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Pavement Rehabilitation and Design Strategy for Heavy Loads in the Energy Development Areas

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16. Abstract

In recent years, rapid energy development in Texas has caused significant damage to many farm-to-market (FM) roads, which traditionally have a thin asphalt surface layer plus a stabilized base directly over the subgrade. These FM roads performed well under normal traffic loads but failed dramatically under the energy-sector truck loads. There is an urgent need to repair many of these badly damaged roadways with a new pavement rehabilitation and design strategy in all energy development areas.

In this project, the researchers analyzed all the traffic data collected by both permanent and portable weigh-in-motion stations around Texas and found that the energy development areas saw much heavier trucks than the non-energy development areas. The researchers concluded that overloading caused significant damage to pavements compared to regular equivalent single-axle loads. The researchers then presented a six-step pavement rehabilitation and design strategy and applied it to assist with pavement designs in four districts using the Texas Flexible Pavement Design System (FPS 21) combined with the latest Texas Mechanistic-Empirical Pavement Design for Flexible Pavements (TxME). Furthermore, the researchers continued surveying the field performance of five existing test sections with full-depth reclamation (FDR). Overall, most FDR test sections performed well. However, some of the FDR test sections had early failures. Therefore, adequate pavement designs with accurate traffic loading as inputs are critical; the combined FPS 21 and TxME check is a useful tool for pavement engineers to design satisfactory roads capable of carrying such heavy loads in energy development areas.

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PAVEMENT REHABILITATION AND DESIGN STRATEGY FOR HEAVY LOADS IN THE ENERGY DEVELOPMENT AREAS

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DISCLAIMER

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

This report is not intended for construction, bidding, or permit purposes. The engineer in charge of the project was Fujie Zhou, P.E. (Texas #95969).

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

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CHAPTER 1. INTRODUCTION

BACKGROUND

In recent years, rapid energy development in Texas has caused significant damage to many farm-to-market (FM) roads, which traditionally have a thin asphalt surface layer plus a stabilized base directly over the subgrade. These roadways were often rehabilitated with full-depth reclamation (FDR), and 2 to 3 percent cement was usually added to the pulverized existing materials. These roadways performed well under normal traffic loads but failed dramatically under the energy-sector truck loads. Figure 1 shows the damaged FM roads. The impact of overloading on pavement damage is not limited to FM roads; it also has significant influence on the pavement life of state highways (SHs) and even interstate highways (IHs). There is an urgent need to repair many of these badly damaged roadways in all energy development areas.

Figure 1. Pavement Damage Caused by Overloaded Trucks in Energy Development Areas.

CHALLENGES OF REPAIRING PAVEMENTS FOR ENERGY DEVELOPMENT AREAS

There are at least five challenges to address the urgent needs of repairing roadways in the energy development areas:

1. *Multiple types of roads*: The majority of the roads in energy development areas are thin FM roadways with 6 inches of granular base and a thin surface layer. However, SHs and IHs are also impacted by overloading.
2. *Weak and non-uniform pavement structure of FM roads*: Existing FM roads typically have less than 2 inches of surface layer and often a combination of multiple surface treatments, which are frequently variable, especially if substantial maintenance has been performed.
3. *Early opening traffic requirement*: One requirement the Texas Department of Transportation (TxDOT) has placed on all rehabilitation work is that if there are no detours available for the FM roads, the existing roadway must be reopened to traffic at the end of each work day. This severely impacts the use of many of the commonly used

stabilizers, such as cement or asphalt emulsions. The opening traffic requirement for highways with multiple lanes (such as IHs) may not be as bad as for FM roads. For those highways with multiple lanes, cement, asphalt emulsions, and other conventional stabilizers may still be applicable.

4. *Excessive traffic loads*: The truck traffic levels have not only often increased 20 to 50 times over the preexisting levels, but in some instances, severely overloaded trucks are being found. In a study of weigh-in-motion (WIM) data collected, it was not uncommon to find trucks running at 50 to 60 percent overloaded. Real concerns have been expressed by pavement designers as to the inadequacy of both the 20-year design load estimates and the average of the 10 heaviest wheel loads daily (ATHWLD), both of which are required inputs within the TxDOT flexible pavement design program.
5. *Available funds*: Many hundreds of miles of pavement have been severely damaged, but only limited rehabilitation funds are available.

REHABILITATION OPTIONS FOR REPAIRING DAMAGED PAVEMENTS

In general, many options are available for repairing damaged pavements, and sometimes it is not easy to determine which one is best. However, answering the following questions can assist in making a better choice:

- What is wrong with the existing pavement? Is the distress limited to the surface (upper pavement layers), or it is a structural problem?
- What does TxDOT really want, and what can it afford?

The answers to these questions will narrow down the rehabilitation options to only those that will be cost-effective considering the nature of the problem and the time frame. Another important consideration is the practicality of various rehabilitation methods. In addition, traffic accommodation, weather conditions, and availability of resources can all have a significant influence on how a project is constructed and may preclude certain options. Based on the nature of the problem, rehabilitation options are divided into two major categories:

- **Surface rehabilitation**. Surface rehabilitation measures often address problems usually within the top 2-inch to 4-inch surface layers. These problems are normally related to asphalt aging and top-down cracking that initiates at the surface. The most often used methods for this type of surface problem include (a) asphalt overlay, (b) milling and inlay, and (c) recycling.
  - **Asphalt overlay**. Paving a thin (1.5- to 2-inch) asphalt overlay on the existing surface is the simplest solution to a surface problem. The good parts of asphalt overlay are short working time and minimal impact on traffic and users. However, many active cracks in the existing surface will reflect quickly through a new (thin) overlay. Thus, it is important to identify the active cracks and treat them

before the asphalt overlay. Additionally, repeated overlays increase road surface elevations that may cause drainage and access problems.

  - **Milling and inlay**. This method often mills the cracked layer and then replaces it with new asphalt mixes. The process is relatively fast, and other benefits include removing the surface problem and maintaining pavement elevation.
  - **Cold in-place recycling**. Generally, this method recycles a relatively thin (4- to 6-inch) layer of asphalt material from the existing pavement. Figure 1 shows an example of cold in-place recycling.
- **Structural rehabilitation**. Different from surface rehabilitation, the focus of structural rehabilitation is to fix the structural problems (such as fatigue cracking, deep rutting, etc.). In most cases, pavement layer materials are still reusable. A lower level of existing pavement being upgraded by strengthening the existing structure is often considered structural rehabilitation. There are three popular options for structural rehabilitation:
  - **Total reconstruction**. This option is often preferred when combined with upgrading, which requires significant changes to the alignment of the road. In this case, a temporary road may be constructed to accommodate existing traffic.
  - **Adding new layers**. Thick asphalt overlays are often the easiest solution to a structural problem where the traffic volumes are high.
  - **FDR (or deep recycling)**. FDR often recycles to the depth in the pavement at which the problem occurs, thereby creating a new thick homogeneous layer that can be strengthened by the addition of stabilizing agents. Additional layers may be added on top of the recycled layer where the pavement is to be significantly upgraded. Stabilizing agents are usually added to the recycled material, especially where the material in the existing pavement is marginal and requires strengthening. Recycling aims for maximum recovery from the existing pavement. In addition to salvaging the material in the upper layers, the pavement structure below the level of recycling remains undisturbed.

OBJECTIVE

The main objective of this project was to assist districts in the energy development areas with designing pavements using pavement design tools.

REPORT ORGANIZATION

Chapter 1 provides background information relative to the project. Chapter 2 introduces WIM data analysis and traffic input for pavement design, and evaluates the difference in equivalent single-axle load (ESAL) calculations between the traditional method and full-load spectrum. Chapter 3 develops guidance for selecting suitable rehabilitation options for flexible pavements. Chapter 4 introduces the new pavement design tool: Texas Mechanistic-Empirical Pavement Design for Flexible Pavements (TxME). Furthermore, pavement design supports for districts in the energy development areas are described in Chapter 4. Chapter 5 documents the pavement performance of field test sections constructed previously. Finally, Chapter 6 summarizes the conclusions and recommendations for this project.

CHAPTER 2. TRAFFIC INPUT FOR PAVEMENT DESIGN

INTRODUCTION

Traffic is one of the critical factors that significantly impact pavement performance and accordingly pavement designs. Currently, Texas's flexible pavement design system (FPS 21) employs an ESAL of 18 kips as a traffic input, while TxME can handle both ESALs and load spectrum inputs. This chapter describes the measured traffic load spectrum and the conversion to ESALs. Also, the limitation of truck factors is discussed.

TXDOT WEIGH-IN-MOTION SENSORS

TxDOT has deployed 41 permanent WIM sensors in 20 TxDOT districts, as shown in Table 1. Some districts have more than one WIM sensor; for example, the Laredo, Pharr, and Wichita Falls Districts have four WIM permanent stations each. Table 1 provides a list of the WIM permanent stations by district along with the type (either bending plate or piezo) and the site name used in the TxDOT GIS file of permanent stations. Figure 2 shows the location of the WIM permanent stations around the state.

Not all WIM stations shown in the GIS file are active at all times. For example, Table 2 shows a query of the 2012 WIM data set that shows the total number of records (or vehicles weighed) for each month by station. Table 2 shows that there were no records collected for Station 502, 540, and several others in January 2012. Table 2 provides a number of records for Station 808, which did not appear in the GIS file. This station was removed in May 2012 and is no longer included in the GIS file.

The data in the WIM file were provided by TxDOT's Transportation Planning and Programming Division in the form of text files. Each text file contained records for all WIM stations for one month. For example, the January 2012 data set contained 2,777,845 records (Table 2). The data in the WIM data set were formatted according to federal standards, as outlined in the TxDOT's Traffic Data and Analysis Manual (*1*).

Table 1. Permanent Stations of Type WIM and WIM/Piezo in GIS File.

No.	Type	Site Name	District
1	WIM	BSIF	Laredo
2	WIM	BSIF	Laredo
3	WIM	BSIF	Pharr
4	WIM	BSIF	Pharr
5	WIM	BSIF	Laredo
6	WIM/Piezo	PZ-4142	Beaumont
7	WIM/Piezo	PZ-502	San Antonio
8	WIM	W-506	Wichita Falls
9	WIM	W-513	Waco
10	WIM	W-514	Dallas
11	WIM/Piezo	PZ-518	San Antonio
12	WIM	W-522	Pharr
13	WIM	W-523	Pharr
14	WIM	W-524	El Paso
15	WIM	W-525	Atlanta
16	WIM	W-526	Atlanta
17	WIM	W-527	Fort Worth
18	WIM	W-528	Wichita Falls
19	WIM	W-529	Wichita Falls
20	WIM	W-530	Wichita Falls
21	WIM	W-531	Laredo
22	WIM	W-532	Austin
23	WIM	W-533	Odessa
24	WIM	W-534	Corpus Christi
25	WIM	W-535	Corpus Christi
26	WIM	W-536	Austin
27	WIM	W-537	Lubbock
28	WIM	W-538	Corpus Christi
29	WIM/Piezo	PZ-539	Dallas
30	WIM	W-540	Odessa
31	WIM	W-541	Atlanta
32	WIM	W-542	Beaumont
33	WIM	W-543	Lubbock
34	WIM	W-544	Brownwood
35	WIM	W-545	Lubbock
36	WIM	W-546	Paris
37	WIM	W-547	Amarillo
38	WIM	W-548	Waco
39	WIM	W-549	Fort Worth
40	WIM	W-550	Fort Worth
41	WIM/Piezo	PZ-800	Bryan

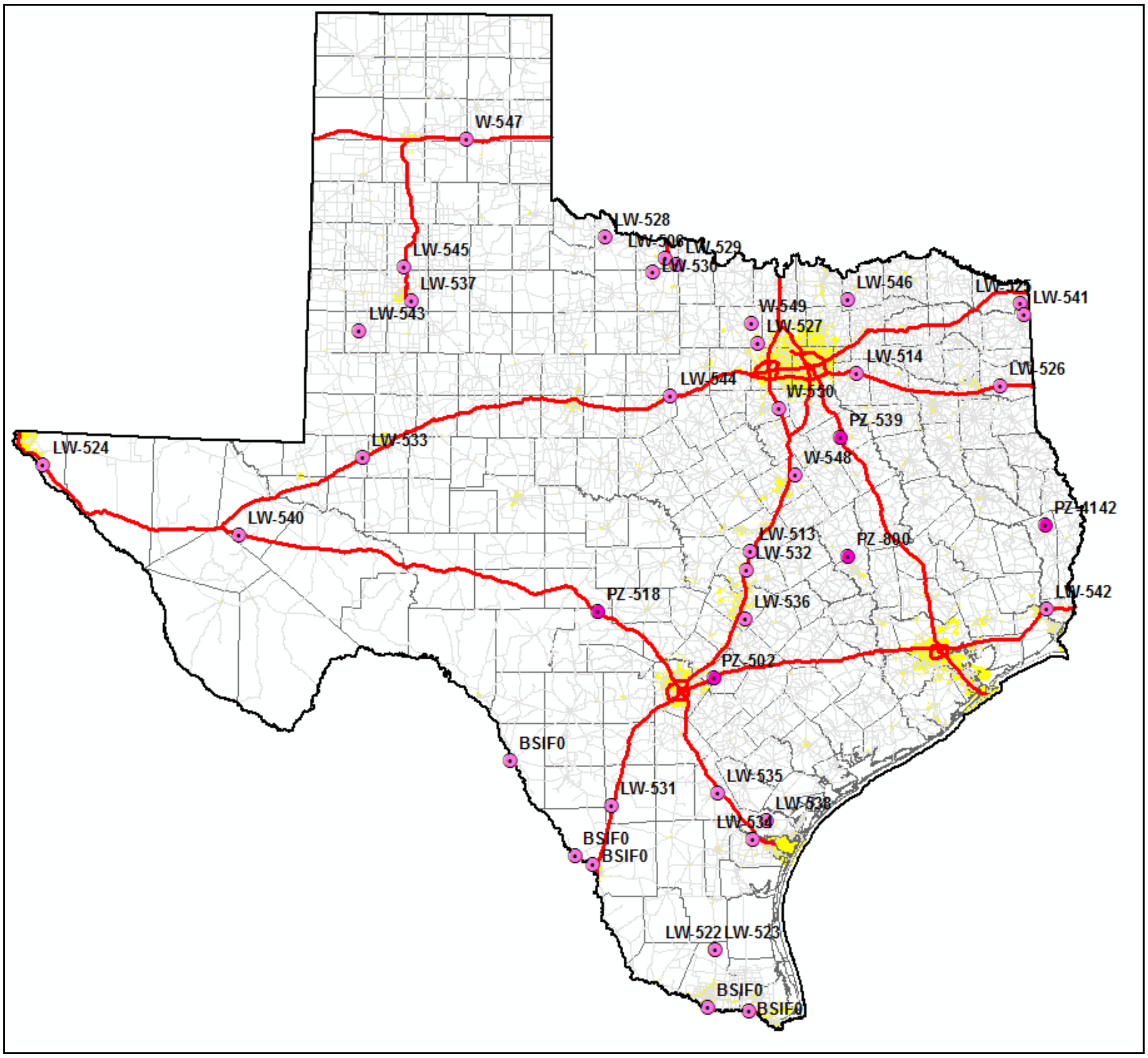


Figure 2. Location of TxDOT Permanent Stations for WIM Data Collection.

Table 2. 2012 WIM Data Set: Number of Records by Station ID.

Station ID	Jan	Feb	Mar	Apr	May	Jun
142	26,326	26,414	27,253	221	29,605	12,533
502	Not available	Not available	Not available	1,738	151,909	63,918
506	105,219	89,111	111,037	84	58,621	48,290
513	287,551	279,010	321,890	3,864	319,916	139,926
518	74,692	72,519	80,472	1,118	79,924	37,698
522	47,409	44,922	50,690	36,725	48,759	49,754
523	100,298	95,635	108,547	1,650	99,519	47,252
524	192,634	161,309	118,980	2,582	147,073	75,901
525	69,160	69,014	73,191	759	67,040	32,354
526	227,622	216,976	239,969	2,329	209,353	99,815
527	71,507	69,404	76,550	642	79,778	30,380
528	72,428	69,762	80,082	1,099	88,390	39,038
529	103,622	124,638	96,027	1,705	137,654	62,421
530	23,845	24,629	25,262	293	27,756	11,524
531	207,241	193,680	224,575	2,563	109,658	90,920
532	34,827	35,603	38,431	391	40,290	19,954
533	300,811	301,761	314,126	3,083	298,895	148,373
535	36,345	46,762	53,880	433	58,292	26,859
536	50,782	49,674	59,452	473	62,344	29,002
537	64,788	61,329	69,481	731	72,289	31,787
538	24,051	24,837	29,439	29,052	30,315	28,905
539	185,643	185,392	201,740	2,626	212,793	89,823
540	46,512	4,719	30,283	691	Not available	Not available
541	6,718	3,003	5,388	80	9,462	3,585
542	244,796	Not available	276,589	2,901	22	66,857
543	8,882	8,868	10,563	100	10,929	4,515
544	160,445	170,333	180,487	2,487	161,128	72,641
800	2,277	2,053	2,653	12	2,268	814
808	1,414	1,731	634	Not available	Not available	Not available
Total	**2,777,845**	**2,433,088**	**2,907,671**	**100,432**	**2,613,982**	**1,364,839**

Table 2. 2012 WIM Data Set: Number of Records by Station ID (Continued).

Station ID	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
142	27,590	14,815	27,224	28,298	28,442	19,107	267,828
502	212,866	84,814	221,375	244,589	275,027	223,059	1,479,295
506	144,292	57,170	104,987	105,234	166,289	408,035	1,398,369
513	302,321	177,259	284,449	280,146	411,096	238,600	3,046,028
518	76,268	42,177	80,334	85,590	97,269	70,417	798,478
522	46,662	48,855	45,171	51,199	50,518	49,270	569,934
523	93,800	52,776	96,029	107,460	125,452	89,426	1,017,844
524	169,125	87,168	166,561	173,112	211,111	160,770	1,666,326
525	57,956	38,364	67,085	70,391	82,763	60,000	688,077
526	204,018	115,943	208,168	216,479	257,004	175,322	2,172,998
527	67,324	38,506	69,168	76,609	87,833	65,243	732,944
528	85,021	47,810	72,458	78,893	111,648	80,959	827,588
529	139,051	75,039	136,126	132,609	164,760	113,730	1,287,382
530	23,650	12,944	24,931	25,804	29,170	24,044	253,852
531	202,051	110,275	192,977	208,764	208,305	161,631	1,912,640
532	41,803	24,360	40,530	44,822	58,950	39,392	419,353
533	302,278	158,610	281,365	73,262	Not available	Not available	2,182,564
535	56,558	31,316	58,769	59,605	72,301	56,386	557,506
536	60,332	22,283	58,262	71,527	89,918	65,289	619,338
537	52,644	161	61,832	67,716	82,062	39,246	604,066
538	29,266	30,400	28,352	28,246	24,881	24,279	332,023
539	18	3	21	131,577	231,300	184,339	1,425,275
540	Not available	Not available	Not available	Not available	Not available	Not available	82,205
541	8,258	4,961	8,398	8,370	9,121	5,127	72,471
542	293,440	172,621	314,708	336,519	363,403	277,993	2,349,849
543	9,302	4,851	8,491	11,755	13,840	8,935	101,031
544	155,172	89,246	154,864	178,693	195,176	154,772	1,675,444
800	1,023	852	2,153	2,278	2,100	1,509	19,992
808	Not available	Not available	Not available	Not available	Not available	Not available	3,779
Total	**2,862,089**	**1,543,579**	**2,814,788**	**2,899,547**	**3,449,739**	**2,796,880**	**28,564,479**

WIM DATA ANALYSIS

Researchers analyzed the data from WIM stations to create the files that can be imported in traffic input for Level 1 load spectra in TxME (as shown in Figure 3). In Figure 3, the main inputs for TxME include two-way annual average daily truck traffic (AADTT), vehicle class distribution and growth, monthly adjustment, and axle load distribution. As mentioned previously, not all the WIM stations are active all the time. A total of 17 WIM stations that have records for at least two years were selected for the analysis, and all these data can be used for load spectra inputs. In addition, portable WIM is used for monitoring traffic on SH 6 and FM 468. FM 468 in the Laredo District is known to be in an energy development area. Table 3 shows all the WIM stations used for data analysis and includes road classification, highway or road name, WIM station ID, and AADTT.

As shown in Table 3, IHs have a very large traffic volume compared to U.S. or state highways. For example, Station 513 on I-35, Station 502 on I-10, and Station 526 on I-20 have AADTTs of 10,867, 8,005, and 7,704, respectively. Some U.S. or state highways have a much lower AADTT (less than 1,000). Generally, FM roads have a very low AADTT. However, FM 468 has a much larger AADTT (i.e., 1,062) due to a large amount of energy-sector trucks.

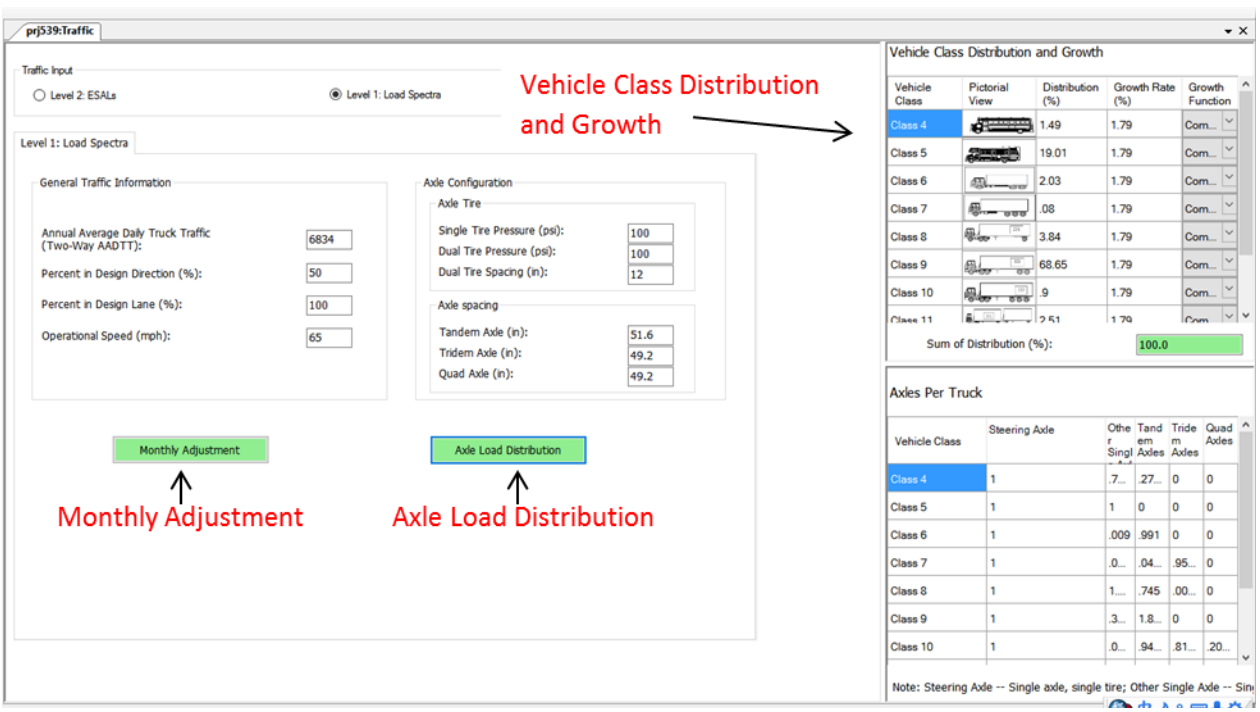


Figure 3. Load Spectrum Traffic Data Inputted in TxME.

Table 3. WIM Stations Selected for Data Analysis.

Highway Classification	Highway ID	Station ID	AADTT
Interstate Highways	I35	513	10,867
	I10	502	8,005
	I20	526	7,704
	I45	539	6,834
	I35	531	6,299
	I20	544	5,767
U.S. or State Highways	US287	506	4,182
	US287	528	3,247
	SH114	527	2,656
	SH130	532	2,269
	US59	535	2,000
	US82	530	919
	US96	142	846
	SH121	546	550
	SH6	Portable WIM	474
	US82	543	372
Farm to Market (FM) Roads	FM468	Portable WIM	1,062
	FM3192	541	251
	FM2223	800	142

ESAL CALCULATIONS FROM TRADITIONAL METHOD AND LOAD SPECTRA

ESAL is an important traffic input in the mechanistic-empirical (M-E) pavement design, which is defined in Huang (*2*) as:

$$ESAL = \sum_{i=1}^{m} F_i \, n_i \qquad 1$$

Where,
m = the number of axle load groups.
Fi = the equivalent axle load factor (EALF) for the i*th*-axle load group.
n_i = the number of passes of the i*th*-axle load group during the design period.

ESAL is calculated using the following equation from Huang (*2*):

$$ESAL = \left(\sum_{i=1}^{m} p_i F_i \right) (ADT)_0 (T)(A)(G)(D)(L)(365)(Y) \qquad 2$$

Where,
p_i = the percentage of total repetitions for the i*th* load group.
F_i = the EALF for the i*th*-axle load group.
$(ADT)_0$ = the average daily traffic at the beginning of the design period.
T = the percentage of trucks in the ADT.

A = the average number of axles per truck.
G = the growth factor.
D = the directional distribution factor.
L = the lane distribution factor.
Y = the design period in years.

The truck factor, defined in the following equation, is used to conveniently compute ESAL:

$$T_f = \left(\sum_{i=1}^{m} p_i F_i \right) (A) \qquad 3$$

Where,
T_f = the number of 18-kip single-axle load applications per truck.

Substituting Equation 3 into Equation 2 results in (*2*):

$$ESAL = (ADT)_0 (T)(T_f)(G)(D)(L)(365)(Y) \qquad 4$$

Traditionally, ESAL is calculated using Equation 4, and truck factors for different classes of highways can be found in Table 6.10 in Huang (*2*).

Another methodology for calculating ESAL is based on traffic load spectra, which is more complex but more accurate. One feature of TxME is to calculate ESAL based on the load spectra input. As mentioned previously, 19 WIM (17 permanent WIM and 2 portable WIM) stations were selected for traffic data analysis. All these data can be used for load spectra input in TxME. Table 4 and Table 5 present the inputs for ESAL calculation and comparisons of ESAL calculations from the traditional method (i.e., Equation 4 using the truck factor) and load spectra in TxME, respectively. Four truck factors were selected from Huang (*2,* Table 6.10) for comparison. Annual growth rate for traffic was assumed to be 1.79 percent, and for a period of 20 years, the total growth factor was 24.3. Figure 4 presents the graphical comparisons. ESALs calculated from all four truck factors were much lower than from TxME load spectra. ESAL was significantly underestimated when using the traditional methodology (i.e., Equation 2). Generally, higher AADTT values generated higher cumulative ESALs, but they were not proportional all the time in the results from the TxME load spectra. For example, although the AADTT of Station 513 was higher than that of Station 526, the cumulative ESAL of Station 513 was less than that of Station 526, which is attributed to different axle load distributions since TxME load spectra include axle load distribution information, whereas the ESALs calculated from truck factors consider AADTT instead of axle load distribution. Overall, the traffic load spectra can provide the best knowledge on traffic load condition, and TxME can directly analyze the impact of overloaded traffic (or load spectra) on pavement life, which is critical for designing pavements to support overloaded traffic areas.

Table 4. Inputs for ESAL Calculations.

Highway ID	Station ID	AADTT	Direction Distribution Factor	Lane Distribution Factor	Annual Growth Rate	Design Period (years)
I35	513	10,867	50%	100%	1.79%	20
I10	502	8,005	50%	100%	1.79%	20
I20	526	7,704	50%	100%	1.79%	20
I45	539	6,834	50%	100%	1.79%	20
I35	531	6,299	50%	100%	1.79%	20
I20	544	5,767	50%	100%	1.79%	20
US287	506	4,182	50%	100%	1.79%	20
US287	528	3,247	50%	100%	1.79%	20
SH114	527	2,656	50%	100%	1.79%	20
SH130	532	2,269	50%	100%	1.79%	20
US59	535	2,000	50%	100%	1.79%	20
US82	530	919	50%	100%	1.79%	20
US96	142	846	50%	100%	1.79%	20
SH121	546	550	50%	100%	1.79%	20
SH6	Portable WIM	474	50%	100%	1.79%	20
US82	543	372	50%	100%	1.79%	20
FM468	Portable WIM	1,062	50%	100%	1.79%	20
FM3192	541	251	50%	100%	1.79%	20
FM2223	800	142	50%	100%	1.79%	20

Table 5. Comparison of ESALs Calculated from Truck Factors and TxME Load Spectra.

Highway ID	Station ID	AADTT	ESAL @ Truck Factor (Urban-Interstate) =0.39	ESAL @ Truck Factor (Urban-principal) =0.21	ESAL @ Truck Factor (Rural-Interstate) =0.52	ESAL @ Truck Factor (Rural-Principal) =0.38)	ESAL from TxME-Load Spectra
I35	513	10,867	18,795,047	10,120,410	25,060,063	18,313,123	49,650,718
I10	502	8,005	13,845,068	7,455,036	18,460,090	13,490,066	32,748,557
I20	526	7,704	13,324,472	7,174,716	17,765,963	12,982,819	50,529,653
I45	539	6,834	11,819,762	6,364,487	15,759,682	11,516,691	37,354,536
I35	531	6,299	10,894,451	5,866,243	14,525,935	10,615,106	26,717,107
I20	544	5,767	9,974,329	5,370,793	13,299,106	9,718,577	28,243,048
US287	506	4,182	7,232,989	3,894,686	9,643,985	7,047,527	36,010,559
US287	528	3,247	5,615,857	3,023,923	7,487,809	5,471,861	17,228,683
SH114	527	2,656	4,593,691	2,473,526	6,124,922	4,475,904	13,479,223
SH130	532	2,269	3,924,355	2,113,114	5,232,473	3,823,730	7,682,393
US59	535	2,000	3,459,105	1,862,595	4,612,140	3,370,410	5,656,394
US82	530	919	1,589,459	855,862	2,119,278	1,548,703	3,120,864
US96	142	846	1,463,201	787,878	1,950,935	1,425,683	4,337,616
SH121	546	550	951,254	512,214	1,268,339	926,863	1,976,022
SH6	Portable WIM	474	819,808	441,435	1,093,077	798,787	1,830,420
US82	543	372	643,394	346,443	857,858	626,896	1,310,763
FM468	Portable WIM	1,062	1,836,785	989,038	2,449,046	1,789,688	11,437,641
FM3129	541	251	434,118	233,756	578,824	422,986	1,652,034
FM2223	800	142	245,596	132,244	327,462	239,299	516,928

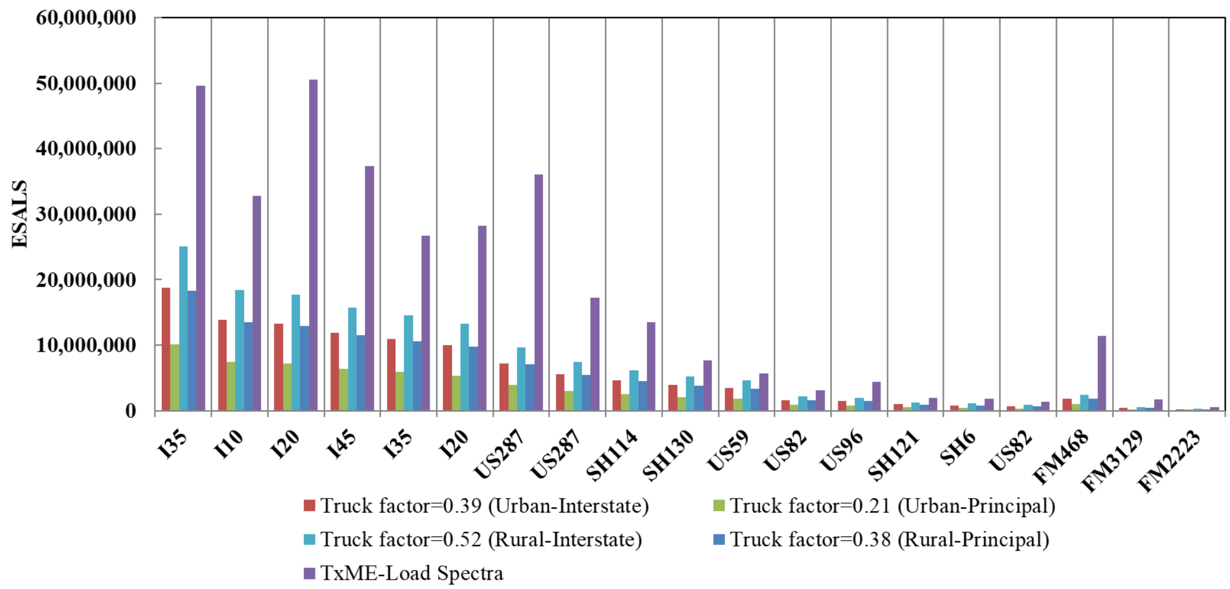


Figure 4. ESALs Calculated from Truck Factors and TxME Load Spectra.

COMPARISON OF TRAFFIC VOLUME AND LOADING FOR ENERGY AND NON-ENERGY AREAS

A better understanding of traffic volume and loading for different classes of highways is important for design of pavement structure for a specific area. In recent years, rapid energy development in Texas has caused significant damage to many FM roads. These roadways performed well under normal traffic loads but failed dramatically under energy-sector trucks. The impact of overloading on pavement damage is not limited to FM roads; it also has significant influence on the pavement life of U.S. highways, SHs, and IHs.

Table 6 summarizes the 19 WIM data sets, including highway name, station ID, AADTT, and ESAL, calculated from TxME load spectra. In addition, all the roads are classified in terms of traffic volume. Figure 5 to Figure 7 show the graphical comparisons of AADTT for IHs, U.S. or state highways, and FM roads, respectively. All the IHs have a much larger traffic AADTT (greater than 5,000). I-20 and I-10 have similar AADTT, but I-20 has a much larger ESAL (from TxME load spectra) than I-10 due to the difference in axle load distribution. U.S. or state highways have high, medium, and low AADTT, as shown in Figure 6. FM 468 is different from other FM roads because it is in an energy development area. When comparing FM 468 with U.S. or state highways, FM 468 has a slightly lower ESAL than SH 114, but it has a much lower AADTT (i.e., 1,062) than SH 114 (i.e., 2,656), which means the energy-sector trucks on FM 468 have a much larger axle load than on SH 114.

Table 6. Summary of the 19 WIM Data Sets.

Highway Classification	Traffic Volume	Highway ID	Station ID	AADTT	ESAL from TxME Load Spectra (20 years)
Interstate Highways	High (AADTT ≥7000)	I35	513	10,867	49,650,718
		I10	502	8,005	32,748,557
		I20	526	7,704	50,529,653
	Medium (7000> AADTT ≥4000)	I45	539	6,834	37,354,536
		I35	531	6,299	26,717,107
		I20	544	5,767	28,243,048
U.S. or State Highways	High (AADTT ≥3000)	US287	506	4,182	36,010,559
		US287	528	3,247	17,228,683
	Medium (3000> AADTT ≥2000)	SH114	527	2,656	13,479,223
		SH130	532	2,269	7,682,393
		US59	535	2,000	5,656,394
	Low (AADTT<2000)	US82	530	919	3,120,864
		US96	142	846	4,337,616
		SH121	546	550	1,976,022
		SH6	Portable WIM	474	1,830,420
		US82	543	372	1,310,763
Farm to Market (FM) Roads	High (AADTT ≥1000)	FM468	Portable WIM	1,062	11,437,641
	Low (AADTT<1000)	FM3129	541	251	1,652,034
		FM2223	800	142	516,928

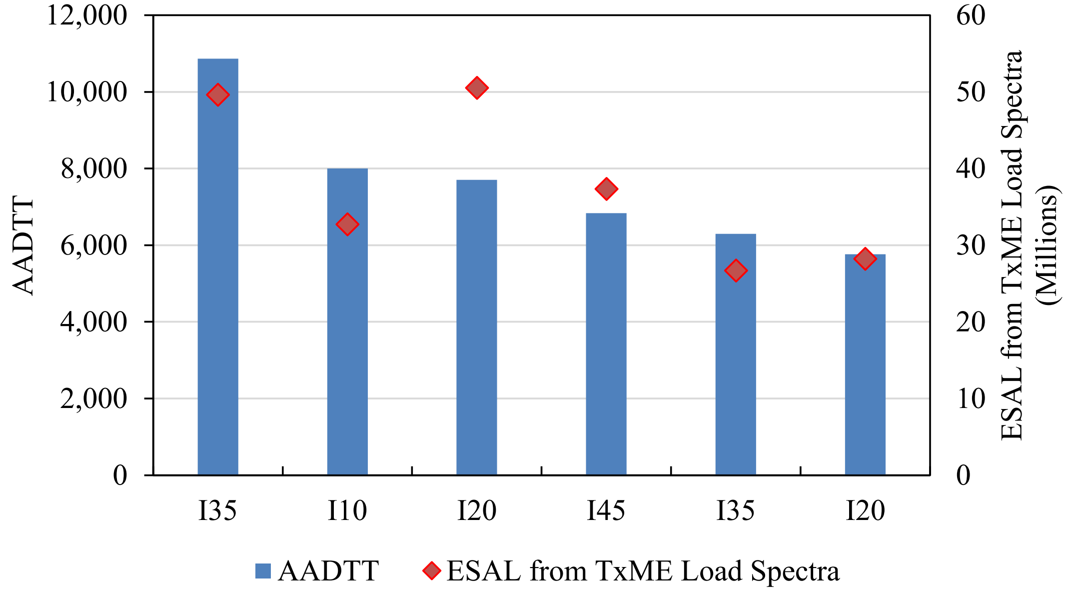


Figure 5. Comparison of AADTT for IHs.

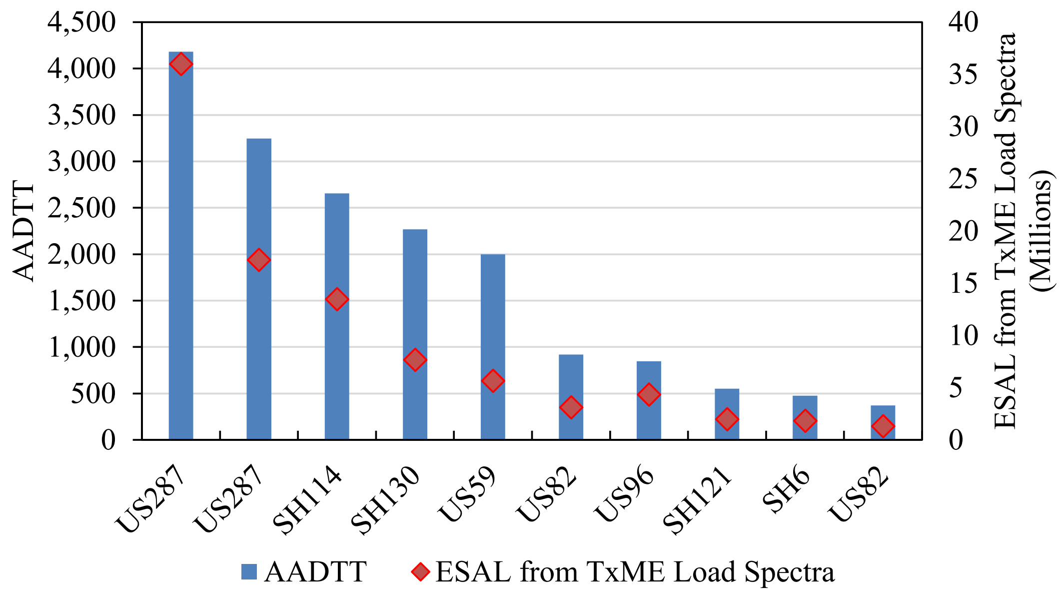


Figure 6. Comparison of AADTT for U.S. and State Highways.

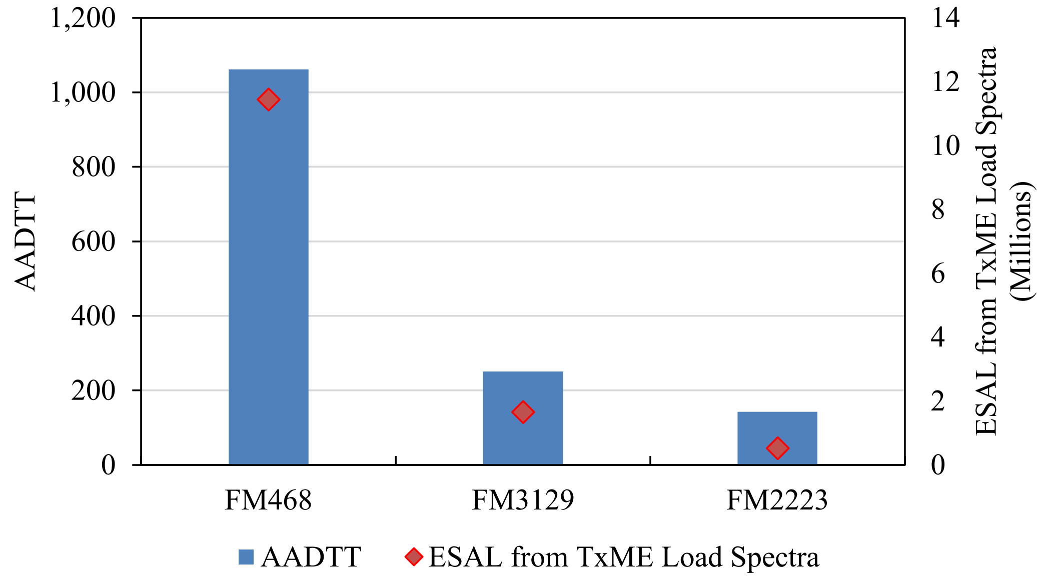


Figure 7. Comparison of AADTT for FM Roads.

COMPARISON OF PREDICTED PERFORMANCES FROM TXME WITH USE OF WIM TRAFFIC DATA INPUTS

As described in this section, a typical pavement structure was used for TxME simulations (as shown in Figure 8). The pavement structure was the same for all the simulations. The variable was the traffic input. The hot mix asphalt (HMA) layer was a dense-graded asphalt mixture, and the default values were used for the material properties. A total of seven WIM data sets representing different traffic volume levels for each road type were selected for TxME load spectra inputs. IHs had two cases of high and medium traffic volumes. U.S. or state highways had three cases of high, medium, and low traffic volumes. FM roads had two cases of high and low traffic volumes. Table 7 summarizes the predicted pavement performances including total rut depths and asphalt concrete (AC) fatigue cracking area.

Figure 9 and Figure 10 present the graphical comparisons. For the rutting performance, an IH has much larger rut depths exceeding the failure criteria after 20 years, which is expected because IHs have a very large AADTT. US 287 with a high AADTT in the group of U.S. or state highways has a rut depth close to the failure criteria. SH 130 and SH 6 have rut depths far below the failure limit. FM 468 has a comparable rut depth as SH 130, which has a medium traffic volume in the group of U.S. or state highways. When looking at the fatigue performances, I-35, I-20, US 287, and FM 468 have cracking areas exceeding the failure limit. Thus, trucks in the energy development areas can cause significant damage to the FM roads due to very large axle loads.

Figure 8. Typical Pavement Structure.

Table 7. Summary of Predicted Pavement Performances Using Load Spectra Inputs.

Highway Classification	Traffic Volume	Highway ID	Station ID	AADTT	ESAL from TxME Load Spectra (20 years)	Results from TxME Load Spectra	
						Total Rut Depth (in.) (Limit:0.5)	AC Fatigue Cracking Area (%) (Limit:50)
Interstate Highways	High	I35	513	10,867	49,650,718	0.63	99.3
	Medium	I20	544	5,767	28,243,048	0.52	95.4
U.S. or State Highways	High	US287	506	4,182	36,010,559	0.48	94.2
	Medium	SH130	532	2,269	7,682,393	0.37	21.7
	Low	SH6	Portable WIM	474	1,830,420	0.21	0.08
Farm to Market (FM) Roads	High	FM468	Portable WIM	1,062	11,437,641	0.38	55
	Low	FM3129	541	251	1,652,034	0.22	0.22

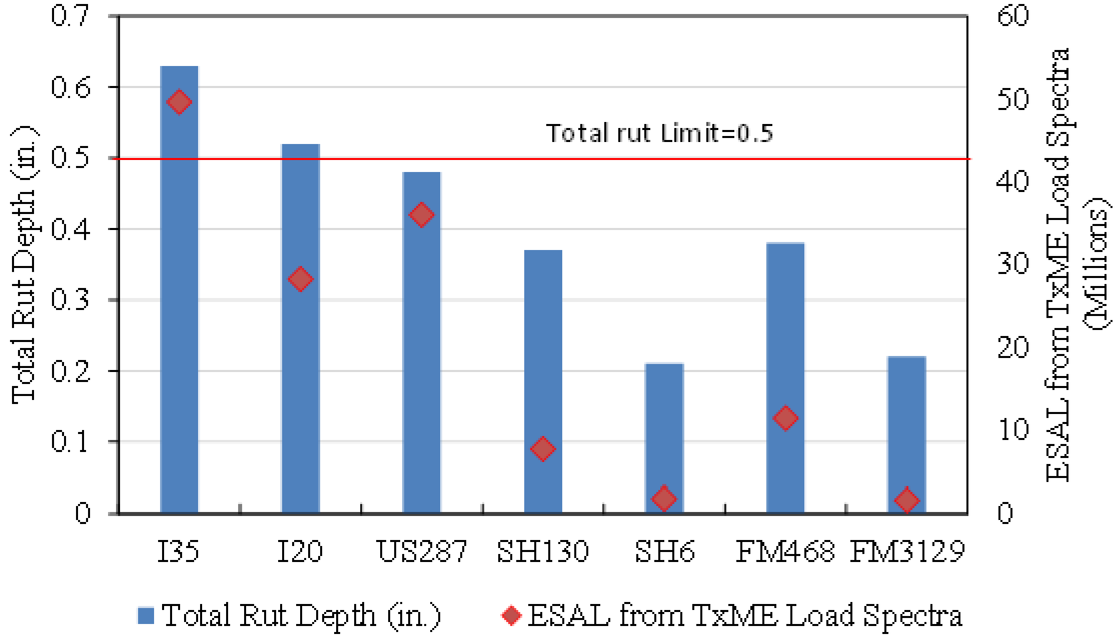


Figure 9. Total Rut Depths from TxME with Load Spectra Inputs.

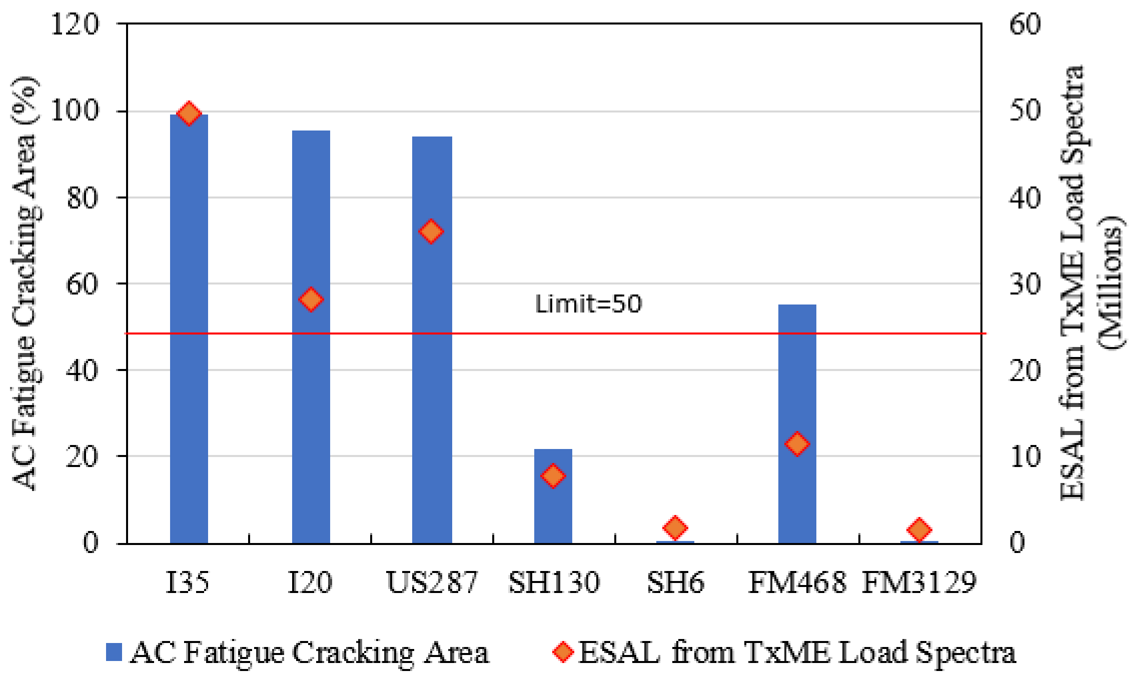


Figure 10. AC Fatigue Cracking Area from TxME with Load Spectra Inputs.

SUMMARY

This chapter discussed traffic in terms of ESALs and load spectra. It also showed the importance of accuracy of truck factors for conversion to EASLs from load spectra. More critically, load spectrum data should be directly used for pavement designs.

CHAPTER 3. SIX-STEP FLEXIBLE PAVEMENT REHABILITATION AND DESIGN STRATEGY FOR HEAVY LOAD TRAFFIC

INTRODUCTION

Pavement repair and rehabilitation are important activities for all highway agencies. Many highway facilities, particularly those used by the energy sector, are experiencing early deterioration due to high traffic volumes and climate conditions, as well as service periods that extend, in some cases, well beyond the facilities' design life. Coupled with this type of deterioration, reduced revenues and purchasing power make the selection of a right rehabilitation strategy that much more critical. As the energy sector begins to recover, more and more miles of pavement are expected to require significant maintenance, rehabilitation, or repair (MRR). Close examination of strategies for MRR of pavements is needed to optimize the expenditure of limited repair funds. Therefore, better decision-making, guidelines, and tools to evaluate and select appropriate MRR strategies are needed so that long-lasting, cost-effective rehabilitation solutions can be identified and implemented.

GUIDANCE FOR SELECTING REHABILITATION OPTIONS FOR ENERGY-SECTOR ROADS

The purpose of selecting an appropriate rehabilitation alternative for energy-sector roads is to provide sufficient pavement structural capacity and performance to support the heavy loads over the pavement's design life. This guidance will help engineers determine appropriate rehabilitation alternatives for flexible pavements with the consideration of existing pavement conditions, traffic loads, and material characteristics. Since most roads used by the energy sector are FM roads with surface treatments or a very thin asphalt layer, the most often used rehabilitation strategy is FDR, followed by two-course surface treatment or an added asphalt layer. Thus, this guidance focuses on the use of FDR for roads in the energy sector.

As shown in Figure 11, the process of selecting an MRR alternative primarily includes six steps to reach a final decision for a sufficient pavement structural design and FDR mix design. Detailed information and procedures on each step are described in the following sections.

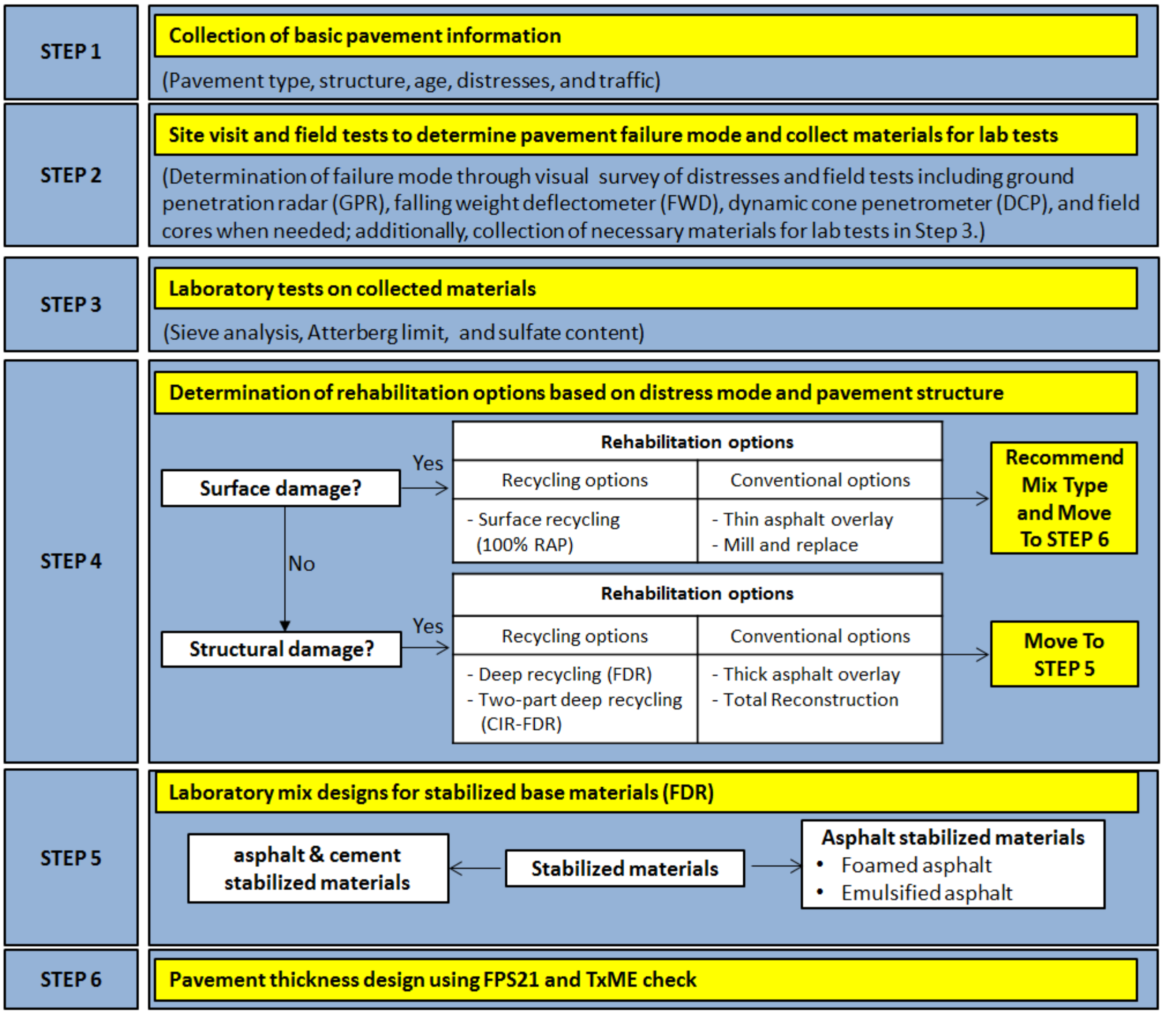


Figure 11. Pavement Rehabilitation Alternative Selection and Design Process for Energy-Sector Roads.

Step 1: Collection of Basic Pavement Information

The existing pavement conditions, structure, and layer materials should be evaluated first. More specifically, to evaluate the existing pavements, the following information is typically needed (at a minimum): soil survey data, traffic data, climate data, pavement condition reports, maintenance records, and existing typical section (control-section-job number). Then, the information gathered should be reviewed; the brief output of the review will include (at a minimum) climate, current traffic, current pavement structure, material types, road condition, and potential problem areas.

Step 2: Site Visit and Field Tests to Determine Pavement Failure Mode and Collect Materials for Laboratory Tests

The main purpose of this step is to define the failure mode and collect materials for further laboratory tests. Generally, a site visit is needed to supplement data from Step 1. To this end, a visual inspection and several field tests are typically required. Visual inspection provides observations such as drainage, geological changes, and valuable clues to recognize the cause of distress of the pavements. The failure mode and type of distress can be classified into the categories shown in Table 8.

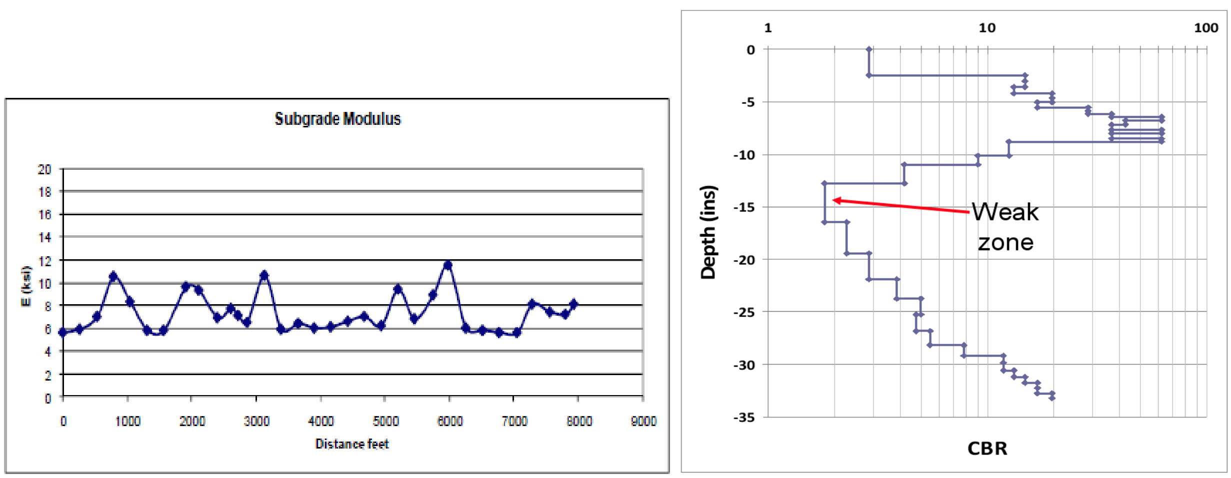
Table 8. Failure Mode and Type of Distress.

Failure Mode	Distress Type	Description
Surface damage	Environmental damage Traffic damage	Raveling (stone loss) Thermal cracking Block cracking Rutting Stripping, bleeding, or polishing
Structural damage	Permanent deformation Cracking	Rutting in wheel paths Lateral shoving Longitudinal in wheel paths Alligator Other (transverse, etc.) Potholes, patches, etc.
Functional damage	Drainage Riding quality	Erosion, washouts, etc. Edge break Undulations, corrugations, etc.

Source: (*3*)

In most cases, a long roadway is not uniform over a long distance in terms of subgrade, pavement structure, and associated maintenance/rehabilitation. Uniform sections can be identified visually by changes in the distress pattern. However, some field tests should be considered to determine uniform sections by extracting core samples or using some forensic study tools, such as ground penetration radar (GPR), falling weight deflectometer (FWD), and dynamic cone penetrometer (DCP). The use of GPR is strongly recommended to determine layer thicknesses and identify changes in pavement structure and potential moisture issues in the pavement. Figure 12 shows an example screenshot of a GPR analysis and identifies the pavement structure. Both FWD and DCP can be used to identify the boundaries between the different uniform sections by assessing the in-situ properties such as the backcalculated modulus and bearing strength of the material in the different layers of the pavement, as shown in Figure 13. Core samples can be used to verify the thickness of the asphalt layers and to perform several laboratory tests for determining volumetric and material properties. Additionally, materials from each pavement layer and subgrade may be needed for further laboratory characterization, FDR mix design, and structural design. Last, new base materials may also be necessary for FDR mix design.

Figure 12. GPR Image Obtained on FM 99.



(a) FWD result (b) DCP result

Figure 13. Example of FWD and DCP Survey Results.

Step 3: Laboratory Tests on Collected Materials

Representative materials from existing layers and subgrade and from new materials (if necessary) should be properly collected and brought back for laboratory tests. As an example, Figure 14 shows the new base, old base, and recycled asphalt pavement (RAP) (existing asphalt layer) collected from FM 99 for the laboratory evaluation. The most often performed laboratory tests include sieve analysis, Atterberg limits, and sulfate content tests. The test results are used for the stabilizer selection process, as shown in Figure 15 (*4*). The detailed information from Step 2 and Step 3 should be summarized to develop the final rehabilitation strategy in Step 4.

Figure 14. Materials Collected from FM 99.

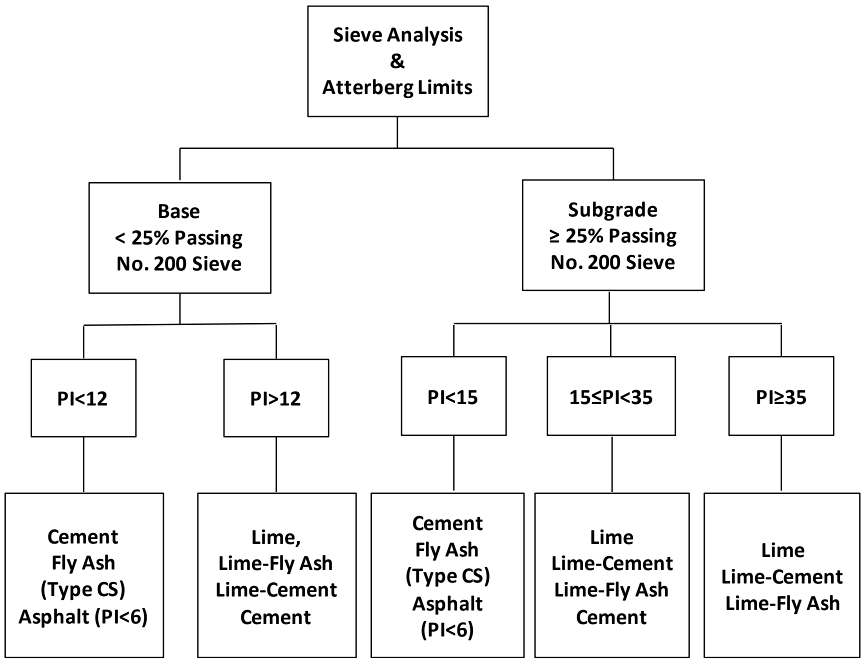


Figure 15. Stabilizer Selection Guidelines.

Step 4: Determination of Rehabilitation of Options Based on Distress Mode and Pavement Structure

There are numerous options for maintaining and rehabilitating pavements. However, each option should be project specific. An appropriate rehabilitation alternative is often determined by the following three major factors:

- Existing pavement conditions and the pavement distress(es) that need(s) to be addressed.
- The quality of material in the recycling horizon.
- The outcome required (i.e., service life expectations).

Rehabilitation options are divided into two major categories based on the nature of the problem:

- Surface rehabilitation.
- Structural rehabilitation.

As illustrated in Figure 16, if the section is a candidate in the surface rehabilitation category (Figure 16a), three options are available:

- Surface recycling.
- Asphalt overlay.
- Mill and replace.

When the type of asphalt mix is recommended or determined, the pavement design is performed using FPS 21 and TxME for asphalt overlays.

For the second category, structural rehabilitation (Figure 16b and Figure 16c), three options are available:

- Deep recycling (e.g., FDR or two-part recycling).
- Thick asphalt overlay.
- Total reconstruction.

If the deep recycling option is chosen, it is necessary to perform laboratory mix designs for stabilized materials, as described in the next step. For the thick asphalt overlay and total reconstruction options, FPS 21, the Texas Asphalt Concrete Overlay Design System (TxACOL) (for overlays), and TxME (for reconstruction) can be used to develop pavement designs.

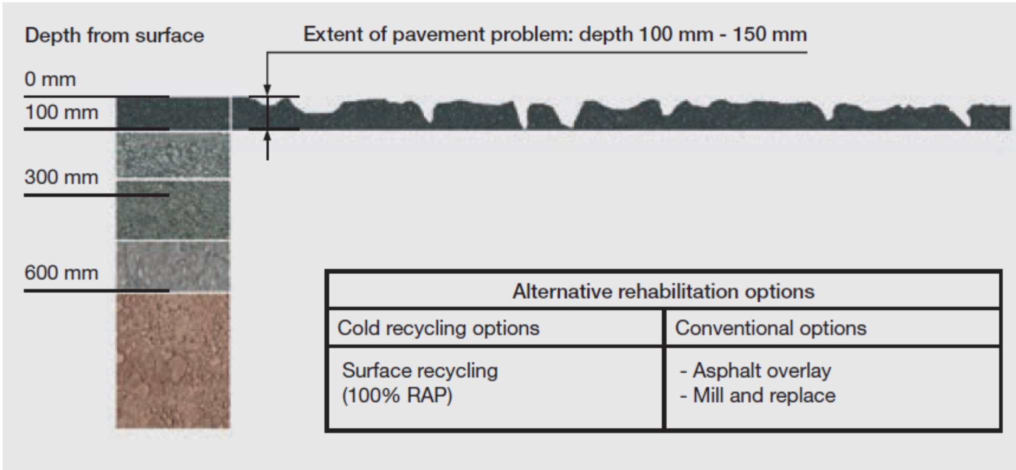
Step 5: Laboratory Mix Designs for Stabilized Materials for FDR Option

Figure 17 shows simplified steps for the mix design process. With the selected recycling option, such as FDR, a series of laboratory tests for the combinations of materials should be performed to select the optimal stabilizer and its content. Typically, three primary stabilizers are used for FDR:

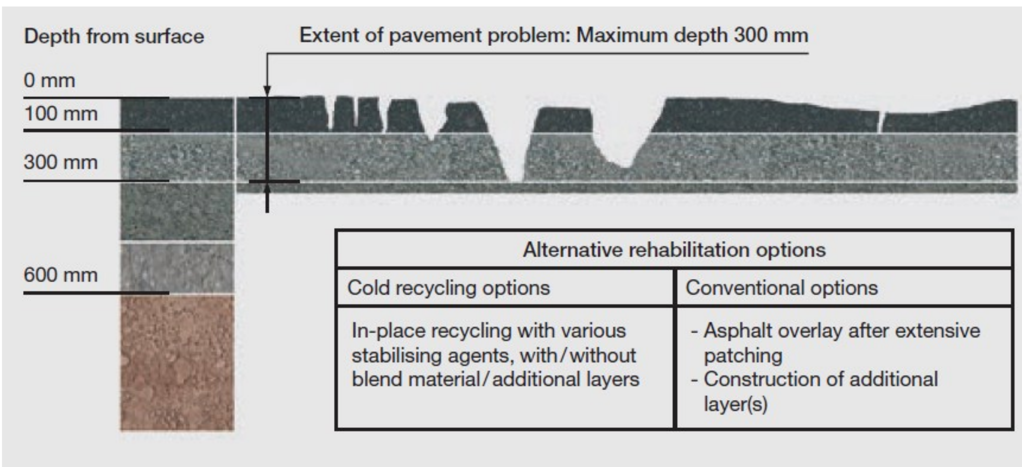
- Asphalt (foamed and emulsion).
- Cement.
- A combination of stabilizers.

However, for energy-sector roads with the requirement of same-day traffic opening, the stabilizers are narrowed down to two choices:

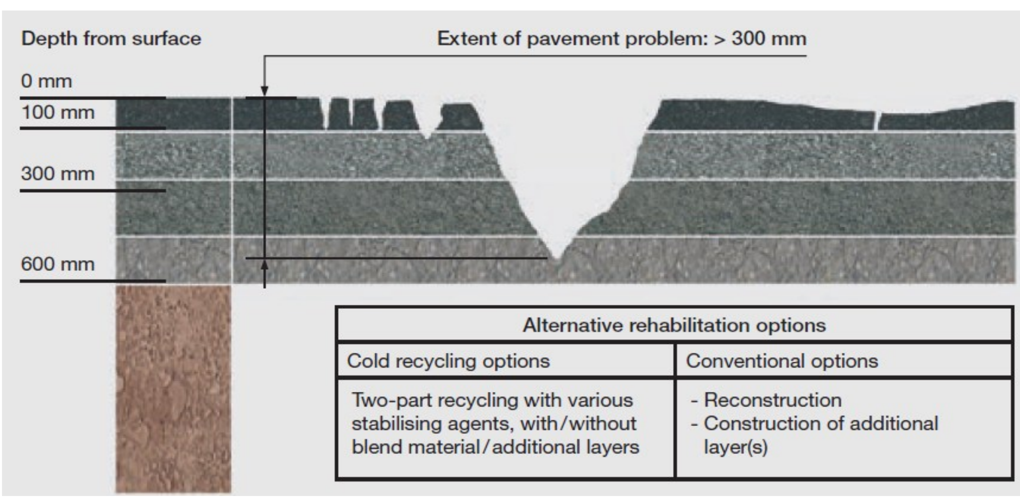
- Asphalt (foamed and emulsion).
- An asphalt-cement/lime combination.



(a) Rehabilitation options for upper pavement/surfacing distress



(b) Rehabilitation options for structural distress in the upper pavement layers



(c) Rehabilitation options for deep-seated structural distress

Source: (*3*)

Figure 16. Three Different Cold Recycling Application Options.

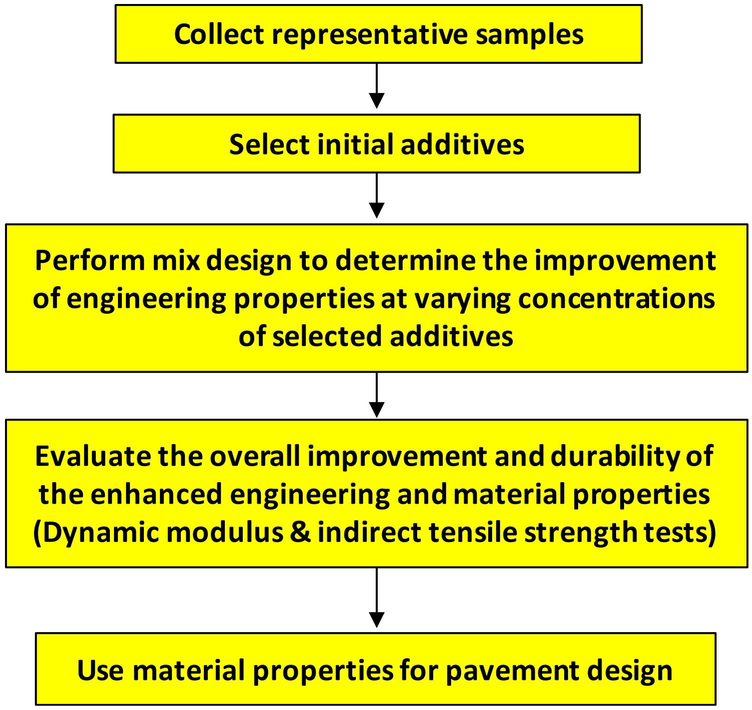


Figure 17. Mix Design Process for Stabilized Materials.

It is critical to select the appropriate stabilizer type and its optimal amount for an effective resulting mix. Preliminary treatment options prior to the mix design can be selected based on the availability and costs of materials, agency experience, and material properties of existing pavement materials. The design procedure (TxDOT Specification 3279) has indirect tension (IDT) strength requirements on both wet-conditioned and dry samples: a minimum dry strength of 45 psi and a minimum wet strength of 30 psi.

Step 6: Pavement Thickness Design Using FPS 21 and TxME Check

FDR projects must also be designed using FPS 21. This could be to calculate the thickness of the flexible base to be placed over the stabilized subbase layer for heavily trafficked sections, or the thickness of the asphalt layer required to carry the design traffic loads over the stabilized base layer. For the reconstruction option, TxME can be used to check the pavement performance in terms of rutting and cracking; for the asphalt overlay option, TxACOL is available to predict both rutting and reflective cracking development in the design period of pavement life.

EXAMPLES OF LABORATORY MIX DESIGN WITH FDR OPTION

FDR is the most often used rehabilitation strategy by districts in the energy development areas. To guide designers in their future FDR projects, several actual field test sections evaluated are presented here as examples for demonstration purposes. These case studies will help engineers perform a laboratory mixture design when an FDR option is selected. The two examples are FM 99 in the Corpus Christi District and FM 906 in the Paris District. The laboratory tests include the plasticity index (PI) test, moisture-density curve test, and IDT tests with different dosages of stabilizers.

FM 99 in the Corpus Christi District

FM 99 is an extremely heavily trafficked energy development roadway in the Corpus Christi District of Texas; the limits of this project were from US 281A to the McMullen County Line. The original plans stated that the roadway is 24 ft wide and has 1 inch of asphaltic materials as a surface layer and 6 inches of flexible base material. A test pit was dug in a representative area, and samples of the materials were obtained for stabilization design in the Texas A&M Transportation Institute lab.

The obtained materials were tested in the laboratory, and the measured PI was 9. For low PI material, cement, fly ash, and asphalt are recommended, as illustrated in Figure 15. Two designs were evaluated using an aggregate blend of 55 percent new base, 27 percent RAP, and 18 percent old base. Foamed asphalt and cement were selected as stabilizers. Two types of mix design with use of both foamed asphalt and cement (i.e., 2.4 percent foamed asphalt + 1.5 percent cement, and 2.75 percent foamed asphalt + 1.5 percent cement) were evaluated.

The mix design was performed following TxDOT Special Specification 3279, which contains the requirements about IDT strengths for both wet-conditioned and dry samples: a minimum dry IDT strength of 45 psi and a minimum wet IDT strength of 30 psi. A total of six samples with 4 inches in diameter and 2 inches in height were compacted for each mix design. These samples were then cured in the oven at 40°C for three days. After curing, three of the samples were submerged in water for 24 hours. After conditioning, the IDT test was performed on both the dry and wet samples. Figure 18 presents the compacted samples and the IDT test setup. Table 9 summarizes the test results including IDT test and unconfined compression strength (UCS). Two mix designs had comparable IDT strengths. The higher dosage of foamed asphalt did not have a significant effect on the IDT strength.

Figure 18. Samples Taken during the Moisture Conditioning and the IDT Test.

Table 9. IDT Results from Foamed Asphalt Samples from FM 99.

	TxDOT Test Method	Spec. 3279 Requirement	1.5% Cement 2.4% Foam	1.5 Cement 2.75 Foam
Dry IDT	Tex-226-F	45 psi	75 psi	77 psi
Wet IDT	Tex-226-F	30 psi	41 psi	39 psi
Min. UCS	Tex-117-E	Report	171 psi	—
Dry Density	—	—	121.5 lb/ft^3	122.4 lb/ft^3
Opt. % Moisture	—	—	7.3%	7.3%

FM 906 in the Paris District

FM 906 is located in the Paris District of Texas; the limits of this project were from FM 196 to US 271. The net length of the roadway was 4.5 miles long. Materials were sampled from the test pit for further laboratory tests and stabilization design (as shown in Figure 19).

Figure 19. Test Pit on FM 906.

Figure 20 shows the materials used for the mix design including existing base, new base, and RAP. Table 10 presents the aggregate gradation for existing base and new base. The measured PIs were 7 and 4 for existing base and new base, respectively. Two combined gradations were evaluated:

- Combination 1: 75 percent existing base and 25 percent RAP.
- Combination 2: 42 percent existing base, 33 percent new base, and 25 percent RAP.

Table 11 presents the optimum moisture content (OMC) and dry density for the two combinations.

Figure 20. Pictures of Collected Soil Materials from FM 906.

Table 10. Aggregate Gradations for Existing Base and New Base.

Sieve Size	% Passing Existing Base (EB)	% Passing New Base (NB)
1¾"	100	100
1¼"	99	95.4
¾"	90.5	78.5
⅜"	66	57.7
#4	55.3	44.1
#40	29	28.2

Table 11. OMC and Dry Density for Two Aggregate Combinations.

Combined Materials	OMC (%)	Dry Density (pcf)
Combination 1	5.4	133
Combination 2	6	131.1

After FDR was chosen for the test sections on FM 906, eight different designs, as shown in Table 12, were performed using both foamed asphalt and emulsion asphalt with and without cement. All designs consisted of 25 percent RAP materials. The IDT tests were performed on these eight designs. Table 13 summarizes the test results. Based on the required IDT strengths in dry and wet conditions, Designs 2 and 5 were the best choices. Adding cement decreased the IDT strength for the case with addition of emulsion asphalt.

Table 12. Evaluated Stabilization Designs.

Design No.	Material %	% RAP	Foamed % (PG 64-22)	Emulsion % (CSS-1H)	Additive
1	75% EB	25%	2.4	—	0%
2	75% EB	25%	2.4	—	1% Cement
3	42% EB, 33% NB	25%	2.4	—	0%
4	42% EB, 33% NB	25%	2.4	—	1% Cement
5	75% EB	25%	—	4	0%
6	75% EB	25%	—	4	1% Cement
7	42% EB, 33% NB	25%	—	4	0%
8	42% EB, 33% NB	25%	—	4	1% Cement

Table 13. IDT Test Results on Stabilization Designs.

Design No.	Material %	% RAP	Foamed % (PG 64-22)	Emulsion % (CSS-1H)	Additive	Dry IDT (psi)	Wet IDT (psi)
1	75% EB	25%	2.4	—	0%	78.9	1.7
2	75% EB	25%	2.4	—	1% Cement	73.3	33.5
3	42% EB, 33% NB	25%	2.4	—	0%	71.3	2.9
4	42% EB, 33% NB	25%	2.4	—	1% Cement	49.3	37.9
5	75% EB	25%	—	4	0%	76.4	50.2
6	75% EB	25%	—	4	1% Cement	53.2	41.1
7	42% EB, 33% NB	25%	—	4	0%	67.5	42.7
8	42% EB, 33% NB	25%	—	4	1% Cement	56.0	49.5

SUMMARY

This chapter presented the six-step flexible pavement rehabilitation and design strategy for heavy traffic loads in energy development areas. It also provided examples of laboratory mix designs for FDR options.

CHAPTER 4. PAVEMENT DESIGN SUPPORT FOR DISTRICTS IN ENERGY DEVELOPMENT AREAS

INTRODUCTION

Texas has undergone a boom in the production of natural gas and crude oil since 2008 due to improvements in the practice of hydraulic fracturing (fracking) of oil- and gas-bearing rock formations. This development of energy sources in Texas had severe impacts on the condition of the state's highway system, estimated to be approximately $2 billion per year, because the process of fracking requires the movement of equipment, materials, and water to establish and complete wells, produce oil, and re-frack on a periodic basis. This activity can translate into 1,000 to 2,000 loaded trucks per well, and with a rate of well completion on the order of 10,000 to 15,000 per year, a total of 10,000,000 to 30,000,000 additional truck trips are being generated annually on FM roads and SHs. The locations of these wells within Texas are generally in rural areas where traditional traffic has been largely passenger vehicles, with occasional agriculture-related truck traffic. The pavements on these rural roads were vastly under-designed for the amount of traffic they are currently serving. Many of these pavements have suffered severe distress in the form of fatigue cracking and shear rutting. To assist districts in the energy development areas with designing adequate pavement structures, the researchers used the latest pavement design tool—TxME—to ensure good performance with low construction cost.

This chapter first describes the TxME design tool and then presents the pavement designs for the energy development areas.

TXME DESCRIPTION

The TxME design system aims to enable TxDOT pavement engineers to take full advantage of new or premium materials and to make more economically reliable designs. Three types of flexible pavement structures can be handled in TxME:

- Surface treated.
- Conventional or thin HMA.
- Perpetual pavement.

For any type of pavement design and analysis, there are four categories of input:

- Pavement structure and associated material properties.
- Traffic loading.
- Climate.
- Reliability.

The following describes these four categories of input and then output to provide an overview of TxME.

Pavement Structure and Associated Material Properties

The user interface aspects of the main screen, pavement structure screen, and material properties input screen are briefly illustrated below.

Main Screen

Figure 21 presents the main screen of the TxME. In this screen, four major input categories are listed on the left side of the node tree: structure, climate, traffic, and reliability. Double-clicking each node activates the corresponding input window on the right side.

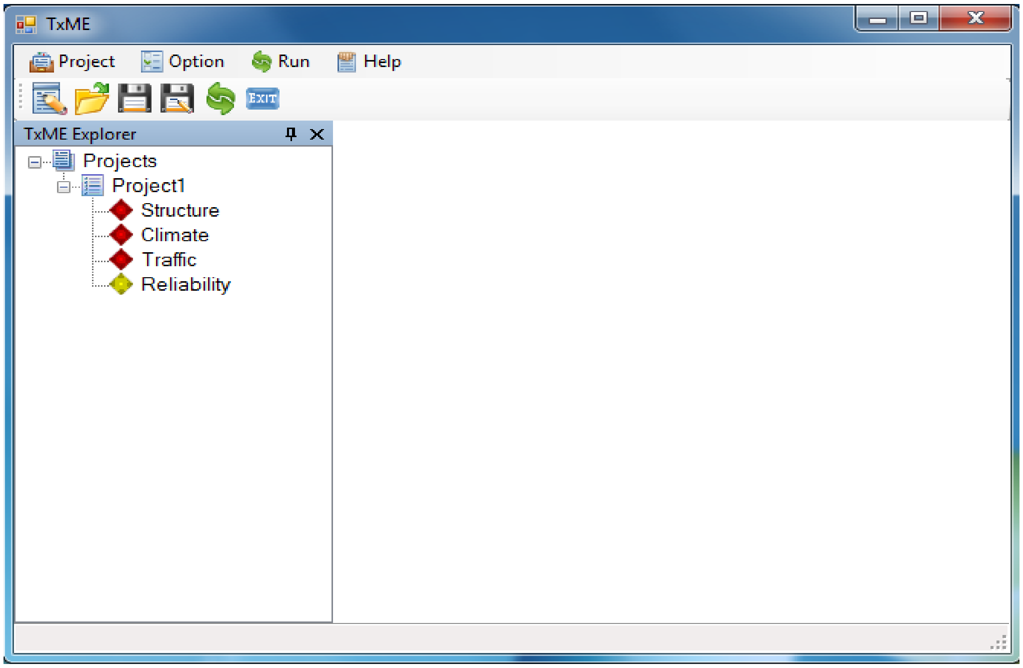


Figure 21. Main Screen of User Interface.

Pavement Structure

Figure 22 presents the pavement structure input screen. On this screen, the upper left window shows the pavement type and location; the upper right window lists available AC layer material, base layer material, and subbase layer material icons; the lower left window shows the pavement structure; and the lower right window shows the layer material properties.

Users can build their own pavement structures by dragging the layer material icons into the pavement structure window. To remove a layer from the pavement structure window, users just need to click the layer and choose "Remove this layer" from the pop-up menu.

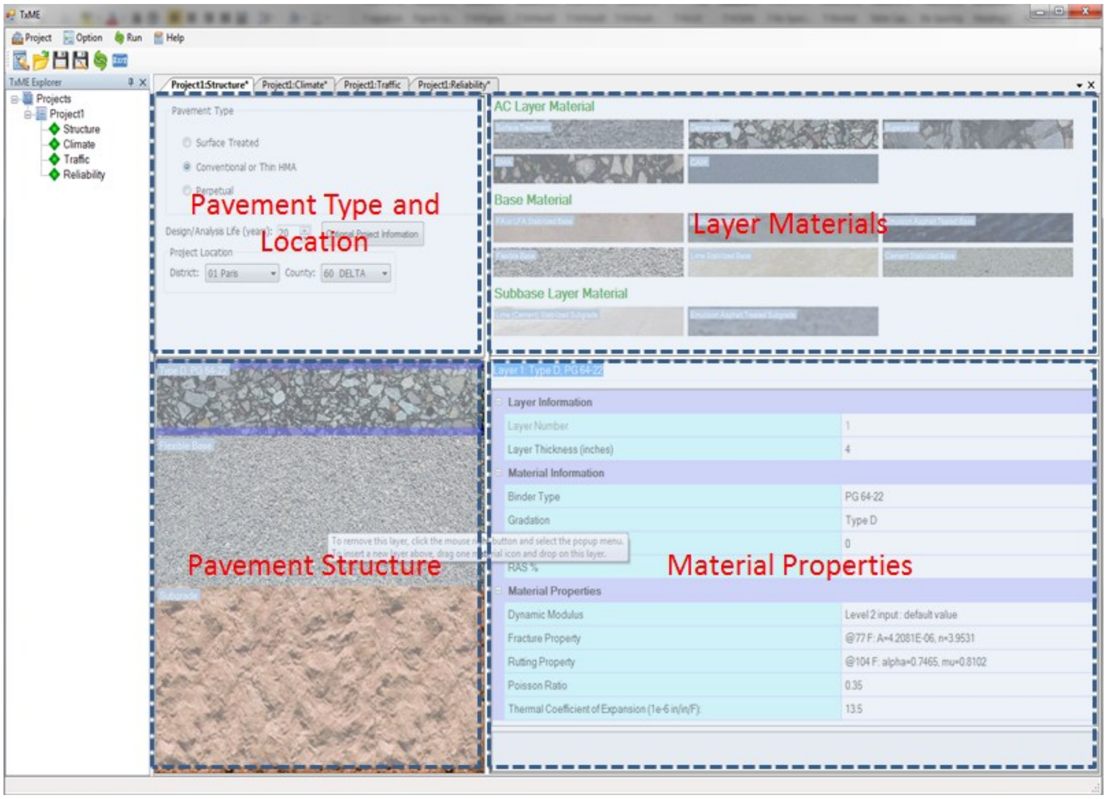


Figure 22. Pavement Structure Information Screen.

Material Properties

As shown in Figure 22, by clicking each layer in the pavement structure window, users can browse or edit the layer thickness and layer material properties in the material properties window. For some property inputs, such as thickness and Poisson's ratio, the user needs to input only a single parameter. For more complicated inputs such as dynamic modulus and fracture/rutting properties, the user needs to click on the item dropdown menu, and the expanded input screen will pop up. Several material property input screens are illustrated in Figures 23–25:

- Figure 23 shows the dynamic modulus inputs for AC layers.
- Figure 24 shows the AC fracture property (default values in Table 14).
- Figure 25 shows the AC rutting property (default values in Table 15).

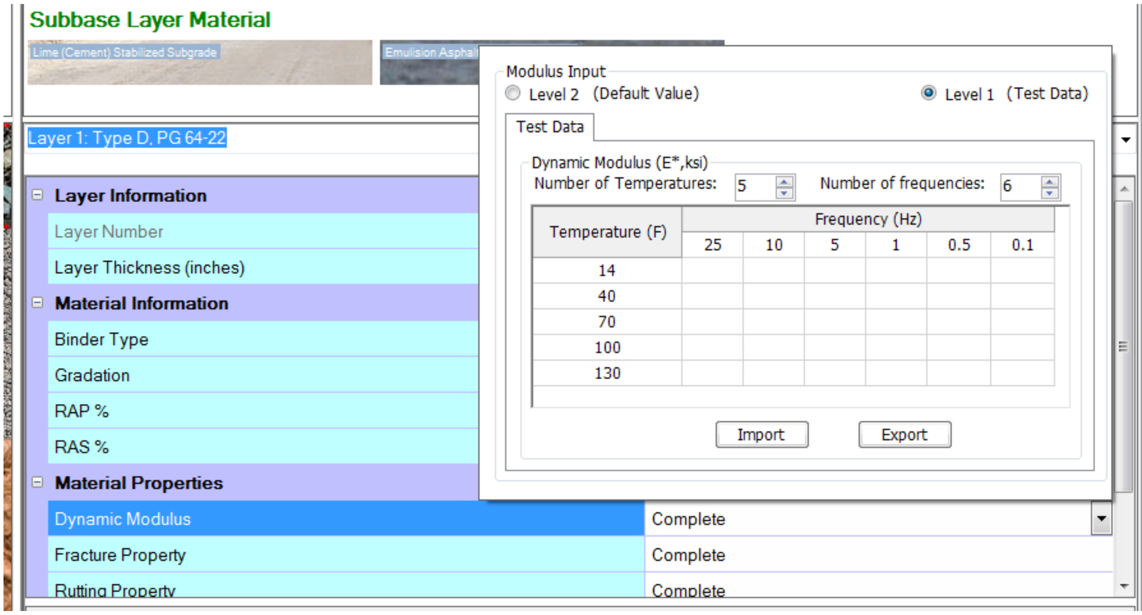


Figure 23. AC Layer Dynamic Modulus Input Screen.

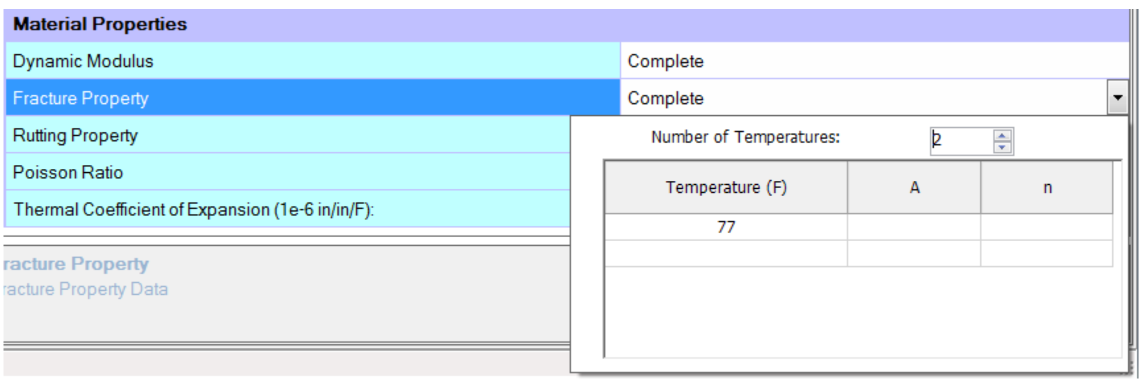


Figure 24. AC Layer Fracture Properties Input Screen.

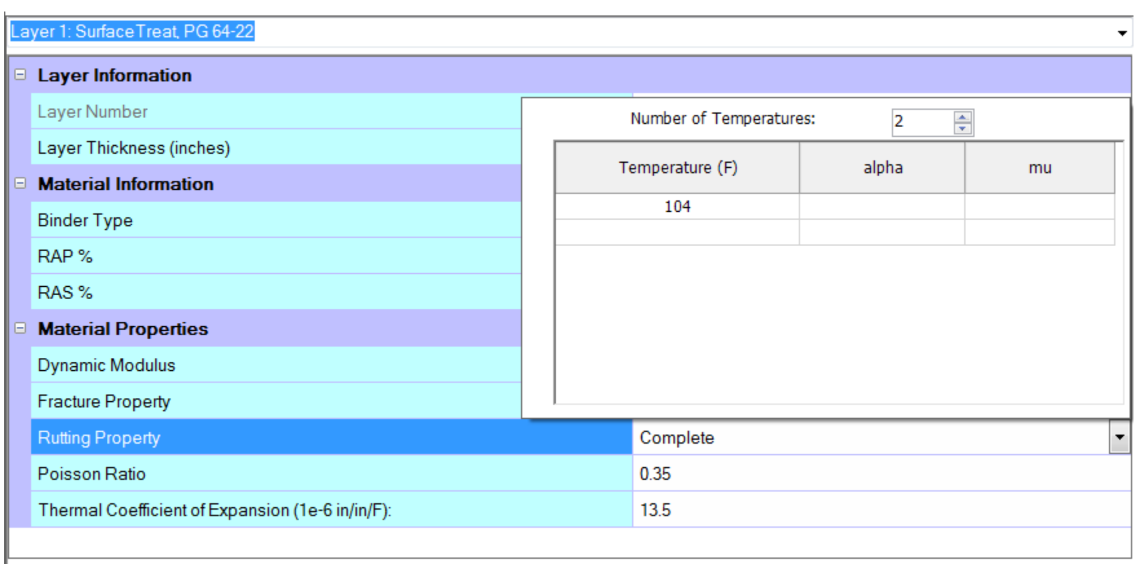


Figure 25. AC Layer Rutting Properties Input Screen.

Table 14. Default Fracture Properties for Typical Virgin Asphalt Mixes Often Used in Texas.

PG	Mix Type	A	n
64-22	Type B	6.4359E-06	3.8374
70-22	Type B	6.8551E-06	3.8201
76-22	Type B	7.3171E-06	3.8023
64-28	Type B	3.1557E-06	4.0323
70-28	Type B	3.7800E-06	3.9828
64-22	Type C	5.2041E-06	3.8948
70-22	Type C	5.5095E-06	3.8792
76-22	Type C	5.8430E-06	3.8630
64-28	Type C	2.8039E-06	4.0645
70-28	Type C	3.3231E-06	4.0179
64-22	Type D	4.2081E-06	3.9531
70-22	Type D	4.4280E-06	3.9391
76-22	Type D	4.6659E-06	3.9248
64-28	Type D	2.4914E-06	4.0969
70-28	Type D	2.9215E-06	4.0532
64-22	Superpave B	6.0544E-06	3.8541
70-22	Superpave B	6.4359E-06	3.8374
76-22	Superpave B	6.8551E-06	3.8201
64-28	Superpave B	3.0241E-06	4.0440
70-28	Superpave B	3.6074E-06	3.9956
64-22	Superpave C	4.9238E-06	3.9100
70-22	Superpave C	5.2041E-06	3.8948
76-22	Superpave C	5.5095E-06	3.8792
64-28	Superpave C	2.6934E-06	4.0755
70-28	Superpave C	3.1804E-06	4.0299
64-22	Superpave D	4.0044E-06	3.9667
70-22	Superpave D	4.2081E-06	3.9531
76-22	Superpave D	4.4280E-06	3.9391
64-28	Superpave D	2.3989E-06	4.1073
70-28	Superpave D	2.8039E-06	4.0645
76-22	SMA-C	9.2769E-08	4.9996
76-22	SMA-D	8.1315E-08	5.0358
76-22	SMA-F	6.0576E-08	5.1166
70-28	SMA-C	9.2769E-08	4.9996
70-28	SMA-D	8.1315E-08	5.0358
70-28	SMA-F	6.0576E-08	5.1166
64-22	RBL	1.1519E-07	4.9402

Table 15. Default Rutting Properties for Typical Virgin Asphalt Mixes Often Used in Texas.

PG	Mix Type	α	μ
64-22	Type B	0.7168	0.6459
70-22	Type B	0.7326	0.6314
76-22	Type B	0.7363	0.6283
64-28	Type B	0.7168	0.6508
70-28	Type B	0.7326	0.6184
64-22	Type C	0.7315	0.7234
70-22	Type C	0.7423	0.7014
76-22	Type C	0.7485	0.6756
64-28	Type C	0.7315	0.7306
70-28	Type C	0.7423	0.6986
64-22	Type D	0.7465	0.8102
70-22	Type D	0.7521	0.7792
76-22	Type D	0.7609	0.7265
64-28	Type D	0.7465	0.8202
70-28	Type D	0.7521	0.7892
64-22	Superpave B	0.7168	0.6459
70-22	Superpave B	0.7326	0.6314
76-22	Superpave B	0.7363	0.6283
64-28	Superpave B	0.7168	0.6508
70-28	Superpave B	0.7323	0.6184
64-22	Superpave C	0.7315	0.7234
70-22	Superpave C	0.7423	0.7014
76-22	Superpave C	0.7485	0.6756
64-28	Superpave C	0.7315	0.7306
70-28	Superpave C	0.7423	0.6986
64-22	Superpave D	0.7465	0.8102
70-22	Superpave D	0.7521	0.7792
76-22	Superpave D	0.7609	0.7265
64-28	Superpave D	0.7465	0.8202
70-28	Superpave D	0.7521	0.7892
76-22	SMA-C	0.7106	0.7761
76-22	SMA-D	0.7106	0.7856
76-22	SMA-F	0.7106	0.8004
70-28	SMA-C	0.7106	0.7761
70-28	SMA-D	0.7106	0.7856
70-28	SMA-F	0.7106	0.8004
64-22	RBL	0.7315	0.7234

Traffic Loading

TxME has two levels of traffic inputs: (a) ESAL input, and (b) axle load spectrum input. The following discussion illustrates the difference between these inputs.

Traffic ESAL (Level 2) Input

Figure 26 shows the traffic ESAL (Level 2) input screen. The most important input is the total ESAL number for 20 years (one lane and one direction). The ADT-Beginning and ADT-End represent average daily traffic in the beginning and in the end, respectively. These values are used to determine the vehicle growth rate. The tire pressure is used to determine the tire contact area. The operational speed (could be posted speed limit, or lower speed in urban traffic) impacts the AC layer modulus since it relates to loading time.

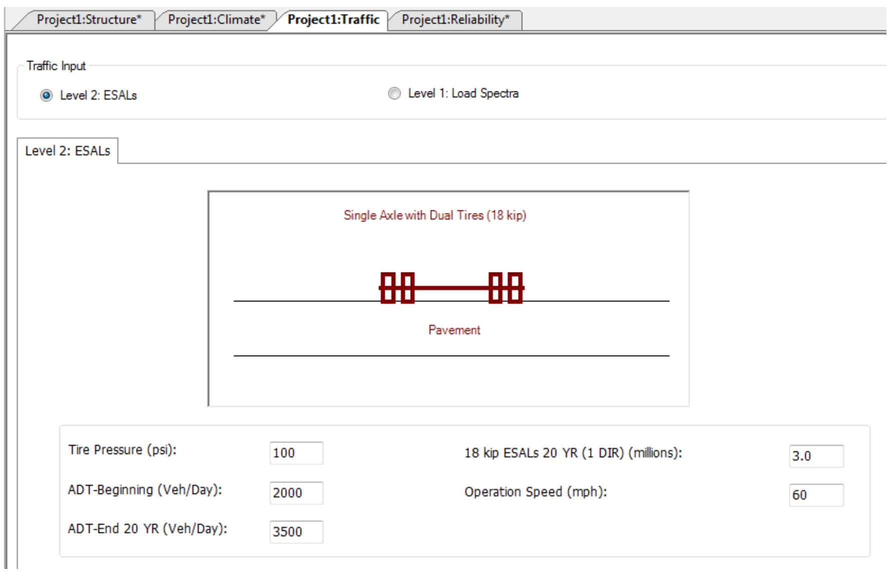


Figure 26. Traffic ESAL (Level 2) Input Screen.

Axle Load Spectra (Level 1) Input

TxME has default load spectrum inputs for IHs, U.S. or state highways, FM roads, and energy-sector roads. Figure 27 shows an input screen with default values for U.S./state highways. In this screen, the left window shows the general information and axle configuration information, such as AADTT number, operational speed, tire pressure, axle spacing, etc.; the upper right window shows the vehicle class distribution and growth rate information; and the lower right window has three additional characteristics of load spectrum: axle load distribution, monthly adjustment factor, and axles per truck. When clicking the buttons shown in yellow, the screens displayed in Figure 28, Figure 29, or Figure 30 pop up. These screens let users view and edit default values for axle load distribution, monthly adjustment factor, and axles per truck.

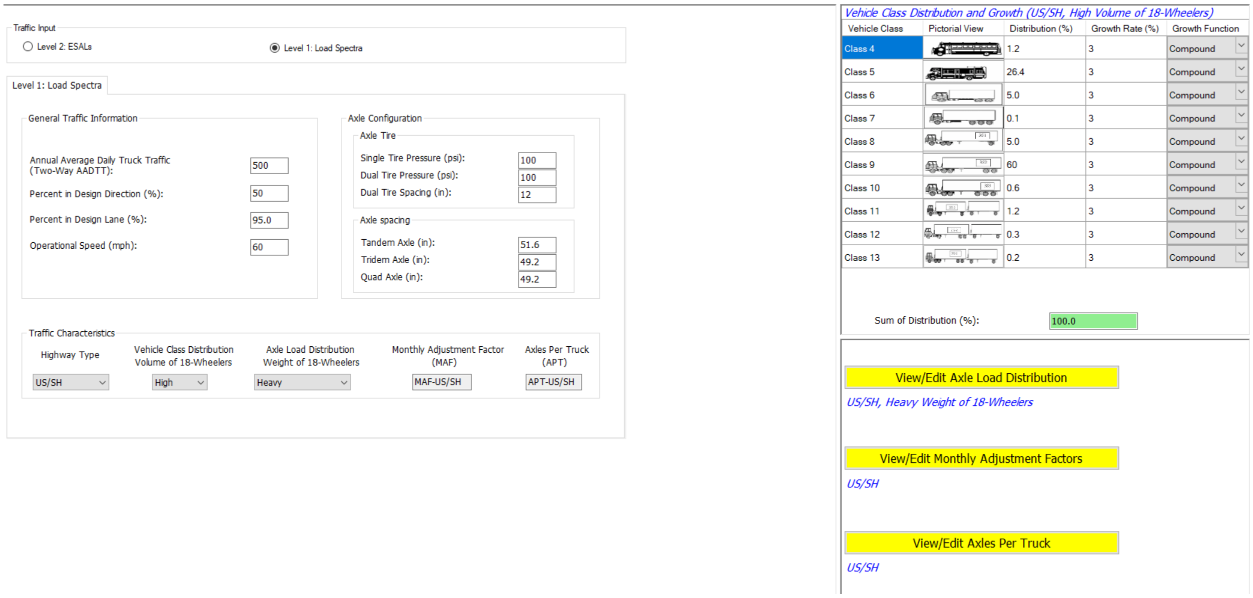


Figure 27. Traffic Load Spectrum (Level 1) Input Screen for U.S./State Highways.

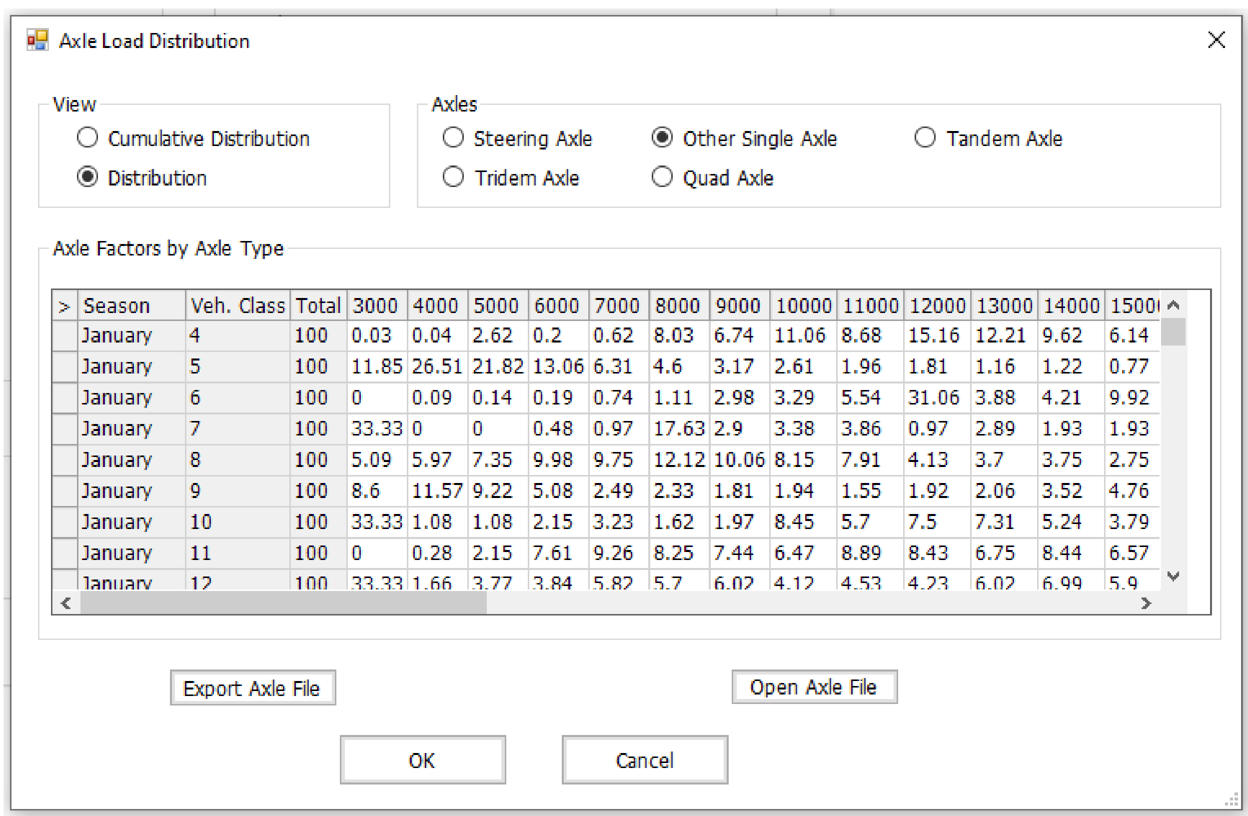


Figure 28. Traffic Axle Load Distribution Input Screen for U.S./State Highways.

Monthly Adjustment

Load MAF From File | Export to MAF File

Monthly Adjustment Factors

Month	Class_4	Class_5	Class_6	Class_7	Class_8	Class_9	Class_10	Class_11	Class_12	Class_13
January	1.16	0.87	0.75	0.32	0.68	0.94	0.32	0.95	0.38	0.23
February	1.23	0.83	0.71	0.34	0.75	0.89	0.31	0.85	0.41	0.26
March	1.4	0.98	0.87	0.63	0.9	0.97	0.34	1.01	0.37	0.42
April	0.79	1.02	1.06	1.59	1.1	1.13	1.62	1.08	1.47	1.64
May	0.77	1.06	1.12	1.42	1.08	1.12	1.53	1.09	1.38	1.7
June	1.38	1.11	0.95	0.44	0.97	0.97	0.35	1	0.3	0.37
July	1.31	0.98	1.07	1.18	1.4	0.96	0.62	0.9	0.57	0.42
August	0.74	1.17	1.24	1.23	1.13	1.12	1.55	1.04	1.45	1.56
September	0.71	0.99	1.02	1.07	0.98	0.97	1.15	0.84	1.41	1.17
October	0.82	1.02	1.11	1.28	1.1	1.02	1.38	1.18	1.68	1.38
November	0.99	1.08	1.15	1.31	1.06	1.04	1.42	1.24	1.46	1.52
December	0.7	0.89	0.94	1.19	0.85	0.86	1.39	0.83	1.11	1.33

OK | Cancel

Figure 29. Traffic Monthly Adjustment Input Screen for U.S./State Highways.

Axles Per Truck

Axles Per Truck

Vehicle Class	Steering Axle	Other Single Axle	Tandem Axles	Tridem Axles	Quad Axles
Class 4	1	0.59	0.41	0	0
Class 5	1	1	0	0	0
Class 6	1	0.01	0.99	0	0
Class 7	1	0.02	0.02	0.96	0
Class 8	1	1.32	0.69	0	0
Class 9	1	0.25	1.87	0	0
Class 10	1	0.03	0.99	0.99	0.02
Class 11	1	3.93	0.04	0	0
Class 12	1	2.75	1.09	0	0
Class 13	1	0.81	1.12	0.45	0.47

Note: Steering Axle -- Single axle, single tire; Other Single Axle -- Single axle, dual tires.

OK

Figure 30. Axles per Truck Input Screen for U.S./State Highways.

Climate

Users can attach the climatic information to a given project location in one of two ways: either by assigning a specific weather station or by using interpolated climatic data based on the coordinates of the location.

Figure 31 presents the climate input screen that appears when users choose a specific weather station. Generally, the left part of the screen allows the user to select a weather station, and the right part shows the summary of the weather data, such as average temperature or precipitation. The tables on the right side will not appear until after a station location is selected (OK button activated). The user can find more detailed information like hourly data by clicking the "Hourly data" tab on the upper right part of the screen.

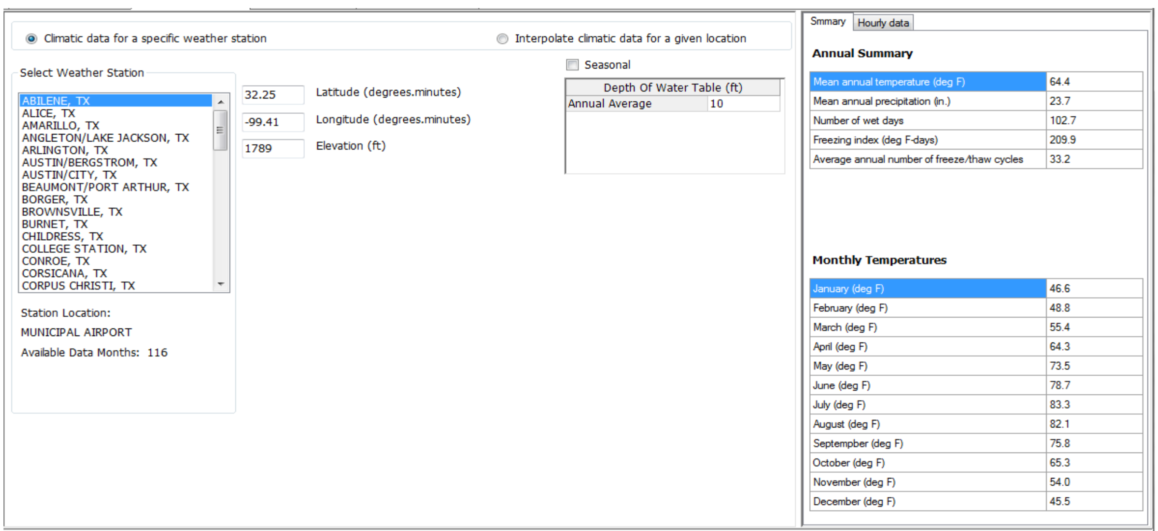


Figure 31. Climate for a Specific Weather Station Input Screen.

For a project location without a pre-listed weather station, users can choose the radio button "Interpolate climatic data for a given location" and the application will provide six weather stations nearby for the user to select for interpolation. Figure 32 presents the user input screen for climate data interpolation. The lines and numbers, such as #1, #2, etc., in the graph show the relative positions and distances from the location defined by the coordinates. The interpolated hourly data information is listed on the right side of the screen.

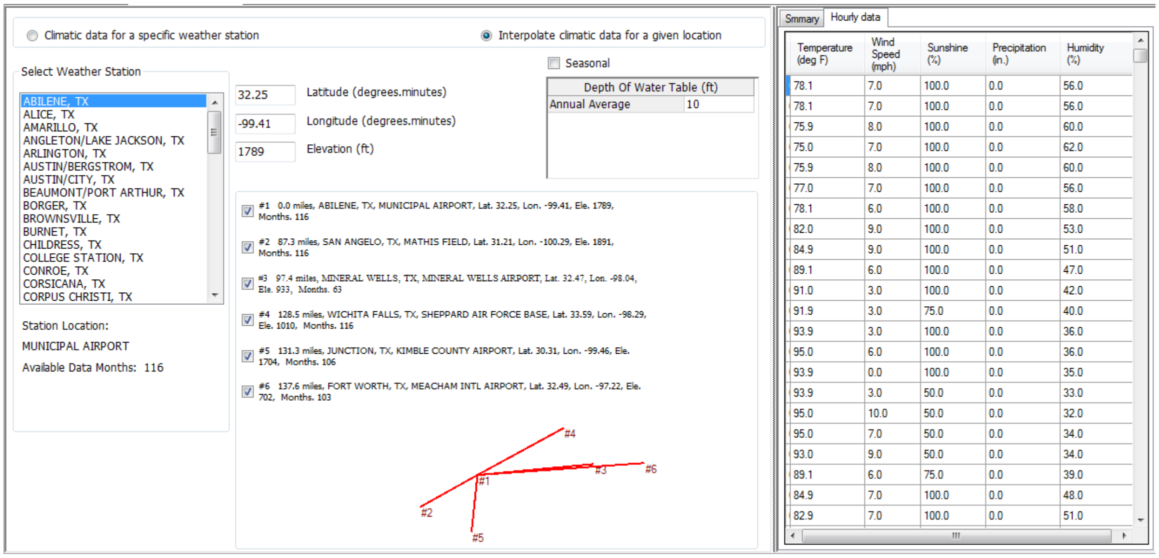


Figure 32. Climatic Data Interpolation Input Screen.

Reliability

Figure 33 presents the reliability-related input screen. For the performance criteria inputs, the user supplies the analysis stop criteria (performance limit) and reliability level in terms of percentage. In TxME, Rosenblueth's 2*n*+1 (*n* is number of variables with uncertainty) method is used to perform the reliability analysis, which has high practical benefit in terms of program operating efficiency for mechanistic-empirical flexible pavement designs (*5*, *6*).

Performance Criteria

Performance	Limit	Reliability (%)
Rutting (inch)	0.5	95
Thermal cracking (ft/mile)	2112	95
Fatigue cracking of AC layer (percent)	50	95

Figure 33. Reliability-Related Input Screen for a Three-Layer Conventional Pavement.

OUTPUT OF TXME

The output of TxME is organized into an Excel® file, which is mainly composed of three parts: the summary of user inputs, the analysis result table, and the distress plots (see Figure 34). The predicted distresses are keyed to the pavement structure and pavement type. The following information discusses and illustrates the output for each pavement type.

Figure 34. Output of TxME in Excel File Format.

CONNECTION WITH FPS 21

FPS 21 is the flexible pavement design system currently used by TxDOT. The user input of FPS 21 includes pavement location, beginning and ending serviceability indices, traffic ESALs, elastic modulus (can be based on FWD backcalculation) of each layer, maximum and minimum thickness of each layer, etc. FPS 21 reports combinations of layer thicknesses that fulfill the performance equation as constrained by the inputs. FPS 21 only uses FWD backcalculated/estimated elastic modulus and Poisson's ratio to represent each layer's properties; it does not use any lab testing data, so it is impossible to determine performance benefits from improved base materials or superior asphalt mixes. To evaluate these benefits, TxME is designed to import pertinent input and output information from FPS 21, and then to incorporate additional specific test results, such as rutting properties or fracture properties, to conduct the performance check. Figure 35 shows the connection concept.

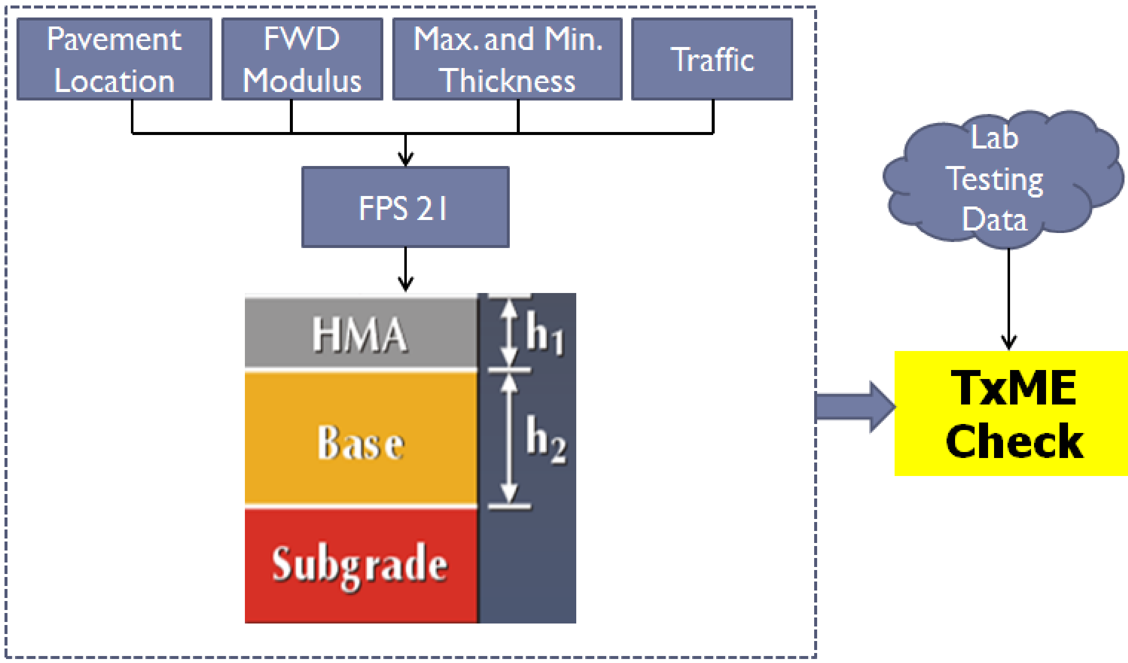


Figure 35. Connection Concept between FPS 21 and TxME.

Figure 36 shows an example of a TxME pavement structure imported from FPS 21 using a specially modified version of the program. By clicking the button "TxME Check" in the FPS 21 screen, TxME will be launched and automatically import the related information, such as pavement location, layer type, layer thickness, ESALs, and so on. The left part of Figure 36 is the FPS 21 recommended design option, and the right part is the TxME pavement structure after importation. TxME also searches the embedded database and provides default values for lab testing data. Users can edit these values if specific lab test results are available.

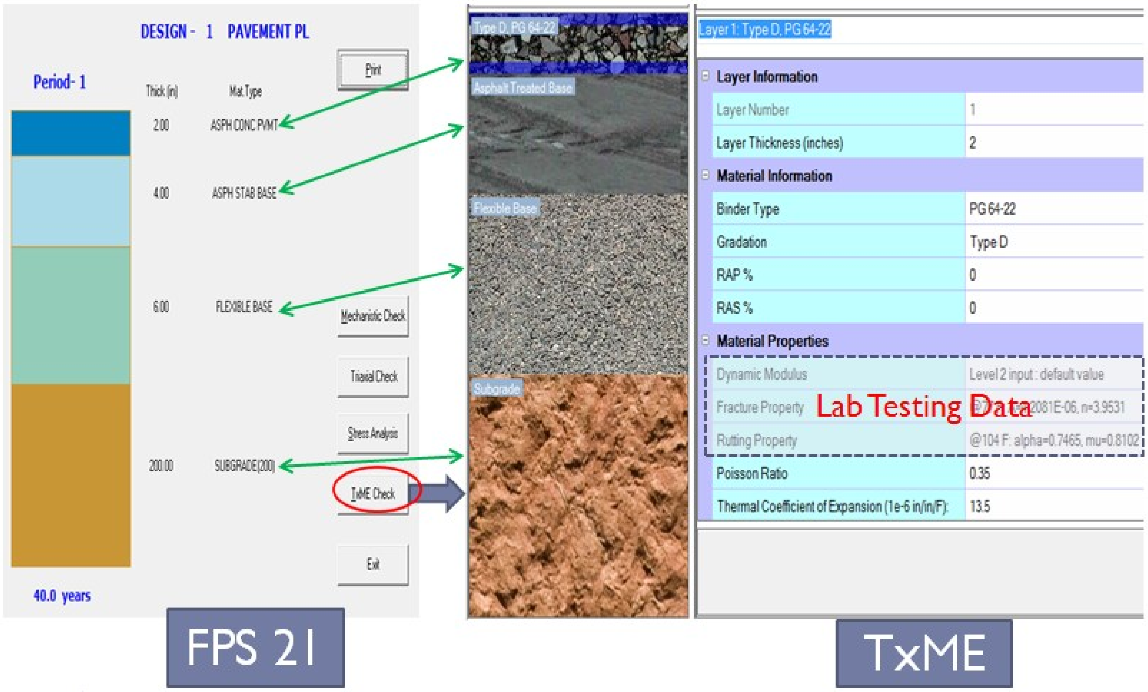


Figure 36. Example of TxME Pavement Structure Imported from FPS 21.

DESIGN SUPPORT TO LAREDO DISTRICT ON FM 468

The FM 468 project in the Laredo District is located in La Salle County and runs from the Dimmit County Line to FM 469, for a length of 10.380 miles. The project location is shown in Figure 37. The current pavement structure is composed of one layer of sealcoat, an 8- to 10-inch cement-treated base, and a clay subgrade. The pavement is in terrible condition, with severe fatigue cracking (Figure 38). FM 468 carries a significant amount of oil-gas traffic. In order to get a more accurate estimation of traffic, a portable WIM was installed on FM 468. Based on the portable WIM data, the following traffic information was used for designing FM 468.

- 2018 ADT: 6,700.
- 2038 ADT: 11,600.
- Flex 18k ESALs: 10,537,000.
- Percent trucks in ADT: 30.8.
- ATHWLD: 12,100.
- Percent tandem axles in ATHWLD: 40.

Based on the available information, pavement design out of FPS 21 consisted of a 3-inch Superpave (SP)-C mix with PG 76-22, 4-inch SP-B mix with PG 70-22, 10-inch flexible base, and 6-inch cement-treated subgrade. The research team performed TxME analyses on FM 468, considering both pavement performance (rutting and fatigue cracking) and initial construction cost. Pavement performance under various combinations of layer thickness, asphalt mix type, binder types, and RAP percentage were analyzed, as shown in Figure 39. Based on pavement performance and initial construction cost (Figure 40), the following pavement design is recommended:

- Surface: 2-inch SP-C with PG 76-22 + 3-inch SP-B with PG 64-22 and 20 percent RAP + 3-inch SP-B with PG 70-22.
- Base: 8-inch flexible base (new material).
- Subgrade: cement treatment of the top 6 inches of existing subgrade.

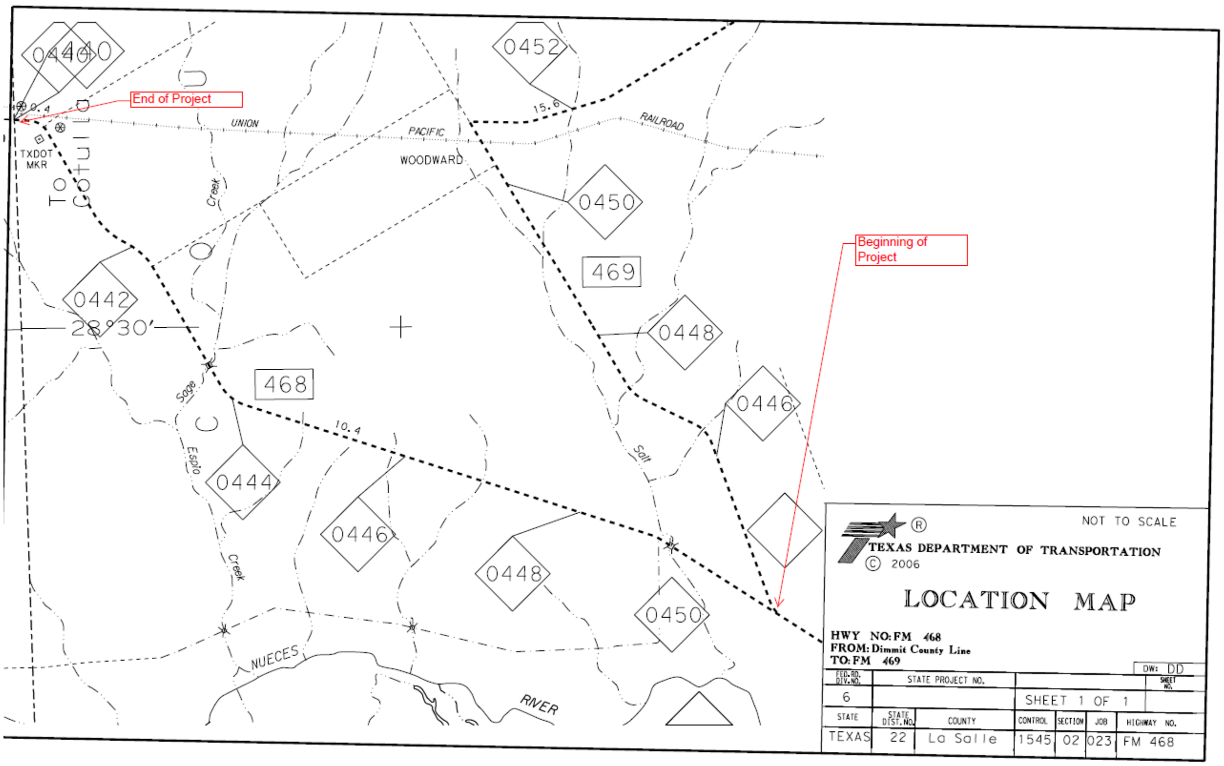


Figure 37. Location of FM 468 Project.

Figure 38. FM 468 Pavement Condition: Severe Wheel Path Fatigue Cracking.

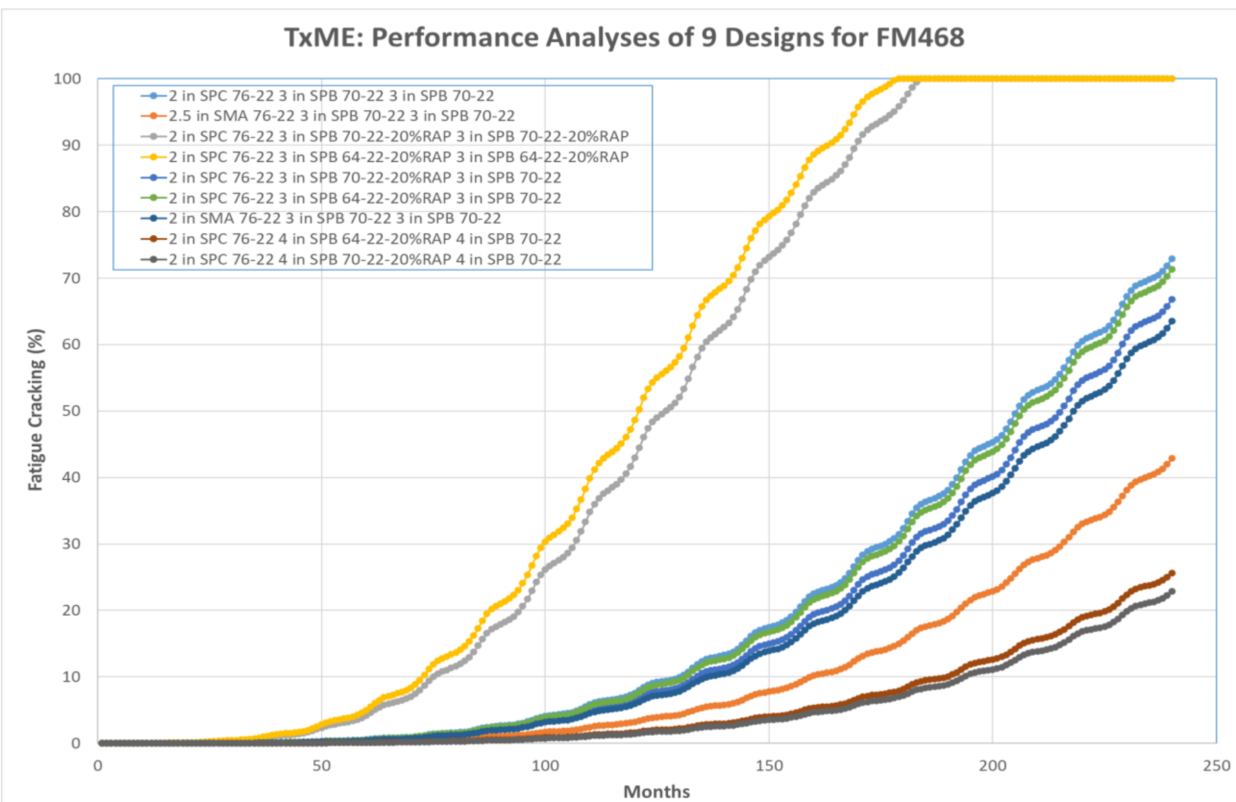


Figure 39. TxME Prediction: Fatigue Cracking Development with Time.

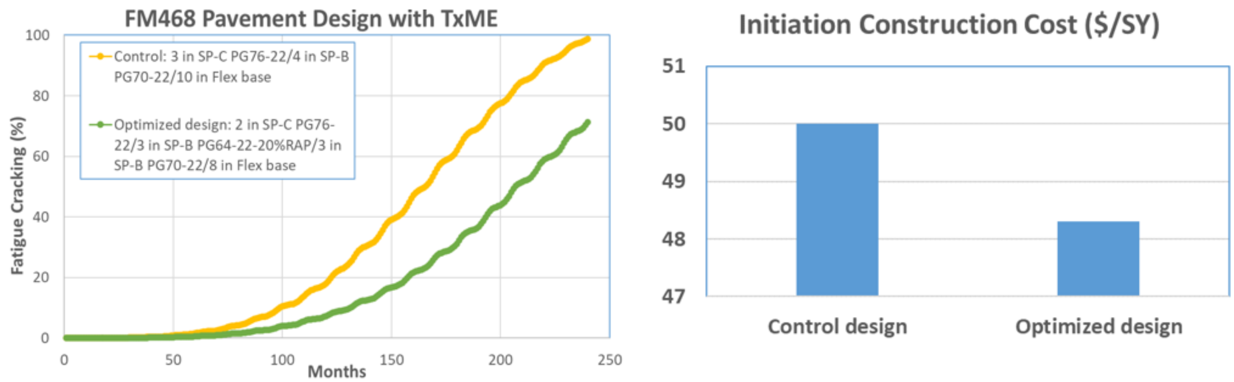


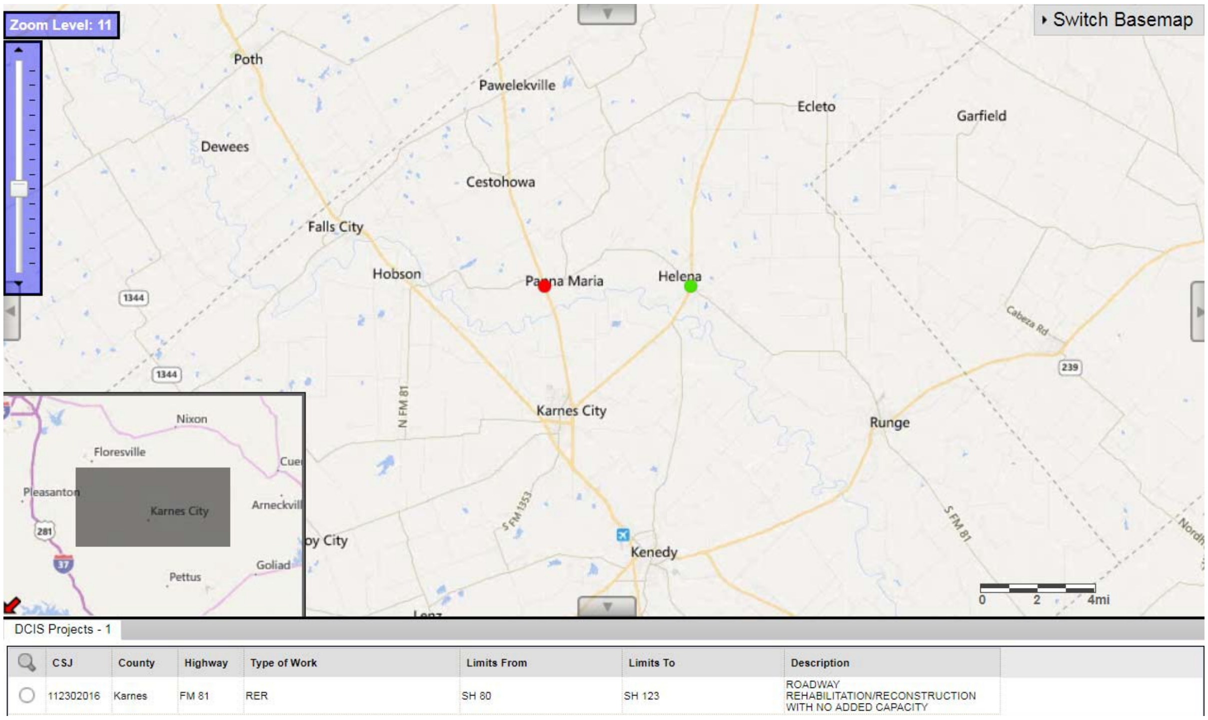
Figure 40. Comparison between the FPS 21 Design and the TxME Recommendation in Terms of Performance and Initial Construction Cost.

DESIGN SUPPORT TO CORPUS CHRISTI DISTRICT ON FM 81 FROM PANNA MARIA TO HELENA

The FM 81 project from Panna Maria to Helena in the Corpus Christi District is located in Karnes County between SH 123 and SH 80, as shown in Figure 41. The pavement is severely damaged (Figure 42) by oil-gas traffic. The current pavement structure is composed of a 1-inch asphalt layer over a granular base and subgrade. There is no portable WIM station available on FM 81. Instead, traffic classification was conducted in October 2019, and traffic count information is shown in Figure 43. The measured ADT in both directions was 1,333, which is not high, but the truck percentage was as high as 63 percent. Based on the collected traffic classification data with a default load distribution for traffic in the energy sector in TxME, the estimated 20-year 18-kip traffic is 7.5 million.

Based on the available information, the research team performed both FPS 21 and TxME design analyses on FM 81, considering rutting, fatigue cracking and construction cost, and elevation constraints. Figure 44 shows an example of TxME analysis in terms of fatigue cracking and initial construction cost. Finally, three pavement design options are recommended:

- For those areas without elevation limitation:
    - Surface: 2-inch SP-D + 4-inch SP-B.
    - Base: 8-inch cement-treated existing base and new base with a maximum 3 percent cement.
- For those areas with three 12-ft lanes and matching existing ground:
    - Surface: 3-inch SP-C + 4-inch SP-B.
    - Base: 8-inch lime-treated existing base/subgrade (a lab design is needed to determine the lime percentage).
- For those areas with two 12-ft lanes and matching existing ground:
    - Surface: 1.5-inch SP-D + 2.5-inch SP-C + 4-inch SP-B.
    - Subgrade: 8-inch lime-treated clay subgrade (a lab design is needed to determine the lime percentage).



CSJ	County	Highway	Type of Work	Limits From	Limits To	Description
112302016	Karnes	FM 81	RER	SH 80	SH 123	ROADWAY REHABILITATION/RECONSTRUCTION WITH NO ADDED CAPACITY

Figure 41. Location of FM 81 Project from Panna Maria to Helena.

Figure 42. FM 81 Pavement Condition: Severe Wheel Path Fatigue Cracking.

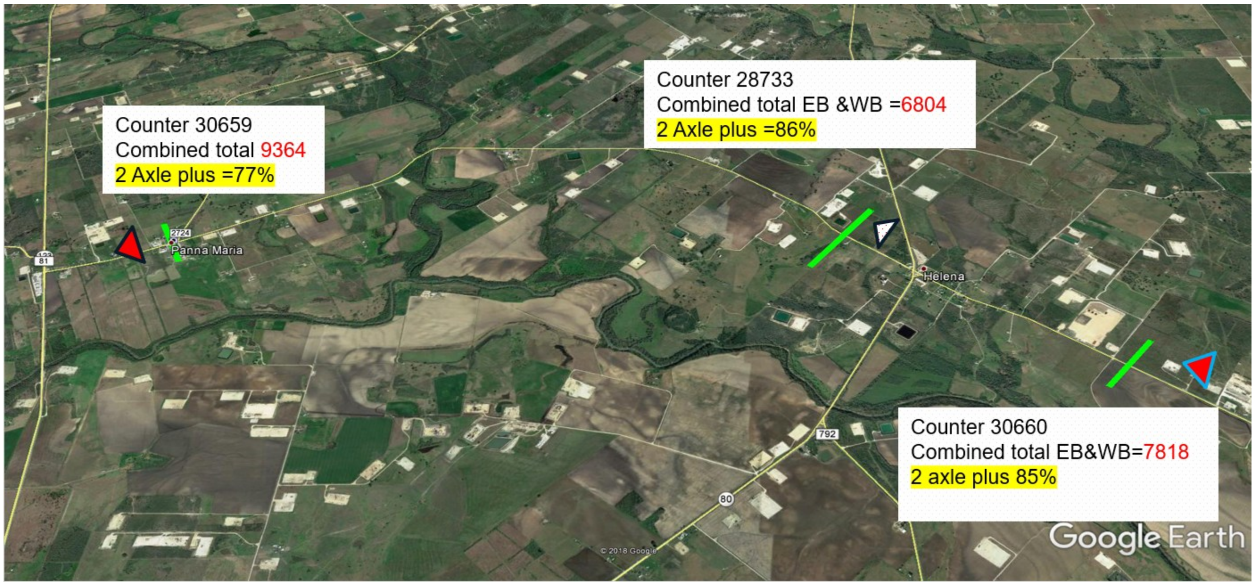


Figure 43. Traffic Classification Data on FM 81.

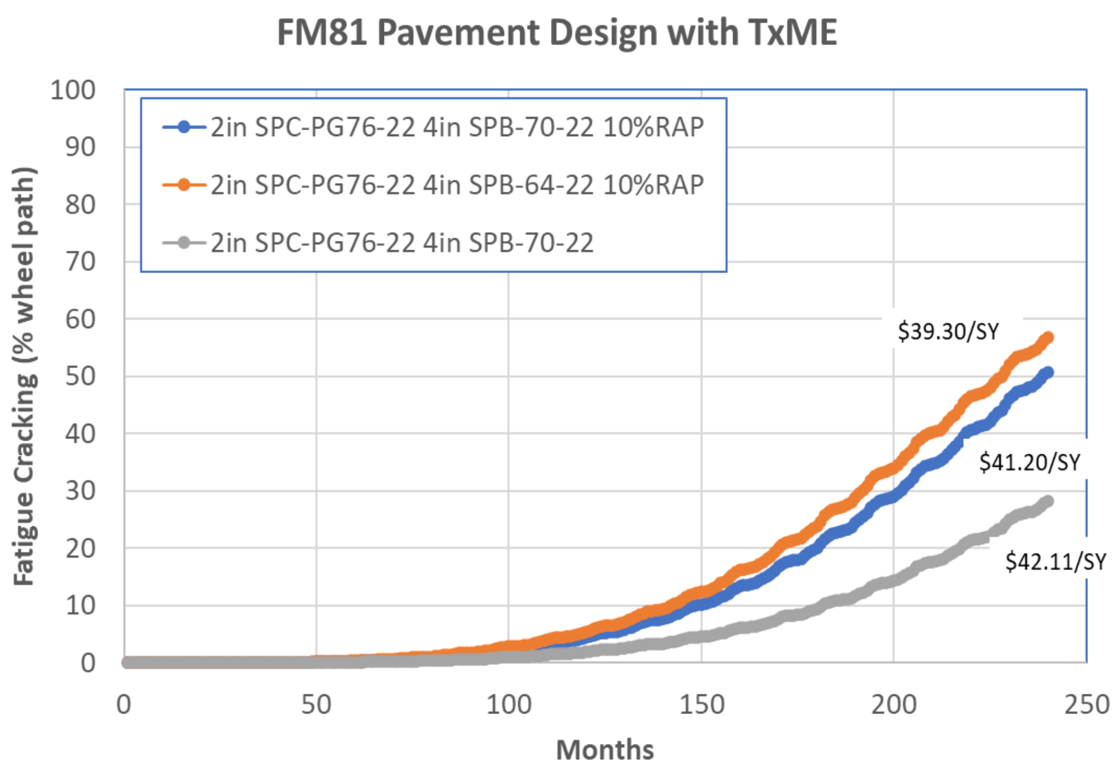


Figure 44. TxME Analyses of FM 81 Design Options.

DESIGN SUPPORT TO CORPUS CHRISTI DISTRICT ON FM 81 FROM HELENA TO RUNGE

The FM 81 project from Helena to Runge in the Corpus Christi District is located in Karnes County between SH 80 and US 72, as shown in Figure 45. Most of this part of FM 81 is a two-lane highway with a thin (about 1-inch thick) asphalt surface layer (Figure 46), but there is a short four-lane section (Figure 47) in the middle where a commercial plant is located. Different from the rest of the two-lane highway, the section with four lanes has a 4- to 6-inch thick asphalt layer that was recently paved. The same traffic estimation (7.5 million ESALs for 20 years) used for designing FM 81 from Panna to Helena was applied here for pavement design. The research team ran both FPS 21 and TxME design analyses, considering rutting, fatigue cracking and construction cost, and similar designs to FM 81 from Panna to Helena. Considering the existing pavement conditions and the consistency of future construction for FM 81 from Panna to Helena to Runge, the two design options listed below are recommended:

- For FM 81 with two lanes:
  - Surface: 2-inch SP-D + 4-inch SP-B.
  - Base: 8-inch cement-treated existing base and new base with a maximum 3 percent cement.
- For FM 81 with four lanes:
  - 2-inch SP-D overlay.

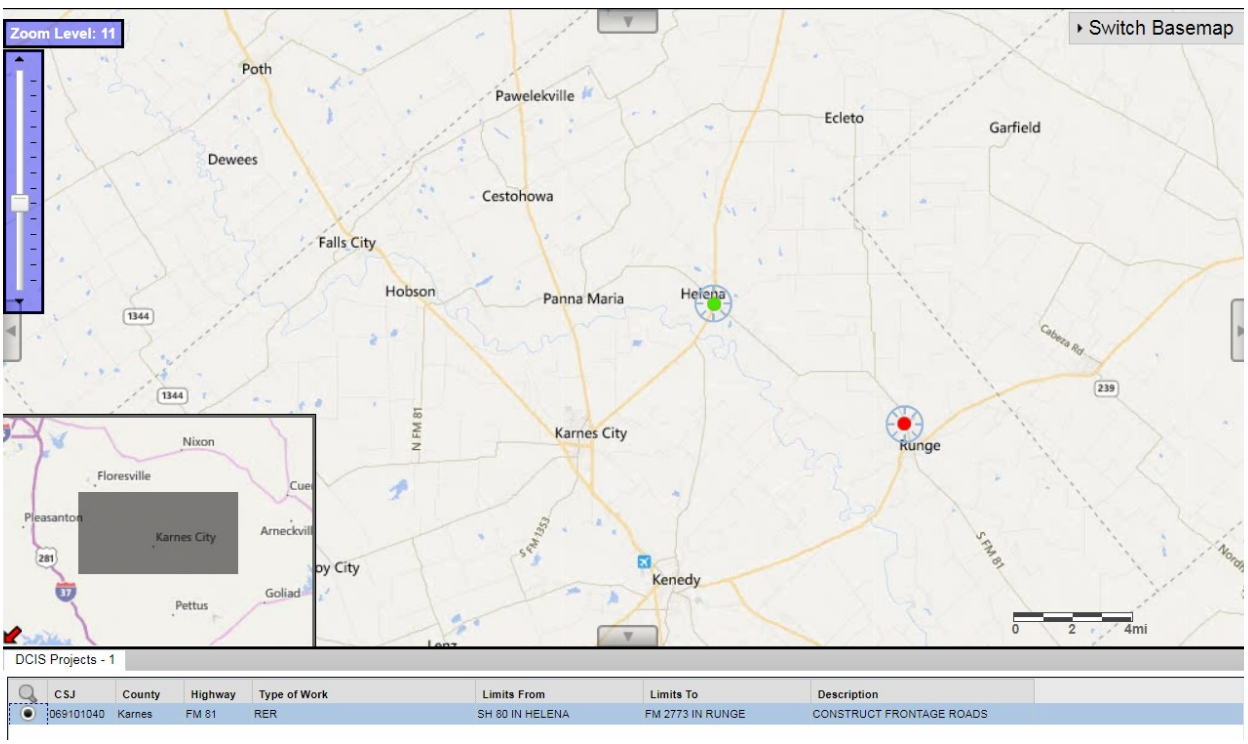


Figure 45. Location of FM 81 Project from Helena to Runge.

Figure 46. FM 81 from Helena to Runge: Two-Lane Section.

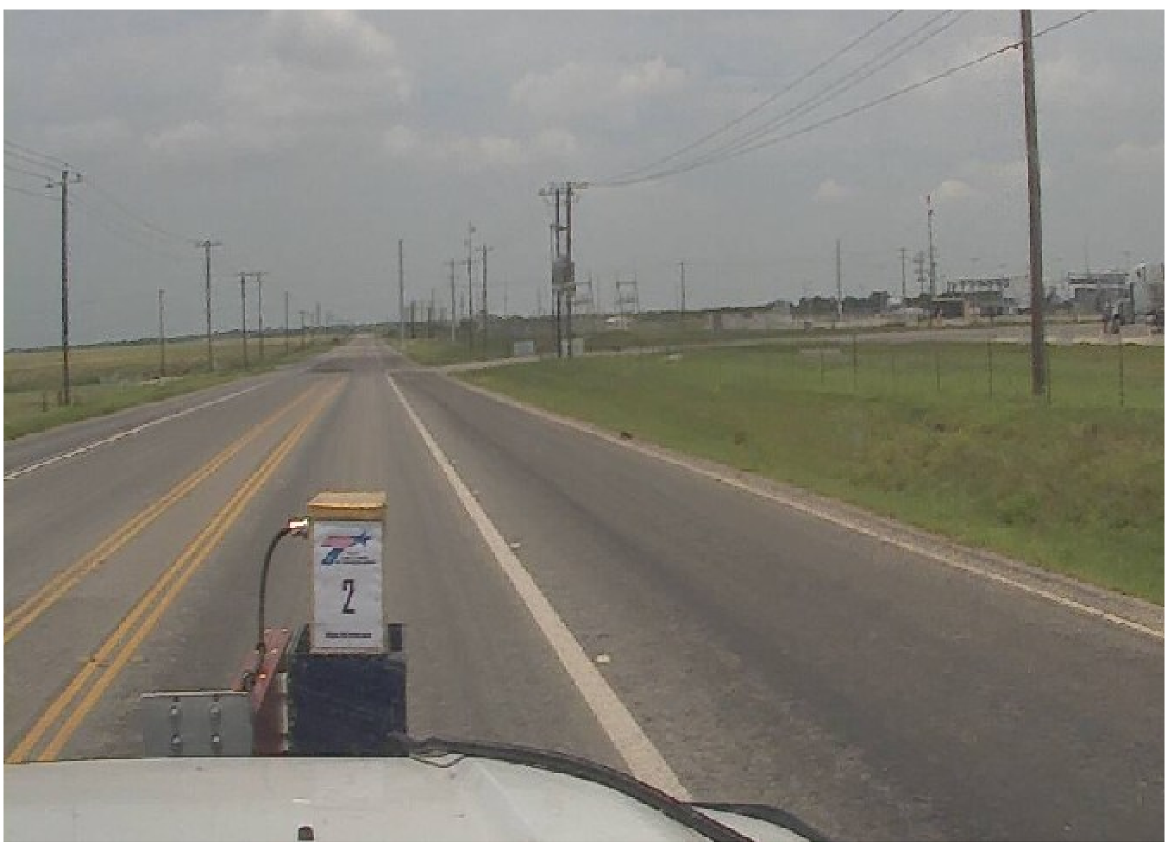


Figure 47. FM 81 from Helena to Runge: Four-Lane Section.

DESIGN SUPPORT TO ODESSA DISTRICT ON SH 18

The SH 18 project in the Odessa District is located in Ward County from south of West 26th Street in Monahans to south of FM 1776, as shown in Figure 48. Figure 49 shows the north and south ends of the project. SH 18 is a four-lane divided highway with a 3-inch asphalt surface layer, 10-inch granular base, and sandy subgrade. The backcalculated modulus for the subgrade is 17 ksi. The design support focused on pavement design and mix design, as described below.

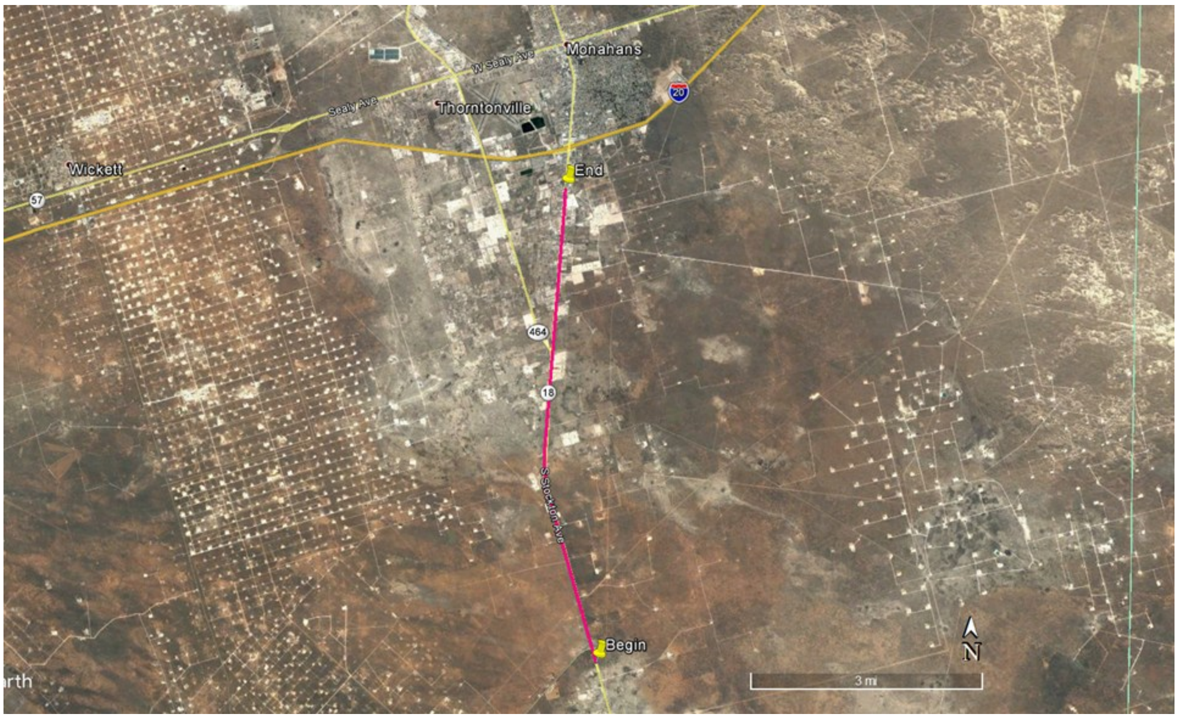


Figure 48. Location of SH 18 Project.

North End

South End

Figure 49. Views of SH 18.

Pavement Design

The estimated traffic information for the main portion of the project is as follows:

- ADT beginning: 8,400.
- ADT ending: 10,000.
- Percent trucks: 4.5.
- 20-year ESALs: 9.8 million.

The pavement design recommended from FPS 21 is to mill the top 3-inch asphalt layer, 9-inch FDR, and then 6-inch AC. Figure 50 shows the TxME analysis result of fatigue cracking development over time. The pavement structure can perform adequately for 10 years before needing a new 2-inch asphalt overlay.

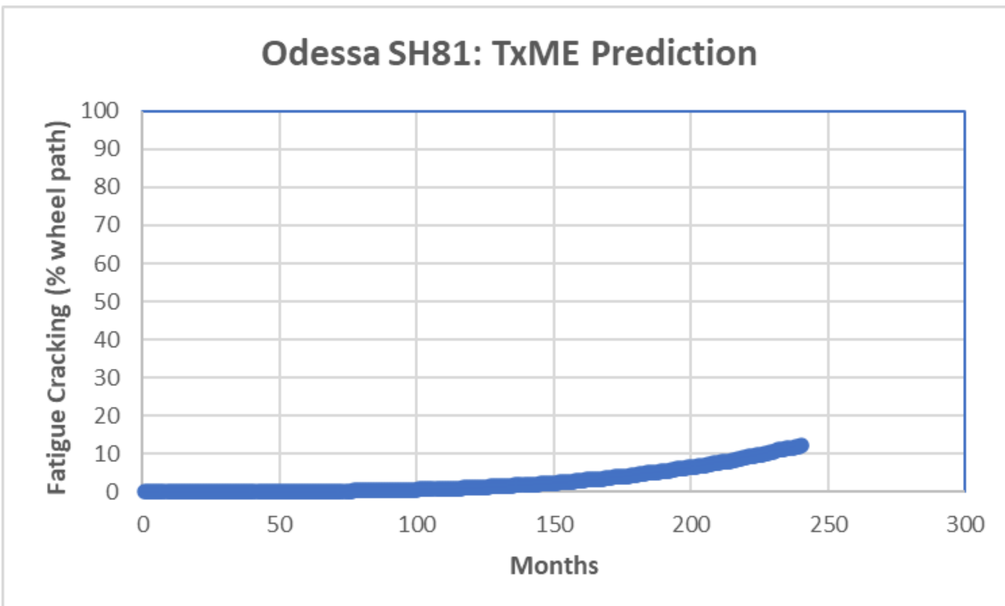


Figure 50. TxME Prediction of SH 18, Odessa.

Mix Design

The research team obtained the base materials from SH 18. The PI of the granular base is around 10. The lab dry density curve with 3 percent cement is shown in Figure 51. Next, the research team performed mix design for cement-treated base with small samples, as described below:

- Compact samples in Superpave gyratory compactor (or Texas gyratory compactor) to +/− 0.3 percent of OMC and +/− 1 pcf of max density.
- For cement, keep 7 days in sealed bag in moisture room.
- After drying, submerge three samples completely in water for 24 ± 1 hr.
- Place remaining three samples in air for 24 ± 1 hr.

- Determine IDT in accordance with Tex-226-F.
- Record IDT strength (psi).

The research team evaluated UCS per Tex-120-E and IDT strength at 2, 3, 4, and 6 percent. Figure 52 and Figure 53 show the UCS and IDT test results. As Figure 52 and Figure 53 illustrate, 2 percent cement is adequate to meet both UCS and IDT strength requirements.

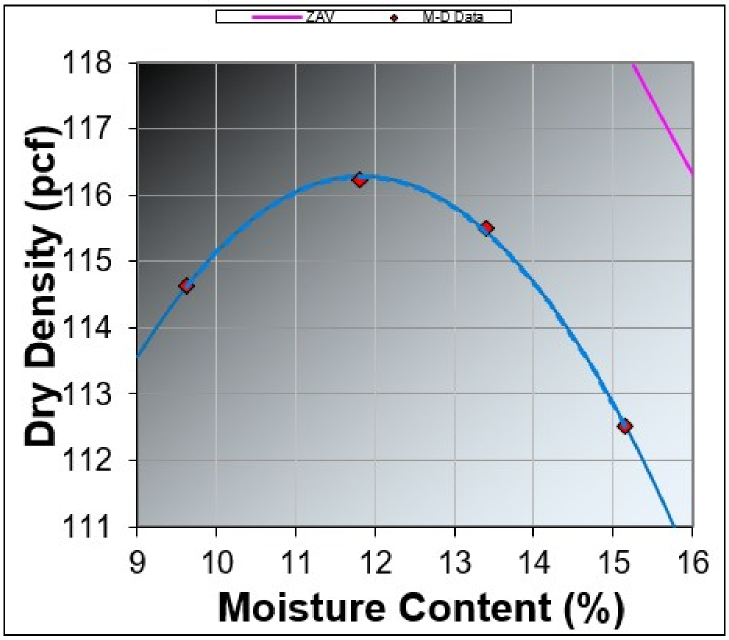


Figure 51. Moisture-Density Curve for SH 18 Base Material.

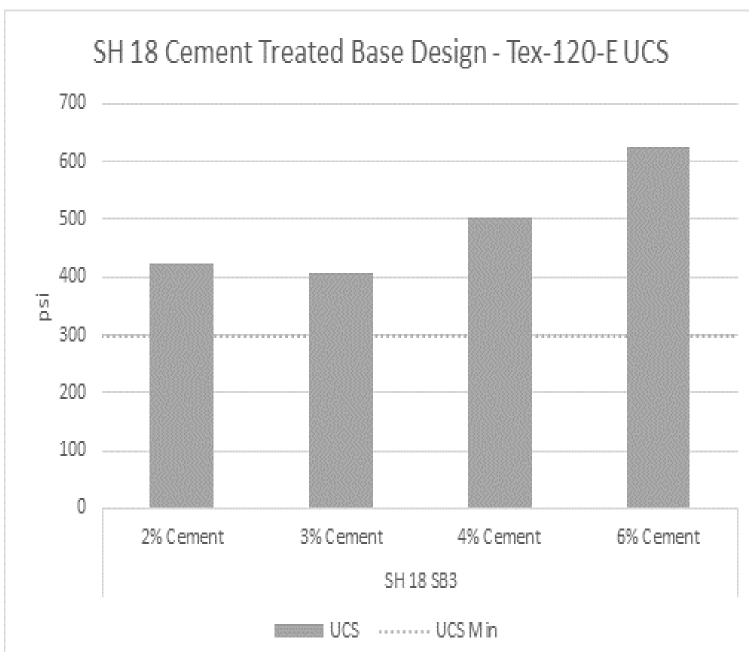


Figure 52. UCS Test Results of SH 18 Base with Four Different Cement Contents.

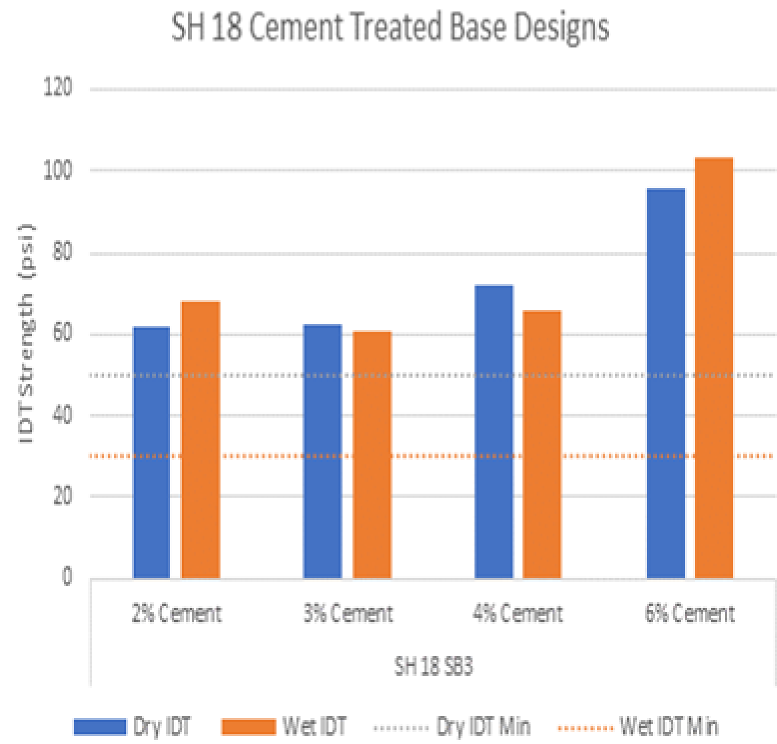


Figure 53. IDT Test Results of SH 18 Base with Four Different Cement Contents.

DESIGN SUPPORT TO AUSTIN DISTRICT ON FM 20

The FM 20 project in the Austin District is located in Bastrop County and runs from the Caldwell County Line to SH 21, for a length of 15 miles. The project location is shown in Figure 54. The current pavement structure is composed of a 2- to 4-inch asphalt layer, granular base with varying thickness, and subgrade. The overall pavement condition is satisfactory except for the first 0.5 miles close to the Caldwell County Line. As shown in Figure 54, there are numerous wells (green dots) around the Caldwell County Line. Thus, the research team focused on pavement design for the first half mile of FM 20 in Bastrop County, where the pavement has considerable fatigue cracking (Figure 55). Thus, a major rehabilitation is warranted.

The estimated total ESAL-associated energy activities are around 15.9 million, as listed below:

- Accumulated ESALs for construction: 11.5 million.
- Accumulated ESALs for production: 4.4 million.

Based on the estimated traffic information, the research team performed FPS 21 and TxME analyses, considering rutting, fatigue cracking, and initial construction cost. Finally, the following pavement design is recommended.

- Surface: 2-inch SP-C with PG 76-22 + 4-inch SP-B with PG 64-22 and 20 percent RAP + 3-inch SP-B with PG 70-22.

- Base: 8-inch flexible base (new material).
- Subgrade: cement treatment of the top 6 inches of existing subgrade.

Figure 56 shows the corresponding fatigue cracking development predicted by TxME.

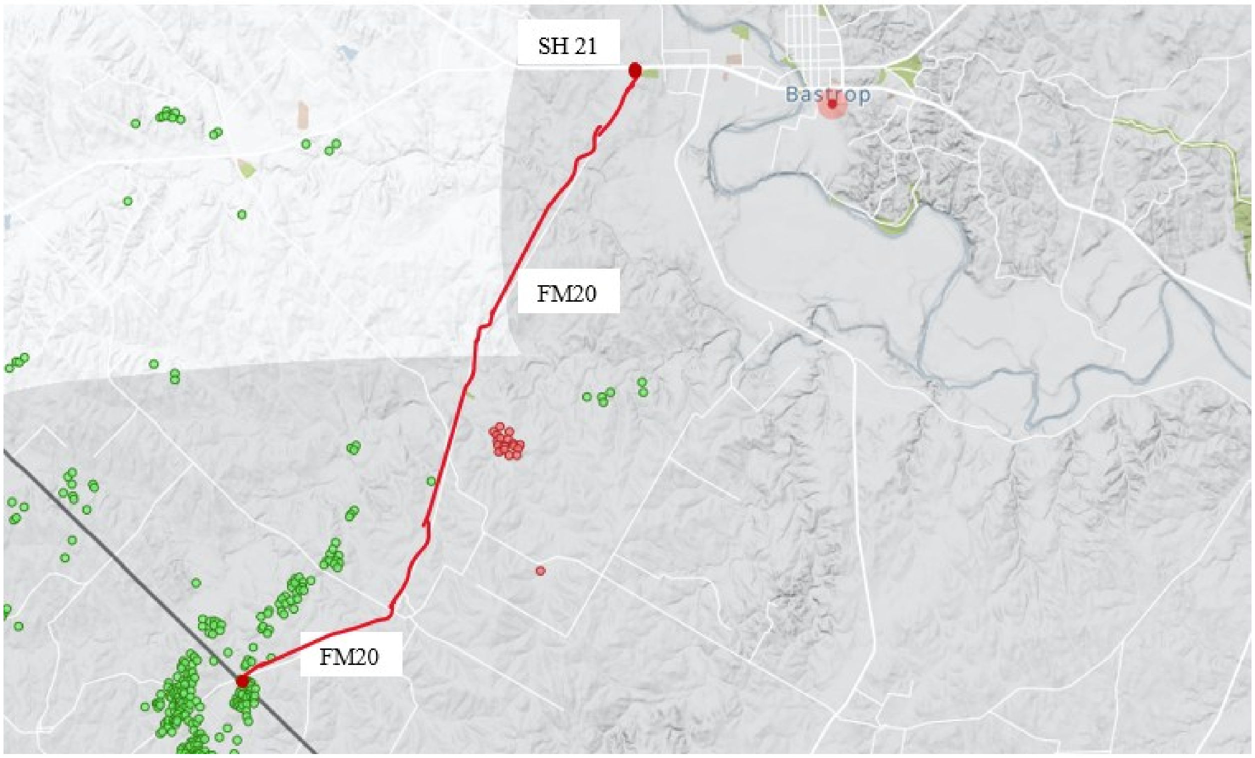


Figure 54. Location of FM 20 Project.

Figure 55. Severe Fatigue Cracking at the Beginning of FM 20.

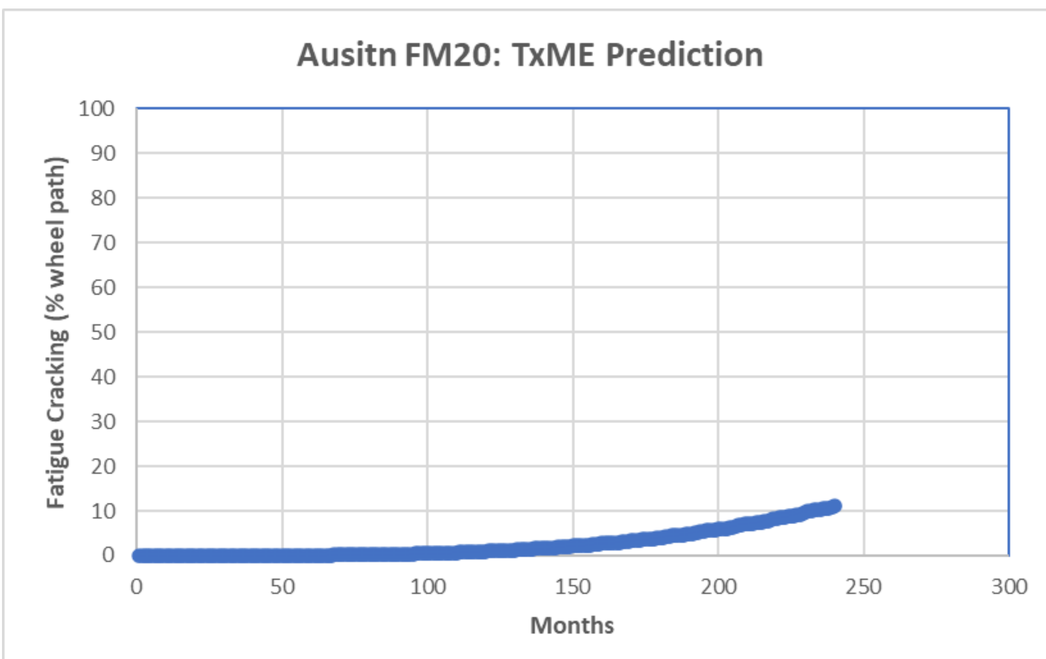


Figure 56. TxME Prediction of FM 20, Austin.

CHAPTER 5. FIELD PERFORMANCE OF PREVIOUS FDR PROJECTS

INTRODUCTION

A total of five projects constructed with FDR option for FM roads, SHs, and IHs under previous research project 0-6839. The chapter presents the field performance of these five FDR projects.

FM 541 PROJECT

The FM 541 project is located in the San Antonio District (as shown in Figure 57) and is a rehabilitation project. The project includes excavating the subgrade and preparing the subgrade, placing a salvaged base treated with lime and adding 12 inches of new flexible base, and performing a two-course surface treatment.

Figure 57. Location of FM 541 Project.

Pavement Design and Construction

A portion of the project implemented FDR with foamed asphalt. Table 16 presents the traffic inputs for the FPS 21 design. Figure 58 presents the FPS 21 pavement design for FM 541.

Table 16. Traffic Inputs for FM 541 in FPS Design.

Design period (years)	20
ADT_beginning	1,033
ADT_ending	1,440
Total ESAL (million) after 20 years	2.4
Percent of trucks	30.9
Surface treatment modulus (ksi)	200
Modulus of stabilized base with foamed asphalt	300
Modulus of subgrade	7

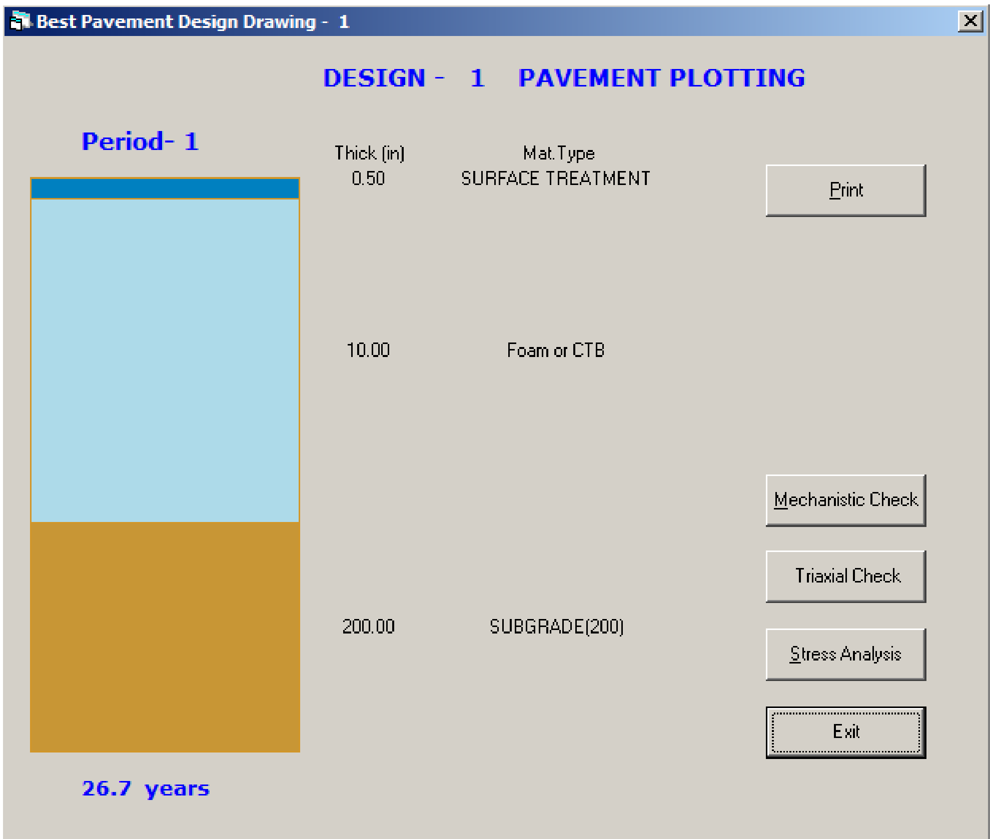


Figure 58. Pavement Design for FM 541.

The western portion of the project was suitable for FDR and constructed using 2.4 percent of foamed asphalt and 1 percent of cement for a 10-inch treatment depth. Figure 59 presents the construction sequence. The section was completed in October 2015.

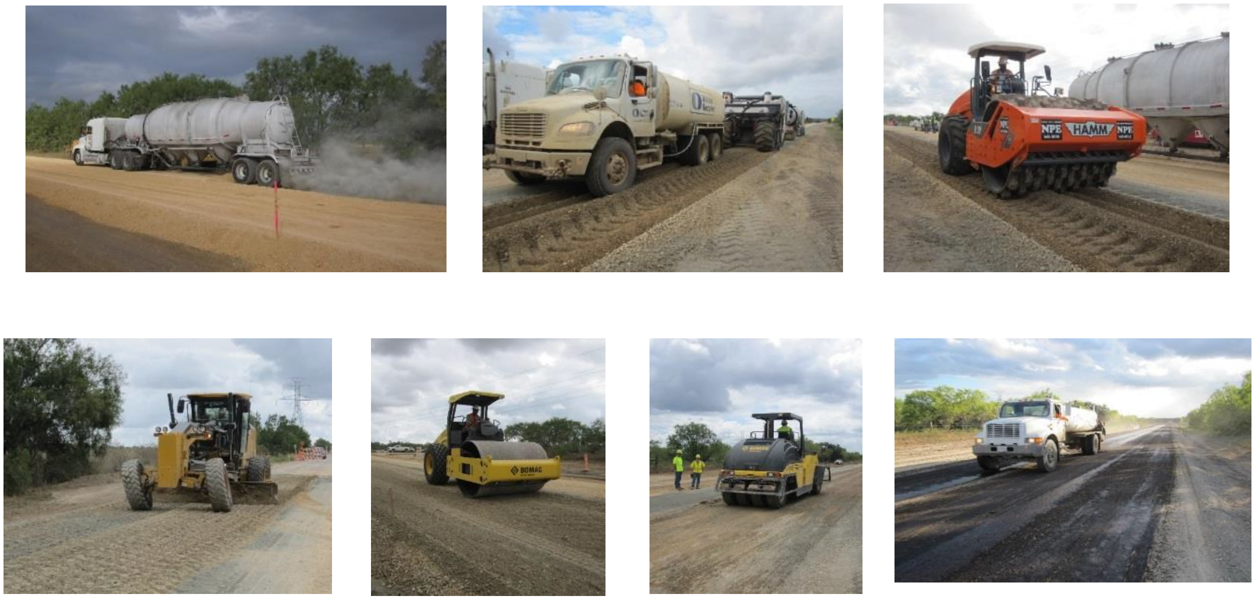


Figure 59. Typical Construction Sequence.

Field Performance Monitoring

After construction, the field survey was conducted four times: September 12, 2017; November 6, 2019; April 22, 2021; and November 26, 2021. Neither cracking nor rutting was observed after two years in September 2017. The first crack was observed in November 2019, and some rutting was observed in one spot. However, the pavement performed well after four years of service. In 2021, the research team surveyed the section twice, and the cracking distress deteriorated rapidly, as shown in Figure 60. Furthermore, the pavement rutted significantly as well, specifically in those fatigue cracking areas. Another asphalt overlay is needed to further support the heavy traffic loads on this roadway in the energy sector.

(a) Cracking Observed in 2019 (b) Cracking Observed in 2021

Figure 60. Pictures of Pavement Surface Cracking on FM 541.

SH 202 PROJECT

The SH 202 project is located in the Corpus Christi District and runs from US 181 to US 183. Figure 61 shows the location.

Figure 61. Location of SH 202 Project.

Pavement Design and Construction

A total of 5 million ESALs was assumed for traffic input for pavement design. The moduli of the stabilized FDR layer, flexible base, and surface treatment were 150 ksi, 40 ksi, and 200 ksi, respectively. The final pavement design chosen by TxDOT was FDR treatment of 10 inches with 3 percent cement and then 6 inches of new flexible base with a three-course surface treatment.

The project was constructed from spring 2016 through fall 2016. Figure 62 shows the construction sequence on SH 202.

Figure 62. Construction Sequence on SH 202.

Field Performance Monitoring

The first field survey was conducted in September 2017, one year after construction. No cracks were observed in the pavement, but some rutting of around 5.2 mm was measured. Another survey was performed in November 2019. The overall pavement condition was very similar to that in September 2017, except that more rutting was measured, as shown in Figure 63. When the research team conducted another survey in April 2021, the test section was paved over. Thus, no further performance survey has been conducted.

Figure 63. Picture of Pavement Rutting on SH 202.

I-10 PROJECT

The I-10 project is located in Reeves County, as shown in Figure 64. A soil survey, GPR, and FWD prior to construction were not performed.

Figure 64. Location of I-10 Project.

Pavement Design and Construction

The pavement design consisted of 7 inches of flexible base to remain in place, 9 inches of emulsion-treated base, and 4 inches of HMA with modulus values of 35, 250, and 500 ksi, respectively. The modulus of subgrade was assumed as 22 ksi. For the FDR layer, 4.5 percent asphalt emulsion and 1 percent cement were used. Construction was completed in winter 2016.

Field Performance Monitoring

The field survey was conducted in September 2017, one year after construction. No cracking but some rutting was observed, as shown in Figure 65. The average rutting depth measured was 6.4 mm in September 2017. When the research team surveyed the section again in November 2019, it was overlaid with a new asphalt surface. Thus, the performance survey was terminated.

Figure 65. Pavement Surface Rutting on I-10.

SH 7 PROJECT

The SH 7 project is located in the Bryan District, as shown in Figure 66.

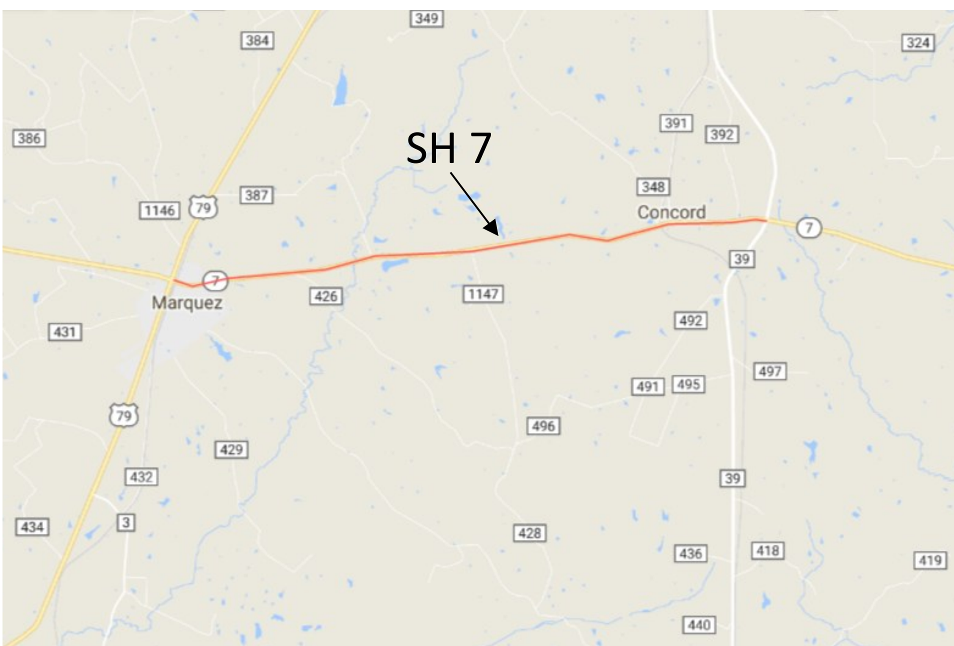


Figure 66. Location of SH 7 Project.

Pavement Design and Construction

A total of 5.8 million ESALs was assumed for traffic input for pavement design. The foamed, stabilized base modulus was assumed as 300 ksi. The pavement design included a 0.5-inch surface treatment, 10-inch FDR treatment, and 4-inch subbase. A 10-inch FDR treatment included two sections: one used 2.4 percent foamed asphalt with 1 percent cement, and the other used only 2.4 percent foamed asphalt. The project was constructed in August 2016.

Field Performance Monitoring

Four field surveys have been conducted on SH 7 since the completion of the construction in 2016. The pavement section with FDR on SH 7 performed very well six years after construction. There was no cracking or rutting observed in the last survey on October 26, 2021 (Figure 67).

(a) (b)

Figure 67. SH 7 Pavement Surface: (a) Cracking and (b) Rutting.

FM 99 PROJECT

FM 99 is an extremely heavily trafficked energy development roadway in the Corpus Christi District of Texas; the limits of this project are from US 281A to the McMullen County Line. The original plans stated that the roadway is 24 ft wide and has 1 inch of asphaltic materials as a surface layer and 6 inches of flexible base material. Figure 68 shows the location of the project.

Figure 68. Location of FM 99 Project.

Pavement Design and Construction

The pavement design information was not available, but the project consisted of three FDR treatments: foamed asphalt treatment (11 inches), cement treatment (11 inches), and cement treatment (8 inches) with 6 inches of flexible base overlay. The FDR layer was treated with 2.4 percent foamed asphalt and 1.5 percent cement. All the foamed work was completed in June 2014.

Field Performance Monitoring

Four field surveys have been conducted since the completion of the construction: in September 2017, November 2019, April 2021, and October 2021. During the first survey in September 2017, longitudinal cracking was spotted, as shown in Figure 69a. Also, an average rutting depth of 4.0 mm (Figure 69b) was measured. In the last survey, more transverse cracking (Figure 70) was observed. The rutting did not progress much.

Figure 69. FM 99 Pavement Surface in September 2017: (a) Cracking and (b) Rutting.

Figure 70. FM 99 Pavement Condition in October 2021: Transverse Cracking.

CHAPTER 6. CONCLUSIONS AND RECOMMENDATION

CONCLUSIONS

Based on the research presented in this report, the following conclusions are made:

- Total ESAL for a design period calculated from the traditional method (i.e., using the equation based on ADT) is much lower than that calculated from the TxME load spectra, which means the total ESAL is significantly underestimated when using the traditional methodology. This is specifically true for FM roads in the energy development areas. Although new truck factors could be developed for different highways, load spectrum data should be directly used for pavement designs.
- The six-step pavement rehabilitation and pavement design strategy and associated nondestructive testing tools should be used for rehabilitating the severely damaged roads in the energy development areas.
- The FPS 21 and TxME check can provide TxDOT pavement engineers with adequate pavement designs to support overloaded heavy traffic in the energy development areas.
- Pavement designs of five field projects in four different districts were developed using both FPS 21 and TxME, considering both field performance and initial construction cost.
- Overall, field projects with FDR performed well. Some sections with two course surface treatments had some early failures due to heavy traffic loads in the energy development areas.

RECOMMENDATION

A combination of FPS 21 and TxME should be implemented when designing pavements for the energy development areas.

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