OPTION 1 MAY HAVE BEEN FORCED)

              OPTION - 5
              PRINT CLASSIFICATION RESULTS TABLE

              OPTION - 6
              PRINT DISCRIMINANT SCORES AND CLASSIFICATION INFORMATION
```

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DISCRIMINANT ANALYSIS OF CONDITION SURVEY DATA                              04 AUG 86

             OPTION - 8
             PRINT A SEPARATE PLOT FOR EACH GROUP

             OPTION -11
             PRINT UNSTANDARDIZED DISCRIMINANT FUNCTION COEFFICIENTS

             OPTION -12
             PRINT CLASSIFICATION FUNCTIONS

END OF FILE ON FILE LOG882
AFTER READING     882 CASES FROM SUBFILE NONAME



DISCRIMINANT ANALYSIS OF CONDITION SURVEY DATA                              04 AUG 86

FILE    NONAME   (CREATION DATE =  04 AUG 86)




ON GROUPS DEFINED BY OVERLAY


           882 (UNWEIGHTED) CASES WERE PROCESSED.
             0 OF THESE WERE EXCLUDED FROM THE ANALYSIS.
           882 (UNWEIGHTEO) CASES WILL BE USED IN THE ANALYSIS.


NUMBER OF CASES BY GROUP

                   NUMBER OF CASES
  OVERLAY     UNWEIGHTED      WEIGHTED   LABEL

        1             56          56.0   YES
        2            826         826.0   NO.

    TOTAL            882         882.0


GROUP MEANS

  OVERLAY          MPOUT            SPOUT            PATCH

        1        2.34643          1.31607          2.54286
        2         .99976           .23269           .50169

    TOTAL        1.08526           .30147           .63129


GROUP STANDARD DEVIATIONS

  OVERLAY          MPOUT            SPOUT            PATCH

        1         .89381           .77946           .73159
        2        1.00464           .39567           .65714

    TOTAL        1.05023           .50438           .82813
```

```
DISCRIMINANT ANALYSIS OF CONDITION SURVEY DATA                                 04 AUG 86



POOLED WITHIN-GROUPS CORRELATION MATRIX

               MPOUT      SPOUT      PATCH

 MPOUT        1.00000
 SPOUT         .29068    1.00000
 PATCH         .34401     .40001    1.00000

CORRELATIONS WHICH CANNOT BE COMPUTED ARE PRINTED AS 99.0.



COVARIANCE MATRIX FOR GROUP          1, YES

             MPOUT             SPOUT             PATCH

 MPOUT        .7988961
 SPOUT       -.3948701E-01     .6075552
 PATCH        .7833766E-01     .1594805          .5352208



COVARIANCE MATRIX FOR GROUP          2, NO.

             MPOUT             SPOUT             PATCH

 MPOUT        1.009309
 SPOUT        .1356443         .1565545
 PATCH        .2372368         .1107809          .4318274
```

```
ON GROUPS DEFINED BY OVERLAY


ANALYSIS NUMBER        1

DIRECT METHOD-  ALL VARIABLES PASSING THE TOLERANCE TEST ARE ENTERED.

     MINIMUM TOLERANCE LEVEL..................  .00100

CANONICAL DISCRIMINANT FUNCTIONS

     MAXIMUM NUMBER OF FUNCTIONS..............       1
     MINIMUM CUMULATIVE PERCENT OF VARIANCE...  100.00
     MAXIMUM SIGNIFICANCE OF WILKS  LAMBDA....  1.0000


PRIOR PROBABILITY FOR EACH GROUP IS  .50000


CLASSIFICATION FUNCTION COEFFICIENTS
(FISHER*S LINEAR DISCRIMINANT FUNCTIONS)

OVERLAY =          1              2
           YES             NO.


MPOUT         .8820743       .8186369
SPOUT         3.852027       .3134341
PATCH         4.343935       .6387049
(CONSTANT)   -9.785784      -1.299050

                                                    CANONICAL DISCRIMINANT FUNCTIONS


                              PERCENT OF  CUMULATIVE    CANONICAL  -   AFTER
FUNCTION  EIGENVALUE   VARIANCE    PERCENT     CORRELATION - FUNCTION  WILKS  LAMBDA

                                                             -    0         .5937240
    1*         .68428    100.00       100.00        .6373979  -

     * MARKS THE   1 FUNCTION(S) TO BE USED IN THE REMAINING ANALYSIS.


STANDARDIZED CANONICAL DISCRIMINANT FUNCTION COEFFICIENTS

             FUNC  1

MPOUT         .01869
SPOUT         .44885
PATCH         .72391
```

```
DISCRIMINANT ANALYSIS OF CONDITION SURVEY DATA                          04 AUG 86


UNSTANDARDIZED CANONICAL DISCRIMINANT FUNCTION COEFFICIENTS

                 FUNC   1

MPOUT          .1872127E-01
SPOUT          1.044289
PATCH          1.093466
(CONSTANT)    -1.025440


CANONICAL DISCRIMINANT FUNCTIONS EVALUATED AT GROUP MEANS (GROUP CENTROIDS)

   GROUP         FUNC   1

      1          3.17337
      2          -.21514

TEST OF EQUALITY OF GROUP COVARIANCE MATRICES USING BOX*S M

   THE RANKS AND NATURAL LOGARITHMS OF DETERMINANTS PRINTED ARE THOSE
   OF THE GROUP COVARIANCE MATRICES.

     GROUP LABEL                      RANK    LOG DETERMINANT

         1 YES                           3         -1.452805
         2 NO.                           3         -3.074330
      POOLED WITHIN-GROUPS
      COVARIANCE MATRIX                  3         -2.849983

   BOX*S M       APPROXIMATE F  DEGREES OF FREEDOM  SIGNIFICANCE
    108.24           17.681         6,       49984.3        .0000
```

```
DISCRIMINANT ANALYSIS OF CONDITION SURVEY DATA                             04 AUG 86    15.54.05.


                 SYMBOLS USED IN PLOTS

                 SYMBOL   GROUP  LABEL
                 ------   -----  --------------------

                   1          1  YES
                   2          2  NO.



                               HISTOGRAM FOR GROUP       1  YES

                                    -- CANONICAL DISCRIMINANT FUNCTION 1 --
             8 +                                                                                 +
               .                                                                                 .
               .                                                                                 .
F              .                                                                                 .
R            6 +                                                          1                      +
E              .                                                          1                      .
Q              .                                                        1 1                      .
U              .                                                        1 1                      .
E            4 +                                                    111 1 1                      +
N              .                                                    111 1 1                      .
C              .                                                 111111 1 1     1                .
Y              .                                                 111111 1 1     1                .
             2 +                                             1  1111111 11111 1 11               +
               .                                             1  1111111 11111 1 11               .
               .                                           1 1 11111111 11111 11111  111         .
               .                                           1 1 11111111 11111 11111  111         .
              OUT.........+.........+.........+.........+.........+.........+.........+.........OUT
                         -6        -4        -2         0         2         4         6
GROUP CENTROIDS                                                         1
                               HISTOGRAM FOR GROUP       2  NO.

                                    -- CANONICAL DISCRIMINANT FUNCTION 1 --
           400 +                                                                                 +
               .                                                                                 .
               .                                                                                 .
F              .                                   2                                             .
R          300 +                                   2                                             +
E              .                                   2                                             .
Q              .                                   2                                             .
U              .                                   2                                             .
E          200 +                                   2                                             +
N              .                                   2                                             .
C              .                                   2                                             .
Y              .                                   2                                             .
           100 +                                   2                                             +
               .                                   2  2                                          .
               .                                   2 2222                                        .
               .                                   222222222222 22                               .
              OUT.........+.........+.........+.........+.........+.........+.........+.........OUT
                         -6        -4        -2         0         2         4         6
GROUP CENTROIDS                                        2
```

```
DISCRIMINANT ANALYSIS OF CONDITION SURVEY DATA                                    04 AUG 86


CLASSIFICATION RESULTS -

                           NO. OF     PREDICTED GROUP MEMBERSHIP
   ACTUAL GROUP             CASES          1          2
--------------------       ------    --------   --------

GROUP         1               56          52          4
YES                                     92.9        7.1

GROUP         2              826          69        757
NO.                                      8.4       91.6

PERCENT OF GROUPED CASES CORRECTLY CLASSIFIED -  91.72

CLASSIFICATION PROCESSING SUMMARY

       882 CASES WERE PROCESSED.
       882 CASES WERE USED FOR PRINTED OUTPUT.

CPU TIME REQUIRED..      2.094 SECONDS

                     FINISH

TOTAL CPU TIME USED..      2.129 SECONDS

RUN COMPLETED

NUMBER OF CONTROL CARDS READ  15
NUMBER OF ERRORS DETECTED      0
```

APPENDIX B. LISTING OF DATA BANK FOR THE CRCP NETWORK IN TEXAS

LISTING OF DESCRIPTION FOR ITEMS INCLUDED IN APPENDIX B

ITEM	DESCRIPTION
HWY	Highway type and number, e.g. IH: Interstate Highway, US: United Satate Highway, and S: State Highway
CFTR	Section ID number
COUNTY	County name
CTRO/SEC/JOB	SDHPT control-section-job numbers
NJOB	SDHPT subsequent job numbers
L	Highway section length (miles)
D	Pavement slab thickness (in.)
CAT	Slab coarse aggregate type: 1 = Silicious River Gravel, 2 = Limestone, 3 = 1&2, 4 = slag, 5 = 1&4 or 2&4.
SBT	Subbase Type: 1 = Asphalt treated, 2 = Cement treated, 3 = Crushed stone , 4= Lime treated.
SOIL	Y for swelling soil, or N if not
RAIN	Average Annual Rainfall (in.)
T	Average Annual Lowest Temperature (^{O}F)
YEAR	Construction date, using 12 as base, e.g. 1964.50 means June 1964
OVER1-OVER4	Date of the first four overlays, using 12 as base, e.g. 86.67 means August 1986
MILE1	Beginning milepost of highway section
MILE2	Ending milepost of highway section
AADT	Average Annual Daily Traffic of 1985
G	Average Annual Daily Traffic Growth Rate
LANE	Number of lanes (each direction)
SHD	Shoulder type: AC: asphalt, PCC: concrete
MAIN	Y if main lane, N if frontage road

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OBS HWY   CFTR COUNTY   CTRO SEC JOB NJOB    L D CAT SBT SOIL RAIN    T

  1 IH30  1001 Hopkins    10   2 23  (50)  6.0 8  2    2 H      43 30.7
  2 IH30  1002 Hopkins   610   1 3   ()    1.6 8  2    2 H      43 30.7
  3 IH30  1003 Hopkins   610   1 4   (13)  6.2 8  2    2 H      43 30.7
  4 IH30  1004 Franklin  610   2 4   (23)  5.6 8  2    2 H      44 30.0
  5 IH30  1005 Franklin  610   2 4   (23)  5.0 8  2    2 L      44 30.0
  6 US75  1008 Grayson    47  13 5   (11)  8.8 8  2    4 L      36 30.0
  7 US75  1011 Grayson    47  13 5   (11)  0.4 8  2    4 L      36 30.0
  8 US271 1012 Lamar     136   7 30  ()    1.8 8  1    3 H      44 30.2
  9 US271 1013 Lamar     136   8 23  ()   10.0 8  1    3 H      44 30.2
 10 US82  1015 Grayson    45  19 4   ()    3.2 8  2    3 L      36 30.0

OBS    YEAR OVER1 OVER2 OVER3 OVER4 MILE1 MILE2  AADT    G LANE SHD MAIN

  1 1964.00 86.67     .     .     . 128.4 134.4 16000 3.53      AC   Y
  2 1964.42   .       .     .     . 134.6 136.2 13700  .        AC   Y
  3 1965.00 86.67     .     .     . 136.2 142.4 12600 3.53      AC   Y
  4 1965.99 85.25     .     .     . 142.4 148.0 13400 3.53      AC   Y
  5 1965.00 85.25     .     .     . 148.0 153.0 13200 3.53           Y
  6 1967.67 87.58     .     .     .  22.1  30.9 16000 5.15      AC   Y
  7 1969.83 87.58     .     .     .  30.9  31.3  2800  .        AC   Y
  8 1971.42   .       .     .     .  11.0  12.8  8300 1.42      AC   Y
  9 1971.00   .       .     .     .   0.0  10.0  7200 1.42           Y
 10 1975.00   .       .     .     .  18.0  21.2 10700 1.42           Y
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OBS HWY    CFTR COUNTY   CTRO SEC JOB NJOB          L  D CAT SBT SOIL RAIN    T

  1 IH30   2002 Parker      8   3 18  (48)     11.700  8   3   3 L       32 33.0
  2 IH30   2012 Tarrant  1068   1 22  (67/86)   0.300  8   3   3 L       32 33.0
  3 IH820  2015 Tarrant     8  13 4   (97)      4.480  8   3   3 L       32 33.0
  4 IH820  2018 Tarrant     8  13 6   (128)     2.300  8   3   4 H       32 33.0
  5 US287  2019 Tarrant   172   6 7   ()        1.800  6   3   3 L       32 33.0
  6 US287  2019 Tarrant   172   6 7   ()        1.800  8   3   3 L       32 33.0
  7 IH820  2020 Tarrant     8  13 7   (128)     3.420  8   3   4 H       32 33.0
  8 IH820  2020 Tarrant     8  13 7   ()        3.420  6   3   4 H       32 33.0
  9 IH820  2021 Tarrant     8  13 9   (128)     4.600  8   2   4 H       32 33.0
 10 IH30   2022 Tarrant  1068   1 36  ()        1.200  8   2   3 L       32 33.0
 11 SH121  2023 Tarrant   363   3 4   (29)      0.800  8   2   3 L       32 33.0
 12 US287  2024 Tarrant   172   6 12  ()        0.900  6   3   3 L       32 33.0
 13 US287  2024 Tarrant   172   6 12  ()        0.900  8   3   3 L       32 33.0
 14 IH820  2026 Tarrant     8  13 13  (77)      2.100  8   3   4 H       32 33.0
 15 IH820  2027 Tarrant     8  14 2   (61)      1.920  8   3   4 H       32 33.0
 16 IH35W  2028 Johnson    14   3 19  ()        8.900  8   2   4 H       32 33.0
 17 US287  2029 Tarrant   172   6 18  ()        0.500  8   3   4 L       32 33.0
 18 US287  2029 Tarrant   172   6 18  ()        0.500  6   3   4 L       32 33.0
 19 IH35W  2030 Tarrant    14  16 57  ()        2.800  8   2   4 L       32 33.0
 20 IH820  2031 Tarrant     8  14 3   (62)      3.400  8   1   3 L       32 33.0
 21 IH30   2032 Tarrant  1068   1 46  (114)     4.800  8   2   4 L       32 33.0
 22 IH35W  2033 Tarrant    14  16 65  ()        3.600  8   2   4 L       32 33.0
 23 IH35W  2034 Tarrant    81  12 1   ()        0.500  8   2   4 L       32 33.0

OBS    YEAR OVER1 OVER2 OVER3 OVER4 MILE1 MILE2    AADT     G LANE SHD     MAIN

  1 1949.50 78.83     .     .     . 414.4 422.8   35000  6.12 1    AC      Y
  2 1960.25 71.58 74.83     .     .     .     .       .     . 2    C&G     Y
  3 1961.50 86.08     .     .     .     .     .       .     . 2    AC      N
  4 1963.33 87.33     .     .     .     .     .       .     . 2    AC      Y
  5 1963.58     .     .     .     .     .     .       .     .              N
  6 1963.58     .     .     .     .     .     .       .     . 3    AC      Y
  7 1963.75 87.33     .     .     .     .     .       .     . 2    AC      Y
  8 1963.75     .     .     .     .     .     .       .     .              N
  9 1963.75 87.33     .     .     .     .     .       .     . 2-3  AC      Y
 10 1964.08     .     .     .     .     .     .       .     . 1.5  AC      Y
 11 1964.17 85.92     .     .     .     .     .       .     . 4    AC      Y
 12 1964.58     .     .     .     .     .     .       .     .              N
 13 1964.58     .     .     .     .     .     .       .     . 3    AC      Y
 14 1965.58 75.17 78.58     .     .     .     .       .     .      AC      Y
 15 1965.58 75.17     .     .     .     .     .       .     . 1    AC      Y
 16 1965.92     .     .     .     .  28.2  37.4   17200  1.11 1    AC      Y
 17 1966.17     .     .     .     .     .     .       .     . 1.5  AC      Y
 18 1966.17     .     .     .     .     .     .       .     .              N
 19 1966.33     .     .     .     .     .     .       .     . 2    AC      Y
 20 1966.67 86.58     .     .     .  16.8  20.6   63000 11.55 1    AC      Y
 21 1967.08 81.99     .     .     . 422.8 431.7   33000  6.12 2    AC      Y
 22 1967.25     .     .     .     .     .     .       .     . 2    AC      Y
 23 1967.25     .     .     .     .     .     .       .     . 2    AC      Y
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OBS HWY   CFTR COUNTY   CTRO SEC JOB NJOB         L  D CAT SBT SOIL RAIN    T

24 SH121  2035 Tarrant   364   1 7   (59)     0.650  8   2   1 L      32 33.0
25 SH121  2036 Tarrant   364   1 8   ()       0.800  6   2   1 L      32 33.0
26 SH121  2036 Tarrant   364   1 12  (59)     2.400  8   2   1 L      32 33.0
27 SH121  2038 Tarrant   363   3 9   (29)     1.800  8   3   1 L      32 33.0
28 SH121  2038 Tarrant   363   3 9   ()       1.800  6   3   1 L      32 33.0
29 IH35W  2039 Tarrant    81  12 2   ()       6.900  8   2   1 L      32 33.0
30 SH121  2040 Tarrant   363   3 11  (29)     2.800  8   2   1 L      32 33.0
31 SH121  2040 Tarrant   363   3 11  ()       2.800  6   2   1 L      32 33.0
32 US287  2041 Tarrant   172   6 26  ()       1.500  8   2   1 H      32 33.0
33 US287  2041 Tarrant   172   6 26  ()       1.500  6   2   1 H      32 33.0
34 SH121  2043 Tarrant   364   1 13  (59)     1.600  8   2   1 L      32 33.0
35 US287  2044 Wise       13   8 44  (64)    10.300  8   2   1 L      30 28.6
36 IH820  2045 Tarrant     8  14 11  ()       1.300  8   2   1 L      32 33.0
37 IH820  2045 Tarrant     8  14 11  ()       1.300  6   2   1 L      32 33.0
38 SH121  2046 Tarrant   363   3 12  (29)     2.800  8   1   1 L      32 33.0
39 SH121  2046 Tarrant   363   3 12  ()       2.800  6   1   1 L      32 33.0
40 IH20   2047 Parker    314   1 32  ()       0.504  8   2   1 L      30 29.9
41 IH20   2048 Parker    314   7 5   ()      11.600  8   2   1 L      30 29.9
42 US287  2049 Tarrant    14  15 2   ()       7.200  6   2   1 L      32 33.0
43 US287  2049 Tarrant    14  15 2   ()       7.200  8   2   1 L      32 33.0
44 US287  2050 Tarrant    14  16 87  ()       2.400  8   2   1 L      32 33.0
45 US287  2050 Tarrant    14  16 87  ()       2.400  6   2   1 L      32 33.0
46 IH20   2051 Parker    314   2 6   ()       1.200  8   2   2 L      29 32.1

OBS   YEAR OVER1 OVER2 OVER3 OVER4 MILE1 MILE2   AADT     G LANE SHD    MAIN

24 1967.50 86.92   .       .     .    .     .       .   .   3    AC     Y
25 1967.50   .     .       .     . 11.5  14.1       .   .            N
26 1970.83 86.92   .       .     . 11.5  14.1 110000  1.11 3    AC     Y
27 1967.67 85.92   .       .     .    .     .       .   .   3    AC     Y
28 1967.67   .     .       .     .    .     .       .   .            N
29 1967.67   .     .       .     .    .     .       .   .   2    AC     Y
30 1968.50 85.92   .       .     .    .     .       .   .   3    AC     Y
31 1968.50   .     .       .     .    .     .       .   .            N
32 1970.25   .     .       .     . 22.4  25.2  43000  1.11      AC     Y
33 1970.25   .     .       .     . 22.4  25.2       .   .            N
34 1972.08 86.92   .       .     .    .     .       .   .   3    AC     Y
35 1969.25 80.75   .       .     . 19.7  30.0  16100  5.15 2    AC     Y
36 1969.99   .     .       .     .    .     .       .   .   2    AC     Y
37 1969.99   .     .       .     .    .     .       .   .            N
38 1970.25 85.92   .       .     . 20.8  23.6  75000  1.11 3    AC     Y
39 1970.25   .     .       .     . 20.8  23.6       .   .            N
40 1970.42   .     .       .     .    .     .       .   .        AC     Y
41 1970.42   .     .       .     .    .     .       .   .        AC     Y
42 1971.42   .     .       .     .  0.0   7.2       .   .            N
43 1971.42   .     .       .     .  0.0   7.2  15400 11.55 1    AC     Y
44 1971.42   .     .       .     .  7.2   9.6  16000 11.50 1    AC     Y
45 1971.42   .     .       .     .    .     .       .   .            N
46 1971.42   .     .       .     . 389.0 390.2  13700  3.69            Y
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OBS HWY   CFTR COUNTY   CTRO SEC JOB NJOB         L  D CAT SBT SOIL RAIN    T

47 IH20   2052 Parker    314   1 33  ()      11.000  8   2   1 L       30 29.9
48 US287  2053 Wise       13   8 51  (78)     3.000  8   2   1 L       30 28.6
49 IH20   2054 PaloPint  314   2 20  ()       7.900  8   2   1 L       29 32.1
50 IH20   2056 Tarrant  2374   5 2   ()       0.400  6   2   1 H       32 33.0
51 IH20   2056 Tarrant  2374   5 2   ()       0.400  8   2   1 H       32 33.0
52 IH20   2058 PaloPint  314   3 17  ()      10.000  8   2   1 L       29 32.1
53 IH20   2059 Erath     314   4 15  ()       5.800  8   2   1 L       29 32.1
54 IH20   2060 Tarrant  2374   5 3   ()       1.800  6   2   1 H       32 33.0
55 IH20   2060 Tarrant  2374   5 3   ()       1.800  8   2   1 H       32 33.0
56 SH114  2063 Tarrant   353   3 27  ()       2.300  8   2   1 H       32 33.0
57 SH360  2066 Tarrant  2266   2 21  ()       2.100  6   2   1 H       32 33.0
58 SH360  2066 Tarrant  2266   2 41  ()       1.700  8   2   1 H       32 33.0
59 IH20   2068 Tarrant  2374   5 4   ()       4.300  6   2   1 L       32 33.0
60 IH20   2068 Tarrant  2374   5 4   ()       4.300  8   2   1 L       32 33.0
61 US287  2069 Tarrant   172   9 3   ()       5.700  6   3   1 L       32 33.0
62 US287  2069 Tarrant   172   9 3   ()       5.700  8   3   1 L       32 33.0
63 IH20   2070 Tarrant  2374   5 5   ()       5.300  6   3   1 H       32 33.0
64 IH20   2070 Tarrant  2374   5 5   (14)     5.300  8   3   1 H       32 33.0
65 SPUR35 2073 Tarrant   364   5 4   ()       3.200  6   3   1 L       32 33.0
66 SPUR35 2073 Tarrant   364   5 4   (23,24)  3.200  8   3   1 L       32 33.0
67 SH360  2074 Tarrant  2266   2 25  ()       1.200  6   3   1 L       32 33.0
68 SH360  2074 Tarrant  2266   2 25  (47)     1.200  8   3   1 L       32 33.0
69 IH35W  2075 Tarrant    14   2 20  ()       6.600  8   2   1 H       32 33.0

OBS   YEAR OVER1 OVER2 OVER3 OVER4 MILE1 MILE2   AADT     G LANE SHD     MAIN

47 1971.50   .     .       .     . 390.4 402.2  15000   3.69             Y
48 1971.83 77.83 87.50     .     .    .     .       .   .   1    AC     Y
49 1972.08   .     .       .     .    .     .       .   .        AC     Y
50 1972.17   .     .       .     .    .     .       .   .               N
51 1972.17   .     .       .     .    .     .       .   .   3    AC     Y
52 1972.33   .     .       .     . 370.0 380.0  12900   3.69      AC     Y
53 1972.33   .     .       .     . 363.6 369.4  12900   3.69 2    AC     Y
54 1973.25   .     .       .     . 444.2 446.0      .   .        AC     N
55 1973.25   .     .       .     . 444.2 446.0  72500 15.80 4    AC     Y
56 1973.83   .     .       .     .    .     .       .   .   1.5  AC     Y
57 1974.25   .     .       .     .    .     .       .   .               N
58 1985.25   .     .       .     .    .     .       .   .   1    C&CONC Y
59 1974.92   .     .       .     .    .     .       .   .        AC     N
60 1974.92   .     .       .     .    .     .       .   .   4    AC     Y
61 1975.50   .     .       .     .    .     .       .   .        AC     N
62 1975.50   .     .       .     .    .     .       .   .   2    AC     Y
63 1975.83   .     .       .     .    .     .       .   .        AC     N
64 1975.83 80.67   .       .     .    .     .       .   .        AC     Y
65 1972.08   .     .       .     .    .     .       .   .               N
66 1972.08 86.92   .       .     .    .     .       .   .   3    AC     Y
67 1976.99   .     .       .     .    .     .       .   .               N
68 1976.99 87.42   .       .     .    .     .       .   .   3    AC     Y
69 1976.92   .     .       .     .  37.6  44.2  57500   1.11 3    AC     Y
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OBS HWY   CFTR COUNTY   CTRO SEC JOB NJOB         L  D CAT SBT SOIL RAIN    T

70 US287   2078 Wise       13    8 48  ()       3.600  8   2   1 L      32 33.0
71 US287   2078 Wise       13    8 48  ()       3.600  6   2   1 L      32 33.0
72 US287   2089 Tarrant   172    9 6   ()       4.000  8   3   1 H      32 33.0
73 IH820   2093 Tarrant     8   15 4   ()       1.260  8   2   1 H      32 33.0
74 IH820   2094 Tarrant     8   15 6   ()       1.850 10   2   1 L      32 33.0
75 IH820   2096 Tarrant     8   15 8   ()       2.100  8   2   1 L      32 33.0
76 IH820   2097 Tarrant     8   14 31  ()       1.600  8   2   1 L      32 33.0
77 IH820   2098 Tarrant     8   14 22  ()       3.800  8   2   1 L      32 33.0
78 IH820   2098 Tarrant     8   14 22  ()       3.800  6   2   1 L      32 33.0

OBS   YEAR OVER1 OVER2 OVER3 OVER4 MILE1 MILE2   AADT     G LANE SHD    MAIN

70 1972.33   .     .       .     .  31.1  33.3  16200  5.15 2    AC     Y
71 1972.33   .     .       .     .  31.1  33.3      .   .               N
72 1982.33   .     .       .     .    .     .       .   .   2    AC     Y
73 1975.75   .     .       .     .    .     .       .   .   3    AC     Y
74 1982.17   .     .       .     .    .     .       .   .   3    CONC   Y
75 1976.17   .     .       .     .    .     .       .   .   3    AC     Y
76 1978.33   .     .       .     .    .     .       .   .   1.5  AC     Y
77 1976.58   .     .       .     .  10.6  14.4  46000 11.50 3    AC     Y
78 1976.58   .     .       .     .  10.6  14.4      .   .               N
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OBS HWY   CFTR COUNTY      CTRO SEC JOB    NJOB          L D CAT SBT SOIL RAIN      T

  1 US277 3001 Wichita      156   7 2/3    ()          3.0 6   2   2 L      27 28.4
  2 US277 3001 Wichita      156   7 2/3    (41)        3.0 8   2   2 L      27 28.4
  3 US277 3003 Wichita      156   7 4      ()          1.8 6   2   2 L      27 28.4
  4 US277 3003 Wichita      156   7 4      (41)        1.8 8   2   2 L      27 28.4
  5 US277 3004 Wichita      156   7 5      ()          5.0 6   2   1 L      27 28.4
  6 US277 3004 Wichita      156   7 5      (41)        5.0 8   2   1 L      27 28.4
  7 US277 3005 Wichita      156   7 6      ()          1.5 6   2   1 L      27 28.4
  8 US277 3005 Wichita      156   7 6      (41)        1.5 8   2   1 L      27 28.4
  9 US287 3006 Wichita       44   1 34     (62)        2.9 8   2   2 L      27 28.4
 10 US287 3007 Wichita       44   1 35     ()          0.9 6   2   2 L      27 28.4
 11 US287 3008 Clay          44   2 27/28  (58)        1.4 8   2   2 L      28 28.2
 12 US287 3010 Wichita       43   8 22     ()          9.1 8   2   2 L      27 28.4
 13 US287 3011 Wilbarge      43   7 15     ()          0.8 8   2   2 L      25 23.8
 14 US281 3012 Wichita      249   1 12     ()          3.7 6   2   2 L      27 28.4
 15 US281 3012 Wichita      249   1 12     ()          3.7 8   2   2 L      27 28.4
 16 US287 3014 Wilbarge      43   5 43     ()          0.9 8   2   1 L      25 23.8
 17 US70  3015 Wilbarge     146   7 8      ()          1.4 6   2   1 L      25 23.8
 18 US70  3015 Wilbarge     146   7 8      ()          1.4 8   2   1 L      25 23.8
 19 US287 3016 Wichita       43   8 26     (39/40/4    5.1 8   2   1 L      27 28.4
 20 US287 3017 Montague      13   5 17     ()          0.7 8   2   1 L      28 28.2
 21 US287 3018 Montague      13   5 18     ()          8.2 8   2   1 L      28 28.2
 22 US287 3019 Clay         224   1 16     ()          0.5 8   2   2 H      28 28.2
 23 US287 3020 Clay         224   1 17     (37)        9.4 8   2   2 L      28 28.2

OBS    YEAR OVER1 OVER2 OVER3 OVER4 MILE1 MILE2  AADT     G LANE SHD MAIN

  1 1964.67   .       .     .     .   8.4  11.4     .    .              N
  2 1964.67 87.50     .     .     .   8.4  11.4 15000 0.08 2      AC    Y
  3 1964.67   .       .     .     .   6.6   8.4     .    .              N
  4 1964.67 87.50     .     .     .   6.6   8.4 12900 0.08 2      AC    Y
  5 1964.99   .       .     .     .   0.0   5.0     .    .              N
  6 1964.99 87.50     .     .     .   0.0   5.0 12900 0.08 2      AC    Y
  7 1964.99   .       .     .     .   5.0   6.6     .    .              N
  8 1964.99 87.50     .     .     .   5.0   6.6 12900 0.08 2      AC    Y
  9 1967.42 87.08     .     .     .     .     . 25000    . 2      AC    Y
 10 1967.17   .       .     .     .     .     . 13100    . 2      AC    Y
 11 1967.92 87.08     .     .     .     .     . 13100    . 2      AC    Y
 12 1968.83   .       .     .     .   0.0   9.1  9600 0.68 1      AC    Y
 13 1968.83   .       .     .     .   0.0   0.8  8700 0.68 2      AC    Y
 14 1968.75   .       .     .     .  16.5  20.2     .    .              N
 15 1968.75   .       .     .     .  16.5  20.2 18600 0.08 2      AC    Y
 16 1969.75   .       .     .     .   0.0   0.2  7300    . 2      AC    Y
 17 1969.75   .       .     .     .     .     .     .    .              N
 18 1969.75   .       .     .     .     .     .  3600    . 3      C&G   Y
 19 1970.75 78.00    81    82    85     .     .  9600    . 1      AC    Y
 20 1972.67   .       .     .     .   0.0   0.8 11700 0.08 1      AC    Y
 21 1972.67   .       .     .     .   0.8   8.8 11700 0.08 1      AC    Y
 22 1972.75   .       .     .     .  13.0  13.5 10200 0.08 2      AC    Y
 23 1972.75 87.08     .     .     .  13.5  23.5 10500 0.08 2-1    AC    Y
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OBS HWY  CFTR COUNTY   CTRO SEC JOB   NJOB        L D CAT SBT SOIL RAIN    T

24 US287 3022 Wilbarge   43    7 23   (36)     10.2 8   2   2 L      25 23.8

OBS   YEAR OVER1 OVER2 OVER3 OVER4 MILE1 MILE2  AADT    G LANE SHD MAIN

24 1973.67 87.08     .     .     .   1.0  11.2  8700 0.68 1    AC  Y
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 OBS HWY  CFTR COUNTY  CTRO SEC JOB    NJOB       L  D CAT SBT SOIL RAIN    T

   1 IH40 4002 Potter   275   1 11     (83)     2.0  8   1   4 L      18 21.7
   2 IH40 4003 Potter   275   1 12     ()       1.1  8   1   2 L      18 21.7
   3 IH40 4004 Potter   275   1 21     ()       1.7  8   1   2 L      18 21.7
   4 IH40 4005 Carson   275   2 12     ()       7.9  8   1   3 L      19 21.5
   5 IH40 4006 Carson   275   3 15     ()       5.2  8   1   1 L      19 21.5
   6 IH40 4007 Potter   275   1 22     (83)     5.0  8   3   2 L      18 21.7
   7 IH40 4008 Potter    90   5 32     (41)     0.6  8   1   2 L      18 21.7
   8 IH40 4009 Potter   275   1 20     ()       4.4  8   1   2 L      18 21.7
   9 IH40 4010 Potter   275   1 31     (83/88)  4.2  8   1   1 L      18 21.7
  10 IH40 4011 Potter    90   5 44     ()       7.0  8   1   2 L      18 21.7
  11 IH40 4021 Carson   275   4 26     ()       4.3  9   1   1 L      19 22.0
  12 IH40 4022 Gray     275   5 19     ()       1.3  9   1   1 L      20 22.5
  13 IH40 4023 Donley   275   8 18     ()       1.6  8   1   1 L      21 23.0
  14 IH40 4024 Gray     275   9 16/17  ()       0.7  8   1   1 L      21 23.0
  15 IH40 4025 Donley   275  10 17     ()       2.2  8   1   1 L      21 23.0
  16 IH40 4026 Gray     275  11 38/39  ()       5.1  8   1   1 L      21 23.0
  17 IH40 4027 Gray     275  11 42     ()       7.1 10   1   1 L      21 23.0
  18 IH40 4028 Gray     275  11 49     ()       4.7 10   1   1 L      21 23.0

 OBS    YEAR OVER1 OVER2 OVER3 OVER4 MILE1 MILE2  AADT    G LANE SHD  MAIN

   1 1964.83 83.99     .     .     .  70.2  72.2 62000 2.61 4-3  AC   Y
   2 1965.92     .     .     .     .  69.0  70.0 57000 2.61 3    AC   Y
   3 1966.67     .     .     .     .  67.2  68.8 39000    . 3    AC   Y
   4 1966.92     .     .     .     .  85.2  93.1  8700 2.61 2    AC   Y
   5 1966.92     .     .     .     .  93.4  98.6  8500 2.61 2    AC   Y
   6 1966.99 83.99     .     .     .  72.4  77.8 14600    . 3    AC   Y
   7 1969.08 69.50     .     .     .  62.1  62.5 10700    . 2    AC   Y
   8 1969.08     .     .     .     .  62.6  67.0 39000 2.61 2-3  AC   Y
   9 1968.99 83.99  85.5     .     .  78.6  82.8 14600 2.61 2    AC   Y
  10 1972.50     .     .     .     .  54.8  61.8 10700 2.61 2    AC   Y
  11 1980.67     .     .     .     . 109.9 114.2  8150    . 2    AC   Y
  12 1978.00     .     .     .     . 114.2 115.5  8200 2.61 2    CONC Y
  13 1980.67     .     .     .     . 123.4 125.0  8200 2.61           Y
  14 1978.92 80.99     .     .     . 126.7 127.4  8700    . 2    CONC Y
  15 1978.00     .     .     .     . 127.4 129.5  8500 2.61           Y
  16 1978.92 80.99     .     .     . 129.6 134.7  8500    . 2    CONC Y
  17 1982.67     .     .     .     . 134.7 141.8  7700    . 1    CONC Y
  18 1984.67     .     .     .     . 141.8 146.6  8600    . 1    CONC Y
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OBS HWY   CFTR COUNTY   CTRO SEC JOB NJOB    L D CAT SBT SOIL RAIN    T    YEAR

  1 IH27 5001 Lubbock    67    7 59  ()   6.8 9   3   1 L      18 24.3 1981.41
  2 IH27 5002 Hale       67    6 32  ()   8.2 9   1   1 L      19 22.8 1981.50
  3 IH27 5003 Lubbock    67    7 60  ()   7.7 9   3   1 L      18 24.3 1982.17
  4 IH27 5004 Hale       67    6 33  ()   1.4 9   2   1 L      19 22.8 1982.17
  5 IH27 5005 Hale       67    5 28  ()   5.2 9   1   4 L      19 22.8 1982.17
  6 IH27 5006 Hale       67    6 34  ()   6.4 9   2   1 L      19 22.8 1982.92
  7 IH27 5007 Hale       67    5 32  ()   1.5 9   2   1 L      19 22.8 1982.92
  8 IH27 5008 Hale       67    4 27  ()   4.8 9   1   1 L      19 22.8 1984.17
  9 IH27 5009 Swisher    67    3 39  ()   1.4 9   1   2 L      18 21.5 1984.17

OBS OVER1  OVER2  OVER3  OVER4  MILE1  MILE2   AADT    G  LANE   SHD    MAIN

 1      .      .      .      .      .      .  10650    .  2      CONC   Y
 2      .      .      .      .      .      .   6500    .  2      CONC   Y
 3      .      .      .      .      .      .   7800    .  2      CONC   Y
 4      .      .      .      .      .      .   7500    .  2      CONC   Y
 5      .      .      .      .   39.0   44.2   7200  4.4  1.5           Y
 6      .      .      .      .      .      .   6700    .  2      CONC   Y
 7      .      .      .      .   37.5   39.0   6700  4.4  1.5           Y
 8      .      .      .      .   53.8   58.6   6800  4.4  2             Y
 9      .      .      .      .   58.8   60.2   6700  4.4  2      AC     Y
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OBS HWY  CFTR COUNTY    CTRO SEC JOB NJOB    L  D CAT SBT SOIL RAIN    T    YEAR

  1 IH35 9001 Falls      15    3 10  (22)  1.8 8    2   3 L      40 33.0 1960.17
  2 IH35 9002 McLennan   15    2 18  (37)  4.0 8    2   3 L      34 35.7 1960.17
  3 IH35 9004 McLennan   15    1 25  ()    1.9 8    1   4 L      34 35.7 1964.99
  4 IH35 9005 McLennan   15    1 30  (108) 0.6 8    3   4 L      34 35.7 1965.58
  5 IH35 9006 Hill       48    9 4   ()    7.4 8    3   3 H      33 32.5 1966.25
  6 IH35 9007 McLennan   15    1 34  ()    0.8 6    3   3 H      34 35.7 1966.75
  7 IH35 9007 McLennan   15    1 34  ()    0.8 8    3   3 H      34 35.7 1966.75
  8 IH35 9008 McLennan   15    1 45  ()    1.0 8    2   3 L      34 35.7 1970.58
  9 IH35 9009 McLennan   15    1 51  ()    1.0 8    1   1 L      34 35.7 1971.33
 10 IH35 9010 McLennan   15    1 60  ()    1.3 8    3   1 L      34 35.7 1972.58

OBS OVER1 OVER2  OVER3  OVER4  MILE1  MILE2   AADT     G  LANE  SHD   MAIN

  1 78.41     .      .      .  313.6  315.4  24000  5.30  2     AC    Y
  2 78.41     .      .      .  315.4  319.4  24000  5.30  2     AC    Y
  3   .       .      .      .  331.5  333.4  47000  5.30  2     AC    Y
  4 81.67     .      .      .  333.4  334.0  54000   .    2     AC    Y
  5   .       .      .      .  371.4  378.8  14100   .    2     CONC  Y
  6   .       .      .      .  334.2  335.0      .   .                N
  7   .       .      .      .  334.2  335.0  54000   .    3     AC    Y
  8   .       .      .      .  335.0  336.0  54000   .    3     AC    Y
  9   .       .      .      .  336.0  337.0   5600  3.38  3     AC    Y
 10   .       .      .      .  337.0  338.3  54000   .    3     CONC  Y
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OBS HWY    CFTR COUNTY    CTRO SEC JOB NJOB      L D CAT SBT SOIL RAIN    T

  1 IH20 10001 VanZandt  495   2 3   (26)    3.6 8   3   2 L    42.4 32.1
  2 IH20 10002 Smith     495   4 3   (33)    6.6 8   2   3 L    43.0 33.5
  3 IH20 10003 Smith     495   4 4   (29/36) 6.0 8   3   2 L    43.0 33.5
  4 IH20 10004 VanZandt  495   3 4   (36)    8.0 8   3   3 L    42.4 32.1
  5 IH20 10005 VanZandt  495   3 3   (27)    8.4 8   3   2 L    42.4 32.1
  6 IH20 10006 VanZandt  495   2 5   (26)    5.0 8   3   2 L    42.4 32.1
  7 IH20 10007 VanZandt  495   2 7   (26)    5.2 8   3   2 L    42.4 32.1
  8 IH20 10008 Gregg     495   7 1   (35)    4.6 8   4   2 L    46.5 33.0
  9 IH20 10009 Smith     495   5 3   ()      8.3 8   3   2 L    43.0 33.5
 10 IH20 10010 Smith     495   5 5   ()      7.4 8   3   2 L    43.0 33.5
 11 IH20 10011 Gregg     495   7 2   (35)    3.8 8   4   2 H    46.5 33.0
 12 IH20 10012 Gregg     495   7 3   (35)    6.4 8   4   2 H    46.5 33.0
 13 IH20 10013 Gregg     495   7 6   ()      1.8 8   4   2 L    46.5 33.0
 14 IH20 10014 Smith     495   6 1   (17)    8.2 8   3   2 L    43.0 33.5

OBS      YEAR OVER1 OVER2 OVER3 OVER4 MILE1 MILE2  AADT G LANE SHD MAIN

  1 1963.33 84.41     .     .     . 523.5 527.1 19300 . 2    AC   Y
  2 1963.50 85.33     .     .     . 543.7 550.3 20000 . 2    AC   Y
  3 1963.92 84.50 86.83     .     . 550.3 556.3 22000 . 2    AC   Y
  4 1963.92 85.67     .     .     . 535.5 543.5 19300 . 2    AC   Y
  5 1964.67 84.41     .     .     . 527.1 535.5 19300 . 2    AC   Y
  6 1965.58 84.41     .     .     . 513.5 518.5 20000 . 2    AC   Y
  7 1965.58 84.41     .     .     . 518.5 523.7 19500 . 2    AC   Y
  8 1965.67 85.33     .     .     . 580.0 584.6 19500 . 2    AC   Y
  9 1965.99     .     .     .     . 556.3 564.6 17800 . 2    AC   Y
 10 1966.25     .     .     .     . 564.1 571.5 17500 . 2    AC   Y
 11 1966.58 85.33     .     .     . 584.7 588.5 19500 . 2    AC   Y
 12 1967.33 85.33     .     .     . 588.5 594.9 19500 . 2    AC   Y
 13 1967.33     .     .     .     . 594.9 596.7 19500 . 2    AC   Y
 14 1966.08 87.50     .     .     . 571.5 579.7 19500 . 2    AC   Y
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OBS HWY    CFTR COUNTY   CTRO SEC JOB   NJOB   L  D CAT SBT SOIL RAIN    T

  1 US59  12107 FortBend   27  12 28/30 ()   6.8 10   1   2 H       44 41.3
  2 BELT8 12901 Harris   3256   2 13    ()   5.1 13   1   2 H       45 39.2
  3 BELT8 12902 Harris   3256   2 14    ()   1.6 13   1   2 H       45 39.2
  4 BELT8 12903 Harris   3256   3 12    ()   0.3 10   1   2 H       45 39.2
  5 BELT8 12904 Harris   3256   3 13    ()   2.5 10   1   2 H       45 39.2
  6 BELT8 12905 Harris   3256   1 19    ()   2.4 10   2   2 H       44 39.2

OBS    YEAR OVER1 OVER2 OVER3 OVER4 MILE1 MILE2  AADT    G LANE SHD MAIN

  1 1976.25     .     .     .     .     .     . 39000   .   2   AC  Y
  2 1986.67     .     .     .     .     .     . 47000 7.46          Y
  3 1986.58     .     .     .     .     .     . 47000 7.46          Y
  4 1985.41     .     .     .     .     .     .     .   .           Y
  5 1985.41     .     .     .     .     .     .     .   .           Y
  6 1985.67     .     .     .     .     .     .     .   .           Y
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OBS HWY      CFTR COUNTY    CTRO SEC JOB   NJOB          L D CAT SBT SOIL RAIN

  1 IH10     13001 Colorado  271   1 8     (35)       2.20 8   1   2 H      41
  2 IH10     13002 Colorado  535   8 4     (37/40)    7.20 8   1   2 L      38
  3 IH10     13003 Colorado  271   1 9     (40)      12.20 8   1   2 L      41
  4 LOOP175  13005 Victoria   88   5 12    (44/42)    8.60 8   1   2 H      38
  5 IH10     13006 Fayette   535   7 6     (25)       4.80 8   1   2 H      38
  6 IH10     13007 Fayette   535   8 12    (48)      10.00 8   1   2 L      38
  7 LOOP175  13008 Victoria   88   5 14    ()         3.20 8   1   2 H      38
  8 US77     13009 Victoria  371   1 30    (39/52)    1.80 8   1   2 L      38
  9 Spur91   13010 Victoria  371   6 3     (10)       1.10 8   1   2 H      38
 10 IH10     13011 Fayette   535   7 9     ()         6.00 8   1   2 H      38
 11 US59     13012 Wharton    89   8 39    (66)       2.62 8   1   2 H      42
 12 IH10     13013 Fayette   535   6 5     ()         5.40 8   1   2 H      38
 13 IH10     13014 Fayette   535   7 10    ()         0.40 8   1   2 L      38
 14 IH10     13015 Fayette   535   6 8     ()         5.60 8   2   2 H      38
 15 IH10     13016 Gonzales  535   5 7     ()         3.60 8   2   1 H      34
 16 IH10     13017 Gonzales  535   4 7     ()         8.40 8   2   2 L      34
 17 US59     13018 Victoria   89   1 36    (61)       7.80 8   1   2 H      38
 18 US59     13019 Jackson    89   3 37    (58)       4.60 8   1   2 H      41
 19 IH10     13020 Gonzales  535   4 8     ()         1.80 8   2   1 L      34
 20 IH10     13021 Gonzales  535   5 9     ()         7.80 8   2   1 H      34
 21 US59     13022 Wharton    89   6 29/30 ()         2.20 8   1   2 H      42
 22 US59     13023 Wharton    89   7 75/76 (100)      4.80 8   1   1 L      42
 23 US59     13024 Wharton    89   7 75    (97)       6.00 8   1   1 H      42

OBS   T     YEAR OVER1 OVER2 OVER3 OVER4 MILE1 MILE2  AADT     G LANE SHD MAIN

  1 40.0 1964.42 81.42     .     .     . 697.2 699.4 22000 5.45 2    AC   Y
  2 39.6 1964.42 81.42 82.92     .     . 689.8 697.0 13300 5.45 2    AC   Y
  3 40.0 1966.92 83.08     .     .     . 699.6 711.8 20000    . 2    AC   Y
  4 43.5 1968.75 84.42 87.58     .     .   0.0   8.6 93000    . 2    AC   Y
  5 39.6 1969.25 86.50     .     .     . 674.6 679.4 12300 5.45 2    AC   Y
  6 39.6 1969.25 86.50     .     .     . 679.4 689.4 13200 5.45 2    AC   Y
  7 43.5 1969.58     .     .     .     .   8.8  12.0  9100    . 2    AC   Y
  8 43.5 1969.58 74.67 85.58     .     .  28.6  29.4  2000    . 2    AC   Y
  9 43.5 1969.58 85.58     .     .     .  12.2  13.6  8800    . 2    AC   Y
 10 39.6 1969.58     .     .     .     . 668.4 674.4 12200    . 2    AC   Y
 11 40.1 1969.67 73.08 80.41 80.81  87.5     .     . 14100    . 2    AC   Y
 12 39.6 1970.41     .     .     .     . 662.4 667.8 12100 5.45 2    AC   Y
 13 39.6 1970.41     .     .     .     . 667.8 668.2 12100    . 2    AC   Y
 14 39.6 1971.83     .     .     .     . 656.6 662.2 12200 5.45 2    AC   Y
 15 40.7 1971.83     .     .     .     . 653.0 656.6 11700 5.45 2    AC   Y
 16 40.7 1972.17     .     .     .     . 634.6 643.0 11700 5.45 2    AC   Y
 17 43.5 1972.25 86.83     .     .     .   0.2   8.0 13600    . 2    AC   Y
 18 43.0 1972.25 83.42     .     .     .  18.0  22.6 12300 5.28 2    AC   Y
 19 40.7 1972.41     .     .     .     . 643.2 645.0 11700    . 2    AC   Y
 20 40.7 1972.41     .     .     .     . 645.2 653.0 12100 5.45 2    AC   Y
 21 40.1 1973.58     .     .     .     .  25.5  27.7 11500    . 2    AC   Y
 22 40.1 1973.58 87.58     .     .     .  20.6  25.4 11800 5.28 2    AC   Y
 23 40.1 1973.58 79.83     .     .     .  17.5  18.9 14100 5.28 2    AC   Y
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 OBS HWY       CFTR COUNTY     CTRO SEC JOB   NJOB          L D CAT SBT SOIL RAIN

 24 US59      13025 Wharton     89    8 52    ()         0.40 8    1   2 H        42
 25 US59      13026 Wharton     89    8 51    ()         2.80 8    1   2 H        42
 26 US59      13027 Wharton     89    7 81    ()         0.40 8    1   2 H        42
 27 US59      13028 Wharton     89    7 80    ()         3.40 8    1   2 H        42
 28 US59      13029 Jackson     89    5 19    (31)       4.80 8    1   3 H        41
 29 US59      13030 Jackson     89    4 34    ()         2.20 8    1   3 L        41
 30 US59      13031 Jackson     89    4 41    (51/48)    1.80 8    1   1 H        41
 31 US59      13032 Jackson     89    4 33    ()         5.00 8    1   2 L        41
 32 US59      13033 Jackson     89    3 42    ()         2.20 8    1   2 L        41

 OBS    T     YEAR OVER1 OVER2 OVER3 OVER4 MILE1 MILE2  AADT      G LANE SHD MAIN

 24 40.1 1972.33   .     .     .      .    6.5    6.9 12600    .   2     AC  Y
 25 40.1 1975.33   .     .     .      .    7.0    9.8 12600    .   2     AC  Y
 26 40.1 1975.33   .     .     .      .   10.0   10.4 11600    .   1     AC  Y
 27 40.1 1975.33   .     .     .      .   10.6   14.0 10600 5.28 1     AC  Y
 28 43.0 1974.58 87.58   .     .      .    0.0    4.8 11100 5.28 2     AC  Y
 29 43.0 1974.58   .     .     .      .    4.8    7.0 10300 5.28 1     AC  Y
 30 43.0 1976.00 84.83 87.58   .      .    7.0    8.8 10900 5.28 2     AC  Y
 31 43.0 1974.50   .     .     .      .    8.8   13.8 10900 5.28 2     AC  Y
 32 43.0 1974.50   .     .     .      .   14.1   16.3 12600 5.28 2     AC  Y
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OBS HWY    CFTR COUNTY CTRO SEC JOB NJOB       L    D CAT SBT SOIL RAIN    T

  1 IH410 15021 Bexar   521   6 1   (52)    3.60  8.0   3   2 L      30 39.8
  2 IH410 15022 Bexar    25   2 40  ()      1.40  8.0   3   2 L      30 39.8
  3 US281 15025 Bexar    73   8 2   (85)    1.20  8.0   2   3 L      30 39.8
  4 US281 15031 Bexar    73   8 4   (63/75) 6.00  8.0   3   2 L      30 39.8
  5 US281 15032 Bexar    73   8 8   (85)    1.20  8.0   2   2 L      30 39.8
  6 US281 15033 Bexar    73   8 22  (85)    1.20  8.0   2   2 L      30 39.8
  7 US281 15034 Bexar    73   8 10  (99)    1.60  8.0   2   2 H      30 39.8
  8 US281 15035 Bexar    73   8 9   (98)    1.60  8.0   2   2 L      30 39.8
  9 US281 15036 Bexar    73   8 41  (99)    2.80  8.0   2   2 H      30 39.8
 10 IH35  15901 Bexar    16   7 75  ()      1.10 13.0   2   3 H      30 39.8
 11 IH35  15902 Bexar    17  10 116 ()      0.90 13.0   2   3 L      30 39.8
 12 IH410 15903 Bexar   521   4 136 (193)   0.77 13.0   2   3 H      30 39.8
 13 IH35  15911 Bexar    16   7 89  ()      2.00 11.5   2   3 H      30 39.8
 14 IH35  15912 Bexar    16   7 81  ()      0.34  9.0   2   1 H      30 39.8
 15 IH35  15913 Bexar    16   7 81  ()      1.76  7.0   2   3 H      30 39.8
 16 IH35  15914 Bexar    16   7 81  ()      0.44 11.5   2   3 H      30 39.8

OBS    YEAR OVER1 OVER2 OVER3 OVER4 MILE1 MILE2  AADT    G LANE  SHD MAIN

  1 1964.92 87.42    .      .     .    .     .      .  .   2     AC  Y
  2 1964.92   .      .      .     .    .     .      .  .   3     AC  Y
  3 1967.67 84.75    .      .     . 140.6 141.8 66000 7.84 3     AC  Y
  4 1969.67 81.25  82.3     .     .    .     .      .  .   4-3-2 AC  Y
  5 1972.17 84.75    .      .     . 143.0 144.2 96000 7.84 4     AC  Y
  6 1972.00 84.75    .      .     . 141.8 143.0  8700 7.84 4     AC  Y
  7 1976.50 86.92    .      .     .    .     .      .  .   3     AC  Y
  8 1976.50 86.92    .      .     .    .     .      .  .   4     AC  Y
  9 1978.25 86.92    .      .     . 145.4 148.2 89000 7.82 3     AC  Y
 10 1983.67   .      .      .     . 167.2 168.3 95000 5.80 2     AC  Y
 11 1983.67   .      .      .     . 165.5 166.4 10700 5.80 2-3   AC  Y
 12 1983.67 87.08    .      .     .    .     .      .  .   2     AC  Y
 13 1987.42   .      .      .     .    .     .      .  .   2     AC  Y
 14 1984.99   .      .      .     .    .     .      .  .   2     AC  Y
 15 1984.99   .      .      .     .    .     .      .  .   2     AC  Y
 16 1984.99   .      .      .     .    .     .      .  .   2     AC  Y
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OBS HWY   CFTR COUNTY   CTRO SEC JOB NJOB    L D CAT SBT SOIL RAIN    T

  1 IH45 17001 Walker    675   7 4   (36) 11.4 8   2   3 L      44 38.8
  2 IH45 17002 Walker    675   6 8   (46) 13.2 8   2   1 L      44 38.8
  3 IH45 17002 Walker    675   6 8   ()   13.2 6   2   1 L      44 38.8
  4 IH45 17003 Leon      675   4 5   (20) 11.8 8   1   1 L      40 37.1
  5 IH45 17004 Madison   675   5 6   (20)  5.8 8   1   1 H      40 38.8
  6 IH45 17005 Madison   675   5 3   (27) 12.7 8   3   1 H      40 38.8
  7 IH45 17006 Freeston  675   1 4   ()    2.1 8   3   1 L      39 34.7
  8 IH45 17007 Leon      675   3 5   ()   16.0 8   1   1 L      40 37.1
  9 IH45 17008 Freeston  675   1 7   ()   12.4 8   2   3 L      39 34.7
 10 IH45 17009 Freeston  675   1 6   ()    0.5 8   1   1 L      39 34.7
 11 IH45 17010 Freeston  675   2 5   (18) 17.0 8   1   1 L      39 34.7
 12 SH6  17011 Brazos     49  12 4   ()   12.6 8   1   1 H      39 39.3

OBS    YEAR OVER1 OVER2 OVER3 OVER4 MILE1 MILE2  AADT    G LANE SHD MAIN

  1 1961.58 84.58     .     .     . 100.8 112.2 23500 7.46 2    AC  Y
  2 1963.92 85.33     .     .     . 118.8 132.0 17100 7.46 2    AC  Y
  3 1963.92   .       .     .     . 118.8 132.0     .  .            N
  4 1967.75 85.84     .     .     . 152.2 164.0 16500 7.46 2    AC  Y
  5 1967.67 85.84     .     .     . 146.4 152.2 16700 7.46 2    AC  Y
  6 1965.84 87.25     .     .     .    .     . 16200  .   2    AC  Y
  7 1968.84   .       .     .     .    .     . 14500  .   2    AC  Y
  8 1969.67   .       .     .     . 165.0 181.0 15500 7.46 2    AC  Y
  9 1971.92   .       .     .     .    .     . 14400  .   2    AC  Y
 10 1971.50   .       .     .     .    .     . 14900  .   2    AC  Y
 11 1971.50 85.75     .     .     .    .     . 14000  .   2    AC  Y
 12 1972.50   .       .     .     .   3.0  15.6 19500 4.51 2    AC  Y
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OBS HWY    CFTR COUNTY CTRO SEC JOB  NJOB         L  D CAT SBT SOIL RAIN    T

  1 US75  18001 Dallas   47   7 16  (82/90)  1.0  9   2   3 L        34 34.9
  2 US75  18002 Dallas   47   7 14  (82/90)  0.8  9   1   3 L        34 34.9
  3 US75  18003 Dallas   47   7 17  (82/90)  1.2  9   2   3 L        34 34.9
  4 US75  18005 Dallas   47   7 22  (82/90)  0.2  9   2   3 L        34 34.9
  5 US75  18006 Dallas   47   7 12  (82/90)  1.2  9   2   3 L        34 34.9
  6 US75  18007 Dallas   47   7 24  (82/90)  1.4  9   2   3 L        34 34.9
  7 US75  18008 Dallas   47   7 26  (82/90)  0.4  9   2   3 L        34 34.9
  8 US75  18009 Dallas   47   7 23  (82/90)  0.4  9   2   3 L        34 34.9
  9 US75  18010 Dallas   47   7 35  (82/90)  1.3  9   3   3 L        34 34.9
 10 US75  18011 Dallas   47   7 34  (82/90)  1.5  9   3   3 L        34 34.9
 11 US75  18013 Dallas   47   7 36  (82/90)  2.2 10   3   3 L        34 34.9
 12 US75  18015 Dallas   47   7 39  (82/90)  3.0 10   3   3 L        34 34.9
 13 US75  18019 Dallas   47   7 47  (82/90)  1.0 10   3   3 L        34 34.9
 14 IH30  18040 Dallas    9  11 19  ()       1.4  8   2   3 L        34 34.9
 15 IH30  18049 Dallas    9  11 20  (77/93,9 1.8 11   2   3 L        34 34.9
 16 I35E  18053 Dallas  442   2 25  (55)     1.0  8   2   3 L        34 34.9
 17 IH30  18054 Dallas    9  11 22  (77/93,9 1.4  8   2   3 L        34 34.9
 18 IH30  18055 Dallas    9  11 23  (77/93,9 1.0  8   2   3 L        34 34.9
 19 I35E  18058 Dallas  442   2 38  ()       1.9  7   2   4 L        34 34.9
 20 I35E  18058 Dallas  442   2 38  ()       1.9  8   2   4 L        34 34.9
 21 IH30  18060 Dallas    9  11 41  ()       0.9  8   3   2 L        34 34.9
 22 I35E  18061 Dallas  442   2 33  ()       2.6  6   2   4 L        34 34.9
 23 I35E  18061 Dallas  442   2 33  ()       2.6  8   2   4 L        34 34.9

OBS    YEAR OVER1 OVER2 OVER3 OVER4 MILE1 MILE2    AADT        G LANE SHD MAIN

  1 1949.58 73.92 78.42     .     .  14.0  15.0  148000     4.79 2    C&G Y
  2 1949.58 73.92 78.42     .     .  13.2  14.0  148000     4.79 2    C&G Y
  3 1950.08 73.92 78.42     .     .  12.0  13.2  148000     4.79 2    C&G Y
  4 1951.50 73.92 78.42     .     .     .     .       .        . 2    C&G Y
  5 1952.33 73.92 78.42     .     .   9.2  10.4   12300     4.79 2    C&G Y
  6 1953.17 73.92 78.42     .     .     .     .       .        . 2    C&G Y
  7 1953.17 73.92 78.42     .     .     .     .       .        . 2    C&G Y
  8 1953.25 73.92 78.42     .     .     .     .       .        . 2    C&G Y
  9 1953.50 73.92 78.42     .     .     .     .       .        . 2    C&G Y
 10 1953.58 73.92 78.42     .     .     .     .       .        . 2    C&G Y
 11 1954.33 73.92 78.42     .     .     .     .       .        . 2    C&G Y
 12 1955.33 73.92 78.42     .     .     .     .       .        . 2    C&G Y
 13 1958.75 73.92 78.42     .     .     .     .       .        . 2    C&G Y
 14 1960.00     .     .     .     .     .     .       .        .          Y
 15 1961.33 73.99 77.84 79.42 84.92     .     .       .        . 4    AC  Y
 16 1962.17 70.84     .     .     .     .     .       .        . 4    C&G Y
 17 1962.84 73.99 77.84 79.42 84.92  49.4  50.8  130000     2.39 4    C&G Y
 18 1963.16 73.99 77.84 79.42 84.00     .     .       .        . 4    AC  Y
 19 1965.58     .     .     .     .     .     .       .        .          N
 20 1963.58     .     .     .     .     .     .       .        . 4-3  AC  Y
 21 1964.84     .     .     .     .     .     .       .        . 4    C&G Y
 22 1964.84     .     .     .     .     .     .       .        .          N
 23 1964.84     .     .     .     .     .     .       .        . 3-2  AC  Y
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OBS HWY    CFTR COUNTY CTRO SEC JOB  NJOB         L   D CAT SBT SOIL RAIN    T

24 IH30   18062 Dallas    9  11 35  ()          0.6  8   2   2 L       34 34.9
25 I35E   18064 Dallas  442   2 38  ()          2.2  6   2   4 L       34 34.9
26 I35E   18064 Dallas  442   2 38  ()          2.2  8   2   4 L       34 34.9
27 IH30   18065 Dallas    9  11 45  ()          0.4  8   2   2 H       34 34.9
28 I35E   18066 Dallas  442   2 36  ()          2.2  6   2   4 L       34 34.9
29 I35E   18066 Dallas  442   2 36  ()          2.2  8   2   4 L       34 34.9
30 I35E   18067 Ellis    48   8 3   (20)        9.0  7   3   4 L       36 33.9
31 I35E   18067 Ellis    48   8 3   (19)        8.8  8   3   4 L       36 33.9
32 IH30   18069 Dallas    9  11 49  ()          0.7  8   2   2 H       34 34.9
33 I35E   18070 Ellis    48   8 6   (13/19)     9.3  8   3   3 L       36 33.9
34 I35W   18071 Denton   81  13 3   ()          3.2  8   2   3 L       34 31.8
35 IH635  18072 Dallas 2374   1 2   ()          3.2  8   2   4 H       34 34.9
36 IH635  18073 Dallas 2374   1 3   ()          4.0  7   2   4 L       34 34.9
37 IH635  18073 Dallas 2374   1 3   ()          4.0  8   2   4 L       34 34.9
38 US75   18074 Dallas    8   8 41  ()          1.6  8   2   4 L       34 34.9
39 IH635  18076 Dallas 2374   1 4   ()          2.0  8   2   4 L       34 34.9
40 US75   18077 Dallas 2374   2 2   ()          2.2  8   3   4 L       34 34.9
41 IH635  18078 Dallas 2374   2 6   ()          1.6  8   2   1 L       34 34.9
42 IH635  18079 Dallas 2374   1 11  ()          6.0  7   2   1 L       34 34.9
43 IH635  18079 Dallas 2374   1 11  ()          6.0  8   2   1 L       34 34.9
44 I35W   18080 Denton   81  13 5   ()         12.8  8   2   1 H       34 31.8
45 US67   18081 Dallas  261   3 19  ()          3.0  7   2   1 L       34 34.9
46 US67   18081 Dallas  261   3 19  ()          3.0  8   2   1 L       34 34.9

OBS   YEAR OVER1 OVER2 OVER3 OVER4 MILE1 MILE2   AADT        G LANE SHD MAIN

24 1965.50   .     .     .     .    44.8  45.4 100000     2.39 3    C&G Y
25 1965.00   .     .     .     .   423.2 425.4      .        .          N
26 1965.00   .     .     .     .   432.2 425.4 125000     3.55          Y
27 1965.84   .     .     .     .      .     .       .        . 3    C&G Y
28 1965.84   .     .     .     .   421.0 423.2      .        .          N
29 1965.84   .     .     .     .   421.0 423.2  64000     3.55 3    AC  Y
30 1966.08 86.67   .     .     .      .     .       .        .          N
31 1966.08 84.16   .     .     .      .     .       .        . 2    AC  Y
32 1966.42   .     .     .     .      .     .       .        . 3    C&G Y
33 1966.50 78.99 84.16   .     .      .     .       .        . 2    AC  Y
34 1966.75   .     .     .     .    67.8  71.0      .        . 2    AC  Y
35 1967.25   .     .     .     .    37.2  40.4  12700     5.15 4    AC  Y
36 1967.58   .     .     .     .    33.2  37.2 190000     6.98          N
37 1967.58   .     .     .     .    33.2  37.2 190000     6.98 4    AC  Y
38 1967.58   .     .     .     .      .     .       .        . 3    AC  Y
39 1968.84   .     .     .     .      .     .       .        . 4    AC  N
40 1968.92   .     .     .     .      .     .       .        . 4    AC  Y
41 1968.92   .     .     .     .      .     .       .        . 4    AC  Y
42 1968.92   .     .     .     .    26.2  32.2      .        .          N
43 1968.92   .     .     .     .    26.2  32.2  14100     6.98 4    AC  Y
44 1969.67   .     .     .     .    71.0  83.8  12200     5.15 2    AC  Y
45 1969.67   .     .     .     .      .     .       .        .          N
46 1969.67   .     .     .     .      .     .       .        . 2-3  AC  Y
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OBS HWY    CFTR COUNTY CTRO SEC JOB  NJOB        L  D CAT SBT SOIL RAIN    T

47 US75   18084 Collin   47  14 6    ()       15.3  8   2   3 L       38 32.6
48 US75   18084 Collin   47  14 6    ()       15.3  7   2   3 L       38 32.6
49 I35W   18086 Denton   81  13 6    ()        1.4  8   2   4 H       34 31.8
50 IH635  18088 Dallas 2374   2 5    (49)      3.4  8   2   2 H       34 34.9
51 IH45   18093 Dallas   92  14 8/25 ()        1.0  8   2   1 L       34 34.9
52 IH45   18100 Dallas   92  14 14   ()        0.5  8   2   2 L       34 34.9
53 US67   18101 Dallas  261   3 21   ()        0.5  8   2   1 L       34 34.9
54 IH20   18103 Dallas 2374   3 12   ()        0.9  8   2   2 L       34 34.9
55 IH20   18106 Dallas 2374   4 2    ()        3.8  8   2   2 L       34 34.9
56 IH20   18107 Dallas 2374   4 3    ()        3.8  8   2   2 H       34 34.9
57 IH20   18110 Dallas 2374   4 5    (17)      5.0  8   2   2 H       34 34.9
58 SH114  18117 Dallas  353   6 4    ()        8.8  8   2   2 H       34 34.9
59 SH114  18118 Dallas  353   4 29   ()        4.4  8   2   2 H       34 34.9
60 SH114  18119 Dallas  353   4 28   ()        1.3  8   2   2 H       34 34.9

OBS    YEAR OVER1 OVER2 OVER3 OVER4 MILE1 MILE2    AADT         G LANE SHD MAIN

47 1969.84     .     .     .     .     .     .        18 26000.00 5.15 2    AC
48 1969.84     .     .     .     .   0.0  18.0         .        .            N
49 1970.50     .     .     .     .  84.0  85.4   13000       5.15 2    AC  Y
50 1971.08     .     .     .     .  18.2  21.6    8600      12.49 4    AC  Y
51 1972.16     .     .     .     . 284.0 285.0   54000       4.79 2.5      Y
52 1973.92     .     .     .     .     .     .       .          . 2.5  AC  Y
53 1973.92     .     .     .     .     .     .       .          . 2    AC  Y
54 1974.25     .     .     .     .     .     .       .          . 4    AC  Y
55 1974.58     .     .     .     . 463.6 467.4   54000      15.80 4    AC  Y
56 1974.67     .     .     .     . 454.8 458.6   62000      15.80 4    AC  Y
57 1975.99 85.75     .     .     .     .     .       .          . 4    AC  Y
58 1971.16     .     .     .     .   1.4  10.2   47500       6.98 4    AC  Y
59 1973.42     .     .     .     .     .     .       .          . 1-3  AC  Y
60 1973.84     .     .     .     .     .     .       .          . 3    AC  Y
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OBS HWY   CFTR COUNTY   CTRO SEC JOB NJOB       L D CAT SBT SOIL RAIN    T

  1 IH20 19001 Harrison  495   10 3   (41)      7.0 8   1   1 L      46 33.3
  2 IH30 19002 Bowie     610    7 5   (39)      5.4 8   1   2 H      47 29.0
  3 IH30 19003 Bowie     610    7 6   (39)      0.4 8   1   2 H      47 29.0
  4 IH20 19004 Harrison  495   10 8   (38)      8.0 8   1   1 L      46 33.3
  5 IH30 19005 Titus     610    3 3   (40)      9.4 8   5   1 L      45 29.8
  6 IH20 19006 Harrison  495    9 4   (26)      6.8 8   1   3 H      46 33.3
  7 IH20 19007 Harrison  495   10 9   ()        0.2 8   1   3 H      46 33.3
  8 IH20 19008 Harrison  495    8 5   (36)      9.8 8   1   3 H      46 33.3
  9 IH20 19009 Harrison  495    8 4   (48)      7.0 8   5   2 L      46 33.3
 10 IH30 19010 Bowie     610    6 5   (25/33)   5.6 8   1   2 H      47 29.0
 11 IH30 19011 Bowie     610    7 10  (39/42)   5.8 8   1   2 H      47 29.0
 12 IH30 19014 Bowie     610    6 3   (25/33)   7.8 8   1   2 H      47 29.0
 13 IH30 19015 Titus     610    3 4   (40)      3.2 8   5   3 L      45 29.8
 14 IH30 19017 Titus     610    3 15  (42)      7.4 8   5   2 L      45 29.8
 15 IH30 19018 Bowie     610    5 8   ()        7.0 8   5   2 L      47 29.0
 16 IH30 19019 Bowie     610    5 9   (21)     10.0 8   1   2 H      47 29.0
 17 IH30 19020 Morris    610    4 6   (15)      7.4 8   5   2 H      45 29.0

OBS    YEAR OVER1 OVER2 OVER3 OVER4 MILE1 MILE2  AADT    G LANE SHD MAIN

  1 1964.84 84.75   .       .     . 642.4 649.4 17900 4.08 2    AC  Y
  2 1965.42 82.42   .       .     . 217.6 223.0 27000  .   2    AC  Y
  3 1965.42 85.42   .       .     . 223.0 223.4 35000  .   2    AC  Y
  4 1965.84 83.84   .       .     . 634.4 642.4 15400  .   2    AC  Y
  5 1966.75 86.67   .       .     . 153.0 162.4 13600  .   2    AC  Y
  6 1966.75 81.75   .       .     . 627.2 634.0 16900 4.08 2    AC  Y
  7 1966.75   .     .       .     . 634.0 634.2 14000  .            Y
  8 1966.84 81.75   .       .     . 617.2 627.0 17100  .   2    AC  Y
  9 1966.92 85.50   .       .     . 610.2 617.2 18700  .   2    AC  Y
 10 1967.42 78.33 83.84     .     . 205.8 211.4 20000 3.53 2    AC  Y
 11 1967.42 82.42 83.84     .     . 211.6 217.4 23000 3.53 2    AC  Y
 12 1967.67 78.33 83.84     .     . 198.0 205.8 18100  .   2    AC  Y
 13 1967.92 86.67   .       .     . 162.4 165.8 13100  .   2    AC  Y
 14 1970.67 86.75   .       .     . 165.8 173.2 13000  .   2    AC  Y
 15 1971.75   .     .       .     . 181.0 188.0 13100  .   2    AC  Y
 16 1972.42 86.33   .       .     . 188.0 198.0 13600 3.53 2    AC  Y
 17 1972.08 86.75   .       .     . 173.6 181.0 12800  .   2    AC  Y
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OBS HWY      CFTR COUNTY     CTRO SEC JOB NJOB        L  D CAT SBT SOIL RAIN    T

  1 SH73    20001 Jefferso    508   4 30  ()        0.5  8   1   2 H      54 42.0
  2 SH347   20002 Jefferso    667   1 28  ()        1.6  7   1   3 H      54 42.0
  3 SH73    20003 Jefferso    508   4 24  ()        3.8  6   1   2 H      54 42.0
  4 SH73    20003 Jefferso    508   4 24  ()        3.8  8   1   2 H      54 42.0
  5 IH10    20004 Jefferso    739   2 6   (56/87)   9.2  8   1   3 H      54 42.0
  6 SH347   20005 Jefferso    667   1 32  ()        2.0  7   1   3 H      54 42.0
  7 SH347   20006 Jefferso    667   1 31  ()        0.7  7   1   3 H      54 42.0
  8 IH10    20009 Jefferso    739   2 9   (78/82)   7.8  8   2   2 L      54 42.0
  9 US96    20011 Jefferso     65   8 72  (140)     3.0  8   2   2 H      54 42.0
 10 SH347   20012 Jefferso    667   1 36  ()        0.8  7   2   2 H      54 42.0
 11 US96    20013 Jefferso     65   8 70  ()        0.4 10   2   2 H      54 42.0
 12 US96    20014 Jefferso     65   8 71  ()        2.8  8   1   2 H      54 42.0
 13 US59    20015 Liberty     177   3 27  (62/65)   2.7  8   1   2 L      50 39.8
 14 US59    20016 Liberty     177   3 28  (62/65)   0.6  8   1   2 L      50 39.8
 15 US90    20017 Jefferso     28   6 31  ()        0.7  8   1   2 H      54 42.0
 16 US90    20018 Jefferso     28   6 32  ()        2.8  8   1   2 H      54 42.0
 17 US96    20019 Hardin       65   5 58  ()        2.2  8   2   2 H      53 40.0
 18 US96    20020 Hardin       65   5 59  ()        0.4  8   2   2 H      53 40.0
 19 US90    20021 Jefferso     28   6 35  ()        5.6  8   1   2 H      54 42.0
 20 US69    20022 Jefferso    200  14 22  ()        1.2  8   1   2 L      54 42.0
 21 US69    20023 Jefferso    200  14 26  ()        1.0  8   1   2 L      54 42.0
 22 SH87    20026 Jefferso    306   3 54  ()        0.6  8   1   2 H      54 42.0

OBS     YEAR OVER1 OVER2 OVER3 OVER4 MILE1 MILE2  AADT    G LANE SHD MAIN

  1 1963.16   .     .       .     .    5.0   5.5 27000    .  2    AC  Y
  2 1963.25   .     .       .     .    0.0   1.6 20400    .  2-3  AC  Y
  3 1963.42   .     .       .     .    1.2   5.0     .    .  1-3  AC  N
  4 1963.42   .     .       .     .    1.2   5.0 25000 3.76  2    AC  Y
  5 1963.50 75.67 84.42     .     . 839.4 848.6 22000 3.76  2    AC  Y
  6 1963.58   .     .       .     .    2.8   4.8 21000    .  2    AC  Y
  7 1964.58   .     .       .     .    4.8   5.5 14100    .  2    AC  Y
  8 1964.92 81.42 82.25     .     . 831.4 839.2 22000 3.76  2    AC  Y
  9 1965.08 86.84   .       .     .    3.4   6.4 26000 3.76  2    AC  Y
 10 1965.33   .     .       .     .    1.6   2.8 21000    .  2    AC  Y
 11 1965.33   .     .       .     .    9.2   9.6 30500    .  2    AC  Y
 12 1965.84   .     .       .     .    6.4   9.2 32000    .  2    AC  Y
 13 1966.67 85.16 86.84     .     .    0.0   2.6 18600    .  2    AC  Y
 14 1966.67 85.16 86.84     .     .    2.6   3.2 23000    .  2    AC  Y
 15 1967.50   .     .       .     .    7.4   8.1 15100    .  2    AC  Y
 16 1967.92   .     .       .     .    4.6   7.4  9800    .  2    AC  Y
 17 1967.75   .     .       .     .    0.0   2.2  8400    .  1    AC  Y
 18 1967.75   .     .       .     .    2.4   2.8  7000    .  1    AC  Y
 19 1969.58   .     .       .     .    0.0   4.6  5900    .  2    AC  Y
 20 1969.50   .     .       .     .    0.0   1.2 31000    .  2    AC  Y
 21 1971.42   .     .       .     .    0.0   2.0 50000 3.76  2    AC  Y
 22 1972.16   .     .       .     .    4.8   5.4  7600    .  2    CRS Y
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OBS HWY   CFTR COUNTY   CTRO SEC JOB NJOB       L D CAT SBT SOIL RAIN    T

  1 IH10 24002 ElPaso   2121   2 1   ()      1.00 8   2   3 H       8 28.9
  2 IH10 24003 ElPaso   2121   2 18  ()      0.80 8   2   2 H       8 28.9
  3 IH10 24004 ElPaso   2121   2 6   ()      2.80 8   2   3 H       8 28.9
  4 IH10 24005 ElPaso   2121   2 9   (71)    1.45 8   2   2 H       8 28.9
  5 IH10 24006 ElPaso   2121   2 19  ()      1.40 8   2   2 H       8 28.9
  6 IH10 24007 ElPaso   2121   2 7   ()      4.20 8   2   3 H       8 28.9
  7 IH10 24008 ElPaso   2121   2 8   ()      2.00 8   2   2 H       8 28.9
  8 IH10 24009 Culberso    3   3 19  (29)    2.80 8   2   1 L      11 30.4
  9 IH10 24010 JeffDavi    3   4 22  (32,33) 7.00 8   2   3 L      12 32.0
 10 IH10 24011 Culberso    3   3 20  (29)    9.80 8   2   3 L      11 30.4
 11 IH10 24012 Culberso    3   2 16  (27)    1.20 8   2   3 L      11 30.4
 12 IH10 24014 Culberso    3   2 17  (27)   12.00 8   2   3 L      11 30.4
 13 IH10 24015 Culberso    3   1 18  (33)    0.40 8   2   3 L      11 30.4
 14 IH10 24020 Culberso    3   1 23  (33)   11.40 8   1   3 L      11 30.4
 15 IH10 24022 Culberso    2  11 25  ()      2.00 8   1   3 L      11 30.4
 16 IH10 24023 Culberso    3   1 22  (33)    1.60 8   1   3 L      11 30.4
 17 US54 24027 ElPaso    167   1 41  ()      1.30 8   2   3 L       8 28.9
 18 US54 24028 ElPaso    167   1 40  ()      3.20 8   2   3 L       8 28.9
 19 US54 24029 ElPaso    167   1 35  ()      2.20 8   2   3 L       8 28.9
 20 US54 24030 ElPaso    167   1 24  ()      0.20 8   2   3 L       8 28.9
 21 US54 24031 ElPaso    167   1 25  ()      0.10 8   2   3 H       8 28.9
 22 US54 24032 ElPaso    167   4 3   ()      0.60 8   2   3 H       8 28.9

OBS    YEAR OVER1 OVER2 OVER3 OVER4 MILE1 MILE2  AADT    G LANE SHD MAIN

  1 1962.00   .     .       .     .    .     .      .  .            Y
  2 1969.92   .     .       .     .  20.2  21.0 121000 5.06 3    AC  Y
  3 1964.00   .     .       .     .  21.0  23.8 122000 5.06          Y
  4 1968.50 86.75     .       .     .    .     .      .  .   5    AC  Y
  5 1968.75   .     .       .     .  18.0  19.4  66000 5.06 4    AC  Y
  6 1969.00   .     .       .     .  13.8  18.0  63000 5.06          Y
  7 1964.84   .     .       .     .    .     .      .  .   4    AC  Y
  8 1969.58 87.08     .       .     . 176.4 179.2   7800 1.78 2    AC  Y
  9 1969.58 87.08 86.84       .     . 179.2 186.2   7800 1.78 2    AC  Y
 10 1970.16 87.08     .       .     . 166.4 176.2      .  .   2    AC  Y
 11 1970.16 87.08     .       .     . 165.2 166.4   7800 1.78 2    AC  Y
 12 1971.99 87.08     .       .     . 153.4 165.4   7900 1.78 2    AC  Y
 13 1971.99 87.08     .       .     . 152.8 153.2      .  .   2    AC  Y
 14 1974.33 87.08     .       .     . 141.4 152.8      .  .   2    AC  Y
 15 1975.84   .     .       .     . 138.0 140.0   7600 1.78 2    AC  Y
 16 1975.84 87.08     .       .     . 140.2 141.8   8000 1.78 2    AC  Y
 17 1980.08   .     .       .     .    .     .      .  .   2          Y
 18 1980.08   .     .       .     .   3.9   7.1  52000 6.65 2          Y
 19 1978.75   .     .       .     .   1.7   3.9  52000 6.65 3    AC  Y
 20 1973.75   .     .       .     .    .     .      .  .   3    AC  Y
 21 1973.75   .     .       .     .    .     .      .  .   3    AC  Y
 22 1981.16   .     .       .     .   0.0   1.8  41000 6.65 5    AC  Y
```

APPENDIX C. NUMBER OF PAVEMENT SECTIONS INCLUDED UNDER VARIOUS TREATMENT COMBINATIONS

```
                                          SAS      00:30 Wednesday, October 28, 1987
                                                                                  23

OBS HWY    CFTR COUNTY   CTRO SEC JOB NJOB     L D CAT SBT SOIL RAIN  T

  1 IH40 25001 Wheeler   275   12 20  ()    13.6 8   3   1 L       22 20
  2 IH40 25002 Wheeler   275   13 24  (43) 12.0 8   3   1 H       22 20
  3 IH40 25003 Wheeler   275   12 31  ()     2.4 8   3   1 L       22 20
  4 IH40 25004 Wheeler   275   13 29  ()     1.4 8   3   1 L       22 20
  5 IH40 25005 Wheeler   275   13 33  ()     0.6 8   3   1 L       22 20

OBS      YEAR OVER1 OVER2 OVER3 OVER4 MILE1 MILE2 AADT G LANE SHD MAIN

  1 1968.50     .     .     .     . 146.2 159.8 8600 . 2    AC   Y
  2 1970.42     .     .     .     . 163.8 175.8 7800 . 2    AC   Y
  3 1973.50     .     .     .     . 160.0 162.4 9200 . 2    AC   Y
  4 1973.50     .     .     .     . 162.4 163.8 7400 . 2    AC   Y
  5 1975.00     .     .     .     . 176.0 176.6 7500 . 2    AC   Y
```

SLAB THICKNESS = 6 INCHES

NON-OVERLAID

SOIL(SWELL)														
RAINFALL			LOW						HIGH					
TEMP(F)			L		M		H		L		M		H	
AGE			L	H	L	H	L	H	L	H	L	H	L	H
SUB TPYE	AGG.TYPE													
ASPHALT TREAT.	SRG	< 15												
		> 15												
	LST	< 15				3						4		
		> 15			1	3						1		
CEMENT TREAT.	SRG	< 15												
		> 15												1
	LST	< 15												
		> 15			1									
LIME TREAT.	SRG	< 15												
		> 15												
	LST	< 15												
		> 15												
CRUSHED STONE	SRG	< 15												
		> 15												
	LST	< 15												
		> 15				2								

SLAB THICKNESS = 6 INCHES

OVERLAID

SOIL(SWELL)			LOW						HIGH					
RAINFALL			L		M		H		L		M		H	
TEMP(F)			L	H	L	H	L	H	L	H	L	H	L	H
SUB TPYE	AGG.TYPE	AGE												
ASPHALT TREAT.	SRG	< 15												
		> 15				1								
	LST	< 15												
		> 15			2	2		1						
CEMENT TREAT.	SRG	< 15												
		> 15												
	LST	< 15												
		> 15			2									
LIME TREAT.	SRG	< 15												
		> 15												
	LST	< 15												
		> 15												
CRUSHED STONE	SRG	< 15												
		> 15												
	LST	< 15												
		> 15												

SLAB THICKNESS = 8 INCHES

NON-OVERLAID

SUB TPYE	AGG.TYPE	SOIL(SWELL)	LOW						HIGH					
		TEMP(F)	L		M		H		L		M		H	
		AGE	L	H	L	H	L	H	L	H	L	H	L	H
ASPHALT TREAT.	SRG	< 15	4											1
		> 15	2			1		2						
	LST	< 15		3	2	9						7		
		> 15	1		3	6					1	2		
CEMENT TREAT.	SRG	< 15	1					2						6
		> 15	3					3						9
	LST	< 15				4					1	3		
		> 15	1	1	3	1			3			3	1	3
LIME TREAT.	SRG	< 15	1					1						
		> 15	1										2	1
	LST	< 15	4						2					
		> 15			1	4		2	3					
CRUSHED STONE	SRG	< 15												
		> 15				1								
	LST	< 15												
		> 15				10					1	3		

SLAB THICKNESS = 8 INCHES

SOIL(SWELL)			OVERLAID											
RAINFALL			LOW						HIGH					
TEMP(F)			L		M		H		L		M		H	
AGE			L	H	L	H	L	H	L	H	L	H	L	H
SUB TPYE	AGG.TYPE													
ASPHALT TREAT.	SRG	< 15												2
		> 15	1			1		4						1
	LST	< 15												
		> 15	1		5	4		1						
CEMENT TREAT.	SRG	< 15												2
		> 15	1					6					6	5
	LST	< 15	1		1	3						3		
		> 15			3		1	1	1			1	3	1
LIME TREAT.	SRG	< 15	2											1
		> 15				1								3
	LST	< 15												
		> 15	4	1		5		3						
CRUSHED STONE	SRG	< 15												
		> 15	1											
	LST	< 15												
		> 15			3	1						1		

SLAB THICKNESS = 9 INCHES

NON-OVERLAID

SOIL(SWELL)			LOW						HIGH					
RAINFALL			L		M		H		L		M		H	
TEMP(F)			L	H	L	H	L	H	L	H	L	H	L	H
SUB TPYE	AGG.TYPE	AGE												
ASPHALT TREAT.	SRG	< 15	4											
		> 15										1		
	LST	< 15	3											
		> 15												
CEMENT TREAT.	SRG	< 15	1											
		> 15												
	LST	< 15												
		> 15												
LIME TREAT.	SRG	< 15												
		> 15												
	LST	< 15												
		> 15												
CRUSHED STONE	SRG	< 15	1											
		> 15												
	LST	< 15												
		> 15												

SLAB THICKNESS = 9 INCHES

SOIL(SWELL)			OVERLAID											
RAINFALL			LOW						HIGH					
TEMP(F)			L		M		H		L		M		H	
SUB TPYE	AGG.TYPE	AGE	L	H	L	H	L	H	L	H	L	H	L	H
ASPHALT TREAT.	SRG	< 15												
		> 15												
	LST	< 15												
		> 15												
CEMENT TREAT.	SRG	< 15												
		> 15												
	LST	< 15												
		> 15												
LIME TREAT.	SRG	< 15												
		> 15				1								
	LST	< 15												
		> 15				7								
CRUSHED STONE	SRG	< 15												
		> 15												
	LST	< 15												
		> 15												

SLAB THICKNESS = 13 INCHES

NON-OVERLAID

SOIL(SWELL)														
RAINFALL			LOW						HIGH					
TEMP(F)			L		M		H		L		M		H	
AGE			L	H	L	H	L	H	L	H	L	H	L	H
AGG.TYPE														
SUB TPYE														
ASPHALT TREAT.	SRG	< 15												
		> 15												
	LST	< 15												
		> 15												
CEMENT TREAT.	SRG	< 15				2								
		> 15												
	LST	< 15												
		> 15												
LIME TREAT.	SRG	< 15												
		> 15												
	LST	< 15				1						1		
		> 15												
CRUSHED STONE	SRG	< 15												
		> 15												
	LST	< 15												
		> 15												

SLAB THICKNESS = 13 INCHES

SOIL(SWELL)			OVERLAID											
RAINFALL			LOW						HIGH					
TEMP(F)			L		M		H		L		M		H	
AGE			L	H	L	H	L	H	L	H	L	H	L	H
SUB TPYE	AGG.TYPE													
ASPHALT TREAT.	SRG	< 15												
		> 15												
	LST	< 15												
		> 15												
CEMENT TREAT.	SRG	< 15												
		> 15												
	LST	< 15												
		> 15												
LIME TREAT.	SRG	< 15												
		> 15												
	LST	< 15										1		
		> 15												
CRUSHED STONE	SRG	< 15												
		> 15												
	LST	< 15												
		> 15												

APPENDIX D. FACTORIALS OF PAVEMENT PROJECTS SELECTED FOR THE EXPERIMENTAL DESIGN

SLAB THICKNESS = 6 INCHES

SOIL(SWELL)			NON-OVERLAID											
RAINFALL			LOW						HIGH					
TEMP(F)			L		M		H		L		M		H	
AGE			L	H	L	H	L	H	L	H	L	H	L	H
SUB TPYE	AGG.TYPE													
ASPHALT TREAT.	SRG	< 15												
		> 15				02046								
	LST	< 15				02098					02060			
		> 15			03004	02049 02050		17002			02041			
CEMENT TREAT.	SRG	< 15												
		> 15												20003
	LST	< 15												
		> 15			03001									
LIME TREAT.	SRG	< 15												
		> 15												
	LST	< 15												
		> 15												
CRUSHED STONE	SRG	< 15												
		> 15												
	LST	< 15												
		> 15				18066								

SLAB THICKNESS = 6 INCHES

SOIL(SWELL)			OVERLAID											
RAINFALL			LOW						HIGH					
TEMP(F)			L		M		H		L		M		H	
AGE			L	H	L	H	L	H	L	H	L	H	L	H
SUB TPYE	AGG.TYPE													
ASPHALT TREAT.	SRG	< 15												
		> 15												
	LST	< 15										02075		
		> 15												
CEMENT TREAT.	SRG	< 15												
		> 15												
	LST	< 15												
		> 15												
LIME TREAT.	SRG	< 15												
		> 15												
	LST	< 15												
		> 15												
CRUSHED STONE	SRG	< 15												
		> 15												
	LST	< 15												
		> 15												

SLAB THICKNESS = 8 INCHES

NON-OVERLAID

SOIL(SWELL)			LOW						HIGH					
RAINFALL			L		M		H		L		M		H	
TEMP(F)			L	H	L	H	L	H	L	H	L	H	L	H
SUB TPYE	AGG.TYPE	AGE												
ASPHALT TREAT.	SRG	< 15	04023 04025					13023						13024 17011
		> 15	04010			02046		17007 19001						17004
	LST	< 15		02059	03018	02098 18093						02060 13021		
		> 15	24009		02044 03004	02049 18079		17002			18080	02041		
CEMENT TREAT.	SRG	< 15	04011					13032						13019 13028
		> 15	04009					13009 20023					19019	13013 20003
	LST	< 15			13020	15032 18106					03019	15036 18107		
		> 15	03011	02051	03001 03010	18062	01005		24006			18088	01001	13015 20011
LIME TREAT.	SRG	< 15	24022					13030						13029
		> 15	04005			02031							01013	
	LST	< 15	24028		01015									
		> 15	24014	24010	18071	02002 18054		18084	24004 24007					
CRUSHED STONE	SRG	< 15												
		> 15				09004								
	LST	< 15												
		> 15			01008	02032 18066 18073					18086	02028 18072		

SLAB THICKNESS = 8 INCHES
OVERLAID

SOIL(SWELL)														
RAINFALL			LOW						HIGH					
TEMP(F)			L		M		H		L		M		H	
AGE			L	H	L	H	L	H	L	H	L	H	L	H
SUB TPYE	AGG.TYPE													
ASPHALT TREAT.	SRG	< 15												13031
		> 15						17003						
	LST	< 15												
		> 15	03014											
CEMENT TREAT.	SRG	< 15												
		> 15						13002					19010	13001
	LST	< 15	03022			15033								
		> 15						20009					01003	
LIME TREAT.	SRG	< 15												
		> 15												19006
	LST	< 15												
		> 15				09002		09001						
CRUSHED STONE	SRG	< 15												
		> 15	04002											
	LST	< 15												
		> 15												

SLAB THICKNESS = 9 INCHES

NON-OVERLAID

SOIL(SWELL)			LOW						HIGH					
RAINFALL			L		M		H		L		M		H	
TEMP(F)			L	H	L	H	L	H	L	H	L	H	L	H
SUB TPYE	AGG.TYPE	AGE												
ASPHALT TREAT.	SRG	< 15	04022 05008											
		> 15												
	LST	< 15	05007											
		> 15												
CEMENT TREAT.	SRG	< 15	05009											
		> 15												
	LST	< 15												
		> 15												
LIME TREAT.	SRG	< 15												
		> 15												
	LST	< 15												
		> 15												
CRUSHED STONE	SRG	< 15	05005											
		> 15												
	LST	< 15												
		> 15												

SLAB THICKNESS = 9 INCHES

OVERLAID

SOIL(SWELL)			LOW						HIGH					
RAINFALL			L		M		H		L		M		H	
TEMP(F)			L	H	L	H	L	H	L	H	L	H	L	H
SUB TPYE	AGG.TYPE	AGE												
ASPHALT TREAT.	SRG	< 15												
		> 15												
	LST	< 15												
		> 15												
CEMENT TREAT.	SRG	< 15												
		> 15												
	LST	< 15												
		> 15												
LIME TREAT.	SRG	< 15												
		> 15				18002								
	LST	< 15												
		> 15				18001 18006								
CRUSHED STONE	SRG	< 15												
		> 15												
	LST	< 15												
		> 15												

SLAB THICKNESS = 13 INCHES

SOIL(SWELL)			NON-OVERLAID											
RAINFALL			LOW						HIGH					
TEMP(F)			L		M		H		L		M		H	
AGE			L	H	L	H	L	H	L	H	L	H	L	H
AGG.TYPE														
SUB TPYE														
ASPHALT TREAT.	SRG	< 15												
		> 15												
	LST	< 15												
		> 15												
CEMENT TREAT.	SRG	< 15			12901 12902									
		> 15												
	LST	< 15												
		> 15												
LIME TREAT.	SRG	< 15												
		> 15												
	LST	< 15				15902						15901		
		> 15												
CRUSHED STONE	SRG	< 15												
		> 15												
	LST	< 15												
		> 15												

APPENDIX E. DATA BASE OF PAVEMENT PROJECTS SELECTED FOR THE EXPERIMENTAL DESIGN

LISTING OF DESCRIPTION FOR ITEMS INCLUDED IN APPENDIX E

ITEM	DESCRIPTION
HWY	Highway type and number, e.g. IH: Interstate Highway, US: United Satate Highway, and S: State Highway
CFTR	Section ID number
COUNTY	County name
CTRO/SEC/JOB	SDHPT control-section-job numbers
NJOB	SDHPT subsequent job numbers
L	Highway section length (miles)
D	Pavement slab thickness (in.)
CAT	Slab coarse aggregate type: 1 = Silicious River Gravel, 2 = Limestone, 3 = 1&2, 4 = slag, 5 = 1&4 or 2&4.
SBT	Subbase Type: 1= Asphalt treated, 2= Cement treated, 3= Crushed stone, 4= Lime treated.
SOIL	Y for swelling soil, or N if not
RAIN	Average Annual Rainfall (in.)
T	Average Annual Lowest Temperature (^{O}F)
YEAR	Construction date, using 12 as base, e.g. 1964.50 means June 1964
MILE1	Beginning milepost of highway section
MILE2	Ending milepost of highway section
AADT	Average Annual Daily Traffic of 1985
G	Average Annual Daily Traffic Growth Rate

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                                      SAS      01:07 Monday, July 20, 1987    7

OBS    HWY      CFTR    COUNTY       CTRO    SEC    JOB       L     D    CAT    SBT

  1    IH30     1001    Hopkins        10      2     23     6.0     8      2      2
  3    IH30     1003    Hopkins       610      1      4     6.2     8      2      2
  5    IH30     1005    Franklin      610      2      4     5.0     8      2      2
  6    US75     1008    Grayson        47     13      5     8.8     8      2      4
  9    US271    1013    Lamar         136      8     23    10.0     8      1      3
 10    US82     1015    Grayson        45     19      4     3.2     8      2      3

OBS    SOIL     RAIN         T     YEAR     MILE1      MILE2       AADT         G

  1    H          43      30.7     1964     128.4      134.4      16000      3.53
  3    H          43      30.7     1965     136.2      142.4      12600      3.53
  5    L          44      30.0     1965     148.0      153.0      13200      3.53
  6    L          36      30.0     1967      22.1       30.9      16000      5.15
  9    H          44      30.2     1971       0.0       10.0       7200      1.42
 10    L          36      30.0     1975      18.0       21.2      10700      1.42
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OBS   HWY       CFTR    COUNTY        CTRO     SEC     JOB        L     D     CAT    SBT

  1   IH30      2002    Parker           8       3      18      8.4     8      3      3
 16   IH35W     2028    Johnson         14       3      19      9.2     8      2      4
 20   IH820     2031    Tarrant          8      14       3      3.8     8      1      3
 21   IH30      2032    Tarrant       1068       1      46      8.9     8      2      4
 32   US287     2041    Tarrant        172       6      26      2.8     8      2      1
 33   US287     2041    Tarrant        172       6      26      2.8     6      2      1
 35   US287     2044    Wise            13       8      44     10.3     8      2      1
 38   SH121     2046    Tarrant        363       3      12      2.8     8      1      1
 39   SH121     2046    Tarrant        363       3      12      2.8     6      1      1
 42   US287     2049    Tarrant         14      15       2      7.2     6      2      1
 43   US287     2049    Tarrant         14      15       2      7.2     8      2      1
 44   US287     2050    Tarrant         14      16      87      2.4     6      2      1
 45   IH20      2051    Parker         314       2       6      1.2     8      2      2
 52   IH20      2059    Erath          314       4      15      5.8     8      2      1
 53   IH20      2060    Tarrant       2374       5       3      1.8     6      2      1
 54   IH20      2060    Tarrant       2374       5       3      1.8     8      2      1
 68   IH35W     2075    Tarrant         14       2      20      6.6     6      2      1
 76   IH820     2098    Tarrant          8      14      22      3.8     8      2      1
 77   IH820     2098    Tarrant          8      14      22      3.8     6      2      1

OBS   SOIL     RAIN        T    YEAR     MILE1     MILE2        AADT          G

  1   L          32     33.0    1949     414.4     422.8       35000       6.12
 16   H          32     33.0    1965      28.2      37.4       17200       1.11
 20   L          32     33.0    1966      16.8      20.6       63000      11.55
 21   L          32     33.0    1967     422.8     431.7       33000       6.12
 32   H          32     33.0    1970      22.4      25.2       43000       1.11
 33   H          32     33.0    1970      22.4      25.2           0       0.00
 35   L          30     28.6    1969      19.7      30.0       16100       5.15
 38   L          32     33.0    1970      20.8      23.6       75000       1.11
 39   L          32     33.0    1970      20.8      23.6           0       0.00
 42   L          32     33.0    1971       0.0       7.2           0       0.00
 43   L          32     33.0    1971       0.0       7.2       15400      11.55
 44   L          32     33.0    1971       7.2       9.6       16000      11.50
 45   L          29     32.1    1971     389.0     390.2       13700       3.69
 52   L          29     32.1    1972     363.6     369.4       12900       3.69
 53   H          32     33.0    1973     444.2     446.0           0       0.00
 54   H          32     33.0    1973     444.2     446.0       72500      15.80
 68   H          32     33.0    1976      37.6      44.2       57500       1.11
 76   L          32     33.0    1976      10.6      14.4       46000      11.50
 77   L          32     33.0    1976      10.6      14.4           0       0.00
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                                        SAS      01:07 Monday, July 20, 1987  12

OBS    HWY      CFTR    COUNTY       CTRO    SEC    JOB       L     D    CAT    SBT

  1    US277    3001    Wichita       156      7      2     3.0     6      2      2
  2    US277    3001    Wichita       156      7      2     3.0     8      2      2
  5    US277    3004    Wichita       156      7      5     5.0     6      2      1
  6    US277    3004    Wichita       156      7      5     5.0     8      2      1
 12    US287    3010    Wichita        43      8     22     9.1     8      2      2
 13    US287    3011    Wilbarge       43      7     15     1.0     8      2      2
 16    US287    3014    Wilbarge       43      5     43     0.2     8      2      1
 21    US287    3018    Montague       13      5     18     8.0     8      2      1
 22    US287    3019    Clay          224      1     16     0.4     8      2      2
 24    US287    3022    Wilbarge       43      7     23    10.2     8      2      2

OBS    SOIL     RAIN        T    YEAR    MILE1     MILE2      AADT        G

  1    L          27     28.4    1964      8.4      11.4     15000     0.08
  2    L          27     28.4    1964      8.4      11.4         0     0.00
  5    L          27     28.4    1969      0.0       5.0         0     0.00
  6    L          27     28.4    1969      0.0       5.0     12900     0.08
 12    L          27     28.4    1968      0.0       9.1      9600     0.68
 13    L          25     23.8    1968      0.0       1.0      8700     0.68
 16    L          25     23.8    1969      0.0       0.2      7300     0.00
 21    L          28     28.2    1972      0.8       8.8     11700     0.08
 22    H          28     28.2    1972     13.1      13.5     10200     0.08
 24    L          25     23.8    1973      1.0      11.2      8700     0.68
```

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                                          SAS     01:07 Monday, July 20, 1987  13

OBS     HWY     CFTR    COUNTY     CTRO     SEC     JOB       L      D     CAT     SBT

  1     IH40    4002    Potter      275       1      11     2.0      8       1       4
  4     IH40    4005    Caroon      275       2      12     7.9      8       1       3
  8     IH40    4009    Potter      275       1      20     4.4      8       1       2
  9     IH40    4010    Potter      275       1      31     4.2      8       1       1
 10     IH40    4011    Potter       90       5      44     7.0      8       1       2
 12     IH40    4022    Gray        275       5      19     1.3      9       1       1
 13     IH40    4023    Donley      275       8      18     1.6      8       1       1
 15     IH40    4025    Donley      275      10      17     2.2      8       1       1

OBS    SOIL     RAIN       T    YEAR     MILE1     MILE2      AADT        G

  1    L          18    21.7    1964      70.2      72.2     62000     2.61
  4    L          19    21.5    1966      85.2      93.1      8700     2.61
  8    L          18    21.7    1968      62.6      67.0     39000     2.61
  9    L          18    21.7    1968      78.6      82.8     14600     2.61
 10    L          18    21.7    1972      54.8      61.8     10700     2.61
 12    L          20    22.5    1978     114.2     115.4      8200     2.61
 13    L          21    23.0    1978     123.4     125.0      8200     2.61
 15    L          21    23.0    1978     127.4     129.5      8500     2.61
```

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                                     SAS     01:07 Monday, July 20, 1987  14

OBS   HWY    CFTR   COUNTY      CTRO    SEC    JOB      L    D    CAT    SBT

 5    IH27   5005   Hale          67      5     28    5.2    9      1      4
 7    IH27   5007   Hale          67      5     32    1.5    9      2      1
 8    IH27   5008   Hale          67      4     27    4.8    9      1      1
 9    IH27   5009   Swisher       67      3     39    1.4    9      1      2

OBS   SOIL   RAIN      T   YEAR    MILE1    MILE2    AADT      G

 5    L        19   22.8   1982     39.0     44.2    7200    4.4
 7    L        19   22.8   1982     37.5     39.0    6700    4.4
 8    L        19   22.8   1983     53.8     58.6    6800    4.4
 9    L        18   21.5   1983     58.8     60.2    6700    4.4
```

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                                             SAS      01:07 Monday, July 20, 1987  15

OBS     HWY     CFTR     COUNTY       CTRO     SEC     JOB       L     D     CAT     SBT

  1     IH35    9001     Falls          15       3      10     1.8     8       2       3
  2     IH35    9002     McClenna       15       2      18     4.0     8       2       3
  3     IH35    9004     McClenna       15       1      25     1.9     8       1       4

OBS     SOIL     RAIN          T     YEAR     MILE1      MILE2       AADT         G

  1     L          40       33.0     1960     313.6      315.4      24000      5.30
  2     L          34       35.7     1960     315.4      319.4      24000      5.30
  3     L          34       35.7     1964     331.5      333.4      47000      5.30
```

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                                        SAS      01:07 Monday, July 20, 1987  17

OBS    HWY        CFTR    COUNTY        CTRO    SEC    JOB       L       D    CAT     SBT

  2    BELT8     12901    Harris        3256      2     13     5.1      13      1       2
  3    BELT8     12902    Harris        3256      2     14     1.6      13      1       2

OBS    SOIL      RAIN          T     YEAR     MILE1     MILE2      AADT        G

  2    H           45       39.2     1982         0         0     47000     7.46
  3    H           45       39.2     1982         0         0     47000     7.46
```

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                                          SAS      01:07 Monday, July 20, 1987  18

OBS    HWY        CFTR    COUNTY       CTRO    SEC     JOB       L    D   CAT    SBT

  1    IH10      13001    Colorado      271      1       8     2.2    8     1      2
  2    IH10      13002    Colorado      535      8       4     7.2    8     1      2
  8    US77      13009    Victoria      371      1       3     1.8    8     1      2
 12    IH10      13013    Fayette       535      6       5     5.4    8     1      2
 14    IH10      13015    Fayette       535      6       8     5.6    8     2      2
 18    US59      13019    Jackson        89      3      37     4.6    8     1      2
 19    IH10      13020    Gonzales      535      4       8     1.8    8     2      1
 20    IH10      13021    Gonzales      535      5       9     7.8    8     2      1
 22    US59      13023    Wharton        89      7      75     4.8    8     1      1
 23    US59      13024    Wharton        89      7      75     6.0    8     1      1
 27    US59      13028    Wharton        89      7      68     3.4    8     1      2
 28    US59      13029    Jackson        89      5      18     4.8    8     1      3
 29    US59      13030    Jackson        89      4      30     2.2    8     1      3
 30    US59      13031    Jackson        89      4      41     1.8    8     1      1
 31    US59      13032    Jackson        89      4      29     5.0    8     1      2

OBS    SOIL    RAIN       T     YEAR     MILE1     MILE2        AADT         G

  1    H         41    40.0     1964     697.2     699.4     22000.0      5.45
  2    L         38    39.6     1964     689.8     697.0     13300.0      5.45
  8    L         38    43.5     1969      28.6      29.4      8500.0      0.00
 12    H         38    39.6     1970     662.4     667.8     12100.0      5.45
 14    H         38    39.6     1971     656.6     662.2     12200.0      5.45
 18    H         41    43.0     1972      18.0      22.6     12300.0      5.28
 19    L         34    40.7     1972     643.2     645.0     11700.0      5.45
 20    H         34    40.7     1972     645.2     653.0     12100.0      5.45
 22    L         42    40.1     1973      20.6      25.4     11800.0      5.28
 23    H         42    40.1     1973      17.5      18.9     14100.0      5.28
 27    H         42    40.1     1972      10.6      14.0     10600.0      5.28
 28    H         41    43.0     1974       0.0       4.8     11100.0      5.28
 29    L         41    43.0     1972       4.8       7.0     10300.0      5.28
 30    H         41    43.0     1976       7.0       8.8     10900.0      5.28
 31    L         41    43.0     1972       8.8      13.8     10900.0      5.28
```

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                                          SAS      01:07 Monday, July 20, 1987  20

OBS   HWY       CFTR    COUNTY    CTRO    SEC    JOB        L        D    CAT

  5   US281    15032    Bexar       73      8      8     1.20      8.0      2
  6   US281    15033    Bexar       73      8     22     1.20      8.0      2
  9   US281    15036    Bexar       73      8     41     2.80      8.0      2
 10   IH35     15901    Bexar       16      7     75     1.40     13.0      2
 11   IH35     15902    Bexar       17     10    116     1.70     13.0      2

OBS   SBT   SOIL   RAIN       T    YEAR    MILE1    MILE2     AADT       G

  5     2   L        30    39.8    1972    143.0    144.2    96000    7.84
  6     2   L        30    39.8    1972    141.8    143.0     8700    7.84
  9     2   H        30    39.8    1978    145.4    148.2    89000    7.82
 10     3   H        30    39.8    1978      0.0      0.0    95000    5.80
 11     3   L        30    39.8    1978      0.0      0.0    10700    5.80
```

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                                          SAS      01:07 Monday, July 20, 1987  21

OBS    HWY     CFTR     COUNTY       CTRO    SEC    JOB        L    D    CAT    SBT

  2    IH45    17002    Walker        675      6      8    13.2    8      2      1
  3    IH45    17002    Walker        675      6      8    13.2    6      2      1
  4    IH45    17003    Leon          675      4      5    11.8    8      1      1
  5    IH45    17004    Madison       675      5      6     5.8    8      1      1
  8    IH45    17007    Leon          675      3      5    16.0    8      1      1
 11    SH06    17011    Brzos          49     12      4    12.6    8      1      1

OBS    SOIL     RAIN        T    YEAR    MILE1    MILE2      AADT        G

  2    L          44     38.8    1963      0.0      0.0     17100     7.46
  3    L          44     38.8    1963    118.8    132.0         0     0.00
  4    L          40     37.1    1967    152.2    164.0     16500     7.46
  5    H          40     38.8    1967    146.4    152.2     16700     7.46
  8    L          40     37.1    1969    165.0    181.0     15500     7.46
 12    H          39     39.3    1972      3.0     15.6     19500     4.51
```

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                                         SAS      01:07 Monday, July 20, 1987  22

OBS     HWY      CFTR    COUNTY     CTRO    SEC    JOB        L      D    CAT    SBT

  1     US75     18001   Dallas       47      7     16      1.0      9      2      3
  2     US75     18002   Dallas       47      7     14      0.8      9      1      3
  5     US75     18006   Dallas       47      7     12      1.2      9      2      3
 17     IH30     18054   Dallas        9     11     22      1.4      8      2      3
 24     IH30     18062   Dallas        9     11     35      0.6      8      2      2
 28     I35E     18066   Dallas      442      2     36      2.2      6      2      4
 29     I35E     18066   Dallas      442      2     36      2.2      8      2      4
 34     I35W     18071   Denton       81     13      3      3.2      8      2      3
 35     IH635    18072   Dallas     2374      1      2      3.2      8      2      4
 36     IH635    18073   Dallas     2374      1      3      4.0      7      2      4
 44     IH635    18079   Dallas     2374      1     11      6.0      8      2      1
 45     I35W     18080   Denton       81     13      5     12.8      8      2      1
 48     US75     18084   Collin       47     14      6     18.0      8      2      3
 50     I35W     18086   Denton       81     13      6      1.4      8      2      4
 51     IH635    18088   Dallas     2374      2      5      3.4      8      2      2
 52     IH45     18093   Dallas       92     14      8      1.0      8      2      1
 56     IH20     18106   Dallas     2374      4      2      3.8      8      2      2
 57     IH20     18107   Dallas     2374      4      3      3.8      8      2      2

OBS     SOIL     RAIN        T     YEAR     MILE1      MILE2        AADT          G

  1     L          34     34.9     1949      14.0       15.0      148000       4.79
  2     L          34     34.9     1949      13.2       14.0      148000       4.79
  5     L          34     34.9     1952       9.2       10.4       12300       4.79
 17     L          34     34.9     1962      49.4       50.8      130000       2.39
 24     L          34     34.9     1965      44.8       45.4      100000       2.39
 28     L          34     34.9     1965     421.0      423.2           0       0.00
 29     L          34     34.9     1965     421.0      423.2       66000       3.55
 34     L          34     31.8     1966      67.8       71.0       12500       5.15
 35     H          34     34.9     1967      37.2       40.4       12700       5.15
 36     L          34     34.9     1967      33.2       37.2      190000       6.98
 44     L          34     34.9     1968      26.2       32.2       14100       6.98
 45     H          34     31.8     1969      71.0       83.8       12200       5.15
 48     L          38     32.6     1969       0.0        0.0          18       0.00
 50     H          34     31.8     1970      84.0       85.4       13000       5.15
 51     H          34     34.9     1970      18.2       21.6        8600      12.49
 52     L          34     34.9     1972     284.0      285.0       54000       4.79
 56     L          34     34.9     1974     463.6      467.4       54000      15.80
 57     H          34     34.9     1974     454.8      458.6       62000      15.80
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                                    SAS     01:07 Monday, July 20, 1987  25

OBS    HWY     CFTR    COUNTY       CTRO    SEC    JOB        L    D    CAT    SBT

  1    IH20    19001   Harrison      495     10      3      7.0    8      1      1
  6    IH20    19006   Harrison      495      9      4      6.8    8      1      3
 10    IH30    19010   Bowie         610      6      5      5.6    8      1      2
 16    IH30    19019   Bowie         610      5      4     10.0    8      1      2

OBS    SOIL    RAIN        T    YEAR    MILE1     MILE2      AADT        G

  1    L         46     33.3    1964    642.4     649.4     17900     4.08
  6    H         46     33.3    1966    627.2     634.0     16900     4.08
 10    H         47     29.0    1967    205.8     211.4     20000     3.53
 16    H         47     29.0    1971    188.0     198.0     13600     3.53
```

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                                            SAS      01:07 Monday, July 20, 1987  26

OBS    HWY        CFTR    COUNTY      CTRO    SEC    JOB      L      D    CAT    SBT

  3    SH73      20003    Jefferso     508      4     24    3.8      6      1      2
  4    SH73      20003    Jefferso     508      4     24    3.8      8      1      2
  8    IH10      20009    Jefferso     739      2      9    7.8      8      2      2
  9    US96      20011    Jefferso      65      8     72    3.0      8      2      2
 21    US69      20023    Jefferso     200     14     26    2.0      8      1      2

OBS    SOIL      RAIN         T    YEAR     MILE1      MILE2       AADT          G

  3    H           54      42.0    1963       1.2        5.0          0       0.00
  4    H           54      42.0    1963       1.2        5.0      25000       3.76
  8    L           54      42.0    1964     831.4      839.2      22000       3.76
  9    H           54      42.0    1965       3.4        6.4      26000       3.76
 21    L           54      42.0    1971       0.0        2.0      50000       3.76
```

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                                         SAS      01:07 Monday, July 20, 1987  27

OBS    HWY      CFTR    COUNTY      CTRO    SEC    JOB       L    D    CAT    SBT

  5    IH10    24006    ElPaso      2121      2     19     1.4    8      2      2
  6    IH10    24007    ElPaso      2121      2      7     4.2    8      2      3
  8    IH10    24009    Culberso       3      3     19     2.8    8      2      1
  9    IH10    24010    JeffDavi       3      4     22     7.0    8      2      3
 12    IH10    24014    Culberso       3      2     17    12.0    8      2      3
 15    IH10    24022    Culberso       2     11     25     2.0    8      1      3
 18    US54    24028    ElPaso       167      1     40     3.2    8      2      3
 22    US54    24032    ElPaso       167      4      3     0.8    8      2      3

OBS    SOIL     RAIN        T    YEAR    MILE1     MILE2       AADT        G

  5    H           8     28.9    1968     18.0      19.4      66000     5.06
  6    H           8     28.9    1969     13.8      18.0      63000     5.06
  8    L          11     30.4    1969    176.4     179.2       7800     1.78
  9    L          12     32.0    1969    179.2     186.2       7800     1.78
 12    L          11     30.4    1971    153.4     165.4       7900     1.78
 15    L          11     30.4    1975    138.0     140.0       7600     1.78
 18    L           8     28.9    1980      3.9       7.1      52000     6.65
 22    H           8     28.9    1980      0.0       1.8      41000     6.65
```
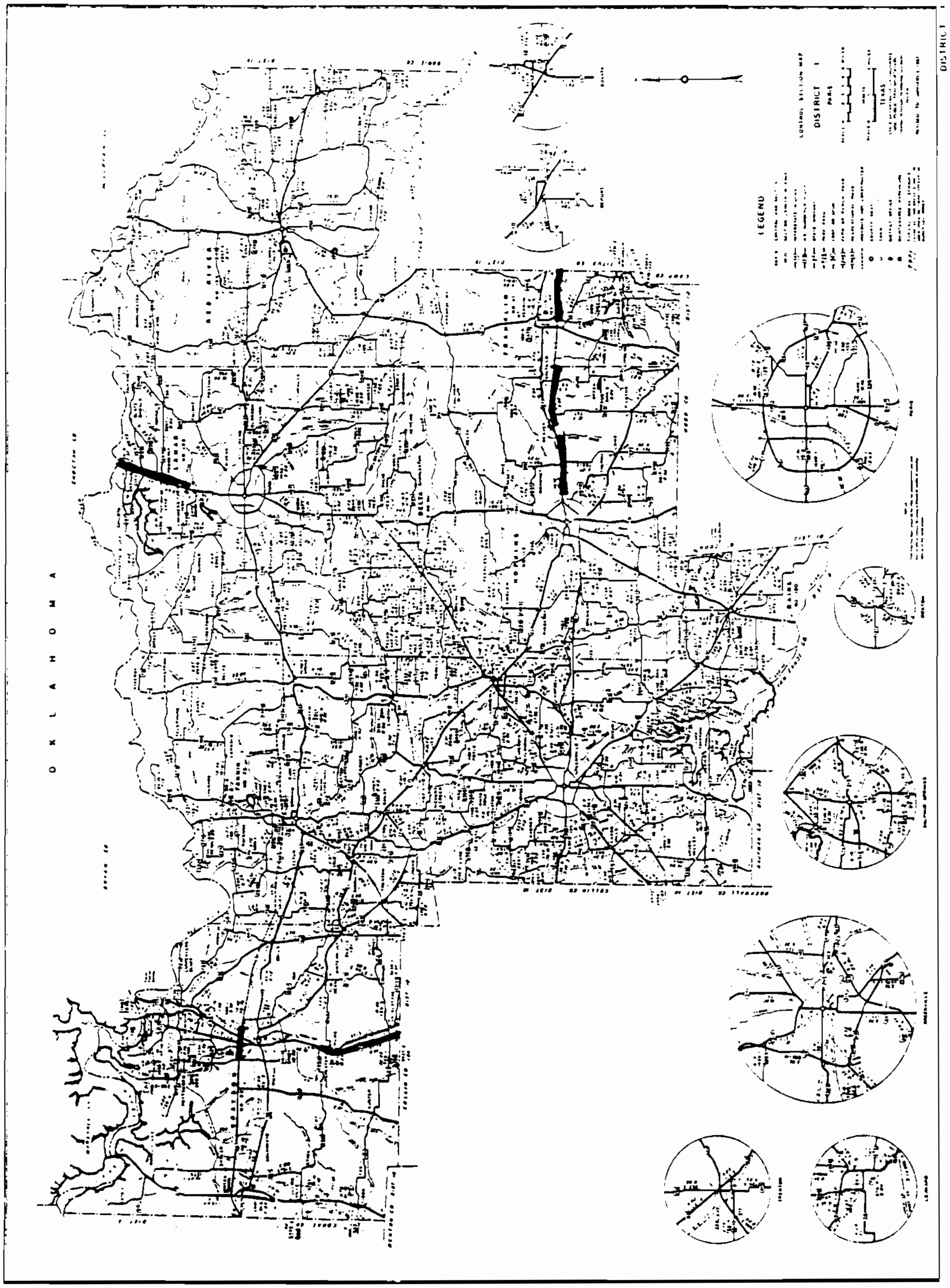
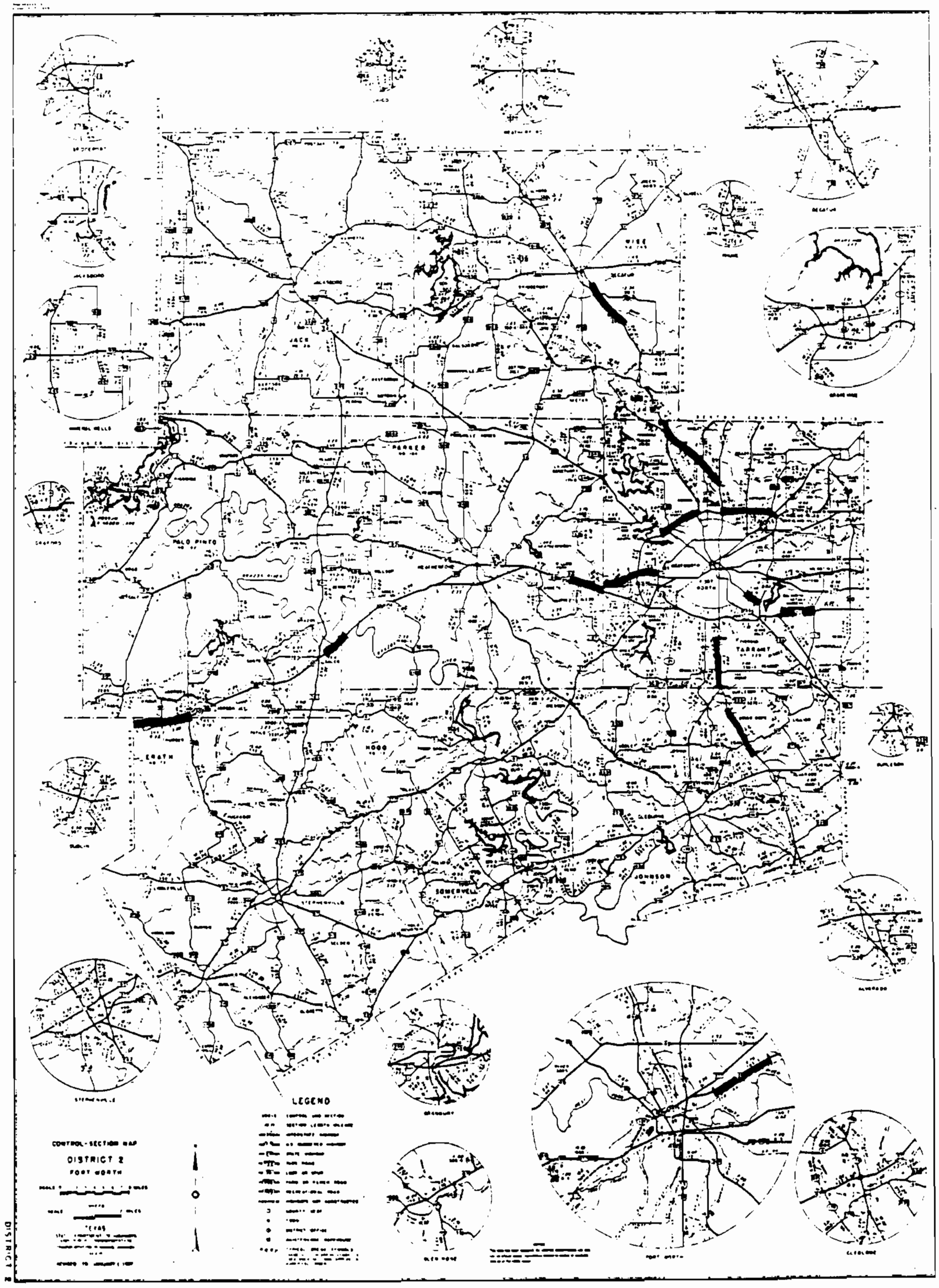
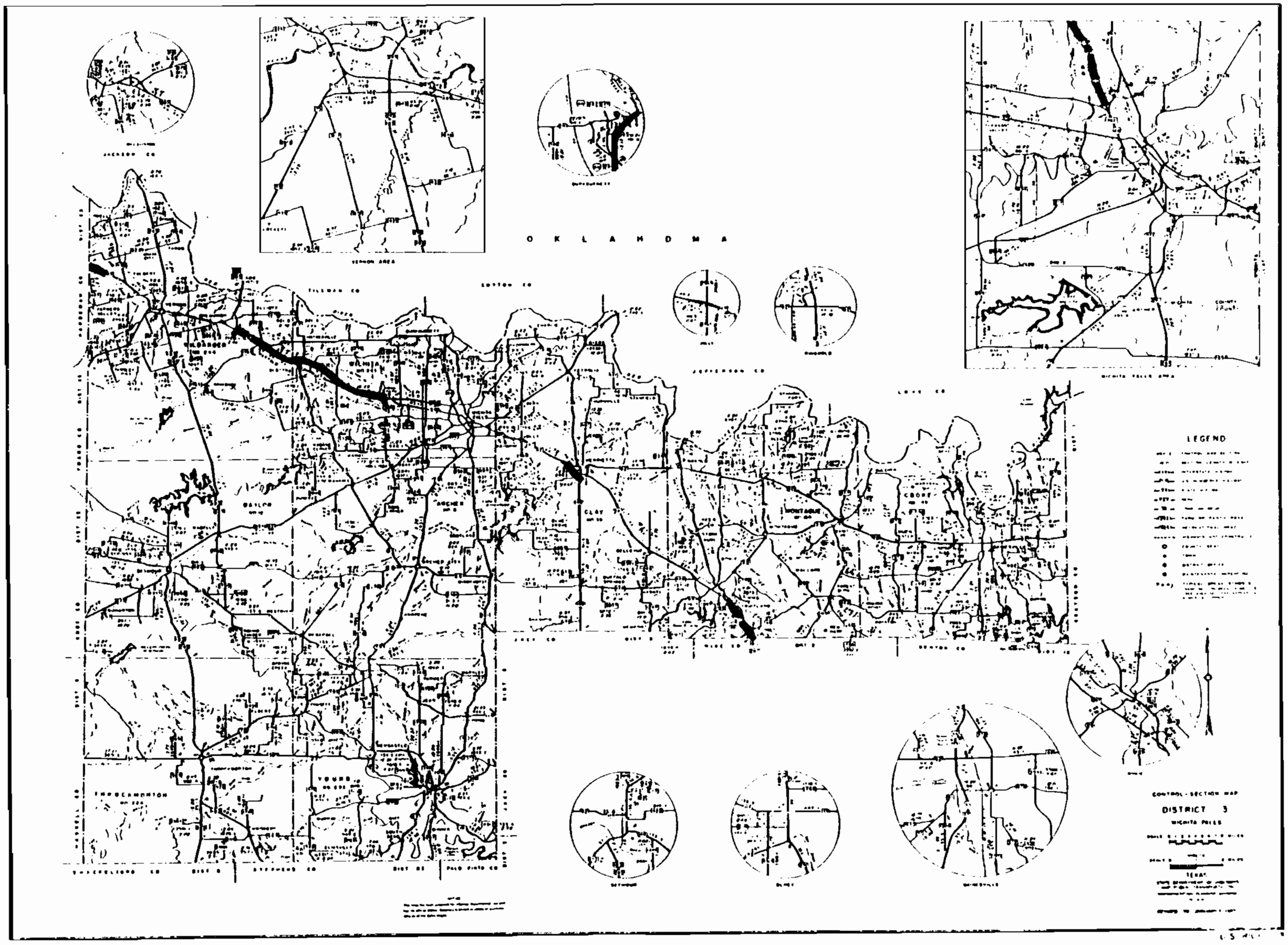

APPENDIX F. A SET OF MAPS SHOWING THE LOCATIONS OF 112 TEST PROJECTS SELECTED FOR FUTURE SURVEYS



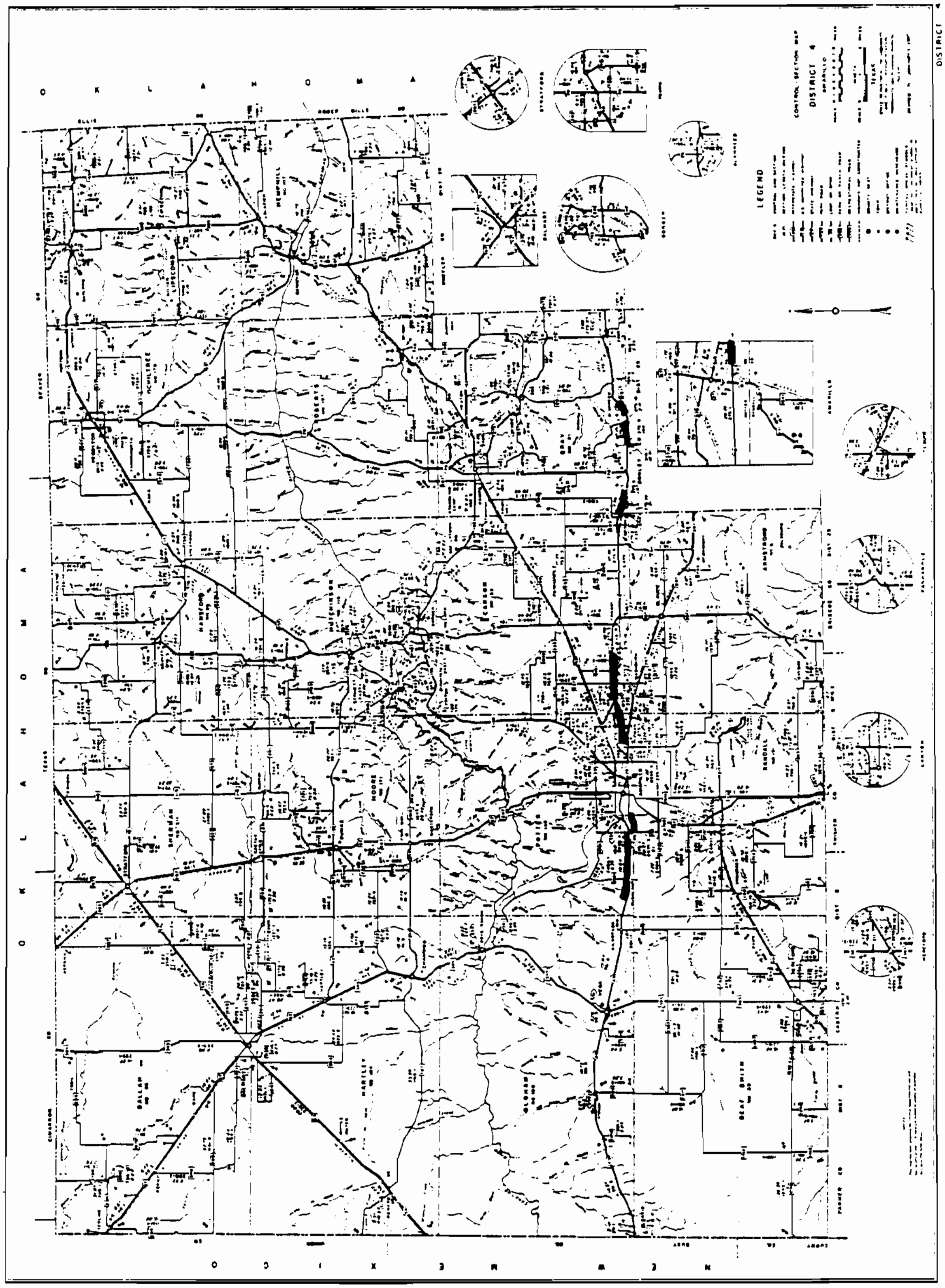
DISTRICT 1


JACK
WISE
PARKER
PALO PINTO
TARRANT
ERATH
HOOD
SOMERVELL
JOHNSON
LEGEND
CONTROL-SECTION MAP
DISTRICT 2
FORT WORTH
TEXAS
DISTRICT 2

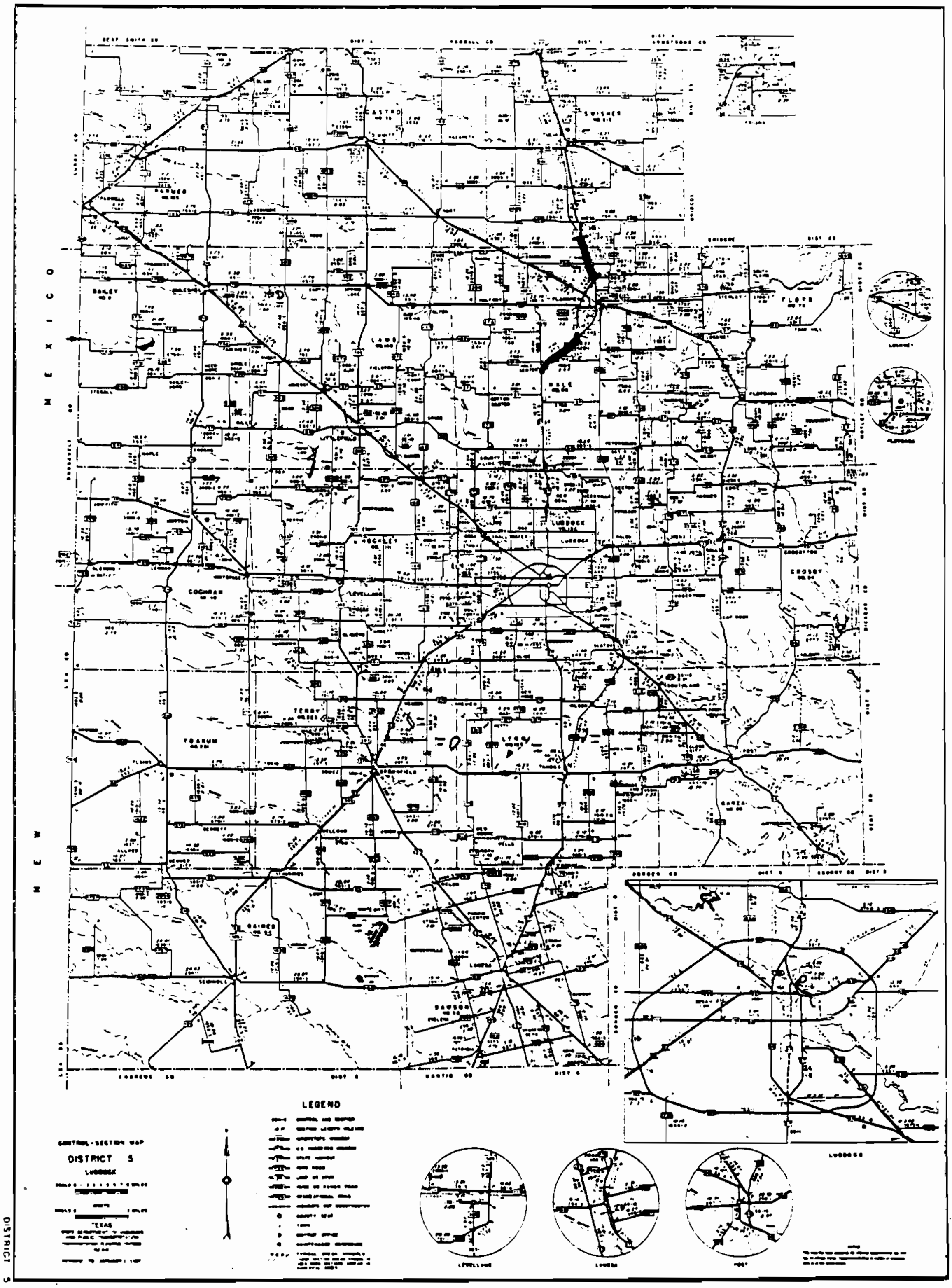
DISTRICT 2


OKLAHOMA
LEGEND
CONTROL-SECTION MAP
DISTRICT 3
WICHITA FALLS
TEXAS

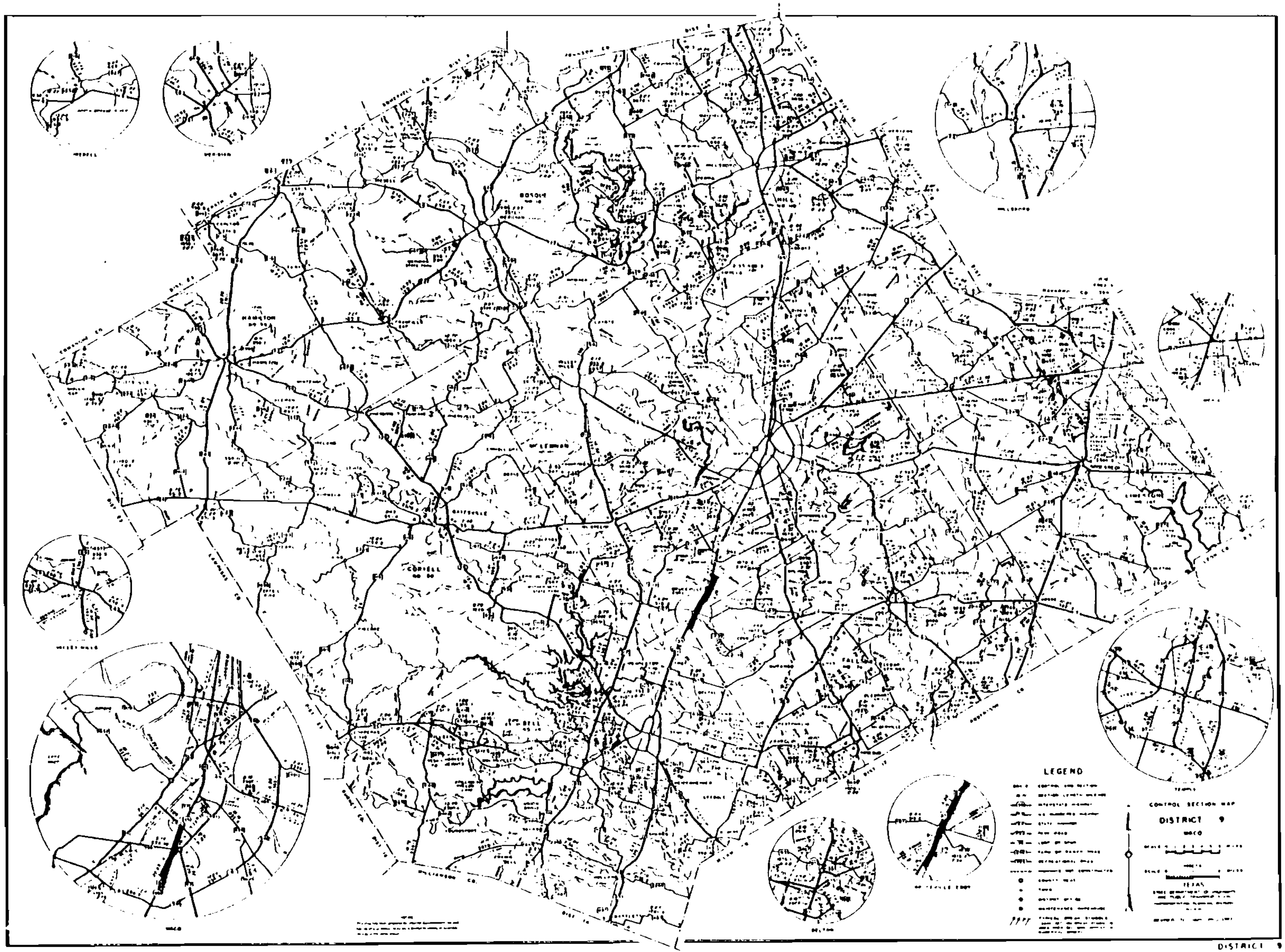
DISTRICT 3


OKLAHOMA
OKLAHOMA
NEW MEXICO
LEGEND
CONTROL SECTION MAP
DISTRICT 4
DISTRICT 4

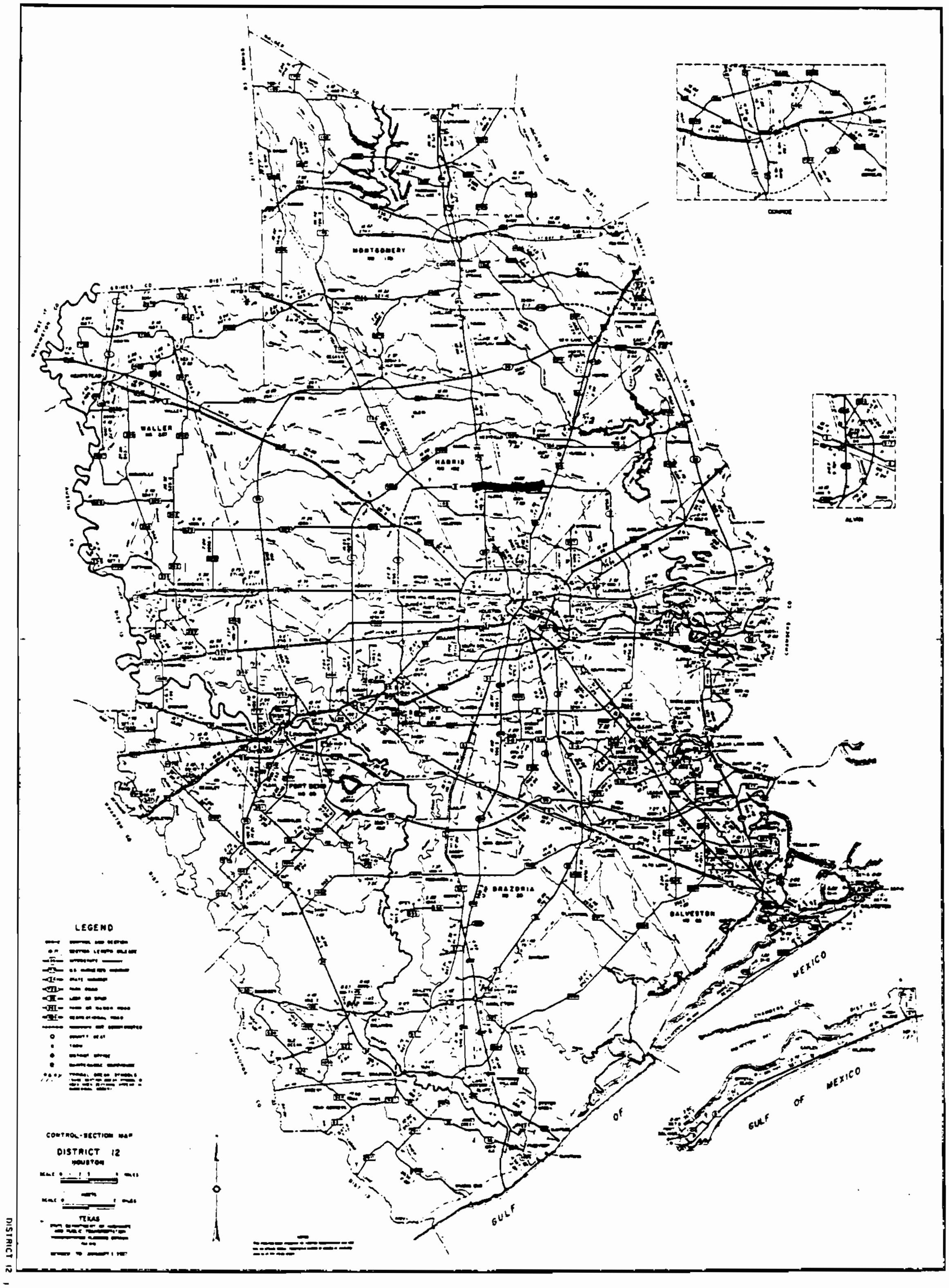
DISTRICT 4


NEW MEXICO
CASTRO
SWISHER
PARMER
BAILEY
LAMB
HALE
FLOYD
HOCKLEY
LUBBOCK
CROSBY
COCHRAN
TERRY
LYNN
YOAKUM
GARZA
GAINES
DAWSON
LEGEND
CONTROL-SECTION MAP
DISTRICT 5
LUBBOCK
TEXAS
LOCKNEY
FLOYDADA
LEVELLAND
LAMESA
POST
DISTRICT 5

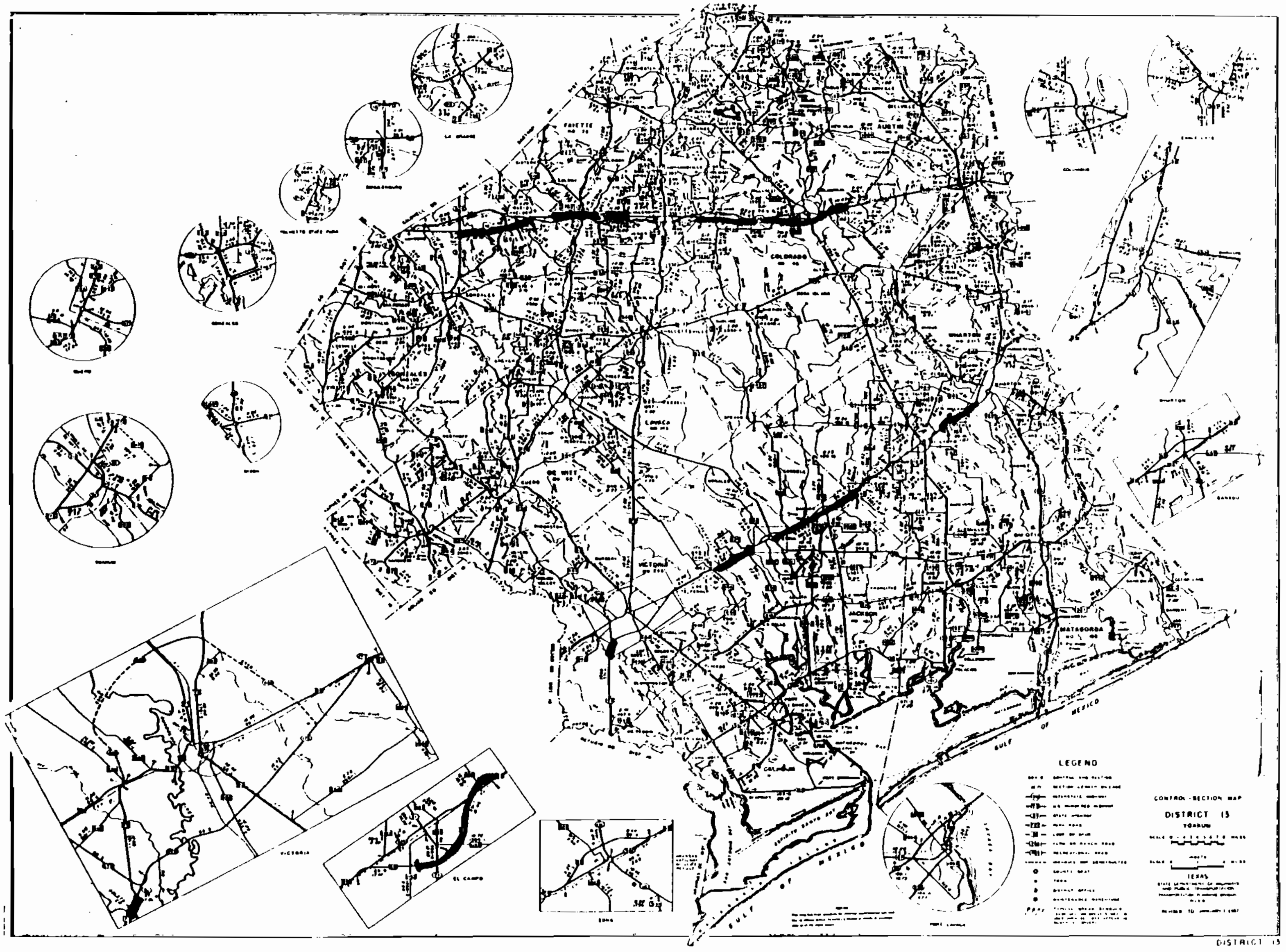
DISTRICT 5



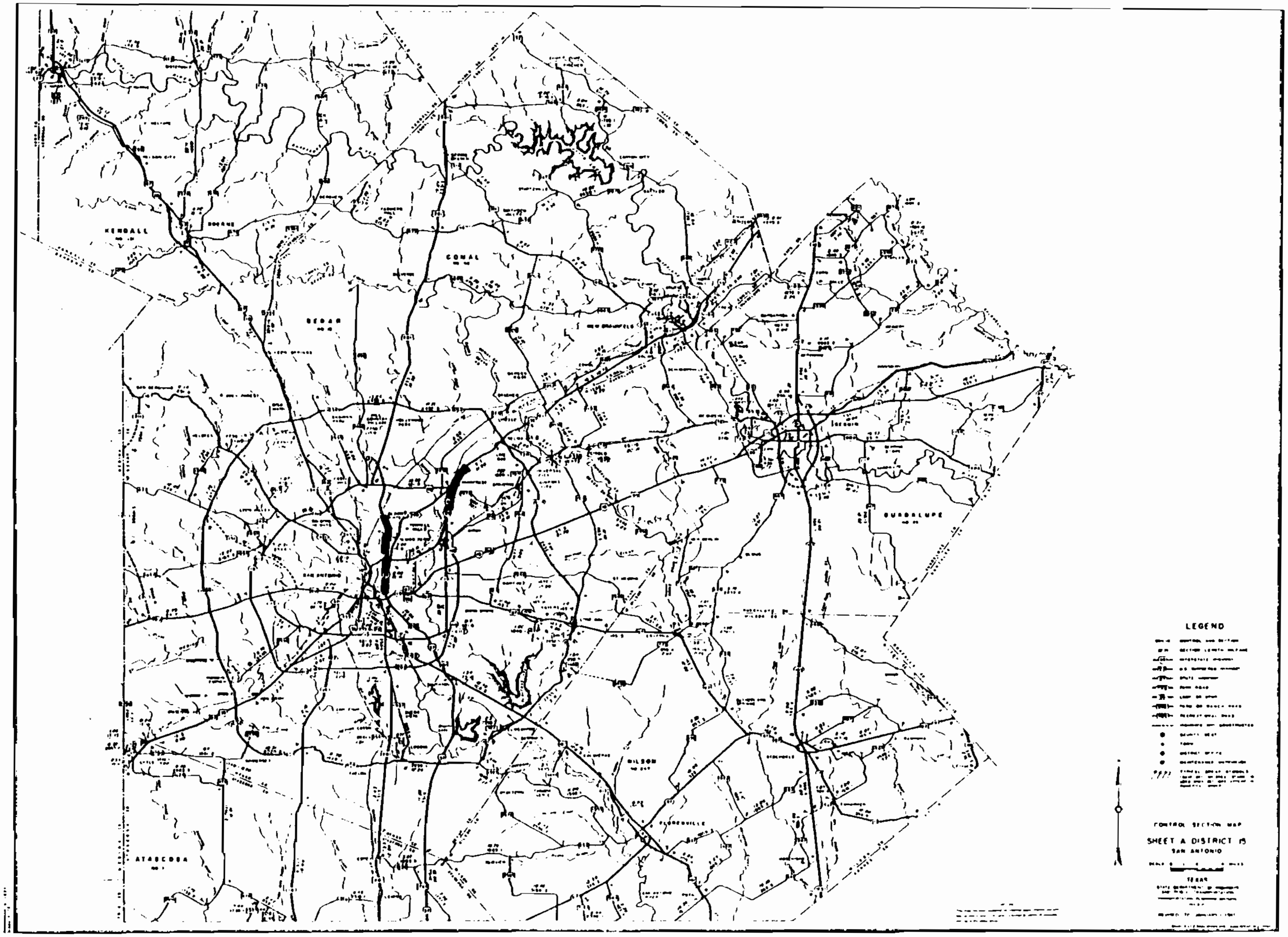
DISTRICT 9


MONTGOMERY
WALLER
HARRIS
FORT BEND
BRAZORIA
GALVESTON
GULF OF MEXICO
CONROE
ALVIN
LEGEND
CONTROL-SECTION MAP
DISTRICT 12
HOUSTON
TEXAS
DISTRICT 12

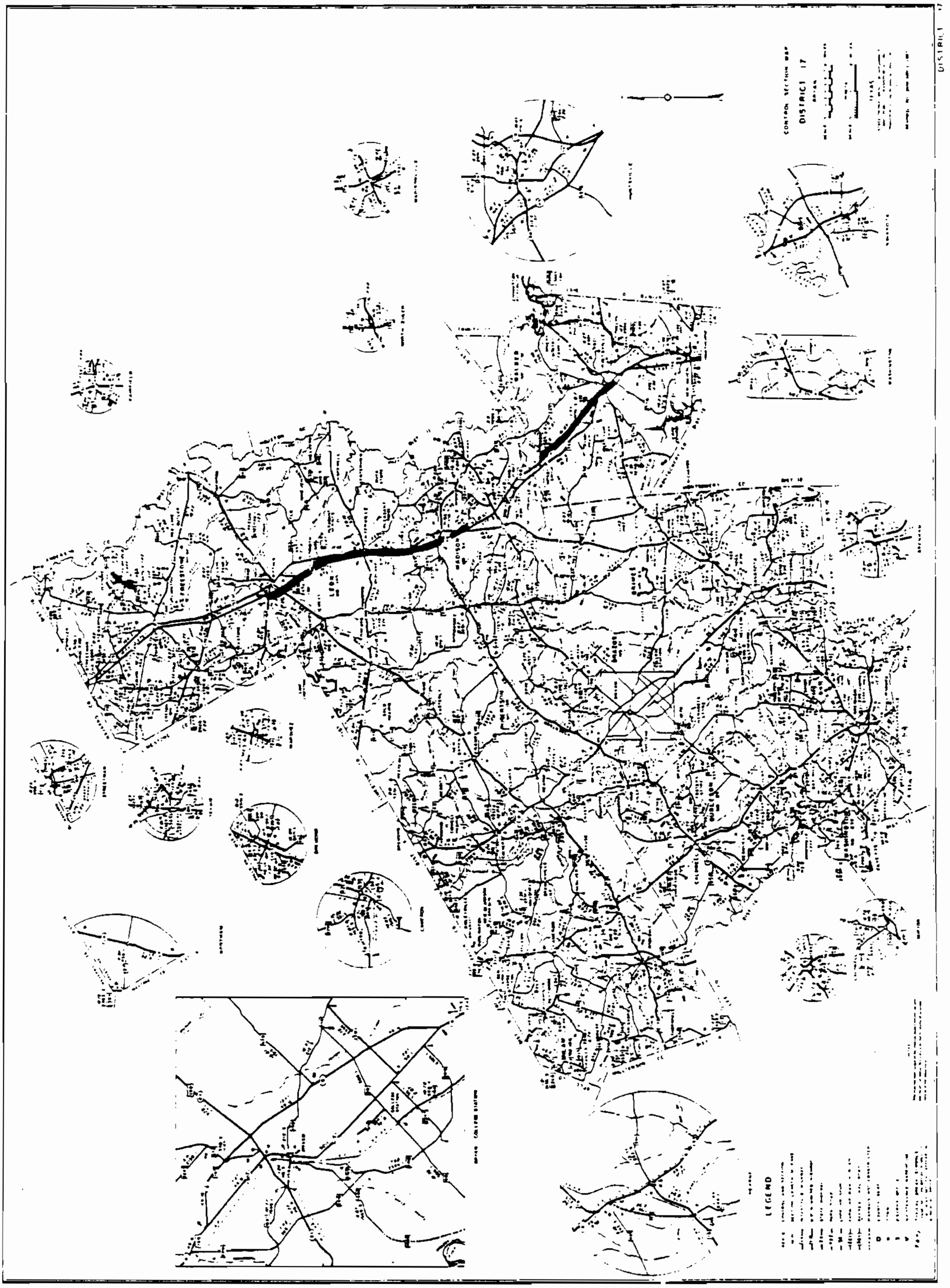
DISTRICT 12


LEGEND
CONTROL-SECTION MAP
DISTRICT 13
YOAKUM
TEXAS
GULF OF MEXICO
VICTORIA
EL CAMPO
DISTRICT 13

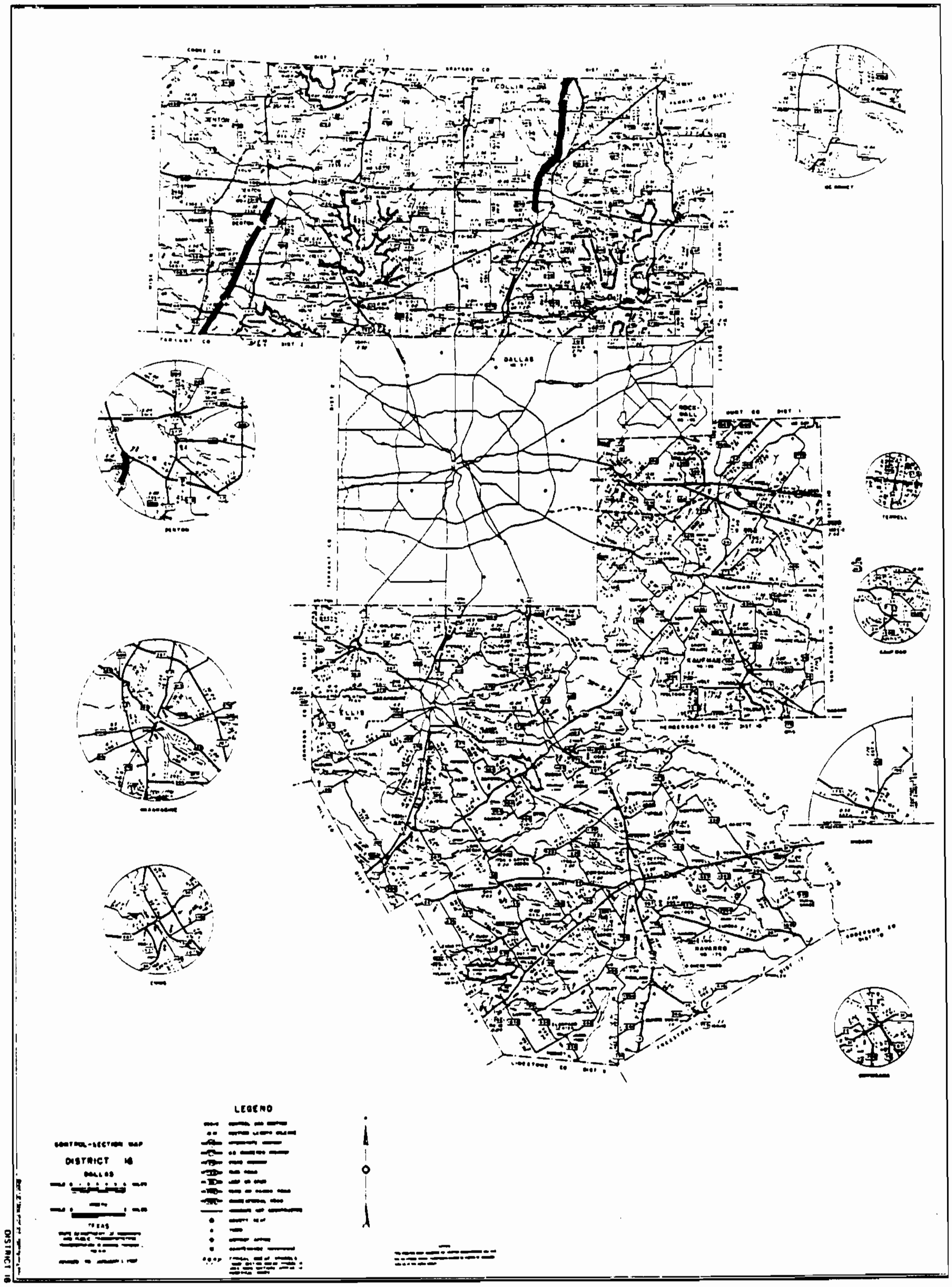
DISTRICT 13



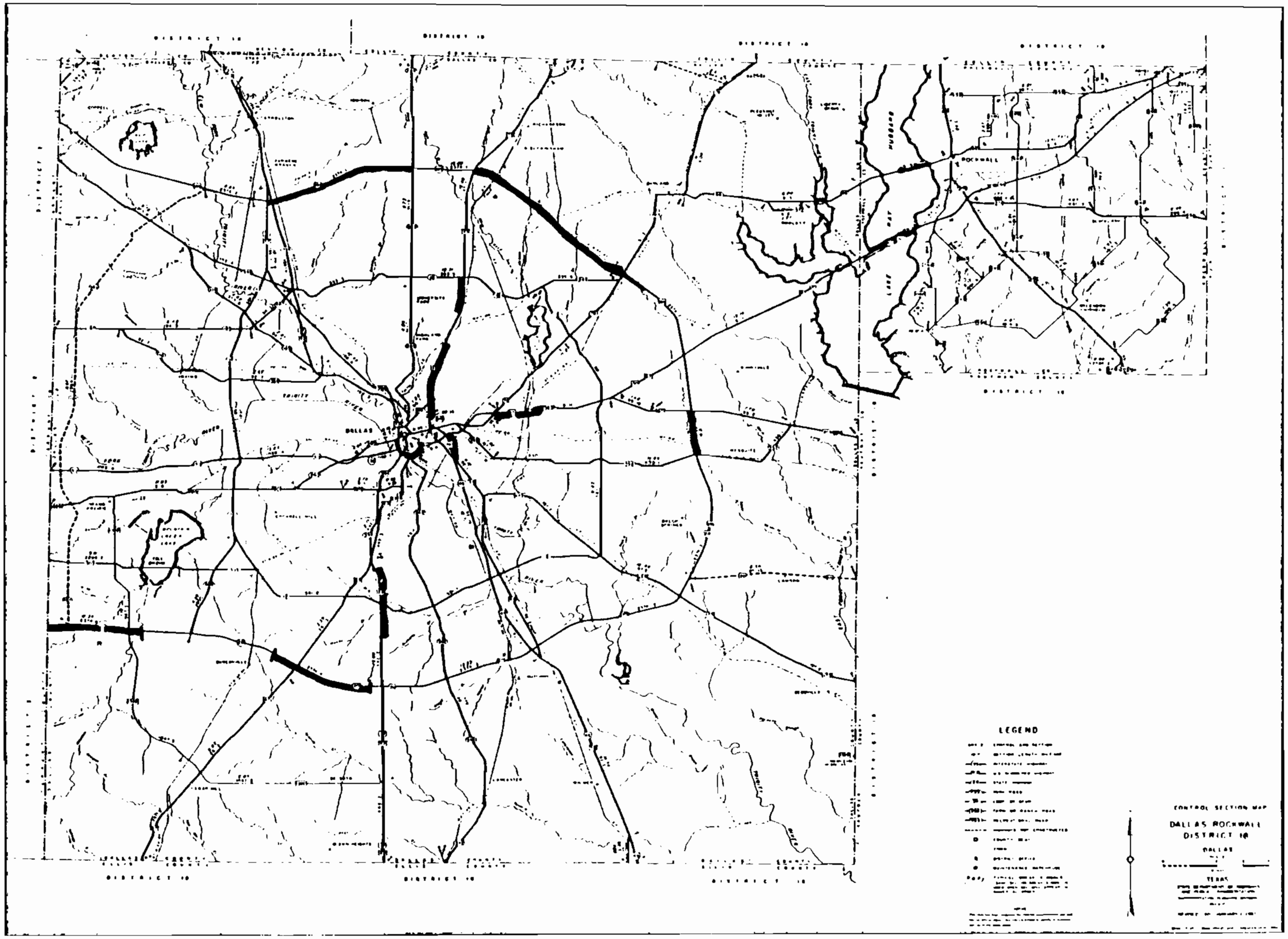
DISTRICT 15


CONTROL SECTION MAP
DISTRICT 17
BRYAN
TEXAS
DISTRICT 17
LEGEND

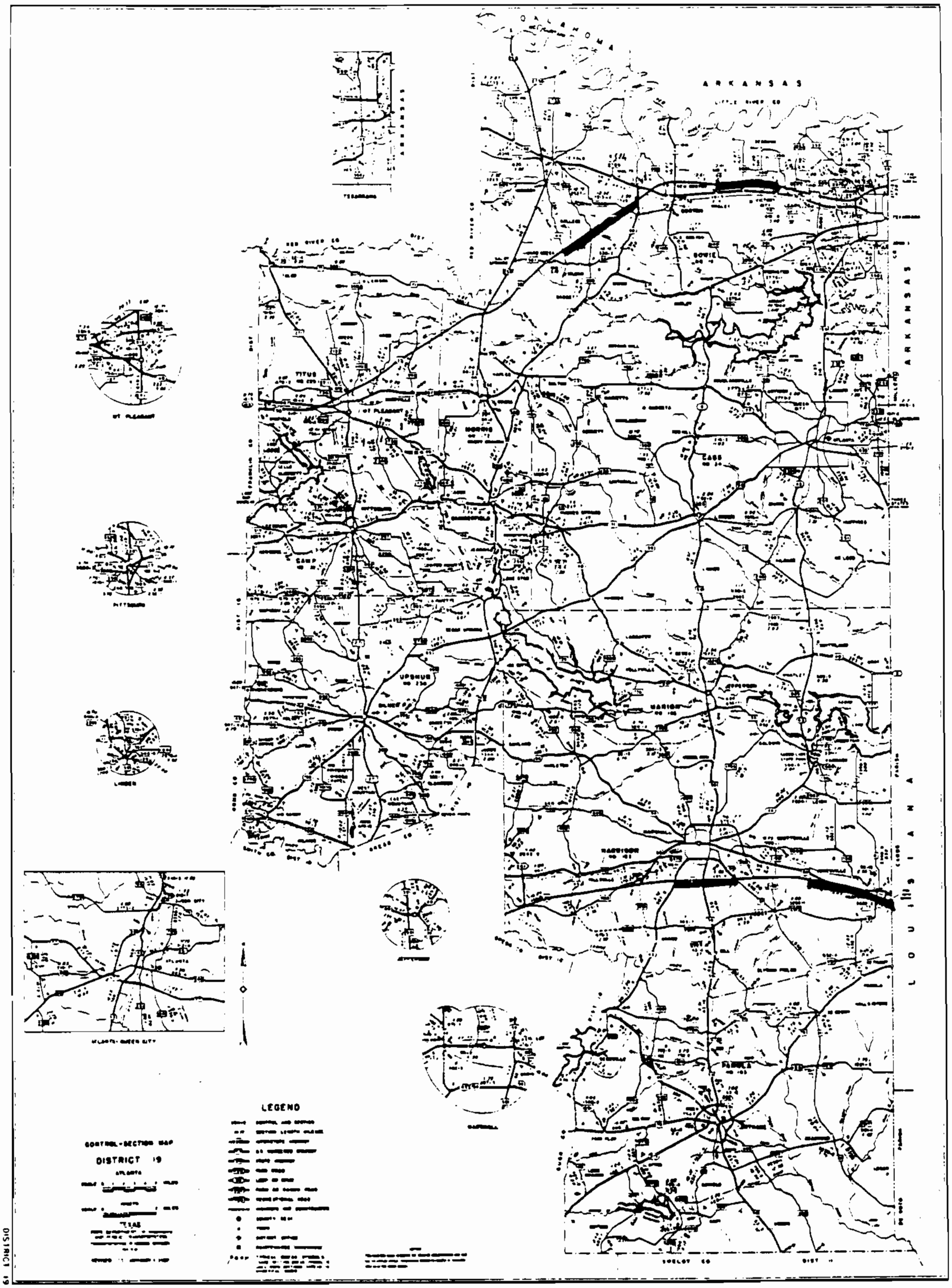
DISTRICT 17



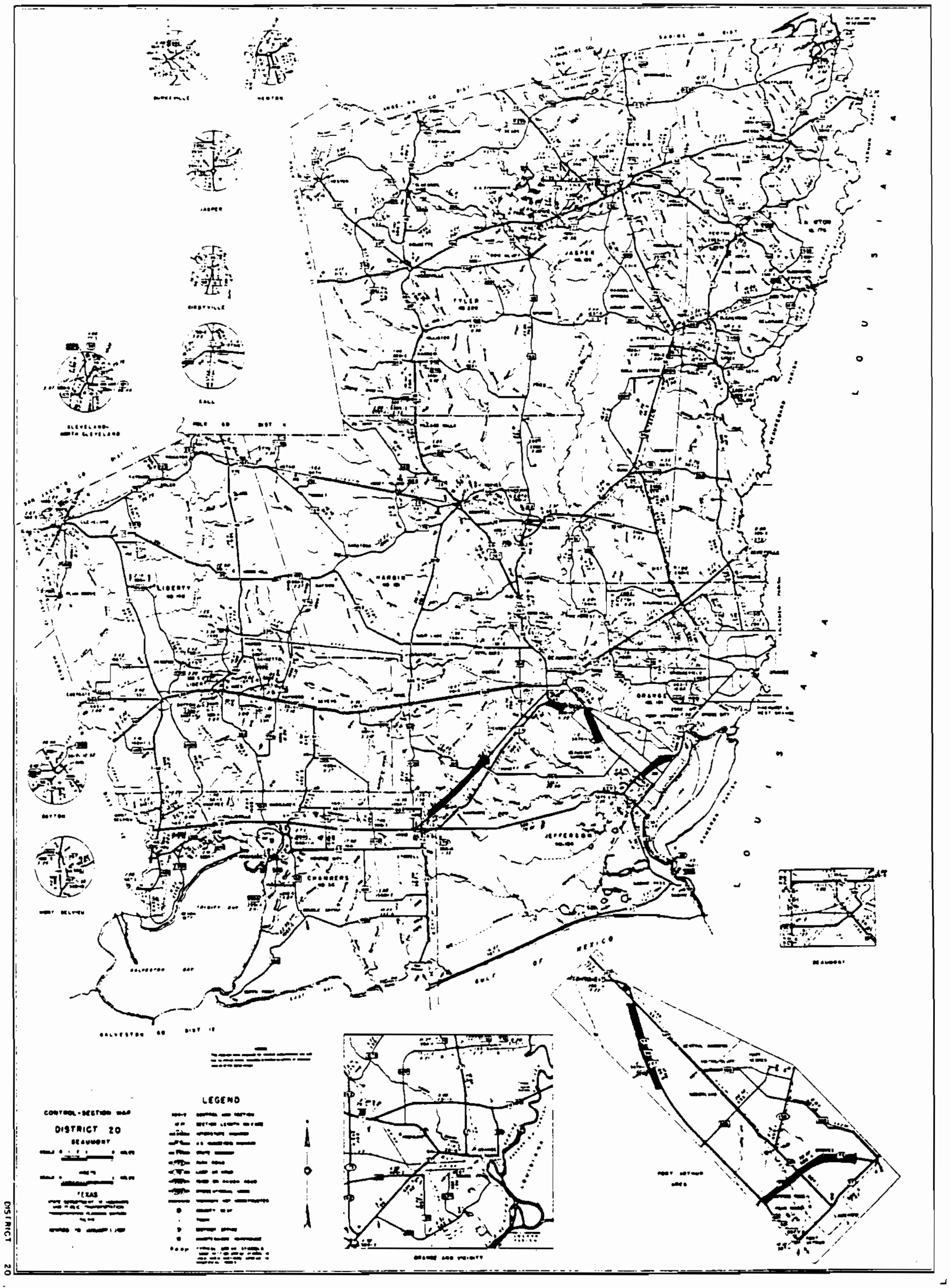
DISTRICT 18A



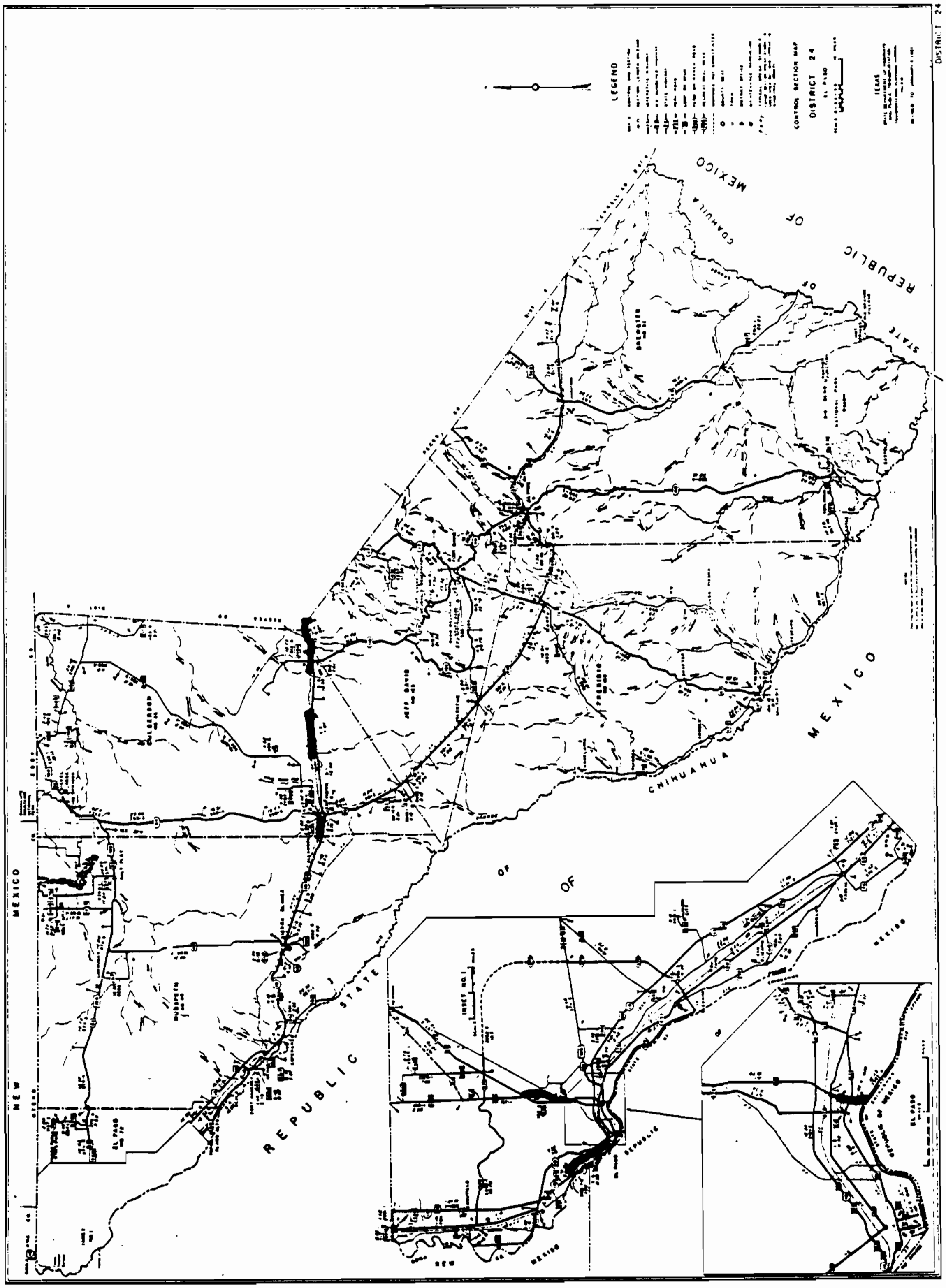
DISTRICT 18 - PART B


OKLAHOMA
ARKANSAS
LOUISIANA
BOWIE
TITUS
CASS
MORRIS
CAMP
UPSHUR
MARION
HARRISON
PANOLA
LEGEND
CONTROL-SECTION MAP
DISTRICT 19
ATLANTA
TEXAS
DISTRICT 19

DISTRICT 19


CONTROL-SECTION MAP
DISTRICT 20
BEAUMONT
TEXAS
LEGEND
LIBERTY
HARDIN
JASPER
TYLER
ORANGE
JEFFERSON
CHAMBERS
LOUISIANA
GULF OF MEXICO
GALVESTON CO DIST 12
DISTRICT 20

DISTRICT 20


NEW MEXICO
REPUBLIC OF MEXICO
STATE OF CHIHUAHUA
COAHUILA
LEGEND
CONTROL SECTION MAP
DISTRICT 24
EL PASO
INSET NO. 1
DISTRICT 24

DISTRICT 24

APPENDIX G. LISTING OF SURVEY RESULTS FOR SELECTED TEST SECTIONS

LISTING OF DESCRIPTION FOR ITEMS INCLUDED IN APPENDIX G

ITEM	DESCRIPTION
CFTR	Section ID number
SECTION	Sequent number of selected test section in the same CRTR project
DIR	Highway direction of selected test section, e.g. W: west bound
DATE	Date for the experimental condition survey (month/ day/ year)
LANES	Number of lanes (each direction)
RATER	Team number
CFP	Profile characteristics for test section, C: cut, F: fill, T: transition and G: at grade
CURVE	Y if test section is along turning curve, N if not
OVR	Y if it is an overlaid section, N if it is not
LEN	Length of test section (feet)
FROM	Beginning milepost or description of starting point
TO	Ending milepost or description
ACP	Number of asphalt concrete patches
PCCP	Number of portland cement concrete patches
NCRK	Number of transverse cracks in the entire test section
BF	Y for bond failure, N for not (overlaid pavement only)
NF	Number of failures (overlaid pavement only)
MPO	Number of minor punchouts
SPO	Number of severe punchous

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SAS                                                                                                 11:38 WEDNESDAY, OCTOBER 28, 1987       1

                       L R   C
        C   S     D    A A   U        F                                                     P   N
     O  F   E O   A    N T C R O  L   R                                                   A C   C      M S
     B  T   C I   T    E E F V V  E   O                         T                         C C   R B N  P P
     S  R   T R   E    S R P E R  N   M                         O                         P P   K F F  O O

     1 1001 1 W 082087 2 1 C N Y 1000 MILE 133.8                MILE 133.6                0 0   0 0 0  . .
     2 1001 2 W 082087 2 1 T Y Y 1000 MILE 133.5                MILE 133.3                0 0   0 0 0  . .
     3 1001 3 W 082087 2 1 G N Y 1000 MILE 132.7                MILE 132.5                0 0   0 0 0  . .
     4 1001 4 W 082087 2 1 C N Y 1000 MILE 131.6                MILE 131.4                0 0   0 0 0  . .
     5 1001 5 W 082087 2 1 F Y Y 1000 MILE 130.4                MILE 130.2                0 0   0 0 0  . .
     6 1001 6 W 082087 2 1 F N Y 1000 JUST AFTER MP 130         MP 129.8                  0 0   0 0 0  . .
     7 1003 1 W 082087 2 1 G N Y 1000 1000 FT E OF MP 142       MP 142                    0 0   0 0 0  . .
     8 1003 2 W 082087 2 1 C N Y 1000 1000 FT E OF MP 141       APPROX MP 141             0 0   0 0 0  . .
     9 1003 3 W 082087 2 1 F N Y 1000 500 FT E OF MP 140        500 FT W OF MP 140        0 0   0 0 0  . .
    10 1003 4 W 082087 2 1 F N Y 1000 MILE 139.8                MILE 139.6                0 0   0 0 0  . .
    11 1003 5 W 082087 2 1 T N Y 1000 MILE 139.4                MILE 139.2                0 0   0 0 0  . .
    12 1003 6 W 082087 2 1 C N Y 1000 138.4                     138.2                     0 0   0 0 0  . .
    13 1005 6 E 082087 2 1 C N Y 1000 MP 149                    1000 FT E OF 149          0 0   0 0 0  . .
    14 1005 1 W 082087 2 1 C N Y 1000 MP 153                    1000 FT W OF 153          0 0   0 0 0  . .
    15 1005 2 W 082087 2 1 F N Y 1000 MP 152                    1000 FT W OF 152          0 0   0 0 0  . .
    16 1005 3 W 082087 2 1 T N Y 1000 0.3 MI W OF 152           0.5 MI W OF 152           0 0   0 0 0  . .
    17 1005 4 W 082087 2 1 F N Y 1000 0.3 MI E OF 151           0.1 MI E OF 151           0 0   0 0 0  . .
    18 1005 5 W 082087 2 1 G N Y 1000 MP 151                    1000 FT W OF 151          0 0   0 0 0  . .
    19 1008 4 N 081987 2 1 C N Y 1000 0.4 MI N MP 29            0.6 MI N MP 29            0 0   0 0 0  . .
    20 1008 5 N 081987 2 1 T N Y 1000 1.6 MI N OF MP 30         1.8 MI N OF MP 30         0 0   0 0 0  . .
    21 1008 6 N 081987 2 1 F N Y 1000 MILE 27                   26.8                      0 0   0 0 0  . .
    22 1008 1 S 081987 2 1 G N Y 1000 500 FT N OF 24            500 FT S OF 24            0 0   0 0 0  . .
    23 1008 2 S 081987 2 1 F N Y  800 4.4 MI S OF MP 22         4.6 MI S OF MP 22         0 0   0 0 0  . .
    24 1008 3 S 081987 2 1 C N Y 1000 300 FT N OF 28            700 FT S OF 28            0 0   0 0 0  . .
    25 1013 1 N 082087 2 1 C N N 1000 0.3 MI S OF MP 9          0.1 MI S OF MP 9          0 0 386 . . 72 0
    26 1013 2 N 082087 2 1 T N N 1000 0.5 MI N OF MP 9          0.7 MI N OF MP 9          0 0 459 . . 63 0
    27 1013 3 N 082087 2 1 C N N 1000 MILE 8.3                  MILE 8.1                  0 0 440 . . 60 0
    28 1013 4 N 082087 2 1 G N N 1000 MILE 7.4                  MILE 7.2                  0 0 355 . .  7 0
    29 1013 5 N 082087 2 1 F N N 1000 MILE 3.1                  MILE 2.9                  0 0 340 . .  6 0
    30 1013 6 N 082087 2 1 F N N 1000 MILE 5.8                  MILE 5.6                  0 0 362 . . 26 0
    31 1015 1 E 081987 2 1 F N N 1000 0.5 MI E OF MP 18         0.7 MI E OF MP 18         0 0 224 . . 10 0
    32 1015 2 E 081987 2 1 C Y N 1000 0.6 E OF 19               0.2 W OF 20               0 0 197 . . 12 0
    33 1015 3 W 081987 2 1 C N N  800 0.2 E OF 20               MP 20                     0 0 164 . .  6 0
    34 1015 4 W 081987 2 1 T N N 1000 0.3 MI W OF 19            0.5 MI W OF 19            0 0 170 . .  3 0
    35 1015 5 W 081987 2 1 F N N  800 600 FT E OF MP 18         400 FT W OF 18            0 0 156 . .  7 0
    36 2002 1 E 080687 3 3 F N N 1000 1000 FT E OF 415 MP                                 0 0 167 . .  9 0
    37 2002 2 E 080687 3 3 C N N 1000 800 FT FROM MP 416                                  0 0 167 . .  0 0
    38 2002 3 E 080687 3 3 C Y N 1000                           3/10 MILE W OF 417        0 0 168 . .  5 0
    39 2002 4 E 080687 3 3 T Y N 1000 2000 FT E OF 417          EXIT 418                  0 0 174 . .  3 0
    40 2002 5 E 080687 3 3 F N N 1000 1000 FT W OF MP 418       AT MP 418                 0 0 193 . .  4 0
    41 2002 6 W 080687 3 3 G N N 1000 1000 FT W OF TARRANT COUN AT COUNTY LINE (END OF PR 0 0 145 . .  1 0
    42 2028 1 N 080487 2 3 C Y N 1000                           4/10 MILE S OF 33         0 1 193 . . 15 0
    43 2028 2 N 080587 2 3 T N N 1000 200 FT N MP 33            1200 FT N MP 33           0 0 159 . .  7 1
    44 2028 1 S 080487 2 3 F Y N 1000 2000 FT S MP 37           3000 FT S MP 37           0 0 151 . .  9 0
    45 2028 2 S 080487 2 3 G N Y 1000 ABOUT 200 FT N 36         ABOUT 800 FT S 36         0 0   0 0 0  . .
    46 2028 3 S 080487 2 3 C N Y 1000 1000 FT S 36              1000 FT N 35              0 0   0 0 0  . .
    47 2031 1 E 080587 2 3 G N Y 1000 200 FT W OF MP 17         1000 E OF MP 17           4 0   0 0 0  . .
    48 2031 2 E 080587 2 3 T N Y 1000 300 FT E OF MP 20                                   0 0   0 0 0  . .
    49 2031 1 W 080587 2 3 C N Y 1000 1200 FT E OF MP 20        200 FT E OF MP 20         0 0   0 0 0  . .
    50 2031 2 W 080587 2 3 F N Y 1000 1000 W OF MP 20           2000 W OF MP 20           0 0   0 0 0  . .
    51 2031 3 W 080587 2 3 C N Y 1000 1500 FT W OF MP 18        1/2 MILE W OF MP 18       4 0   0 0 0  . .
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SAS                                                                      11:38 WEDNESDAY, OCTOBER 28, 1987     2

                    L R   C
     C   S     O    A A   U        F                                                     P  N
  O  F   E D   A    N T C R O   L  R                                                   A C  C       M S
  B  T   C I   T    E E F V V   E  O                         T                         C C  R  B N  P P
  S  R   T R   E    S R P E R   N  M                         O                         P P  K  F F  O O

 52 2031 4 W 080587 2 3 F N Y 1000 2500 FT W OF 18 MP        1500 FT E OF 17 MP        4 0   0 0 0  . .
 53 2032 1 E 080687 3 3 F N N 1000 2200 FT W OF MP 2         200 FT W OF MP 2          0 0 169 . .  3 0
 54 2032 2 E 080687 2 3 C N Y 1000                           2500 W OF EXIT 58         0 0   0 0 0  . .
 55 2032 3 E 080687 3 3 T N N 1000                           AT EXIT 7A                1 1 108 . .  0 1
 56 2032 1 W 080687 3 3 C N N 1000 AT MP 4                   1000 FT W OF MP 4         1 0 106 . .  2 0
 57 2032 2 W 080687 3 3 F Y N 1000                           1500 FT E OF EXIT 18      2 1  43 . .  0 7
 58 2041 1 N 080487 3 3 G N N 1000 0.1 MILE N OF MP 24                                 0 0 173 . . 25 0
 59 2041 2 N 080487 3 3 C N N 1000 0.5 MILE N OF 24 MP       1000 FT N                 0 0 152 . .  0 0
 60 2041 1 S 080487 3 3 F N N 1000 500 FT S OF 24 MP                                   0 0 171 . .  2 0
 61 2044 1 N 080687 2 3 F Y N 1000 6/10 MILE S OF MP 24                                0 0 147 . .  4 0
 62 2044 2 N 080687 2 3 F Y N 1000                           3/10 S OF MP 24           0 0 153 . .  1 0
 63 2044 1 S 080687 2 3 F N Y 1000 1/2 MILE S MP 20                                    0 0   0 0 0  . .
 64 2044 2 S 080687 2 3 C N N 1000 21.5 MILE APPROX                                    0 0 154 . .  2 0
 65 2044 3 S 080687 2 3 C N N 1000 1200 FT N OF MP 22        200 FT N OF MP 22         0 0 150 . .  1 0
 66 2044 4 S 080687 2 3 G Y N 1000 1/10 S OF MP 22           3/10 S OF MP 22           0 0 154 . .  2 0
 67 2044 5 S 080687 2 3 T N N 1000 2000 FT N OF MP 24        1000 FT N OF MP 24        0 0 150 . .  1 0
 68 2046 1 N 080587 3 3 F N Y 1000 200 FT S OF MP 23         BRIDGE OVER HALTON DRIVE  0 0   0 0 0  . .
 69 2046 2 N 080587 3 3 G N Y 1000                           1500 FT S OF MP 23        0 0   0 0 0  . .
 70 2046 1 S 080587 3 3 F N Y 1000 3500 FT N OF 23 MP        1/4 MILE N OF HALTON RD E 0 0   0 0 0  . .
 71 2049 1 N 080587 2 3 C N N 1000 ABOUT 200 FT FROM MP 5    ABOUT 1500 TO 2000 FT N O 0 0 163 . .  5 0
 72 2049 1 S 080587 2 3 F Y N 1000 8/10 MILE S OF MP 0                                 0 2 186 . .  7 0
 73 2049 2 S 080587 2 3 F N N 1000 2.3 MILE S OF MP 0        2.5 MILE S OF MP 0        0 0 179 . .  2 0
 74 2049 3 S 080587 2 3 G N N 1000 3000 FT S MP 3            EXIT TO WILLOW SPRINGS RO 0 0 184 . .  6 0
 75 2049 4 S 080587 2 3 C N N 1000 700 FT N OF MP 4          300 FT S OF MP 4          0 0 175 . . 10 0
 76 2050 1 N 080587 2 3 C N N 1000 ABOUT 1/2 MILE N OF MP 10                           0 1 154 . .  4 0
 77 2050 1 S 080587 2 3 G N N 1000 200 FT S OF MP 8          1200 FT S OF MP 8         0 0 153 . .  3 0
 78 2050 2 S 080587 2 3 G N N 1000 ABOUT 1000 FT S OF MP 9   1/2 MILE N OF MP 10       0 0 148 . .  1 0
 79 2051 1 E 080787 2 3 C Y N 1000 200 FT W OF MP 389                                  0 0 154 . . 15 0
 80 2051 2 E 080787 2 3 F Y N 1000 1200 FT W OF MP 389                                 0 0 167 . . 11 0
 81 2051 1 W 080787 2 3 T Y N 1000                           2000 FT E OF MP 389       0 0 158 . . 11 0
 82 2059 1 E 080787 2 3 C N N 1000                           150 FT W OF MP 365        1 1 164 . . 24 0
 83 2059 2 E 080787 2 3 T N N 1000 250 FT W OF MP 367                                  0 0 183 . . 23 0
 84 2059 1 W 080787 2 3 G N N 1000 300 FT W OF 368 MP                                  0 0 171 . . 12 0
 85 2059 2 W 080787 2 3 C N N 1000 300 FT W OF MP 365                                  1 0 160 . .  9 0
 86 2060 1 E 080487 4 3 F Y N 1000 1000 FT W OF MP 446       15 FT W OF MP 446         0 0 202 . .  9 0
 87 2060 1 W 030487 4 3 C N N 1000 100 FT W OF 445 MP        900 FT W OF 445 MP        0 0 117 . .  3 0
 88 2060 2 W 080487 4 3 T N N 1000 2000 FT W OF 445          3000 FT E OF 444          0 0 126 . . 10 0
 89 2075 1 N 080487 3 3 F N N 1000 (42)                      2000 FT S OF 43           0 0 130 . .  8 0
 90 2075 1 S 080487 3 3 G N N 1000 ABOUT 100 FT N OF MP 44                             0 0 123 . .  7 0
 91 2075 2 S 080487 3 3 F N N 1000 ABOUT 700 FT S MP 43                                0 0 120 . .  4 0
 92 2075 3 S 080487 3 3 C Y N 1000 700 FT S OF 41 MP                                   0 0 131 . .  5 0
 93 2075 4 S 080487 3 3 C Y N 1000 2500 FT S OF 41           S OF 40                   0 0 146 . .  7 0
 94 2098 1 E 080687 3 3 F N N 1000 1000 FT FROM MP 11        6/10 MILE W OF MP 12      0 0 134 . .  5 0
 95 2098 2 E 080687 3 3 G N N 1000 500 FT E OF MP 12         1000 EASTWARD             0 0 166 . .  2 0
 96 2098 1 W 080687 3 3 C N N 1000 2500 FT W OF 13           2500 FT E OF 12           0 0 203 . .  6 0
 97 2098 2 W 080687 3 3 T N N 1000 AT MP 11                  1000 W OF MP 11           2 0 143 . .  0 0
 98 3001 1 N 081787 2 1 C Y N  600 1.2 MI N OF MP 4          1.4 MI N OF MP 4          0 0 126 . . 12 0
 99 3001 2 N 081787 2 1 C N N 1000 0.3 MI S OF MP 6          0.1 MI S OF MP 6          0 0 188 . .  5 0
100 3001 1 S 081787 2 1 G Y N 1000 2.4 MI S OF BACON SWITCH  2.6 MI S OF BACON SWITCH  0 0 194 . . 18 0
101 3001 2 S 081787 2 1 F N N  600 1.2 MI N OF MP 4          NEAR MP 5                 1 0 112 . . 13 0
102 3004 1 N 081887 2 1 F N N 1000 1500 FT S OF MP 12        500 FT S OF MP 12         0 0 209 . . 20 0
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SAS                                                                                           11:38 WEDNESDAY, OCTOBER 28, 1987   3

                    L R   C
      C  S      D   A A   U        F                                                     P  N
 O    F  E D    A   N T C R O    L R                                                   A C  C        M S
 B    T  C I    T   E E F V V    E O                         T                         C C  R  B N   P P
 S    R  T R    E   S R P E R    N M                         O                         P P  K  F F   O O

103 3004 5 N 081887 2 1 T N N  900 1500 FT N OF MP 11                                  2 0 111 . .   5 0
104 3004 2 S 081887 2 1 F Y N 1000 1500 FT S OF MP 14        2500 FT S OF MP 14        0 0 206 . .  10 0
105 3004 3 S 081887 2 1 G N N 1000 600 FT N OF MP 12         400 FT S OF MP 12         0 0 222 . .   9 0
106 3004 4 S 081887 2 1 C N N  800 2000 FT N OF MP 11        1200 FT N OF MP 11        1 0 159 . .   7 0
107 3010 5 N 081887 2 1 F N N  600 1000 FT S OF MP 2         MP 2                      0 0 113 . .   9 0
108 3010 6 N 081887 2 1 C N N 1000 1000 FT S OF MP  3        MP 3                      0 0 164 . .   8 0
109 3010 1 S 081887 2 1 G N N 1000 MP 1                      1000 FT S OF MP 1         0 0 174 . .  15 0
110 3010 2 S 081887 2 1 F N N 1000 1000 FT N OF MP 2         MP 2                      0 0 172 . .   5 0
111 3010 3 S 081887 2 1 C N N 1000 500 FT N OF MP 3          500 FT S OF MP 3          0 0 151 . .  13 0
112 3010 4 S 081887 2 1 T Y N 1000 1500 FT S OF MP 8                                   0 0 195 . .  11 0
113 3011 1 N 081887 2 1 F N N 1000 500 FT NW OF MP 34        1500 FT N OF MP 34        1 0 109 . .   7 0
114 3011 2 N 081887 2 1 T N N 1000 1/2 MI N OF MP 34         3000 FT N OF MP 34        0 0 157 . .  13 0
115 3011 3 N 081887 2 1 C N N  500 3000 FT N OF MP 34        4000 FT N OF MP 34        0 0  95 . .  16 0
116 3011 4 S 081887 2 1 G N N 1000 500 FT N OF MP 34                                   1 0 179 . .   3 0
117 3018 5 N 081887 2 1 C N N 1000 0.4 MI S OF MP 32         0.2 MI S OF MP 32         0 0 127 . .  10 0
118 3018 6 N 081887 2 1 F N N 1000 0.5 MI N OF MP 30         0.7 MI N OF MP 30         0 0 205 . .  10 0
119 3018 1 S 081887 2 1 C N N 1000 0.6 MI S OF US 81 OVERPAS 0.8 MI S OF US 81 OVERPAS 0 0 157 . .   5 0
120 3018 2 S 081887 2 1 G N N 1000 2.3 MI S OF US 81 OVERPAS 2.5 MI S OF US 81 OVERPAS 0 0 208 . .  15 0
121 3018 3 S 081887 2 1 F N N 1000 1.4 MI S OF MP 28         1.6 MI S OF MP 28         0 0 182 . .   5 0
122 3018 4 S 081887 2 1 T N N 1000 1.6 MI S OF MP 28         1.8 MI S OF MP 28         0 0 188 . .   8 0
123 3022 1 N 081887 2 1 G N N 1000 1000 FT N OF MP 24        MP 24                     0 0 190 . .  31 0
124 3022 2 N 081887 2 1 F N N 1000 0.4 MI N OF MP 26         0.6 MI N OF MP 26         0 0 178 . .  27 0
125 3022 3 N 081887 2 1 T N N 1000 4.1 MI E OF LOOP 145      3.9 MI E OF 145           0 0 156 . .   9 0
126 3022 4 N 081887 2 1 C N N 1000 0.4 MI W OF MP 27         0.6 MI W OF MP 27         0 0 163 . .  20 0
127 3022 5 N 081887 2 1 F N N 1000 2500 FT E OF MP 29        1500 FT E OF MP 29        0 0 153 . .  31 0
128 4002 1 W 072687 3 5 F N Y 1000 APPROX 1500 FT W OF 72    1000 FT WESTWARD          0 0   0 0 0   . .
129 4002 2 W 072687 3 5 G N Y 1000 1700 FT E OF 71           700 FT E OF 71            0 0   0 0 0   . .
130 4005 1 E 072987 2 5 G N N 1000 MIDWAY BETWEEN 88 AND 89  1000 FT EASTWARD TOWARD 8 0 0 373 . .  34 1
131 4005 2 E 072987 2 5 F N N 1000 MP 91                     1000 FT E OF 91           0 0 403 . .  24 0
132 4005 1 W 072687 2 5 G N N 1000 1000 FT E TOWARD 93       MP 92                     1 0 354 . .  19 0
133 4005 2 W 072687 2 5 G N N 1000 1000 FT E OF 89           MP 89                     2 2 375 . . 228 0
134 4005 3 W 072687 2 5 G N N 1000 100 FT E OF 86            MP 86                     3 2 385 . .  46 0
135 4009 1 W 072687 3 5 G N N 1000 1000 W OF 67              2000 FT W OF 67           0 0 441 . .  65 0
136 4009 2 W 072687 3 5 C N N 1000 MIDWAY BETWEEN 67 AND 66  1000 WESTWARO             0 0 388 . .  61 0
137 4009 3 W 072687 3 5 F Y N 1000 700 FT W OF 66            1700 FT W OF 66           0 0 387 . .  43 0
138 4009 4 W 072687 3 5 G N N 1000 1000 FT E OF 65           MP 65                     0 0 431 . . 105 0
139 4009 5 W 072687 2 5 C Y N 1000 1500 FT W OF 63           2500 FT W OF 63           0 0 501 . . 356 0
140 4010 1 W 072687 2 5 G N Y 1000 1000 FT E OF 82           MP 82                     0 0   0 0 0   . .
141 4010 2 W 072687 2 5 G N Y 1000 1000 FT E OF 79           MP 79                     0 0   0 1 1   . .
142 4010 3 W 072687 2 5 F N Y 1000 500 FT W OF 79            1500 FT W CF 79           0 0   0 0 0   . .
143 4011 1 E 072787 2 5 G N N 1000 MP 56                     1000 FT E OF 56           0 1 250 . .  11 0
144 4011 2 E 072787 2 5 F N N 1000 1000 FT WESTWARD          MIOWAY BETWEEN 60 AND 61  0 0 318 . .  11 0
145 4011 1 W 072787 2 5 G N N 1000 1000 FT E OF 61           MP 61                     0 0 419 . .   3 0
146 4011 2 W 072787 2 5 F N N 1000 1000 FT EASTWARD          MIOWAY BETWEEN 61 AND 60  0 6 318 . .  42 1
147 4011 3 W 072787 2 5 G N N 1000 1000 FT E OF 56           MP 56                     2 0 338 . .   6 0
148 4022 1 E 072987 2 5 G N N 1000 MP 115                    1000 FT E OF 115          0 0 375 . .  63 0
149 4022 1 W 072687 2 5 G N N 1000 1000 FT E OF 115          MP 115                    0 0 367 . .  37 0
150 4022 2 W 072687 2 5 F Y N 1000 MIDWAY BETWEEN 115 AND 11 1000 FT W TOWARD 114      0 0 335 . . 148 0
151 4023 1 W 072587 2 5 C Y Y 1000 1500 FT W OF 125          1000 FT TOWARDS 124       0 0   5 0 0   . .
152 4023 2 W 072587 2 5 F N Y 1000 MIDWAY BETWEEN 125 AND 12 1000 FT W                 0 0  17 0 0   . .
153 4023 3 W 072587 2 5 G N Y 1000 1000 FT E                 800 FT E OF 123           0 0  15 0 0   . .
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                     L R   C
        C S      0   A A   U        F                                                      P  N
 O      F E D    A   N T C R O   L  R                                                   A  C  C        M S
 B      T C I    T   E E F V V   E  O                         T                         C  C  R  B N   P P
 S      R T R    E   S R P E R   N  M                         O                         P  P  K  F F   O O

154  4025 1 W 072787 2 5 T N N 1000 1000 FT FROM 130          1000 FT TOWARDS 129       0  0 398 . .  15 0
155  4025 2 W 072587 2 5 C Y N 1000 BETWEEN 130 AND 129       1200 FT E OF 129          0  0 364 . .  11 0
156  4025 3 W 072587 2 5 G N N 1000 128+500 FT                1000 FT TOWARD 127        0  0 335 . . 192 0
157  4025 4 W 072587 2 5 F N N 1000 1000 BACK TOWARD 128      700 FT E OF 127           0  0 354 . .  41 0
158  5005 1 N 072887 2 5 G N N 1000 MP 39                     1000 FT N OF 39           0  0 195 . .   5 0
159  5005 2 N 072887 2 5 G N N 1000 1000 FT S OF 43           MP 43                     0  0 357 . .  19 0
160  5005 1 S 072887 2 5 G N N 1000 MP 43                     1000 FT S OF 43           0  0 368 . .   9 0
161  5005 2 S 072887 2 5 F N N 1000 2500 FT N OF 42           1500 FT N OF 42           0  0 348 . .  10 0
162  5007 1 S 072887 2 5 F Y N 1000 MIDWAY BETWEEN 39 AND 38  1000 FT S TOWARDS 38      0  0 148 . .   0 0
163  5007 2 S 072887 2 5 C N N 1000 300 FT N OF 38            700 FT S OF 38            0  0 152 . .   2 0
164  5007 3 S 072887 2 5 G Y N 1000 MP 39                     1000 FT S OF 39           0  0 178 . .   6 0
165  5008 1 N 072887 2 5 G N N 1000 MP 55                     1000 FT N OF 55           0  0 359 . .   3 0
166  5008 2 N 072887 2 5 G N N 1000 2500 FT S OF 56           1500 FT S OF 56           0  0 401 . .   7 0
167  5008 1 S 072887 2 5 G N N 1000 MP 57                     1000 FT S OF 57           0  0 296 . .   0 0
168  5008 2 S 072887 2 5 G Y N 1000 MP 55                     1000 FT S                 0  0 271 . .   1 0
169  5009 1 N 072787 2 5 G N N 1000 MP 60                     1000 FT N OF 60           0  0 332 . .   1 0
170  5009 1 S 072787 2 5 G N N 1000 1000 FT N OF 60           MP 60                     0  0 306 . .   0 0
171  5009 2 S 072787 2 5 G N N 1000 1000 FT N OF 59           MP 59                     0  0 281 . .   1 0
172  9001 1 N 090287 2 1 G N Y 1000 MP 313.6                  MP 313.8                  0  0   0 0 0   . .
173  9001 2 N 090287 2 1 F Y Y 1000 200 FT S OF MP 314        0.2 MI N OF MP 314        0  0   0 0 0   . .
174  9001 3 N 090287 2 1 C N Y 1000 0.6 MI N OF MP 314        0.8 MI N OF MP 314        0  0   0 0 0   . .
175  9001 4 N 090287 2 1 F Y Y 1000 0.1 MI N OF MP 315        0.3 MI N OF MP 315        0  0   4 0 0   . .
176  9001 5 S 090287 2 1 C Y Y 1000 0.1 MI S OF MP 315        0.3 MI S OF MP 315        0  0   0 0 0   . .
177  9002 1 N 090287 2 1 G N Y 1000 0.2 MI N MP 316           0.4 MI N MP 316           0  0   1 0 0   . .
178  9002 2 N 090287 2 1 F N Y 1000 0.1 MI S OF MP 317        0.1 MI N OF MP 317        0  0   0 0 0   . .
179  9002 3 N 090287 2 1 C Y Y 1000 0.1 MI N OF MP 318        0.3 MI N OF MP 318        0  0   0 0 0   . .
180  9002 4 S 090287 2 1 C N Y 1000 0.3 MI S OF MP 319        0.5 MI S OF MP 319        0  0   0 0 0   . .
181  9002 5 S 090287 2 1 F N Y 1000 1.3 MI S OF MP 319        1.5 MI S OF MP 319        0  0   0 0 0   . .
182  9002 6 S 090287 2 1 T N Y 1000 0.2 MI N OF MP 317        MP 317                    0  0   0 0 0   . .
183  9004 3 N 082187 2 1 F N N  800 331.7                     800 FT N                  0  1 121 . .  12 0
184  9004 4 N 082187 2 1 G N N  500 332.4                                               0 10  73 . .  13 0
185  9004 1 S 082187 2 1 C N N 1000 333.3                     333.1                     0 10 145 . .  17 0
186  9004 2 S 082187 2 1 T N N  600 333.1                     332.9                     0  8 112 . .  15 0
187 12901 1 E 082887 3 1 G N N 1000 0.3 MI E OF HARDY TOLL RO 0.5 MI E OF HARDY TOLL RO 0  0 194 . .   4 0
188 12901 2 E 082887 3 1 G N N 1000 0.5 MI E OF HARDY TOLL RO 0.7 MI E OF HARDY TOLL RO 0  0 191 . .   8 0
189 12901 3 W 082887 3 1 G N N 1000 0.3 MI W OF ALDINE WESTFI 0.5 MI W OF ALDINE WESTFI 0  0 177 . .   6 0
190 12901 4 W 082887 3 1 G N N 1000 0.5 MI W OF ALDINE WESTFI 0.7 MI W OF ALDINE WESTFI 0  0 149 . .   5 0
191 12902 1 E 082887 3 1 G N N 1000 1.4 MI E OF IH45          1.6 MI E OF IH45          0  0 232 . .  34 0
192 12902 2 W 082887 3 1 G N N  600 0.2 MI W OF HARDY TOLL RO 0.4 MI W OF HARDY TOLL RO 0  0 107 . .  11 0
193 13001 1 W 082787 2 2 C N Y 1000 699.4                     1000 FT WB                0  0   0 0 0   . .
194 13001 2 W 082787 2 2 F Y Y 1000 697.5                     697.5                     0  0   0 0 0   . .
195 13002 3 W 082887 2 2 C N Y 1000 263 FT FROM MP 695        1000 FT WB                9  0  26 0 0   . .
196 13002 4 W 082887 2 2 G N Y 1000 300 FT FROM MP 693        1000 FT WB                1  0   8 0 0   . .
197 13002 5 W 082887 2 2 T N Y 1000 993.6 FROM MP 692         1000 FT WB                0  0  11 0 0   . .
198 13007 1 E 082787 2 2 C N Y 1000 685                       100 FT EB                 0  0   0 0 0   . .
199 13007 2 E 082787 2 2 C N Y 1000 MP 686                    1000 FT EB                0  0   0 0 0   . .
200 13007 3 E 082787 2 2 T N Y 1000 MP 686.7                  1000 FT EB                0  0   0 0 0   . .
201 13007 4 E 082787 2 2 F N Y 1000 688.25                    1000 FT EB                0  0   0 0 0   . .
202 13007 5 E 082787 2 2 F N Y 1000 688.85                    1000 FT EB MP 689         0  0   0 0 0   . .
203 13009 1 N 082687 2 2 G N N 1000 133 FT FROM COLETO CREEK  1000 FT SB                0  0 286 . .  27 1
204 13009 2 S 082687 2 2 G N Y 1000 133 FT FROM COLETO CREEK  1000 FT                   0  0   0 0 0   . .
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SAS                                                                                    11:38 WEDNESDAY, OCTOBER 28, 1987    5

OBS CFTR  SECT DIR  DATE  LANES RATER CFP CURVE OVR LEN   FROM                TO                        ACP PCCP NCRK BF NF MPO SPO

205 13013  2    W   082887   2     2    C    N    N  1000 MP 667.15           MP 667                     0  0    206 .  .   12  0
206 13013  3    W   082887   2     2    F    N    N  1000 666.55              1000 FT WB 666.4           0  1    230 .  .   14  0
207 13013  4    W   082887   2     2    C    N    N  1000 666.75              1000 FT WB                 0  0    234 .  .   12  2
208 13013  5    W   082887   2     2    F    N    N  1000 663.45              1000 FT 666.6              0  4    308 .  .   27  0
209 13015  4    E   082887   2     2    F    N    N  1000 659.6               1000 EB                    0  0    177 .  .    5  0
210 13015  1    W   082887   2     2    C    N    N  1000 661                 1000 FT WB                 0  0    188 .  .    6  0
211 13015  2    W   082887   2     2    F    N    N  1000 659.75              1000 FT 659.6              0  3    169 .  .    1  0
212 13015  3    W   082887   2     2    C    N    N  1000 659.15              1000 FT WB 659             0  0    196 .  .   11  0
213 13015  5    W   082887   2     2    T    N    N  1000 1330 FT FROM MP 661 330 FT FROM MP 661         0  2    185 .  .    6  0
214 13019  1    N   082687   2     2    G    N    Y  1000 22.6                1000 FT                    0  0      4 0  0    .  .
215 13019  2    N   082687   2     2    G    N    N  1000 MP 20               1000 FT                    1  0    303 .  .   29  0
216 13019  4    N   082687   2     2    T    N    N  1000 MP 23.25            1000 FT                    1  2    279 .  .   19  0
217 13019  3    S   082687   2     2    F    Y    Y  1000 PTO                 1000 FT                    0  0     27 0  0    .  .
218 13020  3    E   082987   2     2    T    N    N  1000 643.84              1000 FT 171 FT MP 644      0  0    125 .  .    5  0
219 13020  1    W   082987   2     2    F    N    N  1000 644.85              1000 FT                    0  1    136 .  .    8  0
220 13020  2    W   082987   2     2    C    N    N  1000 644.26              1000 FT 363 FT FROM MP 64  0  1     98 .  .    7  0
221 13021  3    E   082887   2     2    F    N    N  1000 650.3               1000 FT EB                 0  0    120 .  .    7  0
222 13021  4    E   082887   2     2    C    N    N  1000 651.1               1000FT EB                  0  0    113 .  .    9  0
223 13021  1    W   082887   2     2    G    N    N  1000 652                 1000FT WB                  0  0    103 .  .    4  0
224 13021  2    W   082887   2     2    T    N    N  1000 652.55              652.7                      1  1    124 .  .    4  2
225 13021  5    W   082987   2     2    C    N    N  1000 MP 648.35           1000 FT                    0  0    130 .  .    9  0
226 13023  1    N   082787   2     2    G    N    N  1000 MP 24.45            1000 FT NB 24.3            0  0    296 .  .   21  3
227 13023  2    N   082787   2     2    F    Y    N  1000 24.15               23.9                       0  1    342 .  .   40  1
228 13023  3    N   082787   2     2    G    N    N  1000 23.75               1000 FT NB 23.6            0  3    287 .  .   38  3
229 13023  4    N   082787   2     2    G    N    N  1000 MP 22               1000 FT NB                 0  0    395 .  .   30  0
230 13024  1    N   082787   2     2    G    N    N  1000 18.7                1000 FT NB                 1  0    369 .  .   26  0
231 13024  2    N   082787   2     2    G    Y    N  1000 MP 18.0             1000 FT NB                 0  0    361 .  .   24  0
232 13028  1    N   082787   2     2    G    N    N  1000 MP 12               1000 FT NB                 0  0    211 .  .   11  0
233 13028  3    S   082787   2     2    G    N    N  1000 MP 10.6             1000 FT                    0  1    288 .  .   10  0
234 13028  4    S   082787   2     2    G    N    N  1000 MP 12               1000 FT                    0  0    238 .  .    4  0
235 13029  1    N   082687   2     2    G    N    N  1000 4.15                MP 4 NB                    0  0    402 .  .   49  0
236 13029  2    N   082687   2     2    G    N    Y  1000 MP 2                1000 FT NB                 0  0      0 0  0    .  .
237 13029  3    S   082687   2     2    G    N    N  1000 MP 2                1000 FT SB                 0  1    363 .  .   51  0
238 13030  1    S   082687   2     2    G    N    N  1000 4.8                 1000 FT SB                 0  0    414 .  .   47  0
239 13030  2    S   082687   2     2    G    N    N  1000 5.4                 1000 FT SB                 0  0    364 .  .   23  0
240 13031  1    N   082687   2     2    G    N    Y  1000 8.8                 1000 FT NB                 3  0      9 0  0    .  .
241 13031  2    N   082687   2     2    F    N    Y  1000 8.15                MP 8 NB                    0  0      0 0  0    .  .
242 13032  1    N   082687   2     2    G    Y    N  1000 13.5                1000 FT NB                 0  1    224 .  .   10  0
243 13032  2    N   082687   2     2    G    N    N  1000 11.6                1000 FT NB                 0  0    186 .  .    5  0
244 13032  3    N   082687   2     2    F    N    N  1000 MP 10.5             1000 FT NB                 0  0    303 .  .   21  0
245 13032  4    S   082687   2     2    G    N    N  1000 10.6                1000 FT SB                 0  0    245 .  .    6  0
246 15032  1    N   081987   3     2         N    Y  1000 143                 1000 FT                    0  0      0 0  0    .  .
247 15032  2    N   081987   3     2    G    Y    Y  1000 MP 143.8            MP 143.8 + 1000 FT         0  0      0 0  0    .  .
248 15033  1    N   081987   3     2         N    Y  1000 MP 142              900 FT                     0  0      0 0  0    .  .
249 15036  1    N   081987   3     2    C    Y    Y  1000 145.                1000 FT                    0  0      0 0  0    .  .
250 15036  2    N   081987   3     2    F    N    Y  1000 147.5               1000 FT                    0  0      0 0  0    .  .
251 15036  3    N   081987   3     2    C    N    Y  1000 147.4               1000 FT                    0  0      0 0  0    .  .
252 15901  1    N   081987   4     2    B    N    N   800 800 FT              168                       15  0     84 .  .    0  0
253 15902  1    N   081887   3     2    G    N    Y  1000 166                 1000 FT                    0  0      0 0  0    .  .
254 15902  2    N   081987   3     2         N    Y  1000 EXIT 165            1000 FT                    0  0      1 0  0    .  .
255 17002  1    N   072887   2     1    G    N    N  1000 NEAR MP 122         JUST N OF REST AREA NEAR   0  0    296 .  .   26  0
256 17002  2    S   072887   4     1    G    N    Y  1000 MP 132-0.1 MILE     MP 132-0.3 MILE            0  0      1 0  0    .  .
257 17002  3    S   072887   4     1    F    N    Y  1000 MP 130 + 0.4        MP 130 + 0.2               0  0      6 0  0    .  .
258 17002  4    S   072887   4     1    T    N    Y  1000 NEAR MP 130         MP 130-0.2                 0  0      1 0  0    .  .
259 17002  5    S   072887   4     1    F    N    Y  1000 MP 130-0.7          MP 130-0.5                 0  0      1 0  0    .  .
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SAS                                                                                           11:38 WEDNESDAY, OCTOBER 28, 1987    6

                     L R   C
      C   S     D    A A   U        F                                                   P   N
 O    F   E O   A    N T C R O  L   R                                                 A C   C      M S
 B    T   C I   T    E E F V V  E   O                       T                         C C   R B N  P P
 S    R   T R   E    S R P E R  N   M                       O                         P P   K F F  O O

260 17002 6 S 072887 4 1 C N Y 1000 MP 129-0.5 MILE         MP 129-0.7 MILE           0 0   7 0 0  . .
261 17002 7 S 072887 4 1 C N Y 1000 MP 128-0.7              MP 128-0.9                0 0   3 0 0  . .
262 17003 6 B 082787 2 1 F N Y 1000 MP 158                  .2 MI N MP 158            0 0   0 0 0  . .
263 17003 1 N 082787 2 1 G N Y 1000 MP 152.8                MP 153.0                  0 0   0 0 0  . .
264 17003 1 N 082787 2 1 G N N 1000 152.8                   MP 153                    0 0   0 . .  0 0
265 17003 2 N 082787 2 1 C N Y 1000 MP 153.5                MP 153.7                  0 0   0 0 0  . .
266 17003 2 N 082787 2 1 C N N 1000 153.5                   153.7                     0 0   0 . .  0 0
267 17003 3 N 082787 2 1 F N Y 1000 MP 153.9                MP 154.1                  0 0   0 0 0  . .
268 17003 3 N 082787 2 1 F N N 1000 153.9                   154.1                     0 0   0 . .  0 0
269 17003 4 N 082787 2 1 C N Y 1000 MP 157.2                MP 157.4                  0 0   0 0 0  . .
270 17003 4 N 082787 2 1 C N N 1000 157.2                   157.4                     0 0   0 . .  0 0
271 17003 5 N 082787 2 1 T N Y 1000 MP 157.5                MP 157.7                  0 0   0 0 0  . .
272 17003 5 N 082787 2 1 T N N 1000 157.5                   157.7                     0 0   0 . .  0 0
273 17003 6 N 082787 2 1 F N N 1000 MP 158                  0.2 MI N MP 158           0 0   0 . .  0 0
274 17004 1 S 072987 4 1 G N Y 1000 MP 152-0.2 MILE         MP 152-0.4 MILE           0 0   0 0 0  . .
275 17004 2 S 072987 4 1 C N Y 1000 MP 150-0.2 MILE         NEAR MP 150               0 0   0 0 0  . .
276 17004 3 S 072987 4 1 T N Y 1000 MP 150-0.3 MILE         MP 150-0.5 MILE           1 0   0 0 0  . .
277 17004 4 S 072987 4 1 C N Y 1000 MP 149+0.2 MILE         AT MP 149                 0 0   0 0 0  . .
278 17004 5 S 072987 4 1 F Y Y 1000 MP 149-0.1              MP 149-0.3                0 0   0 0 0  . .
279 17004 6 S 072987 4 1 F N Y 1000 MP 148-0.5 MI           MP 148-0.7 MI             0 0   0 0 0  . .
280 17007 1 S 072987 4 1 G N N 1000 MP 173                  MP 173-0.2 MI             0 0 298 . .  5 0
281 17007 2 S 072987 4 1 C N N 1000 MP 172+0.2 MI           MP 172                    0 0 305 . .  2 0
282 17007 3 S 072987 4 1 F N N 1000 MP 172-0.1 MI           MP 172-0.3 MI             0 0 317 . .  2 0
283 17007 4 S 072987 4 1 F N N 1000 MP 172-0.4 MI           MP 172-0.6 MI             0 0 305 . .  3 0
284 17007 5 S 072987 4 1 T N N 1000 MP 171-0.2 MI           MP 171-0.4 MI             0 0 414 . .  7 0
285 17007 6 S 072987 4 1   N N 1000 MP 170+.2 MI            MP 170                    0 0 394 . .  8 0
286 17011 6 N 072887 4 1 F N N 1000 MP 14.8                 MP 14.6                   0 0 142 . .  2 0
287 17011 1 S 072887 4 1 C N N 1000 MP 7.3                  MP 7.5                    0 0 145 . . 11 0
288 17011 2 S 072887 4 1 G N N 1000 MP 8.6                  MP 8.8                    0 0 125 . . 14 0
289 17011 3 S 072887 4 1 T N N 1000 MP 10.6                 MP 10.8                   3 1 194 . . 22 0
290 17011 4 S 072887 4 1 C N N 1000 MP 10.9                 MP 11.1                   0 0 175 . . 10 0
291 17011 5 S 072887 4 1 F N N 1000 MP 14.6                 MP 14.8                   0 0 159 . .  4 0
292 18054 1 E 081087 4 3 C N Y 1000 500 FT E OF MP 50       500 FT W OF MP 50         0 0   0 0 0  . .
293 18054 1 W 081187 4 3 C N N 1000 600 FT E OF MP 50       500 FT W OF MP 50         0 0   0 . .  0 0
294 18054 2 W 081187 4 3 F N Y 1000 2/10 E OF MP 49         AT 49.2                   0 0   0 0 0  . .
295 18062 1 E 081087 3 3 C Y N 1000                         300 FT E OF MP 46         0 0 141 . . 16 0
296 18062 1 W 081087 3 3 C Y N 1000 350 FT E OF MP 46       200 FT  OF LAMAR ST BRIDG 0 0 126 . . 17 0
297 18066 1 N 080387 3 3 C Y N 1000 122 FT AHEAD 422A EXIT  1000 FT AHEAD             0 0 141 . .  2 0
298 18066 1 S 080387 3 3 F N N 1000 1000 FT N OF MP 422     AT MP 422                 0 0 166 . .  9 0
299 18066 2 S 080387 3 3 C Y N 1000                         NEAR EXIT 421B            0 0 158 . .  9 0
300 18071 1 N 080387 2 3 G N N 1000 230 FT S OF MP 68                                 0 0 115 . .  7 0
301 18071 2 N 081387 2 3 C N N 1000 600 FT S OF MP 69                                 0 0 137 . .  4 0
302 18071 3 N 081387 2 3 T N N 1000 0.3 MILE N OF MP 70                               0 0 130 . .  9 0
303 18071 4 N 081387 2 3 F N N  600 0.8 MILE N OF MP 70                               0 0 141 . .  7 0
304 18071 1 S 081387 2 3 G N N  800 0.5 MILE S OF MP 71                               0 0 157 . . 11 0
305 18071 2 S 081387 2 3 C N N 1000 0.4 MILE S OF MP 70                               0 0 113 . .  4 0
306 18072 1 E 081187 4 3 F N N  600 100 FT E OF MP 26       MP 26.1                   0 0  99 . .  5 0
307 18072 2 E 081187 4 3 G N N 1000                         4/10 W OF 25              0 0 229 . .  5 0
308 18072 3 E 081187 4 3 C N N 1000 300 FT E OF MP 25                                 0 0 191 . . 16 0
309 18072 4 E 081187 4 3 C N N 1000 MP 24.4                                           0 0 180 . . 19 0
310 18072 1 W 081187 4 3 F N N 1000 0.5 MI W OF MP 26       IN FRONT OF RED LOBSTER   0 0 174 . .  8 0
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                     L R   C
      C   S     D    A A   U        F
 O    F   E O   A    N T C R O    L R                                                   A C  C        M  S
 B    T   C I   T    E E F V V    E O                         T                         C C  R  B N  P  P
 S    R   T R   E    S R P E R    N M                         O                         P P  K  F F  O  O

311 18073 1 E 081187 4 3 F Y N  800 AT BEGINNING OF PROJECT   0.5 MI W OF MP 23         0 0 101 . .  9  0
312 18073 1 W 081187 4 3 T Y N 1000 500 FT W OF 289 JCT       IN FRONT OT VALLEY VIEW M 0 0 135 . .  8  0
313 18073 2 W 081187 4 3 C N N  800 800 FT W OF TOLLWAY       ALMOST RIGHT UNDER WELCH  0 0 112 . .  6  0
314 18073 3 W 081187 4 3 C N N 1000 AT 24.2 MILE                                        0 0 190 . . 25  0
315 18079 1 E 081187 4 3 C Y N 1000 AT THE EXIT GREENVILLE AV 200 FT W OF MP 18         0 0 193 . . 10  0
316 18079 1 E 081187 2 3 C N N 1000 1500 FT W OF MP 31        500 FT W OF MP 31         0 0 125 . .  2  0
317 18079 2 E 081187 4 3 C N N 1000 ABRAMS BLVD (BRIDGE)      AT FOREST LANE (BRIDGE)   0 0 165 . .  6  0
318 18079 3 E 081187 4 3 T N N 1000                           AT EXIT 16 (SKILLMONN ST) 0 0 159 . .  2  0
319 18079 4 E 081187 4 3 F Y N 1000 200 FT E OF CITY LIMIT (D 3/10 MI W OF JUPITER RD ( 0 0 204 . . 10  0
320 18079 1 W   1287 4 3 G N N 1000 300 FT W OF JUPITER ROAD  300 FT W OF MP 14         0 0 154 . .  1  0
321 18079 1 W 081187 4 3 F N N 1000 2/10 MI W OF MP 28                                  0 0 146 . .  1  0
322 18079 2 W 081187 2 3 C N N 1000 300 FT W OF MP 31                                   0 0  95 . .  0  0
323 18079 3 W 081187 2 3 G N N 1000 3/10 E OF MP 32           1000 FT WESTWARD          0 0 105 . .  3  0
324 18080 1 N 081387 2 3 F N N  800 0.6 MI N OF MP 72                                   0 0 188 . .  5  0
325 18080 1 S 081387 2 3 T N N 1000 5/10 MI S OF MP 82                                  0 0 231 . . 65 10
326 18080 2 S 081387 2 3 G N N 1000 2/10 MI S OF MP 81                                  0 0 224 . . 11  0
327 18080 3 S 081387 2 3 C N N 1000                           ALMOST AT MP 74           0 0 200 . . 60  0
328 18080 4 S 081387 2 3 C N N 1000 0.6 MI S OF MP 74                                   0 0 235 . .  9  0
329 18080 5 S 081387 2 3 F N N  800                           AT END OF PROJECT (MP 71) 0 0 198 . .  8  0
330 18084 1 N 081287 2 3 T N N 1000                           ALMOST AT MP 15           0 0 232 . .  3  0
331 18084 2 N 081287 2 3 F N N 1000 IN FRONT OF HONDA CARS OF 300 FT S OF MP 14         0 0 221 . . 12  0
332 18084 3 N 081287 2 3 G N N 1000 1/10 MI N OF MP 13                                  0 0 228 . . 10  0
333 18084 4 N 081287 2 3 C Y N 1000 AT MP 12                                            0 1 176 . .  6  0
334 18084 5 N 081287 2 3 F Y N 1000 4/10 MI N OF MP 12        ALMOST AT HONEY CREEK     0 0 187 . .  1  0
335 18084 6 N 081287 2 3 C N N 1000 AT MP 8                                             0 3 156 . .  5  0
336 18086 1 N 081387 2 3 F N N 1000 1000 FT N OF MP 84        53 FT S OF SIGN SAYING BO 0 0 217 . . 34  0
337 18086 2 N 081387 2 3 C Y N 1000 400 FT N OF MP 85                                   0 0 152 . . 16  0
338 18086 1 S 081387 2 3 G N N 1000 1343.7 FT N OF MP 84      343.7 FT N OF MP 84       1 0 215 . . 27  0
339 18088 1 N 081287 4 3 C Y N 1000 1500 FT N OF 352 JCT      0.5 MI S OF MP 6          0 0 154 . . 10  0
340 18088 1 S 081287 4 3 T N Y 1000 MIDDLE OF SECTION AT MP 4 1/2 MI NO OF EXIT 3       0 0   0 0 0  .  .
341 18088 1 S 081287 4 3 F N Y  600                           2000 FT N OF MP 7         0 0   0 0 0  .  .
342 18088 2 S 081287 4 3 C N Y 1000 ABOUT 1000 FT S OF MP 4                             0 0   0 0 0  .  .
343 18088 2 S 081287 4 3 C N Y 1000 400 FT N OF MP 7          600 FT S OF MP 7          0 0   0 0 0  .  .
344 18088 3 S 081287 4 3 C N Y 1000 1500 FT N OF MP 3         500 FT N OF MP 3          0 0   0 0 0  .  .
345 18093 1 S 081087 3 3 G Y N 1000                           2000 FT N  OF MP 283      0 0 156 . .  5  0
346 18104 6 1 W08038 7 4 3 Y N 1000 200 FT W OF MP 467                                  0 0 128 . . 10  0
347 18106 1 E 080387 4 3 C N N 1000 ABOUT 700 FT E 464 MI     1000 FT E OF START        0 0 209 . . 24  0
348 18106 2 E 080387 4 3 F Y N 1000 -1000 FT                  500 FT W OF 466           0 0 163 . .  5  0
349 18106 2 W 080387 4 3 G N N 1000 1000 FT E OF 466          466                       0 0 142 . . 13  0
350 18106 3 W 080387 4 3 F Y N 1000 1000 FT EAST OF           700 FT BEFORE 465 MP      0 0 143 . .  7  0
351 18107 1 E 080487 4 3 C N Y 1000 1000 FT W OF              3/10 MI W OF 456 MP       0 0   1 0 0  .  .
352 18107 2 E 080487 4 3 G N Y 1000 4/10 MI FROM 457          6/10 W OF 458             0 0   0 0 0  .  .
353 18107 1 W 080387 4 3 F N N 1000 RIGHT IN THE EXIT FOR PRA RIGHT ON THE BRIDGE FOR P 0 0 138 . .  3  0
354 18107 2 W 080387 4 3 C N Y 1000 1000 FT E OF 457          MP 457                    0 0   0 0 0  .  .
355 18107 3 W 080487 4 3 F N N 1000                           5/10 MI E OF TARRANT COUN 0 0 128 . . 19  0
356 19001 1 W 082587 2 1 G Y Y 1000 633.8                     633.6                     0 0   1 0 0  .  .
357 19001 2 W 082587 2 1 C N Y 1000 633.2                     633.0                     3 0   9 0 0  .  .
358 19001 3 W 082587 2 1 C N Y 1000 131.9                     131.7                     6 0   1 0 0  .  .
359 19001 4 W 082587 2 1 F N Y 1000 631.2                     MP 631                    2 0   0 1 0  .  .
360 19001 5 W 082587 2 1 T N Y 1000 630.8                     630.6                     2 0  10 0 0  .  .
361 19001 6 W 082587 2 1 F N Y 1000 630.6                     630.4                     3 0   3 0 0  .  .
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SAS                                                                                           11:38 WEDNESDAY, OCTOBER 28, 1987    8

                     L R   C
      C   S     D    A A   U        F                                                     P   N
 O    F   E D   A    N T C R O  L   R                                                   A C   C       M  S
 B    T   C I   T    E E F V V  E   O                         T                         C C   R B N   P  P
 S    R   T R   E    S R P E R  N   M                         O                         P P   K F F   O  O

362 19006 1 W 082587 2 1 F N Y 1000 620.5                     620.3                     0 0  31 0 0   .  .
363 19006 2 W 082587 2 1 T N Y 1000 MP 620                    619.8                     0 0   3 0 0   .  .
364 19006 3 W 082587 2 1 G N Y 1000 619.7                     619.5                     0 0   0 0 0   .  .
365 19006 4 W 082587 2 1 C N Y 1000 619.5                     619.3                     0 0   5 0 0   .  .
366 19006 5 W 082587 2 1 F N Y 1000 619.1                     618.9                     0 0   0 0 0   .  .
367 19006 6 W 082587 2 1 C N Y 1000 618.8                     618.6                     0 0   4 0 0   .  .
368 19010 1 W 082487 2 1 C N Y 1000 211.1                     210.9                     0 0   3 0 0   .  .
369 19010 2 W 082487 2 1 T N Y 1000 210.9                     210.7                     0 0   2 0 0   .  .
370 19010 3 W 082487 2 1 G Y Y 1000 210.5                     210.3                     0 0   0 0 0   .  .
371 19010 4 W 082487 2 1 F N Y  500 208.9                     208.7                     0 0   0 0 0   .  .
372 19010 5 W 082487 2 1 C N Y 1000 208.5                     210.3                     0 0   0 0 0   .  .
373 19010 6 W 082487 2 1 F N Y 1000 207.3                     207.1                     2 0   0 0 0   .  .
374 19019 1 W 082487 2 1 G N Y 1000 197.7                     197.5                     0 0   0 0 0   .  .
375 19019 2 W 082487 2 1 F N Y 1000 197.3                     197.1                     0 0   1 0 0   .  .
376 19019 3 W 082487 2 1 C N Y 1000 MP 197                    196.8                     1 0   0 0 0   .  .
377 19019 4 W 082487 2 1 T N Y 1000 196.8                     196.6                     0 0   0 0 0   .  .
378 19019 5 W 082487 2 1 C N Y 1000 195.8                     195.6                     0 0   1 0 0   .  .
379 19019 6 W 082487 2 1 F N Y 1000 MP 195                    194.8                     0 0   0 0 0   .  .
380 20003 3 E 082687 2 1 F N N  800 0.5 MI E OF US 69/96 AT 9 0.6 MI E OF US 69/96 AT 9 0 0 266 . .  19  0
331 20003 5 E 082687 2 1 G N N  800 0.5 MI E OF US 69/96      0.7 MI E OF US 69/96      0 0 414 . . 305 58
382 20003 1 W 082687 2 1 G N N  800 0.3 MI W OF 32ND ST EXIT  0.5 MI W OF 32ND ST EXIT  0 0 190 . .  33  0
383 20003 2 W 082687 2 1 F N N  800 1.8 MI W OF 32ND ST EB EX 2.0 MI W OF 32ND ST EB EX 3 0 276 . .  17  0
384 20003 4 W 082687 2 1 G N N  500 0.8 MI W OF 32ND ST EB EX 1.0 MI W OF 32ND ST EB EX 1 0 126 . .  15  0
385 20003 6 W 082687 2 1 G N N 1000 0.7 MI E OF US 69/96      0.5 MI E OF US 69/96      0 0 647 . . 257  1
386 20009 1 W 082787 2 1 G N Y 1000 MP 838                    0.2 MI W OF MP 838        0 0   0 0 0   .  .
387 20009 2 W 082787 2 1 G N Y 1000 0.7 MI W OF MP 838        0.9 MI W OF MP 838        0 0   0 0 0   .  .
388 20009 3 W 082787 2 1 F N Y  500 0.2 MI W OF MP 837        0.3 MI W OF MP 837        0 0   2 0 0   .  .
389 20009 4 W 082787 2 1 G N Y 1000 MP 835                    834.8                     0 0   2 0 0   .  .
390 20009 5 W 082787 2 1 G N Y 1000 833.9                     833.7                     0 0   1 0 0   .  .
391 20011 1 S 082687 2 1 G N N 1000 0.9 MI S OF JCT 347       1.1 MI S OF JCT 347       2 0 247 . .  23  5
392 20011 2 S 082687 2 1 G N N 1000 1.1 MI S JCT SH 347       1.3 MI S JCT SH 347       1 0 258 . .  13  1
393 20011 3 S 082687 2 1 G N N 1000 1.4 MI S OF JCT SH 347    1.6 MI S OF JCT SH 347    0 0 260 . .  17  0
394 20011 4 S 082787 2 1 G N N 1000 2.0 MI S JCT SH 347       2.2 MI S JCT SH 347       1 0 249 . .  31  1
395 20023 3 E 082687 2 1 F Y N  700 0.2 MI E OF AVE A         0.4 MI E OF AVE A         0 1 276 . .  17  0
396 20023 4 E 082687 2 1 G Y N  800 0.7 MI E OF AVE A         0.9 MI E OF AVE A         0 0 314 . .   9  0
397 20023 1 W 082687 2 1 F Y N 1000 0.7 MI W OF LOOP 380      0.9 MI W OF LOOP 380      0 0 413 . .  15  0
398 20023 2 W 082687 2 1 G N N  500 1.8 MI W OF LOOP 380      2.0 MI W OF LOOP 380      1 0 188 . .   4  1
399 24006 1 W 080487 4 4 C Y N 1000 ABOUT MP 18.6             SCHUSTER AVE EXIT 18A     0 0 147 . .   9  0
400 24006 2 W 080487 4 4 G Y N 1000 MP 19.1                   MP 18.9                   0 0 141 . .   6  0
401 24007 1 W 080287 4 4 C N N 1000 MP 17.7                   MP 17.5                   0 0 230 . .  22  0
402 24007 2 W 080287 3 4 F Y N 1000 MP 15.85                  MP 15.65                  0 0 222 . .  24  0
403 24007 3 W 080487 4 4 C N N 1000 MP 16.6                   MP 16.4                   0 0 197 . .  12  0
404 24007 4 W 080487 3 4 F N N 1000 MP 14.8                   MP 14.6                   0 0 171 . .  13  0
405 24009 1 E 080187 2 4 G N Y 1000 MP 177.25                 MP 177.45                 0 0   0 0 0   .  .
406 24009 2 E 080487 2 4 C Y Y 1000 MP 178.5                  MP 178.7                  0 0   0 0 0   .  .
407 24009 3 W 080187 2 4 F N Y 1000 50 FT E OF MP 178         MP 177.8                  0 0   0 0 0   .  .
408 24010 5 E 080187 2 4 F N Y 1000 MP 186.2                  MP 186.4                  0 0   0 0 0   .  .
409 24010 1 W 073187 2 4 C N Y 1000 185 MILE - 90 FT          185 MILE - 1090 FT        0 0   0 0 0   .  .
410 24010 2 W 073187 2 4 C N Y 1000 MP 183.7                  MP 183.5                  0 0   0 0 0   .  .
411 24010 3 W 073187 2 4 G Y Y 1000 182.6 MP                  182.4 MP                  0 0   0 0 0   .  .
412 24010 4 W 073187 2 4 T N Y 1000 181.0 MP                  180.8 MP                  0 0   0 0 0   .  .
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SAS                                                                                   11:38 WEDNESOAY, OCTOBER 28, 1987    9

OBS CFTR  SECT DIR  DATE  LANES RATER CFP CURVE OVR LEN  FROM                     TO                  ACP PCCP NCRK BF NF MPO SPO

413 24010  6    W  080187   2     4    F    Y    Y 1000 MP 180.8                  MP 180.6              0   0      0 0  0    .  .
414 24014  1    E  080187   2     4    G    N    Y 1000 120 FT E OF MP 154        1120 FT E OF MP 154   0   0      0 0  0    .  .
415 24014  2    E  080187   2     4    G    N    Y 1000 MP 156                    1000 FT E OF MP 156   0   0      0 0  0    .  .
416 24014  3    E  080187   2     4    C    N    Y 1000 220 FT W OF MP 164        780 FT E OF MP 164    0   0      0 0  0    .  .
417 24014  4    E  080187   2     4    C    Y    Y 1000 MP 165.0                  MP 165.2              0   0      0 0  0    .  .
418 24022  1    E  080287   2     4    C    Y    Y 1000 MP 138.2                  MP 138.4              0   0      0 0  0    .  .
419 24022  2    W  080287   2     4    F    N    Y 1000 MP 139.7                  MP 139.5              0   0      0 0  0    .  .
420 24022  3    W  080287   2     4    G    Y    Y 1000 MP 138.0                  MP 137.8              0   0      0 0  0    .  .
421 24028  1    E  080387   2     4    G    N    N 1000 150 FT W OF MP 4.0        MP 4.2                0   0    132 .  .    3  0
422 24028  2    E  080287   2     4    F    Y    N 1000 MP 5.5                    MP 5.7                0   0    195 .  .    3  0
423 24028  3    E  080387   2     4    F    N    N 1000 200 FT W OF MP 6.0        800 FT E OF MP 6.2    0   0    200 .  .    0  0
424 24091  1    W  080287   2     4    F    N    N 1000 ABOUT MP 97.7             MP 97.5               0   0    172 .  .    5  0
425 24091  2    W  080287   2     4    G    N    N 1000 ABOUT 200 FT W OF MP 93.0 MP 92.8               0   0    126 .  .   12  0
```

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SAS                                                                                11:38 WEDNESDAY, OCTOBER 28, 1987   10

CONTENTS PROCEDURE
CONTENTS OF SAS MEMBER COND87.SDS

CREATED BY CMS USERID FTA0152   ON CPUID FF-3081-022390   AT 11:38 WEDNESDAY, OCTOBER 28, 1987   BY SAS RELEASE 5.16
FILE= COND87   SDS   BLKSIZE=8164   LRECL=160   GENERATED BY PROC SORT
NUMBER OF OBSERVATIONS: 425   NUMBER OF VARIABLES: 19
MEMTYPE:   DATA

----ALPHABETIC LIST OF VARIABLES AND ATTRIBUTES-----
    # VARIABLE TYPE   LENGTH POSITION FORMAT       INFORMAT     LABEL
   13 ACP      NUM         8      104                           ASPHALT PATCHES
   16 BF       NUM         8      128                           BONDING FAILURE? (OVERLAY ONLY)
    7 CFP      CHAR        1       43                           CUT/FILL POSITION
    1 CFTR     NUM         8        4                           CFTR ID NUMBER
    8 CURVE    CHAR        1       44
    4 DATE     CHAR        6       21                           DATE SURVEYED
    3 DIR      CHAR        1       20
   11 FROM     CHAR       25       54
    5 LANES    NUM         8       27                           NUMBER OF LANES
   10 LEN      NUM         8       46                           SECTION LENGTH (FT)
   18 MPO      NUM         8      144                           MINOR PUNCH OUTS (NON-OVERLAID ONLY)
   15 NCRK     NUM         8      120                           NUMBER OF CRACKS
   17 NF       NUM         8      136                           NUMBER OF BOND FAILURES (OVERLAY ONLY)
    9 OVR      CHAR        1       45                           OVERLAID?
   14 PCCP     NUM         8      112                           CEMENT PATCHES
    6 RATER    NUM         8       35                           RATER NO.
    2 SECT     NUM         8       12                           SURVEY SECTION NUMBER
   19 SPO      NUM         8      152                           SEVERE PUNCH OUTS (NON-OVERLAID ONLY)
   12 TO       CHAR       25       79
```