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THE DEVELOPMENT OF A LONG-RANGE REHABILITATION PLAN FOR US-59 IN DISTRICT 11—PRELIMINARY REPORT

Brock E. Hoskins, B. Frank McCullough, and David W. Fowler

RESEARCH REPORT 987-1

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16. Abstract

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conducted for

Texas Department of Transportation

by the

CENTER FOR TRANSPORTATION RESEARCH

Bureau of Engineering Research
THE UNIVERSITY OF TEXAS AT AUSTIN

February 1991

NOT INTENDED FOR CONSTRUCTION,
PERMIT, OR BIDDING PURPOSES

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Study Supervisors

PREFACE

This report contains the data and analysis that were needed to plan and design a series of test sections which will be included in a plan set and let to construction by District 11 (Lufkin, Texas) personnel. The overall objective of the research in the subject project is to develop a long-range rehabilitation plan for US-59 in District 11. To develop such a plan it will be necessary to determine rehabilitation strategies for each section of roadway throughout the district. Information related to the performance and costs of various types of pavement in District 11 will be needed to forecast the desirability of specific strategies. The test sections were designed to develop the performance and cost information.

LIST OF REPORTS

Research Report 987-1, "The Development of a Long-Range Rehabilitation Plan for US-59 in District 11—Preliminary Report," by Brock E. Hoskins, B. Frank McCullough, and David W. Fowler, presents the initial phase of a rehabilitation plan for the entire length of US-59 in District 11 (Lufkin). The report includes the data collection, analysis, and the design for a series of test sections that are to be placed for the purpose of gathering information concerning rehabilitation strategies.

ABSTRACT

In this study, a rehabilitation plan is to be developed for US-59 throughout District 11 (Lufkin). The rehabilitation plan will cover a relatively long time period and could include one or more life cycles. There is the possibility that any one (or a combination) of several pavement designs could be used on a specific section of the highway, depending on the expected life and cost of the treatment. Since some of the possible pavement structures have not been constructed in the district, it was desirable to obtain construction, costs, and some measure of expected life by placing a series of test or observation sections with relatively small lengths. This report contains the preliminary work toward the development of the rehabilitation plan, and the development of several pavement designs that are proposed for the test sections.

Much of the old jointed pavement on US-59 contains shattered slabs that have been overlaid with asphaltic concrete. As a part of the rehabilitation study, the asphaltic concrete was removed from a small area and the old concrete was repaired using polymers and epoxies at the cracks and by removing and inserting new joint assemblies. A portion of this report is devoted to that repair.

SUMMARY

Much of US-59 in District 11 (Lufkin) consists of a four-lane, two-directional facility. The dirt work and base for two of the four lanes were originally constructed in the 1920's and 1930's. A jointed concrete pavement was then constructed in the 1930's and 1940's. The remaining two lanes are generally flexible pavement and were constructed in the 1950's and 1960's. The jointed pavement has deteriorated to the extent that cracks reflect through new overlays after a relatively short service period and that serviceability is lost. Much of the flexible pavement has reached an age of about 30 years. Therefore, it has become advisable to develop a long-range rehabilitation plan which will consider the most advanced construction and rehabilitation designs available. From these, the most cost-effective elements will be selected for the plan. In essence, the rehabilitation plan is the heart of a pavement management system that includes an entire route through the district.

The contents of this report show the initial data collected along the route and the procedures used to develop the pavement designs for several test sections, which are to be constructed in order to collect construction, cost, and serviceability information. The rehabilitation designs suggested are:

Rigid—

Repair PCC/Replace AC Overlay
Break and Seat
Overlay with Flexible Base, then Overlay
Arkansas Mix
Stress Relief Interlayer
AC Overlay

Flexible—

3-inch SBS-Modified Type D AC Overlay
3-inch SBS-Modified Type C AC Overlay
3-inch Type B + 1-1/2-inch Type C AC Overlay
3-inch Type C over existing pavement
Coldmill, 3-inch Type C, 10-inch Flexible Base
Coldmill, 6-inch Type C, 3-inch Type B

IMPLEMENTATION STATEMENT

District 11 personnel have developed a plan set that contains the plans, specifications, and estimate needed for constructing the test sections treated in this report. The job is to be let in the spring of 1991. In addition to the preliminary data collected, the sections are to be monitored during construction and periodically after construction. Construction, cost, and performance information will be used in the lon-range rehabilitation plan.

Much of the information in this report relates to the present roadway condition of US-59. This information will also be used in the development of the long range plan.

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CHAPTER 1. INTRODUCTION

1.1 BACKGROUND

US-59 is one of the principal arterial highway routes in Texas running from Laredo, at the Mexican border, through Houston, to Texarkana. Within District 11, US-59 crosses San Jacinto, Polk, Angelina, Nacogdoches, and Shelby Counties for a total length of 130 miles. The south end of US-59 in District 11 reaches the northeast limits of the Houston metropolitan area. The average daily traffic (ADT) along US-59 from the southern boundary of District 11 to Nacogdoches, approximately 89 miles, is approximately 15,000 vehicles. This section of US-59 is a four-lane, grass-median, divided highway (except in some urbanized areas where a painted median is used) without access control. From Nacogdoches to the northern edge of District 11, approximately 41 miles, US-59 is generally two lanes with some four-lane sections in the urbanized areas, with an ADT of approximately 7,500 vehicles (see Figure 1.1). Because US-59 is one of the principal entries to and exits from Houston, and because its route includes the port of Houston and also passes through the logging and timber industry region of East Texas, trucks compose approximately 30 percent of the traffic.

The existing pavement infrastructure is characterized by a variety of rigid and flexible pavement design concepts, some of which are more than 50 years old. This infrastructure has been modified by various rehabilitation and maintenance activities (e.g., pavement widenings, shoulder additions, asphalt concrete overlays, seal coats, concrete joint repairs and replacements, punchout repairs, and periodic crack sealing). The current pavement structure designs evolved more from exigency and funding limitations than from a planned objective of long service life and minimum maintenance costs. The fact that the existing overall pavement condition on US-59 provides tolerable riding qualities within District 11 is a tribute to the perseverance, diligence, and ingenuity of the district's maintenance organization.

The important role of US-59 in the Texas economy, and in the anticipated growth of the economy, suggests that future traffic demands will only be aggravated by relying on constant and intense maintenance operations to maintain tolerable riding qualities. User costs, owing to delay, escalate very rapidly as traffic increases. Therefore, as traffic increases along US-59, consideration should be given to improving overall pavement quality so that the life cycle of the pavement can be extended substantially. An extended pavement life would decrease the interruptions and the delays caused by maintenance and rehabilitation operations. Thus, a long-range rehabilitation plan is needed for District 11 to optimize the total cost of rehabilitating the highway.

In trustworthy planning of improved long-range pavement performance, much depends upon accurately forecasting not only environmental and traffic conditions, but also the response of a particular pavement design to these conditions. In pavement management, the most reliable guide to future performance is the experience of past performance. Unfortunately, within certain regions of the state, such experience is not available or may not be directly transferable from other regions for some pavement types. Transferability of pavement management experience may not be practical, depending on environmental conditions, traffic conditions, or the cost or the availability of certain materials. There are several plausible methods by which the pavement along US-59 can be restored or replaced. Some of the more attractive methods have not been used in District 11. However, these methods, which have proved successful in other environments and with other pavement infrastructures, may not be adequate for District 11.

1.2 OBJECTIVES

The overall objective of this project is to develop a long-range rehabilitation plan for US-59 in District 11. This plan will estimate the annual cost of rehabilitating and reconstructing all of US-59 within District 11 during a 10- to 15-year period. The plan will also address the project letting

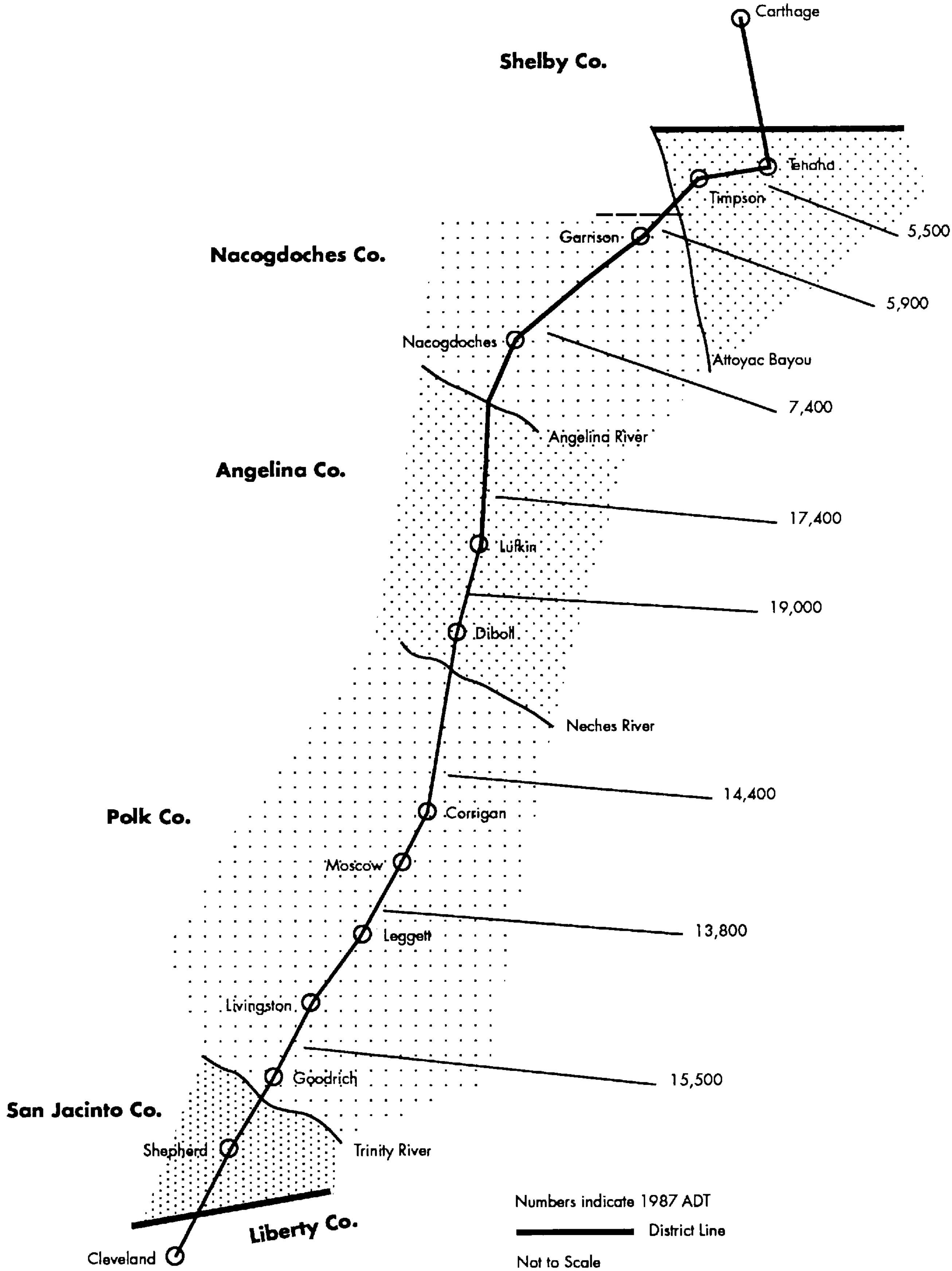


Figure 1.1 A general overview of US-59 in District 11 designating cities, counties, and ADT at selected locations

schedule, alternative types of pavement improvements, and cost for each project. This part of the plan has been named the long-term objective.

A short-term objective will be to plan, to design, to construct, and to monitor the performance of alternate experimental pavement test sections along US-59 at selected locations. It is hypothesized that, by investing a relatively small sum in experimental pavement segments, much insight into future pavement performance can be acquired and applied to the development of the long-range plan.

1.3 PROJECT PHILOSOPHY/MANAGEMENT

Areas of responsibility for this project were divided between the Center for Transportation Research (CTR), the State Department of Highways and Public Transportation (SDHPT), and an expert task force formed as part of the project. The establishment of a group of experts to direct the development of the long-range plan for the rehabilitation of US-59 is paramount to the success of the project. The task force consists of individuals from the Center for Transportation Research, District 11 engineering staff, and State Highway Department Division 8. The task force has not only directed the development of the long-range plan, but initially selected promising rehabilitation methods for use on jointed portland cement concrete (PCC) pavements to be evaluated as part of this project. Periodic meetings of this group have been and will be held on an as-needed basis.

1.4 CONCEPTUAL DESCRIPTION OF THE PROJECT

The main objective of this project is to develop a long-range rehabilitation plan for US-59 in District 11. Therefore, each phase of the project is related to or directed toward developing that plan. This project addresses the need to improve pavement performance service along US-59. Improved performance is defined as providing and maintaining a minimum satisfactory pavement riding quality at the least annual cost (where the cost includes the SDHPT's construction, operational, and maintenance costs as well as the highway users' time, operational, and safety costs during construction and maintenance operations).

The first step in the process of developing the long-range plan is data collection. Several types of information are needed, including an inventory of existing pavement types, pavement conditions, and traffic and load information. These types of information are needed as a basis for the planning process. Once these and other data are obtained, the data will be analyzed based on project delineation, prioritization, and economics. It is essential that the data and information be used for the development of suitable rehabilitation strategies.

The preliminary plan development phase will include an assessment of needs, development of various design strategies, development of traffic handling strategies, and formulation of the design, construction, and monitoring plan for the experimental sections. The performance of the experimental sections will be monitored for approximately three to five years. This will allow for the comparison of the performance of several different rehabilitation alternatives for the purpose of possibly selecting one or more for the long-range plan.

District 11 personnel will develop the long-range plan for rehabilitating US-59. This plan will be based on selecting an optimum rehabilitation strategy for each section of roadway throughout the district. CTR staff will provide assistance in such areas as training in the use of certain analytical tools, and, if needed, in specialized design. The monitoring and evaluation of the performance of the experimental sections will be used to refine and revise the long-range plan. A critical path diagram representing the entire project is shown in Figure 1.2.

1.5 SCOPE

The long-range plan developed as part of this project will be directed toward the needs of US-59 within District 11. However, the framework of this plan may be used for the cost-effective rehabilitation of pavements in other districts throughout the state of Texas. In order to effectively assess various rehabilitation options, a limited number of experimental pavement sections will be placed on US-59. These test sections will be monitored and evaluated to assess data applicable to the rehabilitation of US-59. This report will discuss the following phases of the project: data collection, data analysis, and preliminary plan development including the design, construction, and observation of the experimental sections.

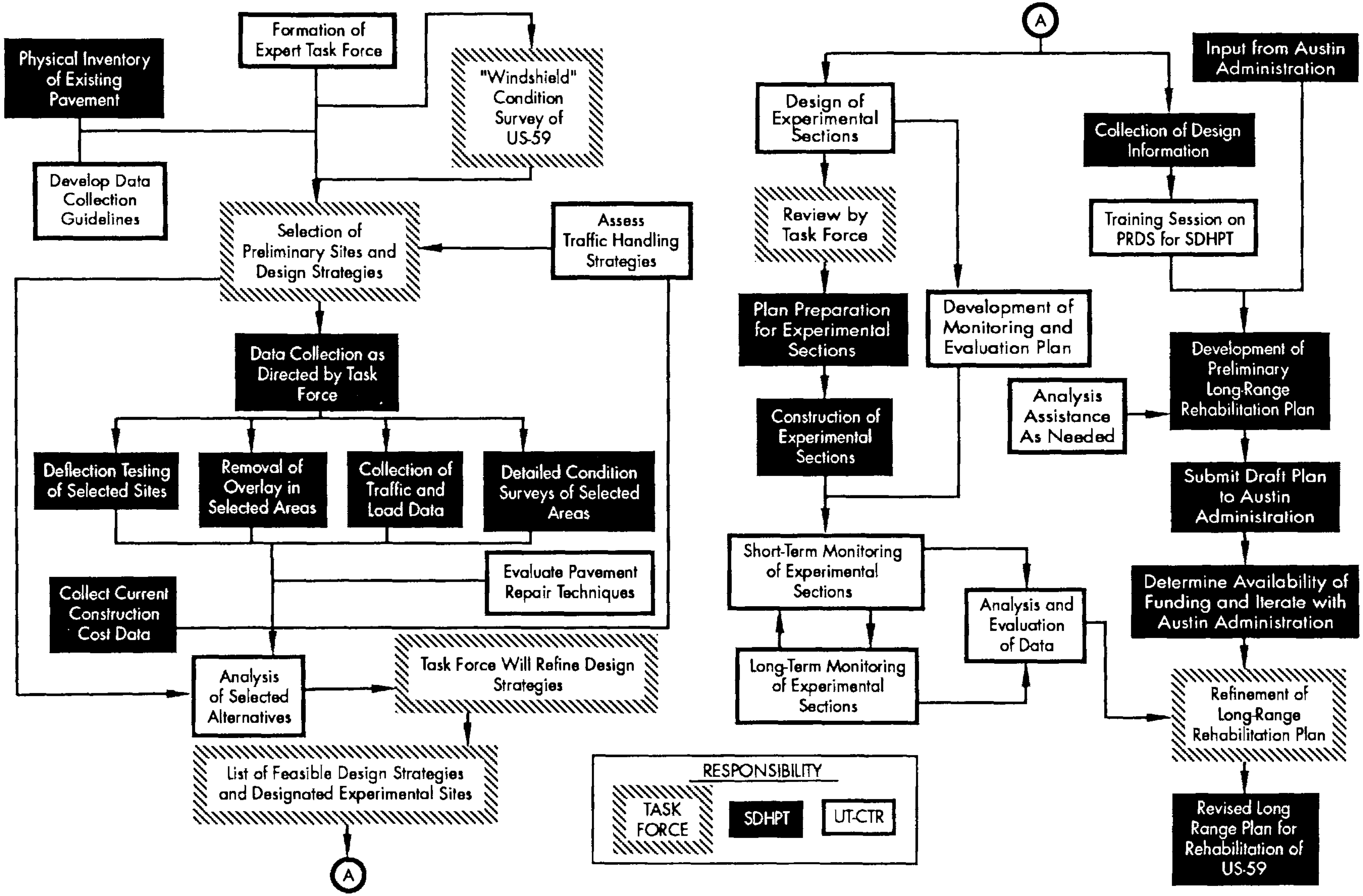


Figure 1.2 Flowchart of work plan showing individual task assignments for developing a long-range rehabilitation plan for US-59 in District 11

CHAPTER 2. DATA COLLECTION

2.1 INTRODUCTION

The data collection phase of this project is most important, as it will have a direct impact on the entire project. The plans for rehabilitation will be based on existing pavement characteristics throughout the district. These characteristics include pavement types, pavement conditions, and traffic and load information, and will be discussed in this chapter. The success of this project depends on an accurate, comprehensive base of information upon which to build.

2.2 PAVEMENT TYPES

The first step in the development of a long-range rehabilitation plan for US-59 was to establish an inventory of the existing pavement. This inventory included a review and summary of state construction, maintenance, and rehabilitation records on US-59. Cores were taken in order to verify specific pavement types and layer thicknesses. These data were used to develop an inventory of the different pavement types on US-59. Identification of existing pavement types was necessary in order to effectively assess rehabilitation options.

The proposal for this project originally identified the need for 1,000 cores along the 560 lane-miles of US-59 in District 11. The purpose for taking cores was to establish material types, material thicknesses, and pavement conditions. The cores were to be taken at approximately 2-mile intervals throughout the district. However, because of manpower shortages within the district, coring operations were performed only in Polk County.

The coring was performed at each milepost, that is, every two miles in the outside lanes in both travel directions. The coring was accomplished during July 1989. Photographs of each core were taken, with an indication of location, direction, material types, and material thicknesses included in each photograph. An example of these photographs is shown in Figure 2.1 (page 6). The nomenclature used for identifying each core is defined in the next column:

Table 2.1 Nomenclature used for cores

Identification	Description
NBL	Northbound lanes
SBL	Southbound lanes
MP	Milepost
ACP	Asphalt concrete pavement
SEAL	Penetration seal coat
LW	Lightweight aggregate
LS	Crushed limestone aggregate
IO	Iron ore aggregate
RG	River gravel
LRA	Limestone rock asphalt

The existing pavement types throughout the district include several variations of asphalt concrete pavements and thickened-edge jointed portland cement concrete pavements, all pavement types having several thin asphalt concrete overlays. A description of each pavement type and respective location within each county is included in Appendix A.

2.3 PAVEMENT CONDITIONS

Once the different types of existing pavements were established, the next step was to determine the present condition of each type. It was extremely important to determine the condition of each pavement type at different locations for the purpose of appropriately evaluating different rehabilitation alternatives. The basic types of information needed include structural integrity, distresses (including type, amount, and severity), and roughness.

2.3.1 Condition Survey Information

The first step in evaluating the general condition of US-59 in District 11 involved a windshield survey. The task force surveyed US-59 to familiarize themselves with the pavement conditions along the roadway and the nature of distresses. The original project proposal recommended a walking survey of 10 percent of US-59 in District 11. This

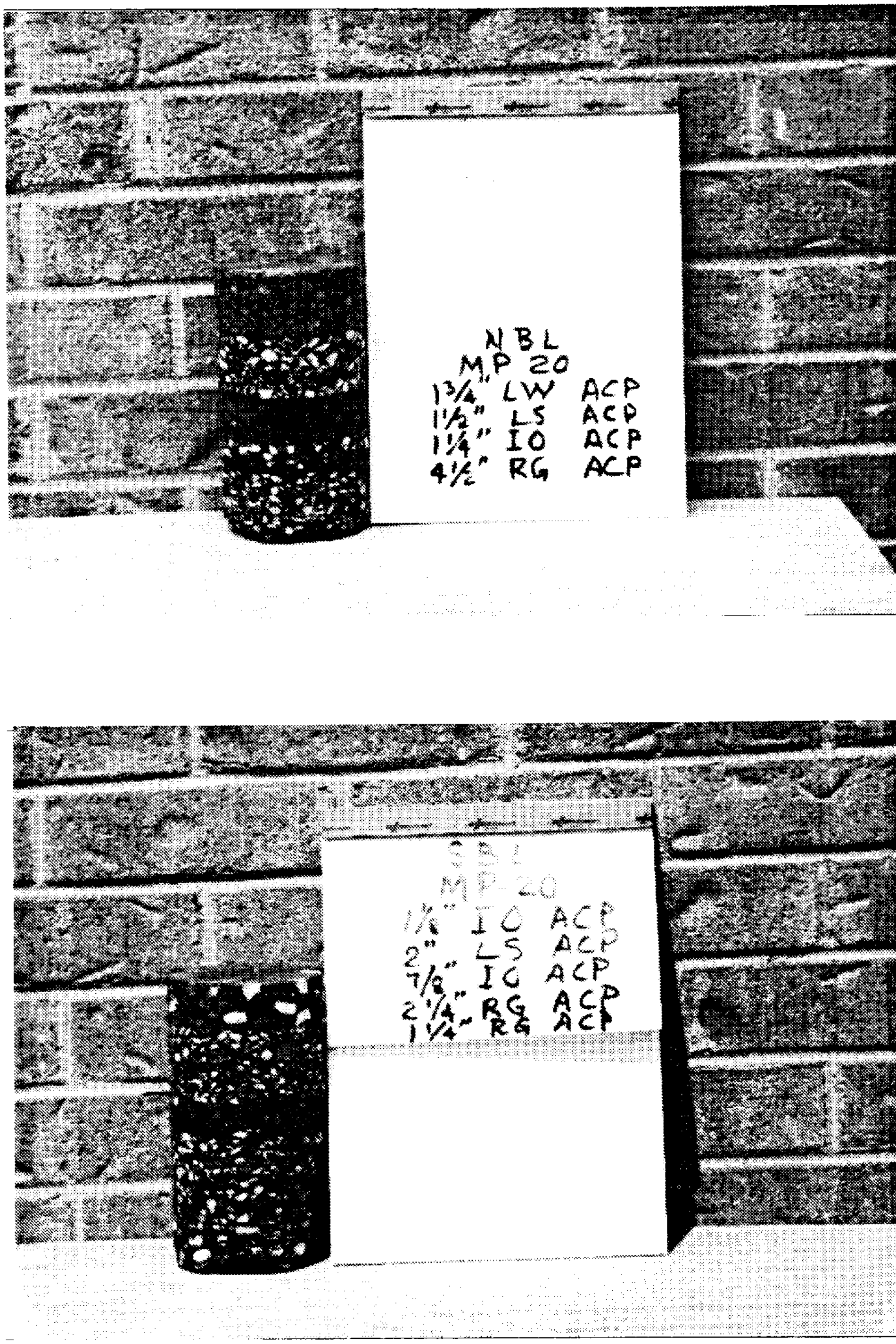


Figure 2.1 Example of core identification

survey was to include 10 percent of the length of each pavement type. Divisions within the 10 percent were to be made in order to account for distress differences at different locations. For example, if one-fourth of the total length of US-59 in District 11 is 9-7-9 jointed concrete pavement (JCP), then one-fourth of the survey was to be conducted on 9-7-9 JCP. A 9-7-9 pavement is identified as a thickened-edge pavement that has a thickness of 7 inches in the center and 9 inches at each edge. Furthermore, if there were 8 miles of 9-7-9 JCP in Polk County and 10 miles of 9-7-9 JCP in San Jacinto County, then 0.8 mile was to be surveyed in Polk County and 1.0 in San Jacinto County. However, because of manpower shortages within the district, the walking surveys were conducted only within the test section locations and will be discussed later.

2.3.2 Automated Road Analyzer

The Automated Road Analyzer (ARAN) was used to videotape the entire length of US-59 in District 11 in June 1989. Using the ARAN instead of manual surveys eliminated the following problems: (1) manpower shortages within the district, (2) safety hazards associated with manual surveys, and (3) traffic delays. The Project Task Force determined that a condition survey of a 10 percent sample of all roadway types in the district was required. Therefore, a one-tenth-mile section was randomly chosen for analysis from each mile of US-59 in District 11. The sections analyzed represented a 10 percent sampling of each roadway type. Condition survey information recorded from the 10 percent sampling included transverse cracking, longitudinal cracking, patching, block cracking, alligator cracking (both wheelpaths), and shattered slabs. The entire length of US-59 in District 11, however, was analyzed for rut depth.

Although the ARAN results are analyzed in Chapter 3, it is emphasized that these ARAN results represent the condition of the pavement sections only at the time of the survey (June 7-8, 1989). These results alone reduce the reliability of determining the performance of the pavement sections.

2.3.3 Falling Weight Deflectometer

The original project proposal called for falling weight deflectometer (FWD) measurements to be taken every 100 feet on the outside lane in both directions throughout the district. The location of each measurement was to be accurately recorded so that the measurement could be repeated at the same location at some later date. However, the only FWD measurements taken were within the test section locations and will be discussed later in Chapter 3.

2.4 TRAFFIC AND LOAD INFORMATION

The historical traffic and load data for US-59 in District 11 will allow for an estimate of the performance of typical sections. Traffic information including load data collected by a weigh-in-motion (WIM) system was furnished by the district. The following information was furnished by the district for each section of US-59 within the district:

(1) average daily traffic (ADT),
(2) percent trucks,
(3) average of the ten heaviest wheel loads (ATHWL),
(4) percent tandem axles in ATHWL, and
(5) number of 18-kip ESAL for a rigid and a flexible pavement.

Traffic and load data were used in the calculations for determining the design life for the rehabilitation alternatives within the test sections. These data will also be used by the district so that future rehabilitation strategies can be evaluated.

2.5 TEST SECTIONS

The data collected within the test sections were much more extensive than for the entire roadway. Extensive data were needed in order to select appropriate rehabilitation alternatives. Data collection techniques included checking records, a windshield survey, condition surveys, coring, FWD measurements, ground-penetrating radar (GPR), and a pilot repair study which will be discussed later.

2.5.1 Background

The Task Force used state records and a windshield survey to select the sites for the test sections. The criteria used for site selection included the following:

(1) minimum disruption to the public;
(2) minimum number of intersections, drives, crossovers, and so forth in the vicinity;
(3) pavement structure should appropriately represent the variety of existing pavement types, specifically considering both rigid and flexible types;
(4) minimum longitudinal grade; and
(5) avoidance of vertical and horizontal curves.

Based on these criteria, two sites were selected for the test sections. Both sites are approximately one mile in length and are located in Polk County in the southbound lanes. The locations of these test sites are shown on the Polk County map in Appendix A.

The first site (rigid section) is located just south of FM 357, beginning at Station 1490 and decreasing in station number. The existing pavement structure for this site is shown in Figure 2.2, and Table 2.2 provides the construction history of the pavement structure.

The second site (flexible section) is located just south of Corrigan, beginning at Station 1060 and decreasing in station number. The existing pavement structure for this site is shown in Figure 2.3, and Table 2.3 provides the construction history.

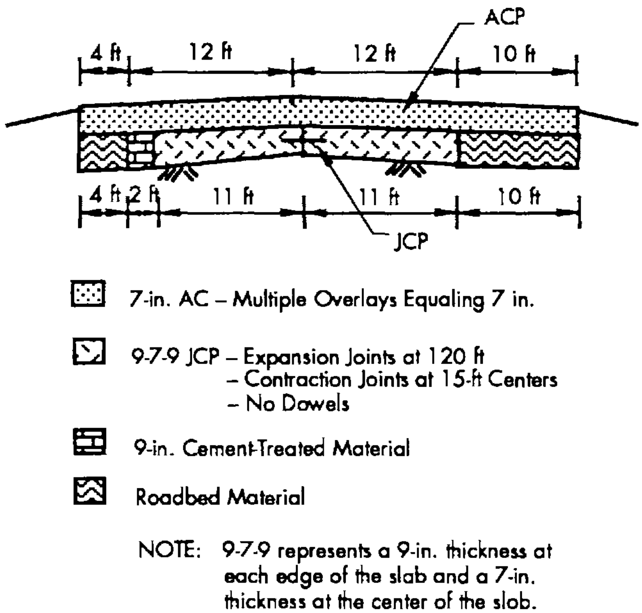


Figure 2.2 Existing cross-section at rigid pavement test site

Table 2.2 Construction history of rigid section

Date	Construction
1943	9-7-9 PCC
1953	1.5-in. AC overlay
1964	1.5-in. AC overlay
1971	1.2-in. AC overlay
1979	1.3-in. AC overlay
1982	1.5-in. AC overlay

2.5.2 Falling Weight Deflectometer

FWD measurements were taken throughout both test sites in June 1989. The objective was to characterize the existing pavement structure in each of the test sites. Deflection measurements, along with pavement layer thicknesses, were used to back-calculate material properties of each pavement layer. The falling weight deflectometer measurements were also used to quantify the structural capacity of the pavement as well as the load transfer efficiency of existing joints and cracks. The following paragraphs discuss the work plan used in collecting the FWD data.

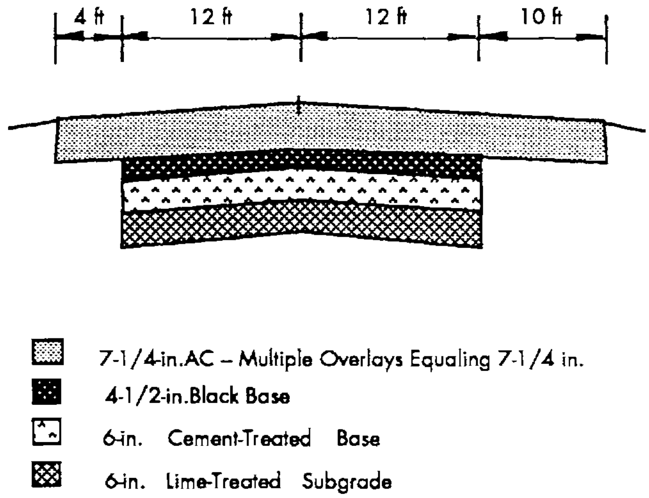


Figure 2.3 Existing cross-section at flexible pavement test site

Table 2.3 Construction history of flexible section

Date	Construction
1966	6-in. lime-treated subgrade 6-in. cement-treated base 4.5-in. black base 1.5-in. ACP
1974	1-in. AC overlay
1978	1.5-in. AC overlay
1985	3.2-in. AC overlay

2.5.2.1 Rigid Sections. The work plan described herein was developed for the Polk County site in which the rigid pavement beneath the asphalt concrete pavement (ACP) overlay(s) has expansion joints at 120 feet with contraction joints centered at 15 feet. The concepts presented could be adapted to other slab lengths and joint configurations without difficulty. Table 2.4 and Figure 2.4 illustrate the procedures and techniques used in taking FWD measurements. All measurements were taken in the outside lane and were not necessarily taken in sequence (1, 2, 3, 4, 5, 6, and 1). The location numbers establish only the location for each measurement.

Additional measurements were taken to assess the load transfer at midspan cracks. Ten midspan cracks were assessed in each mile, provided they were present. This assessment consisted of two measurements: the first, midway between the midspan crack and the nearest upstream contraction joint and the second, adjacent to the midspan crack, as shown in Figure 2.5. These measurements required a maximum of 20 additional readings per mile.

The influence of temperature on deflection measurements is well known. In order to account for the inevitable temperature variation during the course of data collection, a concrete block equipped with instruments for recording temperature was placed beside the roadway.

2.5.2.2 Flexible Sections. Readings were taken every 100 feet throughout the flexible test sites in the outer wheelpath of the outer lane.

2.5.2.3 Data Recording. The location of each deflection measurement was recorded with sufficient accuracy so that the measurement could be repeated at a later date.

2.5.3 Condition Surveys

Walking condition surveys were conducted on the test sites. Condition surveys of the test sites are intended to provide the district and researchers with the initial condition of the pavement within the test areas. This baseline data set will be compared to the after-rehabilitation survey results to assess the effectiveness of each rehabilitation alternative. Test sites with rigid pavement beneath the flexible overlays required more detailed surveys than did the flexible pavement sections.

2.5.3.1 Rigid Sections. The intent of this survey was to record the location of reflective cracking visible in the ACP overlay. Cracks within these sites were mapped on survey forms as accurately as possible. Recorded data include transverse and longitudinal cracks and the location and extent of any patched areas.

2.5.3.2 Flexible Sections. The intent of this survey was to obtain a small sample (approximately 10 percent) of the flexible pavement condition. The data were recorded for three 200-foot sections in each mile of pavement, using the SDHPT format. This format is described in the "1989 Pavement Evaluation System Rater's Manual," dated May 2, 1989. For fractions of a mile, the number of 200-foot sections that were surveyed is shown in Table 2.5.

Chapter 4 of this manual describes, in detail, the information collected. The only change implemented in the survey was to record three 200-foot

Table 2.4 Deflection measurement locations

Location	Description
1	Immediately downstream from the expansion joint
2*	Between the contraction joints (or between the expansion and contraction joints) away from any midspan cracks
3*	Upstream from the contraction joint
4	Adjacent to the expansion joint near outside shoulder
5*	Near pavement edge adjacent to Location 2
6*	Near pavement edge adjacent to Location 3
1*	Downstream from Location 3 on the opposite side of the contraction joint

* Readings at locations 2, 3, 1, 5, and 6 alternated between areas A, B, C, D, E, F, G, and H in successive slabs (i.e., readings were taken in area A in the first slab, in area B in the second slab, etc.).

NOTE: In this context, a slab is defined as the rigid pavement between successive expansion joints.

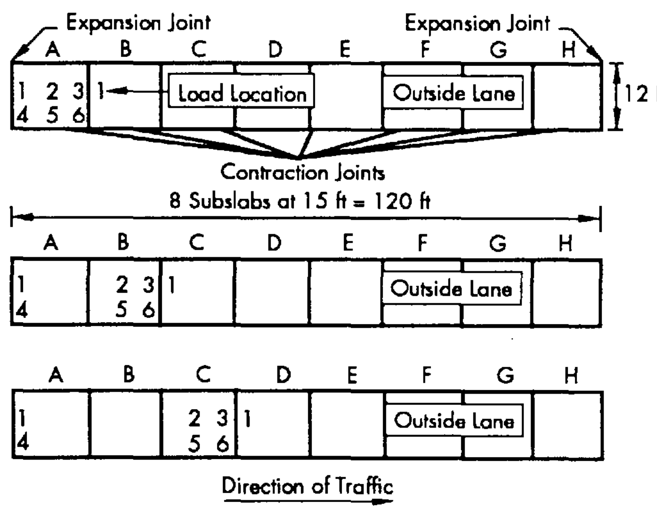


Figure 2.4 Rigid FWD measurement pattern

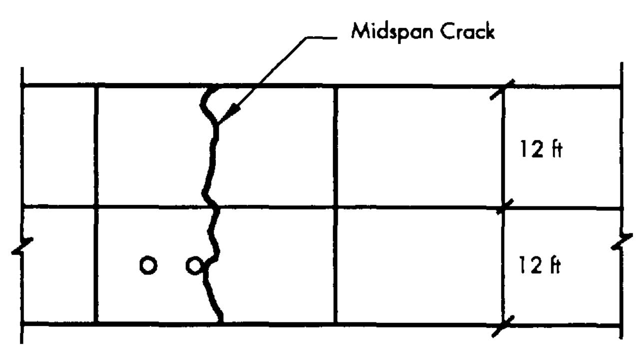


Figure 2.5 Location of midspan crack FWD measurements

Table 2.5 Fractional sections

Length	Number of 200-ft Sections To Be Surveyed
Less that 1/4 mile	1
Between 1/4 and 3/4 of a mile	2
Greater than 3/4 of a mile	3

Table 2.6 Core locations

Station	Lane	Wheel-Path	Expected Stripping	Depth to Stripping (in.)
1055 + 00	S	L	No	
1055 + 00	S	R	Yes	6.7
1033 + 70	S	L	No	
1033 + 40	S	R	Yes	7.5
1026 + 00	R	L	No	
1025 + 80	R	R	Yes	7.3
1017 + 50	R	L	No	
1017 + 65	R	R	Yes	6.6

sections per mile rather than the recommended three 200-foot sections per 2 miles. In addition, the results were recorded individually for each 200-foot section rather than averaged as recommended.

In addition to the survey outlined above, a detailed survey similar to that conducted on the rigid sections was conducted in one of the 200-foot sections per mile or fraction of a mile.

2.5.4 Ground-Penetrating Radar

Pulse Radar, Inc. furnished and operated a ground-penetrating radar (GPR) unit over both lanes of the two test sites on September 12 and 13, 1989. The GPR was used to obtain an indication of the presence and location of any stripped asphalt concrete within the test sites. The GPR gathers data along two lines with each pass. During the demonstration, data were collected in each wheelpath of both lanes. Within the flexible test site, the GPR indicated that the stripped layers are generally six to seven inches below the surface. Cores had not been taken at the time the GPR was operated; however, cores were taken at a later time at the locations identified in Table 2.6 in order to confirm the accuracy of the GPR.

2.5.5 Pilot Repair Study

During the period August 7-10, 1989, repairs were made on a selected area on US-59 in District 11. This project served as a pilot study to determine the effectiveness of various types of concrete repairs that might be used in the flexible-over-rigid test section to be constructed during the next fiscal year. Evaluation of the repaired areas over the following months, coupled with deflection measurements taken before and after the repairs were made, was used to determine the effectiveness of the repair.

The repair site was located just south of the intersection of FM 357 with US-59 in the southbound lanes. Repairs were made between stations 1488 and 1490 on the 9-7-9 jointed concrete pavement following the milling of approximately 7 inches of asphalt concrete. Figure 2.6 shows the repair location before repairs.

Drawings that map the surface cracks before and after the overlay was removed are shown in Appendix B. The inner lane repairs were completed on August 7 and 8, while the outer lane was repaired August 9 and 10. A single lane was maintained for the southbound traffic during these four days. Northbound traffic on US-59 was not visibly affected by the repair activities. Work generally commenced at 7:00 a.m. and continued until approximately 8:00 p.m.

On August 7, after milling, a joint at station 1488+15 was selected for replacement using the precast drop-in unit (Figure 2.7). Sawing and subsequent removal required approximately 4.5 hours. The precast joint was placed on a graded bed of cement-stabilized sand. The filler material, or "zipper," used was Set 45®; it was placed the following day.

Another joint, 120 feet north of the first joint at station 1489+35, was milled to a depth of about 3.5 inches and to a width of 4 feet using the district's milling machine. On the following day, the dowel basket assembly fabricated in Austin was placed and concrete using Type III cement was placed. The milling operation required approximately 30 minutes, and the basket and concrete placement required approximately 1.5 hours (Figure 2.8).

Because both joint repair preparation techniques (sawing and milling) use water to lubricate the cutting heads, there was considerable water standing on the slab following joint preparation. Several hours were spent removing the water and cleaning the slab for monomer placement the following day.

Drying of the cracks and joints using pear burners and additional cleaning of the these areas began on August 8. Air blasting of the cracks was followed by sand blasting in preparation for the monomer treatment. The monomer treatment consisted of filling the cracks with sand and then pouring the monomer over the sand (Figure 2.9). This process formed a polymer concrete seal. Small cracks, less than 0.25 inch, received only the monomer. The asphalt concrete was replaced that evening.

Repairs to the outer lane began on August 9. Rather than using the milling machine to prepare one of the two joints (as was done on the inside lane), both joints were prepared for precast drop-in slabs. Both joints were replaced using the saw technique described previously. One of the joints was "zipped-in" using Set 45® as before.

Crack repairs began on the outer lane on August 10. Most longitudinal cracks were repaired using the monomer treatment. The northernmost slabs were treated with epoxy mortar. The second of the two precast units was "zipped-in" using polymer concrete.

The effectiveness of each type of repair is discussed in Chapter 3. This performance of this repair section will continue to be monitored for several years.

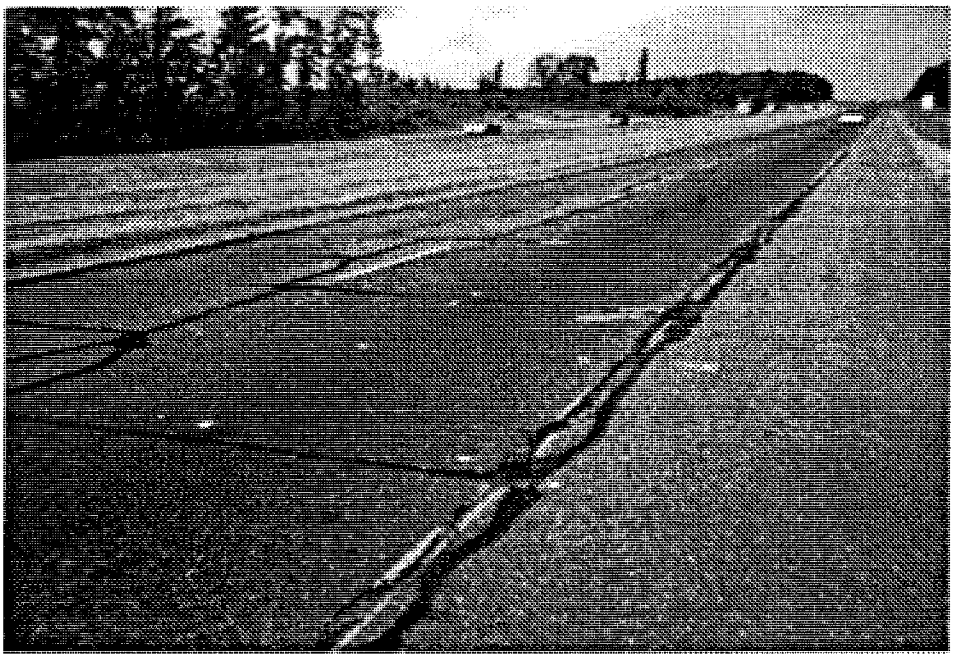


Figure 2.6 Repair location

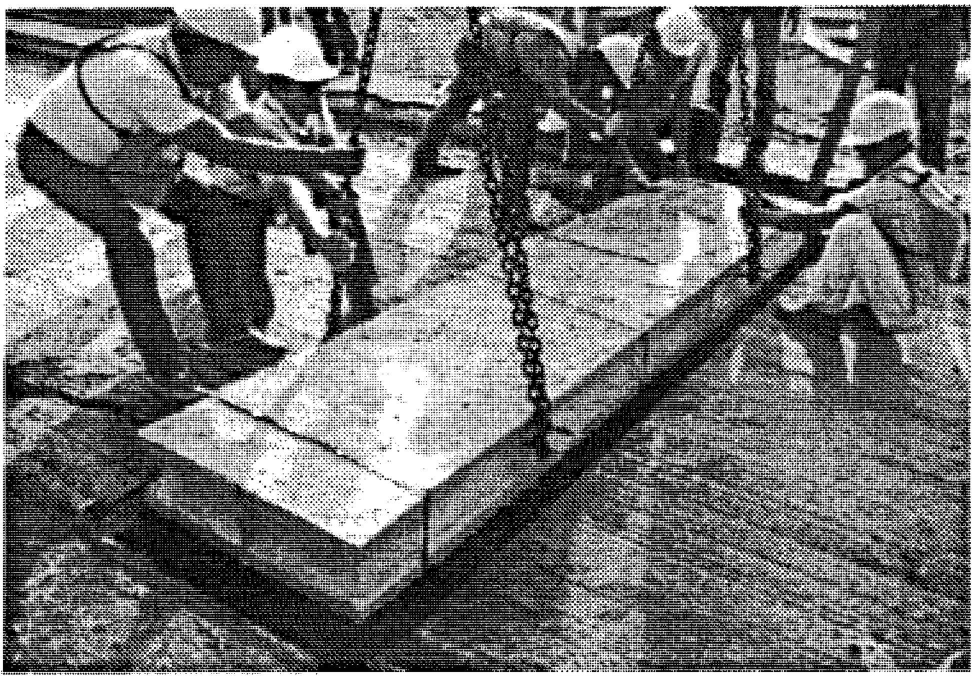


Figure 2.7 Precast slab

Figure 2.8 Milled joint and dowel basket assembly

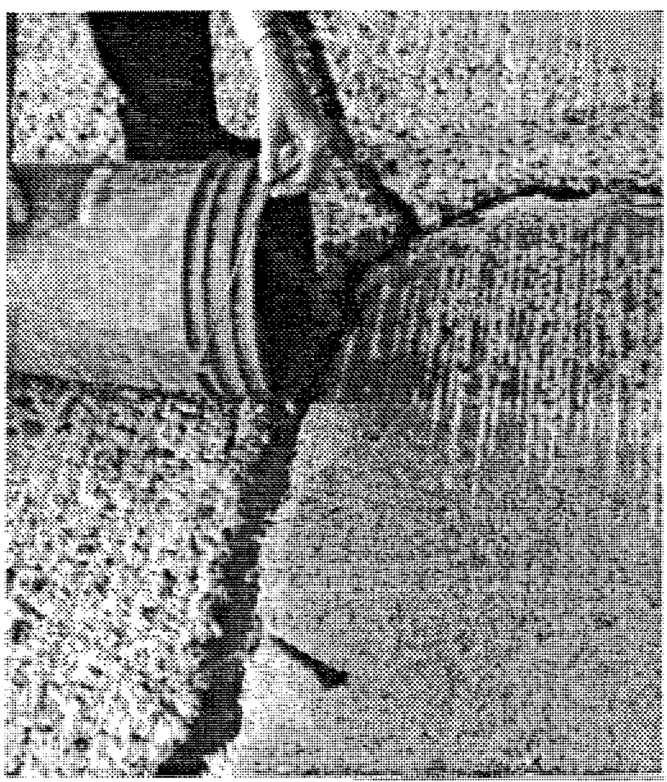


Figure 2.9 Monomer application

CHAPTER 3. DATA ANALYSIS

3.1 INTRODUCTION

It is essential that the data collected be analyzed and used in such a way as to allow for the development of appropriate strategies for rehabilitation. Because of economic and physical constraints, it is obvious that the entire length of US-59 in District 11 will not be rehabilitated at one time. Suitable roadway divisions throughout the district will allow for the rehabilitation of specific roadway sections at the appropriate time. Based on the data collected, priorities must also be established for specific roadway sections in order to develop the proper sequence of rehabilitation. This chapter discusses project delineation and prioritization.

3.2 PROJECT DELINEATION

Based on the large variability of the existing roadway characteristics and discrete funding, it is obvious that the improvement of US-59 in District 11 will have to be divided into several small projects. It is important to differentiate between different pavement types and to consider factors such as thickness of overlays, age of most recent overlay, and condition of pavement section. These and other factors must be considered so that suitable delineations are made throughout the roadway. These delineations will facilitate development of appropriate design strategies for specific sections of roadway.

As evidenced by the state construction records and the cores taken, the existing pavement infrastructure is composed of several types of rigid and flexible pavement types, some of which are more than 50 years old. These pavements have been modified by various rehabilitation and maintenance accretions over the years. It is important that appropriate rehabilitation alternatives be assessed for each pavement type.

Maps of each county showing the locations of each pavement type along with descriptions are given in Appendix A. Table A.1 in Appendix A identifies the composition of each pavement structure in the district. Each county map (Figures A.1 to A.5 in Appendix A) indicates the location of each pavement type along the roadway.

A summary of roadway lengths by pavement types is shown in Table A.2 in Appendix A. It is evident that approximately 50 percent of the roadway is composed of rigid pavement types, and 50 percent is composed of flexible pavement types. The majority of the flexible pavement types were constructed as the roadway was expanded from a two-lane highway to a four-lane divided highway. Pavement type R6 is a 24-foot-wide 10-inch PCC pavement with wrinkle tin joints at 15-foot centers and is the most prevalent rigid pavement type, comprising 10.6 percent of the total roadway miles. Pavement type F1 consists of 4.5 inches of black base, 6 inches of cement-treated base, and 6 inches of lime-treated subgrade, and is the most prevalent flexible pavement type, comprising 17.3 percent of the total roadway miles. All pavement types include a minimum of 1.5 inches of ACP surface course. Polk and Angelina Counties contain the most lane-miles of rigid pavement types while Polk and Nacogdoches Counties contain the most lane-miles of flexible pavement types.

Pavement history tables are given in Appendix C. These tables include the following information:

(1) county;
(2) pavement type;
(3) direction;
(4) original construction date, location, and thickness;
(5) overlay construction date, location, and thickness; and
(6) total pavement thickness.

These pavement history tables provide the information base from which rehabilitation strategies can be developed and assessed. This information may also be used as the basis for several types of analyses regarding pavement performance. For example, comparisons can be made between the long-term performances of different pavement types. An analysis of the overlay information in the tables will provide an indication of the required frequencies and thicknesses of future overlays as well as the expected service life of a specific overlay thickness in a specific county. The cost-effectiveness of thick overlays as compared to thin overlays may also be evaluated.

3.3 PRIORITIZATION

Once the appropriate delineations throughout the project have been made, priorities must be established for specific sections of roadway. An analysis of the data presented in Chapter 2 provides an indication of which sections of roadway need immediate attention.

3.3.1 Condition Survey Information

As stated in Chapter 2, the ARAN was used to conduct condition surveys throughout the entire length of US-59 in District 11. However, the portions of roadway analyzed for the distresses listed in Table 3.1 represent only a 10 percent sampling of each roadway type. The entire length of roadway, however, was analyzed with respect to rut depth. The results represent the condition of the pavement sections only at the time of the survey (June 7-8, 1989).

Along with the analysis of these results, the following factors should also be considered:

(1) The camera cannot detect any crack less than one-eighth of an inch wide, and it is difficult for it to detect a crack up to one-fourth of an inch wide. Consequently, it is possible that many cracks are not discovered. This inadequacy is particularly significant when analyzing alligator cracks.

(2) When the ARAN unit is facing the sun, the pavement directly behind the unit is shaded so much that data cannot be retrieved.

The individual distresses obtained were averaged in two ways: (1) according to pavement type (Table 3.2) and (2) according to pavement type within each county (Table 3.3). The values in

Table 3.1 Distress types

Distress	Description
Transverse cracking	Any full lane-width crack (measured by number of occurrences)
Longitudinal cracking	Any crack parallel or near parallel to the direction of traffic
Patching	Measured in square feet
Block cracking	Measured in square feet
Alligator cracking	Measured in feet and separately for each wheelpath
Shattered slab	Any slab broken into four or more pieces (measured by number of occurrences)

Table 3.2 Condition survey summary by pavement type

Condition Survey Summary By Pavement Type							
	Distress Type (Averages)						
	Cracking						
				Alligator			
Pavement Type	Transverse No.	Longitudinal (ft)	Block (sq ft)	RWP (ft)	LWP (ft)	Patch (sq ft)	Shattered Slab No.
R 1	30	23	0	0	0	0	1
R 2	15	68	0	0	0	0	0
R 3	21	66	0	0	0	0	1
R 4	2	25	0	0	0	0	0
R 5	5	27	0	0	0	0	0
R 6	5	4	0	0	0	0	0
R 7	8	4	0	0	0	1	0
R 8	0	29	0	2	1	2	0
R 9	18	18	0	0	0	0	0
R 11	13	13	0	0	0	0	0
R 13	4	2	0	0	0	0	0
F 1	8	9	0	0	0	0	0
F 2	5	3	0	0	0	0	0
F 3	3	29	0	0	0	0	0
F 4	3	4	0	0	0	0	0
F 5	3	3	0	0	0	0	0
F 6	6	4	0	0	0	3	0
F 7	31	102	0	1	0	0	1

Table 3.3 Condition survey summary by county

Condition Survey Summary By County								
		Distress Type (Averages)						
		Cracking						
					Alligator			
County	Pavement Type	Transverse No.	Longitudinal (ft)	Block (sq ft)	RWP (ft)	LWP (ft)	Patch (sq ft)	Shattered Slab No.
Shelby	R 9	18	18	0	0	0	0	0
	R 11	13	13	0	0	0	0	0
	R 13	8	3	0	0	0	0	0
	F 1	12	6	0	1	1	0	0
	F 4	3	6	0	0	0	0	0
Nacogdoches	R 6	1	0	0	0	0	0	0
	R 7	8	4	0	0	0	1	0
	R 8	0	29	0	2	1	2	0
	R 13	0	0	0	0	0	0	0
	F 1	1	7	0	0	0	0	0
	F 4	4	6	0	0	0	0	0
	F 5	2	0	0	0	0	0	0
Angelina	R 2	1	1	0	0	0	0	0
	R 4	2	25	0	0	0	0	0
	R 6	8	7	0	0	0	0	0
	F 4	1	1	0	0	0	0	0
	F 5	1	2	0	0	0	0	0
	F 6	6	4	0	0	0	3	0
	F 7	31	102	0	1	0	0	1
Polk	R 1	23	36	0	0	0	0	0
	R 2	29	135	0	0	0	0	0
	R 3	21	66	0	0	0	0	1
	R 5	5	27	0	0	0	0	0
	F 1	5	7	0	0	0	0	1
	F 3	3	29	0	0	0	0	0
	F 5	5	6	0	1	1	0	0
San Jacinto	R 1	37	19	0	0	0	0	2
	F 1	15	16	0	0	0	0	0
	F 2	5	3	0	0	0	0	0

the tables are summarized by each one-tenth of a mile section. The description and location of each pavement type has been included. According to the ARAN results, longitudinal and transverse cracking were the only significant distresses. Tables 3.2 and 3.3 show that the quantities of the other distress types are insignificant compared to longitudinal and transverse cracking. Table 3.4 ranks each pavement type from best to worst according to the extent of the distresses. Specific quantities for distresses are shown in Tables 3.2 and 3.3.

In analyzing these results, several factors should be considered. The quantity of each distress for each pavement type represents the average quantity of that distress for that pavement type. The quantity for a specific distress in a specific pavement type may vary significantly between each surveyed section. These analyses are based

Table 3.4 Distress rankings

Surface Type		Transverse Cracking	Longitudinal Cracking
Rigid	Best	R8	R13
	↓	R4	R6, R7
		R13	R11
		R5, R6	R9
		R7	R1
		R11	R4
		R2	R5
		R9	R8
		R3	R3
	Worst	R1	R2
Flexible	Best	F3, F4, F5	F2, F5
	↓	F2	F4, F6
		F6	F1
		F1	F3
	Worst	F7	F7

on pavement type and respective location, as reflected in the county maps and pavement descriptions in Appendix A.

These results alone cannot be used to determine the performance of the pavement sections. For example, with regard to flexible pavements, pavement type F7 seems to have been in the worst condition at the time of the survey. However, this may be the result of several factors, such as the age of the most recent overlay or the use of a poor subgrade material. Significant differences may exist for the same pavement type in different counties. For example, the amount of cracking in pavement type R2 in Polk County is far greater than that in Angelina County. The differences in these quantities could be attributed to factors such as the age of the most recent overlay, the thickness of the overlay, or different soil conditions.

The average rut depth measured for each 0.05-mile section was plotted on graphs for the entire length of roadway. The rut depths were plotted for each wheelpath in each lane. These graphs can be used to determine which sections of roadway, if any, have rut depths that are unacceptable. The graphs can also be used as a baseline from which the progression of rutting can be evaluated. The progression of rut depths should be evaluated based on time and pavement type. Rut depths should be analyzed so that rehabilitation alternatives can be assessed for specific sections of roadway.

As expected, the rut depths are generally greater in the outside lanes. There are sections of roadway that have a rut depth of more than 1 inch. Table 3.5 represents the typical range of rut depths in the outside lane for each county. The largest typical rut depths are present in Nacogdoches County. Typical rut depths in the other counties are basically similar.

Table 3.5 Typical ranges of rut depth by county

County	Rut Depth Range (in.)
Angelina	0.05 – 0.40
Nacogdoches	0.10 – 0.60
Polk	0.05 – 0.40
San Jacinto	0.05 – 0.30
Shelby	0.10 – 0.40

As can be seen in the graphs, the rut depth may fluctuate substantially within a specific section of roadway. It is therefore recommended that, for a specific section of roadway, the rut depth graphs be used to obtain an overall, or average, rut depth.

3.3.2 Falling Weight Deflectometer

If FWD measurements had been taken throughout the entire district as originally proposed, evaluations could have been made regarding structural capacity for specific sections of roadway. However, since FWD measurements were taken only within the test sections, this was not possible.

3.3.3 Traffic

It may be necessary to consider differences in traffic demand when establishing priorities for rehabilitation. For instance, the ADT from Nacogdoches to the northern boundary of the district is approximately half of the ADT throughout the remainder of the district (Figure 1.1 in Chapter 1). Consideration should also be given to the large percentage of trucks present in the traffic volume.

3.3.4 Test Sections

The data collected and analyzed within the test sections were much more extensive than those for the entire roadway. The analysis of the data collected within the test sections has facilitated the selection of appropriate rehabilitation alternatives and has provided an initial baseline of information for monitoring the performance of each test section. This section discusses the analysis of results obtained from FWD measurements, condition surveys, stripping information, traffic information, and the pilot repair study.

3.3.4.1 Falling Weight Deflectometer. FWD measurements were used to back-calculate existing modulus values and to gain an indication of the structural integrity. These measurements will also be compared with the post-rehabilitation measurements in order to assess the effectiveness of each rehabilitation. Plots of deflections throughout both test sites were generated for analysis and are included in Appendix D.

RPEDD1 was used for back-calculating the modulus values in the rigid sections, and FPEDD1 was used for the flexible sections. In addition to FPEDD1, data obtained from other CTR research studies were used in order to estimate suitable modulus values for the flexible sections. The following results were obtained for each pavement section (Tables 3.6 and 3.7).

3.3.4.2 Condition Surveys. Detailed manual condition surveys were performed throughout both test sites. This information was used to develop appropriate rehabilitation strategies for the test sections. For instance, reflective cracking is present

Table 3.6 Rigid section

Layer	Modulus (psi)
7-in. ACP	290,000
7-in. PCC	1,200,000
Subgrade	19,000

Table 3.7 Flexible section

Layer	Modulus (psi)
7-1/4-in. ACP	375,000
4-1/2-in. black base	300,000
6-in. CTB	700,000
Subgrade	25,000

throughout the rigid sections. Therefore, a primary objective of the rehabilitation alternatives for the rigid test site is to reduce reflective cracking. Rutting was present in the flexible sections. Therefore, a primary objective of the rehabilitation alternatives for the flexible test site is to reduce rutting. The condition survey information will also be compared with the post-rehabilitation survey in order to assess the effectiveness of each rehabilitation alternative.

3.3.4.3 Stripping. Plots showing the areas identified by the GPR as containing stripped asphalt concrete were generated for the flexible test site and are included in Appendix D. A total of eight cores were taken from the flexible test section in order to evaluate the accuracy of the GPR results. Four cores were removed from stripped areas, and four were taken from the areas without stripping. Wherever possible, full-depth cores were taken and a note was made of the depth and thickness of the stripped layer. A comparison of the GPR data with the core data is shown in Table 3.8. Because the core data were not completely consistent with the GPR results, different conclusions may be drawn regarding the accuracy of the GPR. The results in Table 3.8 indicate that the GPR results are correct 50 percent of the time. This inconsistency may be caused by misinterpretation of data or by physical limitations of the GPR equipment. However, it appears that the GPR does give a suitable overall indication of the presence and the location of stripping.

The GPR results for the rigid test site showed no significant stripping.

3.3.4.4 Traffic. Traffic data furnished by District 11 for Polk County (from the community of Buck to the Angelina County line) were used to estimate the past and future 18-kip equivalent single axle loads (ESAL) for both test sites. The number of 18-kip ESAL is needed for calculating the design life of each rehabilitation alternative. The following information was furnished by the district for this portion of roadway from 1959 to 1988:

(1) average daily traffic (ADT),
(2) percent trucks,
(3) average of the ten heaviest wheel loads (ATHWL),
(4) percent tandem axles in ATHWL, and
(5) number of 18-kip ESAL for a rigid and a flexible pavement.

Because the original pavement in the rigid test site was constructed in 1943, the number of 18-kip ESAL from 1943 to 1959 had to be estimated for both types of pavement. The future traffic also had to be projected from 1988 for both pavement types. First, 18-kip ESAL versus time was plotted for 1959 to 1988. An exponential curve was then fitted to the data in order to estimate the number of 18-kip ESAL from 1943 to 1959. This curve yielded results inappropriate for projecting future traffic. Therefore, a straight line was fitted to the data so that future traffic could be projected

Table 3.8 Stripping data

Station	Lane	Wheel-path	Expected Stripping	Depth to Stripping (in.)	Field Data: Stripping	Field Data: Depth to Stripping (in.)
1055 + 00	S	L	No		Yes	5.25
1055 + 00	S	R	Yes	6.7	Yes	5.25
1033 + 70	S	L	No		Yes	4.50
1033 + 40	S	R	Yes	7.5	Yes	4.00
1026 + 00	R	L	No		No	
1025 + 80	R	R	Yes	7.3	Yes	5.00
1017 + 50	R	L	No		Yes	5.00
1017 + 65	R	R	Yes	6.6	No	

(Figures 3.1 and 3.2, below). Tables 3.9 and 3.10 (pages 19-22) show the data furnished by the District as well as the past and future annual 18-kip ESAL for both pavement types.

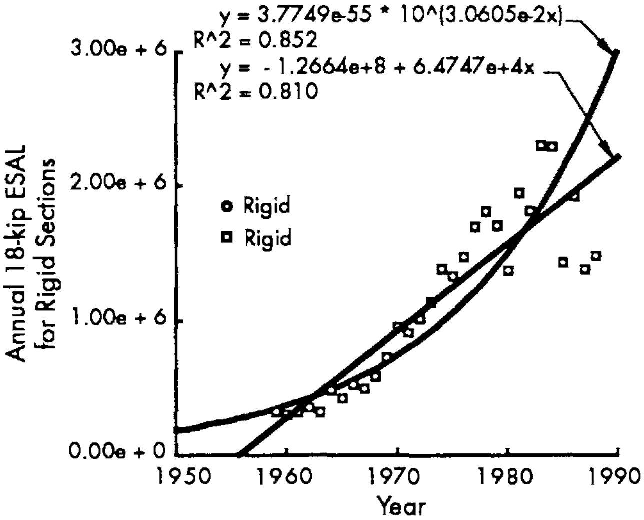


Figure 3.1 Annual 18-kip ESAL versus time for the rigid pavement sections

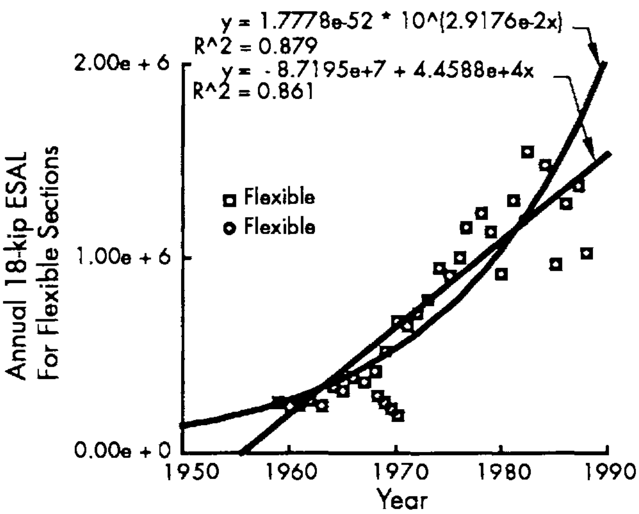


Figure 3.2 Annual 18-kip ESAL versus time for the flexible pavement sections

From 1943 to 1965, the portion of US-59 that included both test sites had two lanes. In 1966, two additional lanes were constructed and opened to traffic, thereby creating the existing four-lane divided highway. To calculate the number of 18-kip ESAL in the critical lane, a 50 percent directional distribution and an 80 percent lane distribution were assumed.

3.3.4.5 Pilot Repair Study. Falling weight deflectometer (FWD) measurements were taken on the concrete pavement before and after repairs. A map indicating the location of repairs, cores, and FWD measurements is included in Appendix B. Analysis of the measurements in the entire repair section showed a 20 percent overall reduction in deflection because of the repairs. The precast slab showed a 22 percent reduction in deflection, based on measurements taken at the joint and adjacent to the slab on both sides of the joint. This reduction represents improved load transfer across the joint, which lowers stress and, consequently, increases pavement life. The increased load transfer also reduces the probability that faulting will occur at the joint and, consequently, reduces the severity of reflective cracking.

For the monomer crack repair, a 30 percent deflection reduction was realized. Deflections were not measured on the dowel basket assembly joint replacement because the concrete needed time to cure. To identify differences in deflection caused by temperature alone, before- and after-repair deflections were compared at a location where no repairs had yet occurred. The change in deflection was insignificant and, in fact, indicated a slight increase. The material costs for these repairs is discussed in Chapter 4.

A visual inspection of the pilot repair site was conducted in December 1989. No significant cracks had developed in the asphalt concrete. This short period, however, cannot be used to determine the performance of the repairs. The site should be monitored for several years in order to properly assess the effectiveness of the repairs. These repair techniques will also be implemented and subsequently monitored in one of the proposed test sections.

Table 3.9 Traffic data for the rigid pavement sections

Year	ADT	ATHWL	% Trucks	% Tandem in ATHWL	Annual 18-kip ESAL	Annual 18-kip ESAL Critical Lane
1943					110,261	55,130
1944					118,311	59,156
1945					126,949	63,475
1946					136,218	68,109
1947					146,164	73,082
1948					156,836	78,418
1949					168,287	84,143
1950					180,574	90,287
1951					193,758	96,879
1952					207,905	103,953
1953					223,085	111,543
1954					239,373	119,687
1955					256,851	128,425
1956					275,604	137,802
1957					295,727	147,863
1958					317,319	158,659
1959	4,250	13,000	21.5	30	324,000	162,000
1960	4,050	12,900	20.3	40	302,000	151,000
1961	4,170	12,900	20.2	40	324,000	162,000
1962	4,450	13,000	20.0	40	356,000	178,000
1963	4,310	12,800	18.0	40	324,000	162,000
1964	4,880	13,200	22.2	40	490,000	245,000
1965	5,280	13,000	17.8	40	432,000	216,000
1966	5,210	13,200	20.7	40	530,000	212,000
1967	5,350	13,200	19.3	40	500,000	200,000
1968	5,780	13,200	19.2	40	588,000	235,200
1969	6,070	13,400	22.1	40	728,000	291,200
1970	6,680	13,600	25.6	30	960,000	384,000
1971	8,020	13,600	20.7	30	918,000	367,200
1972	8,630	13,700	21.3	30	1,020,000	408,000
1973	9,250	13,800	20.8	30	1,114,000	457,600
1974	9,740	13,900	23.0	30	1,380,000	552,000

Table 3.9 Traffic data for the rigid pavement sections (continued)

Year	ADT	ATHWL	% Trucks	% Tandem in ATHWL	Annual 18-kip ESAL	Annual 18-kip ESAL Critical Lane
1975	10,000	13,900	21.3	30	1,336,000	534,400
1976	10,690	13,900	22.0	30	1,470,000	588,000
1977	10,940	14,000	24.5	30	1,698,000	679,200
1978	12,050	14,000	23.5	30	1,812,000	724,800
1979	9,900	13,300	25.5	70	1,704,000	681,600
1980	11,350	13,100	18.0	70	1,374,000	549,600
1981	11,800	13,400	24.6	60	1,952,000	780,800
1982	12,400	14,100	20.8	90	1,816,000	726,400
1983	13,150	14,200	24.1	90	2,312,000	924,800
1984	14,050	14,200	22.3	90	2,294,000	917,600
1985	13,100	13,400	17.4	80	1,432,000	572,800
1986	13,200	13,300	21.9	80	1,930,000	772,000
1987	14,000	13,000	24.4	60	1,386,000	554,400
1988	14,150	12,300	21.3	80	1,480,000	592,000
1989					2,141,783	856,713
1990					2,206,530	882,612
1991					2,271,277	908,511
1992					2,336,024	934,410
1993					2,400,771	960,308
1994					2,465,518	986,207
1995					2,530,265	1,012,106
1996					2,595,012	1,038,005
1997					2,659,759	1,063,904
1998					2,724,506	1,089,802
1999					2,789,253	1,115,701
2000					2,854,000	1,414,600
2001					2,918,747	1,167,499
2002					2,983,494	1,193,398
2003					3,048,241	1,219,296
2004					3,112,988	1,245,195
2005					3,177,735	1,271,094
2006					3,242,482	1,296,993
2007					3,307,229	1,322,892
2008					3,371,976	1,348,790
2009					3,436,723	1,374,689
2010					3,501,470	1,400,588

Table 3.10 Traffic data for the flexible pavement sections

Year	ADT	ATHWL	% Trucks	% Tandem in ATHWL	Annual 18-kip ESAL	Annual 18-kip ESAL Critical Lane
1943					86,866	43,433
1944					92,902	46,451
1945					99,358	49,679
1946					106,262	53,131
1947					113,646	56,823
1948					121,543	60,772
1949					129,989	64,995
1950					139,022	69,511
1951					148,682	74,341
1952					159,014	79,507
1953					170,063	85,032
1954					181,881	90,940
1955					194,519	97,260
1956					208,036	104,018
1957					222,492	111,246
1958					237,953	118,976
1959	4,250	13,000	21.5	30	260,000	130,000
1960	4,050	12,900	20.3	40	240,000	120,000
1961	4,170	12,900	20.2	40	252,000	126,000
1962	4,450	13,000	20.0	40	272,000	136,000
1963	4,310	12,800	18.0	40	244,000	122,000
1964	4,880	13,200	22.2	40	362,000	181,000
1965	5,280	13,000	17.8	40	316,000	158,000
1966	5,210	13,200	20.7	40	384,000	153,600
1967	5,350	13,200	19.3	40	362,000	144,800
1968	5,780	13,200	19.2	40	418,000	167,200
1969	6,070	13,400	22.1	40	514,000	205,600
1970	6,680	13,600	25.6	30	672,000	268,800
1971	8,020	13,600	20.7	30	644,000	257,600
1972	8,630	13,700	21.3	30	716,000	286,400
1973	9,250	13,800	20.8	30	792,000	316,800
1974	9,740	13,900	23.0	30	946,000	378,400

Table 3.10 Traffic data for the flexible pavement sections (continued)

Year	ADT	ATHWL	% Trucks	% Tandem in ATHWL	Annual 18-kip ESAL	Annual 18-kip ESAL Critical Lane
1975	10,000	13,900	21.3	30	912,000	364,800
1976	10,690	13,900	22.0	30	1,004,000	401,600
1977	10,940	14,000	24.5	30	1,156,000	462,400
1978	12,050	14,000	23.5	30	1,230,000	492,000
1979	9,900	13,300	25.5	70	1,148,000	459,200
1980	11,350	13,100	18.0	70	926,000	370,400
1981	11,800	13,400	24.6	60	1,314,000	525,600
1982	12,400	14,100	20.8	90	1,200,000	480,000
1983	13,150	14,200	24.1	90	1,520,000	608,000
1984	14,050	14,200	22.3	90	1,508,000	603,200
1985	13,100	13,400	17.4	80	968,000	387,200
1986	13,200	13,300	21.9	80	1,294,000	517,600
1987	14,000	13,000	24.4	60	1,382,000	552,800
1988	14,150	12,300	21.3	80	1,028,000	411,200
1989					1,490,532	596,213
1990					1,535,120	614,048
1991					1,579,708	631,883
1992					1,624,296	649,718
1993					1,668,884	667,554
1994					1,713,472	685,389
1995					1,758,060	703,224
1996					1,802,648	721,059
1997					1,847,236	738,894
1998					1,891,824	756,730
1999					1,936,412	774,565
2000					1,981,000	792,400
2001					2,025,588	810,235
2002					2,070,176	828,070
2003					2,114,764	845,906
2004					2,159,352	863,741
2005					2,203,940	881,576
2006					2,248,528	899,411
2007					2,293,116	917,246
2008					2,337,704	935,082
2009					2,382,292	952,917
2010					2,426,880	970,752

CHAPTER 4. PRELIMINARY PLAN DEVELOPMENT

4.1 INTRODUCTION

Appropriate analysis and evaluation of data and information are required to identify the present condition and the needs of US-59. An assessment of the project needs will help the district develop appropriate rehabilitation strategies that will be incorporated into the long-range plan. Monitoring the construction and performance of each test section will assist researchers in evaluating the cost-effectiveness of each rehabilitation alternative so the most effective strategies can be selected for the long-range plan. This chapter discusses needs assessment; development of design strategies; traffic handling strategies; and the design, construction, and monitoring of the test sections.

4.2 TEST SECTIONS

Test sections representing several rehabilitation alternatives will be constructed and monitored in order to maximize the application of experience. The results obtained from analyzing the performance of the test sections will aid the district in the development of the long-range plan. This section discusses the design, construction, and monitoring of the test sections.

4.2.1 Design

Based on experience and the needs of US-59 in District 11, the Task Force initially selected several promising alternatives that were applicable to the existing rigid and flexible pavement types in District 11. After much discussion, the task force eliminated several rehabilitation alternatives from the initial selection and agreed to implement those discussed in the following sections. Alternatives were eliminated because of applicability problems, previous implementation experience, or lack of implementation experience within District 11.

The rigid pavement test site will include six test sections, each approximately 1,000 feet, plus a control section at the beginning of the test site. The rigid pavement test sections are located just south of FM 357, beginning at station 1420. The flexible pavement test site will also include six test sections, each approximately 1,000 feet, plus a control section at the beginning of the test site. The flexible pavement test sections are located just south of Corrigan, beginning at station 990 (see Figure 2.3 in Chapter 2). Typical cross-sections are shown for both pavement types in Figures 2.1 and 2.2 in Chapter 2. A plan and a profile of the test sections, including the rehabilitation alternatives, are included for each test site in Figures 4.1 and 4.2.

4.2.1.1 Rigid Test Site. The deflection data were examined in order to ensure that proper locations were chosen for each rehabilitation alternative. Only one portion of the test site was in significantly worse shape than the others, with respect to deflection. The break and seat alternative was chosen for that portion because the PCC is probably already severely cracked. The locations for the other alternatives were chosen so that the smoothest possible transition zones could be provided. A maximum grade change of 0.5 percent should be used for the transitions between test sections.

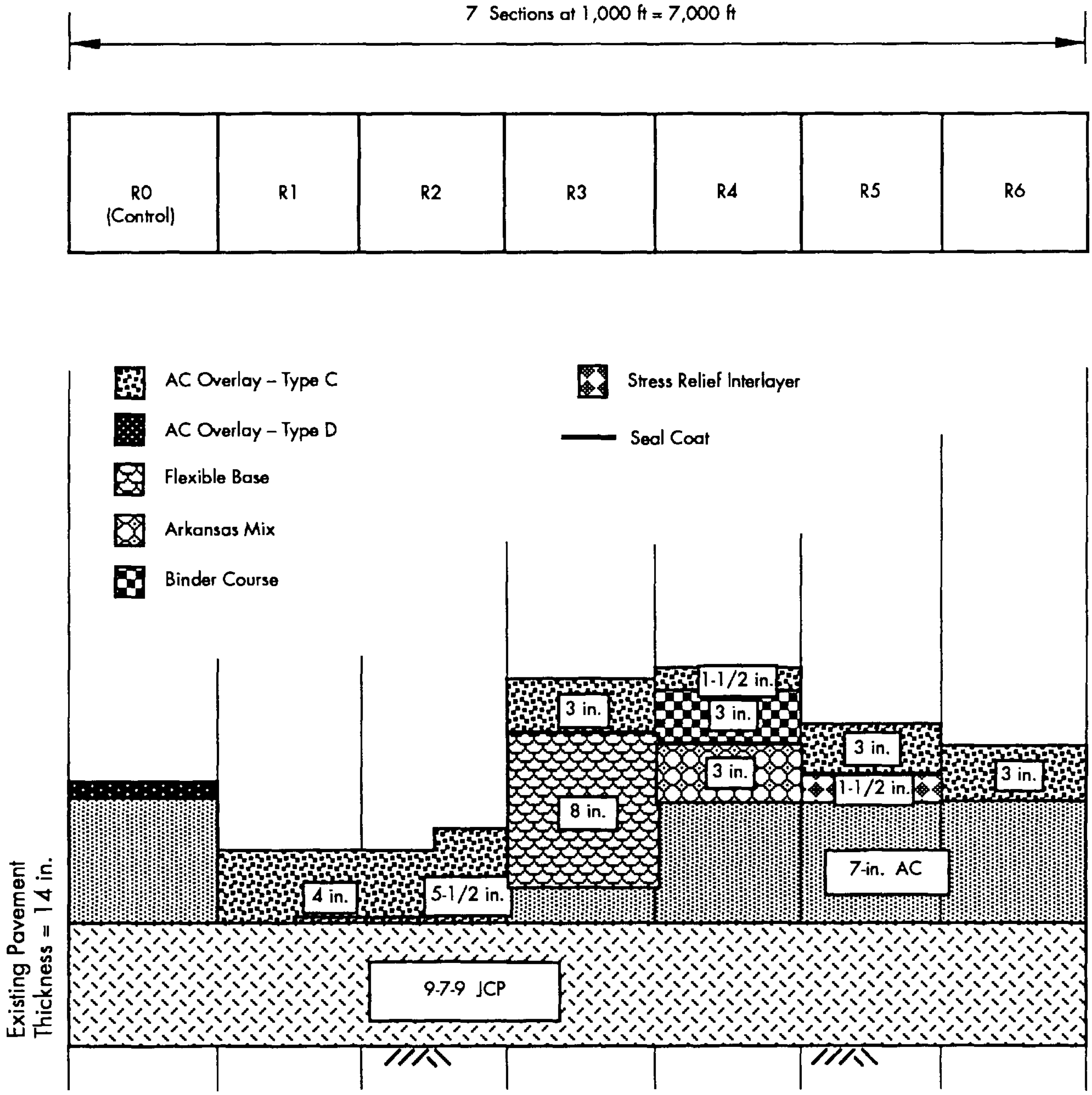
The performance of each test section will be monitored and evaluated with regard to developing distresses. However, the main objective of these test sections is to reduce and retard reflective cracking. Therefore, each test section will be evaluated according to the amount and severity of reflective cracking which occurs during a specific time period. Each test section is described in the following paragraphs.

R0 – Control

Test section R0 will be used as a control section and will include placing the standard Type D AC overlay over the existing AC. The purpose of this section will be to compare the performance of the proposed alternatives and the standard rehabilitation technique used by the district.

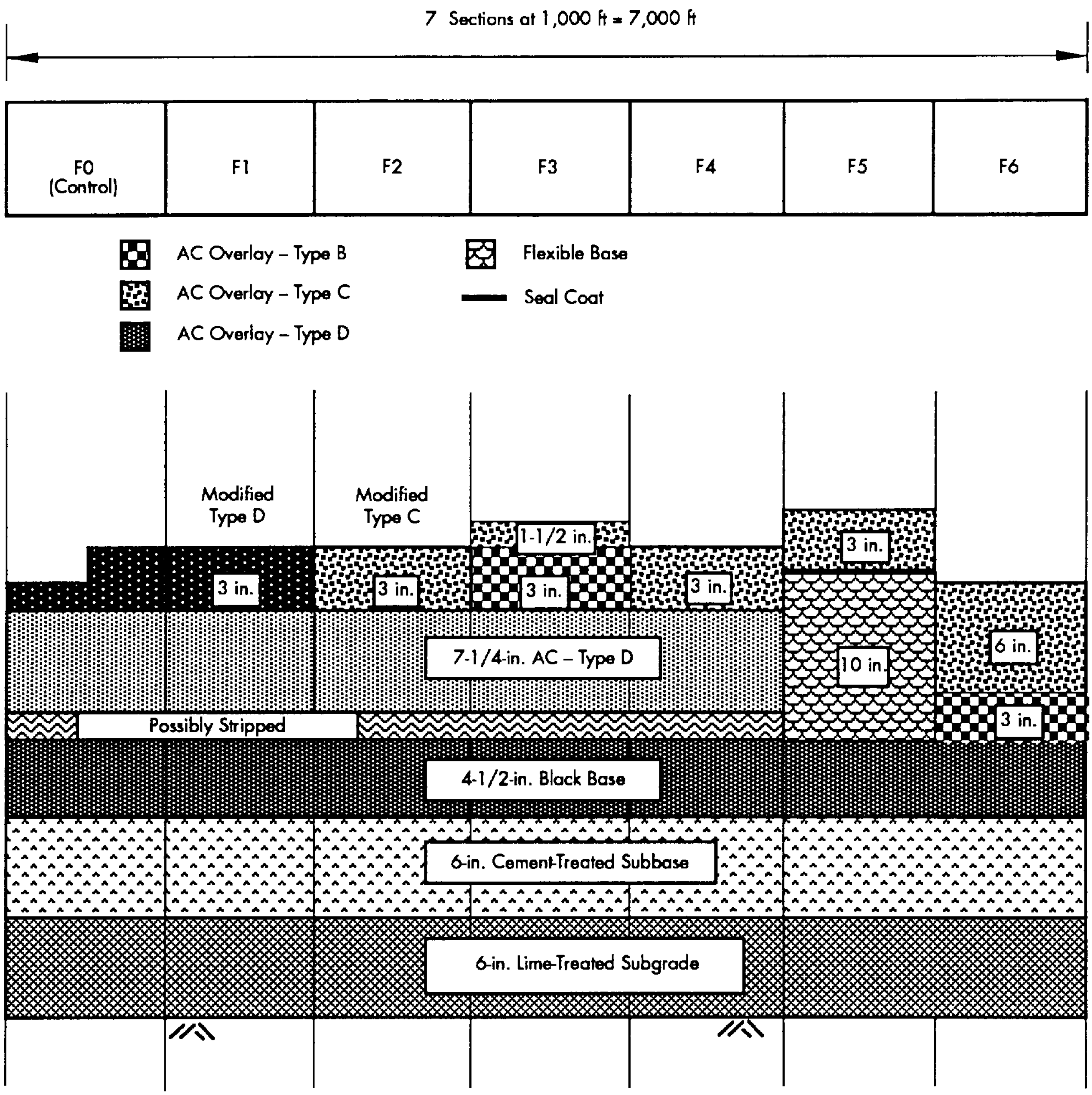
R1 – Repair/Replace PCC + AC Overlay

Test section R1 will include removing the existing AC, repairing and/or replacing the existing PCC, and placing a 4-inch Type C AC overlay over



R0 – AC Overlay – Type D (Control)
R1 – Repair/Replace PCC + AC Overlay
R2 – Break and Seat
R3 – Flexible Base + Overlay
R4 – Arkansas Mix
R5 – Stress Relief Interlayer
R6 – AC Overlay

Figure 4.1 Rigid site — rehabilitation plan and profile



F0 – AC Overlay – Type D (Control)
F1 – SBS Modified AC Overlay – Type D
F2 – SBS Modified AC Overlay – Type C
F3 – AC Overlay – Type C
F4 – AC Overlay – Type C
F5 – Remove Stripped Layer – Flexible Base
F6 – Remove Stripped Layer

Figure 4.2 Flexible site — rehabilitation plan and profile

the PCC. A saw and seal will be applied for the first 500 feet. A seal coat will be applied before placement of the overlay for the second 500 feet. Repair techniques demonstrated in the pilot study that was conducted in August will be used in this section. Overlay thicknesses were determined using the AASHTO Design Guide. A 4-inch overlay is the minimum thickness recommended by the Guide for use over PCC pavement in order to minimize reflective cracking.

The original PCC pavement was widened from 22 feet to 24 feet with a 2-foot-wide strip of cement-treated material prior to overlaying. This material should be removed and replaced with PCC. From both the construction and the performance standpoints, the 2-foot section should be replaced with a 6-foot PCC section. The widened section should be integrated with the existing slab to provide appropriate load transfer. A sleeper slab will be constructed by undercutting the existing slab in lieu of dowels. This will allow for a 4-foot inside shoulder in this area.

The various material costs associated with the repair/replace alternative were determined from the costs encountered during the US-59 pilot study in Lufkin (summer 1989). Crack repair costs are estimated to be $0.57 per linear foot for small cracks (1/4 inch or less) and $0.20 per linear foot for large cracks (greater than 1/4 inch). Lower costs can be realized on larger cracks because sand is used as a filler, which significantly reduces material costs on a per-volume-filled basis. For example, the normal monomer content for large cracks is approximately 15 percent by weight of mortar, while 100 percent monomer is used to fill small cracks. Based on the condition surveys of the area, it is estimated that the cost for large and small crack repair for the 1,000-foot test section will be $490 and $279, respectively.

For spall repairs, the spall cavity is filled with a mortar made of monomer and dried sand, at a cost of approximately $60 per cubic foot. This same material would also be used for patching. The estimated cost for spall repair and patching for the 1,000-foot test section is $600.

Two methods of joint repair were used in the pilot study. Costs will vary depending on which method is chosen. When the existing joint is cut out and replaced with a precast unit, the total material cost per joint per lane is approximately $620. The costs for specific items are as follows: $50 for the dowel basket assembly, $100 for 19 cubic feet of concrete (including delivery), $60 for form lumber (reusable), $10 for joint filler material, and $400 for 10 cubic feet of the rapid-set materials. If 10 joints are replaced in the 1,000-foot test section, the estimated that the cost for this type of joint repair will be $6,200.

For field-placed dowel basket placements, where the existing joint is milled out to approximately half of the slab depth and replaced, the total material cost per joint per lane is approximately $150. The cost for specific items are as follows: $50 for the dowel basket assembly and $100 for the concrete. The estimated cost for this type of joint repair for the 1,000-foot test section is $1,500.

R2 – Break and Seat

Test section R2 will include removing the existing AC, breaking and seating the existing PCC, and placing two different design thicknesses of Type C AC overlays over the PCC. A 4-inch thickness will be used for 500 feet, and a 5-1/2-inch thickness will be used for the remaining 500 feet. A seal coat will be applied before placement of the overlay for the first 500 feet. Overlay thicknesses were determined using the AASHTO Design Guide. A 4-inch overlay is the minimum thickness recommended by the Guide for use over PCC pavement in order to minimize reflective cracking.

The following are recommendations for the break and seat procedure: (1) cracking equipment should be capable of producing full-depth cracking, with a plate-type shoe designed to prevent penetration; (2) pavement should be broken to a nominal size of 24 inches to 36 inches; and (3) seating should be accomplished with two passes of a 50-ton pneumatic-tired roller.

A literature search was performed in order to determine a cost estimate for the break and seat process. The costs for recent break and seat projects (1982 to 1988) in Kansas, Kentucky, and Illinois ranged from $0.25 to $3.00 per square yard, depending on the required size of broken pieces and the size of the project. The cost quoted in the Texas Average Bid Prices is $1.00 per square yard, but that price represents only one project.

R3 – Flexible Base + Overlay

Test section R3 will include removing 5 inches of the existing AC, placing 8 inches of flexible base over the remaining AC, placing a seal coat, and placing a 3-inch Type C AC overlay over the flexible base.

R4 – Arkansas Mix

Test section R4 will include placing 3 inches of Arkansas Mix over the existing AC, placing 3 inches of Type B binder course over the Arkansas Mix, and placing a 1-1/2-inch Type C AC overlay over the binder course.

An Arkansas Mix refers to an open-graded asphalt layer that is placed over an existing deteriorated portland cement concrete pavement in order to reduce reflective cracking. A typical use of this rehabilitation option by the Arkansas Highway and Transportation Department (AHTD) involves placing 3 inches of Arkansas Mix over the existing PCC and, subsequently, 3 to 6 inches of binder course followed by 1-1/2 inches of surface course. Information on the use of Arkansas Mix in Arkansas was provided by Alan Meadors (AHTD) at 501-569-2184. Design information is available in the AHTD Specifications for Construction. The Asphalt Institute also has information regarding the use of crack relief layers.

District 12 has had experience with the construction and evaluation of an open-graded crack relief layer. The performance of a crushed stone bituminous concrete base as a crack relief layer over the existing deteriorated jointed concrete pavement was evaluated in Experimental Project Report No. 606-8. This report discusses the construction, evaluation, and costs of the project. In summary, on a 2.5-mile section of IH-45, with the exception of a 1,000-foot control section, approximately 3-1/2 inches of crushed stone bituminous concrete base were placed on top of the existing 10-inch jointed concrete pavement. Subsequent layers of 150-lb-per-sq-yd Type B hot mix asphaltic concrete pavement (HMACP) level-up, 100-lb-per-sq-yd Type D HMACP level-up, and 1-1/4-inch Type D HMACP surface were placed over the crushed stone bituminous base course.

Most of the problems with placing the mix were eliminated by maintaining the temperature within the desired range at the plant. Since the mix is open-graded, it has a tendency to cool faster. There were problems with the asphalt accumulating in the bottom of the truck beds; thus, the trucks should be cleaned before returning to the plant. A constant grade was difficult to maintain. Since the material cooled quickly, areas would consolidate, resulting in an uneven flow of material to the screed. When the depth of material was not kept constant behind the screed, there was a grade change in the mix.

Construction was completed on August 30, 1981. A post-construction survey was performed on October 8, 1981. Overall results of this survey showed that the 2.5-mile test did not perform better than the 1,000-foot control section. However, the crack-relief material was subjected to traffic, depending on location, from 3 to 6-1/2 months before the subsequent courses of hot mix were completed. This traffic may have contributed to the early appearance of reflective cracks. The pavement has recently been overlaid with a 3-inch Type D HMACP, including the placement of engineering fabric strips (2 feet wide) over the existing cracks.

Based on the materials reviewed to date, recommendations regarding the Arkansas Mix alternative are the following: 3 inches of open-graded asphalt mix, 3 inches of Type B binder course, and a 1-1/2-inch Type C surface course. These recommendations closely resemble the design used for the IH-45 project in District 12. However, all layers of material should be placed before the pavement is opened to traffic.

R5 – Stress Relief Interlayer

Test section R5 will include placing a stress relief interlayer over the existing AC, and a 3-inch Type C AC overlay over the stress relief interlayer. It is recommended that a conventional plant mix seal be used for the stress relief interlayer for the first 500 feet and that an SBS-modified plant mix seal be used for the remaining 500 feet.

R6 – AC Overlay

Test section R6 will include placing a 3-inch Type C AC overlay over the existing AC.

4.2.1.2 Flexible Test Site. The deflection data and the stripping data were examined to ensure that the proper locations were chosen for each rehabilitation alternative. According to the ground-penetrating radar data, the most severe stripping exists in test section F4 (station 1020 to station 1030). The alternatives were also arranged to provide for the smoothest possible transition zones. A maximum grade change of 0.5 percent should be used for the transitions between test sections. The performance of each test section will be monitored and evaluated with regard to developing distresses.

F0 – Control

Test section F0 will be used as a control section and will include placing the standard Type D AC overlay over the existing AC for 500 feet and a 3-inch Type D AC overlay for the remaining 500 feet. The main purpose of the first 500 feet is to compare the performance of the proposed rehabilitation alternatives with the performance of the standard rehabilitation technique used by the district. The main purpose of the remaining 500 feet is to compare the performance of a thicker 3-inch Type D overlay with that of the standard Type D overlay.

F1 – Modified AC Overlay – Type D

Test section F1 will include placing an SBS-modified, 3-inch Type D AC overlay over the existing AC. The main purpose of this section is to compare the performance of an SBS-modified Type D overlay with that of a conventional Type D overlay.

F2 – Modified AC Overlay – Type C

Test section F2 will include placing an SBS-modified 3-inch Type C AC overlay over the existing AC. The main purpose of this section is to compare the performance of an SBS-modified Type C overlay with that of an SBS-modified Type D overlay.

F3 – AC Overlay – Type B and C

Test section F3 will include placing 3 inches of Type B AC and 1-1/2 inches of Type C AC over the existing AC. The main purpose of this test section is to compare the performance of a 4-1/2-inch overlay with that of a 3-inch Type C overlay.

F4 – AC Overlay – Type C

Test section F4 will include placing a 3-inch Type C AC overlay over the existing AC. Within the flexible pavement test site, the most severe stripping occurs in this section. Therefore, the main purpose of this alternative is to compare the performance of this test section with that of test sections F5 and F6, where the existing AC is removed.

F5 – Remove Stripped Layer

Test section F5 will include removing the existing AC (approximately 7 inches), replacing the AC with 10 inches of flexible base, and then applying a seal coat and 3 inches of Type C AC.

F6 – Remove Stripped Layer

Test section F6 will include removing the existing AC (approximately 7 inches), replacing the existing AC with 3 inches of Type B AC, and then applying 6 inches of Type C AC over the 3 inches of Type B AC. The main purpose of this test section is to demonstrate the benefits of removing the stripped portion of pavement.

4.2.2 Construction

The construction of the test sections will begin during the spring of 1991, with construction time estimated at six months. The plans and specifications for the project were developed by Texas SDHPT. Construction monitoring is discussed in the following section.

4.2.3 Monitoring/Analysis Plan

The purpose of this section is to discuss the monitoring plan for the test sections on US-59 in District 11. The monitoring plan will be divided into three main categories: pre-construction, construction, and post-construction. These categories are discussed below.

The results of monitoring the test sections will be used to aid in the development of the long-range rehabilitation plan. Therefore, the main objective of the monitoring effort is to document the performance of each of the test sections. Performance and economics will be used as criteria for the selection of suitable rehabilitation alternatives for the long-range plan.

4.2.3.1 Pre-Construction. Pre-construction monitoring will consist of preparing a before-rehabilitation file on each section. This file will consist of the results from (1) a visual condition survey, (2) FWD measurements, (3) core sampling, (4) rut depth measurements, (5) roughness measurements, and (6) historical records of traffic, overlays, FWD measurements, and stripping. These data will form the basis by which the performance of each section is evaluated.

Two full-depth (penetrating the subgrade) cores are to be taken at third points in each test section in the outside lane in the right wheelpath. The location of each core should be recorded. These cores will be used to verify material thicknesses and to determine moisture contents in the subgrade.

A detailed condition survey will be conducted throughout each test section. Each distress is to be accurately recorded (mapped) on survey forms provided by CTR. A sample survey form is included in Appendix E. Photographs that give a suitable representation of the condition of the pavement should be taken in each section and documented. A condition survey will not be necessary in the break and seat test section or the repair/replace test section before construction.

Rut depth measurements will be taken in the wheelpaths in each test section according to the diagram in Figure 4.3. The rut depth measurements are to be taken at the same locations within each test section. As can be seen in the diagram, five rut depth measurements will be taken in each 500-foot portion. The locations for taking each rut depth measurement are numbered from 1 to 10. These numbers are for identification purposes only. If a test section is divided into more than two portions, extra rut depth measurements may be necessary. Roughness measurements will be taken in the outside wheelpath of each lane in each test section. A California profilograph (or equivalent) should be used for taking roughness measurements. CTR will provide forms (similar to the form in Appendix E) for recording rut depth and roughness measurements.

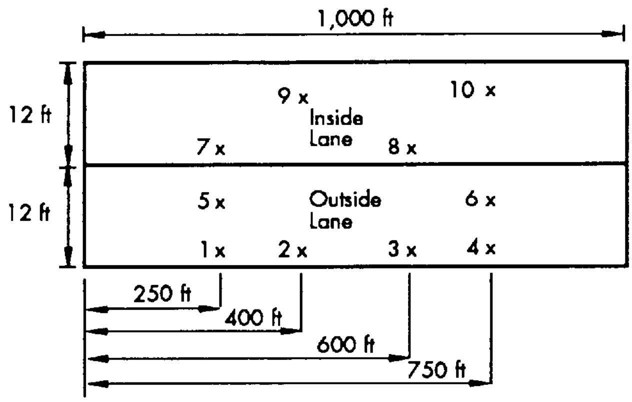


Figure 4.3 Rut depth measurement locations

FWD measurements will be taken in each test section before construction. The measurements should be taken in the same locations as those taken in June 1989. However, some additional measurements will be needed for the test section areas that are located outside of the limits of the original testing area.

For the flexible test sections, FWD measurements will be taken every 100 feet in the outside lane in the outside wheelpath. These measurements should begin at station 990+00 and end at station 1060+00.

For the rigid test sections, FWD measurements will be taken from station 1420+00 to station 1490+00 in the outside lane, according to the guidelines described herein. The information given in Table 4.1 and the work plan diagram in Figure 4.4 illustrate how the FWD measurements should be taken on the rigid sections. The actual stations and respective locations for the majority of the FWD measurements are given in Table 4.2. It is not necessary that the FWD measurements be taken in sequence (1,2,3,4,5,6,1); the location numbers establish the location for each measurement. The FWD measurements taken in June 1989 were taken at the stations and locations given in Table 4.2. For the portion of the rigid test site on which measurements were not previously taken (stations 1420+00 to 1437+06 and 1489+19 to 1490+00), measurements are to be taken according to the guidelines described herein.

Additional measurements are to be taken to assess the load transfer at midspan cracks. A maximum of ten midspan cracks should be assessed in each mile. This assessment should consist of two measurements: the first, midway between the midspan crack and the nearest upstream contraction joint, and the second, adjacent to the midspan crack. The locations of these measurements are shown in Figure 4.5. These measurements will require a maximum of 20 additional readings per mile.

The influence of temperature on deflection measurements is well known. In order to account for the inevitable temperature variation during the course of data collection, a concrete block equipped with instruments for recording temperature should be buried adjacent to the roadway. Temperature should be recorded hourly while taking FWD measurements. The location of each deflection measurement should be recorded with sufficient accuracy so that the measurement can be repeated at some later date.

Table 4.1 Description of deflection measurement locations

Location	Description
1	Immediately downstream from the expansion joint
2*	Between the contraction joints (or between the expansion and contraction joints) away from any midspan cracks
3*	Upstream from the contraction joint
4	Adjacent to the expansion joint near outside shoulder
5*	Near pavement edge adjacent to Location 2
6*	Near pavement edge adjacent to Location 3
1*	Downstream from Location 3 on the opposite side of the contraction joint

* Readings at locations 2, 3, 1, 5, and 6 alternated between areas A, B, C, D, E, F, G, and H in successive slabs (i.e., readings were taken in area A in the first slab, in area B in the second slab, etc.).

NOTE: In this context, a slab is defined as the rigid pavement between successive expansion joints.

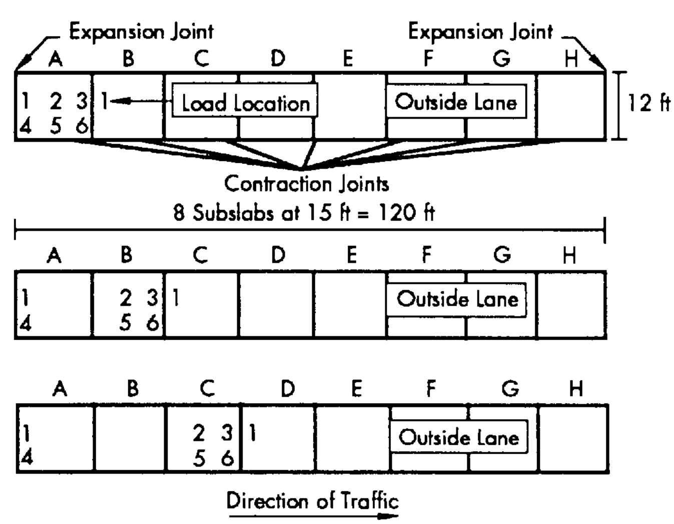


Figure 4.4 Rigid FWD measurement pattern

Table 4.2 FWD measurement stations and locations for rigid test site

Station	Location	Station	Location	Station	Location	Station	Location
1489 + 19	1	1477 + 27	2	1462 + 95	1	1449 + 31	1
1488 + 98	2	1477 + 20	3	1461 + 84	2	1449 + 76	4
1488 + 91	3	1477 + 18	1	1461 + 77	3	1449 + 39	5
1488 + 89	1	1476 + 74	1	1461 + 75	1	1449 + 33	6
1489 + 19	4	1476 + 24	2	1461 + 75	1	1448 + 55	1
1488 + 98	5	1476 + 17	3	1461 + 68	2	1448 + 04	2
1488 + 91	6	1476 + 14	1	1461 + 62	3	1447 + 98	3
1488 + 44	1	1475 + 69	1	1461 + 60	1	1447 + 96	1
1488 + 23	2	1475 + 02	2	1461 + 75	4	1447 + 36	1
1488 + 16	3	1474 + 96	3	1461 + 68	5	1446 + 69	2
1488 + 14	1	1474 + 94	1	1461 + 62	6	1446 + 63	3
1488 + 44	4	1474 + 49	1	1460 + 55	1	1446 + 61	1
1488 + 23	5	1473 + 84	2	1460 + 34	2	1446 + 15	1
1488 + 16	6	1473 + 77	3	1460 + 27	3	1445 + 35	2
1487 + 24	1	1473 + 75	1	1460 + 25	1	1445 + 28	3
1486 + 88	2	1473 + 44	1	1459 + 35	1	1445 + 26	1
1486 + 82	3	1472 + 53	2	1458 + 99	2	1444 + 96	1
1486 + 80	1	1472 + 50	3	1458 + 92	3	1444 + 01	2
1486 + 05	1	1472 + 48	1	1458 + 90	1	1443 + 95	3
1485 + 53	2	1473 + 44	4	1458 + 14	1	1443 + 93	1
1485 + 46	3	1472 + 53	5	1457 + 63	2	1443 + 77	1
1485 + 44	1	1472 + 50	6	1457 + 57	3	1442 + 62	2
1484 + 83	1	1472 + 25	1	1457 + 55	1	1442 + 59	3
1484 + 17	2	1471 + 40	2	1456 + 94	1	1442 + 57	2
1484 + 10	3	1471 + 37	3	1456 + 27	2	1443 + 77	4
1484 + 08	1	1471 + 35	1	1456 + 21	3	1442 + 62	5
1484 + 83	4	1471 + 35	1	1456 + 19	1	1442 + 59	6
1484 + 17	5	1471 + 30	2	1455 + 75	1	1442 + 57	1
1484 + 10	6	1471 + 22	3	1454 + 93	2	1442 + 50	2
1483 + 64	1	1471 + 20	1	1454 + 87	3	1442 + 44	3
1482 + 81	2	1470 + 00	1	1454 + 85	1	1442 + 42	1
1482 + 76	3	1469 + 93	2	1455 + 75	4	1441 + 45	1
1482 + 74	1	1469 + 87	3	1454 + 93	5	1441 + 15	2
1482 + 44	1	1469 + 85	1	1454 + 87	6	1441 + 08	3
1481 + 48	2	1468 + 79	1	1454 + 54	1	1441 + 06	1
1481 + 64	3	1468 + 44	2	1453 + 58	2	1440 + 16	1
1481 + 39	1	1468 + 36	3	1453 + 93	3	1439 + 85	2
1481 + 24	1	1468 + 34	1	1453 + 49	1	1439 + 77	3
1480 + 12	2	1467 + 60	1	1453 + 34	1	1439 + 75	1
1480 + 06	3	1467 + 09	2	1452 + 24	2	1439 + 00	1
1480 + 04	1	1467 + 03	3	1452 + 17	3	1438 + 48	2
1480 + 04	1	1467 + 00	1	1452 + 15	1	1438 + 41	3
1479 + 97	2	1467 + 60	4	1452 + 15	1	1438 + 39	1
1479 + 91	3	1467 + 09	5	1452 + 08	2	1437 + 79	1
1479 + 89	1	1467 + 03	6	1452 + 02	3	1437 + 11	2
1478 + 84	1	1466 + 40	1	1451 + 00	1	1437 + 06	3
1478 + 63	2	1465 + 74	2	1450 + 95	1	1437 + 04	1
1478 + 56	3	1465 + 68	3	1450 + 75	2	1437 + 79	4
1478 + 54	1	1465 + 66	1	1450 + 68	3	1437 + 11	5
1478 + 84	4	1464 + 00	1	1450 + 66	1	1437 + 06	6
1478 + 63	5	1463 + 24	2	1449 + 76	1		
1478 + 56	6	1463 + 18	3	1449 + 39	2		
1477 + 64	1	1463 + 16	1	1449 + 33	3		

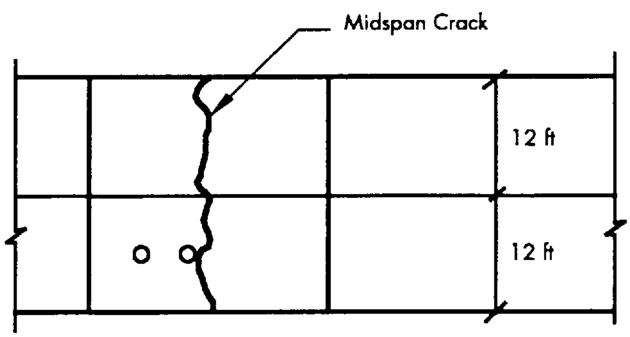


Figure 4.5 Location of mid-span crack FWD measurements

4.2.3.2 Construction. Several types of data will be collected during construction. Information gathered on overlay materials will include asphalt type and quantity in each mixture, in-place densities, and gradation and type of aggregates used. Monitoring of the construction procedures will include recording the condition of the underlying rigid pavement in those sections where the layer is exposed. Asphalt placement rates and any special problems will be noted. Any distresses that develop before construction ends will be documented. A detailed condition survey will be conducted on the repair/replace test section after removal of the asphalt concrete but before repairs. Distresses are to be recorded on the survey form provided by CTR.

Photographs will be taken of the following: paving train, typical construction procedures, stages of construction, and any unusual items. Other items to be recorded include the beginning and the ending of construction time, equipment used, labor force used, weather information, and construction delays. CTR will provide forms (similar to the form in Appendix E) for recording these types of information. CTR will retain copies of the following: construction plans and specifications, bid report, daily construction reports, and mix designs.

4.2.3.3 Post-Construction. After construction is completed at each site, permanent markers, consisting of a brass cap (3-inch diameter) set in a concrete cylinder, will be used to mark the beginning and the end of each test section. The name of the test section and the station will be imprinted on the brass cap of each marker. Each marker will be buried flush with the ground approximately 1 foot from the outside edge of the shoulder. These markers will be furnished by CTR.

Immediately after the construction is completed at each site and before opening to traffic, several types of data will be collected at each test section. Visual condition surveys will be conducted throughout each test section in order to document developing surface distresses, with particular attention given to the formation of reflective cracking. FWD measurements will be taken at each test section in the same locations that were measured before construction. Baseline rut depth measurements will be taken in those locations identified before construction. Roughness measurements will be taken in the outside wheelpath of each lane in each section. Rut depth and roughness measurements are to be recorded on the form provided by CTR.

Cores will be taken immediately after construction in order to obtain the following results:

(1) density,
(2) creep,
(3) resilient modulus,
(4) tensile strength, and
(5) mix characteristics.

Cores will also allow design thicknesses to be verified. In order to obtain suitable results, 15 cores will be taken in each test section in the right wheelpath of the outside lane. Twice as many cores will need to be taken in those sections divided into two 500-foot portions. A total of 270 cores will need to be taken in order to represent each pavement alternative. It is estimated that the cost for having CTR test these cores will be $6,750. This estimate is based on 2.5 hours per core and $10 per hour labor. This total of 270 cores will allow the necessary tests to be conducted at three temperatures. These cores should be taken before the site is opened to traffic and semi-annually thereafter. A diagram of the coring plan is shown in Figure 4.6. A nuclear density gauge, calibrated on the job, is to be used for the collection of any additional density measurements.

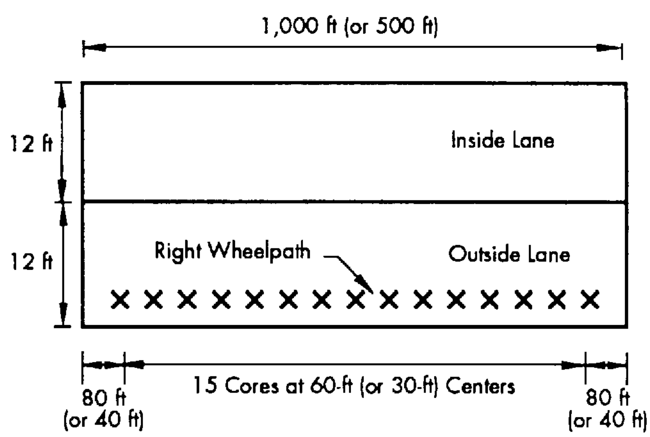


Figure 4.6 Coring plan

After the first set of cores is taken, a minimum of two cores per test section will be taken, semi-annually, thereafter. These two cores will be full depth and will be used to determine densities, tensile strengths, and moisture content of the subgrade. These cores should be taken at the third points in each test section. Additional cores will be taken on an as-needed basis. For example, more cores may need to be taken in a test section where severe rutting occurs.

This set of data will establish the first in a series of future data collections that should occur at the following frequencies. The condition surveys will be conducted monthly for one year, semi-annually for the next two years, and, thereafter, annually if necessary. Rut depth will be measured at the same frequency as the condition surveys and at the same locations as those measured before construction. Roughness measurements will be taken quarterly and FWD measurements will be taken semi-annually. The timeline for the series of data collections for the flexible test site will begin several months after that for the rigid test site. However, during the time period when data are being collected monthly from both sites, the data for both sites will be collected at the same time. The planned monitoring schedule for the first 18 months is shown in Table 4.3.

It should be emphasized that the frequency and the extent of these data collection processes are a general estimate of necessary monitoring. The frequency and the extent of these data collections may need to be modified over time. Some sections will show distresses much sooner than others. These distresses should be documented as they occur. For example, if a specific section exhibits severe rutting within a few months but then virtually does not change thereafter, frequent monitoring will not be necessary in that section while no further distresses are occurring. However, if a section is changing rapidly, the frequency and the extent of certain monitoring efforts may need to be increased. The objective of the monitoring is to document distresses and changes as they occur. Therefore, adjustments should be made to the monitoring schedule as needed.

It has not yet been determined whether CTR or District 11 will collect this data. The expected traveling expenses for CTR to collect the data for the first year are estimated in Table 4.4. Travel time from Austin has been included in the number of days required. Based on these estimates and the monitoring schedule in Table 4.3, the total travel expenses for CTR during the first year of monitoring will be approximately $16,600. This estimate includes only post-construction monitoring.

Traffic and load data will be collected at both the rigid and the flexible test sites. The collection of traffic and load data is extremely important because traffic loading is the predominant cause of damage and wear to pavement structures. Knowledge of the lateral position of wheel loads within the traffic lane is also important for proper engineering design, maintenance, and management of pavements. Weigh-in-motion (WIM) and lateral wheelpath monitoring equipment will collect data on a 24-hour basis. A diagram of the proposed layout of the traffic monitoring instrumentation is shown in Appendix E. Improvements in the load sensors and data processing systems allow the speed, weight of each wheel, number of axles, axle spacing, lane of travel, and time of day of every vehicle passing over the WIM to be recorded for any selected time period. The data will provide the opportunity to relate traffic to the performance of the various rehabilitation alternatives. Air temperature data will also be collected on a 24-hour basis within the WIM instrumentation. These data will allow any correlation between temperature and a specific distress, such as rutting, to be evaluated.

4.3 ASSESS NEEDS

The first step in planning rehabilitation strategies is to identify and to assess the needs of the district. An indication of the needs of the district can be obtained from the data analyzed in Chapter 3. For example, much of the roadway is characterized by reflective cracking of asphalt concrete pavement caused by cracks in the underlying portland cement concrete pavement. For the proposed asphalt concrete overlays, the goal is to reduce rutting as much as possible. Traffic in the district is expected to continue to increase. This continued growth will require better rehabilitation strategies with longer periods between overlays.

4.4 DEVELOP TRAFFIC HANDLING STRATEGIES

User costs escalate rapidly as traffic delay increases. It is, therefore, important to develop the appropriate traffic handling strategy for each rehabilitation project. The most significant factor in selecting a strategy is whether the roadway has two lanes or four lanes. In urban areas, the amount of right-of-way might be a controlling factor. Several common traffic handling strategies are given in Figures 4.7 through 4.10 (page 35). It is expected that Model 4 in Figure 4.10 will be used during the construction of the test sections.

Table 4.3 Monitoring schedule

Rigid Test Site																				
		After Construction (Months)																		
Procedure	Before Construction	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Rut depth	X	X	X	X	X	X	X	X	X	X	X	X	X	X						X
FWD	X	X						X						X						X
Condition survey	X	X	X	X	X	X	X	X	X	X	X	X	X	X						X
Roughness	X	X			X			X			X			X			X			X
Cores (no.)	2	15						2						2						2

Flexible Test Site																				
		After Construction (Months)																		
Procedure	Before Construction	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Rut depth	X	X	X	X	X	X	X	X	X	X	X	X	X	X						X
FWD	X	X						X						X						X
Condition survey	X	X	X	X	X	X	X	X	X	X	X	X	X	X						X
Roughness	X	X			X			X			X			X			X			X
Cores (no.)	2	15						2						2						2

Table 4.4 Estimate of CTR labor and travel expenses for monitoring

	Test Site	Months 0	1	2	3	4	5	6	7	8	9	10	11	12
Condition survey	Rigid	X	X	X	X	X	X	X	X	X	X	X	X	X
	Flexible				X	X	X	X	X	X	X	X	X	X
Rut depth	Rigid	X	X	X	X	X	X	X	X	X	X	X	X	X
	Flexible				X	X	X	X	X	X	X	X	X	X
FWD	Rigid	X			X			X						X
	Flexible				X						X			
Roughness	Rigid	X			X			X			X			X
	Flexible				X			X			X			X
Cores	Rigid	X			X			X						
	Flexible				X						X			X
No. personnel required		4	2	2	4	4	4	4	4	4	4	4	4	4
No. days required		4	3	3	7	4	4	7	4	4	7	4	4	7
Travel cost ($)		1,100	450	450	2,000	1,100	1,100	2,000	1,100	1,100	2,000	1,100	1,100	2,000

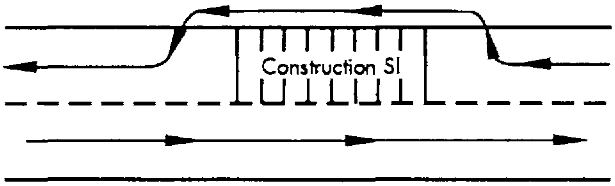


Figure 4.7 Model 1

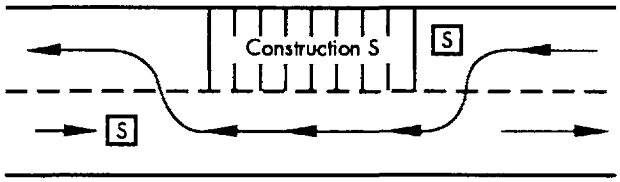


Figure 4.8 Model 2

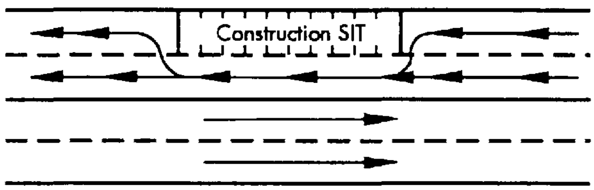


Figure 4.9 Model 3

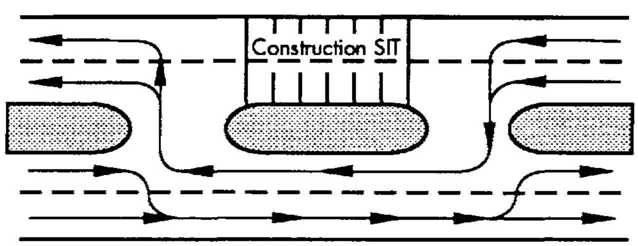


Figure 4.10 Model 4

4.5 DEVELOP DESIGN STRATEGIES

The development of design strategies is the preliminary stage in developing a comprehensive rehabilitation plan. It is obvious from examining the data that several portions of the roadway need immediate attention. The main objective of developing a long-term rehabilitation plan for the district is to implement designs which not only will improve the riding quality of the pavements, but also will yield longer service lives than do the more frequent, thin asphalt concrete overlays. Even though rehabilitation alternatives that yield longer service lives require a higher initial cost, it is expected that they will prove to be more cost-effective because of the reduced frequency of rehabilitation and maintenance operations and the subsequent decrease in traffic delays.

The monitoring and subsequent analyses of the performance of each test section will allow the district to select suitable design strategies. The construction costs for each rehabilitation alternative will be a controlling factor in selecting and evaluating design strategies. Traffic and load data obtained from the WIM system will represent actual current traffic demands and allow for accurate projections of future demand.

It is extremely important that the information and data obtained be appropriately used to evaluate design strategies. The pavement life tables will give an indication of what type of rehabilitation strategy is appropriate for a specific section of roadway and approximately when that strategy is needed. Other information such as condition survey information, PSI, rut depth, and FWD measurements, will give an indication of when some type of rehabilitation is necessary. The form represented in Appendix E is intended to aid the district in determining priorities and evaluating rehabilitation strategies.

CHAPTER 5. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

5.1 SUMMARY

The primary, or long-term, objective of this project is to develop a rehabilitation plan for US-59 in District 11. This plan will address the required annual cost for rehabilitating all of US-59 in District 11 during a 10- to 15-year period, as well as project letting schedules, alternate types of pavement improvements, and individual project costs. At this point in the study, the following have been achieved toward this objective:

(1) Extensive data has been collected and analyzed so that preliminary strategies can be developed.

(2) A computer program, PRDS, was developed for use by the district staff.

The short-term objective of this project is to plan, design, construct, and monitor the performance of test sections that represent several rehabilitation options on US-59. Information gained from the construction and monitoring of the test sections will aid the district in developing the long-range plan. It is expected that the relatively small sum invested in developing the long-range plan, including the planning, design, construction, and monitoring of the test sections, will result in a substantial savings during the rehabilitation period and the service lives of the pavements in District 11. At this point, the following items of planning and design have been accomplished:

(1) After reviewing the current pavement types, pavement conditions, and traffic and load information, a plan for constructing 14 test sections (7 for rigid pavement and 7 for flexible pavement) was submitted and approved by the district.

(2) Plans and specifications for constructing the test sections were developed by the SDHPT.

(3) A monitoring plan for the test sections was developed by CTR.

5.2 CONCLUSIONS

The following is a list of items pertinent to data collection:

(1) An extensive amount and variety of data have been collected for this project.

(2) The data collected within the test sites have adequately allowed for the development of suitable rehabilitation alternatives for the test sections as well as for a pre-rehabilitation base of information from which the effectiveness of each alternative can be evaluated.

(3) The overall set of data needed for the development of the long-range plan is incomplete.

(4) ARAN condition survey information is available for the entire roadway along with suitable traffic and load information. However, because of manpower shortages within District 11 and other limitations, some data collection needs identified in the original project proposal were neglected. For example, detailed manual condition surveys were not conducted except within the test sites and the pilot repair site. In addition, cores were taken at two-mile intervals only in Polk County. No FWD measurements were taken except within the test sites and the pilot repair site.

The following is a list of pertinent items regarding data analysis:

(1) Although considerable analysis has been performed on the many types of data collected, some of the data is still in the process of being analyzed. For example, suitable methods for determining the design life of each rehabilitation alternative are being investigated.

(2) Methods are being investigated for obtaining suitable estimates of the present serviceability index (PSI) for sections of roadway based on ARAN data.

(3) Rut depths have been analyzed according to county but not according to pavement type or traffic volumes. These as well as other analyses will be performed as time permits and as information becomes available.

(4) Using the determined modulus values and traffic information, several attempts have been made to calculate the design life of each alternative. However, the results thus far have been unrealistic.

5.3 RECOMMENDATIONS

The following items are essential to the progress of the project:

(1) Further efforts need to be investigated so that the design life of each test section can be determined.

(2) At the time of this writing (January 1991), it is anticipated that the project for constructing the test sections will be let during the spring of 1991. The results from analyzing the performance of the test sections will be used to improve and aid in the preparation of the comprehensive rehabilitation plan for US-59 in District 11. This work is expected to supply the first estimate of construction costs, deterioration rates, estimated times for future rehabilitation, and types of structures that will be required.

(3) District 11 should continue to develop the long-range plan, and should revise it as short-term and long-term performance results from the test sections become available. CTR will be available to assist in specific areas of the development of the plan.

(4) Once the monitoring of the test sections and the plan are completed, CTR will prepare a report finalizing the total effort. The techniques and procedures used in the project should be described. The various steps involved in the project should be reported, as well as the personnel time and approximate costs. The results of the short-term and long-term monitoring of the test sections should be documented, along with construction procedures and costs. A summary of the long-range plan should be presented, including estimates of the effectiveness of the project.

(5) It is hoped that the framework for this project will be used for the cost-effective rehabilitation of pavements within other districts throughout the state of Texas.

REFERENCES

1. *AASHTO Guide for Design of Pavement Structures*, American Association of State Highway and Transportation Officials, 1986.

2. "Asphalt Overlays for Heavily-Trafficked PCC Pavements," The Asphalt Institute, Information Series No. 177, February 1981.

3. "Breaking/Cracking and Seating Concrete Pavements," National Cooperative Highway Research Program, Synthesis of Highway Practice, NCHRP Synthesis 144, Transportation Reseach Board, National Research Council, March 1989.

4. "Cracking, Seating, and Overlaying PCC Pavement," Initial Report, Kansas Department of Transportation, March 1986.

5. "Evaluation of Crushed Stone Bituminous Concrete Base," Texas State Department of Highways and Public Transportation, Experimental Project Report No. 606-8.

6. Kennedy, Thomas W., "Tensile Characterization of Highway Pavement Materials," Research Report 183-15F, Center for Transportation Research, The University of Texas at Austin, July 1983.

7. Navarro, Domingo, and Thomas W. Kennedy, "Fatigue and Repeated-Load Elastic Characteristics of Inservice Asphalt-Treated Materials," Research Report 183-2, Center for Transportation Research, The University of Texas at Austin, January 1975.

8. "New Mexico Study of Interlayers Used in Reflective Crack Control," *Transportation Research Record No. 1117*, 1987.

9. "1989 Pavement Evaluation System Rater's Manual," Texas State Department of Highways and Public Transportation, May 2, 1989.

10. "Performance Survey of Crushed Stone Crack Relief Layer," Arkansas State Highway and Transportation Department, April 1983.

11. "Portland Cement Concrete Rehabilitation Crack Relief Layer Incorporated into Asphalt Concrete Overlay," The Asphalt Institute, Technical Bulletin No. 4, *ASPHALT*, Spring 1989.

12. *Proceedings*, Association of Asphalt Paving Technologists, Volume 49, 1980.

13. Sharpe, Gary W., Mark Anderson, and Robert C. Deen, "Breaking and Seating of Rigid Pavements," Report UKTRP-87-26, Kentucky Transportation Research Program, College of Engineering, University of Kentucky, Lexington, Kentucky, October 1987.

14. *Standard Specifications for Highway Construction*, Arkansas State Highway and Transportation Department, 1988.

15. "The Crack and Seat Method of Pavement Rehabilitation," Final Report, Physical Research 104, Illinois Department of Transportation, July 1988.

APPENDIX A. PAVEMENT TYPES AND COUNTY MAPS

Table A.1 Pavement key for District 11

Pavement Identifier	Pavement Structure	
FLEXIBLE		
F1	24' x 1-1/2" (min)	ACP
	4-1/2"	3 course Black Base
	6"	Cement Treated Base
	6"	Lime Treated Subgrade
F2	24' x 1-1/2" (min)	ACP
	6"	Cement Stabilized Base
	6"	Flexible Base
F3	24' x 1-1/2" (min)	ACP
	8"	Flexible Base
	6"	Lime Treated Subbase
	4"	Lime Treated Subgrade
F4	24' x 1-1/2" (min)	ACP
	12"	Flexible Base
F5	24' x 1-1/2" (min)	ACP
	12"	Crushed Limestone
F6	24' x 1-1/2" (min)	ACP
	5"	Type D Hot Mix
	6"	Hot Sand Asphalt
F7	24' x 1-1/2" (min)	ACP
	12"	Type D Hot Mix
RIGID		
R1	18'	9-6-9
		Widened to 24'
		3' x 9" extensions each side
		Dowelled expansion joints at 78' 6"
		Contraction joints at 26'2"
		Overlaid with 1-1/2" (min) ACP

R2	22'	9-7-9 Widened 2' Expansion joints at 120' Contraction joints at 15' centers Overlaid with 1-1/2" (min) ACP
R3	22'	8-6-8 Widened with ACP Dowelled expansion joints At 100' Contraction joints at 20' centers Overlaid with 1-1/2" (min) ACP
R4	24'	9-8-9 Expansion joints at 120' Contraction joints at 40' Warping joints at 13'-4" Overlaid with 1-1/2" (min) ACP
R5	24'	9-8-9 Expansion joints at 120' Contraction joints at 40' Warping joints at 13'-4" Original pavement used as median New lanes constructed with: 24' x 1-1/2" ACP (min) 8" Flexible Base 6" Lime Treated Subbase 4" Lime Treated Subgrade Overlaid with 1-1/2" (min) ACP
R6	24'	10" Wrinkle tin joints at 15' Overlaid with 1-1/2" (min) ACP
R7	24'	9-7-9 Expansion joints at 120' Contraction joints at 40' Warping joints at 13'-4" Overlaid with 1-1/2" (min) ACP

Table A.1 Pavement key for District 11 (continued)

R820'	9-7-9	Expansion joints at 78'-6" Dummy joints at 26'-2" Original pavement used as flush median New driving lanes: 1-1/2" (min) ACP 12" iron ore (some cement stabilized)
R9	20'	9-6-9 Expansion joints at 78'-6" Dummy joints at 26'-2" Widened with soil cement Overlaid with 1-1/2" (min) ACP
R11	20'	9-6-9 Expansion joints at 120' Dummy joints at 30' Existing pavement is undivided Centerline offset 3' New pavement 1-1/2" (min) ACP 8" soil cement 8" lime treated subgrade
R13	20'	9-6-9 Expansion joints at 78'-6" Contraction joints at 26'-2" Widening: 1-1/2" (min) ACP 8" Flexible Base 6" Roadbed Treatment 6" Lime Treated Subgrade

Table A.2 Summary of roadway lengths by pavement types (directional miles)

TYPE	COUNTY					TOTAL MILES	PERCENT OF TOTAL
	SHELBY	NACOGODOCHES	ANGELINA	POLK	SAN JACINTO		
F1	2.6	7.7		21.4	10.6	42.3	17.3
F2		2.2			5.5	7.7	3.1
F3				13.8		13.8	5.6
F4	2.9	35.5	1.3			39.7	16.3
F5		1.1	0.7	9		10.8	4.4
F6			3.8			3.8	1.6
F7			4.7			4.7	1.9
					Flexible Subtotal	122.8	50.2
R1				1.4	9.6	11	4.5
R2			0.7	2.6		3.3	1.3
R3				27		27	11
R4			13.8			13.8	5.6
R5				4.5		4.5	1.8
R6		5.4	20.2			25.6	10.6
R7		5.1				5.1	2.1
R8		5.3				5.3	2.2
R9	2.6					2.6	1.1
R11	16.6					16.6	6.8
R13	6.1	0.8				6.9	2.8
					Rigid Subtotal	121.7	49.8
Totals	30.8	63.1	45.2	79.7	25.7	244.5	100

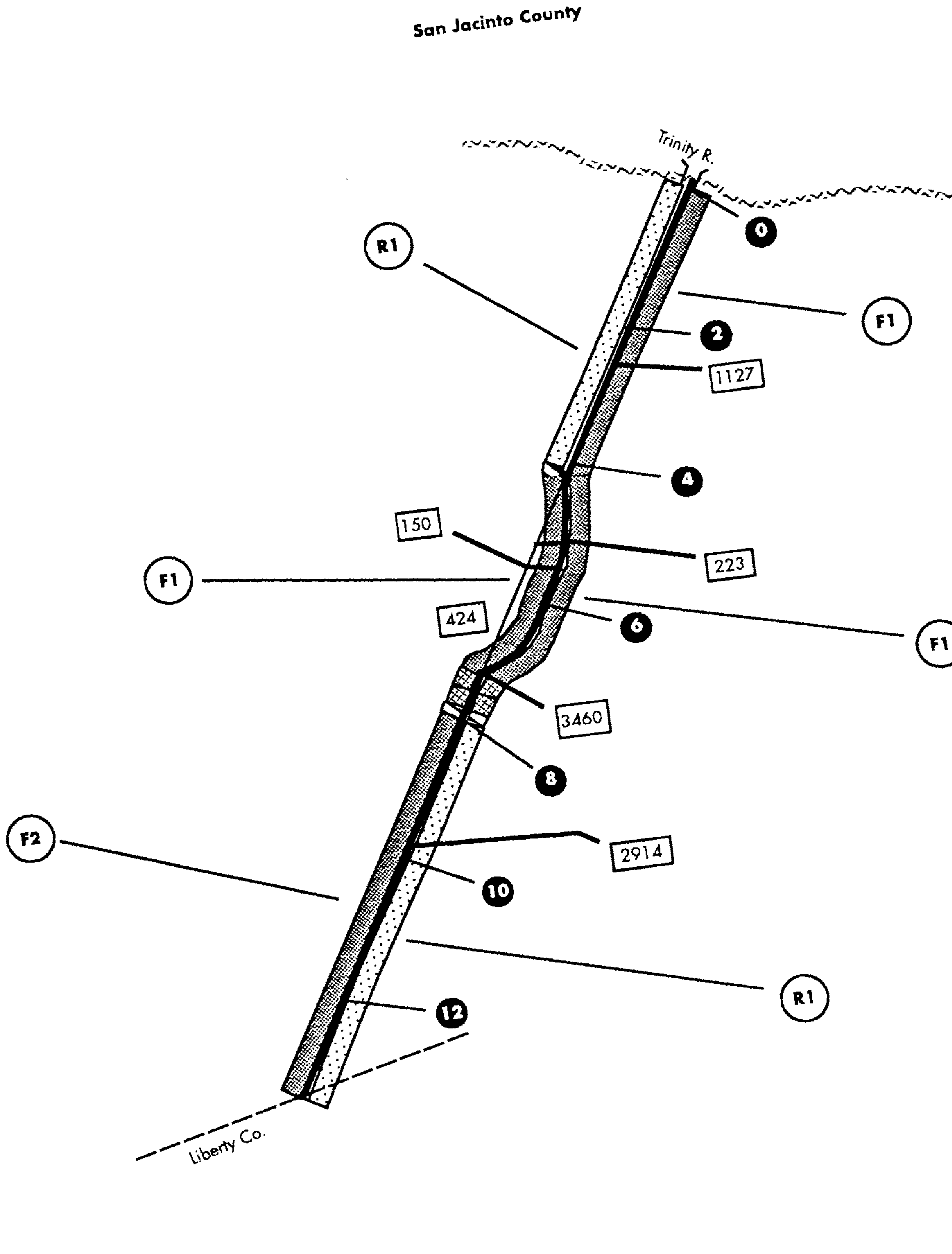


Figure A.1 San Jacinto County

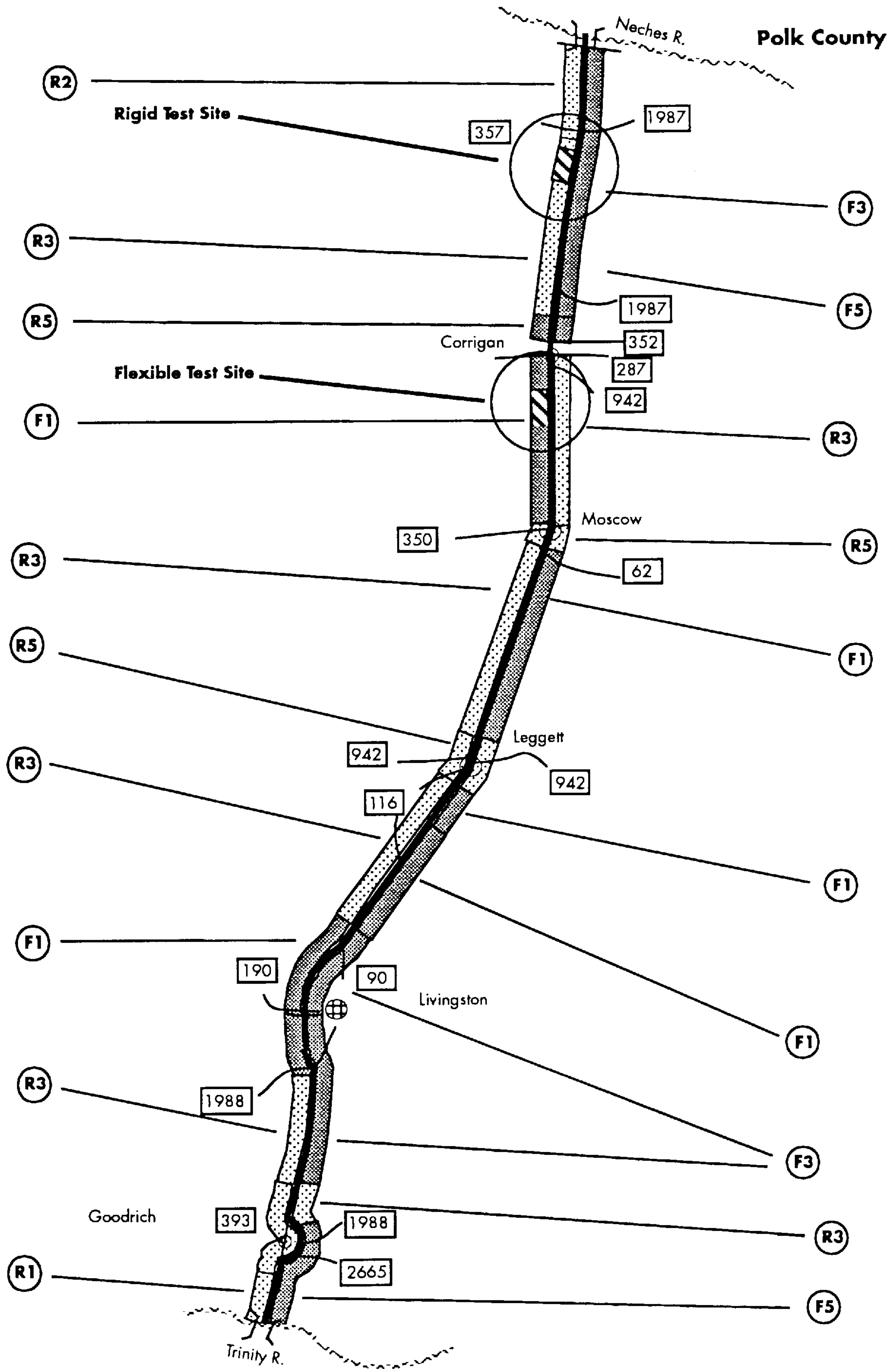


Figure A.2 Polk County

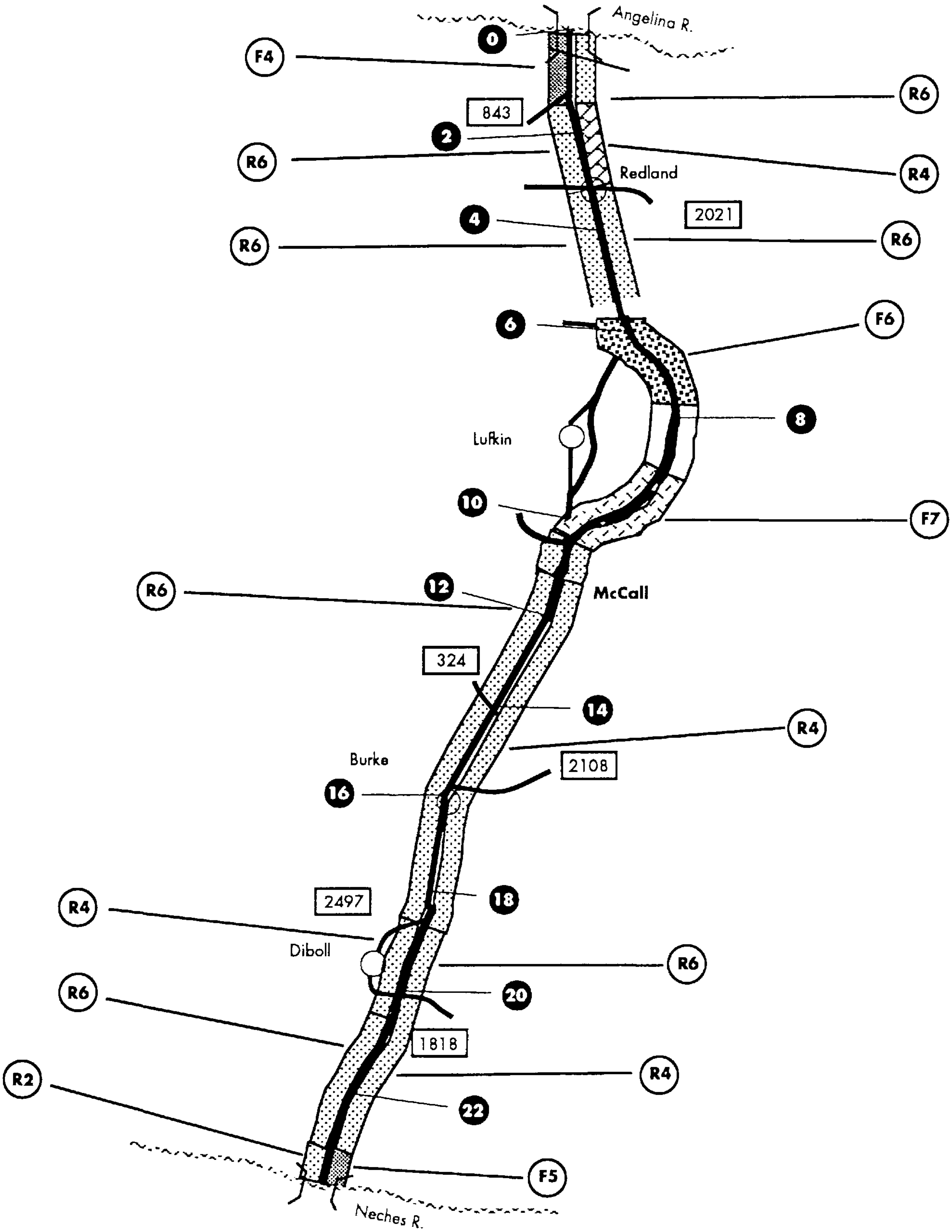


Figure A-3 Angelina County

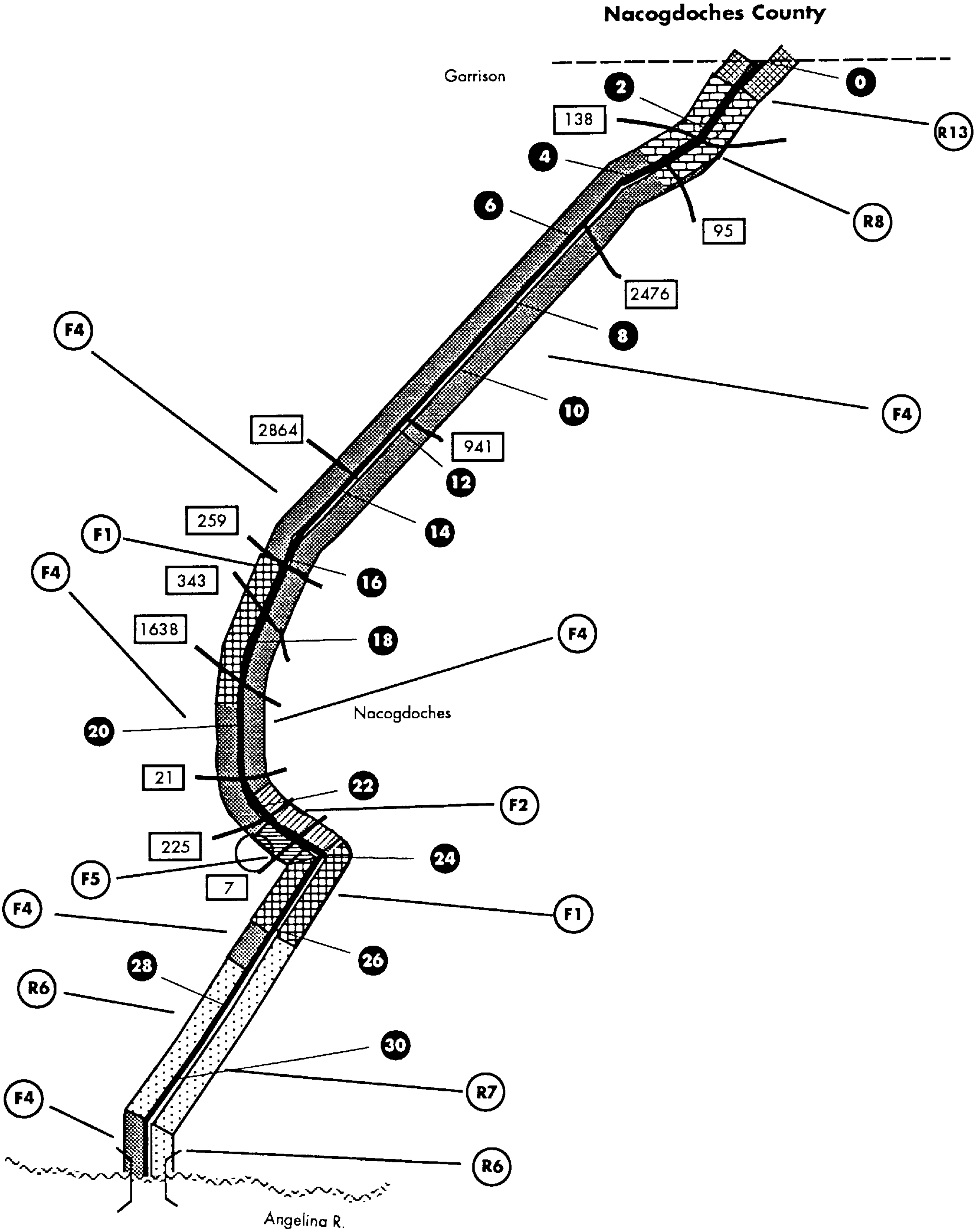


Figure A.4 Nacogdoches County

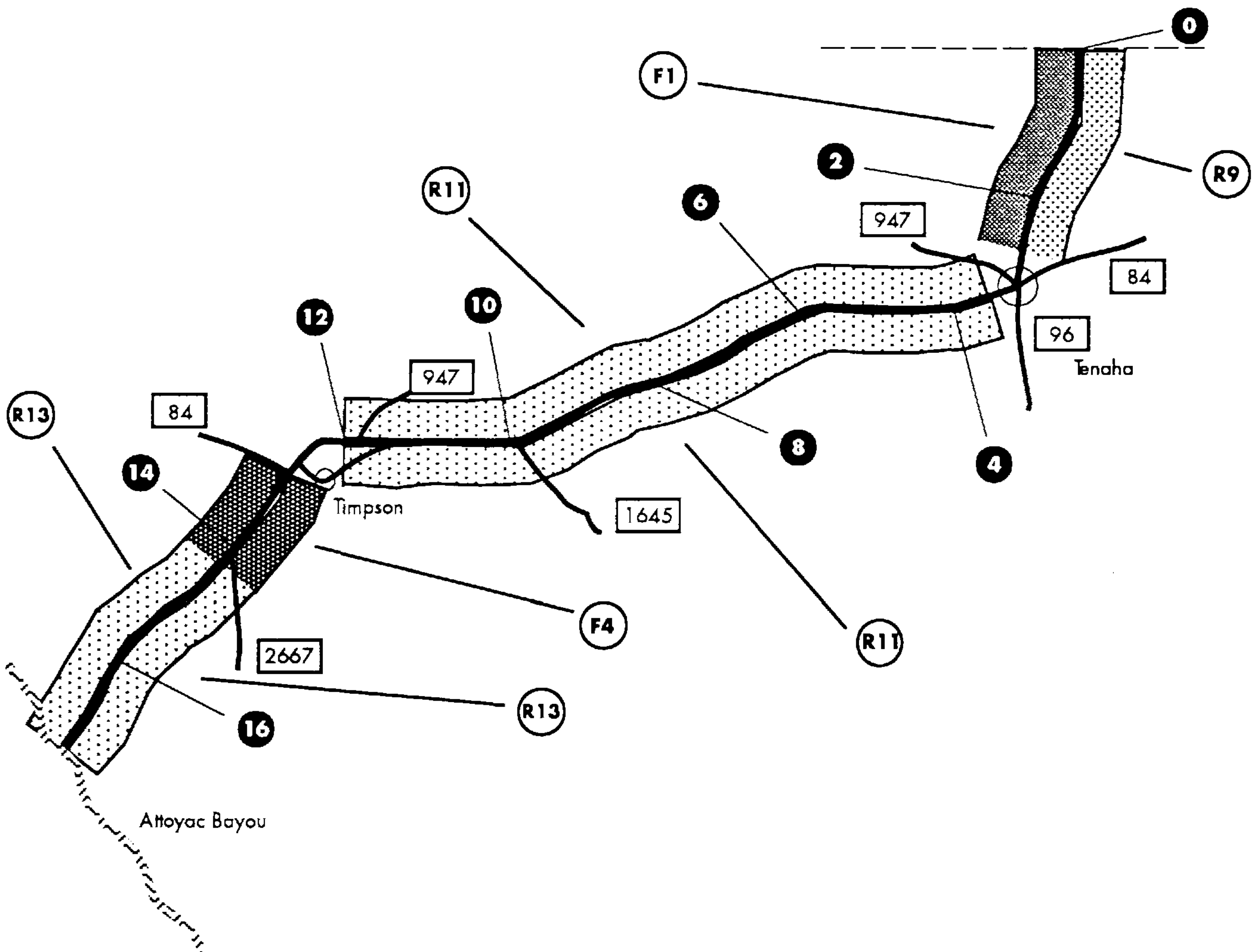


Figure A.5 Shelby County

APPENDIX B. PILOT REPAIR INFORMATION

PROJECT 987, US HIGHWAY 59 SOUTH LUFKIN TEST SECTION DIRECTION: SB LANES:1 & 2 CONCRETE PAVEMENT CRACK DATA SURVEY DATE: 8/7/89 - 8/10/89	KEY: BEFORE AC REMOVAL

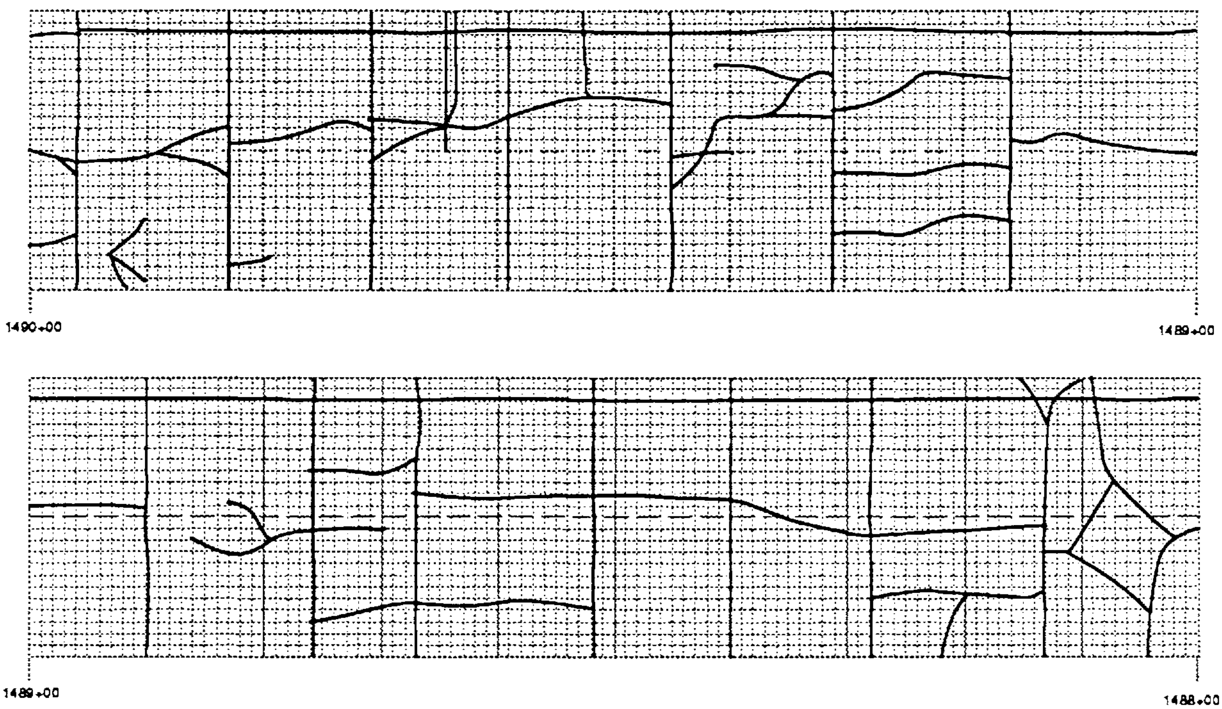
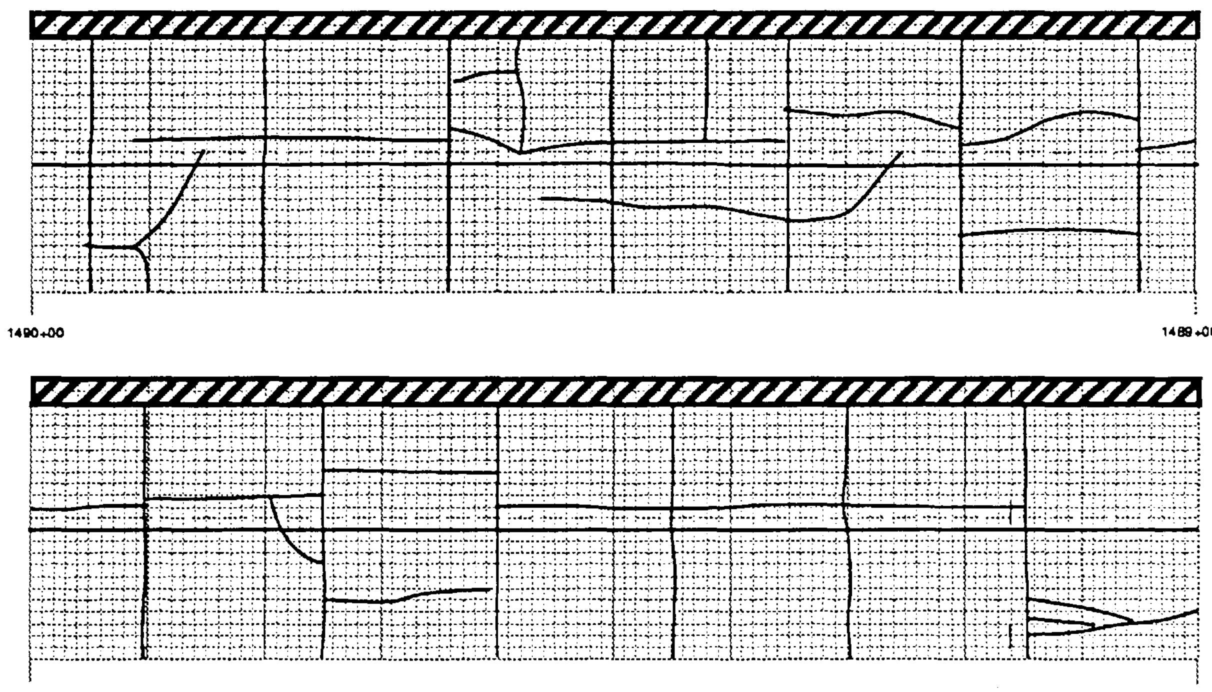


Figure B.1. Surface cracks before overlay removal

PROJECT 987, US HIGHWAY 59 SOUTH OF LUFKIN TEST SECTION DIRECTION: SB LANES: 1 & 2 CONCRETE PAVEMENT CRACK DATA SURVEY DATE: 8/7/89 - 8/10/89	KEY: AFTER AC REMOVAL



Figurte B.2. Surface cracks after overlay removal

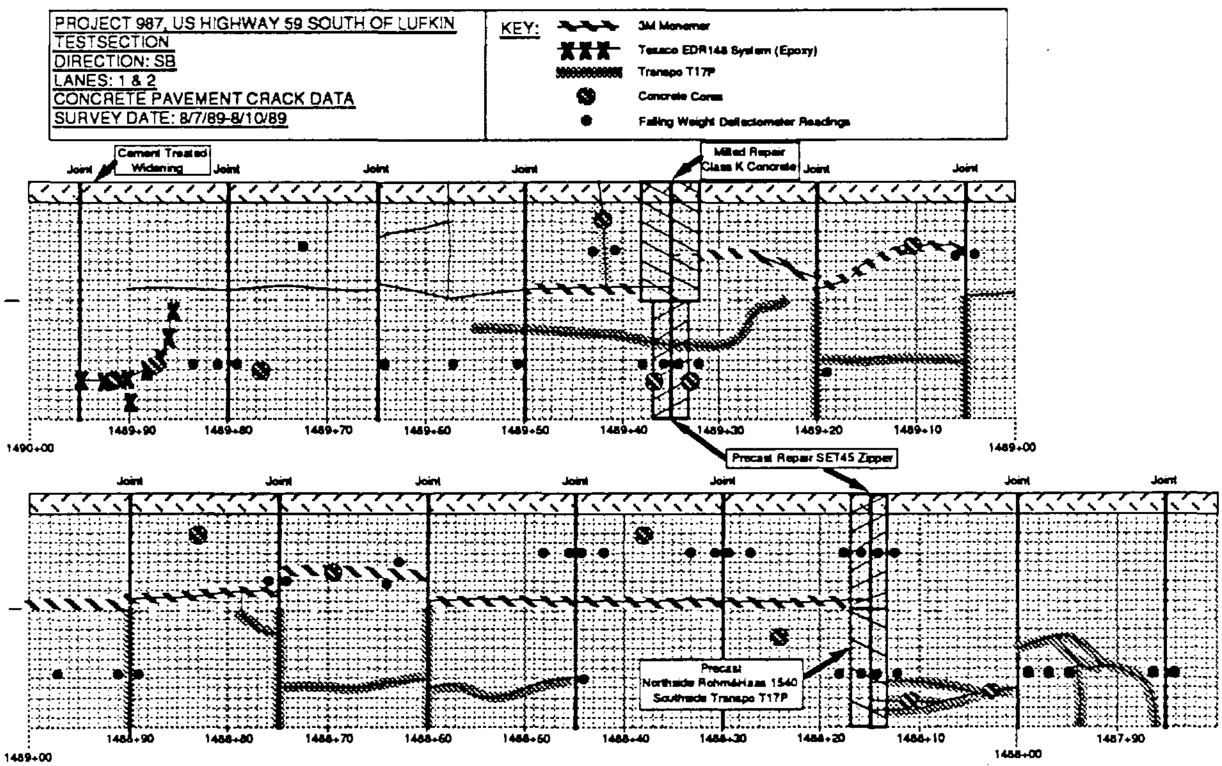


Figure B.3. Map indicating location of repairs, cores, and FWD measurements

APPENDIX C. PAVEMENT HISTORY TABLES

COUNTY	PAVEMENT TYPE	DIRECTION	LOCATION FROM	LOCATION TO	EXPLANATION OF ORIGINAL CONSTRUCTION	DATE OF CONST	OVERLAY FROM	OVERLAY TO	THICKNESS						TOTAL THICKNESS
									06/79	05/82					
SAN JACINTO	F1	NB	0	4.1	1.5" ACP, 4.5" BB, 6" CTB	11/65	0	4.1	1.3	?					1.3
									06/79	09/80					
	F1	NB	4.1	7.4	1.5" ACP, 4.5" BB, 6" CTB	11/65	4.1	7.4	1.3	3.2					4.5
									09/80	07/61	09/70	06/79			
	F2	NB	7.4	8	1.5" ACP, 6" CSB, 6" FL. BS.	07/56	7.4	7.7	3.2						3.2
							7.7	8	3.2	1	1.3	1.3			6.8
									11/49	07/61	03/67	03/82			
	R1	NB	0.08	13.4	9-6-9, 18"	6/30.	8	13.4	2.5	1	1.5	?			5
									11/65	06/79	12/82	11/49	11/65	06/79	
	R1	SB	0	4.1	9-6-9, 18"	6/30.	0	0.7	1.25	1.25	2				4.5
							0.7	4.1			2	2.5	2.5	1.25	8.25
									06/79	09/80					
	F1	SB	4.1	7.4	1.5" ACP, 4.5" BS, 6" CTB	11/65	4.1	7.4	1.3	3.2					4.5
									09/80	07/61	06/79				
	F2	SB	7.4	8	1.5" ACP, 6" FL. BS., 6" CTB	07/56	7.4	7.7	3.2						3.2
							7.7	8	3.2	1	1.3				5.5
									03/67	03/72					
	F2	SB	8	13.4	1.5" ACP, 6" CRB, 6" FL. BS.	10/62	8	13.4	1.5						1.5
							8.2	9.8		1.2					1.2
							12.2	12.5		1.2					1.2

COUNTY	PAVEMENT TYPE	DIRECTION	LOCATION FROM	LOCATION TO	EXPLANATION OF ORIGINAL CONST	DATE OF CONST	OVERLAY FROM	OVERLAY TO	THICKNESS							TOTAL THICKNESS
									9/74	5/78	7/85					
POLK	F1	SB	10.8	14.7	10.5" BS. 1.5" ACP	12/66	10.8	14.7	1	1.5						2.5
									12/59	1/62	8/69	9/61	12/66	7/81	7/85	
	R3	NB & SB	9.5	10.4	8-6-8" 22'	7/41	9.5	10	1.1	1	2					4.1
							10	10.4				1.5	1.5	2		5
									9/61	12/66	7/81					
			10.4	10.8	9-6-9"	10/40	10.4	10.8	1.5	1.5	2					5
									9/61	12/66	7/81					
			10.8	14.7	8-6-8"	7/41	10.8	14.7	1.5	1.5						3
							10.8	13.2			2					2
									9/61	12/66	9/74	5/78	7/85			
	R5	N & SB	14.7	15.5	8-6-8"	7/41	14.7	15.5	1.5	1.5	1	1.5				5.5
									9/61	12/66	10/69	6/79	6/82			
	R3	SB	16.5	22.4	8-6-8"	8/42	15.5	22.4	1.5							1.5
							15.5	20.1		1.5						1.5
							20.1	22.4			1.5					1.5
							21.8	22.4				1.7				1.7
							20.1	22.4					1			1
									9/74	5/78	7/85	9/80	7/85			
	F1	NB	15.5	20.5	10.5" BS. 1.5" ACP	12/66	15.5	16.2	2.5	1.5	7					4
							16.9	20.5	2.5	1.5						4
			20.5	21.8	10.5" BS. 3" ACP	10/69	20.5	21.8				3				3
									9/61	10/69	11/82					
	R6	N & SB	22.4	23.4	8-6-8"	8/42	22.4	23.4	1.5	1.5	1.3					4.3

COUNTY	PAVEMENT TYPE	DIRECTION	LOCATION FROM	LOCATION TO	EXPLANATION OF ORIGINAL CONSTRUCTION	DATE OF CONST	OVERLAY FROM	OVERLAY TO	THICKNESS						TOTAL THICKNESS
									9/56	10/64	10/71	7/79			
POLK	R3	SB	5.9	9.4	8-6-8"	7/41	5.9	8.3	1.2	1.5	1.3	1.3			5.3
176-4							8.3	9.4	?	?	?	?			0
									7/53	7/64	10/63	10/71	6/79	11/82	
	R2	SB	0	2.1	9-7-9"	4/43	0	1.6		1.2	1.5	1.3	1.3	?	5.3
							1.6	2.1	1.5		1.2	1.3	1.3	?	5.3
									7/53	10/63	10/64	10/71	6/79	11/82	
	R2	SB	2.1	5.5	9-7-9"	4/43	2.1	2.8	1.5	1.2		1.3	1.3	?	5.3
							2.8	5.5	1.5		1.5	1.2	1.3	?	5.5
									10/71	6/79	7/79	3/86			
	F3	NB	0	2.9	8" BS. 1.5" ACP	10/63	0	1.4	2.8	1.3		?			4.1
							1.4	2.2			2.8	?			2.8
							2.2	2.8	2.8	1.3		?			4.1
							2.8	2.9			2.8	?			2.8
									7/79	3/86					
	F5	NB	2.9	8.3	14" BS. 1.5" ACP	10/64	2.9	7.4	2.8	?					2.8
							7.4	8.3		?					

COUNTY	PAVEMENT TYPE	DIRECTION	LOCATION FROM	LOCATION TO	EXPLANATION OF ORIGINAL CONSTRUCTION	DATE OF CONST	OVERLAY FROM	OVERLAY TO	THICKNESS						TOTAL THICKNESS
									9/81	10/69	7/81				
POLK	R3	SB	23.4	29.3	8-6-8"	8/42	23.4	29.3	1.5	1.5					3
							26.4	29.3			2				2
									11/79	11/82					
	F1	NB	23.4	28.6	10.5" BS. 3" ACP	10/69	25.5	28.6	1.3						1.3
							23.5	24.8		3.2					3.2
							24.8	25.5		3					3
							25.5	28.6		1.7					1.7
	F1	SB	28.6	31.3	RECON. 22.5" BS. 2.1" ACP	9/81									
	F3	NB	28.6	31.3	RECON, 22.5"B S. 2.1" ACP	9/81									

COUNTY	PAVEMENT TYPE	DIRECTION	LOCATION FROM	LOCATION TO	EXPLANATION OF ORIGINAL CONSTRUCTION	DATE OF CONST	OVERLAYS FROM	OVERLAYS TO	THICKNESS						TOTAL THICKNESS
									8/88	1/04					
POLK	F1	NB	32.2	33.5	1.5" ACP. 1.8" BS.	10/83	31.9	33.5							0
			31.3	33.5	RECON. 12" BS. 2" ACP.	8/79	31.3	33.5							0
		SB	31.3	33.5	RECON. 12" BS. 2" ACP.	8/79									
									6/79	7/81	9/83				
POLK	F3	NB	33.5	36	8" BS. 1.5" ACP.	10/63	33.9	36	1.8	0.7	1				3.5
							33.5	36			3.5				3.5
			33.5	37.8	2.8" ACP.	9/70	33.5	37.8			0.7				0.7
									10/63	6/79	7/81	9/83			
		SB	33.5	36	22' 8-6-8 CONC.	1939	33.5	36	1.5			2			3.6
		NB	36	37.8	22' 8-6-8 CONC.	1939	36	37.8	1.5	1.8	0.7	1			5
									6/79	7/81	9/83				
		NB & SB	37.8	39.7	8-6-8"	1939	37.8	39.7							0
			37.8	39.7	RECON. 8" BS. 1.5" ACP	10/63	37.8	39.7							0
			37.8	39.7	RECON. 13.5" BS. 1.3" ACP.	6/75	37.8	39.7	1.8	2.5	1				5.3
									10/63	9/70	6/79	7/81	9/83		
		SB	39.7	41.4	8-6-8"	1939	39.7	40.8	1.5	1.3	1.8	2.5	1		8.1
			40.8	41.4	WIDEN 9-8-9 TO 24'	4/50	40.8	41.4	1.5	1.3	1.8	2.5			7.1
							40.8	40.9					1		1
									6/79	7/81	9/83				
		NB	39.7	41.4	8-6-8"	1939	39.7	41.4	1.8	2.5	1				5.3

COUNTY	PAVEMENT TYPE	DIRECTION	LOCATION FROM	LOCATION TO	EXPLANATION OF ORIGINAL CONSTRUCTION	DATE OF CONST	OVERLAY FROM	OVERLAY TO	THICKNESS						TOTAL THICKNESS
									10/80						
NACOGDOCHES	F7	SB	26	27.3	11" BS, 1.2" ACP.	6/65									
176-1			26	27.3	RECON. 13.5" BS, 1.2" ACP	11/75	26	26.3	1.5						1.5
							26.3	27.3	4.8						4.8
									5/67	10/80					
	R8	SB	27.3	31.4	10" CONC.	7/62	27.3	31.4	1.5						1.5
							27.3	31.4		4.5					4.5
									7/65	6/67	7/78	7/80			
	F4 — F7	SB	31.4	33.1	21" BS, 1.3" ACP.	8/53	31.4	32.7	1.2						1.2
							31.4	33.1		1.5					1.5
							32.2	33.1			1.5	1.5			3
			31.4	33.1	RECON. 13.5" BS, 3.7" ACP.	5/81									
									11/66	10/80					
	R7	NB	26	31.4	9-7-9 24'	11/46	26	31.4	1.5	4.5					6
									5/67	7/80					
	R8	NB	31.4	33.1	10" CONC. 24'	7/62	31.4	32.7	1.5						1.5
			31.8	33.1	COLD MILL TO CONC.	10/78	31.8	33.1		7					7

COUNTY	PAVEMENT TYPE	DIRECTION	LOCATION FROM	LOCATION TO	EXPLANATION OF ORIGINAL CONSTRUCTION	DATE OF CONST	OVERLAY FROM	OVERLAY TO	THICKNESS						TOTAL THICKNESS
									7/55	7/62	8/80				
NACOGDOCHES	R13	NB & SB	0	1.3	9-6-9 20'	1938	0	1.3	1.2	1.5					2.7
176-6							0	0.9			1.5				1.5
									5/82	7/83					
	F4	NB & SB	1.3	2.8	12" BS. ,1.8" ACP	12/61	1.3	2.4	1						1
							2.4	2.8		1					1
NACOGDOCHES									4/43	8/65	9/75	5/82			
176-7	F4	NB & SB	2.8	16	10.5" BS	1936	2.8	16	1.6	1.2					2.8
			2.8	15.3	RECON. 12" BS. 1 CRS.	5/59	2.7	3.7			3				3
							3.7	4.2			2				2
							4.2	5			3				3
							5	10.7			2				2
							10.7	13			4				4
							13	14.6			3				3
							14.6	15.3			2				2
							2.7	15.3				?			
NACOGDOCHES									9/62	6/67					
176-1	R7	NB&SB	22.8	23.8	9-6-9 & 6" CONC.	1940									
			23.6	23.8	(WIDEN) 7" BS. 3" ACP	5/50	23.5	23.8	4						4
			23	23.6	(WIDEN) 8" CONC.	5/60	22.8	23.6	1						1
			23.5	23.8	RECON. 11" BS. 1.2" ACP.	6/65									
			22.8	23.5	WIDEN OLD 6" W/ 6" CONC.	6/67	22.8	23.5		2.22					2.22
									10/80						
	F1	NB&SB	23.8	26	9-7-9"	11/46									
			23.8	26	RECON. 11" BS. 1.2" ACP.	6/65									
			25.9	26	RECON. 12" BS. 1.2" ACP.	11/75	24.7	26	2.7						2.7

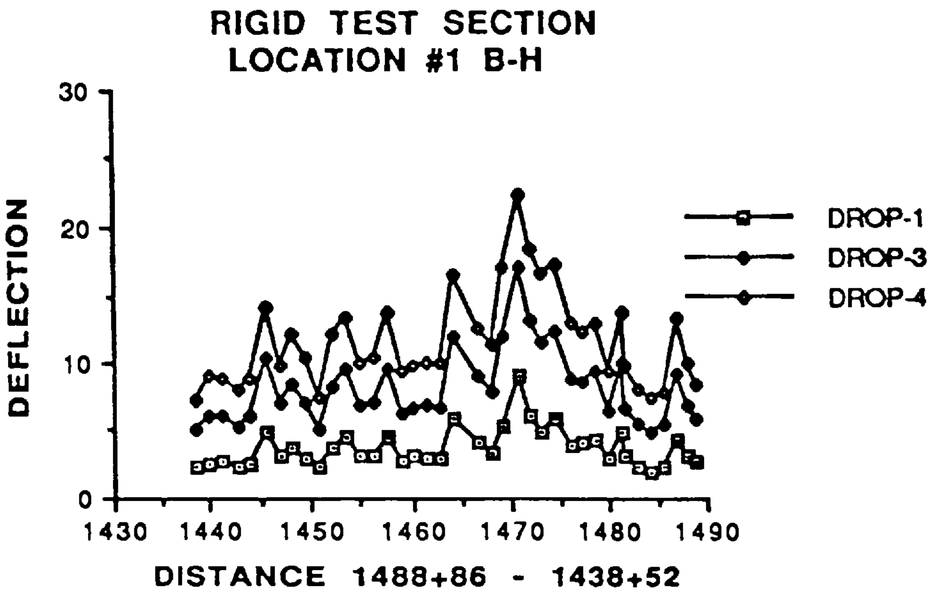
COUNTY	PAVEMENT TYPE	DIRECTION	LOCATION FROM	TO	EXPLANATION OF ORIGINAL CONSTRUCTION	DATE OF CONST	OVERLAY FROM	TO	THICKNESS							TOTAL THICKNESS
									8/53	10/62	2/62	1/67	5/67	3/72	6/73	
ANGELINA	R9	NB & SB	9.3	11.2	9-8-9 20' WIDE	1937	9.7	11.2	2.5							2.5
							10.3	11.2		1.0						1
							9.7	10.3			1.0					1
							9.3	9.7				2.6				2.6
							9.7	10.3					1.1			1.1
							10.3	11.2					1.5			1.5
							9.3	9.7						1.2		1.2
							10.6	11.2						1.2		1.2
							9.7	10.3							1.0	1
									2/61	5/67	7/80	3/81				
	R4	NB	11.2	18.8	9-8-9 24' WIDE	11/48	11.2	18.8	1.5	1.5		2.0				5
							14.1	15.8			1.5					1.5
							16.8	18.8			1.5					1.5
									5/67	12/82						
	R6	NB	18.8	20.2	10" CONC. 24' WIDE	10/62	18.8	20.2	1.5	3.0						4.5
									2/61	5/67	3/81					
	R4	NB	20.2	23.4	9-8-9 24' WIDE	11/48	20.2	23.4	1.5							1.5
							20.2	23.2		1.5	0.5					2
									5/67	10/78	7/80	5/81				
	R6	SB	11.2	18.8	10" CONC. 24' WIDE	10/62	11.2	18.6	1.5							1.5
							11.2	15.8		2.5						2.5
			14.1	15.8	RECON. COLD MILL TO CONC	10/78	14.1	15.8			1.5					1.5
			16.7	18.8	" " " "	10/78	16.7	18.8			1.5	?				1.5
									2/61	5/67	12/82					
	R4	SB	18.8	20.1	9-8-9	11/48	18.8	20.1	1.5	1.5	1.5					4.5
									5/67	5/81						
	R6	SB	20.1	23.2	10" CONC. 24' WIDE	10/62	20.1	23.2	1.5	2.0						3.5

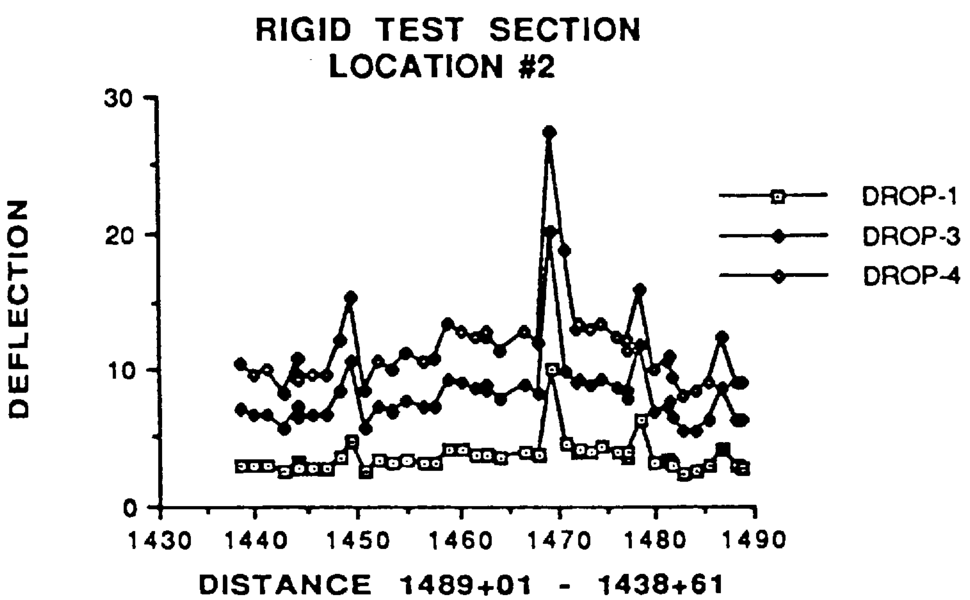
COUNTY	PAVEMENT TYPE	DIRECTION	LOCATION FROM	TO	EXPLANATION OF ORIGINAL CONSTRUCTION	DATE OF CONST	OVERLAY FROM	TO	THICKNESS								TOTAL THICKNESS
									5/45	8/53	8/56	11/63	5/67	7/80	5/81	5/85	
ANGELINA	F4	NB	0	1.2	8" BASE	1921											
			0	1.2	1 CRS. SURFACE	1928											
			0	1.2	RECON. 12" BASE	1936	0	1.2	1.1								1.1
			0	1.2	RECON. 16" BS. 1 CRS.	12/51	0	1.2		1.3	1.2	1.2	1.5				5.2
			0	1.2	COLD MILL ?	10/78	0	1.2						1.5	2.2		3.7
									5/67	7/78	7/80	5/81	5/85				
	R6	SB	0	1.2	10" CONC. 24'	11/63	0	1.2	1.5	1.5	1.5	2.2	?				6.7
									5/67	7/80	5/81	5/85					
	R8	NB & SB	1.2	1.6	10" CONC. 24'	11/63	1.2	1.6	1.5								1.5
			1.2	1.6	COLD MILL TO CONC.	10/78	1.2	1.6		1.5	2.2	?					3.7
									7/80	5/81							
	R8	SB	1.6	2.9	9-7-9 CONC.	7/47											
			1.6	2.9	COLD MILL TO CONC.	10/78	1.6	2.9	1.5	2.2							3.7
									5/67	7/80	5/81	5/85					
	R6	NB	1.6	2.6	10" BS.	11/63	1.6	2.9	1.5								1.5
			1.6	2.6	COLD MILL	10/78	1.6	2.9		1.5	2.2	?					3.7
									5/67	7/80	5/81	5/85					
	R6	NB & SB	2.9	3.9	9-7-9 CONC.	7/47											
			2.9	3.9	RECON. 10" BS.	11/63	2.9	3.9	1.5								1.5
			2.9	3.3	COLD MILL	10/78	2.9	3.9		1.5	2.2	?					3.7
									7/78	7/80	5/81	5/85					
	R6	SB	3.9	4.6	9-7-9 20'	7/47	3.9	4.6	3								3
			4.6	5.3	9-8-9 24'	10/49	3.4	4.3		1.5	1.5	?					3
									5/67	7/80	5/81	5/85					
		NB	3.9	5.3	10" CONC.	11/63	3.9	5.3	1.5								1.5
			3.9	8.3	COLD MILL	10/78	3.8	8.3		1.6	2.2	?					3.7

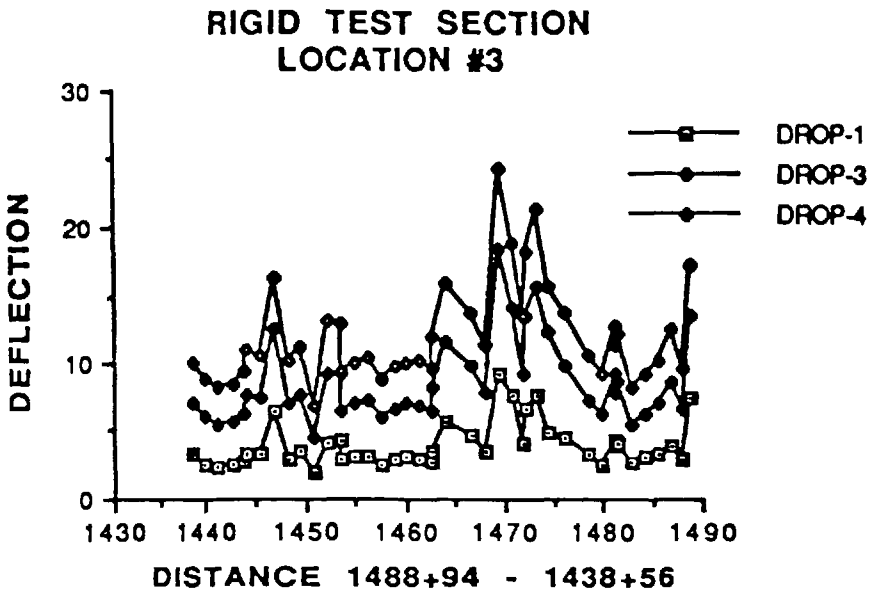
COUNTY	PAVEMENT TYPE	DIRECTION	LOCATION FROM	LOCATION TO	EXPLANATION OF ORIGINAL CONSTRUCTION	DATE OF CONST	OVERLAY FROM	OVERLAY TO	THICKNESS						TOTAL THICKNESS
									5/59	5/67	7/80	5/81	5/85		
ANGELINA	?	SB	5.3	6.5	9-8-9 24'	10/49	5.3	6.5	1.5	1.2					2.7
			5.3	5.8	COLD MILL TO CONC.	7/79	5.3	5.8			1.5	2.2	?		3.7
									5/59	5/67	7/80	5/81	5/86		
	?	NB	5.3	6.5	9-8-9 24'	10/49	5.3	6.5	1.5	1.2					2.7
			5.3	5.8	COLD MILL TO CONC.	10/78	5.3	5.8			1.5	2.2	?		3.7

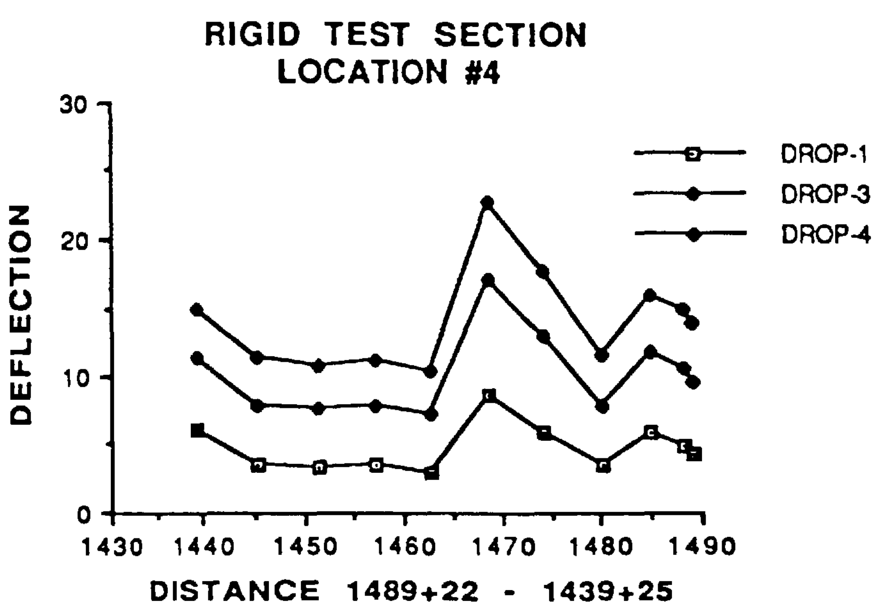
COUNTY	PAVEMENT TYPE	DIRECTION	LOCATION FROM	LOCATION TO	EXPLANATION OF ORIGINAL CONSTRUCTION	DATE OF CONST	OVERLAY FROM	OVERLAY TO	THICKNESS						TOTAL THICKNESS
									2/53	6/75	12/64	9/86			
SHELBY	?	NB & SB	3.6	11.3	9-6-9" CONC.	1935	3.6	11.3	3	2.2	?	?			5.2
175-4			3.6	11.3	WIDEN W/ 8" BS & 1.7" ACP	6/66									0
									6/53						
	?	NB & SB	11.3	11.6	9-6-9" CONC.	1938									0
			11.6	12	6" FLEX. BS., .9" ACP	1939	11.6	12	1.1						1.1
			11.3	11.6	9" CONC.	8/64									0
			11.8	11.8	10" BS. 1.5" ACP.	8/64									0
SHELBY	F4	NB & SB	12.5	12.8	8" BS., .9" 2 CRS	1932									0
175-5			5												0
									7/55	7/62	8/80				
	R13	NB & SB	14.5	17.6	9-6-9" CONC.	1938	14.5	17.6	1.2	1.5	1.5				4.2
									8/80						
	?	NB & SB	12.8	13.3	8" BS. & .9" 2 CRS	1932									0
			12.8	13.3	10" BS. & 1.5" ACP.	8/64	12.8	13.3	3						3
									8/80						
	?	NB & SB	13.3	14.5	8" BS. & .9" 2CRS	1932									0
			13.3	14.5	RECON. 7" BS. .4" ACP.	11/48									0
			13.3	14.5	10" BS. & 1.5" ACP.	8/64	13.3	13.7	3						3

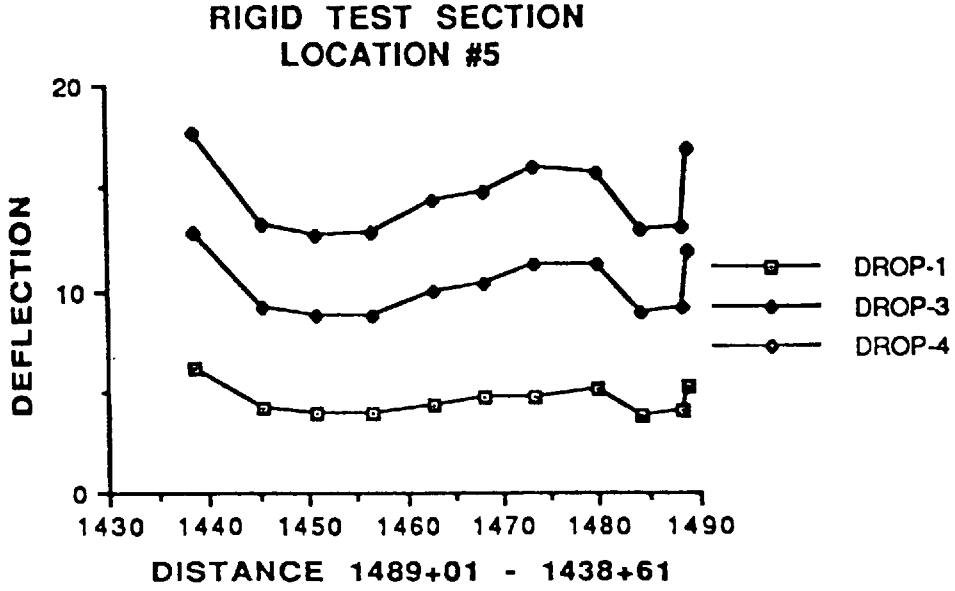
APPENDIX D. DEFLECTION GRAPHS AND GPR PLOTS FOR FLEXIBLE TEST SITE



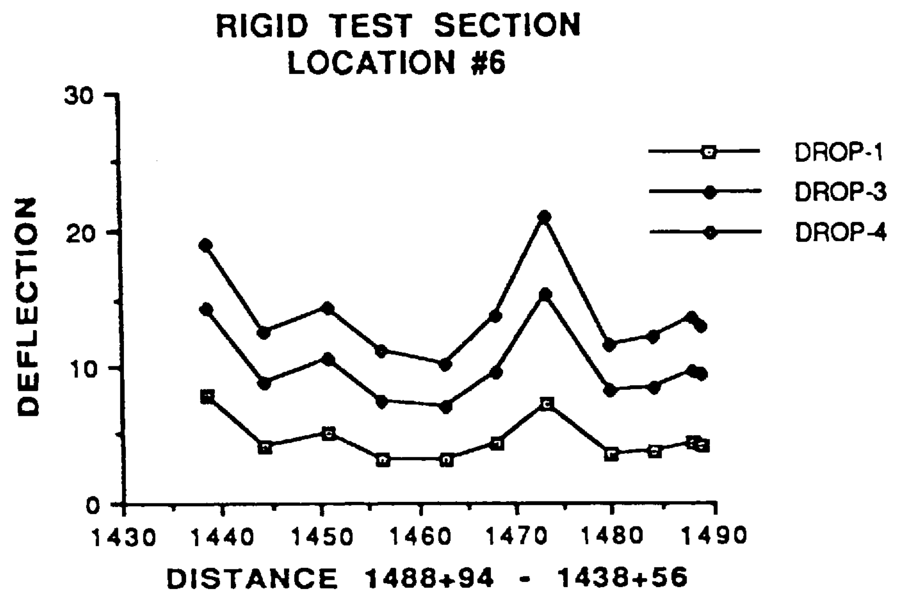



RIGID TEST SECTION
LOCATION #3
DROP-1
DROP-3
DROP-4
DEFLECTION
30
20
10
0
1430
1440
1450
1460
1470
1480
1490
DISTANCE 1488+94 - 1438+56

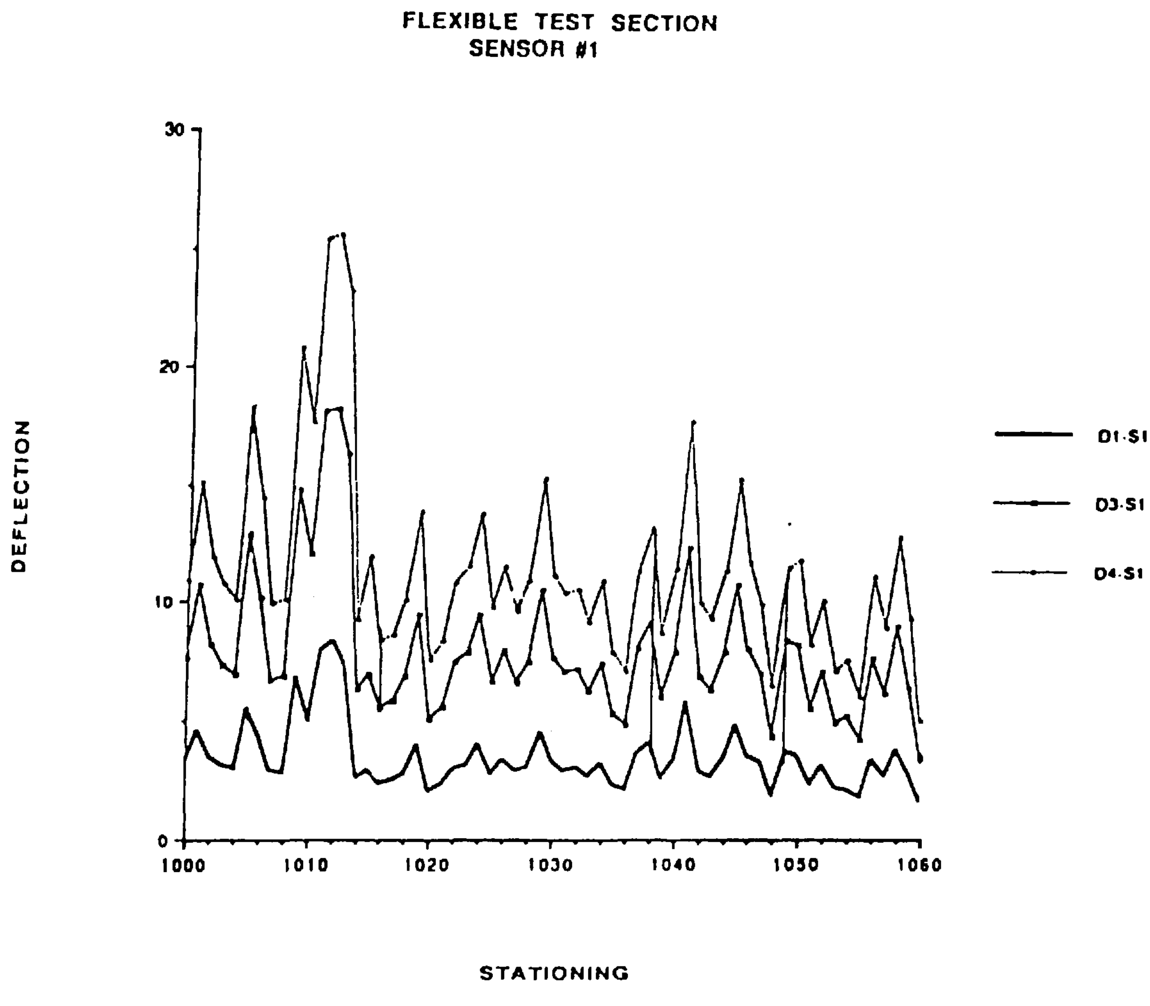

RIGID TEST SECTION
LOCATION #4
DROP-1
DROP-3
DROP-4
DEFLECTION
30
20
10
0
1430
1440
1450
1460
1470
1480
1490
DISTANCE 1489+22 - 1439+25

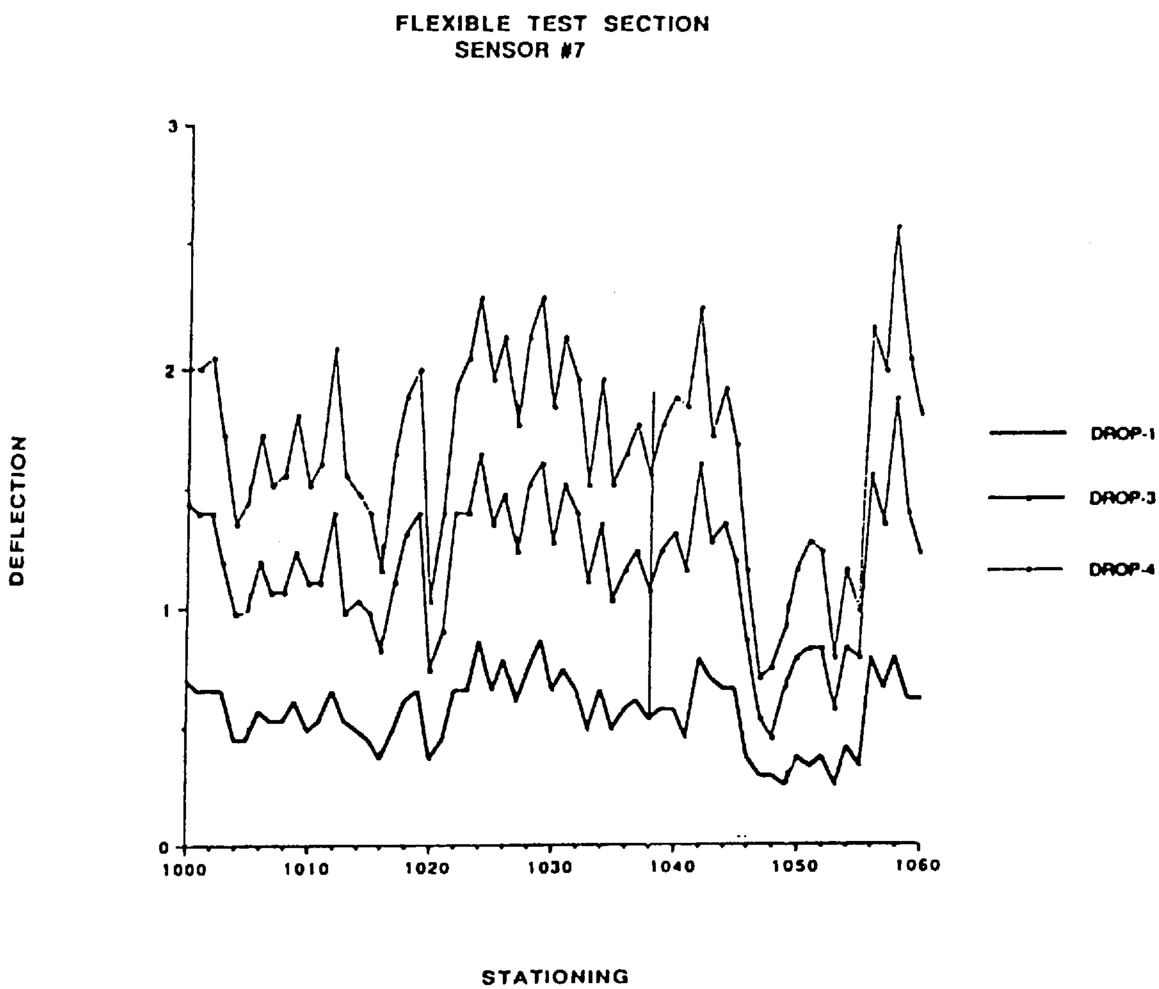


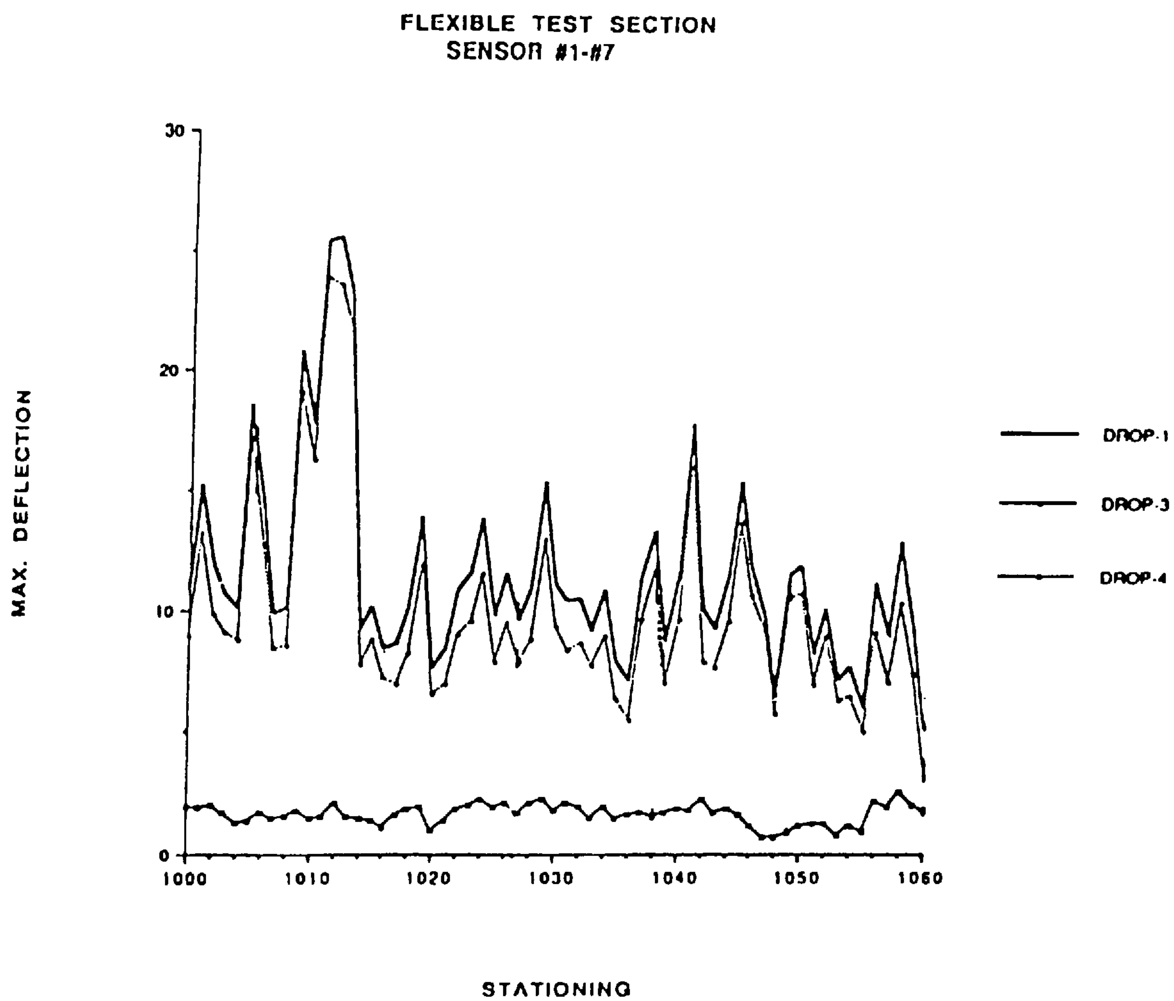
RIGID TEST SECTION
LOCATION #5
20
10
0
DEFLECTION
1430
1440
1450
1460
1470
1480
1490
DISTANCE 1489+01 - 1438+61
DROP-1
DROP-3
DROP-4

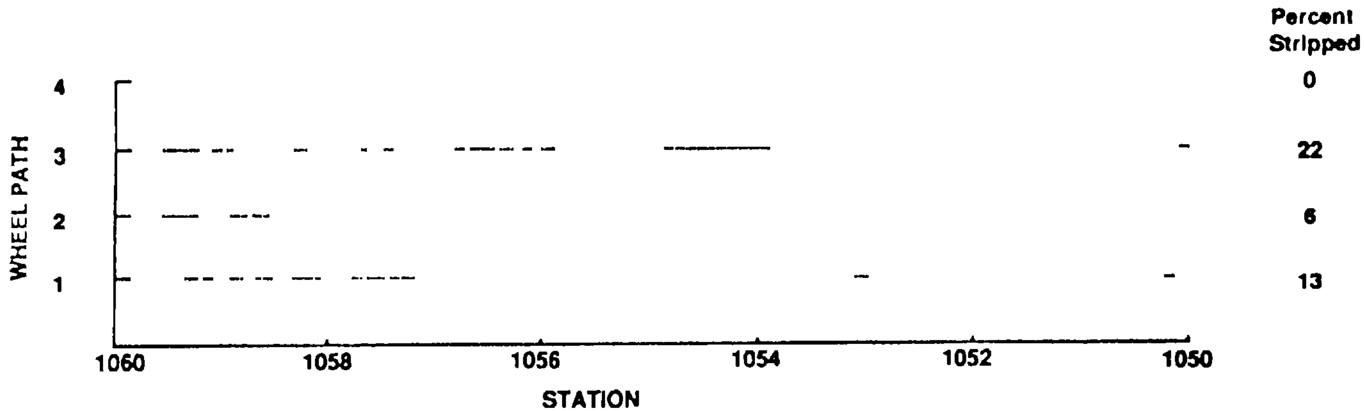


RIGID TEST SECTION
LOCATION #6
30
20
10
0
DEFLECTION
1430
1440
1450
1460
1470
1480
1490
DISTANCE 1488+94 - 1438+56
DROP-1
DROP-3
DROP-4

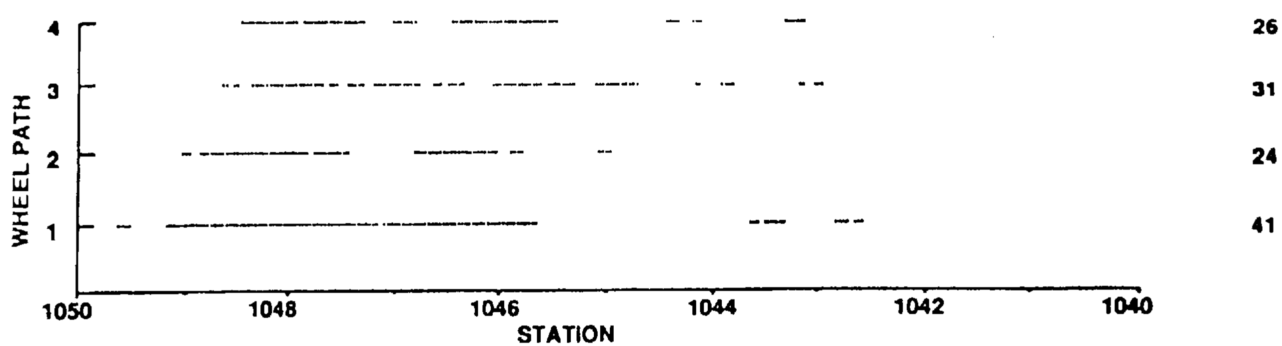

FLEXIBLE TEST SECTION
SENSOR #1
DEFLECTION
30
20
10
0
1000
1010
1020
1030
1040
1050
1060
STATIONING
D1-S1
D3-S1
D4-S1


FLEXIBLE TEST SECTION
SENSOR #7
DEFLECTION
STATIONING
0
1
2
3
1000
1010
1020
1030
1040
1050
1060
DROP-1
DROP-3
DROP-4

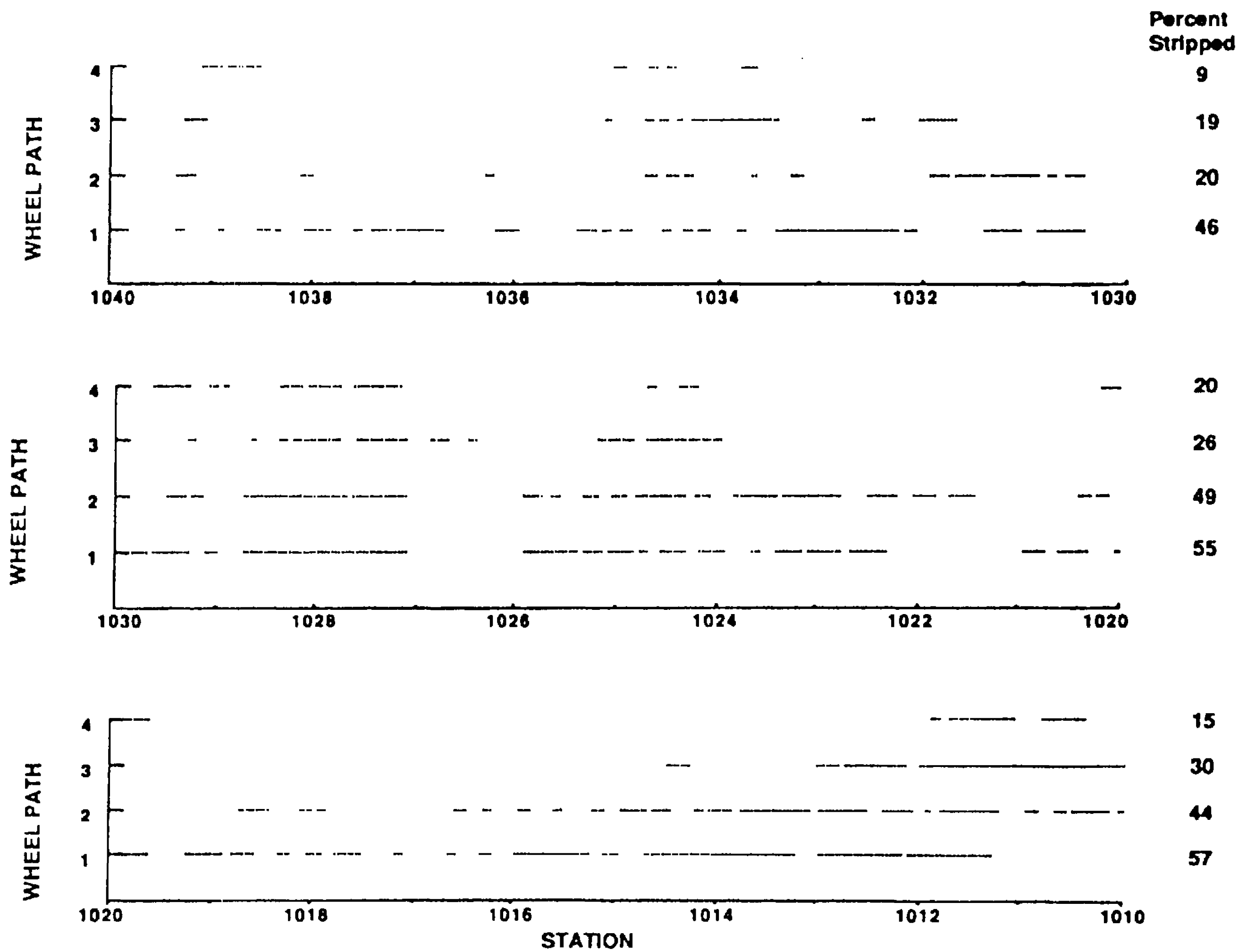

FLEXIBLE TEST SECTION
SENSOR #1-#7
MAX. DEFLECTION
30
20
10
0
1000
1010
1020
1030
1040
1050
1060
STATIONING
DROP-1
DROP-3
DROP-4



Percent Stripped
0
22
6
13
WHEEL PATH
4
3
2
1
1060
1058
1056
1054
1052
1050
STATION



26
31
24
41
WHEEL PATH
4
3
2
1
1050
1048
1046
1044
1042
1040
STATION


Percent Stripped
WHEEL PATH
STATION
1040
1038
1036
1034
1032
1030
1028
1026
1024
1022
1020
1018
1016
1014
1012
1010
9
19
20
46
20
26
49
55
15
30
44
57

APPENDIX E. PERFORMANCE MONITORING MATERIALS

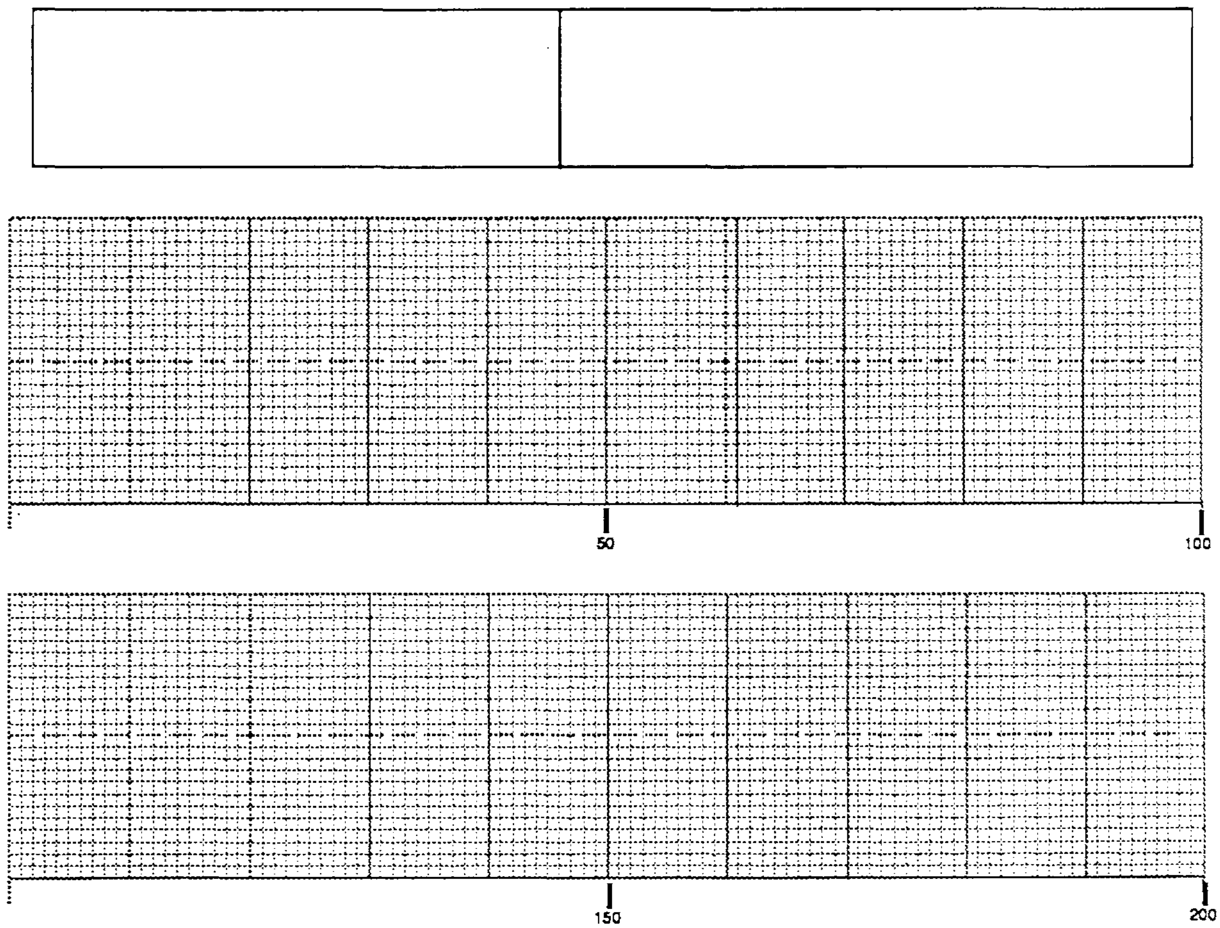


Figure E.1 Survey form

DATE	TEST SECTION	RUT DEPTH										ROUGHNESS MEASURMENT	PSI
		1	2	3	4	5	6	7	8	9	10		

Figure E.2 Rut depth/roughness measurement form

DATE	TEST SECTION	ACTIVITY	BEGIN ACTIVITY	END ACTIVITY	WEATHER/ TEMPERATURE	COMMENTS/ PROBLEMS

Figure E.3 Construction information form

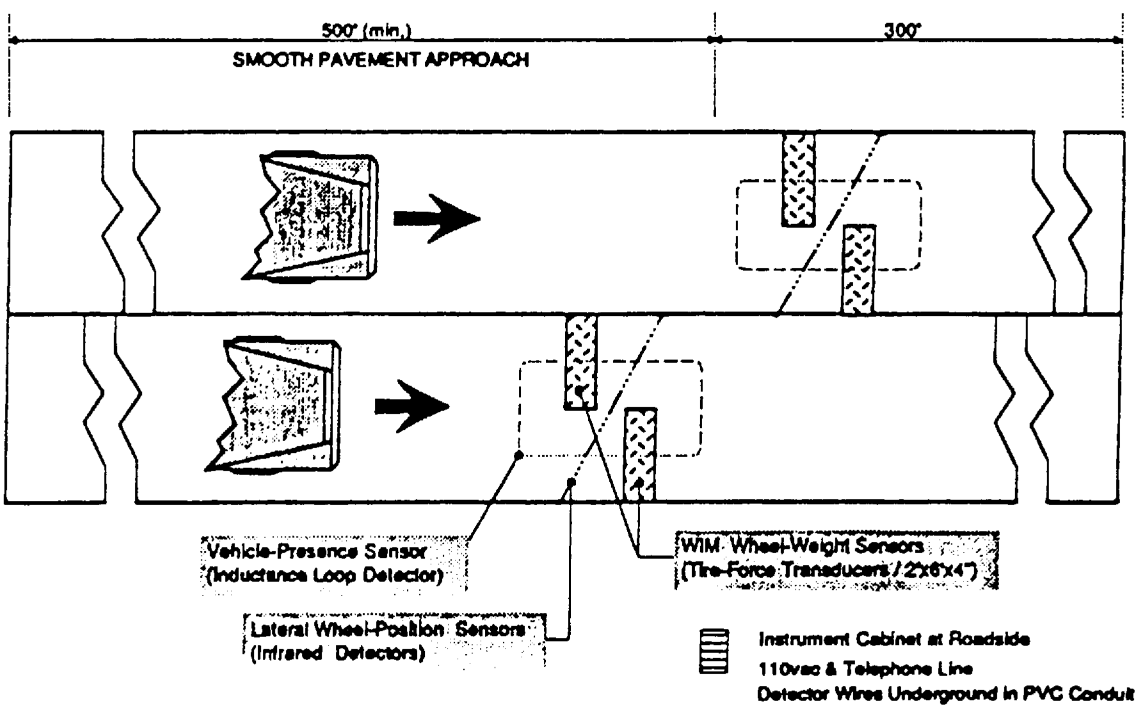


Figure E.4 Traffic monitoring (WIM) layout

		ROADWAY SECTION		MOST RECENT CONSTRUCTION		PSI	AVG RUT	DISTRESSES		EXTENT OF
DATE	DIRECTION	FROM	TO	TYPE	DATE		DEPTH	TYPE	FREQUENCY	STRIPPING

Figure E.5 Rehabilitation strategy form