Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA/TX-12/0-6658-1		

4. Title and Subtitle	5. Report Date
TEXAS FLEXIBLE PAVEMENTS AND OVERLAYS: YEAR 1 REPORT – TEST SECTIONS, DATA COLLECTION, ANALYSES, AND DATA STORAGE SYSTEM	November 2011 Published: June 2012
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
Lubinda F. Walubita, Gautam Das, Elida Espinoza, Jeongho Oh, Tom Scullion, Sang Ick Lee, Jose L. Garibay, Soheil Nazarian, and Imad Abdallah	Report 0-6658-1
9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
Texas Transportation Institute The Texas A&M University System College Station, Texas 77843-3135 Center for Transportation Infrastructure Systems The University of Texas at El Paso, El Paso, Texas 79968-0582	11. Contract or Grant No. Project 0-6658
12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
Texas Department of Transportation Research and Technology Implementation Office P. O. Box 5080 Austin, Texas 78763-5080	Technical Report: November 2010–September 2011
	14. Sponsoring Agency Code

15. Supplementary Notes

Project performed in cooperation with the Texas Department of Transportation and the Federal Highway Administration.
Project Title: Collection of Materials and Performance Data for Texas Flexible Pavements and Overlays
URL: http://tti.tamu.edu/documents/0-6658-1.pdf

16. Abstract

This five-year project was initiated to collect materials and pavement performance data on a minimum of 100 highway test sections around the State of Texas, incorporating both flexible pavements and overlays. Besides being used to calibrate and validate mechanistic-empirical (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.

Towards this goal, this interim report provides a documentation of the work completed in Year 1 of the project including the following: 1) literature review; 2) development of data collection and analysis plans, and 3) field test sections. The MS Access Data Storage System, used for storing and accessing the collected data, is also discussed in this interim report.

17. Key Words	18. Distribution Statement
HMA, Flexible Pavements, Overlays, MS Access, Data Storage System, Test Section, M-E Model	No restrictions. This document is available to the public through NTIS: National Technical Information Service Alexandria, Virginia 22312 http://www.ntis.gov

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	168	

Form DOT F 1700.7 (8-72) **Reproduction of completed page authorized**

TEXAS FLEXIBLE PAVEMENTS AND OVERLAYS: YEAR 1 REPORT – TEST SECTIONS, DATA COLLECTION, ANALYSES, AND DATA STORAGE SYSTEM

by

Lubinda F. Walubita
Associate Transportation Researcher
Texas Transportation Institute

Gautam Das
Associate Transportation Researcher
Texas Transportation Institute

Elida Espinoza
Student Worker
Texas Transportation Institute

Jeongho Oh
Assistant Research Engineer
Texas Transportation Institute

Sang Ick Lee
Assistant Transportation Researcher
Texas Transportation Institute

Tom Scullion
Senior Research Engineer
Texas Transportation Institute

Jose L. Garibay
Researcher
Center for Transportation Infrastructure Systems

Soheil Nazarian, Ph.D., P.E.
Center Director
Center for Transportation Infrastructure Systems

Imad Abdallah, E.I.T.
Associate Director
Center for Transportation Infrastructure Systems

Report 0-6658-1
Project 0-6658
Project Title: Collection of Materials and Performance Data for Texas Flexible Pavements and Overlays

Performed in cooperation with the
Texas Department of Transportation
and the Federal Highway Administration

November 2011
June 2012

TEXAS TRANSPORTATION INSTITUTE
The Texas A&M University System
College Station, Texas 77843-3135

CENTER FOR TRANSPORTATION INFRASTRUCTURE SYSTEMS
University of Texas at El Paso
El Paso, Texas 79968-0582

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 here. 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 United States Government and the State of Texas do not endorse products or manufacturers. Trade or manufacturers' names appear here solely because they are considered essential to the object of this report. The researcher in charge was Lubinda F. Walubita.

ACKNOWLEDGMENTS

This project was conducted for TxDOT, and the authors thank TxDOT and FHWA for their support in funding this research project. In particular, the guidance and technical assistance of the project director (PD) Brett Haggerty, of TxDOT, proved invaluable. The following project advisors also provided valuable input throughout the course of the project and their guidance is duly acknowledged: David Debo, Todd Copenhaver, Jaime Gandara, Stephen Guerra, Joe Leidy, Mark McDaniel, Jerry Peterson, and Billy Pigg.

Special thanks are also extended to the following people for their assistance with the literature review: Hossain A. Tanvir (TTI), Rubayyat Hashmi (TTI), Fujie Zhou (TTI), Sheng Hu (TTI), Tom Freeman (TTI), Lee Gustavus (TTI), Carlos Albitres Chang (UTEP), Manuel Celaya (UTEP), and Jose Garibay (UTEP).

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF NOTATIONS AND SYMBOLS

AASHTO	American Association of State Highway and Transportation Officials
AC	Asphalt-binder content
ALF	Accelerated loading facility
APT	Accelerated pavement testing
Avg	Average
BBR	Bending beam rheometer
CTB	Cement treated base
CV (or COV)	Coefficient of variation
DC	Dry-cold climatic region
DCP	Dynamic Cone Penetrometer
DSR	Dynamic shear rheometer
DW	Dry-warm climatic region
EB	Eastbound
FFRC	Free-free resonant column
FWD	Falling weight deflectometer
GPR	Ground penetrating radar
GPS	Global positioning system
GPS	General pavement studies (when used with respect to the LTPP database)
HMA	Hot-mix asphalt
HMAC	Hot-mix asphalt concrete
HWTT	Hamburg Wheel-tracking test
IDT	Indirect tension test
IR	Infrared
LTTP	Long-term pavement performance
LTRC	Louisiana Transportation Research Center
M	Moderate or mixed climatic region
M-E	Mechanistic-empirical
MTD	Material transfer device
MDD	Multi-depth deflectometer

MSCR	Multi stress creep and recovery
NB	Northbound
NDT	Non-destructive test(ing)
NMAS	Nominal maximum aggregate size
OT	Overlay Tester
PAV	Pressure aging vessel
PCC	Portland concrete cement
PG	Performance grade
PM	Plant-mix
PMC	Project monitoring committee
PMIS	Pavement management information system
PP	Perpetual pavement
QA	Quality assurance
QC	Quality control
RAP	Recycled asphalt pavement
RAS	Recycled asphalt shingles
RTFO	Rolling thin film oven
SB	Southbound
SPS	Special pavement studies (when used with respect to the LTPP database)
Stdev	Standard deviation
TxDOT	Texas Department of Transportation
UCS	Unconfined compressive strength
WB	Westbound
WC	Wet-cold climatic region
WP	Wheel path
WW	Wet-warm climatic region
ε_t	Horizontal tensile strain measured in microns ($\mu\varepsilon$)
ε_v	Vertical compressive strain measured in microns ($\mu\varepsilon$)
ϕ	Symbol phi used to mean diameter
α	Thermal coefficient

CHAPTER 1
INTRODUCTION

Proper calibration of pavement design and rehabilitation performance models to conditions in Texas is essential for cost-efficient flexible pavement design. The degree of excellence with which TxDOT's pavement design models are calibrated will determine how optimally literally billions of dollars of future roadway investment capital will be spent. The magnitude of benefits and consequences involved make this research project one of the more important research efforts the department has undertaken in recent memory.

Collection of quality and reliable pavement performance data on a sustained basis will thus be the main goal of this project. Inevitably, this presents a perfect opportunity to calibrate and validate the current design methods and models for both flexible pavement and overlays. The calibration of these models to the Texas local conditions will result in pavement designs that are more economical in the long term and that have an increased likelihood of performing as expected.

PROJECT OBJECTIVES

The primary objective of this project is to collect materials and pavement performance data on a minimum of 100 highway test sections around the State of Texas. Besides being used to calibrate and validate mechanistic-empirical (M-E) design models, the data will also serve as an ongoing reference data source and/or diagnostic tool for TxDOT engineers and other transportation professionals. Some of the M-E Structural Design Systems to be calibrated under this research project include the following:

- The Flexible Pavement Design System (FPS) design procedure.
- The Texas M-E (TxM-E).
- The Texas Overlay design system.
- The AASHTO Mechanistic-Empirical Pavement Design Guide (M-E PDG).

WORK PLAN AND RESEARCH TASKS

The scope of work to accomplish these objectives will include, but is 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 an MS Access Data Storage System.
- M-E model calibration and validation.
- Demonstration workshop of the data collected.
- Characterization of test section traffic

Figure 1-1 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 data demonstration. This aspect will be covered in Year 1 of the project and is the primary focus of this interim report.
2) Phase II–Data collection. This task will constitute the bulk workload of the whole project and will run for the duration of the project. The tasks incorporate extensive field and laboratory testing to generate data for inputting into the MS Access Data Storage System.
3) Phase III–Model calibration. To be run in Year 3 through Year 5 of the study, this phase will focus on calibrating and validating the M-E Structural Design Systems. It will be executed in liaison with Project 0-6622 (Zhou, 2011).
4) Phase IV–Project management, data demonstration, and report writing. Under the task 'project management,' progress meetings will be held annually to monitor progress and provide updates on the project. In the final year of the project, a workshop will then be held to demonstrate the data collected.

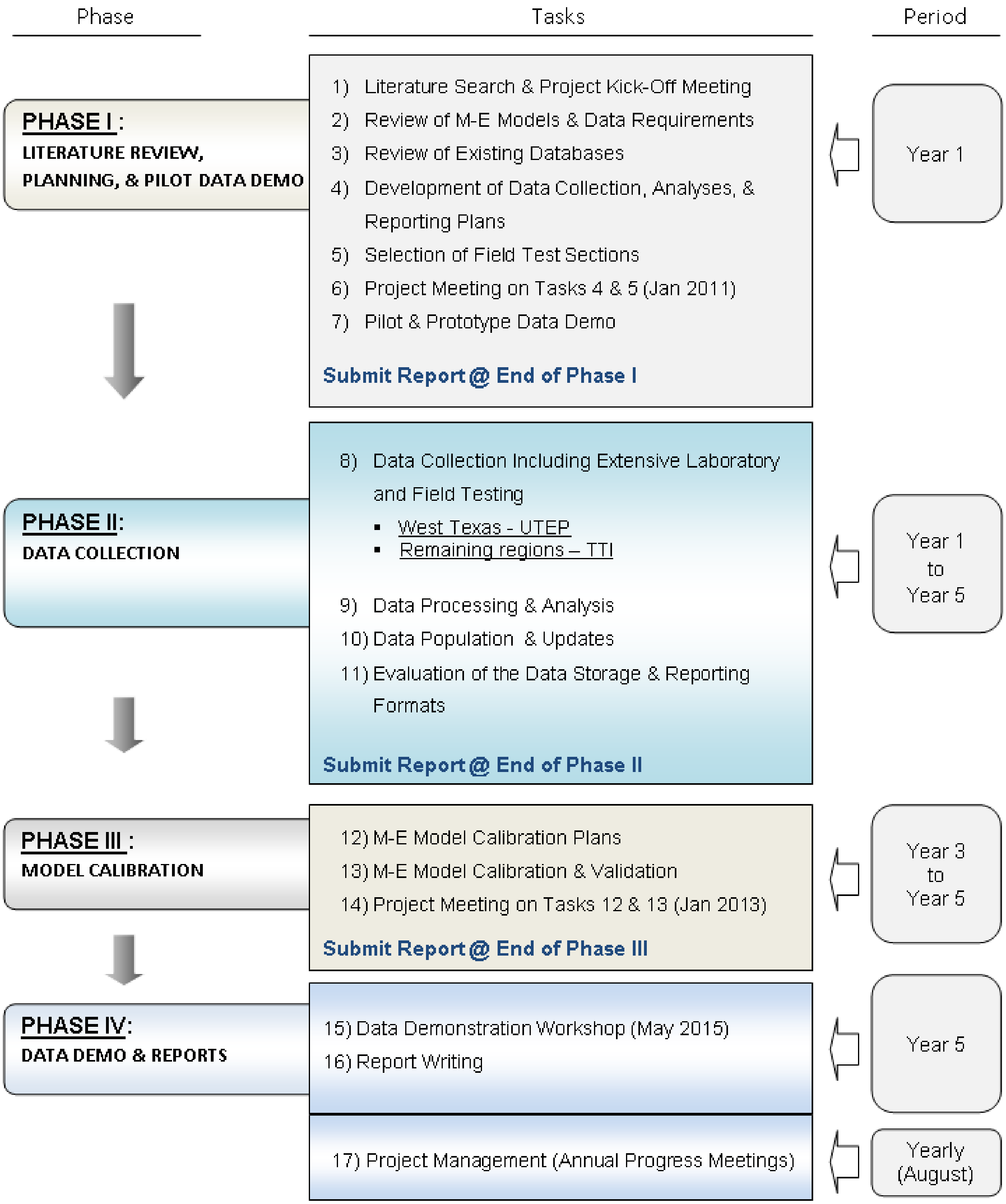


Figure 1-1. Work Plan and Research Tasks.

SCOPE OF WORK AND REPORT CONTENTS

Based on the work plan shown in Figure 1-1, the primary objective of this interim report is to document the work completed in Year 1 of this project, focusing on Phase I work. Itemized as Task 1 through 7 in Figure 1-1, the main scope of work covered under Phase I (Year 1) is:

- Data search and literature review (M-E Structural Design Systems and existing databases).
- Planning–development of data collection plans, data analyses, and reporting plans.
- Development and formulation of laboratory and field tests.
- Formulation of traffic and climatic data collection and analyses plans.
- Selection of field test sections.
- Development of a pilot and prototype MS Access Data Storage System.

While Phase I of the work plan (Figure 1-1) is the primary focus of this interim report, some aspects of Phase II work (data collection) are also presented and discussed in this interim report. These aspects include the following:

- Task 8–Data collection including laboratory and field testing.
- Task 9–Data processing and analyses.
- Task 10–Data population and updating of the pilot MS Access Data Storage System.
- Task 11–Development of a preliminary evaluation and quality check system for the MS Access Data Storage System.

Specifically, the Year 1 work focused on:

- Development of the data collection plans and material sampling.
- Formulation of the criteria for selecting the field test sections.
- Selection of the field test sections and conducting trial testing.
- Development of a pilot MS Access Data Storage System.

Towards these goals, researchers completed a comprehensive review of the M-E Structural Design Systems and the existing databases to aid in the development of the data collection plans and subsequent itemization of the critical data (i.e., type, format, etc.) to be collected. They developed a matrix table to aid in the selection and tracking of the field test sections to ensure wide coverage in terms of pavement type, traffic level, environmental location, etc.

REPORT LAYOUT AND ORGANIZATION

This interim report consists of 11 chapters including this one (Chapter 1) that provides the background, research objectives, methodology, and scope of work. Chapter 2 is the literature review and provides an overview of the review results of the M-E Structural Design Systems and the existing databases. Chapters 3 through 8 are the main backbone of this interim report and cover the following key items:

- Chapter 3–Field test sections.
- Chapter 4–Laboratory testing.
- Chapter 5–Field testing.
- Chapter 6–Traffic data collection.
- Chapter 7–Climatic and environmental data collection.
- Chapter 8–The MS Access Data Storage System.

Chapter 9 is a summation of the interim report with a list of the major findings and recommendations. Ongoing and future planned works are discussed in this chapter. Some appendices containing important data are also included at the end of the report. A CD of the latest prototype (demo) MS Access Data Storage System is also included as integral part of this interim report.

SUMMARY

In this introductory chapter, the background and the research objectives were discussed. The research methodology and scope of work were then described, followed by a description of the report contents. Specifically, this interim report provides a documentation of the work accomplished in Year 1 of the project. In particular, the report focused on Phase I work, which includes literature review, planning, preliminary data collection, and development of a pilot MS Access Data Storage System.

CHAPTER 2
LITERATURE REVIEW

To aid in the development of the data collection plans and itemization of the critical data types to be collected, researchers completed a review of the M-E Structural Design Systems and the existing database system. This chapter presents a discussion of the review results and a summary to highlight the key findings.

REVIEW OF M-E STRUCTURAL DESIGN SYSTEMS

As an integral part of developing the data collection plans, researchers completed a review of the M-E Structural Design Systems, with a particular emphasis on the Data Requirements. This was necessary to ensure that all the critical data items, including the input parameters and output data (distresses), are incorporated in the data collection plans. Additionally, Phase III of this project involves calibration and validation of these M-E Structural Design Systems; hence, the need to know their input data requirements.

Accordingly, the following four M-E Structural Design Systems were reviewed, including the associated software, and are discussed in the subsequent text of this chapter. Appendix A lists the required input parameters and output data for each M-E model.

- The Flexible Pavement System, FPS 19 and 21 W.
- The Texas M-E system (TexM-E).
- The Texas Overlay design and analysis system (TxACOL).
- The M-E pavement design guide (M-E PDG).

The Flexible Pavement System, FPS 19 and 21 W

The Flexible Pavement System, FPS 19 and 21W, are M-E based software that TxDOT traditionally uses for conventional flexible hot mix asphalt (HMA) pavement design. It can be used for:

- Pavement structural design.
- Overlay design.
- Pavement life prediction (cracking/rutting).
- Stress-strain response analysis.

Figure 2-1 shows the FPS 21 software main screen.

Figure 2-1. The FPS 21 Software Main Screen.

The design approach is based on a linear-elastic analysis system; back-calculated FWD modulus values of the pavement layers are used as the key material input property. The user can automatically select the materials and the moduli preferences in the user interface, giving the user a wide range of design options. Thus, the software is very user-friendly and directly generates the pavement layer thickness designs (Walubita et al., 2010).

Appendix A lists the details of the input parameters and output data (distresses) that were reviewed and itemized for incorporation into the data collection plans. The FPS is one of the key M-E Structural Design Systems and associated software to be calibrated and validated in this study. Itemization of the required input and output data was very critical in developing the data collection plans.

The Texas M-E System (TexM-E)

This system is still under development in Study 0-6622 (Zhou 2011). Therefore, review of this system and the associated M-E Structural Design Systems was conducted in close liaison and consultation with the researchers from Study 0-6622. Appendix A lists the preliminary review results of the expected input parameters and output data. As noted in that Appendix, this system is expected to cover various pavement types including the following:

- Thin pavements (≤ 3 inch HMA).
- Regular pavements (> 3 inch HMA).
- Perpetual pavements (Walubita 2011a).

However, it should be emphasized that the TexM-E is still under development and/or modification in Study 0-6622 and as such, review of the M-E Structural Design Systems associated with this system will continue as an ongoing process. Therefore, even the list of the input parameters and output data shown in Appendix A is subject to change.

The Texas Overlay Design and Analysis System (TxACOL)

As the name suggests, the Texas Overlay Design and Analysis System (TxACOL) is used for overlay design and analysis, both over flexible and rigid pavements. The software mainly takes the general project information (including the analysis parameters and criteria) and three input categories, namely: 1) traffic, 2) climate, and 3) structural and material properties as the key input data to execute the reflective crack and rutting prediction analysis. Figure 2-2 illustrates the main screen of the TxACOL software.

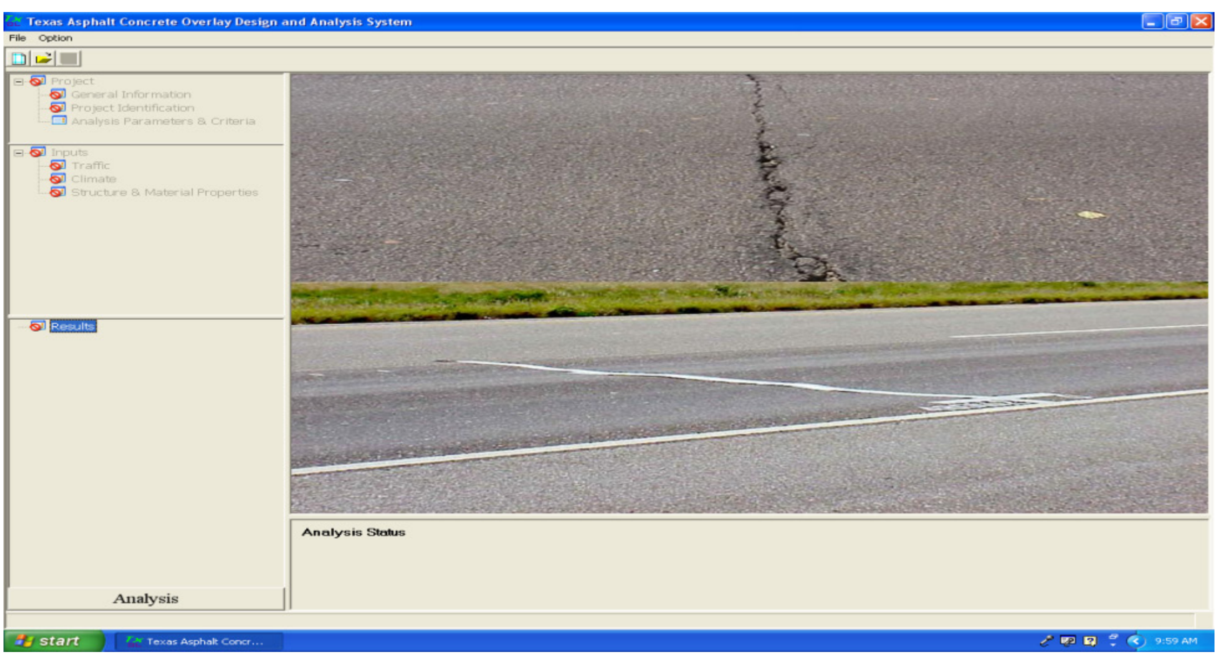


Figure 2-2. The TxACOL Software Main Screen.

During execution, the software creates a summary of all the input data, results, distresses, and performance predictions, in tabular and graphical formats, respectively. Input and output parameters were reviewed and itemized for incorporation into the data collection plans (Chapter 3).

Appendix A notes that the TxACOL system covers various overlay types including the following:

- AC over (PCC) over (CTB).
- AC over PCC over flex (granular) base.
- AC over AC over CTB.
- AC over AC over flex (granular) base.

Full details of this software and the associated M-E Structural Design Systems can be found in other publications (Walubita 2011a).

Like the TexM-E, the TxACOL is also still under modification and implementation in Study 0-5123 (Zhou et al. 2009). As such, review of this software and the associated M-E Structural Design Systems will be an ongoing process and the data items listed in Appendix A will also be modified accordingly.

The M-E Pavement Design Guide (M-E PDG)

The M-E PDG Version 1.1 is an M-E-based analytical software for pavement structural design analysis and performance prediction, within a given service period (AASHTO, 2009). Figure 2-3 shows a pictorial illustration of the M-E PDG Version 1.1 main screen. The researchers are aware that the next generation of M-E PDG; DARWin-ME™ is available from March 2011.

Figure 2-3. The M-E PDG Software Main Screen.

The M-E PDG design procedure is primarily based on pavement performance predictions evaluated against user-specified acceptable levels of distress. However, unlike the FPS, the M-E PDG does not directly generate pavement layer thickness designs. Instead, trial pavement layer thicknesses/combinations are iteratively put into the software and the thicknesses/combinations that meet the prescribed performance criteria are selected as the final designs. The performance predictions include permanent deformation, rutting, cracking (bottom-up and top-down), thermal fracture, and surface roughness (IRI).

Like the other M-E Structural Design Systems and the associated software, the M-E PDG was also reviewed and all the input parameters and output data (distresses) were itemized for incorporation in the data collection plans and subsequent calibration/validation. However, the calibration and validation processes (Phase III) will focus on the first three M-E Structural Design Systems and the associated software, namely the FPS, TxACOL, and TexM-E.

In summary, for each M-E model and associated software that was reviewed, the required input parameters (such as pavement structure data, material properties, traffic data, climate) and output response parameters (i.e., distresses such as rutting, cracking, mechanistic responses, etc.) were listed in MS Excel® Spreadsheets, which are included in this interim report as Appendix A. This review of the M-E Structural Design Systems was a very critical step in ensuring that all the input parameters and output data necessary for calibrating and validating the M-E Structural Design Systems, as well as running the associated software, is incorporated in the data collection plans.

REVIEW OF EXISTING DATABASES

To strengthen the data collection plans, a comprehensive review of some of the currently existing databases in Texas and other state agencies was also conducted to help the researchers plan for the most appropriate data storage system and reporting format. That is, these existing databases served as a reference guide for developing the data storage system as well as assessing the data type and format of collecting the data for this study.

Additionally, this review task was also necessary to evaluate if some of the information from these existing databases could be used in this study. Accordingly, the researchers reviewed and discussed the four databases in the subsequent text. Appendix B of the interim report gives detailed review results for:

- The UT Flexible Pavement Database (FPDB).
- The Texas Perpetual Pavement (PP) Database.
- The Texas Successful Flexible Pavement (TSFP) Database.
- The long-term pavement performance (LTPP) Database.

The UT Flexible Pavement Database (TFPDB), Namely Product 0-6275-P1

Researchers conducted a comprehensive review of the UT database (FPDB), namely Product 0-6275-P1 (Prozzi 2010). Figure 2-4 shows the main user interface screen for this database.

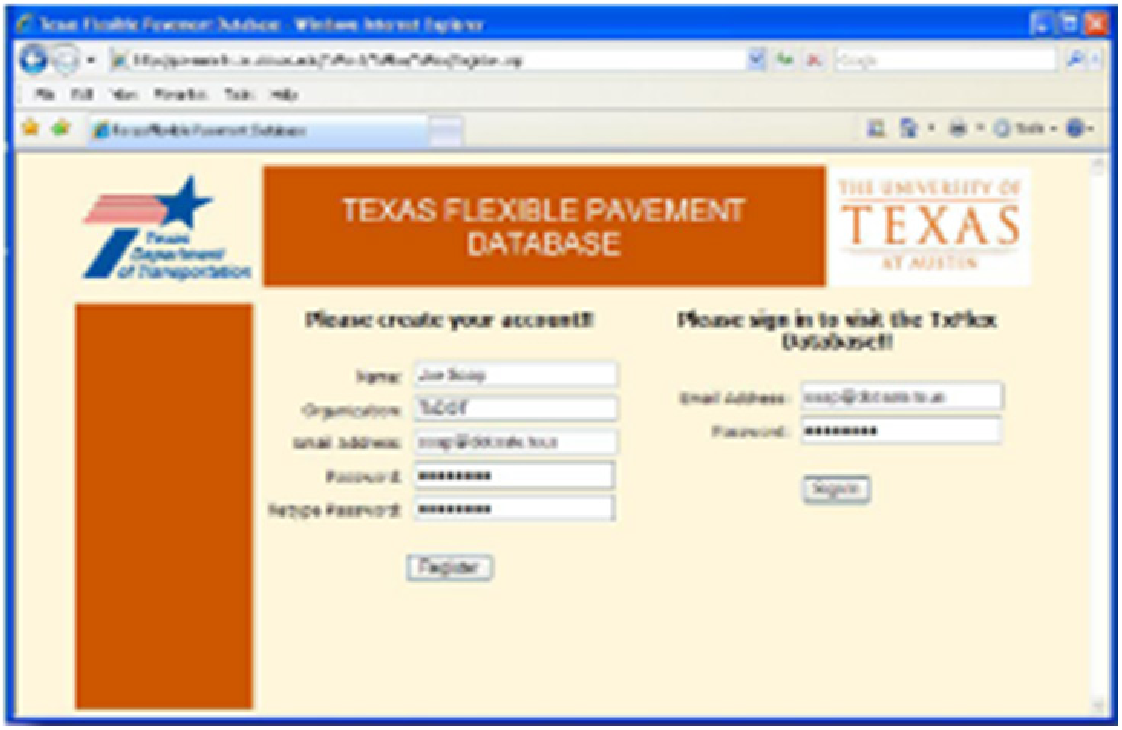


Figure 2-4. The User Interface Screen for the FPDB Database.

While the detailed review results are included in Appendix B, the key attributes of this database include the following:

- The database is web-based and GIS oriented.
- The database has 38 sections, with 32 directly imported from the LTPP database.
- The database covers only six Texas districts: Austin, Bryan, El Paso, San Antonio, Tyler, and Waco.
- The database covers four climatic regions: Wet-Cold, Dry-Warm, Wet-Warm, and Mixed. Dry-Cold was not covered.
- Most of the basic information such as design data, construction data, material properties, periodic performance data, etc., is either nonexistent or incomplete.

Overall, while the database interfacial framework and accessibility attributes may be of help to this study, the actual data content or highway sections will be of little value. Nonetheless, periodic referral will be made for any potential information that may be helpful to this study.

The Texas Perpetual Pavement (PP) Database

TTI developed this database, which has a total of 10 PP sections with comprehensive data content including design, climate, traffic, construction, material properties, periodic performance, and raw data files (see Appendix B [Walubita et al., 2010]). Figure 2-5 shows the user-interface screen for the Texas PP database.

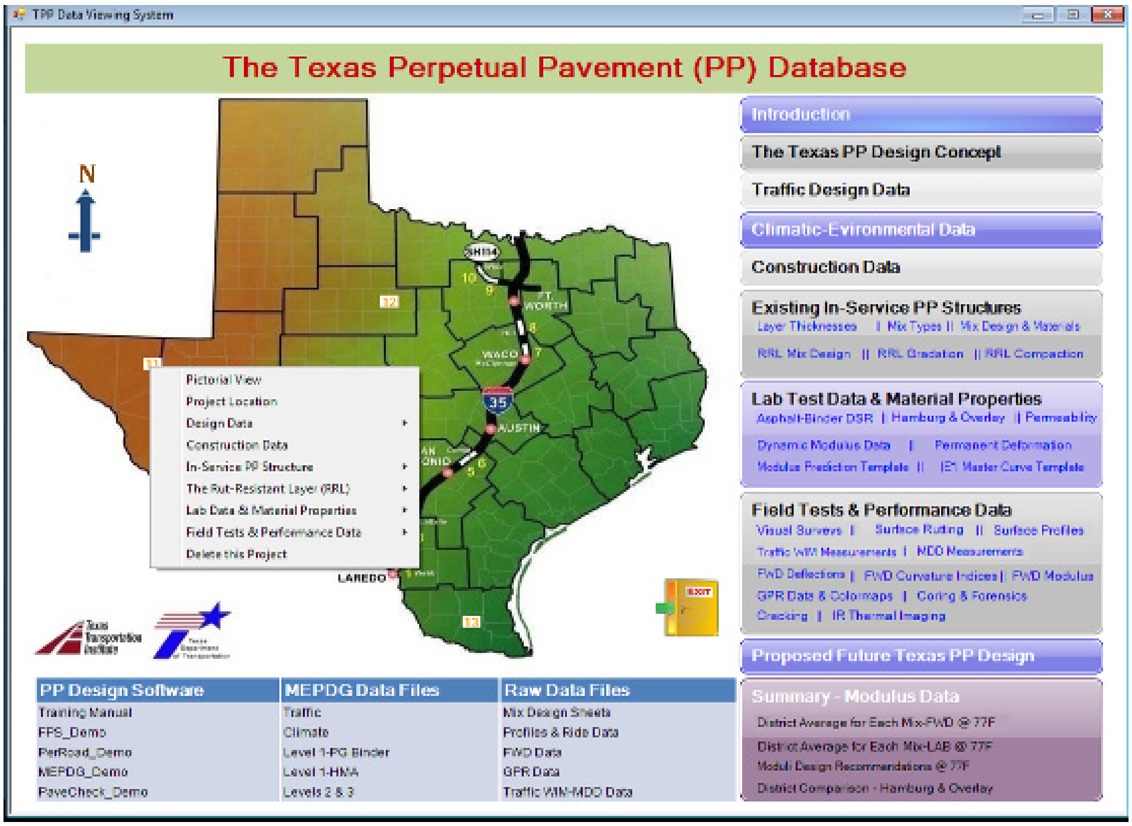


Figure 2-5. The User Interface Screen for the Texas Perpetual Pavement Database.

Overall, this database contains valuable information that is also useful to this study. The highway sections (namely, PP structures) will be integrated into this study as existing field test sections. Specifically, these PP sections are very critical in the calibration and validation processes of the TexM-E Structural Design Systems and its associated software, to be undertaken in Year 3 of this study. From this database, using highway sections that are primarily located on IH 35 and SH 114 may require additional base/subgrade soil sampling and testing along with continued periodic performance monitoring. So, liaison with the respective districts will be a critical aspect for the integration of some of the highway sections.

The Texas Successful Flexible Pavement (TSFP) Database

This database is web-based with 80 highway sections, of which the local TxDOT offices approved only 26 and nominated 54; see Figure 2-6 (Krugler et al. 2007).

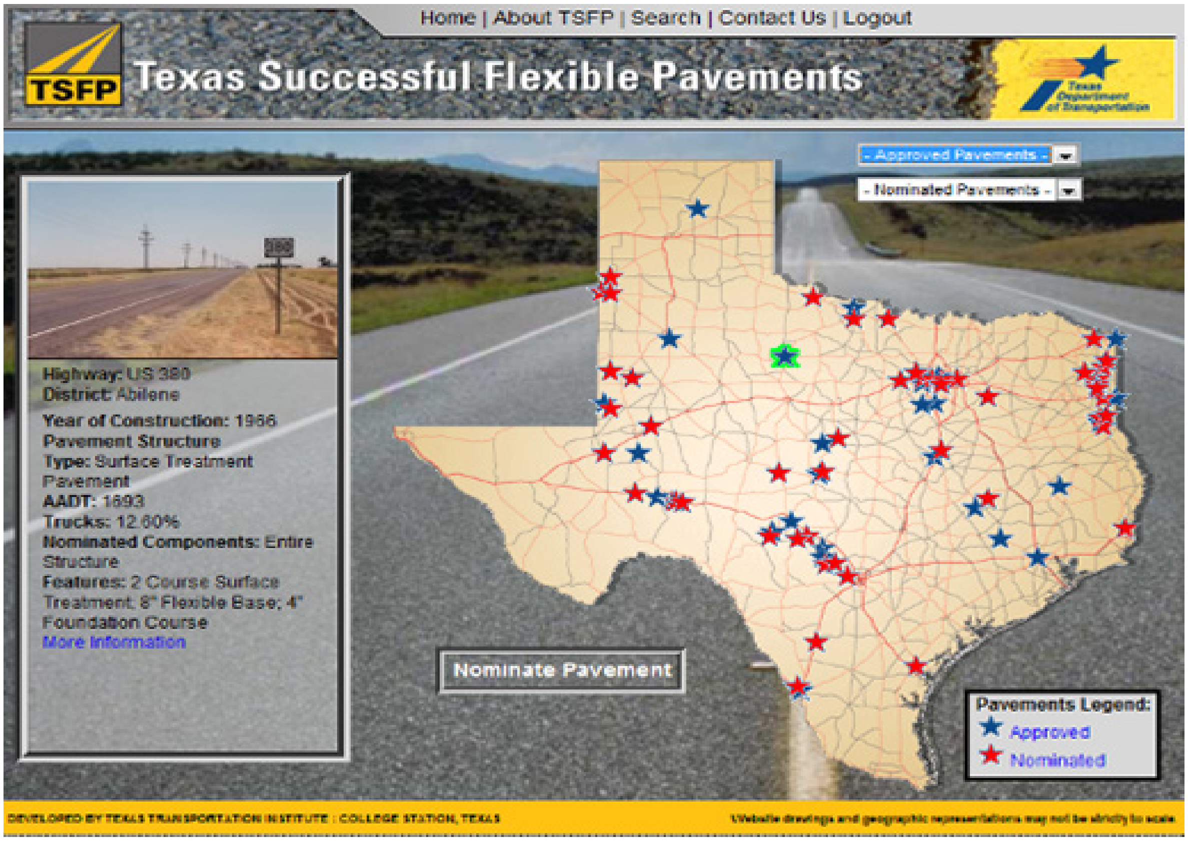


Figure 2-6. The User Interface Screen for the TSFP Database.

Appendix B shows that this database has very scant data that will provide only minimal input to this study. For instance, it has no lab test data or periodic performance data such as rutting progression, other than the condition scores obtained from the PMIS. However, the interfacial framework may be of help when formulating the database framework for this study.

The LTPP Database

This database is web-based with 58 general pavement studies (GPS) and 127 special pavement studies (SPS) highway sections scattered across the nation. Appendix B indicates that the database has limited data with several critical data items such as structural design, mix-design, material properties (i.e., dynamic modulus, permanent deformation, DSR, etc.), traffic (i.e., load spectrum), and performance (i.e., FWD moduli values) unavailable for most of the highway sections. Nonetheless, both the interfacial framework and some highway sections, such as SH 94 (Angelina County with sufficient data) in Texas, may be helpful to this study. Figure 2-7 has an example of the online data content from the LTTP database; Figures 2-8 and 2-9 show the LTTP highway sections in Texas.

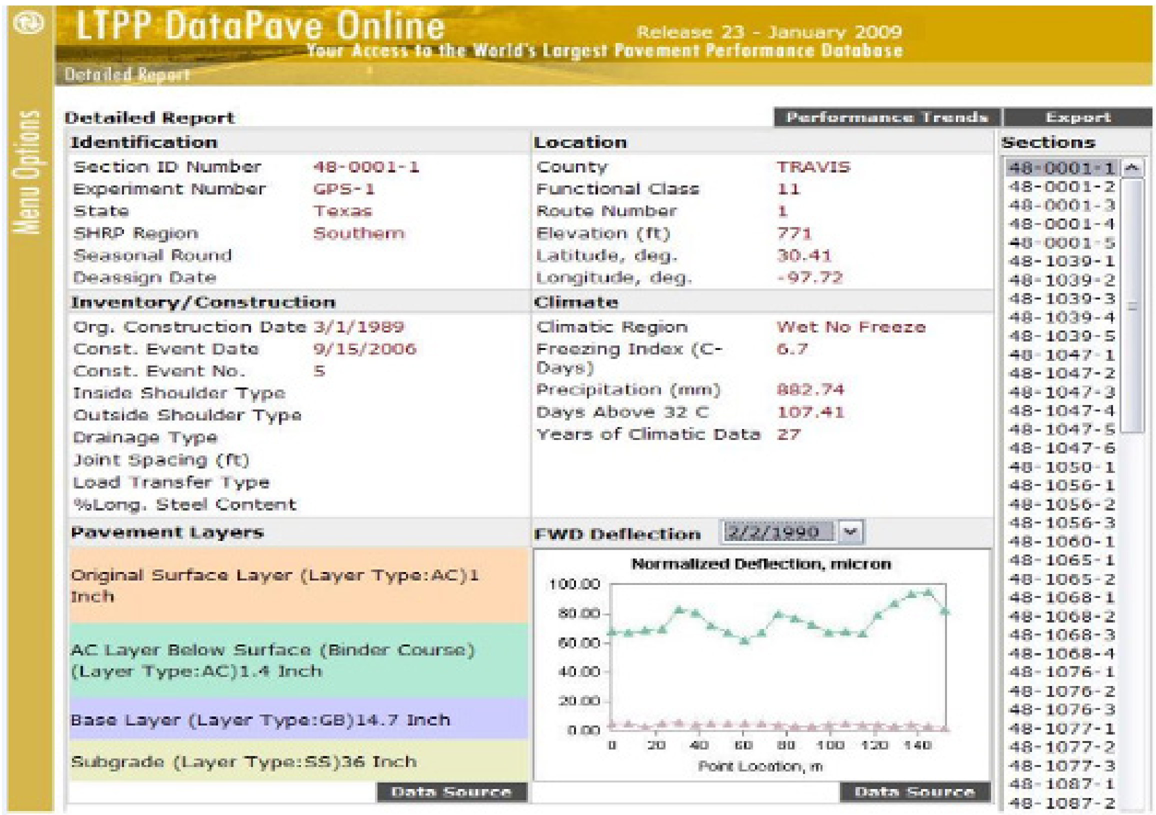


Figure 2-7. The LTPP Database.

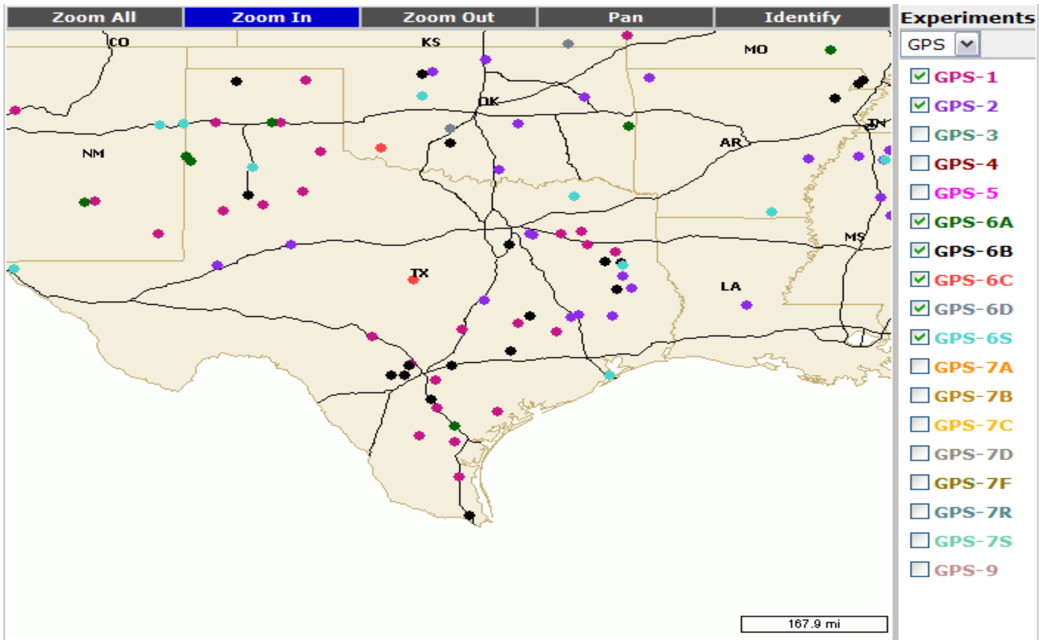


Figure 2-8. LTPP GPS Flexible Pavement Sections Located in Texas.

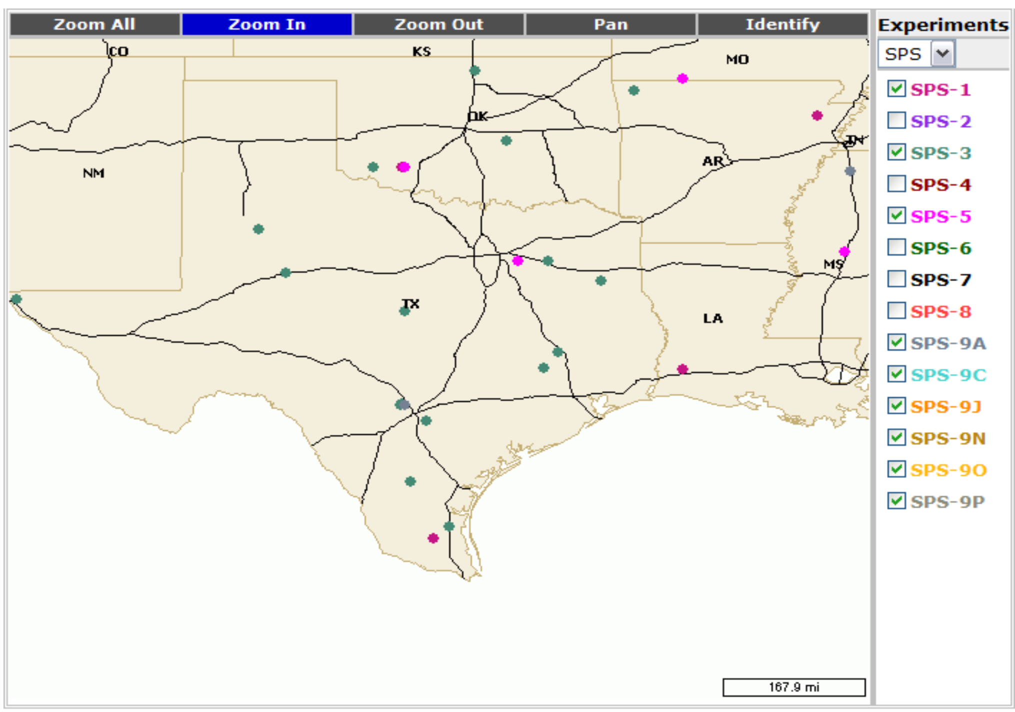


Figure 2-9. LTPP SPS Flexible Pavement Sections Located in Texas.

If sufficient data are available, some of the highway sections shown in Figures 2-8 and 2-9 may be considered for incorporation into this study.

All these existing databases discussed in this chapter will be periodically referenced and constantly reviewed during the course of this study for any potential data found to be valuable. Detailed Excel spreadsheets of the review results of the existing databases are included in Appendix B, as well in the included CD.

SUMMARY

This chapter reviewed four types of M-E Structural Design Systems and the associated software and four existing databases, namely:

- The Flexible Pavement System, FPS 19 and 21 W.
- The Texas M-E system (TexM-E).
- The Texas Asphalt Concrete Overlay design and analysis system (TxACOL).
- The AASHTO M-E pavement design guide (M-E PDG).
- The UT database (Product 0-6275-P1).
- The Texas Perpetual Pavement (PP) database.
- The Texas Successful Flexible Pavement (TSFP) database.
- The LTPP database.

The primary goal of the review task discussed in this chapter was to create a link for the development of data collection plans through: 1) itemization of the M-E structural design data requirements, and 2) formulation of the data storage and report system. Appendices A and B, and the included CD, have the details of the review results.

CHAPTER 3
FIELD TEST SECTIONS

The following items are discussed here, with a summary of key points provided at the end of the chapter:

- The criteria and procedure for selecting the test sections.
- The characteristics and identification of the test sections.
- Tests prior to and during test section selection.
- Coring and material sampling.
- Field test sections to date.

As discussed in Chapter 1, this study calls for the selection of a minimum of 100 highway test sections around Texas that incorporates both flexible pavements and overlays. As shown in Figure 3-1, the climatic distribution of the test sections is:

- UTEP ≥ 30 test sections (DC climatic region)*.
- TTI ≥ 70 test sections (DW, M, WC, and WW climatic regions)*.

*DC = dry-cold, DW = dry-warm, M = moderate; WC = wet-cold; WW = wet- warm.

This distribution of the test sections between UTEP and TTI was based mainly on the resource capacity in terms of facilities, equipment, and personnel. Additionally, UTEP is located in West Texas and, therefore, it was deemed very practical for them to handle the test sections in this climatic region. However, the major economic zone in terms of transportation activities is in the central part of Texas covering the M, WC, and parts of DC and WW climatic regions. That is why the majority of the test sections will be selected from these regions.

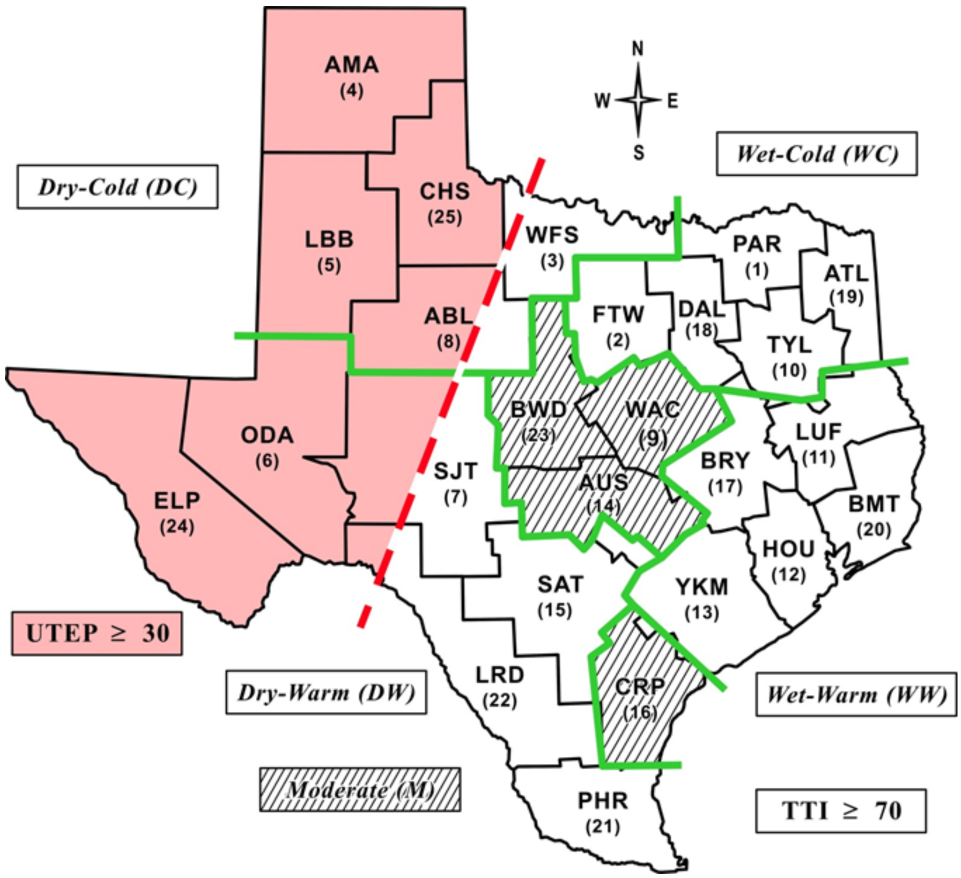


Figure 3-1. Climatic Distribution of the Test Sections between UTEP and TTI.

THE CRITERIA AND PROCEDURES FOR SELECTING TEST SECTIONS

To ensure that all the influencing variables are accounted for, the criteria for selecting the test sections incorporate the factors listed in Table 3-1. In summary, the test sections should not, for instance, be only Overlays or new construction. The coverage should be as broad as possible to cover all the factors in Table 3-1. Otherwise, it will not be feasible to effectively calibrate and validate the M-E Structural Design Systems. So, it is very critical for the researchers ensure that the 100 test sections equitably cover the variables listed in Table 3-1, as well as consider monitoring distress progression that are stipulated in Study 0-6622 (Zhou 2011).

Figure 3-2 shows that the five-step procedure for selecting the test sections involves close liaison with Study 0-6622 subject to TxDOT approval (Zhou 2011). This procedure was designed to ensure that all the stakeholders are involved and that the selected test sections meet their (stakeholders) needs and expectations, particularly Study 0-6622.

Table 3-1. Variables to Consider when Selecting Test Sections.

#	Variable	Minimum	Description	Comment
1	Pavement type	4	• HMA on HMA. • HMA on untreated granular bases. • HMA on treated base. • Surface treatment on untreated and/or treated base.	WMA, RAP, RAS, and perpetual pavements will also be considered.
2	Pavement category	4	• Perpetual. • Typical flexible HMA. • HMA overlay over HMA. • HMA overlay over PCC.	
3	Thickness	2	• Thin (≤ 3 inches). • Thick (> 3 inches).	
4	Traffic levels	2	• Low volume. • High volume.	Include Interstate, State, and Farm roads
5	Environmental types	5	• Dry-warm (DW). • Dry-cold (DC). • Wet-warm (WW). • Wet-cold (WC). • Moderate (mixed) (M).	
6	Age conditions	2	• New construction. • Existing construction.	

Step 1 Researchers (and/or the District) nominate Hwy sections

Step 2 Researchers collect all available existing data.

Step 3 Researchers submit to **Study 0-6622** for review/comments.

Step 4 Researchers submit to **PD/PMC** for review/approval

Step 5 If **APPROVED**, Researchers can then proceed with entry in Master Table & **Data Collection**.

Figure 3-2. Steps and Procedures for Selecting Field Test Sections.

To ensure adherence to the criteria and procedures listed in Table 3-1 and Figure 3-2, respectively, researchers formulated a matrix master table to monitor the test selection process and track the test sections. Table 3-2 shows the matrix master table at the time of this report.

Table 3-2. Matrix Master Table for Tracking Test Sections.

#	Section ID#	Hwy	PVMNT Type				PVMNT Thickness		Traffic Level		Climate-Environment					Age		PVMNT Category			
			A1	A2	A3	A4	B1	B2	C1	C2	D1	D2	D3	D4	D5	F1	F2	G1	G2	G3	G4
1	TTTI-TxDOT-00002	SH 114	√				√		√				√				√	√			
2	TTTI-TxDOT-00003	SH 114	√				√		√				√				√	√			
3	TTTI-TxDOT-00001	US 59	√					√					√			√				√	
4	TTTI-TxDOT-00010	IH 35	√				√		√		√						√	√			
5	TTTI-TxDOT-00011	IH 35	√				√		√		√						√	√			
6		IH 20						√					√			√					√
7		US 190	√						√					√		√				√	
8	TTTI-TxDOT-00007	SH 121	√																		
9	TTTI-TxDOT-00006	US 271						√		√			√			√					√
10	TTTI-TxDOT-00005	Loop 480		√			√		√		√					√			√		
11	TTTI-TxDOT-00004	IH 35		√			√		√						√	√			√		
12	TTTI-TxDOT-00008	US 82		√			√		√				√			√			√		
14	TxDOT_UTEP-00007	US 84 (Scurry)			√		√					√					√			√	
15		US 84										√					√				
16	TxDOT_UTEP-00012	FM 89										√					√				
17	TxDOT_UTEP-00010	US 287					√					√								√	
18	TxDOT_UTEP-00006	FM 1046			√			√				√					√				
19	TxDOT_UTEP-00001	SH 178		√			√				√					√					
20	TxDOT_UTEP-00002	US 62/180		√			√				√					√					
	TxDOT_UTEP-00003	US 62/180		√			√				√					√					
21		Loop 375		√			√				√					√					
22		Loop 375		√			√				√					√					
23		SP 276									√					√					
24	TxDOT_UTEP-00004	US 62			√		√				√					√			√		
25	TxDOT_UTEP-00005	US 70			√		√					√				√			√		
26		FM 37			√							√					√				
28	TxDOT_UTEP-00009	FM2255			√		√					√				√			√		
29		US 87										√					√				
30	TxDOT_UTEP-00008	IH 20 (Reeves)			√		√				√						√		√		
31	TxDOT_UTEP-00011	FM 2833				√		SC				√				√			√		
32	TxDOT_UTEP-00012	FM 89				√		SC				√				√			√		
33	TxDOT_UTEP-00013	SH 20	√				√				√						√			√	
100																					
Total			8	8	7	2	19	4	8	1	12	11	6	1	1	18	12	4	9	5	2

Legend:

A1 HMA on HMA
A2 HMA on Treated Base
A3 HMA on Granular Base
A4 Surface Treatment

B1 Thick
B2 Thin*, SC - Seal coat
C1 High
C2 Low

D1 DW - Dry Warm
D2 DC - Dry Cold
D3 WC - Wet Cold
D4 WW - Wet Warm
D5 M - Moderate (Mixed)

F1 New
F2 Old (existing)

G1 Perpetual
G2 Typical flexible HMA
G3 Overlay (AC-AC)
G4 Overlay (AC-PCC)

*For regular HMA pavements, thin refers to total HMA thickness less than 3 inches; For Overlays, thin refers to new HMA Overlays that are less than 2 inches in thickness.

Table 3-2 shows 31 test sections identified as potential candidates at the time of this interim report. In the variable 'Age,' an almost equal number of new and old (existing) Hwy sections have been identified. In the variable 'Climate-Environment,' more candidate Hwy sections still need to be identified in the WW and M climatic regions. So far, none of the identified surfaced-treated Hwy sections are currently programmed for construction; most existing surface treated pavements simply undergo periodic re-sealing.

However, identifying a Hwy test section and getting TxDOT approval does not automatically guarantee that it will be incorporated in this study. Final acquisition of a test section, despite TxDOT approval, is dependent on many factors including, but not limited to, the Districts and Contractors not always having well-defined or predictable construction or maintenance schedules. Therefore, not all the candidate Hwy sections approved in Table 3-2 will actually be used in this study.

LENGTH AND CHARACTERISTICS OF TEST SECTIONS

As per TxDOT recommendations, researchers will use one 500-ft test section per homogeneous pavement structure, preferably in the outside lane. In cases where the pavement is structurally homogeneous, but other variables such as traffic or age are different, then more than one 500-ft test section may be used from such a highway project. For a candidate section, if the pavement structure varies, such as the number of layers, layer thickness, or materials composition within a highway segment varies, then more than one 500-ft test section may be used. Examples of these scenarios include the following:

- SH 114 (Fort Worth District, Wise County)—same traffic level, environment, and PP structure but two different materials. Two test sections were thus selected: one with SFHMA mix designs, and the second with traditional dense-graded mix designs.
- US 59 (Atlanta District, Panola County)—same traffic level and environment but different overlay structures: one with Petromat® interlayer, another with TruPave® interlayer, and the third, without any interlayer material (denoted as Control). Therefore, three test sections were selected representing Petromat®, TruPave®, and the conventionally constructed Control section.

MARKING AND IDENTIFICATION OF TEST SECTIONS

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

- Painting (white or orange paint) on the shoulders—test section start and end points.
- GPS coordinates—test section start and end points.
- Existing mile marker signs—test section start and end points.
- Offsets from physical landmarks such as intersections, etc.—test section start and end points.
- Road signs—at test section start and end points; see Figure 3-3.

Figure 3-3. Road Signs for the Test Sections.

The road signs should be installed at the appropriate locations following the guidelines outlined in the Texas MUTCD Part 2 signs (Texas MUTCD 2006). In general, the following guidelines must be adhered to:

- At least ±25 ft from the start and end points of the test section, respectively, but not more than 50 ft. However, field conditions may also dictate the exact location of the road signs.

- The lateral offset should not be less than 6 ft from the edge of the shoulder or 12 ft from the edge of the traveled way.
- The mounting height shall be at least 7 ft, measured from the bottom of the sign to the near edge of the pavement surface.
- The signs should be vertically mounted at right angles to the direction of, and facing, the traffic that they are intended to serve.
- If 6 ft lateral offset is unachievable and 30 ft or more is used instead, the mounting height shall be 5 ft above the level of the pavement edge and the signs shall be turned to face the road.

The installed road signs should be left in place for the next five years from the date of installation, unless the project director or TxDOT directs otherwise. However, the road signs should be inspected, at minimum, every after two and half years for any loss in reflectivity. If necessary, they should be replaced accordingly or remedial measures taken.

TESTS PRIOR TO AND DURING TEST SECTION SELECTION

Table 3-3 through 3-6 shows the sequential order of field testing and data collection by pavement type. As discussed in the subsequent text, both the ground penetrating radar (GPR) and falling weight deflectometer (FWD) are being utilized to locate homogeneous sections, particularly in the case of the existing pavement structures and overlays. This is supplemented with coring and Dynamic Cone Penetrometer (DCP) testing.

Table 3-3. Field Testing and Data Collection Sequence for Overlays—New HMA over Existing HMA.

Prior to and during Test Section Selection		During Construction		Just after Construction		Periodic Performance Evaluation up to 5 Years (Twice Per Year; Just after Summer & Winter)	
1	Gather all existing data (design, plans, structural, etc.)	1	Take pictures & video of construction process	1	Take pictures & video	1	Take pictures & video
2	GPR, video, & pictures (homogenous PVMNT structure, thickness, defects, etc.)	2	Record construction method (MTD, truck type (tipper or belly dump], etc.)	2	Check & re-mark the test section start-end points	2	Waking-visual crack surveys • Alligator • Transverse • Longitudinal
3	FWD (homogeneity & structural capacity, modulus) (Plus PSPA if needed)	3	Measure temperatures (Gun and/or IR bar)	3	Coring (6 inch ϕ, min 10 cores)	3	Rut measurements (straightedge)—every 100 ft
4	Select & mark 500 ft test section with cracking, preferably in outside lane	4	Record compaction pattern (number of passes, roller weight, joint roller, etc.)	4	Run GPR if needed (uniformity of new overlay)	4	Check for other distresses, e.g. bleeding, potholes, etc.
5	Identify & record test section start-end points, i.e., GPS coordinates, mile marker, etc.	5	Density (Nuclear gauge or PQI)	5	FWD testing (if needed)—every 25 ft	5	High-speed profiles in WPs
6	Crack mapping—visual/walking survey	6	Measure final HMA mat thickness	6	Run high-speed profiles for smoothness & ride quality	6	FWD testing—every 25 ft
7	Take pictures & video	7	Collect plant-mix material & raw materials (aggregates & binders) for lab testing exactly from test section location or from plant (min 700 lb)	7	Rut measurements (straightedge)— every 100 ft	7	Skid data—from PMIS database
8	Run high-speed profiles			8	Check for any other construction defects	8	GPR, DCP, coring, & auguring as needed
9	Conduct DCP tests (min 6 pts)	8	Obtain QC/QA charts from TxDOT or Contractor	9	Install road signs to identify the test section start-end points	9	PSPA—every 100 ft
10	Coring (& auguring if needed) (6 inch ϕ, min 10 cores)			10	PSPA – every 100 ft		

Table 3-4. Field Testing and Data Collection Sequence for Overlays—New HMA over Existing PCC.

Prior to and during Test Section Selection		During Construction		Just after Construction		Periodic Performance Evaluation up to 5 Years (Twice Per Year; Just after Summer & Winter)	
1	Gather all existing data (design, plans, structural, etc.)	1	Take pictures & video of construction process	1	Take pictures & video	1	Take pictures & video
2	GPR, video, & pictures (homogenous PVMNT structure, thickness, defects, etc.)	2	Record construction method (MTD, truck type (tipper or belly dump], etc.)	2	Check & re-mark the test section start-end points	2	Waking-visual crack surveys • Alligator • Transverse • Longitudinal
3	FWD (LTE)—avoid joints/cracked areas (Plus PSPA if needed)	3	Measure temperatures (Gun and/or IR bar)	3	Coring (6 inch ϕ, min 10 cores)	3	Rut measurements (straightedge)—every 100 ft
4	Select & mark 500 ft test section with cracking, preferably in outside lane	4	Record compaction pattern (number of passes, roller weight, joint roller, etc.)	4	Run GPR if needed (uniformity of new overlay)	4	Check for other distresses (e.g., bleeding, potholes, etc.)
5	Identify & record test section start-end points,, i.e., GPS coordinates, mile marker, etc.	5	Density (Nuclear gauge or PQI)	5	FWD testing (if needed)—every 25 ft	5	High-speed profiles in WPs
6	Crack mapping—visual/walking survey	6	Measure final HMA mat thickness	6	Run high-speed profiles for smoothness & ride quality	6	FWD testing—every 25 ft
7	Measure joint/crack spacing, width, etc	7	Collect plant-mix material & raw materials (aggregates & binders) for lab testing exactly from test section location or from plant (min 700 lb)	7	Rut measurements (straightedge)—every 100 ft	7	Skid data—from PMIS database
8	Record other distresses such as spalling, patches, etc.			8	Check for any other construction defects	8	GPR, DCP, coring, & auguring as needed
9	Take pictures & video	8	Obtain QC/QA charts from TxDOT or Contractor	9	Install road signs to identify the test section start-end points	9	PSPA—every 100 ft
10	Run high-speed profiles			10	PSPA—every 100 ft		
11	Conduct DCP tests (min 6 pts)						
12	Coring (& auguring if needed) (6 inch ϕ, min 10 cores)						

Table 3-5. Field Testing and Data Collection Sequence for New, Reconstruction, or Full-Depth Reclamation.

Prior to and during Test Section Selection		During Construction		Just after Construction		Periodic Performance Evaluation up to 5 Years (Twice Per Year; Just after Summer & Winter)	
1	Initial lab design reports including UCS	1	If available on site, take pictures & video of construction process of each layer	1	Take pictures & video	1	Take pictures & video
2	Initial structural design reports	2	If available on site, record & document the construction process of each layer	2	Run GPR & video	2	Walking-visual crack surveys • Alligator • Transverse • Longitudinal
		3	Collect samples of subgrade soil material; for treated subgrade collect materials separately before stabilization & record the sampling locations (min 450 lb)	3	Select & mark one 500 ft test section, preferably in outside lane; use GPS, mile markers, physical landmarks, etc. to identify test section start-end points	3	Rut measurements (straightedge)— every 100 ft
		4	Collect samples of base materials; for stabilized base collect materials separately before stabilization; preferably at same sampling location as subgrade (min 600 lb per layer)	4	Coring (6 inch ϕ, min 10 cores)	4	Check for other distresses, e.g. bleeding, potholes, etc.
				5	FWD testing (every 25 ft on test section) & PSPA (every 100 ft)	5	High-speed profiles in WPs
		5	Collect samples of plant-mix & raw materials (binders & aggregates); preferably at same sampling location as subgrade/base or from plant (700 lb per layer)	6	Run high-speed profiles for smoothness & ride quality	6	FWD testing—every 25 ft
				7	Rut measurements (straightedge)—every 100 ft	7	Skid data—from PMIS database
		6	Obtain QC/QA charts from TxDOT or Contractor	8	Check for any other construction defects	8	GPR, DCP, coring, & auguring as needed
				9	Install road signs to identify the test section start-end points	9	PSPA—every 100 ft

Table 3-6. Field Testing and Data Collection Sequence for Existing Pavement Sections.

Prior to and during Test Section Selection		During Construction		Just after Construction		Periodic Performance Evaluation up to 5 Years (Twice Per Year; Just after Summer & Winter)	
1	Gather all existing available data (design, plans, structural, construction, layer thicknesses, layer material properties, performance, etc.)					1	Take pictures & video
2	GPR, video, & pictures (homogenous PVMNT structure, thickness, defects, etc.)					2	Waking-visual crack surveys • Alligator • Transverse • Longitudinal
3	FWD testing, preferably in outside lane, outside WP (Plus PSPA if needed)					3	Rut measurements (straightedge)—every 100 ft
4	Select & mark 500 ft test section with cracking, preferably in outside lane					4	Check for other distresses, e.g. bleeding, potholes, etc.
5	Identify & record test section start-end points, i.e., GPS coordinates, mile marker, etc.					5	High-speed profiles in WPs
6	Take pictures & video					6	FWD testing—every 25 ft
7	Crack mapping—visual/walking survey					7	Skid data—from PMIS database
8	Rut measurements (straightedge)—every 100 ft, both WPs					8	GPR, DCP, coring, & auguring as needed
9	Measure & record other distresses such bleeding, etc.					9	PSPA
10	Run high-speed profiles						
11	Conduct DCP tests if needed (min 6 pts)						
12	Coring (& auguring if needed) (6 inch ϕ, min 10 cores)						
13	Material sampling including (HMA, base, soil, etc.) for lab testing if needed						
14	Core height, bore holes, and/or probes for layer thicknesses determination if needed!						

Gathering Existing Data

Tables 3-3 through 3-6 show that gathering existing data should be the first step for all pavement (PVMNT) types in the process of selecting test sections. However, this aspect is even more critical for existing PVMNT structures and Overlays. For the existing PVMNT structures and Hwy projects, if such data as the following are unavailable or cannot be easily obtained, then that PVMNT structure or Hwy project cannot be used for this study:

- Design and structural plans.
- Lab design reports for the subgrade, base, and HMA.
- HMA mix-design sheets.
- Construction data.
- Layer thicknesses and material properties.
- Initial and/or some periodic performance data.

GPR and FWD Testing prior to Test Section Selection

For Overlays and existing PVMNT structures, the GPR supplemented with the FWD are very crucial tests in selecting homogeneous test sections, namely addressing the following key aspects:

- PVMNT structure uniformity.
- Layer thicknesses.
- Potential subsurface defects.
- Structural capacity of existing structure (FWD).
- Layer moduli values (FWD).

Since the GPR does not require traffic control, this should be the first field test for Overlays and existing PVMNT structures prior to selecting test sections. The GPR should preferably be run at least a week prior to the FWD and actual selection of the test sections. The GPR should be run throughout the entire Hwy project in all the lanes in both directions along with the integrated video, pictures, and GPS system. GPR data should then be analyzed to preliminarily select the potential lane direction and test section locations. As discussed in Chapter 5 of this interim report, PaveCheck® software should be used to analyze the GPR data.

Figure 3-4 shows an example of the color map for an existing PVMNT structure on US 59 (Atlanta District, Panola County) prior to Overlay for the SB outside lane.

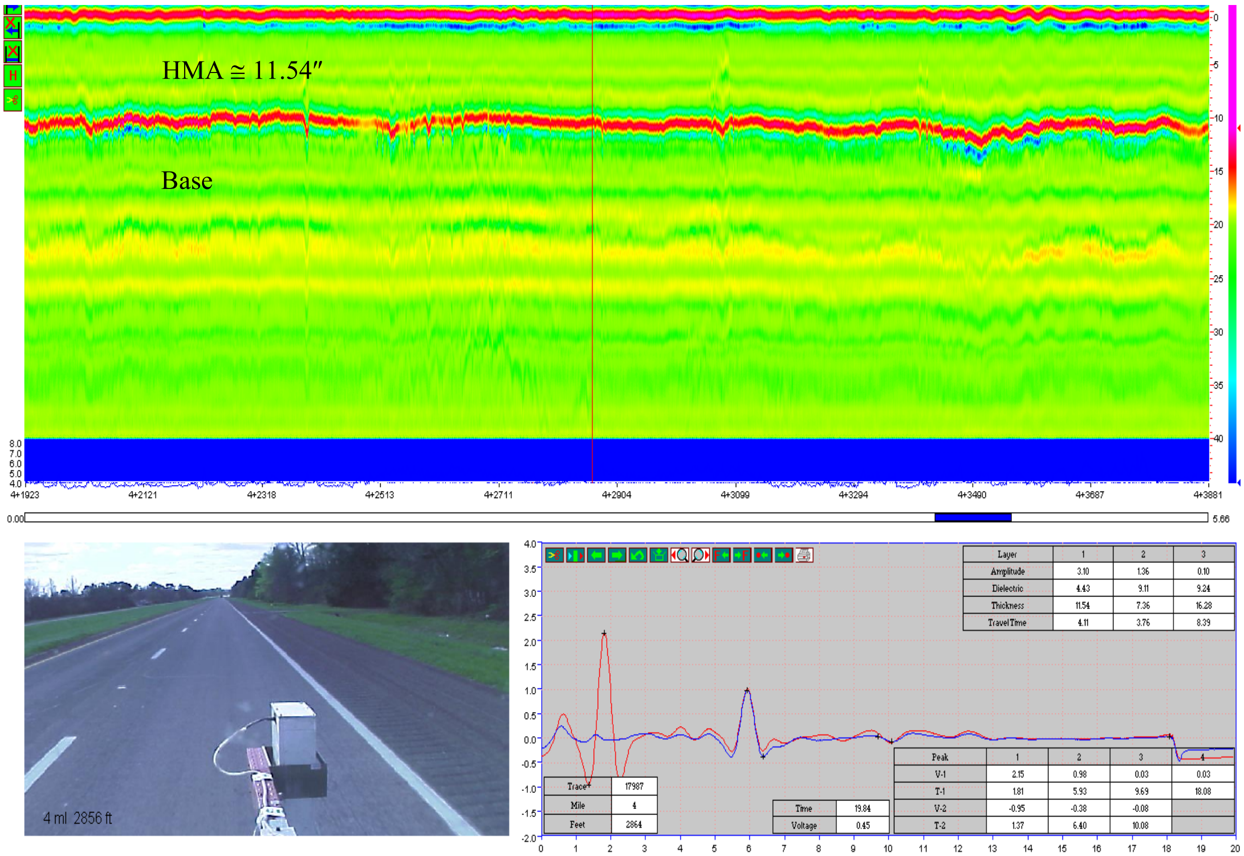


Figure 3-4. GPR Color Map for US 59 (Atlanta District), SB Outside Lane.

Figure 3-4 suggests that both the existing HMA and base layers are fairly uniform in thickness with no major subsurface defects. The existing HMA is about 11.5 inches thick while the base ranges from 13–16 inches thick.

Once a potential lane direction has been identified (e.g., using the GPR), the FWD test should then be run at no more than one-tenth of a mile preferably in the outside wheel path (WP) so as to select a section that is consistent in terms of both structural capacity and modulus for the existing PVMNT structure. In the case of Overlay candidate sections, cracked sections are preferred so as to monitor the crack manifestation in the subsequent performance monitoring program. Additionally, cracked sections are also critical for calibrating and validating the M-E Structural Design Systems.

Reports 0-6658-P1 and 0-6658-P3 (Walubita et al., 2011a, b) discusses that a minimum of one drop of 9 kips FWD loading should suffice. Both the air and pavement temperature at a minimum depth of 1 inch should be measured and recorded (for thin HMA surfaces); preferably both at the start and end of FWD testing, respectively. For thicker HMA surfaces, the in-pavement temperature should be measured at the mid-depth of the layer. Figure 3-5 shows an example of the FWD back-calculated modulus profile using the Modulus 6.0® software.

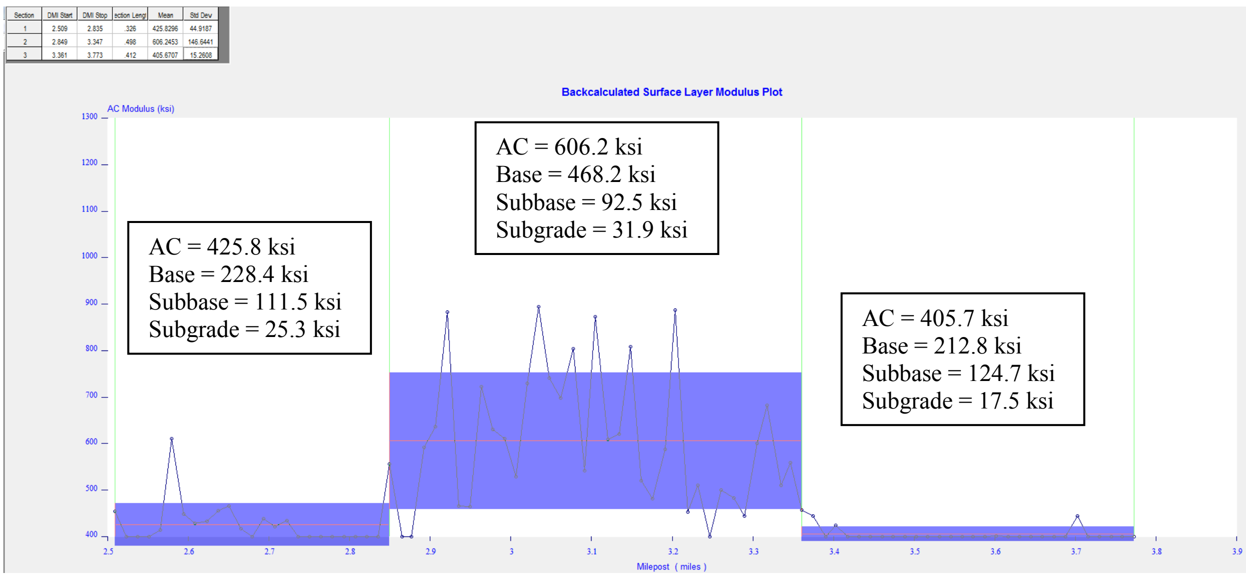


Figure 3-5. Modulus Profile for US 59 (Atlanta District)—Existing HMA Layer.

Clearly, Figure 3-5 shows two distinct homogenous modulus profiles with the PVMNT structure between mile post 2.8 and 3.4 miles having better structural capacity. Therefore, selecting a potential test section will have to be within or outside these mile posts.

Coring and DCP Testing prior to and during Test Section Selection

As discussed in Reports 0-6658-P1 and 0-6658-P3 (Walubita et al. 2011a, b), coring prior to and during test section selection, as well as other tests such as the GPR, is necessary to aid with the following aspects:

- Layer thickness determination.
- Forensic evaluation.
- Determination of the depth-extent of distresses such as cracking.
- Documentation of the existing pavement structure.

- Verifying the homogeneity of the pavement structure.
- Extracting cores for lab testing including in-situ density determination.

For each test section, a minimum of ten 6-inch diameter cores should be extracted, with at least four cores from the outside WP, four cores in between the WP, and at least two from cracked areas. Figure 3-6 shows some cores extracted from US 271 (Paris District) prior to an Overlay. The cores clearly show that the existing PVMNT structure consists of about 5-inch thick HMA and about 9-inch thick PCC (jointed).

Figure 3-6. Cores from US 271 (Paris District) prior to Overlay.

Note also that the core in Figure 3-6 reveals full-depth cracking in the existing AC overlay, mostly occurring at the PCC joints. Documentation of these existing distresses will be very critical in the future performance of this section after new HMA overlay construction.

Although not mandatory, it is strongly recommended to conduct DCP testing during selection of the test sections, particularly on Overlay sections and existing PVMNT structures, namely to aid with the following aspects:

- Layer thickness determination and verification for the base and subgrade.
- Moduli determination for the base and subgrade.
- Selection of a test section with a homogeneous PVMNT structure (i.e., homogeneous base and subgrade).

As discussed in Chapter 5, DCP testing is being conducted at a minimum of six points: three in the WP and three in between the WP. On some PVMNT structures including PCC sections, drilling and/or coring of the upper layers may be necessary so as to directly access the base and/or the subgrade layers for DCP testing. Where need be, DCP testing can also be done in the shoulders, particularly if it cannot be done in the travel lanes. Some examples of DCP testing and data analysis are discussed in Chapter 5 of this interim report.

FIELD TEST SECTIONS TO DATE

At the time of this interim report, the research team has identified and selected up to 35 potential Hwy test sections (see Table 3-2). These Hwy sections cover the following pavement types, with some examples shown in Figure 3-7:

- PP pavements (4).
- New construction (10).
- Overlays (21), both over HMA and PCC, respectively.

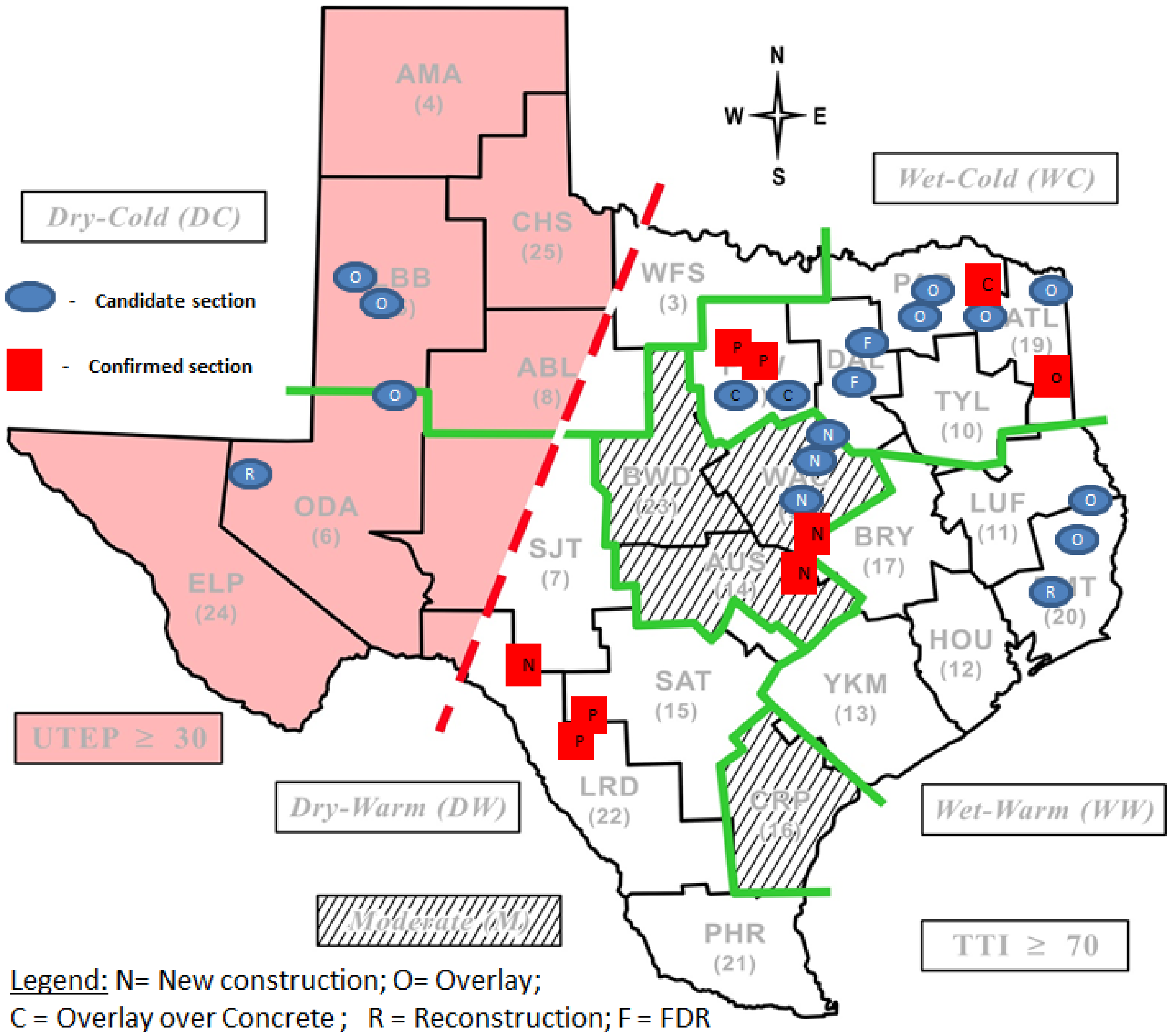


Figure 3-7. Example of Field Test Section Distribution as of June 2011.

Thus far, TTI researchers have physically been to 15 Hwy sections for site meetings, preconstruction surveys, construction monitoring, material sampling, traffic data collection, or field performance testing. UTEP researchers have physically been to five Hwy sections for site meetings, preconstruction surveys, material sampling, or DCP/PSPA testing. Solicitation of more field test sections is currently ongoing with the assistance of the project director.

In comparing their experience in smaller rural cities, which are often not very busy, TTI researchers have faced problems identifying Hwy sections and coordinating field work in larger cities such as Houston, Dallas, Waco, Austin, etc. Therefore, liaison assistance from TxDOT, the

PD and PMC members in these cities is greatly needed. Another problem to highlight is the change in the road construction and maintenance program scheduling by the Districts and contractors that often results in the researchers losing some test sections. Time and again, researchers have had to abandon some potential candidate test sections due to the following reasons:

- Cancellation or postponement of the project.
- Material changes.

SUMMARY

This chapter presented and discussed the test section selection criteria and the sequential order of conducting the field tests and data collection process. In particular, the chapter emphasized that gathering of existing data and GPR testing supplemented with coring, FWD, and DCP testing are very critical in the selection process of test sections, particularly for Overlays and existing PVMNT structures. Overall, close liaison with TxDOT, the Districts, and Contractors is a very critical aspect in the selection of test sections and subsequent collection of data.

CHAPTER 4
LABORATORY TESTING

The bulk work of the data collection for this study involves laboratory and field testing to generate data and material properties for input into the data storage system, as well as use by the M-E models and the associated structural design software. While the field tests are discussed in the next chapter, this chapter discusses the laboratory tests, namely:

- The asphalt-binder tests.
- The HMA mix tests.
- The base (flex and treated) material tests.
- The subgrade soil (raw and treated) tests.

As part of the laboratory test plans, defining and listing the test loading parameters, test conditions, parameters to be measured, data analysis methods, expected output data, and reporting formats for each laboratory test method are very critical aspects to ensure quality data. These aspects are discussed in this chapter. Detailed discussions of the laboratory test plans and data analysis are documented in Reports 0-6658-P1 and 0-6658-P3 (Walubita et al. 2011a, b).

ASPHALT-BINDER TESTS

All the asphalt-binder tests for this study will be conducted on extracted binders from the plant-mix obtained: 1) from haul trucks at the production plant, 2) directly from the HMA mix delivered to the site, or 3) from highway cores. These are sources that all represent in-situ field conditions. If sampled from mix hauled to the site (the preferred option), the plant-mix should be sampled from a minimum of three different trucks, but not more than five. All mix samples should be from deliveries to the travel lane of the test section. The Texas method Tex-210-F will be used for extracting the binders (TxDOT 2011).

The recommended asphalt-binder tests to generate the required rheological and engineering properties as well as performance grade (PG) grading of the extracted binders for this study are:

- The specific gravity (SG).
- The viscosity.
- The dynamic shear rheometer (DSR).

- The bending beam rheometer (BBR).
- The multi-stress creep and recovery (MSCR).
- The elastic recovery (ductility).
- PG grading of the asphalt-binders.

Appendix C of this interim report provides a summary of these 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. 2011a, b, c). As a minimum and for better statistical representation in order to generate the average, standard deviation (Stdev), and coefficient of variance (CV), it is recommended to use three replicate samples per test. Based on the project monitoring committee recommendations, the following modifications and recommendations were made:

- Run the elastic recovery test at 50°F (TxDOT 2004).
- Run the dynamic shear rheometer (DSR) test directly on the extracted binders and treat it as RTFO residue. This will be used for PG grade determination on plant-produced samples.
- Run the MSCR test directly on the extracted binders and treat it as RTFO residue.
- Run the intermediate temperature DSR and BBR on the extracted binders as it is (with no PAV) for mixes with RAP or RAS.
- No PAV testing on any of the extracted binders.
- Consider one replicate for specific gravity (SG), viscosity, and DSR tests because of proven low result variability; and two for the BBR tests. All other binder tests should have a minimum of three replicate samples.
- The approximate material (plant-mix/cores) requirement to conduct all these asphalt-binder tests per mix type or HMA layer is 100 lb.

Based on email communications with the PD and the Director of the TxDOT asphalt-binder laboratory, the following recommendations were made for the elastic recovery (ductility) testing:

1) Performance Graded Asphalt-Binders

- Procedure: ASTM D6084, Testing Procedure A.

- Test Temperature: 50°F.
- Final elongation: 10 ± 0.25 cm.
- Rate of elongation: 5 cm/min.
- Cut: immediately at final elongation.
- Mold configuration: straight spacer, as shown in ASTM D6084.

2) Polymer Modified Asphalt Cements

- Procedure: Tex-539-C.
- Test Temperature: 50°F.
- Final elongation: 20 cm.
- Rate of elongation: 5 cm/min.
- Cut: wait for 5 min ±10 seconds once final elongation is met.
- Mold configuration: v-wedge spacer.

As at the time of this report, asphalt-binder tests had been completed for the highway test sections listed in Table 4-1. Appendix D includes example results for US 59 (Atlanta District, Panola County) for the extracted PG 64-22 asphalt-binder.

Table 4-1. Asphalt-Binders Tested to Date.

#	Test Section#	Section/Hwy	Asphalt-Binder	HMA Mix	PVMNT Type	PVMNT Structure	District, County
1	TxDOT_TTI-00001	US 59	PG 64-22	Type D	Overlay	AC over existing AC over existing LTB	Atlanta, Panola
2	TxDOT_TTI-00013	US 59	PG 64-22	Type D	Overlay	AC over TruPave existing AC over existing LTB	Atlanta, Panola
3	TxDOT_TTI-00014	US 59	PG 64-22	Type D	Overlay	AC over PetroMat over existing AC over existing LTB	Atlanta, Panola
4	TxDOT_TTI-00006	SH 121	PG 76-22	CAM	Overlay	PFC over CAM over existing AC over existing CTB	Paris, Fannin
5	TxDOT_TTI-00004	IH 35	PG 64-22	Type B	New construction	PFC over SMA over Type B over CTB	Waco, Hill

HMA MIX TESTS

All the HMA mix testing for this project will be conducted on plant-mix materials and/or highway cores that represent in-situ field conditions. Raw materials can be considered only if plant-mix materials cannot be obtained or are otherwise unavailable. The plant-mix material will either be hauled from the production plant or directly from the site. If sampled from mix hauled to the site (the preferred option), the plant-mix should be sampled from a minimum of three different trucks, but not more than five. All mix samples should be from the travel lane of the test section. Where extraction tests such as determining the asphalt-binder content and aggregate gradation are required, the test method Tex-210-F will be used (TxDOT 2011). The recommended HMA mix tests to generate the required HMA material properties for this study are:

- Asphalt-binder extractions and gradations.
- The Hamburg Wheel-tracking test (HWTT).
- The Overlay Tester (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 C of this interim report provides a summary of these test procedures and the related test parameters and output data. Reports 0-6658-P1 and 0-6658-P3 (Walubita et al. 2011a, b) have detailed descriptions of these tests along with the data analysis methods. As a minimum, and for better statistical representation in order to generate the average, Stdev, and CV, it is recommended to use three replicate samples per test. Based on project monitoring committee recommendations, the following modifications and recommendations were made:

- The HMA mix volumetrics should be obtained from the TxDOT quality control/quality assurance (QC/QA) testing.
- The plant-mix material may be obtained from the job site or directly from the production plant. However, collecting the plant-mix from the job site should be given preference, unless circumstances do not permit.

- The percentage AC and gradations should be obtained from the QC/QA records. If these are unavailable, researchers may then consider doing the extraction tests using the Texas method Tex-210-F (TxDOT 2011).
- Due to the good repeatability and low variability in the test results, consider one replicate set for the Hamburg test (i.e., one set of two samples instead of three sets of two samples). Additionally, all test samples for this project will be run up to 20,000 load passes. So, in some instances, it may be necessary to set the rut depth criteria over 12.5 mm depending on the expected performance of the HMA mix, i.e., 20 mm or more.
- Maintain all the five test temperatures for the DM test; lower temperature is very critical for low temperature (thermal) cracking while the high temperatures are very critical for rutting, particularly with the increasing frequency of extended high summer temperatures.
- Evaluate and compare the improvised TTI method for measuring the HMA thermal coefficient versus the Tex-428-A, then use the most practical one with the more repeatable and realistic results. Thus far, the simplified TTI method has proved to be the most practical with satisfactory results, and will be utilized throughout the study.
- While QC/QA data will be obtained from the Area Engineers and/or Contractors, the researchers should also try as much as possible to monitor and record construction processes where circumstances permit.
- The approximate sample size (plant-mix/cores) requirement to conduct all these HMA tests per mix type or HMA layer is 500 lb.
- With the exception of the PFC test specimens at 80±2 percent density (i.e., 20±2 percent AV), all the HMA test specimens will be molded to a final cut/cored density of 93±1 percent (i.e., 93±1 percent)

At the time of this report, HMA mix testing had been completed on the highway test sections listed in Table 4-2. Appendix D includes example results for US 59 (Atlanta District, Panola County) for the Type D mix.

Table 4-2. HMA Mixes Tested to Date.

#	Test Section#	Section/Hwy	HMA Mix	Asphalt-Binder	PVMNT Type	PVMNT Structure	District, County
1	TxDOT_TTI-00001	US 59	Type D	PG 64-22	Overlay	AC over existing AC over existing LTB	Atlanta, Panola
2	TxDOT_TTI-00013	US 59	Type D	PG 64-22	Overlay	AC over TruPave® existing AC over existing LTB	Atlanta, Panola
3	TxDOT_TTI-00014	US 59	Type D	PG 64-22	Overlay	AC over PetroMat® over existing AC over existing LTB	Atlanta, Panola
4	TxDOT_TTI-00006	SH 121	CAM	PG 76-22	Overlay	PFC over CAM over existing AC over existing CTB	Paris, Fannin
5	TxDOT_TTI-00004	IH 35	Type B	PG 64-22	New construction	PFC over SMA over Type B over CTB	Waco, Hill

BASE MATERIAL AND SUBGRADE SOIL TESTS

In general, the base and subgrade soil tests relate to the following materials and are summarized in Appendix C:

- Flex base (untreated).
- Treated base (CTB).
- Treated base (asphalt/low stabilizers).
- Subgrade soil (raw).
- Subgrade soil (treated).

The actual test types are enumerated below; Reports 0-6658-P1 and 0-6658-P3 (Walubita et al. 2011a, b) give a detailed description of these tests.

- Sieve analysis.
- Atterberg limits.
- Specific gravity.
- MD Curve.
- Texas Triaxial.
- Resilient modulus.
- Permanent deformation (PD).
- Shear strength.
- Soil suction.
- Unconfined compressive strength.
- Modulus of rupture.

The PD and resilient modulus test for untreated base and subgrade will be conducted in accordance with the test procedure proposed in TxDOT Project 0-5798 (Zhou et al. 2010). With respect to the PD test, researchers became aware that the stress level (15 psi of confining pressure with 30 psi of deviatoric stress) seems conservative for several base materials during the preliminary assessment that UTEP researchers conducted. Therefore, researchers conducted a structural analysis, taking into account various pavement layer moduli and thicknesses to compute the representative stress level to be considered (Nazarian and Oh 2011). The results proposed using 10 psi of confining pressure with 20 psi of deviatoric stress for characterizing PD of base material, and an agreement was made after consulting with the PMC members.

Researchers are currently conducting the PD test to check adequacy of the proposed stress level. The other tests will be conducted using standard TxDOT test methods. In order to measure the soil suction of untreated base and subgrade soil, the plate pressure extractor test procedure (ASTM D2325), although relatively expensive, is proposed because of its accuracy and its ability to generate soil water characteristic curves in a timely fashion. However, TxDOT has suggested using the filter paper method. Currently, the following items are also under investigation:

- The modulus of rupture requires about 3 percent cement, and takes 28 days for curing prior to testing. By comparison, unconfined compressive strength (UCS) sample molding and testing can be completed in seven days. Previously, TTI researchers determined a comparison/correlation between the modulus of rupture and UCS tests in previous studies (Zhou et al. 2010). To optimize the resources and time without compromising quality, UTEP and TTI will conduct the UCS, modulus of rupture, and the IDT for similar CTB materials of about five existing CTB sections so that the best test can be determined for all future testing of this study.
- The resilient modulus testing for untreated base and untreated subgrade soil materials should be conducted according to the loading method proposed in Study 0-5798 (Zhou et al. 2010), while Free-Free Resonant Column (FFRC) test method should be used for treated base and subgrade materials. The PD testing is not conducted for a base material treated with cement or high stabilizer content over 2%. Table 4-3 lists the resilient modulus and PD test methods for each type of materials.

Table 4-3. PD and Mr Tests for Base and Subgrade Materials

Test	Base			Subgrade Soil	
	Flex	**CTB**	**Asphalt/low stabilizers**	**Raw**	**Treated**
Mr	Loading method	FFRC	FFRC	Loading method	FFRC
PD	Loading method	N/A	Test only for asphalt treated and low stabilizer content (i.e., ≤ 2%)	Loading method	Loading method

- For resilient modulus testing on CTB material, the FFRC was used in previous studies with some success. However, the FFRC provides a low strain seismic modulus as opposed to the design (elastic) modulus. When compared to the back-calculated modulus, the seismic modulus is roughly a third in magnitude. For the meantime, the researchers will run the resilient modulus at the reduced stress states (based on the UCS) and obtain the FFRC for the five existing sections to compare with the back-calculated modulus and evaluate the necessity for the resilient modulus test.
- Due to limited data available, there is no threshold limit that can be used to dictate when a material will be needed to be tested for modulus of rupture (i.e., is it stabilized or not). Therefore, modulus of rupture will be run only for cement treated base materials while UCS tests will be performed on all stabilized base and subgrade materials. If the modulus of rupture beams cannot be tested because of lack of adequate stabilization (i.e., beams breaking up during handling, too weak, etc.), then the material will be reclassified as un-stabilized.

As outlined in Reports 0-6658-P1 and 0-6658-P3 (Walubita et al. 2011a, b), the required materials should be sampled at a minimum of three locations within the test section. For flexible bases, the material should be sampled from the windrow. For treated materials, the materials should be gathered before the stabilizing agent is added. For plant-mixed treated materials, the material should be sampled from the plant at three distinct locations within the stock pile. Overall, a minimum of 600 lb of material (200 lb per sampling point) should be collected for bases and 450 lb (150 lb per sampling point) for the subgrade soils.

At the time of this report, a substantial number of subgrade soil and base testing had been completed for the highway test sections listed in Table 4-4. Example results for Loop 480

(Laredo District, Maverick County) for the subgrade and base materials are included in Appendix D.

Table 4-4. Base and Subgrade Materials Tested to Date.

#	Test Section#	Section/Hwy	Material	Treatment	PVMNT Type	PVMNT Structure	District, County
1	TxDOT_TTI-00005	Loop 480	Subgrade soil	None	New construction (Loop 480)	Type C over flex base over subgrade	Laredo, Maverick
2	TxDOT_TTI-00005	Loop 480	Flex base	None	New construction (Loop 480)	Type C over flex base over subgrade	Laredo, Maverick

SEAL COAT MATERIALS

Laboratory tests for seal coat binders are listed in Appendix C (Table C-8). In a nutshell, the tests for the seal coat binders are similar to the asphalt-binder tests for HMA except the differences in the asphalt-binder grading system and the fact that residual recovery testing is required in the case of emulsions; see Appendix C, Table C-8. As documented in Technical Report 0-1710-2 (Walubita et al. 2005), the seal coat binders are graded based on the Surface Performance-Graded (SPG) specification. One 5-gallon (i.e., ≅ 38 lbs) of neat binder obtained either from the plant or directly from the trucks onsite during construction should be more than enough to conduct the entire laboratory tests for seal coat binders.

SUMMARY

This chapter provided an overview of the laboratory work completed in Year 1 of this project, namely:

- Development of the data collection plan.
- Materials testing.
- Data analysis plans for asphalt-binders, HMA mixes, base materials, subgrade soils, and seal coat binders.

At the time of this report, substantial testing had been completed on materials from each of these categories. Note also that in addition to the tests discussed in this chapter, the V-meter may also be used where applicably needed.

CHAPTER 5
FIELD TESTING

The field test program is being successfully pursued with TxDOT's assistance. The primary objective of the field test program is to evaluate the supporting material property characteristics and performance of the pavement layers in-situ. Table 5-1 provides a listing of the field tests being conducted, with some illustrations of how the data is collected and analyzed presented in the subsequent text.

In general, field testing and data collection should be conducted sequentially as follows (see also Chapter 3):

1) Prior to and during test section selection to aid in selecting homogeneous PVMNT sections and also to document the existing PVMNT structural capacity and distresses.
2) During and just after construction to document the construction process and the PVMNT condition just after construction.
3) Periodically, twice per year (just after summer and just after winter), for performance evaluation of the test sections.

As should be noted in Table 5-1, all of the field tests, except for the GPR, require traffic closure during testing. Furthermore, the researchers rely on the TxDOT FWD equipment. As such, close liaison with TxDOT, the Districts, and the Contractors is very crucial insofar as site visits, material sampling, and field testing are concerned.

At the time of this interim report, site visits, test section selection, material sampling, construction monitoring, and performance evaluation had been completed on the Hwy sections listed in Table 5-2. Some illustrative examples of the data analyses and associated results including the DCP and FWD test data are also presented in the subsequent text. Appendix E shows other detailed results. Please refer to Reports 0-6658-P1 and 0-6658-P3 for more example results (Walubita et al. 2011a, b).

Table 5-1. List of Field Tests and Data Characteristics.

<table>
<tr><th>#</th><th>Test</th><th>Test Procedure (Spec)</th><th>Frequency</th><th>Analysis Method</th><th>Output Data (Units)</th><th>Typical Value/ Threshold</th></tr>
<tr><td>1</td><td>Cracking</td><td>Visual-walking surveys (manual counts and tape measurements)
• Alligator cracking
• Longitudinal cracks
• Transverse cracks</td><td rowspan="6">At test section selection and/or just after construction, and thereafter, twice per year (just after winter and summer)</td><td>MS Excel</td><td>Number of cracks; %age cracking; crack length, interspacing of cracks, crack width (severity), crack density</td><td>≤ 25% (alligator)

≤ 1000 ft/mi (longitudinal)</td></tr>
<tr><td>2</td><td>Surface rutting</td><td>Straightedge, wedge, and ruler; ≥ 6 pts @ 100 ft interval; in WPs</td><td>MS Excel</td><td>Rut depth (inch)</td><td>≤ 0.5</td></tr>
<tr><td>3</td><td>Other distress, e.g., bleeding</td><td>Visual-walking surveys</td><td>-</td><td colspan="2">Severity, percentage coverage, etc</td></tr>
<tr><td>4</td><td>Surface profiles</td><td>TTI high-speed profiler; in both WPs</td><td>TxDOT RideQuality Software®</td><td>IRI (inch/mi) and PSI</td><td>30 ≤ IRI≤ 172;

2.5 ≤ PSI ≤ 5.0</td></tr>
<tr><td>5</td><td>PSPA</td><td>Measure at less than or every 100 ft (i.e., ≤ 100 ft)</td><td>PSPA built-in analysis software</td><td colspan="2">Seismic layer modulus (ksi) – HMA, base, subgrade, etc</td></tr>
<tr><td>6</td><td>FWD</td><td>Every 25 ft, 9 kips, ≥ 1 drop, WP</td><td>Modulus 6.1 software and MS Excel®</td><td>Surface deflections (mls) curvature indices, and modulus (ksi)</td><td>≤ 20 mils</td></tr>
<tr><td>7</td><td>GPR</td><td>TTI-TxDOT reports; in outside or right WP</td><td>Prior to test section selection and/or just after construction, and thereafter, as needed</td><td>PaveCheck software</td><td>Layer thickness, forensic defects, etc.</td><td>N/A</td></tr>
<tr><td>8</td><td>Coring</td><td>6-inch diameter, minimum 10 cores (≥ 4 from WP; ≥ 4 in-between WP; ≥ 2 from cracked area)</td><td colspan="2">At test section selection and/or just after construction, and thereafter, as needed</td><td colspan="2">Layer thickness, forensic defects, core density, lab tests, etc.</td></tr>
<tr><td>9</td><td>Skid</td><td colspan="2">From TxDOT PMIS</td><td colspan="3">Texture and SN</td></tr>
<tr><td>10</td><td>DCP</td><td>Min 6 pts (≥3 in WP and ≥3 in-between WP)</td><td>At test section selection and thereafter, as needed</td><td>MS Excel</td><td colspan="2">Layer thickness (inch), and modulus (ksi)</td></tr>
<tr><td>11</td><td>Material sampling</td><td colspan="2">Once during construction or directly from the plant</td><td colspan="3">Subgrade soil, base, HMA, & asphalt-binder testing</td></tr>
</table>

Table 5-2. Site Visits and Field Tests Conducted To Date.

#	Test Section#	Section/Hwy	PVMNT Type	District, County	Type of Site Visit or Field Tests of September 2011
1	TxDOT_TTI-00005	Loop 480	New construction	Laredo, Maverick	Material sampling (base, subgrade) and recording construction process
2	TxDOT_TTI-00001	US 59	Overlay (HMA + HMA + LTB)	Atlanta, Panola	Test section selection, construction, and material sampling (HMA)
3	TxDOT_TTI-00002	SH 114	Perpetual	Fort Worth, Wise	Rut measurements, crack surveys, photos and video, surface temperature, marked test sections, and GPR
4	TxDOT_TTI-00003	SH 114	Perpetual	Fort Worth, Wise	Rut measurements, crack surveys, photos and video, surface temperature, marked test sections, and GPR
5	TxDOT_TTI-00006	SH 121	Overlay (HMA + HMA + LTB)	Paris, Fannin	CAM mix laying
6	TxDOT_TTI-00007	US 271	Overlay (HMA + HMA + PCC)	Paris, Lamar	Traffic data collection, DCP, FWD, crack survey, coring, selected and marked test sections, photos, and video
7	TxDOT_TTI-00010	IH 35	Perpetual	Laredo, La Salle	GPR
8	TxDOT_TTI-00011	IH 35	Perpetual	Laredo, La Salle	GPR

DCP TEST DATA ANALYSIS AND RESULTS

Figure 5-1 shows the research team as they conducted a DCP test at one of several locations where site selection was based on interpretation of GPR and FWD data along a highway segment.

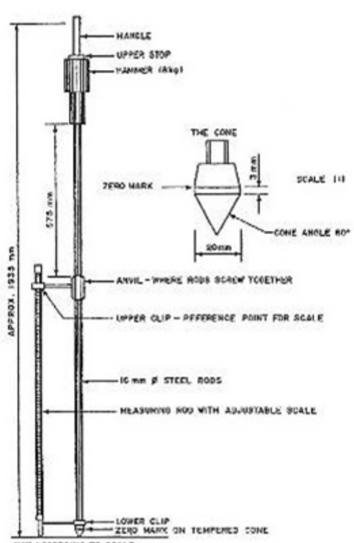


Figure 5-1. Illustration of DCP Testing.

Researchers recorded the penetration depth per the number of blows from the top of the base layer after drilling through the asphalt surface layer. Later, they processed the DCP data to estimate layer moduli from the DCP penetration rate according to the following equation:

$$M_r = 2555\left(\frac{292}{DCPI^{1.12}}\right)^{0.64} \tag{5.1}$$

Where

M_r = resilient modulus in psi.

$DCPI$ = DCP index (penetration rate in mm/blow).

Equation (5.1) is provided as an option in the M-E PDG program for input of layer modulus when DCP data is available.

Researchers first generated a plot that shows the relationship between penetration depth and number of blows. From this plot, they determined the break in slope, indicating the presence of different layers; the effective layer thickness can then be approximated. Using Equation (5.1), researchers computed DCPI for each segment by calculating the slope and then calculated the layer resilient modulus. Note that the unit conversion should be made into SI units to employ Equation (5.1).

US 59 in Atlanta District, Panola County

Based on GPR readings and retrieved asphalt core samples, the composite HMA layer thickness was around 11.0 inches. Therefore, the DCP measurements were made after drilling through the composite HMA layers. Figures 5.2 shows an example of processed DCP data on the US 59 section, located at a transition section between Sections 1 and 2, that captures different penetration rate slopes, indicating the presence of different layers. From the DCP data processing, researchers identified 10 inches of base layer, exhibiting a layer modulus of 91.2 ksi (Eq. 5.1). The sub-base layer yields a lower layer modulus, 43.2 ksi, due to higher penetration rate compared to the first layer. The estimated base layer thickness was comparable to the thickness data from the plan sheet that shows 10 inches of lime-fly ash (LFA) treated base and 8 inches of lime-treated subgrade.

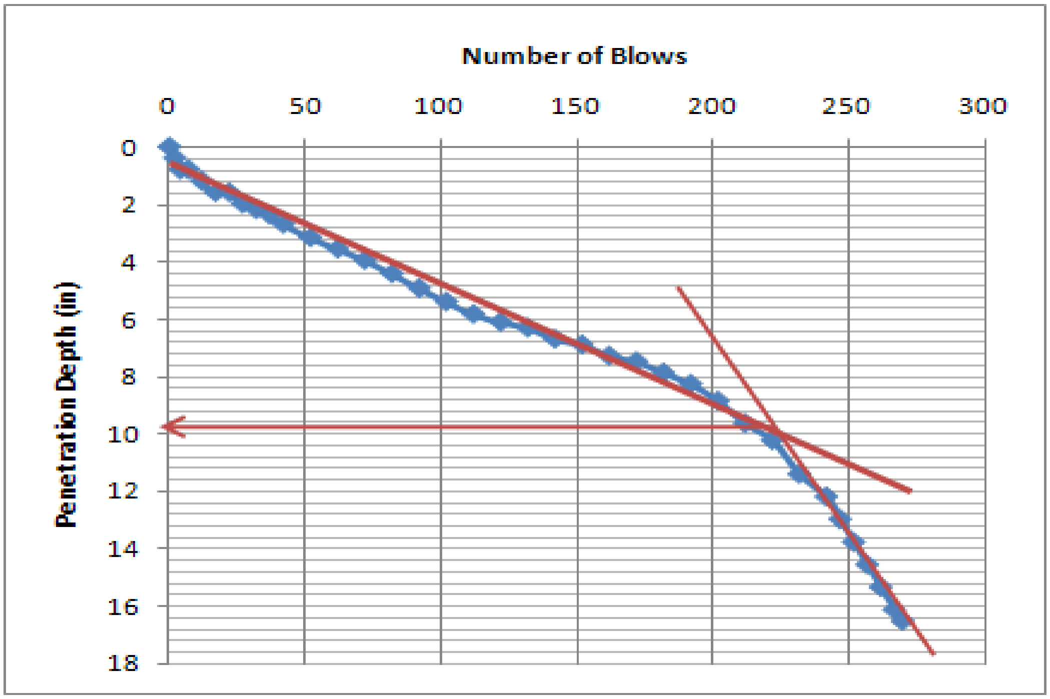


Figure 5-2. DCP Data Analysis on US 59 Section, Panola County.

US 271 in Paris District, Lamar County

This section is a composite pavement having an HMA overlay over a 9-inch jointed PCC slab. Therefore researchers limited the number of DCP testing on this section due to its difficulty in drilling through the PCC layer. One DCP test was conducted after drilling through the PCC slab, and another was attempted in the shoulder area. Figure 5-3 presents DCP data collected within the subgrade beneath the jointed PCC slab. The subgrade as tested exhibited a layer resilient modulus of 5–10 ksi.

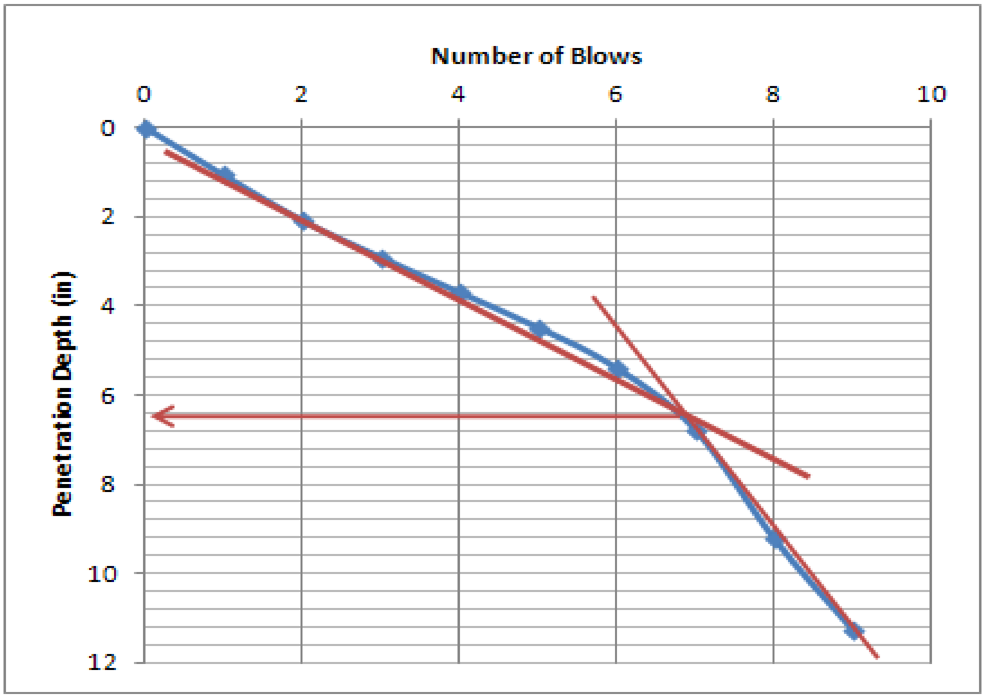


Figure 5-3. DCP Data Analysis on US 271 Section from the Bottom of PCC, Lamar County.

SH 121 in Paris District, Fannin County

Based on GPR readings and retrieved asphalt core samples, the HMA layer thickness was around 4.5 inches, followed by a 9.5-inch cement-treated base layer. Therefore, the DCP measurements were made after both the surface HMA and cement-treated base layers were drilled. Figure 5-4 shows an example of processed DCP data on the SH 121 section, located at 242-ft from the section beginning where the first core was taken. This example captures different slopes, indicating the presence of different layers. From the DCP data processing, researchers found that the subgrade layer has a modulus of 17–26 ksi. Table 5-3 presents the test results on this section. Generally, the results from the six locations seem reasonably consistent for the Layer 1 modulus. The highest modulus along the thinnest effective layer 1 thickness was obtained from location 4. Researchers believe that the DCP penetration appeared to be hindered because of rocks or an unusually stiff intermediate layer. From Table 5-3, it is also worth noting that the upper subgrade appears slightly stiffer than the lower subgrade (designated as Layer 2).

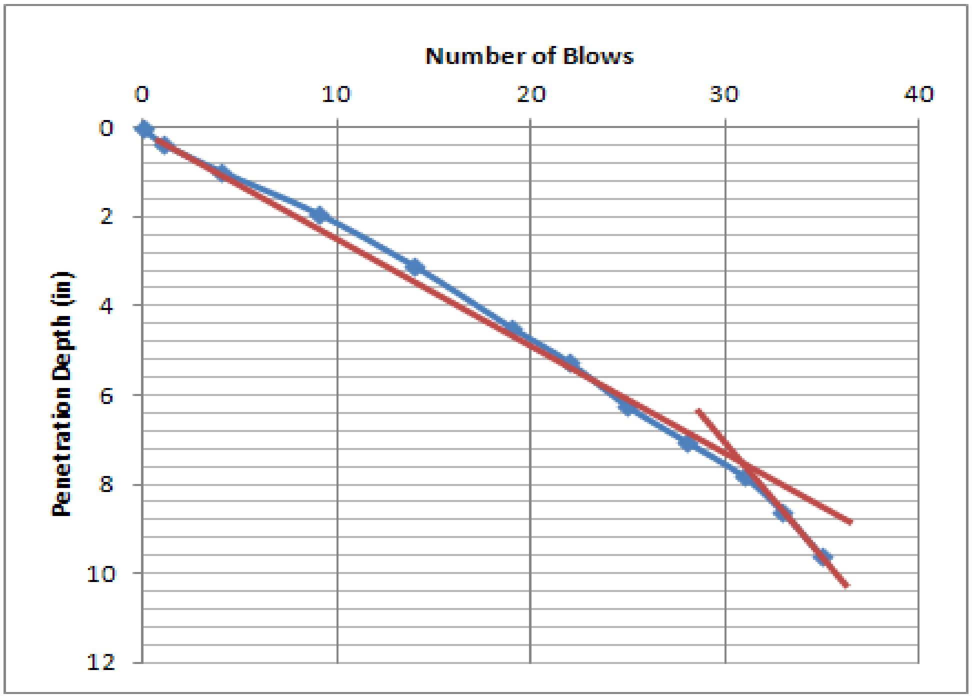


Figure 5-4. DCP Data Analysis on SH 121 Section, Fannin County.

Table 5-3. DCP Test Results of SH 121 Section.

Location	Distance from the Beginning (ft)	Effective Layer 1 Thickness (Inches)	Modulus Layer 1 (ksi)	Modulus Layer 2 (ksi)
1	242	7.6	25.8	17.0
2	281	8.0	18.4	12.2
3	545	7.0	21.3	22.0
4	620	3.5	55.0	16.3
5	950	7.6	18.8	11.1
6	987	5.6	26.5	10.3

FWD TEST DATA ANALYSIS AND RESULTS

The FWD is the primary non-destructive test (NDT) used in TxDOT to evaluate the pavement structural capacity and to estimate layer moduli. The test acquires deflection data that can either be used in a back-calculation procedure to evaluate the existing condition or to predict the remaining life of the structure by interpreting raw deflection indices. These indices include the surface curvature index (SCI), base curvature index (BCI), and the W7 deflection used to evaluate the deep subgrade. Figure 5-5 shows an example of FWD testing on SH 114 (Fort Worth) in summer 2011.

Figure 5-5. FWD Testing on SH 114 (Fort Worth, Summer 2011).

Researchers conducted FWD tests in the outside wheel path at 25-ft intervals using a 9000-lb nominal load. Pavement temperature was measured at the beginning and end of the section at a 1-inch depth to allow for temperature corrections to the HMA layer back-calculated modulus (yielding a design value), and for structural comparison purpose. In addition, both air and PVMNT surface temperatures must also be measured and recorded for entry into the MS Access Data Storage System. At minimum, two temperature measurements of the air, the PVMNT surface, and at 1-inch depth, respectively, must be recorded; one at the start and one at the end of FWD testing, respectively.

More importantly, researchers have taken special precautions to avoid any severely cracked area that could adversely affect the data interpretation during the data collection. Researchers used the MODULUS 6.1 program to analyze the measured deflection basin to back-calculate the layer moduli and estimate structural indices. They used Equation (5-2) to correct the back-calculated FWD modulus to 77°F.

$$E_{77^\circ F} = (T^{2.81} / 200000) * E_{FWD} \qquad (5.2)$$

Where

$E_{77°F}$ = corrected HMA modulus to 77°F in ksi.

E_{FWD} = back-calculated FWD modulus in ksi without any temperature corrections.

T = pavement temperature in °F during FWD test.

Other parameters that can be used from the FWD data include the surface deflections (W1), SCI, BCI, and deep subgrade deflection (W7), to interpret the existing pavement condition without performing back-calculation of layer moduli. Table 5-4 shows how TxDOT uses raw FWD deflection data to establish layer strength classification criteria for rehabilitation design purposes.

Table 5-4. Pavement Interpretation Scheme Based on FWD Data.

Index (mils)	**AC Thickness (in.)**				**Pavement Condition**
	>5"	**2.5 ~ 5"**	**1 ~ 2.5"**	**<1"**	
SCI (W_1-W_2)	< 4	< 6	< 12	< 16	Very good
	4 ~ 6	6 ~ 10	12 ~ 18	16 ~ 24	Good
	6 ~ 8	10 ~ 15	18 ~ 24	24 ~ 32	Moderate
	8 ~ 10	15 ~ 20	24 ~ 30	32 ~ 40	Poor
	>10	>20	>30	>40	Very Poor
BCI (W_2 – W_3)	<2	<3	<4	<8	Very good
	2 ~ 3	3 ~ 5	4 ~ 8	8 ~ 12	Good
	3 ~ 4	5 ~ 8	8 ~ 12	12 ~ 16	Moderate
	4 ~ 5	8 ~ 10	12 ~ 16	16 ~ 20	Poor
	>5	>10	>16	>20	Very Poor
W_7	< 1.0	<1.0	<1.0	<1.0	Very good
	1.0 ~ 1.4	1.0 ~ 1.4	1.0 ~ 1.4	1.0 ~ 1.4	Good
	1.4 ~ 1.8	1.4 ~ 1.8	1.4 ~ 1.8	1.4 ~ 1.8	Moderate
	1.8 ~ 2.2	1.8 ~ 2.2	1.8 ~ 2.2	1.8 ~ 2.2	Poor
	>2.2	>2.2	>2.2	>2.2	Very Poor

Figures 5-6 and 5-7 show the variation of sensor 7 deflections and back-calculated subgrade layer moduli, and SCI and BCI along the US 59 tested section. Based on Table 5-4, the US 59 section is generally deemed structurally sound in terms of W_7, SCI, and BCI. Note that US 271 is a composite pavement section that consists of an asphalt overlay over an existing jointed PCC slab. Researchers attempted to measure the load transfer efficiency (LTE) cross the crack, which seemed to be reflected from a joint in the underlying PCC slab (Figure 5-8), to establish an input for the Texas M-E design system (under development) that requires the LTE for overlay design.

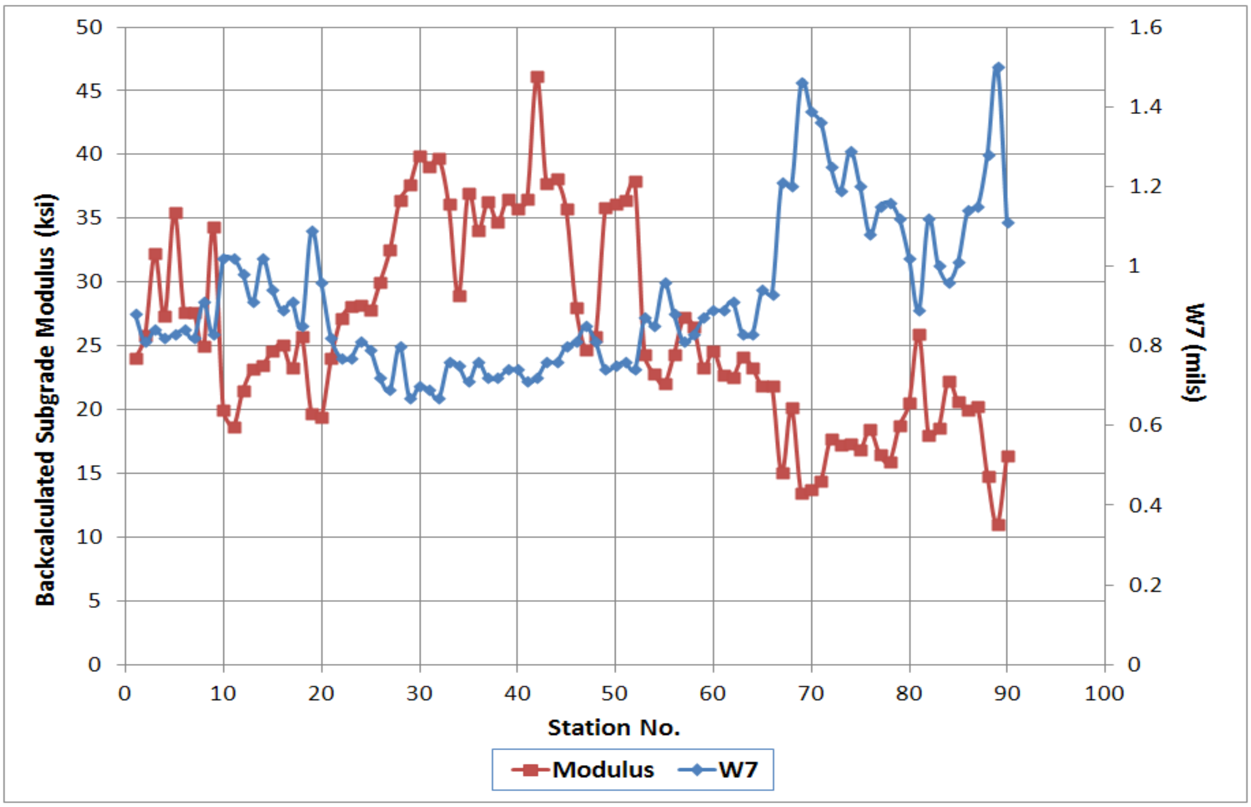


Figure 5-6. Variation of W7 and Back-Calculated Subgrade Modulus on US 59 (Atlanta District).

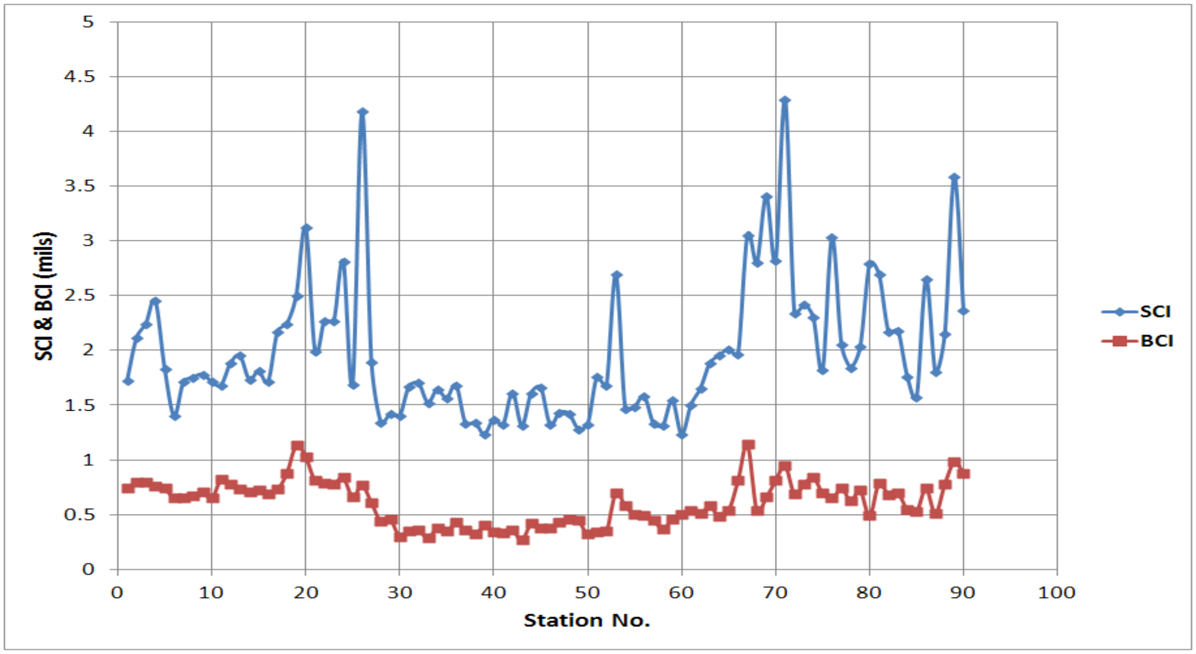


Figure 5-7. Variation of SCI and BCI on US 59 (Atlanta District).

Figure 5-8. Reflective Cracking Observed in US 271 (Paris District).

LTE is determined based on the ratio of the maximum deflection at the joint of the loaded slab and the deflection of the unloaded slab measured right across the joint from the load plate. It is defined as:

$$LTE = \frac{d_u}{d_l} \times 100\,(\%) \qquad (5.3)$$

where d_u and d_l are deflections on the unloaded slab and the loaded slab, respectively. LTE is significantly affected by the aggregate interlock, load transfer device, underlying support conditions, and ambient temperature (Smith et al. 2010). From the testing, researchers obtained an LTE of 49 percent.

A full-depth perpetual pavement section along SH 114 in the Fort Worth District has been monitored from a previous TxDOT Project 0-4822 (Walubita et al. 2010). Researchers revisited the section and conducted FWD testing along the same segments. Figures 5-9 and 5-10 compare deflection data collected during the summer season at different times. Although there is a slight difference in the average pavement surface temperatures, all deflections measured generally matched well, indicating excellent performance up to the date of this report, after more than five years of service.

Table 5-5 summarizes the results of the back-calculation analysis for the indicated test sections. Note that the back-calculated moduli are mean values for entire segment. Appendix E has more details on the FWD data analysis.

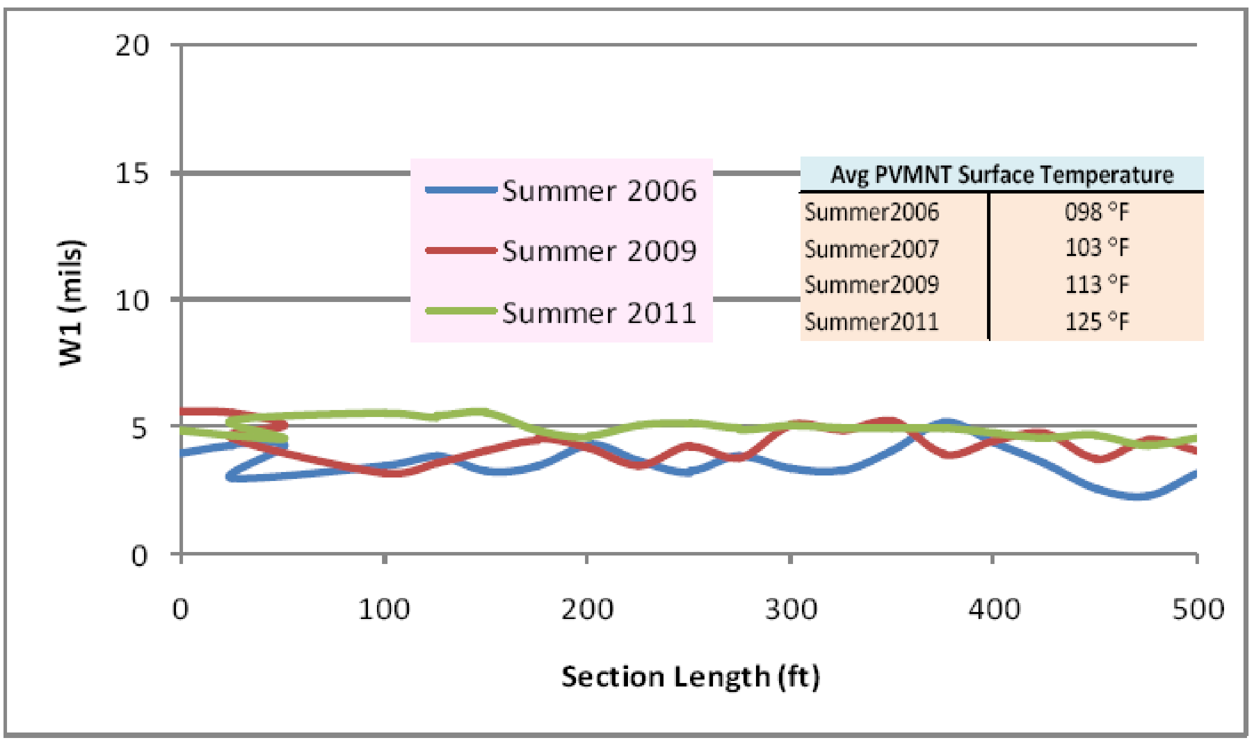


Figure 5-9. FWD W1 Deflection on SH 114 in Wise County.

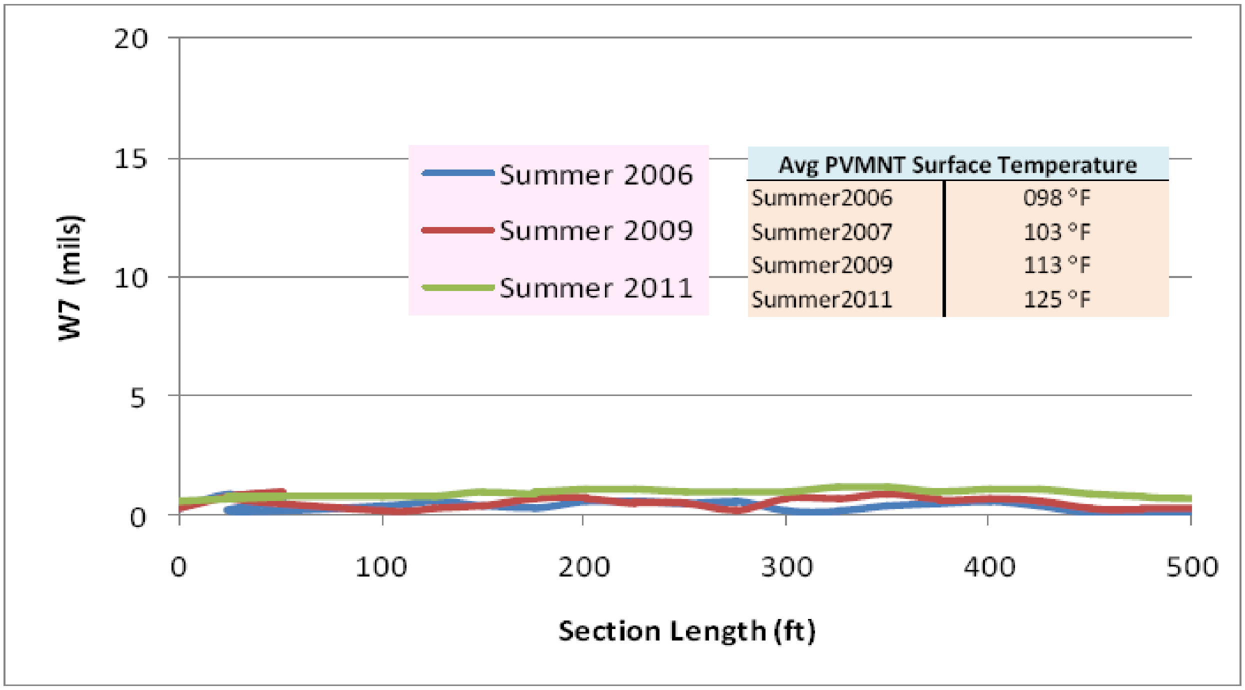


Figure 5-10. FWD W7 Deflection on SH 114 in Wise County.

Table 5-5. Summary of FWD Back-Calculated Layer Modulus.

Test Section ID#	Section/Hwy	Layer/Material	Thickness (in.)	Layer Moduli (ksi)	Design AC Modulus (Corrected to 77°F) (ksi)
TxDOT_TTI-00001	US 59	HMA	11	491.3	822.6
		LFA Base	10	316.6	
		LT Subbase	8	108.3	
		Subgrade	-	25.0	
TxDOT_TTI-00007	US 271	HMA	6.5	185.9	288.2
		PCC (jointed)	9.0	6089.6	
		Subgrade	-	25.3	
TxDOT_TTI-00006	SH 121	HMA	4.5	146.6	374.4
		CTB Base	9.5	7900.1	
		Subgrade	-	17.1	

SEAL COAT PROJECTS

A list of field tests for seal coat projects including construction monitoring and performance evaluation are summarized in Table 5-6. Note that for site selection and construction monitoring, the tests listed in Chapter 3 (Table 3-3 through 3-6) may also apply. Therefore, it is recommended to use Table 5-6 in conjunction with Chapter 3, particularly when selecting a test section and/or during construction monitoring.

SUMMARY

This chapter discussed the work completed to date in terms of field testing and data collection. A list of the recommended field tests along with the data analysis methods, the data output, and some demonstration examples were also presented. In general, close liaison and coordination with TxDOT, the Districts, and the Contractors is a very critical aspect of ensuring success of the field test program.

Table 5-6. List of Field Tests and Data Characteristics for Seal Coat Hwy Sections.

#	Item/Test	Description/Parameters	Reference/Spec	Comment
1	Tests prior to & during test section selection		Chapter 3	Refer to Chapter 3 of this interim report
2	Construction monitoring (also apply the typical construction monitoring done for HMA; Report 0-6658-1)	Asphalt-binder application rate		Ensure to measure at the temperature of placement not at the design rate & temperature.
		Aggregate application rate		
		Asphalt-binder & aggregate temperatures		
3	Field performance tests (Refer to Report 0-6658-1 for detailed test procedures)	Bleeding	Reports 0-1710-2 & Table 5-1	To be conducted twice per year – just after winter & just after summer.
		Aggregate loss	Reports 0-1710-2 & Table 5-1	To be conducted twice per year – just after winter & just after summer.
		Aggregate embedment	Reports 0-1710-2 & Table 5-1	To be conducted twice per year – just after winter & just after summer.
		GPR	Table 5-1	Prior to construction & as needed.
		FWD	Table 5-1	As needed.
		PSPA/SASW	Table 5-1	As needed, but only for seal coats on top of HMA & not for seal coats directly on base.
		High speed profiles	Table 5-1	To be conducted twice per year – just after winter & just after summer.
		DCP	Table 5-1	As needed.
		Coring	Table 5-1	As needed.
3	Other tests			Other tests will be conducted as deemed necessary and/or as TxDOT instructed.

CHAPTER 6
TRAFFIC DATA COLLECTION

Acquiring representative traffic data histories and forecasts is one of the central issues in validating/ calibrating proposed mechanistic-empirical (M-E) pavement designs. The research team made an effort to collect and analyze site specific traffic data with the assistance of Mr. Jim Neidigh of Southern Traffic Services (STS). This chapter documents the analyzed traffic data along with some discussions on several issues that have been identified up to this point.

In general, the minimum traffic data that need to be generated based on the scope of this study include the following:

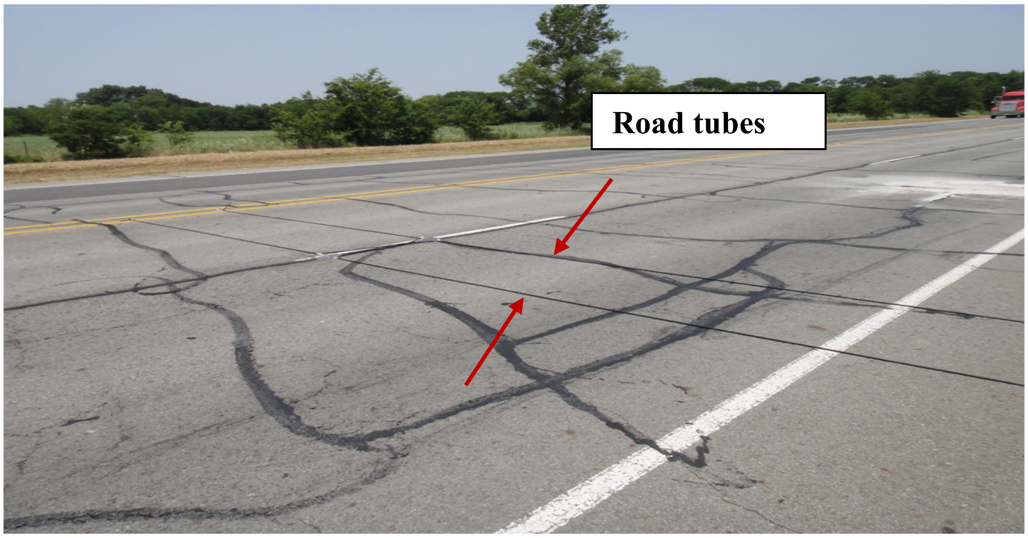
- Traffic volume (ADT, ADTT, etc.)
- Vehicle speed
- Vehicle classification distribution
- Axle weights using available WIM data
- Monthly traffic adjustment factors
- Traffic growth rates

TRAFFIC SENSOR INSTALLATION

Researchers used an STS traffic data recorder along with two pneumatic road tubes to collect traffic count data (see Figure 6-1). Two parallel road tubes are laid over two lanes heading one direction, with a spacing of 39.5 inches. The list of collected traffic count data is as follows:

- Vehicle counts reported by vehicle class (FHWA standard 13 class format).
- Vehicle speed.

The data collection was performed for a 48-hour period at four test sections at the time of this report (US 59, US 271, SH 121, and US 82). Appendix F shows examples of data collected. STS conducted quality checks of the data after data collection, and researchers then analyzed the STS data provided.



(a)

(b)

Figure 6-1. Installation of Road Tubes for Traffic Data Collection; (a) Road Tubes and (b) Data Logger System.

TRAFFIC DATA ANALYSIS

Researchers analyzed traffic data to come up with the following items for the MS Access Data Storage System:

- Average Daily Traffic (ADT): averaged the total number of vehicle counts for the days (48 hours).
- Vehicle Class Distribution: generated vehicle class distribution by dividing vehicle count of each class by the total number of vehicle counted.
- Percent of Truck: computed a percentage of truck by taking a ratio of the summation of vehicle counts corresponding to class 4 to 13 to the total number of vehicles counted.
- Average Daily Truck Traffic (ADTT): computed by multiplying ADT to the percent of truck.
- Average Vehicle Speed: averaged vehicle speeds collected for two days.

As shown in Figure 6-2, there are 13 vehicle classes identified in accordance with the Federal Highway Administration (FHWA) classification system (FHWA 2001).

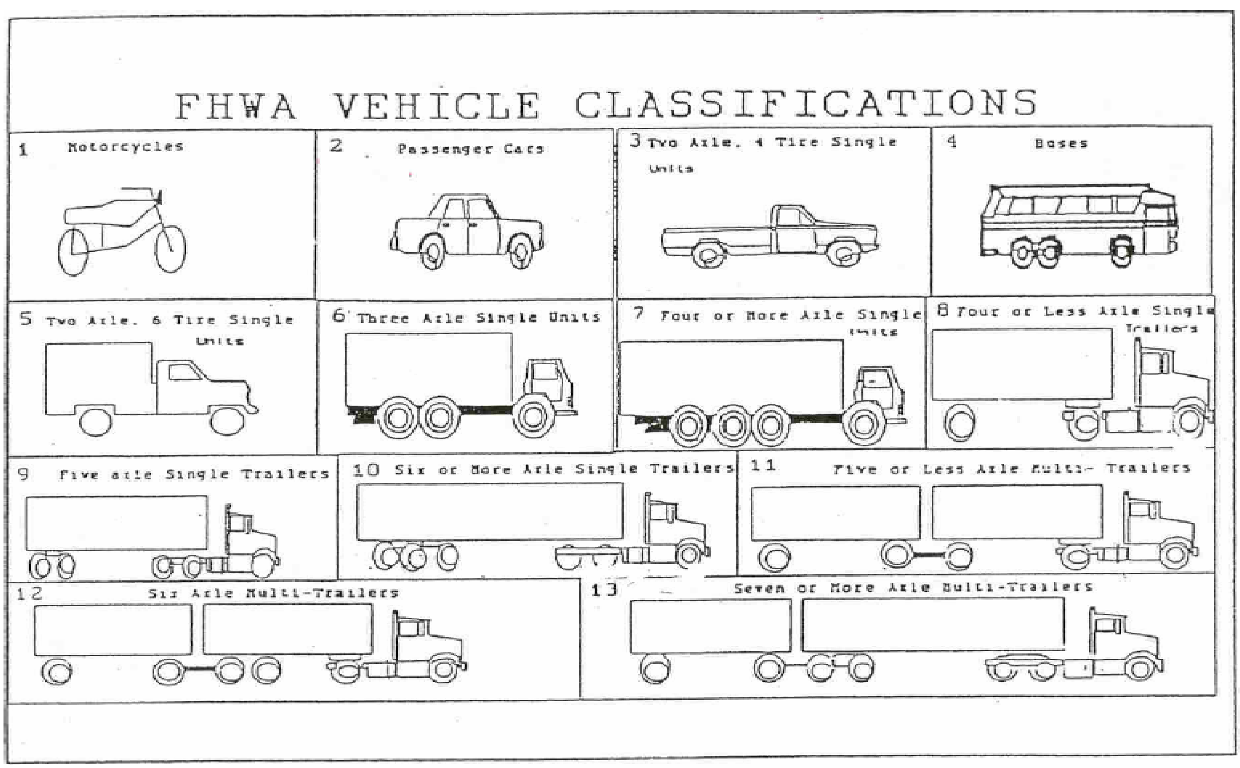


Figure 6-2. FHWA Vehicle Classifications.

With respect to computing the percent trucks, researchers considered class 4 to 13 as heavy vehicles in accordance with the Mechanistic-Empirical Pavement Design Guide (M-E PDG) program. Table 6-1 summarizes the results of the traffic data analysis. The distributions of vehicle classifications are shown from Figures 6-3 to 6-6.

Table 6-1. Summary of Traffic Data Analysis.

Test Section ID#	Section/Hwy	Lane	ADT	% Truck	ADTT	Avg. Speed (mph)
TxDOT_TTI-00001	US 59	Outside SB	3710.5	40.4	1500.5	72.6
		Inside SB	1116.5	23.6	264.0	75.1
TxDOT_TTI-00007	US 271	Outside SB	3624.0	23.8	861.5	67.5
		Inside SB	867.0	13.6	117.5	70.9
TxDOT_TTI-00006	SH 121	Outside NB	2750.5	15.5	427.5	69.6
		Inside NB	394.5	10.1	40.0	71.6
TxDOT_TTI-00008	US 82	Eastbound	4512.0	18.1	816.0	68.8
		Westbound	4667.0	16.2	754.0	64.5

The results indicated that the outside (driving) lane tends to receive a higher traffic level than the inside (passing) lane, which seems to be realistic. Among the monitored sections, US 59 exhibited the highest percent trucks while the highest monitored ADT was on US 82. With respect to vehicle classification, class 2 and 3 (passenger cars and light trucks) accounted for the major portion of vehicles in the traffic stream. The class 9 truck (typically the standard 18-wheeler) was the predominant truck traffic type among the heavy vehicle classes 4 through 13 in this analysis. Note that vehicle weight data are not available at this point; this is associated with the axle load spectra data, one of the key traffic inputs being considered in the M-E PDG.

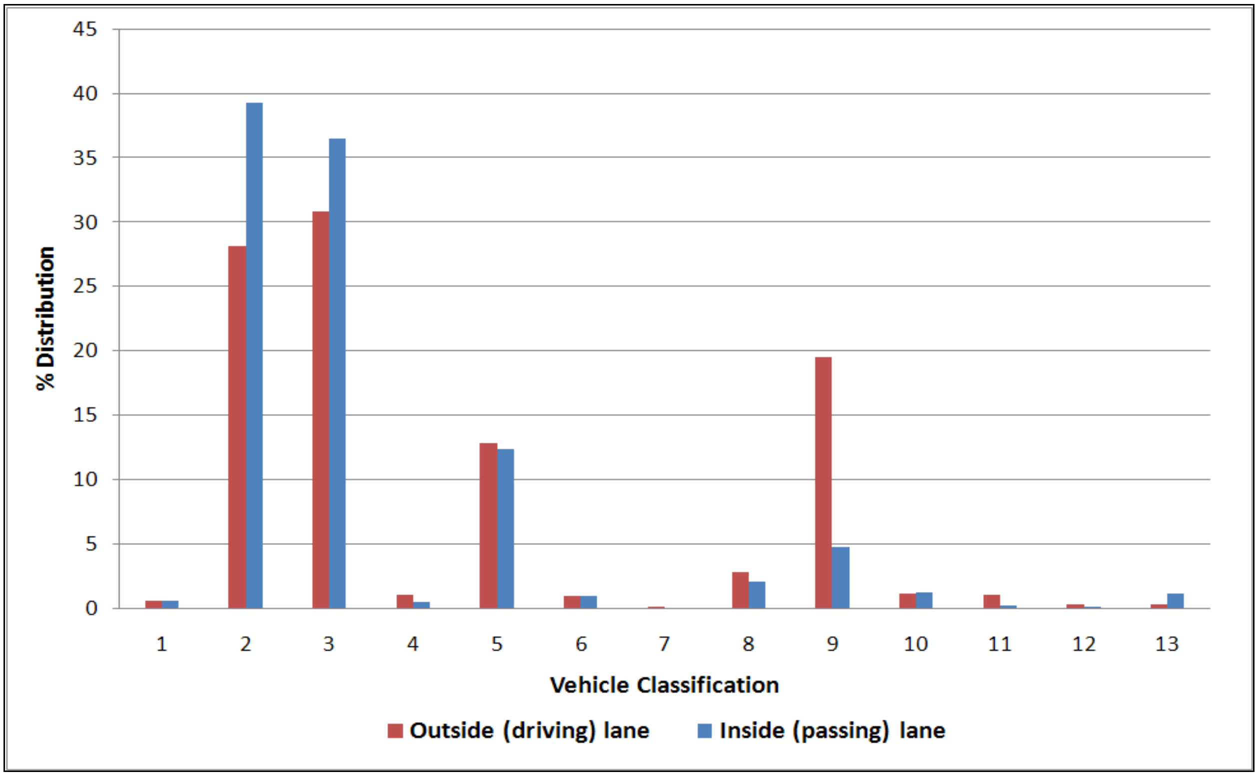


Figure 6-3. Vehicle Class Distribution of US 59 (Atlanta District).

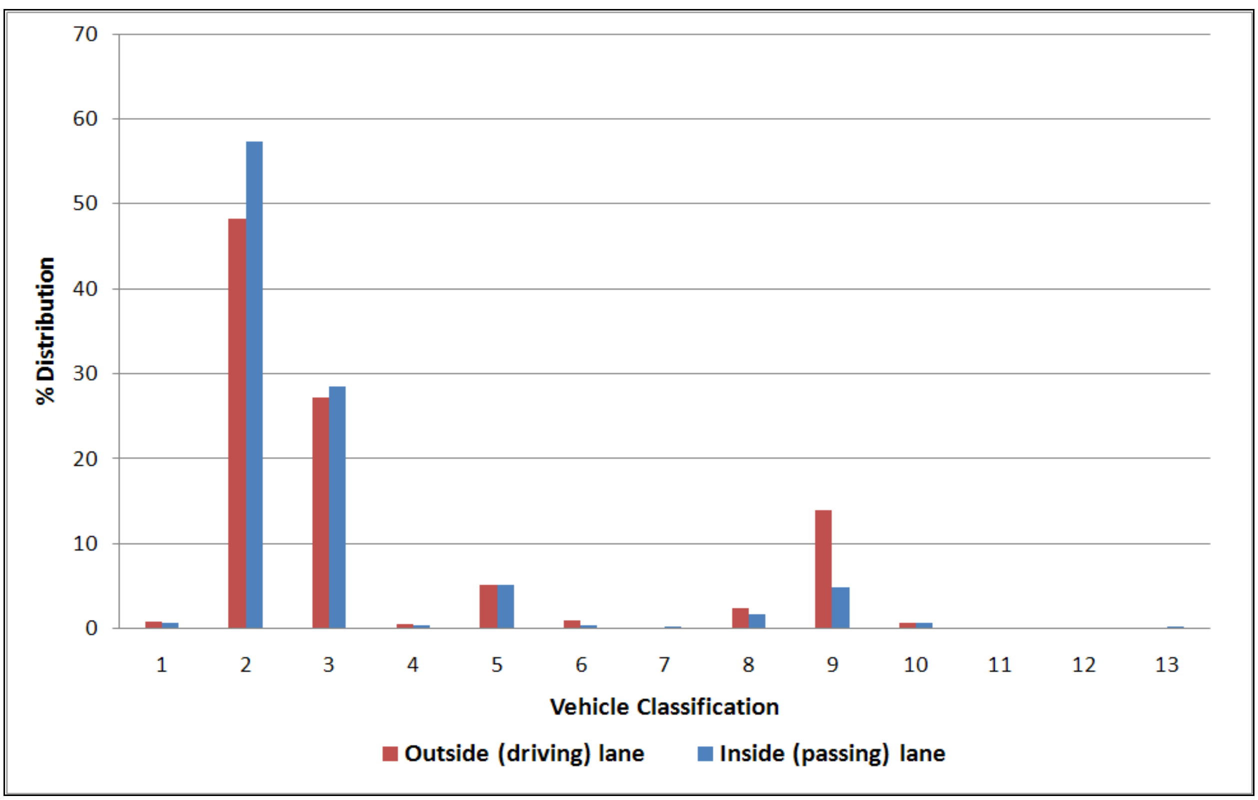


Figure 6-4. Vehicle Class Distribution of US 271 (Paris District).

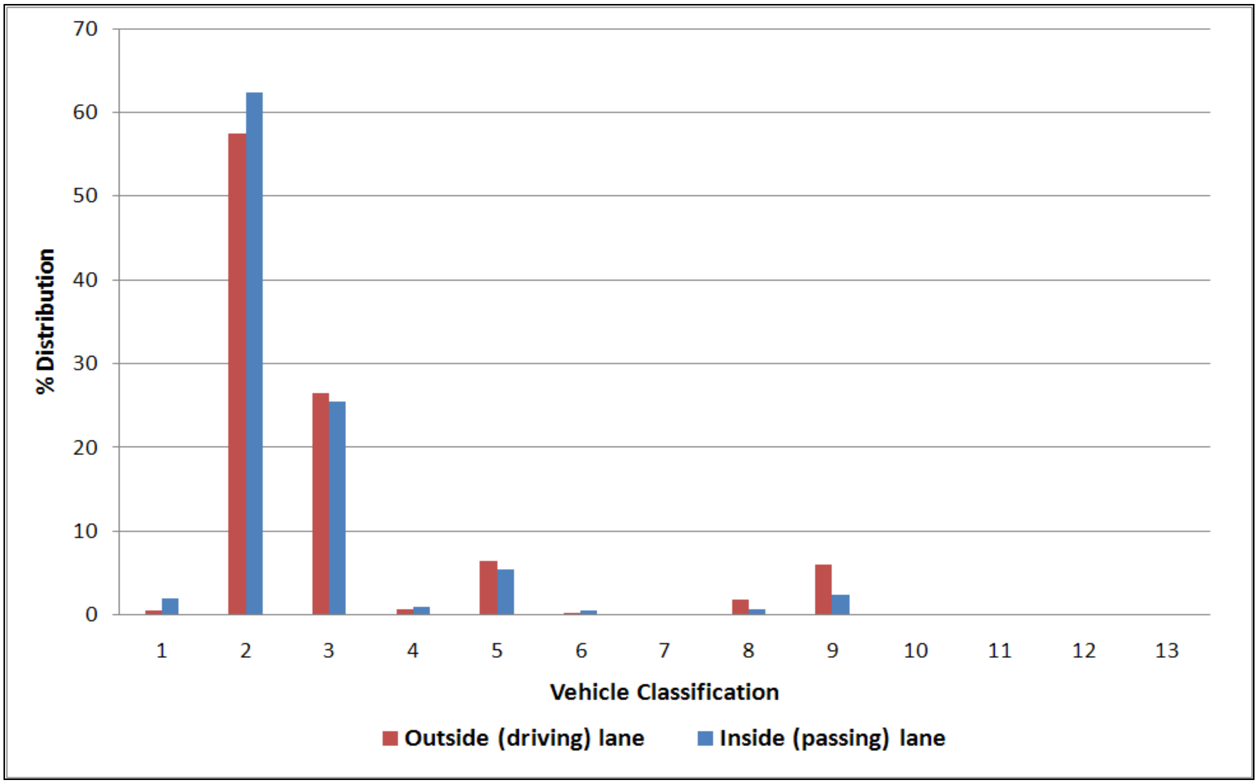


Figure 6-5. Vehicle Class Distribution of SH 121 (Paris District).

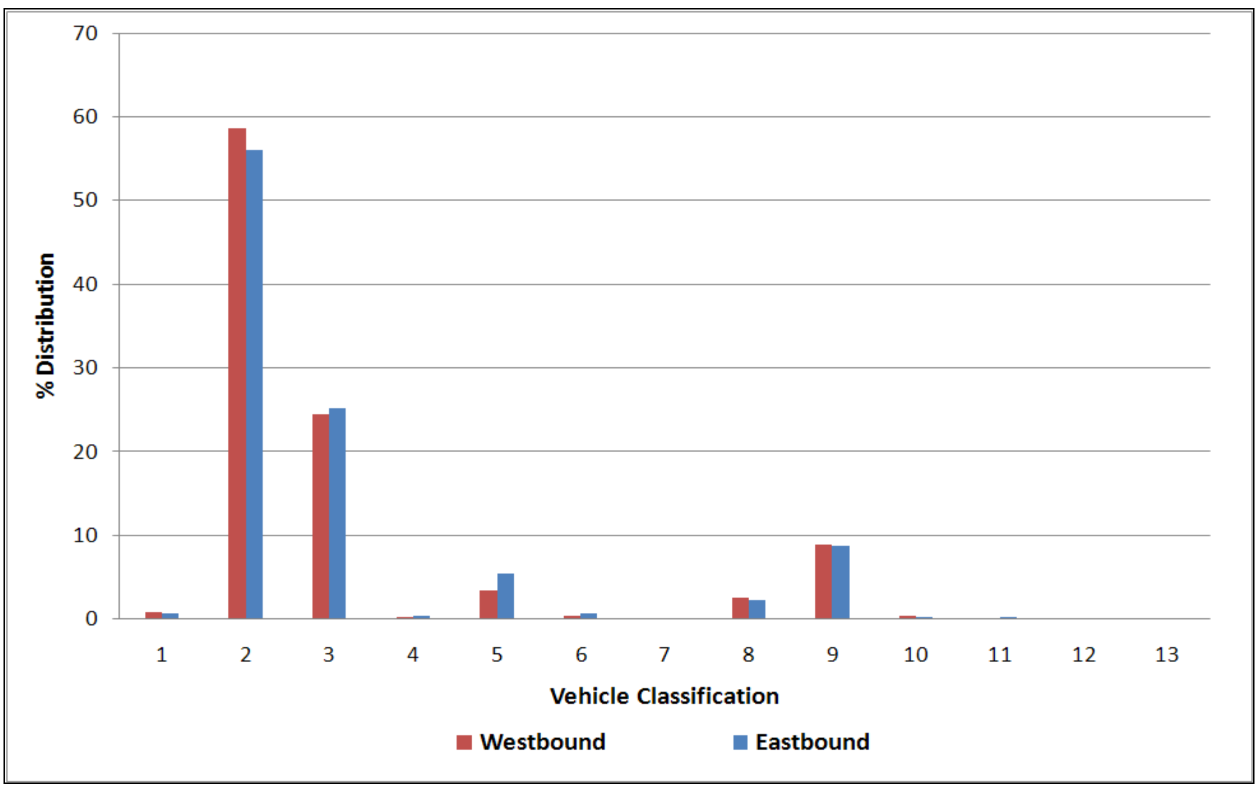


Figure 6-6. Vehicle Class Distribution of US 82 (Paris District).

In consultation with the project monitoring members, researchers compared traffic data of corresponding sections from the Transportation Planning and Programming Division (TP&P) of TxDOT with the site-specific data collected from this project (see Table 6-2). Note that while the ADT from TP&P covers two-way traffic, the ADT that STS collected corresponds to one-way traffic. To compare, researchers approximated one-way ADT by dividing the number of two-way ADT that TP&P collected. In addition, the ADT_STS and %T_STS are composite values by considering two lanes (outside and inside). It was observed that TP&P traffic data generally yielded slightly higher ADT. In terms of percent of truck, the analysis conducted from this project gives higher values than the TP&P data. Researchers believe that further verifications need to be conducted to explain this discrepancy between two data sets.

Table 6-2. Comparison of Key Traffic Data.

Test Section ID#	Section/ Hwy	ADT_ TP&P*	ADT_ STS	%T_ TP&P*	%T_ STS	ADTT_ TP&P	ADTT_ STS
TxDOT_TTI-00001	US 59	6100	4827	14.1	36.5	1720	1765
TxDOT_TTI-00007	US 271	4975	4491	12.0	21.8	1194	979.0
TxDOT_TTI-00006	SH 121	3550	3145	10.6	14.8	752.6	467.5

*Based on 2009 records. The ADT values are assumed one-way ADTs.

SUMMARY

In this chapter, the results of traffic data analysis based on site specific traffic tube counts were discussed. The following findings and recommendations were drawn from this analysis:

- Vehicle classification data were established along with ADT, percent trucks, ADTT, and vehicle speed for four sections monitored, namely: US 59, US 271, SH 121, and US 82.
- As expected, the outside (driving) lanes were found to be more critical for structural design purposes than the inside (passing) lanes by receiving more traffic and heavier trucks, which seems to be realistic.
- The highest percentage of trucks in the traffic stream was monitored on US 59. The largest ADT was counted from US 82.
- Comparison between the site specific data and TP&P data showed a significant discrepancy in terms of ADT.
- Further verification needs to be conducted to resolve this discrepancy before proceeding with additional contracted traffic data collection.
- Two-way data collection will be considered to be consistent with TP&P reporting conventions.
- With an extra financial assistance from TxDOT, the researchers have also purchased their own pneumatic traffic tubes that will be used for the traffic volume counts. Where needed however and on a limited basis only, STS may still be subcontracted for traffic volume counts on certain highways.

CHAPTER 7
CLIMATIC AND ENVIRONMENTAL DATA

Climatic data is one of core inputs in calibrating pavement performance using mechanistic-empirical (M-E) pavement design principles; pavement materials are susceptible to the change of climatic and environmental factors such as temperature, moisture, and humidity that directly impact pavement response. The research team attempted to collect and analyze climatic and environmental data using available web resources. This chapter documents the analyzed climatic data along with discussions on several issues that have been identified up to this point.

In general, the minimum climatic and environmental data that need to be generated based on the scope of this study include the following:

- Air temperatures (i.e., daily, monthly, or yearly, etc.)
- Precipitation (i.e., daily, monthly, or yearly, etc.)
- GPS coordinate locations and elevations
- Depth of ground water table (G.W.T)
- Well location including GPS coordinates and distance from test section.

CLIMATIC DATA GENERATION

Researchers have generated a climatic data file using the AASHTO M-E PDG program so that the generated file can be readily used for the Texas M-E program being developed under Project 0-6622. Note that the Texas M-E system is also incorporating the weather station data available in the M-E PDG. The following steps were taken to generate the climatic file:

- Identify latitude and longitude coordinates of the test section.
- Input the coordinates in the Climate Inputs of the AASHTO M-E PDG program and conduct interpolation to generate a climatic input file as shown in Figure 7-1.
- Generate a climatic file and save as Road ID.icm. Run the M-E PDG using the generated climatic file to produce MonthlyClimateSummary.csv file to check if there are abnormal values to be corrected. For the quality check, the most recent version of climatic data is also extracted from the web browser: http://www7.ncdc.noaa.gov.

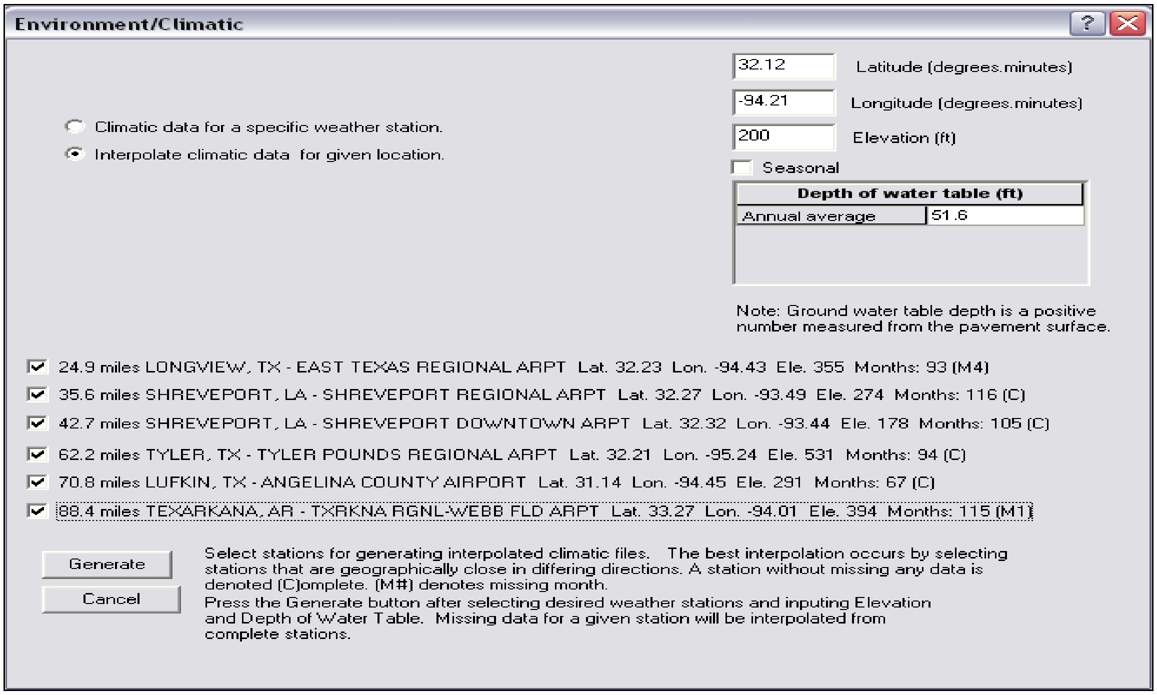


Figure 7-1. M-E PDG Climatic Data Generation Screen.

Using the MonthlyClimateSummary.csv file, researchers generated a summary table along with two charts showing the monthly variation of air temperature and precipitation for the purpose of establishing database entries. Researchers will upload the "*.icm" file of each section into the database system for future flexible pavement performance calibration using the Texas M-E program. Figures 7-2 to 7-4 show an example of processed climatic data for the US 59 section. Appendix G presents processed climatic data for other test sections. The climatic data appear to be reasonable since the comparison shown in Figure 7-4 exhibits good agreement between two data sets, which are based on weather station data used in 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.

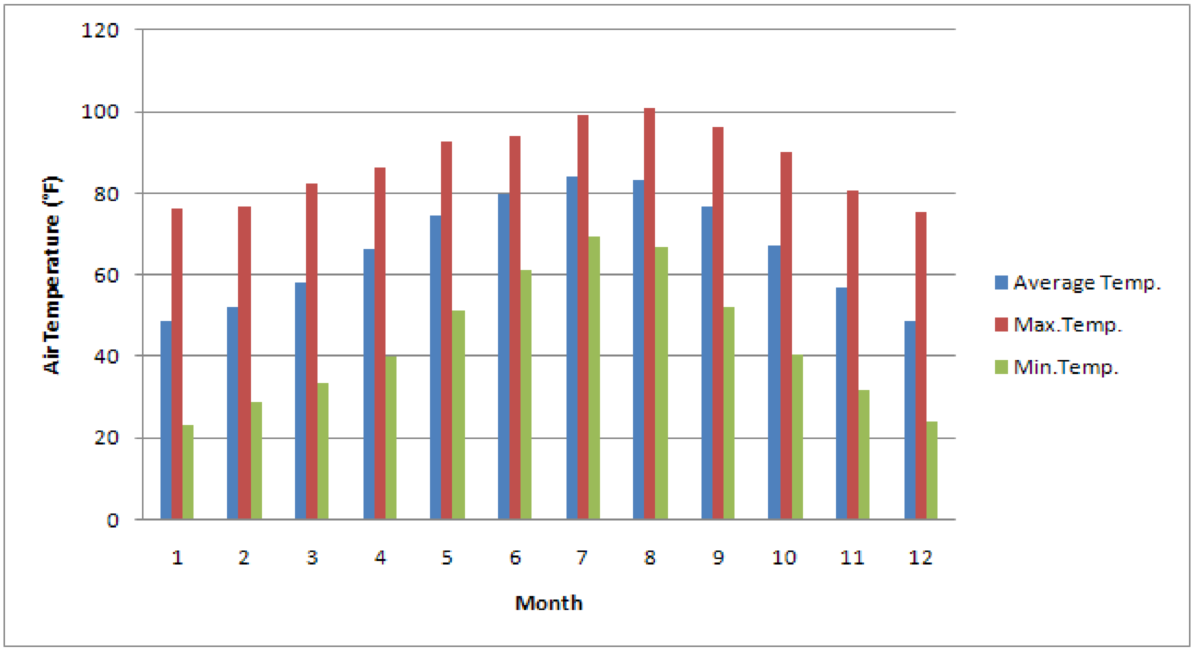


Figure 7-2. Air Temperature Monthly Variation Using M-E PDG Weather Station Data.

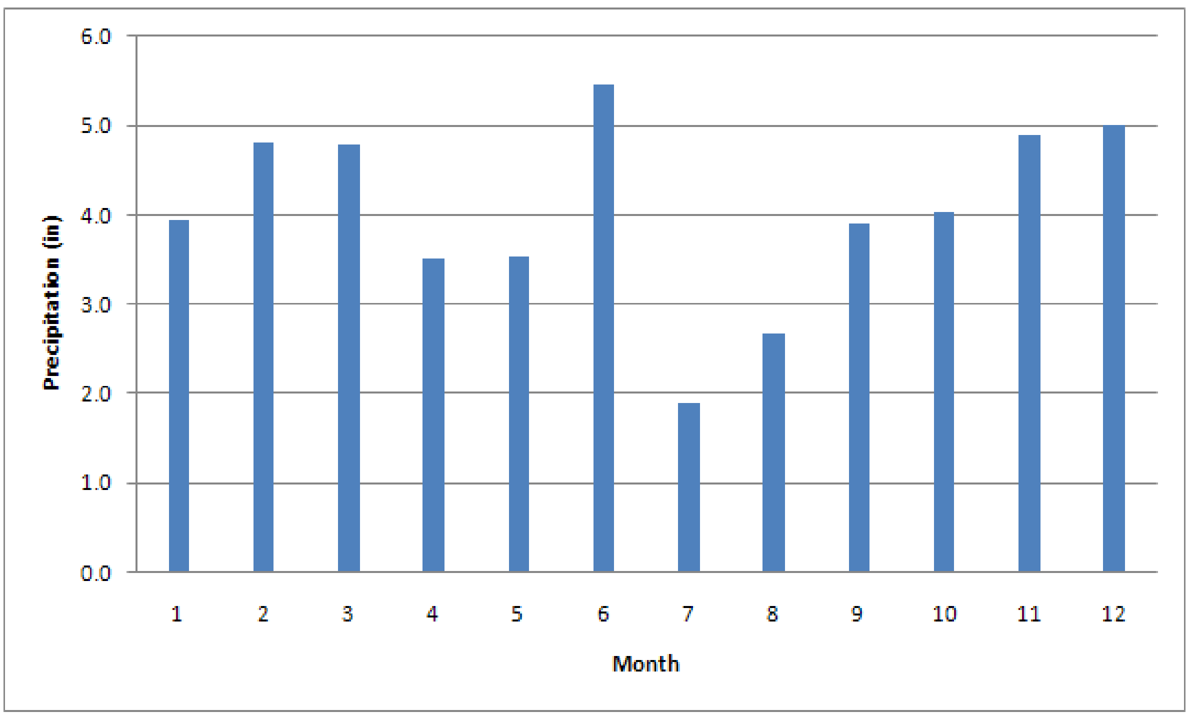


Figure 7-3. Precipitation Monthly Variation Using M-E PDG Weather Station Data.

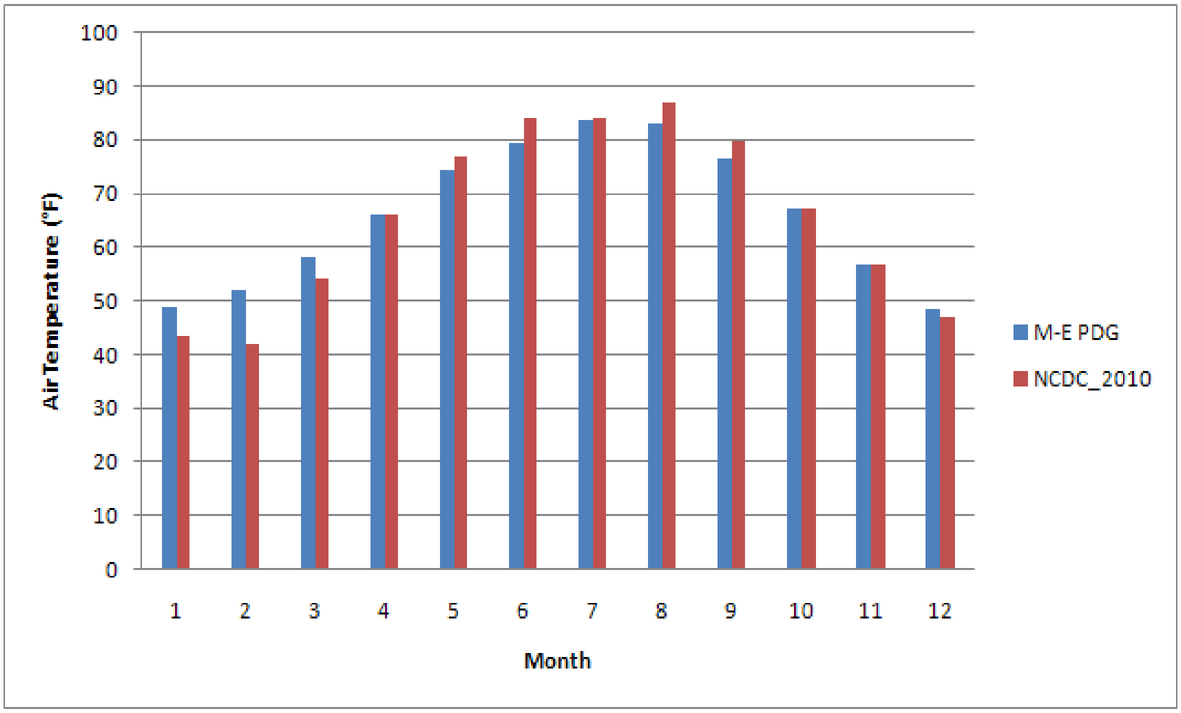


Figure 7-4. Comparison of Monthly Air Temperature Variation between M-E PDG and NCDC Weather Station Data.

GROUNDWATER TABLE DATA

Researchers collected groundwater table data from the web browser: http://nwis.waterdata.usgs.gov.tx.nwis/gwlevels. From this search, initially conducted by county, researchers came to recognize the limitation of available data that correspond to the test section. Researchers chose the closest location to the test section 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):

$$\text{Latitude(rad)} = \frac{\tan^{-1}(1)}{45}\text{Latitude}(^\circ)$$
$$\text{Longitude(rad)} = \frac{\tan^{-1}(1)}{45}\text{Longitude}(^\circ) \tag{7-1}$$

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 (7-2) can be used to calculate the distance in miles between two pairs of latitude/longitude values specified in radians:

$$D = 3949.99\cos^{-1}\left\{\sin Y_1 \sin Y_2 + \cos Y_1 \cos Y_2 \cos\left(X_1 - X_2\right)\right\} \qquad (7\text{-}2)$$

If the county-level data corresponding to the test section is not available, the adjacent counties were investigated to identify an alternative location. Table 7-1 presents the groundwater table depth data. From the table, the highlighted locations are deemed to be representative for providing groundwater table depth data due to its geographical proximity to the test section.

SUMMARY

This chapter presented the results of climatic and groundwater table depth data requirements. The following findings and recommendations were drawn from this analysis:

- Climatic data are being generated using the weather station data incorporated into the M-E PDG along with a quality check. The climatic input file of each test section is being generated for Texas M-E application.
- Groundwater table depth data are being generated using an available online database.

Table 7-1. Groundwater Table Depth Data.

Section/Hwy	County of Section	Section Location	County of Well	Well Location	Distance (mile)	G.W.T. (ft)	Years Collected
US 59	Panola	Lat 32°12′14″ Long 94°20′33″	Panola	Lat 32°01′28″ Long 94°15′12″	13.4	44.8	Sept. 2004
			Panola	Lat 32°03′54″ Long 94°31′03″	14.0	126.35	Sept. 2004
			Panola	**Lat 32°12′14″ Long 94°21′30″**	**0.9**	**51.6**	**Sept. 2004**
			Panola	Lat 32°17′22″ Long 94°28′52″	10.0	42.9	Sept. 2004
US 271	Lamar	Lat 33°51′06″ Long 95°30′34″	Lamar	Lat 33°49′45″ Long 95°49′20″	18.0	12.0	Jan. 1973
			Lamar	**Lat 33°51′21″ Long 95°43′18″**	**12.2**	**122.0**	**May 1970**
SH 121*	Fannin	Lat 33°28′13″ Long 96°16′23″	Grayson	Lat 33°42′36″ Long 96°39′27″	27.6	240.0 ~ 320.0	Jul. 2001 ~ Jan. 2006
			Collin	**Lat 33°14′47″ Long 96°33′50″**	**22.8**	**220.0 ~ 235.0**	**Jul. 2000 ~ June 2004**
US 82**	Grayson	Lat 33°58′69″ Long 96°28′32.87″	**Grayson**	**Lat 33°42′36″ Long 96°39′27″**	**21.7**	**240.0 ~ 320.0**	**Jul. 2001 ~ Jan. 2006**

*No data available for Fannin County.
**Only one location available for Grayson County.
Note: Data in bold represent the groundwater table that is nearest to the specific section.

CHAPTER 8
THE MS ACCESS DATA STORAGE SYSTEM

Chapter 1 pointed out that one of the primary goals of this study is to develop a comprehensive, yet user-friendly, data storage system where the collected data can be efficiently stored and easily/readily accessed. As TxDOT proposed, MS Access 2007® was selected as the data storage medium for this study. Figure 8-1 shows the main user interface screen for the MS Access Data Storage System for Project 0-6658.

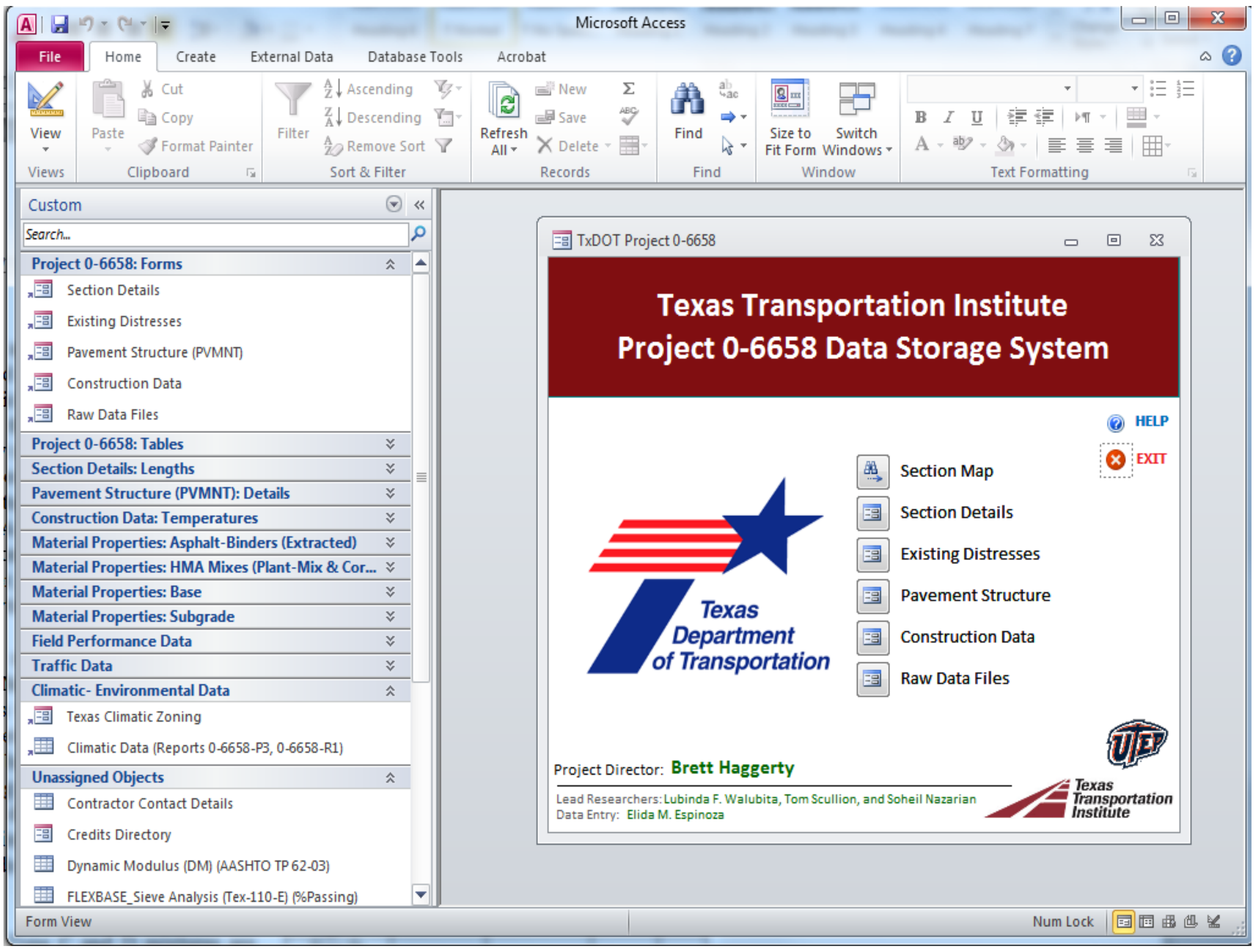


Figure 8-1. Main Screen User-Interface for the Project 0-6658 MS Access Data Storage System.

With the preceding background, this chapter provides a description and discussions of the MS Access Data Storage System in terms of the following aspects:

- Structure and organizational layout.
- Data entry—forms versus tables.
- Data content and accessibility.
- Data quality check and control.
- Challenges and troubleshooting.

While this chapter will limit itself to the above basic aspects of the MS Access Data Storage System and MS Access 2007, a detailed User's Manual will be made available in future publications. A summary of key points concludes the chapter. A prototype demo MS Access Data Storage System is included in a CD in a sleeve on the back cover of this interim report.

STRUCTURE AND ORGANIZATIONAL LAYOUT

Figure 8-2 shows the structure and organizational layout for the Project 0-6658 MS Access Data System. The system consists of the following four main fields: TxDOT contact details, Contractor contact details, Forms, and Tables. In turn, the Forms and Tables consist of the data shown in Figures 8-3 and 8-4.

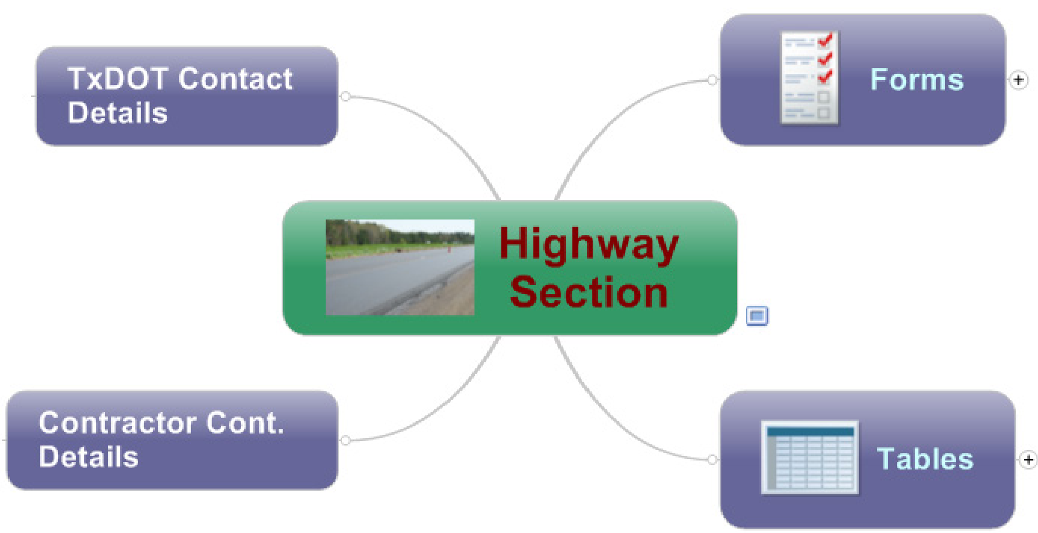


Figure 8-2. Structure for the Project 0-6658 MS Access Data Storage System.

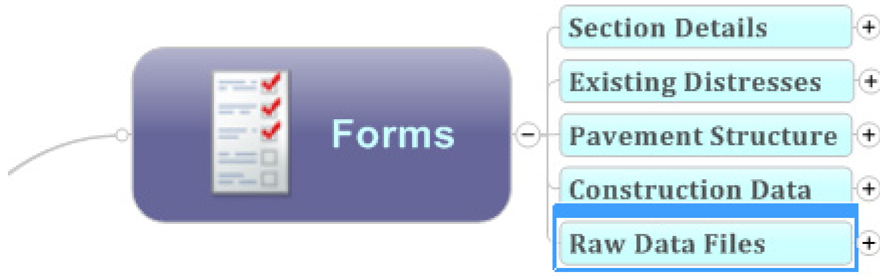


Figure 8-3. List of Data Stored as Forms.

Figure 8-4. List of Data Stored as Tables.

In Figures 8-3 and 8-4, the plus sign (+) next to the data field indicates there is an additional set of data linked to that particular data field. Some examples are shown in the subsequent Figures 8-5 through 8-7 for Section Details, Pavement Structure, Construction Data, Material Properties, and Field Performance Data. Detailed descriptions of these data fields along with the entire structure for the MS Access Data Storage System will be documented in the User's Manual. In general, however, Figures 8-1 through 8-7 provide the fundamental idea and insights into how the Project 0-6658 MS Access Data Storage System is organized and accessed. Refinement of the structural layout will be an ongoing process as more and more data are continuously being obtained. The primary intent is to make both data quantity and quality as simple and accessible as possible without compromising.

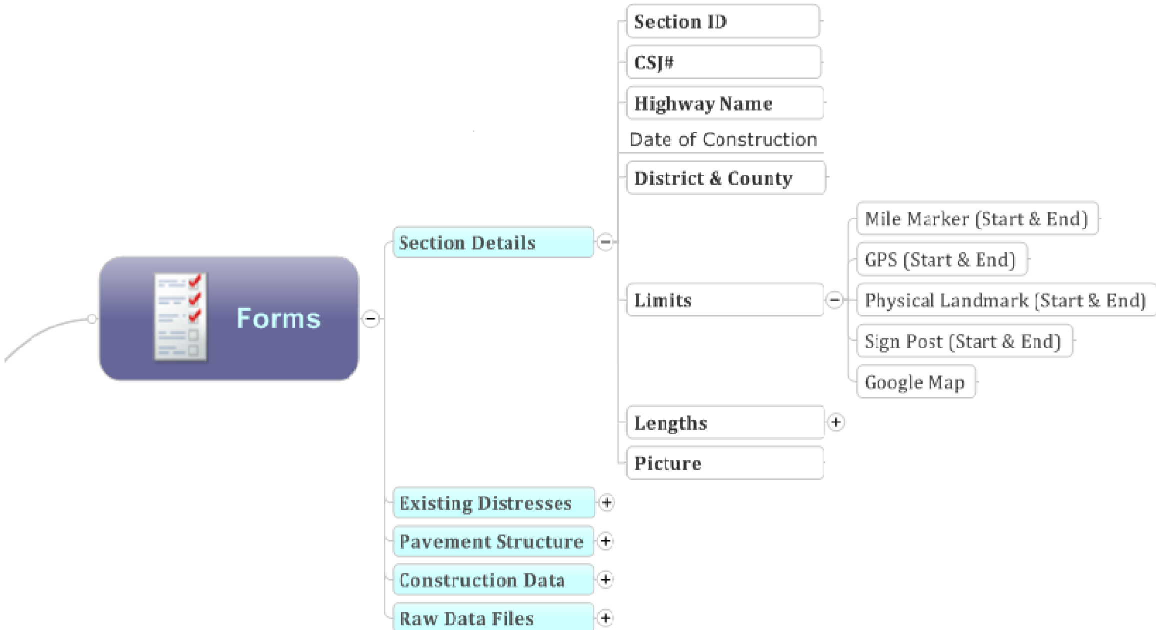


Figure 8-5. Example Data Links and Content for Section Details.

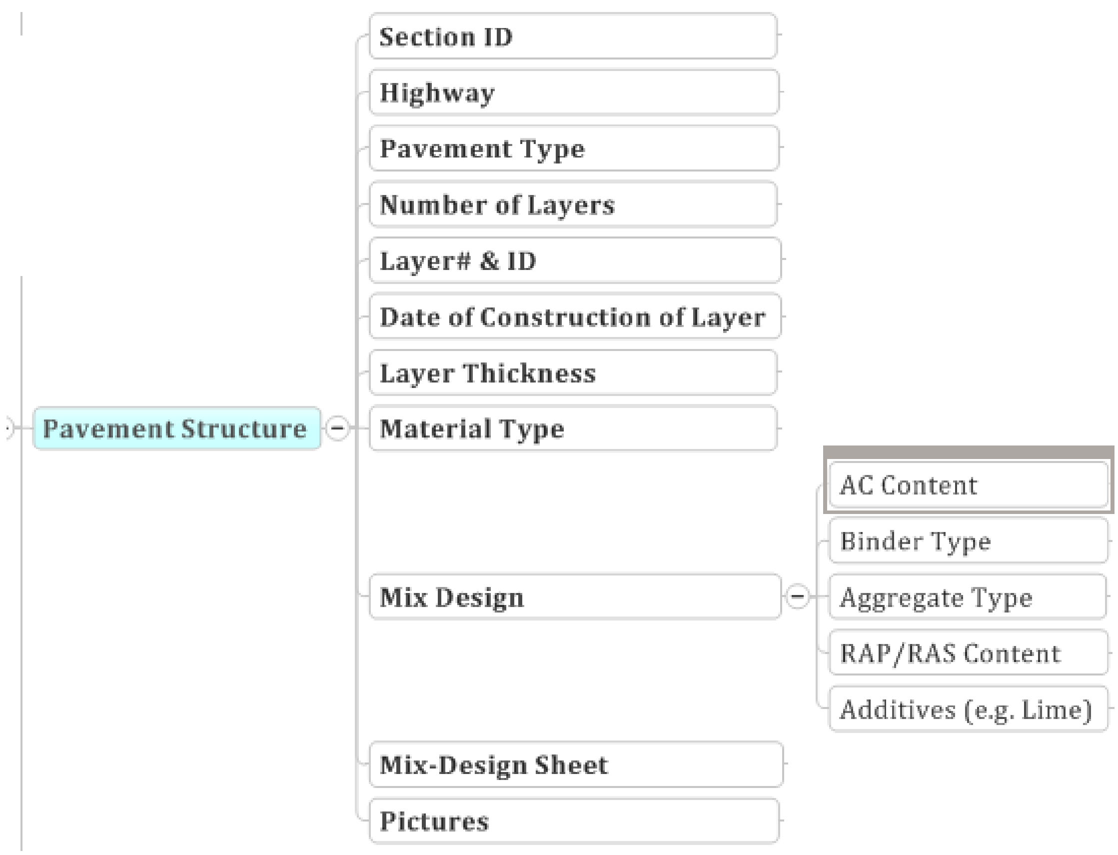


Figure 8-6. Example Data Links and Content for Pavement Structure.

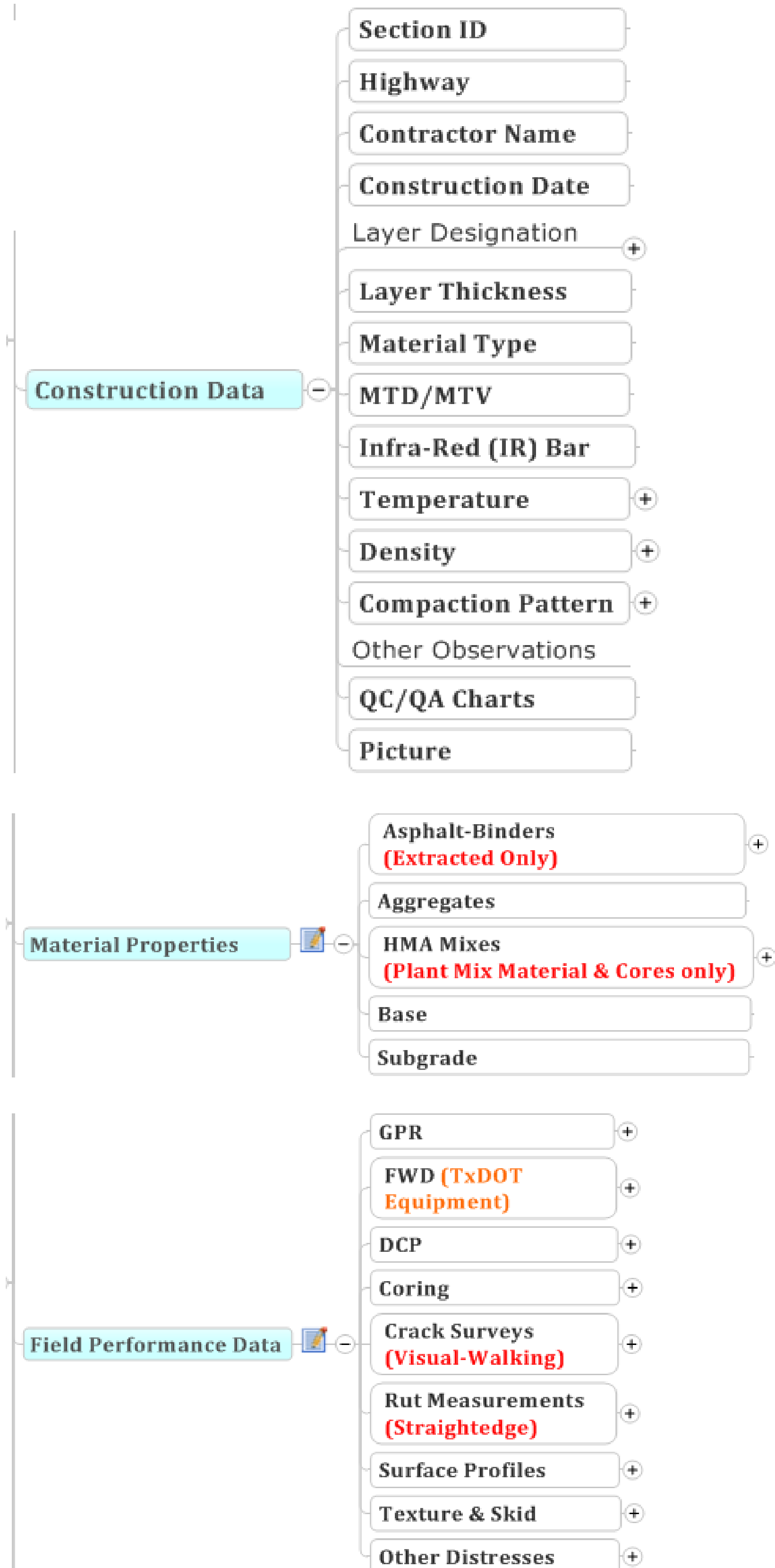


Figure 8-7. Construction Data, Material Properties, and Field Performance Data.

DATA ENTRY—FORMS VERSUS TABLES

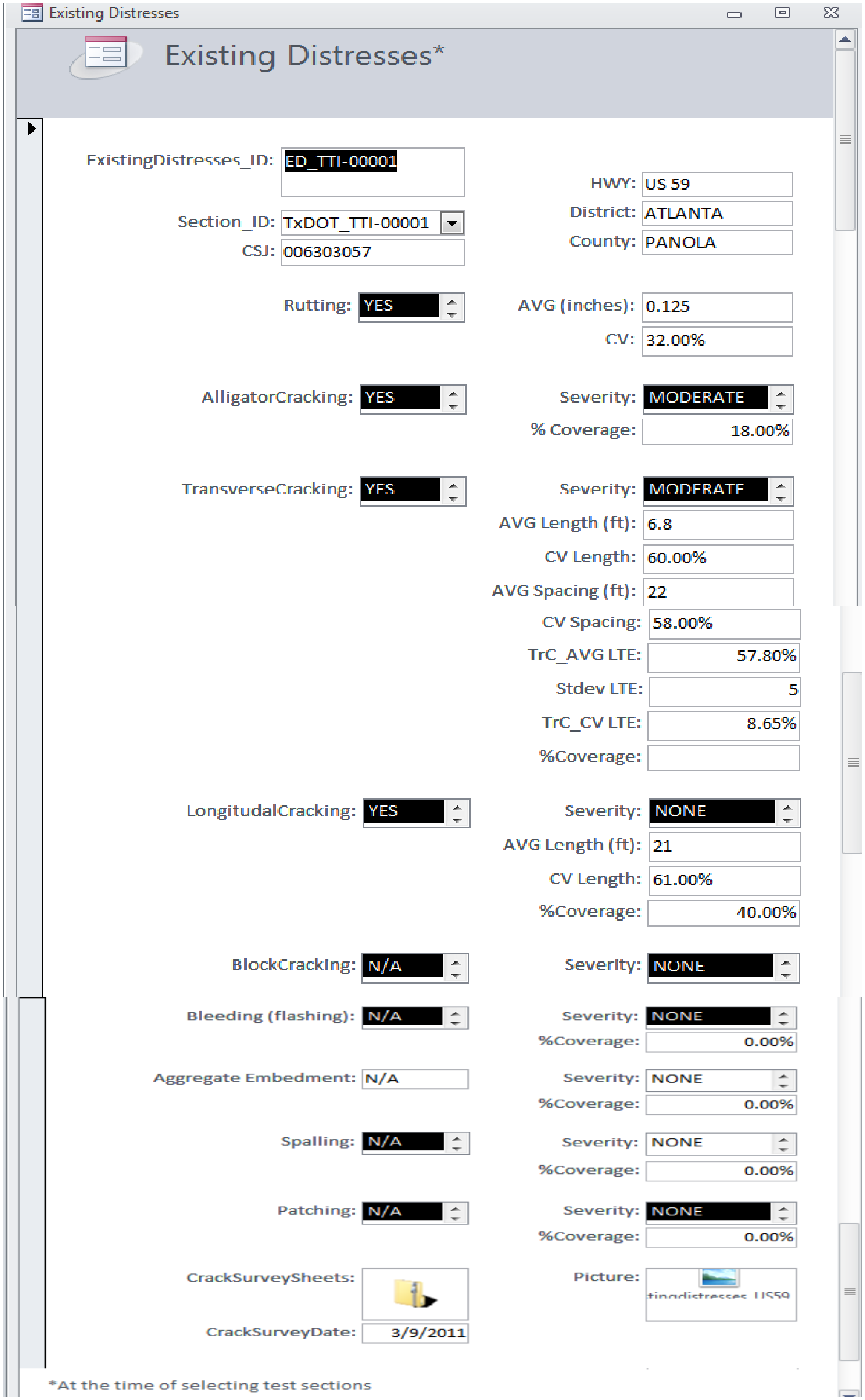
The MS Access Data Storage System was formulated with simplicity, user-friendliness, and ready accessibility in mind. Considering chronological organization and straightforward presentation, data are formatted according to type and utility of the information. Some data are more efficiently presented in the Form style while other data types are best reviewed in the Tabular format. MS Access 2007 also offers various ways to access, display, and present information entered in tabular format, including tables, queries, reports, graphs, bar charts, etc.

The MS Data Storage System uses both the Form and Tabular formats, with the majority of the data entered and viewed as tables or bar charts. For example, Existing Distresses are best entered as a checklist of the various stresses found on the pavement. To better present this information, a form was designed to indicate whether or not a certain distress was identified and, if so, provide the severity, average length of the cracking, etc. When entering in the Data Storage System, the data are also automatically saved in a tabular format. Figure 8-8 shows an example of the Existing Distresses form found in the Project 0-6658 MS Access Data Storage System, while Figures 8-9 and 8-10 are examples of the Existing Distresses table of the same data. Notice how the form offers a more aesthetic and straightforward presentation of the data, making it easier to read.

In general, the choice between a Form and Table is not only governed by the data type, but by other various considerations including the following:

- The method of data collection.
- The preferred method of accessing, displaying, and viewing data.
- The easiest and simplest format of analyzing and interpreting the data.
- The general accepted or standardized format of displaying the data.
- The typical format of utilizing the data in the M-E Structural Design Systems.

For example, while both the Hamburg rutting and Overlay cracking data are better off entered and stored in tabular format, the format of accessing and displaying may be different. The Hamburg data are better analyzed and interpreted in graphical format while bar charts are preferred for the Overlay cracking data (see Figures 8-11 and 8-12).



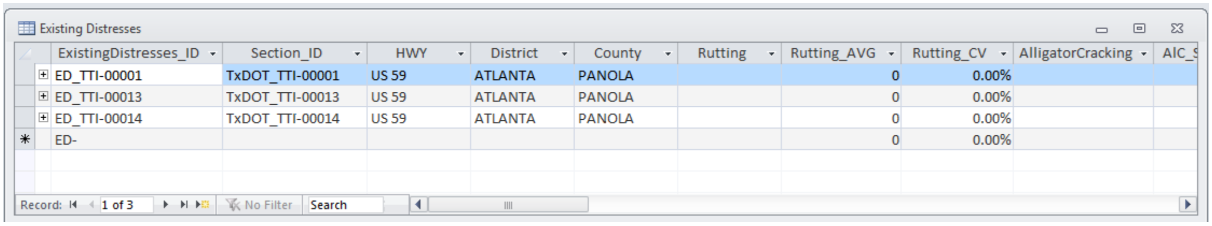
Existing Distresses

Existing Distresses*

ExistingDistresses_ID:	ED_TTI-00001	HWY:	US 59
Section_ID:	TxDOT_TTI-00001	District:	ATLANTA
CSJ:	006303057	County:	PANOLA
Rutting:	YES	AVG (inches):	0.125
		CV:	32.00%
AlligatorCracking:	YES	Severity:	MODERATE
		% Coverage:	18.00%
TransverseCracking:	YES	Severity:	MODERATE
		AVG Length (ft):	6.8
		CV Length:	60.00%
		AVG Spacing (ft):	22
		CV Spacing:	58.00%
		TrC_AVG LTE:	57.80%
		Stdev LTE:	5
		TrC_CV LTE:	8.65%
		%Coverage:	
LongitudalCracking:	YES	Severity:	NONE
		AVG Length (ft):	21
		CV Length:	61.00%
		%Coverage:	40.00%
BlockCracking:	N/A	Severity:	NONE
Bleeding (flashing):	N/A	Severity:	NONE
		%Coverage:	0.00%
Aggregate Embedment:	N/A	Severity:	NONE
		%Coverage:	0.00%
Spalling:	N/A	Severity:	NONE
		%Coverage:	0.00%
Patching:	N/A	Severity:	NONE
		%Coverage:	0.00%
CrackSurveySheets:		Picture:	
CrackSurveyDate:	3/9/2011		

*At the time of selecting test sections

Figure 8-8. Example of Existing Distresses in Form Format.

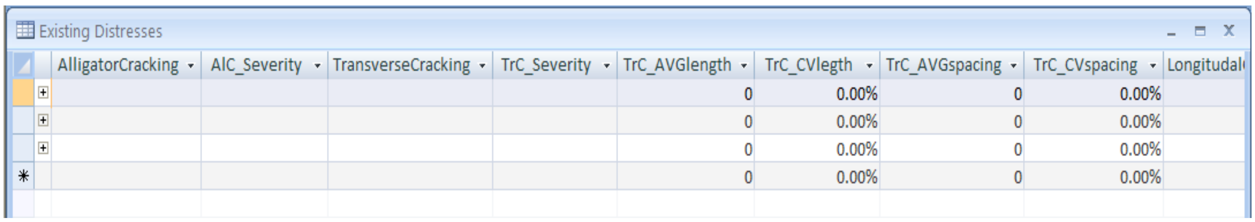


Existing Distresses

	ExistingDistresses_ID	Section_ID	HWY	District	County	Rutting	Rutting_AVG	Rutting_CV	AlligatorCracking	AlC_S
⊞	ED_TTI-00001	TxDOT_TTI-00001	US 59	ATLANTA	PANOLA		0	0.00%		
⊞	ED_TTI-00013	TxDOT_TTI-00013	US 59	ATLANTA	PANOLA		0	0.00%		
⊞	ED_TTI-00014	TxDOT_TTI-00014	US 59	ATLANTA	PANOLA		0	0.00%		
*	ED-						0	0.00%		

Record: 1 of 3 No Filter Search

Figure 8-9. Example of Existing Distresses in Tabular Format (Rutting).



Existing Distresses

	AlligatorCracking	AlC_Severity	TransverseCracking	TrC_Severity	TrC_AVGlength	TrC_CVlegth	TrC_AVGspacing	TrC_CVspacing	Longitudal
⊞					0	0.00%	0	0.00%	
⊞					0	0.00%	0	0.00%	
⊞					0	0.00%	0	0.00%	
*					0	0.00%	0	0.00%	

Figure 8-10. Example of Existing Distresses in Tabular Format (Cracking).

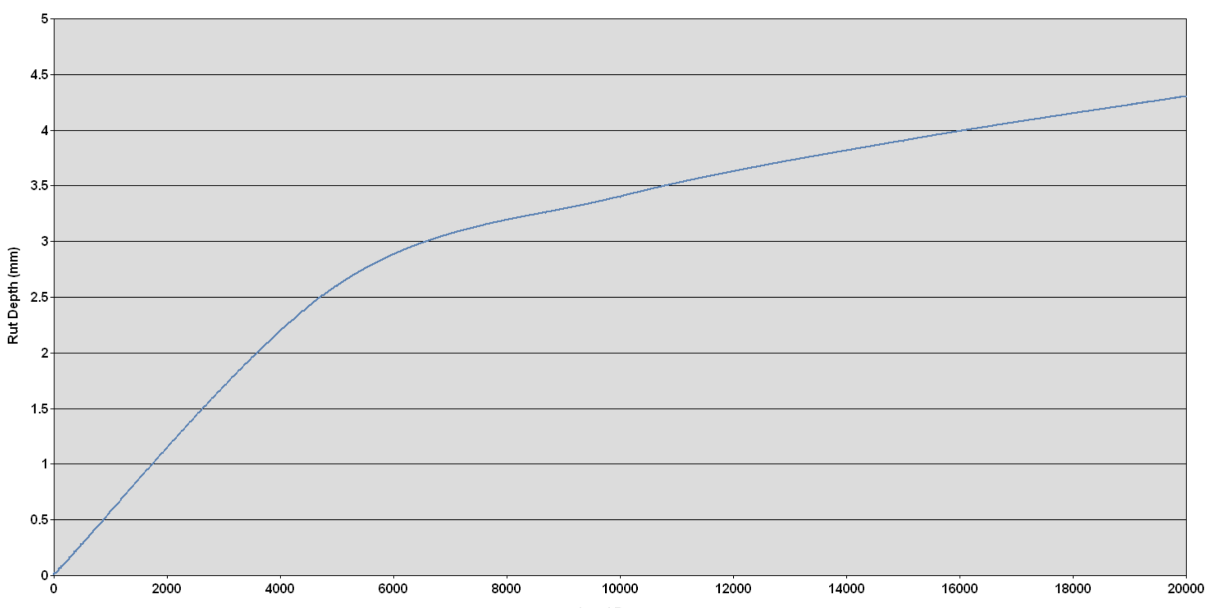


Figure 8-11. Example of Graphical Display for Hamburg Data (US 59, Atlanta District).

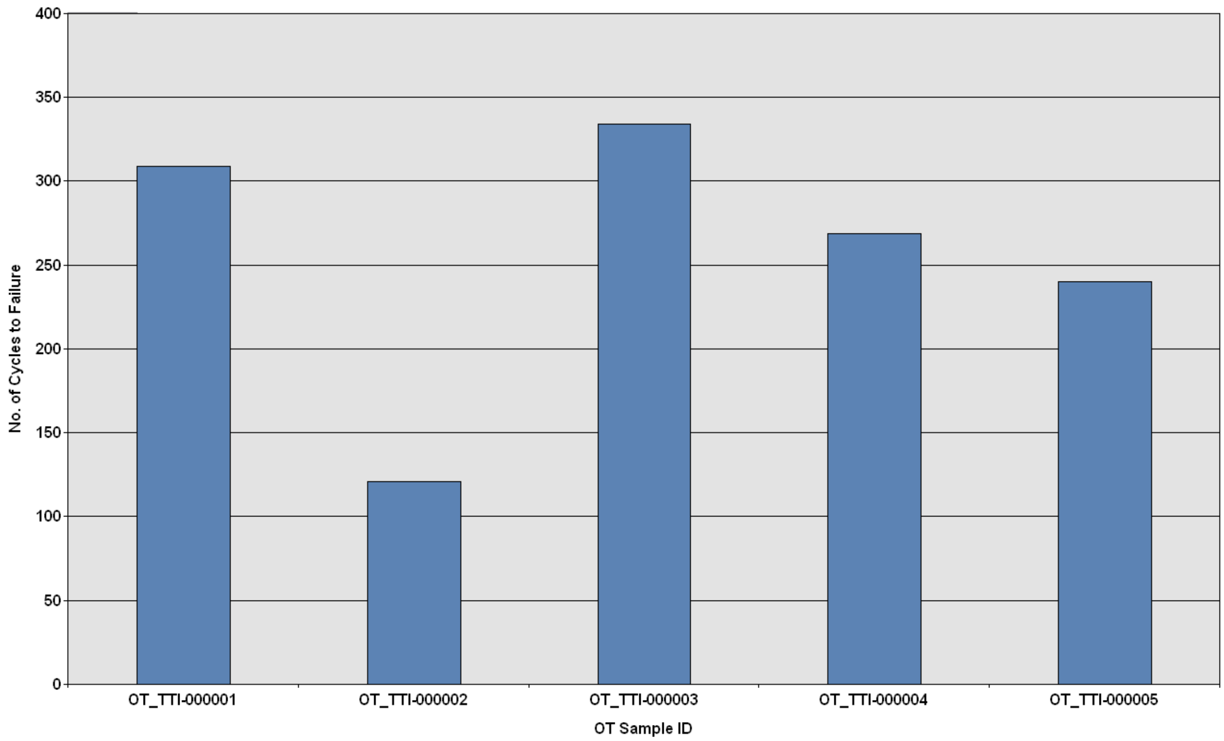


Figure 8-12. Example of Bar Chart Display for Overlay Data (US 59, Atlanta District).

DATA CONTENT AND ACCESSIBILITY

Figure 8-1 shows the Project 0-6658 MS Access Data Storage System is very comprehensive and contains various data types ranging from Section Details to Raw Data Files. Whether it is an Overlay, existing PVMNT structure, or new construction Hwy section, the data items shown in Figure 8-1, which are collected and/or generated as discussed in the preceding Chapters 2 through 7, will be entered and stored in the MS Access Data Storage System. In general, the data content must meet the requirements of Study 0-6622 (Zhou 2011) as well as contain sufficient, quality data for:

- Calibrating and validating M-E Structural Design Systems.
- Routine running of M-E software, design, and analysis of PVMNT structures.
- Ongoing reference data source and/or diagnostic tool for TxDOT engineers and other transportation professionals.

Notice in Figure 8-1 that the data fields also include Site Visits and Raw Data Files (see Figures 8-13 and 8-14). The Site Visits field documents the dates of site visits and the activities performed during those visits. It helps to track the site visits, material sampling, and performance monitoring. For instance, the Site Visits field will indicate when a particular Hwy section was visited and what types of activities were performed. It will also show the date the materials were sampled, very critical information for the plant-mix materials in terms of aging.

Raw data files are included so that users can re-analyze the data as verification, and for their own other purposes and applications. As Figure 8-14 shows, the raw data files are stored as Zip File attachments in the Project 0-6658 MS Access Data Storage System.

Due to its size, the raw GPR data are not entered nor stored in the Data Storage System. However, efforts are being made to limit the GPR data to the 500 ft test sections for possible input into the MS Access Data Storage System. Nonetheless, GPR summary data such as the layer thickness are currently been entered into the MS Access Data Storage System.

Likewise, there is also a limitation on the number of pictures to include, which may be discarded altogether to make room for the more important files.

Site Visits

SiteVisit_ID	Section_ID	HWY	District	County	Date	ActivityType	Activities	Adc
SV_TTI-000000001	TxDOT_TTI-00001	US 59	ATLANTA	PANOLA	3/9/2011	Pre-Construction	GPR, FWD, Crack survey, Coring (12 cores), DCP	
SV_TTI-000000002	TxDOT_TTI-00001	US 59	ATLANTA	PANOLA	3/10/2011	Pre-Construction	Same activities as on 3/9/2011	
SV_TTI-000000003	TxDOT_TTI-00001	US 59	ATLANTA	PANOLA	4/20/2011	Construction	Monitored and recorded construction process,	
SV_TTI-000000004	TxDOT_TTI-00001	US 59	ATLANTA	PANOLA	4/25/2011	Construction	Monitored and recorded construction process,	
SV_TTI-000000005	TxDOT_TTI-00001	US 59	ATLANTA	PANOLA	4/26/2011	Construction	Same activities as on 4/25/2011	
SV_TTI-000000006	TxDOT_TTI-00001	US 59	ATLANTA	PANOLA	5/10/2011	Post-Construction	High speed profiles	
SV_TTI-000000007	TxDOT_TTI-00001	US 59	ATLANTA	PANOLA	6/1/2011	Post-Construction	Coring (10 cores), Rut measurements, Remarke	
SV_TTI-000000008	TxDOT_TTI-00001	US 59	ATLANTA	PANOLA	4/26/2011	Coring & Material Sampling	Material pick-up from Plant in Marshall (7 barre	
SV_TTI-000000009	TxDOT_TTI-00007	US 271	PARIS	LAMAR	4/7/2011	Pre-Construction	GPR	
SV_TTI-000000010	TxDOT_TTI-00007	US 271	PARIS	LAMAR	4/13/2011	Pre-Construction	DCP, FWD, Crack survey, Coring, Selected and r	
SV_TTI-000000011	TxDOT_TTI-00007	US 271	PARIS	LAMAR	5/11/2011	Pre-Construction	High speed profiles	
SV_TTI-000000012	TxDOT_TTI-00006	SH 121	PARIS	FANNIN	5/13/2011	Pre-Construction	GPR	
SV_TTI-000000013	TxDOT_TTI-00004	IH 35	WACO	HILL	6/2/2011	Construction	Material sampling (15 buckets flex base; 15 buc	
SV_TTI-000000014	TxDOT_TTI-00006	SH 121	PARIS	FANNIN	6/7/2011	Pre-Construction	DCP (6 No.), FWD (every 25 ft), Crack survey, Cc	
SV_TTI-000000015	TxDOT_TTI-00008	US 82	PARIS	GRAYSON	6/7/2011	Pre-Construction	Material sampling (6 bags subgrade and 10 bag:	
SV_TTI-000000016	TxDOT_TTI-00009	IH 35	WACO	BELL	6/14/2011	Coring & Material Sampling	700lbs subgrade, 700lbs flex base, Photos	
SV_TTI-000000017	TxDOT_TTI-00004	IH 35	WACO	HILL	6/14/2011	Construction	Photos	
SV_TTI-000000018	TxDOT_TTI-00001	US 59	ATLANTA	PANOLA	6/7/2011	Traffic Counting	Traffic data collection (6/7-9/2011; SB lanes; ST:	
SV_TTI-000000019	TxDOT_TTI-00007	US 271	PARIS	LAMAR	6/7/2011	Traffic Counting	Traffic data collection (6/7-9/2011; SB lanes; ST:	
SV_TTI-000000020	TxDOT_TTI-00006	SH 121	PARIS	FANNIN	6/7/2011	Traffic Counting	Traffic data collection (6/7-9/2011; NB lanes; ST	
SV_TTI-000000021	TxDOT_TTI-00008	US 82	PARIS	GRAYSON	6/7/2011	Traffic Counting	Traffic data collection (6/7-9/2011; EB and WB l:	
SV_TTI-000000022	TxDOT_TTI-00010	IH 35	WACO	LA SALLE	7/7/2011	Post-Construction	GPR	
SV_TTI-000000023	TxDOT_TTI-00011	IH 35	WACO	LA SALLE	7/7/2011	Post-Construction	GPR	
SV_TTI-000000024	TxDOT_TTI-00012	IH 35	WACO	LA SALLE	7/7/2011	Post-Construction	GPR	
SV_TTI-000000025	TxDOT_TTI-00002	SH 114	FORT WORTH	WISE	7/12/2011	Post-Construction	GPR	
SV_TTI-000000026	TxDOT_TTI-00003	SH 114	FORT WORTH	WISE	7/12/2011	Post-Construction	GPR	
SV_TTI-000000027	TxDOT_TTI-00002	SH 114	FORT WORTH	WISE	7/13/2011	Performance Evaluation	Rut measurements, Crack surveys, Photos, Surf	

Record: 1 of 50 No Filter Search

Figure 8-13. Example of Site Visits Extracted from the Project 0-6658 MS Access Data Storage System.

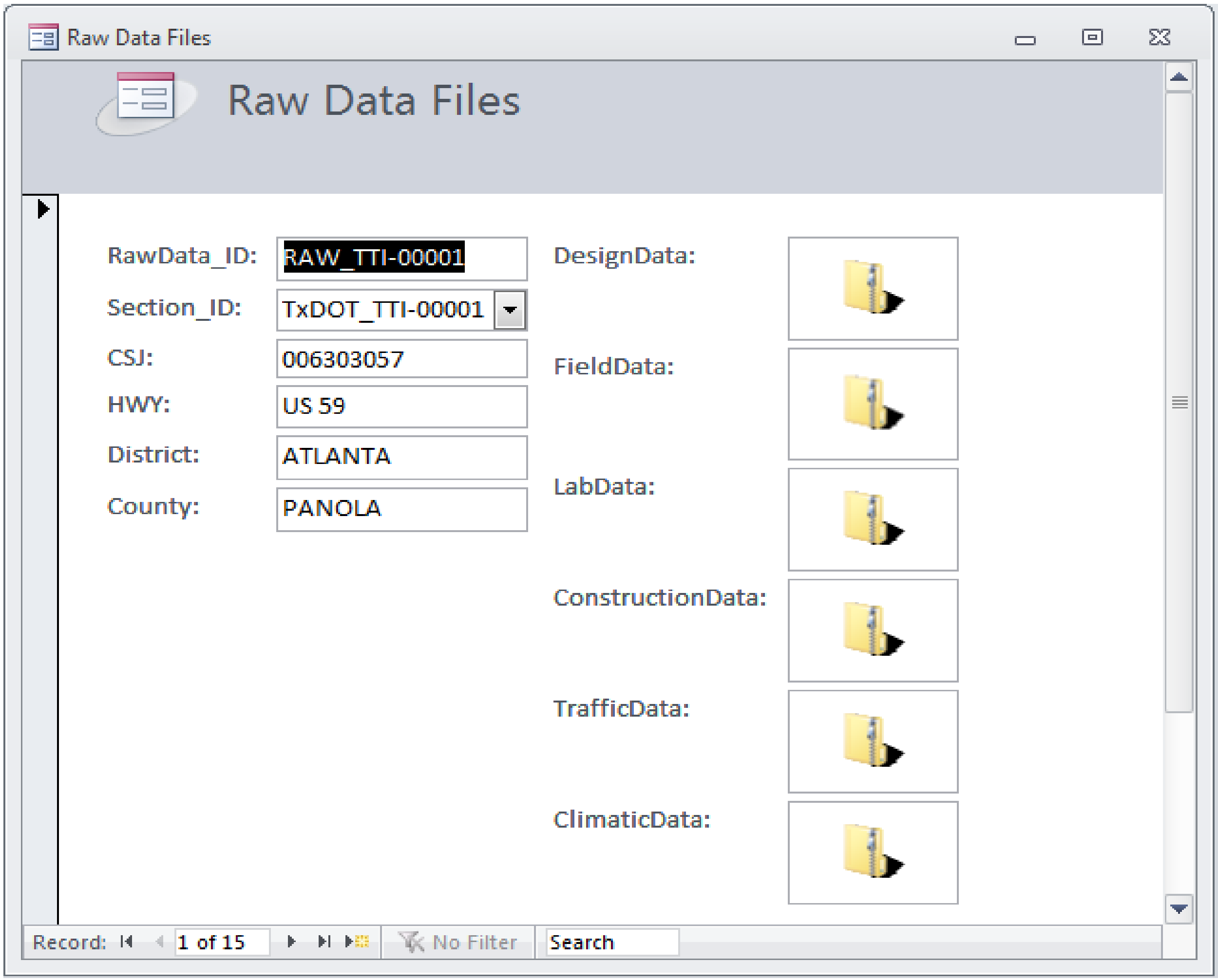


Figure 8-14. Example of Raw Data File Attachments as Zipped Files.

As discussed in the preceding sections, the researchers attempted, as much as possible, to simplify and make the Data Storage System user-friendly for easy accessibility of the data. In the current version of the Project 0-6658 MS Access Data Storage System, depending on how the data were entered/stored, the data may be accessed and displayed in any one of following formats:

- Tables.
- Forms.
- Graphs.
- Bar charts.

DATA QUALITY CHECK AND CONTROL

Data quality is the number one priority of this study. It is meaningless to collect comprehensive data that are erroneous or poorly documented, and consequently cannot be used by anyone. As documented elsewhere (Walubita 2011b), these researchers have developed a comprehensive *Quality Check and Control Manual* for monitoring and controlling the quality of the data going into the MS Access Data Storage System. Figure 8-15 shows a five-step flowchart structure for quality check and control of the data. Appendix H gives a step-by-step description of this flowchart (Walubita 2011b).

CHALLENGES AND TROUBLESHOOTING

Like any other data storage development study, various challenges still exist that need addressing. These challenges include, but are not limited to, the following:

- Potential to generate more than one curve on one graph. This aspect is currently still under investigation, bearing in mind that MS Access 2007 has limited options when compared to the newer versions.
- Potential to export data into other software systems. This is also under investigation and will be very critical when using the data to run the M-E software.
- Mathematical formula and calculations. Since each data item consists of at least two replicate samples, it would be very beneficial if some formula for parameters such as Avg, Stdev, COV, etc., were incorporated in the Data Storage System for automated computations.
- Storage space limitation. Attaching raw data files and pictures is a cause for concern. MS Access 2007 is limited to 2 GB and, therefore, file attachments may need to be discontinued in the future as more and more data are collected.
- MS Access version. Currently MS Access 2007 is being used. However, using the newer version that offers more options is recommended.

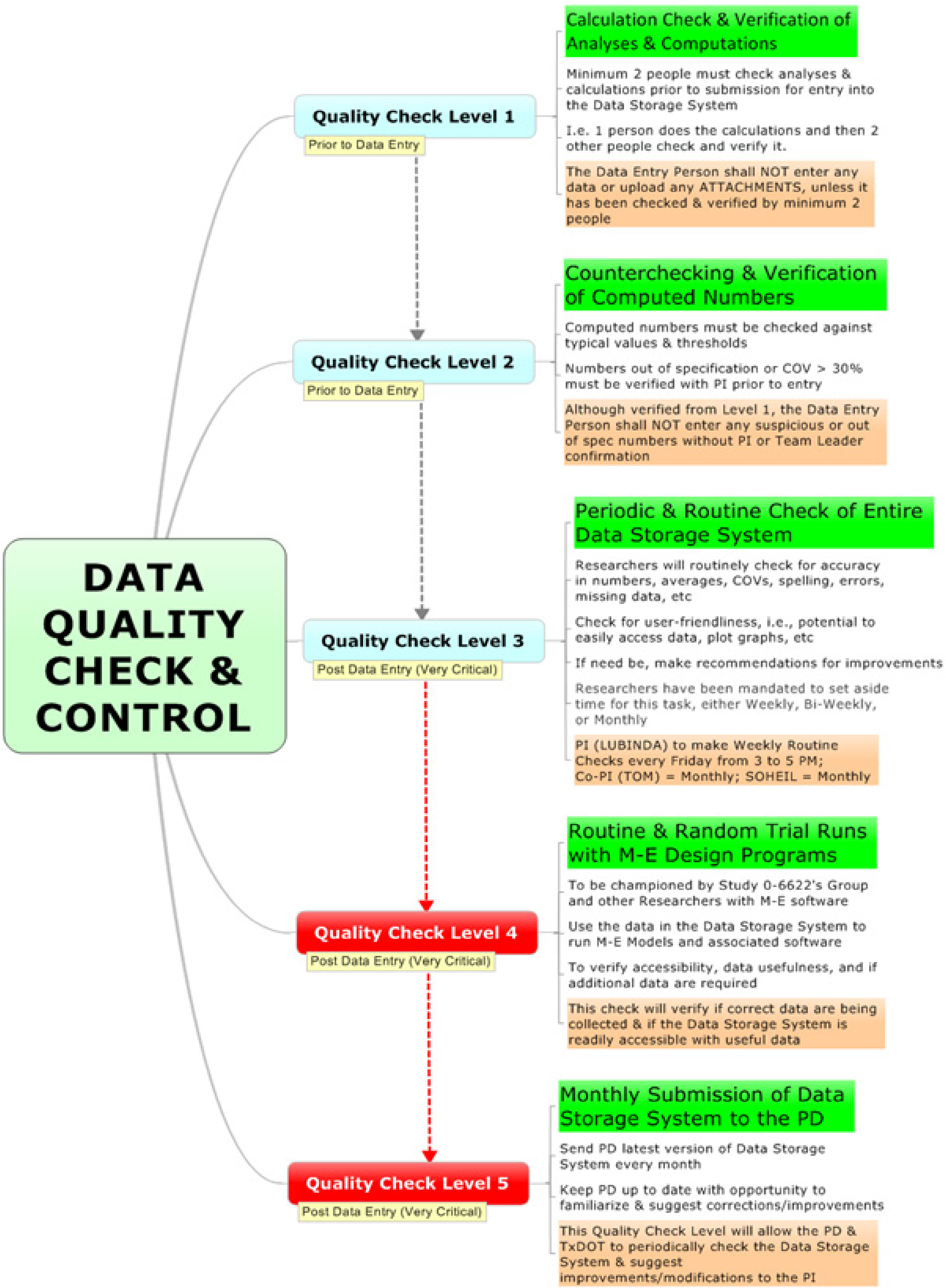


Figure 8-15. Flowchart for Data Quality Check and Control.

TTI-UTEP DATA STORAGE SYSTEM

To provide better quality control and updates in the Data Storage System, TTI and UTEP are separately maintaining their own individual data storage systems. The two data storage systems will be merged together towards the end of the project. In an experiment, the researchers successfully merged two trial dummy data storage systems. To avoid duplication, the test sections are identified as:

- TTI sections = TxDOT_TTI-XXXXX
- UTEP sections = TxDOT_UTEP-XXXXX

Likewise, each data field and its associated data sets are identified differently. These aspects will all be discussed in details in the User's Manual that these researchers will publish.

SUMMARY

This chapter provided a basic description of the Project 0-6658 MS Access Data Storage System with a focus on the following key items:

- Structure and organizational layout.
- Data entry—forms versus tables.
- Data content and accessibility.
- Data quality check and control.
- Challenges and troubleshooting.

CHAPTER 9
SUMMARY AND RECOMMENDATIONS

This interim report documents the work completed in Year 1 of this five-year study. As discussed in Chapters 2 through 8, the following activities have been completed:

- Data search and literature review of M-E Structural Design Systems and existing databases.
- Development of data collection, analysis, and reporting plans.
- Selection of field test sections. To date, up to 35 highway sections have been identified incorporating perpetual pavements, overlays, and new construction projects.
- Laboratory testing of asphalt-binders, HMA mixes, base material, and subgrade soils. Testing of these materials has been completed on a minimum of two test sections at the time of this report.
- Field testing including NDT and forensics on at least two test sections.
- Traffic and climatic data collection on at least two test sections.
- Development of a pilot data storage system in MS Access 2007. To date, the TTI MS Access Data Storage System contains over 10 test sections.

However, some challenges came up in the course of this study and need to be addressed. These include the following:

- Finalization of the base and subgrade soil tests, namely the PD, resilient modulus, and modulus of rupture. Research is currently ongoing in conjunction with Study 0-6622 (Zhou 2011) to develop and finalize these test protocols.
- A clear definition of the traffic data to be collected and the analysis methods. Currently, this is not clearly specified, so efforts are ongoing to address this issue.
- Lastly, TxDOT assistance is imperative in:
    - Solicitation of test sections.
    - Coordination of field tests particularly prior to and during construction.
    - Scheduling FWD equipment.

REFERENCES

AASHTO (2008). "Mechanistic-Empirical Pavement Design Guide." *A Manual of Practice*, Interim Edition.

Apeagyei, A. K., E. V. Dave, W. G. Buttlar (2008), "Effect of Cooling Rate on Thermal Cracking of Asphalt Concrete Pavements," *Journal of the Association of Asphalt Paving Technologists*, Volume: 77, pp. 709–738.

Federal Highway Administration, *Guide to LTPP Traffic Data Collection and Processing* (2001). FHWA, Washington, DC.

Krugler, P., C. Chang Albitres, T. Scullion, and A. Chowdhury (2007), "Analysis of Successful Flexible Pavement Sections in Texas—including Development of a Web Site and Database," Research Report No. FHWA/TX-08/0-5472-1, College Station, TX.

Nazarian, S. and J. Oh (2011). "Base and Subgrade Soil Testing." Tech Memo, 0-6658, RMC-1, Texas Transportation Institute, Texas A&M University, College Station, TX.

Oh, J., and E. G. Fernando (2008), "Development of Thickness Design Tables Based on the M-E PDG," Research Report No. BDH10-1, Texas Transportation Institute, College Station, TX.

Prozzi, J. (2010). Product 0-6275-P1. *Online Texas Flexible Pavement Database in MS Access*. University of Texas at Austin. Center for Transportation Research (CTR) and the University of Texas at Tyler (UT-Tyler). Austin, TX.

Smith, K. D., J. E. Bruinsma, M. J. Wade, K. Chatti, J. M. Vandenbossche, and H. T. Yu (2010). Using Falling Weight Deflectometer Data with Mechanistic-Empirical Design and Analysis, Vol. 1. Final Report. Applied Pavement Technology, Inc.

TxDOT (2006). *Manual on Uniform Traffic Control Devices*, Part 2: Signs. Austin, TX.

TxDOT (2004). "Standard Specifications for Construction and Maintenance of Highways, Streets, and Bridges." Austin, TX.

TxDOT (2011) Online Manuals: ftp://ftp.dot.state.tx.us/pub/txdot-info/cmd/mpl/brsqc.pdf Accessed September 2011, USA.

Walubita, L. F., W. Liu, and T. Scullion (2010), "The Texas Perpetual Pavements: Experience Overview and the Way Forward," Technical Report: 0-4822-3, Texas Transportation Institute, Texas A&M University, College Station, TX. http://tti.tamu.edu/documents/0-4822-3.pdf

Walubita, L. F., (2011a), "Task 2: Review of M-E Structural Design Systems," Tech Memo 0-6658, RMC-1, Texas Transportation Institute, Texas A&M University, College Station, TX.

Walubita, L. F., (2011b), "Quality Check and Control Manual for the Project 0-6658 MS Access Data Storage System." Draft Report, Texas Transportation Institute, Texas A&M University, College Station, TX.

Walubita, L.F., E. Espinoza, G. Das, J. Oh, T. Scullion, S. Nazarian, and I. Abdallah (2011a). "Texas Flexible Pavements and Overlays: Development of Data Collection Plans." Draft Technical Report: 0-6658-P1, Texas Transportation Institute, Texas A&M University, College Station, TX.

Walubita, L.F., E. Espinoza, G. Das, J. Oh, T. Scullion, S. Nazarian, and I. Abdallah (2011b). "Texas Flexible Pavements and Overlays: Review and Analysis of Existing Databases" Draft Technical Report: 0-6658-P6, Texas Transportation Institute, Texas A&M University, College Station, TX.

Walubita, L.F., E. Espinoza, G. Das, J. Oh, T. Scullion, S. Nazarian, and I. Abdallah (2011c). "Texas Flexible Pavements and Overlays: Data Analysis Plans and Reporting Format." Draft Technical Report: 0-6658-P3, Texas Transportation Institute, Texas A&M University, College Station, TX.

Walubita, L. F., A. Epps Martin, and C. J. Glover. A Surface Performance-Graded (SPG) Specification for Surface Treatment Binders: Development and Initial Validation. Technical Report 0-1710-2. , Texas Transportation Institute, Texas A&M University, College Station, TX. http://tti.tamu.edu/documents/0-1710-2.pdf

Zhou, F, S. Hu, X. Hu, and T. Scullion (2009), "Mechanistic-Empirical Asphalt Overlay Thickness Design and Analysis System," Technical Report: 0-5123-3, Texas Transportation Institute, Texas A&M University, College Station TX. http://tti.tamu.edu/documents/0-5123-3.pdf

Zhou, F., E. G. Fernando, and T. Scullion (2010). Development, Calibration, and Validation of Performance Prediction Models for the Texas M-E Flexible Pavement Design System. Technical Report: 0-5798-2, Texas Transportation Institute, Texas A&M University, College Station, TX. http://tti.tamu.edu/documents/0-5798-2.pdf

Zhou, F. (2011). Implementation of the Texas Mechanistic Empirical Thickness Design System (TexME). Ongoing Project 0-6622. Texas Transportation Institute, Texas A&M University, College Station, TX.

APPENDIX A: INPUT AND OUTPUT DATA FOR M-E STRUCTURAL DESIGN SYSTEMS AND ASSOCIATED SOFTWARE

Table A-1. List of Input Parameters and Data Requirements – The FPS Software.

#	Item	#	Description
1	General Information	a.	Problem#
		b.	Highway
		c.	District
		d.	County
		e.	Control
		f.	Section
		g.	Date
		h.	Job
2	Basic Design Criteria	a.	Length of analysis period (yrs)
		b.	Min time to first overlay (yrs)
		c.	Min time between overlays (yrs)
		d.	Design confidence level 95.0%
		e.	Intial serviceability index
		f.	Final serviceability index
		g.	Serviceability index after overlay
		h.	District temperature constant
		i.	Interest rate (%)
3	Program Controls	a.	Max funds/Sq. YD, INIT Const
		b.	Max thickness, INIT Const
		c.	Max thickness, all overlays
4	Traffic Data	a.	ADT begin (veh/day)
		b.	ADT end 20 Yr (veh/day)
		c.	18 kip ESALs 20 Yr - 1 Direction (millions)
		d.	Avg App Speed to OV Zone
		e.	Avg Speed OV Direction
		f.	Avg Speed Non-OV Direction
		g.	Percent ADT/HR Construction
		h.	Percent trucks in ADT
5	Const & Maint. Data	a.	Min Overlay thickness (in)
		b.	Overlay const. time, Hr/Day
		c.	ACP comp. density, Tons/CY
		d.	ACP production rate, Tons/Hr
		e.	Width of each lane, ft.
		f.	First year cost, RTN Maint.
		g.	Ann. Inc. Incr in Maint. Cost
6	Detour Design for Overlays	a.	Detour Model during Overlays
		b.	Total number of lanes
		c.	Num open lanes, overlay direction
		d.	Num open lanes, NON OV direction
		e.	Dist. Traffic slowed, OV direction
		f.	Dist. Traffic slowed, Non-OV direction
		g.	Detour distance, overlay zone
7	Structure & Material Properties	a.	Layer
		b.	Material Name
		c.	Cost per CY
		d.	Modulus E (ksi)
		e.	Min Depth
		f.	Max Depth
		g.	Salvage PCT
		h.	Poisson's ratio

Table A-2. List of Output Response Check – The FPS 21 Software.

#	Response	#	Response Check	Measurement Method	Test Procedure/Standard	Proposed Frequency of Measurement Per Year	Proposed Time of Measurement	Target Sections Per Year	Proposed Section Identifiers
1	Mechanistic verification	a.	Tensile strain @ bottom of HMA	N/A	-	-	-	-	-
		b.	Compressive strain on top of subgrade	N/A	-	-	-	-	-
2	Triaxial check	a.	Subgrade Triaxial class	Where applicable, will measure it when we collect soil samples	-	1	Where applicable, will measure it when we collect soil samples	-	-
		b.	Cohesiometer value (Cm)	Where applicable, will measure it when we collect soil samples	-	1	Where applicable, will measure it when we collect soil samples	-	-
3	Stress-strain analysis (under single tire, dual tire, & FWD loading)	a.	Compressive stress & strain	-	-	-		-	-
		b.	Tensile stress & strain	-	-	-		-	-
		c.	Deflections	-	-	-		-	-

Note

Must be exactly at the same location for each survey!	YES
How long the section will be?	500 ft
Number of replicate test sections per Hwy section	≥1
How many cross sections are going to be measured in the selected test section, e.g., for rutting?	≥3

Table A-3. List of Input Parameters and Data Requirements – The TxACOL Software (AC-PCC-CTB).

#	Item	#	Description	Proposed Test Procedure	Comment
1	General Information	a.	Type of AC overlay design		
		b.	Design life (yrs)		
		c.	Construction month & yr		
		d.	Traffic open month & yr		
2	Project Identification	a.	District		
		b.	County		
		c.	CSJ#		
		d.	Functional Class		
		e.	Date		
		f.	Reference mark format		
		g.	Reference mark (start-end)		
3	Analysis Parameters & Criteria	a.	Project name		
		b.	Reflective cracking rate (%), e.g., 50%		
		c.	AC rutting (in), e.g., 0.5		
4	Traffic	a.	ADT begin (veh/day)		
		b.	ADT end 20 Yr (veh/day)		
		c.	18 kip ESALs 20 Yr - 1 Direction (millions)		
		d.	Operation speed (mph)		
5	Climate	a.	EICM weather station data		
		b.	Lat & long location (degrees.minutes)		
		c.	Elevation (ft)		
6.1	Structure & Material Properties – HMA overlay (s)	a.	Layer thickness (in)		
		b.	Material type		
		c.	Thermal coefficient of expansion	Default or AASHTO TP60?	≥ 3 replicates
		d.	Poisson's ratio		
		e.	Binder DSR properties (PG grade, viscosity, etc)	AASHTO T 315	≥ 3 replicates
		f.	Dynamic modulus	AASHTO TP 62-03	≥ 3 replicates
		g.	Rutting parameters: *alpha* & *mu*	VESYS Test Protocol: Report 0-5798	≥ 3 replicates
		h.	Fracture parameters: *A* & *n* for fatigue/reflection cracking	OT Test Method: Tex-248-F	≥ 3 replicates
		i.	Volumetrics (AC content, AV, density, VMA, gradations, etc)	Tex-204, Tex-207-F, Tex-236-F	≥ 3 replicates
6.2	Structure & Material Properties – Existing JPCP/CRCP	a.	Material Type		
		b.	Thickness		
		c.	Thermal Coefficient of Expansion	Default or Texas Tech Procedure or AASHTO TP60?	
		d.	Poisson's ratio		
		e.	Joint/Crack Spacing (ft)		
		f.	PCC Modulus (ksi)	FWD testing (TxDOT equipment)	
		g.	LTE	FWD testing (TxDOT equipment)	
6.3	Structure & Material Properties – Existing CTB Base	a.	Material Type		
		b.	Thickness		
		c.	Poisson's ratio		
		d.	Thermal Coefficient of Expansion		
		e.	Typical Modulus (ksi)	FWD testing (TxDOT equipment)	
6.4	Structure & Material Properties – Subgrade layer	a.	Material Type		
		b.	Thickness		
		c.	Poisson's ratio		
		d.	Typical Modulus (ksi)	FWD testing (TxDOT equipment)	
		e.	Monthly modulus (ksi)	FWD testing (TxDOT equipment)	

Note
Material properties need average value and standard deviation ≥ 3 replicates

Table A-4. List of Input Parameters and Data Requirements – The TxACOL Software (AC-PCC-Granular Base).

#	Item	#	Description	Proposed Test Procedure	Comment
1	General Information	a.	Type of AC overlay design		
		b.	Design life (yrs)		
		c.	Construction month & yr		
		d.	Traffic open month & yr		
2	Project Identification	a.	District		
		b.	County		
		c.	CSJ#		
		d.	Functional Class		
		e.	Date		
		f.	Reference mark format		
		g.	Reference mark (start-end)		
3	Analysis Parameters & Criteria	a.	Project name		
		b.	Reflective cracking rate (%), e.g., 50%		
		c.	AC rutting (in), e.g., 0.5		
4	Traffic	a.	ADT begin (veh/day)		
		b.	ADT end 20 Yr (veh/day)		
		c.	18 kip ESALs 20 Yr - 1 Direction (millions)		
		d.	Operation speed (mph)		
5	Climate	a.	EICM weather station data		
		b.	Lat & long location (degrees.minutes)		
		c.	Elevation (ft)		
6.1	Structure & Material Properties – HMA overlay (s)	a.	Layer thickness (in)		
		b.	Material type		
		c.	Thermal coefficient of expansion	Default or AASHTO TP60?	≥ 3 replicates
		d.	Poisson's ratio		
		e.	Binder DSR properties (PG grade, viscosity, etc)	AASHTO T 315	≥ 3 replicates
		f.	Dynamic modulus	AASHTO TP 62-03	≥ 3 replicates
		g.	Rutting parameters: *alpha* & *mu*	VESYS Test Protocol: Report 0-5798	≥ 3 replicates
		h.	Fracture parameters: *A* & *n* for fatigue/reflection cracking	OT Test Method: Tex-248-F	≥ 3 replicates
		i.	Volumetrics (AC content, AV, density, VMA, gradations, etc)	Tex-204, Tex-207-F, Tex-236-F	≥ 3 replicates
6.2	Structure & Material Properties – Existing JPCP/CRCP	a.	Material Type		
		b.	Thickness		
		c.	Thermal Coefficient of Expansion	Default or Texas Tech Procedure or AASHTO TP60?	
		d.	Poisson's ratio		
		e.	Joint/Crack Spacing (ft)		
		f.	PCC Modulus (ksi)	FWD testing (TxDOT equipment)	
		g.	LTE	FWD testing (TxDOT equipment)	
6.3	Structure & Material Properties – Existing Granular Base	a.	Material Type		
		b.	Thickness		
		c.	Poisson's ratio		
		d.	Typical Modulus (ksi)	FWD testing (TxDOT equipment)	
		e.	Monthly Modulus (ksi)	FWD testing (TxDOT equipment)	
6.4	Structure & Material Properties – Subgrade layer	a.	Material Type		
		b.	Thickness		
		c.	Poisson's ratio		
		d.	Typical Modulus (ksi)	FWD testing (TxDOT equipment)	
		e.	Monthly modulus (ksi)	FWD testing (TxDOT equipment)	

Note
Material properties need average value and standard deviation ≥ 3 replicates

Table A-5. List of Input Parameters and Data Requirements – The TxACOL Software (AC-AC-CTB).

#	Item	#	Description	Data Type	Required Parameters	Proposed Test Procedure	Comment
1	General Information	a.	Type of AC overlay design				
		b.	Design life (yrs)				
		c.	Construction month & yr				
		d.	Traffic open month & yr				
2	Project Identification	a.	District				
		b.	County				
		c.	CSJ#				
		d.	Functional Class				
		e.	Date				
		f.	Reference mark format				
		g.	Reference mark (start-end)				
3	Analysis Parameters & Criteria	a.	Project name				
		b.	Reflective cracking rate (%), e.g., 50%				
		c.	AC rutting (in), e.g., 0.5 inches				
4	Traffic	a.	ADT begin (veh/day)				
		b.	ADT end 20 Yr (veh/day)				
		c.	18 kip ESALs 20 Yr - 1 Direction (millions)				
		d.	Operation speed (mph)				
5	Climate	a.	EICM weather station data				
		b.	Lat & long location (degrees.minutes)				
		c.	Elevation (ft)				
6.1	Structure & Material Properties – HMA overlay (s)	a.	Layer thickness (in)				
		b.	Material type				
		c.	Thermal coefficient of expansion			Default or AASHTO TP60?	≥ 3 replicates
		d.	Poisson's ratio				
		e.	Binder DSR properties (PG grade, viscosity, etc)			AASHTO T 315	≥ 3 replicates
		f.	Dynamic modulus			AASHTO TP 62-03	≥ 3 replicates
		g.	Rutting parameters: *alpha* & *mu*			VESYS Test Protocol: Report 0-5798	≥ 3 replicates
		h.	Fracture parameters: *A* & *n* for fatigue/reflection cracking			OT Test Method: Tex-248-F	≥ 3 replicates
		i.	Volumetrics (AC content, AV, density, VMA, gradations, etc)			Tex-204, Tex-207-F, Tex-236-F	≥ 3 replicates
6.2	Structure & Material Properties – Existing HMA	a.	Material Type				
		b.	Thickness				
		c.	Thermal Coefficient of Expansion			User, Default, or IDT	
		d.	Poisson's ratio				
		e.	Cracking Type	1) Alligator/ longitudinal/ block cracking	a) Severity Level (Low/Medium/High)		
					b) No. of Temperatures (FWD Backcalculated Modulus)		
					c) Temperature (s) (°F)		
					d) FWD Modulus (ksi)	FWD testing (TxDOT equipment)	
				2) Transverse cracking	a) Crack Spacing (ft)		
					b) Severity Level (Low/Medium/High)		
					c) LTE		
					d) No. of Temperatures (FWD Backcalculated Modulus)		
					e) Temperature (s) (°F)		
					f) FWD Modulus (ksi)	FWD testing (TxDOT equipment)	
6.3	Structure & Material Properties – Existing CTB Base	a.	Material Type				
		b.	Thickness				
		c.	Thermal coefficient of expansion			User or Default	
		d.	Poisson's ratio				
		e.	Typical Modulus (ksi)			FWD testing (TxDOT equipment)	
		f.	Monthly Modulus (ksi)			FWD testing (TxDOT equipment)	
6.4	Structure & Material Properties – Subgrade layer	a.	Material Type				
		b.	Thickness				
		c.	Poisson's ratio				
		d.	Typical Modulus (ksi)			FWD testing (TxDOT equipment)	
		e.	Monthly modulus (ksi)			FWD testing (TxDOT equipment)	

Note

Material properties need average value and standard deviation ≥ 3 replicates

Table A-6. List of Input Parameters and Data Requirements – The TxACOL Software (AC-AC-Granular Base).

#	Item	#	Description	Data Type	Required Parameters	Proposed Test Procedure	Replicate Samples Per Material/Layer
1	General Information	a.	Type of AC overlay design				
		b.	Design life (yrs)				
		c.	Construction month & yr				
		d.	Traffic open month & yr				
2	Project Identification	a.	District				
		b.	County				
		c.	CSJ#				
		d.	Functional Class				
		e.	Date				
		f.	Reference mark format				
		g.	Reference mark (start-end)				
3	Analysis Parameters & Criteria	a.	Project name				
		b.	Reflective cracking rate (%), e.g., 50%				
		c.	AC rutting (in), e.g., 0.5				
4	Traffic	a.	ADT begin (veh/day)				
		b.	ADT end 20 Yr (veh/day)				
		c.	18 kip ESALs 20 Yr - 1 Direction (millions)				
		d.	Operation speed (mph)				
5	Climate	a.	EICM weather station data				
		b.	Lat & long location (degrees.minutes)				
		c.	Elevation (ft)				
6.1	Structure & Material Properties – HMA overlay (s)	a.	Layer thickness (in)				
		b.	Material type				
		c.	Thermal coefficient of expansion			User, Default, or IDT	
		d.	Poisson's ratio				
		e.	Binder DSR properties (PG grade, viscosity, etc)			AASHTO T 315	≥ 3 replicates
		f.	Dynamic modulus			AASHTO TP 62-03	≥ 3 replicates
		g.	Rutting parameters: *alpha* & *mu*			VESYS Test Protocol: Report 0-5798	≥ 3 replicates
		h.	Fracture parameters: *A* & *n* for fatigue/reflection cracking			OT Test Method: Tex-248-F	≥ 3 replicates
		i.	Volumetrics (AC content, AV, density, VMA, gradations, etc)			Tex-204, Tex-207-F, Tex-236-F	≥ 3 replicates
6.2	Structure & Material Properties – Existing HMA	a.	Material Type				
		b.	Thickness				
		c.	Thermal Coefficient of Expansion			User, Default, or IDT	
		d.	Poisson's ratio				
		e.	Cracking Type	1) Alligator/ longitudinal/ block cracking	a) Severity Level (Low/Medium/High)		
					b) No. of Temperatures (FWD Backcalculated Modulus)		
					c) Temperature (s) (°F)		
					d) FWD Modulus (ksi)	FWD testing (TxDOT equipment)	
				2) Transverse cracking	a) Crack Spacing (ft)		
					b) Severity Level (Low/Medium/High)		
					c) LTE		
					d) No. of Temperatures (FWD Backcalculated Modulus)		
					e) Temperature (s) (°F)		
					f) FWD Modulus (ksi)	FWD testing (TxDOT equipment)	
6.3	Structure & Material Properties – Existing Granular Base	a.	Material Type				
		b.	Thickness				
		c.	Poisson's ratio				
		d.	Typical Modulus (ksi)			FWD testing (TxDOT equipment)	
		e.	Monthly Modulus (ksi)			FWD testing (TxDOT equipment)	
6.4	Structure & Material Properties – Subgrade layer	a.	Material Type				
		b.	Thickness				
		c.	Poisson's ratio				
		d.	Typical Modulus (ksi)			FWD testing (TxDOT equipment)	
		e.	Monthly modulus (ksi)			FWD testing (TxDOT equipment)	

Note

Material properties need average value and standard deviation ≥ 3 replicates

Table A-7. List of Output Distresses – The TxACOL Software.

#	Distress	#	Parameters to be Measured	Measurement Method	Test Procedure/Standard	Proposed Frequency of Measurement Per Year	Proposed Time of Measurement	Target Sections Per Year	Proposed Section Identifiers
1	Cracking - existing HMA	a.	Number of cracks	Visual-walking survey		1	At selection of test section prior to Overlay placement	50	a. Hwy name
		b.	Length of crack						b. Mile marker
		c.	%age cracking (calculate)						c. GPS cordinates
		d.							d. Manual marking (painting; magnesium nails in shoulder, etc)
		e.							e. Distance reference marking (DMI)
		f.							f. Existing landmarks
2	Load transfer efficiency (LTE)	a.		FWD	TxDOT	1	At selection of test section prior to Overlay placement		
3	Reflective cracking - HMA overlay	a.	Number of cracks	Visual-walking survey		2	Just after Winter & after Summer	50	a. Hwy name
		b.	Length of crack						b. Mile marker
		c.	%age cracking (calculate)						c. GPS cordinates
		d.							d. Manual marking (painting; magnesium nails in shoulder, etc)
		e.							e. Distance reference marking (DMI)
		f.							f. Existing landmarks
4	Rutting	a.	Rut depth in wheel path	a. Straightedge		2	Just after Winter & after Summer	50	a. Hwy name
		b.	Deformation for each layer if applicable	b. Do trenching where necessary					b. Mile marker
		c.							c. GPS cordinates
		d.							d. Manual marking (painting; magnesium nails in shoulder, etc)
		e.							e. Distance reference marking (DMI)
		f.							f. Existing landmarks
5	Other distresses	a.	Bleeding, etc as observed			See Item# 4	See Item# 4	See Item# 4	See Item# 4

Note

Must be exactly at the same location for each survey!	YES
How long the section will be?	500 ft
Number of replicate test sections per Hwy section	≥1
How many cross sections are going to be measured in the selected test section, e.g., for rutting?	≥3

Table A-8. List of Input Parameters and Data Requirements – The TxM-E (Thin Pavements).

#	Item	#	Description	Proposed Test Procedure	Comment
1	General information	a.	Design life (yrs)		
		b.	Construction month & yr		
		c.	Traffic open month & yr		
2	Project Identification	a.	District		
		b.	County		
		c.	CSJ#		
		d.	Functional Class		
		e.	Date		
		f.	Reference mark format		
		g.	Reference mark (start-end)		
3	General pavement structure information	a.	Material type		
		b.	Number layers & thicknesses		
		c.	Etc		
4	Traffic	a.	Average of the ten heaviest (single axle) wheel loads, dual tire spacing, and tire pressure		
		b.	Average of the ten heaviest tandem axle wheel loads, axle spacing, dual tire spacing, tire pressure		
		c.	ESALs (ADT begin (veh/day), ADT end 20 Yr (veh/day), 18 kip ESALs 20 Yr - 1 Direction (millions))		
		d.	Or load spectra (Growth rate, ADT, % trucks, speed, etc.)		
5	Environment	a.	EICM weather station data		
		b.	Lat & long location (degrees.minutes), and elevation		
		c.	Seasonal water table		
6.1	Material Properties - HMA/WMA/RAP	a.	Asphalt-binder DSR properties (PG grade, viscosity, etc)	AASHTO T 315	
		b.	Volumetrics (AC content, AV, aggregate specific gravity, VMA, gradations, etc)	Tex-200-F, Tex-204-F, Tex-210-F or TxDOT QC/QA	
		c.	Dynamic modulus	AASHTO 62-03 (or later version)	≥ 3 replicates
		d.	Poisson's ratio		
6.2	Material Properties - Granular Base	a.	Resilient modulus, Mr	0-5798-P1	≥ 3 replicates
		b.	Permanent deformation parameters: alpha & mu	0-5798-P1	≥ 3 replicates
		c.	Grade & gradations (matching EICM requirements)		
		d.	Poisson's ratio		
		e.	Soil classification (optional)		
		f.	Atterberg limit: Plasticity Index and Liquid limit		
		g.	Maximum dry unit weight		
		h.	Specific gravity, Gs		
		i.	Optimum gravimetric moisture content		
		j.	Saturated hydraulic conductivity		
		k.	Soil water characteristic Curve coefficients	Filter paper method	
6.3	Material Properties - Subgrade Soils	a.	Resilient modulus, Mr	0-5798-P1	≥ 3 replicates
		b.	Permanent deformation parameters: alpha & mu	Tex 117-E	≥ 3 replicates
		c.	Shear failure: C-phi values and corresponding moisture content		
		d.	Grade & gradations (matching EICM requirements)		
		e.	Poisson's ratio		
		f.	Soil classification (optional)		
		g.	Atterberg limit: Plasticity Index and Liquid limit		
		h.	Maximum dry unit weight		
		i.	Specific gravity, Gs		
		j.	Optimum gravimetric moisture content		
		k.	Saturated hydraulic conductivity		
		l.	Soil water characteristic Curve coefficients	Filter paper method	
6.4	Material Properties - Stabilized materials	a.	Resilient modulus (or seismic modulus)		
		b.	Modulus of rupture		
		c.	UCS – unconfined compression strength		
		d.	Crushing resistance/model parameters		
		e.	Poisson's ratio	Default	

Note
Material properties need average value and standard deviation ≥ 3 replicates

Table A-9. List of Input Parameters and Data Requirements – The TxM-E (Regular and Perpetual Pavements).

#	Item	#	Description	Proposed Test Procedure	Comment
1	General information	a.	Design life (yrs)		
		b.	Construction month & yr		
		c.	Traffic open month & yr		
2	Project Identification	a.	District		
		b.	County		
		c.	CSJ#		
		d.	Functional Class		
		e.	Date		
		f.	Reference mark format		
		g.	Reference mark (start-end)		
3	General pavement structure information	a.	Material type		
		b.	Number layers & thicknesses		
		c.	Etc		
	Traffic	a.	ESALs (ADT begin (veh/day), ADT end 20 Yr (veh/day), 18 kip ESALs 20 Yr - 1 Direction (millions), traffic speed)		
		b.	Full load spectra (Growth rate, ADT, % trucks, speed, etc.)		
5	Environment	a.	EICM weather station data		
		b.	Lat & long location (degrees.minutes), and elevation		
		c.	Seasonal water table		
6.1	Material Properties - HMA/WMA/RAP/RAS	a.	Mix type		
		b.	Layer thickness		
		c.	Binder type and asphalt-binder DSR properties (PG grade, viscosity, G* master curve, Phase angle, etc)	AASHTO T 315	
		d.	Volumetrics (AC content, AV, aggregate specific gravity, VMA, gradations, etc)	Tex-200-F, Tex-204-F, Tex-210-F or TxDOT QC/QA	
		e.	Dynamic modulus	AASHTO 62-03 (or newer version)	≥ 3 replicates
		f.	Rutting parameters: *alpha* & *mu*	0-5798-P1	≥ 3 replicates
		g.	Fracture parameters: *A* & *n* for fatigue/reflection cracking	revised 0-5798-P1 (two-step test)	≥ 3 replicates
		h.	Low temperature cracking – IDT strength & creep compliance	AASHTO T 322 or IDT (Tex-226-F)	
		i.	Coefficient of Thermal Expansion	D IDT (Tex-226-F)	
		j.	Top-down cracking: IDT strength & creep compliance at temperature 10C	Tex-226-F(IDT), AASHTO T 322	
		k.	Endurance limit parameters for perpetual pavement		
6.2	Material Properties - Granular Base	a.	Resilient modulus, Mr	0-5798-P1	≥ 3 replicates
		b.	Permanent deformation parameters: alpha & mu	0-5798-P1	≥ 3 replicates
		c.	Grade & gradations (matching EICM requirements)		
		d.	Poisson's ratio		
		e.	Soil classification (optional)		
		f.	Atterberg limit: Plasticity Index and Liquid limit		
		g.	Maximum dry unit weight		
		h.	Specific gravity, Gs		
		i.	Optimum gravimetric moisture content		
		j.	Saturated hydraulic conductivity		
		k.	Soil water characteristic Curve coefficients	Filter paper method	
6.3	Material Properties - Subgrade Soils	a.	Resilient modulus, Mr	0-5798-P1	≥ 3 replicates
		b.	Permanent deformation parameters: alpha & mu	0-5798-P1	≥ 3 replicates
		c.	Shear failure: C-phi values and corresponding moisture content	Tex 117-E	≥ 3 replicates
		d.	Grade & gradations (matching EICM requirements)		
		e.	Poisson's ratio		
		f.	Soil classification (optional)		
		g.	Atterberg limit: Plasticity Index and Liquid limit		
		h.	Maximum dry unit weight		
		i.	Specific gravity, Gs		
		j.	Optimum gravimetric moisture content		
		k.	Saturated hydraulic conductivity		
		l.	Soil water characteristic Curve coefficients		
6.4	Material Properties - Stabilized materials	a.	Resilient modulus (or seismic modulus)	Filter paper method	
		b.	Modulus of rupture		
		c.	UCS – unconfined compression strength		
		d.	Crushing resistance/model parameters	0-6622 being developed	≥ 3 replicates
		e.	Poisson's ratio	User	

Note
Material properties need average value and standard deviation ≥ 3 replicates

Table A-10. List of Output Distresses – The TxM-E Software (Thin, Regular, and Perpetual Pavements).

#	Distress	Parameters to be Measured	Measurement Method	Test Specification	Proposed Frequency of Measurement Per Year	Proposed Time of Measurement	Target Sections Per Year	Comment
1	Rutting	Total surface rut depth & layer deformation where applicable	Straightedge & trenching (where applicable)		≥ 2	Just after Winter & after Summer	50	Thin, regular, & perpetual pavements
2	Fatigue Cracking	Lane width, number of cracking, %age cracking			≥ 2	Just after Winter & after Summer	50	Thin, regular, & perpetual pavements
3	Low-temp. Cracking				≥ 2	Just after Winter & after Summer	50	Regular & perpetual pavements
4	Top-down Cracking				≥ 2	Just after Winter & after Summer	50	Regular & perpetual pavements
5	Crushing failure				≥ 2	Just after Winter & after Summer	50	Note that crushing failure would be more typical for thin pavements, since the level of stress under regular and perpetual systems should be low enough to prevent crushing of base materials.
6	Shear failure				≥ 2	Just after Winter & after Summer	50	Particularly for thin pavements

Note

Must be exactly at the same location for each survey!	YES
How long the section will be?	500 ft
Number of reploicate test sections per Hwy section	≥1
How many cross sections are going to be measured in the selected test section, e.g., for rutting?	≥3

Proposed section identifiers:

a. Hwy name
b. Mile marker
c. GPS cordinates
d. Manual marking (painting, magnesium nails in shoulders, etc)
e. Distance reference marking (DMI)
f. Existing landmarks

Table A-11. List of Input Parameters and Data Requirements – The M-E PDG.

#	Item	#	Description	Proposed Test Procedure	Comment
1	General Information	a.	Project Name	User	
		b.	Design Life (yrs)	User	
		c.	Base/Subgrade Construction Month/Year	User	
		d.	Pavement Construction Month/Year	Default	
		e.	Traffic Open Month/Year	Default	
		f.	Section	User	
		g.	Date	User	
		h.	Job	User	
		i.	Type of Design	User	
2	Site/Project Identification	a.	Location	User	
		b.	Project ID	User	
		c.	Section ID	User	
		d.	Date	User	
		e.	Station/milepost format	User	
		f.	Station/milepost begin	User	
		g.	Station/milepost end	User	
		h.	Traffic direction	User	
3	Analysis Parameters	a.	Project Name	User	
		b.	Initial IRI (in/mi)	User	
		c.	Terminal IRI (in/mi)	User	
		d.	AC Surface Down cracking long. Cracking (ft/mi)	Default	
		e.	AC bottom up cracking Alligator Cracking (%)	Default	
		f.	AC thermal fracture (ft/mi)	Default	
		g.	Chemically stabilized layer fatigue fracture (%)	Default	
		h.	Permanent Deformation - Total Pavement (in)	Default	
		i.	Permanent Deformation - AC Only (in)	Default	
4	Traffic	a.	Design Life (yrs)	User	
		b.	Opening Date	User	
		c.	Initial two-way AADTT	TPP	
		d.	Number of lanes in design direction	User	
		e.	Percent of trucks in design direction (%)	TPP	
		f.	Percent of trucks in design lane (%)	TPP	
		g.	Operational Speed (mph)	TPP	
4.1	Traffic Volume Adjustment Factors	a.	4.1.1. Monthly adjustment	TPP	
		b.	4.1.2. Vehicle Class Distribution	TPP	
		c.	4.1.3. Hourly Distribution	TPP	
		d.	4.1.4. Traffic growth factors	TPP	
4.2	Axle Load Distribution Factors	a.	Single axle	Default	
		b.	Tandem axle	Default	
		c.	Tridem axle	Default	
		d.	Quad axle	Default	
4.3	General Traffic Inputs	a.	Mean wheel location (inches from the lane marking)	Default	
		b.	Traffic wander standard deviation (in.)	Default	
		c.	Design lane width (ft.) (note: Not slab width)	Default	
4.3.1	Number Axles/Truck			User or Default	
4.3.2	Axle Configuration	a.	Avergae Axle width (edge to edge) outside dimensions, ft.	Default	
		b.	Dual tire spacing (in.)	Default	
		c.	Tire Pressure (psi)	Default	
		d.	Tandem Axle spacing (in.)	Default	
		e.	Tridem Axle spacing (in.)	Default	
		f.	Quad Axle spacing (in.)	Default	
4.3.3	Wheelbase	a.	Average Axle spacing (ft.)	Default	
		b.	Percent of trucks (%)	TPP	
5	Climate	a.	Latitude (degrees. Minutes)	User	
		b.	Longitude (degrees. Minutes)	User	
		c.	Elevation (ft)	User	
		d.	Depth of water table (ft) (Spring, Summer, Fall, Winter)	User	
6	Structure	a.	Surface short wave absorptivity	Default	
		b.	Layer	User	
		c.	Type	User	
		d.	Material	User	
		e.	Thickness	User	
		f.	Interface	Default	
		a.	For overlay design:		
		b.	Level1: existing rutting & milled thickness	User	
		c.	Level2: existing rutting, crack (%) in existing AC, & milled thickness	User	
		d.	Level3: milled thickness, total rutting, & pavement rating (Excellent, Good, fair, poor, & very poor)	User	
		e.	Fatigue analysis endurance limit (national calibration based on no endurance limit	User	
7	HMA (Use Level 3 if most data is unavailable)	a.	Dynamic modulus --------- Level 1	NCHRP 1-28A or AASHTO TP 62	
		b.	DSR -------- Level 1 ~ 3	AASHTO T315	
		c.	Gradation -------- Level 2 & 3	User/Default	
		d.	Effective binder content	User/Default	
		e.	Air void	User/Default	
		f.	Total unit weight	User/Default	
		g.	Poisson's ratio	User	
		h.	Thermal conductivity	ASTM E 1952	
		i.	Shear capacity asphalt	ASTM D 2766	
		j.	Tensile strength & Creep compliance	AASHTO T322	
8	Base & Subgrade (Use Level 3 if most data is unavailable)	a.	Resilient modulus	NCHRP 1-28A or AASHTO T307	
		b.	Soil classification		
		c.	Gradation	AASHTO T27	
		d.	Atterberg limit	AASHTO T90 (PL,PI) & T89 (LL)	
		e.	Maximum dry unit weight	AASHTO T99 or T180	
		f.	Specific gravity (calculated or tested)	AASHTO T100	
		g.	Optimum gravimetric moisture content	AASHTO T99 or T180	
		h.	Saturated hydraulic conductivity (calculated)	ASTM E 1952	
		i.	Degree of saturation at optimum (calculated)	ASTM D 2766	
		j.	Coefficient of later pressure	User or Default	
		k.	Soil suction coefficients (tested or calculated)	Filter paper method	
		l.	DCP data	Current Texas practice!	

Note

Material properties need average value and standard deviation ≥ 3 replicates

Table A-12. List of Output Distresses- The M-E PDG.

#	Distress	Parameters to be Measured	Measurement Method	Test Procedure/Standard	Proposed Frequency of Measurement Per Year	Proposed Time of Measurement	Target Sections Per Year
1	Surface roughness	IRI	High speed profiles	TTI Profiler	2	Summer & Winter	100
2	Rutting	Total surface rut depth & layer deformation where applicable	Straightedge & trenching (where applicable)	Straightedge & trenching (where applicable)	2	Summer & Winter	50
3	Cracking	Top-down, alligator, thermal, etc	Visual/walk surveys	Visual/walk surveys	2	Summer & Winter	50

Note

Must be exactly at the same location for each survey!	YES
How long the section will be?	500 ft
Number of replicate test sections per Hwy section	≥1
How many cross sections are going to be measured in the selected test section, e.g., for rutting?	≥3

Proposed section identifiers:

a. Hwy name
b. Mile marker
c. GPS coordinates
d. Manual marking (painting, magnesium nails in shoulder, etc)
e. Distance reference marking (DMI)
f. Existing landmarks

APPENDIX B: REVIEW RESULTS OF EXISTING DATABASES

Table B-1. Example List of Available Data in the UT Database.

#	Item	Description	Texas 38 Sections ID TXTF09001	TXTF09002	TXTF09003	TXTF24036	TXTF24037	TXTF24020	TXTF24021
		AADT_ALL_VEHIC_2WAY	✓	✓	✓	✓	✓	✓	✓
		AADT_TRUCK_COMBO_2WAY (4/38)	X	X	X	✓	✓	✓	✓
		Aggregate gradation	x	✓	✓	✓	✓	✓	✓
1	General Information	Aggregate source of material	X	✓	✓	✓	✓	✓	✓
		Aggregate type of current layer	X	✓	✓	✓	✓	✓	✓
		Air temperature	✓	✓	✓	✓	✓	✓	✓
		ANL_KESAL_LTPP_LN_YR (4/38)	X	X	X	✓	✓	✓	✓
		Beginning point lateral	✓	✓	✓	✓	✓	✓	✓
		Beginning point longitudinal	✓	✓	✓	✓	✓	✓	✓
		Beginning term (24/38)	✓	✓	✓	✓	✓	✓	✓
		Beginning term displacement (24/38)	✓	✓	✓	✓	✓	✓	✓
2	Peformance	Climate	✓	✓	✓	✓	✓	✓	✓
		Construction ID	✓	✓	✓	✓	✓	✓	✓
		Control Section job number (28/38)	X	X	X	✓	✓	✓	✓
		County ID	✓	✓	✓	✓	✓	✓	✓
		Crack ID	✓	✓	✓	✓	✓	✓	✓
		Date of FWD test (minus)	✓	✓	✓	✓	✓	✓	✓
		Deflection 1-7 (minus)	✓	✓	✓	✓	✓	✓	✓
3	FWD (normalized deflection based on 9 kips)	Distance from origin	✓	✓	✓	✓	✓	✓	✓
		District name	✓	✓	✓	✓	✓	✓	✓
		End point lateral	X	X	X	✓	✓	✓	✓
		End point longitudinal	X	X	X	✓	✓	✓	✓
		End term (12/38)	X	X	X	✓	✓	✓	✓
4	Traffic	End term displacement (12/38)	X	X	X	✓	✓	✓	✓
		Facility type	X	✓	✓	✓	✓	✓	✓
5	Material	FWD ID	X	✓	✓	✓	✓	✓	
		IRI AVERAGE	X	✓	✓	✓	✓	✓	✓
		IRI ID	✓	✓	✓	✓	✓	✓	✓
		IRI VALUE (LEFT WHEEL PATH)	✓	✓	✓	✓	✓	✓	✓
		IRI VALUE (RIGHT WHEEL PATH)	✓	✓	✓	✓	✓	✓	✓
		Lane ID	✓	✓	✓	✓	✓	✓	✓
		Layer construction date	X	X	X	X	X	X	X
		Layer detail	✓	✓	✓	✓	✓	✓	✓
		Layer number	✓	✓	✓	✓	✓	✓	✓
		Layer opened to traffic date	X	X	✓	X	X	X	X
		Layer removal date	X	✓	✓	✓	✓	✓	✓
		Layer thickness mean	✓	✓	✓	✓	✓	✓	✓
		Layer thickness standard deviation	✓	✓	✓	✓	✓	✓	✓
6		Layer type	✓	✓	✓	✓	✓	✓	✓
		LLH_DEPTH	✓	✓	✓	✓	✓	✓	✓
		Load dropped on pavement	X	X	X	✓	✓	✓	✓
		MAX_MEAN	✓	✓	✓	✓	✓	✓	✓
		Layer number	✓	✓	✓	✓	✓	✓	✓
		Number of layers after construction	X	✓	✓	✓	✓	✓	✓
		Number of layers before construction	✓	X	X	✓	✓	✓	✓
		Number of lifts	✓	✓	X	✓	✓	✓	✓
		Number of new layers	✓	✓	✓	✓	✓	✓	✓
		Number of removed layers	✓	✓	✓	✓	✓	✓	✓
		Original database	✓	✓	✓	✓	✓	✓	✓
		Pavement temperature at 1in depth	X	X	✓	✓	✓	✓	✓
		PROFILE DATE	✓	✓	✓	✓	✓	✓	✓
7		Project type (16/38)	X	X	X	✓	✓	✓	✓
		RLH_DEPTH	✓	✓	✓	✓	✓	✓	✓
		Roadw ay number	✓	✓	✓	✓	✓	✓	✓
		Roadw ay type	✓	✓	✓	✓	✓	✓	✓
		RUT_TST_METHOD	✓	✓	✓	✓	✓	✓	✓
		Section	✓	✓	✓	✓	✓	✓	✓
		Sieve analysis	✓	✓	✓	✓	✓	✓	✓
		STOP DISTANCE	✓	✓	✓	✓	✓	✓	✓
		Structure type	✓	✓	✓	✓	✓	✓	✓
		Surface temperature	X	X	✓	✓	✓	✓	✓
		Survey date	✓	✓	✓	✓	✓	✓	✓

Table B-1. Example List of Available Data in the UT Database (Continued).

#	Item	Description	TXTF09001	TXTF09002	TXTF09003	TXTF24036	TXTF24037	TXTF24020	TXTF24021
		Total alligator cracking	✓	✓	✓	✓	✓	✓	✓
		Total block cracking area (22/38)	✓	✓	✓	✓	✓	✓	✓
8		Total length of longitudinal cracks	✓	✓	✓	✓	✓	✓	✓
		Total number of transverse crack	✓	✓	✓	✓	✓	✓	✓
		Total number of block crack (22/38)	✓	✓	✓	✓	✓	✓	✓
		Traffic ID	✓	✓	✓	✓	✓	✓	✓
		Year record	✓	✓	✓	✓	✓	✓	✓
		No backcalculation modulus results	X	X	X	X	X	X	X
		No crushing failure data	X	X	X	X	X	X	X
		No DSR data	X	X	X	X	X	X	X
		No dynamic modulus, resilient modulus, and suction	X	X	X	X	X	X	X
		No Hamburg rutting or repeated loading test data	X	X	X	X	X	X	X
		No lab crack or fracture data	X	X	X	X	X	X	X
		No LTE data	X	X	X	X	X	X	X
		No Overlay data	X	X	X	X	X	X	X
9		**No skid or texture data**	X	X	X	X	X	X	X
		~~Atterberg limits~~	X	X	X	X	X	X	X
		~~Axle count by KESALs~~	X	X	X	X	X	X	X
		~~Traffic count (AADT & AADTT)~~	X	X	X	X	X	X	X
		~~State default axle load spectra~~	X	X	X	X	X	X	X
		~~SCI~~	X	X	X	X	X	X	X
		~~Route number~~	X	X	X	X	X	X	X
		~~Maximum dry density and optimum moisture content~~	X	X	X	X	X	X	X
		~~HMA mix properties (VMA, Gmm, Gmb, and air void)~~	X	X	X	X	X	X	X
		~~Functional class~~	X	X	X	X	X	X	X
		~~BCI~~	X	X	X	X	X	X	X
		~~BDI~~	X	X	X	X	X	X	X
		~~Problem #~~	X	X	X	X	X	X	X
		~~Highway~~	X	X	X	X	X	X	X
		~~Control~~	X	X	X	X	X	X	X
		~~Length of Analysis period~~	X	X	X	X	X	X	X
		~~Min time to first overlay (yrs)~~	X	X	X	X	X	X	X
		~~Min time between overlays (yrs)~~	X	X	X	X	X	X	X
		~~Design confidence level 95.0%~~	X	X	X	X	X	X	X
		~~Intial serviceability index~~	X	X	X	X	X	X	X
		~~Final serviceability index~~	X	X	X	X	X	X	X
		~~Serviceability index after overlay~~	X	X	X	X	X	X	X
		~~Interest rate (%)~~	X	X	X	X	X	X	X
		~~Max funds/Sq. YD, INIT Const~~	X	X	X	X	X	X	X
		~~Max thickness, INIT Const~~	X	X	X	X	X	X	X
		~~Max thickness, all overlays~~	X	X	X	X	X	X	X
		~~ADT begin (veh/day)~~	X	X	X	X	X	X	X
		~~ADT end 20 Yr (veh/day)~~	X	X	X	X	X	X	X
		~~Avg App Speed to OV Zone~~	X	X	X	X	X	X	X
		~~Avg Speed OV Direction~~	X	X	X	X	X	X	X
		~~Avg Speed Non-OV Direction~~	X	X	X	X	X	X	X
		~~Percent ADT/HR Construction~~	X	X	X	X	X	X	X
		~~Percent trucks in ADT~~	X	X	X	X	X	X	X
		~~Min Overlay thickness (in)~~	X	X	X	X	X	X	X
		~~Overlay const. time, Hr/Day~~	X	X	X	X	X	X	X
		~~ACP comp. density, Tons/CY~~	X	X	X	X	X	X	X
		~~ACP production rate, Tons/Hr~~	X	X	X	X	X	X	X
		~~Width of each lane, ft.~~	X	X	X	X	X	X	X
		~~First year cost, RTN Maint.~~	X	X	X	X	X	X	X
		~~Ann. Inc. Incr in Maint. Cost~~	X	X	X	X	X	X	X
		~~Detour Model during Overlays~~	X	X	X	X	X	X	X
		~~Num open lanes, overlay direction~~	X	X	X	X	X	X	X
		Num open lanes, NON OV direction	X	X	X	X	X	X	X
		~~Dist. Traffic slowed, OV direction~~	X	X	X	X	X	X	X
		~~Dist. Traffic slowed, Non-OV direction~~	X	X	X	X	X	X	X
		~~Detour distance, overlay zone~~	X	X	X	X	X	X	X
		~~Material Name~~	X	X	X	X	X	X	X
		~~Cost per CY~~	X	X	X	X	X	X	X
		~~Modulus E (ksi)~~	X	X	X	X	X	X	X
		~~Min Depth~~	X	X	X	X	X	X	X
		~~Max Depth~~	X	X	X	X	X	X	X
		~~Salvage PCT~~	X	X	X	X	X	X	X
		~~Poisson's ratio~~	X	X	X	X	X	X	X

Table B-2. List of Data Available in the UT FP Database.

#	Data Item	#	Available Data in the UT Database!!!	Availabel Data Characteristics in the UT Database Include the Following:	Comment
1	General Information	a.	38 Hwy sections (32 are from the LTPP database)		
		b.	Section ID		
		c.	County		
		d.	Functional class		
		e.	Route number		
		f.	GPS - slevation, Lat, and Longitude		
		g.	Climatic region		
		h.	PVMNT layers (layer thickness, material type)		
2	Design data				
3	PVMNT structure data				
4	Construction data				
5	Climatic & environemental data				
6	Traffic data	a.	State default axle load spectra		
		b.	Traffic count (AADT & AADTT)		
		c.	Axle count by KESALs		
7	Lab testing & matrial properties data	a.	Construction date for each layer		
		b.	Layer thickness		
		c.	AC Gradation		
		d.	Binder properties (asphalt content, viscosity @ 60 and 135 °C, penetration @ 25°C, Ductility)		
		e.	HMA mix properties (VMA, Gmm, Gmb, and air void)		
		f.	Base/subbase/subgrade gradation		
		g.	Atterberg limits		
		h.	Maximum dry density and optimum moisture content		
		i.	**No DSR data**		
		j.	**No Hamburg rutting or repeated loading test data**		
		k.	**No lab crack or fracture data**		
		l.	**No dynamic modulus, resilient modulus, and suction**		
		m.			
8	Field performance & response data	a.	Rutting based on 1.8m straight-edge (in)		
		b.	IRI (in/mile)		
		c.	No. of transverse cracking		
		d.	Longitudinal cracking-non wheel path in feet		
		e.	Block cracking in square feet		
		f.	Alligator cracking in square feet		
		g.	FWD (normalized deflection based on 9 kips)	a) D1 & D7 plots with 500 ft; b) mean & stdev of D1 & D7; c) SCI, BDI, & BCI	
		h.	**No FWD back-calculation results such as modulus**		
		i.	**No skid or texture data**		
		j.	**No crushing failure data**		
		k.	**No LTE data**		
9	Other available data in the UT (CTR) database	a.			
		b.			
		c.			
		d.			
		e.			

Table B-3. List of Data Available in the Texas PP Database.

#	Data Item	#	Available Data in the Texas PP Database!!!	Availabel Data Characteristics in the Texas PP Database Include the Following:	Comment
1	General information	1	**10 PP Hwy sections in total**	a) 8 on IH 35 (4 in Laredo, 2 in San Antonio, & 2 in Waco) b) 2 on SH 114 (Fort Worth)	
		2	Project location details	CSJ#, project#, project limits, district/county, TRM location, GPS location, geographical location, etc	
		3	Section length	Avg. ≅ 4.5 miles	
		4	Section age	Avg. ≅ 4.5 yrs	
		5	Last data collection date	Sumer 2009	Was done by LUBINDA
2	Design data	1	Traffic data	ADT, ESALs, etc	WIM stations on IH 35 (Laredo) & SH 114
		2	Structural design data	Design concept, layer thicknesses, materials, etc	
		3	HMA mix-design data	Typical TxDOT mix-design sheets for all layers	
		4	Moduli values	For each material type/layer	
3	PVMNT structure data	1	PVMNT type	Perpetual	
		2	HMA material	PFC, SMA, ¾" SFHMA, 1" SFHMA, RBL	
		3	HMA thickness	Avg. ≅ 22 inches	
		4	Base material	Typical ≅ 6% lime treatment	
		5	Base thickness	Avg. ≅ 8 inches	
		6	Subgrade	All Hwy sections - natural compacted soil material	
		7	Total PVMNT structure thickness	Avg. ≅ 30 inches	
4	Construction data	1	Project details	CSJ#, project#, project limits, district/county, TRM location, etc	
		2	Contractor name	All Hwy sections	
		3	Date of construction	All Hwy sections	
		4	IR thermal data	SH 114 only	
		5	Compaction data	Mostly for Rut-Resistant Layers (RRL)	
5	Climatic & environemental data	1	Climatic region	Covered three: Dry-warm (Laredo & San Antonio), Moderate (Waco), & Wet-cold (Fort Worth)	
		2	Pavement temperatures	As a function of PVMNT depth, season, & district	
		3	EICM temperature data	Fort Worth - Alliance Airport	
6	Traffic data	1	ADT	Begin - end (20 yr projection)	
		2	Growth rate	All Hwy sections	
		3	%Trucks	All Hwy sections	
		4	ESALS	20 yr estimates	
		5	**WIM data**	**IH 35 (Laredo near Cotulla) & SH 114 (Fort Worth)**	
7	Lab testing & material properties data	1	Asphalt-binders	PG grade, DSR @ 10 rad/s @ multiple temperatures, etc	Lab includes samples from: a) raw materials; b) plant-mix; & c) field cores
		2	Aggregates	Gradations including extractions	
		3	Volumetrics	Rice, AC cotent, extractions, etc	
		4	Hamburg - rutting data	Rut depth & number of load passes for each HMA material/layer	
		5	Overlay - cracking data	Number of cycles to failure for each HMA material/layer	
		6	Dynamic modulus (DM)	For all HMA materials/layers	
		7	Repeated load permanent deformation test data	For SH 114 only	
		8	Permeability data	For all HMA mix types	
8	Field performance & response data	1	Visual survey data & photographs	Periodic data along entire section	Last field testing and performance data collection on all 10 PP sections was conducted by LUBINDA in Sumer 2009
		2	Crack survey data	Periodic data along entire section	
		3	Surface rutting (with straightedge)	Periodic data along entire section	
		4	Surface profiles (ride quality)	IRI - periodic data along entire section	
		5	FWD deflections	Periodic data along entire section	
		6	FWD curvature indices	Periodic data along entire section	
		7	Backcalulated FWD modulus	For all layers: HMA, bases, & subgrade	
			District avg. FWD moduli values	Avg. value for each layer	
		8	Cores & forensics (X-Ray CT data)	SeOn all Hwy sections at selected locations	
		9	GPR data & colormaps	Periodic data along entire section	
		10	Traffic WIM measurements	On IH 35 (Laredo) & SH 114 (Fort Worth)	
		11	MDD measurements	IH 35 (Laredo, Cotulla)	
9	Other available data in the Texas PP database	1	Raw data files	a) HMA mix-design sheets b) Raw data include profiles & ride data, FWD data, GPR data, traffic WIM-MDD data, etc	Users can re-process the data if they want!!!
		2	MEPDG data files	Traffic, climate, Level-1 PG binder data, Level-1 HMA data, & Levels 2 & 3 data	
		3	PP Design Software	Training manual, FPS_Demo, PerRoad_Demo, MEPDG_Demo, & PaveCheck_Demo	

Table B-4. List of Data Available in the TSFP Database.

#	Data Item	#	Available Data in the TSFP Database!!!	Availabel Data Characteristics in the TSFP Database Include the Following:	Comment
1	General information	1	26 Approved & 54 Nominated Hwy sections		
		2	Project Location Details	Highway/District/County, GPS Location, Beginning TRM, Distance from beginning TRM, End TRM, Distance from end TRM.	
		3	Roadway function		
		4	Nominated components		
		5	Nomination year		
		6	Features		
		7	Number of through lanes		
		8	Lane width		
		9	Lane evaluated		
		10	Total section length		
		11	Pavement structure type		
		12	Inside Shoulder		
		13	Surface type		
		14	Paved width		
		15	Outside Shoulder		
		16	Surface type		
		17	Paved width		
2	Design data	1	Layer Information	Depth, Pavement layer, Specifications.	
		2	Shoulder information	Base type, Base thickness, Surface type, Paved width, Total width (for inside & outside shoulder)	
		3	Design traffic		
		4	Pavement design reports		
3	PVMNT structure data	a.	Included in Item #2 (design data)		
4	Construction data	a.	General Information	Contractor, Year of construction, Control section Job no, Pavement structure type	
		b.	Layer information	Depth, Pavement layer, Specifications.	
		c.	Test Reports		
		d.	Mixture design reports		
5	Climatic & environemental data	a.	Avg. Max Temperature for Hottest Month		
		b.	Avg. Min Temperature for Coldest Month		
		c.	Avg. Annual Rainfall		
6	Traffic data	a.	AADT		
		b.	Trucks		
		c.	Cumulative Traffic		
		d.	Traffic data source		
		e.	Year		
7	Lab testing & material properties data	a.	DCP Testing	For Base/Subgrade	
		b.	Elastic modulus		
		c.	Elastic modulus Avg.		
		d.	CBR		
		e.	CBR Avg.		
		f.	mm/Blow		
		g.	mm/Blow Avg.		
8	Field performance & response data	a.	Condition Scores	From TxDOT's Pavement Management Information System (PMIS)	
		b.	Distress Scores		
		c.	Ride Scores		
		d.	International Roughness Index		
		e.	GPR testing		
		f.	FWD Modulus value	For Base/Subgrade	
		g.	Modulus standard deviation	For Base/Subgrade	
		h.	Measured Deflections Plot		
		i.	Back Calculated Moduli values		
9	Other available data in the TSFP database - Maintenance Data	a.	Responsibility	Maintenance office	
		b.	Expenditures	3 Year Lane Mile Cost	
		c.	Last pavement overlay		
		d.	Last pavement seal		

Table B-5. Example List of Data Available in the LTPP Database.

Data Item	#	Available Data in the LTPP Database	TXLT01001	TXLT04001	TXLT04002	TXLT05001	TXLT05002	TXLT05003	TXLT08001	TXLT21003~ TXLT21021	TXLT21015	TXLT17017	TXLT17018
General information	1	58 GPS & 127 SPS Hwy sections	SH19@ Lamar Co.	SH40@Carson Co.	US83@Ochiltree Co.	SH62@Terry Co.	SH289@Lubbock Co.	FM445@Hale Co.	IH20@Mitchell Co.	US281@Hidalgo	US281@Hidalgo	FM2223@Brazos	FM2223@Brazos
	2	Section ID No.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	3	Experiment No.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	4	State	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	5	SHRP Region	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	6	Seasonal Round											
	7	Deassign Date	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	8	County	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	9	Functional class	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	10	Route Number	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	11	Elevation	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	12	Lane evaluated	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	13	GPS Location	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
PVMNT structure data (thickness, material type)	a.	Original surface layer	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	b.	AC layer below surface	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	c.	Base layer	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	d.	Subgrade	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Construction data	a.	Org. Construction date	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	b.	Const. Event date	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	c.	Const. Event No.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	d.	Inside shoulder type											
	e.	Outside shoulder type											
	f.	Drainage type											
Climatic & environemental data	a.	Climatic region	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	b.	Freezing index											
	c.	Precipitation											
	d.	Days above 32 °C											
	e.	Years of climatic data											
Traffic data	a.	Traffic count (AADT & AADTT)	✓	✓	✓	✓	✓	✓	✓	✓	✓	X	X
	b.	Axle count (KESALs)	✓	✓	✓	✓	✓	✓	✓	X	✓	X	X
	c.	Axle load spectra	state default	state default	state default	state default	state default	state default	state default	state default	state default	state default	state default
Lab testing & material properties data	AC	a. core examination & thickness	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
		b. bulk & maximum specific gravity	✓	✓	✓	✓	✓	✓	✓	✓	X	✓	X
		c. asphalt content	✓	✓	✓	✓	✓	✓	✓	✓	✓	X	✓
		d. gradation	✓	✓	X	✓	✓	✓	✓	X	✓	✓	✓
		e. resilient modulus, tensile strength, and creep complia	✓	X	X	X	✓	X	X	✓	✓	✓	✓
		f. DSR	X	X	X	X	X	X	X	X	X	X	X
		g.viscosity, penetration	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
	Base & Soil	a. particle size distribution	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
		b. atterberg limit	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
		c. moisutre-density relations	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
		d. resilient modulus	X	X	✓	✓	✓	✓	X		✓	✓	✓
		e. permeability of granular base/subbase											
		f. natural moisture content											
		g. specific gravity											
Field performance & response	1	FWD Deflection	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	2	IRI	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	3	Longitudinal crack	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	4	Transverse crack	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	5	Alligator crack	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	6	Rutting	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Other available data in the LTPP database													

<u>Legend for the Color Coding:</u>

(yellow)	Lab testing = IDT, Creep, & M_R data is available; Field performance = data is available for 1990–1994
(orange)	Data was not checked; so it must be checked in the course of the study.

APPENDIX C: LIST OF LAB TESTS – ASPHALT-BINDERS, HMA MIXES, BASE MATERIALS, AND SUBGRADE SOILS

Table C-1. Asphalt-Binder Tests (Extracted Binders Only).

#	Test	Spec	Test Parameters	Output Data	Sample Replicates			Time (hrs)		Material Requirement (grams)	
					TTI	UTEP	*TxDOT Recom.*	Sample Prep	Testing	Asphalt-Binder	Plant-Mix
1	Specific gravity (SG)	T 228	As per spec	Specific gravity	3		*1*[a]	2	2	40	2000
2	Viscosity	T 316	135 °C	Viscosity	3		*1*[a]	1	1	40	2000
3	DSR[c]	T 315	As per spec	True grade, G*, & G*/Sin(δ)	3		*1*[a]	2	3	30	1500
4	DSR – RTFO	T 240	As per spec	True grade, G*, & G*/Sin(δ)	3		*0*[b]	4	3	30	1500
5	DSR _ PAV	R 28	As per spec	G*, G*.Sin(δ), & true grade	3		*0*[b]	24	3	30	1500
6	MSCR	TP 70	As per spec; min. 3 test temperatures per binder	R100, R3200, R_{diff}, $J_{nr}100$, $J_{nr}3200$, & $J_{nr-diff}$	9		*9 (3 x 3 temps)*	4	6	60	3000
7	BBR[c]	T 313 R28	As per spec; min. 2 temps	Stiffness, m-value	6 (3 x 2 temps)		*2*[a] (1 x 2 temps)	26	4	120	7000
8	Elastic recovery (ductility)	(D 6084-A)	As per TxDOT spec @ 50 °F	Elastic recovery	3		*3*	8	2	100	6000
9	Binder PG grading	M 320, Item 300, MP 19	As per spec	PG grade	-	-	-	-	-	-	-
Total material to sample from the field					33	0	*17*	71	24	450	24500 **(≥ 65 lbs)**

Note: *a* – Results for first test sections were very repeatable with CV less than 5%, so no need for three or more replicates; *b* – Tests will be done on extracted binders only and treated as RTFO residue, so no need for RTFO or PAV; *c* – Also run the intermediate temperature DSR and BBR on the extracted binders as it is (with no PAV) for mixes with RAP or RAS.

Table C-2. HMA Mix Tests (Plant-Mix/Cores Only).

#	Test	Spec	Test Parameters	Output Data	Sample Replicates			Time (hrs)		Material Requirement (grams)
					TTI	UTEP	*TxDOT Recom.*	Sample Prep	Testing	
1	AC extraction	Tex-210-F [a]	As per spec	AC % (by weight)	3		***3***	2	16	5000
2		Tex-236-F	As per spec	AC%	3		***0***[b]	2	5	5000
3	Aggregate gradation	Tex-200-F	As per spec	Particle size distribution	3		***3***	14	1	(Aggregates from Tex-210-F)
4	Hamburg	Tex-242-F	As per spec; run all samples up to 20 000 load passes	Rut depth and number of wheel passes	3 (3 sets of 2)		***1***[c] *(1 set of 2)*	24	14	20000
5	Overlay	Tex-248-F	0.025 inch, 93% load drop, 77 °F	Max load & number of cycles to failure	5		***5***	72	36	25000
6	OT fracture properties	Report 0-5798-2, PP 97 (DM + OT)		*A* & *n*	5		***5***	80	14	25000
7	Dynamic modulus (DM)	AASHTO TP 62-03	As per spec; 5 temps; 6 frequencies.	Dynamic modulus	3		***3***	72	120	22000
8	Permanent deformation (RLPD)	Report 0-5798 (New)	(a)104 °F, 20 psi, & 10 000 cycles, & (b) 122°F, 20 psi, & 10 000 cycles,	α, μ , & microstrains	6 (3 x 2 temps)		***6*** (3 x 2 temps)	72	27	45000
9	Indirect tension (IDT)	Tex-226-F	As per spec	IDT strength	3	-	***3***	72	2	15000
10	Thermal coefficient	TTI improvised	14 – 104 °F	Thermal coefficient (α)	3		***3***	72	36	22000
		Tex-428-A								
Total material to sample from the field (Target test specimen AV =7±1%; except for PFC test specimens at 20±2% AV)					37		***32***	482	271	184000 **(≥ 405 lbs)**

Note: *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 CV less than 5%, so no need for three replicate sets.

Table C-3. Base Tests (Flex).

#	Test	Spec	Test Parameters	Output Data	Sample Replicates			Time (hrs)		Material Requirement
					TTI	UTEP	***TxDOT Recom.***	Sample Prep	Testing	
1	Sieve analysis [a, b]	Tex-110-E		Gradation	3	Stock	***Stock (Tex-110-E for +#40 & Tex-111-E for -#40)***	1 hr (24 hrs)	8 hrs	700 lbs [c]
2	Atterberg Limits [a]	Tex-104-E, 105-E, 106-E		PI, LL, & PL	3	2 [d]	***1+[g]***	1 hr (12 hrs)	2 hrs	3 lbs
3	Specific gravity	ASTM C-127, 128		SG value	3	2 [d]	***2[d]***	1 hr (19 hrs)	1 hr (12 hrs)	12 lbs
4	Wet Ball Mill [a, e]	Tex-116-E		Wet Ball Mill value	3	2 [d]	***0***	1 hr (2hrs)	3hrs (24 hrs)	22 lbs
5	MD Curve [a]	Tex-113-E	6″ x 8″	MDD, OMC	3	2 [d]	***1+[g]***	1 hr (4–12hrs)	2 hrs	160 lbs
6	Texas Triaxial	Tex-117-E	6″ x 8″	Classification, C, & ϕ	3	2 [d]	***1[f]***	5 hrs (10 days)	4 hrs	240 lbs
7	Resilient modulus	Tech Memo (1-28A)	6″ x 12″ OMC	k- parameters	3	2 [d]	***2[d]***	1 hr (24 hrs)	10 hrs	70 lbs
8	Permanent deformation	Tech Memo (1-28A)	6″ x 12″ OMC	α & μ	3	2 [d]	***2[d]***	1 hr (24 hrs)	10 hrs	70 lbs
9	Shear strength	Tex-143	6″ x 8″	C and ϕ	3	2 [d]	***2[d]***	1 hr (24 hrs)	4 hrs	120 lbs
10	Soil suction	Filter paper		Suction coefficient	3					
Total material to sample from the field										**≥ 700 lbs**

Note: * – Time in parenthesis refers to wait (cure) time, *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* – This represents the minimum total amount of material sampled from the field and used in Steps 2-9, *d* – A third test is performed if the duplicate results vary with a wide margin, *e* – If available use from TXDOT QC 1+ - Researchers to run one test, if the results match the districts, they can use district results; if not, the researchers will run two samples, *f* – One sample at each confining pressure, *g* – Plus one sample for every change in material.

Table C-4. Base Tests (Treated – CTB).

#	Test	Spec	Test Parameters	Output Data	Sample Replicates			Time (hrs)		Material Requirement
					TTI	UTEP	*TxDOT Recom.*	Sample Prep	Testing	
1	Sieve analysis[a, b]	Tex-110-E		Gradation	3	Stock	***Stock***	1 hr (24 hrs)	8 hrs	550 lbs[c]
2	Atterberg Limit[d]	Tex-104-E, 105-E, 106-E		PI, LL, & PL	3	2[f]	*1+*[j]	1 hr (12 hrs)	2 hrs	6 lbs
3	Sulfate content[d]	Tex-145-E		Sulfate content	3	2[f]	***0***	1 hr (12 hrs)	2 hrs	1 lb
4	Wet Ball Mill[d]	Tex-116-E		Wet Ball Mill value	3	2[f]	***0***	1 hr (2 hrs)	3hrs (24 hrs)	22 lbs
5	MD Curve[e]	Tex-113-E		MDD & OMC	3	2[f]	*1+*[j]	1 hr (4–12hrs)	2 hrs	160 lbs
6	Unconfined compressive strength[e]	Tex-120-E etc.		UCS	3	2[f]	*1*[i]	1 hr (7 days)	1 hr	40 lbs
7	Resilient modulus[e, h]	Zero confinement		k- parameters	3	2[f]	*2*[f]	1 hr (7 days)	2 hrs	70 lbs
8	Modulus of rupture[e, g]	Tex-448-A		Modulus of Rupture	3	2[f]	*2*[f]	6 hrs (7 days)	1 hr	140 lbs
Total material to sample from the field										**≥ 550 lbs**

Note: * – Time in parenthesis refers to wait (cure) time, *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* – This represents the minimum total amount of material sampled from the field and used in Tests 2–8, d – Test is performed before treatment , *e* – Test is performed after treatment, *f* – A third test is performed if the duplicate results vary with a wide margin, *g* – Test only for cement treated (>4%), h – Run FFRC instead of RM at zero confinement, *i* – Includes running three samples at the cement content, *j* – Plus one sample for every change in material.

Table C-5. Base Tests (Treated – Asphalt/Low Stabilizers).

#	Test	Spec	Test Parameters	Output Data	Sample Replicates			Time (hrs)		Material Requirement
					TTI	UTEP	*TxDOT Recom.*	Sample Prep	Testing	
1	Sieve analysis[a, b]	Tex-110-E		Gradation	3	Stock	***Stock***	1 hr (24 hrs)	8 hrs	550 lbs[c]
2	Atterberg Limit[d]	Tex-104-E, 105-E, 106-E		PI, LL, & PL	3	2[f]	***1+***[j]	1 hr (12 hrs)	2 hrs	6 lbs
3	Sulfate content[d]	Tex-145-E		Sulfate content	3	2[f]	***0***	1 hr (12 hrs)	2 hrs	1 lb
4	Wet Ball Mill[d]	Tex-116-E		Wet Ball Mill value	3	2[f]	***0***	1 hr (2 hrs)	3hrs (24 hrs)	22 lbs
5	MD Curve[e]	Tex-113-E		MDD & OMC	3	2[f]	***1+***[j]	1 hr (4–12hrs)	2 hrs	160 lbs
6	Unconfined compressive strength[e]	Tex-120-E etc.		UCS	3	2[f]	***1***[g]	1 hr (7 days)	1 hr	40 lbs
7	Resilient modulus[e, h]	Zero confinement		k- parameters	3	2[f]	***2***[f]	1 hr (7 days)	2 hrs	70 lbs
8	Permanent deformation[e, g]	Zero confinement		α & μ	3	2[f]	***2***[f]	1 hr (7 days)	10 hrs	70 lbs
Total material to sample from the field										**≥ 550 lbs**

Note: * – Time in parenthesis refers to wait (cure) time, *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* – This represents the minimum total amount of material sampled from the field and used in Tests 2–8, *d* – Test is performed before treatment , *e* – Test is performed after treatment, f – A third test is performed if the duplicate results vary with a wide margin, *g* – Test only for asphalt treated and low stabilizer content (< 2%), *h* – Run FFRC instead of RM at zero confinement, *i* – Includes running three samples, *j* – Plus one sample for every change in material.

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

#	Test	Spec	Test Parameters	Output Data	Sample Replicates			Time (hrs)		Material Requirement
					TTI	UTEP	*TxDOT Recom.*	Sample Prep	Testing	
1	Sieve Analysis[a, b]			Gradation	3	Stock	***Stock (Tex-110-E, Part I for +#40 and Part II for -#40 [hydrometer])***	1 hr (24 hrs)	8 hrs	310 lbs[c]
2	Atterberg limits	Tex-104-E, 105-E, 106-E		PI, LL, & PL	3	2[d]	***1+[e]***	1 hr (12 hrs)	2 hrs	3 lbs
3	Specific gravity	Tex-108-E		SG value	3	2[d]	***2[d]***	1 hr (19 hrs)	1 hr (12 hrs)	1 lb
4	Sulfate content	Tex-145-E		Sulfate content	3	2[d]	***0***	1 hr (12 hrs)	2 hrs	1 lb
5	Organic content	Tex-408-A		Organic content	3	2[d]	***0***	1 hr (24 hrs)	2 hrs	1 lb
6	MD curve	Tex-114-E		MDD & OMC	3	2[d]	***1+[e]***	1 hr (4–12 hrs)	2 hrs	80 lbs
7	Texas Triaxial	Tex-117-E		Classification, C, & ϕ	3	2[d]	***1***	1 hr (10 days)	6 hrs	120 lbs
8	Resilient modulus	Tech Memo (1-28A)	4″ x 8″	k- parameters	3	2[d]	***2[d]***	1 hr (24 hrs)	10 hrs	20 lbs
9	Permanent deformation	Tech Memo (1-28A)	4″ x 8″	α & μ	3	2[d]	***2[d]***	1 hr (24 hrs)	10 hrs	20 lbs
10	Shear strength	Tex-143		C & ϕ	3	2[d]	***2[d]***	1 hr (24 hrs)	8 hrs	60 lbs
11	Soil suction	Filter paper (or pressure plate)		Suction coefficient	3					
Total material to sample from the field										**≥ 310 lbs**

Note: * – Time in parenthesis refers to wait (cure) time, *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* – This represents the minimum total amount of material sampled from the field and used in Tests 2-10, *d* – A third test is performed if the duplicate results vary with a wide margin, *e* – Plus one sample for every change in material.

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

#	Test	Spec	Test Parameters	Output Data	Sample Replicates			Time (hrs)		Material Requirement
					TTI	UTEP	*TxDOT Recom.*	Sample Prep	Testing	
1	Gradation[a, b]	Tex-110-E		Gradation	3	Stock	***Stock (Tex-110-E, Part I for +#40 and Part II for -#40 [hydrometer])***	1 hr (24 hrs)	8 hrs	150 lbs[c]
2	Atterberg limits[d, e]	Tex-104-E, 105-E, 106-E		PI, LL, & PL	3	2[f]	***1+[h]***	1 hr (12 hrs)	2 hrs	6 lbs
3	Sulfate content[e]	Tex-145-E		Sulfate content	3	2[f]	***2[d]***	1 hr (12 hrs)	2 hrs	1 lb
4	Organic content[e]	Tex-408-A		Organic content	3	2[f]	***0***	1 hr (24 hrs)	2 hrs	1 lb
5	MD Curve[e]	Tex-114-E		MDD & OMC	3	2[f]	***0***	1 hr (4–12hrs)	2 hrs	80 lbs
6	Unconfined compressive strength[e]	Tex-121-E etc.		UCS	3	2[f]	***1+[h]***	1 hr (7 days)	1 hr	20 lbs
7	Resilient modulus[e, g]	Zero confinement		k- parameters	3	2[f]	***2[d]***	1 hr (7 days)	2 hrs	20 lbs
8	Permanent deformation[e]	Zero confinement		α & μ	3	2[f]	***2[d]***	1 hr (7 days)	10 hrs	20 lbs
Total material to sample from the field										**≥ 150 lbs**

Note: * – Time in parenthesis refers to wait (cure) time*,* *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 – This represents the minimum total amount of material sampled from the field and used in Tests 2-8, d – Test is performed before treatment , *e* – Test is performed after treatment, *f* – A third test is performed if the duplicate results vary with a wide margin, *g* – Run FFRC instead of RM at zero confinement, *h* – Plus one sample for every change in material.

Table C-8: Lab Tests for Seal Coat Binders
(Neat Asphalt-Binders: Obtained Directly from the Plant or Truck [Onsite during Construction])

#	Test	Spec	Parameters	Sample Replicates			Comments
				TTI	UTEP	*TxDOT Recommendation*	
1	Residual recovery in case of Emulsions	Texas Oven (6 hr @ 60 °C)	Residual recovery	3 (≅ 60 grams)		*3*	Silicon sheets may be obtained from Bed Bath & Beyond
2	Viscosity	T 316	Viscosity	1 (≅ 40 grams)		*1*	
3	Specific gravity	T 228	SG	1 (40 g)		*1*	
4	RTFO & PAV	T 240, R 28		1 (≅ 60 grams)		*1*	
5	DSR	T 315	G*, & G*/Sin(δ)	1 (≅ 60 grams)		*1*	
6	MSCR	TP 70	Jnr, Jnr ratio % recoverable strain	9 *(3 x 3 temps)* (≅ 60 grams)		*9 (3 x 3 temps)*	
7	BBR	T 313	S & m-values	2 *(1 x 2 temps)* (≅ 60 grams)		*2 (1 x 2 temps)*	
8	Elastic recovery	D 6084	% recovery	3 (≅ 100 grams)		*3*	
9	SPG grading	Report 0-1710-2	SPG binder grade	-		-	Include the reference document for this estimate (Report 0-1710-2)
Total number of replicates				21		*21*	
Approximate material requirement = 1 five-gallon (≅ 38 lbs) bucket of neat binder obtained either from the plant or directly from the truck onsite during construction.							

APPENDIX D: EXAMPLE LAB TEST RESULTS

PG 64-22 (Extracted, US 59)	Sample# 1	Sample# 2	Sample# 3	Avg	Stdev	CV
Specific Gravity	1.057	1.055	1.054	1.055	0.001	0.10%
Viscosity (mPa.s)	138	131	130	133	4.112	3.10%

Figure D-1. Specific Gravity and Viscosity (Extracted PG 64-22, US 59, Atlanta District).

BBR Test Results - PG 64-22 (Extracted, US 59)				Specifications	
Test Temperature （℃）	Sample	m-value	Stiffness (MPa)	m-value	Stiffness
-18	Sample# 1	0.361	183	≥ 0.3	≤ 300 MPa
	Sample# 2	0.350	187		
	Sample# 3	0.350	192		
	Avg	0.354	187		
	Stdev	0.006	4.509		
	CV	1.80%	2.41%		
-24	Sample# 1	0.291	401		
	Sample# 2	0.272	421		
	Sample# 3	0.292	413		
	Avg	0.285	412		
	Stdev	0.011	10.066		
	CV	3.95%	2.45%		

Figure D-2. BBR Results (Extracted PG 64-22, US 59, Atlanta District).

Neat : DSR-RTFO

	T#1 = 58 °C			T#2 = 64 °C			T#3 = 70 °C			TruGrade Temp (°C)
	G*	δ(°)	G*/Sin (δ)	G*	δ(°)	G*/Sin (δ)	G*	δ(°)	G*/Sin (δ)	
Sample# 1	6.52	84.70	6.55	2.69	86.50	2.70	1.19	87.60	1.20	65.50
Sample# 2	6.48	84.90	6.50	2.75	86.60	2.76	1.25	87.70	1.25	65.69
Sample# 3	6.46	84.90	6.48	2.80	86.60	2.81	1.25	87.70	1.25	65.79
Avg.	6.49	84.83	6.51	2.75	86.57	2.76	1.23	87.67	1.23	65.66
COV	0.47%	0.14%	0.55%	2.01%	0.07%	2.00%	2.82%	0.07%	2.34%	0.22%

Extracted : DSR (No RTFO) – Considered as RTFO Residue

	T#1 = 58 °C			T#2 = 64 °C			T#3 = 70 °C			TruGrade Temp (°C)
	G*	δ(°)	G*/Sin (δ)	G*	δ(°)	G*/Sin (δ)	G*	δ(°)	G*/Sin (δ)	
Sample# 1	7.14	82.90	7.20	3.24	84.90	3.25	1.59	86.40	1.59	67.26
Sample# 2	7.00	82.90	7.06	3.13	85.00	3.14	1.50	86.40	1.51	66.90
Sample# 3	6.03	83.30	6.08	2.67	85.20	2.68	1.25	86.60	1.25	65.55
Avg.	6.72	83.03	6.78	3.01	85.03	3.02	1.45	86.47	1.45	66.57
COV	8.99%	0.28%	9.00%	10.03%	0.18%	10.00%	12.18%	0.13%	12.26%	1.35%

Legend: G* = complex modulus (kPa); δ = phase angle (°)

Threshold: G*/Sin (δ) ≥ 2.20 kPa

Figure D-3. DSR Test Results (PG 64-22, US 59, Atlanta District).

Neat : MSCR-RTFO

	Sample Set# 1, T= 52 °C						Sample Set# 2, T= 58 °C						Sample Set# 3, T= 64 °C					
	R100	R3200	R_{diff} (%)	Jnr 100	J_{nr} 3200	$J_{nr-diff}$ (%)	R100	R3200	R_{diff} (%)	Jnr 100	J_{nr} 3200	$J_{nr-diff}$ (%)	R100	R3200	R_{diff} (%)	Jnr 100	J_{nr} 3200	$J_{nr-diff}$ (%)
Sample# 1	6.9	5.6	18.8	7.207E-06	7.142E-06	-0.9	3.55	1.76	50.51	1.861E-05	1.906E-05	2.42	1.86	0.51	72.85	4.571E-05	4.890E-05	6.98
Sample# 2	7.4	5.7	23.3	6.809E-06	6.927E-06	1.7	3.35	1.67	50.33	1.875E-05	1.928E-05	2.78	1.80	0.49	73.04	4.677E-05	4.807E-05	2.78
Sample# 3	6.9	6.0	12.9	6.290E-06	6.232E-06	-0.9	3.52	1.79	49.27	1.822E-05	1.881E-05	3.22	1.62	0.46	71.74	4.697E-05	4.930E-05	4.97
Avg.	7.07	5.76	18.33	6.768E-06	6.767E-06	-0.04	3.48	1.74	50.04	1.853E-05	1.905E-05	2.81	1.76	0.48	72.54	4.648E-05	4.876E-05	4.91
COV	3.85%	3.44%	28.58%	6.79%	7.03%	-	3.03%	3.60%	1.33%	1.50%	1.24%	14.28%	7.20%	5.02%	0.97%	1.46%	1.29%	42.78%

Extracted : MSCR (No RTFO) – Considered as RTFO Residue

	Sample Set# 1, T= 52 °C						Sample Set# 2, T= 58 °C						Sample Set# 3, T= 64 °C					
	R100	R3200	R_{diff} (%)	Jnr 100	J_{nr} 3200	$J_{nr-diff}$ (%)	R100	R3200	R_{diff} (%)	Jnr 100	J_{nr} 3200	$J_{nr-diff}$ (%)	R100	R3200	R_{diff} (%)	Jnr 100	J_{nr} 3200	$J_{nr-diff}$ (%)
Sample# 1	10.16	8.19	19.39	6.599E-06	6.571E-06	-0.41	6.71	2.66	60.31	1.882E-05	1.990E-05	5.72	4.33	1.21	72.00	3.593E-05	3.839E-05	6.86
Sample# 2	11.24	8.02	28.66	6.616E-06	6.702E-06	1.31	6.89	2.77	59.87	1.841E-05	1.957E-05	6.31	4.68	0.95	79.76	4.308E-05	4.884E-05	13.38
Sample# 3	11.31	8.19	27.59	6.327E-06	6.487E-06	2.52	6.36	2.77	56.42	1.784E-05	1.875E-05	5.14	4.11	1.15	71.99	3.650E-05	3.961E-05	8.52
Avg.	10.90	8.13	25.21	6.514E-06	6.587E-06	1.14	6.65	2.73	58.87	1.836E-05	1.941E-05	5.72	4.37	1.10	74.58	3.850E-05	4.228E-05	9.59
COV	5.90%	1.25%	20.10%	2.48%	1.64%	129.49%	4.11%	2.25%	3.62%	2.70%	3.05%	10.26%	6.62%	12.51%	6.01%	10.33%	13.52%	35.30%

Threshold: $J_{nr}3200 \leq 4.0\ kPa^{-1}$; $J_{nr-diff}(\%) \leq 75$

Figure D-4. MSCR Test Results (PG 64-22, US 59, Atlanta District).

	Final PG Grade
Item 300	PG 64-22
AASHTO M320	PG 64-22
AASHTO MP 19	PG 64-22

Figure D-5. Asphalt-Binder PG Grading (PG 64-22, US 59, Atlanta District).

Sample Set #1

Sample Set #2

Type D: PM
5.1%PG 64-22 + Quartzite + 20% RAP

US 59 SB (Atlanta District; Panola County)

	AC Content	
	Sample Set# 1, Tex-206-F	Sample Set# 2, Tex-210-F
Sample# 1	5.0%	5.4%
Sample# 2	5.1%	5.5%
Sample# 3	4.8%	5.4%
Avg.	5.0%	5.4%
COV	3.2%	1.06%

Figure D-6. Asphalt-Binder Extraction Tests.

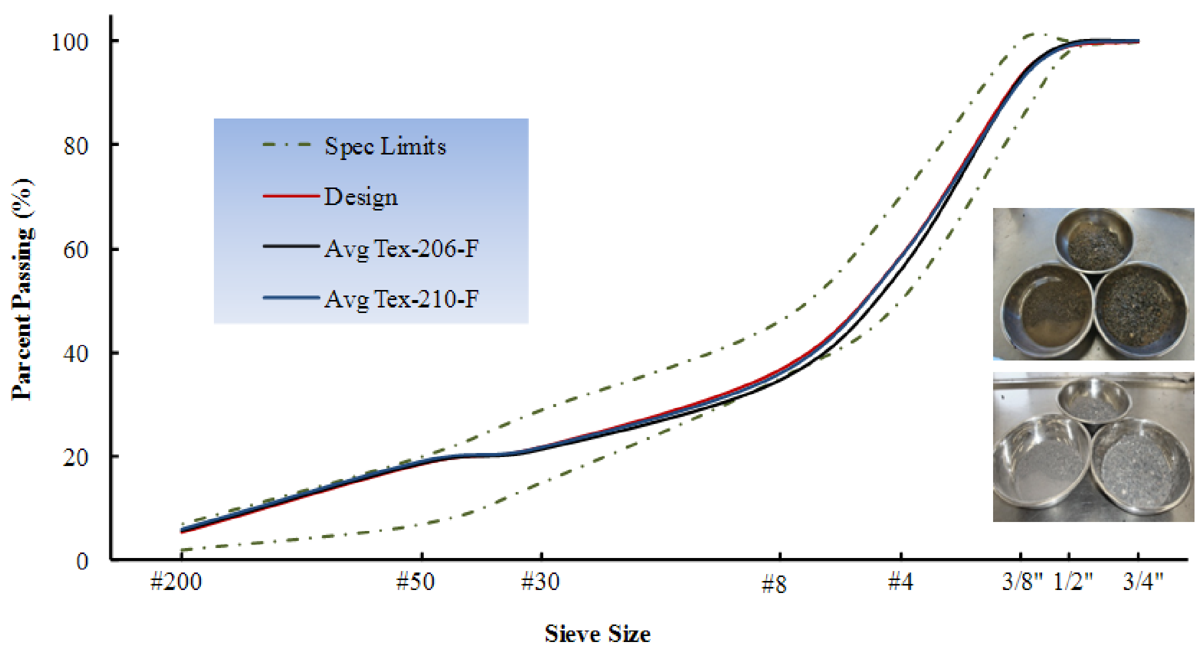


Figure D-7. Aggregate Gradation Extractions (Type D Mix, US 59, Atlanta District).

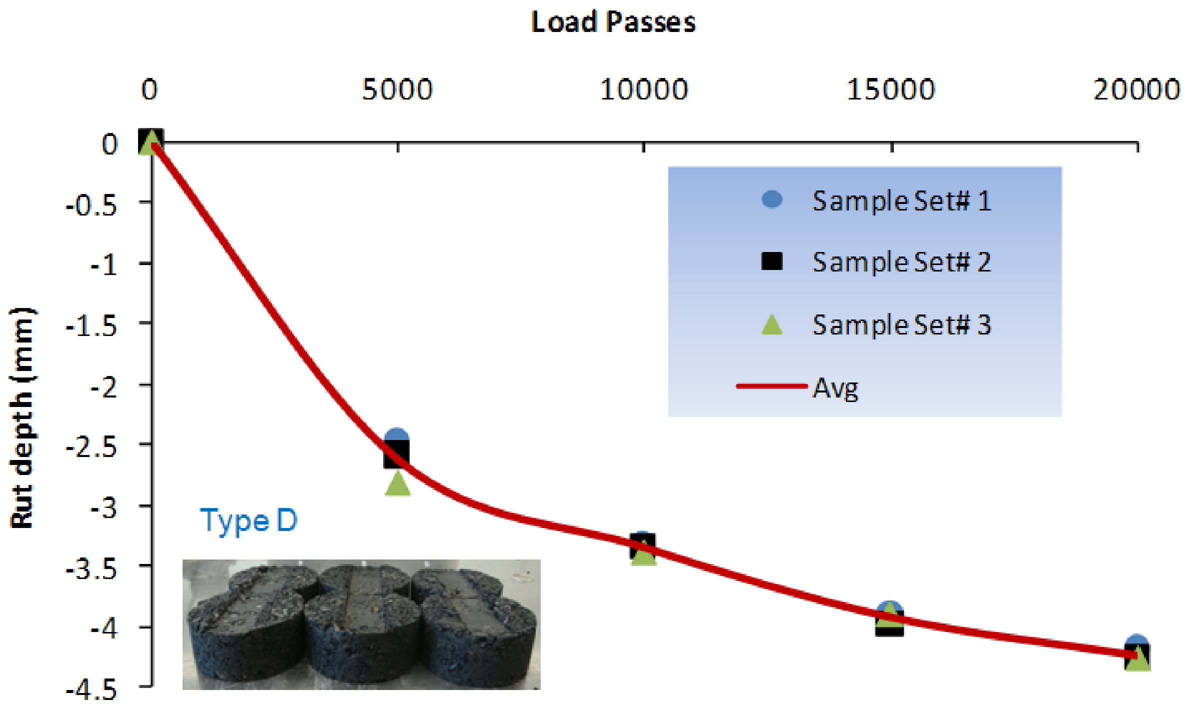
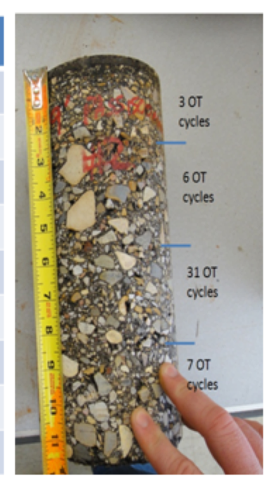


Figure D-8. Hamburg Test Results (Type D Mix, US 59, Atlanta District).

Type D:
5.1%PG 64-22 + Quartzite + 20% RAP

US 59 SB (Atlanta District; Panola County)

	AV (7±1)	Peak Load (lbs)	OT Cycles
Sample# 1	6.8%	695	309
Sample# 2	6.1%	700	121
Sample# 3	6.4%	773	334
Sample# 4	6.3%	757	269
Sample# 5	6.6%	839	240
Avg (all)	6.4%	753	255
COV (all)	4.3%	7.9%	32.6%
Avg (best 3)	6.4%	717	304
COV (best 3)	2.4%	5.0%	11%



Threshold: OT Cycles ≥ 300

Figure D-9. Overlay Test Results (Type D Mix, US 59, Atlanta District).

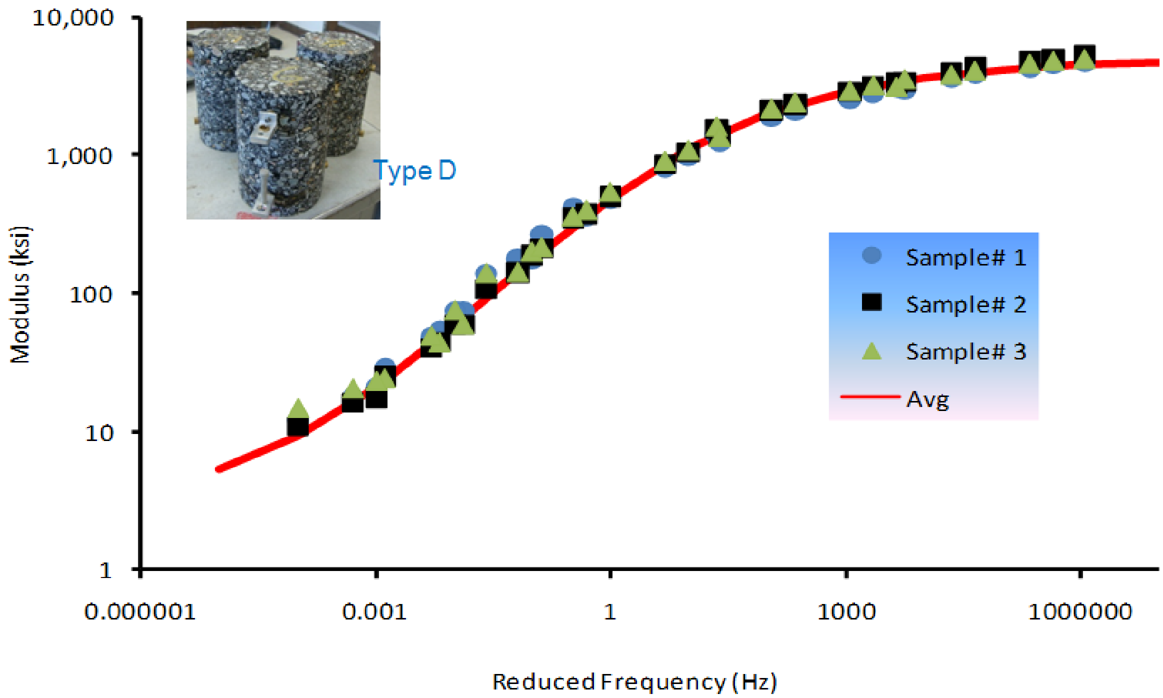


Figure D-10. Dynamic Modulus Master-Curve (Type D Mix, US 59, Atlanta District).

Type D:
5.1%PG 64-22 + Quartzite + 20% RAP

US 59 SB (Atlanta District; Panola County)

	Sample Set# 1, T= 40 °C			Sample Set# 2, T= 50 °C		
	AV (7±1)	Alpha (α)	mu (μ)	AV (7±1)	Alpha (α)	mu (μ)
Sample# 1	8.0%	0.6436	0.58	7.2%	0.5912	0.31
Sample# 2	7.9%	0.6218	0.51	6.9%	0.6872	0.49
Sample# 3	7.3%	0.6145	0.50	7.5%	0.7073	0.65
Avg.	7.7%	0.6266	0.53	7.2%	0.6619	0.48
COV	3.9%	2.4%	8.0%	3.6%	9.4%	35.2%

Figure D-11. RLPD Test Results (Type D Mix, US 59, Atlanta District).

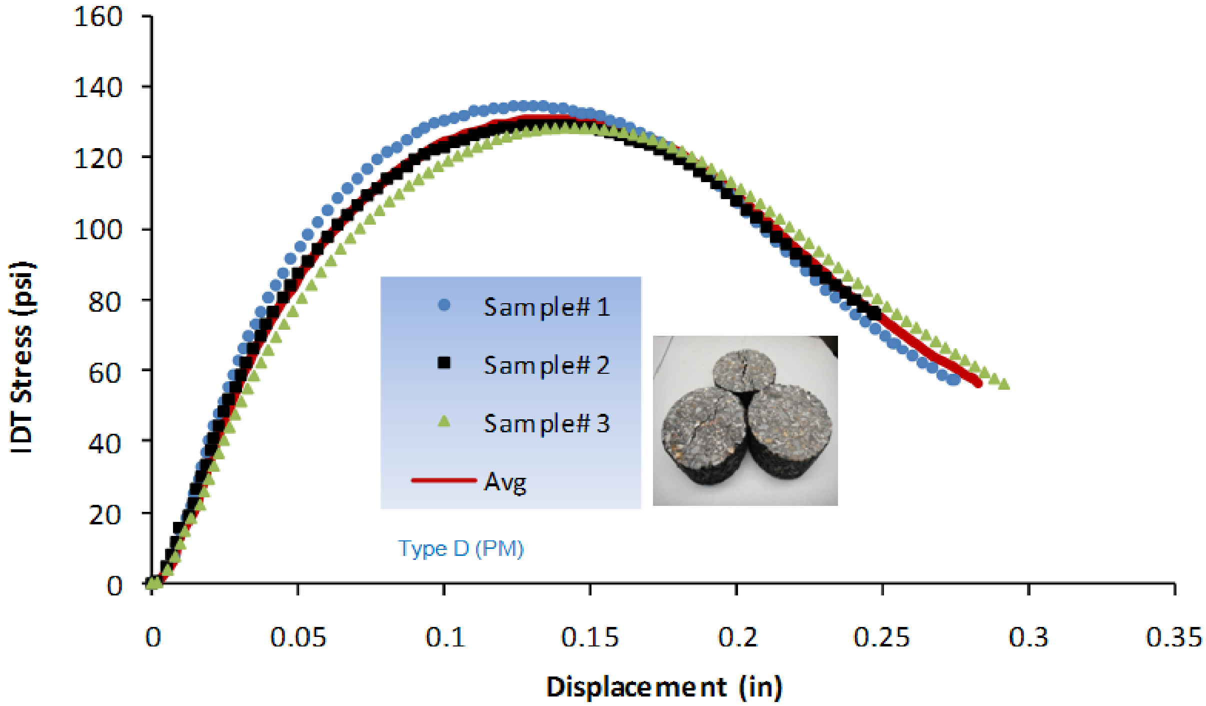


Figure D-12. IDT Test Results (Type D Mix, US 59, Atlanta District).

Temp. range tried:
-10 °C to +40 °C

Type D: 5.1%PG 64-22 + Quartzite + 20% RAP
US 59 SB (Atlanta District; Panola County)

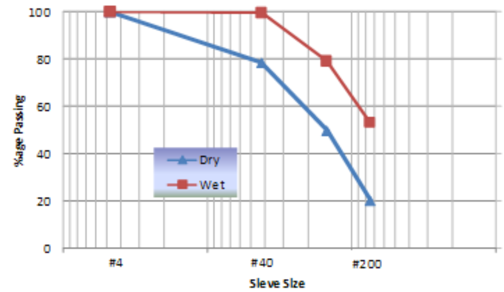
Literature Range: 1.137 – 3.512 E-05 (Mamlouk et al. 2005)

Sample	AV (7±1)	α (in/in/°F)
Sample 1	7.4%	1.05E-05
Sample 2	6.9%	1.92E-05
Sample 3	7.3%	0.93E-05
Avg.	7.2%	1.30E-05
COV	3.3%	41.5%

Figure D-13. Thermal Coefficient Test Results (Type D Mix, US 59, Atlanta District).

Dry

Sandy Clay soil
Loop 480
(Laredo District)
Station 2154+00

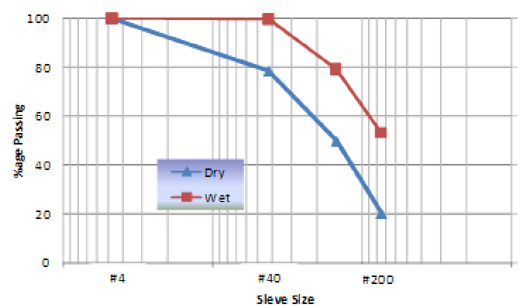


	Sample #1	Sample #2	Sample #3	%age Passing		
Seive Size	%age Passing	%age Passing	%age Passing	Avg	Stdev	CV
No. 4	100.0%	100.0%	100.0%	100.0%	0.00%	0.00%
No. 40	77.5%	77.9%	79.9%	78.4%	1.32%	1.68%
No. 100	50.0%	49.7%	49.5%	49.7%	0.25%	0.51%
No. 200	20.9%	20.5%	18.9%	20.1%	1.05%	5.22%
Pan	0.0%	0.0%	0.0%	0.0%		

Figure D-14. Soil Sieve Analysis – Dry.

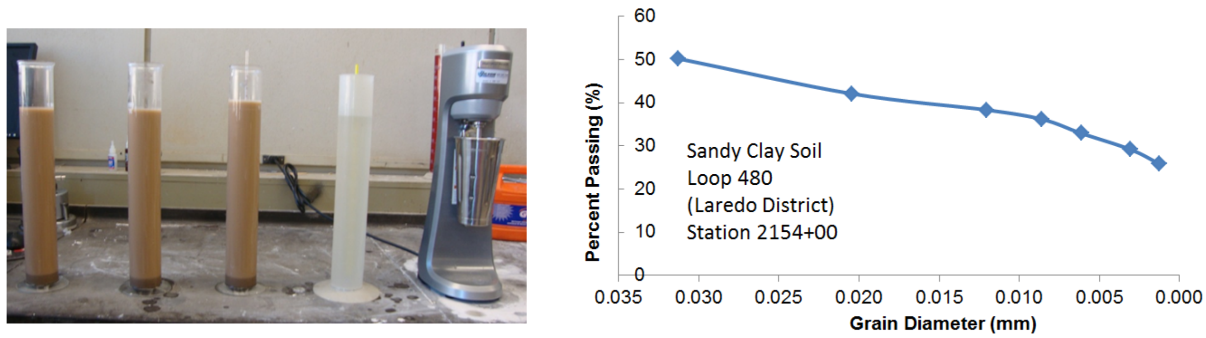
Wet

Sandy Clay soil
Loop 480
(Laredo District)
Station 2154+00



	Sample #1	Sample #2	Sample #3	%age Passing		
Seive Size	%age Passing	%age Passing	%age Passing	Avg	Stdev	CV
No. 4	100.0%	100.0%	100.0%	100.0%	0.0%	0.0%
No. 40	99.5%	99.6%	99.5%	99.5%	0.0%	0.0%
No. 100	80.5%	80.8%	79.1%	80.1%	0.9%	1.1%
No. 200	54.0%	52.2%	53.1%	53.1%	0.9%	1.7%

Figure D-15. Soil Sieve Analysis – Wet.



	Sample #1				Sample #2				Sample #3				Average			
Intervals	Readings	L (cm)	d (mm)	Ps (%)	Readings	L (cm)	d (mm)	Ps (%)	Readings	L (cm)	d (mm)	Ps (%)	d (mm)	Cov	Ps (%)	Cov
2	31	11.2	0.031	50	31	11.2	0.031	50	31	11.2	0.031	50	**0.031**	0%	**50**	0%
5	26	12	0.020	42	26	12	0.020	42	26	12	0.020	42	**0.020**	0%	**42**	0%
15	24	12.4	0.012	39	24	12.4	0.012	39	23	12.5	0.012	37	**0.012**	0.23%	**38**	2.44%
30	23	12.5	0.009	37	22	12.7	0.009	36	22	12.7	0.009	36	**0.009**	0.46%	**36**	2.59%
60	21	12.9	0.006	34	20	13.0	0.006	32	20	12.9	0.006	32	**0.006**	0.22%	**33**	2.84%
250	18	13.3	0.003	29	18	13.3	0.003	29	18	13.3	0.003	29	**0.003**	0%	**29**	0%
1440	16	13.7	0.001	26	16	13.7	0.001	26	16	13.7	0.001	26	**0.001**	0%	**26**	0%

Figure D-16. Hydrometer Test Results.

Sandy Clay soil
Loop 480 (Laredo District)
Station 2154+00

Spec	Material Property	Sample Replicate			Avg	Stdev	COV
		#1	#2	#3			
Tex-104-E	LL	15	15	16	15	0.6	3.8%
Tex-105-E	PL	10	11	10	10	**0.6**	**5.6%**
Tex-106-E	PI	5	5	6	5	**0.6**	**10.8%**

Figure D-17. Atterberg Limits.

	G (Specific Gravity)
Sample# 1	2.57
Sample# 2	2.62
Sample# 3	2.60
Avg	2.60
Sdtev	0.02
CV	0.94%

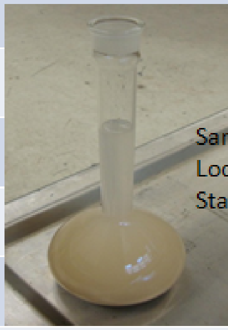


Figure D-18. Specific Gravity Results.

	Parts per Million (PPM)
Sample# 1	100
Sample# 2	140
Sample# 3	100
Avg	**113**
Stdev	**23**
CV	**20.4%**

Figure D-19. Sulfate Content Results.

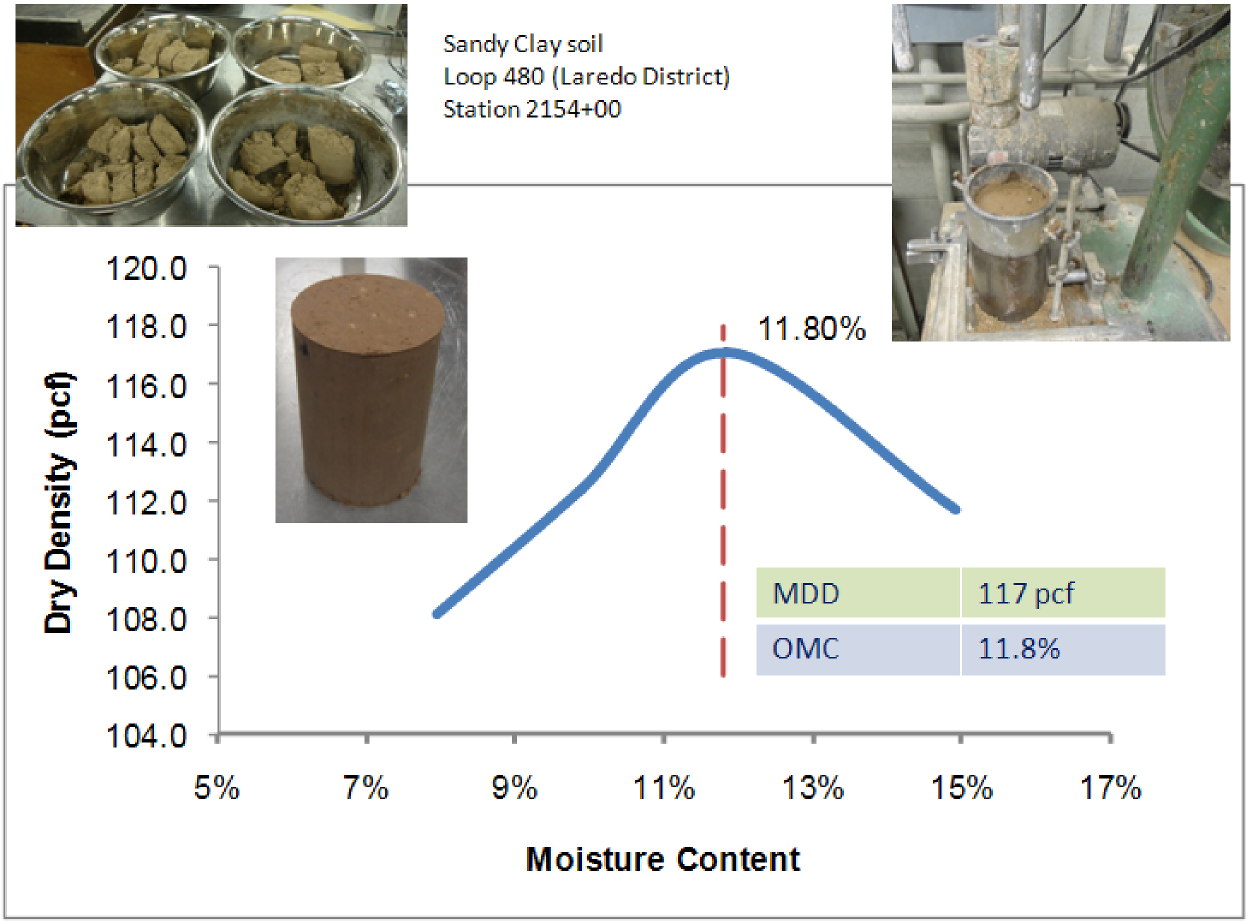


Figure D-20. Moisture Density Curve.

APPENDIX E: FWD BACKCALCULATION RESULTS

TTI MODULUS ANALYSIS SYSTEM (SUMMARY REPORT) (Version 6.1)

District:3 (Northwest Florida)
County :55 (Leon)
Highway/Road: 19183 US0059S

	Thickness (in)	MODULI RANGE (psi) Minimum	Maximum	Poisson Ratio Values
Pavement:	11.00	400,000	1,500,000	H1: v = 0.38
Base:	10.00	50,000	500,000	H2: v = 0.35
Subbase:	8.00	10,000	150,000	H3: v = 0.35
Subgrade:	141.49 (by DB)	10,000		H4: v = 0.40

Station	Load (lbs)	Measured Deflection (mils): R1	R2	R3	R4	R5	R6	R7	Calculated Moduli values (ksi): SURF(E1)	BASE(E2)	SUBB(E3)	SUBG(E4)	Absolute ERR/Sens	Dpth to Bedrock	
2.509	9,303	4.70	2.98	2.24	1.73	1.33	1.05	0.88	454.2	185.0	144.4	23.1	0.58	168.7	
2.523	9,263	5.22	3.11	2.31	1.73	1.30	0.99	0.81	400.0	124.9	149.4	24.2	0.79	136.8	*
2.537	9,211	5.30	3.06	2.26	1.68	1.28	0.99	0.84	400.0	116.5	150.0	24.7	1.72	151.9	*
2.551	9,231	5.36	2.91	2.15	1.60	1.22	0.97	0.82	400.0	114.0	150.0	26.1	3.50	185.2	*
2.565	9,529	4.61	2.78	2.04	1.56	1.22	0.96	0.83	413.5	223.1	150.0	26.5	1.14	159.1	*
2.579	10,320	4.10	2.70	2.05	1.59	1.26	1.00	0.84	610.5	273.7	150.0	27.1	0.95	163.0	*
2.594	9,624	4.32	2.61	1.96	1.52	1.19	0.98	0.82	448.8	500.0	21.6	31.8	3.31	300.0	*
2.608	9,394	4.61	2.86	2.19	1.68	1.34	1.06	0.91	429.1	500.0	10.0	30.9	3.13	171.3	*
2.623	9,434	4.58	2.80	2.09	1.59	1.22	0.96	0.83	432.9	204.0	150.0	25.9	0.78	162.4	*
2.637	9,243	5.01	3.30	2.65	2.05	1.67	1.28	1.02	455.9	217.5	126.4	17.9	1.05	145.1	
2.650	9,132	5.07	3.39	2.57	1.98	1.59	1.26	1.02	465.0	150.9	150.0	18.5	0.85	159.6	*
2.665	9,438	5.22	3.34	2.56	1.96	1.45	1.18	0.98	417.1	212.0	76.3	21.8	1.32	178.2	
2.679	9,422	5.06	3.11	2.38	1.83	1.40	1.09	0.91	400.0	208.5	116.0	22.6	0.57	155.4	*
2.693	9,597	4.83	3.10	2.39	1.90	1.51	1.20	1.02	438.0	259.7	149.7	20.5	0.56	173.2	*
2.707	9,537	4.79	2.98	2.26	1.75	1.39	1.14	0.94	421.0	500.0	10.0	29.6	3.51	171.0	*
2.722	9,430	4.61	2.90	2.21	1.70	1.35	1.07	0.89	434.0	500.0	10.0	30.6	2.82	173.7	*
2.736	9,136	5.27	3.10	2.37	1.84	1.43	1.13	0.91	400.0	153.7	150.0	21.3	1.74	148.5	*
2.750	9,513	5.52	3.28	2.40	1.79	1.34	1.06	0.85	400.0	111.9	150.0	23.9	1.57	149.1	*
2.764	9,692	6.98	4.48	3.35	2.44	1.82	1.33	1.09	400.0	69.0	85.2	18.6	1.05	122.4	*
2.778	9,100	7.00	3.88	2.85	2.13	1.62	1.19	0.96	400.0	50.0	150.0	19.6	4.21	119.6	*
2.793	9,152	5.11	3.12	2.31	1.78	1.34	1.04	0.82	400.0	142.6	150.0	22.8	0.66	130.8	*
2.807	9,227	5.21	2.94	2.15	1.58	1.23	0.95	0.77	400.0	120.9	150.0	26.1	2.64	149.4	*
2.821	9,251	5.10	2.83	2.05	1.55	1.16	0.96	0.77	400.0	133.5	150.0	27.0	3.50	183.6	*
2.835	9,358	5.59	2.78	1.94	1.48	1.17	0.93	0.81	400.0	102.2	150.0	28.9	7.27	169.7	*
2.849	9,672	4.25	2.56	1.90	1.52	1.20	0.98	0.79	556.0	500.0	10.4	34.6	6.11	131.6	*
2.865	9,108	6.72	2.54	1.77	1.29	1.03	0.83	0.72	400.0	56.1	150.0	34.2	14.91	300.0	*
2.877	9,271	4.24	2.35	1.74	1.32	1.03	0.83	0.69	400.0	270.6	150.0	30.9	2.15	171.3	*
2.892	9,370	3.41	2.07	1.63	1.30	1.07	0.89	0.80	591.5	500.0	113.4	30.4	3.58	300.0	*
2.906	9,176	3.38	1.96	1.50	1.23	0.98	0.81	0.67	636.1	500.0	19.7	41.4	7.00	141.4	*
2.921	9,394	3.06	1.66	1.36	1.17	0.99	0.82	0.70	882.9	500.0	22.0	44.5	11.92	300.0	*
2.935	9,323	3.52	1.85	1.50	1.19	0.94	0.81	0.69	465.2	500.0	150.0	34.2	4.05	300.0	*
2.949	9,156	3.56	1.86	1.50	1.24	1.00	0.83	0.67	464.7	500.0	132.2	32.9	5.25	121.3	*
2.963	9,128	3.42	1.90	1.61	1.33	1.09	0.86	0.76	721.7	500.0	13.9	39.8	8.84	138.2	*
2.977	9,481	3.81	2.17	1.79	1.44	1.17	0.98	0.75	630.4	500.0	15.2	35.7	7.54	102.7	*
2.992	9,330	3.52	1.96	1.61	1.31	0.98	0.83	0.71	610.3	500.0	22.5	39.2	6.36	151.5	*
3.006	9,148	3.78	2.10	1.67	1.34	1.07	0.93	0.76	529.2	500.0	17.8	37.4	7.61	300.0	*
3.020	9,501	3.26	1.93	1.57	1.32	1.09	0.87	0.72	729.6	500.0	97.3	30.9	5.14	137.2	*
3.034	9,327	3.18	1.84	1.52	1.29	1.10	0.88	0.72	894.2	500.0	28.5	35.0	8.87	125.5	*
3.048	9,219	3.13	1.90	1.50	1.24	1.05	0.86	0.74	741.0	500.0	97.3	31.1	5.71	300.0	*
3.062	9,068	3.21	1.84	1.50	1.27	1.07	0.86	0.74	698.2	500.0	97.3	30.5	6.46	300.0	*
3.077	9,323	3.07	1.75	1.42	1.24	1.01	0.84	0.71	804.1	500.0	97.3	32.7	7.23	300.0	*
3.091	9,624	3.41	1.80	1.44	1.20	1.00	0.84	0.72	541.1	500.0	150.0	35.2	6.65	300.0	*
3.105	9,843	3.07	1.76	1.49	1.26	1.06	0.89	0.76	872.3	500.0	83.4	35.3	8.55	300.0	*
3.120	9,569	3.63	2.02	1.60	1.30	1.08	0.88	0.76	608.8	500.0	26.2	37.8	8.05	300.0	*
3.134	9,124	3.60	1.94	1.56	1.30	1.07	0.89	0.80	620.6	500.0	16.0	39.2	9.64	300.0	*
3.148	9,132	3.35	2.03	1.65	1.38	1.17	0.97	0.81	808.6	500.0	27.1	30.7	7.72	300.0	*
3.162	9,108	3.68	2.25	1.82	1.50	1.24	1.00	0.85	520.3	500.0	150.0	24.3	2.33	300.0	*
3.176	9,068	3.75	2.33	1.87	1.46	1.19	0.96	0.81	481.5	480.9	150.0	24.8	1.03	300.0	*
3.191	9,084	3.30	2.02	1.57	1.27	0.99	0.91	0.74	588.2	500.0	113.4	30.6	4.08	300.0	*
3.204	9,104	3.07	1.75	1.43	1.20	1.04	0.88	0.75	887.3	500.0	38.7	34.6	10.02	300.0	*
3.219	9,048	3.63	1.87	1.53	1.27	1.05	0.89	0.76	453.1	500.0	132.2	31.3	6.40	300.0	*
3.232	9,247	3.57	1.89	1.54	1.30	1.07	0.89	0.74	509.9	500.0	132.2	30.9	6.18	140.8	*
3.247	8,842	5.37	2.68	1.98	1.59	1.27	1.03	0.87	400.0	132.2	150.0	24.8	7.29	300.0	*
3.261	9,438	4.16	2.70	2.12	1.69	1.39	1.11	0.85	499.9	500.0	68.0	23.3	1.72	108.0	*
3.276	9,410	4.15	2.67	2.17	1.78	1.43	1.15	0.96	483.2	500.0	132.5	20.8	0.34	300.0	*
3.290	9,172	4.03	2.45	1.96	1.62	1.30	1.05	0.88	444.0	500.0	150.0	22.9	1.05	300.0	*
3.305	9,291	3.52	2.19	1.74	1.46	1.14	0.96	0.81	601.0	500.0	102.4	27.2	2.87	300.0	*
3.318	9,064	3.44	2.13	1.76	1.46	1.21	1.00	0.83	681.5	500.0	71.6	26.2	4.72	151.3	*
3.335	8,969	3.97	2.43	1.97	1.65	1.31	1.06	0.87	509.8	500.0	64.6	23.6	3.01	143.3	*
3.347	9,080	3.59	2.36	1.86	1.49	1.20	1.01	0.89	558.8	472.7	150.0	23.7	1.70	300.0	*
3.361	9,013	4.13	2.63	2.09	1.70	1.35	1.10	0.89	457.4	500.0	90.4	21.9	1.03	139.2	*
3.375	8,937	4.23	2.58	2.07	1.70	1.36	1.11	0.91	444.1	500.0	61.4	22.9	2.52	149.6	*
3.390	8,965	4.65	2.77	2.19	1.77	1.33	1.02	0.83	400.0	500.0	10.0	29.0	2.31	131.0	*
3.403	8,874	4.51	2.56	2.08	1.66	1.31	1.07	0.83	424.2	500.0	10.0	29.9	5.30	115.2	*
3.418	8,925	4.97	2.96	2.42	1.94	1.46	1.18	0.94	400.0	224.9	147.6	19.3	2.19	300.0	*
3.432	9,319	5.30	3.34	2.53	1.91	1.47	1.14	0.93	400.0	178.4	95.2	21.7	0.69	158.1	*
3.446	8,913	7.55	4.50	3.36	2.56	1.94	1.53	1.21	400.0	50.0	120.5	15.2	3.72	152.3	*
3.461	8,897	6.02	3.22	2.68	2.22	1.81	1.48	1.20	400.0	161.4	150.0	15.9	5.56	150.1	*
3.474	8,909	7.33	3.92	3.26	2.68	2.19	1.78	1.46	400.0	90.6	132.3	13.2	6.80	178.1	*
3.489	9,017	7.10	4.28	3.47	2.81	2.21	1.75	1.39	400.0	89.9	128.9	12.9	3.23	147.4	*
3.503	8,941	8.53	4.24	3.29	2.65	2.10	1.68	1.36	400.0	50.0	141.5	14.1	8.51	165.0	*
3.517	9,438	5.91	3.57	2.88	2.42	1.95	1.57	1.25	400.0	203.1	150.0	15.1	2.73	131.2	*
3.532	9,132	6.05	3.63	2.85	2.28	1.81	1.46	1.19	400.0	128.2	150.0	16.2	2.65	165.8	*
3.546	9,152	6.36	4.06	3.22	2.48	2.00	1.61	1.29	400.0	110.1	144.1	14.4	1.78	161.8	*
3.560	8,830	5.39	3.57	2.87	2.26	1.81	1.48	1.20	400.2	197.5	138.1	14.9	0.99	166.4	*
3.573	8,901	6.53	3.50	2.85	2.41	1.79	1.48	1.08	400.0	105.0	150.0	15.7	5.93	166.7	*
3.588	8,858	5.77	3.72	2.98	2.36	1.88	1.48	1.15	400.0	142.1	147.2	14.7	0.81	129.1	*
3.602	8,802	5.50	3.66	3.03	2.35	1.90	1.56	1.16	400.8	199.4	134.7	14.0	1.46	111.2	*
3.617	8,818	5.29	3.26	2.54	2.13	1.73	1.40	1.12	400.0	219.4	150.0	16.1	2.35	132.4	*
3.631	8,878	5.61	2.82	2.33	1.91	1.55	1.26	1.02	400.0	180.9	150.0	19.3	6.38	144.2	*
3.645	8,846	6.20	3.51	2.72	2.13	1.48	1.25	0.89	400.0	76.4	150.0	19.0	4.83	116.1	*
3.659	8,814	5.54	3.37	2.69	2.16	1.74	1.40	1.12	400.0	167.4	150.0	16.1	2.15	144.4	*
3.674	8,890	5.59	3.41	2.71	2.18	1.76	1.41	1.00	400.0	164.7	150.0	16.1	2.19	91.2	*
3.688	9,005	4.59	2.83	2.28	1.85	1.51	1.20	0.96	400.0	382.8	150.0	19.1	0.75	134.4	*
3.703	8,981	4.57	3.00	2.47	1.94	1.57	1.23	1.01	443.5	431.7	68.2	18.9	0.63	164.8	
3.716	9,307	5.98	3.33	2.59	2.09	1.70	1.38	1.14	400.0	145.2	150.0	18.2	4.94	173.6	*
3.730	9,152	4.92	3.12	2.61	2.18	1.76	1.44	1.15	400.0	427.4	150.0	15.7	0.84	132.6	*
3.745	9,227	6.15	4.00	3.22	2.62	2.07	1.63	1.28	400.0	150.1	137.2	13.7	1.05	133.0	*
3.758	8,854	8.77	5.19	4.21	3.38	2.58	1.98	1.50	400.0	50.0	93.8	11.2	4.18	124.7	*
3.773	8,993	6.41	4.05	3.17	2.45	1.92	1.45	1.11	400.0	83.8	150.0	15.2	1.64	124.9	*
Mean:		4.79	2.83	2.22	1.76	1.40	1.13	0.92	491.3	316.6	108.3	25.0	3.90	170.5	
Std. Dev:		1.28	0.76	0.59	0.46	0.35	0.27	0.19	134.3	179.6	51.5	7.9	3.01	53.7	
Var Coeff(%):		26.70	26.96	26.72	25.91	24.89	23.55	20.90	27.3	56.7	47.6	31.5	77.08	31.5	

Figure E-1. FWD Results, US59 in Panola County.

TTI MODULUS ANALYSIS SYSTEM (SUMMARY REPORT) (Version 6.0)

District:1 (Paris)
County :139 (LAMAR)
Highway/Road: US0271

	Thickness(in)	MODULI RANGE(psi) Minimum	Maximum	Poisson Ratio Values
Pavement:	6.50	100,000	1,040,000	H1: v = 0.38
Base:	9.00	2,000,000	7,000,000	H2: v = 0.20
Subbase:	0.00			H3: v = 0.00
Subgrade:	278.35(by DB)	10,000		H4: v = 0.40

Station	Load (lbs)	Measured Deflection (mils): R1	R2	R3	R4	R5	R6	R7	Calculated Moduli values (ksi): SURF(E1)	BASE(E2)	SUBB(E3)	SUBG(E4)	Absolute ERR/Sens	Dpth to Bedrock	
8.000	8,167	4.07	2.26	2.26	1.87	1.48	1.35	1.05	223.7	7000.0	0.0	23.8	3.80	300.0	*
24.000	7,857	4.78	2.78	2.74	2.27	1.78	1.55	1.19	186.5	5808.4	0.0	18.6	2.80	300.0	
40.000	8,016	3.90	2.24	2.22	1.80	1.44	1.27	1.06	232.8	7000.0	0.0	23.9	2.90	300.0	*
54.000	7,809	4.35	2.41	2.39	1.93	1.54	1.33	1.07	189.3	6676.1	0.0	22.0	2.56	300.0	
70.000	7,686	3.96	2.03	1.94	1.60	1.25	1.11	0.87	186.7	7000.0	0.0	28.0	2.81	300.0	*
86.000	7,658	4.33	2.40	2.31	1.89	1.49	1.30	1.02	184.6	6319.0	0.0	22.6	2.41	300.0	
100.000	7,710	4.10	2.22	2.22	1.81	1.43	1.24	1.02	195.3	7000.0	0.0	23.7	2.97	300.0	*
108.000	7,602	3.76	2.08	2.02	1.74	1.33	1.24	0.89	221.9	7000.0	0.0	24.6	4.07	300.0	*
117.000	7,781	3.80	2.10	2.09	1.64	1.28	1.15	0.80	216.6	6890.3	0.0	26.5	3.50	300.0	
133.000	7,467	4.61	2.48	2.36	1.85	1.39	1.19	0.93	169.1	3910.3	0.0	25.1	3.00	300.0	
154.000	7,658	3.58	1.95	1.92	1.58	1.29	1.13	0.90	237.2	7000.0	0.0	26.8	2.97	300.0	*
164.000	7,726	3.83	1.93	1.87	1.50	1.17	1.01	0.80	189.9	7000.0	0.0	30.5	2.68	300.0	*
180.000	7,436	4.44	2.30	2.21	1.76	1.35	1.11	0.86	166.0	4618.2	0.0	26.2	2.54	300.0	
195.000	7,527	3.86	1.92	1.90	1.53	1.24	1.08	0.90	187.1	7000.0	0.0	28.4	3.01	300.0	*
210.000	7,753	3.92	2.02	1.95	1.55	1.20	1.08	0.88	189.4	6920.8	0.0	29.1	3.18	300.0	
227.000	7,785	4.52	2.82	2.81	2.40	1.80	1.66	1.16	227.9	6289.5	0.0	17.4	4.08	186.7	
271.000	7,523	4.65	2.07	1.90	1.55	1.22	1.05	0.76	130.1	6413.8	0.0	29.1	1.70	300.0	
287.000	7,503	5.54	2.93	2.70	2.16	1.63	1.52	1.07	132.7	4066.9	0.0	20.8	3.38	300.0	
303.000	6,991	4.30	2.58	2.54	2.13	1.65	1.44	1.11	197.4	5555.0	0.0	17.9	2.97	300.0	
317.000	7,491	5.54	3.41	3.41	2.76	2.15	1.84	1.42	177.4	3882.7	0.0	15.1	3.08	300.0	
347.000	7,523	4.60	2.26	2.24	1.91	1.59	1.52	1.28	163.6	7000.0	0.0	21.0	4.57	300.0	*
363.000	7,614	4.87	2.90	2.87	2.35	1.84	1.61	1.27	187.4	5155.1	0.0	17.6	2.96	300.0	
379.000	7,598	3.77	1.98	1.94	1.56	1.20	1.08	0.77	200.5	7000.0	0.0	28.2	3.42	300.0	*
409.000	7,662	4.19	2.07	2.00	1.61	1.26	1.15	0.81	167.8	7000.0	0.0	27.5	3.31	300.0	*
424.000	7,670	4.81	2.04	1.94	1.57	1.24	1.04	0.74	124.2	6695.5	0.0	29.3	1.81	79.9	
439.000	7,527	3.88	2.04	1.95	1.56	1.21	1.05	0.82	191.3	6199.1	0.0	28.6	2.58	300.0	
454.000	7,682	3.69	1.80	1.80	1.36	1.03	0.87	0.60	194.7	5708.0	0.0	35.3	3.44	300.0	
471.000	7,455	3.91	1.89	1.87	1.47	1.14	0.98	0.78	172.2	6795.2	0.0	30.3	2.96	300.0	
485.000	7,686	4.06	2.39	2.35	1.85	1.43	1.23	0.96	225.4	4874.8	0.0	23.9	3.01	300.0	
492.000	7,519	4.41	2.31	2.31	1.96	1.55	1.35	1.04	172.1	7000.0	0.0	21.3	3.16	300.0	*
172.000	7,741	5.91	2.71	1.63	0.99	0.72	0.70	0.58	122.5	2000.0	0.0	40.8	17.42	92.6	*
Mean:		4.32	2.30	2.21	1.79	1.40	1.23	0.95	185.9	6089.6	0.0	25.3	3.52	293.9	
Std. Dev:		0.57	0.37	0.38	0.35	0.27	0.25	0.19	30.6	1267.0	0.0	5.5	2.65	154.6	
Var Coeff(%):		13.30	16.30	17.34	19.57	19.67	19.89	20.54	16.5	20.8	0.0	21.6	75.24	52.6	

Figure E-2. FWD Results, US 271 in Lamar County.

TTI MODULUS ANALYSIS SYSTEM (SUMMARY REPORT) (Version 6.0)

District:1 (Paris)
County :75 (FANNIN)
Highway/Road: sh0121

	Thickness(in)	MODULI RANGE(psi) Minimum	Maximum	Poisson Ratio Values
Pavement:	4.50	20,000	460,000	H1: v = 0.38
Base:	9.50	100,000	10,000,000	H2: v = 0.25
Subbase:	0.00			H3: v = 0.00
Subgrade:	286.00(by DB)	10,000		H4: v = 0.40

Station	Load (lbs)	Measured Deflection (mils): R1	R2	R3	R4	R5	R6	R7	Calculated Moduli values (ksi): SURF(E1)	BASE(E2)	SUBB(E3)	SUBG(E4)	Absolute ERR/Sens	Dpth to Bedrock	
0.000	10,518	5.96	3.56	3.43	2.91	2.35	2.26	2.06	136.1	9065.4	0.0	17.2	2.82	300.0	
0.000	10,633	6.11	3.57	3.41	2.93	2.37	2.31	2.10	127.4	9974.8	0.0	16.9	2.72	300.0	
26.000	10,459	6.22	3.40	3.35	2.89	2.33	2.31	2.13	116.6	10000.0	0.0	17.2	3.52	300.0	*
50.000	10,578	6.04	3.75	3.59	3.03	2.45	2.39	2.14	143.4	8582.4	0.0	16.4	3.07	300.0	
75.000	10,669	5.80	3.48	3.39	2.92	2.35	2.26	2.05	144.0	10000.0	0.0	16.9	2.91	300.0	*
100.000	10,852	9.48	5.23	4.71	3.82	2.87	2.67	2.40	81.9	3228.4	0.0	17.2	2.94	300.0	
126.000	10,872	7.80	3.77	3.52	3.05	2.47	2.40	2.17	79.7	9399.6	0.0	17.3	2.51	300.0	
175.000	10,606	6.49	3.88	3.77	3.24	2.61	2.45	2.22	127.3	8476.4	0.0	15.6	2.65	300.0	
200.000	10,451	5.33	3.38	3.28	2.87	2.24	2.13	1.87	171.7	9198.1	0.0	17.5	3.21	300.0	
226.000	10,526	6.07	3.73	3.61	3.05	2.41	2.28	2.08	144.0	7501.2	0.0	17.3	3.06	300.0	
251.000	10,729	5.74	3.58	3.48	2.97	2.35	2.14	1.97	162.4	7662.1	0.0	18.4	2.75	300.0	
276.000	10,554	6.59	3.89	3.74	3.10	2.45	2.27	2.04	125.4	6366.4	0.0	18.1	2.82	300.0	
300.000	10,661	6.67	3.66	3.57	3.06	2.42	2.31	2.03	109.6	8908.3	0.0	17.3	3.08	300.0	
326.000	10,796	7.63	3.65	3.56	3.02	2.44	2.26	2.00	82.3	8619.8	0.0	18.1	2.44	300.0	
350.000	10,133	5.88	3.74	3.60	3.03	2.37	2.23	1.98	154.8	6555.9	0.0	17.2	3.13	300.0	
375.000	10,618	7.11	4.28	3.98	3.20	2.58	2.39	2.11	120.4	5024.5	0.0	18.1	2.99	300.0	
400.000	10,216	8.31	5.33	4.76	3.82	2.84	2.61	2.23	119.1	2541.7	0.0	16.3	3.04	213.9	
425.000	10,296	6.31	3.81	3.72	3.13	2.47	2.34	2.17	131.7	7307.6	0.0	16.5	3.18	300.0	
450.000	10,665	3.96	3.41	3.29	2.85	2.31	2.21	2.03	460.0	10000.0	0.0	17.1	4.16	300.0	*
475.000	10,498	5.38	3.48	3.47	2.96	2.38	2.29	2.03	181.0	10000.0	0.0	16.0	3.30	300.0	*
501.000	10,606	6.01	3.89	3.74	3.19	2.51	2.42	2.09	160.7	7488.8	0.0	16.1	3.19	300.0	
Mean:		6.42	3.83	3.67	3.10	2.46	2.33	2.09	146.6	7900.1	0.0	17.1	3.02	300.0	
Std. Dev:		1.16	0.53	0.40	0.26	0.16	0.13	0.11	77.0	2159.5	0.0	0.7	0.37	25.2	
Var Coeff(%):		18.13	13.71	10.79	8.52	6.46	5.70	5.34	52.5	27.3	0.0	4.3	12.24	8.4	

Figure E-3. FWD Results, SH 121 in Fannin County.

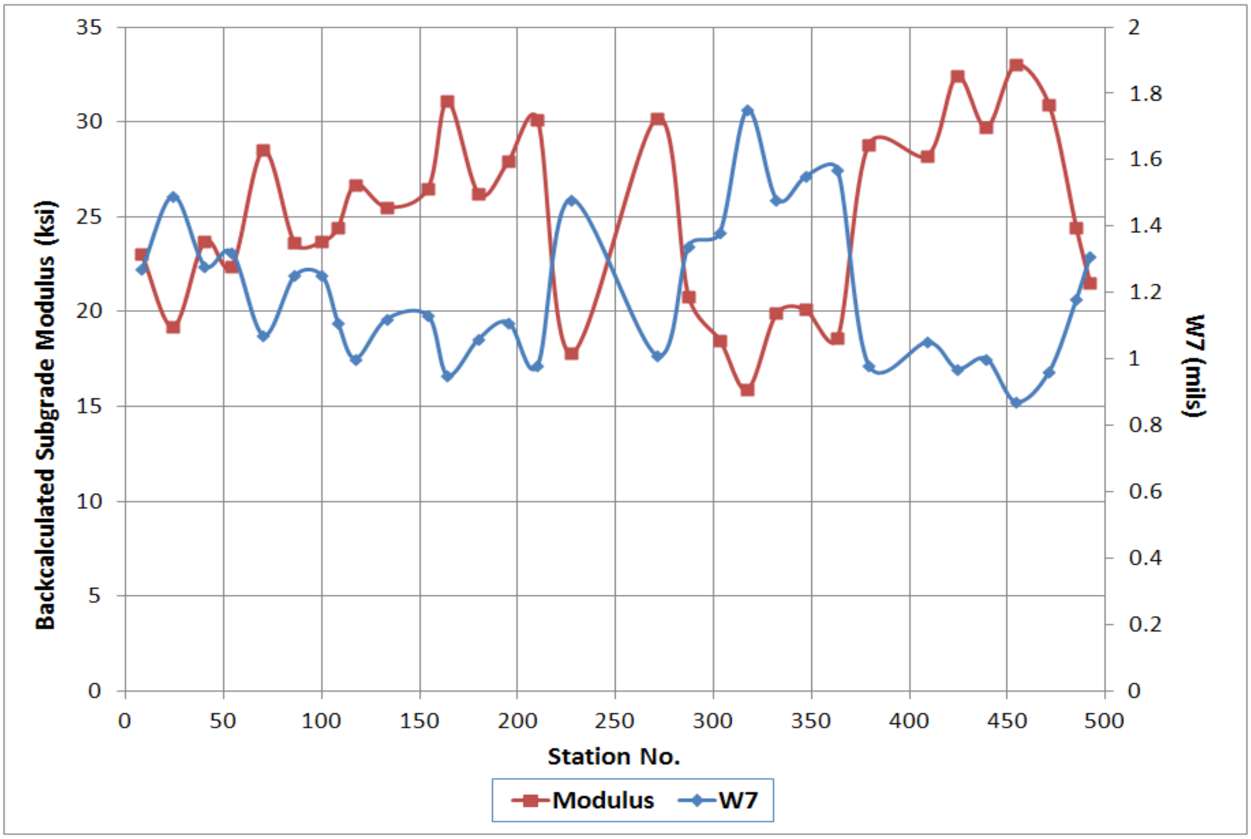


Figure E-4. FWD Sensor W7 versus Back-Calculated Subgrade Modulus, US 271.

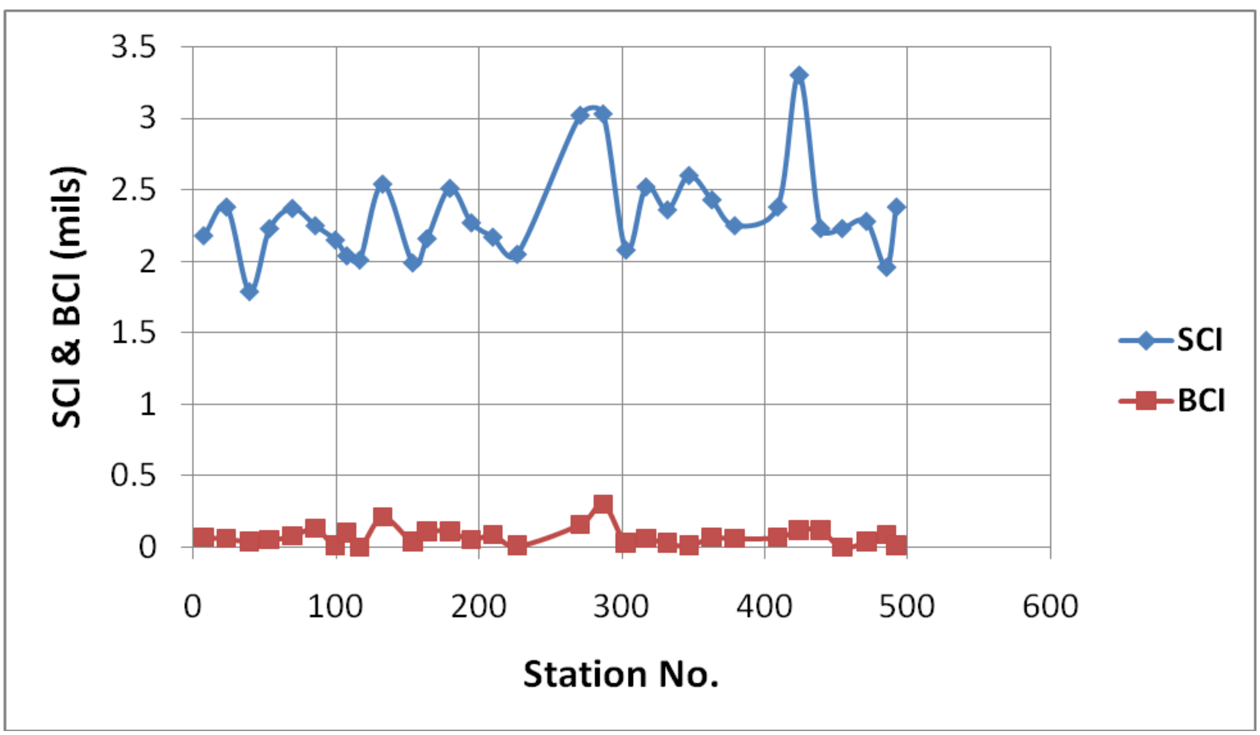


Figure E-5. SCI and BCI, US 271 (Paris District).

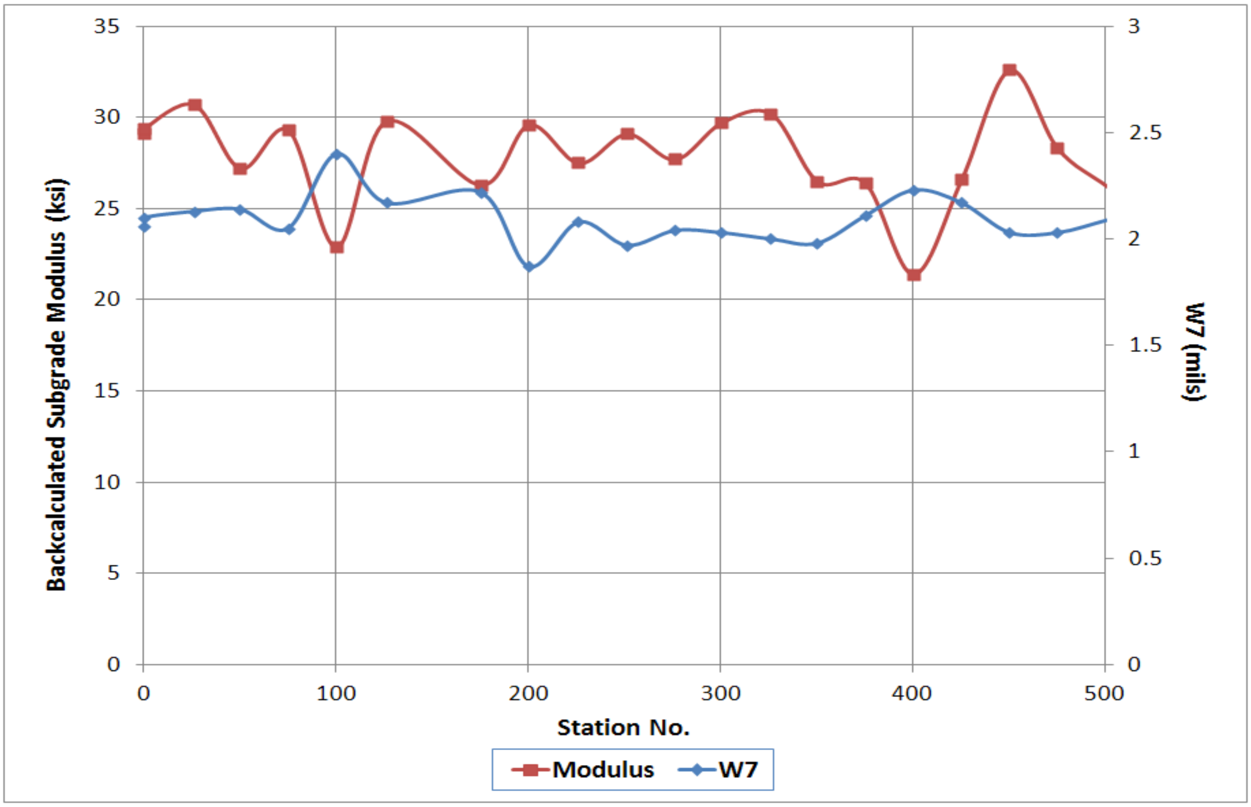


Figure E-6. FWD Sensor W7 versus Back-Calculated Subgrade Modulus, SH 121.

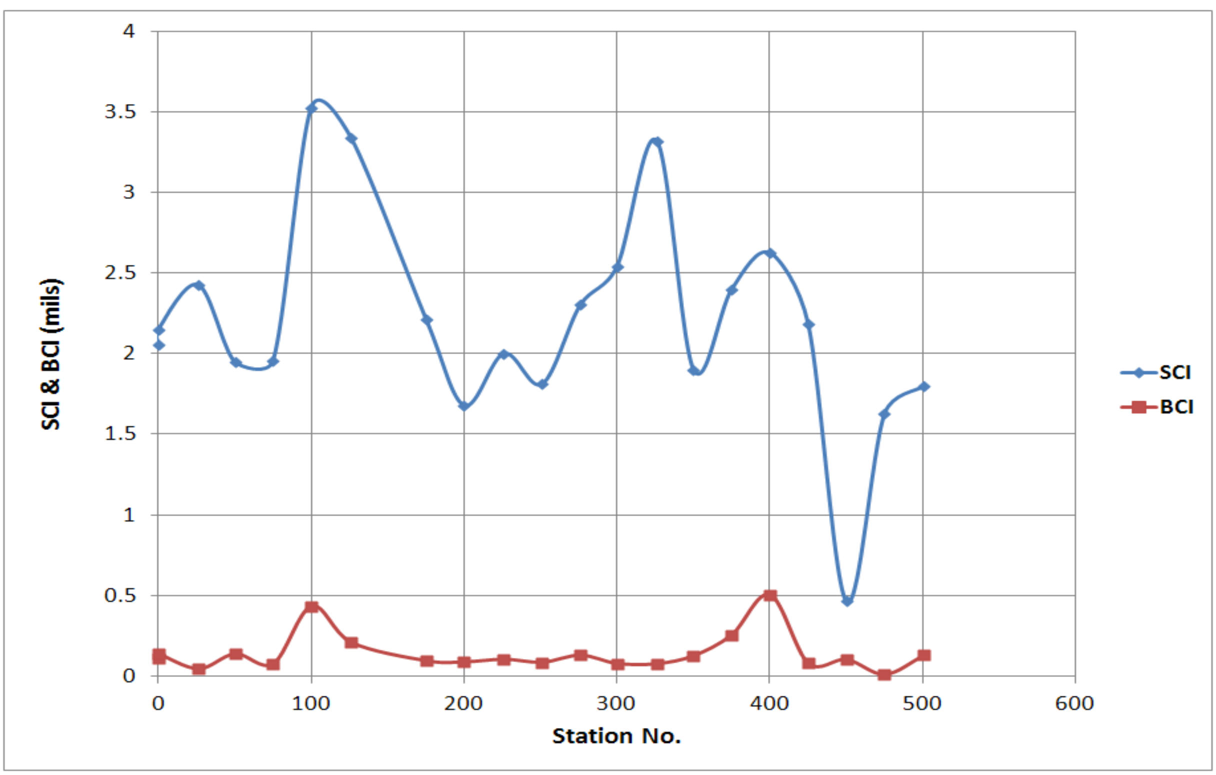


Figure E-7. SCI and BCI, SH 121 (Paris District).

APPENDIX F: EXAMPLE OF COLLECTED TRAFFIC DATA

```
Southern Traffic Services
Class

US59 ONE MILE SOUTH OF MILE MARKER 308          SB SLOW

Datasets:
Site:   [C6027] C6027
Direction:      1 - North bound, A hit first., Lane: 0
Survey Duration:        13:34 Monday, June 06, 2011 => 10:53 Wednesday, June 15, 2011
File:   G:\DATA\2011\Private\11062\C602715JUN2011.EC0 (Plus)
Identifier:     S539WSX5 MC56-L5 [MC55] (c)Microcom 19Oct04
Algorithm:      Factory default
Data type:      Axle sensors - Paired (Class, Speed, Count)

Profile:
Filter time:    14:00 Monday, June 06, 2011 => 14:00 Wednesday, June 08, 2011
Included classes:       1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
Speed range:    5 - 100 mph.
Direction:      North (bound)
Separation:     All - (Headway)
Name:   Factory default profile
Scheme: Vehicle classification (Scheme F2)
Units:  Non metric (ft, mi, ft/s, mph, lb, ton)

Column Legend:
 0  [Time]      24-hour time (0000 - 2359)
 1  [Total]     Number in time step
 2  [Cls]       Class totals
 3  [Mean]      Average speed
 4  [Vpp]       Percentile speed

Monday, June 06, 2011
```

Time	Total	Cls 1	Cls 2	Cls 3	Cls 4	Cls 5	Cls 6	Cls 7	Cls 8	Cls 9	Cls 10	Cls 11	Cls 12	Cls 13	Mean	Vpp 85
1400	52	1	19	16	2	6	1	0	3	2	1	1	0	0	71.7	77.8
1415	67	0	25	23	0	3	2	0	1	9	2	1	1	0	72.5	77.2
1430	60	0	24	22	0	5	1	0	3	5	0	0	0	0	71.6	79.4
1445	67	0	33	17	0	6	0	0	1	10	0	0	0	0	73.5	77.2
1500	60	0	20	21	0	5	0	0	1	12	1	0	0	0	71.7	78.7
1515	46	0	11	18	0	6	0	2	4	5	0	0	0	0	74.7	81.4
1530	69	2	26	20	0	11	0	0	3	5	0	1	0	1	72.5	77.2
1545	57	0	30	21	0	3	0	0	2	1	0	0	0	0	70.6	75.2
1600	66	0	32	19	1	9	0	0	2	2	0	1	0	0	72.7	77.8
1615	66	0	26	16	0	12	0	0	3	9	0	0	0	0	73.8	80.1
1630	55	0	17	26	0	6	1	1	1	2	1	0	0	0	71.9	77.6
1645	56	0	21	23	0	0	0	0	1	11	0	0	0	0	74.8	80.1
1700	69	1	27	19	2	9	1	0	0	9	0	1	0	0	73.4	78.7
1715	50	1	17	12	0	9	0	0	0	11	0	0	0	0	73.7	80.1
1730	45	0	15	13	2	7	3	0	0	5	0	0	0	0	73.4	77.4
1745	49	0	15	23	0	6	0	0	1	3	0	1	0	0	75.0	79.6
1800	49	0	19	17	2	7	0	0	0	4	0	0	0	0	73.4	80.1
1815	48	0	13	12	0	6	1	1	1	14	0	0	0	0	73.0	77.8
1830	43	0	21	14	0	3	0	0	0	5	0	0	0	0	71.7	76.5
1845	42	0	18	12	1	1	0	0	2	7	0	1	0	0	75.1	79.9
1900	29	0	8	7	1	8	1	0	0	4	0	0	0	0	70.2	79.0
1915	38	0	11	12	0	1	0	0	2	11	1	0	0	0	74.9	79.6
1930	43	0	16	10	0	0	0	0	3	12	0	2	0	0	70.9	77.2
1945	27	0	5	7	1	2	0	0	1	9	0	2	0	0	73.1	79.4
2000	34	0	15	9	0	7	0	0	0	3	0	0	0	0	72.0	79.4
2015	31	0	6	12	0	5	0	0	2	5	1	0	0	0	74.2	77.8
2030	34	0	10	6	0	2	1	0	0	13	2	0	0	0	69.7	74.5
2045	28	0	13	5	0	1	0	0	0	9	0	0	0	0	69.8	72.7
2100	20	0	9	5	0	1	0	0	0	5	0	0	0	0	69.4	74.3
2115	31	0	7	9	0	4	0	0	1	8	0	1	1	0	69.7	74.3
2130	17	0	8	5	0	0	0	0	0	3	0	1	0	0	71.2	74.7

Figure F-1. Snapshot of Collected Traffic Data from US 59.

2145	19	0	6	6	0	2	0	0	0	3	1	1	0	0	70.7	73.8
2200	19	1	6	5	0	2	0	0	0	5	0	0	0	0	70.6	73.6
2215	22	0	5	3	0	3	1	0	0	9	1	0	0	0	70.0	75.4
2230	18	0	6	5	0	0	0	0	0	7	0	0	0	0	72.5	77.6
2245	20	0	6	3	0	1	0	0	0	8	0	2	0	0	67.9	72.3
2300	11	0	0	4	0	2	0	0	0	5	0	0	0	0	72.7	76.5
2315	13	0	3	2	0	2	0	0	0	6	0	0	0	0	68.0	70.9
2330	8	0	2	5	0	0	0	0	0	1	0	0	0	0	71.4	-
2345	16	0	4	3	1	1	0	0	0	7	0	0	0	0	70.2	74.3
00-00	1594	6	575	487	13	164	13	4	38	264	11	16	2	1	72.4	78.5

* Tuesday, June 07, 2011

Time	Total	Cls 1	Cls 2	Cls 3	Cls 4	Cls 5	Cls 6	Cls 7	Cls 8	Cls 9	Cls 10	Cls 11	Cls 12	Cls 13	Mean	Vpp 85
0000	12	0	3	5	0	0	0	0	0	3	1	0	0	0	69.5	73.1
0015	7	0	1	2	0	0	0	0	1	3	0	0	0	0	72.3	-
0030	9	0	2	2	0	0	0	0	0	4	0	1	0	0	70.4	-
0045	4	0	0	1	0	0	0	0	0	3	0	0	0	0	69.2	-
0100	8	0	2	3	0	1	0	0	0	2	0	0	0	0	73.1	-
0115	15	1	1	4	0	1	2	0	2	2	1	1	0	0	69.8	72.7
0130	7	0	1	3	0	0	0	0	0	3	0	0	0	0	69.4	-
0145	6	0	1	2	0	0	0	0	0	2	0	1	0	0	65.0	-
0200	9	0	1	2	0	1	0	0	0	4	0	1	0	0	71.4	-
0215	5	0	0	1	0	1	0	0	0	2	0	1	0	0	74.5	-
0230	10	1	1	2	0	0	0	0	0	4	0	1	1	0	75.2	-
0245	3	0	0	1	0	1	0	0	0	1	0	0	0	0	74.7	-
0300	7	0	2	0	0	0	0	0	0	3	0	2	0	0	72.8	-
0315	7	0	0	1	0	1	0	0	0	4	0	0	1	0	74.9	-
0330	11	0	3	2	0	1	0	0	0	4	0	1	0	0	70.9	73.1
0345	12	0	2	0	0	2	0	0	0	5	0	3	0	0	72.8	75.2
0400	19	0	3	4	0	4	0	0	1	5	0	1	1	0	72.3	80.8
0415	21	0	7	1	1	2	0	0	2	5	0	2	1	0	70.9	77.4
0430	14	0	5	3	0	1	0	0	0	5	0	0	0	0	69.6	72.9
0445	22	0	7	9	0	1	0	0	1	4	0	0	0	0	69.9	76.1
0500	22	0	5	6	1	1	0	0	1	8	0	0	0	0	73.6	77.8
0515	31	1	5	9	0	3	2	0	2	8	1	0	0	0	71.6	76.3
0530	52	0	10	20	0	6	0	0	0	14	0	1	1	0	72.3	77.2
0545	43	0	5	18	0	11	2	0	0	6	0	1	0	0	73.1	77.0
0600	44	0	8	13	0	17	0	0	1	5	0	0	0	0	75.6	79.9
0615	56	0	11	18	1	17	0	0	0	8	0	0	1	0	74.9	80.1
0630	56	1	8	23	0	12	0	0	2	10	0	0	0	0	75.3	80.1
0645	59	0	11	19	1	17	1	0	2	7	1	0	0	0	78.3	85.7
0700	49	0	8	14	1	14	1	0	2	7	0	0	1	1	75.9	79.0
0715	50	0	12	18	0	12	0	0	4	4	0	0	0	0	75.0	79.6
0730	56	0	12	23	1	7	0	0	3	7	2	1	0	0	73.4	78.5
0745	68	0	22	28	0	6	0	0	3	7	0	1	1	0	76.0	80.8
0800	52	0	15	17	1	8	0	0	2	6	2	1	0	0	75.3	80.8
0815	48	0	8	22	2	8	0	0	2	6	0	0	0	0	74.0	80.1
0830	63	0	8	16	0	16	4	1	2	15	1	0	0	0	75.0	79.6
0845	51	0	8	14	1	12	0	0	2	10	3	1	0	0	75.3	80.3
0900	61	0	14	22	2	7	2	0	1	12	0	0	0	1	76.7	80.8
0915	54	0	11	17	0	14	1	0	3	8	0	0	0	0	74.6	81.6
0930	44	0	13	9	0	9	1	0	2	7	2	1	0	0	76.3	80.1
0945	54	0	15	16	1	9	0	0	4	8	0	1	0	0	74.3	80.8
1000	50	1	11	15	2	9	0	0	3	9	0	0	0	0	73.4	82.5
1015	44	0	12	12	0	8	1	0	1	9	1	0	0	0	72.9	79.2
1030	47	0	12	17	0	6	2	0	0	9	1	0	0	0	75.1	80.8
1045	50	0	10	15	0	9	1	0	2	12	0	1	0	0	73.2	77.8
1100	50	0	9	16	1	5	1	0	0	16	1	1	0	0	74.7	80.3
1115	37	1	12	10	0	7	1	0	1	3	0	2	0	0	72.8	79.0
1130	62	1	21	15	0	13	0	0	3	8	1	0	0	0	73.5	78.7
1145	52	0	17	14	0	8	1	0	2	9	1	0	0	0	74.6	78.7
1200	54	0	10	14	3	12	0	0	2	12	1	0	0	0	71.9	76.7
1215	39	2	5	11	1	4	0	0	3	6	2	1	1	3	72.5	82.1
1230	57	0	21	18	1	7	2	0	1	6	1	0	0	0	72.7	77.8

Figure F-1. Snapshot of Collected Traffic Data from US 59 (Continued).

1230	57	0	21	18	1	7	2	0	1	6	1	0	0	0	72.7	77.8
1245	48	0	20	15	0	9	0	0	0	3	1	0	0	0	71.7	77.0
1300	55	2	17	18	1	3	3	0	1	7	0	0	2	1	71.2	77.2
1315	59	0	15	19	1	10	1	0	1	9	2	0	0	1	71.5	78.7
1330	62	0	27	16	1	6	0	0	3	7	2	0	0	0	72.0	76.5
1345	54	0	27	16	0	2	1	0	0	7	1	0	0	0	71.0	78.3
1400	62	0	16	26	1	7	0	0	5	4	3	0	0	0	73.5	78.3
1415	48	1	12	10	0	10	1	0	2	6	4	1	1	0	73.2	79.4
1430	65	0	24	21	0	9	1	0	3	4	2	0	1	0	73.9	79.2
1445	68	0	21	19	0	8	0	1	3	11	3	0	1	1	72.8	77.0
1500	41	0	12	14	0	3	0	0	0	11	1	0	0	0	72.4	77.0
1515	67	1	23	19	0	7	0	0	5	12	0	0	0	0	72.2	76.5
1530	60	1	12	19	0	14	0	0	2	11	1	0	0	0	70.8	77.4
1545	72	2	27	19	1	9	1	0	1	11	0	1	0	0	72.6	78.3
1600	50	0	10	15	0	11	0	0	2	11	1	0	0	0	73.5	79.9
1615	59	1	18	24	0	7	1	0	0	8	0	0	0	0	72.0	78.5
1630	51	0	19	22	1	3	1	0	0	5	0	0	0	0	72.2	78.1
1645	51	0	17	13	2	11	0	0	1	7	0	0	0	0	73.7	80.1
1700	59	0	19	16	0	8	0	0	1	13	1	1	0	0	72.2	77.2
1715	55	0	20	15	4	7	1	0	0	7	1	0	0	0	76.1	80.3
1730	56	1	16	20	1	4	0	0	1	12	0	1	0	0	74.3	80.1
1745	55	0	15	18	1	2	1	0	0	17	0	1	0	0	74.8	81.4
1800	49	2	17	12	0	3	0	0	1	13	0	0	1	0	72.4	77.6
1815	58	0	17	14	0	7	0	0	0	19	1	0	0	0	73.3	78.3
1830	47	1	16	13	0	3	0	0	2	11	1	0	0	0	76.1	84.3
1845	46	0	13	12	0	9	0	0	3	9	0	0	0	0	73.4	79.0
1900	50	0	16	16	0	4	3	0	0	11	0	0	0	0	72.3	80.8
1915	28	0	7	8	0	3	0	0	3	7	0	0	0	0	74.1	78.3
1930	51	0	16	17	1	6	0	0	1	10	0	0	0	0	75.4	80.3
1945	36	1	7	4	0	6	1	0	2	14	1	0	0	0	72.0	80.8
2000	39	0	6	18	0	5	0	0	1	9	0	0	0	0	74.0	79.0
2015	22	0	7	7	0	1	0	0	0	6	1	0	0	0	72.8	76.3
2030	36	0	7	12	0	3	0	0	0	12	1	0	0	1	72.4	77.6
2045	34	0	11	11	0	3	0	0	1	6	0	2	0	0	71.0	76.1
2100	24	0	2	14	0	1	0	0	0	7	0	0	0	0	71.8	74.7
2115	22	1	5	6	0	2	0	0	0	7	0	0	1	0	69.6	73.8
2130	29	0	8	8	0	2	1	0	0	8	1	1	0	0	71.7	77.6
2145	32	0	8	11	0	3	0	0	1	9	0	0	0	0	72.0	74.9
2200	22	0	5	6	1	1	0	0	0	7	1	1	0	0	70.8	72.3
2215	18	1	2	6	0	1	0	0	0	8	0	0	0	0	71.8	75.6
2230	20	0	2	7	0	2	0	0	1	7	0	0	1	0	72.1	76.1
2245	10	1	0	4	0	2	1	0	1	1	0	0	0	0	74.3	-
2300	20	0	5	5	0	2	0	0	1	7	0	0	0	0	71.0	74.0
2315	14	0	2	2	0	2	0	0	0	8	0	0	0	0	67.6	70.5
2330	12	0	3	0	0	0	0	0	1	7	0	0	1	0	68.4	72.7
2345	11	0	2	0	0	1	0	0	0	8	0	0	0	0	71.8	76.1
00-00	3690	25	962	1134	37	533	43	2	113	724	53	37	18	9	73.3	79.2

Wednesday, June 08, 2011

Time	Total	Cls 1	Cls 2	Cls 3	Cls 4	Cls 5	Cls 6	Cls 7	Cls 8	Cls 9	Cls 10	Cls 11	Cls 12	Cls 13	Mean	Vpp 85
0000	14	0	1	2	0	1	0	0	0	10	0	0	0	0	70.9	74.0
0015	9	0	1	2	0	0	0	0	1	5	0	0	0	0	66.4	-
0030	3	0	2	0	0	0	0	0	0	1	0	0	0	0	73.9	-
0045	7	0	2	2	0	0	0	0	0	3	0	0	0	0	72.5	-
0100	3	0	1	0	0	0	0	0	0	1	0	1	0	0	66.7	-
0115	14	0	3	2	0	1	0	0	0	7	0	0	1	0	65.9	69.8
0130	11	0	1	1	1	1	0	0	0	7	0	0	0	0	70.3	74.5
0145	4	0	1	2	1	0	0	0	0	0	0	0	0	0	73.0	-
0200	7	0	0	3	0	1	0	0	0	1	0	2	0	0	71.9	-
0215	10	0	1	2	1	2	0	0	0	4	0	0	0	0	68.1	-
0230	8	0	0	0	0	1	0	0	0	7	0	0	0	0	70.0	-
0245	9	0	0	1	1	2	0	0	0	2	0	3	0	0	67.1	-
0300	9	0	0	1	0	1	0	0	0	7	0	0	0	0	65.9	-
0315	14	0	1	3	0	1	0	0	0	7	0	2	0	0	69.7	72.9

Figure F-1. Snapshot of Collected Traffic Data from US 59 (Continued).

0330	8	0	0	0	0	0	0	0	0	7	0	1	0	0	70.5	-
0345	7	0	1	1	0	0	0	0	0	4	0	0	0	1	69.8	-
0400	18	0	2	1	0	0	0	0	0	12	1	1	1	0	68.7	72.5
0415	19	0	4	4	0	1	0	0	1	8	0	1	0	0	68.1	70.0
0430	21	0	4	4	0	0	0	0	0	10	1	1	1	0	68.1	70.9
0445	28	0	6	2	0	4	0	0	0	12	1	2	0	1	68.4	74.7
0500	23	0	6	8	2	3	0	0	0	3	0	1	0	0	69.6	78.1
0515	21	0	5	5	1	4	0	0	0	5	0	0	1	0	71.5	76.3
0530	36	0	6	17	0	3	0	0	1	9	0	0	0	0	69.0	74.0
0545	50	0	10	20	0	11	1	0	2	6	0	0	0	0	72.4	76.7
0600	54	0	12	14	2	13	0	1	2	9	0	1	0	0	73.1	77.6
0615	48	0	8	18	0	13	0	0	0	8	1	0	0	0	74.1	78.3
0630	67	1	17	22	0	11	0	0	4	10	2	0	0	0	73.1	78.3
0645	70	0	18	24	1	13	0	1	1	8	3	1	0	0	73.1	77.8
0700	55	0	12	21	0	9	0	0	1	8	1	2	1	0	76.1	80.8
0715	50	1	15	21	0	7	0	0	1	5	0	0	0	0	73.1	78.5
0730	68	0	15	24	0	13	1	0	2	13	0	0	0	0	74.0	79.9
0745	80	0	24	26	0	9	2	0	3	16	0	0	0	0	73.7	79.4
0800	52	0	21	16	0	3	1	0	1	8	0	2	0	0	74.6	78.1
0815	48	1	13	20	0	3	0	1	0	10	0	0	0	0	72.8	78.5
0830	50	1	19	15	1	5	0	0	2	7	0	0	0	0	73.6	78.5
0845	53	0	11	23	0	4	1	0	4	8	1	1	0	0	72.7	78.3
0900	53	0	17	15	0	7	1	0	1	10	2	0	0	0	72.8	77.4
0915	52	0	9	14	2	7	0	0	4	15	0	1	0	0	73.3	78.3
0930	46	1	8	12	0	7	0	0	1	16	1	0	0	0	73.6	79.6
0945	56	2	22	11	3	2	1	0	3	12	0	0	0	0	71.0	76.3
1000	59	1	10	13	3	12	2	0	2	13	1	0	0	2	73.8	79.6
1015	49	1	11	15	0	8	0	0	0	12	1	0	0	1	72.2	78.3
1030	43	0	11	10	1	5	0	0	0	16	0	0	0	0	72.3	77.0
1045	49	1	14	18	0	4	1	0	0	9	1	0	0	1	71.3	77.6
1100	39	1	7	14	0	6	0	0	1	7	1	1	0	1	72.5	75.2
1115	65	2	20	24	2	8	1	0	2	6	0	0	0	0	73.0	77.8
1130	60	0	21	17	0	10	0	0	0	10	0	0	0	2	74.1	78.1
1145	45	0	14	14	1	2	0	0	5	9	0	0	0	0	70.1	74.9
1200	58	0	15	24	0	8	3	0	1	6	0	1	0	0	72.2	77.6
1215	51	0	17	18	0	3	0	0	0	12	1	0	0	0	72.8	78.1
1230	60	0	15	21	0	8	1	0	2	11	2	0	0	0	72.3	77.2
1245	40	0	9	15	1	7	1	0	1	6	0	0	0	0	71.8	77.0
1300	57	0	21	17	1	3	1	0	2	10	0	1	0	1	71.5	76.3
1315	64	0	20	22	1	5	1	0	3	9	1	0	0	2	71.0	76.7
1330	71	0	27	19	1	4	0	0	4	13	0	2	0	1	68.9	74.9
1345	72	0	23	24	2	3	0	0	3	14	1	0	1	1	72.8	77.6
00-00	2137	13	554	664	29	259	19	3	61	464	23	28	6	14	72.2	77.8

Figure F-1. Snapshot of Collected Traffic Data from US 59 (Continued).

APPENDIX G: EXAMPLE OF CLIMATIC DATA

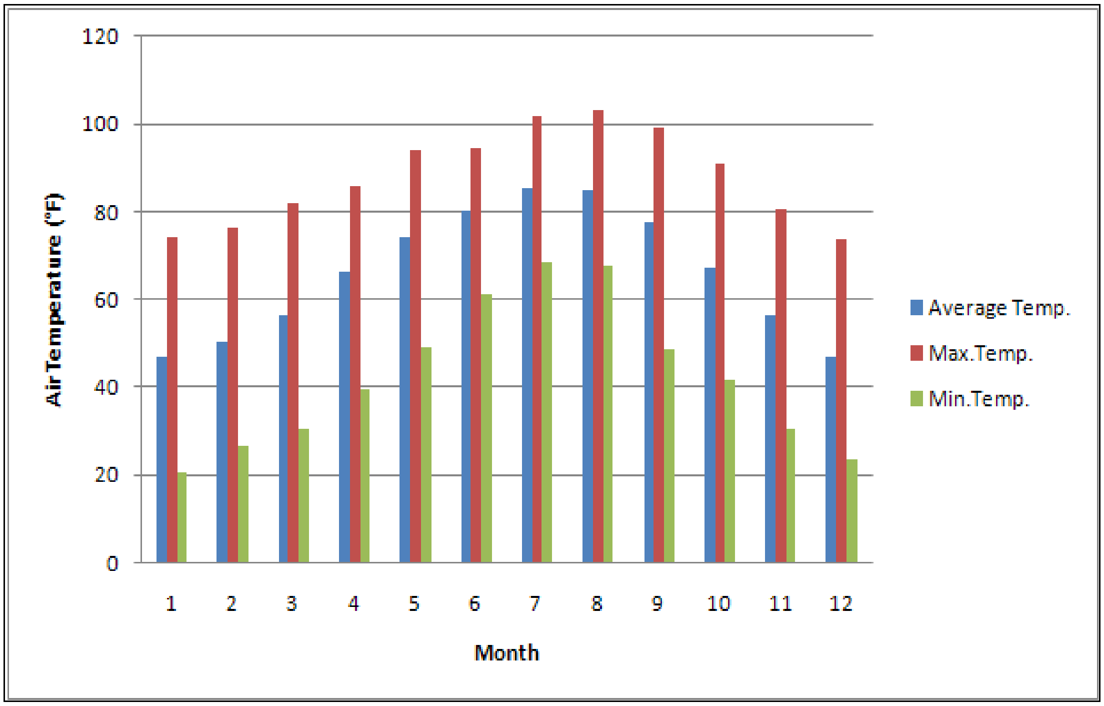


Figure G-1. Monthly Average Air Temperature, US 271.

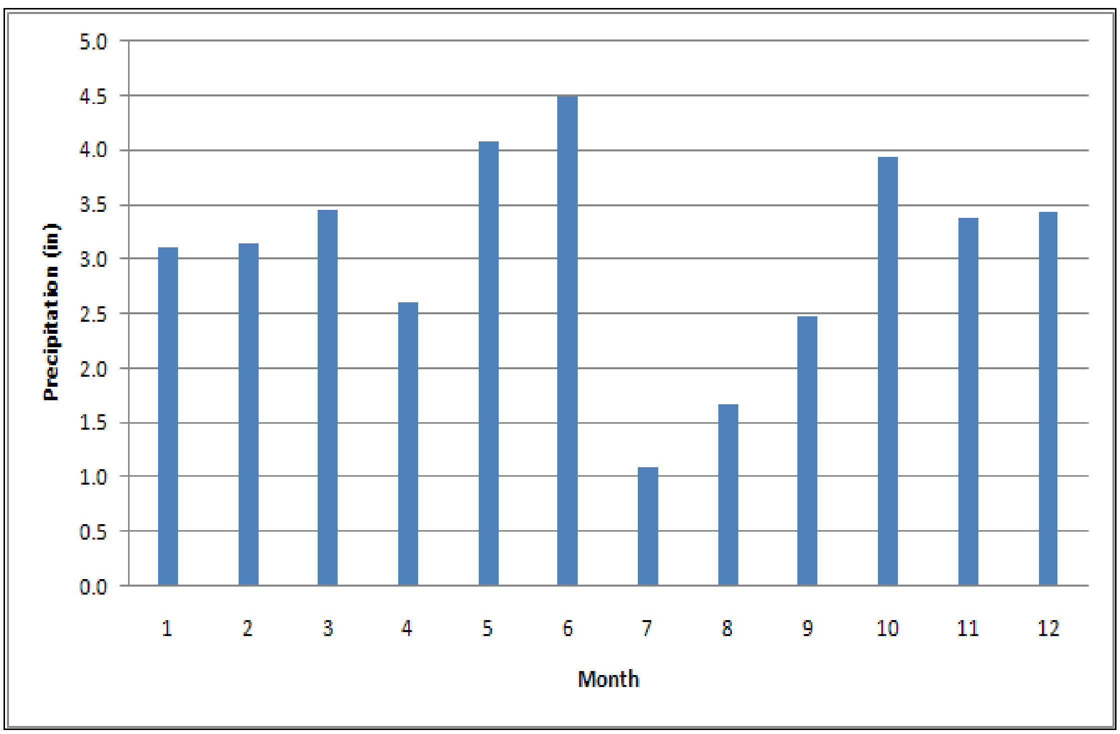


Figure G-2. Monthly Average Precipitation, US 271.

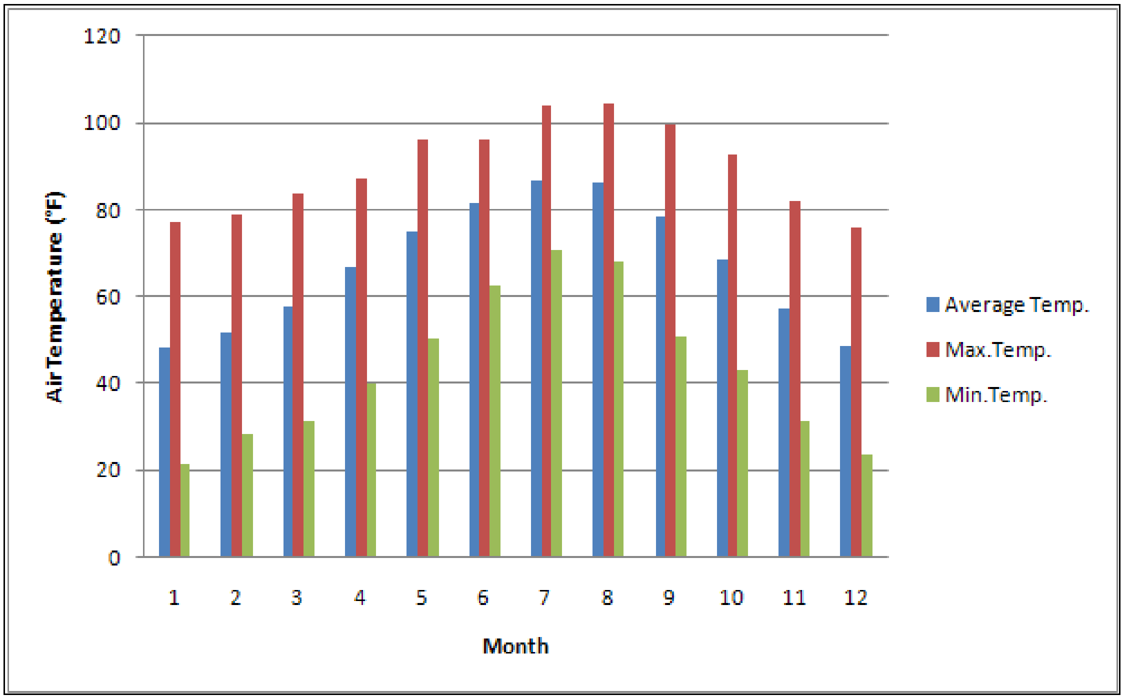


Figure G-3. Monthly Average Air Temperature, SH 121.

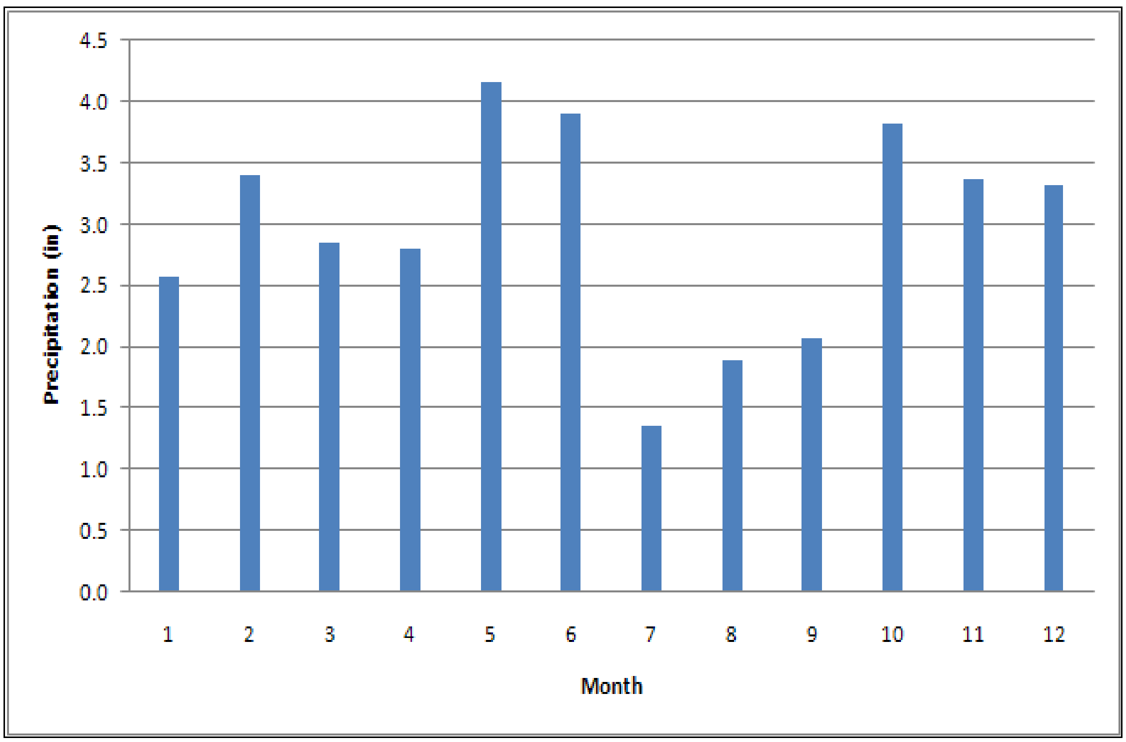


Figure G-4. Monthly Average Precipitation, SH 121.

APPENDIX H: DESCRIPTION OF THE STEPS OF THE DATA QUALITY CHECK AND CONTROL FOR THE MS ACCESS DATA STORAGE SYSTEM

Quality Check Level 1:

Calculation Check and Verification of Analyses and Computations

1) This step shall be performed prior to entering data into the Data Storage System.

2) All calculations and computations including methods used shall be checked and verified by at least two people prior to being submitted for entry into the Data Storage System.

3) Accordingly, the Data Entry Person shall **NOT** enter into the Data Storage System any data items that have **NOT** been checked and verified by at least two people.

4) For example, if **LUBINDA** does the calculations such as the AVG, COV, etc., two other people such as **DAS** and then **JEONG,** should check both the calculations, method used, and the computed numbers prior to being submitted to **ELIDA** for entry into the Data Storage System. A demonstration is shown below.

   [1] **LUBINDA** (**<u>Does the Calculations</u>**) ⇒ [2] DAS (**<u>Check# 1</u>**) ⇒ [3] JEONG (**<u>Check# 2</u>**) ⇒ [4] ELIDA (**<u>Enter into the System</u>**)

5) Likewise, the Data Entry Person shall **NOT** upload any ATTACHMENTS to the Data Storage System that have **NOT** been checked and verified by at least two people. All DATA ITEMS and ATTACHMENTS must be checked and verified by at least two people.

Quality Check Level 2:

Counterchecking and Verification of Computed Numbers

1) This step shall be performed prior to entering data into the Data Storage System and after Quality Check Level 1 has been completed.

2) Under this Quality Check Level, the computed numbers shall be counterchecked against typical values and thresholds.

3) Any numbers out of specification, suspicious numbers, or COV value greater than 30% shall be confirmed and checked with the PI prior to entry into the Data Storage System. For instance, if the OT numbers show a COV less than 5%, the Data Entry Person shall consult with the PI or Team Leader prior to entering such data.

4) For instance, typical AC levels range between 4 and 8%, HMA moduli rarely exceeds 5 000 ksi unless for SFHMA mixes, etc; numbers out of these range shall be checked with the PI prior to entry into the Data Storage System. Also, Rice numbers typically range between 2.300 to 2.600; therefore, any numbers outside of this range shall be checked with the PI prior to entering into the Data Storage System.

5) In the near future, the PI and Researchers will try as much as possible to list the range of typical number results for the Data Entry Person to refer to when entering data into the Data Storage System.

Quality Check Level 3:

Periodic and Routine Check of the Entire Data Storage System

1) On a periodic basis, Researchers shall check the entire Data Storage System, as a minimum, for the following items:

   - Accuracy of the data
   - If the numbers make sense and are consistent with typical values.
   - Spelling
   - User-friendliness and accessibility such as plotting graphs, etc.
   - Any suggestions for further improvements, modifications, etc.
   - Referential integrity maintenance, in accordance to related data

2) Accordingly, the **PI** (LUBINDA) shall perform his Quality Check on a *Weekly* basis every Friday from 3 to 5 PM. The **Co-PI** (TOM) shall do this on a *Monthly* basis. The **UTEP Lead** (SOHEIL) shall perform his quality check every month.

3) Other Researchers are also expected to set aside some time to perform a *Weekly*, *Bi-Weekly*, or *Monthly* Quality Check of the Data Storage System.

4) <u>Other than the Data Entry Person, **NO** other person shall enter any data or make modifications to the Data Storage System.</u> A reporting "Form" system as indicated in Tables H-1 and H-2 shall be used for this purpose and then, the form should be given to the Data Entry person for their action.

5) An example of a check carried by LUBINDA is shown in Table H-3. A blank form is also included in Table H-4.

6) After addressing the comments, the Data Entry Person shall accordingly inform and give an updated/corrected version of the Data Storage System to the Individual who did the Quality Check of the actions taken so that corrections/updates undertaken can be re-verified.

Quality Check Level 4:

Routine and Random Trial Runs with the M-E Structural Design Systems

1) This step will involve using the data in the Data Storage System to routinely and randomly run the M-E Structural Design Systems and associated software to verify the accuracy and usefulness of the data.

2) This step will be conducted by Researchers having access to the M-E Structural Design Systems and Study 0-6622's Research Group. Close liaison with Study 0-6622 will be very critical for this step.

3) Additionally, such runs will aid in validating the M-E Structural Design Systems as we go along, since performance data will be collected periodically, i.e., twice per year. For instance, the US 59 data is complete, so the TxACOL software can be run both to check the data and predict performance that can be validated with the ongoing periodic performance monitoring. As an example, the PI and one of Study 0-6622's Group Members are currently trying to run the TxACOL software for US 59 (TxDOT_TTI-00001).

4) Overall, these M-E Model and software runs will aid in assessing the following:

   - User-friendliness and accessibility of the Data Storage System.
   - Quality check for the accuracy and usefulness of the data.
   - Any missing or additional data that needs to be added to the data collection plans.

Quality Check Level 5:

Monthly Submission of the Data Storage System to the PD

1) On a monthly basis, a latest version (updated) of the Data Storage System will be submitted to the PD.

2) At his convenience, the PD will familiarize himself with the Data Storage System, access it or even run some M-E Structural Design Systems and advise the PI of any shortfalls or modifications/improvements to be made.

3) Periodic submission of the Data Storage System has many advantages including but not limited to the following:

   - The PD and TxDOT will be kept up-to-date with progress on the Data Storage System.
   - It will give the PD and TxDOT an opportunity to access and check the Data Storage System and recommend corrections or improvements to be made or the collection of any additional data.
   - It will aid in keeping the PI informed about the current needs of TxDOT and any corrections that are to be made, rather than waiting to do it at the end.

Table H-1. Internal TTI Data Quality Check and Control Plan.

#	Name of Reviewer	Critical Items to Check For	Date & Time the Check Was Performed	Findings, Comments, Suggestions, & Recommendations	Action Taken by PI & ELIDA
1	JUN	**Asphalt-binder data, HMA data**, spelling, & any other data looking suspicious or out of specification.	Weekly		
2	HOSSAIN	**OT data, Hamburg data**, spelling, & any other data looking suspicious or out of specification.	Weekly		
3	ABU	**All lab data items (material properties),** spelling, & any other data looking suspicious or out of specification.	Weekly		
4	RUBAYYAT	**All lab data (material properties),** spelling, & any other data looking suspicious or out of specification.	Weekly		
5	JASON	**Field data items,** spelling, & any other data looking suspicious or out of specification.	Weekly		
6	DAS	**ALL data items,** including spelling, & any other data looking suspicious or out of specification.	Weekly		
7	JEONG	**All field data items, base & soil data**, spelling, & any other data looking suspicious or out of specification.	Bi-Weekly		
8	**LUBINDA**	**ALL data items,** including spelling, & any other data looking suspicious or out of specification.	Weekly; Every Friday 3:00 – 5:00 PM		
9	**TOM**	**ALL data items,** including spelling, & any other data looking suspicious or out of specification.	Monthly		
10	Study 0-6622 Researchers	**ALL data items,** including spelling, & any other data looking suspicious or out of specification.	Bi-Weekly		

Table H-2. Internal UTEP Data Quality Check and Control Plan.

#	Name of Reviewer	Critical Items to Check For	Date & Time the Check Was Performed	Findings, Comments, Suggestions, & Recommendations	Action Taken by UTEP Lead
1	Martin	**Asphalt-binder data,** spelling, & any other data looking suspicious or out of specification.	Weekly		
2	Daniel	**HMA data,** spelling, & any other data looking suspicious or out of specification.	Weekly		
3	Jose Luis	**Base/Soil (Index tests),** spelling, & any other data looking suspicious or out of specification.	Weekly		
4	Eric	**Base/Soil (Strength/Stiffness tests),** spelling, & any other data looking suspicious or out of specification.	Weekly		
5	Sergio	**Field data items,** spelling, & any other data looking suspicious or out of specification.	Weekly		
6	Jose	**All lab data items,** spelling, & any other data looking suspicious or out of specification.	Weekly		
7	Deren	**All field data items,** spelling, & any other data looking suspicious or out of specification.	Weekly		
8	IMAD	**All data items,** spelling, & any other data looking suspicious or out of specification.	Bi-Weekly		
9	Nazarian	**All data items,** spelling, & any other data looking suspicious or out of specification.	Monthly		

Table H-3. Example Data Quality Check Form.

#	Name of Reviewer	Date & Time the Check Was Performed	Item	Observations & Findings	Suggestions & Recommendations	Action Taken by PI & ELIDA
1	LUBINDA	July 8th 2011 (3–5 PM)	Section Details	End physical landmark for TxDOT_TTI-00001 is still blank.	Liaise with DAS/JASON to address this!	Corrected
2	LUBINDA	July 8th 2011 (3–5 PM)	Existing Distresses	Most of the Fields including the Crack Survey Date are still blank.	Please address this!	
3	LUBINDA	July 8th 2011 (3–5 PM)	PVMNT	Include picture for the PVMNT X-Section and also complete details for the New HMA Overlay such as layer construction date, mix-design details, etc.		
4	LUBINDA	July 8th 2011 (3–5 PM)	Gradations	I am unable to draw two curves on one graph!	Please, explore!!	
5	LUBINDA	July 8th 2011 (3–5 PM)	AVG & COV		Explore possibilities to automatically calculate AVG & COV.	

Table H-4. Data Quality Check Blank Form.

#	Name of Reviewer	Date & Time the Check Was Performed	Item	Observations & Findings	Suggestions & Recommendations	Action Taken by PI & ELIDA