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16. Abstract

This report describes the development of a jointed concrete pavement database that will form part of a Pavement Management Information System for Texas. Relevant topics discussed include the identification of variables, a statewide selection of pavement projects through an experimental design, the collection of performance information through a visual condition survey, and database contents, organization, and access. Also explored are other possible uses of the database, including overlay design, pavement materials selection, and pavement design at the project level. The report also discusses a preliminary analysis of the information collected through a distress index. In this analysis, the distress variables collected in the field are reduced to a single value and related to the different design variables of every pavement project investigated.

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.by

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Research Report 1342-2

Research Project 0-1342
Updating and Maintaining the Rigid Pavement Condition Survey Database

conducted for the

Texas Department of Transportation

in cooperation with the

U.S. Department of Transportation
Federal Highway Administration

by the

CENTER FOR TRANSPORTATION RESEARCH
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THE UNIVERSITY OF TEXAS AT AUSTIN

September 1994

IMPLEMENTATION STATEMENT

This report describes the development of a jointed concrete pavement database that will be used as part of a Pavement Management Information System for the state of Texas. Ultimately, this database will also be useful in overlay design, pavement materials selection, and in pavement design at the project level.

Prepared in cooperation with the Texas Department of Transportation and the
U.S. Department of Transportation, Federal Highway Administration.

DISCLAIMERS

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

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SUMMARY

This report describes the development of a jointed concrete pavement database that will form part of a Pavement Management Information System for Texas. Relevant topics discussed include the identification of variables, a statewide selection of pavement projects through an experimental design, the collection of performance information through a visual condition survey, and database contents, organization, and access. Also explored are other possible uses of the database, including overlay design, pavement materials selection, and pavement design at the project level. The report also discusses a preliminary analysis of the information collected through a distress index. In this analysis, the distress variables collected in the field are reduced to a single value and related to the different design variables of every pavement project investigated.

CHAPTER 1. INTRODUCTION

1.1 BACKGROUND

With the Interstate Highway Program now completed, pavement engineers are turning their attention away from new road construction to the maintenance and rehabilitation of existing roadways. As part of this effort, state departments of transportation are developing and implementing rehabilitation strategies that can (1) assess the physical condition of their highways, (2) prioritize projects for maintenance, and (3) identify strategies that will assist in the allocation of scarce resources. In addition, these rehabilitation strategies — termed *pavement management systems* (PMS) — can be used as data sources in efforts to develop or improve pavement design methods.

For their part, the Texas Department of Transportation (TxDOT) is currently implementing a pavement management system to assist the agency with the state's more than 123,000 km (76,509 centerline miles) of highway pavements, which includes 2,135 km (1,326 miles) of continuously reinforced concrete pavement (CRCP) and 1,397 km (868 miles) of jointed concrete pavement (JCP). State planners expect that, once in place, a PMS will help in budget allocations and in the selection of maintenance and rehabilitation strategies for the statewide highway network. However, an equally important component of this PMS will be the pavement database.

1.2 OBJECTIVES

While pavement engineers have access to reliable databases for ACP and CRCP highways (Ref 2), there are at present no databases dedicated to jointed concrete pavement (JCP). As indicated above, Texas has many kilometers of JCP highways in service; and knowing how those pavements are performing is very important for an effective PMS and for pavement design applications. Thus, the purpose of this study is to develop a JCP database capable of (1) assessing the current condition of the Texas JCP network in terms of distress manifestations, and (2) evaluating the performance of this type of pavement, as influenced by the exposure to time, traffic, and regional climate. The inclusion in the database of the structural characteristics of every individual pavement will make it possible for engineers to evaluate the performance of different design and construction criteria. Moreover, this database will provide the information needed to develop reliable pavement performance prediction models suitable for incorporation in the Texas PMS. Like any database, the JCP database will need to be updated through continued surveying and monitoring of the state's pavement sections.

Another objective of this study is to provide the data needed for several ongoing projects. From a review of the considerable number of overlaid jointed concrete pavements, the project hopes to obtain the kind of information that can lead to better overlay design procedures. And an evaluation of the various materials used in the construction of the pavement can determine the affect these variables have on the performance of the pavement sections.

1.3 RESEARCH APPROACH

Since the main purpose of this database is the evaluation of pavement performance, we developed an experimental design in which we used, once the significant variables affecting pavement performance were identified, a factorial procedure to select the optimum sample of test sections representative of the Texas JCP highway network. The resulting factorial was composed of such structural and environmental factors as slab thickness, slab length, dowels, aggregate type, moisture, temperature, and pavement age. Figure 1.1 shows the research approach.

The Texas JCP population was identified using information obtained from several sources, including TxDOT's Pavement Evaluation System (PES) files, pavement sections used in the Long-Term Pavement Performance studies of the Strategic Highway Research Program (SHRP), the JCP database developed by the Center for Transportation Research (CTR), and pavement sections identified by an earlier CTR research project (Ref 3).

The variables collected from TxDOT pavement project records were included in the database. The cells of the factorial design were filled according to the individual characteristics of each pavement; through a statistical process, optimum samples of test sections were selected as candidates for a condition survey. The condition survey was then undertaken to collect distress information for the JCP test sections selected. This provided the performance information necessary for the database.

As a first step in the database loading process, we evaluated the pavement information collected in the field surveys; potential outliers were also identified before inclusion in the database. Condition survey results were summarized and presented in charts and tables to represent the database demographics. A distress index allowed us to evaluate the condition of the pavement sections in a single value. We then reviewed preliminary findings relating pavement performance to design variables, along with a summary of pavement condition as it relates to the different design variables included.

1.4 SCOPE AND ORGANIZATION

Chapter 2 discusses concepts and definitions of pavement distress and performance. Chapter 3 evaluates the main design factors influencing pavement performance; it then identifies measurable performance indicators in terms of distress manifestations. The set-up for the factorial design is described in Chapter 4.

Chapter 5 discusses the selection of candidate highway projects for the condition survey and for inclusion in the database. Procedures for the collection of design, construction, environmental, maintenance, and traffic data are also outlined in this chapter. Chapter 6 describes the field condition survey for the test sections selected. The preliminary analyses of distress and performance indicators obtained from the JCP database collection efforts are included in Chapter 7. Chapter 8 next describes the database contents, their access, and potential implementation. Finally, Chapter 9 provides conclusions and recommendations.

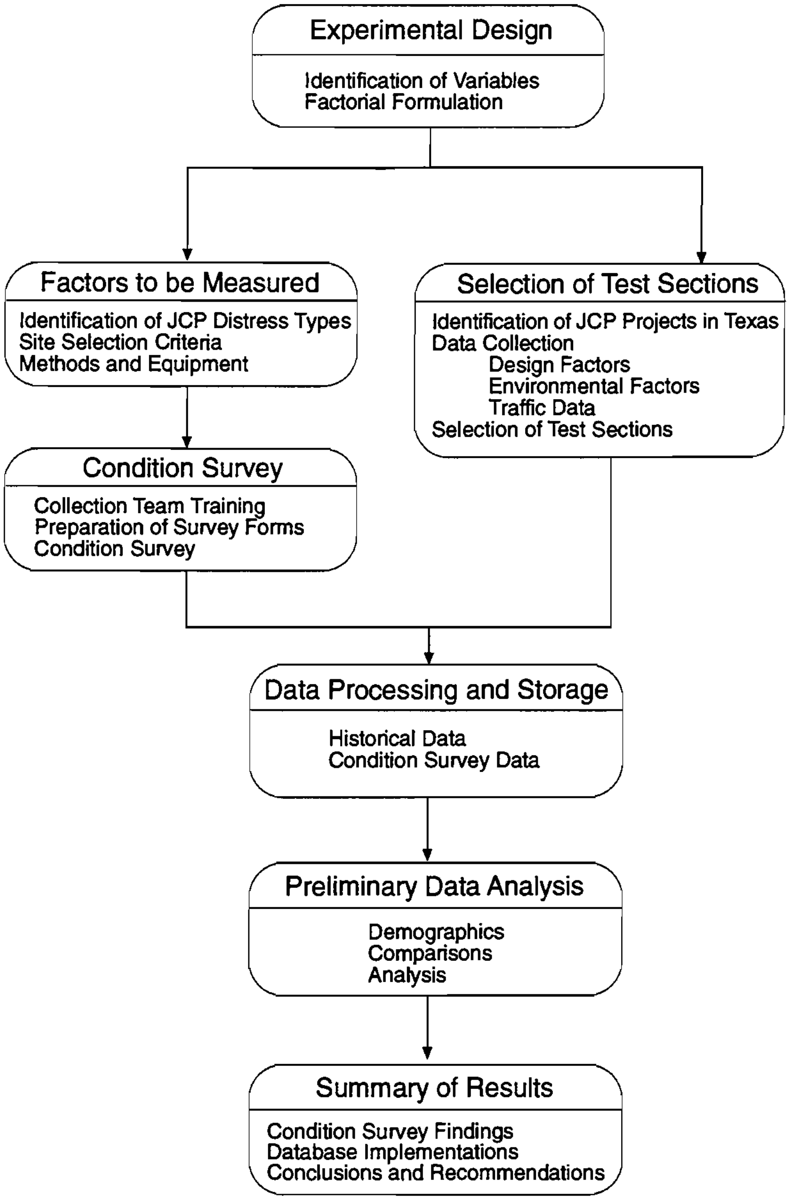


Figure 1.1 Research approach used in developing the JCP database

CHAPTER 2. DATABASE FUNDAMENTALS

2.1 INTRODUCTION

As indicated in Chapter 1, the JCP database will serve as a source of information for updating pavement performance curves in the Texas PMS. This chapter presents the main concepts involved in the development of the JCP database, including its characteristics and function within the Texas PMS.

2.2 LITERATURE REVIEW

Both the Road Test One in Maryland and the AASHO Road Test in Illinois (Ref 4) were early efforts to determine the effects of construction variables on the performance of rigid pavements. While these studies yielded much new information, the effective application of the findings is limited to those sites whose climate and soil conditions replicate those of the location where the original experiments were performed. Several other research projects, using procedures similar to those used in the AASHO Road Test, have likewise obtained experimental results limited to specific locations.

In an effort to overcome site-specific findings, researchers increasingly began to perform their experiments on pavements at different locations (i.e., pavements subject to different conditions of traffic, environment, and design procedures). Based on these experiences, guidelines for conducting such research uniformly and systematically were developed (Ref 5).

A present example of this multi-site research approach is the current long-term, nationwide pavement performance program (LTPP) underway as part of the Strategic Highway Research Program (SHRP). More wide-ranging than the AASHO Road Test, the LTPP is expected to (1) improve current pavement design procedures and maintenance/rehabilitation strategies, (2) determine the effects of different construction procedures and maintenance activities, (3) assist in the evaluation of the structural, environmental, and load conditions of existing pavements, and (4) promote the development of a national concrete pavement database (Ref 6).

For Texas, a CRCP database has been maintained since 1974, with periodic condition surveys serving to update the database. Subsequent studies evaluating the results from such field investigations have expanded the knowledge of the factors influencing rigid pavement performance (Refs 7, 8, 9, 10, 11).

2.3 PAVEMENT PERFORMANCE

According to AASHTO, performance of a pavement structure can be defined in three ways: (1) functional performance, (2) structural performance, and (3) safety performance. Functional performance of a pavement is often defined as the level of serviceability provided to the user — in other words, how well the pavement serves the user. Riding comfort (or riding quality) is the relevant characteristic considered for this purpose, usually assessed through the serviceability index developed by Irick and Carey for the AASHO Road Test (Refs 12, 13). Structural performance relates to the physical condition of the pavement, as described by the occurrence of any distress manifestation that reduces its load-carrying capability or that requires maintenance (Ref 12). Finally, the safety performance of a pavement refers to the frictional resistance (skid resistance) provided at the pavement/tire interface (Ref 12).

2.4 PERFORMANCE INDICATORS

Performance indicators are described in the literature as measurements that define the present condition of the pavement in terms of riding quality, distress manifestations, or skid resistance.

2.4.1 Distress Index

The distress index is defined as the combination of individual distresses in a single variable that represents the performance of the pavement at a specific point in time. Equation 2.1 and Figure 2.1 show the mathematical and graphical representation of the distress index, respectively.

$$DI = Ao + \sum Ai * D \qquad \text{(Eq. 2.1)}$$

where:

DI = Distress Index,

A_o = Constant,

A_i = Weighting factor to account for the contribution of every distress manifestation to the distress index, and

D_i = Present level of the i^{th} distress.

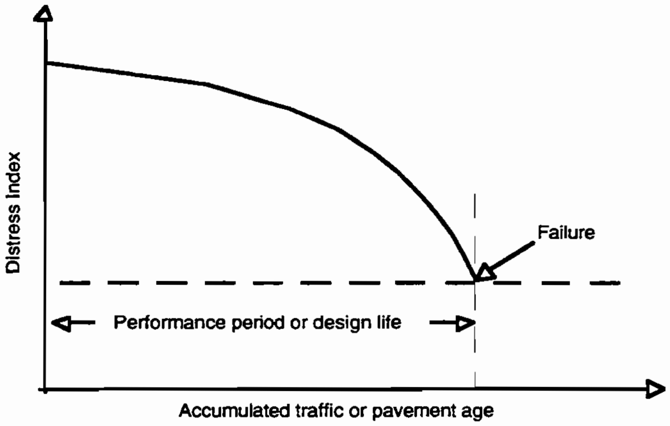


Figure 2.1. History of distress index as a function of accumulated traffic or age

The development of such relationships as those presented in Eq. 2.1 requires statistical techniques to relate distress to a given measure of the performance of the pavement structure. A good example of the use of this statistical technique is the serviceability index developed by Irick and Carey for the AASHO Road Test (Ref 13).

2.4.2 Serviceability Index

The AASHTO Road Test of the 1960s used the serviceability index concept to evaluate the relative performance of pavements. This concept, based on user opinion of the serviceability of the roadway, was calibrated using pavement roughness and distress manifestations. Through regression analysis, a model based on user opinion of roughness (or riding comfort) was considered as a function of the distress manifestations present in the pavement (Ref 13).

2.4.3 Other Distress Index Equations

In a recent study, Gutierrez de Velasco obtained Texas pavement data from condition surveys performed in 1974 and 1978. One of his main conclusions was that, while the PSI was constant for several highway sections, the level of distress in terms of number of failures per mile increased as the accumulated ESALs increased (Ref 10). This conclusion was attributed to TxDOT's continual maintenance and rehabilitation activities, which kept the pavement surface smooth though the pavement was at the end of its service life. As a result, several subsequent studies have sought a better way of identifying the actual condition of the pavement with more realistic distress index equations (Refs 11, 14).

2.4.4 Decision Criteria Index

From the surveys performed in 1974 and 1978 on the Texas rigid pavements, it was found that, based on the second survey, several sections had been overlaid. This was the catalyst for developing a decision criteria index to indicate when CRCP should receive major rehabilitation (e.g., an overlay). The decision criteria index was defined as the threshold of pavement condition acceptability. A distress index below the decision criteria index would indicate a pavement with a level of distress that required major maintenance or rehabilitation. A discriminant analysis technique was applied to separate (probabilistically) those pavements that are in good shape (and therefore not in need of an overlay) from those pavements that require an overlay because of their bad condition (Ref 9).

2.5 PAVEMENT PERFORMANCE MODELS

In general, current structural design methods strive for stress-strain levels that ensure that the structure will be safe and failure-free throughout its design life. In the case of pavements, the failure concept is related to the level of distress that the pavement possesses when it is no longer functional, owing to the low serviceability provided or the increased maintenance and user costs involved. Based on this concept, engineers have tried to relate the different design factors that allow the structure a given design life to a distress index above that of low serviceability (Ref 15).

This highlights the importance of evaluating design factors according to the level of distress they impose on the pavement structure, by relating pavement distress to pavement performance. Through experimental tests (e.g., AASHO), several performance models have been developed that relate the occurrence of distress to the design variables (Ref 15).

2.6 DIAGNOSTIC STUDIES FOR STRUCTURAL EVALUATION

Although the results of pavement distress surveys give valuable information on the status of pavement structures, the consideration of data on pavement deflections, load transfer, and other structural measures, that summarize the structural or load carrying capacity of the pavement and subgrade support, are considered important indicators of the structural performance of the pavement (Refs 12, 15).

2.7 DIRECTIONS FOR THE JCP DATABASE

The concepts stated above are the basis for the JCP database, which will provide support for the development of a better distress index and better performance prediction models. The inclusion of three principal types of information was considered necessary for the JCP database:

1. Design factors: Intended to provide the necessary information about the pavement structure in terms of design and construction, age, traffic loads, maintenance and rehabilitation, and environmental issues.
2. Performance variables: Quantifying the type, number, and severity of distresses as discussed previously will help in the evaluation of the present pavement performance. This will be accomplished through a representation of pavement test sections from each of the geographical and climatic regions in Texas. Periodic condition surveys will give the performance history of the pavement network through a considerable period of time, permitting the implementation of better modeling techniques.
3. Diagnostic data: Reported in terms of deflections, load transfer of the pavement structure, and subgrade support, these data will assist in the determination of a more reliable measure of the load-carrying capacity of a JCP pavement structure.

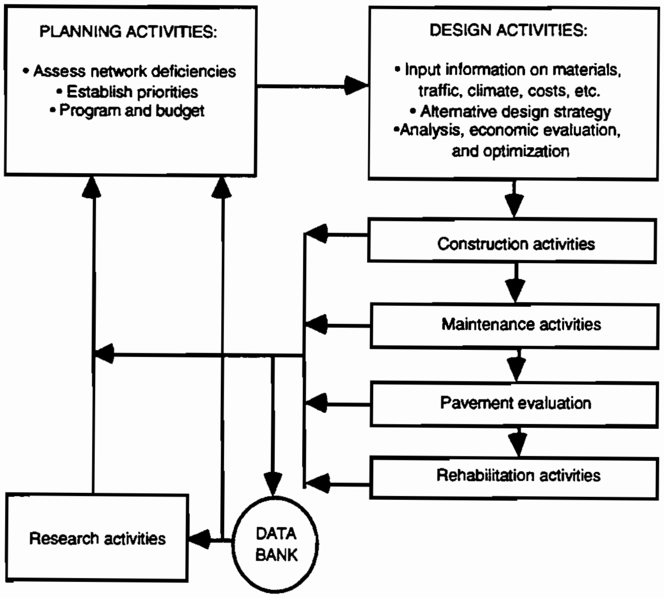


Figure 2.2. Diagram of an integrated PMS (Ref 12)

CHAPTER 3. DESIGN FACTORS AND PERFORMANCE VARIABLES

3.1 INTRODUCTION

This chapter identifies the specific variables to be stored in the JCP database. The variables are divided in two main groups: design factors and performance variables. Design factors include such variables as structural pavement characteristics, environmental and traffic conditions, and the maintenance and rehabilitation activities that act as the input variables for the pavement system. Performance variables are indicators of the condition of the pavement structure; they include measurements of roughness, distresses, and deflections (i.e., the response variables for the pavement system). This chapter discusses both design factors and performance variables.

3.2 DESIGN FACTORS AFFECTING PAVEMENT PERFORMANCE

As discussed in this section, factors influencing the performance of concrete pavements have been investigated from both mechanistic and empirical points of view.

3.2.1 Mechanistic Models

Mechanistic models make use of theory to predict the failure or distress parameter. These models take into account the pertinent material properties and determine how the magnitude of the stress or strain parameters relate to the failure or performance level desired (Ref 16); fundamental material properties (e.g., stress-strain or resulting deflections) are used to explain the influence of internal or external forces over the pavement system (i.e., forces associated with shrinkage of the concrete as a result of wheel loads and/or environmental factors). Some limitations relate to the theory selected and assumptions made when determining such relationships.

The analysis of stress in rigid pavements is mostly based on the work of Westergaard. According to other researchers (Ref 16), factors that induce stress in the pavement system include:

1. Restrained temperature and moisture deformations,
2. Externally applied forces,
3. Volume changes in the supporting material, and
4. Loss of subgrade support.

Subsequent mechanistic studies have expanded the knowledge of pavement behavior. Theoretical models for rigid pavements have also been developed that analyze the early response of the pavement to changes in temperature and traffic loads, and to friction between the PCC slab and the subgrade or subbase material (Refs 17, 18). Variables that influence pavement performance in mechanistic models are listed in Table 3.1.

3.2.2 Empirical Models

Empirical models are based on correlations made from field studies through the use of statistical techniques. Unfortunately, the results are considered valid only within the limited range of data used in such developmental studies. One of the first efforts to identify the characteristics and factors influencing pavements was the 1949 Maryland Road Test (Ref 4). That investigation found that: (1) cracking progress was related to the occurrence of pumping; (2) cracking was more extensive in cuts than on fills; (3) pumping was followed by a loss of subgrade support and an increase in pavement stress; (4) speed influenced measured deflections; (5) temperature and warping influenced stress and deflections; and (6) load configuration and type of subgrade had a significant effect on pavement deterioration. The AASHTO Road Test, which investigated (among other things) pavement serviceability, was another important study in the evaluation of pavement performance (Ref 19).

Table 3.1. Design factors recognized by mechanistic models

Variable Type	Variable
Structural factors:	Slab thickness Slab length or width Frictional resistance Modulus of elasticity of concrete Modulus of rupture of concrete Modulus of elasticity of steel Load transfer coefficient Concrete thermal coefficient Steel thermal coefficient Coarse aggregate type Subbase material Subbase stabilization Modulus of subgrade reaction Subgrade material
Environmental factors:	Temperature drop Moisture
Load factors:	Traffic: Tire pressure Total load (18-kip ESAL) Position of loading on the pavement Wheel configuration Number of load repetitions

A Concrete Pavement Evaluation System (COPES) study developed by the Transportation Research Board (TRB) and sponsored by AASHTO and the FHWA evaluated concrete pavement performance by analyzing pavement data collected in six states. Significant factors influencing pavement performance found in the COPES study include: slab thickness, slab length, dowel diameter, use of tied PCC shoulders, use of stabilized base materials, slab reinforcement, provision of subdrainage, provision and maintenance of joint seals, use of reactive aggregates, subgrade type, PCC modules of rupture, precipitation, freezing index, annual temperature range, and traffic loads expressed in ESALs (Ref 20).

Using road tests, pavement evaluations, and existing mathematical models (theory), the 1986 AASHTO *Design Guide* (Ref 12) developed an equation for rigid pavements that was based on several design factors, as shown in the following relationship:

$$W_{18} = f\{ Z_R, S_o, D, \Delta PSI, P_t, S'_c, C_d, J, E_c, k \} \qquad \text{(Eq. 3.1)}$$

where:

W_{18} = Predicted number of 18-kip equivalent single axle load applications,

Z_R = Standard normal deviate,

S_o = Combined standard error of the traffic prediction and performance prediction,

D = Slab Thickness,

ΔPSI = Difference between the initial design serviceability, (Pi), and the final design serviceability, (Pt),

S'_c = Modulus of rupture of PCC,

C_d = Coefficient of drainage,

J = Coefficient of load transfer,

E_c = Modulus of elasticity for PCC, and

k = Modulus of subgrade reaction.

Other factors affecting pavement performance that are also considered in the AASHTO *Guide* include: joint spacing, coarse aggregate type, water-cement ratio, cement type, reinforcing steel, load transfer devices, type of stabilization of the subbase, and type of shoulders.

3.2.3 Additional Design Factors

Field survey studies, discussions with TxDOT officials, and studies performed on concrete pavements by CTR (Refs 21, 22) assisted us in identifying pavement age, coarse aggregate type, roadbed type, and use of control joints as additional design factors.

3.3 SELECTION OF FACTORS

Based on the factors identified in the previous sections, Table 3.2 lists the most significant variables affecting pavement performance. As discussed below, these will serve as a basis for selecting variables to be included in the JCP database.

3.3.1 Structural Variables

Slab thickness: Refers to the thickness of the portland cement concrete layer built on the top surface of the pavement structure. The magnitude of traffic loads, the number of applications, the concrete tensile stresses, and the modulus of subgrade reaction are the main factors used for the design of the slab thickness.

Slab length: Joint spacing, through its interaction with temperature changes and subbase friction, affects the development of transversal cracking. Joint spacing for plain concrete pavements in Texas has been reported as constant between 3.048 and 6.069 m (10 and 20 feet), while jointed reinforced concrete pavements (JRCP) have joint spacing normally between 7.62 to 18.288 m (25 and 60 feet) (Ref 23), though in some cases up to 36.576 m (120 feet).

Table 3.2. Design variables to be collected for inclusion in the database

Variable type	Variable
Structural variables:	Slab thickness Slab length Slab reinforcement Coarse aggregate type Presence of dowels Presence of tied PCC shoulders Subbase type Presence of control joints
Environmental variables:	Average annual rainfall Average lowest temperature Road bed soil type
Load variables:	Traffic: cumulative AADT Pavement age

Slab reinforcement: The type of reinforcement commonly used is welded wire fabric or metal bars. This variable is collected for JRC pavements, since steel percentage and bar size are designed to prevent temperature-related slab cracking.

Coarse aggregate type (CAT): The coarse aggregate type influences the grain interlock (or load transfer coefficient), the flexural strength of the PCC pavement, and the thermal coefficient of the concrete, as has been reported in several studies (Refs 21, 22)

Dowels: Load transfer between pavement slabs is obtained by placing dowel bars or some other mechanical system across joints. While JRCP sections in Texas commonly include dowels in their designs, their use in plain concrete pavements was not so common in the past, and a significant reduction in performance is expected for pavements not using load transfer devices.

Shoulder type: Joint deficiencies between the travel lanes and the shoulder are mainly attributed to the encroachment of heavy loads onto the shoulder and to the type of materials commonly used for the shoulder surface. Although monolithic or tied PCC shoulders are highly desirable, economic considerations have led to the use of earth, granular, or asphalt materials.

Subbase type: The subbase, which generally consists of granular or stabilized material, is the pavement layer intended to provide a strong and uniform transition between the concrete slab and the subgrade. The common types of stabilization include asphalt-treated, PCC-treated, lime-treated, or natural crushed stone. Frictional resistance between the slab and the subbase and temperature changes in the pavement slab are considered principal causes of shrinkage cracking.

Modulus of subgrade reaction: Stresses caused by bending of the concrete slab are highly dependent on the modulus of subgrade reaction "k," which is a measure of slab support.

PCC modulus of rupture: This is intended to be a function of CAT, water-cement ratio, and cement content. Although the modulus of rupture for JCPs has been specified by TxDOT as approximately 4.96 E+06 Pa (720 psi) at 28 days (Ref 24), it is desirable to include either water-cement ratio or cement content into the database, whichever is most readily available from TxDOT records to account for variability.

Drainage: This item has been identified by the AASHTO *Guide* as an important factor in pavement performance, affecting as it does subgrade strength and base erodability. A variable to differentiate between "improved" and "unimproved drainage" will be considered for incorporation in the database.

3.3.2 Environmental Variables

Average annual rainfall: Precipitation contributes to the moisture content (infiltration) of the pavement structure. Several studies have identified moisture as the principal cause of pumping and blow ups (i.e., if it interacts with subgrade soils containing swelling clays). As a way of quantifying the effect of precipitation or moisture, average annual rainfall is considered as a proxy variable.

Temperature: Mechanistic models attribute the development of transverse cracks to temperature drop. This correlation can be captured by collecting average annual lowest temperature as a factor. Also, the effect of frost heave can be determined through the interaction of moisture and temperature.

Roadbed soil type: Although roadbed soil (in terms of particle size or other specifications) does not affect performance of the pavement, the presence of active clay may lead to moisture-related volume changes. Since swelling characteristics are important for non-reinforced pavements, the classification of roadbed type by swelling and non-swelling soils captures the effects of this factor.

Roadbed grading type: The effect of grading on pavement performance has been documented in several studies (Refs 4, 11). This variable captures the influence of cut, fill, transition, and at-grade-built pavements.

3.3.3 Load Variables

Traffic: The load experience of the pavement structure is one of the most important variables in pavement performance evaluations. Information on this variable needs to include (at a minimum) estimates of the number of axle loads that pass over the section each year in each of several weight classes (Ref 5).

Although the 18-kip equivalent single axle load (ESAL) would give one of the more reliable traffic load indicators, obtaining such variable involves collecting a number of other variables, including annual average daily traffic (AADT), truck percentage, truck category distribution, and truck weight distribution. Thus, the cumulative AADT (as recorded from the initial opening of the pavement to traffic) will be obtained; using traffic models developed by CTR (Ref 2), we will estimate the approximate number of applied ESALs.

Pavement age: Distresses usually do not develop immediately after the completion of the pavement; rather, they develop over time in response to the action of traffic and the environment.

Therefore, the number of years since construction plays an important role, since it affects the performance of the pavement and since it interacts with the other two factors.

Annual daily load (cumulative ESALs/age): Collecting both traffic loads and age will allow us to study the performance of pavements that accumulate the same number of axle loads over different periods of time.

3.4 PERFORMANCE VARIABLES FOR JCP

Several studies have identified the main distress manifestations present in JCPs (Refs 3, 20, 25). Measuring every type of distress for the pavements to be surveyed would involve an enormous effort practically impossible in terms of time and cost. It is, therefore, desirable to develop a short list of distress types to be surveyed. Since certain distresses have a greater influence on pavement performance and structural capacity than others, these significant distress types should be surveyed.

Distresses to be recorded during condition surveys are in accordance with the TACS Table; that is, the table of parameter values used for input in the performance curves for the Texas PMIS. This table includes the distress for which the PMIS performance models need to be developed and updated.

Table 3.3 lists the distress types to be included in the database (their definitions and collection procedures will be discussed in Chapter 6). Because the surveys need to consider the condition of both overlaid and non-overlaid pavements, a list of distresses for both cases is included separately.

Table 3.3. List of distresses for overlaid and non-overlaid JCP

Non-overlaid JCP	Overlaid JCP
Cracking	
Corner breaks Durability "D" cracking Longitudinal cracking Transverse cracking	Alligator cracking Block cracking Reflective cracking Longitudinal cracks Transverse cracks Corner breaks
Joint deficiencies	
Spalling of longitudinal and transverse joints/cracks Faulting of transverse joints/cracks	Faulted joints
Miscellaneous distresses	
AC and PCC patches Punchouts	Rutting AC patches Punchouts

3.5 PAVEMENT IDENTIFICATION DATA

These data cover all information required for identification of the pavement test sections. Table 3.4 lists all data required for identification of the pavement projects and test sections to be surveyed.

Table 3.4. Pavement identification data to be collected

Data type	**Items to be collected**
Identification	Highway functional classification Highway number designation Pavement type (JCP, JRCP) Rural / urban Control-section-job Mileposts Reference markers CFTR number Direction
Geometric details	No. and width of lanes Roadbed type

CHAPTER 4. EXPERIMENTAL DESIGN

4.1 INTRODUCTION

An experimental design is a systematic approach that allows a researcher to investigate the effects of one or more factors in an experimental unit. Since experiments consisting of two or more factors can have an individual or joint influence on the response, one-factor-at-a-time experiments do not allow the proper assessment of the combined effects of the factors. Thus, factorial experiments are particularly effective in evaluating joint-factor effects. Furthermore, because they obviate the need for separate experiments, factorial experiments save time and resources (Refs 26, 27).

4.2 USE OF AN EXPERIMENTAL DESIGN FOR THE JCP DATABASE

As discussed previously, the database will serve as a source of information for the TxDOT PMIS and for other pavement investigations. Accordingly, we developed an experimental design to guarantee that the information contained in the database would provide precise information on the factors that affect pavement performance. A factorial experiment will ensure the cost-effective expenditure of resources available for the data collection effort, while also ensuring that sufficient data are collected to support reliable statistical analyses.

4.3 CANDIDATE TEST SECTIONS

In selecting candidate sections for testing, we considered the pros and cons of both existing pavements and new experimental pavements. Because existing pavements have, as a function of their longevity, a history of traffic loads and environmental cycles, their performance is much more readily evaluated. Conversely, new experimental pavements require many years of study before their performance can be reliably assessed.

Yet the strict construction control associated with new experimental pavements permits (using relatively few test sections) a more precise assessment of the effects caused by the different design factors. Conversely, the variations and lack of records in construction procedures for existing pavement projects can obscure the effects of significant variables, requiring more test sections to assess performance results. In addition, groups of existing pavements are not always representative of a wide range of design practices, since their availability depends of the design procedures employed for the local highway network in question; with new experimental pavements, the addition of factors of interest not found in existing test sections can be introduced relatively easily. Finally, in terms of costs, the time and expense required for the study of new experimental pavements exceed those involved in the study of existing pavements.

Thus, in reviewing the advantages and disadvantages of each type of candidate test section, we concluded that existing, in-service pavements would more easily allow us to meet the project objectives.

4.4. SAMPLING FACTORIAL PROCEDURE

With our decision to use existing sections, every JCP section in the Texas highway network became a viable candidate. Because such a large sampling was considered impractical, we focused our attention on determining the minimum number of test sections we might survey that would yield the best results for the evaluation of the different effects. Assisting in this effort was a recent CTR report (Ref 24) that documented the factorial design used to select Texas JCP sections for monitoring. Thus, in our study, design factors that influence the performance of JCP were identified based on the more significant design factors, and a sampling factorial was developed for the selection of JCP sections as candidates for a condition survey. The sampling procedure used in the selection of test sections consisted of a fractional factorial design, one intended to capture the effects of all the factor levels using a minimum of test sections.

Sampling factorials developed for both JCP and JRCP sections, illustrated in Figures 4.1 and 4.2, are mostly based on the results reported in Chapter 3. The final selection of the factors, as well as the number of levels and midpoint values, was decided following a meeting of CTR staff and TxDOT officials. Significant factors considered for the JCP factorials include coarse aggregate type, pavement age, PCC thickness, temperature, moisture, dowels, and slab length.

PAVEMENT TYPE: PLAIN

AGE: NEW<= 15 yrs
OLD > 15 yrs

Aggregate			Limestone				Siliceous			
Thickness			<10 in. (low)		>=10 in. (high)		<10 in. (low)		>=10 in. (high)	
Age			New	Old	New	Old	New	Old	New	Old
Temperature	Moisture	Dowels								
Freeze	Wet	Y	1	9	17	25	33	41	49	57
		N	2	10	18	26	34	42	50	58
	Dry	Y	3	11	19	27	35	43	51	59
		N	4	12	20	28	36	44	52	60
No Freeze	Dry	Y	5	13	21	29	37	45	53	61
		N	6	14	22	30	38	46	54	62
	Wet	Y	7	15	23	31	39	47	55	63
		N	8	16	24	32	40	48	56	64

1 inch=2.54 cm

Figure 4.1. Factorial design for jointed plain concrete pavements

Coarse aggregate type: The impact on pavement performance for the type of coarse aggregate used has been highlighted in various studies (Refs 21, 22). For Texas, the construction of concrete pavements includes basically two typical types of coarse aggregate: siliceous river gravel and limestone. Both aggregate types were selected as levels in the factorial.

Pavement age: Pavements up to 15 years were considered "new" and pavements older than 15 years were considered "old," since 15 years is the estimated average service life of a JCP without overlay construction.

PCC thickness: Because the slab thicknesses of JCP projects range from 15.24 to 33.02 cm (6 to 13 inches), the midpoint value was selected as 25.4 cm (10 inches), so that pavements with a thickness of 25.4 cm (10 inches) or greater were clustered in the "high" category, and pavements with a thickness less than 25.4 cm (10 inches) were clustered in the "low" category.

PAVEMENT TYPE: REINFORCED

SLAB: <= 45 ft Short
> 45 ft Long

AGE: NEW<= 15 yrs
OLD > 15 yrs

		Aggregate	Limestone				Siliceous			
		Thickness	<10 in. (low)		>=10 in. (high)		<10 in. (low)		>=10 in. (high)	
		Age	New	Old	New	Old	New	Old	New	Old
Temperature	Moisture	Slab Length								
Freeze	Wet	SHT	1	9	17	25	33	41	49	57
		LNG	2	10	18	26	34	42	50	58
	Dry	SHT	3	11	19	27	35	43	51	59
		LNG	4	12	20	28	36	44	52	60
No Freeze	Dry	SHT	5	13	21	29	37	45	53	61
		LNG	6	14	22	30	38	46	54	62
	Wet	SHT	7	15	23	31	39	47	55	63
		LNG	8	16	24	32	40	48	56	64

1 foot=.3048 m 1 inch=2.54 cm

Figure 4.2. Factorial for jointed reinforced concrete pavements

Climate: Using the Thornwaite Moisture Index and the Mean Freezing Index (Ref 28), we divided Texas into the four climatic regions illustrated in Figure 4.3a. Then, for the purpose of the factorial design, temperature and moisture were considered as two separate factors with two levels each. Temperature was captured by the Mean Freezing Index and test sections were classified in terms of freezing or no-freezing temperatures. On the other hand, moisture was defined in terms of the wet and dry regions according to the Thornwaite Moisture Index (TMI). Test sections within a negative TMI region were considered "dry," while test sections within a positive TMI region are considered "wet." For ease of classification, and since the delineation of the four climatic zones varies depending of the season of the year, we divided the state into the "x" and "y" axes (with their origin in Bryan) illustrated in Figure 4.3b.

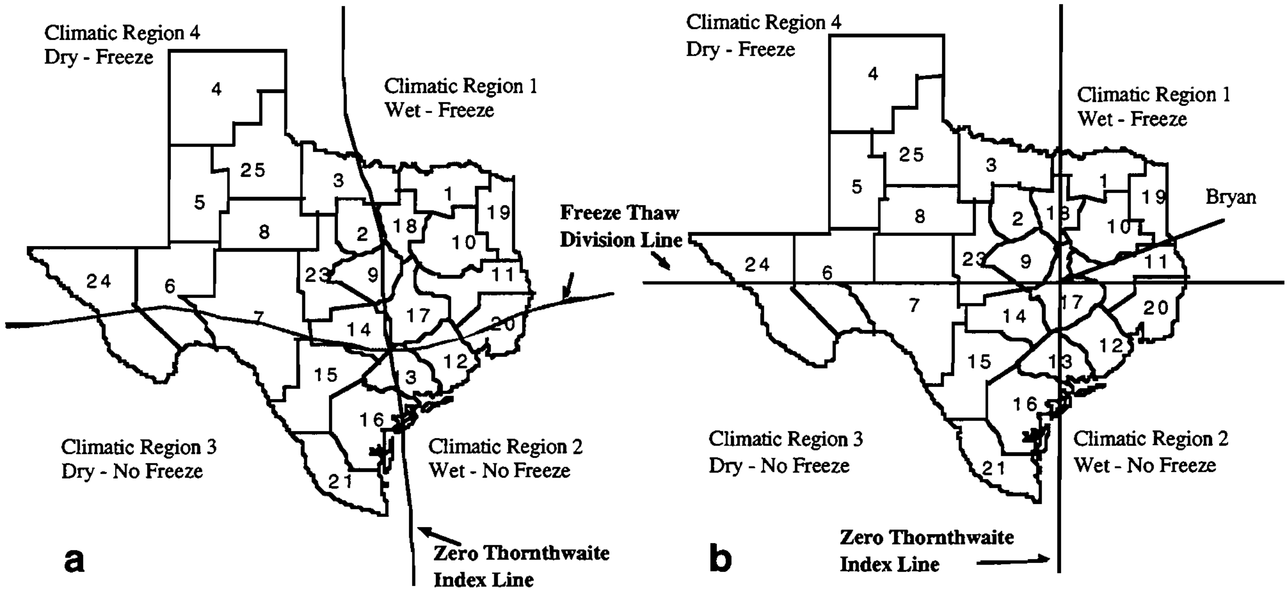


Figure 4.3. Texas climatic regions

Dowels: Because JRC pavements have always included dowels in their designs (according to TxDOT officials), this was not considered a factor. However, for jointed plain concrete pavements, load transfer between slabs was captured by the presence or absence of dowels as a factor.

Slab length: The joint spacing for jointed plain concrete pavements in Texas ranges from 3.04 to 6.09 m (10 to 20 feet), with no significant difference in their performance expected. For JRCPs, slab lengths range between 7.62 to 18.288 m (25 to 60 feet), with the effects of frictional resistance consequently expected to have a greater impact on performance for these pavements. For this reason, JRCPs included slab length as a factor, with a midpoint value of 13.716 m (45 feet). Pavement slabs 13.716 m (45 feet) or shorter are considered "short," while pavements with longer slab lengths are considered "long."

Although for both pavement types, age and PCC thickness are classified into low and high, they will be collected as continuous variables for storage into the database. Appendix C includes a

SAS program that computes the row and column of the sampling factorial according to the design information for every pavement project.

4.4 CONSIDERATION OF OTHER FACTORS AS COVARIATES

There are additional factors included in the experimental design that are expected to influence pavement performance, as already discussed in previous chapters. These factors, considered as covariates, are listed below.

1. Traffic
2. Roadbed Swelling Potential
3. Average Annual Lowest Temperature
4. Average Annual Rainfall
5. Presence of Tied PCC Shoulders
6. Subbase Treatment
7. Presence of Control Joints

4.5 EVALUATION OF THE EXPERIMENTAL DESIGNS

In summary, for both JCP and JRCP projects, the factorial experiment is bounded by six factors with two levels per factor. Table 4.1 shows the factors selected and the levels per factor for each pavement type. The 2^6 factorial experiments presented produce a total of 64 cells for each pavement type. This was considered a completely randomized design, since every cell in the factorial has an equal chance of being a representative.

Table 4.1. Factors and levels used in the experimental design

Factor	**Level 1**	**Level 2**	**Pavement Type**
Coarse aggregate type	Limestone	SRG*	JCP and JRCP
Pavement age	<= 15 years	> 15 years	JCP and JRCP
PCC thickness	< 10" (25.4 cm)	>= 10" (25.4 cm)	JCP and JRCP
Temperature	Freeze	No freeze	JCP and JRCP
Moisture	Wet	Dry	JCP and JRCP
Dowels	Yes	No	JCP
Slab length	Long	Short	JRCP

**SRG = Siliceous River Gravel*

The investigation of all the factors — as well as the interactions occurring between them — will produce a model consisting of 23 parameters, as expressed in Eq. 4.1:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \ldots + \beta_{21} X_{21} + \varepsilon \qquad \text{(Eq. 4.1)}$$

where:

Y = Resulting response variable,

β_0 = Intercept,

β_1 = Regression coefficient due to factor X1,

X_1 = Coarse aggregate type,

$_2$ = Regression coefficient due to factor X2,

X_2 = Pavement age,

•

•

•

β_{21} = Regression coefficient due to the interaction Moisture * Dowels (in the case of JCP) or Moisture * Slab length (in the case of JRCP), and

ε = Disturbance Term.

In a recent CTR study (Project 1342), the program, "Algorithms for the Construction of Experimental Designs" (ACED), was used to investigate how well the parameters in the model could be estimated according to the number of cells filled with pavement projects. This computerized routine was also used to determine the number of projects to be chosen per cell according to the level of significant correlations produced, and to determine the optimum cells that could give the best results for the analysis of joint factor effects.

In this type of analysis it is advisable that the continuous values for the factors be used so that the effects of an unbalanced design are diminished. For instance, instead of considering the factor thickness as "high" or "low," the actual value, i.e., 22.86 cm (9 inches), could be used. It was also suggested that, as a general rule, no more than three observations per cell be included in the analysis.

CHAPTER 5. DATA COLLECTION PROCEDURES AND SELECTION OF TEST SECTIONS

5.1 IDENTIFICATION OF THE TEXAS JCP POPULATION

Developing a pavement database for Texas jointed concrete pavements required, as a first step, the identification of all Texas JCP projects. This chapter reviews the data collection procedures and describes the selection of the test sections.

5.1.1 Project 1908

CTR Report 1908-1, "Preliminary Distress and Performance Prediction Models for Concrete Pavements in Texas," provided much useful information regarding rigid pavement maintenance and rehabilitation (Ref 3). In that study, researchers sent to every Texas district a questionnaire of maintenance and rehabilitation (M&R) activities; from the responses, they compiled a 7-year history (1983-1990) of each district's M&R activities, including dates and kinds of activities performed on every pavement section within the district's jurisdiction. The JCP projects we extracted from the 1908-1 report were of great relevance to the database, since they minimized the M&R data collection efforts.

5.1.2 CTR Database

The Center for Transportation Research maintains a database of Texas JCP projects it surveyed in 1982 and 1984. The database includes the project's thickness, load transfer type, slab length, reinforcement type, and completion date.

5.1.3 SHRP projects

The Strategic Highway Research Program (SHRP) is a 5-year, $150 million federal program focusing on asphalt, highway operations, concrete, structures, and pavement performance. From a SHRP report on rigid pavements in Texas (Ref 6), we identified for inclusion in the database the location of all Texas pavement sections serving as SHRP test sections.

5.1.4 PES files

We extracted jointed plain and jointed reinforced concrete pavement data for the years 1989 and 1990 from the Pavement Evaluation System (PES) computerized files maintained by TxDOT.

5.1.5 TxDOT Road Inventory Files (RI-2)

We also extracted Texas JCP construction project information from the RI-2 files maintained by TxDOT's Transportation Planning and Programming Division (TPPD). Because these files are not computerized, we performed a manual search. Another problem was the fact that these files contain only surface codes for every section, meaning that an exhaustive search was required in order to locate JCP projects in every RI-2 file for each county. Consequently, we restricted the search mainly to projects having more priority in the factorial. Basing our decision on pavement age and on the climatic zone of every county, we selected those RI-2 files that had greater possibilities of having priority projects.

In addition, we contacted TxDOT district engineers to inquire about newly built sections not yet part of TxDOT's records. TxDOT personnel from the Design Division were contacted to obtain a list of districts where new JCP projects had been built.

5.1.6 Data Identifiers (Inventory data)

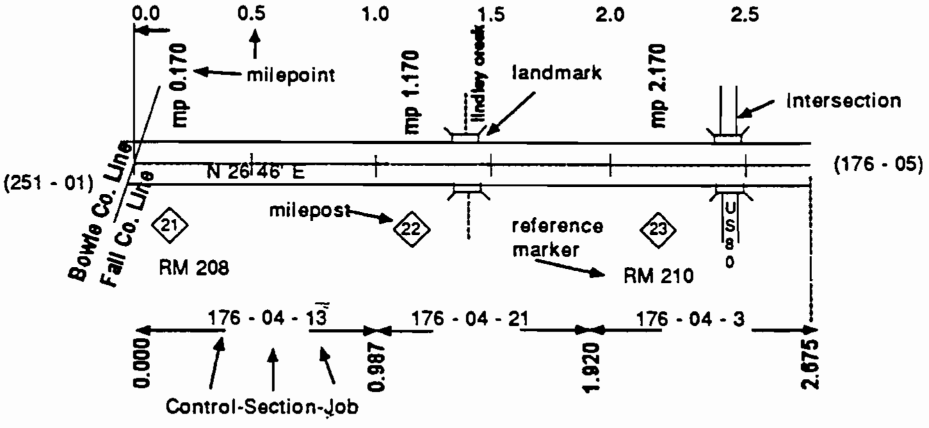
Matching test section identifiers involved much effort, since TxDOT is at present converting to a new highway identification system. Figure 5.1 illustrates the different highway segment identifiers used by TxDOT. Test sections can be identified in one of the following forms:

Control, Section, and Job number (C-S-J): This is the number assigned to the pavement construction project. The control and section are specific to a segment of highway containing several maintenance and construction jobs. This identifier was used to collect pavement design information from TxDOT records management division and from road life files located in the TPPD.

Control, Section, and Mileposts: These are found in the Road Inventory files (RI-1) at TPPD. The mileposts are the concrete posts located at every mile on the interstate highway system.

Control, Section, and Boundary Milepoints: These are found in the RI-1 and RI-2 files and are used to collect traffic information.

Highway Number, Functional Classification, and Reference Markers: This is expected to become the standardized system for identifying Texas roads (Ref 29).



Control-Section 176 - 04 for SH0075

Figure 5.1. Highway segment identifiers presently used by TxDOT (1 mile=1.61 km)

5.2 COLLECTION OF INVENTORY DATA AND DESIGN INFORMATION

This section describes the collection of inventory data and design information included in the JCP database. Appendix D contains a sample of the forms prepared for the collection of the variables contained in the database. As mentioned in previous chapters, the kind of data to be collected for the database was divided into design factors and performance variables. The following section refers to the documentation of design factors, while Chapter 6 describes the procedures for the collection of performance variables. Table 5.1 summarizes the data sources used to obtain JCP design information.

Table 5.1. Design data sources

Design variables	**Sources**
PCC thickness Slab length Reinforcement Dowels	TxDOT project design plans
Coarse aggregate type	Material testing reports, from folder # 5 of the project correspondence
Subbase type	Road inventory and road life files
Construction completion date Maintenance and rehabilitation Shoulder type	TxDOT TPPD road life files
Roadbed type	Condition survey
Average lowest temperature Average annual precipitation	World Weather database
Soil type	Texas land resources map
Traffic (AADT, % trucks, etc.)	TxDOT TPPD traffic logs

5.2.1 Structural Data

Information on pavement thickness, slab length, type of reinforcement (if any), and load transfer devices (e.g., dowels) could be extracted from design plans stored at TxDOT's Equipment and Procurement Division (D-4), Records Management Section. This survey involved looking at the plans for every JCP project located through the county and matching C-S-J identifiers, as discussed above. For recently built pavements, this information, if not found in D-4, was obtained by contacting the district in which the project is located.

The subbase type was also obtained from the design files; when not available, it could be easily extracted from the Road Inventory files and Road Life files located at TPPD (control, section, and milepoints were needed for the collection of this information).

The coarse aggregate type for every project could be determined using the Material Testing Reports and Core Test Reports, which are included in Folder #5 of the Project Correspondence. While these files are customarily stored on microfilm, the files for recently built projects may still be stored as loose paper copies; in any case, both microfilm and paper copies are available in the Records Management Section in D-4. Before a pavement is built, contractors usually submit more than one type of coarse aggregate to the Materials and Tests Division (D-9) for certification and approval. Once examined, the contractors choose one of the approved aggregates for use in the construction. This procedure produces several Material Test Reports. A procedure to check the coarse aggregate ultimately used in the construction was proposed by Chou (Ref 11); it consists of finding the company and pit of the coarse aggregate based on the Core Test Report, and then matching it with the corresponding Aggregate Test Report, where the coarse aggregate type is recorded.

Two possible sources were available for the collection of shoulder type: design plans and Road Life (RL) files stored at TPPD. The RL files were judged the better source, since the design plans could not reflect any change in shoulder type owing to subsequent M&R activities.

Roadbed grading type was recorded during the field surveys, when test sections were selected for cut, fill, transition, or at grade.

5.2.2 Environmental Factors

Average lowest temperature and average annual precipitation information for 160 temperature/precipitation stations located in Texas was easily extracted from the World Weather Database available in compact disc format from the Engineering Library of The University of Texas at Austin. This database contains information from the National Oceanic and Atmospheric Administration (NOAA) records for a period spanning three decades (1951-1980).

Items collected from the CD database included average lowest temperature for the coldest month, average lowest temperature for the hottest month, and average annual precipitation in inches. The identification of the weather stations consists of the station name, latitude, longitude and elevation. The need to collect information on weather or soil type for every specific test section underscores the value of using a Geographical Positioning Systems (GPS) for pavement databases. Finally, the roadbed soil type was obtained in terms of the swelling characteristics. This procedure involved locating every test section on the Texas Land Resources Map.

5.2.3 Maintenance and Rehabilitation Information

Maintenance and rehabilitation information, as previously illustrated in Figure 2.1, is a very important component of any pavement database expected to support the development and updating of PMIS pavement performance curves. For the collection of M&R activities, it was necessary to obtain a list of test sections previously surveyed, so that information regarding the precise location of the pavement section could be obtained.

CTR Report 1908-1 (Ref 3) was one of the sources used to retrieve information on M&R activities. Maintenance information categorized as either preventive, light, moderate, or heavy was available for the period 1983 to 1990. The data are identified by district, county, highway number, functional classification, and starting and ending reference markers.

From TxDOT's TPPD, M&R pavement history information could also be extracted from the Road Life files, which are updated to reflect jobs performed by contractors. Although these files do not contain M&R performed by the TxDOT district offices, a considerable portion of the M&R activities is performed by contractors, and it is expected that most of the information will be captured using this procedure.

Collecting M&R information for each pavement unit involved searching the Road Life files for maintenance jobs performed within the boundaries of the construction projects. The kinds of maintenance jobs found most often were overlays, seal coats, and shoulder repairs. The scope of the work, date of maintenance, job limits, and overlay thickness (if any) were recorded in the maintenance sheets prepared for that purpose. The M&R forms used are included in Appendix D.

Since the Road Life files are updated only through 1985, it was necessary to look at current files where M&R activities are stored in computerized format. These files contain maintenance activities performed since 1985 (the files are updated through 1992).

The computerized files are ordered by district, county, C-S-J, and milepoint limits. The brief description for each job includes such information as type of job, overlay thickness (if any), seal coat, base placement, surface placement, and shoulder improvement. After receiving from TxDOT's TPPD Data Management Section a cartridge of these files, we developed a computer program to read the job numbers, limits, and maintenance information, so as to obtain a summary of M&R information for every JCP project surveyed.

5.2.4 Collection of Traffic Data

Traffic information dating back to 1968 was collected from TPPD traffic logs stored on microfiche. Traffic information for earlier years was extracted from district traffic maps. Appendix C includes a SAS program that extrapolates AADTs prior to 1968 using an exponential regression model. The data available in traffic logs include AADT, truck percentage, traffic yearly percent increment, average ten heaviest wheel loads (ATHWL), directional distribution, and percent tandem axles.

AADT information was collected for every test section surveyed. Since the collection of the remaining factors entailed a very exhausting process, those traffic factors were extracted only for 1975, 1980, and 1990, for every pavement project. For identification purposes, it was necessary to know the control, section, and highway milepoints for every test section.

The use of regression models developed in a study for CRCP test sections was used to obtain the cumulative ESALs for the JCP database (Ref 2). Appendix C contains an SAS program that converts AADT to ESALs according to the traffic model developed in CTR Report 472-6.

5.3 DATA REDUCTION

The objective of the field collection plan was to obtain precise data cost-effectively and quickly. The selection of projects was based on an iterative process in which projects identified from the sources investigated were classified in terms of the factorial design presented in the previous chapter. Although a total of 317 pavement projects was obtained, not all the projects identified were selected, since some of them were very old projects with several overlays, or were recently reconstructed with another pavement type. In some cases, the design information was not available in plans, or the plans were not found; other projects were too short to serve as experimental test sections.

After collecting the main design factors listed in the sampling factorial procedure, we considered 193 projects for inclusion in the database, of which only 166 projects met the requirements for the factorial — that is, some of the projects had a coarse aggregate classification other than limestone or siliceous river gravel.

The 166 projects filled 29 cells of the JCP factorial, and 20 cells of the JRCP factorial. Figures 5.2 and 5.3 show that some cells were filled with one project only, while others had up to 16 projects. (There were no JCP projects in the dry-no freeze climatic zone of Texas.)

Because the field collection plan could accommodate a survey of 50 projects for each of the JCP and JRCP pavement types, the project selections required a stratified sampling procedure.

PAVEMENT TYPE: PLAIN

AGE: NEW<= 15 yrs
OLD > 15 yrs

Temperature	Moisture	Dowels	Limestone				Siliceous			
		Thickness	<10 in. (low)		>=10 in. (high)		<10 in. (low)		>=10 in. (high)	
		Age	New	Old	New	Old	New	Old	New	Old
Freeze	Wet	Y	1 **1**	9	17	25 **1**	33	41 **4**	49	57 **1**
		N	2	10 **2**	18	26 **3**	34	42	50	58 **4**
	Dry	Y	3 **4**	11 **2**	19 **4**	27 **3**	35 **2**	43 **1**	51 **3**	59
		N	4 **2**	12 **5**	20 **1**	28 **5**	36	44	52	60
No Freeze	Dry	Y	5	13	21	29	37	45	53	61
		N	6	14 **1**	22	30	38	46 **2**	54	62
	Wet	Y	7 **1**	15	23	31	39	47 **2**	55	63
		N	8	16 **1**	24	32 **1**	40	48 **4**	56 **1**	64 **3**

1 inch=2.54 cm

Figure 5.2. Factorial cells filled by JCP test sections

PAVEMENT TYPE: REINFORCED

SLAB: <= 45 ft Short
> 45 ft Long

AGE: NEW<= 15 yrs
OLD > 15 yrs

Aggregate			Limestone				Siliceous			
Thickness			<10 in. (low)		>=10 in. (high)		<10 in. (low)		>=10 in. (high)	
Age			New	Old	New	Old	New	Old	New	Old
Temperature	Moisture	Slab Length								
Freeze	Wet	SHT	1	9	17	25	33	41 1	49	57
		LNG	2	10	18	26	34 1	42 1	50	58
	Dry	SHT	3 1	11 4	19	27 3	35 2	43 3	51	59
		LNG	4	12 4	20	28	36 1	44 3	52	60
No Freeze	Dry	SHT	5	13	21	29	37	45	53	61
		LNG	6	14	22	30	38	46 1	54	62
	Wet	SHT	7	15	23	31	39	47 5	55	63 3
		LNG	8	16 3	24 1	32 3	40 3	48 11	56 9	64 16

1 inch=2.54 cm 1 foot=.3048 m

Figure 5.3. Factorial cells filled by JRCP test sections

5.4 DATA STRATIFICATION

A priority rank was included in the list of candidate projects submitted to the survey team. This priority rank was computed according to the following factors in order of importance:

1. Number of projects per factorial cell: If there were just one project in a cell, it must be collected as a first priority.
2. If two or more projects fall in one cell, the newer and older projects have priority (this increased the probability of including one overlaid and one non-overlaid project per cell).
3. The priority of cells with more than two projects was established based on the availability of maintenance information. Consequently, projects with maintenance information had priority.

CHAPTER 6. FIELD DATA COLLECTION PROCEDURES

6.1 INTRODUCTION

This chapter describes the criteria used to select the test sections for the field condition survey. It also introduces the procedures used for measuring distress manifestations, and presents the main results of, and problems associated with, the condition surveys.

6.2 SITE SELECTION CRITERIA FOR TEST SECTIONS

Candidate pavement projects for the condition survey were selected according to the factorial design introduced in Chapter 3. Of some concern was the variation in individual project length (they ranged from a few hundred feet to several miles long). Knowing the importance of selecting experimental test sections of uniform length within projects (so that structural characteristics, construction procedures, materials, traffic loads, and foundation soil conditions are constant throughout the entire highway segment), we referred to a condition survey performed by CTR in 1987. In that survey, Chou and others developed site selection criteria for CRCP test sections based on TxDOT and CTR recommendations (Ref 11). Because the proposed criteria established for the 1987 condition survey provided positive results, they were adopted for the selection of JCP test sections. Important recommendations from that report include the following:

1. Test Section Length: It has been mentioned that the roadbed type influences the performance of pavements. Since the average length of uniform roadbed construction was considered to be 304.8 m (1000 feet), this was adopted as the unit length of sections selected for the condition survey.
2. Number of Test Sections Selected from Each Project: The length of the project and the roadbed type dictate the number of test sections to be selected. For pavement projects shorter than or equal to 4.83 km (3 miles), one cut, one fill, one at-grade, and one transition between a cut and a fill section should be selected when possible. For projects longer than 4.83 km (3 miles), two cuts, two fills, one at-grade, and one transition should be selected. When the required number of test sections is not available for a specific project, a note will be made on the survey sheet. Cut, fill, transition and at-grade roadbed types are illustrated in Figure 6.1. A cut exists when the highway profile is 1.524 m (5 feet) or higher than the adjacent land. A fill is identified when the highway profile is 1.524 m (5 feet) or lower than the adjacent land. The passage from a cut to a fill or vice versa is called a transition. Finally, when the difference in height between the highway and the adjacent land is less than 1.524 m (5 feet), the roadbed is said to be at-grade.
3. Additional provisions: For safety reasons, avoid sections on the downhill side of the road; close to or on a bridge; and close to a highway entrance, ramp, or exit.

6.3 MEASUREMENT METHODS FOR DISTRESS MANIFESTATIONS

The following describes the distresses to be collected for non-overlaid and overlaid pavements. Also discussed are the main causes for such manifestations, and how the distresses are to be surveyed.

6.3.1 Non-overlaid Pavements

Punchouts are formed when two transverse cracks are intersected by a longitudinal crack (producing a block). The levels of severity are classified as minor and severe. Minor punchouts consist of hairline cracks having few signs of spalling and no movement under traffic loads; severe punchouts consist of wide cracks that show signs of pumping and movement of the block under traffic loads (Ref 11). The number of punchouts within the sample unit is collected according to severity level.

Durability "D" Cracking is defined as a series of closely spaced, crescent-shaped hairline cracks that appear at the slab surface adjacent and roughly parallel to transversal and longitudinal joints, cracks, and slab edges. "D" cracking is usually caused by expansive pressures of certain types of coarse aggregates under the action of freeze-thaw cycles (Ref 20). The number of "D" cracking failures is recorded for the total sample unit.

Corner Breaks are defined as a crack intersecting a transverse and a longitudinal joint or an edge at a distance of less than 1.8288 m (6 feet) from the corner of the slab on each side. A corner break results from the combination of traffic loads, poor load transfer at the joint, and thermal-curling and moisture-warping stresses (Ref 20). The total number of corner breaks existing in the sample unit is counted and recorded.

Spalling of Longitudinal and Transverse Joints and Cracks is defined as the cracking, breaking, or chipping of the slab edges within 0.6 m (2 feet) of the joint or crack. Spalling is usually a result of excessive stress at the joint or crack, which can be created by infiltration of incompressible materials (causing the slab to expand), deficient load transfer devices, and/or heavy repeated traffic loads (Ref 20). The number of spalled joints and cracks within the sample unit is recorded.

Faulting of Transverse Joints and Cracks is defined as a shift in elevation across a joint or crack. Faulting is primarily caused by accumulation of loose material under the approach slab, and by depression of the leave slab. The loose material is generated by the pumping induced by heavy loads and slab warping and/or curling (Ref 20). The number of total occurrences of this distress within the sample unit is collected.

AC and PCC patches are portions of the original distressed pavement slab that have been removed and filled with asphalt or portland cement concrete material to the full depth of the surrounding concrete slab (Ref 20). Their severity level is measured according to total occurrences within .0929-4.64 m^2 (1-50 square feet), 4.73-13.9 m^2 (51-150 square feet), and >13.9 m^2 (>150 square feet). The number of occurrences in each of the above categories is recorded for every 60.96 m (200 feet).

Longitudinal Cracks are cracks parallel to the pavement centerline that generally occur as a result of improper construction of longitudinal joints. The number of slabs with longitudinal cracks within the sample unit is recorded.

Transverse Cracks are linear cracks running perpendicular to the pavement centerline. They are caused by repetition of heavy traffic loads, thermal and moisture gradient stresses, and by drying shrinkage stresses (Ref 20). The number of cracks within the sample unit is recorded.

Crack spacing is also recorded by measuring the accumulative distance from the starting point of the test section to each crack for the first 60.96 m (200 feet) only.

Shoulder condition is a verbal description of the condition of the shoulder recorded in terms of such observed distresses as joint deficiencies between the pavement and the shoulder, level differences, signs of scuffing, or any indication of problems with subsurface drainage (Ref 11).

6.3.2 Overlaid Pavements

Alligator Cracking is formed by a series of interconnected cracks that produce a grid of cracks less than 0.3048 m (1 foot) long. This manifestation is a result of repeated traffic loads that fatigue the asphalt surface (Ref 25). The percent of the total surface area for the rated lanes is recorded in the distress survey, as specified by the TxDOT PMIS.

Block Cracking: Similar to alligator cracking, block cracks are cracks forming rectangular pieces of asphalt surface between 0.0929 m^2 (1 square foot) and 9.29 m^2 (100 square feet) (Ref 25). This is also recorded as the percent of the total surface for the rated lanes.

Rutting is the longitudinal surface depression observed at the wheel path. It is caused by displacement of the asphalt under the action of the wheel loads. The severity levels include shallow rutting, which ranges from 1.27 to 2.54 cm (0.5 to 1.0 inches), and deep rutting, which ranges from 2.54 to 7.62 cm (1.0 to 3.0 inches). Rutting is recorded as the percent of the area having the distress for the sample unit.

AC patches, faulted joints, slabs with reflected cracks, punchouts, and shoulder condition are also collected for overlaid pavements. The collection procedure for these manifestations is similar to that employed for non-overlaid pavements.

6.3.3 Condition Survey Forms

Three survey sheets were designed for use in the field data collection. As illustrated in Figure 6.1, all the information necessary for the identification of the test section is recorded in survey sheet No. 1. Such identification includes the district number and county name where the section is located, the control-section-job number for the construction project, the highway number and classification, number of lanes, direction being surveyed, survey date, rater's initials, a verbal description of the location, the roadbed type, and horizontal alignment for the test section.

The same CFTR numbering system employed for the condition survey of CRC pavements was also adopted for our survey. The CFTR is a five-digit number whose first two digits indicate the Texas district number in which the section is located; the last three digits are the consecutive numbering of the projects surveyed for that district. The number of the section for that pavement project is also recorded (e.g., the number 18025-2 refers to the second test section of a pavement project located in District 18, where there are 24 pavement projects already surveyed).

For the visual condition survey, one form for overlaid and another for non-overlaid concrete pavements were used, as shown in Figures 6.2 and 6.3. Similar to sheet 1, these forms contain the CFTR number, date of survey, and rater's initials. Latitude, longitude, and the reference markers for the start and end points of the test section are also recorded in these forms. Each of the survey forms contains the pertinent spaces to record the distress manifestations. A few lines are also included for a brief description of the shoulder condition and for general comments.

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

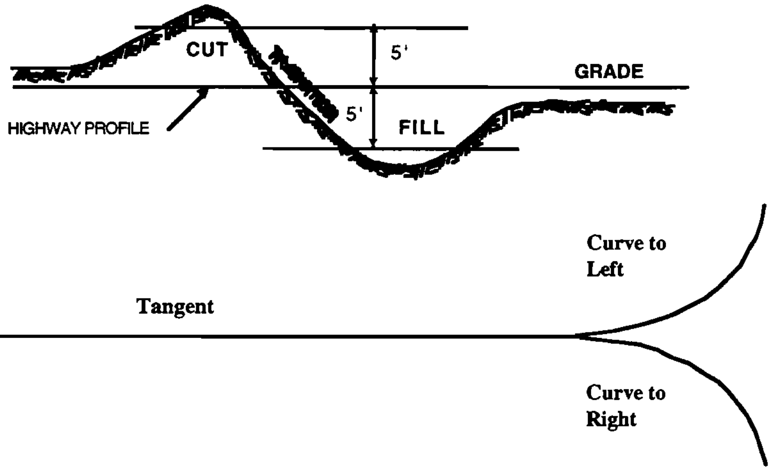


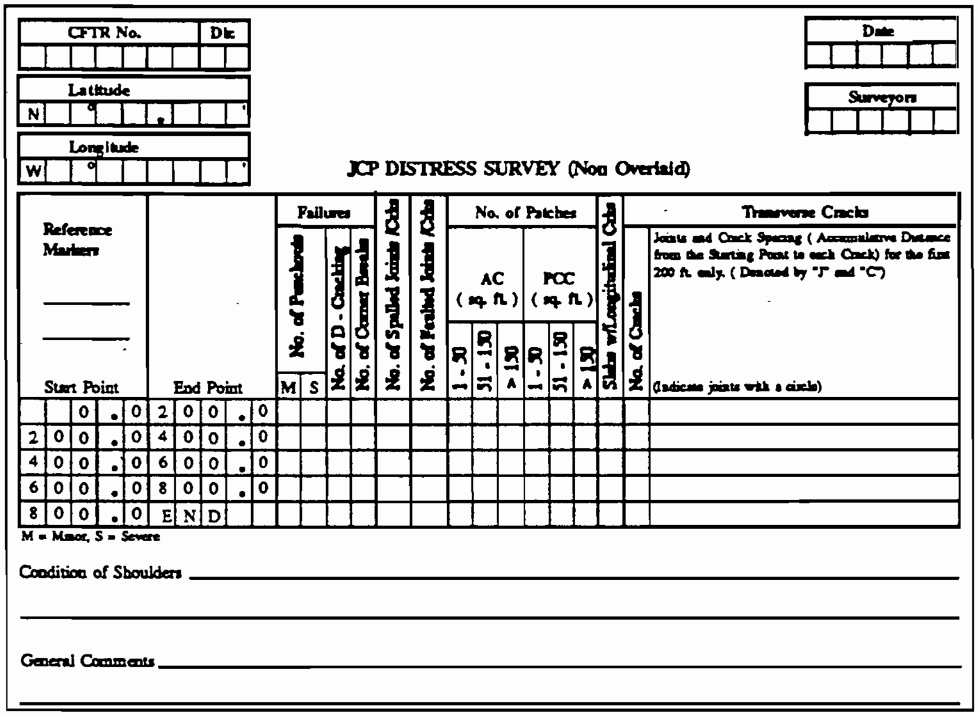
Figure 6.1. Survey form for identification of the test section (Sheet 1)

6.3.4 Pilot Study

A pilot study reviewed the survey forms for possible problems. Because the survey teams had extensive experience with condition surveys relating to CRCP pavements, very little additional training was required for their survey of JCP sections. Major differences in the JCP survey included the definition, level of distress, and procedures used to measure distresses not present in CRC pavements (e.g., corner breaks and faulted joints). A short training program instructed the team on the use of the JCP forms.

6.3.5 Global Positioning System (GPS)

A pilot study evaluated the use of GPS equipment in pavement condition surveys. While such equipment proved inadequate for locating test sections (primarily because its degree of imprecision exceeds 60.69 m [200 feet]), we nevertheless decided to include the GPS latitude and longitude information in the data base. (In the near future, when more accurate systems are developed and when current military restrictions are lifted, GPS systems should prove extremely reliable in identifying test sections.)



CFTR No. | Dir

Latitude N ° . '

Longitude W ° '

Date

Surveyors

JCP DISTRESS SURVEY (Non Overlaid)

Reference Markers

______

______

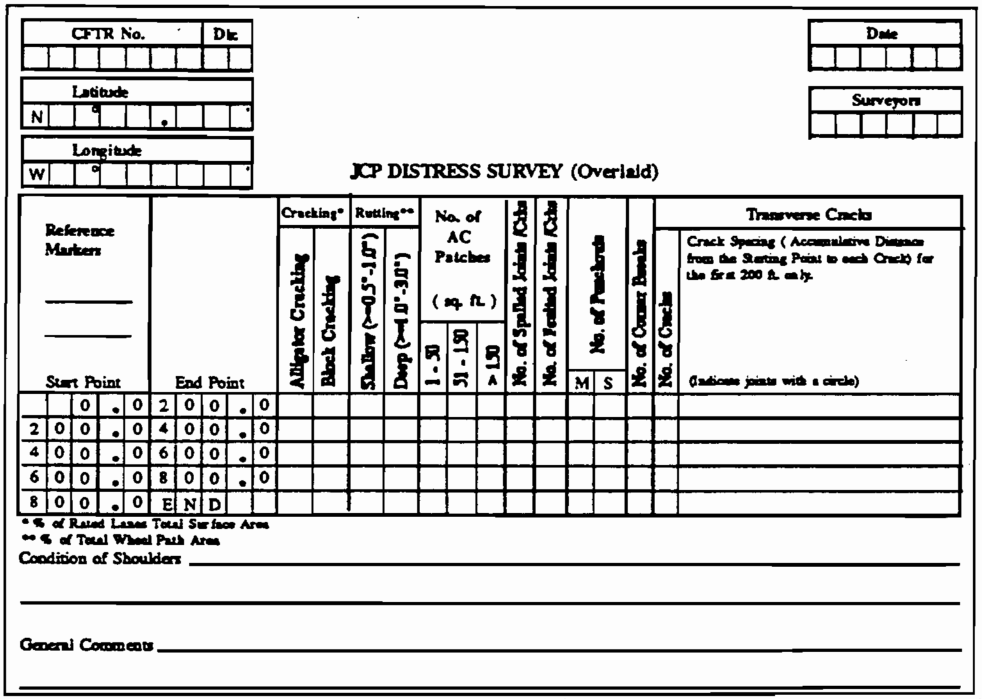
Start Point	End Point	Failures: No. of Punchouts M	Failures: No. of Punchouts S	No. of D - Cracking	No. of Corner Breaks	No. of Spalled Joints /Cks	No. of Faulted Joints /Cks	No. of Patches AC (sq. ft.) 1 - 50	51 - 150	> 150	PCC (sq. ft.) 1 - 50	51 - 150	> 150	Slabs w/Longitudinal Cks	Transverse Cracks: No. of Cracks	Joints and Crack Spacing (Accumulative Distance from the Starting Point to each Crack) for the first 200 ft. only. (Denoted by "J" and "C") (Indicate joints with a circle)
0.0	200.0															
200.0	400.0															
400.0	600.0															
600.0	800.0															
800.0	END															

M = Minor, S = Severe

Condition of Shoulders ______

General Comments ______

Figure 6.2. *Condition survey form for non-overlaid pavements (Sheet 2a)*



CFTR No. | Dir

Latitude N ° . '

Longitude W ° '

Date

Surveyors

JCP DISTRESS SURVEY (Overlaid)

Reference Markers

______

______

Start Point	End Point	Cracking*: Alligator Cracking	Cracking*: Block Cracking	Rutting**: Shallow (>=0.5"-1.0")	Rutting**: Deep (>=1.0"-3.0")	No. of AC Patches (sq. ft.) 1 - 50	51 - 150	> 150	No. of Spalled Joints /Cks	No. of Faulted Joints /Cks	No. of Punchouts M	No. of Punchouts S	No. of Corner Breaks	Transverse Cracks: No. of Cracks	Crack Spacing (Accumulative Distance from the Starting Point to each Crack) for the first 200 ft. only. (Indicate joints with a circle)
0.0	200.0														
200.0	400.0														
400.0	600.0														
600.0	800.0														
800.0	END														

* % of Rated Lanes Total Surface Area

** % of Total Wheel Path Area

Condition of Shoulders ______

General Comments ______

Figure 6.3. *Condition survey form for overlaid pavements (Sheet 2b)*

6.4 CONDITION SURVEY PROCEDURES

The following outlines the main procedures and tools used in the visual condition survey of the JCP test sections.

6.4.1 Procedures

Procedures developed by Chou (Ref 11) were adopted for the field condition survey. First, two-member survey teams were sent into the field to identify the JCP projects, using the location information provided from the design plans. A verbal description was provided, along with the start and end mileposts for the location of every project. Once a JCP project was identified, the number of test sections was selected according to the length of the project. The procedure used to survey every section is summarized below:

1. Once the test section is identified, the odometer of the vehicle is used to roughly define the start and end points of the test section. The odometer is sufficiently accurate, since subsequent surveys will rely on paint markers (see #3) and GPS coordinates.
2. The vehicle (hazard lights on) is parked on the shoulder close to the end point of the section. Then, the surveyors walk toward the starting point of that test section, in the direction opposite the traffic (for safety reasons). The identification data are recorded on the first survey sheet.
3. Only the outside lane of the roadway is surveyed. The first point (ending point) is marked by spray-painting a 0.30-m (1-foot-long) stripe on the shoulder extending from the pavement edge.
4. For recording the distance, a rolatape is set at zero and placed on the painted stripe. A stripe is marked every 60.96 m (200 feet), with the cumulative distance from the starting point recorded beside the stripe. Since the measurement started backwards from the end point, the distance is marked in the following order: 243.84 m (800 feet), 182.88 m(600 ft), 121.92 m (400 ft) and 200 feet (60.96 m), considering a 304.8-m (1000-foot-long) test section. As a reference for future surveys, the test section is then identified with the CFTR number marked on both ends of the section.
5. The cumulative distance from the starting point to each crack is recorded for the first 60.96 m (200 feet) using a recorder and Rolatape; this measurement is later recorded on the survey sheets.
6. Data collected for each distress are recorded on the second survey sheet. One person measures the distance and marks the pavement, while another counts, for a non-overlaid section, the number of punchouts, D-cracking, corner breaks, spalled joints and cracks, faults, repair patches, and cracks; for an overlaid section, ACP cracking, rutting, repair patches, punchouts, faults, and reflected cracks are recorded. The shoulder condition and any pertinent comments are also recorded.
7. The first 60.96 m (200 feet) of the test section is video-taped to provide an overview of the section. The CFTR test section number is written on cardboard and placed onto the pavement for the video records.
8. Latitude and longitudinal information is obtained from the GPS system and recorded in the survey sheets for the starting point of every test section.

6.4.2 Equipment and check list

The equipment used in collecting field survey information included the following:

1. field survey forms
2. spray paint
3. Rolatape or distance measuring wheel
4. tape recorder
5. video camera and numbered pieces of cardboard for picture identification
6. highway maps for location of projects to survey
7. list of projects with location information
8. safety vests and hats
9. GPS equipment

6.5 CONDITION SURVEY PROBLEMS

The problems encountered during the field condition survey are listed below:

1. Owing to identification problems, some test sections were not surveyed (or were surveyed within different construction projects). Mileposts provided in the field collection lists were not always useful, since some test sections were already identified with reference markers in the field. Although a brief description was available in the construction records, some were vague as to the exact location of the project. To overcome such problems, we used the TPPD Road Inventory files to verify that the reference markers of the test sections surveyed fell within the boundaries of the control-section-job project for which design information was collected; otherwise, design information was collected for those test sections.
2. Some test sections fell short of our target 304.8-m (1000-foot) length.
3. The heavy traffic in urban areas did not permit the survey of some test sections.
4. JCP distresses could not be recorded on recently overlaid sections.
5. A few projects believed to be JCP projects turned out to be CRCP or AC pavements. Such errors were most likely the result of information not updated since 1992.

6.6 CONDITION SURVEY SUMMARY STATISTICS

This section discusses the condition survey results in terms of the demographics for the test sections collected. As illustrated in Table 6.1, a total of 68 JCP and JRC pavement projects were surveyed in approximately equal proportion. The number of test sections for each pavement type is also similar, resulting in a total of 145.

Table 6.1. Pavement type distribution

Pavement Type	Projects	Cumulative %	Test Sections	Cumulative %
JCP	32	47.06	73	50.34
JRCP	36	100	72	100

Figure 6.4 shows the distribution of projects over a total of 14 districts. It is clearly observed that the majority of surveys were performed in the districts of Houston, Dallas, and Beaumont, with 18, 15, and 11 construction projects, respectively. The location of the test sections (according to the climatic regions described in Chapter 4) is shown in Figure 6.5.

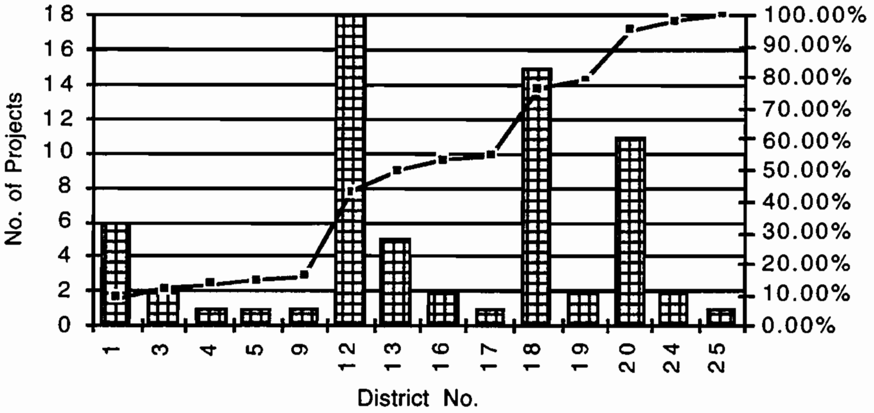


Figure 6.4. Distribution of 68 pavement projects throughout the districts

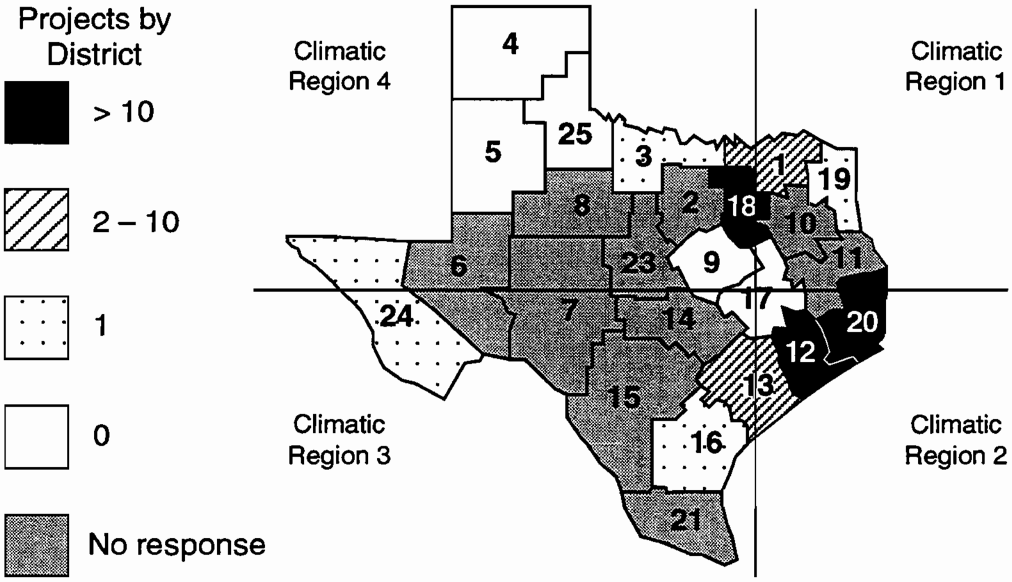


Figure 6.5. Texas map with districts containing projects surveyed

The number of test sections per construction project is summarized in Figure 6.6. This chart shows that more than 80 percent of the projects contain at least two sections, and that a maximum of four test sections was collected per project.

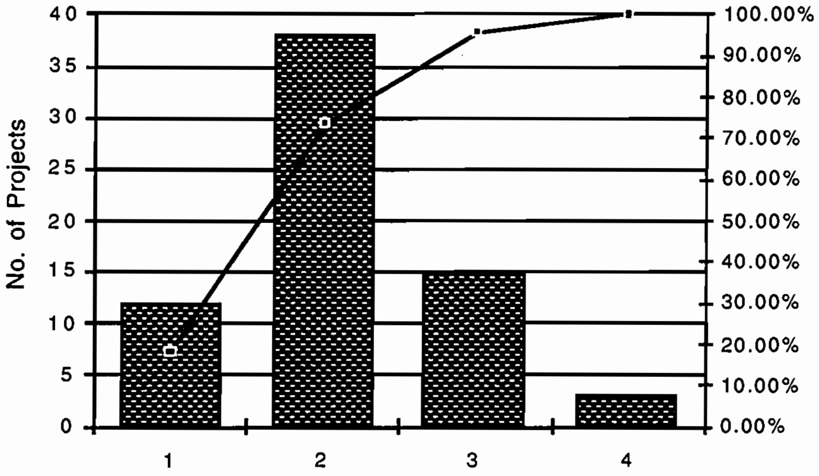


Figure 6.6. Number of test sections per construction project

Figure 6.7 summarizes the highway functional classification distribution of test sections surveyed. It can be observed that the condition survey was mostly performed on test sections for Interstate, U.S., and state highways.

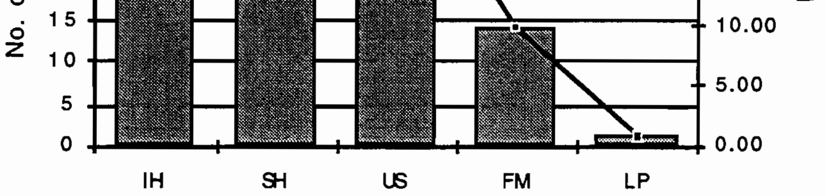


Figure 6.7. Highway functional classification distribution

Figure 6.8 shows the distribution of number of lanes per direction for the test sections surveyed. The majority of the test sections were obtained from highways with two lanes per direction, which is consistent with the functional classification distribution reported previously.

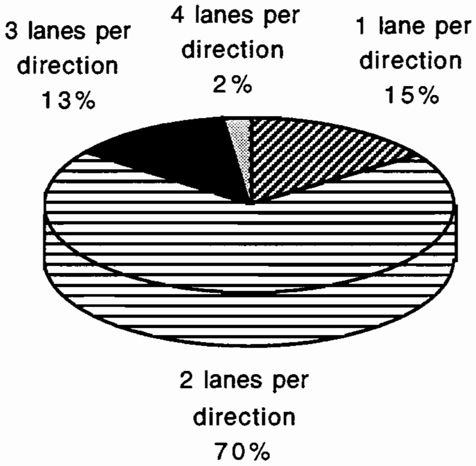


Figure 6.8. Distribution of test section lanes per direction

Figure 6.9 shows the roadbed type distribution in terms of cut, fill, transition, and at-grade sections. This chart reflects the predominantly flat terrain of highways in Texas (i.e., the condition of almost half of the test sections was at-grade).

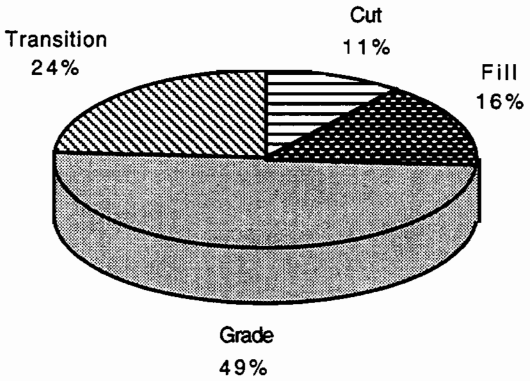


Figure 6.9. Roadbed type distribution

Figure 6.10 shows the age distribution of the test sections. Two main conclusions can be derived from this chart. The projects surveyed are on average 25-27 years old, and around 17 percent of the projects are less than 15 years old. This indicates that, since the midpoint value for the factorial is 15 years, the experimental design is unbalanced in terms of age.

Figure 6.10 shows the age distribution of the test sections. Two main conclusions can be derived from this chart. The projects surveyed are on average 25-27 years old, and around 17 percent of the projects are less than 15 years old. This indicates that since the midpoint value for the factorial is 15 years, the experimental design is unbalanced in terms of age.

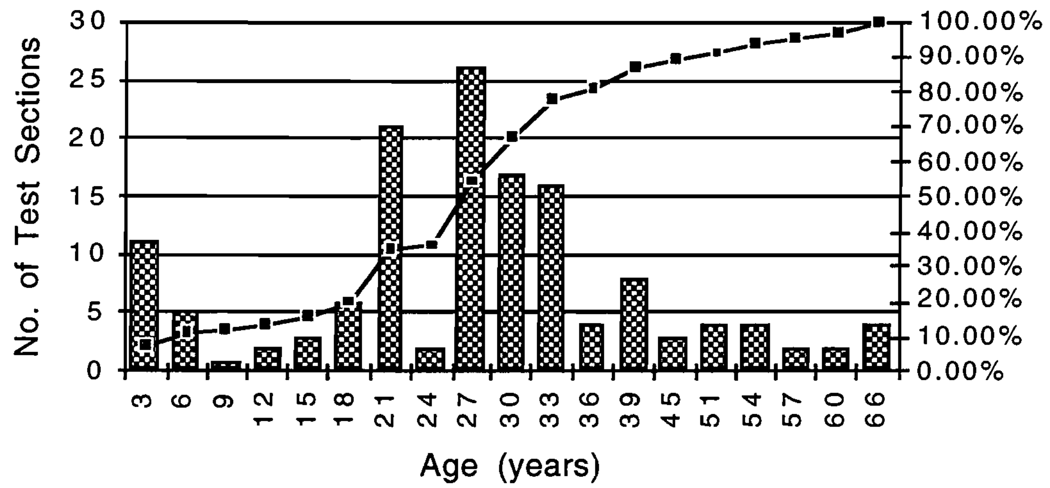


Figure 6.10. Age distribution of test sections surveyed

The number of overlaid vs. non overlaid test sections is presented in Table 6.2. Despite the age of the pavement projects, a good portion of non-overlaid pavements could be captured.

Table 6.2. Overlaid vs. non-overlaid test sections

Status	Frequency	Percent
Non-overlaid	81	55.9
Overlaid	64	44.1

Finally, Table 6.3 shows the coarse aggregate type (CAT) distribution, and Figure 6.11 shows the thickness distribution of the test sections surveyed. Based on the CAT distribution, one-third of the test sections was built with limestone, and almost two-thirds were built with siliceous river gravel aggregates. The thicknesses of test sections ranged from 15.2 to 33 cm (6 to 13 inches), with a significant number of pavements having thicknesses of 25.4 cm (10 inches).

Table 6.3. Coarse aggregate type distribution

Cat	Frequency	Percent
Limestone	48	33.8
Siliceous	88	62.0
Other	6	4.2

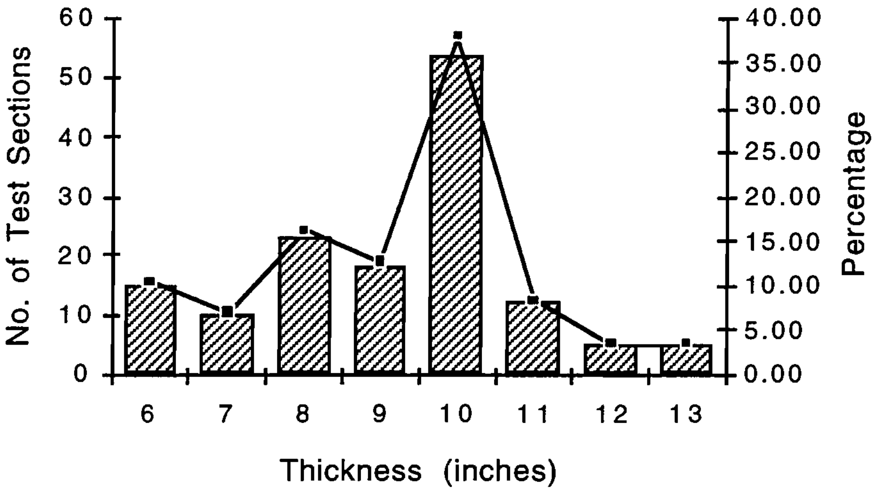


Figure 6.11. Slab thickness distribution (1 inch=2.54 cm)

6.7 CHAPTER SUMMARY

This chapter described the selection of test sections in the field. Along with a uniform length of 304.8 m (1000 feet), most of the procedures were adapted from the procedures proposed for the survey of CRC pavements in Texas. The distress manifestations to be surveyed were defined, along with the collection methods, for overlaid and non-overlaid pavements. In a discussion of the use of GPS systems for identification of test sections in the field, it was concluded that more accurate equipment is needed for this purpose. The procedures observed in the field for data collection were described, and the results obtained in the field were presented in terms of statistical summaries for the test sections collected.

The field collection was performed in 14 districts, for a total of 68 pavement projects investigated and 145 test sections surveyed. A total of 73 JCP and 72 JRCP test sections were collected, providing a balanced number of test sections for each pavement type. Finally, despite the age of the pavement projects selected, 81 non-overlaid and 64 overlaid test sections were collected.

CHAPTER 7. PRELIMINARY DATA ANALYSIS

7.1 INTRODUCTION

In this chapter, condition survey results are presented in terms of a distress index (DI) that represents the distress condition of each of the test sections investigated. A statistical analysis procedure will summarize the performance of the pavement projects according to the different design variables.

7.2 DISTRESS INDEX

As previously discussed in Chapter 2, a distress index would allow researchers to summarize condition survey results and to make comparisons with the design variables collected for every pavement project. Accordingly, we considered developing such a distress index for JCP. This, however, proved untenable for several reasons: (1) Developing a new distress index would require an examination of every distress manifestation in order to determine the limiting amount of distress for every distress type; and (2) relationships between distresses would need to be established through statistical techniques to obtain the weighting factors for use in the distress index equation, in a conceptual approach similar to the one developed by Chou (Ref 11). Thus, a lack of essential distress information, coupled with the need to perform several other time-consuming tasks, rendered this option beyond the scope of the study.

As an alternative, we decided that the distress index developed by Chou (Ref 11) could be used as a preliminary indicator of the performance of the pavement sections surveyed. Yet, at the same time, we were aware of the obvious limitations inherent in such an approach: For example, since that distress index was obtained from a CRCP population, it cannot precisely represent all of the distress manifestations commonly observed in jointed concrete pavements. Nevertheless, we considered Chou's distress index adequate for studying the relationships between pavement condition and pavement design variables. Thus, the distress index equation developed by Chou (Ref 11) is expressed as:

$$Z = 1.0 - 0.0071 (MPUNT) - 0.3978 (SPUNT) -.4165 (PATCH) \qquad \text{(Eq. 7.1)}$$

where:

Z = Distress Index or Zeta score,
MPUNT = minor punchouts per mile + 1,
SPUNT = severe punchouts per mile + 1, and
PATCH = total patches per mile + 1.

We expected this equation to provide a rough estimate of the distress level of every pavement test section. This will be shown in the following sections.

7.3 PAVEMENT CONDITION BY DISTRICTS

To summarize the average pavement condition for each of the different districts where pavements were investigated, it was necessary to classify every test section according to the cumulative traffic loads and presence of asphalt overlays. For this purpose, cumulative traffic loads were categorized as "LOW" for less than 20×10^6 ESAL applications, and considered as "HIGH" for 20×10^6 or more ESAL applications. In the same fashion, overlaid and non-overlaid test sections were separately studied.

7.3.1 DI for Non-overlaid Test Sections

Figure 7.1 shows the average distress index for non-overlaid test sections in the different districts (according to the levels of load applications previously described). As expected, test sections with low traffic loads showed an average distress index above 0.5, scoring higher than those with more load applications. Particular cases, such as represented by District 5, can be analyzed only by considering all the design variables involved for these pavements.

7.3.2 Distress Index for Overlaid Test Sections

The pavement condition of overlaid test sections proved to be much better than that for the non-overlaid test sections. From Figure 7.2, it may also be observed that pavements with low traffic loads demonstrated a better pavement condition than those with a greater number of load applications. In the case of District 20, where the opposite is true, pavements with high cumulative load applications could have been recently overlaid (obscuring their real condition) or they could have been designed under a better set of design variables.

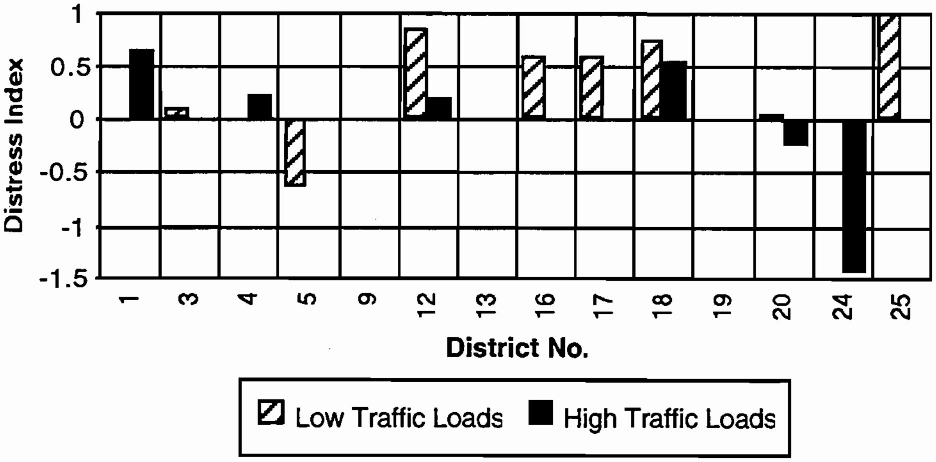


Figure 7.1. Average DI according to load applications for non-overlaid pavements

Figure 7.2. Average DI according to load applications for overlaid pavements

7.3.3 Comparison of DI for Overlaid and Non-overlaid Test Sections

Figure 7.3 compares overlaid and non-overlaid test sections in terms of a distress index. In general, overlaid sections were in better condition in every traffic category.

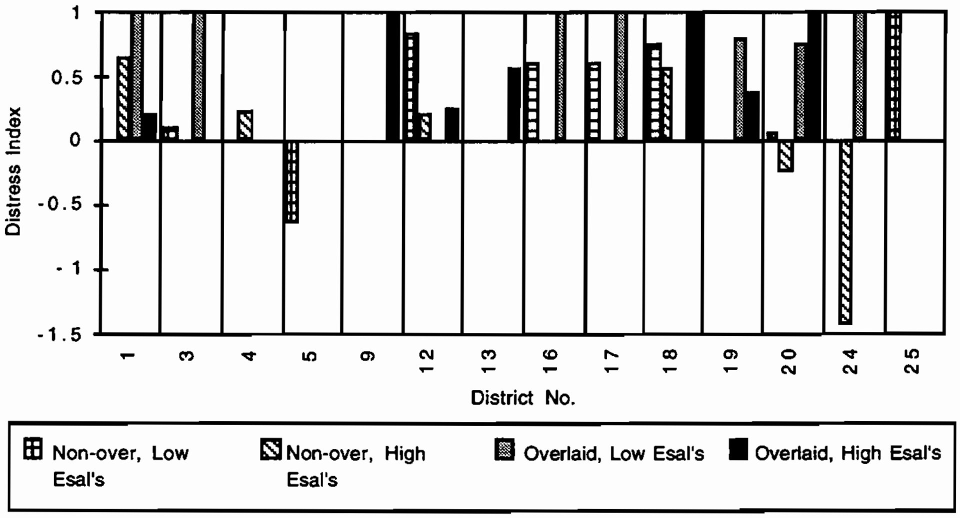


Figure 7.3. Average DI according to load applications for overlaid and non-overlaid pavements

7.4 ANALYSIS OF DISTRESS INDEX AS RELATED TO DESIGN VARIABLES

For the preliminary analysis of pavement performance (as related to the several design variables), the factorial design discussed in previous chapters served as the experimental design for the analysis procedure that follows. We classified pavement sections as either plain or reinforced, and then performed an analysis of variance (ANOVA) for each pavement type.

Again, overlaid and non-overlaid sections showed significant differences in terms of pavement condition. As a first step, we considered analyzing overlaid and non-overlaid test sections separately; however, the insufficient degree of freedom in the model led us to combine the analyses, with overlay status included as a factor.

The factorial design was defined in terms of two-level factors; these included age, coarse aggregate type, freezing index, moisture, slab thickness, and presence of load transfer devices or slab length — all according to the pavement type. The following analysis introduces cumulative ESALs replacing age, average temperature for the coldest month replacing freezing index, average annual precipitation replacing moisture, and slab thickness used as a continuous variable. The factors introduced in the analysis are shown in Table 7.1.

Table 7.1. Factors considered in the preliminary analysis

Variable	Abbreviation	Type
Cumulative ESALs	TOTESAL	Continuous
Average Temperature for the coldest month	COLD	Continuous
Average Annual Precipitation	RAIN	Continuous
Coarse Aggregate Type	CAT	Class
Slab Thickness	THK	Continuous
Dowels (for plain JCP)	DOW	Class
Slab Length (for JRCP)	SLGTH	Continuous
Overlay Status	OVER	Class

Introducing continuous variables for traffic, thickness, and environmental variables is expected to give better results for the analysis.

7.4.1 ANOVA for Plain JCP Test Sections

An analysis of variance was performed using the General Linear Models (GLM) procedure available in the SAS programming language (a procedure capable of analyzing unbalanced designs). Table 7.2 shows the results for the model, including the most significant variables. With 72 observations introduced, we obtained an R-Square of 0.77 and 54 degrees of freedom for error computation.

Two types of sum-of-square errors and probabilities are reported: TYPE I lists the sum of squares for each variable as if they were entered one at a time into the model in the order specified to the program (thus, if there is any variance that is common to two or more variables, it will be attributed to the variable that is entered first); TYPE III sum of squares gives the sum of squares that would be obtained for each variable if it were entered last into the model. This means that the effect of each variable is computed after considering all other factors.

The results presented here are the product of several attempts to find the best arrangement of variables capable of producing a model that optimizes the significance of the F-probabilities for the TYPE III sum of squares.

Table 7.2. Summary of ANOVA results for plain jointed concrete pavements

Source	**DF**	**Sum of Squares**	**Pr>F**	**R-Square**
Model	17	28.01229895	0.0001	0.771886
Error	54	8.27840631		
Corrected Total	71	36.29070526		

Variables	**DF**	**Type I SS**	**Pr > F**	**Type III SS**	**Pr > F**
TOTESAL	1	1.77579494	0.0013	0.78955809	0.0273
TOTESAL*CAT	1	1.13778787	0.0087	2.23455107	0.0003
RAIN	1	0.30877371	0.1616	0.38366552	0.1195
THK	1	1.94905891	0.0008	2.39300975	0.0002
DOW	1	0.23839463	0.2178	7.45444341	0.0001
CAT	1	1.84475457	0.0010	1.46411283	0.0032
OVER	1	0.03495420	0.6349	3.30467882	0.0001
THK*CAT	1	0.01196614	0.7810	2.25694929	0.0003
TOTESAL*THK	1	0.21947527	0.2367	1.47168792	0.0031
RAIN*COLD	1	0.95899856	0.0154	0.88604188	0.0197
RAIN*THK	1	0.04595016	0.5863	0.71846683	0.0348
RAIN*DOW	1	10.23494371	0.0001	6.96011123	0.0001
RAIN*OVER	1	0.47277333	0.0847	2.87943960	0.0001
COLD*DOW	2	3.05667479	0.0002	6.19445134	0.0001
CAT*OVER	1	2.13197814	0.0005	3.02335656	0.0001
THK*DOW	1	3.59002001	0.0001	3.59002001	0.0001

Number of observations in data set = 73
Dependent Variable: Z

7.4.2 ANOVA for Reinforced JCP Test Sections

Table 7.3 summarizes the findings obtained through the ANOVA performed on JRCP test sections. In general, the factorial for JRCP test sections showed results less positive than those for the factorial for plain JCP. Several factors were not identified as significant at the 5-percent level of confidence; a modest R-Square of 0.55 is the result of that analysis.

Despite the approximate distress index selected to estimate the performance of the pavement test sections investigated, good results were obtained from the ANOVAs performed on both pavement types. However, we strongly recommend the development of a more appropriate distress index equation that can account for distresses that are characteristic of jointed concrete pavements.

Table 7.3. Summary of analysis of variance results for JRC pavements

Source	DF	Sum of Squares	Pr > F	R-Square	
Model	12	19.34630241	0.0001	0.550704	
Error	56	15.78379731			
Corrected Total	68	35.13009972			
Variables	**DF**	**Type I SS**	**Pr > F**	**Type III SS**	**Pr > F**
TOTESAL	1	1.67764951	0.0179	2.60107547	0.0036
COLD	1	4.88597953	0.0001	1.58022939	0.0214
TOTESAL*CAT	1	1.39353169	0.0302	0.34495167	0.2733
SLGTH	1	0.29379286	0.3117	1.55233707	0.0225
RAIN	1	1.86074661	0.0129	0.37941433	0.2509
OVER	1	3.63173771	0.0007	1.71547432	0.0167
COLD*THK	1	0.13373708	0.4938	1.88940099	0.0122
RAIN*THK	1	0.26305630	0.3382	0.87301955	0.0839
TOTESAL*RAIN	1	1.77679220	0.0150	2.94479948	0.0021
SLGTH*THK	1	0.88437957	0.0819	1.73863884	0.0160
COLD*RAIN	1	0.15337095	0.4638	0.69913489	0.1209
SLGTH*OVER	1	2.39152840	0.0051	2.39152840	0.0051

Number of observations in data set = 69
Dependent Variable: Z

7.5 CHAPTER SUMMARY

This chapter presented the results of the condition survey summarized in a distress index equation. The pavement condition was represented by the distress index developed by Chou, and the average pavement performance was summarized as attributed to the different districts and under varied cumulative traffic loads and overlay pavement status. Significant findings were that pavement condition is much better for sections that experience low traffic loads and are constituted of overlaid pavements.

An ANOVA was performed for both plain JCP and JRCP test sections. The factorial designs were considered a basis for the analytical procedures that required the inclusion of overlay status. In addition, continuous values for such variables as traffic, thickness, precipitation, and temperature were used in place of their category counterparts.

In general, the ANOVAs on both pavements showed positive results in terms of significant factors and two-way interactions. The chapter concludes by recommending the development of a better distress index equation — one that could account for the common distress manifestations found in jointed concrete pavements.

CHAPTER 8. DATABASE DEVELOPMENT AND IMPLEMENTATION

8.1 INTRODUCTION

All components for the database previously presented were based on an extensive literature survey and on engineering work. With the database design factors, performance variables, and identification information having been collected, this chapter explains the tasks performed for the design, structure, and organization of the database. In addition, it makes suggestions for possible implementation.

8.2 DESIGN AND STRUCTURE OF THE DATABASE

For reasons of compatibility and uniformity, we decided that, in designing the JCP database, we would follow closely the guidelines used to design CTR's existing CRCP database (Ref 2).

8.2.1 Language

Several attributes were considered in selecting the JCP database language. Such characteristics as continuous support, ease of use, power, portability, and internal documentation commended the use of the SAS programming language for information storage. SAS programming language contains database, statistical, and reporting capabilities supported in a variety of platforms, among them The University of Texas' IBM 3081 mainframe, IBM's PCs, and TxDOT's IBM mainframe.

8.2.2 Contents and Organization

The database is divided into five separate files: master file, condition survey file, crack spacing file, traffic data file, and maintenance data file. These are described below.

Master File: As illustrated in Table 8.1, this file contains all the identification and design information. The main fields include the CFTR and construction project number, completion date, location, structural, and environmental information. Appendix A contains a partial listing of the master file.

Condition Survey File: This file includes all the information collected from the field for every test section surveyed. The CFTR number permits the connection of the information contained in the condition survey file with the master file and the other files composing the database. Table 8.2 lists the name and provides a brief description of the items stored in this file. Location, geometric details, and distresses surveyed in the field form the main body of this file. Appendix B contains a partial listing of the condition survey file.

Crack Spacing File: Information on crack spacing was included in a separate file. The cumulative distance from the first point of each test section to every crack for the first 200 feet (60.96 m) was collected in the field. Table 8.3 illustrates the contents of this file.

Table 8.1. Master file contents

Item	Description
CFTR	Section id number
SECT	Subsection surveyed
DIR	Direction surveyed
COUNTY	County name
HWY	Highway designation
CTRL	TxDOT control number
SEC	TxDOT section number
JOB	TxDOT construction job number
PVT	Pavement type: 1 = plain, 2 = reinforced
CDATE	Project completion date (years)
MP1	Beginning milepost for the construction project (Interstate highways)
MP2	Ending milepost for the construction project (Interstate highways)
RM1	Beginning reference marker for the construction project (Texas highways)
RM2	Ending reference marker for the construction project (Texas highways)
LEN	Project length (miles)
D	Pavement thickness (in.)
DOW	Presence of load transfer devices (dowels)
CAT	Coarse aggregate type: 1 = limestone, 2 = SRG, 3=1&2, 4 = other
SBT	Subbase type: 1=ac treated, 2=pc treated, 3=lime treated, 4=crshd. stone
SHLD	Shoulder type
SOIL	Y for swelling soil, N if not
COLD	Average lowest temperature (°F)
HOT	Average highest temperature (°F)
RAIN	Average annual rainfall (in.)
CD	Coefficient of drainage

Table 8.2. Condition survey file contents

Item	Description
CFTR	Section ID number
SECT	Subsection surveyed
DIR	Direction surveyed
DATE	Date surveyed
LANES	Number of lanes (each direction)
RATER	Rater code
RBD	Roadbed type: c = cut, f = fill, t = transition, g = at grade
CURVE	Horizontal curve (y or n)
OVER	Overlay (y or n)
MP1	Beginning milepost for the subsection surveyed (Interstate highways)
MP2	Ending milepost for the subsection surveyed (Interstate highways)
RM1	Beginning reference marker for the subsection surveyed (Texas highways)
RM2	Ending reference marker for the subsection surveyed (Texas highways)
LEN	Length surveyed (ft)
MPO	Minor punchouts
SPO	Severe punchouts
DCRK	Number of durability "D" cracking
CBRKS	Number of corner breaks
SPALL	Number of spalled longitudinal and transverse joints/cracks
FAULT	Number of faulted of transverse joints/cracks
ACP1	Number of asphalt patches (1-50 sq. ft. / .09-4.64 m^2)
ACP51	Number of asphalt patches (51-150 sq. ft. / 4.74-13.9 m^2)
ACP150	Number of asphalt patches (>150 sq. ft. / 13.9 m^2)
PCC1	Number of portland cement concrete patches (1-50 sq. ft. / .09-4.64 m^2)
PCC51	Number of portland cement concrete patches (51-150 sq. ft. / 4.74-13.9 m^2)
PCC150	Number of portland cement concrete patches (>150 sq. ft. / 13.9 m^2)
LCRK	Number of slabs with longitudinal cracks
TCRK	Number of transverse cracks for first 200 ft. (60.9 m)
ACRK	Alligator cracking (% of rated lanes total surface area)
BCRK	Block cracking (% of rated lanes total surface area)
SRUT	Shallow rutting (% of total wheel path area)
DRUT	Deep rutting (% of total wheel path area)

Table 8.3. Crack spacing file

Item	Description
CFTR	Section ID number
SECT	Subsection surveyed
DIR	Direction surveyed
CRK	Individual crack spacing

Traffic Data File: This file contains the cumulative AADT history for every test section (dating from initial project construction). Additional items include the CFTR number for indexing with other files, and such traffic factors as truck percentage, directional distribution, average ten heaviest wheel loads (ATHWL), and estimated 18-kip ESALs, as shown in Table 8.4.

Table 8.4. Traffic file contents

Item	Description
CFTR	Section ID number
SECT	Subsection
DIR	Direction
AADT	Annual average daily traffic
PTRUCK	Percent trucks
DIST	Directional distribution
ATHWL	Avg. 10 heaviest wheel loads
PTAND	Percent tandem axles
ESAL	18-kip equivalent single axle loads (estimated)

Maintenance and Rehabilitation Data File: As shown in Table 8.5, this file contains the complete M&R history of the pavement, including overlay thickness and such miscellaneous activities as seal coats, shoulder improvement, slurry seals, and the widening of existing concrete. It is important to note that M&R activities are current only up to 1992.

Table 8.5. Maintenance and rehabilitation file contents

Item	Description
CFTR	Section ID number
SECT	Subsection
DIR	Direction
OV1-OV3	Date of first three overlays
OVT1-OVT3	Thickness of first three overlays (in.)
MISC	Description and date of miscellaneous activities
COMM	Comments

Developing the database was mainly a matter of generating SAS programs to read raw data input into a PC or Macintosh computer; from this input, corresponding SAS permanent data sets were created for storage in the IBM 3081 mainframe computer located at The University of Texas at Austin. Figure 8.1 shows the steps considered in creating the final permanent data sets.

8.2.3 Access

The database for JCP pavements will be located on the same disk and file that contains the CRCP database. A 1989 CTR report (Ref 2) provides the necessary instructions and procedures for handling the data in the CRCP database. These same instructions and procedures are applicable to the JCP database. Essentially, the database is accessed from the IBM mainframe computer located at The University of Texas at Austin (running under CMS) by typing the following commands:

```
CP LINK FTAO152 196 195 RR P472

ACCESS 195 Q
```

It is recommended that users acquaint themselves with the list of variables contained in each data set. If just one data set is needed, the user can gain immediate access to SAS procedures for analysis and reports. If two or more files are required for the data needed in the analysis, it will be necessary to merge them with an SAS data step. Appendix C lists some of the SAS programs used in developing the SAS database.

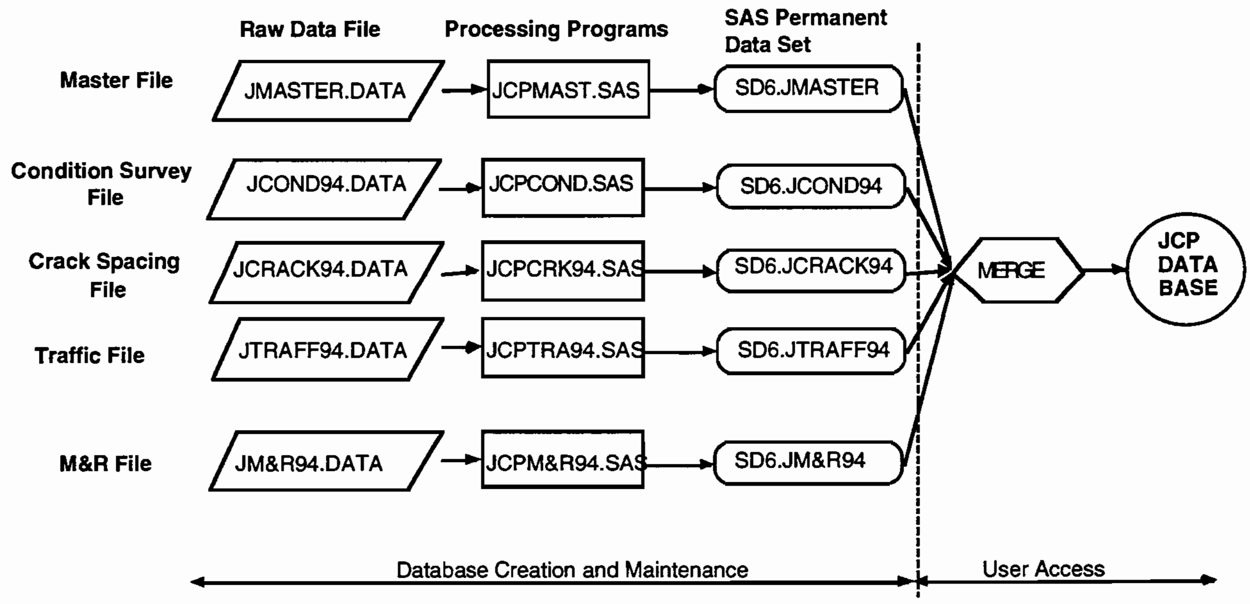


Figure 8.1. Steps used in creating the database

8.3 DATABASE IMPLEMENTATION

The JCP database developed in this project provides information on the actual pavement condition (in terms of distress manifestations) of a sample of pavement projects extracted from the Texas JCP network. Structural characteristics and information on time, environment, and traffic exposure of each of the pavements selected have been included. In developing the database, we envisioned an implementation plan that included the items presented below.

8.3.1 PMS

This database will provide the information needed to develop and update the pavement performance prediction models to be incorporated in the Texas PMS design module. The continuous updating of the database through pavement surveying and monitoring will provide the feedback necessary to maintain a reliable Pavement Management Information System.

8.3.2 Implementation with Other Studies

Overlay Design: Information on the design factors and distress condition of overlaid pavements will yield a better understanding of the factors to be considered in designing ACP overlays for use on rigid pavements.

Coarse Aggregate Type Studies: The sampling factorial procedure considered the inclusion of pavements built with limestone and siliceous river gravel aggregates. Information on the performance of the pavement selected will permit the evaluation of sections built with different coarse aggregate types.

Distress Index Equations: Although this database contains information on a single condition survey, future condition surveys can build on this effort, providing in time the kind of information required for the development of more reliable distress index equations for use with JCP pavements.

Pavement Design Studies: The database includes recently built pavements of greater thicknesses. Tracking the performance such designs can be used to improve pavement design procedures.

8.4 CHAPTER SUMMARY

This chapter presented all the procedures required for the manipulation and storage of the information collected. The SAS programming language was selected for the generation of the permanent databank to be stored in the IBM 3081 mainframe located at The University of Texas at Austin. Four data sets compose the JCP database: the master file (containing identification and design information), the condition survey file (containing all data items collected in the field), the crack spacing file, and the traffic data file. Finally, several database applications were presented.

CHAPTER 9. CONCLUSIONS AND RECOMMENDATIONS

9.1 SUMMARY

This report documented the development of a jointed concrete pavement database. In this effort, we identified the main variables affecting pavement performance, including common JCP distress manifestations. With the use of a sampling factorial procedure, several pavement projects were selected for a statewide field condition survey. A distress index was used to obtain a general overview of the current condition of the surveyed pavements. Finally, all the information collected was stored into a computerized database that will allow other researchers to retrieve specific information for use in pavement research. This chapter presents the conclusions and recommendations drawn from this study.

9.2 CONCLUSIONS

Following the selection of significant design variables from mechanistic and empirical points of view, an experimental design was used to form the basis for the statewide selection of pavement projects. The only major limitation was the unavailability of test sections having the design characteristics that, if included, would provide a balanced factorial experiment.

From a survey of Texas JCP projects, 193 were selected for inclusion in the database. However, only 166 of such projects met the requirements for the factorial; this number was further reduced according to the collection plan and to time and resource constraints. At present, 68 projects have been surveyed, for a total of 145 pavement test sections.

A preliminary analysis performed on the pavements involved capturing the condition survey results through a distress index equation. Several variables, showed to be significant from the ANOVA models and from the distress index equation, provided reliable results. Nevertheless, we urge that a more appropriate distress index be developed for jointed concrete pavements.

Finally, the system adopted for developing the database proved effective in handling information, creating reports, and performing powerful statistical analysis.

9.3 RECOMMENDATIONS

In addition to routine maintenance, the JCP database developed in this study will require updating through the input of (1) periodic pavement condition surveys, (2) new concrete pavement projects, and (3) structural information gained through future diagnostic surveys. The following are recommendations for the continuing development of the database:

1. Maintenance and rehabilitation information is an essential part of a database that will be used to develop pavement performance models. For the present database, minimum M&R information was collected (e.g., overlay date and thickness, seal coats, and shoulder improvement). We suggest a procedure capable of obtaining more comprehensive maintenance and rehabilitation information be developed.

2. It is important that the database be constantly updated through the continued survey of JCP pavements in Texas. It is also necessary to add to the database new JCP projects selected through a re-analysis of the factorial design that will keep distress and performance prediction models actualized.
3. The database also requires information on deflections, roughness, and pavement profile characteristics (i.e., information provided by diagnostic surveys). This will permit a better assessment of pavement condition in terms of structural characteristics and will enhance the performance of the prediction models.
4. The distress index used for this study was introduced only as a preliminary measure for the evaluation of results obtained in developing the database. Therefore, it is strongly recommended that a more accurate distress index for jointed concrete pavements be developed.
5. While the use of the GPS for test section location did not prove effective in this study, we nevertheless expect that more accurate systems will be available in the future. Hence, its use is encouraged for future field survey investigation. An improved GPS will better link with other databases and will more easily identify test sections in the field.

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APPENDIX A:

MASTER FILE LISTING

Table A.1 Master File Partial Listing

CFTR	SECT	DIR	COUNTY	HWY	CTRL	SEC	JOB	PVT	CDATE	THK	CAT	DOW	SLGTH
1101	1	S	HUNT	US0069	202	10	8	PL	1980.22	9	L	Y	15.0
1101	2	S	HUNT	US0069	202	10	8	PL	1980.22	9	L	Y	15.0
1101	3	S	HUNT	US0069	9	15	1	PL	1955.37	10	L	N	15.0
1102	1	E	HOPKINS	IH0030	10	2	11	PL	1956.88	10	L	Y	15.0
1102	2	E	HOPKINS	IH0030	10	2	11	PL	1956.88	10	L	Y	15.0
1601	1	E	LAMAR	US0082	45	9	12	PL	1946.78	8	S	Y	13.3
1601	2	E	LAMAR	US0082	45	9	12	PL	1946.78	8	S	Y	13.3
3589	1	S	WICHITA	SH0240	156	3	15	PL	1958.96	10	L	N	15.0
3589	2	S	WICHITA	SH0240	156	3	15	PL	1958.96	10	L	N	15.0
3589	3	S	WICHITA	SH0240	156	3	15	PL	1958.96	10	L	N	15.0
3593	1	N	WILBARGE	US0287	43	5	37	PL	1965.55	10	L	N	15.0
4101	1	N	DALLAM	US0087	40	3	12	RF	1940.2	6	S	.	30.0
4101	1	S	DALLAM	US0087	40	3	12	RF	1940.2	6	S	.	30.0
5601	1	E	PARMER	SH0086	302	1	1	RF	1940.53	6	S	.	20.0
5601	1	W	PARMER	SH0086	302	1	1	RF	1940.53	6	S	.	20.0
9601	1	N	LIMESTON	SH0014	93	5	7	RF	1935	6	S	.	78.5
9601	2	N	LIMESTON	SH0014	93	5	7	RF	1935	6	S	.	78.5
12505	1	S	BRAZORIA	SH0035	179	1	14	RF	1955.13	10	S	.	30.0
12505	2	N	BRAZORIA	SH0035	179	1	14	RF	1955.13	10	S	.	30.0
12509	1	N	MONTGOME	IH0045	110	4	36	PL	1960.13	6	S	N	15.0
12509	2	N	MONTGOME	IH0045	110	4	36	PL	1960.13	6	S	N	15.0
12509	3	N	MONTGOME	IH0045	110	4	36	PL	1960.13	6	S	N	15.0
12509	4	N	MONTGOME	IH0045	110	4	36	PL	1960.13	6	S	N	15.0
12513	1	N	MONTGOME	IH0045	110	4	37	PL	1960.8	11	S	N	15.0
12513	2	N	MONTGOME	IH0045	110	4	37	PL	1960.8	11	S	N	15.0
12526	1	N	HARRIS	IH0045	110	5	18	RF	1961.96	10	S	.	60.0
12535	1	N	MONTGOME	IH0045	675	8	3	PL	1962.96	8	S	Y	15.0
12535	2	N	MONTGOME	IH0045	675	8	3	PL	1962.96	8	S	Y	15.0
12535	3	N	MONTGOME	IH0045	675	8	3	PL	1962.96	8	S	Y	15.0
12537	1	N	HARRIS	IH0045	110	5	17	RF	1963.29	10	L	.	60.0
12537	2	N	HARRIS	IH0045	110	5	17	RF	1963.29	10	L	.	60.0
12540	1	N	MONTGOME	IH0045	675	8	2	RF	1963.71	10	S	.	60.0
12553	1	N	BRAZORIA	SH0035	178	2	23	RF	1964.8	10	L	.	60.0
12553	2	N	BRAZORIA	SH0035	178	2	23	RF	1964.8	10	L	.	60.0
12554	1	N	BRAZORIA	SH0035	178	3	46	RF	1964.8	10	S	.	60.0

Table A.1 Master File Partial Listing (continued)

CFTR	SECT	DIR	COUNTY	HWY	CTRL	SEC	JOB	PVT	CDATE	THK	CAT	DOW	SLGTH
12564	1	E	HARRIS	US0225	502	1	35	RF	1966.88	10	S	.	60.0
12564	2	E	HARRIS	US0225	502	1	35	RF	1966.88	10	S	.	60.0
12576	1	W	WALLER	IH0010	271	4	17	RF	1967.3	10	S	.	60.0
12590	1	N	GALVESTO	SH0146	389	6	30	RF	1971.89	10	S	.	60.0
12590	2	N	GALVESTO	SH0146	389	6	30	RF	1971.89	10	S	.	60.0
12601	1	N	GALVESTO	SH0003	51	3	6	RF	1928	7	S	.	60.0
12601	2	N	GALVESTO	SH0003	51	3	10	RF	1928	7	L	.	60.0
12602	1	S	GALVESTO	SH0003	51	3	5	RF	1928	7	S	.	60.0
12602	2	S	GALVESTO	SH0003	51	3	5	RF	1928	7	S	.	60.0
12603	1	W	HARRIS	IH0010	271	6	12	RF	1966.88	10	S	.	61.5
12603	2	W	HARRIS	IH0010	271	6	12	RF	1966.88	10	S	.	61.5
12603	3	W	HARRIS	IH0010	271	6	12	RF	1966.88	10	S	.	61.5
12603	4	W	HARRIS	IH0010	271	6	12	RF	1966.88	10	S	.	61.5
12604	1	N	HARRIS	SH0146	389	5	44	RF	1972.47	10	S	.	60.5
12604	2	N	HARRIS	SH0146	389	5	44	RF	1972.47	10	S	.	60.5
12604	3	N	HARRIS	SH0146	389	5	44	RF	1972.47	10	S	.	60.5
12606	1	S	FORTBEND	US0059	27	12	5	RF	1962.6	10	S	.	61.5
12606	2	S	FORTBEND	US0059	27	12	20	RF	1973.33	10	S	.	60.5
12607	1	N	FORTBEND	US0059	27	12	23	RF	1976.14	10	S	.	60.5
12607	2	N	FORTBEND	US0059	27	12	23	RF	1976.14	10	S	.	60.5
12607	3	N	FORTBEND	US0059	27	12	23	RF	1976.14	10	S	.	60.5
13501	1	S	MATAGORD	SH0035	179	4	30	RF	1961.29	10	L	.	60.0
13501	2	S	MATAGORD	SH0035	179	4	30	RF	1961.29	10	L	.	60.0
13509	1	W	AUSTIN	IH0010	271	2	14	RF	1966.8	10	S	.	60.0
13509	2	W	AUSTIN	IH0010	271	2	14	RF	1966.8	10	S	.	60.0
13510	1	W	AUSTIN	IH0010	271	2	15	RF	1966.96	10	S	.	60.0
13510	2	W	AUSTIN	IH0010	271	2	15	RF	1966.96	10	S	.	60.0
13512	1	W	AUSTIN	IH0010	271	3	11	RF	1966.96	10	S	.	60.0
13513	1	W	AUSTIN	IH0010	271	3	12	RF	1967.3	10	S	.	60.0
13513	2	W	AUSTIN	IH0010	271	3	12	RF	1967.3	10	S	.	60.0
16570	1	E	NUECES	SH0357	1069	1	1	RF	1941.78	6	S	.	100.0
16570	2	E	NUECES	SH0357	1069	1	1	RF	1941.78	6	S	.	100.0
16601	1	E	NUECES	FM0665	1052	2	1	PL	1942.28	7	S	N	15.0
16601	2	E	NUECES	FM0665	1052	2	1	PL	1942.28	7	S	N	15.0
17602	1	S	WASHINGT	FM1155	315	12	4	PL	1933	7	L	N	15.0
17602	2	S	WASHINGT	FM1155	315	12	4	PL	1933	7	L	N	15.0

Table A.1 Master File Partial Listing (continued)

CFTR	SECT	DIR	COUNTY	HWY	CTRL	SEC	JOB	PVT	CDATE	THK	CAT	DOW	SLGTH
18120	1	N	DALLAS	SH0342	48	1	22	RF	1969.14	8	S	.	60.5
18120	2	N	DALLAS	SH0342	48	1	22	RF	1969.14	8	S	.	60.5
18164	1	E	DALLAS	SH0352	430	1	19	PL	1965.8	8	L	N	15.0
18164	2	E	DALLAS	SH0352	430	1	19	PL	1965.8	8	L	N	15.0
18164	3	E	DALLAS	SH0352	430	1	19	PL	1965.8	8	L	N	15.0
18170	1	E	DALLAS	LP0244	353	5	42	PL	1959.88	6	L	N	15.0
18525	1	N	DALLAS	IH0035E	196	3	31	PL	1959.63	11	M	Y	12.0
18541	1	E	DALLAS	IH0030	9	11	19	PL	1960.29	8	L	N	15.0
18601	1	N	DALLAS	US0067	261	2	28	PL	1979.97	9	S	Y	15.0
18601	1	S	DALLAS	US0067	261	2	28	PL	1979.97	11	S	Y	15.0
18602	1	N	ELLIS	IH0035E	48	4	50	PL	1990.81	13	L	Y	15.0
18602	2	N	ELLIS	IH0035E	48	4	50	PL	1990.81	13	L	Y	15.0
18602	3	N	ELLIS	IH0035E	48	4	50	PL	1990.81	13	L	Y	15.0
18603	1	E	COLLIN	FM0546	1013	1	8	RF	1970.63	6	S	.	15.0
18603	2	E	COLLIN	FM0546	1013	1	8	RF	1970.63	6	S	.	15.0
18604	1	E	COLLIN	FM3038	3132	1	2	RF	1970.63	6	S	.	15.0
18604	2	E	COLLIN	FM3038	3132	1	2	RF	1970.63	6	S	.	15.0
18605	1	S	KAUFMAN	SH0034	173	4	21	PL	1975.84	8	L	Y	15.0
18605	2	S	KAUFMAN	SH0034	173	4	21	PL	1975.84	8	L	Y	15.0
18606	1	W	KAUFMAN	IH0020	95	14	10	PL	1988.73	12	S	Y	15.0
18606	2	W	KAUFMAN	IH0020	95	14	10	PL	1988.73	12	S	Y	15.0
18606	3	W	KAUFMAN	IH0020	95	14	10	PL	1988.73	12	S	Y	15.0
18607	1	W	ROCKWALL	IH0030	9	12	50	PL	1987.31	11	S	Y	15.0
18607	2	W	ROCKWALL	IH0030	9	12	50	PL	1987.31	11	S	Y	15.0
18607	3	W	ROCKWALL	IH0030	9	12	50	PL	1987.31	11	S	Y	15.0
18608	1	S	DENTON	IH0035E	196	2	62	PL	1983.56	10	L	Y	15.0
18609	1	E	DENTON	SH0121	364	3	63	PL	1991.75	10	L	Y	15.0
18609	2	E	DENTON	SH0121	364	3	63	PL	1991.75	10	L	Y	15.0
18610	1	N	DENTON	IH0035	195	2	35	PL	1990.9	11	L	Y	15.0
18610	2	N	DENTON	IH0035	195	2	35	PL	1990.9	11	L	Y	15.0
18610	3	N	DENTON	IH0035	195	2	35	PL	1990.9	11	L	Y	15.0
19101	1	E	HARRISON	IH0020	495	10	8	PL	1965.8	8	S	Y	15.0
19101	2	E	HARRISON	IH0020	495	10	8	PL	1965.8	8	S	Y	15.0
19101	3	E	HARRISON	IH0020	495	10	8	PL	1965.8	8	S	Y	15.0
19101	4	E	HARRISON	IH0020	495	10	8	PL	1965.8	8	S	Y	15.0
19102	1	W	HARRISON	IH0020	495	10	3	PL	1964.8	8	S	Y	15.0
19102	2	W	HARRISON	IH0020	495	10	3	PL	1964.8	8	S	Y	15.0

Table A.1 Master File Partial Listing (continued)

CFTR	SECT	DIR	COUNTY	HWY	CTRL	SEC	JOB	PVT	CDATE	THK	CAT	DOW	SLGTH
20574	1	N	JASPER	US0096	64	8	24	RF	1977.39	9	S	.	60.0
20574	2	N	JASPER	US0096	64	8	24	RF	1977.39	9	S	.	60.0
20574	3	N	JASPER	US0096	64	8	24	RF	1977.39	9	S	.	60.0
20575	1	N	JASPER	US0096	64	8	16	RF	1971.47	9	S	.	60.5
20575	2	N	JASPER	US0096	64	8	16	RF	1971.47	9	S	.	60.5
20575	3	N	JASPER	US0096	64	8	24	RF	1977.39	9	S	.	60.0
20578	1	S	JEFFERSO	SH0073	508	4	18	PL	1960.29	11	L	N	15.0
20578	2	S	JEFFERSO	SH0073	508	4	18	PL	1960.29	11	L	N	15.0
20584	1	S	JEFFERSO	US0069	200	14	29	RF	1971.3	9	S	.	60.0
20584	2	S	JEFFERSO	US0069	200	14	29	RF	1971.3	9	S	.	60.0
20586	1	W	JEFFERSO	FM365	932	1	39	PL	1975.06	9	L	Y	15.0
20586	2	W	JEFFERSO	FM365	932	1	39	PL	1975.06	9	L	Y	15.0
20587	1	S	JEFFERSO	FM0366	667	2	1	PL	1952.79	8	S	N	15.0
20587	2	S	JEFFERSO	FM0366	667	2	1	PL	1952.79	8	S	N	15.0
20587	3	S	JEFFERSO	FM0366	667	2	1	PL	1952.79	8	S	N	15.0
20590	1	E	LIBERTY	US0090	28	3	59	RF	1970.89	10	S	.	60.0
20590	2	E	LIBERTY	US0090	28	3	59	RF	1970.89	10	S	.	60.0
20601	1	N	JASPER	US0096	64	8	16	RF	1971.47	9	S	.	60.5
20601	2	N	JASPER	US0096	64	8	16	RF	1971.47	9	S	.	60.5
20601	3	N	JASPER	US0096	64	8	16	RF	1971.47	9	S	.	60.5
20602	1	E	JEFFERSO	US0090	28	6	39	RF	1971.97	10	S	.	60.5
20602	2	E	JEFFERSO	US0090	28	6	39	RF	1971.97	10	S	.	60.5
20603	1	N	ORANGE	FM0105	710	2	39	RF	1985.33	9	S	.	60.5
24601	1	N	ELPASO	US0085	1	4	29	PL	1957.21	10	L	N	15.0
24601	2	S	ELPASO	US0085	1	4	29	PL	1957.21	10	L	N	15.0
25601	1	N	CHILDRES	US0287	43	1	44	PL	1987.56	13	L	N	15.0
25601	2	S	CHILDRES	US0287	43	1	44	PL	1987.56	13	L	N	15.0

Table A.1 Master File Partial Listing (continued)

CFTR	SECT	DIR	RM1	RM2	MP1	MP2	LGTH	SHLD	SOIL	RAIN	COLD	HOT
1101	1	S	250.48	251.66	.	.	1.176	ACP	HS	40.43	30	95
1101	2	S	250.48	251.66	.	.	1.176	ACP	HS	40.43	30	95
1101	3	S	250.48	254.12	.	.	2.406	ACP	HS	40.43	30	95
1102	1	E	.	.	123.87	125.37	3.457	ACP	HS	44.16	31	95
1102	2	E	.	.	123.87	125.37	3.457	ACP	HS	44.16	31	95
1601	1	E	702.70	703.54	.	.	1.288	ACP	NS	44.97	30	94
1601	2	E	702.70	703.54	.	.	1.288	ACP	NS	44.97	30	94
3589	1	S	467.81	471.29	.	.	3.495	C&G	MS	26.73	28	99
3589	2	S	467.81	471.29	.	.	3.495	C&G	MS	26.73	28	99
3589	3	S	467.81	471.29	.	.	3.495	C&G	MS	26.73	28	99
3593	1	N	468.27	469.20	.	.	0.934	ACP	NS	25.25	28	99
4101	1	N	54.90	55.15	.	.	0.265	NONE	NS	16.45	18	91
4101	1	S	54.90	55.15	.	.	0.265	C&G	NS	16.45	18	91
5601	1	E	0.00	0.27	.	.	0.265	C&G	NS	16.08	20	91
5601	1	W	0.00	0.27	.	.	0.265	C&G	NS	16.08	20	91
9601	1	N	361.60	365.45	.	.	7.620	ACP	HS	36.00	36	97
9601	2	N	361.60	365.45	.	.	7.620	ACP	HS	36.00	36	97
12505	1	S	517.16	522.06	.	.	0.444	ACP	HS	52.28	42	92
12505	2	N	517.16	522.06	.	.	0.444	ACP	HS	52.28	42	92
12509	1	N	.	.	79.91	84.04	2.452	ACP	NS	46.60	38	95
12509	2	N	.	.	80.04	84.17	2.452	ACP	NS	46.60	38	95
12509	3	N	.	.	80.02	84.16	2.452	ACP	NS	46.60	38	95
12509	4	N	.	.	80.02	84.16	2.452	ACP	NS	46.60	38	95
12513	1	N	.	.	73.60	80.04	6.439	ACP	NS	46.60	38	95
12513	2	N	.	.	73.60	80.04	6.439	ACP	NS	46.60	38	95
12526	1	N	.	.	65.74	66.37	0.637	ACP	NS	46.60	38	95
12535	1	N	.	.	84.34	91.28	6.940	ACP	HS	46.60	38	95
12535	2	N	.	.	84.31	91.25	6.940	ACP	HS	46.60	38	95
12535	3	N	.	.	84.32	91.26	6.940	ACP	HS	46.60	38	95
12537	1	N	.	.	66.77	72.73	2.262	ACP	NS	46.60	38	95
12537	2	N	.	.	66.83	72.79	2.262	ACP	NS	46.60	38	95
12540	1	N	.	.	91.10	98.22	7.123	ACP	HS	46.60	38	95
12553	1	N	482.25	495.25	.	.	2.510	ACP	HS	44.77	41	94
12553	2	N	482.25	495.25	.	.	2.510	ACP	HS	44.77	41	94
12554	1	N	495.22	496.24	.	.	1.130	ACP	MS	52.28	42	92

Table A.1 Master File Partial Listing (continued)

CFTR	SECT	DIR	RM1	RM2	MP1	MP2	LGTH	SHLD	SOIL	RAIN	COLD	HOT
12564	1	E	688.00	689.62	.	.	1.600	ACP	MS	44.77	41	94
12564	2	E	688.00	689.62	.	.	1.600	ACP	MS	44.77	41	94
12576	1	W	.	.	730.85	733.14	2.291	ACP	NS	43.87	41	94
12590	1	N	512.77	513.74	.	.	0.981	ACP	MS	40.24	48	88
12590	2	N	512.77	513.74	.	.	0.981	ACP	MS	40.24	48	88
12601	1	N	507.84	508.00	.	.	0.157	ACP	MS	40.24	48	88
12601	2	N	503.62	507.84	.	.	3.300	ACP	MS	40.24	48	88
12602	1	S	498.32	502.69	.	.	4.961	ACP	MS	40.24	48	88
12602	2	S	498.32	502.69	.	.	4.961	ACP	MS	40.24	48	88
12603	1	W	.	.	741.79	751.03	9.200	ACP	NS	43.87	41	94
12603	2	W	.	.	741.79	751.03	9.200	ACP	NS	43.87	41	94
12603	3	W	.	.	741.80	751.04	9.200	ACP	NS	43.87	41	94
12603	4	W	.	.	741.79	751.04	9.200	ACP	NS	43.87	41	94
12604	1	N	493.07	500.35	.	.	7.281	ACP	HS	44.77	41	94
12604	2	N	493.21	500.49	.	.	7.281	ACP	HS	44.77	41	94
12604	3	N	493.21	500.49	.	.	7.281	PCC	HS	44.77	41	94
12606	1	S	529.65	530.13	.	.	0.477	ACP	HS	43.87	41	94
12606	2	S	530.45	532.52	.	.	2.070	ACP	HS	43.87	41	94
12607	1	N	532.44	540.84	.	.	7.882	ACP	HS	43.87	41	94
12607	2	N	532.60	541.00	.	.	7.882	ACP	HS	43.87	41	94
12607	3	N	532.60	541.00	.	.	7.882	ACP	HS	43.87	41	94
13501	1	S	555.89	556.67	.	.	1.698	ACP	MS	43.89	42	93
13501	2	S	555.89	556.67	.	.	1.698	ACP	MS	43.89	42	93
13509	1	W	.	.	711.89	717.81	5.926	ACP	NS	43.87	41	94
13509	2	W	.	.	711.89	717.81	5.926	ACP	NS	39.72	39	97
13510	1	W	.	.	717.81	720.40	2.587	ACP	NS	39.72	39	97
13510	2	W	.	.	717.81	720.40	2.587	ACP	NS	39.72	39	97
13512	1	W	.	.	720.52	721.43	1.025	ACP	NS	39.72	39	97
13513	1	W	.	.	721.43	727.20	5.778	ACP	NS	39.72	39	97
13513	2	W	.	.	721.43	727.20	5.778	ACP	NS	39.72	39	97
16570	1	E	556.05	559.15	.	.	3.144	ACP	MS	26.68	49	90
16570	2	E	556.05	559.15	.	.	4.284	ACP	MS	26.68	49	90
16601	1	E	560.07	561.54	.	.	1.483	ACP	MS	26.68	49	90
16601	2	E	560.07	561.54	.	.	1.483	ACP	MS	26.68	49	90
17602	1	S	432.00	433.40	.	.	1.408	EARTH	HS	39.72	39	97
17602	2	S	432.00	433.40	.	.	1.408	EARTH	HS	39.72	39	97

Table A.1 Master File Partial Listing (Continued).

CFTR	SECT	DIR	RM1	RM2	MP1	MP2	LGTH	SHLD	SOIL	RAIN	COLD	HOT
18120	1	N	273.19	275.92	.	.	2.679	C&G	NS	34.16	35	96
18120	2	N	273.19	275.92	.	.	2.679	C&G	NS	34.16	35	96
18164	1	E	590.68	594.62	.	.	3.900	ACP	NS	34.16	35	96
18164	2	E	590.68	594.62	.	.	3.900	C&G	NS	34.16	35	96
18164	3	E	594.55	597.91	.	.	3.900	C&G	NS	34.16	35	96
18170	1	E	591.45	594.11	.	.	2.575	C&G	.	34.16	35	96
18525	1	N	.	.	428.85	429.96	1.114	ACP	NS	29.45	34	98
18541	1	E	.	.	.	.	3.358	ACP	NS	34.16	35	96
18601	1	N	417.49	418.80	.	.	1.306	ACP	NS	29.45	34	98
18601	1	S	417.49	418.80	.	.	1.306	ACP	NS	29.45	34	98
18602	1	N	.	.	397.38	408.34	10.812	PCC	NS	36.25	33	97
18602	2	N	.	.	397.42	408.38	10.812	PCC	NS	36.25	33	97
18602	3	N	.	.	397.34	408.30	10.812	PCC	NS	36.25	33	97
18603	1	E	238.03	238.99	.	.	0.957	C&G	NS	36.88	33	96
18603	2	E	238.03	238.99	.	.	0.957	C&G	NS	36.88	33	96
18604	1	E	594.71	595.63	.	.	0.918	C&G	NS	36.88	33	96
18604	2	E	594.71	595.63	.	.	0.918	C&G	NS	36.88	33	96
18605	1	S	312.64	314.19	.	.	1.553	C&G	HS	38.18	32	97
18605	2	S	312.64	314.19	.	.	1.553	C&G	HS	38.18	32	97
18606	1	W	.	.	495.59	499.29	4.451	PCC	HS	38.18	32	97
18606	2	W	.	.	495.59	499.29	4.451	PCC	HS	38.18	32	97
18606	3	W	.	.	459.59	463.29	4.451	PCC	HS	38.18	32	97
18607	1	W	.	.	69.03	79.82	10.805	PCC	HS	34.16	35	96
18607	2	W	.	.	68.53	79.32	10.805	PCC	HS	34.16	35	96
18607	3	W	.	.	69.53	80.32	10.805	PCC	HS	34.16	35	96
18608	1	S	448.90	448.70	.	.	1.003	ACP	MS	33.53	32	96
18609	1	E	270.28	272.35	.	.	2.078	PCC	MS	33.53	32	96
18609	2	E	270.28	272.35	.	.	2.098	PCC	MS	33.53	32	96
18610	1	N	.	.	471.51	482.67	11.261	PCC	MS	33.53	32	96
18610	2	N	.	.	471.51	482.67	11.261	PCC	MS	33.53	32	96
18610	3	N	.	.	471.51	482.67	11.261	PCC	MS	33.53	32	96
19101	1	E	.	.	620.67	629.10	8.201	ACP	MS	46.41	33	94
19101	2	E	.	.	620.67	629.10	8.201	ACP	MS	46.41	33	94
19101	3	E	.	.	620.67	629.10	8.201	ACP	MS	46.41	33	94
19101	4	E	.	.	620.67	629.10	8.201	ACP	MS	46.41	33	94
19102	1	W	.	.	629.09	636.12	7.064	ACP	MS	46.41	33	94
19102	2	W	.	.	629.09	636.12	7.064	ACP	MS	46.41	33	94

Table A.1 Master File Partial Listing (continued)

CFTR	SECT	DIR	RM1	RM2	MP1	MP2	LGTH	SHLD	SOIL	RAIN	COLD	HOT
20574	1	N	383.66	388.85	.	.	4.867	ACP	NS	41.48	38	94
20574	2	N	383.66	388.85	.	.	4.867	ACP	NS	41.48	38	94
20574	3	N	383.66	388.85	.	.	4.867	ACP	NS	41.48	38	94
20575	1	N	388.85	391.70	.	.	2.851	ACP	NS	41.48	38	94
20575	2	N	388.85	391.70	.	.	2.851	ACP	NS	41.48	38	94
20575	3	N	383.66	388.85	.	.	4.867	ACP	NS	41.48	38	94
20578	1	S	766.84	768.14	.	.	1.213	ACP	MS	52.79	42	93
20578	2	S	766.81	768.11	.	.	1.213	ACP	MS	52.79	42	93
20584	1	S	526.88	529.26	.	.	2.427	PCC	HS	52.79	42	93
20584	2	S	526.88	529.26	.	.	2.427	ACP	HS	52.79	42	93
20586	1	W	771.74	773.84	.	.	1.795	C&G	HS	52.79	42	93
20586	2	W	771.74	773.84	.	.	1.795	NONE	HS	52.79	42	93
20587	1	S	449.24	455.76	.	.	7.927	C&G	.	52.79	42	93
20587	2	S	449.24	455.76	.	.	7.927	PCC	.	52.79	42	93
20587	3	S	449.24	455.76	.	.	7.927	C&G	.	52.79	42	93
20590	1	E	864.07	871.50	.	.	1.417	ACP	HS	50.65	40	94
20590	2	E	864.07	871.50	.	.	1.417	ACP	HS	50.65	40	94
20601	1	N	388.85	391.70	.	.	2.851	ACP	NS	41.48	38	94
20601	2	N	388.84	391.69	.	.	2.851	ACP	NS	41.48	38	94
20601	3	N	388.84	391.69	.	.	2.851	ACP	NS	41.48	38	94
20602	1	E	902.30	906.07	.	.	3.774	ACP	HS	50.65	40	94
20602	2	E	902.30	906.07	.	.	3.774	ACP	HS	50.65	40	94
20603	1	N	439.37	440.98	.	.	1.612	C&G	MS	52.79	42	93
24601	1	N	322.61	323.62	.	.	1.015	C&G	HS	7.87	27	97
24601	2	S	322.61	323.62	.	.	1.015	C&G	HS	7.87	27	97
25601	1	N	232.00	232.20	.	.	1.140	C&G	NS	19.89	26	96
25601	2	S	232.00	232.20	.	.	1.140	C&G	NS	19.89	26	96

APPENDIX B:

LISTING OF CONDITION SURVEY RESULTS FOR SELECTED TEST SECTIONS

Table B.1 Condition Survey File Partial Listing

CFTR	SECT	DIR	DATE	LEN	LANES	RBED	CURVE	OVER	RM 1	RM 2	MP 1	MP 2	MPO	SPO	DCRK
1101	1	S	41894	1000	2	C	T	N	251.10	251.29	.	.	0	0	1
1101	2	S	41894	1000	2	F	C	N	251.50	251.69	.	.	0	0	0
1101	3	S	41894	1000	2	T	C	N	252.00	252.19	.	.	0	0	0
1102	1	E	41894	1000	2	G	C	N	.	.	122.20	122.40	0	0	2
1102	2	E	41894	1000	2	T	T	Y	.	.	123.00	123.19	2	0	.
1601	1	E	62294	1000	1	G	T	Y	703.00	703.20	.	.	0	0	.
1601	2	E	62294	1000	1	G	T	Y	703.20	703.40	.	.	0	0	.
3589	1	S	63094	1000	1	G	T	Y	467.50	467.70	.	.	0	0	.
3589	2	S	63094	1000	2	G	T	N	468.00	468.20	.	.	0	0	7
3589	3	S	63094	1000	2	C	C	N	469.05	469.25	.	.	0	0	3
3593	1	N	63094	1000	2	F	T	N	469.40	469.20	.	.	0	0	0
4101	1	N	51794	1000	2	T	C	N	54.90	55.15	.	.	0	0	2
4101	1	S	51794	1000	2	T	C	N	54.90	55.15	.	.	0	0	1
5601	1	E	72094	1000	1	T	T	N	0.00	0.27	.	.	0	0	22
5601	1	W	72094	1000	1	T	T	N	0.00	0.27	.	.	2	0	5
9601	1	N	62094	1000	1	G	T	Y	363.80	364.00	.	.	0	0	.
9601	2	N	62094	1000	1	G	T	Y	363.60	363.80	.	.	0	0	.
12505	1	S	52594	1000	1	F	C	Y	522.00	522.20	.	.	0	0	.
12505	2	N	52594	1000	1	F	T	Y	519.80	520.00	.	.	0	0	.
12509	1	N	51094	1000	2	G	T	Y	.	.	80.00	80.20	3	0	.
12509	2	N	51094	1000	2	G	T	Y	.	.	81.00	81.20	1	0	.
12509	3	N	51094	1000	2	F	T	Y	.	.	83.00	83.20	0	0	.
12509	4	N	51094	1000	2	T	T	Y	.	.	83.20	83.40	0	0	.
12513	1	N	51094	1000	3	G	T	Y	.	.	75.00	75.20	0	0	.
12513	2	N	51094	1000	3	G	T	Y	.	.	76.00	76.20	0	0	.
12526	1	N	50994	1000	3	G	T	Y	.	.	66.00	66.20	0	0	.
12535	1	N	51094	600	2	G	C	Y	.	.	85.00	85.20	0	0	.
12535	2	N	51094	1000	2	T	T	Y	.	.	88.00	88.20	0	0	.
12535	3	N	51094	1000	2	G	T	Y	.	.	89.00	89.20	0	0	.
12537	1	N	50994	1000	2	G	C	Y	.	.	67.00	67.20	0	0	.
12537	2	N	50994	1000	2	G	C	Y	.	.	68.00	68.20	1	0	.
12540	1	N	51094	1000	2	T	T	Y	.	.	92.00	92.20	0	0	.
12553	1	N	52594	1000	2	G	T	N	493.80	494.00	.	.	0	0	0
12553	2	N	52594	1000	2	G	T	N	493.60	493.80	.	.	0	0	0
12554	1	N	52594	1000	2	G	C	N	495.80	496.00	.	.	0	0	0
12564	1	E	51194	1000	4	T	T	Y	688.00	688.20	.	.	0	0	.
12564	2	E	51194	1000	3	.	.	Y	688.20	688.40	.	.	6	0	.
12576	1	W	50694	1000	2	C	C	Y	.	.	731.80	732.00	0	0	.
12590	1	N	50594	1000	2	T	C	N	513.10	513.30	.	.	0	0	0
12590	2	N	50594	600	2	F	C	N	512.80	512.90	.	.	0	0	0

Table B.1 Condition Survey File Partial Listing (continued)

CFTR	SECT	DIR	DATE	LEN	LANES	RBED	CURVE	OVER	RM1	RM2	MP1	MP2	MPO	SPO	DCRK
12601	1	N	50594	1000	2	G	T	Y	507.80	508.00	.	.	0	0	.
12601	2	N	50594	1000	2	G	T	Y	507.60	507.80	.	.	0	0	.
12602	1	S	50594	1000	1	G	T	Y	500.00	500.20	.	.	0	0	.
12602	2	S	50594	1000	1	G	T	Y	500.20	500.40	.	.	0	0	.
12603	1	W	50694	1000	3	C	C	N	.	.	748.80	749.00	0	0	0
12603	2	W	50694	1000	3	G	T	N	.	.	745.80	746.00	0	0	0
12603	3	W	50694	1000	3	T	T	N	.	.	744.80	745.00	0	0	1
12603	4	W	50694	1000	3	G	T	N	.	.	743.80	744.00	0	0	0
12604	1	N	51194	1000	2	F	T	N	497.80	498.00	.	.	0	0	0
12604	2	N	51194	1000	2	G	C	N	496.90	497.10	.	.	0	0	0
12604	3	N	51194	1000	2	G	C	N	495.80	496.00	.	.	0	0	0
12606	1	S	52694	1000	3	T	C	Y	530.00	530.20	.	.	0	0	.
12606	2	S	52694	1000	2	T	T	N	532.00	532.20	.	.	0	0	0
12607	1	N	52694	1000	2	G	C	N	539.80	540.00	.	.	0	0	0
12607	2	N	52694	1000	2	T	T	N	537.80	538.00	.	.	0	0	0
12607	3	N	52694	1000	2	F	T	N	535.80	536.00	.	.	0	0	1
13501	1	S	53194	1000	2	G	T	Y	556.00	556.20	.	.	0	0	.
13501	2	S	53194	1000	2	T	T	Y	556.20	556.40	.	.	0	0	.
13509	1	W	51294	1000	2	G	T	Y			716.80	717.00	0	0	.
13509	2	W	51294	1000	2	G	T	Y			714.80	715.00	4	0	.
13510	1	W	51294	1000	2	C	C	Y	.	.	718.80	719.00	2	0	.
13510	2	W	51294	1000	2	T	T	Y	.	.	718.60	718.80	0	0	.
13512	1	W	51294	1000	2	T	T	Y	.	.	720.80	721.00	9	0	.
13513	1	W	51294	1000	2	G	T	Y	.	.	726.80	727.00	0	0	.
13513	2	W	51294	1000	2	G	T	Y	.	.	725.80	726.00	0	0	.
16570	1	E	60194	1000	1	G	T	Y	556.10	556.30	.	.	0	0	.
16570	2	E	60194	1000	1	G	T	Y	556.30	556.50	.	.	0	0	.
16601	1	E	60194	1000	1	G	T	N	560.10	560.30	.	.	0	0	1
16601	2	E	60194	1000	1	G	T	N	560.30	560.50	.	.	0	0	0
17601	1	E	71894	1000	2	G	T	N	432.00	432.20	.	.	0	0	0
17601	2	E	71494	1000	2	G	C	N	433.00	433.20	.	.	0	0	0
18120	1	N	60694	1000	3	G	T	N	276.25	276.44	.	.	0	0	7
18120	2	N	60694	1000	3	T	C	N	276.25	276.44	.	.	0	0	11
18164	1	E	61494	1000	3	T	C	N	592.00	592.20	.	.	0	0	0
18164	2	E	61494	1000	3	C	C	N	594.00	594.20	.	.	0	0	0
18164	3	E	61494	600	3	G	T	N	596.00	596.20	.	.	0	0	1
18170	1	E	60694	1000	3	G	T	N	594.00	594.20	.	.	0	0	0
18525	1	N	61694	1000	4	F	C	Y	.	.	428.80	429.00	0	0	.
18541	1	E	61494	1000	4	C	C	Y	.	.	51.20	51.40	0	0	.

Table B.1 Condition Survey File Partial Listing (continued)

CFTR	SECT	DIR	DATE	LEN	LANES	RBED	CURVE	OVER	RM 1	RM 2	MP 1	MP 2	MPO	SPO	DCRK
18601	1	N	61694	1000	2	T	T	N	417.80	418.00	.	.	0	0	1
18601	1	S	61694	1000	2	T	T	N	417.80	418.00	.	.	0	0	0
18602	1	N	62194	1000	2	T	C	N	.	.	398.00	398.20	0	0	0
18602	2	N	62194	1000	2	T	C	N	.	.	399.00	399.20	0	0	0
18602	3	N	62194	1000	2	G	T	N	.	.	404.00	404.20	0	0	0
18603	1	E	62194	1000	3	G	T	N	238.00	238.20	.	.	0	0	1
18603	2	E	62194	1000	3	G	C	N	238.20	238.40	.	.	3	0	0
18604	1	E	62194	1000	2	.	.	N	595.00	595.20	.	.	0	0	0
18604	2	E	62194	1000	2	G	T	N	595.20	595.40	.	.	0	0	0
18605	1	S	62294	1000	2	G	C	N	314.00	314.20	.	.	0	0	0
18605	2	S	62294	800	2	.	C	N	313.80	314.00	.	.	0	0	0
18606	1	W	62294	1000	2	F	C	N	.	.	497.60	497.80	0	0	0
18606	2	W	62294	1000	2	C	T	N	.	.	496.80	497.00	0	0	0
18606	3	W	62294	1000	2	T	C	N	.	.	495.70	495.90	0	0	0
18607	1	W	62294	1000	2	T	T	N	.	.	75.80	76.00	0	0	0
18607	2	W	62294	1000	2	F	T	N	.	.	75.60	75.80	0	0	0
18607	3	W	62294	1000	2	G	C	N	.	.	71.80	72.00	0	0	0
18608	1	S	70694	1000	3	C	C	Y	448.90	448.70	.	.	0	0	.
18609	1	E	70694	1000	2	F	T	N	272.60	272.80	.	.	0	0	0
18609	2	E	70694	1000	2	F	C	N	273.10	273.30	.	.	0	0	0
18610	1	N	70694	1000	2	T	T	N	.	.	472.00	472.20	0	0	0
18610	2	N	70694	1000	2	F	C	N	.	.	474.00	474.20	0	0	0
18610	3	N	70694	1000	2	C	T	N	.	.	472.20	477.40	0	0	0
19101	1	E	41994	1000	2	T	T	Y	.	.	621.20	621.40	0	0	.
19101	2	E	41994	1000	2	G	T	Y	.	.	621.60	621.80	2	0	.
19101	3	E	41994	1000	2	C	T	Y	.	.	622.00	622.20	0	0	.
19101	4	E	41994	1000	2	T	T	Y	.	.	623.00	623.20	0	0	.
19102	1	W	41994	1000	2	G	T	Y	.	.	632.60	632.80	0	0	.
19102	2	W	41994	1000	2	T	T	Y	.	.	631.80	632.00	0	0	.
20574	1	N	42094	1000	2	G	T	N	387.80	388.00	.	.	0	0	0
20574	2	N	42094	1000	2	T	T	N	387.60	387.80	.	.	0	0	2
20574	3	N	42094	1000	2	C	T	N	387.40	387.60	.	.	0	0	1
20575	1	N	42094	1000	2	F	T	N	389.80	390.00	.	.	1	0	4
20575	2	N	42094	1000	2	T	C	N	390.30	390.50	.	.	0	0	1
20575	3	N	42094	1000	2	C	C	N	387.80	388.00	.	.	0	1	3
20578	1	S	50394	1000	2	F	T	Y	763.80	764.00	.	.	0	0	.
20578	2	S	50394	1000	2	F	T	Y	762.70	762.90	.	.	28	0	.
20584	1	S	42094	1000	2	T	T	N	527.90	528.10	.	.	1	0	7
20584	2	S	42094	1000	2	F	T	N	528.20	528.40	.	.	1	0	5
20586	1	W	50394	1000	1	G	T	N	773.80	774.00	.	.	0	0	6
20586	2	W	50394	1000	1	G	T	N	773.35	773.55	.	.	0	0	13

Table B.1 Condition Survey File Partial Listing (continued)

CFTR	SECT	DIR	DATE	LEN	LANES	RBED	CURVE	OVER	RM1	RM2	MP1	MP2	MPO	SPO	DCRK
20587	1	S	42094	1000	2	G	T	N	450.00	450.20	.	.	0	0	0
20587	2	S	42094	1000	2	G	T	N	452.00	452.20	.	.	0	0	1
20587	3	S	42094	1000	2	G	C	N	454.00	454.20	.	.	0	0	0
20590	1	E	42194	1000	2	G	T	N	865.00	865.20	.	.	0	0	2
20590	2	E	42194	1000	2	G	T	N	866.00	866.20	.	.	0	0	1
20601	1	N	42094	1000	2	C	T	N	391.50	391.70	.	.	1	0	8
20601	2	N	42094	1000	2	G	T	N	390.80	391.00	.	.	0	0	2
20601	3	N	42094	1000	2	F	T	N	390.45	390.65	.	.	0	0	3
20602	1	E	42194	1000	2	G	T	Y	902.00	902.20	.	.	0	0	.
20602	2	E	42194	1000	2	G	T	N	902.80	903.00	.	.	0	0	0
20603	1	N	50294	1000	.	G	C	N	439.80	440.00	.	.	0	0	0
24601	1	N	72794	1000	2	G	C	N	323.42	323.62	.	.	2	0	0
24601	2	S	72794	1000	2	F	C	N	323.42	323.62	.	.	0	0	1
25601	1	N	63094	1000	2	G	T	N	232.00	232.20	.	.	0	0	0
25601	2	S	63094	1000	2	G	T	N	232.00	232.20	.	.	0	0	0

Table B.1 Condition Survey File Partial Listing (continued)

CFTR	SECT	DIR	CBRKS	SPALL	FAULT	ACP1	ACP51	ACP150	PCC1	PCC51	PCC150	LCRCK	TCRCK	ACRCK	BCRCK	SRUT	DRUT
1101	1	S	0	1	0	0	0	0	0	0	0	3	66	.	.	.	.
1101	2	S	0	0	0	0	0	0	0	0	0	0	67	.	.	.	.
1101	3	S	0	0	0	0	0	0	0	0	0	0	64	.	.	.	.
1102	1	E	0	10	0	5	0	0	0	0	0	0	53	.	.	.	.
1102	2	E	0	.	0	8	0	0	.	.	.	0	41	0	0	0	0
1601	1	E	0	.	0	0	0	0	.	.	.	0	81	0	0	0	0
1601	2	E	0	.	0	0	0	0	.	.	.	0	66	0	0	0	0
3589	1	S	0	.	0	0	0	0	.	.	.	0	51	0	0	0	0
3589	2	S	0	0	0	5	0	0	0	0	0	6	72	.	.	.	.
3589	3	S	2	0	0	4	0	0	0	0	0	0	67	.	.	.	.
3593	1	N	0	0	0	0	0	0	0	0	0	24	66	.	.	.	.
4101	1	N	0	6	0	0	1	0	0	0	0	4	95	.	.	.	.
4101	1	S	0	0	0	0	0	0	1	0	0	5	76	.	.	.	.
5601	1	E	8	0	0	12	0	0	0	0	0	34	51	.	.	.	.
5601	1	W	4	0	0	7	0	0	0	0	0	33	50	.	.	.	.
9601	1	N	0	.	0	0	0	0	.	.	.	0	0	0	0	0	0
9601	2	N	0	.	0	0	0	0	.	.	.	0	0	0	0	0	0
12505	1	S	0	.	0	0	0	0	.	.	.	0	46	0	0	0	0
12505	2	N	0	.	0	0	0	0	.	.	.	0	66	0	0	0	0
12509	1	N	0	.	0	4	0	2	.	.	.	0	45	2.4	0	0	0
12509	2	N	0	.	0	2	0	0	.	.	.	0	55	1.4	0	0	0
12509	3	N	0	.	0	1	0	0	.	.	.	0	16	0	0	0	0
12509	4	N	0	.	0	4	3	0	.	.	.	0	41	0	0	0	0
12513	1	N	0	.	0	10	0	0	.	.	.	0	54	0	0	0	0
12513	2	N	0	.	0	0	0	0	.	.	.	0	48	0	0	0	0
12526	1	N	0	.	0	19	3	0	.	.	.	0	26	0	0	0	0
12535	1	N	0	.	0	6	2	0	.	.	.	0	14	0	0	0	0
12535	2	N	0	.	0	1	0	0	.	.	.	0	32	0	0	0	0
12535	3	N	0	.	0	4	0	0	.	.	.	0	22	0	0	0	0
12537	1	N	0	.	0	9	4	0	.	.	.	1	27	0	0	0	0
12537	2	N	0	.	0	15	10	6	.	.	.	1	134	0	10	0	0
12540	1	N	0	.	0	0	0	0	.	.	.	0	35	0	0	0	0
12553	1	N	0	0	3	0	1	0	0	0	0	0	21	.	.	.	.
12553	2	N	0	1	8	2	0	0	0	3	0	0	56	.	.	.	.
12554	1	N	0	1	10	1	0	0	0	2	0	0	39	.	.	.	.
12564	1	E	0	.	0	0	0	0	.	.	.	0	14	0	0	0	0
12564	2	E	0	.	0	1	0	0	.	.	.	0	18	0	0	0	0
12576	1	W	0	.	0	0	0	0	.	.	.	0	26	0	0	0	0
12590	1	N	0	20	0	0	0	0	0	0	0	0	51	.	.	.	.
12590	2	N	0	15	1	0	0	0	0	0	0	0	32	.	.	.	.

Table B.1 Condition Survey File Partial Listing (continued)

CFTR	SECT	DIR	CBRKS	SPALL	FAULT	ACP1	ACP51	ACP150	PCC1	PCC51	PCC150	LCRCK	TCRCK	ACRCK	BCRCK	SRUT	DRUT
12601	1	N	0	.	0	0	0	0	.	.	.	0	0	0	0	0	0
12601	2	N	0	.	0	0	0	0	.	.	.	0	3	0	0	0	0
12602	1	S	0	.	0	0	0	0	.	.	.	0	54	0	0	0	0
12602	2	S	0	.	0	0	0	0	.	.	.	0	46	0	0	0	0
12603	1	W	0	0	1	0	0	0	2	0	0	1	35	.	.	.	.
12603	2	W	0	3	0	2	0	0	2	2	0	0	60	.	.	.	.
12603	3	W	0	2	1	3	0	0	0	1	0	0	67	.	.	.	.
12603	4	W	0	4	1	0	0	0	1	0	0	0	38	.	.	.	.
12604	1	N	0	2	2	0	0	0	0	0	0	0	56	.	.	.	.
12604	2	N	0	0	2	1	0	0	0	0	0	0	63	.	.	.	.
12604	3	N	1	0	7	0	0	0	0	0	0	0	54	.	.	.	.
12606	1	S	0	.	0	0	0	0	.	.	.	0	32	0	0	0	0
12606	2	S	1	0	9	0	0	0	0	0	0	0	64	.	.	.	.
12607	1	N	0	26	1	0	0	0	0	0	0	0	51	.	.	.	.
12607	2	N	1	14	0	0	0	0	0	0	0	0	58	.	.	.	.
12607	3	N	0	17	3	0	0	0	0	0	1	0	49	.	.	.	.
13501	1	S	0	.	0	0	0	0	.	.	.	0	53	0	0	0	0
13501	2	S	0	.	0	1	0	0	.	.	.	0	65	0	0	0	0
13509	1	W	0	.	0	0	0	0	.	.	.	0	23	0	0	0	0
13509	2	W	0	.	0	0	0	0	.	.	.	0	28	0	0	0	0
13510	1	W	0	.	0	8	0	0	.	.	.	0	41	1	0	0	0
13510	2	W	0	.	0	0	0	0	.	.	.	0	27	0	0	0	0
13512	1	W	0	.	0	1	0	0	.	.	.	0	27	0	0	0	0
13513	1	W	0	.	0	1	0	0	.	.	.	0	18	1	0	0	0
13513	2	W	0	.	0	0	0	0	.	.	.	0	31	1	0	0	0
16570	1	E	0	.	0	0	0	0	.	.	.	0	73	0	0	0	0
16570	2	E	0	.	0	0	0	0	.	.	.	0	63	0	0	0	0
16601	1	E	0	0	0	0	0	0	0	0	0	0	69	.	.	.	.
16601	2	E	0	0	0	0	0	0	0	0	1	1	75	.	.	.	.
17601	1	E	0	0	2	0	0	0	0	0	1	4	80	.	.	.	.
17601	2	E	0	0	0	0	0	0	0	0	0	12	59	.	.	.	.
18120	1	N	4	0	0	7	0	0	0	0	0	6	24	.	.	.	.
18120	2	N	0	0	0	5	0	0	0	0	0	3	18	.	.	.	.
18164	1	E	0	1	0	1	0	0	0	0	0	0	69	.	.	.	.
18164	2	E	1	0	0	0	0	0	0	0	0	0	72	.	.	.	.
18164	3	E	1	3	0	2	0	0	0	0	0	0	19	.	.	.	.
18170	1	E	0	0	0	0	1	0	0	1	0	2	68	.	.	.	.
18525	1	N	0	.	0	0	0	0	.	.	.	0	0	0	0	0	0
18541	1	E	0	.	0	0	0	0	.	.	.	0	53	0	0	0	0

Table B.1 Condition Survey File Partial Listing (continued)

CFTR	SECT	DIR	CBRKS	SPALL	FAULT	ACP1	ACP51	ACP150	PCC1	PCC51	PCC150	LCRCK	TCRCK	ACRCK	BCRCK	SRUT	DRUT
18601	1	N	0	0	0	1	0	0	0	0	0	2	67	.	.	.	.
18601	1	S	0	0	0	0	0	0	0	0	0	0	65	.	.	.	.
18602	1	N	0	0	0	0	0	0	0	0	0	4	67	.	.	.	.
18602	2	N	0	0	0	0	0	0	0	0	0	2	66	.	.	.	.
18602	3	N	0	0	0	0	0	0	0	0	0	0	67	.	.	.	.
18603	1	E	0	0	0	0	0	0	0	0	5	35	77	.	.	.	.
18603	2	E	1	0	0	3	0	0	0	0	0	7	72	.	.	.	.
18604	1	E	0	0	0	0	0	0	0	0	0	0	70	.	.	.	.
18604	2	E	0	0	0	0	0	0	0	0	0	0	71	.	.	.	.
18605	1	S	0	0	0	0	0	0	0	0	0	0	71	.	.	.	.
18605	2	S	0	0	0	0	0	0	0	0	0	0	53	.	.	.	.
18606	1	W	0	0	0	0	0	0	0	0	0	0	66	.	.	.	.
18606	2	W	0	0	0	0	0	0	0	0	0	28	67	.	.	.	.
18606	3	W	0	0	0	0	0	0	0	0	0	26	66	.	.	.	.
18607	1	W	0	0	0	0	0	0	0	0	0	0	66	.	.	.	.
18607	2	W	0	0	0	0	0	0	0	0	0	0	67	.	.	.	.
18607	3	W	0	0	0	0	0	0	0	0	0	0	67	.	.	.	.
18608	1	S	0	.	0	0	0	0	.	.	.	0	0	0	0	0	0
18609	1	E	0	0	0	0	0	0	0	0	0	0	67	.	.	.	.
18609	2	E	0	0	0	0	0	0	0	0	0	2	66	.	.	.	.
18610	1	N	0	0	0	0	0	0	0	0	0	0	69	.	.	.	.
18610	2	N	0	0	0	0	0	0	0	0	0	0	66	.	.	.	.
18610	3	N	0	0	0	0	0	0	0	0	0	0	66	.	.	.	.
19101	1	E	0	.	0	3	0	0	.	.	.	0	71	0	0	0	0
19101	2	E	0	.	0	2	0	0	.	.	.	0	30	0	0	0	0
19101	3	E	0	.	0	0	0	0	.	.	.	0	48	0	0	0	0
19101	4	E	0	.	0	0	0	0	.	.	.	0	49	0	0	0	0
19102	1	W	0	.	0	1	0	0	.	.	.	0	28	0	0	0	0
19102	2	W	0	.	0	0	1	0	.	.	.	0	4	0	0	0	0
20574	1	N	0	0	0	0	0	0	0	0	0	0	51	.	.	.	.
20574	2	N	4	0	0	2	0	0	0	0	0	0	52	.	.	.	.
20574	3	N	1	0	2	0	0	0	0	0	0	0	51	.	.	.	.
20575	1	N	9	1	7	1	0	0	6	0	1	0	68	.	.	.	.
20575	2	N	1	1	6	3	0	0	4	1	0	0	64	.	.	.	.
20575	3	N	3	3	3	1	0	0	2	1	1	0	75	.	.	.	.
20578	1	S	0	.	0	0	0	0	.	.	.	0	97	0	16	0	0
20578	2	S	0	.	0	0	0	0	.	.	.	1	23	0	19	0	0
20584	1	S	6	8	4	7	0	0	0	1	1	3	84	.	.	.	.
20584	2	S	4	15	8	4	0	0	2	0	1	0	68	.	.	.	.
20586	1	W	30	9	47	5	0	0	1	0	0	60	68	.	.	.	.
20586	2	W	5	67	68	54	0	1	0	0	0	67	68	.	.	.	.

Table B.1 Condition Survey File Partial Listing (continued)

CFTR	SECT	DIR	CBRKS	SPALL	FAULT	ACP1	ACP51	ACP150	PCC1	PCC51	PCC150	LCRCK	TCRCK	ACRCK	BCRCK	SRUT	DRUT
20587	1	S	0	0	0	0	0	0	0	0	0	0	17	.	.	.	.
20587	2	S	0	0	0	0	0	0	0	0	0	0	70	.	.	.	.
20587	3	S	0	0	0	0	0	0	0	0	0	0	68	.	.	.	.
20590	1	E	1	9	16	9	0	0	0	0	0	0	34	.	.	.	.
20590	2	E	1	9	15	1	0	0	1	1	0	0	27	.	.	.	.
20601	1	N	3	23	1	6	0	0	2	0	0	0	55	.	.	.	.
20601	2	N	8	3	4	6	0	0	6	2	0	1	68	.	.	.	.
20601	3	N	7	4	6	4	0	0	2	2	0	0	67	.	.	.	.
20602	1	E	0	.	0	0	1	0	.	.	.	0	5	0	0	0	0
20602	2	E	1	18	17	1	0	0	0	0	0	0	50	.	.	.	.
20603	1	N	0	0	0	0	0	0	0	0	0	0	65	.	.	.	.
24601	1	N	1	0	0	0	0	0	56	0	0	0	70	.	.	.	.
24601	2	S	1	15	0	0	0	0	74	0	0	19	65	.	.	.	.
25601	1	N	0	0	0	0	0	0	0	0	0	0	74	.	.	.	.
25601	2	S	0	0	0	0	0	0	0	0	0	0	68	.	.	.	.

APPENDIX C:

LISTING OF SAS PROGRAMS

```
/**********************************************************
*     THIS PROGRAM COMPUTES THE ROW AND COLUMN              *
*     OF THE FACTORIAL CELLS ACCORDING TO THE               *
*     DESIGN INFORMATION PROVIDED                           *
*                                    By Mauricio Ruiz     *
**********************************************************/
LIBNAME SDS 'A';
FILENAME OUT 'JCPFACD TXT A';
DATA A; SET SDS.MASTER;
  X =0;
  IF CAT = '1' THEN X = 1;     ELSE IF CAT = '2' THEN X = 5;
    IF THK = . THEN X1=0;
     ELSE IF THK < 10 THEN X1= X;
     ELSE IF THK >=10 AND X > 0 THEN X1= X + 2;
      X2=0;
      IF CDATE = . THEN X2=0;
       ELSE IF CDATE >= 1979 THEN X2 =X1;
       ELSE IF CDATE < 1979 AND X1>0 THEN  X2 = X1+1;
  Y=0;
  IF CLI = 1 THEN Y = 1;     ELSE IF CLI = 2 THEN Y = 3;
   ELSE IF CLI = 3 THEN Y = 5;     ELSE IF CLI = 4 THEN Y = 7;
Z=0;
IF PVT = 'RF' THEN Z = Y;
    Y1 = 0;
    IF DOW = 'Y' THEN Y1= Y;
     ELSE IF DOW = 'N' AND Y > 0 THEN Y1= Y+1;
    Z1 =0;
    IF SLGTH <=45 THEN Z1=Z;
      ELSE IF SLGTH >45 AND Z>0  THEN Z1=Z+1;
    IF PVT = 'RF' THEN Y1 = Z1;
DATA _NULL_; SET A;  /**** X1 AND Y1 ARE THE ROW AND COLUMN OF
                          THE FACTORIAL CELLS RESPECTIVELLY *****/
  FILE OUT;
  PUT C '05'X S '05'X J '05'X CFTR '05'X DIR '05'X  CAT '05'X THK '05'X
  DOW '05'X CDATE '05'X CLI '05'X SLGTH '05'X PVT '05'X Y1 '05'X X2
  '05'X OVER;
  RUN;
```

```
/*************************************************************
*       PROGRAM TO MERGE THE TRAFFIC, MASTER, AND            *
*       CRACK SPACING FILES                                  *
*                                                          *
*************************************************************/
 PROC SORT DATA = SDS.TRAFF;
    BY CFTR SEC DIR;
 RUN;
 PROC SORT DATA=SDS.MASTER;
    BY CFTR SEC DIR;
 RUN;
 DATA B;
 MERGE SDS.TRAFF (IN=OK) SDS.MASTER;
    BY CFTR SEC DIR;
  IF OK;
  RUN;

 PROC SORT DATA = B;
    BY CFTR SEC DIR;  RUN;
 PROC SORT DATA=SDS.JCPCRACK;
    BY CFTR SEC DIR;   RUN;
 DATA SDS.CRKANAL;
 MERGE B (IN=OK) SDS.JCPCRACK;
    BY CFTR SEC DIR;
  IF OK; RUN;

/*** A Series of KEEP or DROP statements can be used to work only work
        with the variables needed from every file ***/
```

```
/************************************************************
*      PROGRAM TO EXTRAPOLATE AADT's                         *
*                                                            *
*      This programs uses an exponential regression model to extrapolate  *
*      AADT's for years before 1968.                         *
************************************************************/

LIBNAME SDS 'A';
DATA A; SET SDS.JCPAADTM;  /** DATA SET CONTAINING AADT'S AND
                               CONSTRUCTION DATE **/
LENGTH YR68-YR93 4;
ARRAY AADT[*] AADT68-AADT93;
ARRAY YR[*] YR68-YR93;

DO I=1 TO DIM(AADT);
  IF AADT[I] = . THEN YR[I] = .;   /**MISSING YEARS FOR MISSING ADT'S**/
  ELSE IF AADT[I] ^= . THEN YR[I]= I+67;
  AADT[I]=LOG(AADT[I]);    /*** FOR EXPONENTIAL REGRESSION ANALYSIS **/
 END;

SUMADT = SUM (OF AADT68-AADT93);  /***COMPUTE INPUTS FOR MODEL **/
SUMYR  = SUM (OF YR68-YR93);      /***DO NOT CONSIDER MISSING VALUES **/
AVGADT = MEAN (OF AADT68-AADT93);
AVGYR = MEAN (OF YR68-YR93);
SMYRADT = 0; SMQDIFYR = 0;

DO I=1 TO DIM(AADT);
 IF YR[I] ^= . AND AADT[I] ^= . THEN
  SMYRADT=SMYRADT+(YR[I]-AVGYR)*(AADT[I]-AVGADT);
 IF YR[I] ^= . THEN
  SMQDIFYR=SMQDIFYR+(YR[I]-AVGYR)**2;
END;

NUM=N(OF AADT68-AADT93);   /** GET TOTAL OF NON-MISSING AADT'S **/
IF SMQDIFYR NE 0 THEN
B1=(SMYRADT)/SMQDIFYR;            /**COEFS OF LN(Y)=LN(BO)+B1(X) ***/
IF NUM = 0 THEN B0=0; IF NUM = 0 THEN B1 = 0;
ELSE IF NUM>0 THEN   B0=EXP(1/NUM*(SUMADT-B1*SUMYR));

DO I=1 TO DIM(AADT);
  AADT[I]= EXP(AADT[I]);   /** Return to Original Values of AADT's **/
 END;
RUN;


/**** ESTIMATE FOR MISSING AADT'S ******/
DATA SDS.COMPAADT; SET A;
```

```
KEEP AADT68-AADT93 CDATE B0 B1 CFTR DIR;
 /*** ASSUMING CDATE > 1925 ***/  LENGTH YER25-YER93 4;
LENGTH AADT25-AADT67 4;
YEARSTAR=FLOOR(CDATE-1900)+1; /** START 1 YR AFTER CONST DATE**/
ARRAY YER(*) YER25-YER93;   ARRAY ADT4(*) AADT25-AADT93;
DO T=1 TO DIM(YER);
  J=24 + T;
  YER[T]=J;
  IF J<YEARSTAR THEN ADT4[T] = 0;
END;
B=(YEARSTAR-24);                          /** YEAR 1 STARTS IN 1925***/
/*** ESTIMATE WITHIN CDATE AND 1993 ***/
IF B NE . THEN DO;
DO K=B TO DIM(ADT4) BY 1;
  IF ADT4[K] = . OR ADT4[K] = 0 THEN
  ADT4[K]=B0*EXP(B1*YER[K]);              /***ESTIMATING  MODEL *****/
 END;
END;
TOTAADT = SUM (OF AADT25-AADT93);
KEEP CDATE CFTR DIR B0 B1 AADT25-AADT93 TOTAADT;
RUN;

/** SDS.COMPAADT WILL CONTAIN ALL AADT'S**/
```

```
/*************************************************************
*      THIS PROGRAM CONVERTS FROM AADT TO ESAL LOADS *
*      ACCORDING TO   MODEL DEVELOPED IN CTR RR 472-6   *
*                                              Model 2         *
*                              Program Developed By Mauricio Ruiz    *
**************************************************************/

LIBNAME SDS 'A';
DATA SDS.JCPESAL; SET SDS.JCPAADT; /** CONVERT FROM AADT TO ESAL**/
LENGTH YR25-YR93 4; LENGTH ESAL25-ESAL93 4;
ARRAY YR[*] YR25-YR93;  /** ASSIGNING YEARS TO AADT'S **/
DO I = 1 TO DIM(YR);
YR[I]=I+24;
END;
DIS =FLOOR(CFTR/100000); /** CFTR HAS 7 DIGITS (LAST TWO = SECTION**/
HWYCLAS = SUBSTR(HWY,1,2);

/*** INITIALIZING DUMMY VARS FOR THE MODEL ***/
H1=0; /*** OTHER THAN IH HWY ***/
IF HWYCLAS='IH' THEN H1=-3499293;
H2 = 343147; /*** FOR DISTRICTS 12,17,18,20 ASSUMING NO OTHERS***/
IF DIS=1 OR DIS=5 OR DIS=25 THEN H2=176955;
ELSE IF DIS=3 THEN H2=-1978928;
ELSE IF DIS=4 OR DIS=16 THEN H2=-2580881;
ELSE IF DIS=9 THEN H2=-4041762;
ELSE IF DIS=13 THEN H2=-2034159;
ELSE IF DIS=19 THEN H2=1102543;
ELSE IF DIS=24 THEN H2=0;
H3= 150.09;
IF DIS=1 OR DIS=5 OR DIS=25 THEN H3=114.23;
ELSE IF DIS=3 THEN H3=80.46;
ELSE IF DIS=4 OR DIS=16 THEN H3=33.02;
ELSE IF DIS=9 THEN H3=53.37;
ELSE IF DIS=13 THEN H3=70.91;
ELSE IF DIS=19 THEN H3=63.36;
ELSE IF DIS=24 THEN H3=183.04;
H4=0;
IF HWYCLAS='IH' AND DIS=1 THEN H4=786459;
IF HWYCLAS='IH' AND DIS=5 THEN H4=786459;
IF HWYCLAS='IH' AND DIS=25 THEN H4=786459;
IF HWYCLAS='IH' AND DIS=13 THEN H4=567627;
H5=0;      /** FOR OTHER COMBINATIONS ***/
IF HWYCLAS='IH' THEN H5=44119;
H6=-16829;  /** OTHER DISTRICTS **/
IF DIS=1 OR DIS=5 OR DIS=25 THEN H6=-12172;
ELSE IF DIS=3 THEN H6=26769;
ELSE IF DIS=4 OR DIS=16 THEN H6=41802;
```

```
ELSE IF DIS=9 THEN H6=62560;
ELSE IF DIS=13 THEN H6=22873;
ELSE IF DIS=19 THEN H6=-7951;
ELSE IF DIS=24 THEN H6=0;

ARRAY AADT(*) AADT25-AADT93;
ARRAY ESAL(*) ESAL25-ESAL93;

DO I=1 TO DIM(YR);       /*** MODEL USED FOR CONVERTION ***/
ESAL[I]=0;
IF AADT[I] NE 0 THEN  DO;
ESAL[I]=H1+H2+12.037*YR[I]+H3*AADT[I]+H4+H5*YR[I]+H6*YR[I]-433658;
 END;
IF ESAL[I]<0 THEN ESAL[I]=AADT[I]*144.29;
END;

TOTESAL = SUM (OF ESAL25-ESAL93);     /*** COMPUTES CUMMULATIVE
ESALS**/
KEEP CDATE CFTR DIR ESAL25-ESAL93 TOTESAL;
RUN;
/** SDS.JCPESAL WILL CONTAIN ALL ESAL'S**/
```

```
/*****************************************************************
*     THIS PROGRAM CONVERTS A TXT FILE AS SAVED      *
*     FROM A SPREAD SHEET (WITH TABS B/W DATA)              *
*     TO A SAS DATA SET                                      *
*                                                            *
*                                  By Mauricio Ruiz          *
*****************************************************************/
FILENAME INP 'JCPAADT TXT A';
LIBNAME SDS 'A';
DATA JCPAADT.SDS;
INFILE INP DELIMITER='05'X;    /*** DELIMITER('05'X) = TABS  ***/
INPUT CFTR SEC DIR $ CDATE  AADT68-AADT93;
RUN;
```

APPENDIX D:

DATA SHEETS USED

Design Information Sample Sheet

District 01 County Hunt Highway US0069

Control - Section - Job : 400 - 1 - 11

Completion Date (mm - yy): ______ - ______

Pavement Type: Plain Reinforced

Coarse Aggregate Type ______________________________

Slab Thickness: ________ in.

Slab Length: _________ ft.

Load Transfer Devices: Y N

Shoulder Type______________________

Subbase Type______________________ Thickness____

From: ______________________________________

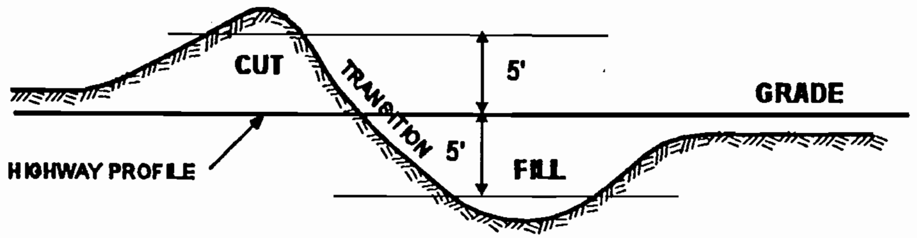
To: ______________________________________

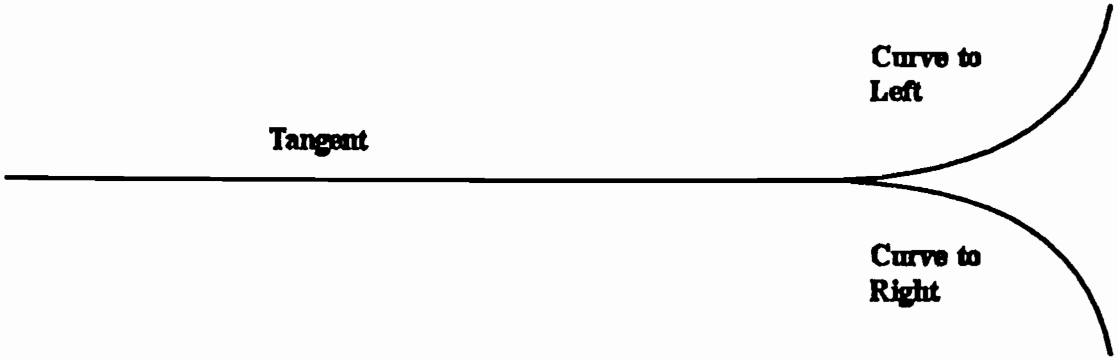
Comments: ______________________________________

____

Survey form for identification of the test section (Sample Sheet 1)

District	**Control - Section - Job**	**Highway**	**CFTR No.**	**Dir.**	**County**	**Date** **Mo / Day / Yr**
	— —		—			/ /
Location: **From**		**To**			**No. of Lanes**	**Raters**





Condition survey form for non-overlaid pavements (Sample Sheet 2a)

CFTR No.	Diz

Latitude
N ° . '

Longitude
W ° '

Date

Surveyors

JCP DISTRESS SURVEY (Non Overlaid)

Reference Markers ______ ______		Failures						No. of Patches							Transverse Cracks	
		No. of Punchouts		No. of D - Cracking	No. of Corner Breaks	No. of Spalled Joints /Crks	No. of Faulted Joints /Crks	AC (sq. ft)			PCC (sq. ft)			Slabs w/Longitudinal Crks	No. of Cracks	Joints and Crack Spacing (Accumulative Distance from the Starting Point to each Crack) for the first 200 ft. only. (Denoted by "J" and "C")
Start Point	End Point	M	S					1 - 50	51 - 150	> 150	1 - 50	51 - 150	> 150			(Indicate joints with a circle)
0 . 0	2 0 0 . 0															
2 0 0 . 0	4 0 0 . 0															
4 0 0 . 0	6 0 0 . 0															
6 0 0 . 0	8 0 0 . 0															
8 0 0 . 0	E N D															

M = Minor, S = Severe

Condition of Shoulders ______________________________

____

General Comments ______________________________

____

Condition survey form for overlaid pavements (Sample Sheet 2b)

CFTR No. | Dir

Latitude N ° . '

Longitude W ° '

Date

Surveyors

JCP DISTRESS SURVEY (Overlaid)

Reference Markers		Cracking*		Rutting**		No. of AC Patches (sq. ft.)			No. of Spalled Joints /Crks	No. of Faulted Joints /Crks	No. of Punchouts		No. of Corner Breaks	Transverse Cracks	
Start Point	End Point	Alligator Cracking	Block Cracking	Shallow (>=0.5"-1.0")	Deep (>=1.0"-3.0")	1 - 50	51 - 150	> 150			M	S		No. of Cracks	Crack Spacing (Accumulative Distance from the Starting Point to each Crack) for the first 200 ft. only. (Indicate joints with a circle)
0.0	200.0														
200.0	400.0														
400.0	600.0														
600.0	800.0														
800.0	END														

* % of Rated Lanes Total Surface Area

** % of Total Wheel Path Area

Condition of Shoulders ____________________

General Comments ____________________

Traffic Information Sample Sheet

District 01 County Hunt Highway US0069

CFTR 1101 Section 2 Direction S

Start Reference Marker 251.5 End Reference Marker 251.69

Start Milepost______ End Milepost______

Start Milepoint 3.23 End Milepoint 3.42

Completion Date 1955

Year	AADT	Year	AADT	Year	AADT
1968		1977		1986	
1969		1978		1987	
1970		1979		1988	
1971		1980		1989	
1972		1981		1990	
1973		1982		1991	
1974		1983		1992	
1975		1984		1993	
1976		1985			

Yearly % Increment ______ ATHWL ___________

Directional Distribution____ % Tandem Axles _____

Truck Percentage ________

Comments: ____

Maintenance and Rehabilitation Information Sample Sheet

District 01 County Delta Highway SH0019

CFTR 1551 Section 1 Direction E

Control - Section - Job : 400 - 1 - 11

Start Reference Marker 222.25 End Reference Marker 222.45

Start Milepost______ End Milepost______

Start Milepoint 18.2 End Milepoint 18.4

Completion Date 1970

Activity	**Date**	**Thickness**	**From Milepoint**	**To Milepoint**	**Job No.**

Comments: ____

____