



Designing Pavements to Support the Heavy Loads in the Energy Development Areas

Technical Report 0-6839-P1 & P2

Cooperative Research Program

TEXAS A&M TRANSPORTATION INSTITUTE
COLLEGE STATION, TEXAS

in cooperation with the
Federal Highway Administration and the Texas
Department of Transportation
<http://tti.tamu.edu/documents/0-6839-P1-P2.pdf>

TxDOT Project 0-6839
Workshop:
**Designing Pavements to Support
the Heavy Loads in the Energy
Development Areas**

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Texas A&M Transportation Institute

Project 0-6839 Research Team

Austin, Tx; February 26, 2018

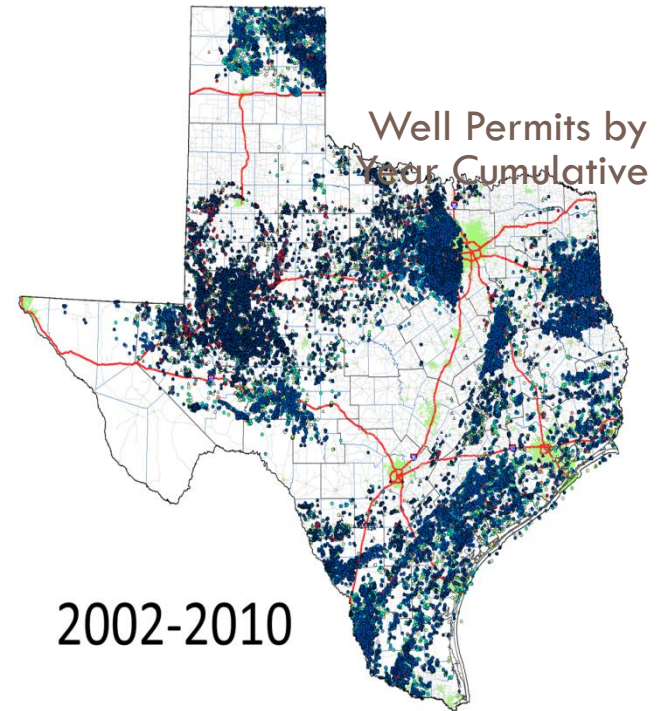
Outline

- Project overview and objectives
- Concrete pavement options
- Flexible pavement options
- Implementation plan

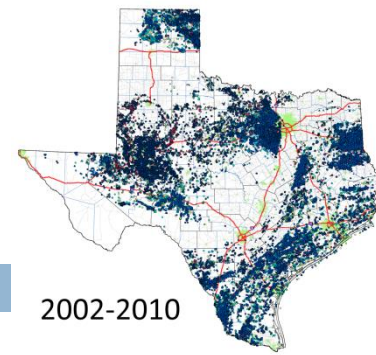


Project Overview

- Energy development areas
 - ▣ Heavy traffic and sever failure



Project Overview



- “Features” and challenges of pavement design
 - ▣ Early opening requirements (**no detours; end of day**)
 - ▣ Weak/thin existing materials (**most FM roads**)
 - ▣ Excessive traffic loads (**50-60% overload**)
 - ▣ Available funds (**limited fund vs. miles and miles**)

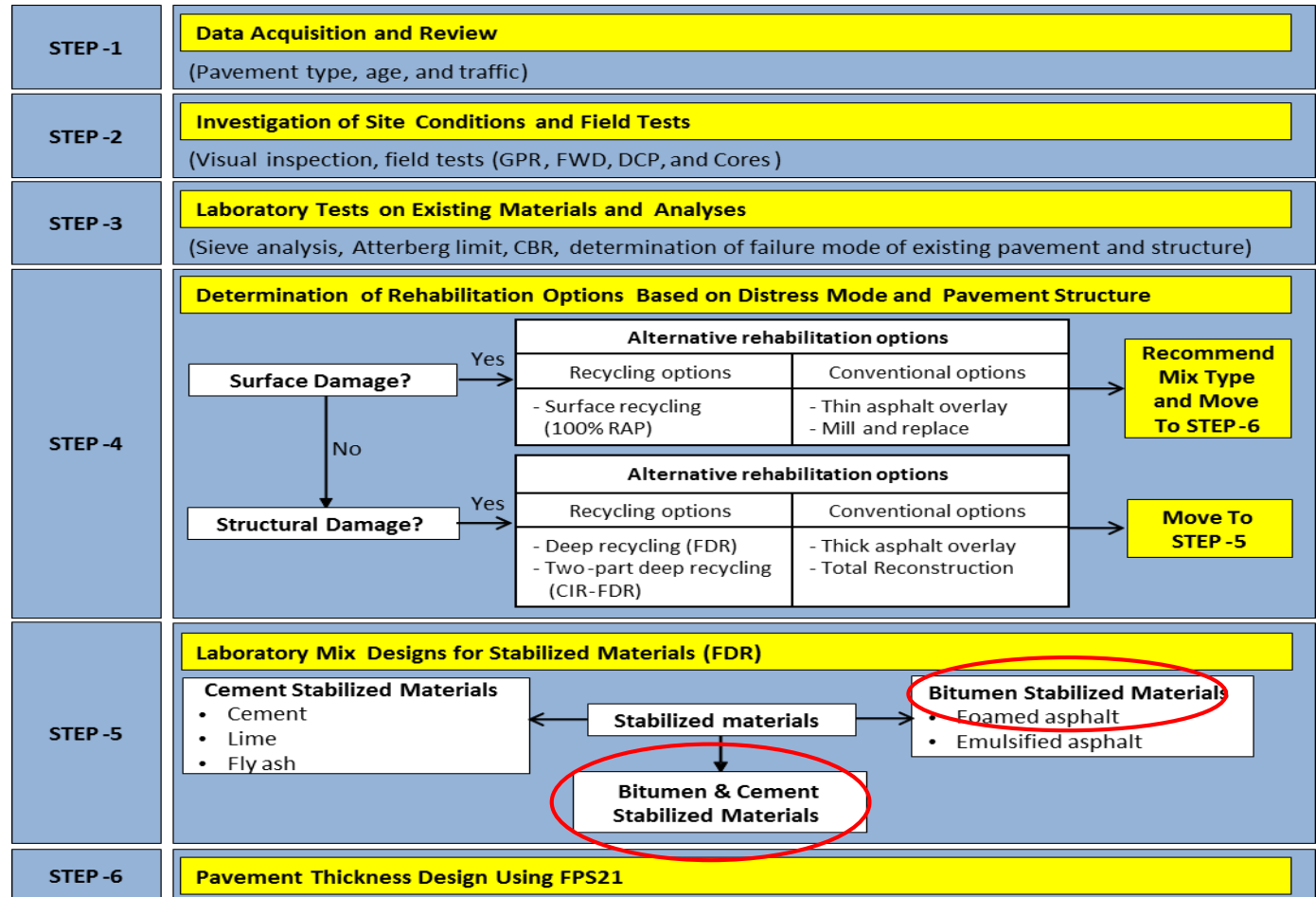
Project Main Objectives



- Develop materials options suitable for early trafficking
- Recommend pavement designs that are structurally adequate for overloaded vehicles
- Work with Districts to design, construct, and monitor test sections with new materials and design approaches

Selecting rehabilitation options

□ 6 steps



Selecting rehabilitation options: case study

Material Collection and Laboratory Test (Step-3)



Sieve Analysis / Plastic Index / Proctor Test

Gradation % Passing		
Sieve	Existing Base	New Base
1 3/4 "	100	100
1 1/4 "	99.0	95.4
3/4 "	90.5	78.5
3/8 "	66.0	57.7
# 4	55.3	44.1
# 40	29.0	28.2
Plasticity Index	7	4
Combined Materials	OMC (%)	Dry Density (pcf)
75% Existing Base & 25% RAP	5.4	133.0
42% Existing Base, 33% New Base, & 25% RAP	6.0	131.1

Selecting rehabilitation options: case study

Rehabilitation Method Selection (Step-4): We select FDR for this study

Laboratory Mix Designs on FDR Mixes (Step-5)

Design #	Material %	%RAP	Foamed % (PG64-22)	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

8 FDR Mixes



Moisture Conditioning



Design #	Material %	%RAP	Foamed % (PG64-22)	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

Selecting rehabilitation options: case study

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Selecting rehabilitation options: **case study**

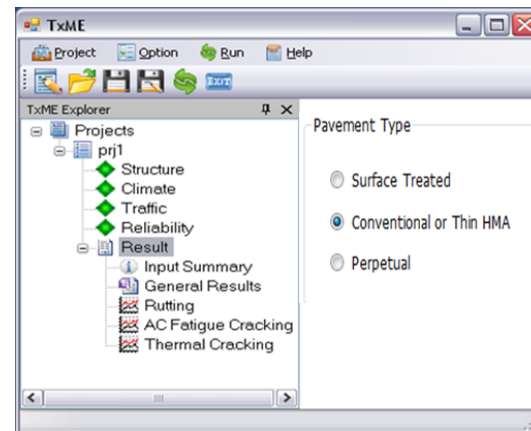
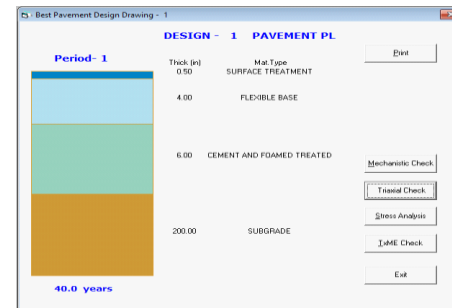


Pavement Thickness Design using FPS 21(Step-6)

	FM 99	FM 906	FM 541
AADT (2015)	3,352	904	697
Future AADT (2035)	6,710	1,810	1,400
Truck Percent (%)	4.9	4.3	22.8
Speed Limit (MPH)	60	55	55
Number of Lanes	2	2	2
18 kip ESAL for 20-year (millions)	1.144	0.271	1.111
Variables used for ESAL calculation	Design years=20 Dir. Distribution=0.5 Lane Distribution=1.0 Growth Rate (%)=3.50 Truck Factor= 1.35	Design years=20 Dir. Distribution=0.5 Lane Distribution=1.0 Growth Rate (%)=3.53 Truck Factor= 1.35	Design years=20 Dir. Distribution=0.5 Lane Distribution=1.0 Growth Rate (%)=3.54 Truck Factor= 1.35
Subgrade Modulus (ksi)	19.5	10	14.3

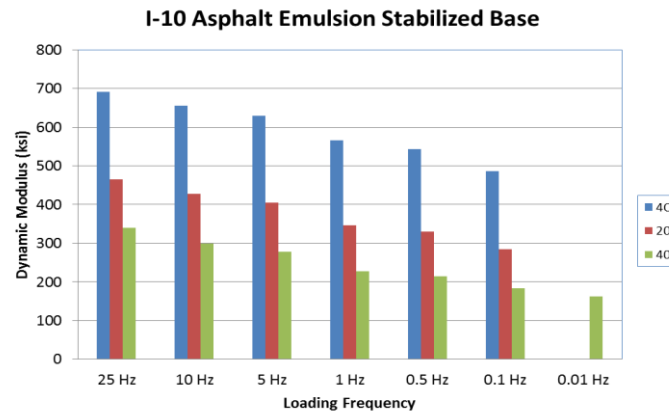
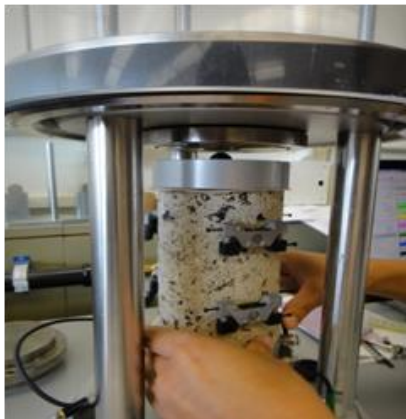
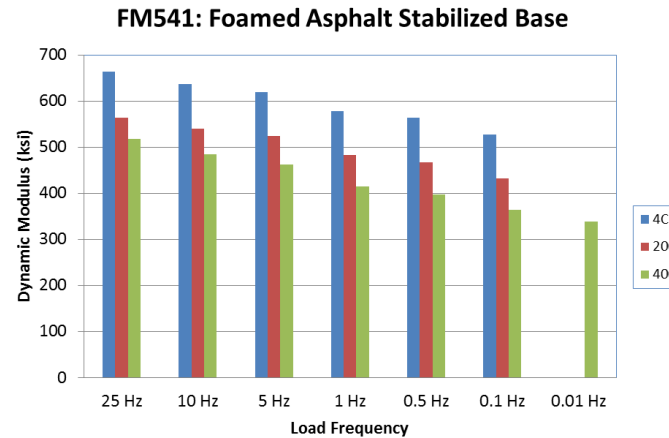
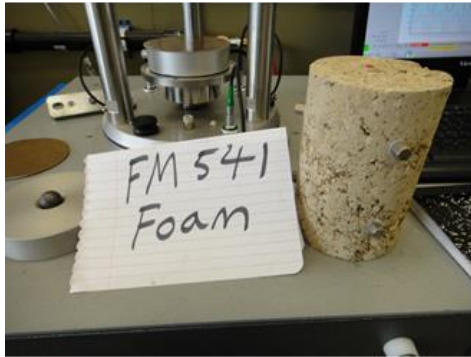
Pavement structural design

- FPS21
 - Modulus
 - Traffic: ESALs
 - Design life
- Texas Triaxial check
 - One pass shear failure
- TxME check
 - Load spectra
 - Rutting
 - Cracking



Pavement structural design

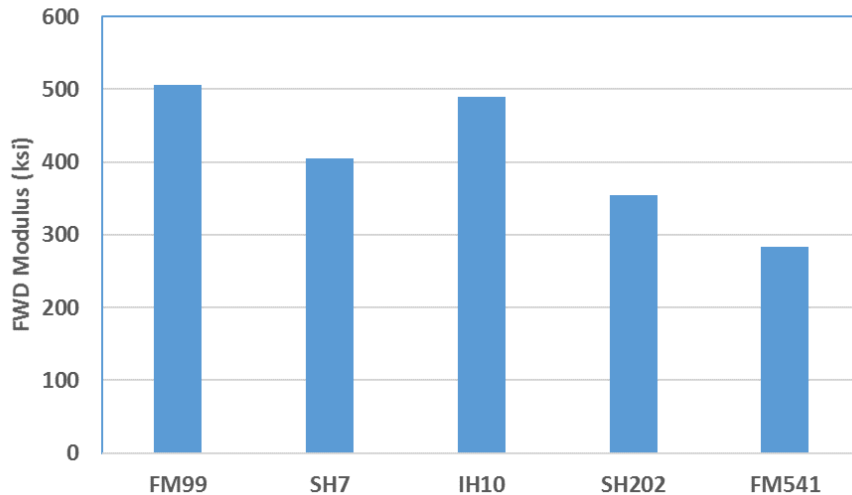
□ FDR materials moduli: laboratory measurement



Pavement structural design

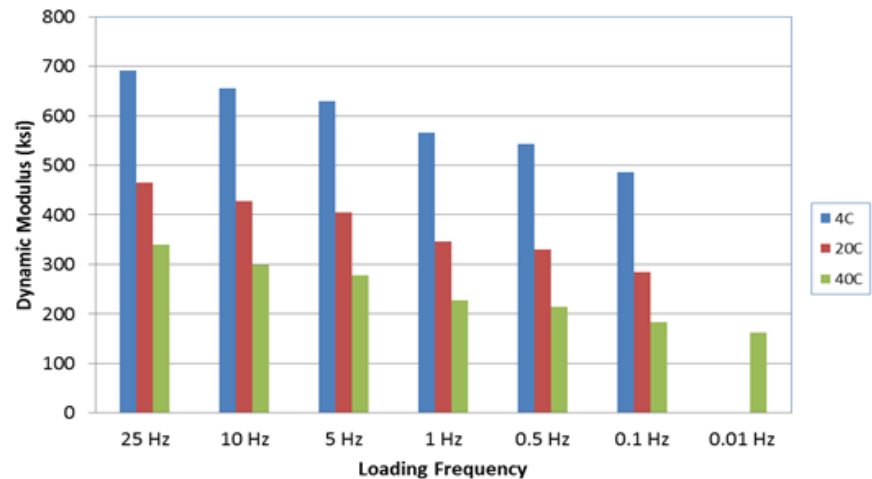
□ FDR materials moduli: lab vs. FWD (field)

Field Modulus



Recommended modulus:
300 ksi











I-10 Asphalt Emulsion Stabilized Base



Pavement structural design

- Traffic: load spectrum; Case study: FM468

Vehicle Class Distribution & Growth

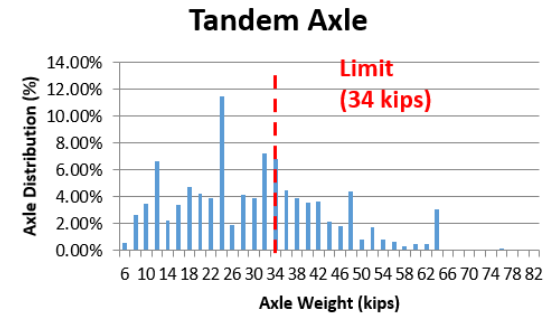
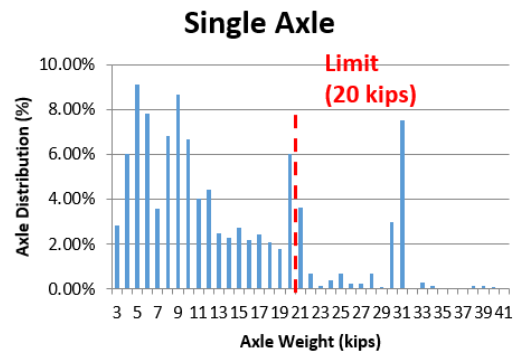
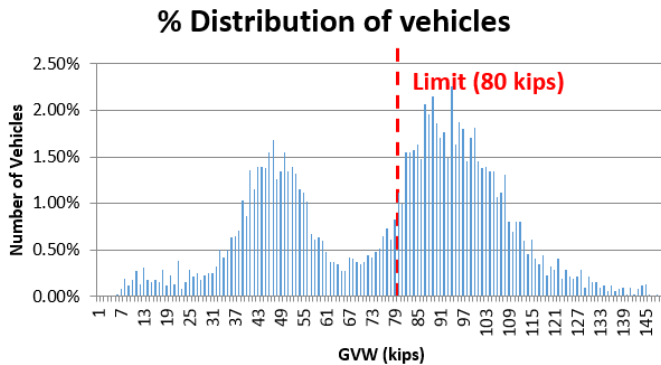
Vehicle Class	Pictorial View	Distribution (%)
Class04		0.94
Class05		3.24
Class06		2.87
Class07		0.40
Class08		2.51
Class09		86.88
Class10		2.97
Class11		0.00
Class12		0.08
Class13		0.11
Sum of Distribution =		100.00%

Pavement structural design

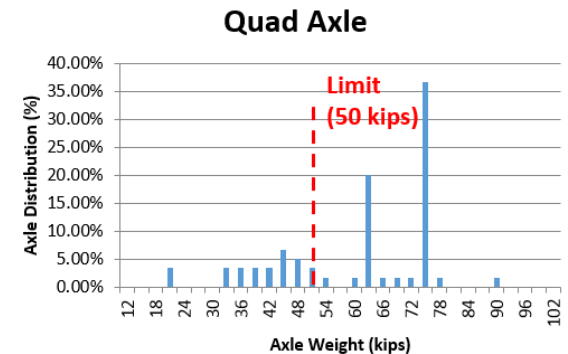
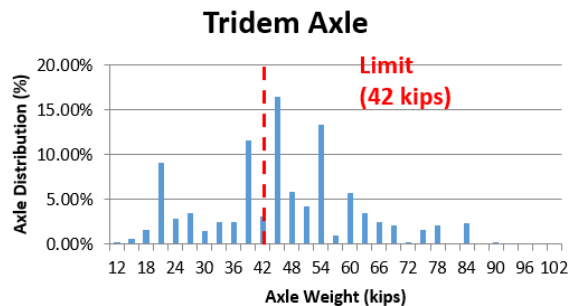
Traffic: load spectrum; Case study: FM468

GVW & Axle Load Distribution

Portable WIM | 16-Days Traffic Data Collection | GVW = Gross Vehicle Weight



Axle Type	Daily Count
Steering Axles	326
Non-steering Single Axles	32
Tandem Axles	588
Tridem Axles	10
Quad Axles	2

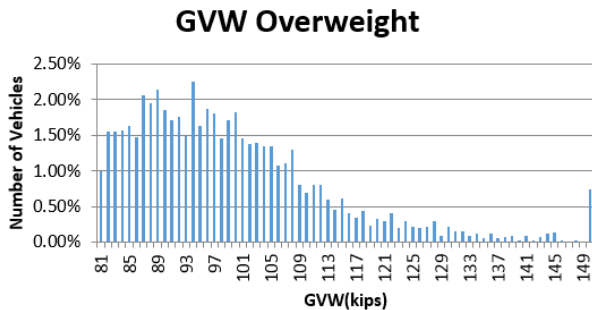


Pavement structural design

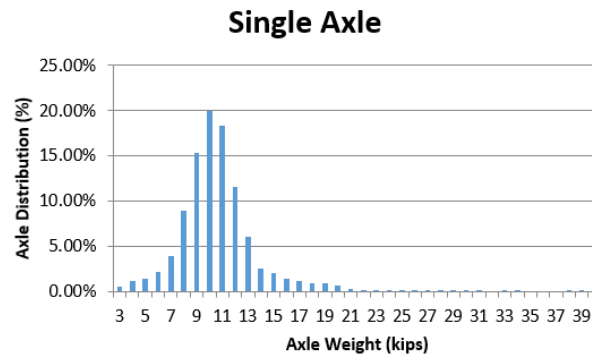
□ Traffic: load spectrum; Case study: FM468

Overloading & Overweight Data

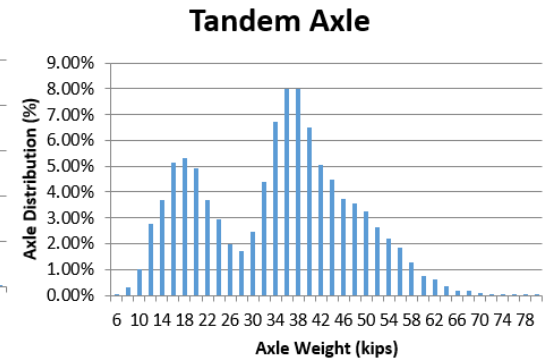
Portable WIM | 16-Days Traffic Data Collection



55.75 % Overloaded Trucks Daily
(GVW \geq 80 kips)



1.39 % Overloaded Trucks Daily
(Single Axle Weight \geq 20 kips)



52.92 % Overloaded Trucks Daily
(Tandem Axle Weight \geq 34 kips)

Over-Weight Summary	Daily Overweight Count (% of Total)	Maximum Overweight Recorded	Legal Limit	%age Overweight
GVW Overweight (\geq 80 kips)	182(55.75%)	411 kips	80 kips	414%
Single Axles (\geq 20 kips)	5(1.39%)	41kips	20 kips	105%
Tandem Axles (\geq 34 kips)	311(52.92%)	80 kips 90 kips	34 kips	135.3%
Tridem Axles (\geq 42 kips)	4(41.03%)	90 kips	42 kips	114.3%
Quad Axles (\geq 50 kips)	1(48.48%)		50 kips	80%

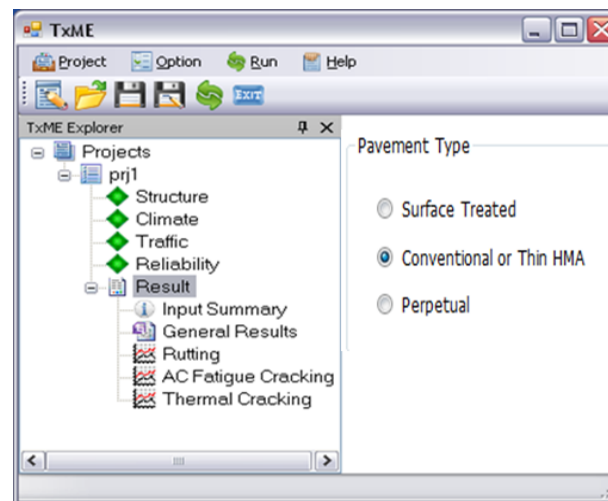
Pavement structural design

□ Traffic: load spectrum vs. ESAL

Highway ID	Station ID	AADTT	ESAL from TxME Load Spectra (20 years)
I35	513	10,867	49,650,718
I10	502	8,005	32,748,557
I20	526	7,704	50,529,653
I45	539	6,834	37,354,536
I35	531	6,299	26,717,107
I20	544	5,767	28,243,048
US287	506	4,182	36,010,559
US287	528	3,247	17,228,683
SH114	527	2,656	13,479,223
SH130	532	2,269	7,682,393
US59	535	2,000	5,656,394
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
FM468	Portable WIM	1,062	11,437,641
FM3129	541	251	1,652,034
FM2223	800	142	516,928

Pavement structural design

- TxME check
 - load spectrum



Pavement structural design

□ TxME check

The screenshot displays the TxME software interface, which is used for pavement structural design. The interface is divided into several sections:

- Project Explorer:** Shows a tree view of the project structure, including 'Structure', 'Climate', 'Traffic', and 'Reliability'.
- Pavement Type:** Includes radio buttons for 'Surface Treated', 'Conventional or Thin HMA' (selected), and 'Repetual'. It also features a 'Design/Analysis Life (years): 20' and 'Project Location' dropdowns for 'District: 01 Paris' and 'County: 60 DELTA'.
- Material Selection:** A grid of material options for 'AC Layer Material', 'Base Material', and 'Subbase Layer Material'. A red box highlights the 'AC Layer Material' section.
- Pavement Structure:** A cross-sectional diagram showing three layers: 'Type D, PG 64-22' (top), 'Flexible Base' (middle), and 'Subgrade' (bottom). A red box highlights this section.
- Material Property Table:** A table detailing the properties for 'Layer 1, Type D, PG 64-22'. A red box highlights this section.

Red text annotations are overlaid on the image:

- 'Pavement type and location' is placed over the Pavement Type and Project Location fields.
- 'Layer Material' is placed over the AC Layer Material selection area.
- 'Pavement Structure' is placed over the cross-sectional diagram.
- 'Material property' is placed over the material property table.

Layer Information	
Layer Number	1
Layer Thickness (inches)	4
Material Information	
Binder Type	PG 64-22
Gradation	Type D
RAS %	0
Material Properties	
Dynamic Modulus	Level 2 input: default value
Fracture Property	@ 77 F: A=4.2081E-06, n=3.9531
Rutting Property	@ 104 F: alpha=0.7465, mu=0.8102
Poisson Ratio	0.35
Thermal Coefficient of Expansion (1e-6 in/in/F)	13.5

Pavement structural design

□ TxME check: load spectrum

Traffic Input

Level 2: ESALS Level 1: Load Spectra

Level 1: Load Spectra

General Traffic Information

Traffic Two-way AADTT:

Number of Lanes in Design Direction:

Percent of Trucks in Design Lane (%):

Operation Speed (mph):

Axle Configuration

Axle Tire

Single Tire Pressure (psi):

Dual Tire Pressure (psi):

Dual Tire Spacing (in):

Axle spacing

Tandem Axle (in):

Tridem Axle (in):

Quad Axle (in):

Axle Load Distribution

View: Cumulative Distribution Distribution

Axes: Steering Axle Other Single Axle Tandem Axle

Tridem Axle Quad Axle

Axle Factors by Axle Type

> Season	Veh. Class	Total	3000	4000	5000	6000	7000	8000	9000	10000	11000	12000	13000	14000	15000
January	4	100.00	1.8	0.96	2.91	3.99	6.8	11.47	11.3	10.97	9.88	8.54	7.33	5.55	4.23
January	5	100.00	10.05	13.21	16.42	10.61	9.22	8.27	7.12	5.85	4.53	3.46	2.56	1.92	1.54
January	6	100.00	2.47	1.78	3.45	3.95	6.7	8.45	11.85	13.57	12.13	9.48	6.83	5.05	3.74
January	7	100.00	2.14	0.55	2.42	2.7	3.21	5.81	5.26	7.39	6.85	7.42	8.99	8.15	7.77
January	8	100.00	11.65	5.37	7.84	6.99	7.99	9.63	9.93	8.51	6.47	5.19	3.99	3.38	2.73
January	9	100.00	1.74	1.37	2.84	3.53	4.93	8.43	13.67	17.68	16.71	11.57	6.09	3.52	1.91
January	10	100.00	3.64	1.24	2.36	3.38	5.18	8.35	13.85	17.35	16.21	10.27	6.52	3.94	2.33
January	11	100.00	3.55	2.91	5.19	5.27	6.32	6.98	8.08	9.68	8.55	7.29	7.16	5.65	4.77
January	12	100.00	6.68	2.29	4.87	5.86	5.47	8.86	9.58	9.94	8.59	7.11	5.87	6.61	4.55

Vehicle Class Distribution and Growth

Vehicle Class	Pictorial View	Distribution (%)	Growth Rate (%)	Growth Function
Class 4		1.8	4	Compound
Class 5		24.6	4	Compound
Class 6		7.6	4	Compound
Class 7		0.5	4	Compound
Class 8		1.1	4	Compound
Class 9		31.3	4	Compound
Class 10		9.8	4	Compound
Class 11		0.8	4	Compound
Class 12		3.3	4	Compound
Class 13		15.3	4	Compound
Sum of Distribution (%):		100.0		

Axes Per Truck

Vehicle Class	Steering Axle	Other Single Axle	Tandem Axles	Tridem Axles	Quad Axles
Class 4	0	1.62	0.39	0	0
Class 5	0	2	0	0	0
Class 6	0	1.02	0.99	0	0
Class 7	0	1	0.26	0.83	0
Class 8	0	2.38	0.67	0	0
Class 9	0	1.19	1.09	0.89	0
Class 10	0	4.29	0.26	0.06	0
Class 11	0	3.52	1.14	0.06	0
Class 12	0	2.15	2.13	0.35	0
Class 13	0				

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

General Information

Axle Configuration

Vehicle Class Distribution and Growth

Axes per Truck

Pavement structural design

□ TxME check: performance prediction

Project

General Information

Type of Design: Surface Treated Pavement
 Design Life: 20 years

Construction Information

Pavement Construction: Jul 2000
 Traffic Open: Jul 2000

Project Identification

District: 01 Paris
 County: 60 DELTA
 CSI: Major Collectors
 Functional Class: Jun-25-2013
 Date: Feet: 00+00

Climate

Weather Station: Interpolated
 Latitude (degrees minutes): 32.25
 Longitude (degrees minutes): -89.41
 Elevation (ft): 1789

Water Table

Annual Average (ft): 10

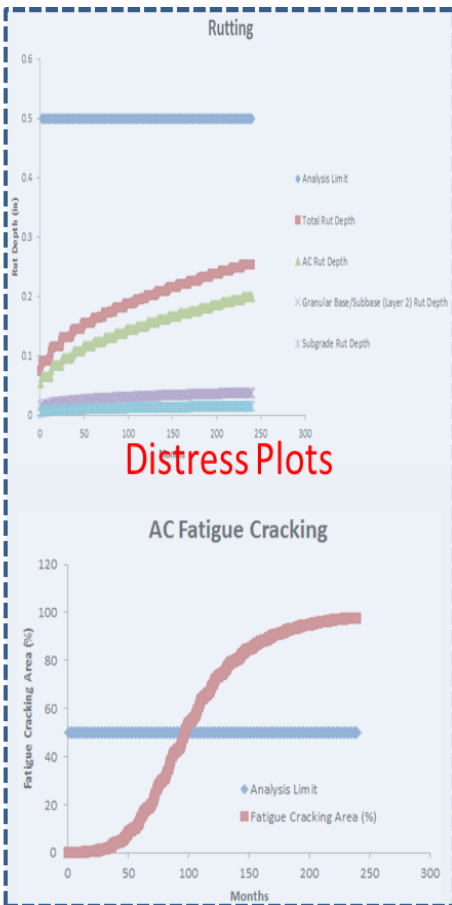
Average Monthly Temperature

Month	Temperature (deg F)
January	46.6
February	48.8
March	55.4
April	64.3
May	73.5
June	78.7
July	83.3
August	82.1
September	75.9
October	66.3

Input Summary

Month No.	Month, Year	Cumulative Monthly ESALS	Modulus (ksi)		Predicted Distresses			
			SR In-In (Layer Z)	Subgrade	Total Rut Depth (in)	Surface Treated Layer Rut Depth	Subgrade Rut Depth (in)	Stabilized Base Cracking Area (%)
1	Jul 2000	9467	200	4	0.029436318	3.21E-06	0.029436318	78.60094295
2	Aug 2000	18934	200	4	0.022311189	3.90E-06	0.022311189	97.20224244
3	Sep 2000	28399	200	4	0.023801005	3.94E-06	0.023801005	98.65134465
4	Oct 2000	37863	200	4	0.024895900	3.94E-06	0.024895127	98.58265487
5	Nov 2000	47325	200	4	0.025568844	3.94E-06	0.025562903	99.30566209
6	Dec 2000	56787	200	4	0.026139059	3.94E-06	0.026115110	99.18388562
7	Jan 2001	65659	200	4	0.026630206	3.94E-06	0.026630184	99.25432229
8	Feb 2001	74210	200	4	0.027083689	3.94E-06	0.027079747	99.31917708
9	Mar 2001	82677	200	4	0.027613105	3.94E-06	0.027609184	99.40382291
10	Apr 2001	91039	200	4	0.028132645	3.94E-06	0.028138706	99.52655444
11	May 2001	99296	200	4	0.028740616	3.96E-06	0.028686491	99.69602507
12	Jun 2001	107450	200	4	0.029336513	3.97E-06	0.029338616	99.82273122
13	Jul 2001	115493	200	4	0.029919513	4.00E-06	0.029928833	99.91496395
14	Aug 2001	123222	200	4	0.030589900	4.07E-06	0.030594836	99.95249538
15	Sep 2001	130483	200	4	0.03134006	4.09E-06	0.031395506	99.96209118
16	Oct 2001	137260	200	4	0.031779054	4.09E-06	0.03178796	99.96991278
17	Nov 2001	143721	200	4	0.032044832	4.09E-06	0.032092627	99.96795489
18	Dec 2001	149498	200	4	0.0322821	4.10E-06	0.032277005	99.96874364
19	Jan 2002	154725	200	4	0.032513942	4.10E-06	0.032520884	99.96986022
20	Feb 2002	159305	200	4	0.032729276	4.10E-06	0.03272408	99.97096238
21	Mar 2002	163862	200	4	0.03291539	4.10E-06	0.03296644	99.9727272
22	Apr 2002	167943	200	4	0.03329318	4.10E-06	0.033287222	99.97530617
23	May 2002	171720	200	4	0.033661716	4.11E-06	0.033656607	99.97845778
24	Jun 2002	175381	200	4	0.034049432	4.21E-06	0.034042239	99.98478221
25	Jul 2002	178950	200	4	0.034477951	4.60E-06	0.034471791	99.9894202
26	Aug 2002	182479	200	4	0.034880324	5.88E-06	0.034874447	99.99233872
27	Sep 2002	185642	200	4	0.035196262	8.89E-06	0.035196262	99.99344388
28	Oct 2002	188532	200	4	0.035441689	8.89E-06	0.035453774	99.99386228
29	Nov 2002	191276	200	4	0.035623384	8.89E-06	0.035617489	99.99405381
30	Dec 2002	193845	200	4	0.035784633	8.89E-06	0.03578738	99.99418228
31	Jan 2003	196244	200	4	0.035926467	8.89E-06	0.035927951	99.99428881

Result Table



Pavement structural design

□ TxME check

Influence of Material Properties

Variable inputs

- Fracture properties of dense grade type-D: 20, **40**, and 100 overlay cycles
- FDR Modulus (ksi): 300, **150**, 75

Fixed inputs

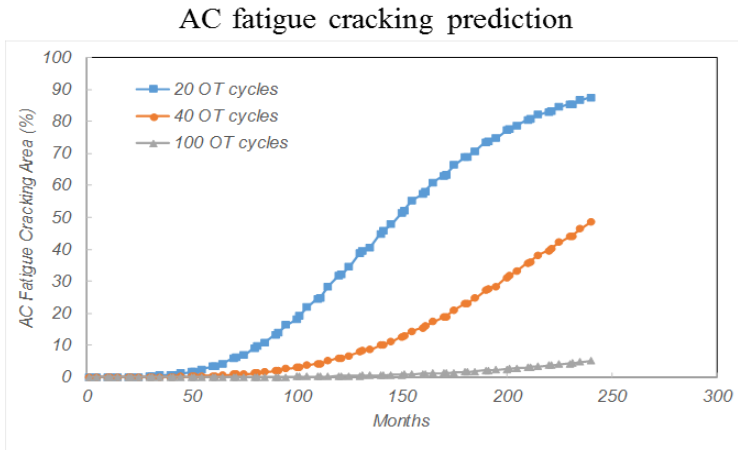
- **Traffic: Traffic spectra from Station 535**
- Subgrade Modulus (ksi): 14.3.
- Climate: San Antonio, TX

FM541 Design #3

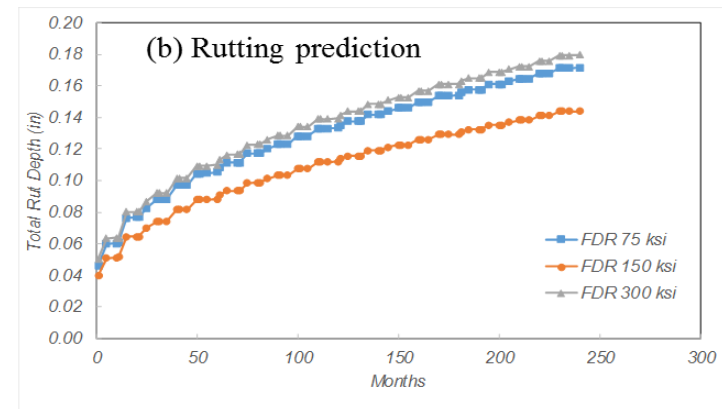
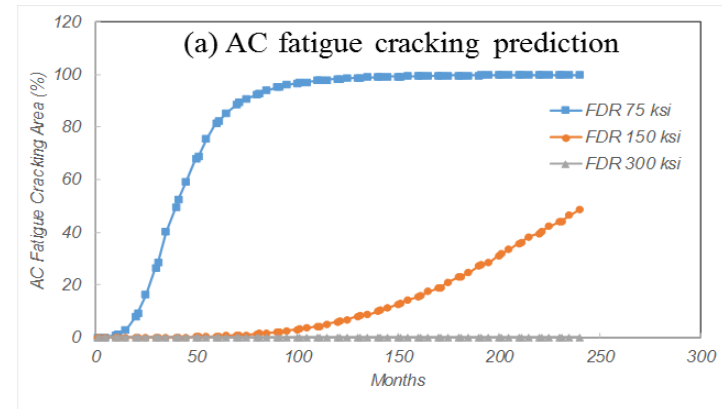


Pavement structural design

□ TxME check



Influence of Fracture Property of Mix



Influence of Modulus of FDR Mix

Field test sections



- FM541: foamed asphalt stabilization
- SH202: foamed asphalt stabilization
- I10: asphalt emulsion stabilization
- SH7: foamed asphalt stabilization
- FM99: foamed asphalt stabilization
- US281 / SH123: concrete pavement

Field test sections

□ FM541: foamed asphalt stabilization

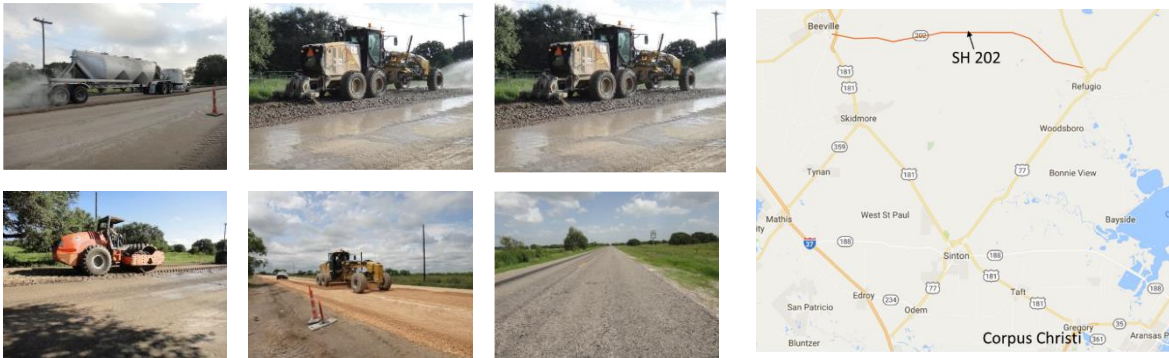


After 2 years: no cracking; average rut depth: 2.9 mm



Field test sections

□ SH202: foamed asphalt stabilization



After 1.5 years: no cracking; average rut depth: 5.4 mm



Field test sections

□ IH 10: asphalt emulsion stabilization

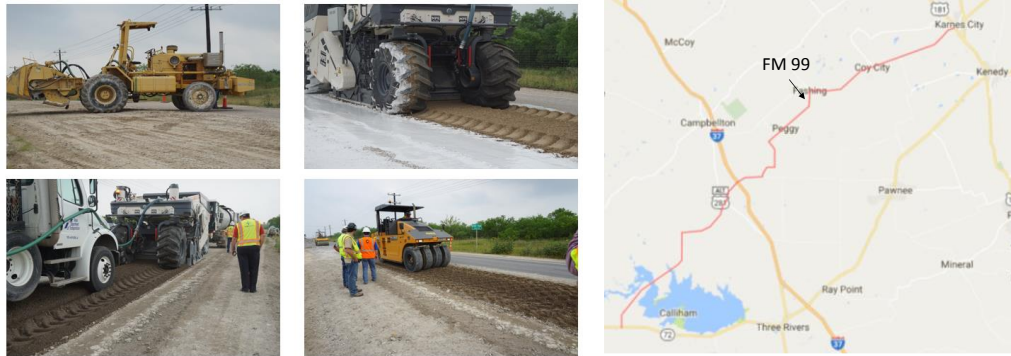


After 1.5 years: no cracking; average rut depth: 6.4 mm



Field test sections


□ FM99: foamed asphalt stabilization



After 3.5 years: limited longitudinal cracking; rut depth: 4 mm



Implementation plan

- 
- Develop and teach workshops
 - ▣ Rehabilitation options
 - ▣ Mix design
 - ▣ Structural design
 - Construct sections: foamed vs. emulsion
 - Continue to monitor existing field test sections
 - Document US281 / SH123 construction



Thank You All!

Questions???