TTI: 0-6658

Texas Flexible Pavements and Overlays: Year 5 Report—Complete Data Documentation

Technical Report 0-6658-3

Cooperative Research Program

TEXAS A&M TRANSPORTATION INSTITUTE
COLLEGE STATION, TEXAS

in cooperation with the
Federal Highway Administration and the
Texas Department of Transportation
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16. Abstract

Proper calibration and validation of pavement design and performance models to Texas conditions is essential for cost-effective flexible pavement design, performance predictions, and maintenance/rehab strategies. The veracity of the calibration of the Texas Department of Transportation pavement design models will determine how optimally billions of dollars of future roadway investment capital will be spent. For proper calibration/validation and tangible benefits, quality and reliable pavement performance data should be collected on a sustained basis. In order to accomplish the task of data collection, this five-year project was initiated to develop a comprehensive data storage system (DSS) of material properties and performance data for Texas flexible pavements and overlays. The objective of the project was to collect materials and pavement performance data on a minimum of 100 highway test sections around Texas. In total, the DSS comprises 112 highway test sections scattered across Texas.

This report documents all the work performed, methods used, and results completed throughout the project. These tasks included gathering design and construction data of test sections, executing laboratory and field performance testing, collecting traffic and climate data, and developing the data repository system consisting of the DSS and a raw data storage system (RDSSP). Finally, recommendations for the continuation of data collection to enable further calibration of performance models are given.

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HMA, Flexible Pavements, Overlays, MS Access, Data Storage System, DSS, RDSSP, Test Section, M-E Model, Field Performance

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DISCLAIMER

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the Federal Highway Administration (FHWA) or the Texas Department of Transportation (TxDOT). This report does not constitute a standard, specification, or regulation, nor is it intended for construction, bidding, or permit purposes. The researcher in charge was Lubinda F. Walubita.

The United States Government and the State of Texas do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.

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LIST OF ABBREVIATIONS AND SYMBOLS

AADT	Annual average daily traffic
AADTT	Annual average daily truck traffic
AASHTO	American Association of State Highway and Transportation Officials
AC	Asphalt concrete
ADT	Average daily traffic
ADTT	Average daily truck traffic
AMDTT	Average monthly daily truck traffic
AVG	Average
BBR	Bending beam rheometer
CTB	Cement-treated base
CTIS	Center for Transportation Infrastructure Systems
CV	Coefficient of variation
DC	Dry-cold climatic region
DCP	Dynamic cone penetrometer
DM	Dynamic modulus
DSR	Dynamic shear rheometer
DSS	Data storage system
DW	Dry-warm climatic region
ESAL	Equivalent axle single load
FDR	Full depth reclamation
FFRC	Free-free resonance column
FHWA	Federal Highway Administration
FN	Flow number
FPS	Flexible pavement design system
FWD	Falling weight deflectometer
GPS	Global positioning system
GPR	Ground penetrating radar
GWT	Ground water table
HMA	Hot-mix asphalt
HWTT	Hamburg Wheel tracking test
IDT	Indirect-tension
IRI	International Roughness Index
LTB	Lime-treated base
LTE	Load transfer efficiency
LTPP	long-term pavement performance
M	Moderate climatic region
MAF	Monthly adjustment factor
MD	Moisture-density
M-E	Mechanistic-empirical
M-E PDG	Mechanistic-Empirical Pavement Design Guide
MoR	Modulus of rupture
MS	Microsoft©
MSCR	Multi-stress creep and recovery
NCDC	National Climatic Data Center

MTD	Material transfer device
NDT	Non-destructive test
OT	Overlay tester
PCC	Portland cement concrete
PD	Project director
PDF	Portable document format
PG	Performance grade
PMIS	Pavement Management Information System
PP	Perpetual Pavement
PSI	Pavement serviceability index
RLPD	Repeated load permanent deformation
QC/QA	Quality control/Quality assurance
RAP	Recycled asphalt pavement
RAS	Recycled asphalt shingles
RDSSP	Raw data storage system for project
SPST	Simple punching shear test
STDEV	Standard deviation
TPP	Transportation Planning and Programming
TTI	Texas A&M Transportation Institute
TxACOL	Texas Asphalt Concrete Overlay Design and Analysis System
TxDOT	Texas Department of Transportation
TxME	Texas Mechanistic-Empirical Flexible Pavement Design System
UCS	Unconfined compressive strength
UTEP	University of Texas at El Paso
WC	Wet-cold climatic region
WIM	Weigh-in-motion
WMA	Warm-mix asphalt
WW	Wet-warm climatic region

CHAPTER 1
INTRODUCTION

Proper calibration of pavement mechanistic-empirical (M-E) design and rehabilitation performance models to conditions in Texas is essential for cost-effective flexible pavement designs. For proper calibration and tangible benefits, quality and reliable pavement performance data should be collected on a sustained basis. The veracity of the calibration of TxDOT's pavement design models will determine how optimally billions of dollars of future roadway investment capital will be spent. In order to facilitate orderly data collection, this study developed a comprehensive database system containing material properties and performance data for flexible pavement and HMA overlaid test sections in Texas.

PROJECT OBJECTIVES

This project established and monitored pavement test sections, and developed a data storage system (DSS) of materials and pavement performance data on more than 100 flexible pavement test sections around Texas. The M-E Structural Design Systems targeted for calibration using data in the DSS include the following:

- The Flexible Pavement Design System (FPS) design procedure.
- The Texas M-E (TxME).
- The Texas Asphalt Concrete Overlay Design and Analysis System (TxACOL).
- The American Association of State Highway and Transportation Officials (AASHTO) Mechanistic-Empirical Pavement Design Guide (M-E PDG).
- Besides being used to calibrate M-E design models, the data collected will also serve as an ongoing reference data source and/or diagnostic tool for TxDOT engineers and other transportation professionals.

RESEARCH TASKS AND WORK PLAN

The scope of work to accomplish these objectives included, but was not limited to, the following activities:

- Selection of field test sections across the state.
- Extensive laboratory testing and material property characterization.
- Field testing and periodic performance monitoring.
- Literature review of M-E Structural Design Systems and evaluation of existing databases.
- Development and population of a Microsoft© (MS) Access DSS.
- M-E model calibration and validation.
- Demonstration workshop of the data collected.
- Characterization of test section traffic.
- Traffic and climatic data collection specific to the test sections.

Figure 1 summarizes the four-phase work plan and the associated research tasks; it also includes the specific tasks and the periods of execution. The four phases were designed to specifically address the following key aspects of the project:

1. Phase I–Literature review, planning, and pilot database demonstration. This aspect was covered in Year 1 of the project and is the primary focus of this final report.
2. Phase II–Data collection. This task constituted the bulk of the workload for the whole project and ran for the duration of the project. The tasks incorporated extensive field and laboratory testing to generate data for input into the MS Access DSS.
3. Phase III–Model calibration. Phase III ran in Year 3 through Year 5 of the study; this phase focused on calibrating and validating the M-E Structural Design Systems.
4. Phase IV–Project management, database demonstration, and report writing. Under the task project management, researchers held progress meetings annually to monitor progress and provide updates on the project. In the final year of the project, a workshop was held to demonstrate the utility of the data collected.

Phase	Tasks	Period
PHASE I: LITERATURE REVIEW, PLANNING, & PILOT DATA DEMO	1) Literature search & project kick-off meeting 2) Review of M-E models & data requirements 3) Review of existing databases 4) Development of data collection, analyses, & reporting plans 5) Selection of field test sections 6) Project meeting on Tasks 4 & 5 7) Pilot & prototype data demo Submit report @ End of Phase I	Year 1
PHASE II: DATA COLLECTION	8) Data collection including extensive laboratory and field testing • West Texas – UTEP • Remaining regions – TTI 9) Data processing & analysis 10) Data population & updates 11) Evaluation of the data storage & reporting formats	Year 1 to 5
PHASE III: MODEL CALIBRATION	12) M-E model calibration plans 13) M-E model calibration & validation 14) Project meeting on Tasks 12 & 13 Submit report @ End of Phase II & III	Year 3 to 5
PHASE IV: DATA DEMO & REPORTS	15) Data demonstration workshop (June 2015) 16) Report writing	Year 5
	17) Project management (Annual progress meeting)	Yearly (August)

Figure 1. Work Plan and Research Tasks.

REPORT CONTENT AND ORGANIZATION

Based on the work plan and research tasks in Figure 1, the primary objective of this final report is to document the work performed, methods used, and results completed throughout this project. The main scope of work covered in this project was:

- Selecting test sections.
- Assembling test section design and construction data.
- Performing laboratory testing.
- Conducting field performance testing.
- Collecting traffic and climatic data.
- Developing the DSS.

This final report consists of 10 chapters that provide comprehensive information on this project, such as background, research objectives, and scope of work. Chapters 2 through 9 are the main backbone of this interim report and cover the following key items:

- Chapter 2—List of highway test sections.
- Chapter 3—Test sections and pavement design data.
- Chapter 4—Test sections and construction data collection.
- Chapter 5—Laboratory testing and measurements.
- Chapter 6—Field performance testing and data collection.
- Chapter 7—Traffic data collection.
- Chapter 8—Climatic and environmental data collection.
- Chapter 9—Data storage and management.

Chapter 10 summarizes the final report with a list of major findings and recommendations. Some appendices containing important data are also included at the end of the report. A CD of the latest version of MS Access DSS is also included as an integral part of this report.

SUMMARY

This introductory chapter discussed the background and the research objectives. The research methodology and scope of work were then described, followed by a description of the report contents. Specifically, this final report provides documentation of the work accomplished throughout the whole period of the project.

CHAPTER 2
LIST OF HIGHWAY TEST SECTIONS

Chapter 2 provides the number and location of test sections, the selection criteria for test sections, and the list of test sections by category—including pavement type, district, climate zone, and service life. It also provides a summary of key points at the end of the chapter.

NUMBER AND LOCATION OF TEST SECTIONS

To collect pavement materials and performance data, this project called for selecting a minimum of 100 highway test sections around Texas that incorporate both new or reconstructed flexible pavements and HMA overlays of in-service flexible pavements. In total, 112 highway test sections were selected, with the distribution between the Center for Transportation Infrastructure Systems (CTIS) and the Texas A&M Transportation Institute (TTI) as follows:

- UTEP = 33 test sections.
- TTI = 79 test sections.

This distribution of the test sections between the two agencies was based on the resource capacity in terms of facilities, equipment, and personnel. Additionally, since UTEP is located in West Texas, it was deemed very practical for them to handle the test sections in the Dry-Cold (DC) and Dry-Warm (DW) climatic regions. TTI handled the central and eastern parts of Texas, covering Moderate (M), Wet-Cold (WC), Wet-Warm (WW), and parts of DC and DW climatic regions, as shown in Figure 2.

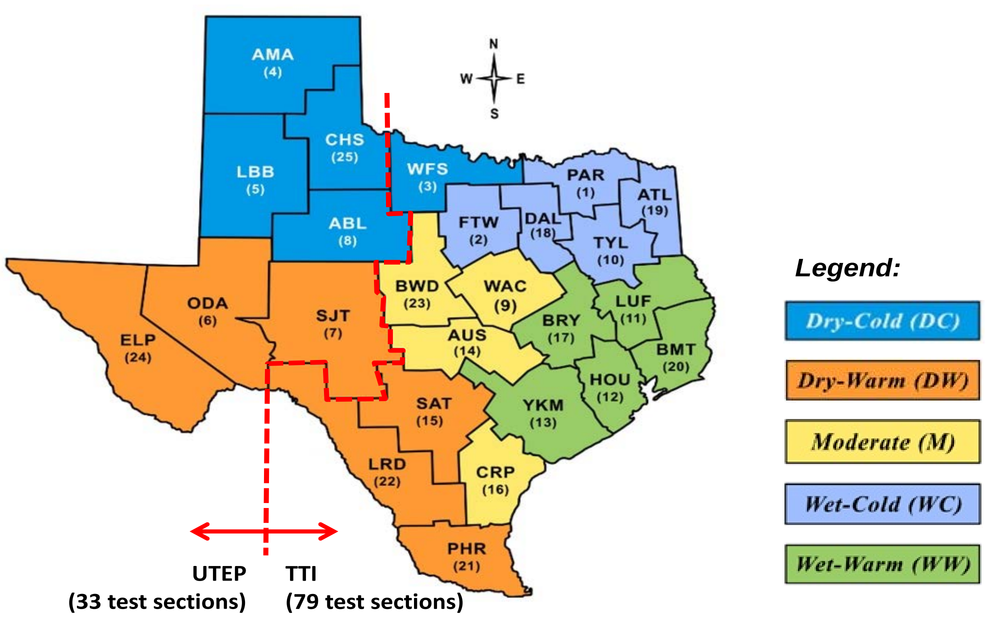


Figure 2. Climatic Distribution of Test Sections between UTEP and TTI.

CRITERIA FOR SELECTING TEST SECTIONS

In order to collect pertinent data to effectively calibrate and validate the M-E models and software, the test sections were selected based on the influencing variables listed in Table 1. For instance, the test sections should not include only HMA overlays or new construction; instead, the coverage needed to be as broad as possible to cover all the variables. Therefore, it was very critical that the test sections equitably cover the variables listed in Table 1, as well as considerations for monitoring distress by time.

Table 1. Variables for Selecting Test Sections.

No.	Variable	Description	Comment
1	Pavement type	• Perpetual • Hot-mix asphalt (HMA) overlay • Full depth reclamation (FDR) • New construction	
2	Surface/Sublayer type	• HMA on HMA • HMA on flex base • HMA on treated base (cement-treated base [CTB], lime-treated base [LTB], and asphalt) • HMA on Portland cement concrete (PCC) • Surface treatments (seal coat, etc.)	Warm-mix asphalt (WMA), recycled asphalt pavement (RAP), recycled asphalt shingles (RAS), and perpetual pavements (PPs) were also considered
3	Surface thickness	• Thin (≤ 3 in.) • Thick (> 3 in.)	
4	Traffic levels	• Low volume • High volume	Include interstate, state, and farm roads
5	Environmental types	• DW • DC • WW • WC • M	

As per TxDOT recommendations, the length of test sections was set to 500 ft per homogenous pavement structure, preferably in the outside lane. In cases where the pavement structure varied, such as the number of layers, layer thickness, or materials composition within a highway segment, then more than one 500-ft test section may have been used from such a highway project. Table 2 lists the test sections greater than 500 ft in length due to different pavement structures within a single project.

Table 2. List of Test Sections Greater than 500ft in Length.

Highway	District/County	Length	Direction/Lane	Note
US 59	Atlanta/Panola	720 ft	Westbound/ Outside	Different interlayer for HMA overlay – Sec01 No-interlayer – Sec13 Petromat – Sec14 TruPavet
US 59	Atlanta/Panola	720 ft	Westbound/ Inside	Different interlayer for HMA overlay – Sec73 No-interlayer – Sec74 Petromat – Sec75 TruPavet
US 59	Atlanta/Panola	1,000 ft	Westbound/ Outside	Different binder contents of HMA overlay – Sec61 5.2% – Sec62 5.5% – Sec72 5.2%
SPUR 400	Laredo/Webb	1,000 ft	Westbound/ Outside	
LOOP 20	Laredo/Webb	1,000 ft	Southbound/ Outside	

TEST SECTIONS IN THE DATABASE

Although the study called for the selection of a minimum of 100 highway test sections around Texas, in the end, the research team was able to secure 112 test sections across Texas, consisting of 79 test sections for TTI and 33 test sections for UTEP. The test sections were selected based on a reasonable distribution over the design variables that include pavement type, district, climate zone, and service life.

Pavement Type

As listed in Table 3, the test sections identified in this study comprised PP, HMA overlays, FDR, and new construction. Each type of pavement was subdivided according to material types used for the base layer, namely, flex or treated material. Figure 3 illustrates the location of test sections by pavement type, as well as permanent TxDOT weigh-in-motion (WIM) stations across Texas.

Table 3. Test Sections by Pavement Type.

No.	Pavement Type	Base Layer Type	Agency		Total
			TTI	UTEP	
1	Perpetual		11		11
2	Overlay	CTB	5		5
3		Flex base	14	15	29
4		LTB	11		11
5		PCC	5		5
6		Asphalt base	3		3
7	FDR	Flex base	4	2	6
8		CTB	8		8
9	New Construction	Flex base	12		12
10		CTB	1	12	13
11		Lime/fly-ash treated base		1	1
12		Emulsion		1	1
13	Seal Coat	Flex Base	5	2	7
	Total		79	33	112

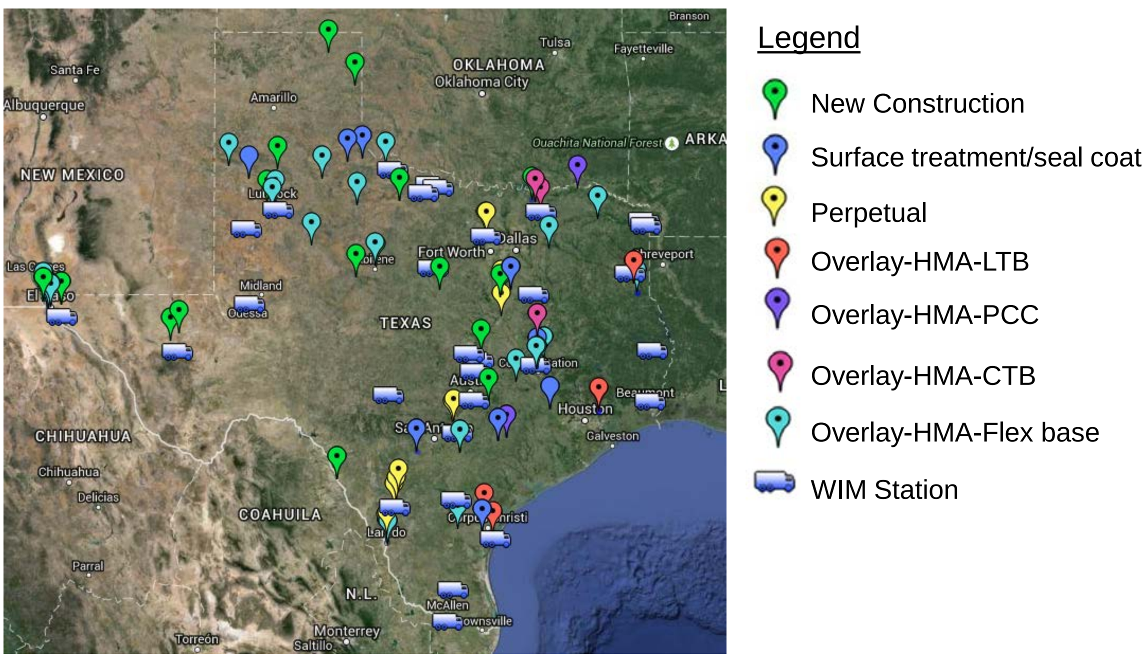


Figure 3. Location of Test Sections and WIM Stations.

District and Climatic Zone

The Texas climatic zones consist of five regions including DC, DW, M, WC, and WW, as shown in Figure 2. Each climatic region has different annual temperature and precipitation and freeze/thaw cycles that affect the development of pavement distresses such as thermal cracking or rutting. Therefore, collecting information from each climatic region was imperative in order to calibrate M-E distress models sensitive to climatic effects. Consequently, the research team identified and selected all test sections with an effort toward acquiring pavement performance data from all climatic regions. Also, in order to assist the TxDOT districts and help engineers make better decisions for rehab strategy selections and design-related issues, the test sections were selected from 21 districts out of 25. Table 4 presents the number of test sections distributed by TxDOT climatic zone and district.

Table 4. Test Sections by Climatic Zone and District.

Climatic Zone	District		No. of Test Sections
	No.	Name	
Dry-Cold	3	Wichita Falls	2
	4	Amarillo	1
	5	Lubbock	7
	8	Abilene	4
	25	Childress	6
Dry-Warm	6	Odessa	2
	7	San Angelo	–
	15	San Antonio	6
	24	El Paso	13
	21	Pharr	–
	22	Laredo	13
Moderate	9	Waco	6
	14	Austin	2
	16	Corpus Christi	8
	23	Brownwood	–
Wet-Cold	1	Paris	4
	2	Fort Worth	3
	10	Tyler	2
	18	Dallas	2
	19	Atlanta	11
Wet-Warm	11	Lufkin	–
	12	Houston	4
	13	Yoakum	4
	17	Bryan	11
	20	Beaumont	1
	Total		112

Service Life

Because typical flexible pavement design parameters are established based on a 20-year analysis period, the test sections needed to be monitored so that the design and material properties could be correlated to the actual field performance of the pavement. However, a majority of the test sections (around 70 percent) sourced in this study are relatively early in their service life. The limited performance data is characterized by little to no distress over the 5-year duration of this project. Only PP sections that were constructed between 2003 and 2008 were older than five years, and they exhibited no significant distresses on the test sections. Table 5 and Figure 4 present the distribution of test sections by service life.

Table 5. Distribution of Test Sections by Service Life.

Age (Year)	TTI		UTEP		Total	
	No.	**%**	**No.**	**%**	**Number**	**%**
Under construction	6	7.6	–		6	5.4
1	26	32.9	–		26	23.2
2	5	6.3	10	30.3	15	13.4
3	14	17.7	14	42.4	28	25.0
4	8	10.1	9	27.3	17	15.2
5	10	12.7	–		10	8.9
> 5	10	12.7	–		10	8.9
Total	79	100	33	100	112	100

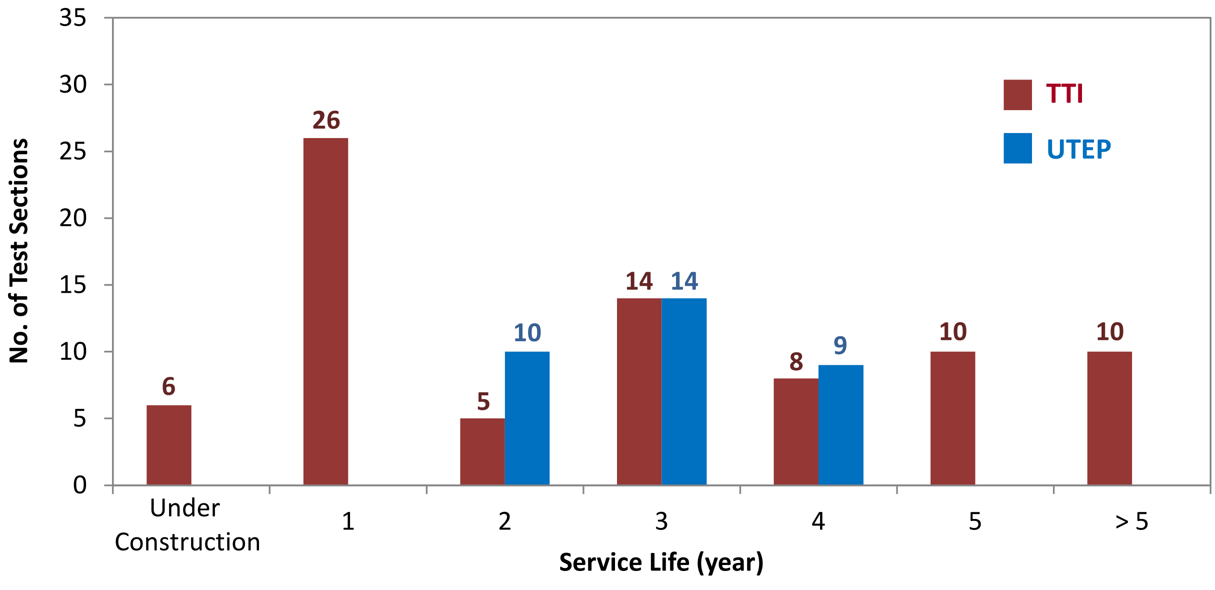


Figure 4. Distribution of Test Sections by Service Life.

In order to facilitate the effective and accurate calibration of the performance models in the current and future analysis software tools developed for or by TxDOT (e.g., TxME, TxACOL), a more complete history of field performance data is required. Even though performance data until failure is desirable, at a minimum, five years' worth of field performance data is required to project performance trends for well-performing or early failing pavements.

TEST SECTIONS IDENTIFICATION—ROAD SIGNS

Once a test section has been selected, the start and end points were marked using the following identifiers:

- Painting (white or orange paint) on the shoulders: start/end points and every 100 ft of test section.
- Global positioning system (GPS) coordinates: start/end points and every 100 ft of test section.
- Offsets from established Texas Reference Markers (TRM): nearest start/end points of test section.
- Offsets from near physical landmarks such as intersections: start/end points of test section.
- Road signs: at 50 ft from start/end points of test section.

The road signs were installed at the appropriate locations following the guidelines outlined in the Texas *Manual on Uniform Traffic Control Devices* Part 2 signs (TxDOT 2006) as follows:

- At 50 ft from the start and end points of the test section, respectively; however, field conditions may also have dictated the exact location of the road signs.
- The signs were vertically mounted at right angles to the direction of, and facing, the traffic that they are intended to serve.
- The lateral offset was not less than 6 ft from the edge of the shoulder or 12 ft from the edge of the traveled way.

Figure 5 illustrates road signs installation at a test section.

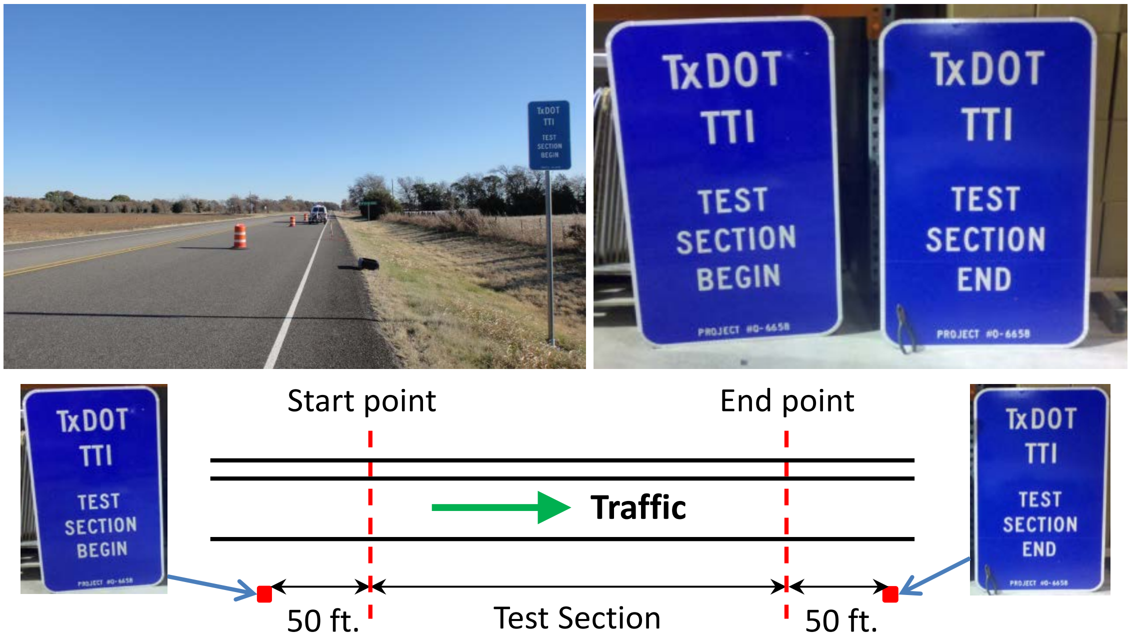


Figure 5. Installation of Road Signs at Test Section.

SUMMARY

This chapter presented and discussed the test-section selection criteria and the selected test sections to date. A total of 112 test sections were chosen and distributed in accordance with the pavement type, climatic zone, district, and service life. However, due to the limited project duration, the test sections were relatively new, with very limited field performance data indicating little to no distresses to date. Even though performance data until failure was desirable, at a minimum, five years' worth of field performance data was required to project performance trends for well-performing or early failing pavements. Therefore, field performance monitoring and data collection must continue to establish the effectiveness and accuracy of the performance predictive capability of the M-E models.

CHAPTER 3
TEST SECTIONS AND PAVEMENT DESIGN DATA

Gathering pavement design data is the first step in the process of selecting test sections and collecting material and field data in this study. Researchers successfully obtained, with TxDOT's assistance, the design data, which included the following:

- Pavement design report.
- Pavement typical sections.
- HMA mix design report.

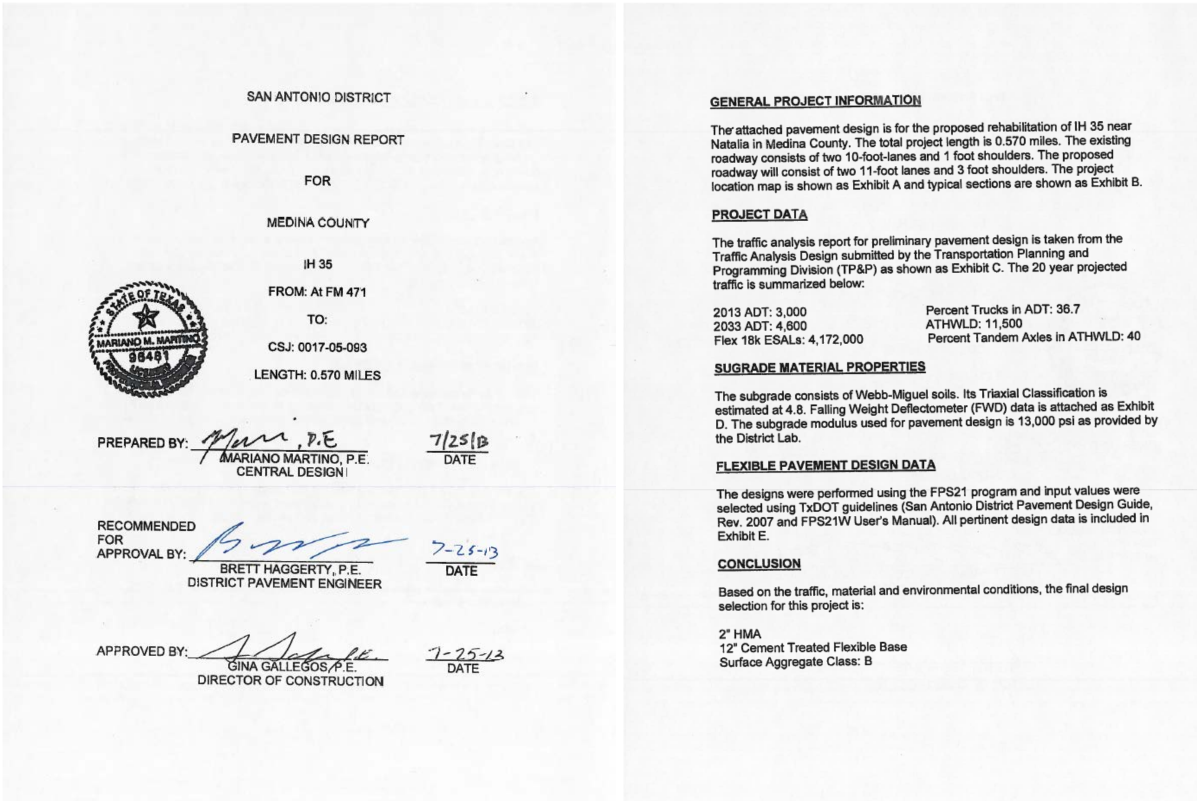
Pavement design data of each test section were collected and stored in the database system developed in this study.

PAVEMENT DESIGN REPORT

A pavement design report is a formal engineering document that presents all analyses, data, policies, and other considerations used to design the structural aspects of a pavement. The report includes the following (TxDOT 2011):

- Cover sheet showing highway designation, district, county, project control-section-job number, geographical limits, etc.
- Narrative discussing the overall objective, site particulars, Pavement Management Information System (PMIS) data analysis/pavement condition surveys for 3-R projects, conclusions, and recommended pavement structure.
- Location map and soils map of project area.
- Existing and proposed typical sections.
- Project-specific factors used for selecting the pavement type.
- Transportation Planning and Programming (TPP) Division traffic data, identification of base grade chosen, and results of non-destructive test (NDT) such as falling weight deflectometer (FWD).
- Design input values and output, etc.

As listed directly above, since the pavement design report includes all information needed for pavement design, it was very critical to obtain it in the process of selecting a test section and collecting data prior to construction in this study. Figure 6 shows the parts of a pavement design report for IH 35 frontage road in San Antonio District, which is a TTI test section (TxDOT_TTI-00037).



SAN ANTONIO DISTRICT

PAVEMENT DESIGN REPORT

FOR

MEDINA COUNTY

IH 35

FROM: At FM 471

TO:

CSJ: 0017-05-093

LENGTH: 0.570 MILES

PREPARED BY: MARIANO MARTINO, P.E. CENTRAL DESIGN — 7/25/13 DATE

RECOMMENDED FOR APPROVAL BY: BRETT HAGGERTY, P.E. DISTRICT PAVEMENT ENGINEER — 7-25-13 DATE

APPROVED BY: GINA GALLEGOS, P.E. DIRECTOR OF CONSTRUCTION — 7-25-13 DATE

GENERAL PROJECT INFORMATION

The attached pavement design is for the proposed rehabilitation of IH 35 near Natalia in Medina County. The total project length is 0.570 miles. The existing roadway consists of two 10-foot-lanes and 1 foot shoulders. The proposed roadway will consist of two 11-foot lanes and 3 foot shoulders. The project location map is shown as Exhibit A and typical sections are shown as Exhibit B.

PROJECT DATA

The traffic analysis report for preliminary pavement design is taken from the Traffic Analysis Design submitted by the Transportation Planning and Programming Division (TP&P) as shown as Exhibit C. The 20 year projected traffic is summarized below:

2013 ADT: 3,000 — Percent Trucks in ADT: 36.7
2033 ADT: 4,600 — ATHWLD: 11,500
Flex 18k ESALs: 4,172,000 — Percent Tandem Axles in ATHWLD: 40

SUGRADE MATERIAL PROPERTIES

The subgrade consists of Webb-Miguel soils. Its Triaxial Classification is estimated at 4.8. Falling Weight Deflectometer (FWD) data is attached as Exhibit D. The subgrade modulus used for pavement design is 13,000 psi as provided by the District Lab.

FLEXIBLE PAVEMENT DESIGN DATA

The designs were performed using the FPS21 program and input values were selected using TxDOT guidelines (San Antonio District Pavement Design Guide, Rev. 2007 and FPS21W User's Manual). All pertinent design data is included in Exhibit E.

CONCLUSION

Based on the traffic, material and environmental conditions, the final design selection for this project is:

2" HMA
12" Cement Treated Flexible Base
Surface Aggregate Class: B

Figure 6. Pavement Design Report of IH 35 Frontage Road (San Antonio District).

PAVEMENT TYPICAL SECTION

According to the TxDOT Glossary, the typical section shows usual roadway cross-sectional features, including the following (TxDOT 2013):

- Lane and shoulder widths.
- Limits of surfacing.
- Pavement structure data.
- Travel lane and shoulder cross slopes.
- Typical right-of-way limits.
- Typical traffic-barrier location-median width and slopes.
- Curb location and geometry, etc.

Therefore, collecting typical section sheets of test sections was necessary to achieve the information of lane width and pavement structure, including the base and subgrade treatment type and depth, thickness, and type of surfacing material. Especially in the case of HMA overlay on existing structure test sections, the pavement typical section sheet, as illustrated in Figure 7, supplemented with the ground penetrating radar (GPR), is a very crucial reference for addressing the layer thickness and material types. The typical sections were obtained from the district or area engineers with TxDOT's assistance.

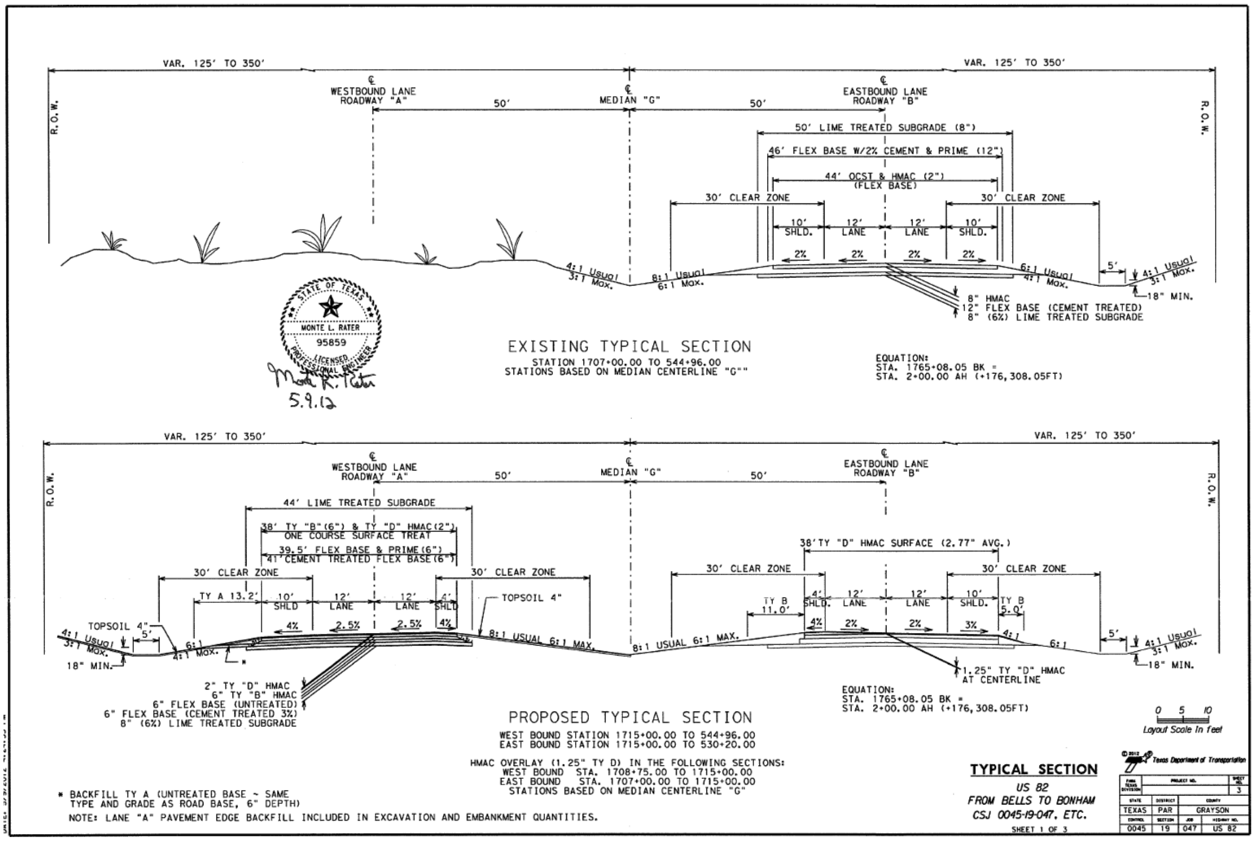


Figure 7. Pavement Typical Section of US 82 (Paris District).

HMA MIX DESIGN REPORT

The HMA mix design report is an Excel-based macro-driven workbook addressing all aspects of mixture design. Design reports were obtained for the flexible pavement test sections selected in this project, along with sampled HMA materials used for laboratory evaluation. The following data were obtained for newly placed HMA in this study:

- Mix type.
- Binder type, performance grade (PG), and asphalt content.
- Contents of RAP and RAS.
- Antistripping agent type and content.
- Aggregate gradation, type, and source.
- Target density and specific gravity (Rice value), etc.

In order to compare the information from the mix design report with the actual HMA mix placed in the field, the laboratory testing was conducted using plant mix obtained from the plant or from the HMA mix delivered to the site, which will be discussed in Chapter 5. The mix design reports were obtained from TxDOT engineers, contractors, or plants with TxDOT assistance. Figure 8 shows an example of a combine gradation table in an HMA mix design report.

TEXAS DEPARTMENT OF TRANSPORTATION
VULCAN MATERIALS-SAN ANTONIO
HMACP MIXTURE DESIGN : COMBINED GRADATION

Refresh Workbook — File Version: 02/03/14 08:35:17

SAMPLE ID:	15510200140610	SAMPLE DATE:	6/16/2014
LOT NUMBER:	MIX DESIGN	LETTING DATE:	12/04/2013
SAMPLE STATUS:	COMPLETE	CONTROLLING CSJ:	0017-05-093
COUNTY:	MEDINA	SPEC YEAR:	2004
SAMPLED BY:	CLINT HAMPSON	SPEC ITEM:	VARIOUS
SAMPLE LOCATION:		SPECIAL PROVISION:	
MATERIAL CODE:	0340CM0000	MIX TYPE:	SS3268_D_Fine_Surface
MATERIAL NAME:	ITEM 340 COMPLETE MIX ALL MIX TYPES		
PRODUCER:	M1501501401514:VULCAN MATERIALS, HELOTES		
AREA ENGINEER:	EDDIE REYES	PROJECT MANAGER:	ROY MUMME
COURSE\LIFT:	Surface	STATION:	
DIST. FROM CL:			

WMA Additive in Design?	No
Target Discharge Temp., ºF:	
WMA TECHNOLOGY:	
WMA RATE:	UNITS:
CONTRACTOR DESIGN # :	VMC305010270

Maximum Allowable, %	
Frac RAP:	20.0
Unfrac RAP:	10.0
RAS:	5.0
RB Ratio:	20.0

Recycled Binder, %	
Bin No.8 :	0.6
Bin No.9 :	0.0
Bin No.10 :	0.0
Total	***0.6***

Use this value in the QC/QA template>>

Ratio of Recycled to Total Binder, % *(based on binder percent (%) entered below in this worksheet)*
11.5

	AGGREGATE BIN FRACTIONS							"RECYCLED MATERIALS"			
	Bin No.1	Bin No.2	Bin No.3	Bin No.4	Bin No.5	Bin No.6	Bin No.7	Bin No.8	Bin No.9	Bin No.10	
Aggregate Source:	Limestone_Dolom	Limestone_Dolom	Limestone_Dolom					Fractionated RAP			Material Type
Aggregate Pit:	Helotes	Helotes	Helotes								Material Source
Aggregate Number:	1501514	1501514	1501514						Tear-off		RAS Type
Sample ID:	GR.4	Gr.5	Man Sand	Silica Sand							Sample ID
Recycled Asphalt Binder (%)								4.2			
Hydrated Lime?:								14.8 (% of Tot. Mix)	(% of Tot. Mix)	(% of Tot. Mix)	
Individual Bin (%):	23.2 Percent	25.0 Percent	27.0 Percent	9.8 Percent	Percent	Percent	Percent	15.0 (% of Aggreg)	(% of Aggreg)	(% of Aggreg)	

Sieve Size:	Bin No.1 Cum.% Passing	Bin No.1 *Wtd Cum. %*	Bin No.2 Cum.% Passing	Bin No.2 *Wtd Cum. %*	Bin No.3 Cum.% Passing	Bin No.3 *Wtd Cum. %*	Bin No.4 Cum.% Passing	Bin No.4 *Wtd Cum. %*	Bin No.5 Cum.% Passing	Bin No.5 *Wtd Cum. %*	Bin No.6 Cum.% Passing	Bin No.6 *Wtd Cum. %*	Bin No.7 Cum.% Passing	Bin No.7 *Wtd Cum. %*
3/4"	100.0	23.2	100.0	25.0	100.0	27.0	100.0	9.8						
1/2"	99.7	23.1	99.8	25.0	100.0	27.0	100.0	9.8						
3/8"	82.6	19.2	90.7	22.7	100.0	27.0	100.0	9.8						
No. 4	29.5	6.8	55.2	13.8	99.0	26.7	100.0	9.8						
No. 8	15.0	3.5	9.1	2.3	79.0	21.3	99.9	9.8						
No. 30	2.0	0.5	2.2	0.6	30.8	8.3	91.0	8.9						
No. 50	1.8	0.4	2.0	0.5	13.5	3.6	57.0	5.6						
No. 200	1.3	0.3	2.0	0.5	4.5	1.2	9.9	1.0						

Sieve Size:	Bin No.8 Cum.% Passing	Bin No.8 *Wtd Cum. %*	Bin No.9 Cum.% Passing	Bin No.9 *Wtd Cum. %*	Bin No.10 Cum.% Passing	Bin No.10 *Wtd Cum. %*	Combined Gradation: Total Bin 100.0% Cum. % Passing	Lower & Upper Specification Limits: Lower	Upper	Within Spec's	*Restricted Zone: Lower*	*Upper*	*Within Spec's*	Individual % Retained	Cumulative % Retained	Sieve Size
3/4"	100.0	15.0					100.0	100.0	100.0	Yes				0.0	0.0	3/4"
1/2"	100.0	15.0					99.9	98.0	100.0	Yes				0.1	0.1	1/2"
3/8"	99.8	15.0					93.6	85.0	100.0	Yes				6.3	6.4	3/8"
No. 4	81.4	12.2					69.4	50.0	70.0	Yes				24.2	30.6	No. 4
No. 8	56.2	8.4					45.3	35.0	46.0	Yes				24.1	54.7	No. 8
No. 30	14.5	2.2					20.4	15.0	29.0	Yes				24.9	79.6	No. 30
No. 50	13.8	2.1					12.2	7.0	20.0	Yes				8.2	87.8	No. 50
No. 200	3.4	0.5					3.5	2.0	7.0	Yes				8.7	96.5	No. 200

(Bold Italic) Not within specifications ***(Bold Italic)*** Not within specificaitons- Restricted Zone *(Italic)* Not cumulative

Lift Thickness, in:		Binder Substitution?	Yes	Binder Originally Specified:	PG 70-22	Substitute Binder:	PG 64-22
Asphalt Source:	Valero 64-22	Binder Percent, (%):	5.2	Asphalt Spec. Grav.:	1.037		
Antistripping Agent:	Pretech Pavegrip	Percent, (%):	0.75				

Figure 8. Mixture gradation sheet (Mix Design Report) for IH 35 Frontage Road (San Antonio District).

SUMMARY

This chapter presented and discussed the pavement design data of the test sections, including the pavement design report, pavement typical section, and HMA mix design report. Gathering the pavement design data was the first step in the process of selecting test sections, a necessary step prior to collecting material and field-testing data in this study. All the pavement design data collected with TxDOT assistance were stored in the database system developed in this study.

CHAPTER 4
TEST SECTIONS AND CONSTRUCTION DATA COLLECTION

In general, after selecting a test section, field-testing and data collection were conducted sequentially in the following order:

1. Pre-construction testing to collect the existing pavement structural capacity and distresses.
2. During-construction testing to document the construction process and quality control/quality assurance (QC/QA) testing and to sample materials.
3. Post-construction testing to document the pavement condition just after construction.
4. Periodic post-construction testing to collect field performance data.

The purpose of the field test program is to evaluate the supporting layers' material property characteristics and performance of pavement layers in-situ (Walubita et al. 2012a). This chapter will discuss the data collection at the pre-, during-, and post-construction stages of the test sections.

PRE-CONSTRUCTION TESTING AND EXISTING DISTRESSES

Just after selecting a test section, pre-construction testing was performed to establish the existing pavement conditions, including structural capacity and surface distresses. Especially, this testing is more critical for existing pavement structures of the sections to be overlaid. The following field-testing was conducted as part of the pre-construction testing:

- GPR and FWD.
- Coring and Dynamic Cone Penetrometer (DCP).
- Existing distress surveys including crack mapping and surface rut measurements.
- High-speed profiles.
- Pictures and/or video.

GPR and FWD Testing

For existing pavement structures for sections to be overlaid, the GPR and the FWD are important survey tools used to obtain existing structural conditions including: layer thickness, subsurface defects, structural capacity, and layer moduli values. The PaveCheck and Modulus 6.0 programs were used to analyze the GPR data and back-calculate the FWD deflection data, respectively. The GPR data are stored in the raw data storage system for project (RDSSP) in the PaveCheck file format. Figure 9 shows an example of an existing pavement structure on US 59 (Atlanta District, Panola County) prior to overlay construction (Walubita et al. 2012a). The figure shows non-major subsurface defects and fairly uniform thicknesses of both existing HMA and base layers. The FWD data collected during the pre-construction testing are also stored in the RDSSP in the Modulus file format.

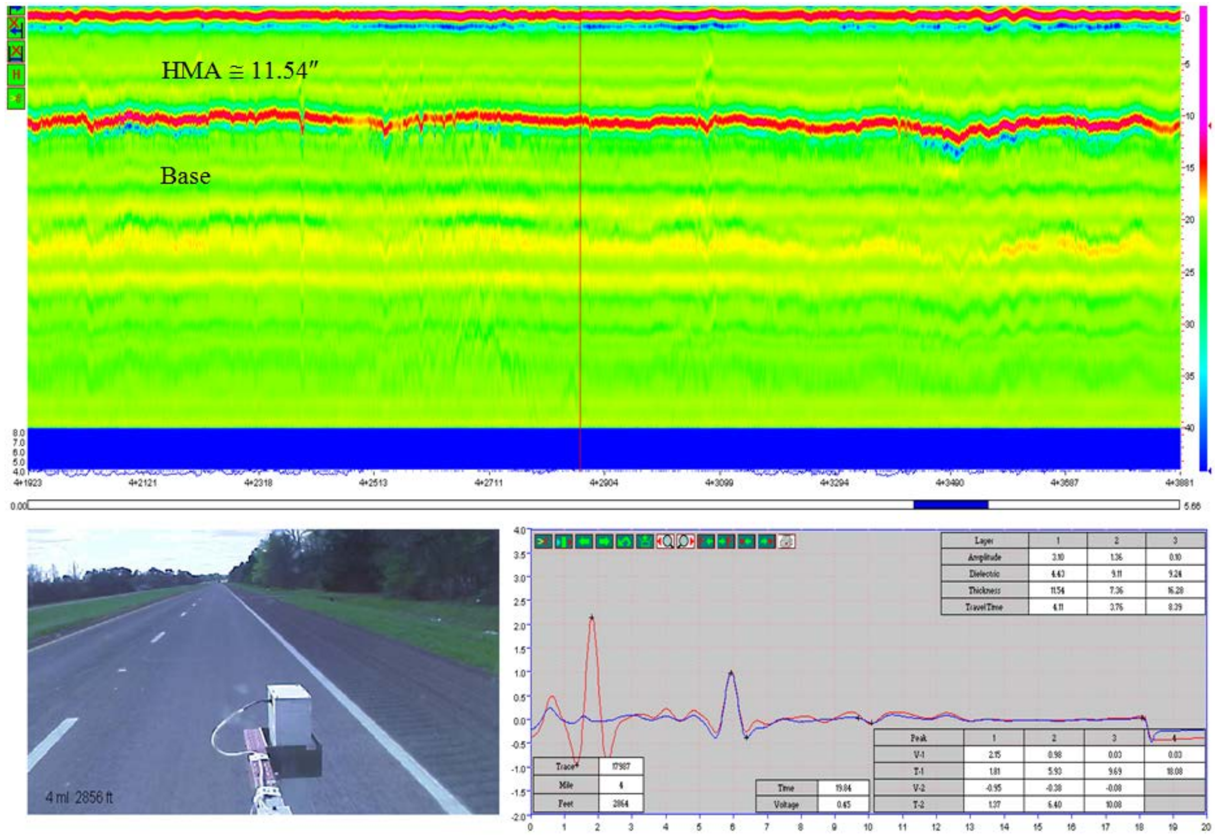


Figure 9. GPR Color Map for US 59 (Atlanta District).

Coring and DCP Testing

Coring at the pre-construction stage was necessary to aid in determining the pavement structure and thickness of existing layer(s) and to perform forensic evaluation. Also, the extracted cores were used for lab testing, including in-situ density determination. A minimum of six, 6-in. diameter cores were extracted from outside, inside, and between the wheel paths of the start and end points of the test section, respectively. In some cases, at least two cores were extracted from a cracked area. Figure 10 shows the cores extracted from SH 7 (Bryan District) before an overlay; one was cored from outside the wheel path and the other at a transverse crack. The cores presented the existing pavement structure, consisting of 4-in. HMA and 10.5-in. CTB. DCP testing was conducted at a minimum of six points at similar positions to where the coring was done. On some pavement structures, including PCC or CTB sections, the upper layers were cored or drilled to directly access the unbound base and/or the subgrade layers for DCP testing.

Figure 10. Cores from SH 7 before Overlay (Bryan District).

Existing Distress Survey

Especially for an overlay test section, the documentation of existing surface distress is a very important feature for evaluating pavement performance, such as reflective cracking that is expected at some point after the new HMA overlay construction. Thus, all types of existing distresses, including rutting and longitudinal, transverse, or fatigue cracking, were recorded prior to overlay construction. Figure 11 presents an example of the pre-construction distress survey, which is the mapped cracks on the SH 121 (Paris District) test section. The existing distress data were entered in the DSS, and the survey sheet was scanned and stored in the RDSSP in portable document format (PDF).

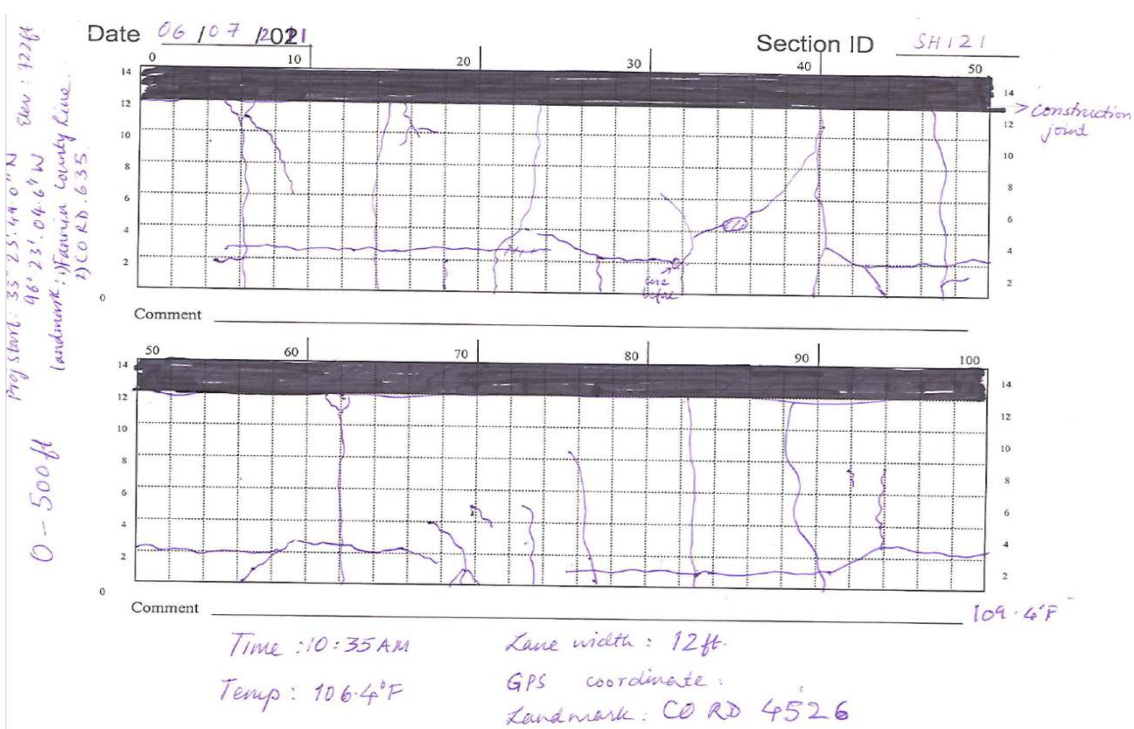


Figure 11. Existing Distress Survey Sheet of SH 121 (Paris District).

High-Speed Profile and Picture/Video

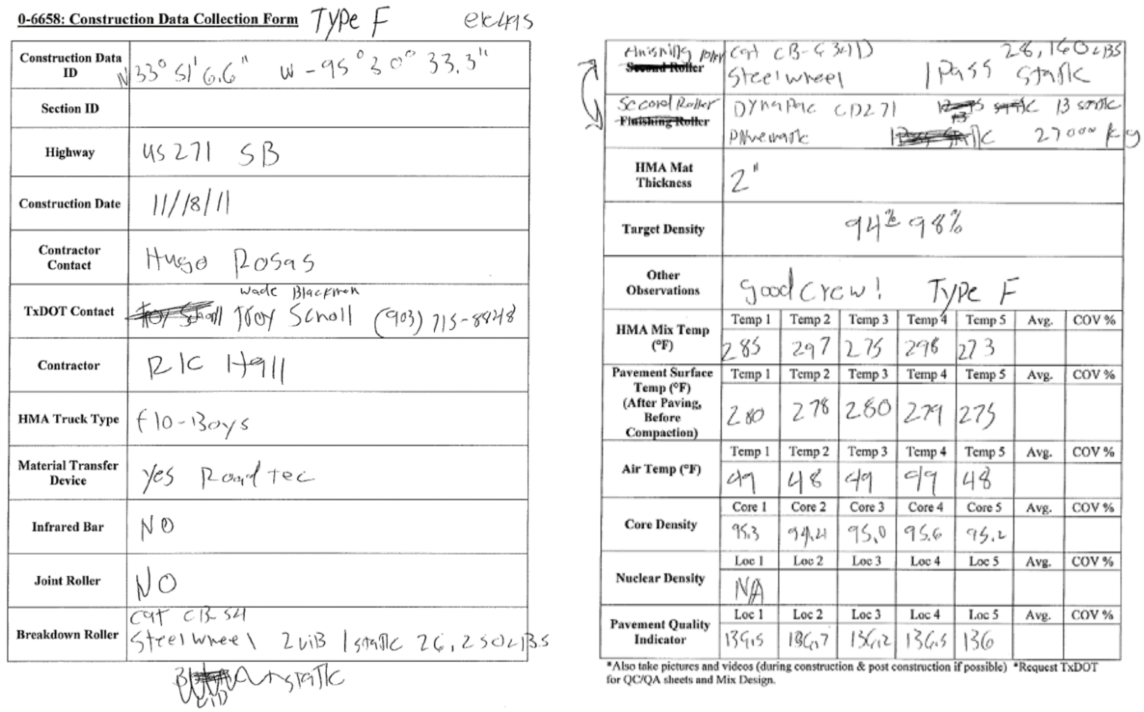
For existing pavement structures to be overlaid, high-speed profiling was performed to evaluate the smoothness and ride quality prior to overlay construction. The profiler was run in both outside and inside wheel paths, and the profile data were processed into the International Roughness Index (IRI, inch/mile) and Pavement Serviceability Index (PSI) using the RideQuality software developed by TxDOT. Still photos and/or video were taken along test sections and to specifically document cracked areas as needed during the pre-construction testing. The video of the test section can be viewed in PaveCheck, since the GPR survey integrates continuous video collection during the survey process.

CONSTRUCTION DOCUMENTATION AND DATA COLLECTION

The construction information of each test section was collected and documented during construction. Construction data are mainly collected during the placing of HMA layers and sampling materials; the data include:

- Construction method:
  - Material transfer device.
  - Truck type (tipper or belly dump).
- Compaction pattern:
  - Number of passes.
  - Roller types and weights.
- Temperature measurements:
  - HMA mixture.
  - Pavement surface after paving and before compaction.
- Density:
  - Nuclear gage.
  - Cores.
- HMA mat thickness.
- Contractor information.
- QC/QA chart from TxDOT or contractor.
- Photos and/or video.

Figure 12 presents the data collection form, including the construction information collected from US 271 (Paris District) during construction.



0-6658: Construction Data Collection Form Type F

Construction Data ID	N 33° 51' 6.6" W -95° 30' 33.3"
Section ID	
Highway	US 271 SB
Construction Date	11/8/11
Contractor Contact	Hugo Rosas
TxDOT Contact	Wade Blackmon; Troy Scholl (903) 715-8848
Contractor	RK Hall
HMA Truck Type	F10-Boys
Material Transfer Device	yes Roadtec
Infrared Bar	NO
Joint Roller	NO
Breakdown Roller	Cat CB 54 Steel wheel 2 vib 1 static 26,250 LBS

Finishing Roller (~~Second Roller~~)	Cat CB-534D Steel wheel 1 Pass static 26,160 LBS						
Second Roller (~~Finishing Roller~~)	Dynapac CP271 Pneumatic 13 static 27000 kg						
HMA Mat Thickness	2"						
Target Density	94%-98%						
Other Observations	good crew! Type F						
HMA Mix Temp (°F)	Temp 1	Temp 2	Temp 3	Temp 4	Temp 5	Avg.	COV %
	285	297	275	298	273		
Pavement Surface Temp (°F) (After Paving, Before Compaction)	Temp 1	Temp 2	Temp 3	Temp 4	Temp 5	Avg.	COV %
	280	278	280	279	275		
Air Temp (°F)	Temp 1	Temp 2	Temp 3	Temp 4	Temp 5	Avg.	COV %
	49	48	49	49	48		
Core Density	Core 1	Core 2	Core 3	Core 4	Core 5	Avg.	COV %
	95.3	94.24	95.0	95.6	95.2		
Nuclear Density	Loc 1	Loc 2	Loc 3	Loc 4	Loc 5	Avg.	COV %
	NA						
Pavement Quality Indicator	Loc 1	Loc 2	Loc 3	Loc 4	Loc 5	Avg.	COV %
	139.5	136.7	136.2	136.5	136		

*Also take pictures and videos (during construction & post construction if possible) *Request TxDOT for QC/QA sheets and Mix Design.

Figure 12. Construction Data Collection Form of US 271 (Paris District).

MATERIAL SAMPLING

All laboratory tests, including those for subgrade soil, base, HMA, and asphalt binder, were conducted using the materials sampled during each stage of construction. For the base and subgrade soil testing, the materials were sampled from the test sections when these materials were available, such as new construction and FDR sections. The quantity of material required was three 55-gallon barrels and was sampled either from the construction site or from the quarry or pit material stockpiles. The materials were collected from a minimum of three locations within the test section of the construction site and at three distinct locations within the stockpile, respectively, as outlined in reports 0-6658-P1 and 0-6658-P3 (Walubita et al. 2011, 2012b). For treated base and soil materials, the raw materials were sampled before the stabilizing agent was added. All materials were sampled from the travel lane of the test section.

HMA testing for this project was performed mainly on plant-mixed materials. Raw materials and highway cores that represented in-situ field conditions were considered only if plant-mixed materials could not be sampled or were otherwise unavailable. The plant-mixed material was hauled either directly from the construction site or from the production plant. If the material was sampled from mix hauled to the site, the plant mix was sampled from a minimum of three different trucks, but not more than five. All mix samples were collected from the travel lane of the test section. Also, the asphalt binder was extracted from the HMA material sampled and was used to conduct the asphalt-binder testing. Figure 13 depicts the base and HMA material sampling during field construction.

Figure 13. Sampling Base and HMA Materials during Construction.

POST-CONSTRUCTION TESTING

Soon after construction, in order to collect and document the pavement condition and check for construction defects, the research team performed post-construction testing that included the following:

- Taking pictures and/or video.
- Checking and re-marking the start/end points on the surface of the test section using marking paint.
- Coring new surface layers.
- Performing GPR and/or FWD.
- Taking high-speed profile.
- Surveying for surface distress.
  - Visual crack survey.
  - Rut measurement (every 100 ft).
- Installing start/end road signs at the test section.

Post-construction testing should preferably be performed before the road opens to traffic but after construction is complete. Figure 14 shows the post-construction testing just after construction at US 82 (Paris District).

Figure 14. Post-Construction Testing at US 82 (Paris District).

SUMMARY

This chapter presented and discussed the sequential order of conducting the field-testing and data collection process at the following stages:

- Pre-construction.
- During construction.
- Post-construction.

Pre-construction testing focused on the collection of existing pavement conditions such as structural capacity and surface distress. Those pavement conditions were collected and evaluated through GPR, FWD, DCP, coring, crack mapping, and video/pictures. During construction, construction information, including HMA compaction pattern, temperature and density measurement, and contractor information, was collected to check the construction QC/QA. As well, the materials were sampled during construction to allow follow-on laboratory testing of the HMA, asphalt-binder, base, and subgrade soil materials. Lastly, post-construction testing was conducted to document the pavement condition and check for construction defects of test sections by taking pictures/video, highway cores, GPR, FWD, and surface distress surveys.

CHAPTER 5
LABORATORY TESTING AND MEASUREMENTS

The data collection and analysis for this study involved laboratory testing and measurements to generate material properties for the database and facilitate calibration of the M-E models and associated structural design software. The material properties of each pavement layer are critical inputs to predict the pavement performance through the M-E models. Therefore, measuring material properties in the laboratory using materials collected from a test section offered the best scenario to generate pavement material properties for input into the DSS as well as the M-E models. This chapter discusses the laboratory test plans and data collected in this study, including testing on:

- Asphalt-binders .
- HMA mixtures.
- Base and subgrade soils.
- Supplementary material characteristics.

Defining and listing the test parameters, test conditions, parameters to be measured, data analysis methods, and reporting formats of each laboratory test are discussed and documented in reports 0-6658-P1, 0-6658-P3, and 0-6658-1 (Walubita et al. 2011, 2012a, 2012b).

ASPHALT-BINDER TESTS

All asphalt-binder tests for this study were conducted on extracted binders from the plant mix obtained from haul trucks at the production plant or directly from the HMA mix delivered to the test section site. These are sources that are representative of in-situ field conditions. If sampled from mix hauled to the test section site, the plant mix was sampled from a minimum of three different trucks, but not more than five. All mix samples were from deliveries to the travel lane of the test section. Test method Tex-210-F and 236-F were used for extracting the binders (TxDOT 2015). The asphalt-binder tests used to generate the required rheological and engineering properties as well as PG grading of the extracted binders for this study are:

- Specific gravity.
- Viscosity.
- Dynamic shear rheometer (DSR).
- Multi-stress creep and recovery (MSCR).
- Bending beam rheometer (BBR).
- Elastic recovery (ductility).
- PG grading of asphalt-binders.

Appendix A provides a summary of the test procedures and the related test parameters and output data. Detailed descriptions of these tests and the data analysis methods can be found in reports 0-6658-P1 and 0-6658-P3 (Walubita et al. 2011, 2012b). For better statistical representation in assessing the average, standard deviation (STDEV), and coefficient of variation (CV), each HMA test was performed using a minimum of three replicate samples.

For surface-treated sections, the neat asphalt-binder was obtained either from the plant or directly from the asphalt distributor trucks onsite during construction to allow for subsequent laboratory tests. The tests for the seal coat binders are similar to the asphalt-binder tests for HMA except for the differences in the asphalt-binder grading system and the fact that residual recovery testing is required in the case of emulsions. All test data from the seal coat binders are stored in the asphalt-binders group in the DSS. By the end of the study, asphalt-binder tests were completed for all highway test sections for which asphalt binder samples were available. Table 6 lists the number of test data by category of each asphalt-binder collected in the study.

Table 6. Asphalt-Binder Data Collected into the Database.

No.	Test Type	Number of Data		Total
		TTI	UTEP	
1	Specific Gravity	143	43	186
2	Viscosity	123	85	208
3	DSR	176	84	260
4	MSCR	180	120	300
5	BBR	91	83	174
6	Elastic Recovery	135	81	216
7	PG Grading	67	62	129

HMA MIX TESTS

HMA testing was conducted mainly on plant-mixed materials sampled from the construction site or from the production plant, as described in Chapter 4. Samples were collected similarly to the way they were collected for asphalt-binder testing; if sampled from mix hauled to the site, the plant mix was sampled from a minimum of three different trucks, but not more than five. All mix samples were collected from the travel lane of the test section. The HMA mix tests used to generate the required HMA material properties for this study included the following:

- Asphalt-binder extractions and gradations.
- The Hamburg Wheel tracking test (HWTT).
- The Overlay Test (OT).
- The OT for measuring fracture properties.
- The dynamic modulus (DM).
- The repeated load permanent deformation (RLPD) test.

- The indirect-tension (IDT) test.
- The HMA thermal coefficient test.

Appendix A provides a summary of the test procedures and the related test parameters and output data. Detailed descriptions of the tests, along with the data analysis methods, can be found in reports 0-6658-P1 and 0-6658-P3 (Walubita et al. 2011, 2012b). For better statistical representation in assessing the average, standard deviation, and CV, each HMA test was performed using a minimum of three replicate samples. For the OTs, five samples were run, including regular OT, OT fracture, and monotonic OT, to decrease the CV. Table 7 lists the number of HMA test data by category collected in the study.

Table 7. HMA Mix Data Collected into the Database.

No.	Test Type	Number of Data		Total
		TTI	UTEP	
1	Volumetrics	93	34	127
2	Asphalt Concrete (AC) Extractions	165	94	259
3	Gradation Extractions	244	39	283
4	RLPD	340	131	471
5	HWTT (Tex-242-F)	179	69	248
6	DM	1,200	340	1,540
7	OT (Tex-248-F)	399	165	564
8	IDT	179	77	256
9	OT Fracture Properties	273	165	438
10	Thermal Coefficient	172	100	272

BASE AND SUBGRADE SOIL TESTS

In general, the pavement base and subgrade soil tests relate to the following materials:

- Flex base (untreated).
- Treated base (using cement, lime, asphalt, or fly ash).
- Subgrade soil (raw).
- Subgrade soil (using cement, lime, or fly ash).

The base and subgrade soil tests were conducted using materials sampled from the test sections from which samples were accessible in quantities necessary for testing, such as new construction and FDR sections. The required materials were sampled either from the construction site or from the quarry or pit stockpiles. The materials were collected at a minimum of three locations within the test section at the construction site and at three distinct locations within the stockpile, respectively, as outlined in reports 0-6658-P1 and 0-6658-P3 (Walubita et al. 2011, 2012b). For treated base and soil materials, the raw materials were sampled from the site and the stabilizing agent was added later in the laboratory. The base and subgrade soil tests used to generate the required material properties for this study are:

- Sieve analysis.
- Atterberg limits.
- Specific gravity.
- Moisture-Density (MD) curve.
- Texas Triaxial.
- Free-free resonance column (FFRC).
- Resilient modulus.
- Permanent deformation.
- Shear strength.
- Unconfined compressive strength (UCS).
- Modulus of rupture (MoR).

Appendix A provides a summary of the test procedures and the related test parameters and output data. Detailed descriptions of these tests along with the data analysis methods can be found in reports 0-6658-P1 and 0-6658-P3 (Walubita et al. 2011, 2012b). Table 8 lists the number of the base and subgrade soil test data by category collected in the study.

Table 8. Base and Subgrade Material Data Collected into the Database.

Material	No.	Test Type	Number of Data				Total	
			TTI		UTEP			
			Flex	Treated	Flex	Treated	Flex	Treated
Base	1	Sieve Analysis	57	27	3	48	60	75
	2	Atterberg Limits	36	22	2	24	38	46
	3	Specific Gravity	34	–	2	–	36	–
	4	MD Curve	17	9	2	32	19	41
	5	Texas Triaxial	12	–	2	–	14	–
	6	Shear Strength	28	–	2	–	30	–
	7	Resilient Modulus	18	–	2	–	20	–
	8	Permanent Deformation	16	–	2	–	18	–
	9	UCS	–	31	–	38	–	69
	10	MoR	–	19	–	4	–	23
	11	Soil Classification	17	9	1	16	18	25
	12	FFRC	16	29	3	27	19	56
Subgrade	1	Sieve Analysis	45	27	32	3	77	30
	2	Atterberg Limits	33	20	24	2	57	22
	3	Specific Gravity	32	–	24	–	56	–
	4	Sulfate Content	–	6	–	1	–	7
	5	MD Curve	15	9	24	2	39	11
	6	Texas Triaxial	13	–	24	–	37	–
	7	Shear Strength	26	–	24	–	50	–
	8	Resilient Modulus	32	2	24	1	56	3
	9	Permanent Deformation	30	8	24	1	54	9
	10	UCS	–	25	–	2	–	27
	11	Soil Classification	15	8	12	1	27	9
	12	FFRC	28	23	12	3	40	26

SUPPLEMENTARY TESTS

One objective of this study was to help TxDOT engineers and transportation professionals to make better decisions in the pavement design and maintenance strategies selection process by providing an ongoing reference data source. To facilitate the inclusion of additional material characterization parameters, supplementary lab test data acquired by the research team for other engineering analysis and research purposes were added to the DSS. Although these supplementary data were not required as M-E input parameters nor were they mandated under this study, these material properties serve as an additional source of information to improve the decision making process in selecting design and rehabilitation strategies. That is, the data can be correlated with quantifiable field performance data in the DSS to develop prediction or evaluation models related to material properties and field performance (e.g., correlation between the simple punching shear test (SPST) data and surface rutting data). Accordingly, the research team collected the following supplementary data:

- HMA: Flow number (FN), OT monotonic, shear properties (SPST).
- Treated base: sulfate content.
- CTB, laboratory mixed: UCS, MoR, FFRC, IDT.

Because of the limited number of CTB test sections available, the cement-variation lab study was conducted by adding cement (2, 3, and 4 percent) into the flex base material in the lab after conducting all the standard base tests. These additional test data were used to evaluate the properties of CTB under this range of cement contents. Table 9 lists the number of the supplementary test data by category collected in the study. Figure 15 presents the MoR and IDT tests using CTB mixed in the lab.

Table 9. Supplementary Data Collected into the Database.

No.	Material	Test	Number of Data		Total
			TTI	UTEP	
1	HMA	Flow Number	129	–	129
2		OT Monotonic	193	–	193
3		SPST	147	–	147
4	Treated base	Sulfate Content	–	32	32
5	Flex base + cement	UCS	28	–	28
6		MoR	24	–	24
7		FFRC	10	–	10
8		IDT	12	–	12

Figure 15. Lab Mixed CTB Test: (a) IDT and (b) MoR.

SUMMARY

This chapter provided an overview of the laboratory testing and measurements completed in this project, including testing on:

- Asphalt-binders.
- HMA mixtures.
- Base and subgrade soils.
- Supplementary material characteristics.

Measurements of these material properties in the laboratory using materials collected from each test section was the best scenario to generate the input parameters to run the M-E models and associated design software and to adjust the calibration factors for local conditions. The extra effort to collect supplementary lab test data should provide additional useful materials properties for other engineering analysis and research purposes.

CHAPTER 6
FIELD PERFORMANCE SURVEYS AND DATA COLLECTION

The field performance data were collected from all test sections using the three-phase criteria of, prior to, during, and just after construction, as described in Chapter 4. After these preliminary field data collections, the periodic field performance evaluations were conducted twice per year (just after summer and just after winter) with the support of TxDOT for the traffic control. The primary objective of the field surveys was to evaluate the pavement performance and the supporting material properties of the in situ pavement layers. In addition, certain field performance data, such as rutting and cracking histories is the source of empirical data for the calibration of the M-E models in comparing predicted and actual pavement performance. Table 10 lists the field performance survey conducted in this study.

Table 10. List of Field Performance Surveys and Data Characteristics.

No	Test	Output
1	Surface Cracking	• Crack length/width • # of cracks • % of cracking and/or severity
2	Surface Rutting	• Rut depth (in.)
3	Other distress	• Severity and % coverage
4	Surface profiles	• IRI (inch/mile) • PSI
5	FWD	• Surface deflections • Back-calculated modulus • Load transfer efficiency (LTE)
6	DCP	• Layer thickness • Modulus
7	Picture/Video	• Latest test section picture • Distressed/cracked areas

VISUAL CRACK SURVEY AND SURFACE RUT MEASUREMENT

The present condition of the pavement surface is one of the main elements used to describe the overall condition of the highway system and offers a critical indicator of the need for maintenance and rehabilitation. Also, the pavement performance history and corresponding material properties, climate, and traffic information can be used for calibrating the M-E models because the associated M-E software predicts the pavement performance in terms of the distress on surface, including cracking and rutting. For these reasons, the visual crack survey and rut measurement were conducted at periodic intervals for the test sections selected for the project. Table 11 presents the procedure and output data of surface distress surveys performed in this study. Figure 16 presents the field performance data collection sheet used in this study. Appendix B provides the definition and measurement method of each surface distress and the guidelines for how to determine the input values required for the DSS.

Table 11. Surface Distress Survey and Data Characteristics.

No.	Test	Test Procedure	Output Data
1	Surface Cracking	• Visual-walking surveys • Alligator cracking • Block cracking • Transverse cracking • Longitudinal cracking	• Crack length/width • # of cracks • % of cracking and/or severity
2	Surface Rutting	Straightedge at 100-ft interval in both wheel paths	Rut depth (in.)
3	Other distress	• Visual-walking surveys • Raveling • Bleeding • Patching • Spalling	• Severity and % coverage

Test Section ID# TxDOT TTI-00014 (Petro Mat)

Hwy: US 59 Direction: South Date: 06/24/2015 Time: 09:50 AM

Material/Mix Type: Type D Weather Condition: Sunny

Lane: Outside District: Atlanta County: Panola

Distance		0 ft.	100 ft.	200 ft.	300 ft.	400 ft.	500 ft.	600 ft.	700 ft.	720 ft.
Mile Marker										
GPS Coordinates	N	32° 11' 51.7"	32° 11' 50.7"	32° 11' 49.8"	32° 11' 48.8"	32° 11' 47.9"	32° 11' 46.8"	32° 11' 45.9"	32° 11' 45"	32° 11' 44.9"
	W	94° 20' 30.1"	94° 20' 29.9"	94° 20' 29.5"	94° 20' 29.2"	94° 20' 28.7"	94° 20' 28.5"	94° 20' 28"	94° 20' 27.7"	94° 20' 27.6"
Elevation (ft)		287	286	294	302	293	309	310	294	293
Rut Depth (in)	LWP*	3/16	2/16	3/16	3/16	3/16	3/16	2/16	3/16	4/16
	RWP	2/16	2/16	1/16	2/16	2/16	2/16	2/16	2/16	2/16
Cracking						Long. at 432'~440'	Long. at 541'~544'	Trans. at 670'		
Other Distresses										
Air temperature (°F)		86	86	86	86	86	86	87	87	87
PVMNT Surface temp. (°F)		104	105	105.5	106	106.5	107	108	108.5	108.5
Comments										
Nov. '14 Rut Depth (in)	LWP*	2/16	3/16	3/16	3/16	2/16	3/16	2/16	3/16	4/16
	RWP	1/16	1/16	1/16	2/16	1/16	2/16	1/16	2/16	2/16
Apr. '14 Rut Depth (in)	LWP*	3/16	2/16	3/16	2/16	2/16	3/16	2/16	2/16	2/16
	RWP	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	2/16

*LWP= Left Wheel Path, RWP= Right Wheel Path

(Refer to Report 0-6658-1 for detailed list of field tests or the "Help" function on the MS Access Data Storage System) Surveyed by: Sang Ick Lee

Figure 16. Field Performance Data Collection Sheet of US 59 (Atlanta District).

Figure 17 shows the examples of distress progression of three test sections of US 59 in the Atlanta District that have been in service for 4 years since the overlay placement. While the rutting increased over time, the longitudinal cracking showed less than 2 percent coverage with low severity, which means that those sections showed good field performance without critical failures.

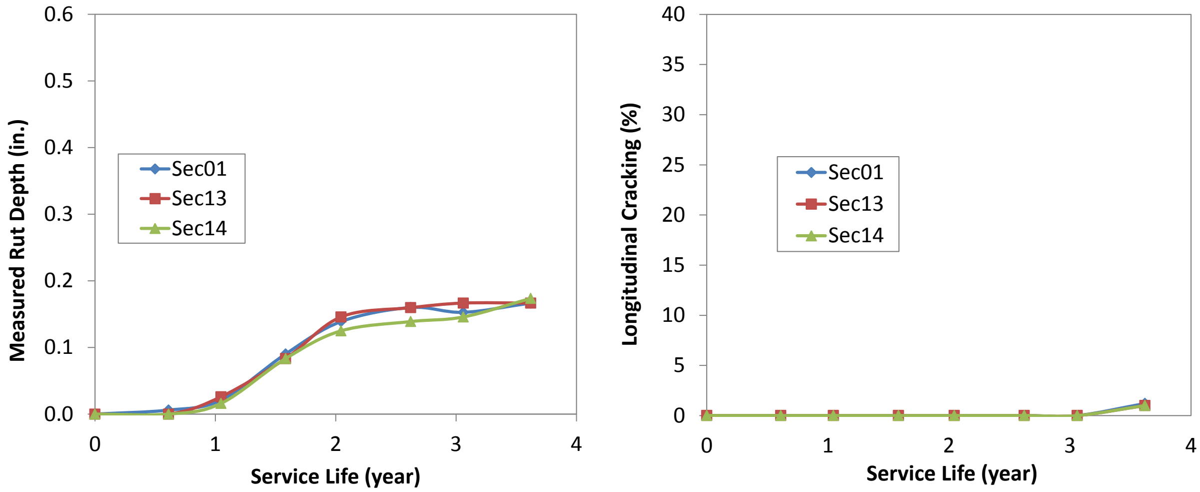


Figure 17. Rutting and Longitudinal Cracking Performance of US 59 (Atlanta District).

FWD TESTING

The FWD is the primary NDT device used in TxDOT to evaluate the pavement structural capacity and to estimate layer moduli. The test acquired deflection data for back-calculating the modulus of each layer using the MODULUS 6.0 program. Deflection testing was conducted with TxDOT assistance in the outside wheel path at 25-ft intervals using a 9,000-lb nominal load as shown in Figure 18. Pavement temperature was measured at the beginning and end of the section with a thermocouple at a 1-in. depth to allow for temperature corrections to the HMA layer back-calculated modulus. In addition, both air and pavement surface temperatures were measured and recorded for entry into the DSS. From the FWD testing, the following data were collected for the DSS:

- 9-kip normalized FWD deflections.
- FWD back-calculated modulus of each layer.
- FWD LTE for PCC or CTB sections.
- Pavement surface, ambient air, and in-pavement temperatures at the time of testing.

Figure 18. FWD Testing on US 271 (Atlanta District).

DCP TESTING AND CORING

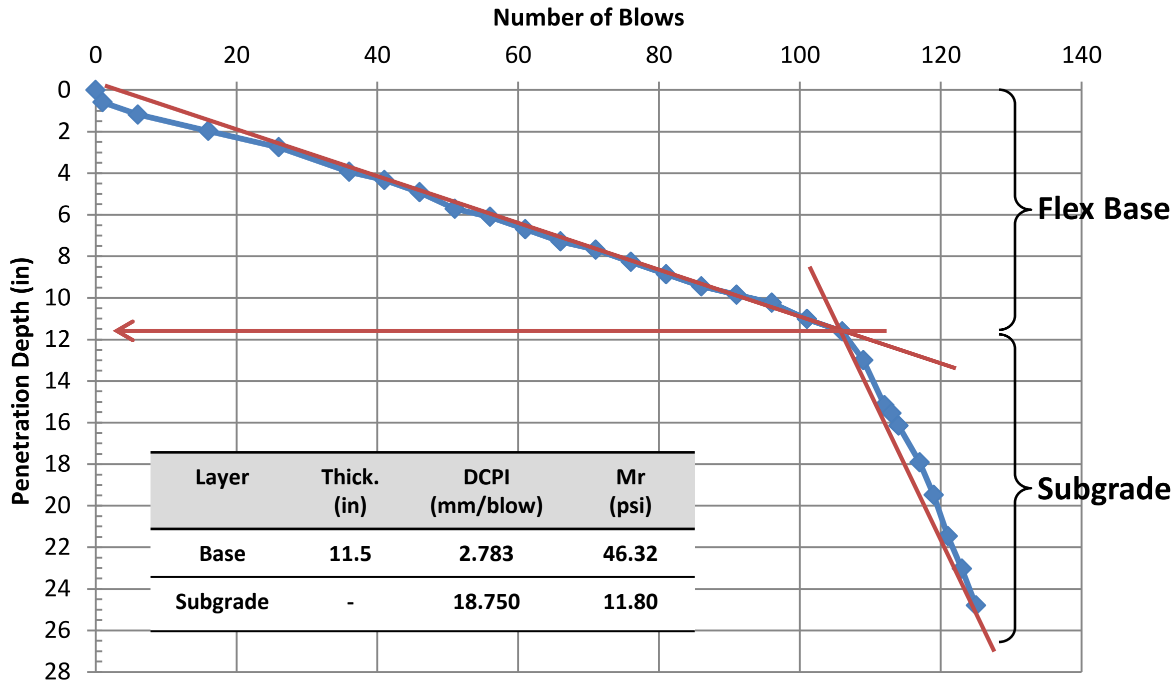
The DCP testing and coring were conducted at several in-service test sections. During the selection process for test sections or at pre-construction testing, DCP evaluations and coring were performed, particularly on overlay candidate sections and existing pavement structures, for layer thickness determination and verification of base or subgrade layer stiffness properties. On the other hand, the DCP testing and coring were conducted for in-service test sections where testing could not be done prior to or during construction, such as new construction or FDR sections, or as needed based on the interpretation of GPR or FWD data. The DCP data were processed to estimate layer moduli from the DCP penetration rate according to the following equation (Walubita et al. 2012a):

$$M_r = 2555\left(\frac{292}{DCPI^{1.12}}\right)^{0.64} \tag{6.1}$$

Where,

M_r = resilient modulus in psi.
$DCPI$ = DCP index (penetration rate in mm/blow).

The processed modulus data and layer thickness is stored in the field performance data group of the DSS. Figure 19 and Figure 20 illustrates an example of the processed DCP data, including layer thicknesses and estimated modulus, and the cored sample, from SH 304 in Austin District.



Layer	Thick. (in)	DCPI (mm/blow)	Mr (psi)
Base	11.5	2.783	46.32
Subgrade	-	18.750	11.80

Figure 19. DCP Data Analysis on SH 304 (Austin District).

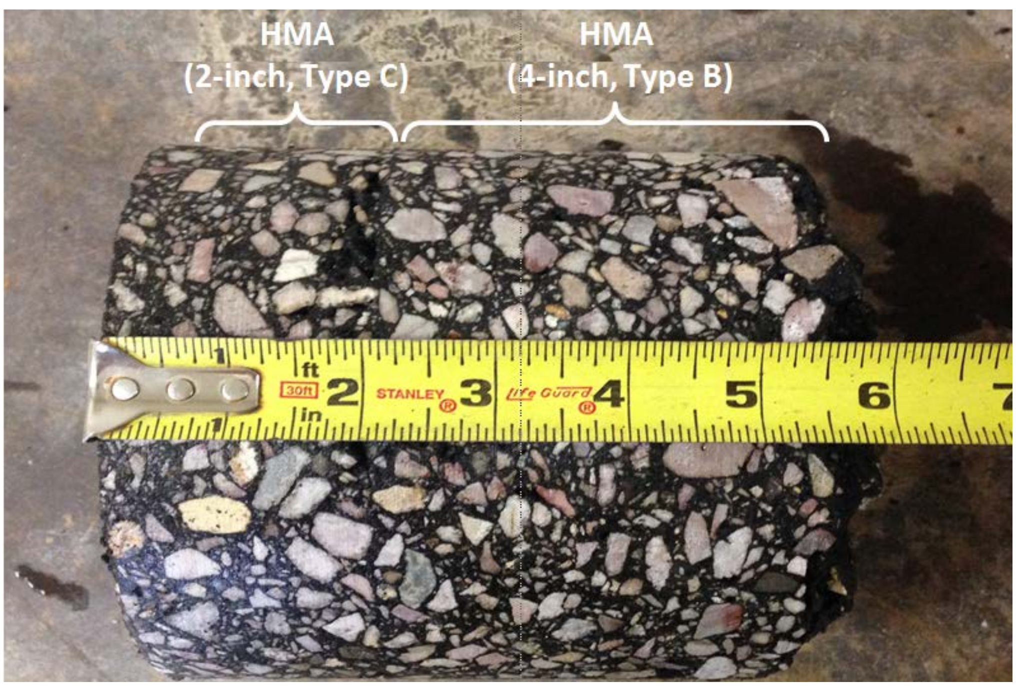


Figure 20. Cores from SH 304 after Construction (Austin District).

HIGH-SPEED PROFILE

High-speed profiling was performed to evaluate the smoothness or ride quality during the periodic field performance evaluation of the test section. Profiles were acquired in both outside and inside wheel paths and the profile data were processed into the IRI (inch/mile) and PSI using the RideQuality software developed by TxDOT. Figure 21 shows a screen capture from the RideQuality software and an example of a processed report from US 59 in the Atlanta District.

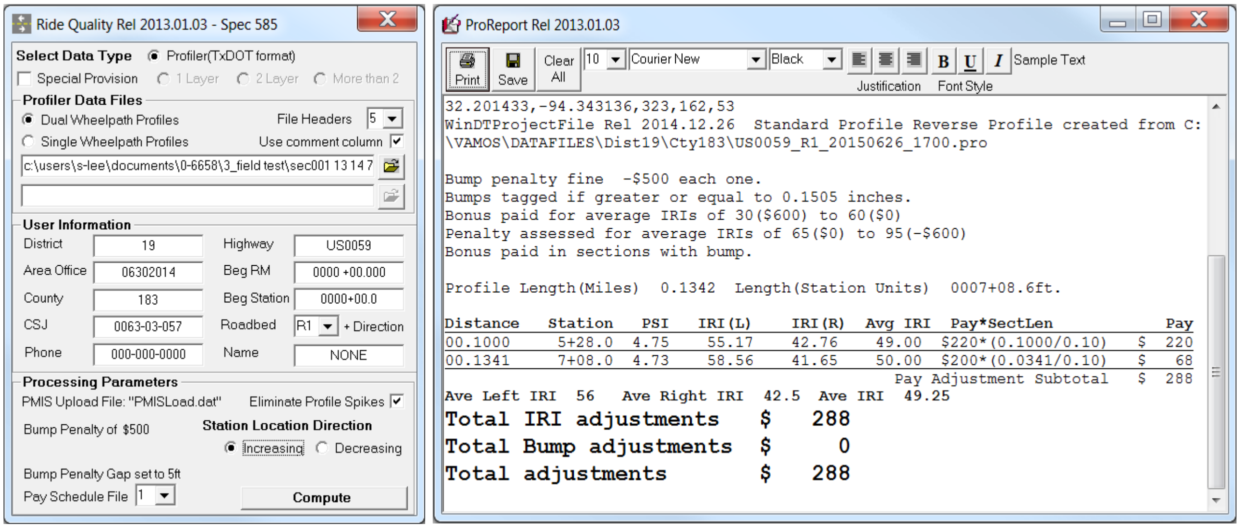


Figure 21. Ride Quality Software and Processed Report on US 59 (Atlanta District).

The processed profiling data are stored in the Surface Profile PSI and IRI table in the DSS, including:

- Average, standard deviation, and CV of PSI.
- IRIs of left wheel and right wheel paths.
- Average, standard deviation, and CV of IRI.

The measured IRI history from the test can be used to calibrate and adjust IRI calibration factors. Figure 22 present an example of the IRI history of test sections for US 59 in the Atlanta District.

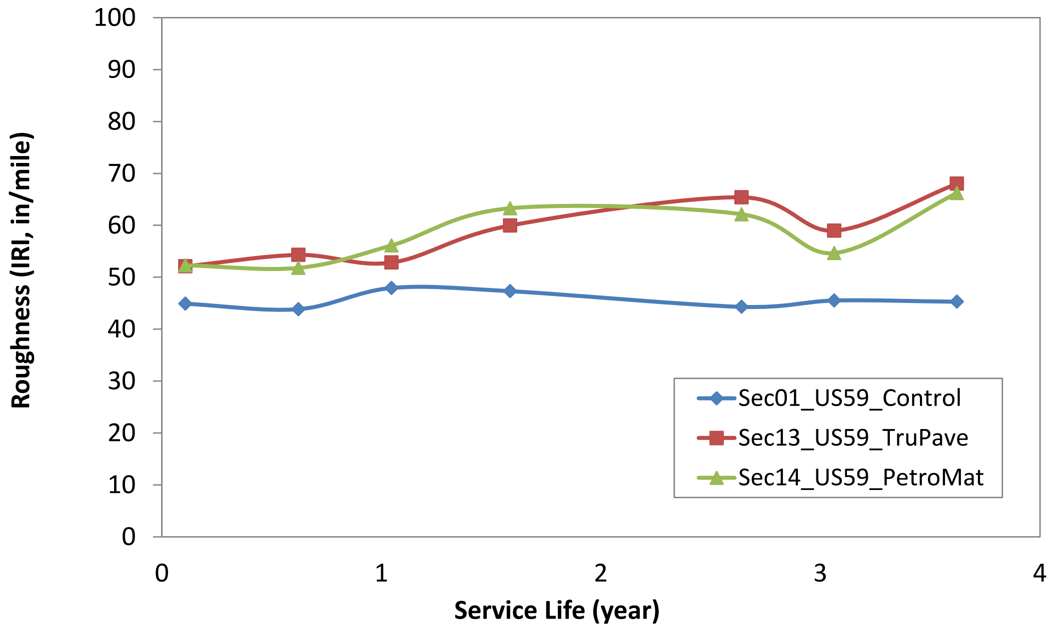


Figure 22. History of IRI of US 59 Section (Atlanta District).

PICTURES AND VIDEO

Pictures were taken at every field performance survey. The complete view of each test section was taken to update the Google picture on the map in order to provide the latest pictures of test sections in the DSS. Also, the pictures and video were taken as needed, such as at critical or abnormal distress areas found during the field performance survey. The videos of test sections can be viewed from GPR data since the GPR was running throughout the test section along with the integrated video and GPS. Figure 23 shows the latest Google picture and cracked area taken during the field performance testing on US 59 in the Atlanta District.

Figure 23. Google Picture and Surface Cracking on US 59 Section (Atlanta District).

FIELD PERFORMANCE DATA ANALYSIS AND POPULATION OF THE DSS

Field performance data collected from each test section was analyzed and stored in the DSS developed for this study. All field data were analyzed and processed to fulfill the data requirements for the Texas M-E models and related software and to serve as an ongoing reference data source for TxDOT engineers and other transportation professionals. Detailed descriptions of the data analysis methods can be found in reports 0-6658-P1 and 0-6658-P3 (Walubita et al. 2011, 2012b). Table 12 lists the number of the field performance data by category collected in the study.

Table 12. Field Performance Data Collected into the Database.

No.	Test Type	Number of Data		Total
		TTI	UTEP	
1	Test Segment GPS Location (500/720/1,000 ft)	67/6/6	33/–/ –	100/6/6
2	Visual Surface Survey	148	129	277
3	Surface Rutting & Temperature	148	131	279
4	Surface Profile—PSI & IRI	153	25	178
5	9 kips Normalized FWD Deflections	106	57	163
6	FWD Back-calculated Modulus	428	210	638
7	FWD Load Transfer Efficiency	64	–	64
8	DCP Test Data	26	11	37
9	Alligator/Block/Transvers/Longitudinal Cracking	148/148/148/148	129/129/129/129	277/277/277/277
10	Other Distresses	148	129	277
11	GPR Survey	70	31	101

SUMMARY

This chapter discussed the methods used and the work completed for field performance surveys and data collection in this study. The field performance data collected from the test sections were analyzed and processed based on the data requirements for the M-E models and related TxDOT software, and stored in the database system. Note that the periodic field performance survey was performed twice per year for each test section with the support of the corresponding TxDOT district office, which also provided traffic control for full lane closures.

CHAPTER 7
TRAFFIC DATA COLLECTION

The accurate and efficient collection of traffic data, including vehicle count, classification, and weight (load spectra) data, is a critical component of transportation infrastructure management. As a part of the project, this research team made an elaborative effort to collect and analyze site-specific traffic data for a wide variety of Texas flexible pavements and HMA overlay sections with different levels of traffic loading in different climatic zones of Texas (Walubita et al. 2012a). This chapter documents the various traffic parameters included in the DSS and the traffic data collection and analysis techniques used specifically for this project.

VEHICLE CLASSIFICATIONS AND TRAFFIC VOLUME

FHWA classifies vehicles into 13 classes depending on whether they carry passengers or commodities. In addition, non-passenger vehicles, which are from Class 4 to Class 13, are further divided by the number of axles and the trailer units. While a bus (vehicle Class 4) is a passenger vehicle, the term truck traffic is assumed to include both trucks and buses since buses have axle loads commensurate with truck classes. Figure 24 presents the FHWA vehicle classification scheme.

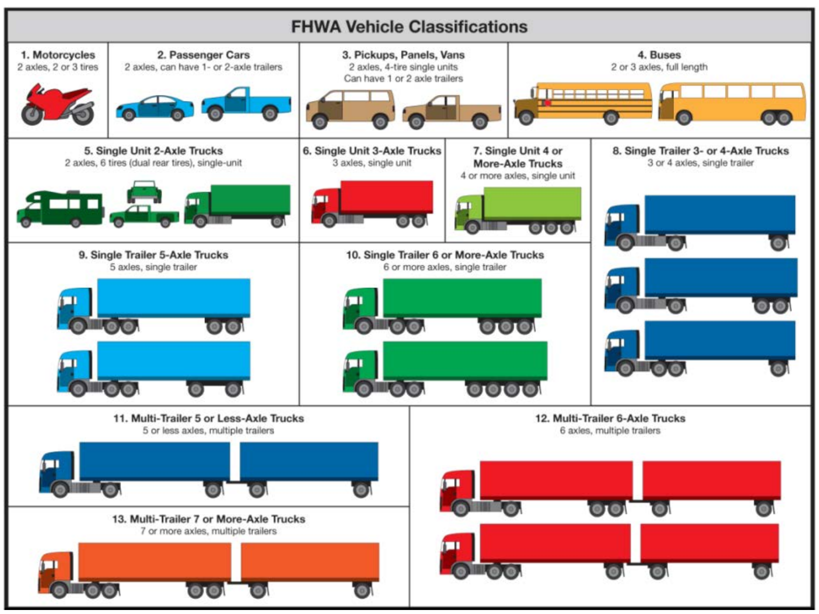


Figure 24. FHWA Vehicle Classifications.

Several parameters are used to characterize the magnitude of traffic for pavement design purposes. The most commonly used parameters are discussed in the following paragraphs.

Average Daily Traffic

Average daily traffic (ADT) reflects the average number of vehicles that travel through a segment of roadway (both directions) over a 24-hour period. ADT is sometimes called the annual average daily traffic (AADT) to show that the data has been factored to an annual average using seasonal factors developed from automatic traffic recorders (e.g., WIM stations) that collect data continuously throughout the year. ADT is the most basic unit of traffic monitoring and is essential for developing traffic forecasts.

Truck Percentage

Often in traffic analyses and forecasting, only the heavier traffic load groups are considered (i.e., the truck traffic, Classes 4 through 13), since the light-axle load groups (i.e., Classes 1 through 3) do not contribute significantly to load-related distresses. Therefore, the percentage of trucks in the total ADT or AADT is included in the list of traffic parameters and is used to calculate the average daily truck traffic (ADTT).

Average Daily Truck Traffic

ADTT is the average number of trucks that travel through a segment of roadway (both directions) over a 24-hour period. ADTT is sometimes called the annual average daily truck traffic (AADTT) to show that the data has been factored to an annual average using seasonal factors. ADTT can be determined by multiplying ADT by the percent trucks:

$$ADTT = ADT \times \%Truck \tag{7.1}$$

Growth Rate

Growth rate is the yearly rate of traffic growth as a percentage of the initial ADT. Growth rate is often used to calculate the projected ADT (or ADTT) at the end of the design period using the following compound and/or linear growth formulae:

$$ADT_{end} = ADT_{beginning}\left[\left(1+r\right)^{N-1}\right] \tag{7.2}$$

$$ADT_{end} = ADT_{beginning} + Nr \tag{7.3}$$

Where,

r = growth rate.
N = design period (in years).

Among these, the compound growth rate (Equation 7.2) is the more common method of estimating projected traffic and has been used in this study. In addition to the total traffic volume (ADT), specific growth rates can also be defined to describe yearly growth in the truck traffic volume (ADTT) as well as yearly growth in the average ESALs/truck or the truck traffic load spectrum.

Equivalent Single Axle Load

To design a highway pavement, it is necessary to predict the number of repetitions of each axle load group during the design period. Since different axle load groups impart varying levels of damage to the pavement, the concept of equivalent single axle load (ESAL) was established from the data collected at the AASHO road test to establish a damage relationship for comparing the effects of axles carrying different loads. The reference axle load is an 18,000-lb (80 kN) single axle with dual tires. ESAL, more commonly termed the 18-kip ESAL or 80-kN ESAL, is mathematically defined as follows:

$$ESAL = \sum_{i=1}^{m} F_i n_i \tag{7.4}$$

Where,

m = the number of axle load groups.
F_i = Equivalent Axle Load Factor for the *i*th-axle load group.
n_i = the number of passes of the *i*th-axle load group during the design period.

The use of Equation 7.4 for calculating the ESAL requires traffic volume as well as weight information, preferably from a WIM station. However, a simplistic method for estimating cumulative ESALs has been developed by AASHTO and is routinely used by pavement designers for highways where WIM data are not available, and it has been used in this study to calculate cumulative ESALs over the design period. (Huang, 2004):

$$ESAL = (ADT)_o (T)(T_f)(G)(D)(L)(Y)(365) \tag{7.5}$$

Where,

ADT_o = the initial two-way ADT.
T = percent of heavy truck (Class 4 or higher).
T_f = truck equivalency factor(average number of ESALs per truck).
G = average traffic volume growth factor = $\frac{1+(1+r)^{Y-1}}{2}$.
D = directional distribution factor (% of trucks in design direction).
L = lane distribution factor (% of trucks in design lane).
Y = design period in years.

AXLE LOAD DISTRIBUTION FACTORS OR AXLE LOAD SPECTRA

In traditional pavement design methods, traffic loading is usually represented by parameters such as ADT, percent trucks, ADTT, and ESALs (AASHTO, 1993). However, more recently, mechanistic-empirical design methods have been developed that take advantage of evaluating the axle load spectra that more realistically represent the vehicle loads in pavement designs. These spectra represent the percentage of the total axle applications within each load interval for single, tandem, tridem, and quad axles. Using axle load spectra as the traffic input, the M-E PDG method is able to analyze the impacts of varying traffic loads on pavement and provide an optimal pavement structural design. Figure 25 presents an example of a typical axle load spectra for single axles for each truck class (M-E PDG default axle load distribution factor values).

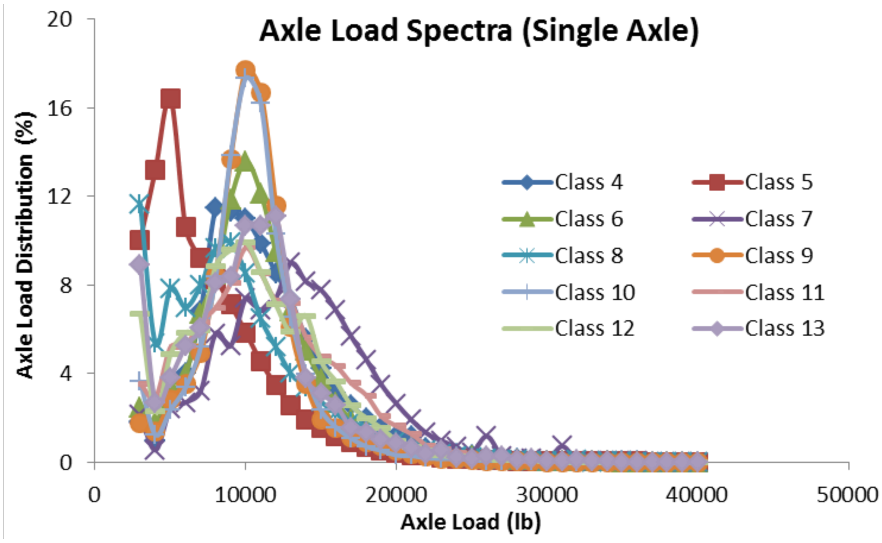


Figure 25. Typical Single-Axle Load Spectra (Percentages) for Each Truck Class.

Site-specific load spectra data are usually obtained by analyzing WIM station data, which presents problems since most WIM systems are not located near test section locations. For this study, load spectra data were mostly obtained from cluster analysis of traffic volume data (collected using pneumatic tubes).

HOURLY AND MONTHLY TRAFFIC ADJUSTMENT FACTORS

In the M-E PDG method, traffic adjustment factors are used to reflect the changes in traffic at different times. Traffic conditions (quality and volume) at any highway section are affected by the season/month of the year as well as the time of the day, depending on the unique characteristics of the highway's geographic location and the locality it serves. Although, 'time of the day effects' are less critical, and therefore, ignored in case of flexible pavement design as opposed to rigid pavement design, most ME software include the hourly adjustment factors as traffic input. Therefore, two sets of traffic adjustment factors were included in the DSS, namely:

- The monthly adjustment factor (MAF).
- The hourly adjustment factor (HAF) [rigid pavements only].

Monthly Adjustment Factor

The MAF is a ratio to adjust the average annual daily truck traffic into monthly truck traffic. This is a way to account for the seasonality effects of truck class volumes operating over the pavement section. MAFs are constant over time and all monthly values for a specific truck class must total 12.00. The monthly adjustment factors are important to the distress prediction models, especially when the properties of the paving materials and soils vary by season.

If the ADTT for each month of the year is known for a specific highway section, then MAF can be calculated by the following equation (NCHRP 2004):

$$MAF_i = \frac{AMDTT_i}{\sum_{i=1}^{12} AMDTT_i} \times 12 \tag{7.6}$$

Where,

MAF_i = Monthly adjustment factor for month *i*.
$AMDTT_i$ = Average monthly daily truck traffic for month *i*.

Equation 7.6 can be expanded to calculate MAF for each truck class as follows:

$$MAF_{ij} = \frac{AMDTT_{ij}}{\sum_{i=1}^{12} AMDTT_{ij}} \times 12 \tag{7.7}$$

Where,

MAF_{ij} = Monthly adjustment factor for month *i* for truck Class j.
$AMDTT_{ij}$ = Average monthly daily truck traffic for month *i* for truck Class j.

Hourly Adjustment Factor

HAF, as the term describes, is the fraction (in percentage) of truck traffic traveling in a given hour relative to the 24-hour period. It is calculated from the hourly truck volume count measured over time by dividing the average annual traffic within a particular hour by the AADT. The hourly adjustment factors are constant over time and between traffic classes. The sum of the 24-hourly distribution factors should equal 100.

If the average truck traffic volume for each hour of the day is known for a specific highway section, then HAF can be calculated by the following equation (NCHRP 2004):

$$HAF_i = \frac{AHTT_i}{\sum_{i=1}^{24} AHTT_i} \times 100\% \tag{7.8}$$

Where,

HAF_i = Hourly adjustment factor for hour *i*.
$AHTT_i$ = Average hourly truck traffic for hour *i*.

Naturally, for most highways, the HAF varies a great deal depending on the hour of the day; however, as an input parameter to the M-E PDG, HAFs do not have any significant influence on the predicted pavement performance, particularly for flexible pavements (Jiang et al. 2008).

TRAFFIC DATA COLLECTION AND POPULATION OF THE DSS

Two methods were used for populating DSS with traffic data, namely:

- Traffic data collection using pneumatic traffic tubes for all test sections.
- Analysis of WIM traffic data.

Traffic Data Collection Using Pneumatic Traffic Tubes

Pneumatic tube traffic counting systems were used as the primary method of field traffic data collection for Project 0-6658. Figure 26 presents the steps involved in pneumatic tube traffic data collection and analysis.

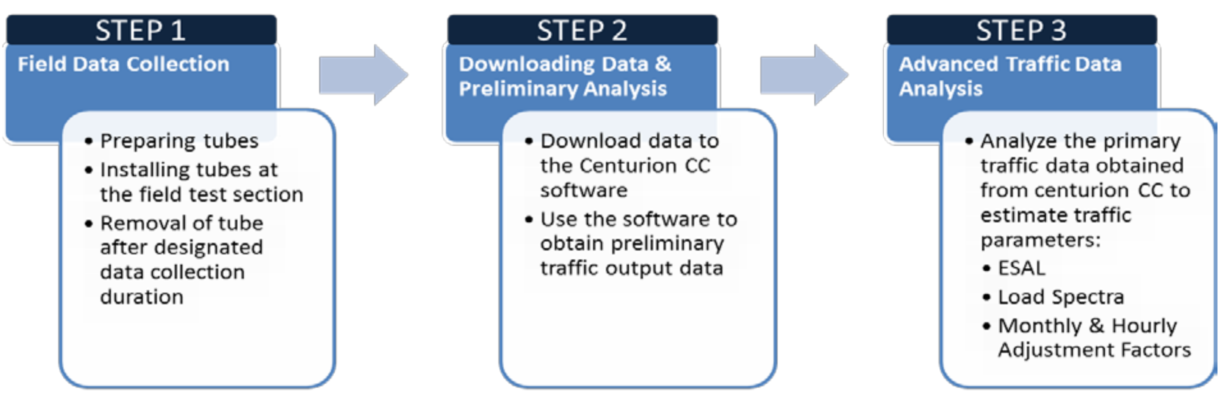


Figure 26. The Steps Involved in Pneumatic Tube Traffic Data Collection and Analysis.

Pneumatic road tube technology (Figure 27) uses rubber tubes placed across traffic lanes in a specific configuration. When a pair of wheels (on one axle) hits the tube, air pressure in the compressed tube activates a recording device (Counter or classifier) that notes the time of the event. Based on the pattern of these times (for instance, the length of the interval between the time that two axles of a typical vehicle activate the counter), the device will match each compression event to a particular vehicle according to the FHWA vehicle classification system (Figure 24). Two tubes attached to the same counter can be placed a set distance apart in order to determine speed by measuring the interval between the time an axle hits the first tube and the time it hits the second tube. The following information about each vehicle passing over the tubes can be stored in memory: time, speed, number of axles, spacing between each axle, overall length, and bin classification.

Figure 27. Traffic Tubes and Counter/Classifier.

Traffic Data from WIM Stations

Where available, traffic data from WIM stations were collected and analyzed for subsequent inclusion in the DSS. The WIM data also provided means for comparing and verifying the traffic data collected using the pneumatic tubes. The TPP division of TxDOT currently collects WIM data at up to 31 sites (Figure 28). Data are polled from all working sites 365 days annually for future reference. The number of WIM locations for which data are available varies each year due to construction, road conditions, and road WIM hardware.

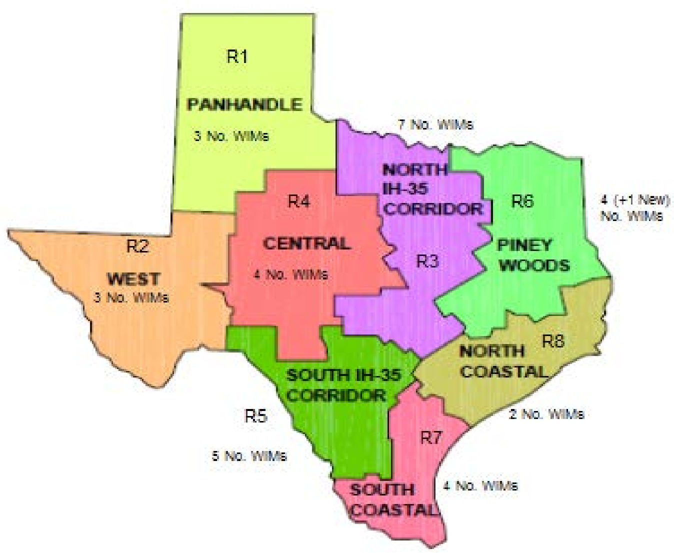


Figure 28. Texas WIM Station Regional Distribution.

Traffic Data Analysis and Population of the DSS

Analysis procedures and templates were developed to facilitate easy traffic data analysis for both pneumatic tube and WIM data. The data collection techniques and step-by-step analysis procedures, along with developed templates and programs are summarized in the report 0-6658-P8 (Walubita et al. 2015b). Table 13 presents the number of the traffic data collected by category from the tests sections in the study.

Table 13. Traffic Data Included into the Database.

No.	Test Type	Number of Data		Total
		TTI	UTEP	
1	Volume & Classification	200	52	252
2	Monthly Adjustment Factors	228	–	228
3	Hourly Adjustment Factor	73	44	117
4	Load Spectra (Steering/Non-steering single)	1,755/1,755	975/975	2,730/2,730
5	Load Spectra (Tandem/Tridem/Quad)	1,755/1,395/1,395	975/775/775	2,730/2,170/2,170
6	Truck Distribution & Growth (Axles per truck)	210	–	210
7	Texas WIM Station Locations	32		32

SUMMARY

Field traffic data were collected and analyzed as part of Project 0-6658 to obtain key traffic parameters to be included in the DSS. This chapter presented an overview of the various traffic parameters that were included in the DSS and briefly discussed the data collection and analysis procedures. The traffic parameters included the following:

- Volume and classification parameters (ADT, ADTT, truck percentage, FHWA vehicle class distributions, ESALs, etc.).
- Gross vehicle weight and axle load parameters (axle load spectra, number of axles per vehicle, etc.).
- Adjustment factors (hourly and monthly adjustment factors).

CHAPTER 8
CLIMATIC AND ENVIRONMENTAL DATA COLLECTION

Climatic data are one of the core inputs in calibrating pavement performance using M-E pavement design principles. Pavement materials are susceptible to changes in climatic and environmental factors such as temperature, moisture, and humidity that directly impact pavement response. Therefore, the research team collected and analyzed climatic and environmental data for each of the test sections in the DSS using various available climatic and environmental data resources. Climatic input files were also generated for these test sections for subsequent use in the M-E design methods.

TEXAS CLIMATIC ZONING

Based on temperature and precipitation records, TxDOT districts have been divided into five climatic zones, as shown in Figure 29, namely:

- DC zone.
- DW zone.
- WC zone.
- WW zone.
- M zone.

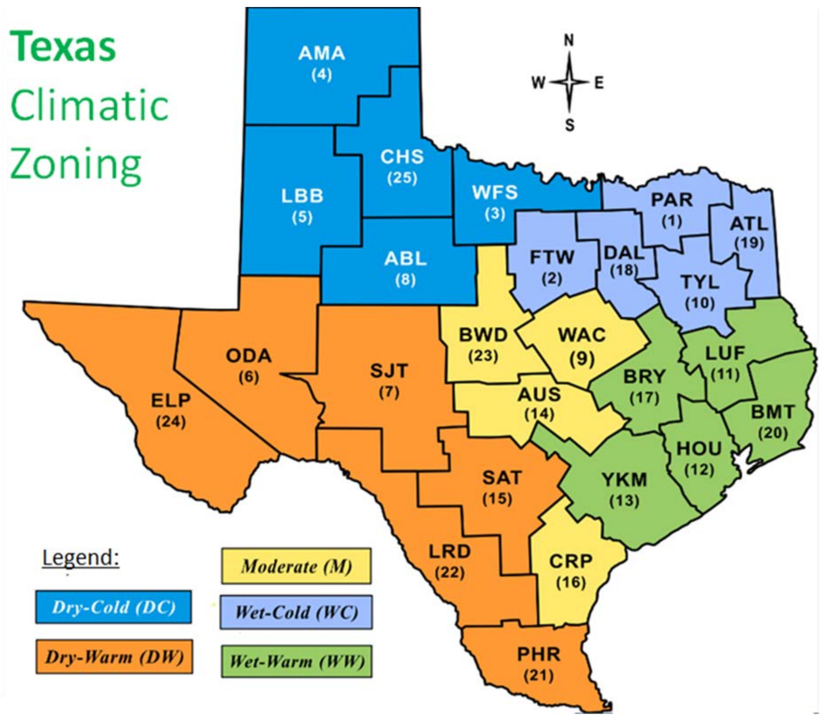


Figure 29. Texas Climatic Zones.

CLIMATIC DATA COLLECTION

Site-specific climatic data were generated for all the test sections in the DSS. In general, the following climatic and environmental data were included in the DSS:

- Air temperatures (minimum, maximum, and average on daily, monthly, and yearly basis, etc.).
- Precipitation (e.g., daily, monthly, or yearly).
- GPS coordinate locations and elevations.
- Depth of ground water table (GWT).
- Well location, including GPS coordinates and distance from test section.

Various climatic data recording and reporting resources were utilized to gather the necessary climatic data for the test sections; these resources included the National Environmental Satellite Data and Information Service from the National Oceanic and Atmospheric Administration (NOAA), the Weather Warehouse (the online weather portal of Weather Source LLC), and the atmospheric science department of the Texas A&M University. The groundwater table data were collected from the U.S. Geological Survey's National Water Information System database. The location closest to the corresponding DSS test section was chosen in terms of latitude and longitudinal coordinates to provide groundwater table depth. To determine the distance between the well location and test section based on latitude-longitude coordinates, the coordinates were first converted from degrees to radians using the following equations (Oh and Fernando 2008):

$$\text{Latitude(rad)} = \frac{\tan^{-1}(1)}{45}\text{Latitude}(^\circ)$$
$$\text{Longitude(rad)} = \frac{\tan^{-1}(1)}{45}\text{Longitude}(^\circ) \qquad (8\text{-}1)$$

Then, if X_1 and Y_1 are the longitude and latitude, respectively, of a test section in radians, and X_2 and Y_2 are the corresponding coordinates for a given well location, the *Great Circle Distance Formula* given in Equation (8-2) can be used to calculate the distance in miles between two pairs of latitude/longitude values specified in radians:

$$D = 3949.99\cos^{-1}\left\{\sin Y_1 \sin Y_2 + \cos Y_1 \cos Y_2 \cos\left(X_1 - X_2\right)\right\} \qquad (8\text{-}2)$$

If the county-level data corresponding to the test section was not available, the adjacent counties were investigated to identify an alternative location. Table 14 lists the number and categories of the climatic-environmental data collected in the study.

Table 14. Climatic–Environmental Data Collected into the Database.

No.	Climatic Data Type	Number of Data		Total
		TTI	UTEP	
1	Climatic Data • Air temperature • Precipitation • Wind speed • Number of wet days • GWT	1,551	396	1,947

Also, the climatic data input files were generated using the M-E PDG and TxACOL programs and saved in the DSS so that the generated input files can be used for corresponding programs. The following steps were taken to generate climatic files for the M-E PDG and TxACOL programs:

1. Select "Interpolate climatic data for given location" for M-E PDG and TxACOL programs (Figure 30).
2. Enter the GPS coordinate (latitude, longitude, and elevation) of test section.
3. Select weather stations geographically close to the test section in differing directions.
4. Generate a climatic file and save as Highway_ID.icm.

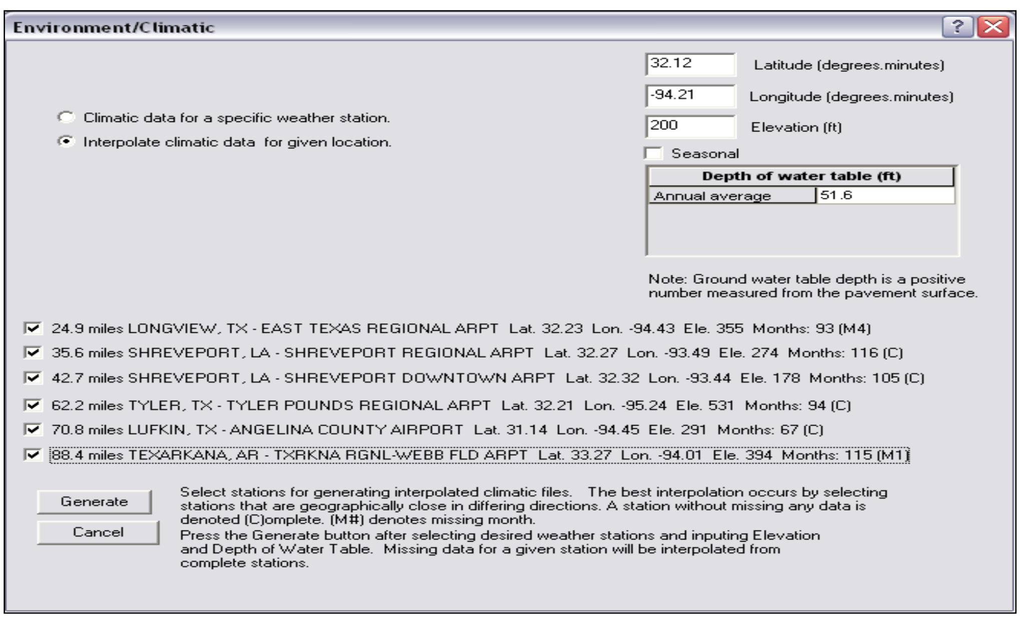


Figure 30. M-E PDG Climatic Data Generation Screen.

The other M-E software such as TxME does not have the function to generate and save the climate data files for later use, so the climate data should be generated anew whenever running the software for pavement design.

CLIMATIC DATA ANALYSIS

The collected climatic data were analyzed to obtain monthly and yearly variations of the climatic parameters. Figure 31 to Figure 33 show examples of processed climatic data for the US 59 section. The climatic data appear to be reasonable since the comparison shown in Figure 33 exhibits good agreement between two data sets, namely the weather station data from the M-E PDG and a specific weather station from Carthage, Texas, developed by the National Climatic Data Center (NCDC). Note that while the M-E PDG weather station data are averaged from 1996 to 2005, the NCDC data are based only on 2010 data for the comparison.

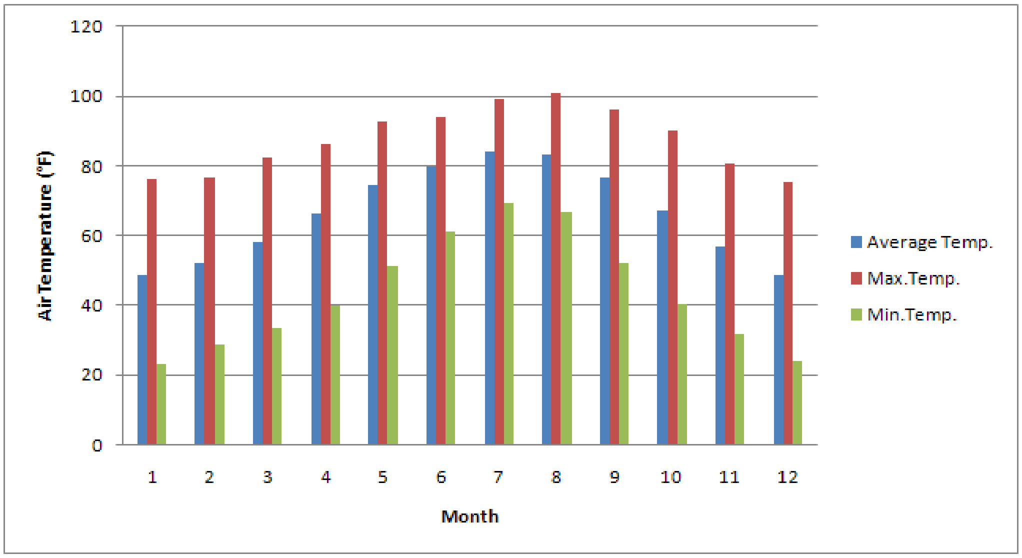


Figure 31. Air Temperature Monthly Variation Using M-E PDG Weather Station Data.

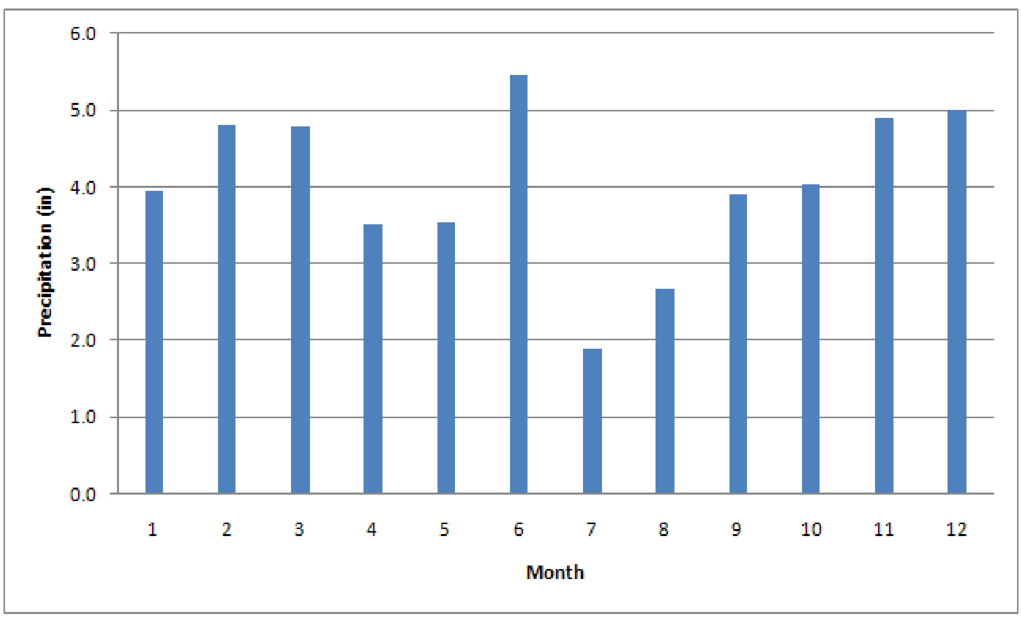


Figure 32. Precipitation Monthly Variation Using M-E PDG Weather Station Data.

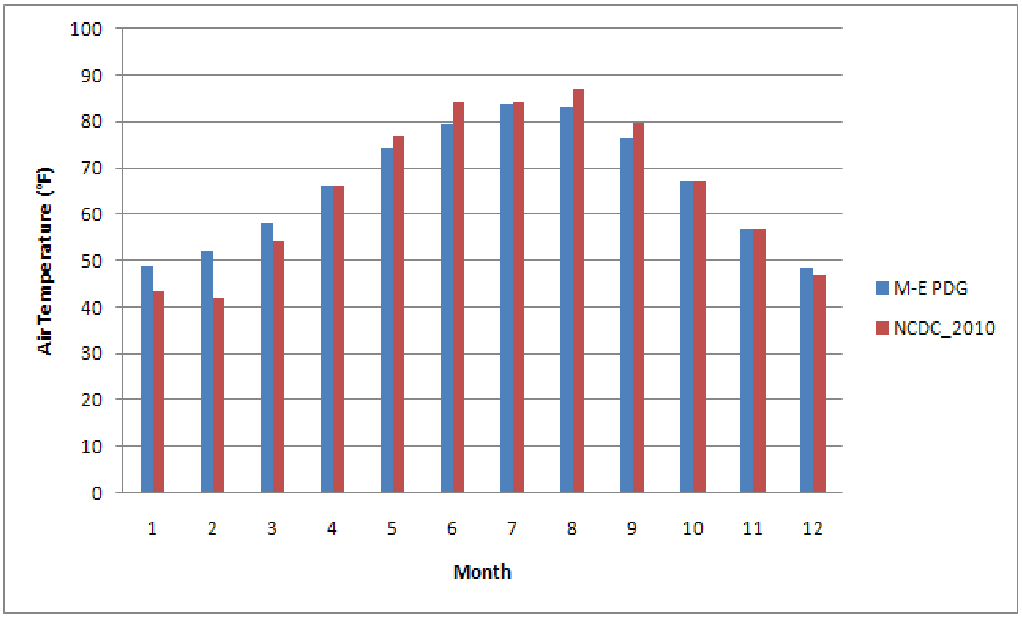


Figure 33. Comparison of Monthly Air Temperature Variation between M-E PDG and NCDC Weather Station Data.

SUMMARY

Pavement materials are susceptible to changes in climatic and environmental factors such as temperature, moisture, and humidity that directly impact pavement response. Thus, climatic data are a core input for pavement design and analysis using an M-E pavement design approach as well as for calibrating the M-E models, and were therefore included in the DSS. This chapter presented a summary of the climatic and environmental data collected for inclusion in the DSS. Both readily available online climatic data sources and M-E design software climatic databases, such as M-E PDG and TxACOL, were used to generate climatic and environmental data for the DSS test sections. In general, the data obtained from these two sources show good agreement, and can therefore be used in lieu of one another.

CHAPTER 9
DATA STORAGE AND MANAGEMENT

A database is considered useful only if it is populated with sufficient data, both in terms of quantity and accuracy. Accordingly, the research team collected information related to pavement design and construction as well as a variety of both laboratory and field data described in Chapters 4 through 8. In order to fulfill these database requirements and make data categories more manageable, the DSS was developed using two repositories, one for the processed data and one for the unprocessed raw data. The databases are:

- MS Access® DSS for the processed data.
- RDSSP for the unprocessed raw data.

A CD of the data storage systems is included as an integral part of this report.

DATA STORAGE SYSTEM

For the processed data, MS Access was selected as the database platform due to its commercial availability, familiarity, user-friendliness, and ready availability to TxDOT engineers. Figure 34 shows the DSS main menu screenshot.

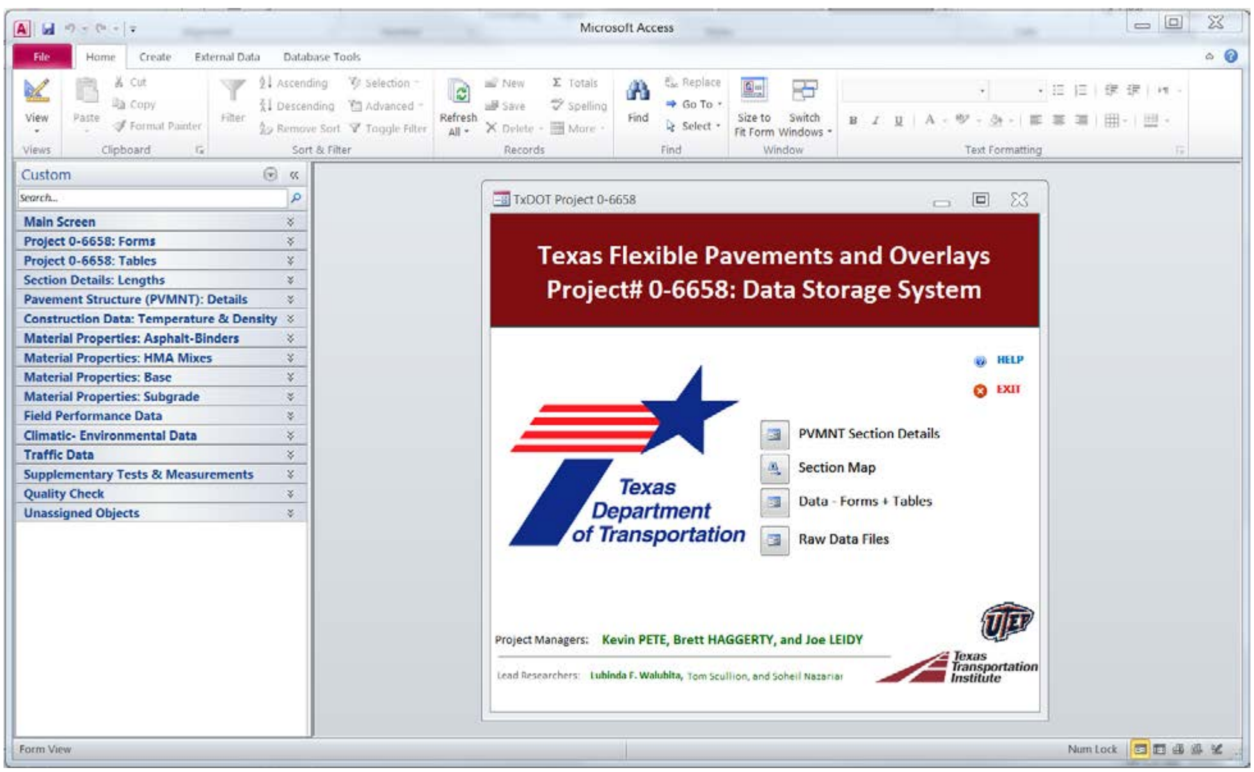


Figure 34. The DSS—Main Menu Screenshot.

Database Structure

The DSS consists of a variety of both laboratory and field data, including but not limited to, the following:

- Design data and drawings, including pavement cross sections.
- Construction data, QC/QA charts, and coring.
- Material properties of each pavement layer (through both lab and field-testing).
- Field-testing and pavement performance data.
- Traffic data, including volume, classification, vehicle speeds, and load spectra.
- Climatic data, including temperature and precipitation in Texas' five climatic zones.
- Supplementary material properties of HMA and CTB mixed in the lab.

The DSS consists mainly of three data storage objects—section map, forms, and tables—as illustrated in Figure 35. Each object provides information on all test sections identified in this study.

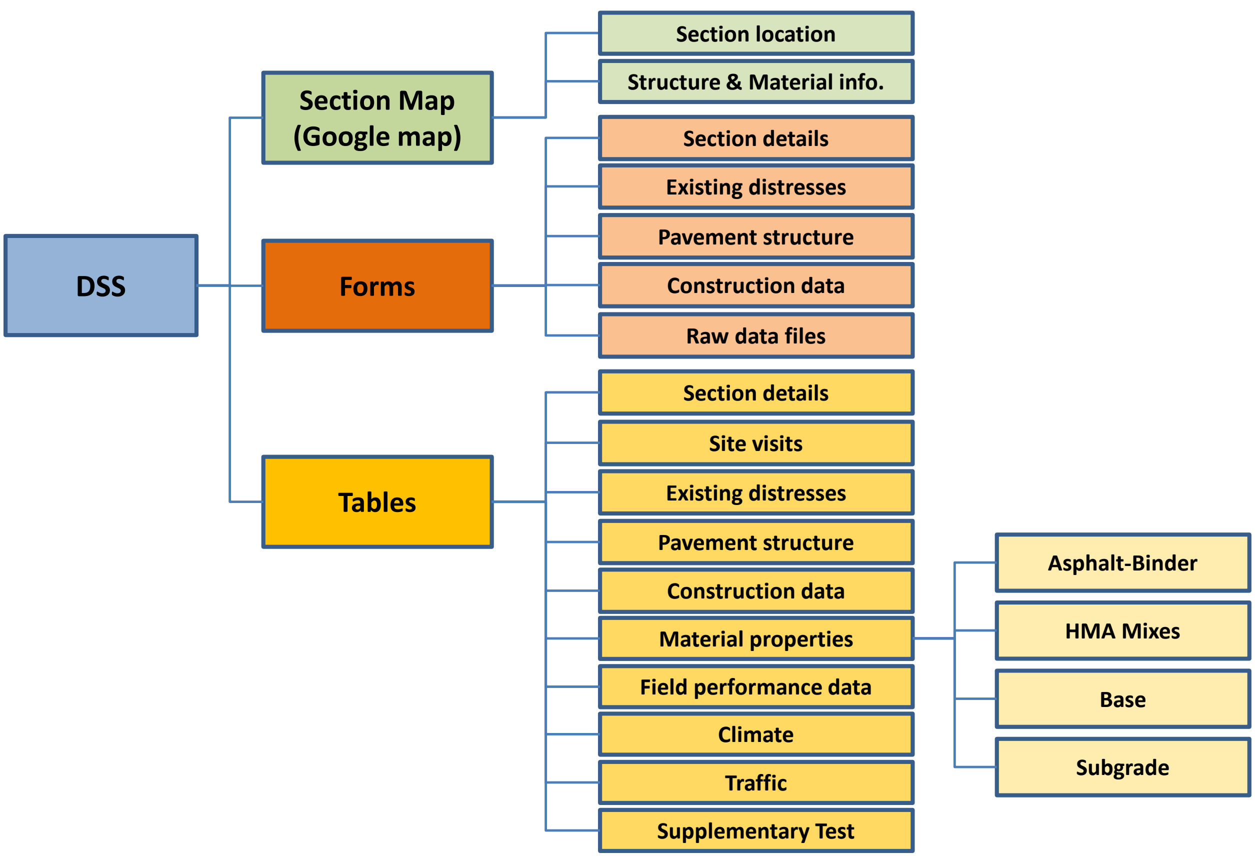


Figure 35. Structure of DSS.

Section Map

Left clicking on the Section Map in the DSS main switchboard opens the Google® map in a web browser, which shows the location and type of highway test sections and WIM station locations around Texas, as illustrated in Figure 36. Clicking on any test section on the map displays the latest section picture and corresponding pavement structure information. From the section map, users can easily identify the general information on the test section, including location, number of layers, material type, layer thickness, and construction year. As an example, Figure 37 shows the Google picture of the test section on US 271 in the Paris District.

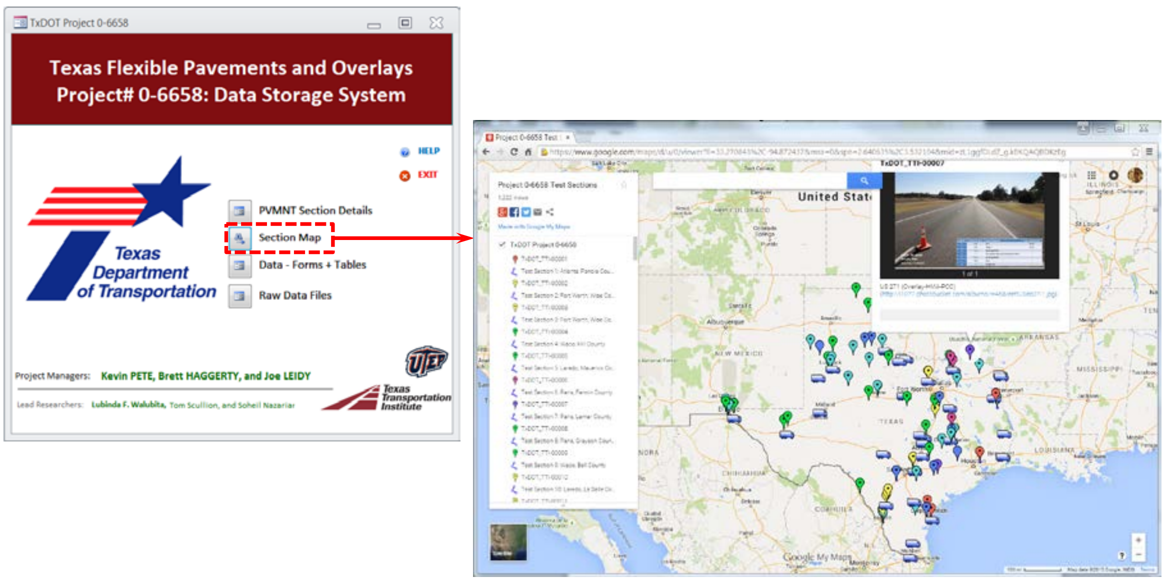


Figure 36. Section Map.

Figure 37. Google Picture of US 271 (Paris District).

DSS Data Entry: Form and Table

The data contents collected in this study are stored in the two formats of Forms and/or Tables. The forms allow the user to view one data entry at a time. They provide easy access to view the contents of the data entries rather than fields or columns. They also store files such as design drawings, field surveying sheets, pictures, etc. The forms in MS Access are all grouped in one chapter, and the bottom left arrows on the form window provide the user access to all section entries in the form, as shown in Figure 38. In contrast, the tables are used to store and organize the data by fields in columns so all data entries can be viewed at once, as illustrated in Figure 39. Also, MS Access offers various ways to access, display, and present information entered in the table format, including graphs and bar charts, which are described in the following subchapters. Some data are more efficiently presented in the Forms format while other data contents are best reviewed in the Tables format. Table 15 presents the list of data stored in the Tables and/or Forms formats.

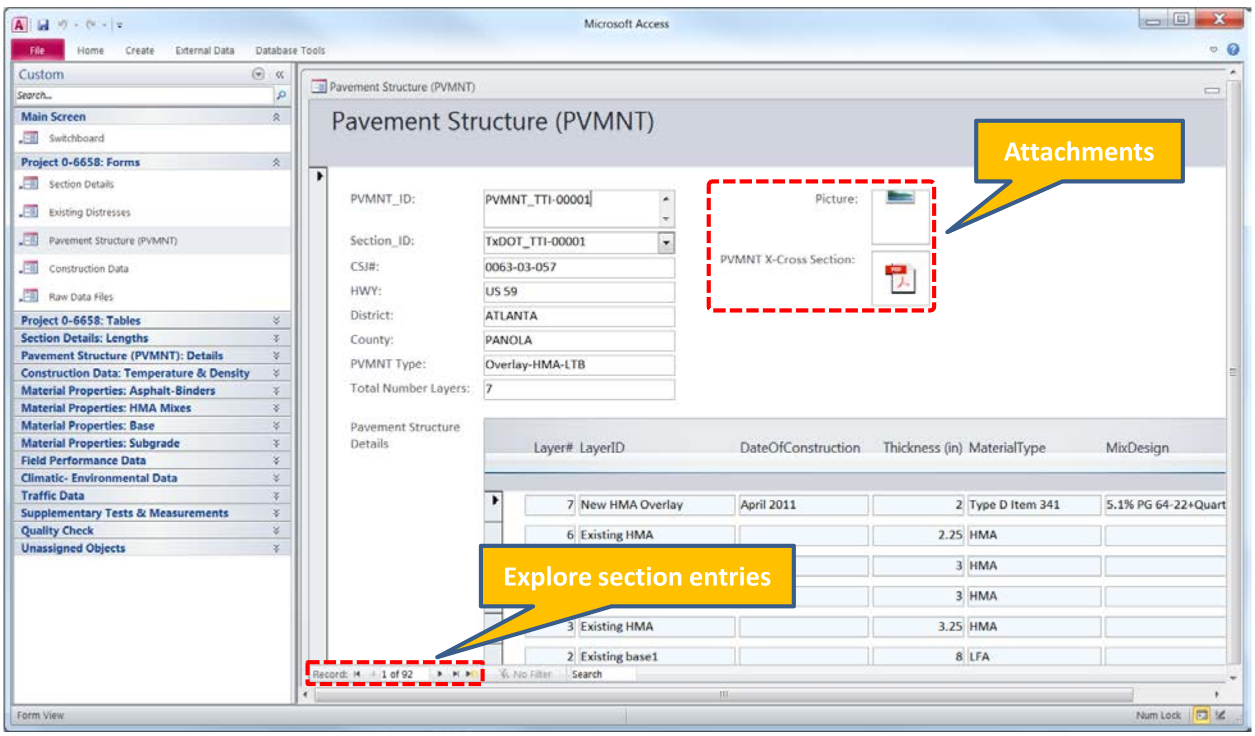


Figure 38. Database Objects: Forms.

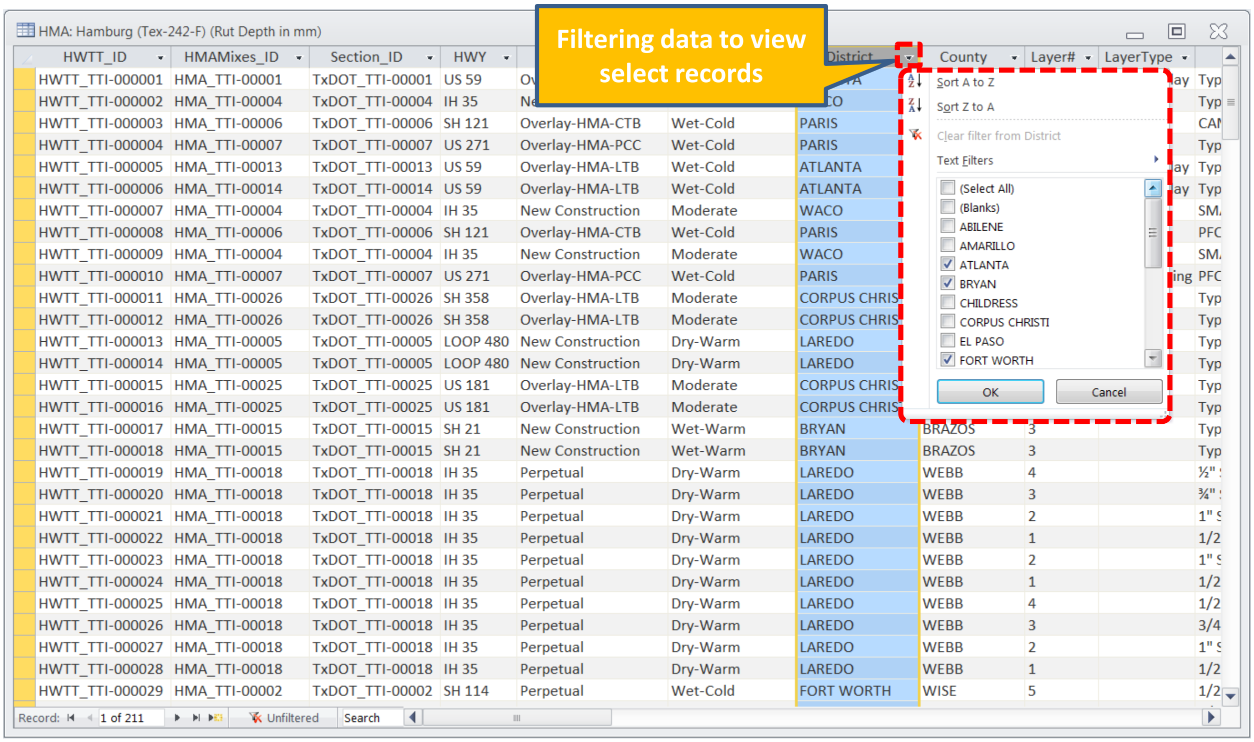


Figure 39. Database Objects: Table.

Table 15. List of Data Content Stored in Form and Table.

No.	Data Content	Form	Table
1	Section details	Yes	Yes
2	Site visits	No	Yes
3	Existing distresses (overlays only)	Yes	Yes
4	Pavement structure	Yes	Yes
5	Construction data	Yes	Yes
6	Material properties	No	Yes
7	Field performance	No	Yes
8	Climatic data	No	Yes
9	Traffic	No	Yes
10	Supplementary tests	No	Yes

Help Function

The Help function shown on the upper right side in the switchboard provides links to the information related to this project and DSS. Clicking on this button displays the following information: user's manual, technical reports, test procedures and specifications, data collection forms, M-E pavement software, and credits directory, as seen in Figure 40. By double clicking each field, a zipped attachment screen provides users access to all data entries in the Help function. Figure 41 shows the contents included in Help.

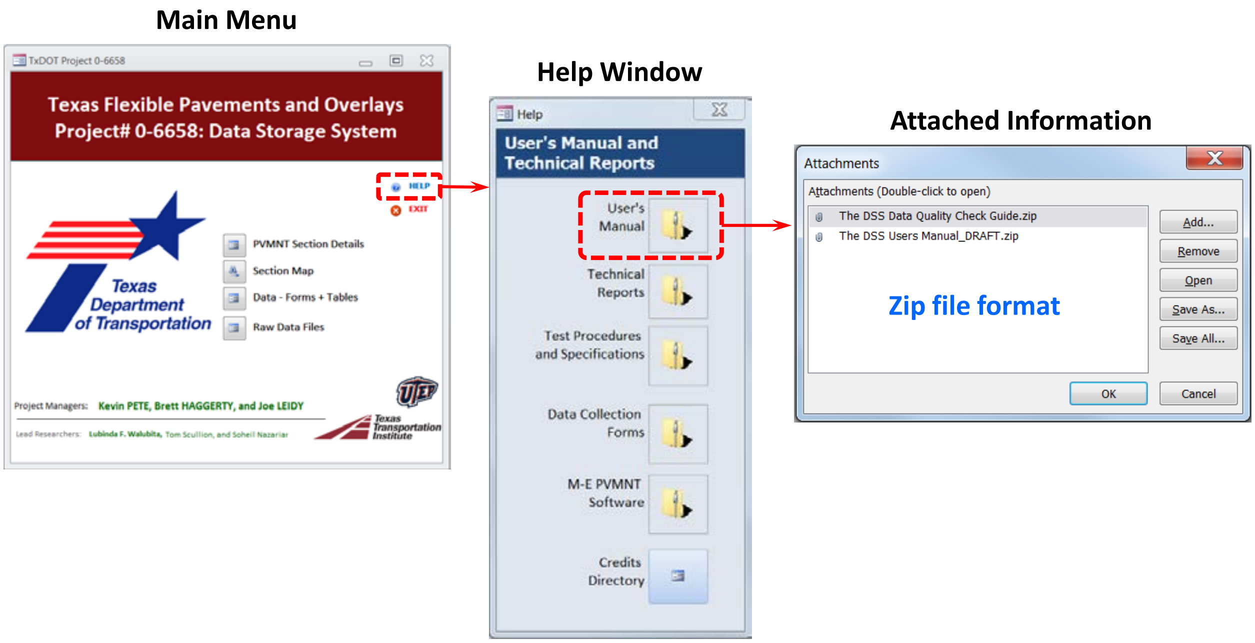


Figure 40. Opening User's Manual Files in Help.

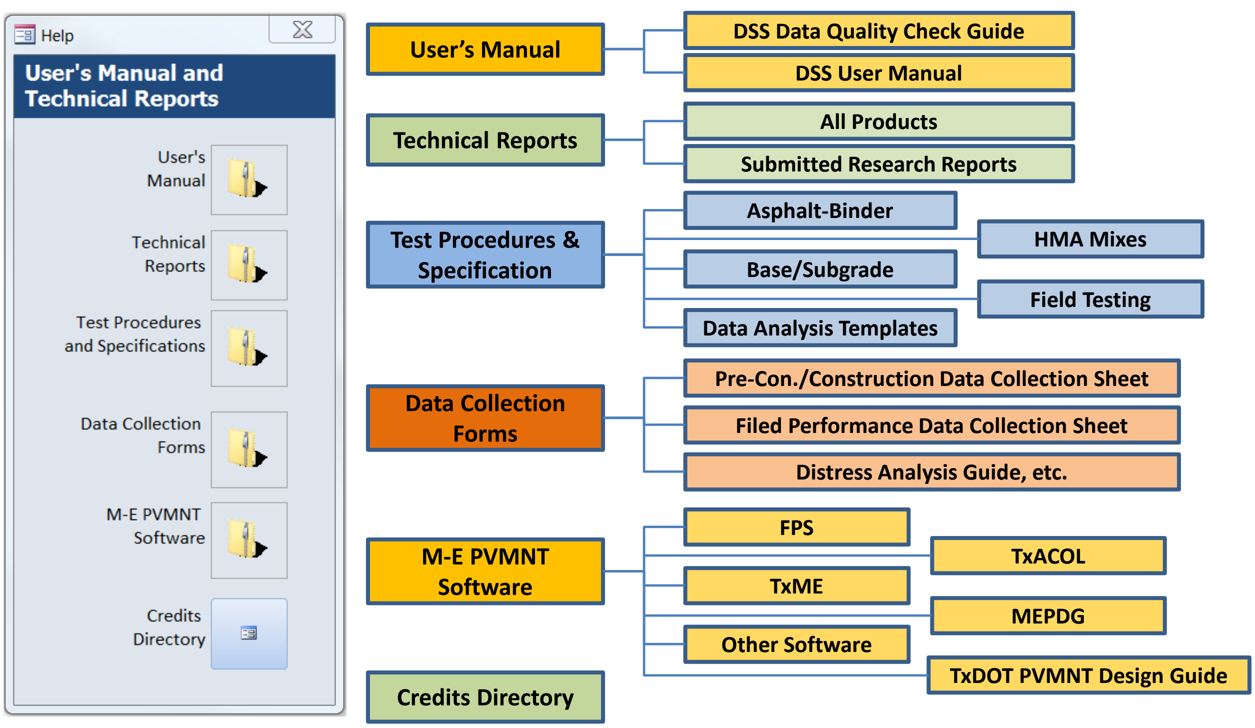


Figure 41. Data Contents in Help.

DSS Data Access and Navigation

The MS Access database used as the platform of DSS provides structured storage for the data so that users can readily access and retrieve the data for general use. The DSS provides options for exporting data directly to an MS-supported format (e.g., MS Word®, MS Excel®, PDF) but not directly to third-party software. However, one can export the data to an MS-supported format and then manipulate it as required. Additionally, the MS Access DSS also allows direct emailing through MS Outlook®. Figure 42 shows an example of an Excel file exported from the DSS and emailed through the MS Outlook. Also, Figure 43 displays an example of a Pivot table and chart generated from the DSS. The detailed description on DSS data access and navigation can be found in reports 0-6658-P2 and 0-6658-P4 (Walubita et al. 2015a, 2013).

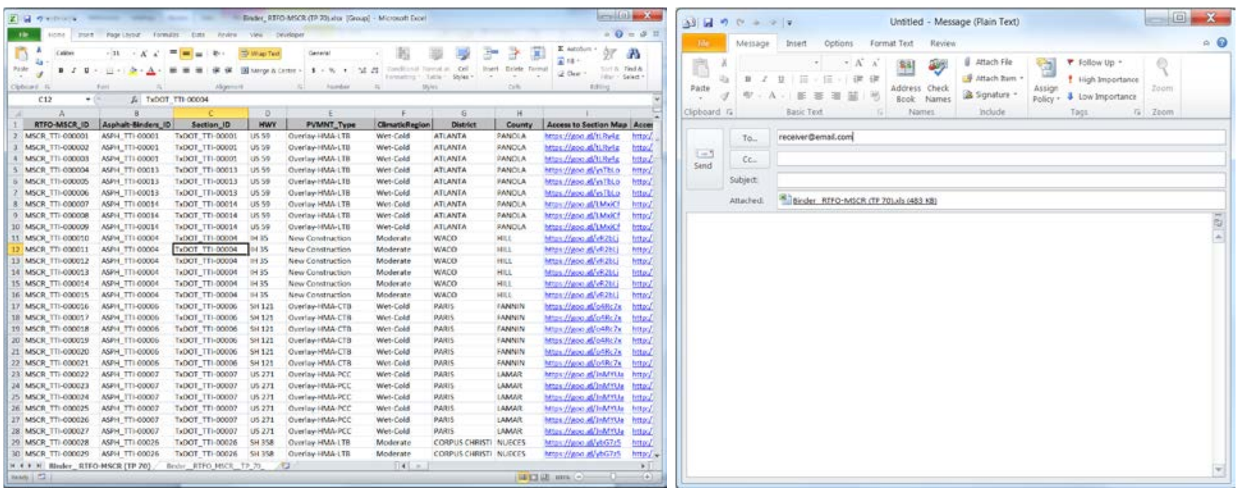


Figure 42. Exporting Excel Spreadsheet and Emailing an Exported File.

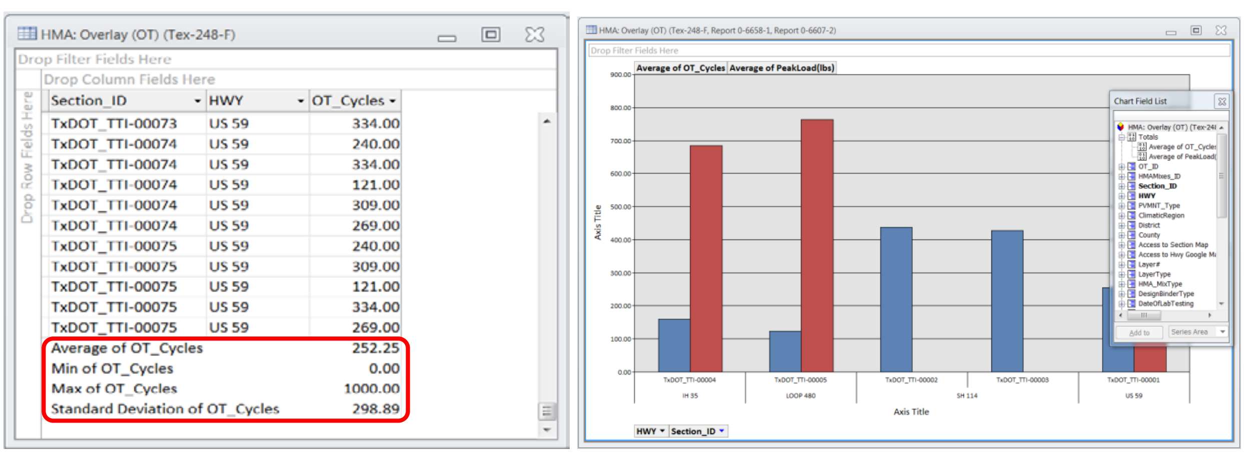


Figure 43. Pivot Table and Chart in DSS.

RAW DATA STORAGE SYSTEM

The raw data files for all the data measured and collected in this study are concurrently kept in the RDSSP (see Figure 44) as a backup and in order to provide user opportunities for data verification and future analyses when necessary.

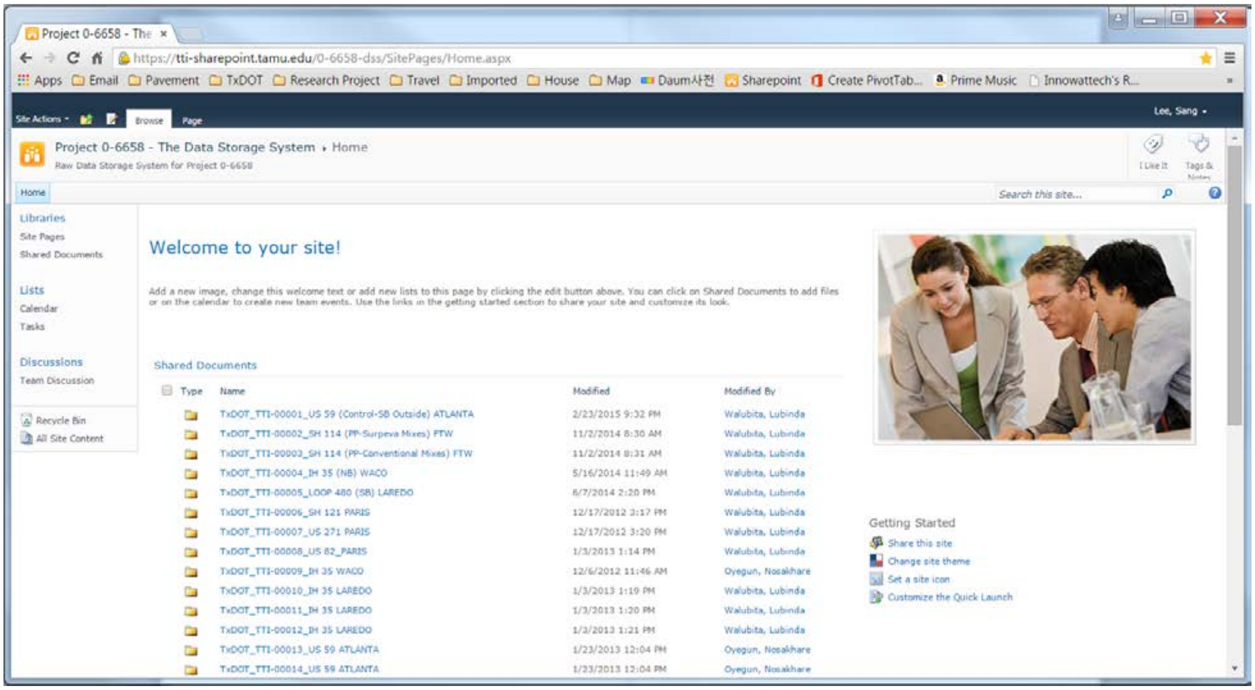


Figure 44. The RDSSP Website.

Data Structure and Entry

The RDSSP contains all raw unprocessed data collected from the field and laboratory, which is catalogued by test section. Figure 45 illustrates the structure and data contents of the RDSSP.

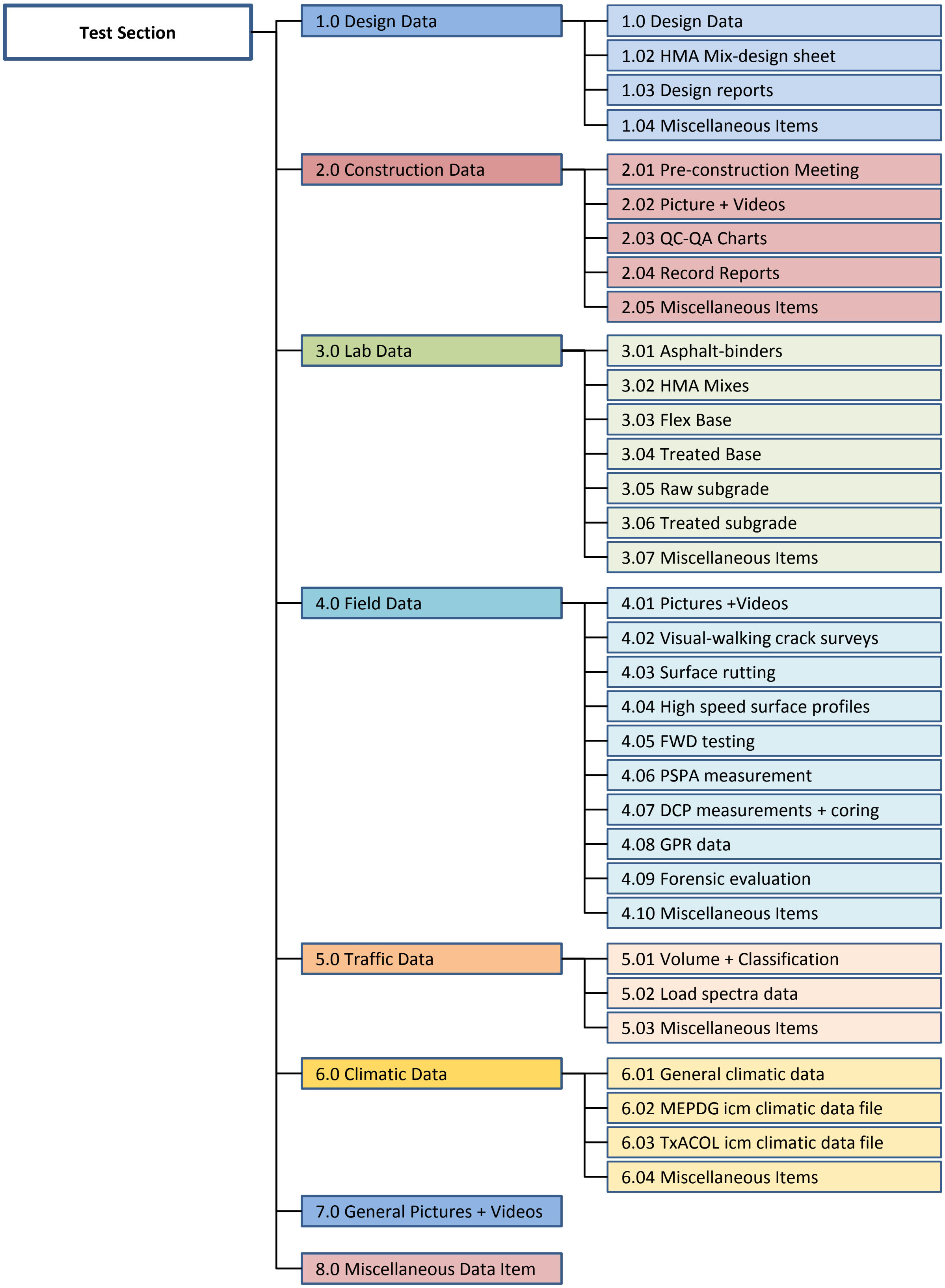


Figure 45. Data Structure of RDSSP.

Data Access and Navigation

For easy accessibility, the RDSSP is linked to the DSS via a "Raw Data Files" function on the DSS main screen. Clicking on the button displays the Raw Data Prompt dialogue box, which shows the destinations of the raw data collected listed by responsible research agency (see Figure 46).

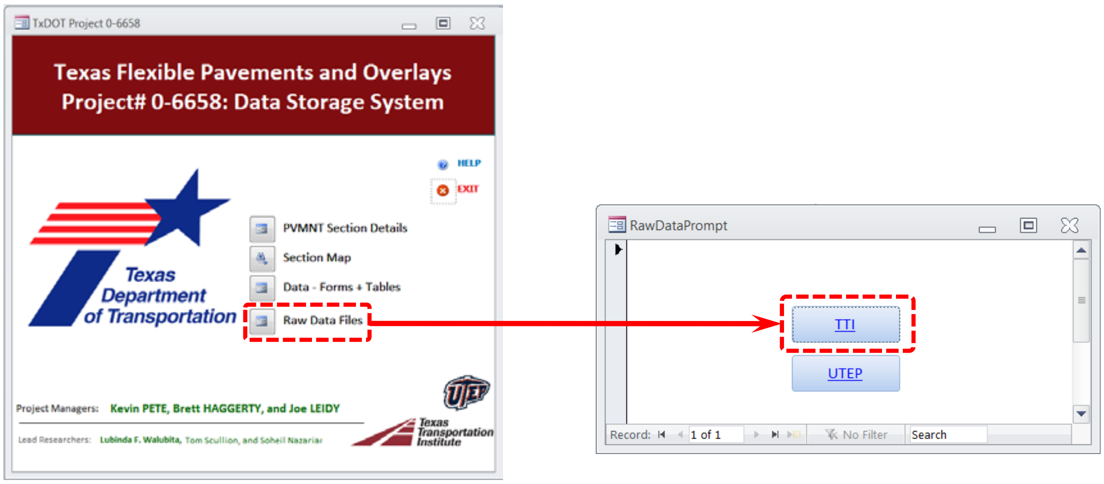


Figure 46. Opening the RDSSP Website.

When specifying a destination, TTI or UTEP, the linked website opens in a web browser containing the data. Upon selecting a test section and then a data folder to be accessed, users can access and download the data files and email the link. Figure 47 illustrates how to email a link and download a copy of a selected file in the RDSSP.

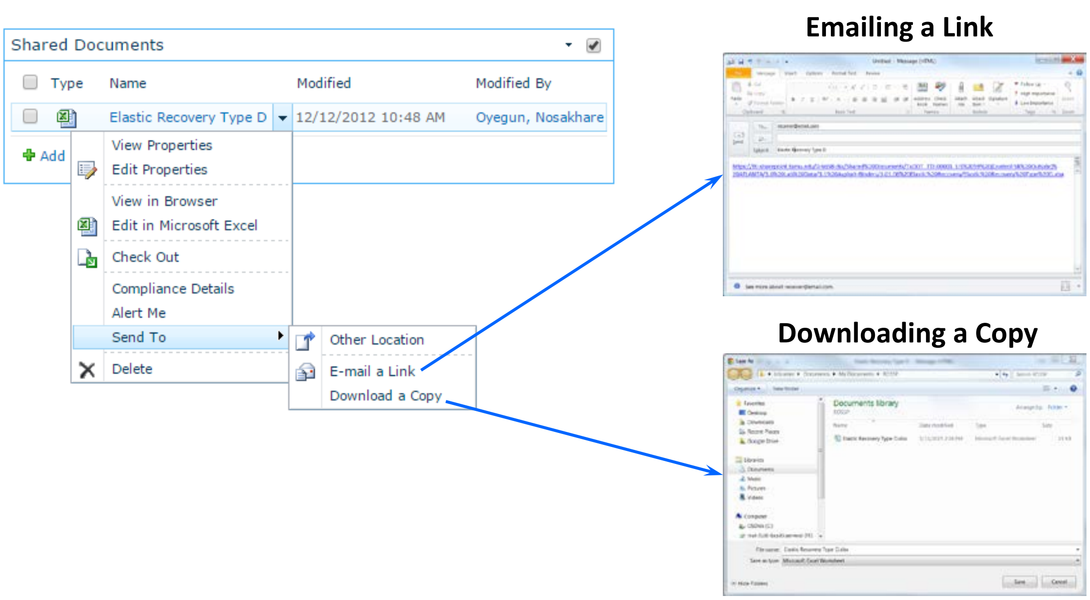


Figure 47. Emailing or Downloading Data from RDSSP.

DATA ANALYSIS AND QUALITY CHECKS

To ensure data quality, a quality control process consisting of a series of checks was developed and performed on data entered in the DSS; the procedure is as follows (Walubita et al. 2012a):

- Step 1: Calculation check and verification of data analysis and computation.
  - Check analyses and calculations prior to entering data into the DSS and RDSSP.
- Step 2: Counter checking and verification of computed numbers.
  - Countercheck the computed numbers against typical values and thresholds.
  - Verify if the numbers are out of specification or CV>30 percent.
- Step 3: Periodic and routine check of the entire DSS.
  - Routinely check for accuracy in numbers, average, CVs, errors, missing data, etc.
  - Check for user-friendliness and accessibility such as plotting graph, etc.
- Step 4: Routine and random trial runs with the M-E models and associated software.
  - Routinely and randomly run the M-E software using the data.
  - Verify accuracy, data usefulness, and if additional data are required.
- Step 5: Monthly submission of the DSS to the PD.
  - Send the latest version of DSS to PD every month.
  - Keep the PD up to date with opportunities to familiarize and suggest correction or improvement of the DSS and RDSSP.

Detailed descriptions of the comprehensive quality check and control process can be found in report 0-6658-P1 (Walubita et al. 2011).

SUMMARY

This chapter provided the description of the Project 0-6658 data repository system, namely the DSS for the processed data and the RDSSP for unprocessed raw data, with a focus on the data content, structure, and accessibility. As discussed in the chapter, each database is well organized to provide the data required for running Texas M-E models and related software and to provide the pavement section data as an ongoing reference source and general diagnostic tool for TxDOT engineers and other transportation professionals. The DSS provides options for exporting data directly to preferred formats (e.g., Excel sheet, PDF, or text) and emailing the data through MS Outlook, while the RDSSP supports downloading data files or emailing a link containing a data file.

CHAPTER 10
SUMMARY AND RECOMMENDATIONS

This final report documents and provides the work performed, methods used, and results achieved in Project 0-6658, *Collection of Material and Performance Data for Texas Flexible Pavements and Overlays*. This study was undertaken by the research team to collect and develop the DSS of materials and pavement performance data on over 100 flexible pavements and HMA overlaid highway test sections around Texas. Quality and reliable pavement material and performance data is used for proper calibration and validation of M-E design and rehabilitation performance models to conditions in Texas, enabling more cost-effective flexible pavement design. In addition, the data collected also serves as an ongoing reference data resource and/or diagnostic tool for TxDOT engineers and other transportation professionals. This five-year project consisted of four phases to address the main objectives of the study:

- Phase I—Literature review, planning, and pilot data demonstration.
- Phase II—Laboratory and field performance data collection and analysis.
- Phase III—M-E model calibration.
- Phase IV—Project management, data demonstration, and report writing.

This final chapter provides a summary of the overall work, conclusions drawn, and recommendations drawn from this study.

HIGHWAY TEST SECTIONS

To collect pertinent data to fulfill the objectives of the study, the test sections were selected based on influencing variables such as pavement type, traffic levels, environmental types, and so forth.

- The objective of the project was to collect materials and pavement performance data on a minimum of 100 highway test sections around the State of Texas that incorporate both flexible pavements and HMA overlays. At end of the study, the DSS comprised data from 112 highway test sections, with the distribution between UTEP and TTI as:
  - UTEP = 33 test sections.
  - TTI = 79 test sections.
- The length of the typical test section was set to 500 ft per homogenous pavement structure, preferably in the outside lane. However, on highway projects where the pavement structure varied within a highway segment, more than one 500-ft test section was used.
- The test sections were comprised of different pavement types, namely, PP, HMA overlays, FDR, and new construction. Each pavement type was subdivided according to material types used for the base layer such as flex (granular) or treated material.

- The research team identified and selected test sections with an effort to distribute the sections throughout the five climatic regions of Texas—DC, DW, M, WC, and WW. Also, the test sections were selected from 21 TxDOT districts out of 25 in order to help TxDOT district engineers make better decisions for rehab strategy selections and design-related issues.

DESIGN AND CONSTRUCTION DATA COLLECTION

The collection of pavement design data was the first step for all test sections in the process of selecting test sections, and collecting material and field performance data in this study. After this, construction data was collected prior to, during, and just after construction stages of each test section.

- The pavement design information, including the pavement design report, the pavement typical sections, and the HMA mix design report, were collected for the test section with TxDOT's assistance.
- Just after selecting a test section, pre-construction testing was performed to collect existing pavement conditions, including structural capacity and surface distresses. The field-testing included GPR, FWD, coring, DCP, existing distress survey, high-speed profiling, and taking pictures and video.
- During construction, the construction information of each test section was collected and documented to check the construction QC/QA, with TxDOT and the contractor's assistance. It included the construction method, compaction pattern, temperature and density measurements, and more. Also, the materials were sampled during construction to perform the HMA, asphalt-binder, base, and subgrade soil laboratory tests.
- Just after construction, the research team performed post-construction testing to collect and document the pavement condition and check for construction defects; these tests included coring new surface layers, GPR, FWD, high-speed profiling, surface distress survey, and more.

LABORATORY TESTING AND DATA COLLECTION

Pavement material properties of samples collected from the test section during construction were measured and analyzed in the laboratory for the following materials: asphalt binders, HMA mixes, and base and subgrade soils

- All asphalt-binder tests were conducted on extracted binders from the plant mix obtained from haul trucks at the production plant or directly from the HMA mix delivered to the test section site. These were sources that represent as-delivered materials used in the test section. The tests included the following:
    - Specific gravity.
    - Viscosity.

- DSR.
  - MSCR.
  - BBR.
  - Elastic recovery (ductility).
  - PG grading of asphalt binders.
- HMA testing was conducted mainly using specimens compacted in the laboratory from plant-mix materials sampled at the construction site or from the production plant. For better statistical representation, each HMA test was performed using three replicate samples. For the OTs, five samples were run, including regular OT, OT fracture, and monotonic OT, to decrease the CV. HMA mix tests to generate the required HMA material properties for this study included the following:
  - Binder extractions/gradation.
  - HWTT.
  - OT.
  - Fracture OT.
  - DM.
  - RLPD.
  - IDT.
  - HMA thermal coefficient test.
- The following base and subgrade soil tests were conducted using materials sampled from the construction site or from the quarry or pit stockpiles, when accessible, such as at new construction and FDR sections:
  - Sieve analysis.
  - Atterberg limits.
  - Specific gravity.
  - MD curve.
  - Texas Triaxial.
  - FFRC.
  - Resilient modulus.
  - Permanent deformation.
  - Shear strength.
  - UCS.
  - MoR.
- To further enhance the DSS planned data catalogue, the research team collected supplementary lab test data as a bonus effort, potentially benefitting other engineering analysis and research. Although the supplementary data were not required as M-E input parameters nor were they mandated under this study, the collected material properties can serve as a useful data source to improve pavement design and rehab strategies for Texas. The supplemental tests included:
  - HMA: FN, OT monotonic, SPST.
  - Treated base: sulfate content.
  - CTB, laboratory mixed: UCS, MoR, FFRC, IDT.

FIELD PERFORMANCE SURVEYS AND DATA COLLECTION

The primary objective of the field-survey program was to evaluate the performance of the in-situ pavement layers and the supporting material property characteristics. In addition, certain field performance data such as rutting and cracking histories is the source for the empirical data necessary in calibrating the M-E models that predict performance. . Therefore, the periodic field performance evaluations were conducted twice per year (just after summer and just after winter), where TxDOT provided support for traffic control.

- The visual crack survey and rut measurement were conducted to identify the present condition of the pavement surface and provide the pavement performance history used for the M-E model calibrations. The survey includes quantifying surface cracking (alligator, block, transverse, and longitudinal cracking), surface rutting (at 100-ft interval), and other distress (raveling, bleeding, patching, etc.)
- FWD surveys were conducted in the outside wheel path at 25-ft intervals using a 9,000-lb nominal load, with TxDOT assistance. From these surveys, normalized raw deflections, FWD back-calculated modulus, and LTE of PCC slabs or CTB sections were computed and stored in the DSS.
- DCP testing and HMA coring were conducted for in-service test sections when testing could not be done prior to or during construction, such as for new construction or FDR sections. These tests were also conducted as needed, based on the interpretation of GPR or FWD data analysis. The estimated base and/or subgrade layer moduli and the layer thickness data were collected and stored in the DSS.
- High-speed profiling was performed to evaluate the term is synonymous with ride quality ride quality in both outside and inside wheel paths. The profiling data were processed into the IRI (inch/mile) and PSI using the RideQuality software.
- Center-line pictures were taken at every field performance testing to update the Google map in order to provide the latest pictures in the DSS. Also, pictures and video were taken where needed, such as at severe or abnormal distress areas found during the field performance testing.

TRAFFIC AND CLIMATIC DATA COLLECTION

Accurate traffic and climatic data are a critical consideration for highway pavement design as well as a significant input to predict the pavement performance through the M-E models. As a part of the DSS, the research team made an elaborate effort to collect and analyze site-specific data for a wide variety of Texas flexible pavements and HMA overlay sections with different levels of traffic loading in different climatic zones of Texas.

- The traffic data were collected from two sources, namely, pneumatic traffic tubes as the primary source and traffic data from TxDOT WIM stations where available.

- Analysis procedures and templates were developed in this study in order to facilitate easy traffic data analysis for both pneumatic tube and WIM data. The following traffic parameters required to run the M-E models and software were collected, analyzed, and stored in the DSS:
  - Volume and classification parameters (ADT, ADTT, truck percentage, etc.).
  - Gross vehicle weight and axle load parameters (ESAL, axle load spectra, number of axles per vehicle, etc.).
  - Adjustment factors (hourly and monthly adjustment factors).
- Site-specific climatic data were generated for all the test sections in the DSS. In general, the following climatic and environmental data were included in the DSS:
  - Air temperatures and precipitations.
  - GPS coordinate locations and elevations.
  - GWT and well location including GPS coordinates and distance from test section.

DATA STORAGE AND MANAGEMENT

In order to address database requirements for storage capacity and accuracy, the DSS was developed as a two repository system: the MS Access DSS for the processed data and the RDSSP for the unprocessed raw data.

- MS Access was selected as the platform for the DSS due to its commercial availability, familiarity, user-friendliness, and ready availability to TxDOT engineers. The DSS consists mainly of three data storage objects—section map, forms, and tables—to store the data measured and collected throughout this entire study.
- The MS Access database used as the platform for the DSS provides functions for exporting data directly to an MS-supported format (Word, Excel, or PDF) but not directly to third-party software. Also, the DSS allows users to email a data table with a specific format.
- The raw data files for all the data measured and collected in this study are concurrently kept in the RDSSP as a backup and in order to provide opportunities for data verification and future analyses when necessary. The RDSSP allows users to access and download the data files and email the links.
- The quality control process, consisting of a series of checks, was developed and actively used for monitoring and controlling the quality of the data in the DSS and RDSSP.

RECOMMENDATIONS

Overall, 112 test sections were identified and distributed judiciously across the state in accordance with the pavement type, climatic zone, district, and service life. However, around 70 percent of the test sections sourced in this study are relatively early in their service life (≤ 3 years) with very limited field performance data, showing little to no distresses at all due to the limited project duration . Only PP sections are older than five years, all constructed before 2008, but they have no significant distress on the test sections. Thus, continued monitoring and performance evaluation of the test sections is strongly recommended.

In consideration of the work performed in this study, the following challenges and recommendations were noted:

- Because typical flexible pavement design parameters are established based on a 20-year analysis period, the sections need to be monitored over a longer time period (≥ 5 years) so that the design and material properties can be correlated to the actual field performances of the pavements over a typical expected life. However, 75 test sections out of 112 selected under this project were constructed within the last three years, and thus far, they have satisfactory field performances with little to no distresses over their relatively short service lives. That is, no progressive distresses such as fatigue or reflection cracking are available for use in the calibration of the M-E models and associated software.
- Continued field performance monitoring and data collection is strongly recommended to allow measured distresses to be correlated to traffic, climatic, and material properties, thus facilitating the effective and accurate calibration of the Texas M-E models.
- Collection of field performance data up to terminal failure (≥ 5 years) will serve as an effective data source in aiding TxDOT districts and engineers to make better decisions for rehab strategy selections and design-related issues.
- Complete field performance data with corresponding material properties, traffic, and climatic data will facilitate the proper calibration of the Texas M-E models and associated software.

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APPENDIX A: LIST OF LAB TESTS

Table A-1. Asphalt-Binder Test (Extracted Binders Only).

#	Test	Spec	Test Parameters	Output Data	Sample Replicates			Comment
					TTI	UTEP	*TxDOT Recommendation*	
1	AC extraction	Tex-210-F[a]	As per spec	N/A – just binder	≥ 65 lb		≥ 65 lb	Extract enough to run all the necessary tests (i.e., about 100 lb)
2	Specific gravity	T 228	As per spec	Specific gravity	3		*1*[a]	Report 0-6658-1
3	Viscosity	T 316	135 °C	Viscosity	3		*1*[a]	Report 0-6658-1
4	DSR[b]	T 315	As per spec	True grade, G*, and G*/Sin(δ)	3		*1*[a]	Report 0-6658-1
5	DSR – RTFO	T 240	As per spec	True grade, G*, and G*/Sin(δ)	3		*0*[c]	Report 0-6658-1
6	DSR _ PAV	R 28	As per spec	G*, G*/Sin(δ), and true grade	3		*0*[c]	Report 0-6658-1
7	MSCR	TP 70	As per spec; min 3 test temperatures per binder	R100, R3200, R_{diff}, $J_{nr}100$, $J_{nr}3200$, and $J_{nr-diff}$	9		*9* *(3 × 3 temps)*	Report 0-6658-1
8	BBR[b]	T 313, R 28	As per spec; min 2 temps	Stiffness, m-value	6 (3 × 2 temps)		*2*[a] (1 × 2 temps)	Report 0-6658-1
9	Elastic recovery (ductility)	(D 6084-A)	As per TxDOT spec @ 50°F	Elastic recovery	3		*3*	Report 0-6658-1
10	Binder PG grading	M 320, Item 300, MP 19	As per spec	PG grade	–	–	–	Report 0-6658-1
Total number of replicates					33		*17*	

Note: Approximate material requirement ≥ 65 lb of plant mix (better to target 100 lb).

[a] Results for first test sections were repeatable with CV less than 5 percent, so no need for three or more replicates.

[b] Run the intermediate temperature DSR and BBR on the extracted binders as is (with no PAV) for mixes with RAP or RAS.

[c] Tests will be done on extracted binders only and treated as rolling thin-film oven (RTFO) residue, so no need for RTFO or pressure aging vessel (PAV).

Table A-2. HMA Mix Tests (Plant Mix and Cores Only).

#	Test	Spec	Test Parameters	Output Data	Sample Replicates			Comment
					TTI	UTEP	***TxDOT Recommend.***	
1	AC extraction	Tex-210-F[a]	As per spec	AC % (by weight)	3		***3***	
		Tex-236-F	As per spec	AC %	3		***0***[b]	
2	Aggregate gradation	Tex-200-F	As per spec	Particle size distribution	3		***3***	Use aggregates from Tex-210-F
3	HWTT	Tex-242-F	As per spec, but run all samples to 20,000 load passes	Test temp., rut depth and number of wheel passes (i.e., 0, 5,000, 10,000, 15,000, and 20,000)	3 (3 sets of 2)		***1***[c] *(1 set of 2)*	During testing, it is recommended to set the maximum rut depth to about 25 mm (instead of 12.5 mm)
4	OT	Tex-248-F	0.025 in., 93% load drop, 77°F	Test temperature, max load, and cycles to failure	5		***5***	
5	OT fracture properties	-	0.017 in. @ 77°F for 100 cycles	Test temp., *E(OT)*, *A*, and *n*	5		***5***	Test parameters recommended from Study 0-6622
6	DM	AASHTO TP 62-03	As per spec; 5 temps; 6 frequencies	Dynamic modulus (|E|), temperature, and frequency	3		***3***	Report 0-6658-1
7	RLPD	Reports 0-6658-P3 and 0-6658-1	(a)104°F, 20 psi, and 10,000 cycles, and (b) 122°F, 10 psi, and 10,000 cycles	Test temperatures, α, μ , and microstrains	6 (3 × 2 temps)		***6*** (3 × 2 temps)	Report 0-6658-1
8	IDT	Tex-226-F	As per spec	Test temp., IDT strength, and displacement @ peak load	3	–	***3***	Report 0-6658-1
9	Thermal coefficient	Reports 0-6658-P3 and 0-6658-1	14–104°F	Thermal coefficient (α)	3		***3***	Report 0-6658-1
10	FN	Reports 0-6658-P3 and 0-6658-1	50°C, 30 psi	Test temp., FN, Time to FN, accumulated microstrain @ FN (εP), and εP/FN	3		**–**	Report 0-6658-1
11	OT monotonic	Report 0-6607-2	0.125 in./min @ 77°F	Peak load, HMA tensile strength, strain, Fracture energy (FE), FE index	5	–	**–**	Report 0-6607-2
Total number of replicates					45		***32***	

Note: Approximate material requirement ≥ 405 lb of plant mix (better to target 450 lb).
[a] Test to be performed only if data cannot be obtained from QC/QA records.
[b] No need to do Tex-236-F if Tex-210-F is being conducted, though time consuming and costly, TxDOT prefers Tex-210 because it is more accurate.
[c] Results for first test sections were very repeatable with coefficient of variation less than 5%, so no need for 3 replicate sets.

Table A-3. Base Tests (Flex).

#	Test	Spec	Test Parameters	Output Data	Sample Replicates			Comments
					TTI	UTEP	***TxDOT Recom.***	
1	Sieve analysis[a,b]	Tex-110-E	As per spec	Gradation	3	Stock	*Stock (Tex-110-E for +#40 and Tex-111-E for −#40)*	Report 0-6658-1
2	Atterberg limits[a]	Tex-104-E, Tex-105-E, Tex-106-E	As per spec	PI, LL, and PL	3	2[d]	*1+*	Report 0-6658-1
3	Specific gravity	ASTM C-127, 128	As per spec	Specific gravity value	3	2[d]	*2*[c]	Report 0-6658-1
4	Wet Ball Mill[a,d]	Tex-116-E	As per spec	Wet Ball Mill value	3	2[d]	*0*	Report 0-6658-1
5	MD Curve[a]	Tex-113-E	6″ × 8″	MDD, OMC	3	2[d]	*1+*	Report 0-6658-1
6	Texas Triaxial	Tex-117-E	6″ × 8″	Classification, C, and ϕ	3	2[d]	*1*[e]	Report 0-6658-1
7	Resilient modulus	NCHRP 1-28A	6″ × 12″ OMC	k-parameters	3	2[d]	*2*[c]	Report 0-6658-1
8	Permanent deformation	NCHRP 1-28A	6″ × 12″ OMC	α and μ	3	2[d]	*2*[c]	Report 0-6658-1
9	Shear strength	Tex-143	6″ × 8″	C and ϕ	3	2[d]	*2*[c]	Report 0-6658-1
10	Soil suction	ASTM D5298		Suction coefficient	3	–	*0*	Report 0-6658-1
Total material to sample from the field					33		*11*	

Note: Approximate material requirement ≥ 700 lb (better to target 800 lb or more).

[a] Perform sieve analysis and compare gradation to TxDOT. If gradation matches, then use TxDOT QC data; otherwise, run test.

[b] Include sieves #100 and #200, which will be washed.

[c] A third test is performed if the duplicate results vary by a wide margin.

[d] If available, use from TxDOT QC. Researchers to run one test, if the results match the districts, they can use district results; if not, the researchers will run two samples.

[e] One sample at each confining pressure.

Table A-4. Base Tests (Treated—CTB).

#	Test	Spec	Test Parameters	Output Data	Sample Replicates			Comments
					TTI	UTEP	*TxDOT Recom.*	
1	Sieve analysis[a,b]	Tex-110-E	As per spec	Gradation	3	Stock	*Stock*	Report 0-6658-1
2	Atterberg limit[d]	Tex-104-E, Tex-105-E, Tex-106-E	As per spec	PI, LL, and PL	3	2[f]	*1+*	Report 0-6658-1
3	Sulfate content[c]	Tex-145-E	As per spec	Sulfate content	3	2[f]	*0*	Report 0-6658-1
4	Wet Ball Mill[c]	Tex-116-E	As per spec	Wet Ball Mill value	3	2[f]	*0*	Report 0-6658-1
5	MD Curve[d]	Tex-113-E	As per spec	MDD and OMC	3	2[f]	*1+*	Report 0-6658-1
6	Unconfined compressive strength[d]	Tex-120-E, Tex-121-E	As per spec	UCS	3	2[f]	*1[h]*	Report 0-6658-1
7	Resilient modulus[d,g]	NCHRP 1-28A	6″ × 12″ OMC	k-parameters	3	2[f]	*2[e]*	Zero confinement, Report 0-6658-1
8[i]	Modulus of rupture[d,f]	-	Beam 6″ × 6″ × 12″ OMC	Modulus of rupture	3	2[f]	*2[e]*	ASTM D1632, ASTM C78, Report 0-6658-1
Total material to sample from the field					24		*7*	

Note: Approximate material requirement ≥ 550 lb (better to target 600 lb or more).
[a] Perform sieve analysis and compare gradation to TxDOT. If gradation matches then use TxDOT QC data; otherwise; run test.
[b] Include sieves #100 and #200.
[c] Test is performed before treatment.
[d] Test is performed after treatment.
[e] A third test is performed if the duplicate results vary by a wide margin.
[f] Test only for cement treated (>2%).
[g] Run FFRC instead of resilient modulus test at zero confinement.
[h] Includes running three samples at the cement content.
[i] When the cement stabilization content is 2 percent or less, reclassify the material as "untreated base" and test according to that protocol. For all other materials that have more than 2 percent stabilization content, leave them as a treated material, and if the modulus of rupture specimens cannot be fabricated, make a note in the DSS in the comments field.

Table A-5. Base Tests (Treated—Asphalt/Low Stabilizers).

#	Test	Spec	Test Parameters	Output Data	Sample Replicates			Comments
					TTI	UTEP	*TxDOT Recom.*	
1	Sieve analysis[a,b]	Tex-110-E	As per spec	Gradation	3	Stock	*Stock*	Report 0-6658-1
2	Atterberg limit[c]	Tex-104-E, Tex-105-E, Tex-106-E	As per spec	PI, LL, and PL	3	2[f]	*1+*	Report 0-6658-1
3	Sulfate content[c]	Tex-145-E	As per spec	Sulfate content	3	2[f]	*0*	Report 0-6658-1
4	Wet Ball Mill[c]	Tex-116-E	As per spec	Wet Ball Mill value	3	2[f]	*0*	Report 0-6658-1
5	MD Curve[d]	Tex-113-E	As per spec	Optimum moisture content and maximum dry density	3	2[f]	*1+*	Report 0-6658-1
6	Unconfined compressive strength[d]	Tex-120-E, Tex-121-E	As per spec	UCS	3	2[f]	*1*[f]	Report 0-6658-1
7	Resilient modulus[d,g]	NCHRP 1-28A	6″ × 12″ OMC	k-parameters	3	2[f]	*2*[e]	Zero confinement, Report 0-6658-1
8	Permanent deformation[d,,f]	NCHRP 1-28A	6″ × 12″ OMC	α and μ	3	2[f]	*2*[e]	Zero confinement, Report 0-6658-1
Total material to sample from the field					24		*9*	

Note: Approximate material requirement ≥ 550 lb (better to target 600 lb or more).

[a] Perform sieve analysis and compare gradation to TxDOT. If gradation matches then use TxDOT QC data, otherwise run test.

[b] Include sieves #100 and #200.

[c] Test is performed before treatment.

[d] Test is performed after treatment.

[e] A third test is performed if the duplicate results vary by a wide margin.

[f] Test only for asphalt treated and low stabilizer content (< 2%).

[g] Run FFRC instead of resilient modulus test at zero confinement.

Table A-6. Subgrade Soil Tests (Raw).

#	Test	Spec	Test Parameters	Output Data	Sample Replicates			Comment
					TTI	UTEP	*TxDOT Recommendation*	
1	Sieve Analysis[a,b]	Tex-110-E	As per spec	Gradation	3	Stock	*Stock (Tex-110-E, Part I for +#40 and Part II for –#40 [hydrometer])*	Report 0-6658-1
2	Atterberg limits	Tex-104-E, Tex-105-E, Tex-106-E	As per spec	PI, LL, and PL	3	2[d]	*1+*	Report 0-6658-1
3	Specific gravity	Tex-108-E	As per spec	SG value	3	2[d]	*2*[c]	Report 0-6658-1
4	Sulfate content	Tex-145-E	As per spec	Sulfate content	3	2[d]	*0*	Report 0-6658-1
5	Organic content	Tex-408-A	As per spec	Organic content	3	2[d]	*0*	Report 0-6658-1
6	MD curve	Tex-114-E	As per spec	MDD and OMC	3	2[d]	*1+*	Report 0-6658-1
7	Texas triaxial	Tex-117-E	As per spec	Classification, C, and ϕ	3	2[d]	*1*	Report 0-6658-1
8	Resilient modulus	NCHRP 1-28A	4″ × 8″ OMC	k-parameters	3	2[d]	*2*[c]	Report 0-6658-1
9	Permanent deformation	NCHRP 1-28A	4″ × 8″ OMC	α and μ	3	2[d]	*2*[c]	Report 0-6658-1
10	Shear strength	Tex-143	As per spec	C and ϕ	3	2[d]	*2*[c]	Report 0-6658-1
11	Soil suction	ASTM D5298		Suction coefficient	3	–	*0*	Report 0-6658-1
Total material to sample from the field					33		*11*	

Note: Approximate material requirement ≥ 350 lb (better to target 400 lb or more).

[a] Perform sieve analysis and compare gradation to TxDOT. If gradation matches, then use TxDOT QC data; otherwise, run test.

[b] Include sieves #100 and #200.

[c] A third test is performed if the duplicate results vary by a wide margin.

[d] Plus one sample for every change in material.

Table A-7. Subgrade Soil Tests (Treated).

#	Test	Spec	Test Parameters	Output Data	Sample Replicates			Comment
					TTI	UTEP	*TxDOT Recom.*	
1	Sieve analysis[a,b]	Tex-110-E	As per spec	Gradation	3	Stock	*Stock (Tex-110-E, Part I for +#40 and Part II for −#40 [hydrometer])*	Report 0-6658-1
2	Atterberg limits[c,d]	Tex-104-E, Tex-105-E, Tex-106-E	As per spec	PI, LL, and PL	3	2[f]	*1+*[g]	Report 0-6658-1
3	Sulfate content[d]	Tex-145-E	As per spec	Sulfate content	3	2[f]	*2*[e]	Report 0-6658-1
4	Organic content[d]	Tex-408-A	As per spec	Organic content	3	2[f]	*0*	Report 0-6658-1
5	MD Curve[d]	Tex-114-E	As per spec	MDD and OMC	3	2[f]	*0*	Report 0-6658-1
6	Unconfined compressive strength[d]	Tex-120-E, Tex-121-E	As per spec	UCS	3	2[f]	*1+*	Report 0-6658-1
7	Resilient modulus[d,f]	NCHRP 1-28A	4″ × 8″ OMC	k-parameters	3	2[f]	*2*[d]	Report 0-6658-1
8	Permanent deformation[d]	NCHRP 1-28A	4″ × 8″ OMC	α and μ	3	2[f]	*2*[d]	Report 0-6658-1
Total material to sample from the field					24		*8*	

Note: Approximate material requirement ≥ 150 lb (better to target 200 lb or more).
[a] Perform sieve analysis and compare gradation to TxDOT. If gradation matches then use TxDOT QC data, otherwise run test.
[b] Include sieves #100 and #200.
[c] Test is performed before treatment.
[d] Test is performed after treatment.
[e] A third test is performed if the duplicate results vary by a wide margin.
[f] Run FFRC instead of resilient modulus test at zero confinement.
[g] Plus one sample for every change in material.

Table A-8. Lab Tests (Neat Asphalt-Binders: Obtained Directly from the Plant or Truck [Onsite during Construction]).

#	Test	Spec	Parameters	Sample Replicates			Comments/Reference
				TTI	UTEP	*TxDOT Recommendation*	
1	Residual recovery (Emulsions only)	Texas Oven (6 hr @ 60°C)	Residual recovery	3 (60 g)		*3*	Silicon sheets may be obtained from Bed, Bath and Beyond Report 0-6658-1
2	Viscosity	T 316	Viscosity	1 (40 g)		*1*	Report 0-6658-1
3	Specific gravity	T 228	Specific gravity	1 (40 g)		*1*	Report 0-6658-1
4	RTFO and PAV	T 240, R 28		1 (60 g)		*1*	Report 0-6658-1
5	DSR	T 315	G*, and G*/Sin(δ)	1 (60 g)		*1*	Report 0-6658-1
6	MSCR	TP 70	Jnr, Jnr ratio % recoverable strain	9 *(3 × 3 temps)* (60 g)		*9 (3 × 3 temps)*	Report 0-6658-1
7	BBR	T 313	S and m-values	2 *(1 × 2 temps)* (60 g)		*2 (1 × 2 temps)*	Report 0-6658-1
8	Elastic recovery	D 6084	% recovery	3 (100 g)		*3*	Report 0-6658-1
9	SPG grading	Report 0-1710-2	SPG binder grade	–		–	1) Report 0-1710-2 2) Report 0-6658-1
Total number of replicates				21		*21*	

Note: Approximate material requirement = one 5-gal (≅ 38 lb) bucket of neat binder obtained either from the plant or directly from the truck onsite during construction.

APPENDIX B: SURFACE DISTRESS IDENTIFICATION AND ANALYSIS

The present condition of the pavement surface is one of critical interest to state agency personnel and engineers because it describes the overall condition of the state-maintained highway system and offers a critical indicator of the need for maintenance and rehabilitation. Also, the pavement condition history, with corresponding material properties, climate, and traffic information, can be used as a reference for decision-making on designing and building roadways in future. In order to determine the condition of pavement surfaces, various automated instruments have been used in the highway industry. However, since the instruments do not provide all information needed to characterize the pavement condition, it is necessary to conduct a visual distress survey along with an automated survey to obtain information that is more comprehensive. For these reasons, the visual survey is conducted for all project test sections in Project 0-6658 *Collection of Materials and Performance Data for Texas Flexible Pavements and Overlays* at the stages of pre-construction, post-construction, and in service.

This guide defines the methods to be used for conducting visual evaluations of the test sections and provides an aid to the users of the Project 0-6658 MS Access DSS by addressing the following:

- The definition of each flexible pavement surface distress type and severity
- How to measure and rate each surface distress and determine its severity.
- Guidelines for how to determine the input values required for the DSS.

All surface distress definitions, measurement methods, and rating categories in this guide were based mainly on the TxDOT PMIS Rater's Manual. However, the Long-Term Pavement Performance (LTPP) Distress Identification Guide was used to define some conditions in cases where certain information such as severity levels was unavailable in the TxDOT Rater's Manual.

RUTTING

Definition

Longitudinal surface depression in a wheel path, which is consolidation or lateral movement of the pavement materials due to traffic loads, as presented Figure B-1.

How to Rate

Rutting is rated for each wheel path using an approved method of measurement (a minimum of a 6-ft straight edge and a depth measuring device).

1. Measure the rut depth at 100-ft intervals for each wheel path throughout the test section.
2. Add together the measured rut depths and calculate the average (AVG) and CV of the rut depths.

(a) Severe Rutting on US 96 **(b) Rutting Measurement**

Figure B-1. Rutting.

ALLIGATOR CRACKING

Definition

Interconnecting cracks that form small, irregularly shaped blocks, which occur in the wheel paths, as presented in Figure B-2. Blocks formed by alligator cracks are less than 1 ft by 1 ft, while larger blocks are rated as block cracking.

(a) Low Severity **(b) Moderate Severity** **(c) High Severity**

Figure B-2. Alligator Cracking.

How to Rate

Alligator cracking is rated as the percentage (%) cracked in each wheel path through the test section regardless of the crack's width.

1. Measure the total length of alligator cracking throughout each wheel path on the test section.
2. Calculate the % coverage by the ratio of the total alligator crack length to the length of wheel paths of test section (i.e., 2 × length of test section).

Severity Levels (by LTPP Guide)

Low: an area of cracks with no or only a few connecting cracks; cracks are not spalled or sealed; pumping is not evident (Figure B-3).

Moderate: an area of interconnected cracks forming a complete pattern; cracks may be slightly spalled; cracks may be sealed; pumping is not evident (Figure B-3).

High: an area of moderately or severely spalled interconnected cracks forming a complete pattern; pieces may move when subjected to traffic; cracks may be sealed; pumping may be evident (Figure B-3).

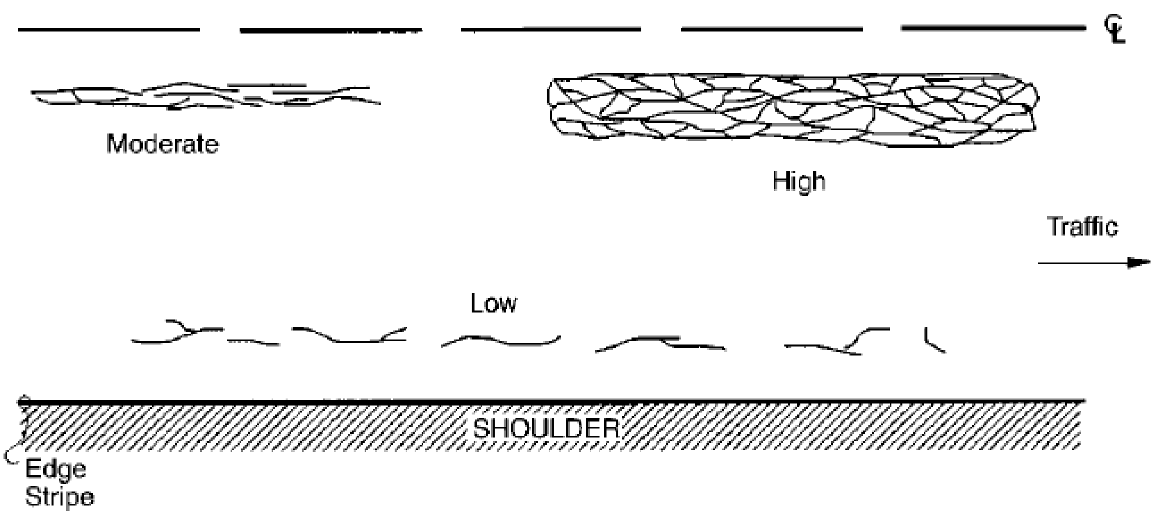

Figure B-3. Severity of Alligator Cracking.

BLOCK CRACKING

Definition

Interconnecting cracks that divide the pavement surface into approximately rectangular pieces, varying in size from 1 ft by 1 ft up to 10 ft by 10 ft. The block cracking is not load-associated because it is commonly caused by shrinkage of the asphalt concrete or by shrinkage of stabilized based courses, as presented Figure B-4.

Figure B-4. Block Cracking.

How to Rate

Block cracking is rated as the percentage (%) of the test section's total surface area, regardless of crack's width.

1. Measure the total length of block cracking, regardless of width, throughout the test section.
2. Calculate the % coverage by the ratio of the total blocking crack length to the length of test section.

Severity Levels (by LTPP Guide)

Low: Cracks with a mean width ≤ 0.25 in. (6 mm); or sealed cracks with sealant material in good condition and with a width that cannot be determined.

Moderate: Cracks with a mean width > 0.25 in. (6 mm) and ≤ 0.75 in. (19 mm); or any crack with a mean width ≤ 0.75 in. (19 mm) and adjacent low severity random cracking.

High: Cracks with a mean width > 0.75 in. (19 mm); or any crack with a mean width ≤ 0.75 in (19 mm) and adjacent moderate to high severity random cracking.

TRANSVERSE CRACKING

Definition

Cracks or breaks that travel at right angles to the pavement centerline. Joint cracks and reflective cracks may be identified as transverse cracking as presented Figure B-5.

How to Rate

1. AVG and CV Length:
    a. Measure the length of each transverse crack and count the number of cracks through test section.
    b. Calculate the AVG and CV of the transverse crack length.

2. AVG and CV Spacing:
    a. Measure distance between each adjacent transverse crack throughout test section.
    b. Calculate the AVG and CV of the distances.
3. TrC_AVG, STDEV, and Trc_CV LTE:
    a. Using an FWD, measure all LTE cross the cracks that are reflected from a joint in the underlying PCC slab.
    b. Calculate the AVG, STDEV, and CV for LTEs.
4. % Coverage: (No definition in TxDOT or LTPP Guide).

Severity Levels (LTPP Guide)

- **Low**: an unsealed crack with a mean width ≤ 0.25 in. (6 mm); or sealed cracks with sealant material in good condition and with a width that cannot be determined.
- **Moderate**: any crack with a mean width > 0.25 in. (6 mm) and ≤ 0.75 in.(19 mm); or any crack with a mean width ≤ 0.75 in. (19 mm) and adjacent low severity random cracking.
- **High**: any cracks with a mean width > 0.75 in. (19 mm); or any crack with a mean width ≤ 0.75 in. (19 mm) and adjacent moderate to high severity random cracking.

(a) Low Severity **(b) Moderate Severity** **(c) High Severity**

Figure B-5. Transverse Cracking.

LONGITUDINAL CRACKING

Definition

Cracks or breaks that run approximately parallel to the pavement centerline, as presented Figure B-6.

How to Rate

1. AVG, STDEV, and CV Length:
    a. Measure the length of each longitudinal crack throughout the test section and assess the total crack length.
    b. Count the number of the cracks throughout the test section.
    c. Calculate the AVG and STDEV.
2. % Coverage: Calculate the ratio of the total crack length to the length of test section.

Severity Levels (LTPP Guide)

- **Low**: a crack with a mean width ≤ 0.25 in. (6 mm); or a sealed crack with sealant material in good condition and with a width that cannot be determined.
- **Moderate**: any crack with a mean width > 0.25 in. (6 mm) and ≤ 0.75 in. (19 mm); or any crack with a mean width ≤ 0.75 in. (19 mm) and adjacent low severity random cracking.
- **High**: any cracks with a mean width > 0.75 in. (19 mm); or any crack with a mean width ≤ 0.75 in. (19 mm) and adjacent moderate to high severity random cracking.

Figure B-6. Longitudinal Cracking.

RAVELING (AGGREGATE LOSS)

Definition

Progressive disintegration of the surface by the dislodging of aggregate particles due to stripping and by the loss of asphalt binder due to hardening, as presented Figure B-7.

Figure B-7. Raveling.

How to Rate

1. Raveling is rated as the percentage (%) of the test section's total surface area.
2. % Coverage: the ratio of the affected surface area to the total surface area of test section.

Severity Levels (TxDOT PMIS)

- **Low**: 1–10 of % coverage.
- **Moderate**: 11–50 of % coverage.
- **High**: > 50 of % coverage.

BLEEDING (FLUSHING)

Definition

Excess bituminous binder occurring on pavement surface, usually found in the wheel paths, which creates a shiny, glass-like, reflecting surface that usually becomes sticky (due to high AC or low air void content), as presented Figure B-8.

Figure B-8. Bleeding (Flushing).

How to Rate

Bleeding is rated as the percentage (%) in each wheel path through the test section.

1. Measure the total length of affected area throughout each wheel path on the test section.
2. Calculate the % coverage by the ratio of the total affected length to the length of wheel paths of test section (i.e., 2 × length of test section).

Severity Levels (TxDOT PMIS)

- **Low**: 1–10 of % coverage.
- **Moderate**: 11–50 of % coverage.
- **High**: > 50 of % coverage.

PATCHING

Definition

Portion of pavement surface that has been removed and replaced or additional material applied to the pavement after original construction, as presented Figure B-9.

Figure B-9. Patching.

How to Rate

Patching is rated according to the percentage of the total surface area of test section. All patching measured throughout the test section is converted to full lane-width patching.

1. Measure the length of each patching through the test section and assess the total length of patching.
2. Calculate the % coverage by the ratio of the total length of patching to the length of test section.

Severity Levels (LTPP Guide)

- **Low**: Patch has, at most, low severity distress of any type including rutting < 0.25 in.; pumping is not evident.
- **Moderate**: Patch has moderate severity distress of any type or rutting from 0.25 in. to 0.5 in.; pumping is not evident.
- **High**: Patch has high severity distress of any type including rutting > 0.5 in., or the patch has additional different patch material within it; pumping may be evident.