



Texas Mechanistic-Empirical Flexible Pavement Design and Analysis System (TxME) Instructor Guide

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Cooperative Research Program

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**Texas Mechanistic-Empirical Flexible Pavement Design
and Analysis System (TxME)
Instructor Guide**

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Introduction

For a long period, pavement design was mainly conducted empirically due to its complexity essence. Over the past several decades, there has been growing interest in mechanistic pavement modeling that can take full consideration of specific materials, pavement structure, traffic condition, climatic condition, etc. This enables designers to take full advantage of new materials and to make more economical and reliable pavement designs.

For example, the current Texas Department of Transportation (TxDOT) flexible pavement design system (FPS) implemented in the mid-1990s has limitations in that it does not use any results from laboratory testing, so it is impossible to determine benefits from improved base materials or superior asphalt mixes. The development of the new flexible pavement design system named Texas Mechanistic-Empirical Flexible Pavement Design and Analysis System (TxME) can cover the shortage by taking full consideration of the influential factors including pavement structure, traffic volume, and environmental condition. Previous study and sensitivity analysis show that TxME can make rational predictions under different combinations of pavement structure, climate, and traffic load. It can be used for:

- AC mixture design.
- Thickness design, for surface treatment, conventional or thin hot mix asphalt (HMA), or perpetual pavement.
- AC thermal cracking analysis or prediction.
- AC fatigue cracking analysis or prediction.
- Rutting analysis or prediction, including AC rutting, flexible base/subgrade rutting.
- Stabilized base fatigue cracking analysis for surface treatment or thin HMA pavement with stabilized base layer.
- Endurance limit analysis for perpetual pavement.

TxME can also be used as a performance check tool for design options recommended by the TxDOT FPS design system. As a new generation of flexible pavement design tool, TxME:

- Enables designers to take full advantage of new materials.
- Has simple and friendly user interfaces.
- Is compatible with the currently used TxDOT pavement software FPS 21W.
- Provides default material property values based on previous Texas frequently used materials.
- Outputs well-organized data that can be easily incorporated into electronic documents and reports.
- Runs fast.

Course Overview

The TxME course is a half day course intended to provide advanced, in-depth, hands-on understanding of a new flexible pavement design and performance analysis system. The course is designed to cover:

- Mechanistic-Empirical design concept.
- Full view of TxME.
- Features of TxME.

TxME Instructor Guide

- Basic pavement performance models.
- Key input parameters.
- Pavement design and analysis processes.
- TxME outputs.

This course is designed to help TxDOT pavement engineers to routinely design long lasting while economical flexible pavements.

Course Organization

One or two instructors will present this half day course using the curriculum materials, which includes an Instructor Guide, a student handbook, and a software CD. In addition, the instructors need internet access and projector equipment.

The course is designed to run for four instructional hours, typically from 8:00 a.m. to 12:00 p.m. or from 1:00 p.m. to 5:00 p.m. The instructional time may vary plus or minus 30 minutes depending on the course sponsor.

The complete lesson plan is composed of:

- TxME Overview.
- TxME Inputs.
- TxME Outputs.
- Connection with FPS 21.
- Examples and Exercises.

Table 1 displays the standard composition and timing of the course.

Table 1. Course Outline.

	Lesson Description	Est. Time (minutes)
TxME Overview	What is TxME; Relationship with FPS 21; What TxME does; TxME features	20
TxME Inputs	Main screen; Pavement structure; Material property; Traffic; Climate; Reliability	40
TxME Outputs	General; Rutting; Cracking; Endurance Limit; Reliability results	20
Connection with FPS 21	Concept; Interface	40
Examples and Exercises	5 examples and 2 exercises	100
	Total minutes	220

Course Coordination

Usually, a TxDOT Training Coordinator will submit a request for the course with requested dates and training sites to the contractor's course scheduler, who in turn, will contact the course contractor. The contractor will then contact the TxDOT Training Coordinator to

discuss possible dates for the course. Once a list of potential dates is compiled, the contractor will check on the availability of the instructors. The contractor will confirm the delivery date with the TxDOT Training Coordinator, Course Scheduler, and instructors. Then the course session is formally scheduled for the agreed dates and training site. This also will authorize the contractor to conduct the course. A confirmation is emailed to the instructors.

The contractor will communicate with the host DOT Coordinator to: 1) confirm times of instruction; 2) obtain directions to training facility; and 3) discuss host requirements.

Class Size

The maximum class size permitted is 20 people; however, the smaller the class size, the better, with a minimum of 5. The software CD along with the participant student handbook should be placed at each participant's seat by the TxDOT Training Coordinator prior to the beginning of the class. A desktop computer should be provided for each participant. TxDOT will provide sign-in sheets, pencils, etc. The TxDOT Training Coordinator needs to notify the contractor's Course Scheduler concerning any changes to the number of students.

Host Agency Responsibilities

Host agency is responsible for visual aids for this course, which include the following:

- LCD projector compatible with a notebook computer (e.g., InFocus® or similar make).
- Cable necessary to connect projector to computer, if possible.
- Electronic remote to advance slides in PowerPoint® presentation (if available).
- Projection screen.
- Laser pointer (if available).
- Whiteboard with dry erase pens and eraser.

All equipment should be placed in the room for the instructors to check a half hour prior to the course.

Room Requirements

Instructors will arrange the classroom as they deem most appropriate given the number of participants. All participants should be able to see the screen and instructors. Participants and instructors should be able to move about the room without obstruction.

A preparation table and presentation table should be provided for the instructors. The presentation table will be for the audiovisual equipment, and the preparation table will be for the instructors' materials. The room should be in a quiet area and have a lighting system that permits convenient dimming of the lights, especially where the screen is located.

Training Site

Great care should be taken to select a room that is handicap accessible and will not be overcrowded, too hot or too cold, or subject to outside distractions. The instructors should provide any specific requirements for the training facility so that the training coordinator may:

- Reserve a training room for the duration of the course.
- Check to see if anyone else will be using the room for nighttime functions.
- Determine if books and equipment can be left in the room. Training courses, requiring special equipment or computers, must have after-hours security.

Participants and Instructors

Participants and instructors should be:

- Informed of course starting and ending times.
- Advised on training site address.
- Furnished with maps.
- Advised on parking arrangements.

Final Arrangements

Instructors will be responsible for:

- Reconfirming the training facilities.
- Discussing the seating arrangements and who will set up the room.
- Discussing what time the room is unlocked/locked.
- Checking to make sure a technician is available in case there are problems setting up the room or if something goes wrong during the course.

One Day before the course:

- Set-up the Classroom.
- Organize the participant materials.
- Post directional signs.
- Test all equipment.

During the course:

- Instructors will identify whom they should contact if they need assistance.
- Instructors will provide a copy of the student handbook and software CD for all course participants.

After the course:

- Instructors will check to make sure students have the course evaluation forms.
- Students will complete evaluations.
- Clean up room and turn off lights and electronic equipment as needed.

Participant Requirements

TxDOT should provide notepads and pens, or instruct participants to bring notepads and pens with them. All students should be provided the permission or authorization to run programs and to copy/delete files on their computer.

Target Audience

TxME is a half-day course for TxDOT pavement engineers, including pavement managers.

This course is designed for those individuals seeking to expand their knowledge and understanding of mechanistic-empirical pavement design system. This is an advanced level course, and it focuses heavily on comprehensive pavement performance models, advanced material characterization, and how those models can be applied to develop reliable and economical pavement designs. For example, the course will focus on the aspects of pavement cracking and rutting prediction to demonstrate the influence of the pavement material and pavement thickness, and to select the best combination. Participants will learn to design pavements for given traffic and climate condition and to meet the required performance criteria. Time will not be devoted to definitional and introductory material; participants are expected to have a working knowledge of the complete design processes.

Please note that initial course delivery is aimed at TxDOT pavement engineers, but the course is equally suitable for other state DOT or pavement design agencies.

Course Goal

The purpose of this course is to:

- Provide advanced, in-depth understanding about the flexible pavement design.
- Understand the importance of mechanistic-empirical models in pavement performance prediction.
- Examine the influence of key input parameters such as climate, traffic, pavement structure, and material property.
- Explore different combinations of material design and thickness design and choose the best option.
- Examine the issues of some kind of materials or pavement structures may cause.

Again, since this is an advanced course, participants should be familiar with basic information and understanding of material characterization and pavement design.

The goal of this course is to help pavement engineers to design more reliable and economical flexible pavements.

Course Outcomes

At the end of this course, participants will be able to:

- Gain in-depth understanding of performance models and material properties.
- Be familiar with the TxME interfaces, functions, and features.
- Examine the influence of climate, traffic, pavement structure, and material property.
- Use the TxME to conduct flexible performance analysis and design for three types of flexible pavements: thin surface, conventional, and perpetual pavement.
- Connect the TxME with the current TxDOT FPS 21 and select best design option.

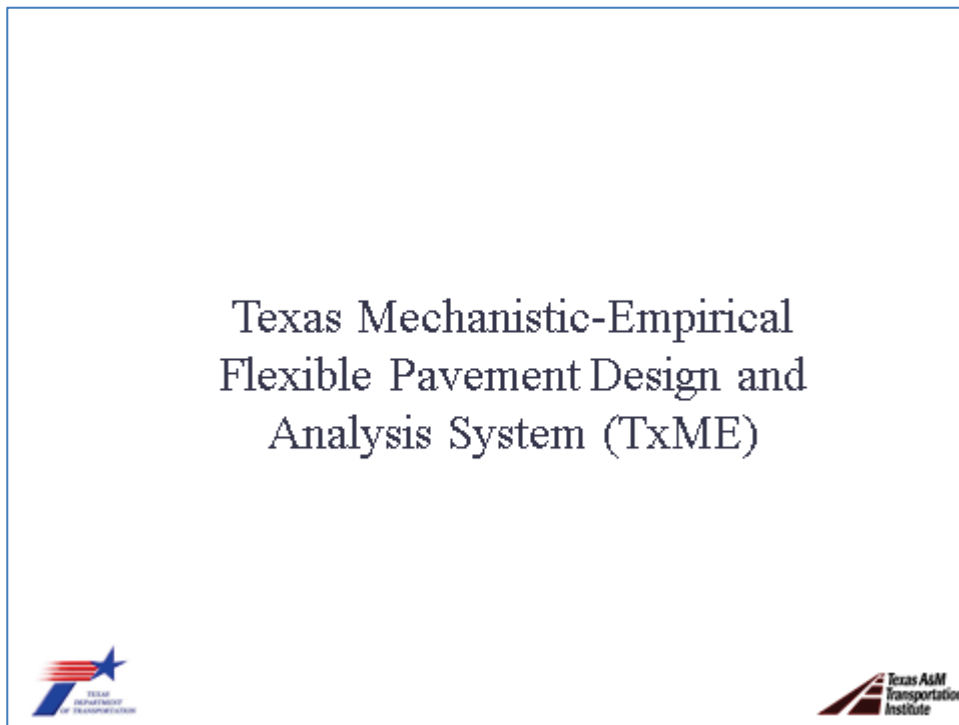
Course Agenda

Table 2 provides the course agenda.

Table 2. Course Agenda.

Time	Lesson Title	Lengths (Minutes)
8:00 a.m.–8:20 a.m. (or 1:00 p.m.–1:20 p.m.)	TxME Overview	20
8:20 a.m.–9:00 a.m. (or 1:20 p.m.–2:00 p.m.)	TxME Inputs	40
9:00 a.m.–9:20 a.m. (or 2:00 p.m.–2:20 p.m.)	TxME Outputs	20
9:20 a.m.–9:40 a.m. (or 2:20 p.m.–2:40 p.m.)	Break	20
9:40 a.m.–10:20 a.m. (or 2:40 p.m.–3:20 p.m.)	Connection with FPS 21	40
10:20 a.m.–12:00 p.m. (or 3:20 p.m.–5:00 p.m.)	Examples and Exercises	100



Course Modules



Key Message:	Training title
Interactivity:	Tell: In this lesson we will learn how to use TxME to perform flexible pavement design and analysis
Notes:	NA

Outline

- ▶ TxME Overview
- ▶ TxME Inputs
- ▶ TxME Outputs
- ▶ Connection with FPS 21
- ▶ Examples and Exercises

Key Message:	Outline
Interactivity:	<p>Tell: This lesson will include 5 parts:</p> <ul style="list-style-type: none"> ▪ Overview. ▪ Inputs. ▪ Outputs. ▪ Connection with FPS. ▪ Examples and Exercises.
Notes:	NA

TxME Overview - What's TxME?

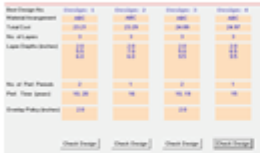
- ▶ It is a flexible pavement design tool
 - ▶ Surface-treated pavement
 - ▶ Conventional or thin HMA pavement
 - ▶ Perpetual pavement

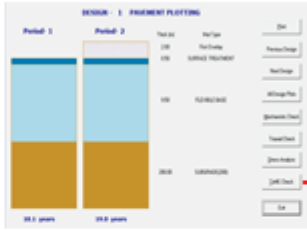
- ▶ It helps TxDOT engineers to
 - ▶ Consider value of premium materials
 - ▶ Analyze impact of load spectrum
 - ▶ Consider specific climatic conditions
 - ▶ Design more reliable and economical pavements

Key Message:	What is TxME?
Interactivity:	<p>Tell: TxME is flexible pavement design tool. Three types of flexible pavements are considered in this tool:</p> <ul style="list-style-type: none"> ▪ Surface-treated pavement (layer thickness can be ignored). ▪ Conventional pavement (layer thickness 2–6 inches). ▪ Perpetual pavement (layer thickness > 6 inches). <p>Tell: TxME can help TxDOT engineers to do the following that can't be completed by other empirical design method:</p> <ul style="list-style-type: none"> ▪ Take advantage of premium materials. ▪ Analyze impact of load spectrum. ▪ Consider specific climatic conditions. ▪ Consider the reliability/variability of inputs.
Notes:	NA

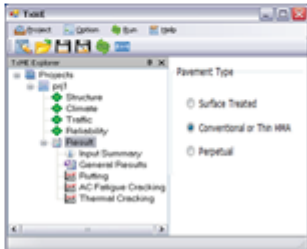

TxME Overview – Relationship with FPS21



- ▶ FPS21:
 - ▶ Overall design options





- ▶ TxME: Mechanistic Check
 - ▶ Specific layer material properties
 - ▶ Specific climatic conditions
 - ▶ Specific traffic (load spectrum)
 - ▶ Specific variability: Inputs






Key Message:	Relationship between TxME and FPS 21
Interactivity:	<p>Ask: Has anyone used FPS?</p> <p>Follow up: What’s the input of material property for each layer in the FPS?</p> <p>Tell: The FPS design system implemented in the mid-1990s has limitations in that it does not use any results from laboratory testing. The inputs are mainly FWD backcalculated layer modulus. It does not consider specific layer material properties, climatic condition, vehicle axle load distribution, etc. It can provide design options in terms of different layer thick combinations.</p> <p>Tell: TxME can automatically incorporate the FPS design options and generate TxME format project files that adopt default values for material properties. The user can further refine these properties according to actual lab testing results. This way the TxME can check and compare the performance of each design option and select the best one.</p>
Notes:	Based on the answers from audience, the instructor may need to provide more detailed information about FPS.

TxME Overview – What TxME Does?



- ▶ **Surface Treatment Pavements: Predict-**
 - ▶ **Granular Base Rutting**
 - ▶ Pavements with granular base
 - ▶ **Stabilized Base Fatigue Cracking**
 - ▶ Pavements with stabilized base
- ▶ **Subgrade Rutting**

Key Message:	What TxME does for surface treat pavement design and analysis
Interactivity:	<p>Tell: Since the thickness of the surface treated layer is often less than 1 inch, normally this layer is not counted as a structural layer. For this kind of pavement:</p> <ul style="list-style-type: none"> ▪ If the base layer is granular base, the rut depth in the base layer will be determined. ▪ If the base layer is stabilized base, the base fatigue cracking will be determined. ▪ For both cases, the subgrade rutting will be determined. ▪ It is assumed the based fatigue cracking will reflect on surface at no time since the surface treated layer is very thin. ▪ It is also assumed the rutting the surfaced treated layer can be ignored, so the total rut depth equals base layer rut depth (if granular base) plus subgrade rut depth.
Notes:	You should be no more than 10 minutes into the lesson at this point.

TxME Overview - What TxME Does?



- ▶ **Conventional or Thin HMA Pavements: Predict-**
 - ▶ AC Rutting
 - ▶ AC Fatigue Cracking
 - ▶ AC Thermal Cracking
 - ▶ Subgrade Rutting
 - ▶ Granular Base Rutting
 - ▶ Pavements with granular base
 - ▶ Stabilized Base Fatigue Cracking
 - ▶ Pavements with stabilized base

Key Message:	What TxME does for conventional pavements
Interactivity:	<p>Tell: Conventional pavement refer to that the HMA layer thickness is usually between 2–6 inches. For this kind of pavement:</p> <ul style="list-style-type: none"> ▪ The rut depth, fatigue cracking, and thermal cracking of AC layer will be determined. ▪ If the base layer is granular base, the rut depth in the base layer will be determined. ▪ If the base layer is stabilized base, the base fatigue cracking will be determined. ▪ For both cases, the subgrade rutting will be determined.
Notes:	NA

TxME Overview – What TxME Does?



- ▶ **Perpetual Pavements: Predict-**
 - ▶ AC Rutting
 - ▶ AC Thermal Cracking
 - ▶ Subgrade Rutting
 - ▶ Granular Base Rutting
 - ▶ Pavements with granular base
 - ▶ Endurance Limit






Key Message:	What TxME does for perpetual pavements
Interactivity:	<p>Tell: Perpetual pavements refer to that the HMA layer thickness is usually larger than 6 inches. For this kind of pavement:</p> <ul style="list-style-type: none"> ▪ The rut depth and thermal cracking of AC layer will be determined. ▪ Subgrade rut depth will be determined. ▪ If the base layer is granular base, the rut depth in the base layer will be determined. ▪ Notice there is no fatigue cracking was determined. ▪ Endurance limit will be determined and to be compared with criteria to check if the pavement is really perpetual.
Notes:	NA

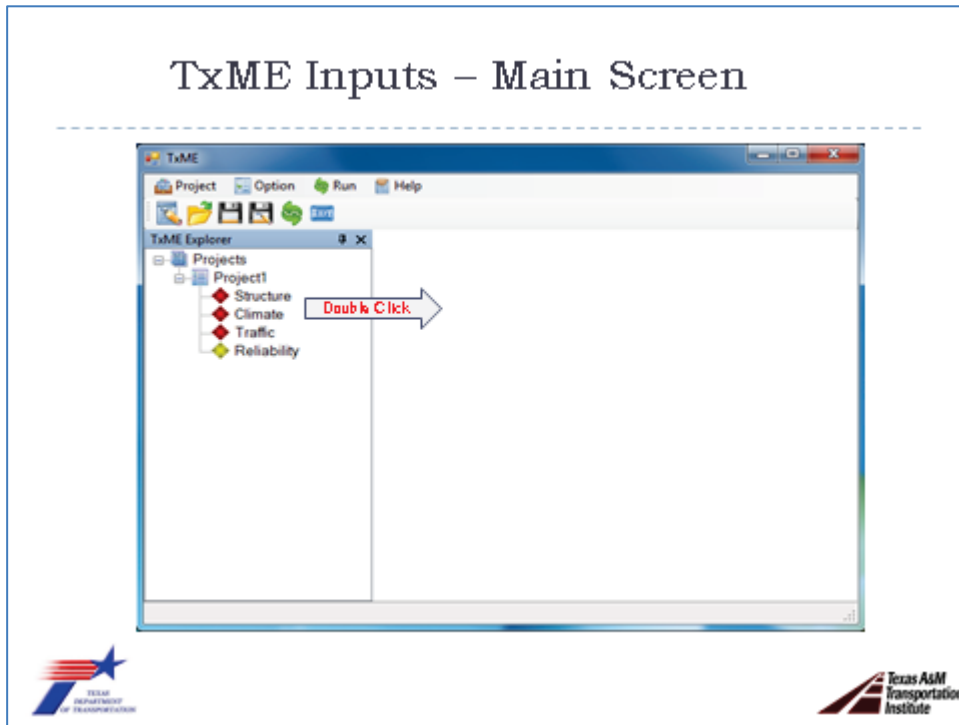
TxME Overview - Features

- ▶ Close tie with FPS 21
- ▶ Modulus plus fracture/rutting properties
- ▶ Advanced M-E modeling
- ▶ Accurate climatic impact simulation
- ▶ Traffic load spectrum incorporation
- ▶ Authentic reliability-based processing
- ▶ Monthly distress prediction
- ▶ Friendly user interface
- ▶ Fast running speed

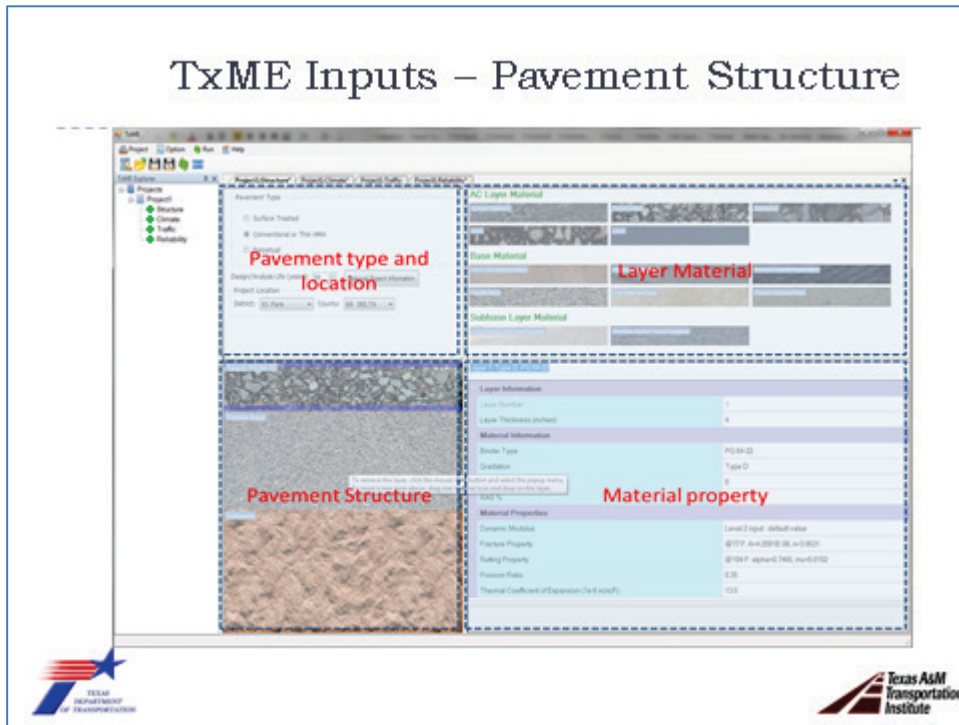



Key Message:	Features of TxME
Interactivity:	<p>Tell: TxME has the following features:</p> <ul style="list-style-type: none"> ▪ Close tie with FPS 21 (i.e., the input information of FPS will be automatically collected and processed by TxME). ▪ Performance based material properties. ▪ Mechanistic modeling. ▪ Climatic impact simulation, considering hourly temperature and moisture data. ▪ Vehicle axle load spectrum incorporation. ▪ Considering the variability of input, is authentic reliability-based prediction. ▪ Friendly user interface. ▪ Running fast.
Notes:	NA



<p>Key Message:</p>	<p>Inputs: Main Screen</p>
<p>Interactivity:</p>	<p>Tell: Main screen shows four parts of input:</p> <ul style="list-style-type: none"> ▪ Pavement structure, including each layer thicknesses and material properties. ▪ Climate, including the hourly data of air temperature, sunshine, precipitation, etc. ▪ Traffic, can be equivalent standard axle loads (ESALs) or axle load spectrum data. ▪ Reliability, including the performance criteria, reliability level, and key input variation information.
<p>Notes:</p>	<p>You should be no more than 20 minutes into the lesson at this point.</p>



<p>Key Message:</p>	<p>Inputs: Pavement Structure</p>
<p>Interactivity:</p>	<p>Tell: 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 sub-base layer material icons; the lower left window shows the pavement structure; and the lower right window shows the layer material property.</p> <p>Tell: 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.</p>
<p>Notes:</p>	<p>NA</p>

TxME Inputs – Material Property

Dynamic Modulus Input

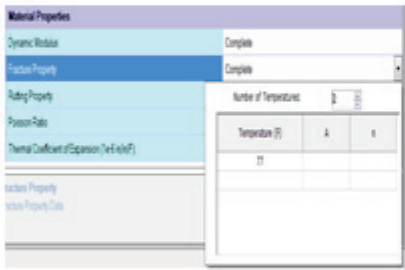
Sample $|E^*|$ values (ksi)


	25Hz	10Hz	5Hz	1Hz	0.5Hz	0.1Hz
14°F	2346.7	2307.4	2175	1810	1682	1378
40°F	1843	1687	1498	1080	916	619
70°F	820	597	467	280	223	139
100°F	161	118	96	64	54	40
130°F	61	50	43	32	29	23


Key Message:	Inputs: Material Property – Dynamic Modulus
Interactivity:	<p>Tell: By clicking each layer in the pavement structure window, users can browse or edit this layer thickness and layer material property in the material property window. For some property inputs such as Thickness, Poisson Ratio, etc., the user only needs to input some numbers. For more complicated inputs such as dynamic modulus and fracture/rutting property, the user needs to click the item and the corresponding input screen will pop up.</p> <p>Tell: The dynamic modulus of AC can be determined by Universal Test Machine (UTM) or Asphalt Mixture Performance Tester (AMPT) machine. The moduli are determined at different temperatures and at different frequencies. In the performance model, the real time modulus will be determined based on the actual pavement temperature and traffic loading frequency.</p>
Notes:	NA



TxME Inputs – Material Property

Fracture Property





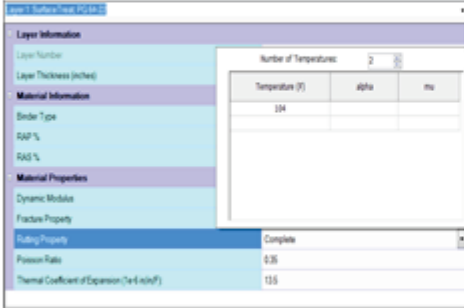


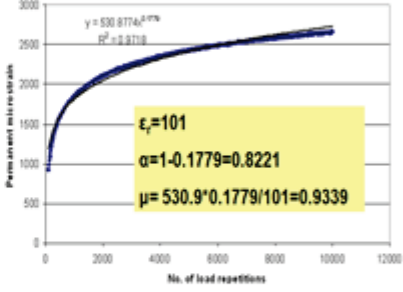
Key Message:	Inputs: Material Property – Fracture Property
Interactivity:	<p>Tell: The fracture properties A and n can be determined by Overlay Tester. The specimen is glued on two plates, one is fixed and the other is able to move horizontally. By repeatedly moving horizontally, the vertical crack will develop in the specimen and propagate from bottom to top. The fracture properties are used to indicate the crack propagation speed, which are main parameters in the crack related models in TxME.</p>
Notes:	NA

TxME Inputs – Material Property

Rutting Property





10,000 load repetitions
0.1s loading+0.9s rest



$$\mu = \frac{ab}{\epsilon_r}$$

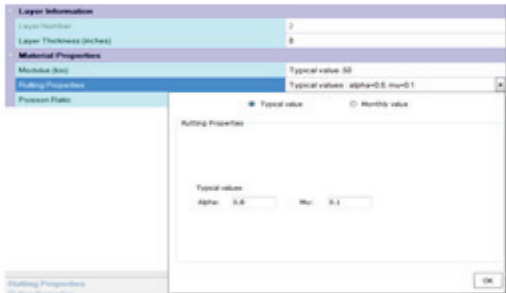
$$\alpha = 1 - b$$

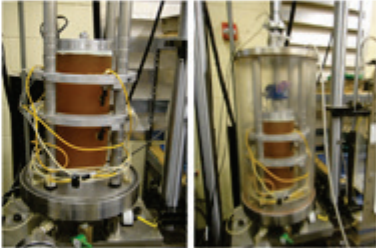
Key Message:	Inputs: Material Property – Rutting Property for AC
Interactivity:	<p>Tell: The rutting properties Alpha and mu can be determined by repeated load test. Similar as dynamic modulus test, the test machine can be UTM or AMPT. The specimen is also the same. By repeatedly loading, the specimen will develop permanent deformation. Alpha and mu are determined by the permanent deformation curve, which are main parameters to determine layer rut depth during traffic loading.</p>
Notes:	NA

TxME Inputs – Material Property



Rutting Properties of Granular Base/Subgrade



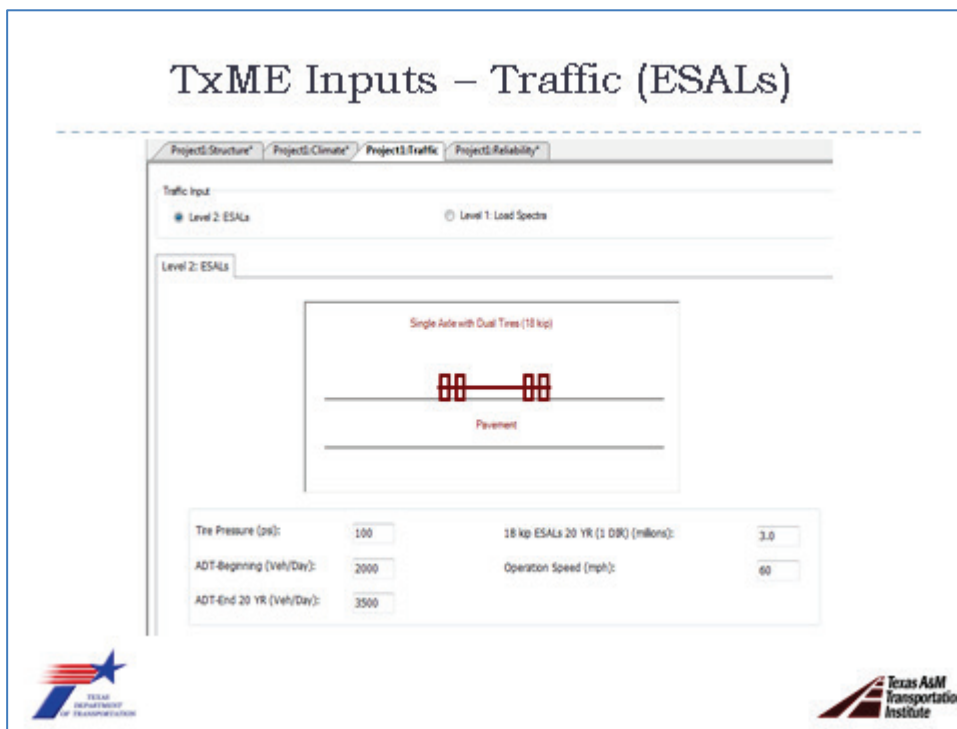
10,000 load repetitions



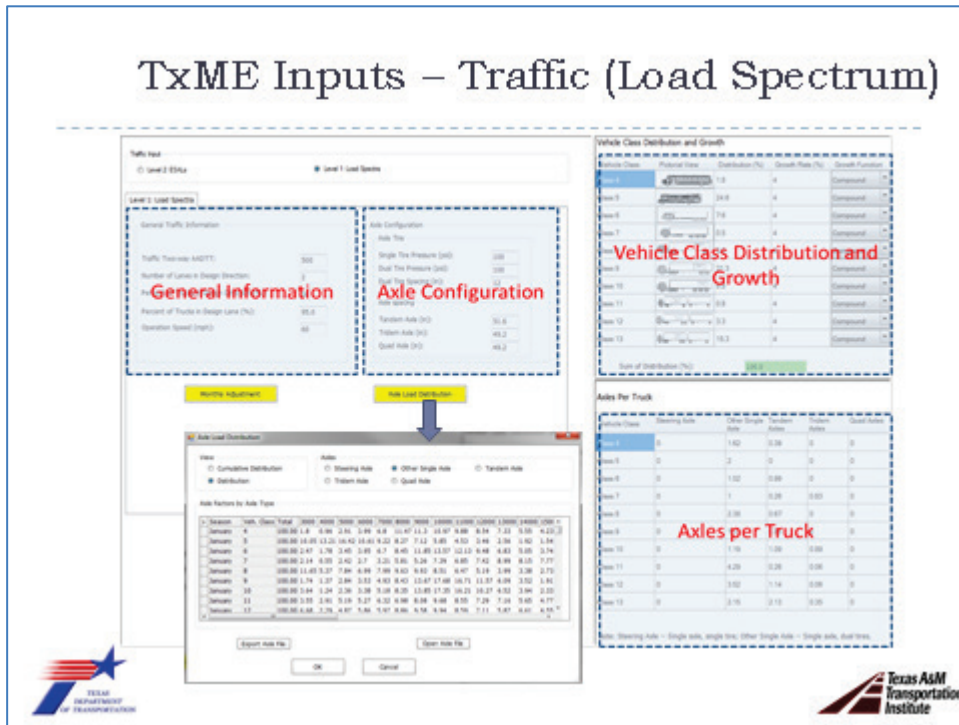
Loading conditions	Granular base	Subgrade soil
Deviator stress	20 psi	8 psi
Confining stress	10 psi	4 psi

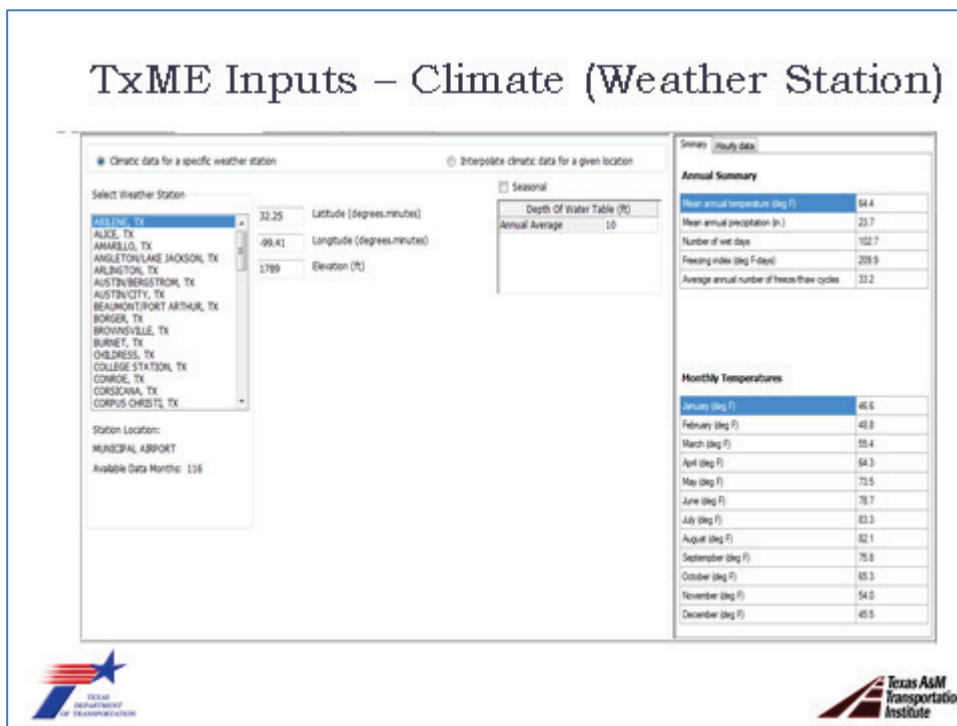
Key Message:	Inputs: Material Property – Rutting Property for flexible base and subgrade
Interactivity:	Tell: The rutting property for flexible base and subgrade is determined in a similar way as AC material. However, these test need to apply confining stress. The rutting models in TxME for AC layer, flexible base layer, and subgrade layer are similar.
Notes:	You should be no more than 40 minutes into the lesson at this point.



Key Message:	Inputs: Traffic ESALs
Interactivity:	<p>Tell: ESALs input is a Level 2 input, which takes simple numbers. The most important input is the total ESAL number during 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 operation speed impacts the AC layer modulus since it relates to loading time.</p>
Notes:	NA



<p>Key Message:</p>	<p>Inputs: Traffic Load Spectrum</p>
<p>Interactivity:</p>	<p>Tell: In this screen, the left windows shows the general information and axle configuration information such as average annual daily total truck (AADTT) number, operation speed, tire pressure, axle spacing, etc.; the upper right window shows the vehicle class distribution and growth rate information; and the lower right window shows the axle numbers for each vehicle class. By clicking the “Monthly Adjustment” or “Axle Load Distribution” button other screens will pop up. These screens let users define the axle load distributions for each vehicle class and their monthly variations.</p>
<p>Notes:</p>	<p>NA</p>

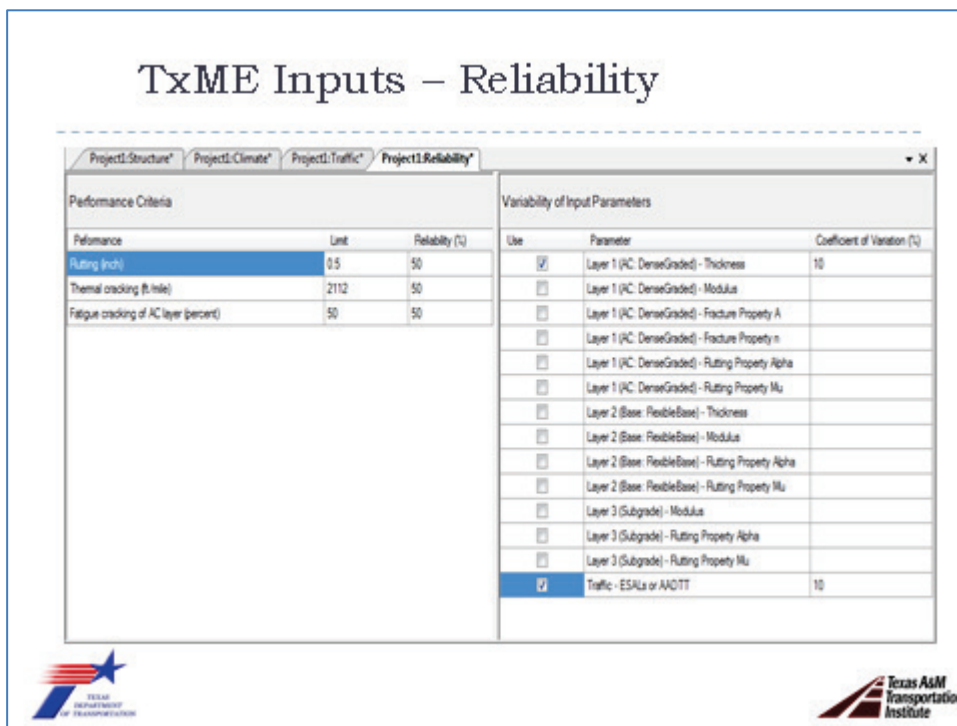


Key Message:	Inputs: Climate - Weather Station
Interactivity:	<p>Tell: There are two ways to attach the climatic information to a given project location: users can either assign a specific weather station or use interpolated climatic data based on the coordinates of the location.</p> <p>Tell: when users choose a specific weather station. Generally, the left part of screen lets the user select a weather station, and the right part shows the summary of the weather data, such as average temperature or precipitation. The user can look into more detailed information like hourly data by clicking the “Hourly data” tab on the upper right.</p>
Notes:	NA

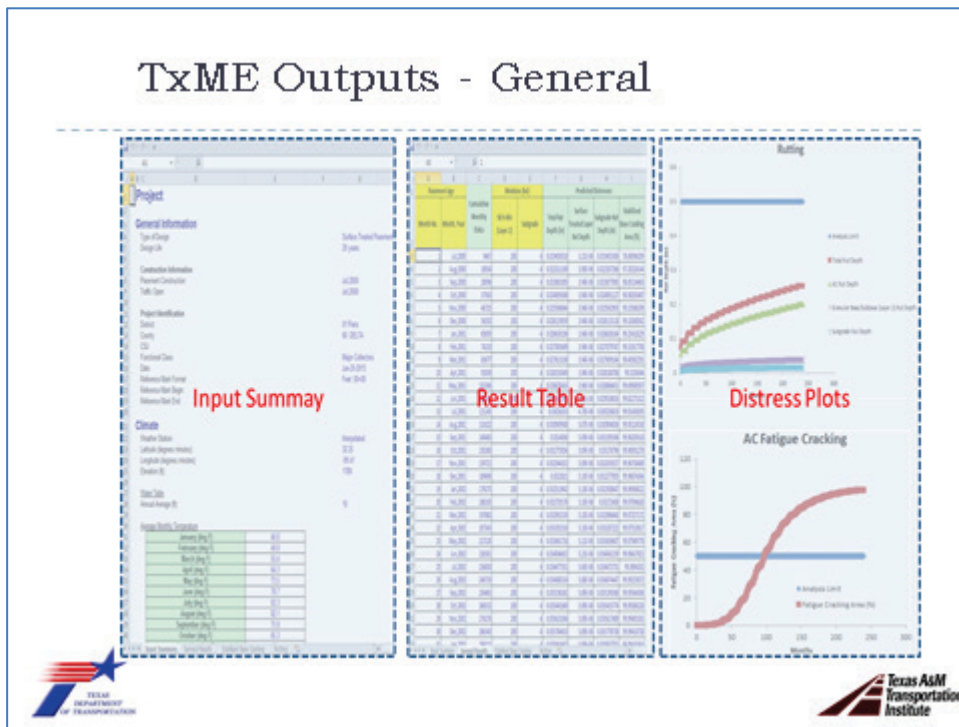
TxME Inputs – Climate (Interpolation)

Temperature (deg F)	Wind Speed (mph)	Sunshine (h)	Precipitation (in)	Humidity (%)
78.1	7.0	100.0	0.0	56.0
78.1	7.0	100.0	0.0	56.0
75.9	8.0	100.0	0.0	60.0
75.0	7.0	100.0	0.0	62.0
75.9	8.0	100.0	0.0	60.0
77.0	7.0	100.0	0.0	56.0
78.1	6.0	100.0	0.0	58.0
82.0	9.0	100.0	0.0	53.0
84.9	9.0	100.0	0.0	51.0
88.1	6.0	100.0	0.0	47.0
91.0	3.0	100.0	0.0	42.0
91.9	3.0	75.0	0.0	40.0
93.9	3.0	100.0	0.0	36.0
95.0	6.0	100.0	0.0	36.0
93.9	0.0	100.0	0.0	38.0
93.9	3.0	50.0	0.0	33.0
95.0	10.0	90.0	0.0	32.0
95.0	7.0	50.0	0.0	34.0
93.0	9.0	50.0	0.0	34.0
88.1	6.0	75.0	0.0	39.0
84.9	7.0	100.0	0.0	48.0
82.9	7.0	100.0	0.0	51.0

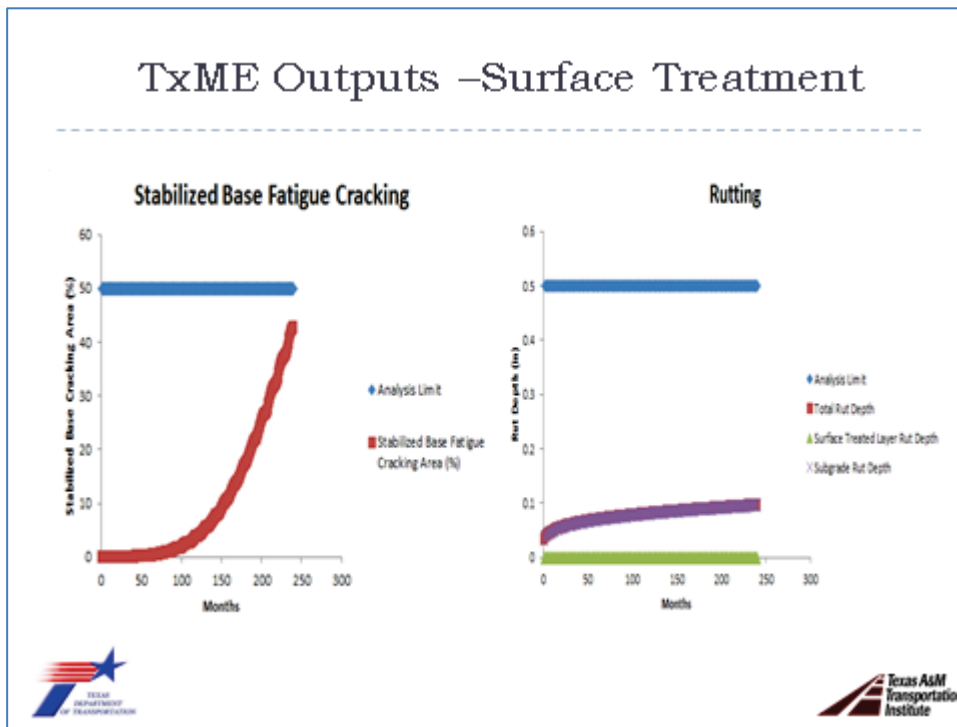
Key Message:	Inputs: Climate - Interpolation
Interactivity:	Tell: For a project location without a dedicated weather station, users can choose the radio button “Interpolate climatic data for a given location,” and the application will provide six weather stations nearby for the user to select for interpolation. The screen presents the user input screen for climate data interpolation. The lines and numbers such as “#1, #2...” in the graph show the relative positions and distances from the location defined by the coordinates. The interpolated hourly data information is listed in the right part of the screen.
Notes:	NA



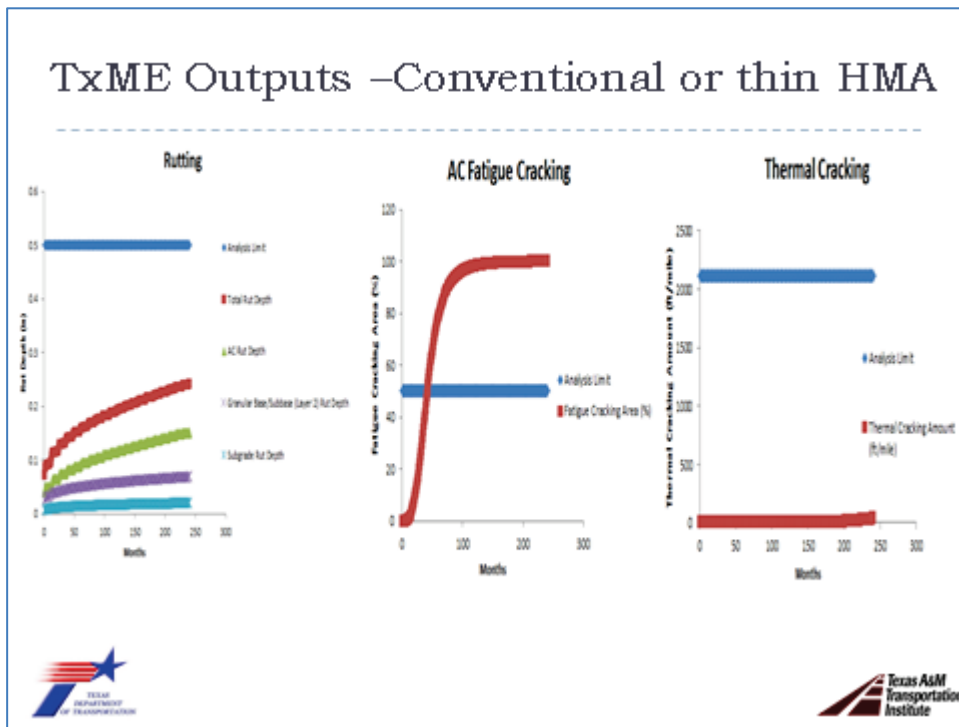
Key Message:	Inputs: Reliability
Interactivity:	<p>Tell: Two input categories are displayed in this screen. On the left side are the performance criteria inputs, and on the right side are the variability inputs. For the performance criteria inputs, the user supplies the analysis stop criteria (performance limit) and reliability level in terms of percentage. For variability inputs, the user checks the applicable checkboxes and modifies the coefficient of variation value.</p> <p>Tell: Both performance criteria and variability parameters are related to pavement structure and pavement type. Whenever the pavement structure or pavement type changes, these parameters are changed accordingly.</p>
Notes:	Note if no input parameter is selected to input coefficient of variance value, the prediction is deemed as deterministic and no reliability analysis will be involved.



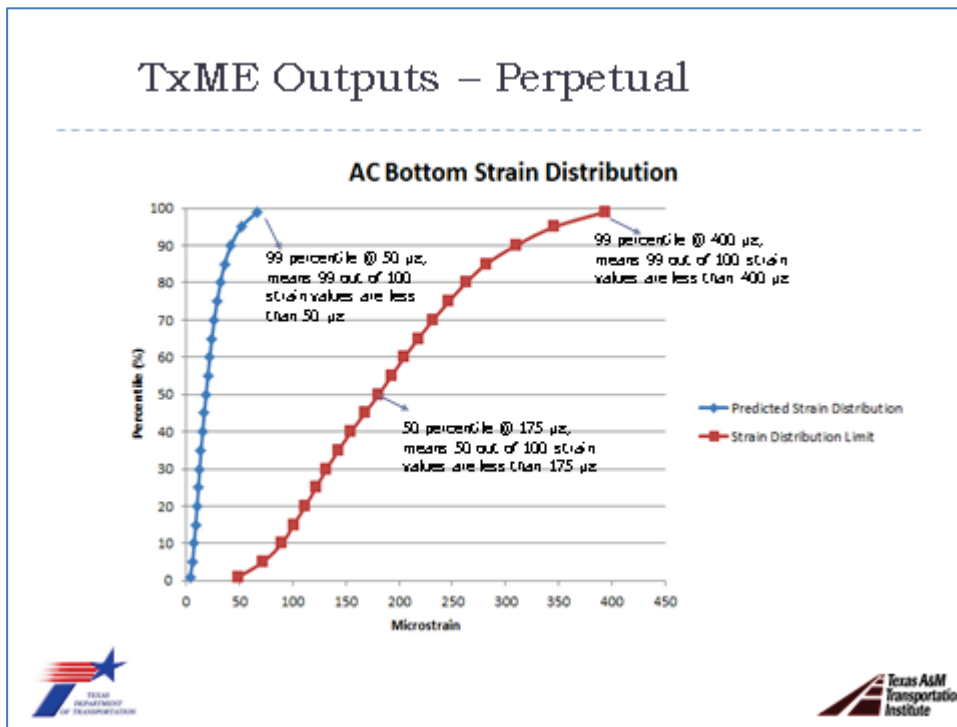
Key Message:	Outputs - General
Interactivity:	<p>Tell: The output of TxME is organized into an Excel® file, which is mainly composed of three parts: the summary of user’s inputs, the analysis result table, and the distress plots. The predicted distresses are different depending on pavement structure and pavement type.</p>
Notes:	You should be no more than 60 minutes into the lesson at this point.



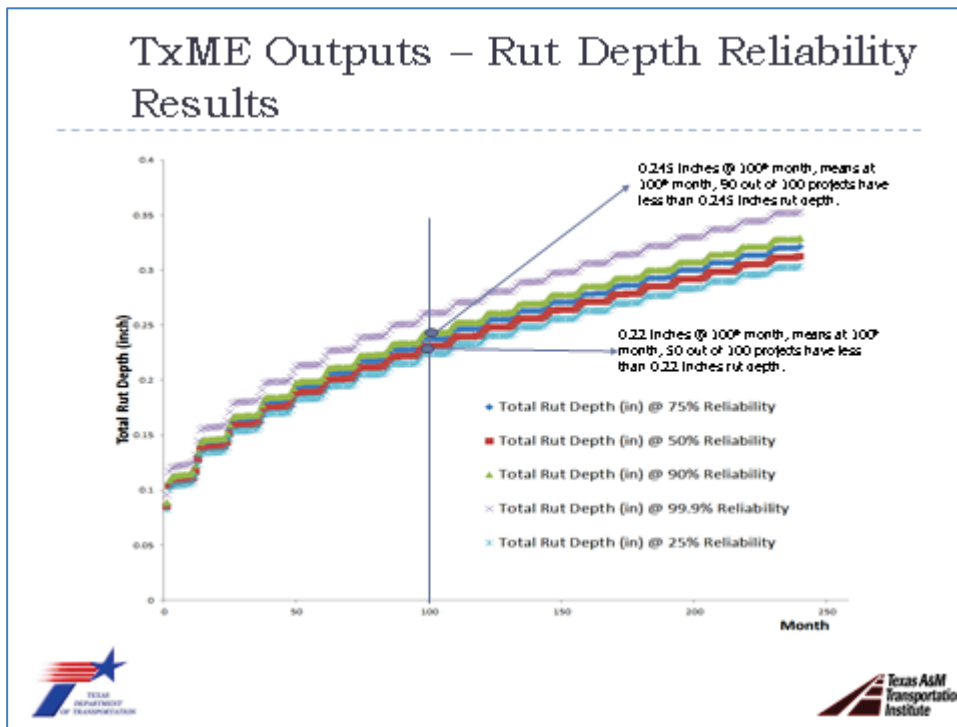
Key Message:	Outputs for surface treated pavement
Interactivity:	<p>Tell: For surface treated pavement with flexible base, only rutting result is predicted and plotted. For surface treated pavement with stabilized base, both rutting and stabilized fatigue cracking are predicted and plotted. Note that the rut depth of stabilized base is ignored</p> <p>Tell: If there are more than two base or subbase layers, of which some are flexible and the others are stabilized, TxME will predict the stabilized fatigue cracking only if the stabilized base layer is just under the AC layer. The rut depth of flexible base layer is always predicted no matter where the layer is.</p>
Notes:	NA



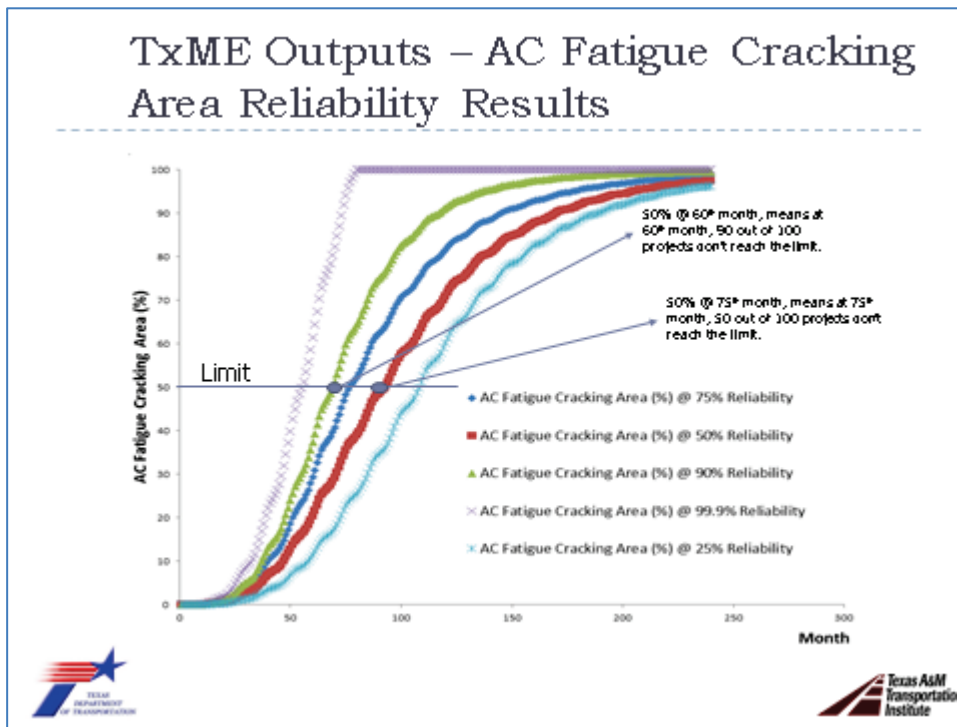
Key Message:	Outputs for conventional pavement
Interactivity:	<p>Tell: Typical outputs of conventional or thin HMA pavement with flexible base includes rutting, AC fatigue cracking, and AC thermal cracking. The rutting includes AC layer rutting, flexible base layer rutting, and subgrade rutting. Similar to surface treated pavement, if the first base layer (counted from top to bottom) is stabilized layer, the stabilized base fatigue cracking is also predicted and plotted.</p>
Notes:	NA



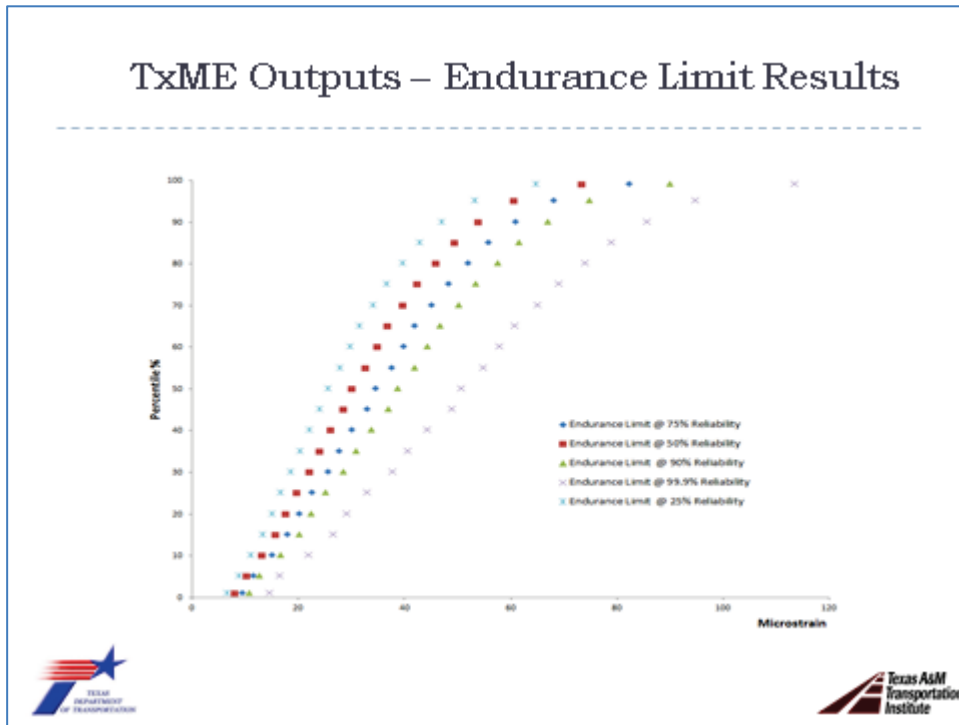
Key Message:	Outputs for perpetual pavement
Interactivity:	<p>Tell: For perpetual pavement analysis, endurance limit is determined according to the traffic input level.</p> <ul style="list-style-type: none"> ▪ For ESALs input (Level 2), the endurance limit is actually the maximum bottom strain of AC layer under the standard 18 kip single axle dual tire load. ▪ For load spectrum input (Level 1), the endurance limit is frequency of AC layer bottom strain distribution under different axle load level. <p>Tell: If the predicted strain distribution is at the left side of the strain distribution limit, the pavement is deemed as perpetual.</p> <p>Tell: Other typical output of perpetual pavement is similar to conventional pavement, which includes rutting, AC fatigue cracking, and AC thermal cracking.</p>
Notes:	There is no stabilized fatigue cracking analysis for perpetual pavement since normally the AC layers are thick enough to prevent the happening of fatigue cracking in the stabilized base layer.



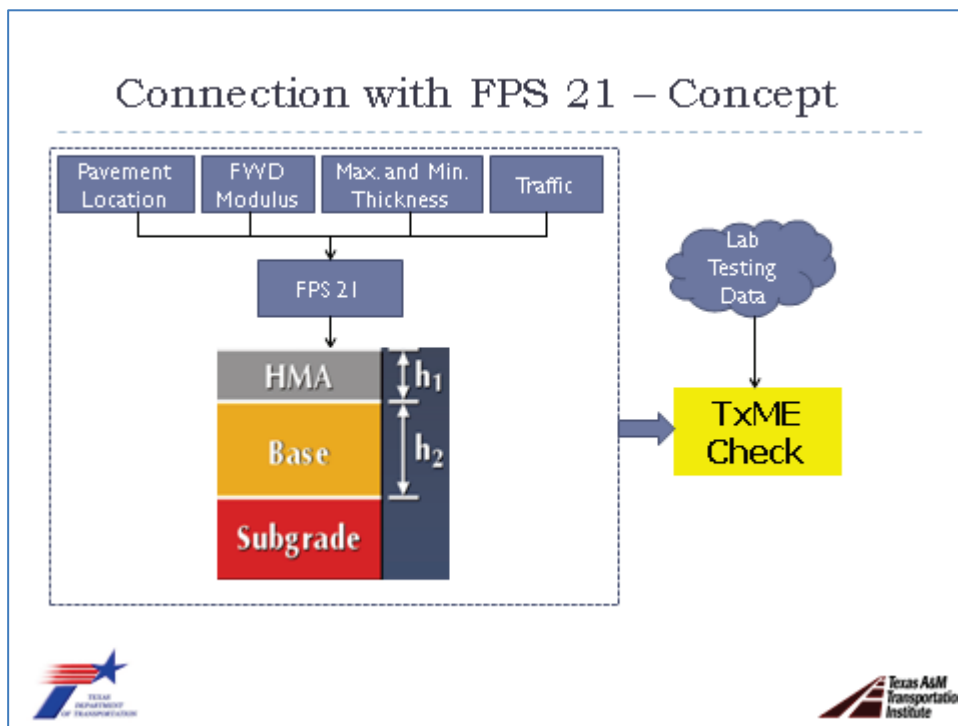
Key Message:	Outputs – rut depth reliability results
Interactivity:	<p>Tell: This screen shows the rutting comparison among different reliability levels. For rut depth prediction, the higher reliability level, the higher predicted distress value at given time. For example, this screen shows that at 100th month, the predicted rut depth is 0.245 inches at 90% reliability level, while 0.22 inches at 50% reliability level.</p> <p>Tell: 90% reliable means 90 out of 100 projects will have less rut depth than the prediction value.</p>
Notes:	NA



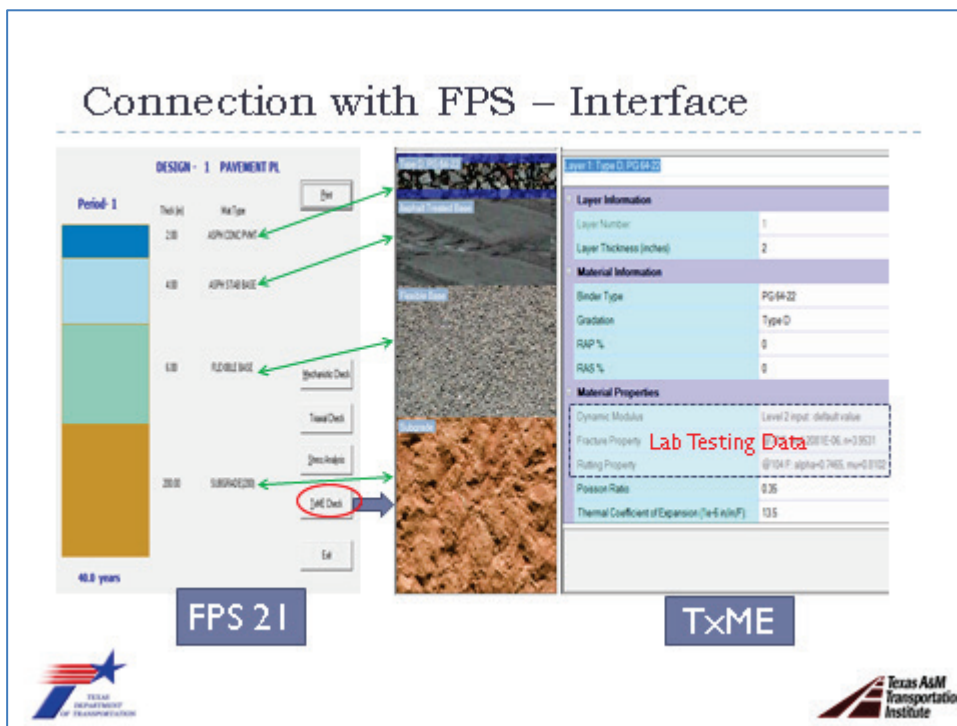
Key Message:	Outputs – AC fatigue cracking reliability results
Interactivity:	<p>Tell: This screen shows the AC fatigue cracking comparison among different reliability levels. For AC fatigue cracking area (%), the higher reliability level, the higher predicted distress value at given time.</p> <p>Tell: The screen can also be seen from another angle. Let's look at the performance limit value: 50%. The horizontal line touches the 90% reliability level result curve at 60th month while it touches the 50% reliability level result curve at 75th month. This means that 10 out of 100 projects will probably reach the limit at 60th month and 50 out of 100 projects will probably reach the limit at 75th month.</p>
Notes:	NA



Key Message:	Outputs – Endurance limit reliability results
Interactivity:	<p>Tell: This screen shows the endurance limit comparison among different reliability levels. Note that the x-axis is microstrain and y-axis the percentile. The higher the reliability level, the bigger predicted microstrain value at the given percentile.</p> <p>Tell: Remember if the predicted strain distribution is at the left side of the strain distribution limit, the pavement is deemed as perpetual.</p>
Notes:	You should be no more than 80 minutes into the lesson at this point.




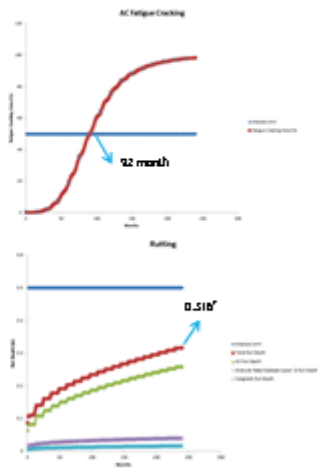

Key Message:	Concept of connection with FPS
Interactivity:	<p>Tell: The users input of FPS 21 includes pavement location, traffic ESALs, FWD modulus of each layer, maximum and minimum thickness of each layer, etc. The output of FPS 21 is available layer thickness combinations. Note that FPS 21 only use FWD modulus to represent each layer’s property, it does not use any lab testing data so it is impossible to determine benefits from improved base materials or superior asphalt mixes. To determine these benefits, TxME is designed to import the input and output information from FPS 21, plus some specific test results such as rutting property or fracture property, to conduct the performance check.</p>
Notes:	NA



<p>Key Message:</p>	<p>Interface of connection with FPS</p>
<p>Interactivity:</p>	<p>Tell: By clicking the button “TxME Check” in the FPS 21 screen, the 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 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.</p>
<p>Notes:</p>	<p>NA</p>

Examples 1 – ESALs


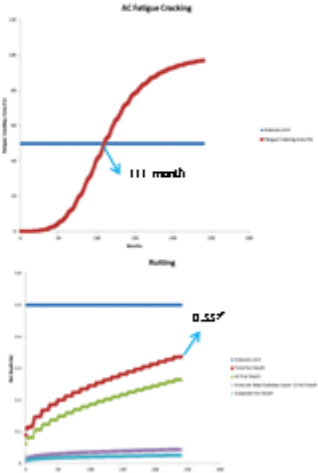

- ▶ **Pavement Structure – Conventional or thin HMA**
 - ▶ 4" AC/8" Flexible base/Subgrade
- ▶ **Material Property**
 - ▶ AC: PG 64-22, Type D
 - ▶ Flexible base: 50 ksi; Subgrade: 4 ksi
- ▶ **Climate**
 - ▶ Weather Station: Austin/City, TX
- ▶ **Traffic**
 - ▶ ESALs: 3 Million
- ▶ **Reliability**
 - ▶ Default: Deterministic

Key Message:	Example 1
Interactivity:	<p>Tell: Now we will start to create a pavement project to perform analysis. Assuming this pavement is in Austin and is a conventional 4-inch AC pavement. The AC material is the most common used material in Texas: Type D and the binder is Performance Grade (PG) 64-22. The traffic is 3-million ESALs (20 years). For this case we will perform deterministic analysis, which means we do not consider variability for the inputs. Since we didn't conduct specific lab testing for the material, so the defaults value of these material properties will be taken as input. We can view these values in the software, for example, fracture properties, rutting properties, etc.</p> <p>Tell: Let's launch the TxME program and create a project, build a pavement structure, and input the parameter values step by step through the user interfaces.</p> <p>Tell: After complete all the inputs, let's click the "Run" button to run analysis, the result will be automatically organized into Excel format and show up.</p>
Notes:	You should demonstrate the processes step by step using TxME program, while letting students follow these steps by themselves using their computers. Answer questions and help to solve problems that students may have.

Examples 2 – Load Spectrum

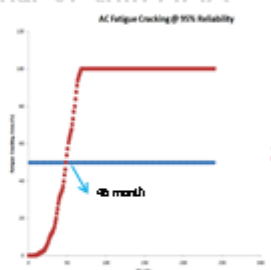
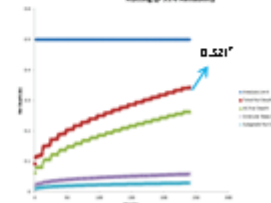
- ▶ **Pavement Structure – Conventional or thin HMA**
 - ▶ 4"AC/8"Flexible base/Subgrade
- ▶ **Material Property**
 - ▶ AC: PG 64-22, Type D
 - ▶ Flexible base: 50 ksi; Subgrade: 4 ksi
- ▶ **Climate**
 - ▶ Weather Station: Austin/City, TX
- ▶ **Traffic**
 - ▶ Load Spectrum: 500 AADTT
(Equals to 3.16 Million ESALs according to Asphalt Institute Equivalent Axle Load Factors)
- ▶ **Reliability**
 - ▶ Default: Deterministic







Key Message:	Example 2
Interactivity:	<p>Tell: In this example, we will try Level 1 traffic input – load spectrum. We set the AADTT value to be 500, which is equal to 3.16 million ESALs of 20 years according to Asphalt Institute Equivalent Axle Load factors.</p> <p>Tell: Use the “save as” function to save the previous project into a new project with a different name. Change the traffic input level from “Level 2” to “Level 1” by clicking the radio button. Input the AADTT value and keep the other parameters unchanged, and then click the “Run” button.</p> <p>ASK: Compare the result of load spectrum input with that of ESALs input, what conclusions you can make?</p> <p>Follow Up: Since the traffic volumes are close between the ESALs and load spectrum, the results (fatigue cracking and rutting) are comparable. However, depending on the axle load distribution or other factors, the difference between them can be bigger.</p>
Notes:	Let students follow these steps by themselves on their computers.

Examples 3 – Reliability

- ▶ **Pavement Structure – Conventional or thin HMA**
 - ▶ 4"AC/8"Flexible base/Subgrade
- ▶ **Material Property**
 - ▶ AC: PG 64-22, Type D
 - ▶ Flexible base: 50 ksi; Subgrade: 4 ksi
- ▶ **Climate**
 - ▶ Weather Station: Austin/City, TX
- ▶ **Traffic**
 - ▶ ESALs: 3 Million
- ▶ **Reliability**
 - ▶ AC Thickness CV: 15%;
 - ▶ Flexible base modulus CV: 20%
 - ▶ Reliability Level: 95%

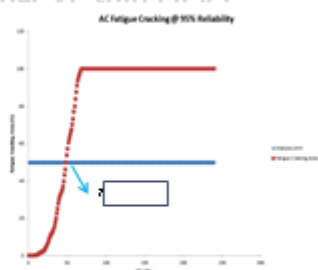
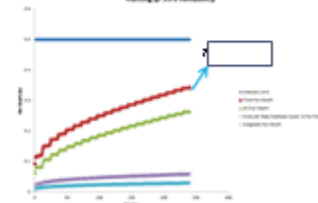








Key Message:	Example 3
Interactivity:	<p>Tell: In this case, we will try reliability based analysis and learn the impacting factors. We will keep the same pavement structure, material property, climate condition, and traffic (ESALs) as previous examples, but assuming variabilities for some input parameters. For example, the coefficient of variation (CV) of AC layer thickness is 15%, and the CV of the flexible base modulus is 20%. These values are possible values and can be determined by statistical calculation of the actual measured value. In this example, we want the look at the prediction result at 95% reliability level.</p> <p>Tell: To input the abovementioned numbers, we need double click the “Reliability” node in the left part of TxME screen. In the reliability related input screen, check the applicable checkboxes and modify the coefficient of variation value. Notice then values will automatic show up in the “Reliability (%)” column. The default value is “50”, and we can change it to “95.”</p>
Notes:	Let students follow these steps by themselves on their computers.

Exercises 1– (Load Spectrum + Reliability)

- ▶ **Pavement Structure – Conventional or thin HMA**
 - ▶ 4"AC/8"Flexible base/Subgrade
- ▶ **Material Property**
 - ▶ AC: PG 64-22, Type D
 - ▶ Flexible base: 50 ksi; Subgrade: 4 ksi
- ▶ **Climate**
 - ▶ Weather Station: Austin/City, TX
- ▶ **Traffic**
 - ▶ Load Spectrum: 500 AADTT
- ▶ **Reliability**
 - ▶ AC Thickness CV: 15%;
 - ▶ Flexible base modulus CV: 20%
 - ▶ Reliability Level: 95%

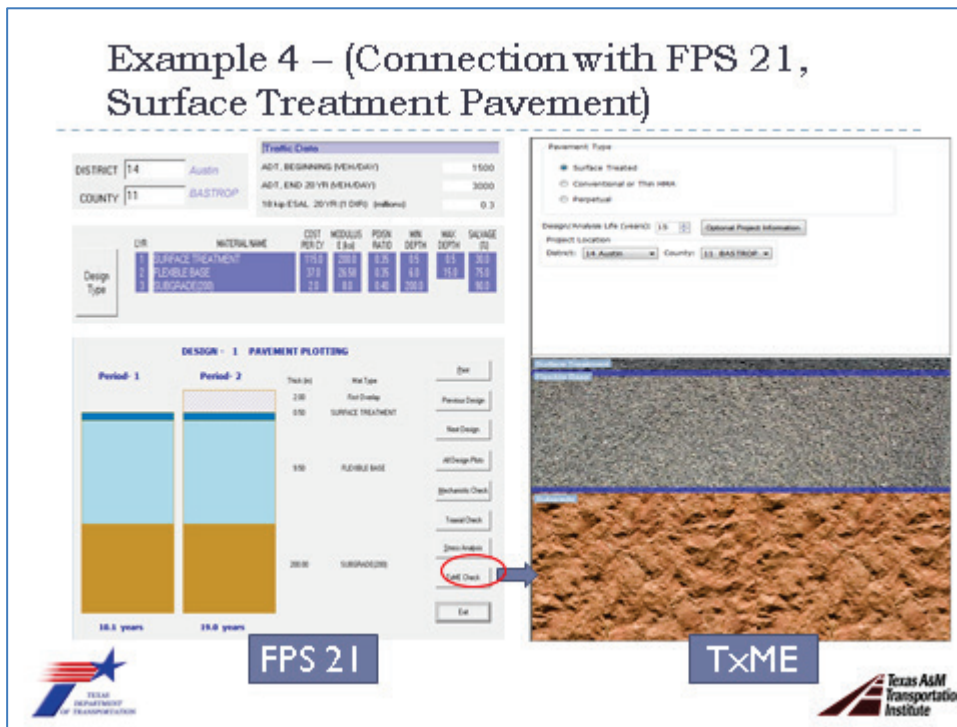



Key Message:	Exercise 1
Interactivity:	<p>Tell: Now let's do the exercise. In this case we want to perform load spectrum and reliability based analysis. The input parameters are:</p> <p>Traffic:</p> <ul style="list-style-type: none"> ▪ Load Spectrum: 500 AADTT. <p>Reliability Parameters:</p> <ul style="list-style-type: none"> ▪ AC Thickness CV: 15%. ▪ Flexible base modulus CV: 20%. ▪ Reliability Level: 95%. <p>Other Inputs: same as previous samples</p> <p>ASK: What's the result?</p> <p>Follow Up: Help students to complete the analysis and get the correct result.</p>
Notes:	Let students create, edit, and run the project on their own and answer their questions.

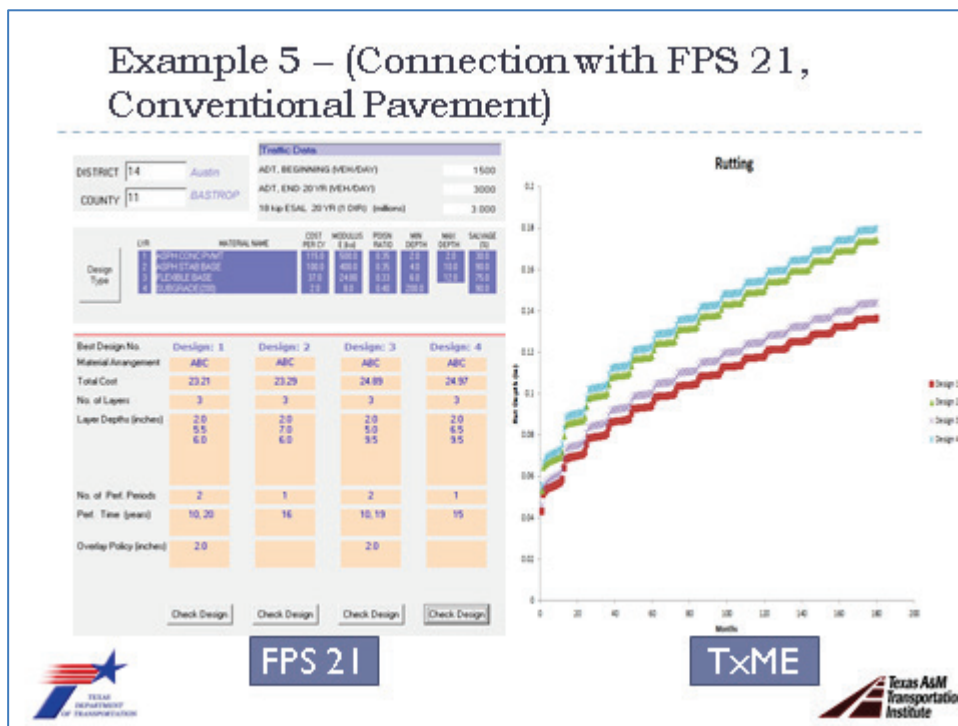
Exercises 2– (AC: SMA)

- ▶ **Pavement Structure – Conventional or thin HMA**
 - ▶ 4"AC/8"Flexible base/Subgrade
- ▶ **Material Property**
 - ▶ AC: PG 76-22, SMA D
 - ▶ Flexible base: 50 ksi; Subgrade: 4 ksi
- ▶ **Climate**
 - ▶ Weather Station: Austin/City, TX
- ▶ **Traffic**
 - ▶ Load Spectrum: 500 AADTT
- ▶ **Reliability**
 - ▶ AC Thickness CV: 15%;
 - ▶ Flexible base modulus CV: 20%
 - ▶ Reliability Level: 95%

Key Message:	Exercise 2
Interactivity:	<p>Tell: For this exercise, we want to learn the influence of different material. Change the AC material from Type D, PG 64-22 to Stone Mastic Asphalt (SMA)-D, PG 76-22, and keep all the other parameters unchanged.</p> <p>ASK: What’s the result? How is it compared to the previous exercise?</p> <p>Follow Up: Help students to complete the analysis and get the correct result.</p>
Notes:	Let students save the project as a new one, change the corresponding inputs, run the project on their own, and answer their questions.



<p>Key Message:</p>	<p>Connection with FPS 21- Surface Treatment</p>
<p>Interactivity:</p>	<p>Tell: This screen lists the key input interfaces of FPS 21:</p> <ul style="list-style-type: none"> ▪ District and County. ▪ Traffic Data. ▪ Design Type – Surface Treatment. ▪ Output – Design Options. <p>Tell: For each option, there is a “TxME Check” button. Click that button, and a corresponding TxME project will be created automatically. This TxME project will automatically incorporate the input of FPS and assign default values for material properties that do not exist in FPS (e.g., AC fracture properties and rutting properties). Notice the pavement type, layer thicknesses, project locations are all taken from FPS. By clicking the “Run” button in TxME, the corresponding performance will be predicted and compared.</p>
<p>Notes:</p>	<p>You should demonstrate the processes step by step using FPS 21 and TxME program, while letting students follow these steps by themselves on their computers. Answer questions and help to solve problems that students may have.</p>



Key Message:	Connection with FPS 21- Conventional Pavement
Interactivity:	Tell: This case demonstrates how the TxME performs prediction and comparison for FPS 21 conventional pavement design options. Similar to the previous example, the FPS 21 provides four design options. For each option, TxME automatically incorporated the corresponding input and predicted the performance. Take rutting comparison as an example, it can be found that the design option 1 has the lowest rut depth.
Notes:	You should demonstrate the processes step by step using FPS 21 and TxME program, while letting students follow these steps by themselves on their computers. Answer questions and help to solve problems that students may have.

Acronym and Abbreviation List

AADTT	Annual Average Daily Truck Traffic
AC	Asphalt concrete
AMPT	Asphalt Mixture Performance Tester
CV	Coefficient of Variation
ESAL	Equivalent Standard Axle Load
FPS	Flexible Pavement Design System
FWD	Falling Weight Deflectometer
HMA	Hot Mixture Asphalt
PG	Performance Grade
SMA	Stone Mastic Asphalt
TxDOT	Texas Department of Transportation
TxME	Texas Mechanistic-Empirical Flexible Pavement Design and Analysis System
UTM	Universal Test Machine

Training Evaluation Form

for participants in TxME Trainings

Date: _____

Title and location of training:

Trainer:

Instructions: Please indicate your level of agreement with statements listed below in #1–7.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1. The objectives of the training were clearly defined.	0	0	0	0	0
2. The topics covered were relevant to me.	0	0	0	0	0
3. The materials distributed were helpful.	0	0	0	0	0
4. This training experience will be useful in my work.	0	0	0	0	0
5. The trainer was knowledgeable about the training topics.	0	0	0	0	0
6. The time allotted for the training was sufficient.	0	0	0	0	0
7. The meeting room and facilities were adequate and comfortable.	0	0	0	0	0

8. What did you like most about this training?

9. What aspects of the training could be improved?

10. Please share other comments here:

Thank you for your feedback!

