Texas Department of Transportation

FLEXIBLE PAVEMENT DESIGN SYSTEM FPS 23: USER MANUAL

November 2025

Contents

Chapter 1. Introduction

The Flexible Pavement System (FPS) is deflection-based pavement design software routinely used by the Texas Department of Transportation (TxDOT) for: (1) pavement structural (thickness) design, (2) structural overlay design, (3) stress-strain response analysis, and (4) pavement life and distress (rutting and cracking) prediction.

FPS 23 is the most recent version of this design system developed by the Texas A&M Transportation Institute (TTI) for TxDOT. The program includes a new Texas Mechanistic-Empirical design package (TxME), while it retains much of the familiarity of FPS 21. FPS 23 is intended to replace FPS 21, which has been implemented since the 2000s. Both programs incorporate the same design principle and have substantially identical inputs. FPS 23 produces identical thickness designs to FPS 21, in addition incorporating the TxME as a design check and the recommendations from TxDOT Pavement Manual.

The FPS design approach is based on a linear-elastic analysis system, and the key material inputs are the backcalculated modulus values of the pavement layers. For in-place materials, these are obtained from testing with the Falling Weight Deflectometer (FWD) and processing the data with the backcalculation software MODULUS 7. For newly placed materials, realistic average moduli values for the main structural layers in typical Texas pavements are supplied based on user experience, with recommended values available in TxDOT Pavement Manual. Districts are encouraged to test existing pavements and generate design moduli values for their local materials. The FPS design process is comprised of the following two steps:

(1) generate a trial pavement structure with proposed design thicknesses, and
(2) check the proposed design with modified Texas triaxial, mechanistic, and TxME checks.

The FPS system has an embedded design equation relating the computed surface curvature index (difference of the W_1 and W_2 deflections) of the pavement to the loss in serviceability. As described below the design checks are principally based on either mechanistic design concepts, which compute fatigue life and subgrade rutting potential, or the Modified Texas Triaxial criteria, which evaluates the impact of the anticipated heaviest load on the proposed pavement structure. The recent addition is the advanced TxME comprehensive pavement design check and performance prediction models.

1.1 Modified Texas Triaxial Check

The Modified Texas Triaxial criterion was developed to prevent a shear failure in the subgrade soil under the heaviest wheel load anticipated for the pavement section. Results of the analysis will recommend the total thickness of granular base, stabilized materials, and hot mix asphalt (HMA) surface to prevent shear failures in the subgrade. Currently the Triaxial check is mandated for all flexible pavement designs developed for TxDOT maintained highways.

1.2 Mechanistic Design Check

The mechanistic design check computes and checks the sufficiency of the mechanistic responses in terms of maximum induced horizontal tensile strain at the bottom of the lowest HMA layer and the maximum vertical compressive strain on top of the subgrade. Standard models are available to convert these values into the number of standard 18-kip load applications until either cracking or subgrade rutting criteria occurs. The mechanistic design check is recommended for all pavements with HMA surfaces. Currently the mechanistic design check is not required for pavement design approval (with the exception of pavements deliberately designed as "perpetual"), but it should be run for informational purposes on all HMA designs. It is strongly recommended to run the fatigue cracking analysis for all designs where the recommended HMA thickness is between 2 and 4 inches. In a typical flexible pavement, the maximum tensile strains at the bottom of the asphalt layer tend to occur in the thickness range of 2 to 4 inches. These strains cause the load associated fatigue cracking of the asphalt layer.

1.3 Mechanistic-Empirical (TxME) Design Check

TxME is comprehensive Mechanistic-Empirical (M-E) based software to assist TxDOT engineers to optimize design decisions. It can be used for:

- Thickness design validation, for surface treatment, conventional asphalt concrete (AC), or perpetual pavements.
- Evaluation of the impact of recycled materials on pavement life predictions[1].
- Impact of varying mix [Dense-Graded vs. Superpave vs. Stone-Matrix Asphalt (SMA)] and binder type on pavement life predictions
- Prediction of pavement distress performance during the design life, including:
  - Rutting of AC, flexible base, asphalt treated, and subgrade layers.
  - AC fatigue cracking (bottom-up cracking model)
  - AC thermal cracking
  - Stabilized base fatigue cracking

The TxME design check empowers TxDOT designers to leverage new materials, fostering more economical and dependable designs. Key features of TxME encompass:

- Built in material properties for all typically used pavement layers

[1] Care must be exercised when evaluating the impact of reclaimed asphalt pavement (RAP) and reclaimed asphalt shingles (RAS) on pavements with multiple HMA layers. The current version is based on cracking starting at the bottom layer. The impact of higher RAP and RAS contents on surface layer will generate misleading results. Future versions of this package will incorporate a top-down cracking model.

- M-E modeling, calibrated with extensive field performance data
- Performance-based material characterization
- Incorporation of traffic load spectrum in addition to traditional 18-kip Equivalent Single Axle Load (ESAL) estimates
- Reliability-based pavement distress performance prediction
- User-friendly interface
- Seamless integration with FPS.

Chapter 2. FPS 23 System Requirements and Loading Instructions

2.1 System Requirements

The system requirements are as follows:

- FPS 23 requires a Windows 7, or later operating system.
- At least a 1.0 GHz processor speed and a minimum of 1 GB disk space are recommended to run FPS 23.

The software is provided in an executable set up program, which loads the software and puts the FPS 23 icon on the desktop. FPS 23 is loaded first followed by TxME. The most recent versions of the FPS 23 and TxME software can be downloaded from the Software Center[2] or the link.

2.2 Installation Setup for FPS 23 and TxME

The program is supplied in an executable file called FPS23SetupVx-x_*mm-dd-yyyy*.exe, where the version number and effective date of the current version is included as part of the file name. Running the setup program will cause the screen shown in Figure 1 to be displayed.

[2] Available TxDOT internally only

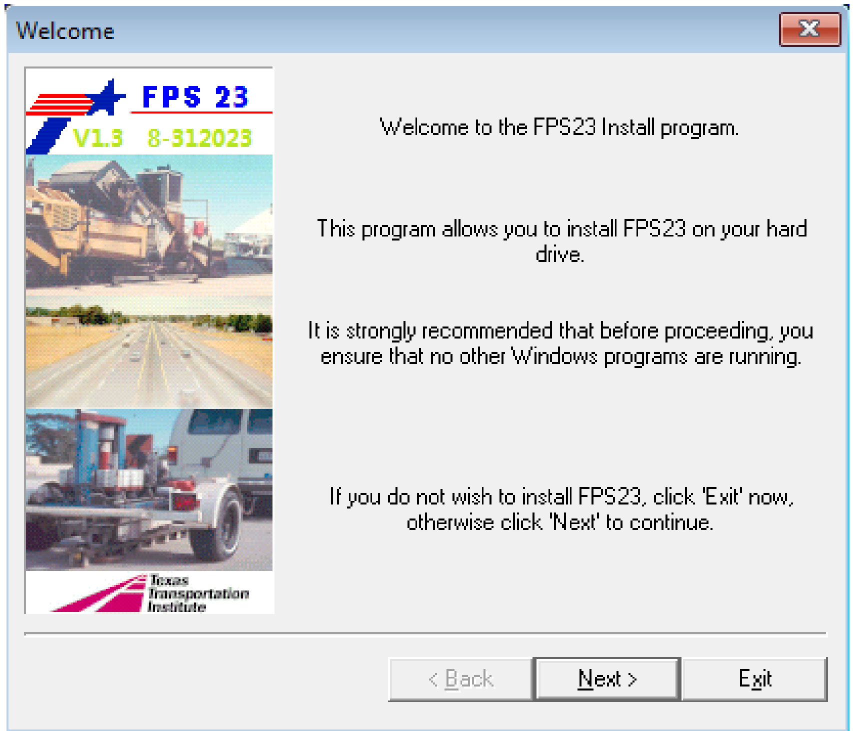


Figure 1. Opening Screen of FPS 23 Setup Program.

The user selects the 'Next" button and then an information screen comes up with the latest version information and instructions if an old version is installed. Refer to Figure 2. Use the "Next" button then specify the folder location where the FPS 23 program is to be stored (Figure 3). After that the screen shown in Figure 4 is displayed. To load the program, select the "Start" button.

Figure 2. FPS 23 Setup Information Screen

Figure 3. FPS 23 Setup Directory Screen

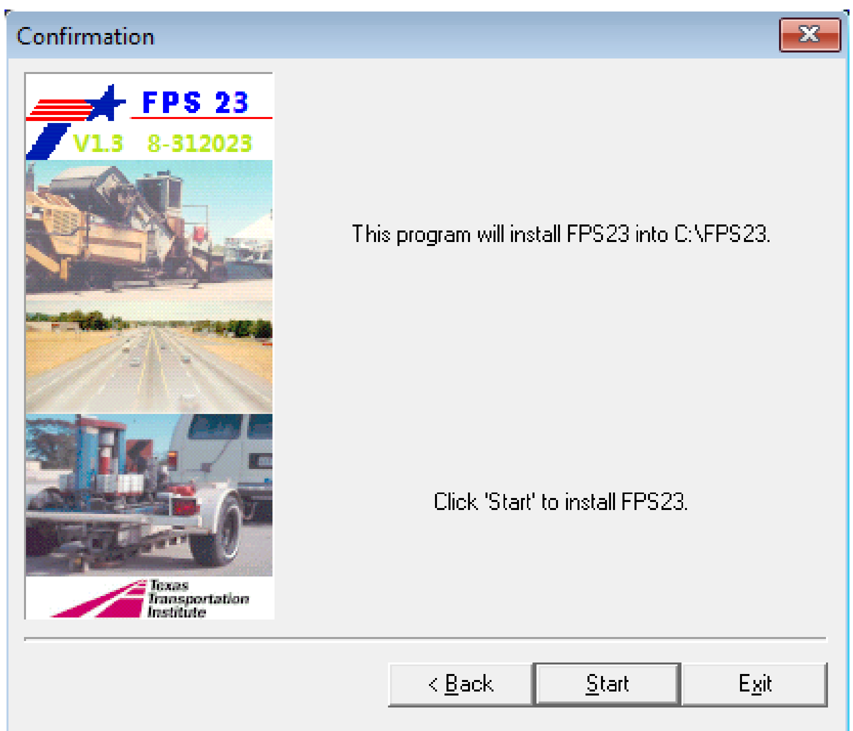


Figure 4. Setup Program Screen Following Selection of Drive Storage Location.

In most computers the program will display the message shown in Figure 5 asking if the user wants to overwrite existing DLLs. In all cases reply **NO** as the system is trying load an older version of the DLL.

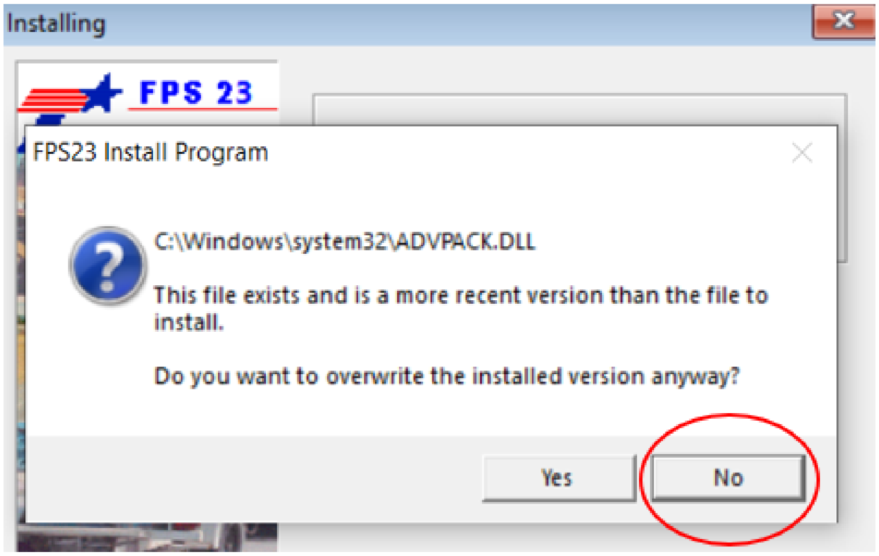
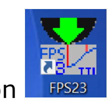


Figure 5. Overwrite DLL Dialogue Box.

Install TxME

The most recent version of TxME will be identified as follows, "TxMEInstall_Vx-x_mm-dd-yyyy.msi", where the latest version number and effective date is included as part of the file name. Double-click the application and follow the prompts to complete the TxME installation.

With the steps above, FPS 23 and TxME should be successfully installed. The FPS 23 icon 

and TxME icons 

should appear on your desktop.

Chapter 3 Running the FPS 23 Design Software

Click on the FPS 23 icon which was placed on the desktop screen after installation of the software, to run the program (Figure 6).

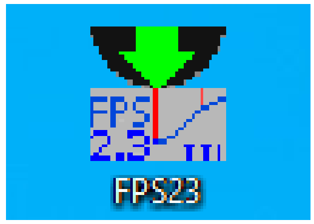


Figure 6. FPS 23 Icon

3.1 Main Menu (with Version Number Date)

In most cases, the user is interested in generating a flexible pavement design and will select the FPS Pavement Design button from the main menu (Figure 7). The Stress Analysis Tool will be described later, it provides a simple analysis package to calculate stress, strains or defections for any pavement structure.

Figure 7. FPS 23 Main Menu.

3.2 Setting up a Design Problem in the FPS 23 System

Select the Main Menu FPS Pavement Design Option to develop pavement designs.

3.2.1 Project Administrative Data Inputs

The project administrative data input screen appears (Figure 8). By clicking on the District input box, a map is provided where the user can select the District and County. (Figure 9). Based on County name updated default subgrade modulus values are provided within FPS 23. Also, a database of county soil types with average Texas Triaxial Class values is automatically uploaded for later use in the computation of Triaxial Thickness. Make sure there are inputs in the Problem, Highway, Control, Section, and Job boxes to describe the design work while the date is automatically added. The user can input 5 lines of Comments about the project being run, these will appear as a header in the design output file. There is an option to recall an existing design (.dat file) which has been stored in an earlier run. Use the blue arrow to go to the next input page.

Figure 8. FPS 23 Project Administrative Data Input Screen.

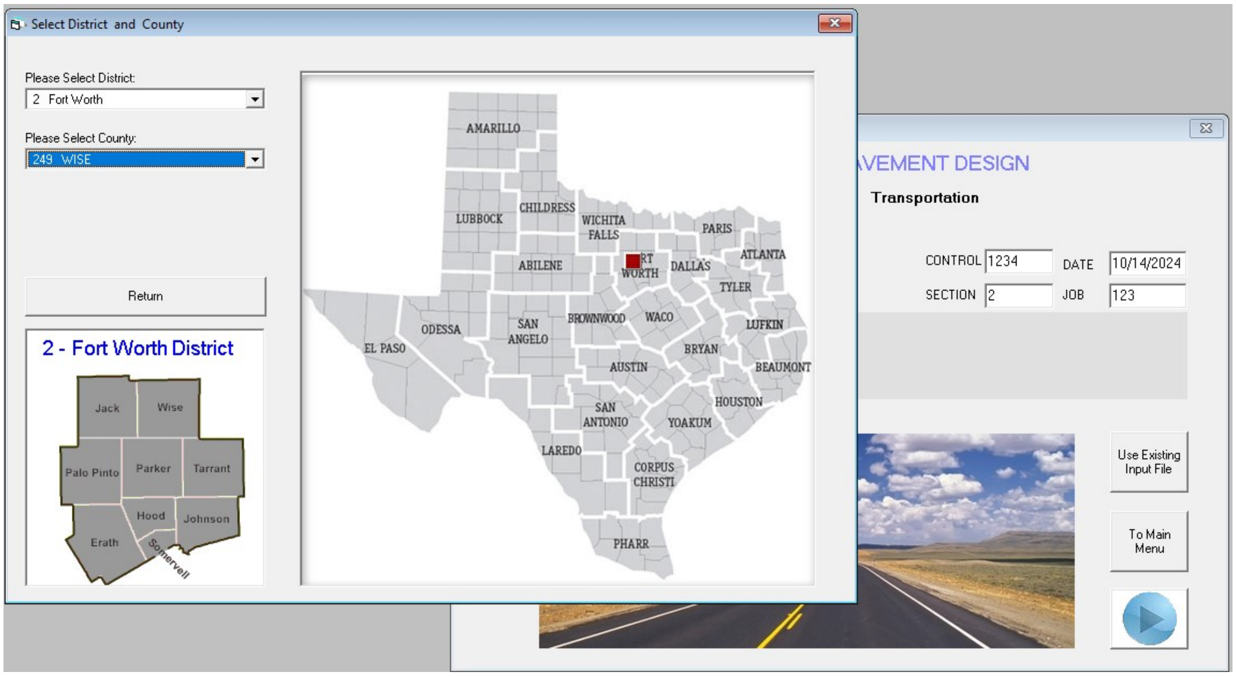


Figure 9. FPS 23 District and County Selection Screen

3.2.2 Input Design Data Screen

In this version of FPS 23 all of the basic design criteria and traffic data are entered on the second input screen (Figure 10). A HELP menu is provided; click on any field, select F1, and a description of the variable and allowable values will be displayed. These details are not provided in this report, and the user is advised to consult the HELP menu within the program directly. Table 1 shows the basic design and traffic inputs required.

Table 1. Basic Design, Program Controls, and Traffic Inputs

Basic Design Criteria	Program Controls	Traffic Data
Length of analysis period (years)	Max funds per sy for initial construction ($)	ADT, beginning (veh/day)
Minimum time to first overlay (years)	Max total thickness of initial construction	ADT, end of 20 years (veh/day)
Minimum time between overlays (years)	Max total thickness of all overlays (inches)	18-kip EASL, 20 yr (1 direction) millions
Design confidence level		Average approach speed to Overlay zone (mph)
Initial serviceability index		Average speed in zone (overlay direction) (mph)
Final serviceability index		Average speed in zone (non-overlay direction) (mph)
Serviceability index after overlaying		% of ADT/Hr of construction
District temperature constant		Percent trucks in ADT
Interest rate (percentage)		

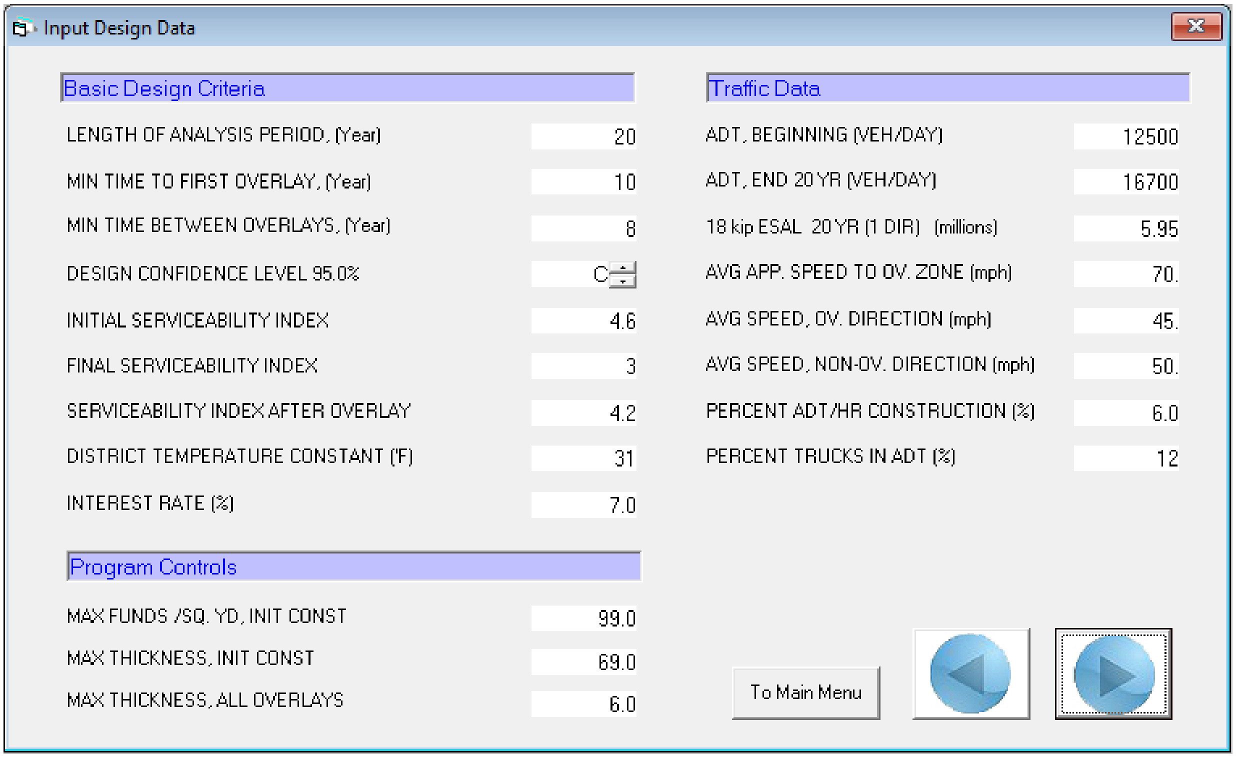


Figure 10. FPS 23 Basic Design and Traffic Inputs.

The blue arrows are for moving between pages. Using the right-hand arrow advances you to the final design input page that initially appears as shown in Figure 11.

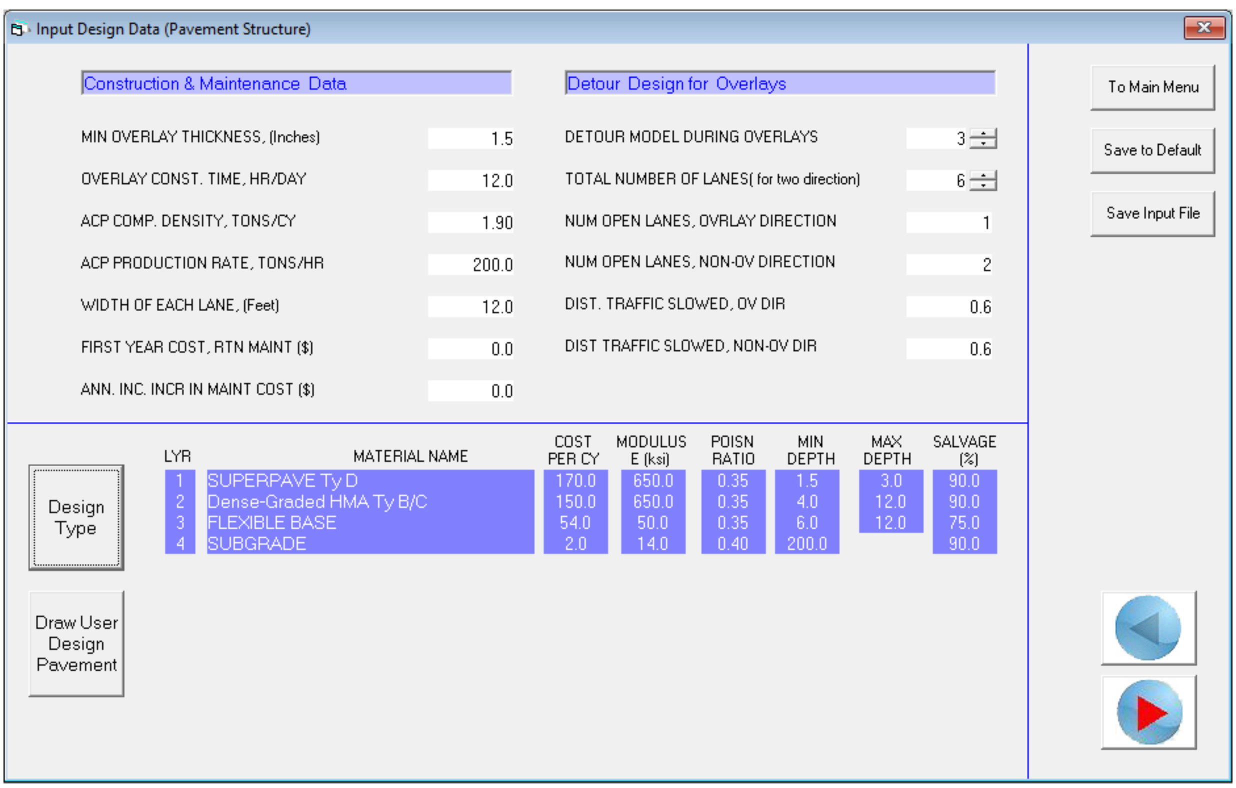


Figure 11. Final FPS 23 Input Screen Initial View.

3.2.3 Input Design Data (Pavement Structure)

There are 2 sections of the input screen, the first section includes the inputs shown in Table 2.

Table 2. Design Data Inputs

Construction and Maintenance Data	Detour Design for Overlays
Minimum overlay thickness	Detour model used during overlaying
Overlay construction time (hrs/day)	Total number of lanes of the facility
Asphalt compaction density (tons/cy)	Number of lanes open, overlay direction
Asphalt concrete production rate (tons/hr)	Number of lanes open, non-overlay direction
Width of each lane (ft)	Distance traffic is slowed (overlay direction) (miles)
1st-yr cost of routine maintenance (dollars/lane mile)	Distance traffic is slowed (non-overlay direction) (miles)
Annual incremental increase in maintenance (dollars/lane mile)	Detour distance around overlay zone (miles)

The second section defines the pavement structure under consideration, with the following information needed:

- Layer number with layer 1 being the surface material.
- Material name
- Cost per cubic yard
- Modulus (E) in ksi
- Poisson's Ratio of each layer
- Minimum depth of each layer in inches
- Maximum depth of each layer in inches
- Salvage value of the layer in percent.

As described with the first input design data screen, A HELP menu is provided; click on any field, hit the F1 button, and a description of the variable and allowable values will be displayed. These details are not provided in this report, and the user is advised to consult the HELP menu within the program directly.

Selecting a Traffic Detour Model

Detour models are the same as used in FPS 21. The designer is assisted in selecting the correct model by means of a graphical display. Enter the detour model (anticipated for future overlays) for this project by entering the appropriate number in the first field under "Detour Design for Overlays." A graphic will appear that displays the anticipated mode of handling traffic for the future overlay (Figure 12 and Figure 13).

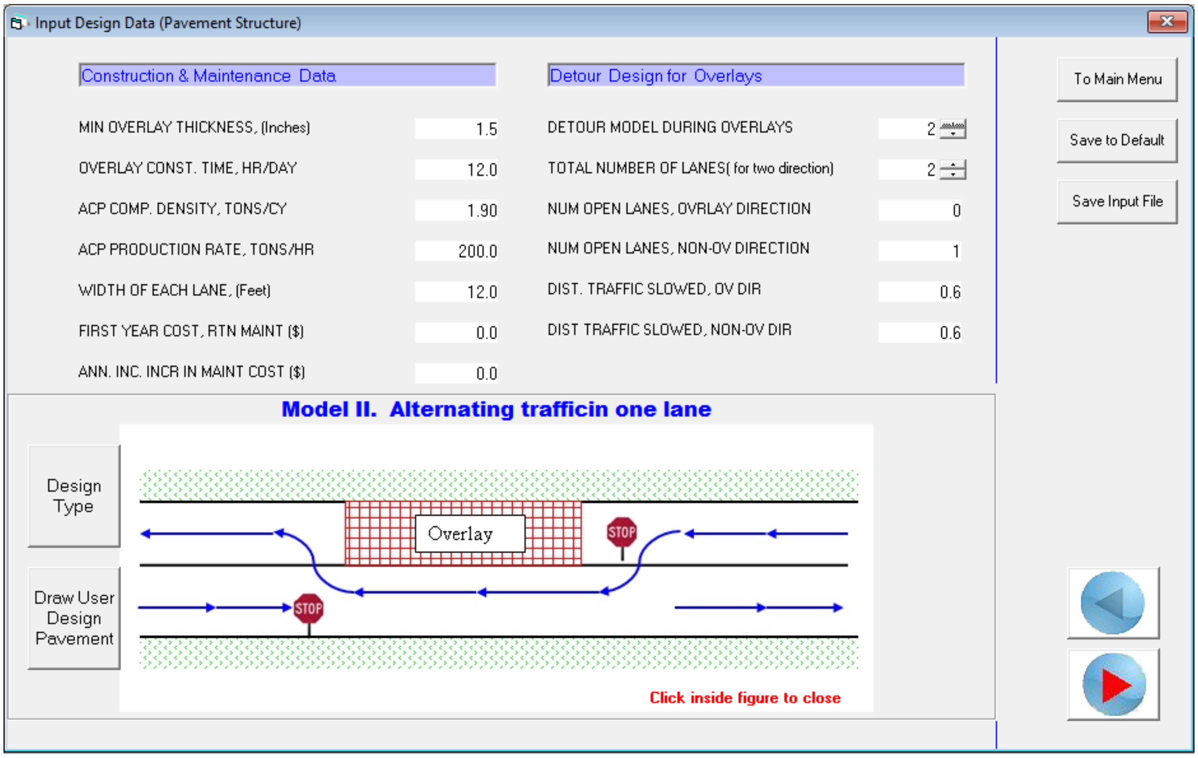


Figure 12. Graphic Corresponding to Selected Detour Model.

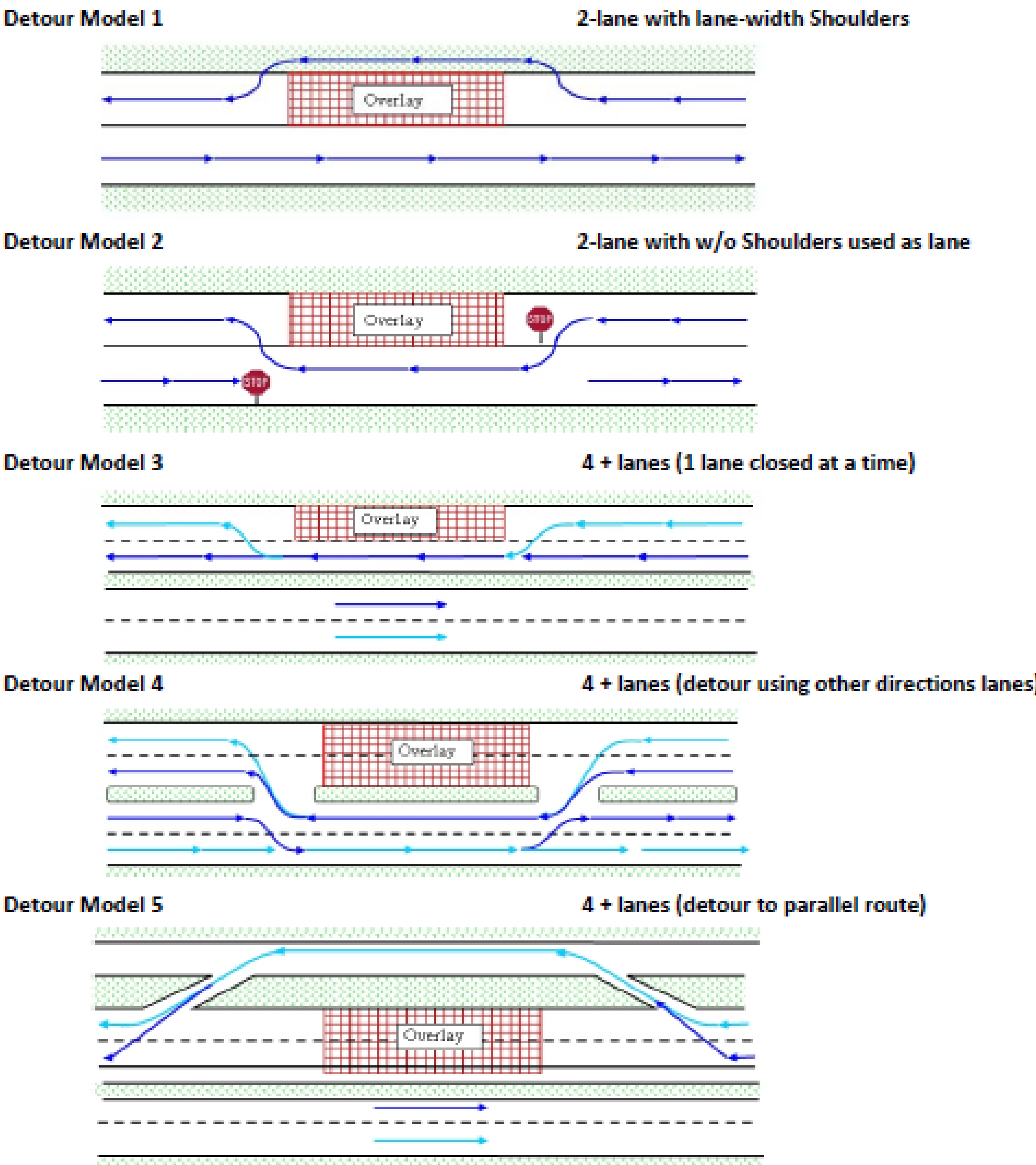


Figure 13. Detour Models

Click inside the model graphic to hide the graphic and return to the original screen.

3.2.4 Selecting a Pavement Design Type

Click on **Design Type** to view the design type options screen shown in Figure 14. By selecting any design type option, a template will be revealed for that type of structure.

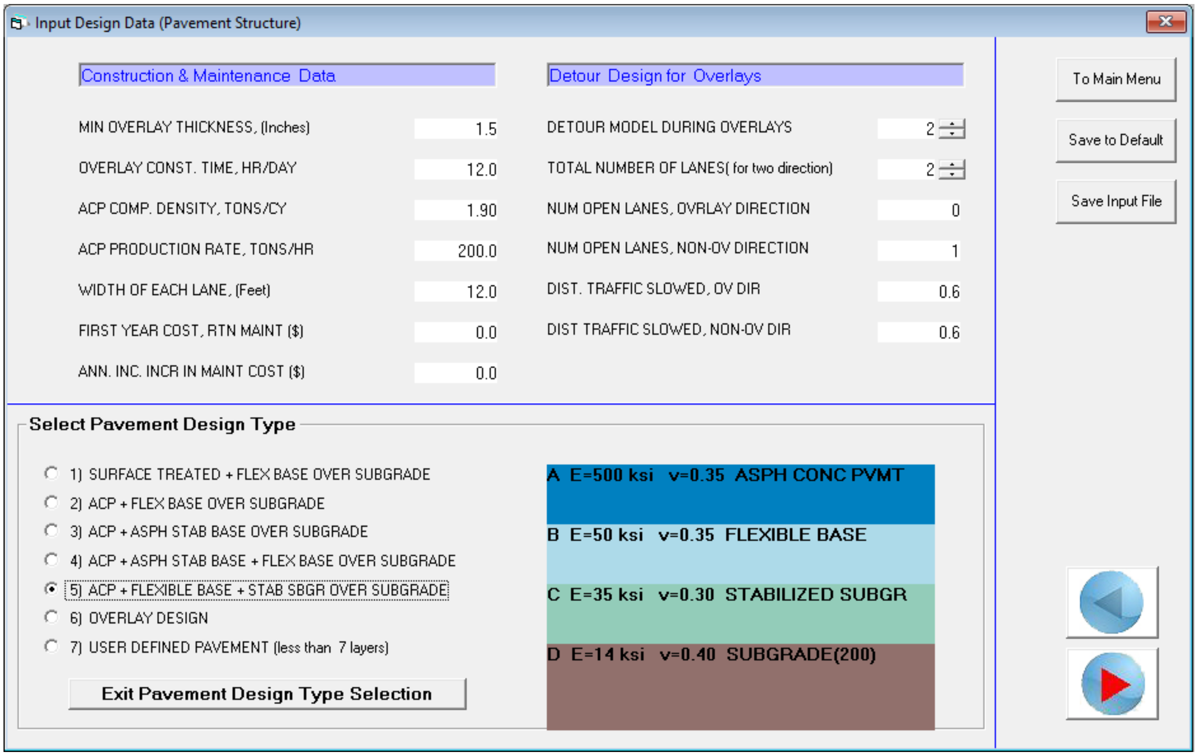
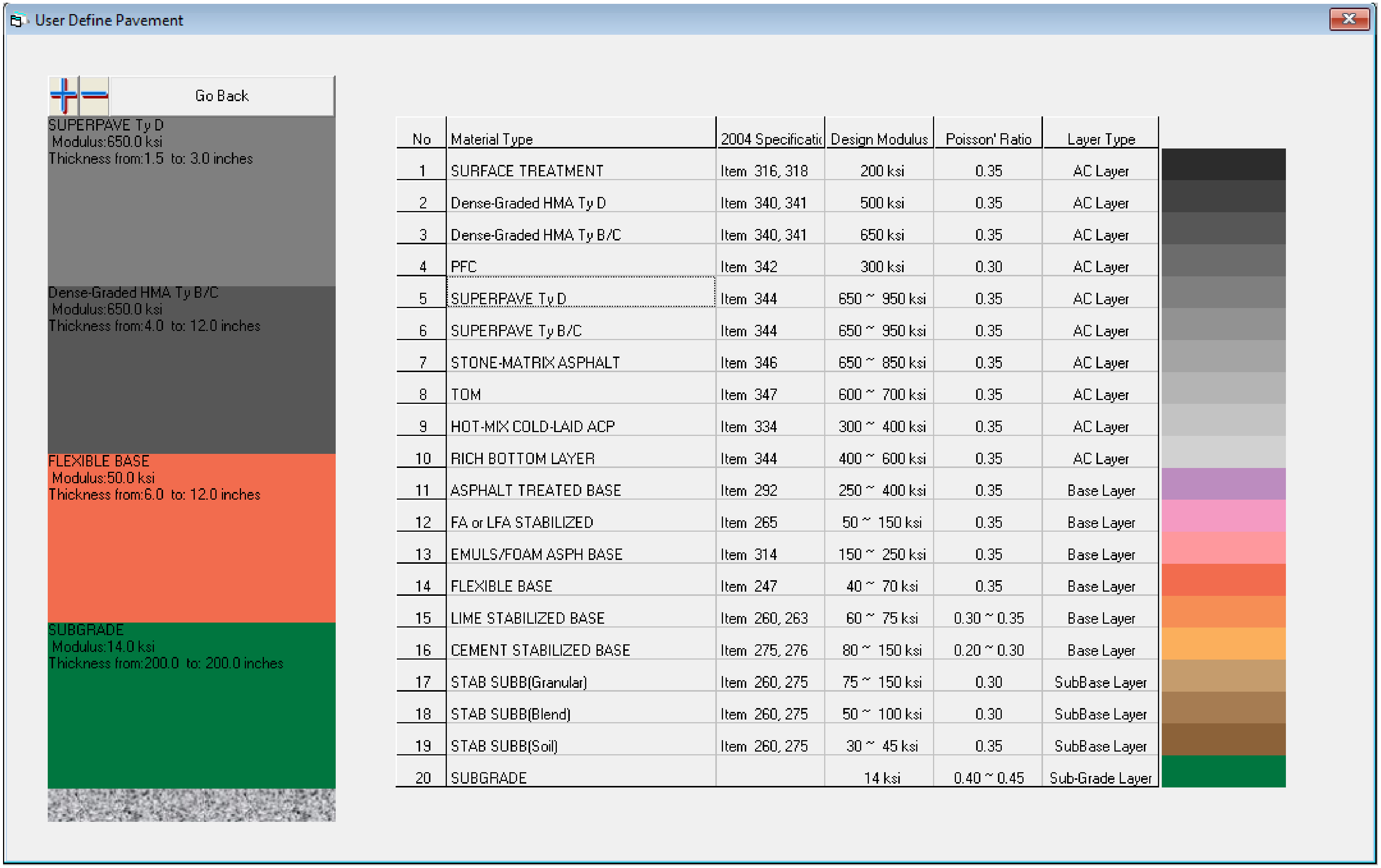


Figure 14. Design Type Options.

Design option 1 is used when the final surface is a surface treatment. The same performance model is used for option 1 and option 2 pavement types. An important feature of FPS 23 is Pavement Design Type 7 (user defined pavement); for this example, select 7 and click on the **Exit Pavement Design Type Selection** button.

This option is intended to be used for multi-layered pavement systems where four or more pavement layers are to be designed. This option will not permit designs of less than four layers including the subgrade. When you first enter the screen shown below a tentative pavement structure is shown with four blank layers. There are 20 material types from which the designer can build a pavement structure. To build the pavement structure shown in Figure 15:

1. Press the + button to increase the number of layers in the pavement up to 7 layers.
2. Use the drag and drop feature. Go to the material type; select the material type by clicking it with the left mouse button. Hold the button down and drag the layer into the proposed pavement structure. Start with the subgrade; click it and drag it to the lowest layer (layer 1 is the surface), then add pavement layers. For this example, use Superpave Type D as the surface, Dense Graded Type B/C, and flexible base above the subgrade to complete the pavement structure as shown in Figure 15.
3. Press the **Go back** button to view the layer material parameters and modified if desired.



No	Material Type	2004 Specificati	Design Modulus	Poisson' Ratio	Layer Type
1	SURFACE TREATMENT	Item 316, 318	200 ksi	0.35	AC Layer
2	Dense-Graded HMA Ty D	Item 340, 341	500 ksi	0.35	AC Layer
3	Dense-Graded HMA Ty B/C	Item 340, 341	650 ksi	0.35	AC Layer
4	PFC	Item 342	300 ksi	0.30	AC Layer
5	SUPERPAVE Ty D	Item 344	650 ~ 950 ksi	0.35	AC Layer
6	SUPERPAVE Ty B/C	Item 344	650 ~ 950 ksi	0.35	AC Layer
7	STONE-MATRIX ASPHALT	Item 346	650 ~ 850 ksi	0.35	AC Layer
8	TOM	Item 347	600 ~ 700 ksi	0.35	AC Layer
9	HOT-MIX COLD-LAID ACP	Item 334	300 ~ 400 ksi	0.35	AC Layer
10	RICH BOTTOM LAYER	Item 344	400 ~ 600 ksi	0.35	AC Layer
11	ASPHALT TREATED BASE	Item 292	250 ~ 400 ksi	0.35	Base Layer
12	FA or LFA STABILIZED	Item 265	50 ~ 150 ksi	0.35	Base Layer
13	EMULS/FOAM ASPH BASE	Item 314	150 ~ 250 ksi	0.35	Base Layer
14	FLEXIBLE BASE	Item 247	40 ~ 70 ksi	0.35	Base Layer
15	LIME STABILIZED BASE	Item 260, 263	60 ~ 75 ksi	0.30 ~ 0.35	Base Layer
16	CEMENT STABILIZED BASE	Item 275, 276	80 ~ 150 ksi	0.20 ~ 0.30	Base Layer
17	STAB SUBB(Granular)	Item 260, 275	75 ~ 150 ksi	0.30	SubBase Layer
18	STAB SUBB(Blend)	Item 260, 275	50 ~ 100 ksi	0.30	SubBase Layer
19	STAB SUBB(Soil)	Item 260, 275	30 ~ 45 ksi	0.35	SubBase Layer
20	SUBGRADE		14 ksi	0.40 ~ 0.45	Sub-Grade Layer

Figure 15. Building a Structure in the "User Defined Pavement" Option.

Editing the Material Parameters Table

After clicking on the **Go back** button the screen shown in Figure 16 will appear that allows access to the layer material parameters table. Edit the material type description, layer moduli, and thickness ranges as desired. The default layer moduli are those currently recommended by TxDOT for design but should be overwritten when district experience dictates. In this design example, there are 2 layers where the required thickness will be designed. The first is the Dense Graded Type B (Item 341) layer. It has a user defined thickness ranging from 3 to 12 inches. The second is the flexible base layer which has thickness ranging from 10 to 12 inches; all other layers have fixed thicknesses. The goal is to determine the thickness of these layers to carry the cumulative design traffic loads.

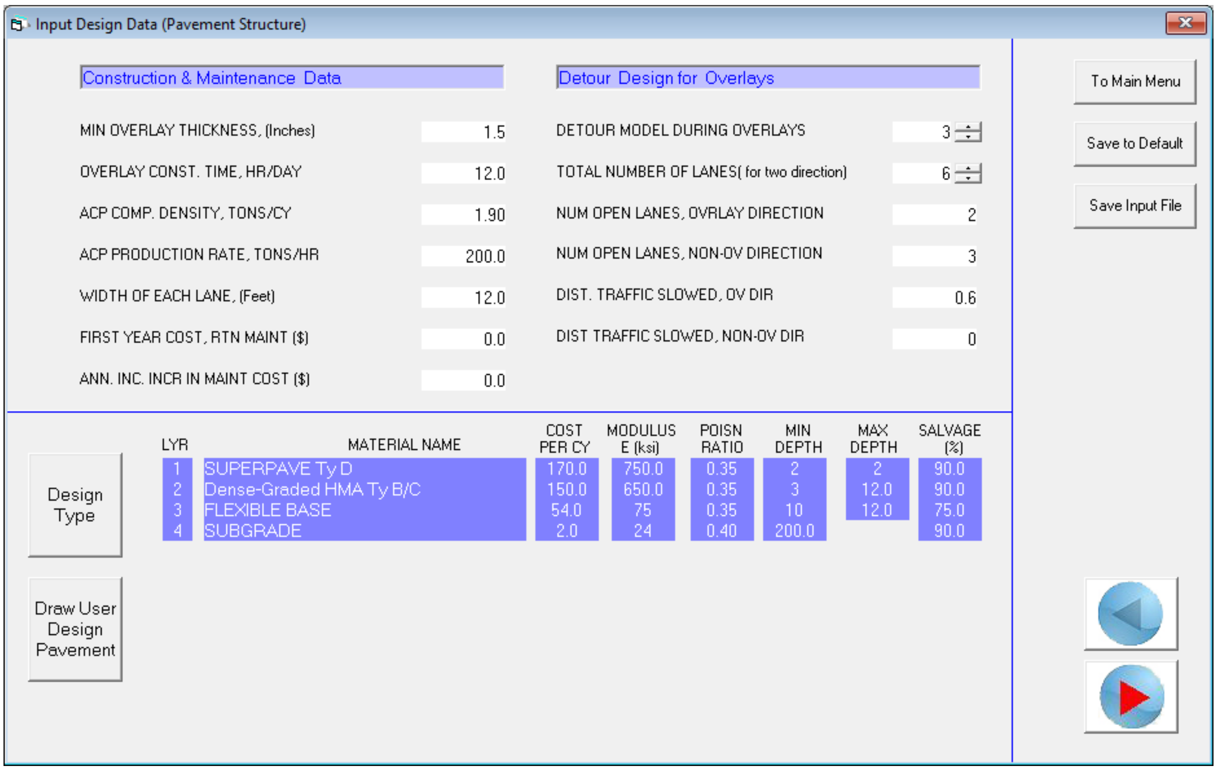


Figure 16. Accessing the Layer Material Parameters Table.

3.3 Running FPS 23 and Interpreting the Results

The program is run by selecting the red arrow button shown in Figure 16. For the inputs provided the five possible designs shown in Figure 17 will be generated. These are ranked according to lowest cost per square yard. If a "**NO best design found**" is displayed as shown in Figure 18, it means the provided range of thicknesses is inadequate to achieve at a pavement design that meets the Time to First Overlay period. Therefore, adjustments are required, and a re-run should be conducted.

Figure 17. Feasible Design Results Options.

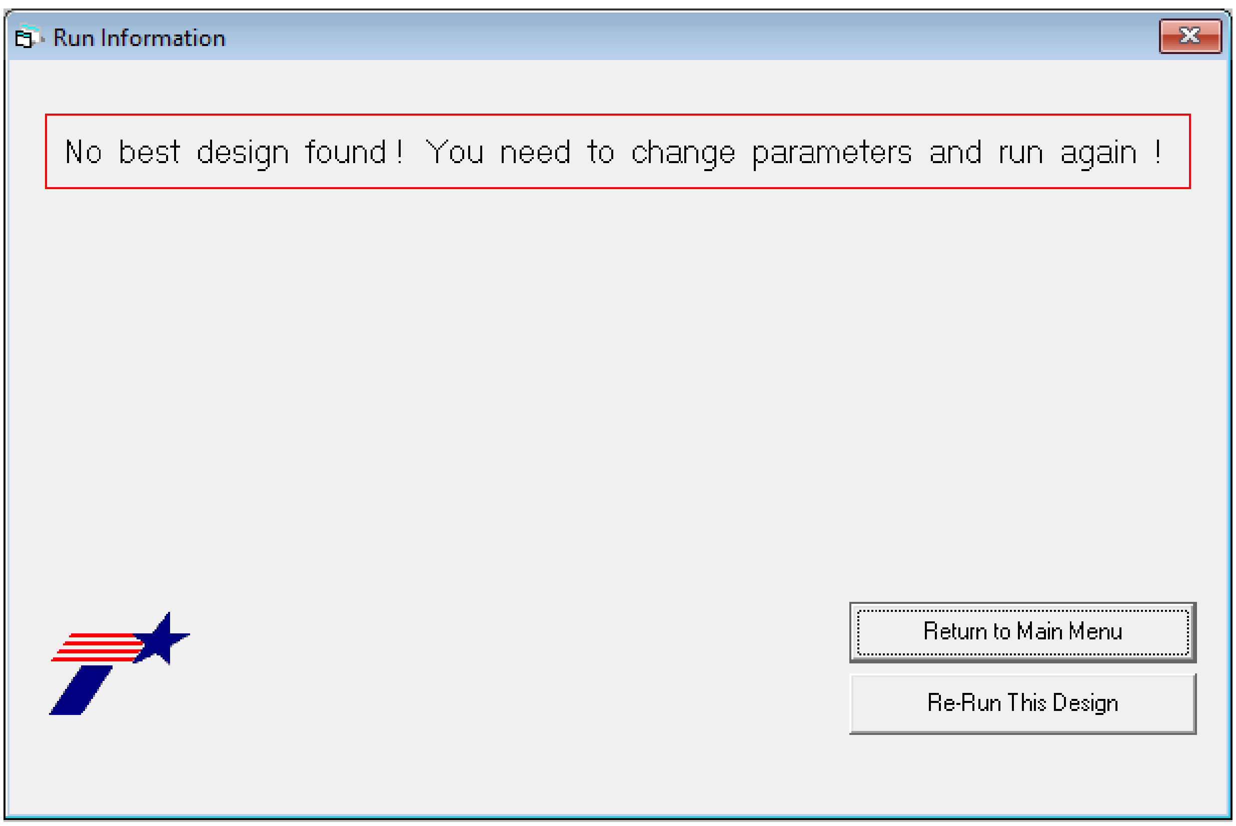


Figure 18. No Best Design Found Display.

The designer must select one of these feasible designs for follow-up structural checking. Design 1 is the most cost effective and is projected to last the specified minimum time to first overlay of 14 years (which is greater than the time to first overlay of 12 years specified in Figure 10), but then requires an overlay to reach the full 20-year design life. Designs 4 and 5 are predicted to last 20 years without requiring an overlay. For this example, it is proposed to perform a design check on Design 1; so, click on the **Check Design** button under that column. The selected design shown in Figure 19 will appear (Pavement Plotting Screen).

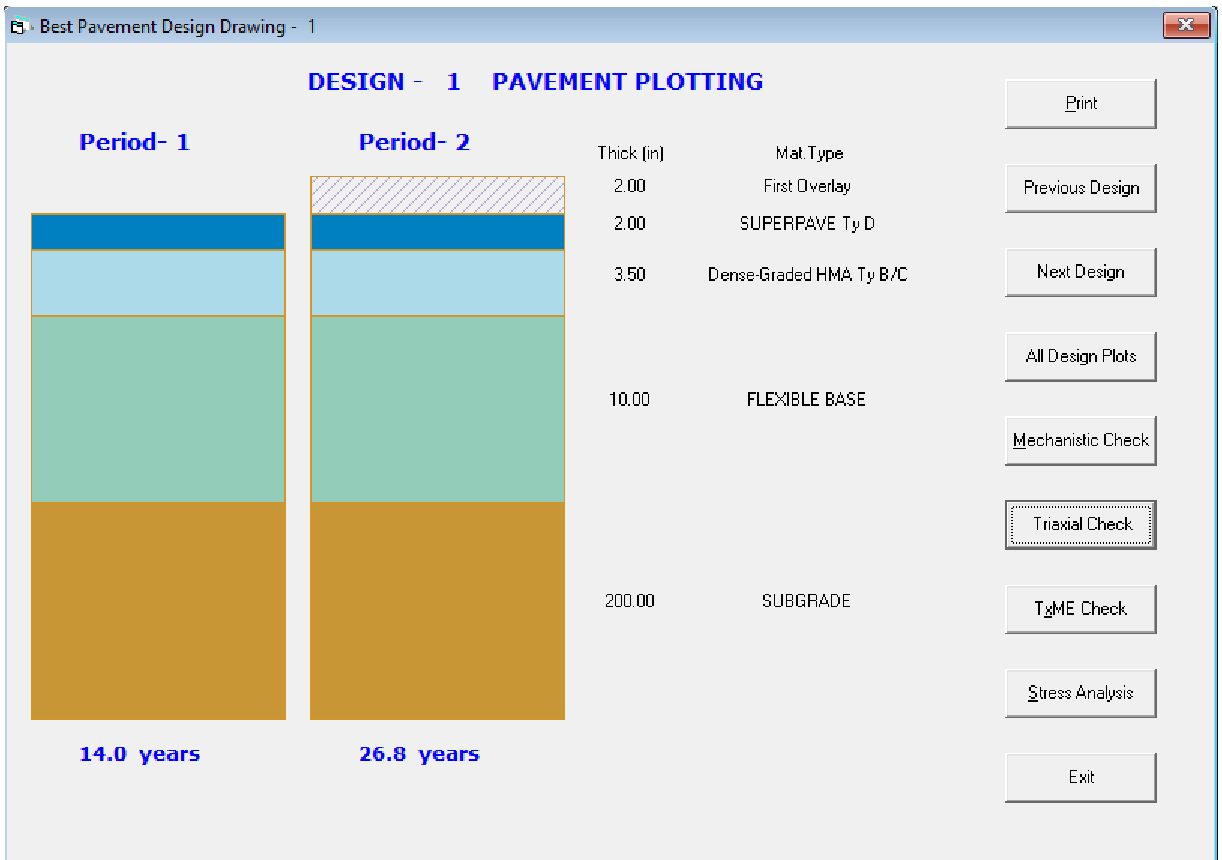


Figure 19. Design Selected for Further Evaluation by Design Checks.

To perform a check of this structure the designer is recommended to run the **Modified Triaxial Check**, the **Mechanistic Check** and the **TxME check.** Each will be described below.

3.3.1 The Modified Texas Triaxial Check

The Modified Triaxial check is mandatory for all pavement designs in Texas, although as previously stated the results may be waived with justification by the approving engineer. Select **Triaxial Check** in the pavement plotting screen (Figure 20). The screen shown in Figure 20 will appear. The designer should input the following information:

- The Average of the Ten Heaviest Wheel Loads Daily (ATHWLD)
  - From TPP traffic report or site-specific Portable Weigh-In-Motion (pWIM) study
- Percentage of Tandem Axles in ATHWLD
  - From TPP traffic report or site specific pWIM study
  - Refer to Pavement Manual for tandem axle guidance.
- Modified Cohesiometer Value (C_m)
  - Use the Reference button for a table of C_m values (Figure 21)
  - Refer to district SOP or Pavement Manual to estimate C_m values for materials not shown in the reference table.
- Subgrade Texas Triaxial Classification (TTC). Three options for supplying the TTC are provided for in this version of FPS 23.
  - Option 1 (as selected in Figure 20) requires the designer to input the value based on laboratory tests, historic lab data, and/or experience.
  - Option 2 allows the user to estimate the TTC based on the soil Plasticity Index. If this option is selected, a field appears, and the user inputs the controlling soil PI for the project. The TTC is automatically calculated.
  - Option 3 recalls a database of soils information for the applicable Texas County and posts it to the Texas Triaxial Design Check Screen as shown in the Figure 22. When this is selected, the Unified Soil Classification System (USCS) soil type, the percentage of the county that is covered by each soil type, and the recommended TTC for each soil are displayed. Select the controlling soil type to input its TTC value into the Modified Texas Triaxial calculation.

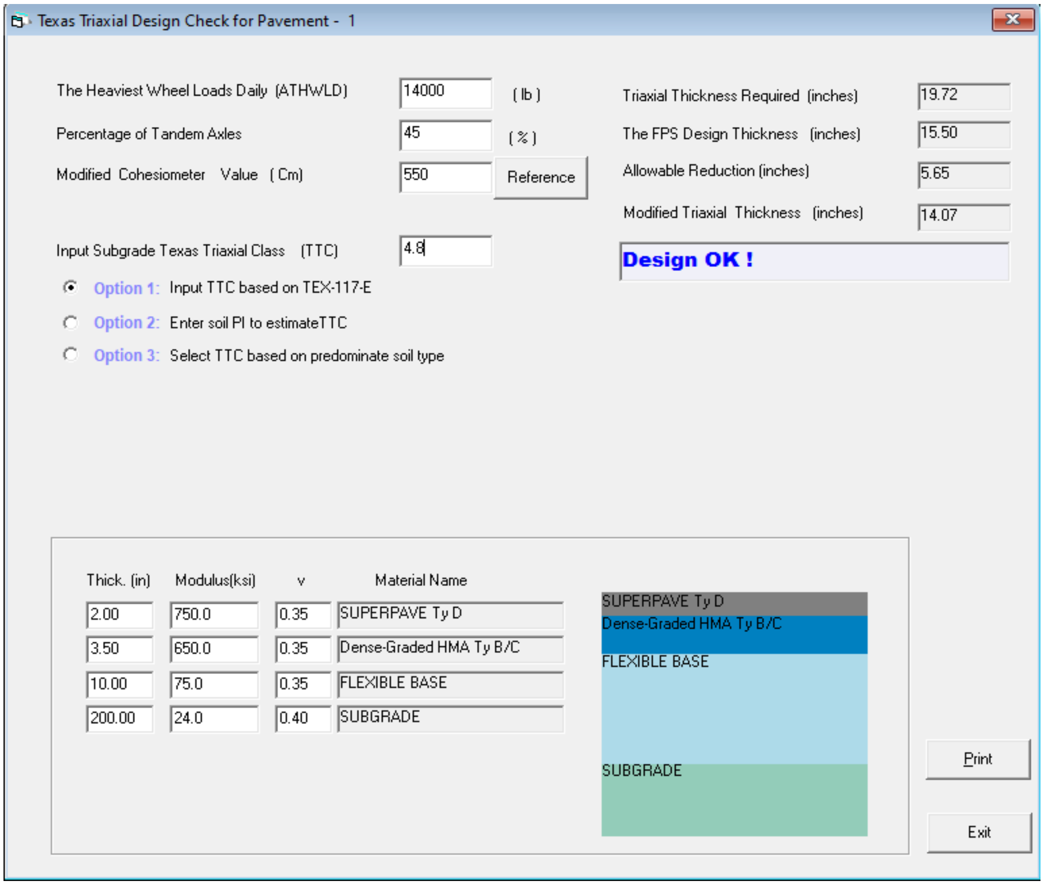


Figure 20. Modified Texas Triaxial Check Input Screen.

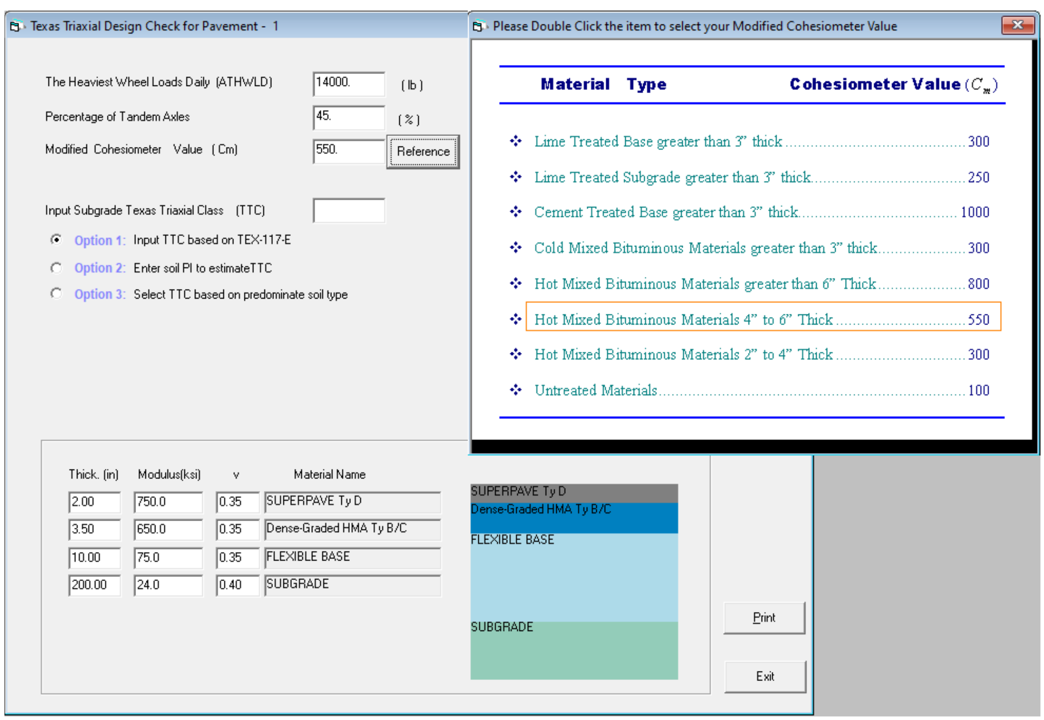


Figure 21. Modified Texas Triaxial Check Cohesiometer Reference Screen.

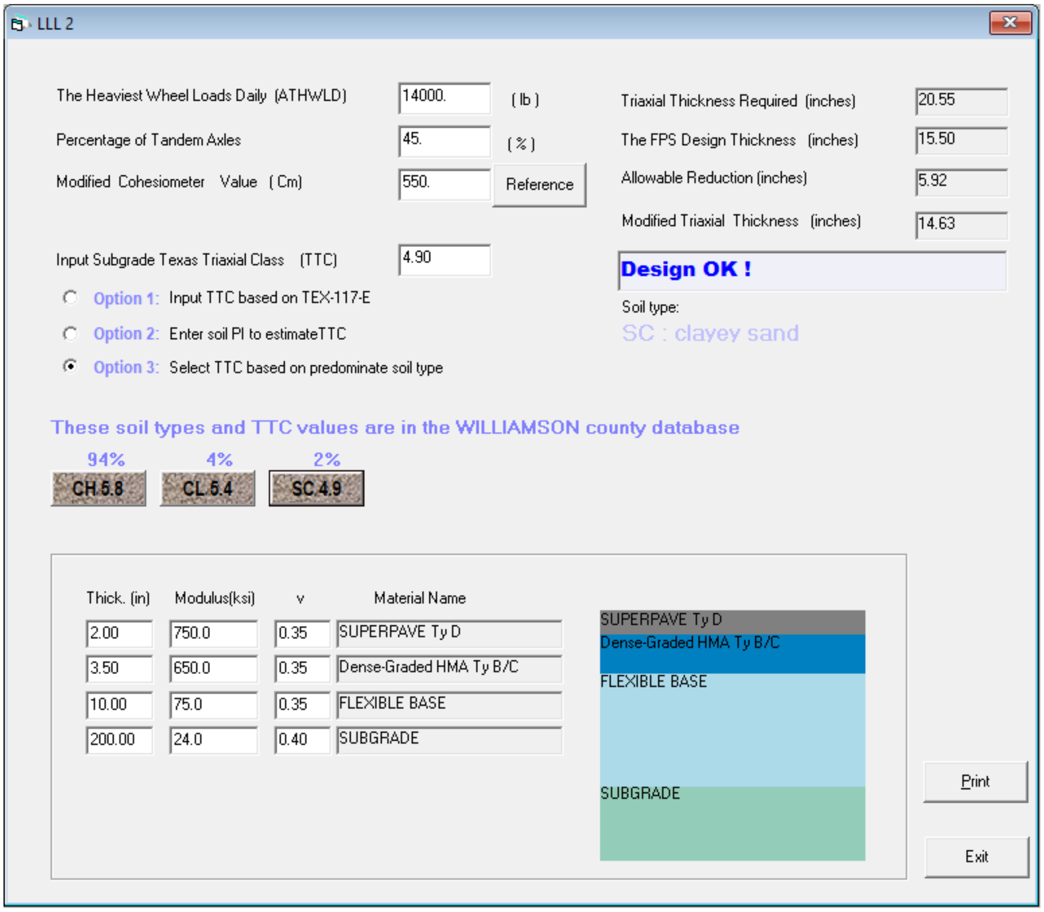
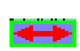


Figure 22. Option 3 for Selecting the Soil TTC from Soils Database.

In the example, the selected soil type is the SC (Clayey Sand), which is reported to cover 2% percent of the selected county. This soil in this county corresponds to a TTC value of 4.90, which is entered as the input to the calculation. For this particular pavement design, the total HMA thickness of 15.5 inches was used and the modified Cohesiometer value was set at 550 based on the Table shown in Figure 21. This pavement structure meets the Triaxial check. The FPS 23 design consists of 15.5 inches of cover over the subgrade. For this check the total amount of cover required was 14.6 inches. Details on using this design check are more fully described by accessing the program HELP menu and in its development is documented in TTI's research report 4519-1 by Fernando et al, dated June 2008 [Link].

3.3.2 The Mechanistic Check

Select the **Mechanistic Check** button shown in Figure 19, the screen shown in Figure 23 appears. Ensure the small green box under the **Vary Thickness** heading to the layer being designed (in this case, only the 3.5-inch SP layer). The Vary Thickness can be dragged to the layer of interest and the analysis will be performed for the design thickness and for variations around that thickness. Also move (click and drag) the tensile strain computation location  to the bottom of the lowest HMA layer, in this case the Dense Grade Ty B/C. Note that the compressive strain indicator  cannot be moved since the evaluation location is always at the top of the subgrade. Then select **Run.**

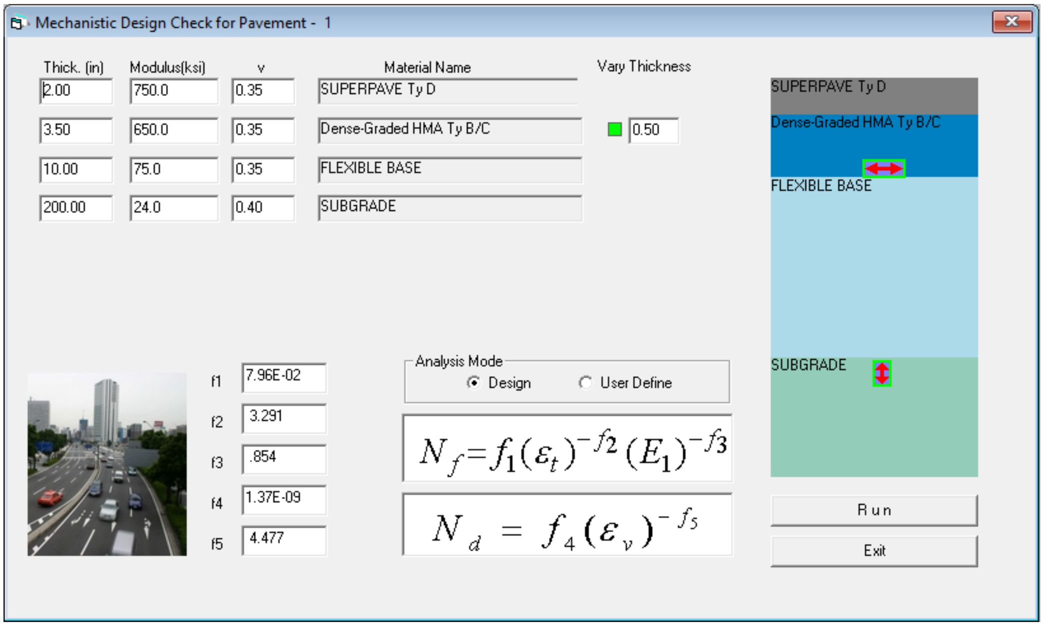


Figure 23. Mechanistic Design Check Input Screen

When selecting **Design** in the Analysis Mode shown in Figure 23, the user cannot change the pavement structure. However, by selecting **User Define,** the thickness and layer moduli values can be changed. This allows some flexibility in evaluating alternate materials and/or thicknesses without re-running FPS.

The results of the mechanistic analysis are shown in Figure 24. In FPS 23, the mechanistic check is performed on the traffic loads accumulated over the FPS-computed time to first overlay (as opposed to the 20-year cumulative loading). For most flexible pavement designs, this time to first overlay will be less than the standard 20-year analysis period. In the example given below the computed time to first overlay is 14 years; for that period the estimated traffic is 3.97 million ESALs. The mechanistic check is performed to check that this traffic level passes the fatigue and subgrade rutting criteria built into FPS 23. 200 million ESALs is the maximum value considered by program for both cracking and rutting. The designer evaluates the **Pavement Life** section and notes the following:

- The estimated number of 18-kip repetitions to failure in HMA fatigue is 9.50M (well above the estimated 18-kips applied by year 14 of 3.97M).
- The estimated number of 18-kip repetitions to failure in subgrade rutting is 38.35M (well above the design traffic applied by year 14 of 3.97M)
- The computed strain for the HMA tensile cracking is 109 micro-strains and for subgrade rutting is 212 micro-strains

- The provided graphs show predicted rutting and cracking calculations for variations in the Dense-Graded Type B/C base, the pavement would fail in cracking if the layer was placed at 2 inches or less
- Repetitions to failure of 18-kip ESALs in both of these modes exceed the cumulative ESALs predicted by FPS by time to first overlay and the Check Result message validates this.

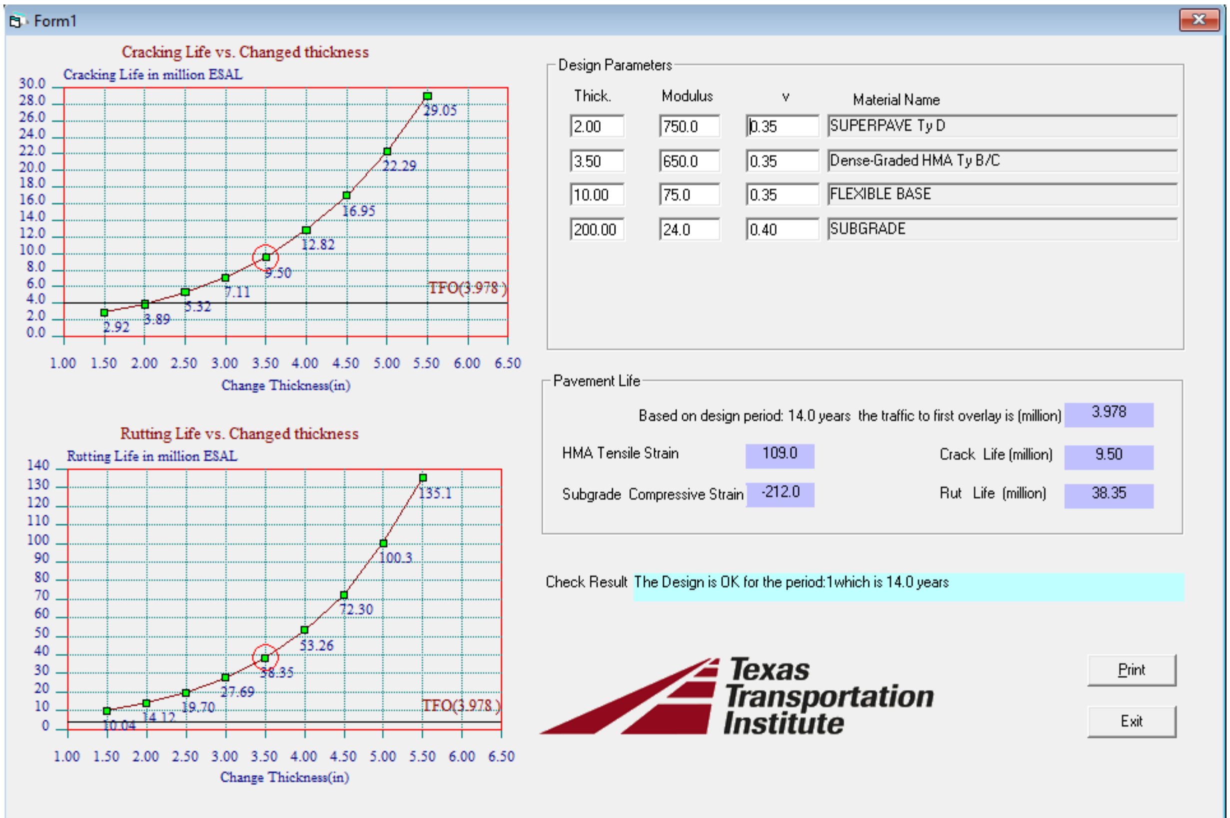


Figure 24. Mechanistic Design Check Results.

This structure passes all of the mechanistic design checks. Details on using this design check are more fully described by accessing the program HELP menu. The results of the mechanistic design check are currently for informational purposes only. However, it is strongly recommended that all pavements where an intermediate thickness of HMA is recommended (2 to 4 inches) be checked for fatigue cracking. In a typical flexible pavement, the maximum tensile strains at the bottom of the asphalt layer tend to occur in the thickness range of 2 to 4 inches. These strains cause the load associated fatigue cracking of the asphalt layer.

3.3.3 TxME Check

TxME is an advanced M-E check and performance analysis package that TxDOT engineers can use to optimize design decisions. It automatically processes all pavement design information entered into and generated from FPS23 to predict pavement field performance in terms rutting and cracking. Figure 25 illustrates this connection between FPS23 and TxME. For new materials, lab testing can be conducted to measure rutting and fracture properties for TxME check. Details on the TxME development are documented in TTI's research report 0-5798-2 by Zhou et al., dated August 2010 [Link], 0-6622-2 by Hu et al., dated January 2014 [Link], 5-6622-01-R1 by Hu et al., dated February 2019 [Link].

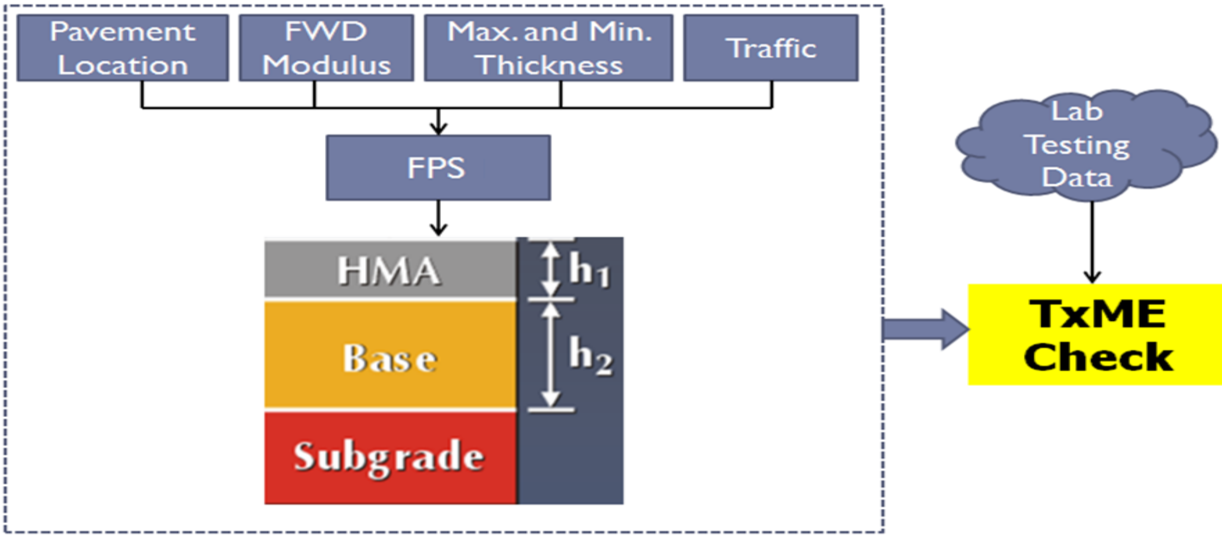


Figure 25. Connection Concept between FPS and TxME.

TxME Main Screen

Click on the TxME Check button in Figure 19 and TxME will be launched. Figure 26 displays the primary interface and layout of the TxME design check and performance analysis software.

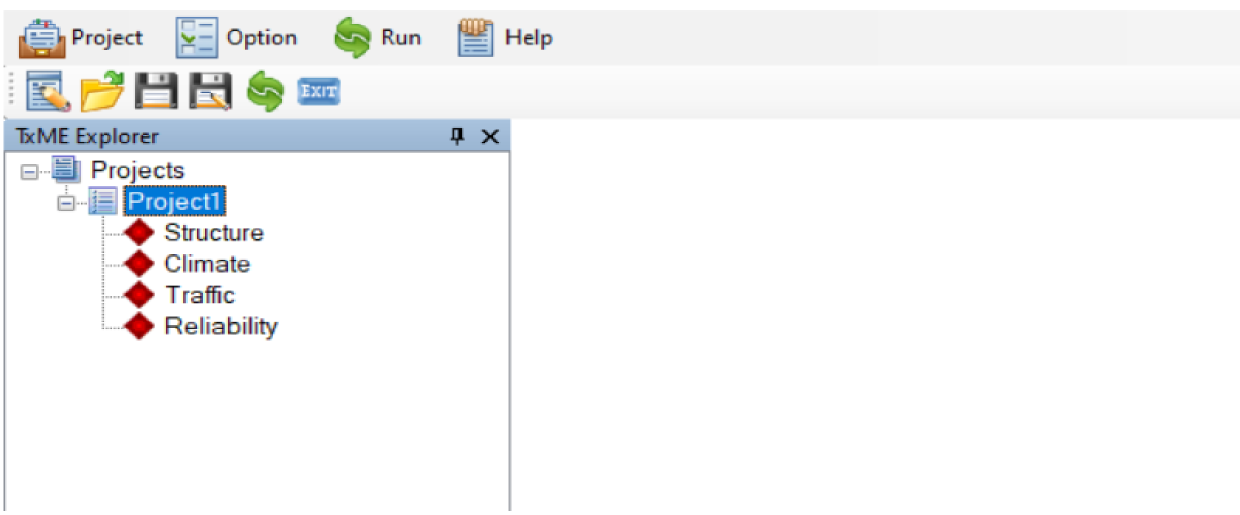


Figure 26. Initial Main Screen of TxME.

Pavement design inputs are organized into four main categories: Structure, Climate, Traffic, and Reliability. Double-clicking each tree node opens the corresponding input window on the right side. The tree node icon's color indicates input status: red for incomplete and green for complete. Once all four tree nodes become green, users can start the analysis by clicking the "Run" menu or button, as detailed in the following sections. The software forecasts various outcomes such as AC fatigue cracking, AC rutting, AC thermal cracking, flexible base/asphalt treated/subgrade rutting, and cement/lime stabilized base fatigue cracking based on pavement type and structure.

The following details the screens in the order of structure, climate, traffic, reliability, and output of the TxME design check and performance analysis software. Comprehensive description of the TxME interface and variables are provided in the program's HELP function. Access this information by pressing F1 or clicking "Help" menu. This manual doesn't include these details, and users are directed to the in-program HELP menu for further information.

Structure Input

Double-clicking the tree node Structure will open the structure input screen, as shown in Figure 27. This screen comprises various sections: the upper left window indicates the pavement type and location; the upper right window lists available AC layer, base layer, and sub-base layer material icons. The lower left window exhibits the pavement structure imported from FPS 23 (or users defined), while the lower right window displays material information and properties of a layer selected and highlighted on the pavement structure window.

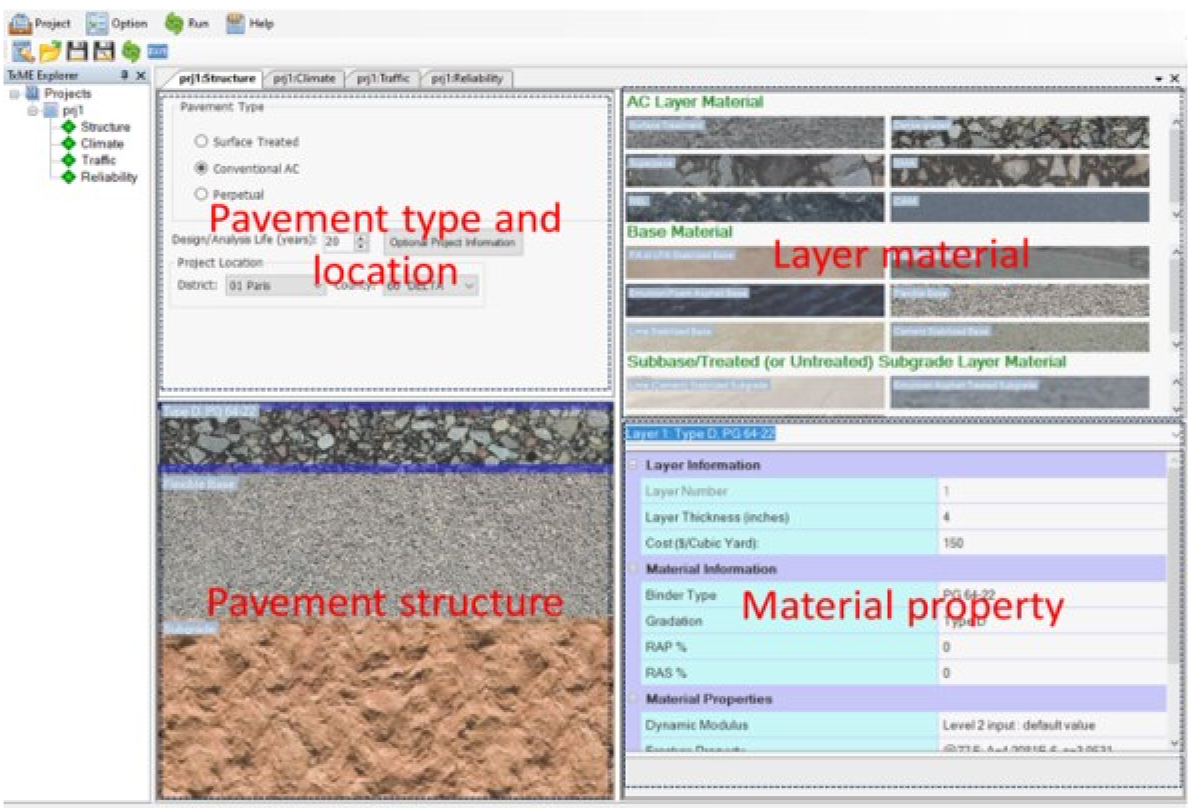


Figure 27. Pavement Structure Information Screen.

The pavement type and location, design life, layer type, and layer thickness will be automatically imported from FPS 23. TxME also loads the default material properties for each pavement structural layer. If needed, users can modify the pavement type and structure imported from the FPS 23 design. Additionally, layer material properties can be replaced if specific lab test results are available. The steps for making these changes are outlined below.

Pavement Type and Location

Three types of flexible pavement can be analyzed in the TxME, as shown in Figure 28.

- **Surface Treated**: A thin protective layer, usually under 1 in., applied to a base course.
- **Conventional AC**: A common flexible pavement structure consisting of AC layer, with a combination of flexible or stabilized base, and/or granular subbase or modified soil layers.
- **Perpetual**: A strong foundation with three or more AC layers, typically totaling over 14 inches in AC thickness.

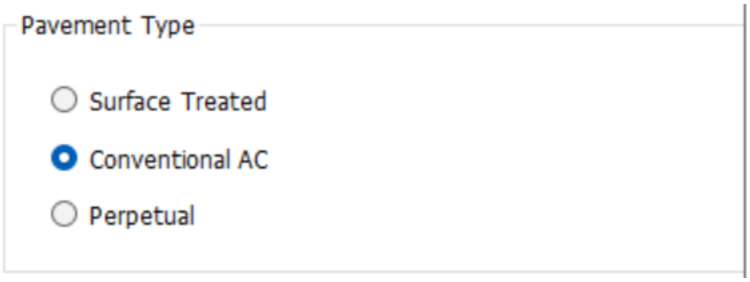


Figure 28. Pavement Type Selection in TxME Design.

Since TxME automatically assigns pavement type based on the FPS 23 design output, there is no need for users to select a pavement type. However, users can select a pavement type by clicking the corresponding radio button. Note that changing the pavement type will generate a new default pavement structure, which may overwrite previously entered layer data. A warning message (Figure 29) will appear to confirm the change before proceeding.

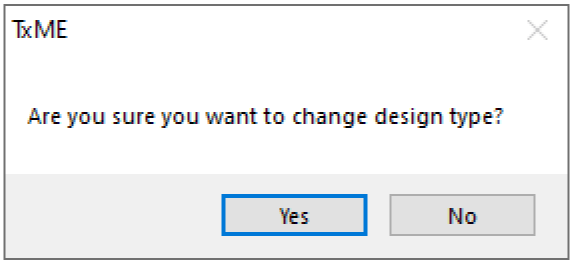


Figure 29. Message Box When Users Choose to Change Pavement Type.

Figure 30 shows the pavement design life and location information.

- **Design/Analysis Life (years)**: The span of time for which the pavement is planned to be analyzed, which is imported from FPS 23.
- **Project Location**: The district and county name in which the pavement section is located. Such information is automatically loaded into TxME from FPS 23.

Figure 30. Pavement Design Life and Location Inputs.

Clicking the button 

will open the optional project information input screen, as shown in Figure 31. Users can change such information or accept the default values by clicking the OK button. The information includes:

- Asphalt Layer Construction Month and Year
- Traffic Open Month and Year
- Reference Mark Format, Begin, and End
- CSJ#
- Functional Class
- Analysis Date

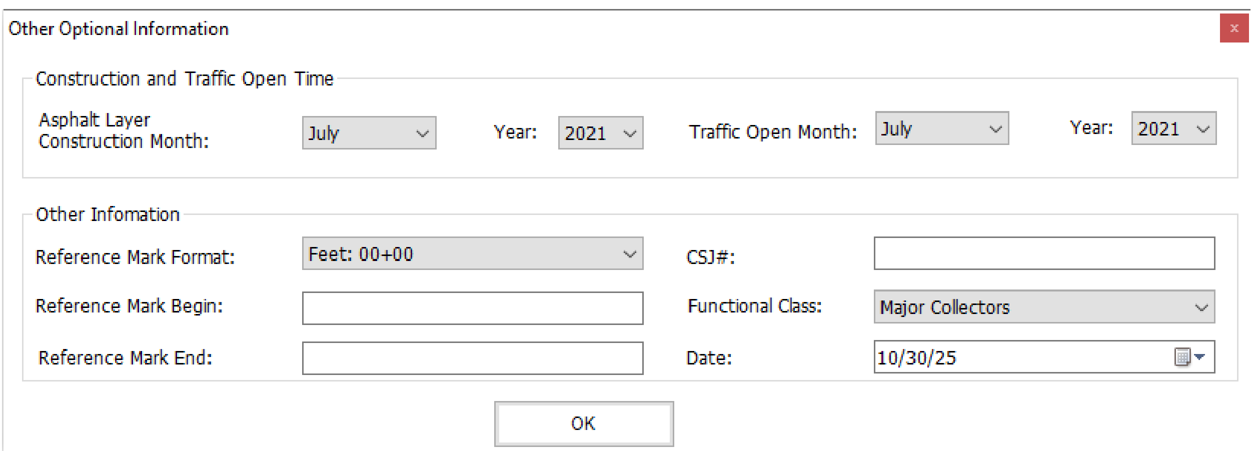


Figure 31. Optional Project Information Inputs.

<u>Layer Material</u>

Figure 32 shows the various material options for each layer in case that users need to modify the pavement structure imported from FPS 23, including:

- **AC Layer Material Options**: Surface Treatment, Dense-graded, Superpave, Stone Matrix Asphalt (SMA), Crack Attenuating Mixture (CAM), and Rich Bottom Layer (RBL).
- **Base Material Options:** Fly-Ash (FA) or Lime Fly-Ash (LFA) Stabilized, Asphalt Treated, Emulsion Asphalt Treated, Flexible, Lime Stabilized, and Cement Stabilized.
- **Subbase or Treated/Untreated Subgrade Material Options:** Lime or Cement Stabilized Subgrade, Emulsion Asphalt Treated Subgrade, and Shallow Subgrade. This layer differs from the natural subgrade layer and typically has a higher modulus.

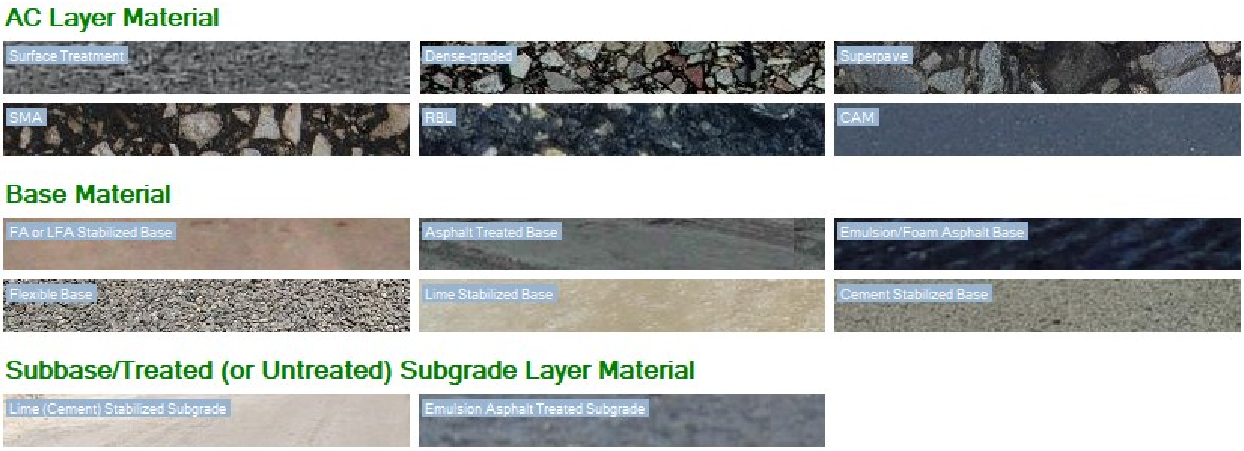


Figure 32. Pavement Layer Material Options.

When hovering over any layer material icon, a tooltip will appear with the message: "*Drag this material icon and drop it onto a pavement layer. The new layer will be inserted **above** the selected layer.*" If needed, users can construct their own pavement structures by dragging layer material icons into the pavement structure window. To remove a layer, click the right mouse button on it and select "Remove this layer" from the pop-up menu.

Pavement Structure

Figure 33 shows an example of a conventional AC pavement structure.

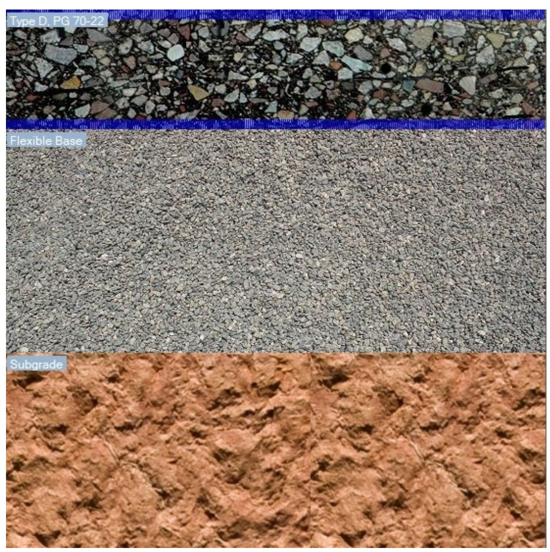


Figure 33. Example of a Conventional AC Pavement Structure.

When needed, users can modify the pavement structure through the following actions:

- **Adding a Layer**: Drag and drop a layer material icon into the pavement structure window by clicking and holding the icon, then releasing it at the target location. If a prohibitive icon ⊘ appears while dragging a material icon over a layer, it indicates that the material cannot be placed on top of that layer. For example, a flexible base layer cannot be placed above an AC layer.

- **Deleting a Layer:** To delete a layer from the pavement structure, ***right-click*** on the layer and select "***Remove this layer***" from the pop-up menu. Note that the subgrade layer is always included by default and cannot be removed.
- **Modifying Layer information and properties:** The layer information and material properties can be modified in the material property window. Details are provided below.

Material Property

TxME allows users to modify layer type/thickness and material properties in the **Material Property** window by clicking on each layer in the **Pavement Structure** window, even though default values are assigned to each layer.

AC Layer Material Property

Figure 34 shows a typical AC layer property input window.

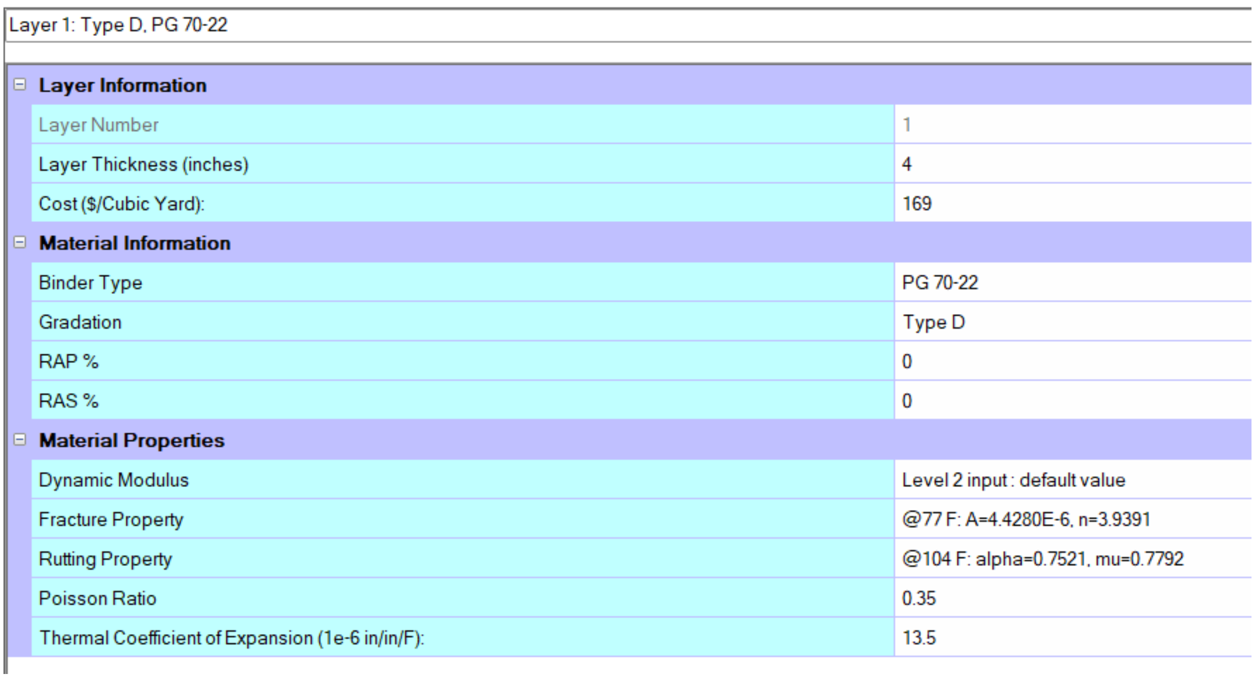


Figure 34. AC Layer Property Input Window.

The AC layer inputs include:

- Layer Information
  - Layer Number: This is a read-only field and cannot be modified by the user. The topmost layer is designated as Layer #1.
  - Layer Thickness (in): Specifies the thickness of the layer in inches.
  - Cost ($/Cubic Yard): Represents the initial construction cost of the layer, calculated per cubic yard. Users can modify the cost based on their own District/Area construction practices.

- Material Information
  - Binder Type: Indicates the asphalt binder PG grade, available for selection from a drop-down list. PG 70-22 is the default binder for common mixes, while PG 76-22 and PG64-22 are for SMA mixes and rich bottom layer, respectively. Users should ensure that the binder type matches the mix design for each specific layer and adjust the binder type input as needed.
  - Gradation: Specifies the mixture gradation type, available for selection from a drop-down list. D mix is the default gradation for surface layers, while B is the default for intermediate and base layers. Users should review their designs and adjust the gradation input as needed.
  - RAP % and RAS %: Specifies the percentage of RAP (and RAS) used in the mixture. The default setting is 0% RAP/RAS. Users should ensure that the percentage of RAP and RAS matches the mix design for each specific layer and make necessary adjustment as needed.
- Material Properties
  - Dynamic Modulus: Clicking this input opens a window for entering the dynamic modulus of the AC mixture (Figure 35). While "Level 2 (Default Value)" is the default, users can select "Level 1 (Test Data)" and input the measured dynamic modulus values (ksi).
  - Fracture and Rutting: Clicking their input open a window for entering the fracture and rutting properties of the AC mixture. (Figure 36 and Figure 37). Default values are provided for each mixture type.
  - Poisson's Ratio: A default Poisson's ratio of 0.35 is assigned for all AC mixtures.
  - Thermal Coefficient of Expansion (1e-6 in/in/F): A default value of 13.5 in/in/F is used for all AC mixtures.

Note that all default AC material properties in TxME are obtained from the asphalt materials used in the state of Texas.

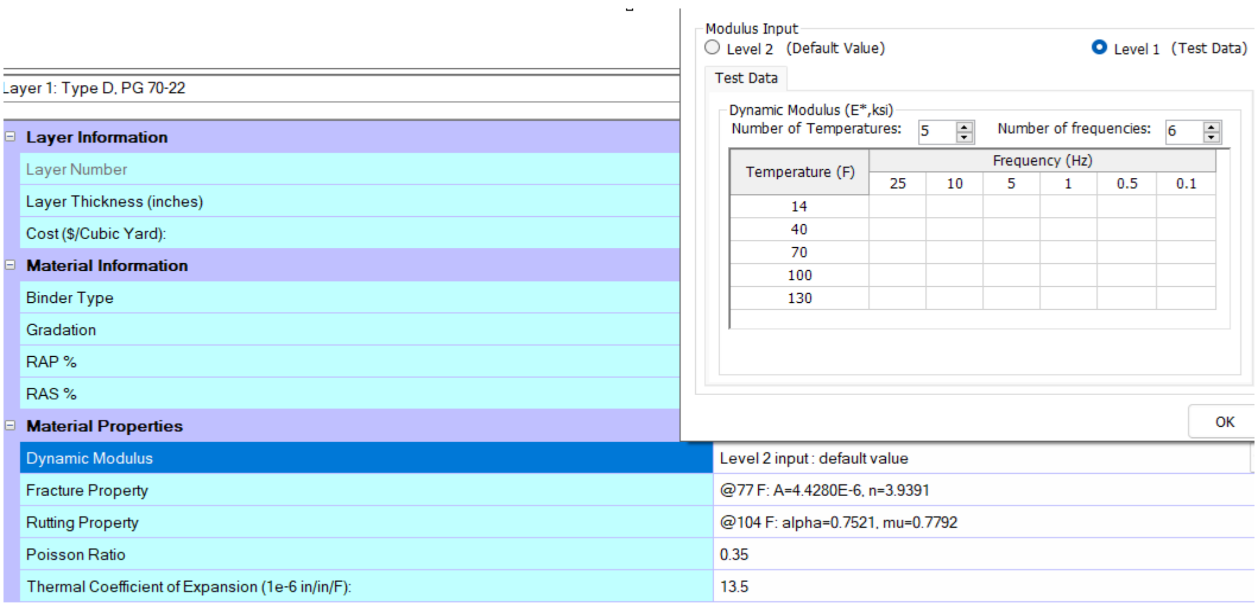


Figure 35. AC Layer Dynamic Modulus Input Screen.

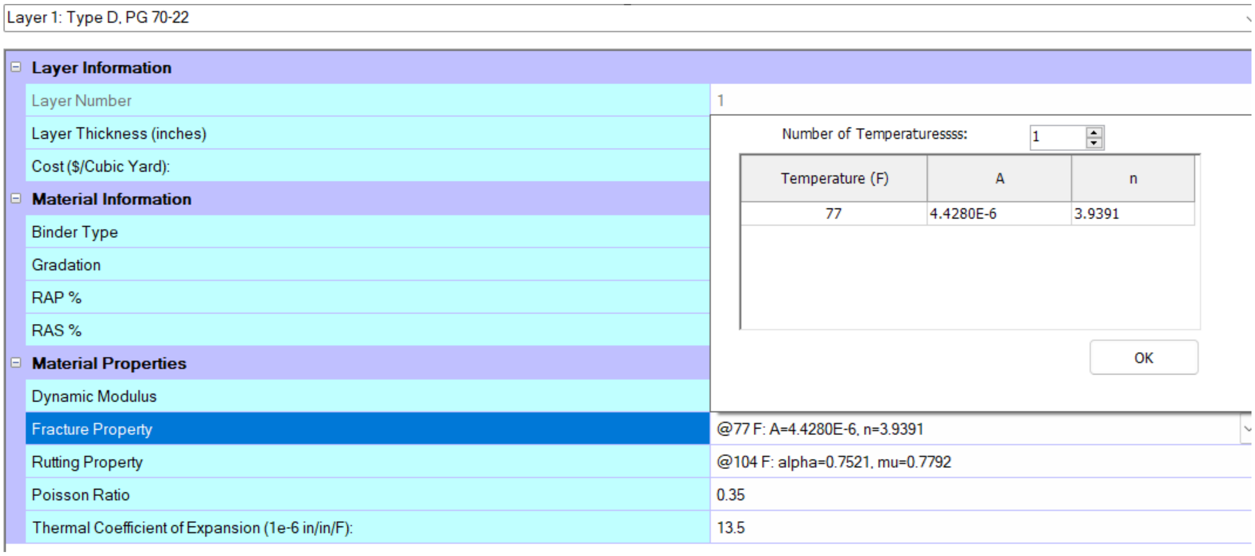


Figure 36. AC Layer Fracture Properties Input Screen.

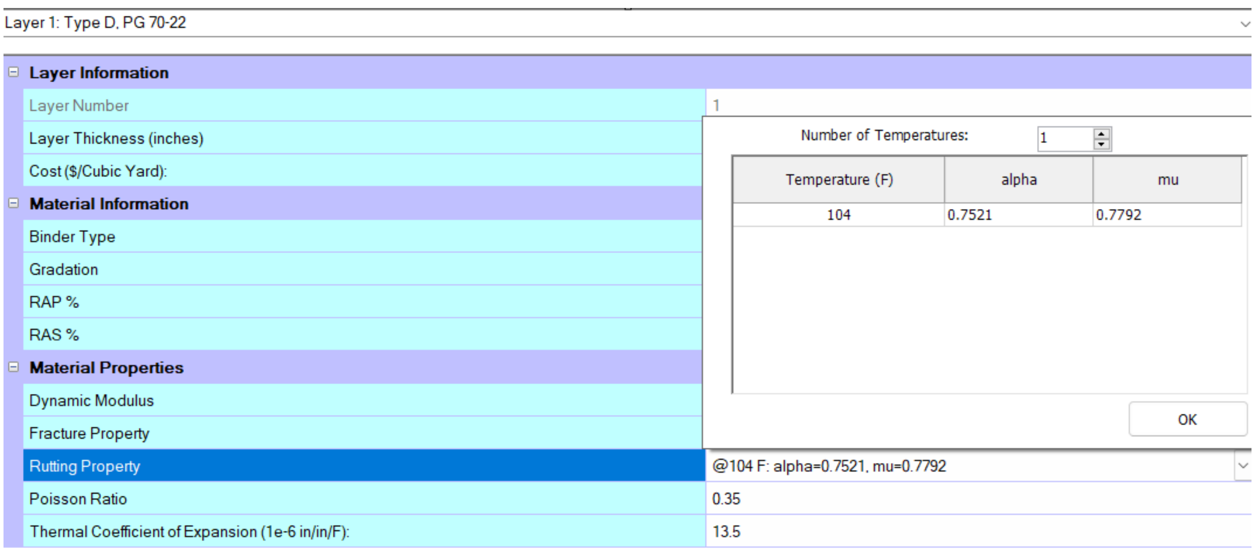


Figure 37. AC Layer Rutting Properties Input Screen.

<u>Base Layer Material Property</u>

The base layers in TxME can be categorized into three types based on the materials as:

- flexible base,
- asphalt treated base including emulsion/foam, and
- cement stabilized base including FA, LFA, and lime.

Both flexible base and asphalt treated base materials require rutting property inputs, while the cement stabilized base requires cracking property inputs. Note that the default material properties are provided depending on the base type.

The material property input screens for the flexible base and the asphalt treated base are the same. Figure 38 shows a typical material property input screen for the flexible base.

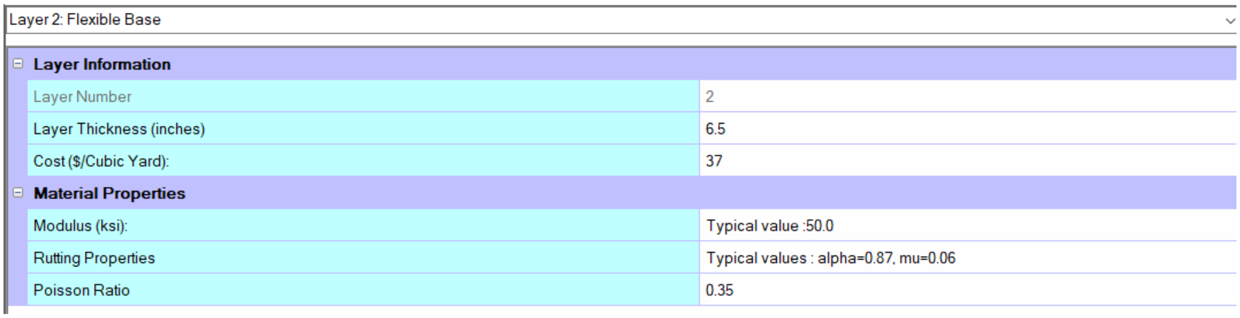


Figure 38. Flexible Base Material Properties Input Screen.

The flexible or asphalt treated base layer inputs include:

- Layer Information
  - Layer Number: This is a read-only field and cannot be modified by the user.
  - Layer Thickness (in.): Specifies the thickness of the layer in inches.
  - Cost ($/Cubic Yard): Represents the initial construction cost of the layer. Users can modify the cost based on their own District/Area construction practices.
- Material Properties
  - Modulus (ksi): Represents the base layer modulus, such as the FWD backcalculated modulus. This modulus value is automatically imported from FPS 23 but can be adjusted as needed. Clicking this input opens a flexible base modulus window, where users can enter a typical or monthly value (Figure 39).
  - Rutting Property: Defines the rutting properties of the base layer. Clicking this input opens a window where users can input either a typical value or monthly values (Figure 40).
  - Poisson Ratio: A default Poisson's ratio of 0.35 is assigned for the flexible and asphalt treated base layers.

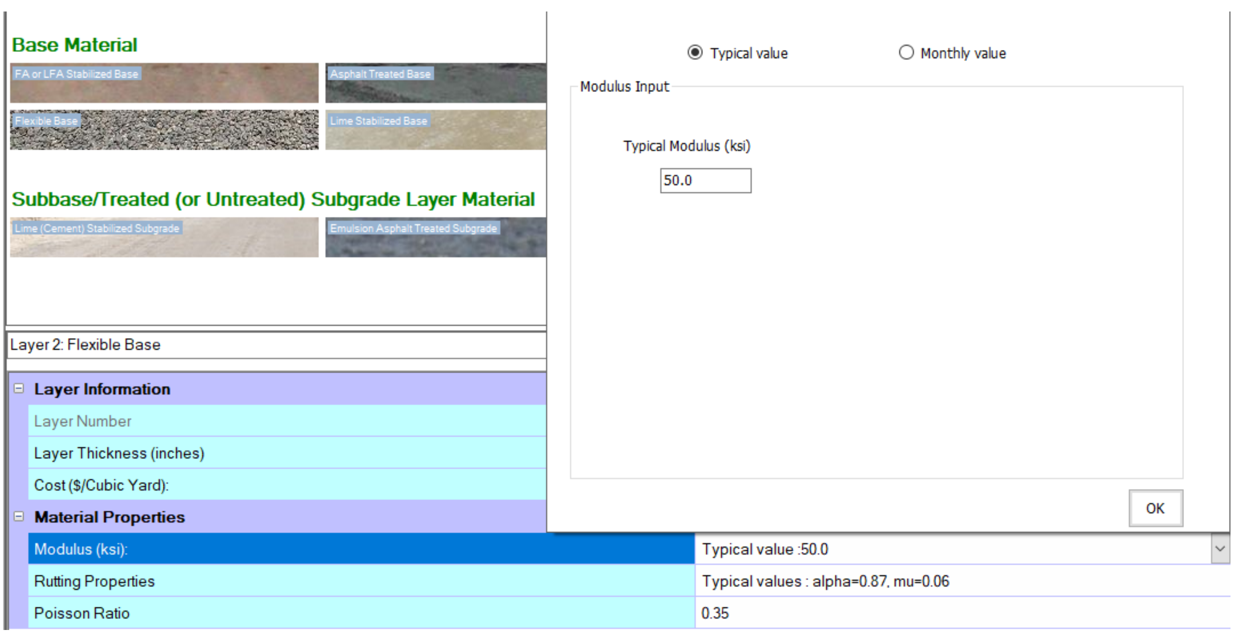


Figure 39. Flexible Base Typical Modulus Input Screen.

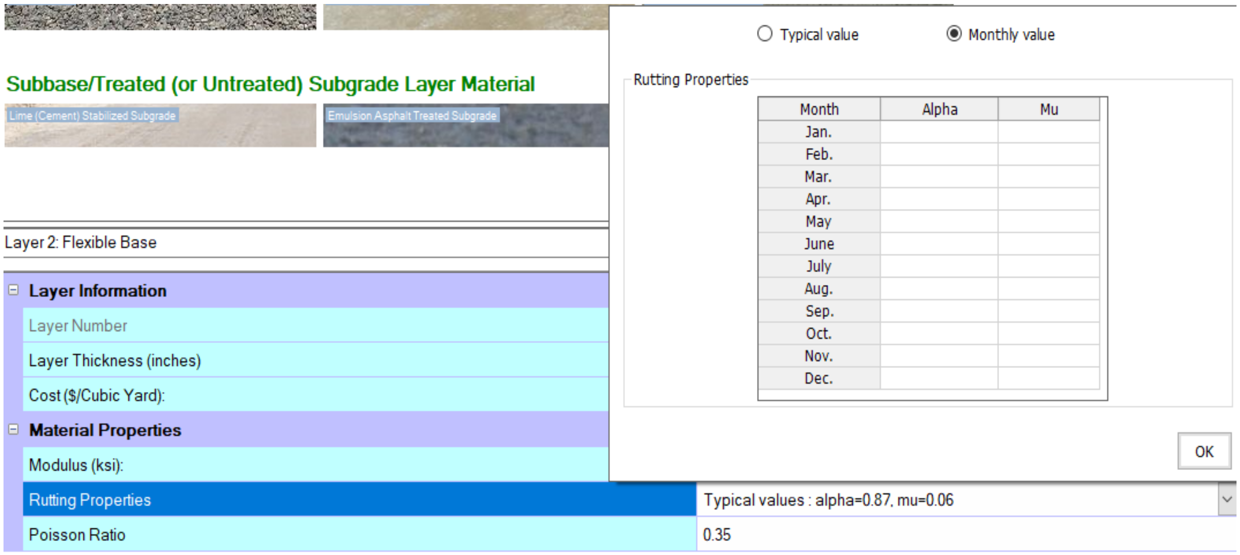


Figure 40. Flexible Base Rutting Properties Input Screen.

As shown in Figure 41, the cement stabilized base materials require fatigue cracking property inputs as well as modulus:

- Modulus of Rupture (psi): Defines the maximum tensile stress of the cement stabilized material just before it yields in a flexure test, also known as flexural strength (psi).
- Fatigue Cracking Parameters B1 and B2: Define the fatigue cracking properties and are used to determine its fatigue cracking life.

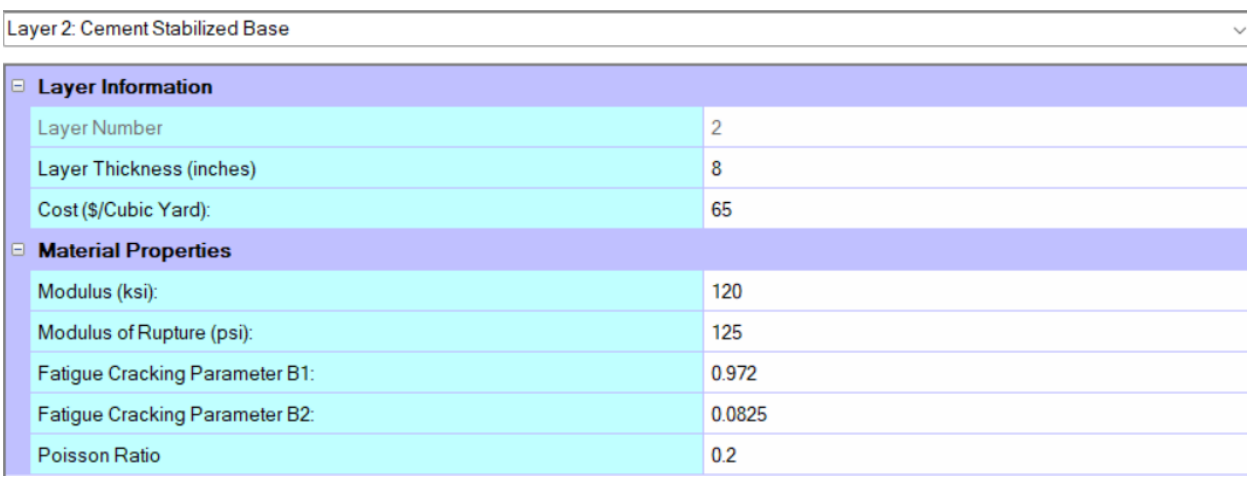


Figure 41. Cement (or FA, FLA, lime) Stabilized Base Properties Input Screen.

Note the fatigue cracking analysis of the cement stabilized base layer is executed only under the surface-treated or conventional AC pavement design at the following layer:

- a single cement stabilized base layer placed directly beneath the AC layers, or
- the last layer in the multiple cement stabilized base layers.

If a crack relief layer (e.g., flexible or asphalt treated base layer) is placed between the AC and the cement stabilized layer, the fatigue cracking of the cement stabilized layer is assumed not to occur and will not be analyzed.

Subbase Layer Material Property

The subbase layer types are the same as the base layer in terms of modulus, rutting, or fatigue cracking property, depending on the material type. For example, emulsion asphalt treated subgrade require rutting inputs, while lime (cement) stabilized subgrade require cracking inputs. Users can refer to the description of base layer material properties for further details

Note that if a lime (cement) stabilized subgrade layer is placed beneath a flexible base or asphalt treated base layer, fatigue cracking of this subbase layer is assumed not to occur and will not be analyzed.

Subgrade Layer Material Property

The subgrade layer inputs share a similar input screen to that of the flexible base, except that there is no cost input field.

Climate Input

Double-clicking the tree node Climate will open the climate input screen, as shown in Figure 42. Users can choose between two options for linking climatic information to a project location using radio buttons: **Climatic data for a specific weather station** or **Interpolate climatic data for a given location** based on the project's GPS coordinates.

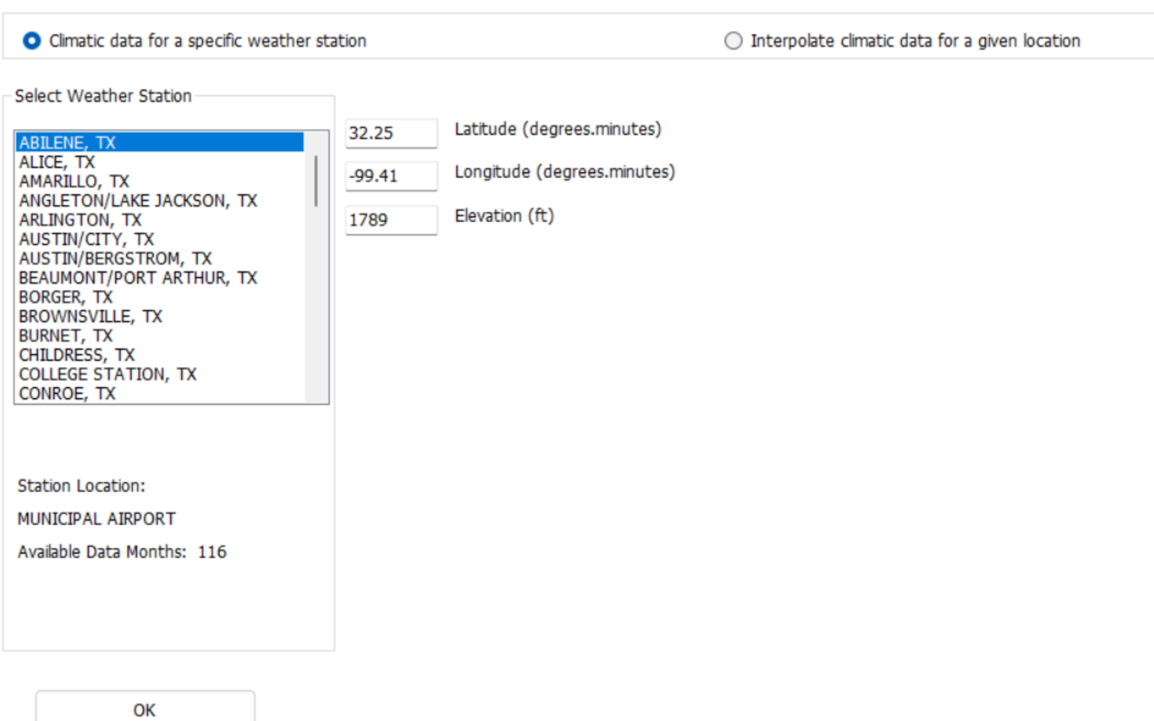


Figure 42. Climate Input Screen.

TxME uses district and county information imported from FPS23 to recommend the nearest weather station. Users only need to click 'OK' to confirm the highlighted selection. Each station is linked to an hourly climatic data file ('.hcd'), stored in the 'hcd' directory during TxME installation. TxME applies this hourly climatic data to determine temperature variations along the pavement depth. Additionally, TxME provides a summary with average temperature and precipitation, offering users a quick review of the data.

If a project location lacks a designated weather station, users can choose the "**Interpolate climatic data for a given location**" option. This enables the application to recommend up to six nearby weather stations for interpolation based on GPS coordinates. More details are available in the "Help" file, accessible via the "Help" menu or the F1 key.

Traffic Input

Double-clicking the tree node Traffic will open the traffic input screen with a message box prompting to enter the operational speed, as shown in Figure 43. There are two levels of traffic inputs in TxME: **Level 2: ESALs** and **Level 1: Load Spectra**. Users can select the traffic input level by clicking the corresponding radio button.

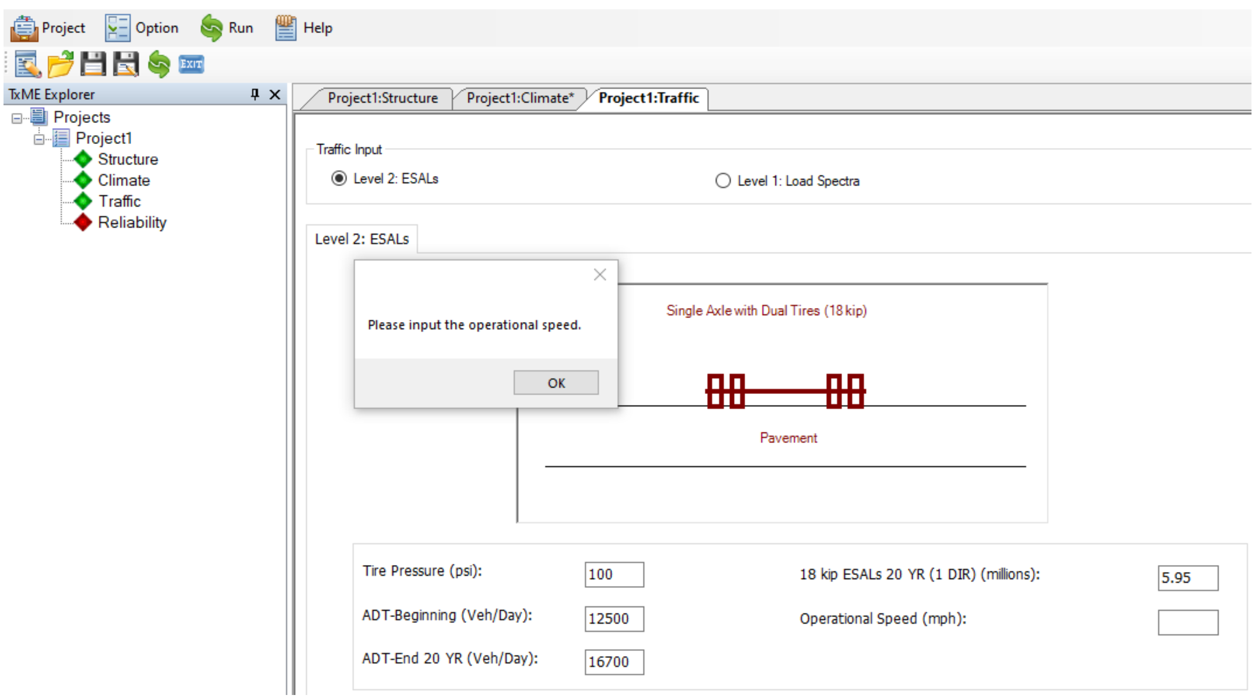


Figure 43. Traffic Input screen

Level 2: ESALs Input

Figure 44 shows the Level 2: ESALs input screen. Note that the ADT-Beginning, ADT-End, and 18-kip ESALs are automatically populated with values from FPS 23; however, the user must input the Operational Speed.

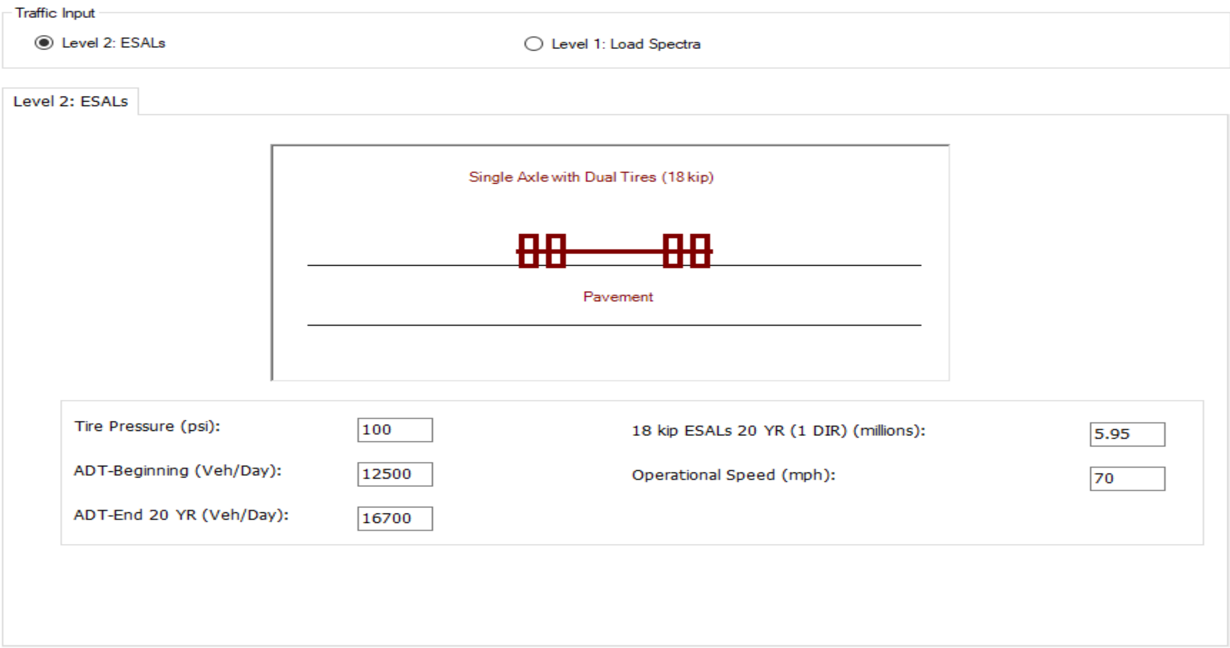


Figure 44. Traffic ESALs (Level 2) Input screen.

The Level 2 inputs include:

- **Tire Pressure (psi)**: The hot inflation pressure. The default tire pressure value is 100 psi.
- **ADT-Beginning and End 20YR (Veh/Day):** Average Daily Traffic (ADT) in both directions at the beginning and the end of the 20-year period.
- **18-kip ESALs 20 YR (1 DIR) (millions)**: The accumulated number of 18-kip ESALs in one direction over 20 years, measured in millions.
- **Operation Speed (mph)**: The average speed of traffic, measured in miles per hour (mph).

Level 1: Load Spectra Input

When load spectra input data is available, users can select Level 1 to perform load spectra analysis. The load spectra data can be obtained from the traffic data collected by portable or permanent WIM system. As show in Figure 45, the traffic load spectra (Level 1) input screen, the upper left panel presents **General Traffic Information** and **Axle Configuration** details. The upper right panel displays vehicle class distribution and growth rate information. The lower right panel contains buttons for:

- *View/Edit Axle Load Distribution*
- *View/Edit Monthly Adjustment Factors*
- *View/Edit Axles Per Truck*

In Figure 45, the "Annual Average Daily Truck Traffic (Two-way AADTT)" is calculated by multiplying 'ADT, BEGINNING (VEH/DAY)' by 'PERCENT TRUCKS IN ADT (%)' entered in FPS 23. Additionally, TxME provides default load spectrum inputs for various Texas road traffic scenarios, grouped under **Traffic Characteristics** in the lower left panel. The system automatically loads default values for vehicle class distribution, axle load distribution, monthly adjustment factors, and axles per truck based on the following characteristics:

- Highway type: Energy sector, IH, SH, or FM
- Volume of 18-wheeler (Class 9): high, medium, or low
- Axle weight of 18-wheeler (Class 9): heavy, medium, or light

More details about "Level 1: Load Spectra" inputs are available in the "Help" file, accessible via the "Help" menu or the F1 key.

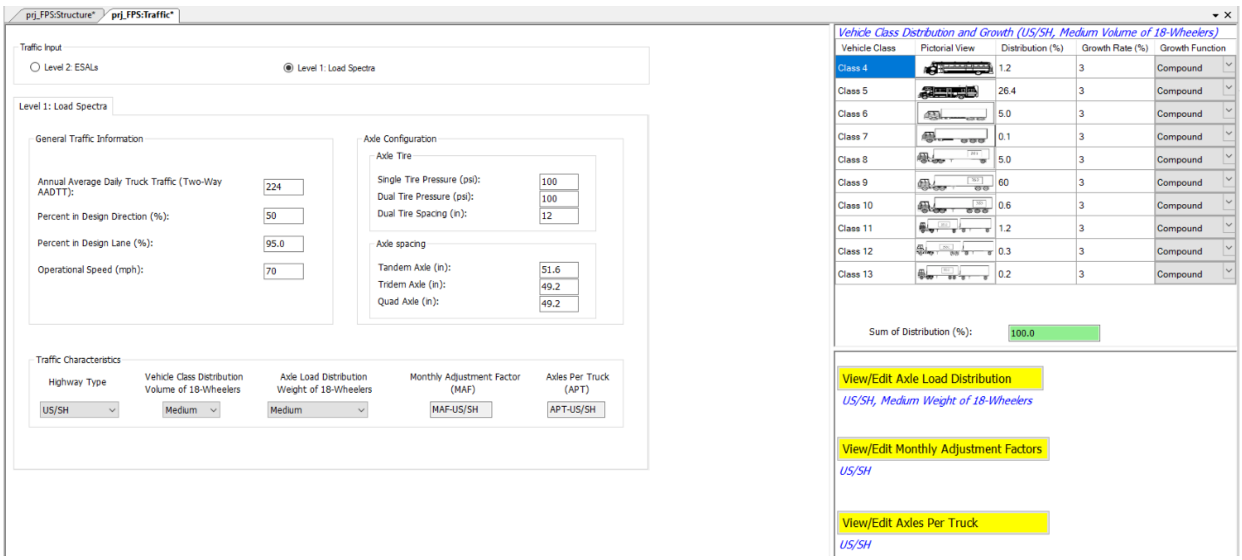
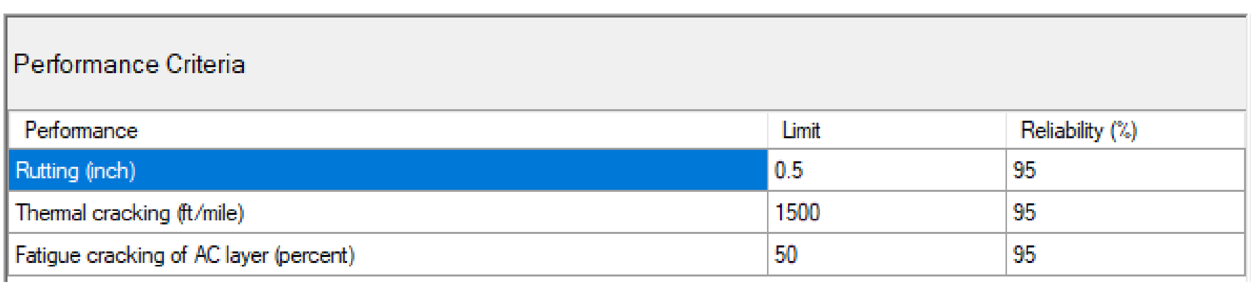


Figure 45. Traffic Load Spectra (Level 1) Input Screen.

Reliability Related Input

Double-clicking the tree node Reliability will open the reliability-related input screen, as shown in Figure 46. The figure displays the input screen for a three-layer conventional AC pavement (flexible base) within TxME. The reliability level is consistent with FPS 23, and users can edit it. While TxME provides default analysis failure criteria (performance limits), users can adjust these limits to align with project-specific requirements based on engineering judgment.

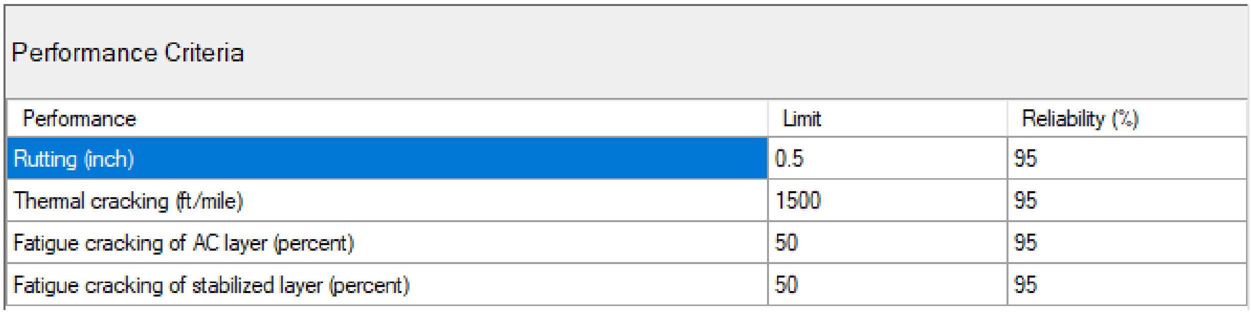


Performance Criteria

Performance	Limit	Reliability (%)
Rutting (inch)	0.5	95
Thermal cracking (ft/mile)	1500	95
Fatigue cracking of AC layer (percent)	50	95

Figure 46. Reliability Related Input Screen for a Three-Layer Conventional AC Pavement with Flexible Base.

The performance criteria are linked to both the pavement structure and pavement type. When either the pavement structure or type changes, these parameters are updated accordingly. Figure 47 shows an example of the performance criteria of the cement stabilized base layer, indicating the "Fatigue cracking of stabilized layer" entry.


Performance Criteria

Performance	Limit	Reliability (%)
Rutting (inch)	0.5	95
Thermal cracking (ft/mile)	1500	95
Fatigue cracking of AC layer (percent)	50	95
Fatigue cracking of stabilized layer (percent)	50	95

Figure 47. Reliability Related Input Screen for a Pavement with CTB Layer.

The default performance limits are provided in Table 3.

Table 3. Default Performance limits by Pavement Type

Performance	Surface Treated	Conventional AC	Perpetual
Rutting (in.)	0.75	0.5	0.35
Thermal Cracking (ft./mile)	-	1,500	500
Fatigue Cracking of AC Layer (%)	-	50	15
Fatigue Cracking of Stabilized Layer (%)	50	50	-

Output

After entering or verifying the pavement design data, users can run the TxME analysis by clicking the "**Run**" button (Figure 48). The analysis typically completes in under two minutes, though duration may vary based on factors like pavement design or analysis life. The program generates a summary of project inputs, distress, and performance predictions in both tabular and graphical formats, with graphs created in Microsoft Excel® for easy incorporation into reports.

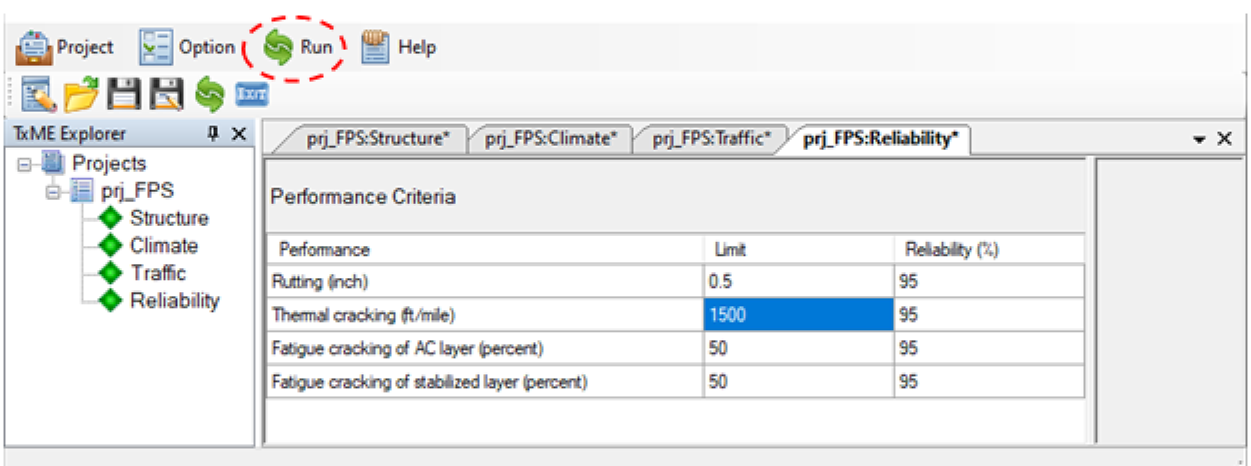


Figure 48. Running TxME Analysis

The Excel spreadsheets consist of three main sections: user input summary, analysis result table, and distress plots (Figure 49). Predicted distresses differ depending on the pavement structure and type as listed in Table 4.

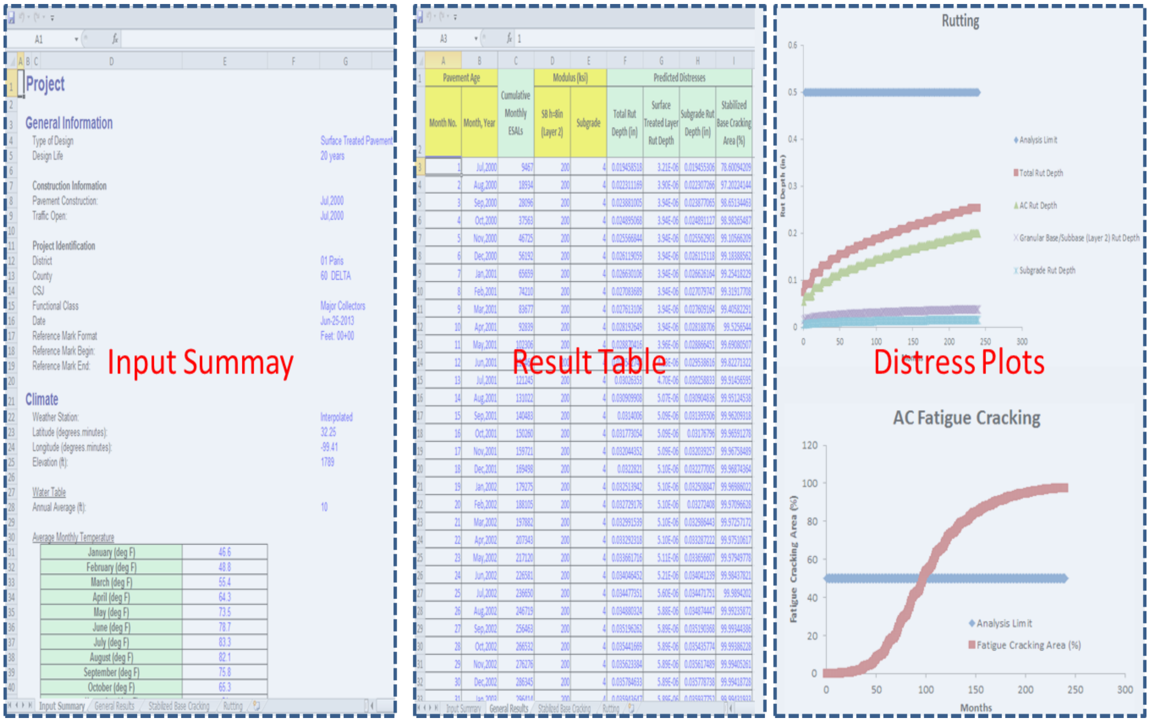


Figure 49. Output of TxME in Excel File Format.

Table 4. TxME Distress Prediction by Pavement and Material Types

Pavement Type/Layer		Rutting	Fatigue Cracking	Thermal Cracking
AC Layer	Surface Treatment	√		
	Conventional	√	√	√
	Perpetual	√	√	√
Base/Subbase/ Subgrade	Flexible base, natural subgrade	√		
	Asphalt treated base/subbase	√		
	Cement stabilized base/subbase		√*	

* Fatigue cracking of stabilized base/subbase layer is not analyzed for the perpetual pavement.

Figure 50 presents an example of the standard output from an analysis of conventional AC pavement with a flexible base over subgrade, including rutting, AC fatigue cracking, and AC thermal cracking predictions.

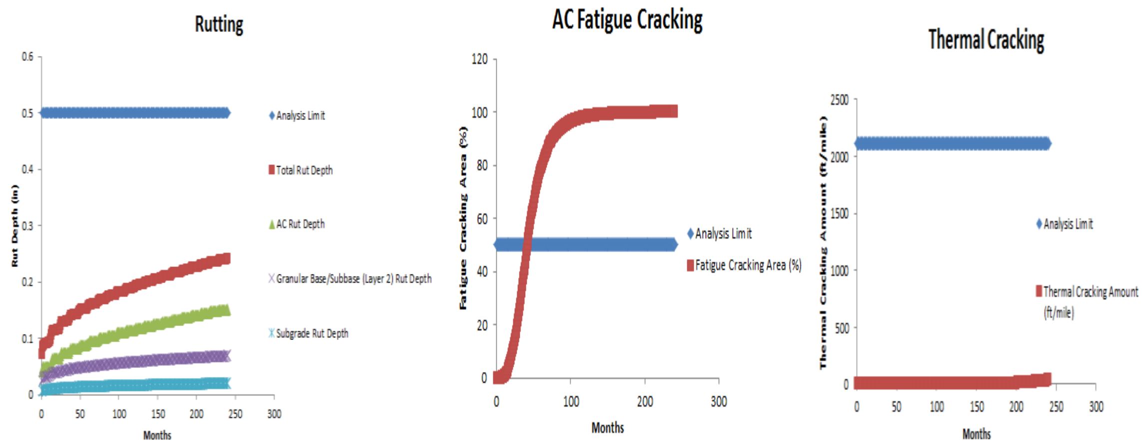


Figure 50. Output From the Analysis of a Conventional AC Pavement.

If the output does not meet the threshold or expectations, users can modify the pavement structure—such as increasing the pavement layer thickness, changing the asphalt mix design (e.g., switching the binder from PG 64-22 to PG 70-28), or reducing the RAP percentage—to rerun the TxME analysis and identify the optimal design.

3.4 Stress Analysis Tool (Post FPS Design Analysis)

Another user option in FPS 23 is Stress and Strain Analysis, that can be accessed by **Stress Analysis** button in the Pavement Plotting screen (Figure 19). The stress analysis tool can also be run separately from the main menu shown in Figure 7. Regardless of how it is executed, the simulated FWD deflection bowl for the proposed pavement design can be generated as shown in Figure 51. The analysis may be utilized as post-construction check to verify design requirements were achieved, or during design to identify structures that might exhibit a deflection deemed suitable for project requirements.

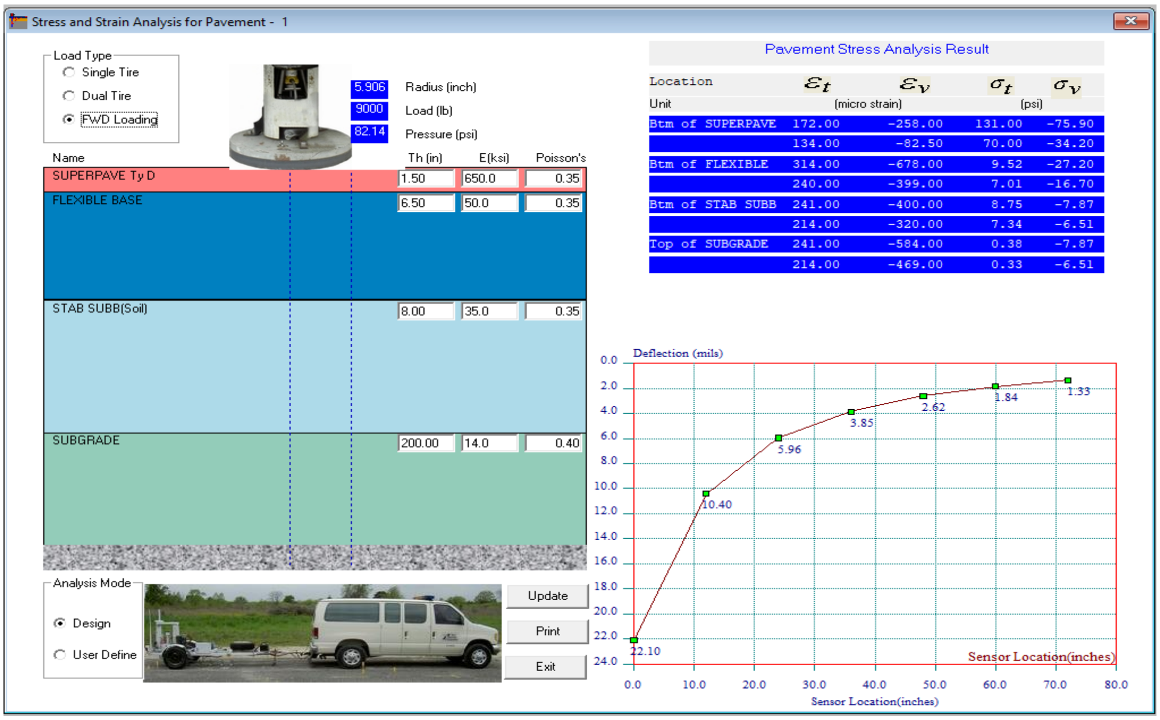


Figure 51. Stress Analysis Tool as Accessed from the Pavement Plotting Screen.

The FWD deflection bowl presented in Figure 51 should be measured in the field when the pavement structure was built as designed thickness and modulus of each layer in FPS 23. Thus, field FWD deflections significantly higher than this would be a cause for concern.

When accessed from the Main Menu, this is a stand-alone tool that does not require a previous run of FPS 23 for pavement structural information. In this analysis routine, user can predict stresses, strains, and deflections for a pavement structure with up to seven layers. These predictions can be used to simulate different loading weights or configurations including single or dual tiers or FWD plate. Details on using this analysis tool are more fully described by accessing the program HELP menu.

Appendix A. FPS 23 Typical Default Inputs

Table A1 offers typical modulus values based on pavement materials. Table A2 offers the recommended design moduli and cohesiometer values for Flex base and Recycled layers. Districts are encouraged to generate their own values based on their construction histories (for example Initial SI values) and layer moduli values with their materials (based on FWD testing).

Table A1. Recommended Design Modulus Values for FPS 23

2024 Specification	Material Type	Design Modulus	Poisson's Ratio	Comment
Item 316	Seal Coat	200 - 250 ksi	0.35	Considered in the structural design only when placed on the surface. Not considered when used as an underseal.
Item 330	Limestone Rock Asphalt Pavement	200 - 350 ksi	0.35	Material typically placed as asphalt stabilized base or surface for low volume roads.
Item 334	Hot-Mix Cold-Laid ACP	300 - 400 ksi	0.35	
Item 341	Dense-Graded Hot-Mix Asphalt (DG)	Combined HMA thickness: ≤ 4 in. use 500 ksi 4 in. < T ≤ 8 in. use 650 ksi > 8 in. use 850 ksi	0.35	
Item 342	Permeable Friction Course (PFC)	300 ksi	0.35	Thinness of the lift and high air voids do not allow significant contribution to the overall structural capacity.
Item 344, 346, 347	Superpave (SP) Stone-Matrix Asphalt (SMA) Thin Overlay Mixes (TOM)	Combined HMA thickness: ≤ 4.0 in. use 650 ksi 4 in. < T ≤ 6 in. use 750 ksi > 6.0 in. use 850 ksi	0.35	
Item 247	Flexible Base	If historic data not available, modulus shall be no greater than 3-4 times the subgrade modulus or use FPS default, whichever is lower. Typical range 40-70 ksi.	0.35	In general, a finer graded base will have lower moduli than one that is a coarser gradation. As angularity and soundness of particles decrease, modulus will decrease to the lower end of the scale. Limiting the minus 200 clay fraction will improve resistance to moisture damage.
Item 260	Lime Treated Base	60 - 75 ksi	0.30 - 0.35	Use Tex-121-E, "Lime Treated Materials" to establish optimum lime content. Long-term stiffness improvement will depend on concentration used and affinity of base material to undergo permanent chemical bonding.

2024 Specification	Material Type	Design Modulus	Poisson's Ratio	Comment
Item 275, 276	Cement Treated Base	80 - 150 ksi	0.25 - 0.30	Use Tex-120-E, "Cement Treated Materials" to establish optimum cement content. For Item 276, a minimum 7-day unconfined compressive strength of 300 psi is established for Class L stabilized base. TTI research indicates that higher strengths can lead to detrimental shrinkage cracking. Micro cracking is encouraged for higher strengths. Also, very stiff, stabilized bases are not modeled effectively in FPS 23. Higher design moduli shall not be used.
Item 291	Foamed Asphalt Treatment (Base)	200 ksi	0.35	Contact MTD –Soils & Aggregates section for assistance in establishing optimum asphalt content and recommendations for adding cement or other filler material.
Item 292	Asphalt Treatment (base)	250 - 400 ksi	0.35	Use Tex-126-E, "Molding, Testing, and Evaluating Bituminous Black Base Materials," asphalt content.
Item 290	Emulsified Asphalt Treatment (Base)	200 ksi	0.35	Contact MTD –Soils & Aggregates section for assistance in establishing optimum emulsion concentration and recommendations for adding cement or other filler material. Humid/wet regions require special considerations to ensure proper curing.
Item 265 (Removed from Spec. 2024)	Fly Ash or Lime-Fly Ash Treated Base	60 - 75 ksi	0.30	Use Tex-127-E, "Lime Fly-Ash Compressive Strength Test Methods," to establish optimum fly ash or lime fly ash content.
Item 260, 275	Lime or Cement Treated Subgrade	30 - 45 ksi	0.30	Use Tex-121-E or Tex-120-E, Parts 1, to establish optimum lime or cement content for permanent stabilization. Long-term stiffness improvement will depend on concentration used and affinity of subgrade material to undergo permanent chemical bonding. For cases when a subgrade will be treated using lower lime content (e.g., 2-3% lime) to provide a working platform for construction equipment and a platform to improve compaction effort of the overlying layers, *this layer shall not be accounted for in the structural design.*
Item 314, Item 290	Emulsified Asphalt Treatment (Subgrade)	15 - 25 ksi	0.35	Contact MNT – Pavement Asset Management Section for assistance in establishing optimum emulsion concentration.

2024 Specification	Material Type	Design Modulus	Poisson's Ratio	Comment
(Existing)	Subgrade	Priority should be to use the project-specific backcalculated subgrade modulus. Defaults by county are available in the FPS design program. Typical range is 6-20 ksi.	0.35 - 0.45	Use of a backcalculated modulus is preferred. FPS 23 defaults to the average county subgrade modulus taken from a limited number of tests. For new highway construction on a new right-of-way, deflection testing on an adjacent highway, or intersecting highways can provide data for backcalculation. Alternatively, elastic modulus correlations to field or laboratory derived CBR or the program default may be used. Wetter or more highly plastic materials warrant higher Poisson ratios.

Table A2. Recommended Design Moduli and Cohesiometer values for Flex base and Recycled layers

FPS Design Input Screen	Modulus Value	Poisson's Ratio	Cohesiometer Value (Cm) for Modified Texas Triaxial
Existing Thin Hot Mix	*500 ksi or Backcalculated from FWD data	0.35	Add existing HMA thickness to new HMA overlay thickness; use Cm value for total HMA thickness
Existing Pavement – Scarified, Reshaped and Compacted	~3 times the subgrade modulus	0.35	Use 100 for untreated materials, or select another layer with higher credit
Stabilize Exist Pav/Subgrade: a) Mostly granular base (75% or more base) b) Blend subgrade & base (50% to 75% base) c) Mostly subgrade (<50% base)	 a) 100 ksi b) 65 ksi c) 35 ksi	 a) 0.30 b) 0.30 c) 0.35	 a) 800 b) 650 c) 300
New Flexible Base (on top of existing structure/base)	Gr 1-2: 70 ksi Gr 5: 50 ksi	0.35	Use 100 for untreated materials, or select another layer with higher credit
1st 8" lift of new flexible base (when multiple lifts are required)	~3 times the subgrade modulus	0.35	Use 100 for untreated materials, or select another layer with higher credit

Appendix B. Example Design: Conventional Pavement Case

This appendix provides a comprehensive example of using FPS 23 to develop a conventional pavement design for TxDOT. The four phases of the Pavement Design process used by TxDOT are as follows:

- **Phase 1.** The initial pavement design thicknesses are generated using the FPS 23. This is a deflection-based approach which models the loss of pavement serviceability with time. The initial design is then checked and revised based on the following 3 design checks.
- **Phase 2.** The mandatory check is the use of the Texas Triaxial Design Check which ensures that there is adequate pavement thickness to accommodate the heaviest loads that are anticipated, without inducing shear failure of the subgrade.
- **Phase 3.** The optional Mechanistic check is then performed to estimate the life until either HMA cracking or subgrade rutting failure occurs based on computations of stresses and strains within the structure.
- **Phase 4**. The TxME package provides an advanced Mechanistic-Empirical check to evaluate the impact of changes of the materials properties on predicted performance. For the HMA layer this includes mix type, binder type and impact of RAP and RAS content.

Summary outputs from each phase of the design must be captured by the designer and incorporated into the mandatory pavement design report.

PHASE 1 FPS 23 Initial Designs

This example is an FM Road in the Fort Worth District, Wise County. The design type selected uses the Type 7 structure (ACP surface, flex base, stabilized subgrade on natural subgrade). For this design, the following FPS inputs are used to generate an initial set of feasible designs:

- Length of Analysis Period 20 years
- Minimum Time to First Overlay 10 years
- Initial and Terminal SI 4.5 and 3.0
- Serviceability Index after Overlay 4.2
- Confidence Level 95.0% (C)
- Current ADT and 20-year ADT 2,040 and 3,640
- Cumulative ESALs 1.2 M
- Percent Trucks 11%
- ATHWLDs and % Tandems 11,000 lb. and 40%
- HMA modulus 500 ksi (allowable Range 2 to 4 inches)
- HMA Type Dense Graded Ty D with a PG64-22 (For TxME check)
- Flex Base modulus 50 ksi (allowable range 6 to 12 inches)
- Stab. Subgrade modulus 35 ksi (fixed thickness of 8 inches)
- Subgrade modulus 12 ksi at 200-in Depth to Bedrock

As described in Chapter 3 of this manual, the designer will first run FPS 23 to generate a selection of feasible designs. Using the above inputs, Figure B.1 shows the passing thickness design options.

Figure B.1. Feasible Design Results.

Based on these design options, the designer would like to investigate and check Design 2. Clicking on the **Check Design** button under the Design 2 column generates the pavement plot with design check options, as shown in Figure B.2 is generated.

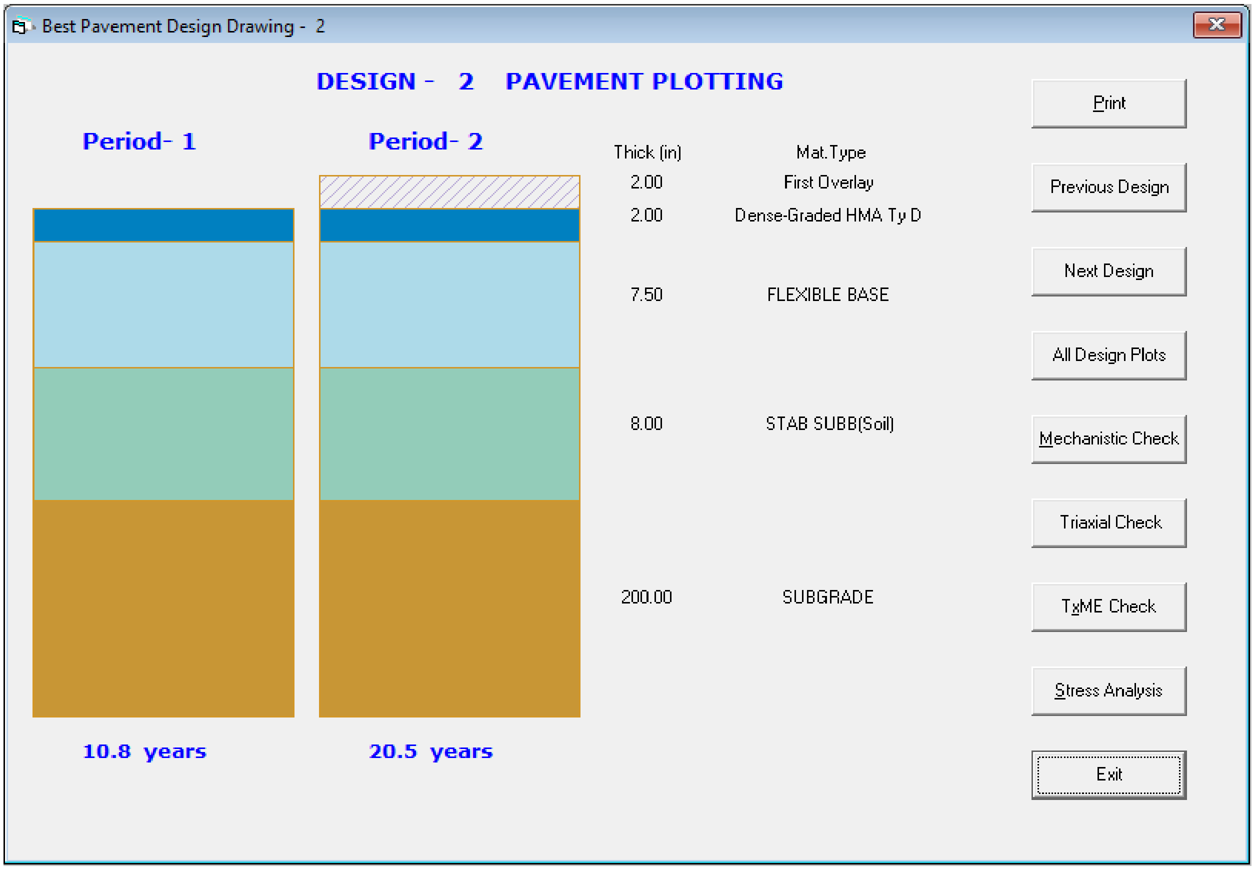


Figure B.2. Design 2 selected for Further Evaluation by Texas Triaxial, Mechanistic, and TxME Checks.

PHASE 2 Texas Triaxial Design Check

The Texas Triaxial Design check is currently mandatory for all flexible pavement designs in Texas. Once the initial screen opens, the designer enters 11,000 lb. for the ATHWLD (as provided by the TPP Division or specific-specific pWIM study) and the % of Tandem axles in the traffic stream. The computation in this design check predicts the total thickness of surface, base, and subbase layers needed to protect the subgrade from shear failures under the heaviest design load. It assumes that the initial pavement materials are surface treatment with untreated (flexible) base. This check was intended to ensure the low volume roadways will have sufficient thickness for the anticipated heaviest wheel load. The system was expanded to give thickness benefit for alternate materials combinations. This was implemented using a Modified Cohesiometer value to provide a thickness reduction for stiffer materials. Hitting the **Reference Button** in the initial screen the drop-down table shown below in Figure B.3 is displayed. As the initial design from Phase 1 recommended a treated subbase and 2 inches of HMA, the table is reviewed and the largest Cohesiometer value should be selected, in this case the value of 300 was input.

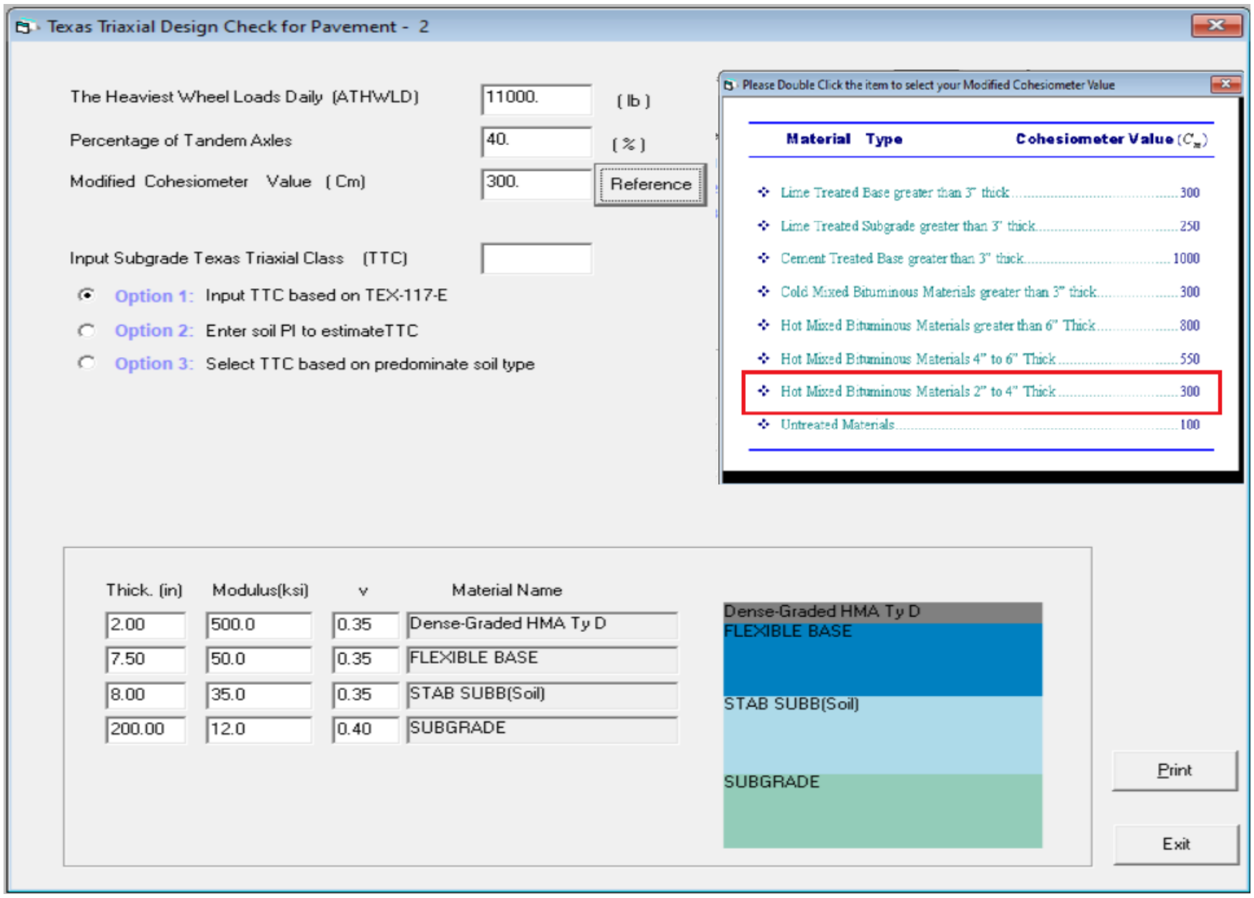


Figure B.3. Input screen for the Texas Triaxial Check Routine.

The next step is to specify the pavement subgrade strength, which is entered as a Texas Triaxial Class (TTC). This system was developed largely in the 1950 and 60's when TxDOT did Triaxial strength testing on most of the soils found around Texas using test method Tex-117-E. Full details of the development of the TTC and thickness curves is well summarized in TTI report 0-4519-1 by Fernando E. et al, from June 2008. The TTC values range from 3.0 to 6.5, which are the low values found only in the rocky areas of West Texas, whereas the values of 6 and above are in the highly plastic clay areas of East Texas.

To assist the designer to select the best TTC for any projects, FPS 23 provides three options as:

- Option 1 assumes that the designer knows the TTC for the project based on the laboratory testing result with Tex-117-E (this option is rarely used).
- Option 2 is to enter the Plasticity Index (PI) for the project soils (the worst selected in the drill logs for the top of the raw subgrade is used).
- Option 3 is to use the provided default values which are stored for each county in Texas. It shows the different soil types found in a county with their associated TTC values. For this project, the CL (clay) soils was selected with a TTC of 4.0 for Wise County as shown in Figure B.4.

In the boxes in the upper right of Figure B.4, the program estimates that the total thickness of upper layers required to protect the subgrade for the heaviest loads. In this case, 12.01 inches is required above the subgrade. With the use of 2-inch HMA layer (Cohesiometer value 300), a 1.86-inch thickness reduction is allowed, resulting in a Modified Triaxial Thickness of 10.16 inches. Therefore, the FPS Design Thickness of 17.50 inches is sufficient, as displaying **Design OK** in the window.

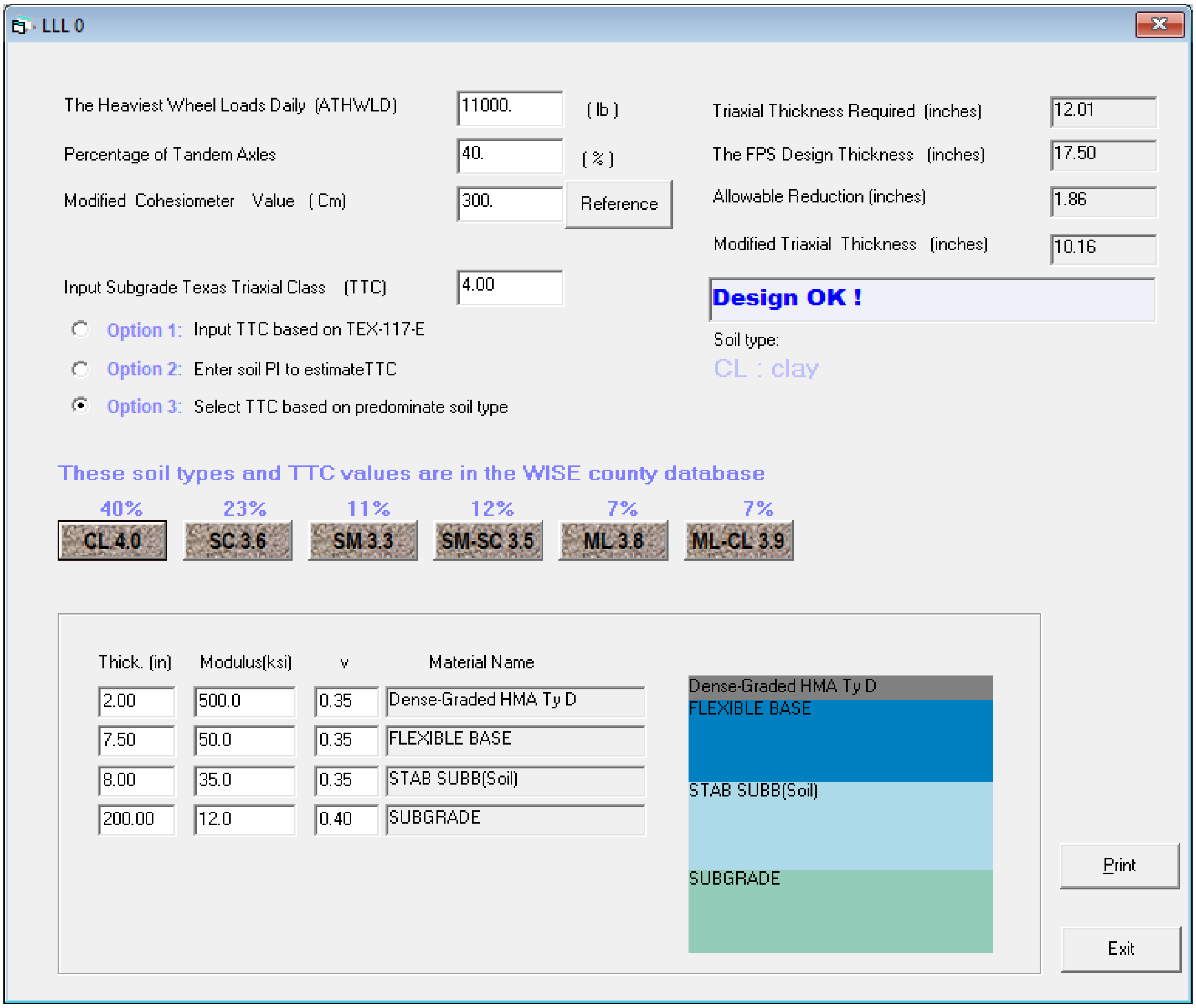


Figure B.4. The Texas Triaxial Results Screen Showing a Passing Design.

The Triaxial Check is often the controlling check especially for lower volume roadways which are carrying seasonal heavy loads. If the Phase 1 design fails in the TTC check, it should be upgraded based on the modified triaxial thickness required to get a passing TTC design.

PHASE 3 Mechanistic Design Check

By selecting the **Mechanistic Check** button in Figure B.2, the Mechanistic Design Check screen will appear as shown in Figure B.5.

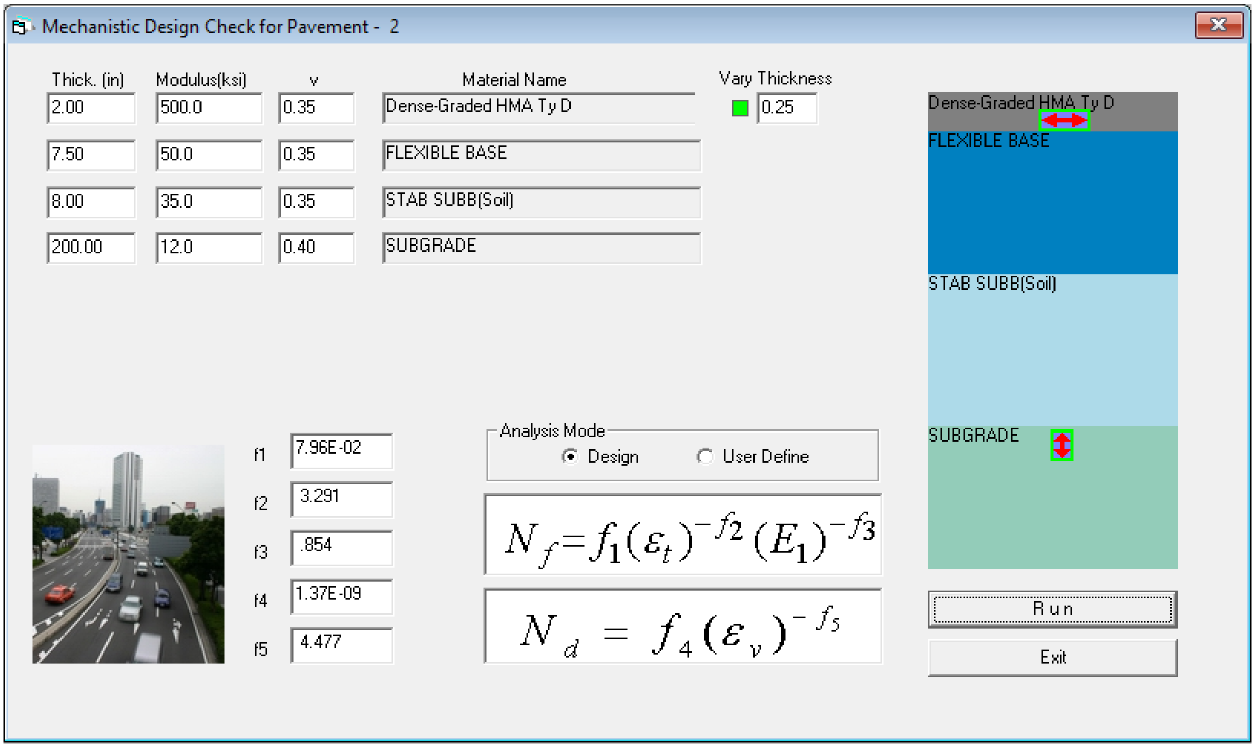
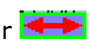


Figure B.5. Mechanistic Design Check Input Screen.

The upper left of the screen displays the structural layer material parameters generated in the Phase 1 design. The designer wishes to evaluate the sensitivity of the HMA layer thickness; so, the green box beneath the **Vary Thickness** heading is dragged to this HMA layer and the thickness increment is set to 0.25 inches. The designer then verifies that the tensile strain indicator  is located at the bottom of the HMA layer. The allowable number of load repetitions to limit the AC fatigue cracking and subgrade rutting will be computed using the default Asphalt Institute (AI) models.

The AI models used in FPS 23 date back to the early 1980s. In the case of the fatigue cracking performance equation, the parameters apply to a typical dense-graded HMA mixture with 5 percent air voids, using an unmodified binder at 11 percent by mixture volume (roughly 4.8 to 5.0 percent asphalt content by weight). The AI failure criteria is 20 percent of the total lane area, which is equivalent to about 45 percent in wheel path cracking. In the case of subgrade rutting, the AI performance equations are for subgrade rutting only, it does not evaluate the susceptibility of the flexible base or HMA layers to rutting and failure is defined as 0.5 inches rutting as evaluated at the surface of the pavement.

The fatigue and rutting performance equation fields have active links to several other fatigue or rutting performance equations that the designer can select for alternate evaluations. Also, the designer can directly input alternate coefficient values (f_1 through f_5) to any of these performance equations by overwriting the defaults. For example, Craus et al. (1984) concluded that for HMA surfaces thinner than 4.0 inches, f_1 = 0.0636[1] for the AI fatigue performance model, which effectively reduces the number of repetitions to failure for thinner HMA surfaces. Nevertheless, revising the coefficient values in all equations is not recommended.

Once the designer has made all desired inputs, the **Run** button is selected, and the mechanistic analysis output is displayed as in Figure B.6

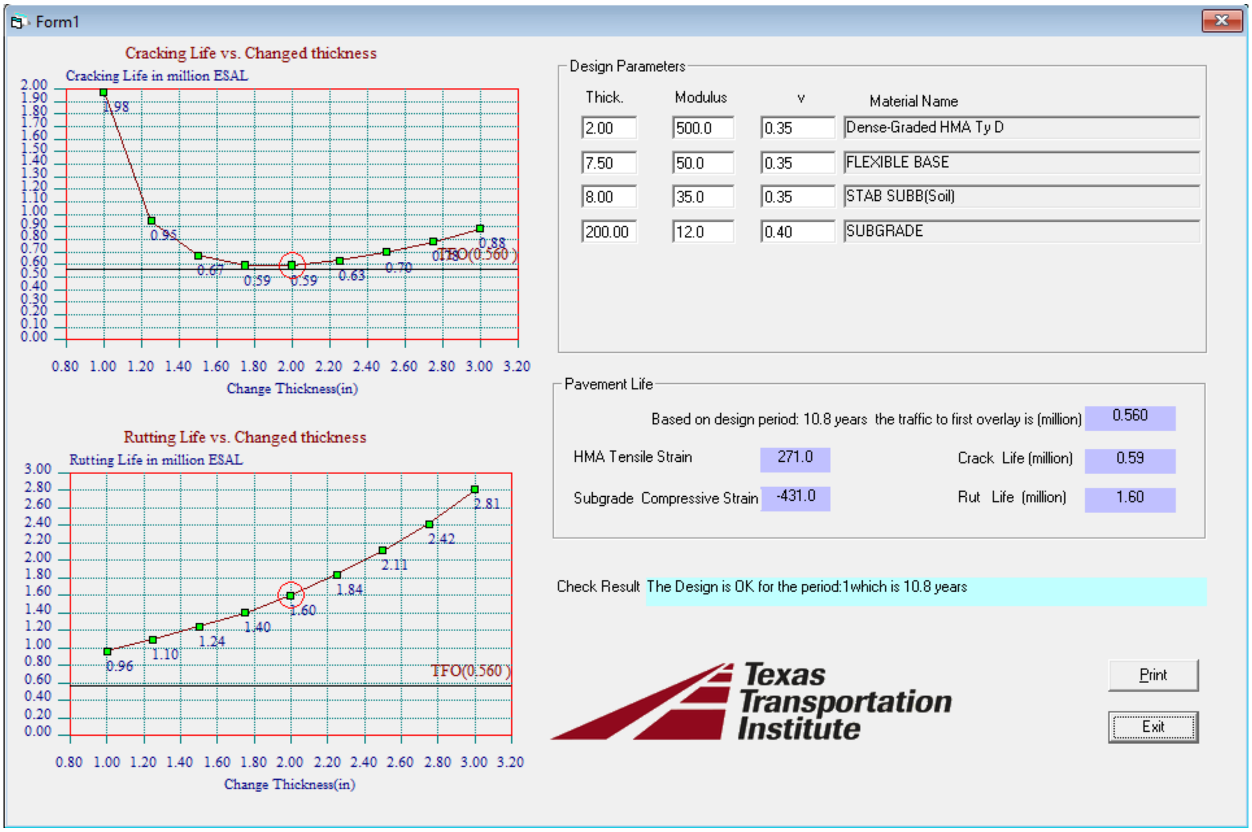


Figure B.6. Mechanistic Design Check Results.

In the **Pavement Life** section, the designer notes the following:

- The estimated cumulative 18-kip ESALs at 10.8 years of the first overlay is 0.56M.
- The estimated cumulative 18-kip ESALs to failure in fatigue is 0.59M (~105 percent of the projected ESALs at the first overlay period).
- The estimated cumulative 18-kip ESALs to failure in subgrade rutting is 1.60M (~285 percent of the projected ESALs at the first overlay period).
- Neither of these failure modes are likely to occur before the first overlay (10.8 years) and the Check Result message notes the design is **"OK".** (However, the design pavement is very close to the fatigue cracking limit so that is anticipated to be the eventual failure mode)

In the left side of the screen, the designer can evaluate the effect on rutting and cracking performance by adjusting the HMA layer thickness in 0.25 inches increments. Projected ESAL to failure is plotted on y-axis and the HMA layer thickness variation is plotted on x-axis. Also, the horizontal line in each plot shows the estimated ESALs to failure at the end of the Time to First Overlay (TFO) period (10.8 years in the initial design). In the case of fatigue cracking, the 2-inch HMA thickness has the lowest fatigue life, just above the minimum required. Either reducing or increasing the HMA thickness will generate longer life until cracking failure. While increasing the surface thickness has also some benefit on predicted rutting life, the fatigue cracking is the main concern with this design.

The structural parameters given in the table at the upper right are for reference purposes only and cannot be edited from this location. The designer now wishes to evaluate the mechanistic performance of a design using slightly thicker HMA and thinner base layers, without having to re-run FPS (a final run of FPS is required after any follow-on mechanistic evaluation if the designer alters the layer thicknesses, moduli, etc.). Select the **Exit** button to return to the Mechanistic Checks input screen. Now the designer decides to select the **User Define** option in the **Analysis Mode** section at the center of the screen (Figure B.7). The designer overwrites the FPS-generated design thicknesses for the HMA surface by entering 3.0 inches and the Flexible Base thickness by entering 6.0 inches. Also, the designer would now like to evaluate the sensitivity of increasing the HMA thickness in 0.25 inches increments, so the green box under the **Vary Thickness** heading is dragged to the surface layer.

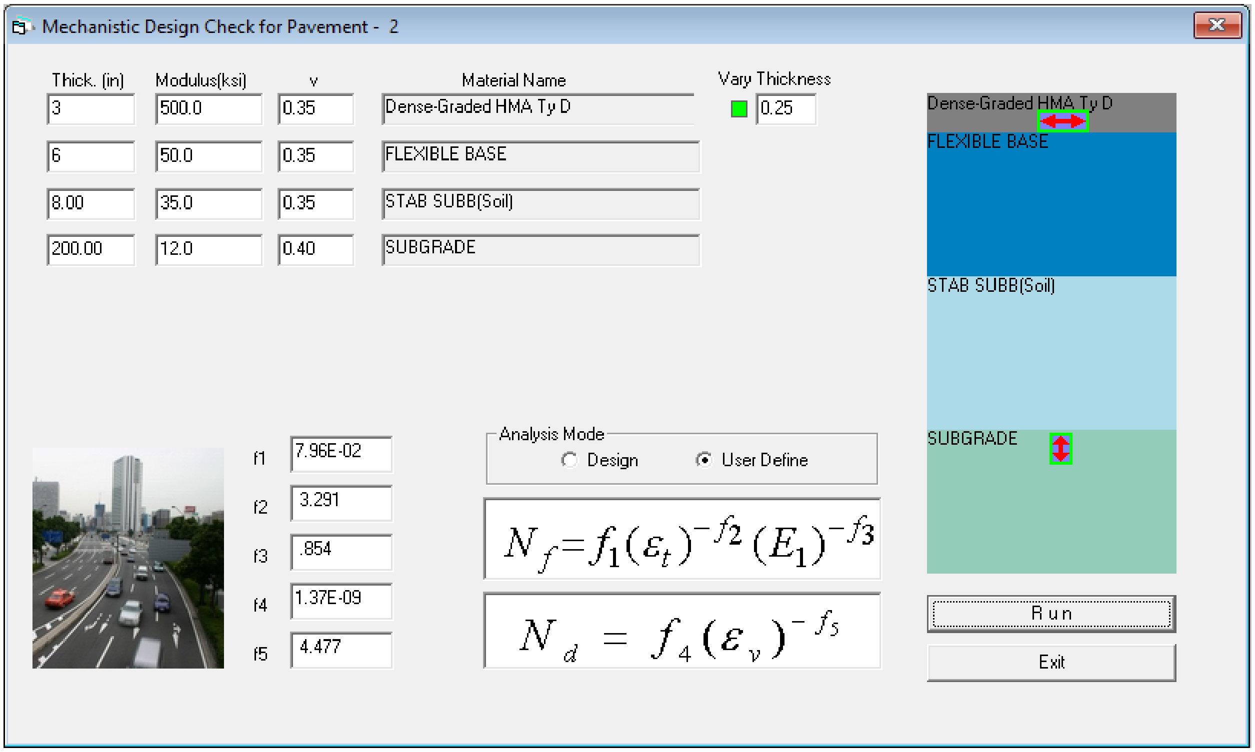


Figure B.7. Mechanistic Design Checks in the User Define Mode.

Once all desired changes are made, the designer again selects **Run** and the mechanistic analysis output is re-displayed as shown in Figure B.8. Again, the designer evaluates the **Pavement Life** section and notes the following:

- The estimated cumulative 18-kip ESALs 10.8 years of the first overlay is 0.56M.
- The estimated cumulative 18-kip ESALs to failure in fatigue is 0.84M (~150 percent of the projected ESALs at the first overlay period).
- The estimated cumulative 18-kip ESALs to failure in subgrade rutting is 1.69M (~302 percent of the projected ESALs at the first overlay period).
- The cumulative 18-kip ESALs in both failure modes exceed the cumulative ESALs to the first overlay and the Check Result message validates this. This adjusted FPS option is in better balance with these checks.

By looking at the left-hand side of the screen, the designer can evaluate the effect on the performance for these two failure criteria by adjusting the HMA layer thickness in 0.25 inches increments. The increase of the HMA thickness from 2 to 3 inches substantial raises the predicted fatigue and rutting life above the TFO minimum required.

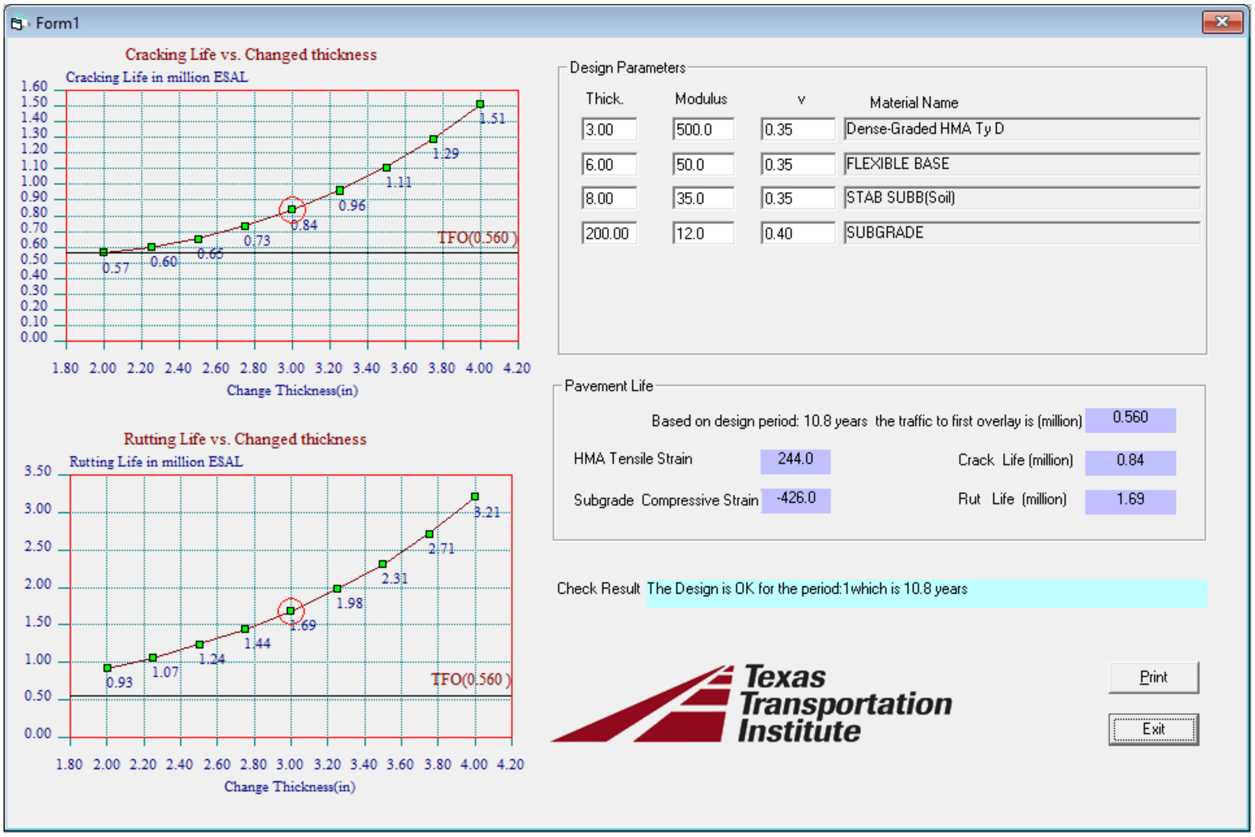


Figure B.8. Mechanistic Analysis Following User Define Inputs.

The user is advised that the mechanistic models used in this program are less sophisticated than current state-of-the-art practice. The models do not consider material-specific behavior, the effects of the environment, variable axle loading, traffic wander, and other factors. Therefore, the user should not rely solely on the outcome of this check. However, it is prudent to carefully consider any large difference between the projected cumulated ESALs to the first overlay and those for failure in the two mechanistic models. The use of this check is strongly recommended when the proposed surface thickness is in 2 to 4 inches range which is where the higher tensile strains are computed, and the lowest fatigue life is anticipated.

PHASE 4 TxME Design Checks and Sensitivity Analysis

Clicking the "**TxME Check**" button (Figure B.2) opens the main input screen in TxME (Figure B.9). By default, the TxME project is named "prj_FPS" and saved in the "projects" folder where TxME is installed. Users can rename the project and change the save location by clicking the "Save As" menu or button (Figure B.10) to save all files related to the design project.

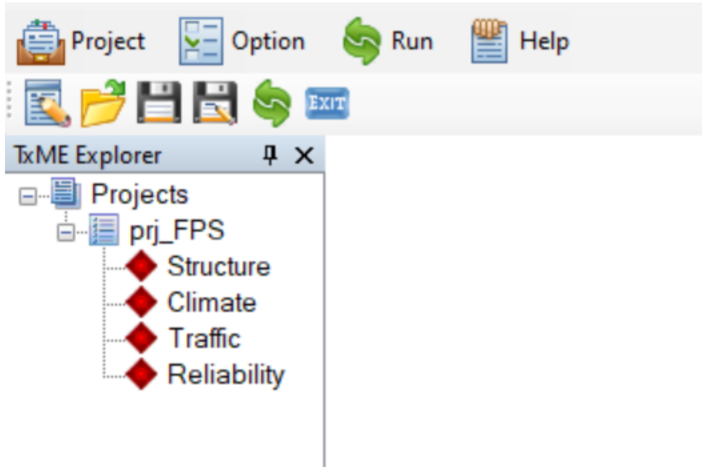


Figure B.9. TxME Main Screen Opened By Clicking the "TxME Check" Button.

Figure B.10. TxME "Save As" Menu.

Double-clicking the tree node Structure will open the structure input screen. The icon color changes to green, and the pavement type, project location, structure details (layer type, thickness, modulus, etc.) are transferred from FPS 23 to TxME, as shown in Figure B.11.

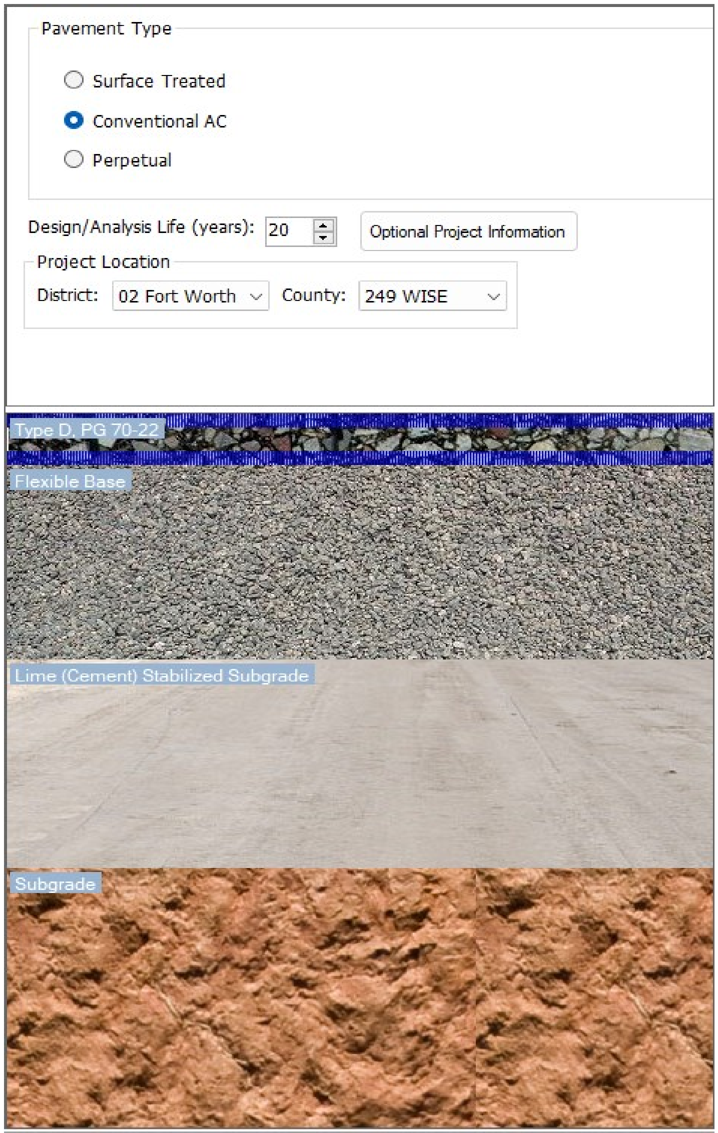
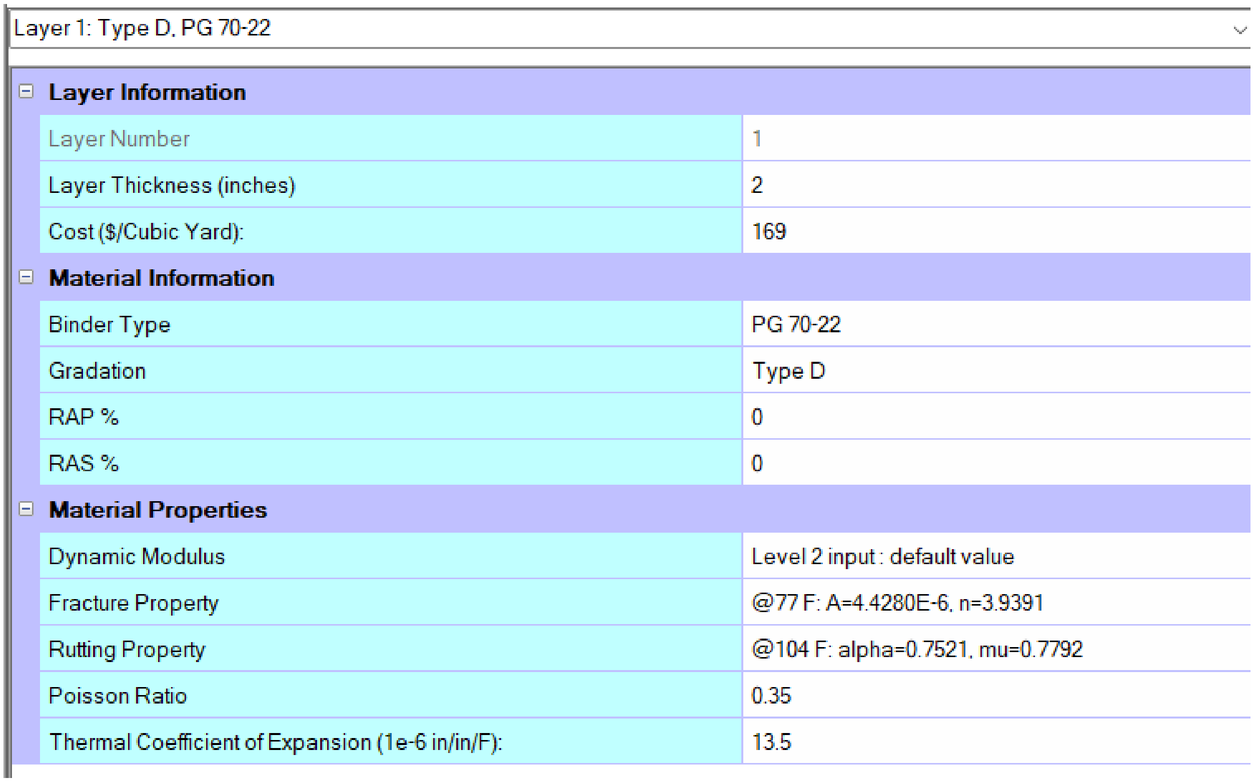


Figure B.11. Pavement Structure Information Transferred from FPS 23 to TxME.

Figure B.12 shows the TxME AC layer material property input screen. Note that in FPS 23, the binder type and gradation are not specified. However, in TxME, users can either accept the default binder and gradation type or select a different one if specific information is available. Additionally, users can enter fracture properties, rutting properties, or dynamic modulus values if test data are available. This enables designers to leverage state-of-the-art mechanistic-empirical (ME) models to more precisely evaluate the impact of AC binder/gradation type and material properties on predicted rutting and cracking performance.

Similarly, for base, subbase, and subgrade layers, the modulus value is automatically transferred from FPS 23 to TxME. However, users can input more detailed information, such as rutting properties, if they prefer to use their local materials properties. This allows designers to make more accurate performance predictions.



Layer 1: Type D, PG 70-22

Layer Information	
Layer Number	1
Layer Thickness (inches)	2
Cost ($/Cubic Yard):	169
Material Information	
Binder Type	PG 70-22
Gradation	Type D
RAP %	0
RAS %	0
Material Properties	
Dynamic Modulus	Level 2 input : default value
Fracture Property	@77 F: A=4.4280E-6, n=3.9391
Rutting Property	@104 F: alpha=0.7521, mu=0.7792
Poisson Ratio	0.35
Thermal Coefficient of Expansion (1e-6 in/in/F):	13.5

Figure B.12. TxME AC Layer Material Property Input Screen.

Double-clicking the tree node Climate will open the climate input screen, as shown in Figure B.13. TxME automatically selects and highlights the nearest weather station based on the project location in FPS 23. Users only need to click the "OK" button to confirm the selection. Then, the icon turns green, indicating the climate input is complete.

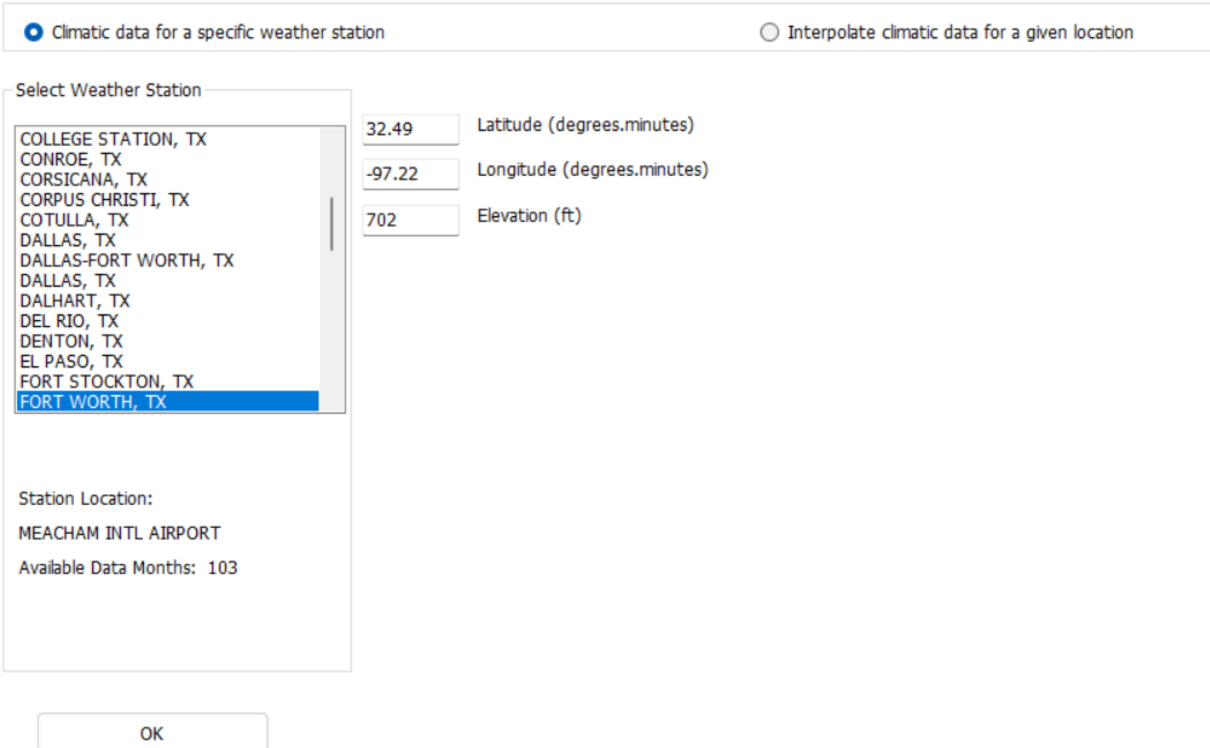


Figure B.13. TxME Climate Input Screen.

Double-clicking the tree node Traffic will open the traffic input screen, as shown in Figure B.14. The ADT-Beginning, ADT-End, and 18-kip ESALs are automatically populated with values from FPS 23; however, the user must input the Operational Speed. In this example, the assumed speed is 70 mph.

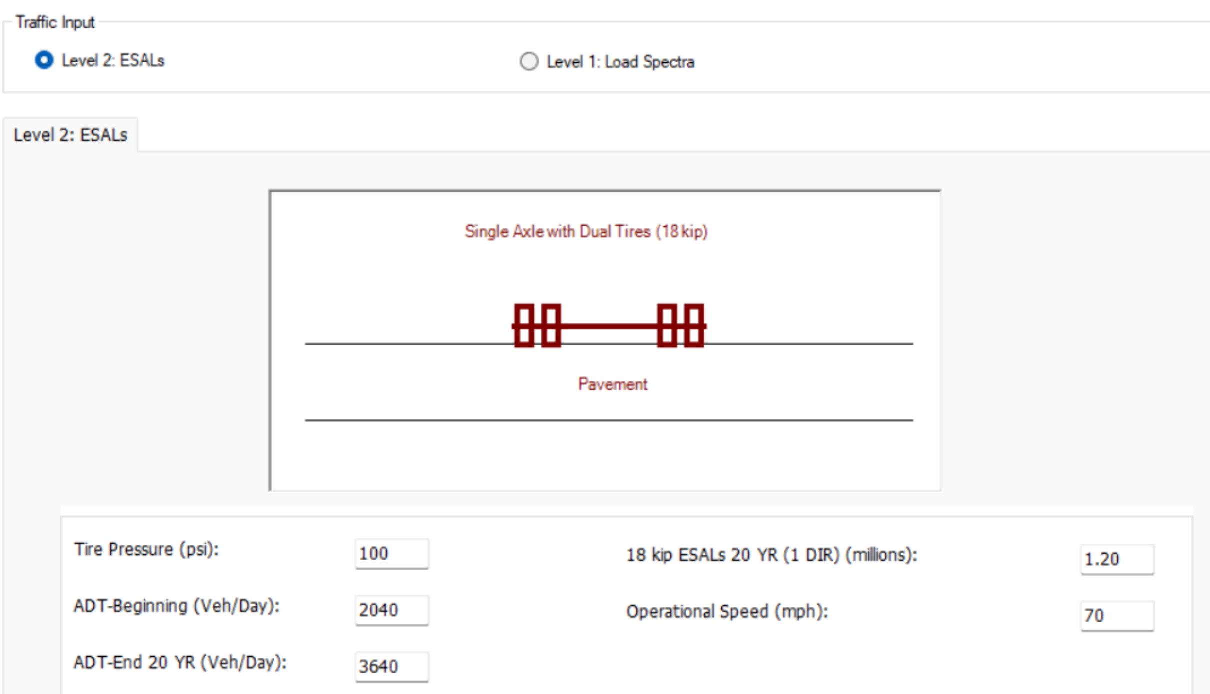
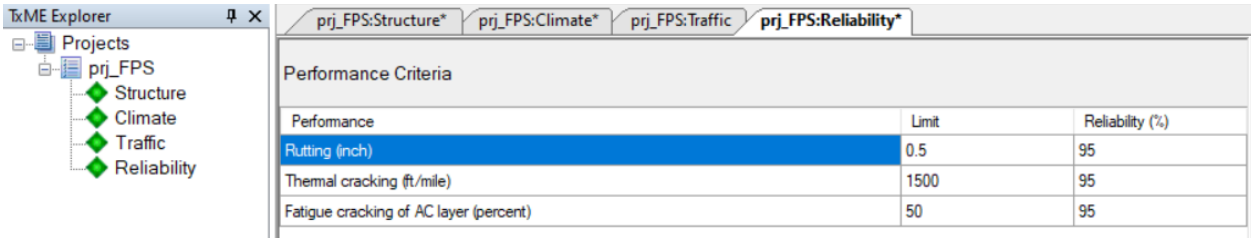


Figure B.14. TxME Traffic Input Screen.

Double-clicking the tree node Reliability will open the reliability-related input screen, as shown in Figure B.15.



Performance	Limit	Reliability (%)
Rutting (inch)	0.5	95
Thermal cracking (ft/mile)	1500	95
Fatigue cracking of AC layer (percent)	50	95

Figure B.15. TxME Reliability Input Screen.

When all four tree nodes turn green, it indicates that the input is complete, and the program is ready to run the analysis. Click the "Run" menu or button, and TxME will begin the analysis, outputting the results in Excel format. Figure B.16 displays the predicted rutting and cracking life for the selected FPS 23 pavement design option. The horizontal lines in both plots represent the cracking and rutting failure limits provided in the reliability input screen.

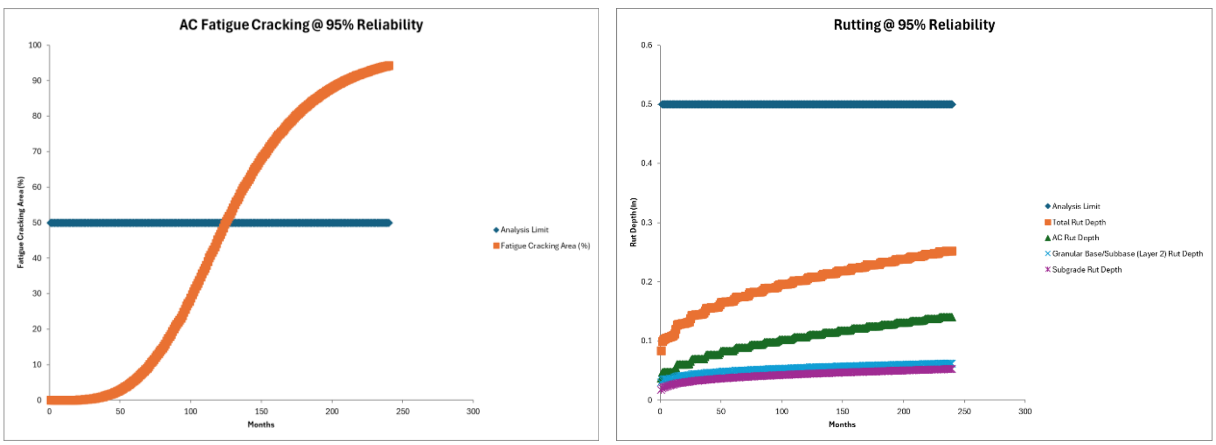


Figure B.16. TxME Predicted Cracking and Rutting Life.

From Figure B.16, the estimated cracking failure is approximately 125 months, with no concerns raised regarding the rutting life, as the total rut depth reaches around 0.25 inches after 20-year.

The TxME check enables the designer to assess the impact of incorporating RAP and RAS into the AC layer. Figure B.17 illustrates the changes to the material properties when 25% RAP is added to the surface AC mix. Note that both the fracture and rutting material properties are automatically updated accordingly.

Layer 1: Type D, PG 70-22	
Layer Information	
Layer Number	1
Layer Thickness (inches)	2
Cost ($/Cubic Yard):	147.2
Material Information	
Binder Type	PG 70-22
Gradation	Type D
RAP %	25
RAS %	0
Material Properties	
Dynamic Modulus	Level 2 input : default value
Fracture Property	@77 F: A=4.3739E-5, n=3.4609
Rutting Property	@104 F: alpha=0.7842, mu=0.7792
Poisson Ratio	0.35
Thermal Coefficient of Expansion (1e-6 in/in/F):	13.5

Figure B.17. Updated Material Properties for AC Layer with the Incorporation of 25% RAP.

When the AC layer incorporate 25% RAP, as shown in Figure B.18, the cracking life decreases from 125 months to 84 months while the total rut depth is reduced to approximately 0.16 inches, compared to 0.25 inches with no RAP.

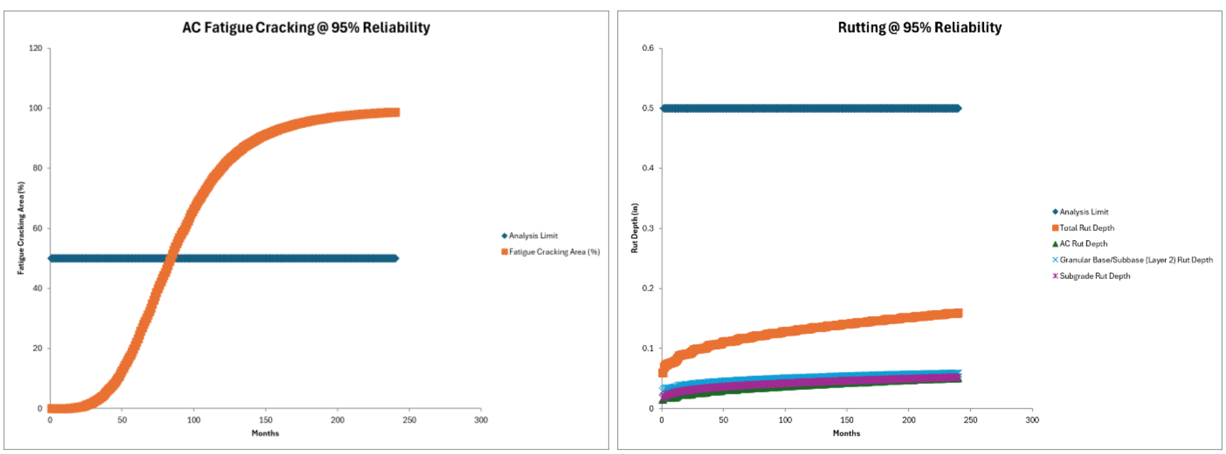


Figure B.18. Predicted Cracking and Rutting Life for the AC Mix with 25% RAP.

TxME also offers the option to consider a premium mix instead of the Dense Grade mix. An additional run was conducted to evaluate the benefits of switching to SMA, one of premium mixes. The results, shown in Figure B.19, indicate that the cracking life exceeds the 20-year design period and the total rut depth is about 0.17 inches.

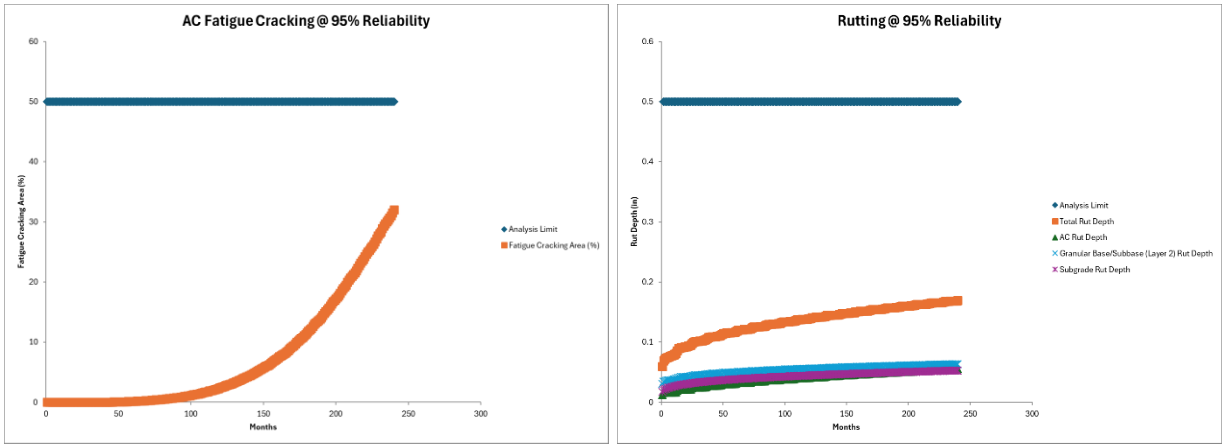


Figure B.19. Predicted Cracking and Rutting Life with SMA Mix with PG 76-22.

A sensitivity analysis was conducted on several mix design options available to engineers to assess their impact on the critical predicted cracking life of the proposed pavement structure. These options included variations in mixture type, PG binder, layer thickness, and the use of RAP. The results are shown in Table B.1 below.

Table B.1 Sensitivity Analysis of Changing Surface AC Properties on the Predicted Cracking Life

Mix Type	Binder	Thickness (in.)	% RAP	Months until cracking failure
Dense-Graded Type D	PG 70-22	2.0	0	125
			25	84
		3.0	0	191
	PG 64-22	2.0	0	131
SMA	PG 76-22	2.0	0	240+

Appendix C. Example Design: Perpetual Pavement Case

Appendix C shows a comprehensive example of using FPS 23 to develop a perpetual pavement design. Perpetual pavements are designed to meet a limiting strain criteria. The estimated strain can be found through the mechanistic design check. If these mechanistic benchmarks are not exceeded, then there is a very high likelihood that the pavement will not suffer traditional bottom-up fatiguing or full-depth (subgrade failure) rutting. Thinner structures are generally subjected to similar maximum axle loads but offer insufficient stiffness or thickness to stay below the limiting criteria. As with other design criteria, these limiting strain criteria presuppose that quality materials are used and that proper construction procedures are followed. The limiting strain criteria reported by experts in the field (such as Nunn and Monismith) are:

- tensile strain at the bottom of the composite HMA layers: < 70 μ-strain,
- compressive strain at the top of the subgrade: < 200 μ-strain.

Use the following steps in FPS 23 to design a perpetual pavement:

1. Pavement design Type 7 (User Defined) is recommended for this type of structure.
2. Select a 30-yr. length of analysis period.
3. Use a confidence level of 'C' (95%).
4. Use lane distribution reduction factors when three or more lanes are planned in one direction to adjust the 20-yr. cumulative 18-kip ESALs.
5. Enter the 20-yr. cumulative ESALs (or adjusted ESALs) in the 18-kip ESAL field.
6. Select a "time to first overlay" of 15 yr.
7. Follow general guidelines for all other inputs. Note elevated moduli values are permitted for all HMA layers based on total thickness. Select the red arrow button to run the design.

This example is a US Highway in the Dallas District, Kaufman County. The design type selected was a Type 7 structure. For purposes of this design, the following FPS inputs were used to generate an initial set of feasible designs (Figure C.1):

- Minimum Time to First Overlay 15 years
- Initial SI 4.8
- Terminal SI 3.0
- Serviceability Index after Overlay 4.2
- Confidence Level 95.0% (C)
- Current ADT 28,000
- 20 Year ADT 57,000
- Cumulative ESALs 75.0 M (adjust for a 6-lane facility with a factor of 0.7)
- Percent Trucks 32.0%
- Layer moduli Use Defaults

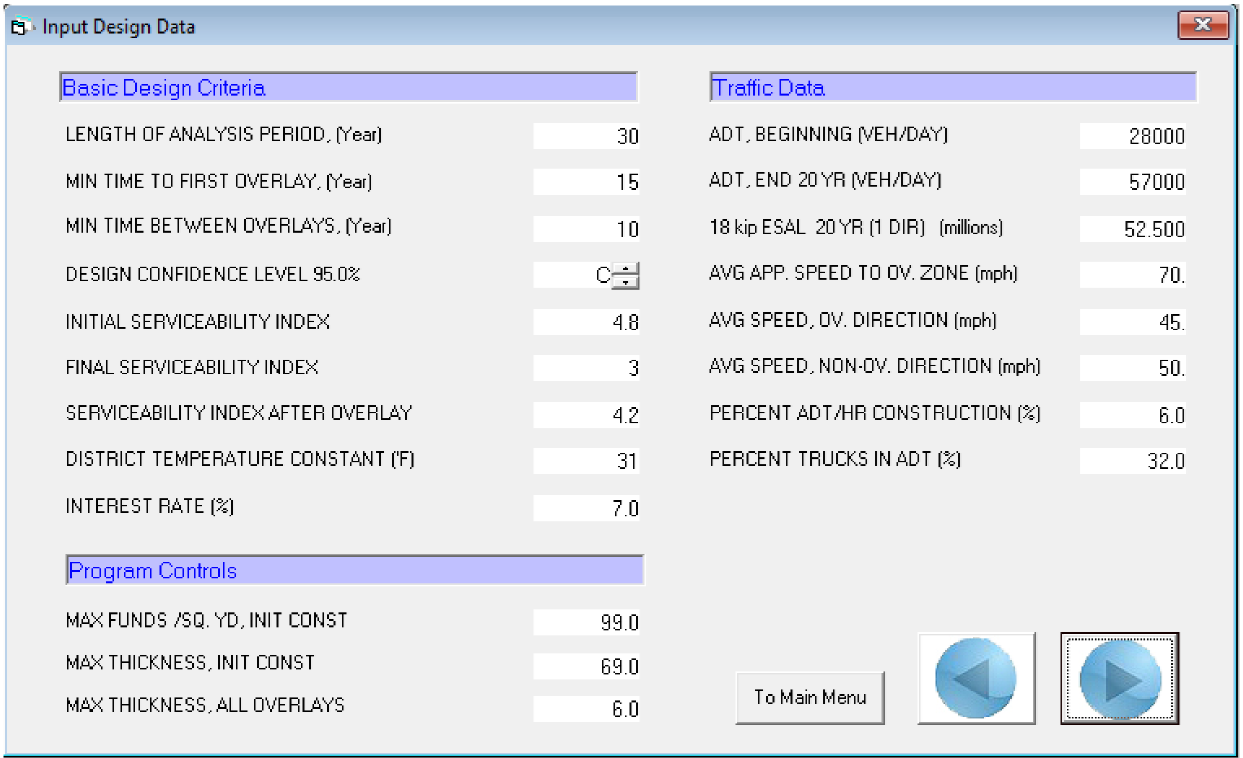
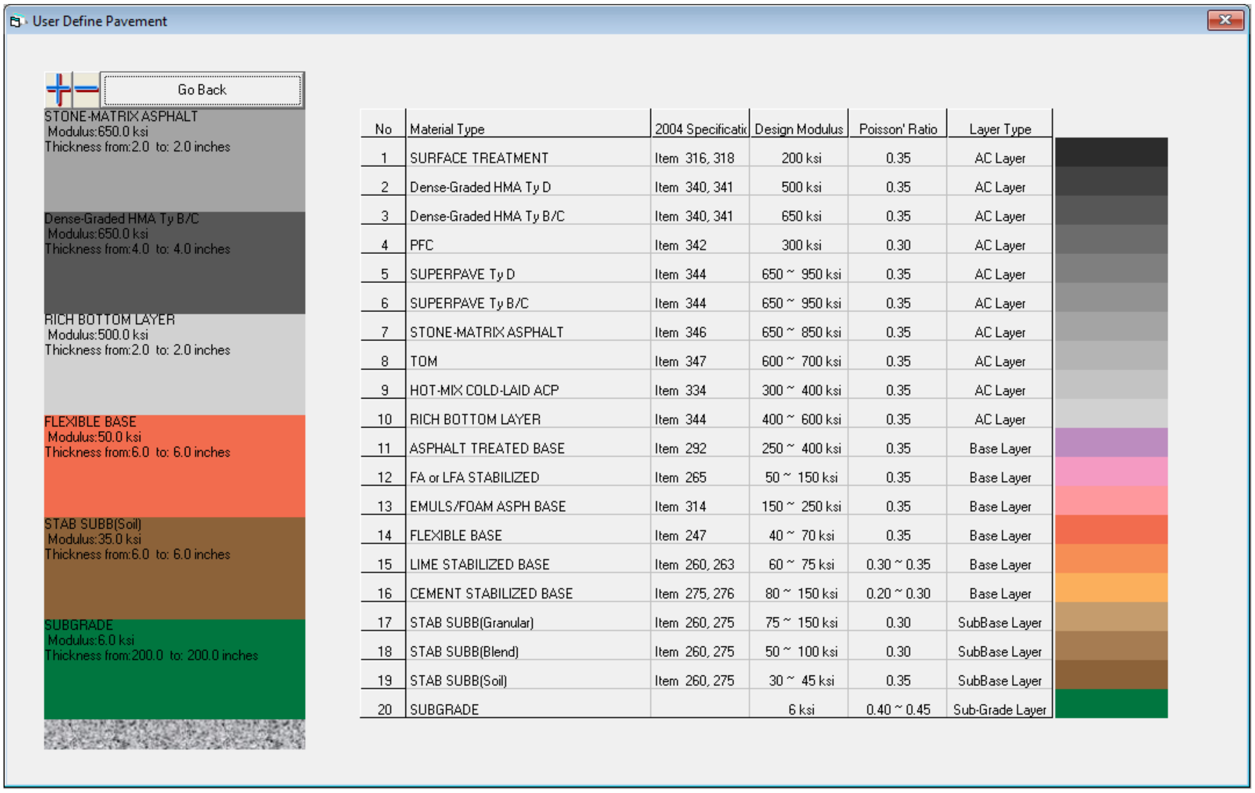


Figure C.1. Input Design Data.

Use the following layers for the pavement structure (Figure C.2 and C.3):

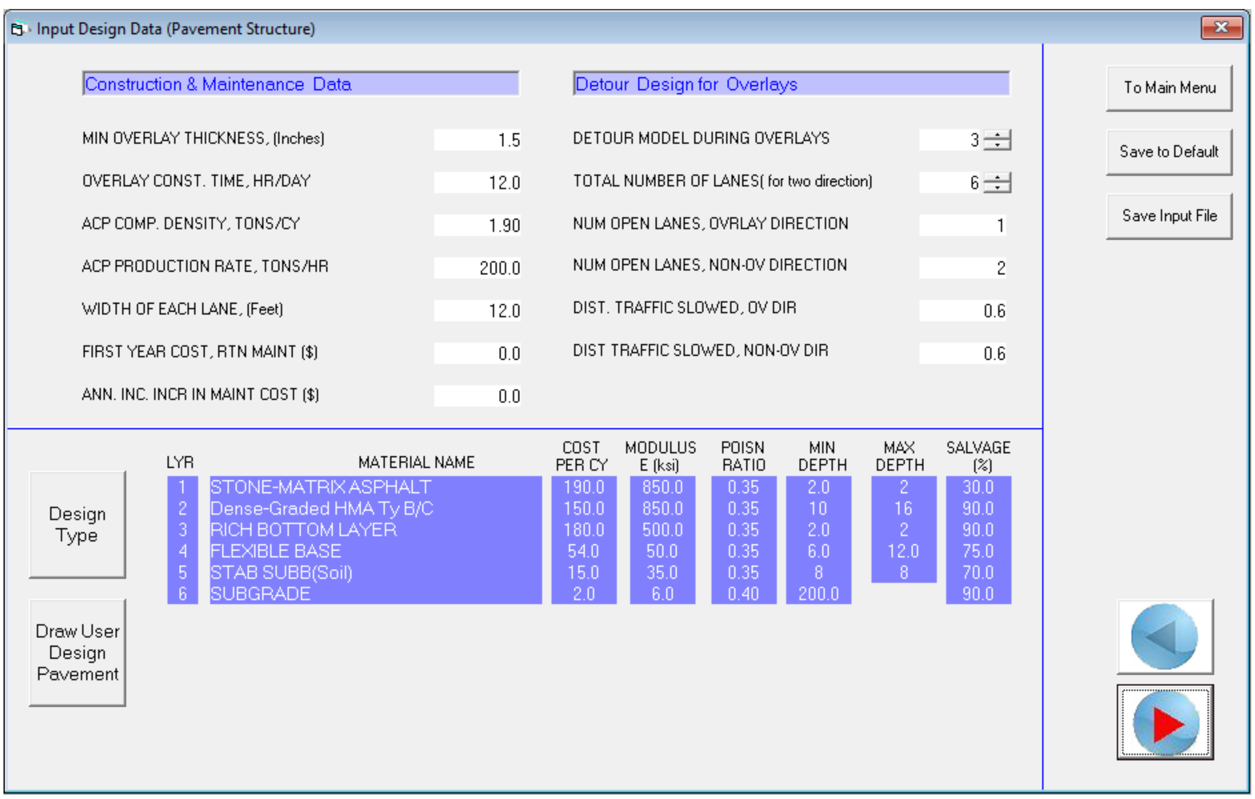
- SMA surface fix at 2 inches
- Dense-Graded Ty B/C variable thickness
- Rich Bottom Layer (RBL) fix at 2 inches
- Flexible Base variable thickness
- Lime Treated Subgrade fix at 8 inches
- Subgrade use County default value in FPS 23

Based on the recommendation provided in Appendix A of this report, a modulus value of 850ksi was used for all HMA layers. However, the RBL layer modulus value is fixed at 500 ksi as recommended in the Pavement Design Manual.



No	Material Type	2004 Specificatio	Design Modulus	Poisson' Ratio	Layer Type
1	SURFACE TREATMENT	Item 316, 318	200 ksi	0.35	AC Layer
2	Dense-Graded HMA Ty D	Item 340, 341	500 ksi	0.35	AC Layer
3	Dense-Graded HMA Ty B/C	Item 340, 341	650 ksi	0.35	AC Layer
4	PFC	Item 342	300 ksi	0.30	AC Layer
5	SUPERPAVE Ty D	Item 344	650 ~ 950 ksi	0.35	AC Layer
6	SUPERPAVE Ty B/C	Item 344	650 ~ 950 ksi	0.35	AC Layer
7	STONE-MATRIX ASPHALT	Item 346	650 ~ 850 ksi	0.35	AC Layer
8	TOM	Item 347	600 ~ 700 ksi	0.35	AC Layer
9	HOT-MIX COLD-LAID ACP	Item 334	300 ~ 400 ksi	0.35	AC Layer
10	RICH BOTTOM LAYER	Item 344	400 ~ 600 ksi	0.35	AC Layer
11	ASPHALT TREATED BASE	Item 292	250 ~ 400 ksi	0.35	Base Layer
12	FA or LFA STABILIZED	Item 265	50 ~ 150 ksi	0.35	Base Layer
13	EMULS/FOAM ASPH BASE	Item 314	150 ~ 250 ksi	0.35	Base Layer
14	FLEXIBLE BASE	Item 247	40 ~ 70 ksi	0.35	Base Layer
15	LIME STABILIZED BASE	Item 260, 263	60 ~ 75 ksi	0.30 ~ 0.35	Base Layer
16	CEMENT STABILIZED BASE	Item 275, 276	80 ~ 150 ksi	0.20 ~ 0.30	Base Layer
17	STAB SUBB(Granular)	Item 260, 275	75 ~ 150 ksi	0.30	SubBase Layer
18	STAB SUBB(Blend)	Item 260, 275	50 ~ 100 ksi	0.30	SubBase Layer
19	STAB SUBB(Soil)	Item 260, 275	30 ~ 45 ksi	0.35	SubBase Layer
20	SUBGRADE		6 ksi	0.40 ~ 0.45	Sub-Grade Layer

Figure C.2. Pavement Layers selected in Design Type 7.



LYR	MATERIAL NAME	COST PER CY	MODULUS E (ksi)	POISN RATIO	MIN DEPTH	MAX DEPTH	SALVAGE (%)
1	STONE-MATRIX ASPHALT	190.0	850.0	0.35	2.0	2	30.0
2	Dense-Graded HMA Ty B/C	150.0	850.0	0.35	10	16	90.0
3	RICH BOTTOM LAYER	180.0	500.0	0.35	2.0	2	90.0
4	FLEXIBLE BASE	54.0	50.0	0.35	6.0	12.0	75.0
5	STAB SUBB(Soil)	15.0	35.0	0.35	8	8	70.0
6	SUBGRADE	2.0	6.0	0.40	200.0		90.0

Figure C.3. Input Design Data (Pavement Structure).

Use the Red arrow button to run the program and evaluate the design options. In this case 24 design options were generated (Figure C.4). The next page button and previous page button are used to page through all the designs. For this example, it was decided to select a pavement structure where all 5 layers are proposed, therefore Design 10 (Figure C.5) was selected for evaluation through the limiting strain criteria by running the mechanistic check.

Figure C.4. FPS Pavement Design Results.

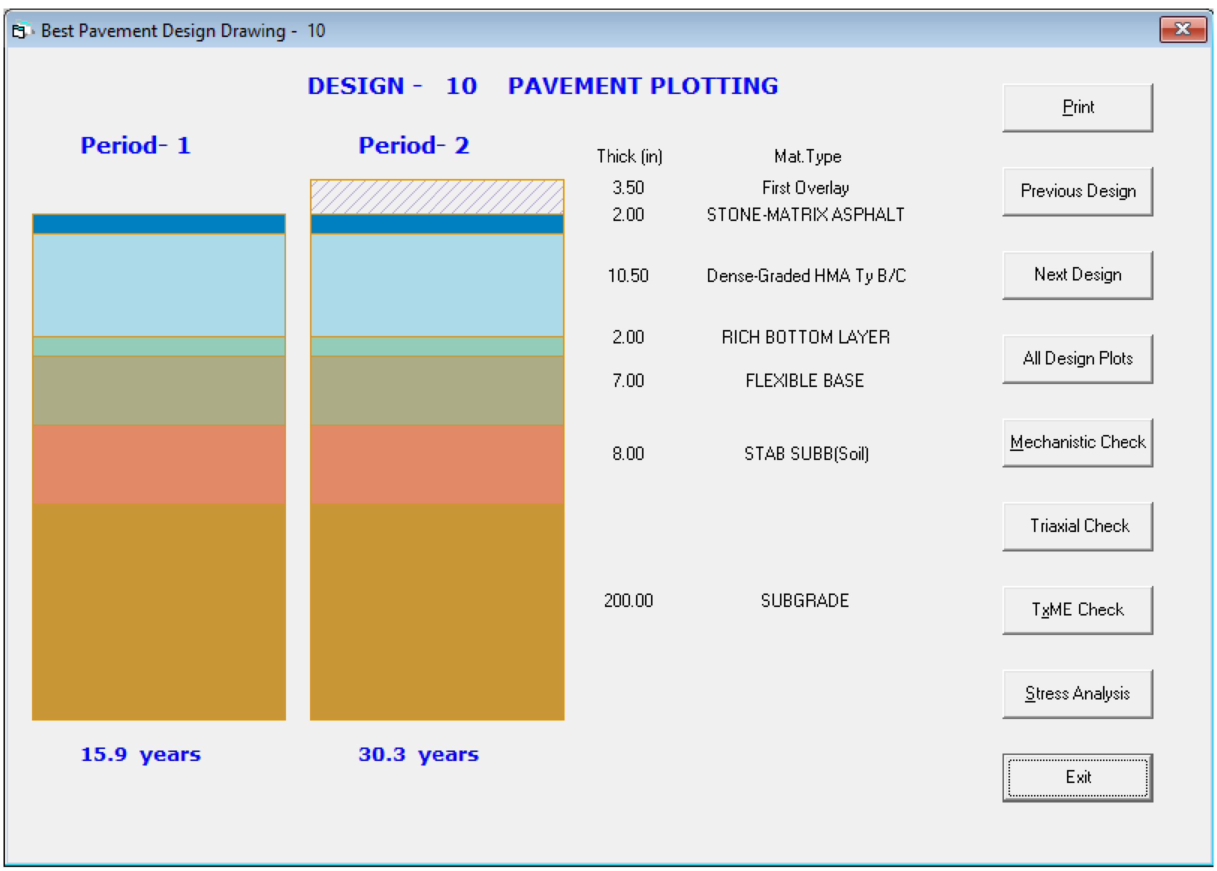
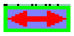


Figure C.5 The selected design to be used in Mechanistic and TxME checks

Mechanistic Design Check

Figure C.6 shows the input screen for the Mechanistic Design Check. In this case, the Dense-Graded Ty B/C layer will have the "Vary Thickness" button in one-inch increments, and the tensile strain indicator  should be moved to the bottom of the Rich Bottom Layer.

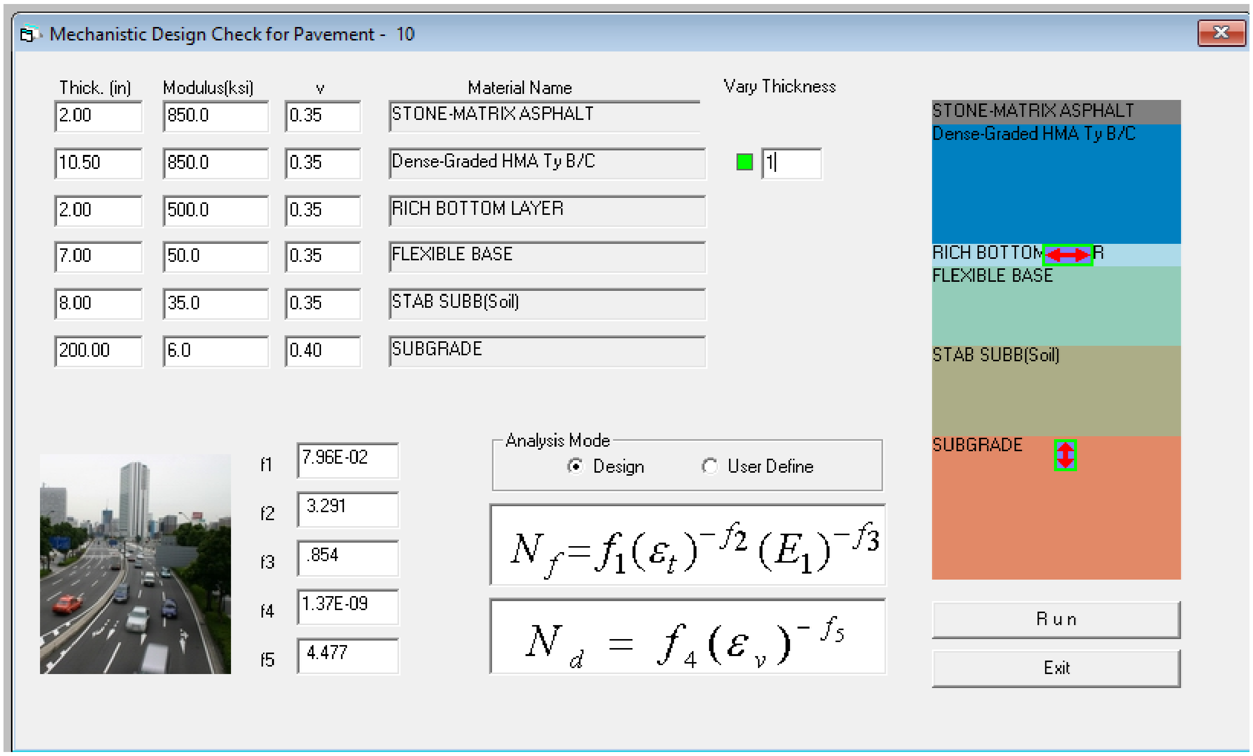


Figure C.6. Mechanistic Design Check Input Screen.

The results of the mechanistic analysis are shown in Figure C.7. In FPS 23, the mechanistic check is performed on the traffic loads accumulated over the FPS-computed time to first overlay (as opposed to the 30-year cumulative loading). For most flexible pavement designs, this period will be less than the standard 15-year analysis period. In the example given below the computed time to first overlay is 15.9 years; for that period the estimated traffic is 38.5 million ESALs. The mechanistic check is performed to check that this traffic level passes the fatigue and subgrade rutting criteria built into FPS 23. In both cases with the proposed pavement structure the cracking and fatigue lives are close to 200 million ESALs, which is the maximum value considered by program.

For this case, the designer must also verify that the perpetual pavement limiting strain criteria are not exceeded. These criteria are:

- Tensile strain at the bottom of the HMA less than 70 micro strain (computed value 42).
- Vertical compressive strain at the top of the subgrade less than 200 micro strain (computed value 114).

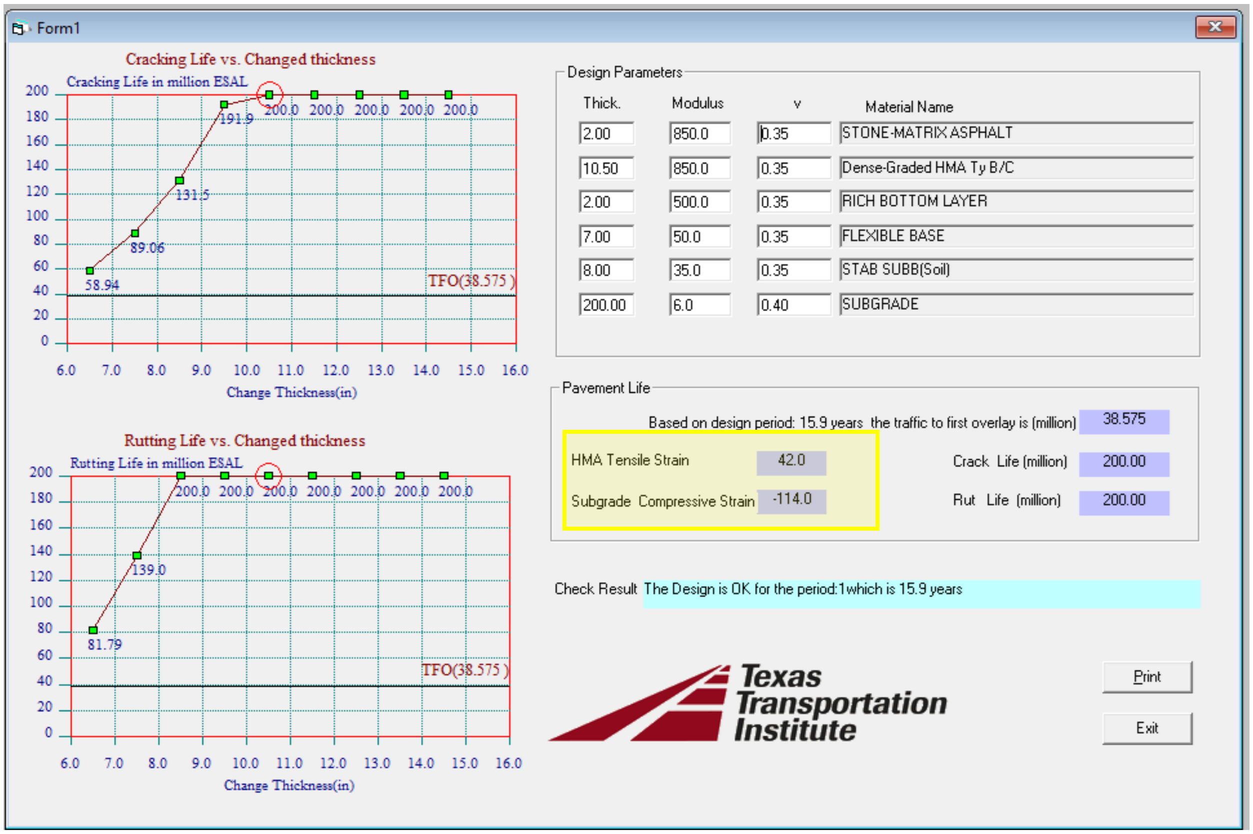


Figure C.7. Mechanistic Design Check Results.

TxME Check

Clicking the "TxME Check" button, the following screen is generated for the FPS 23 proposed perpetual pavement structure.

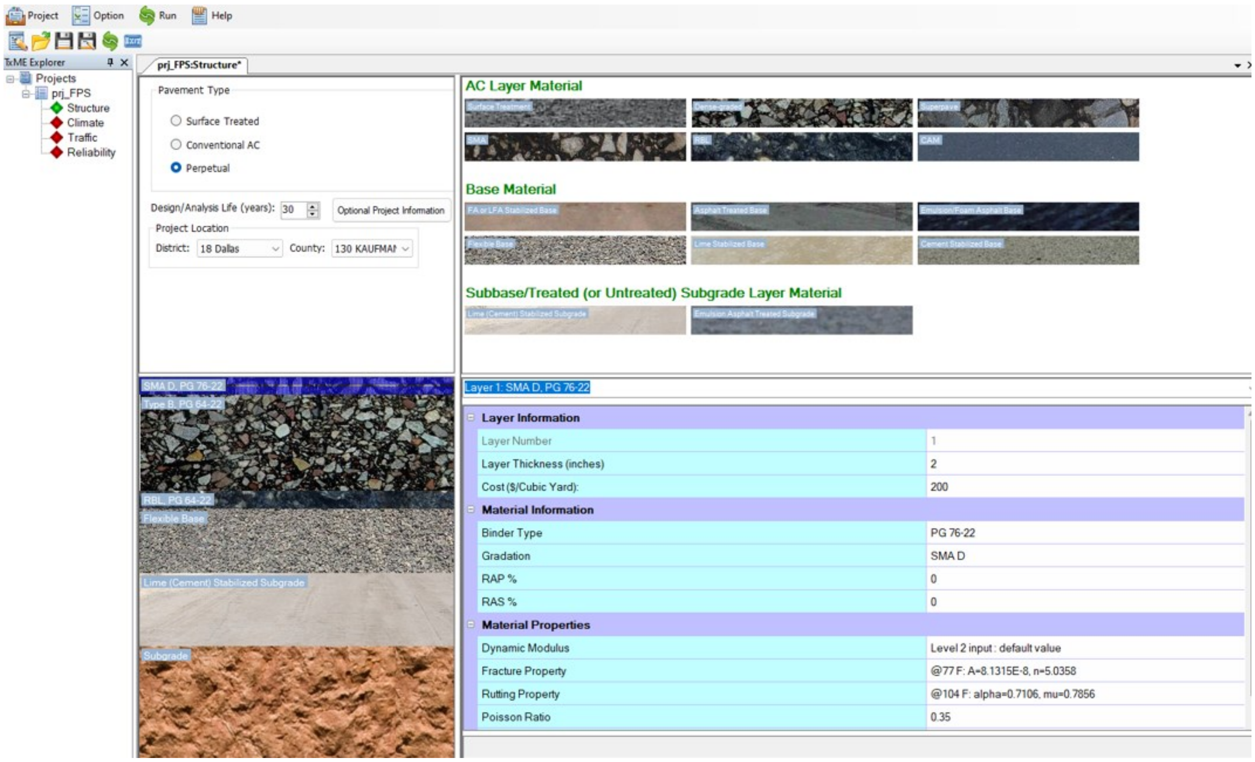


Figure C.8. Perpetual Pavement Design screen in TxME.

In this design, the SMA surfacing utilizes a PG 76-22 binder, while the 10.5 inches of Dense-Graded Type B incorporates as default a PG 70-22 binder, the binder type can be changed within TxME. The predicted rutting and cracking life for this pavement structure is shown in Figures C.9 and C.10. As shown, the proposed pavement structure meets TxME's rutting and cracking criteria.

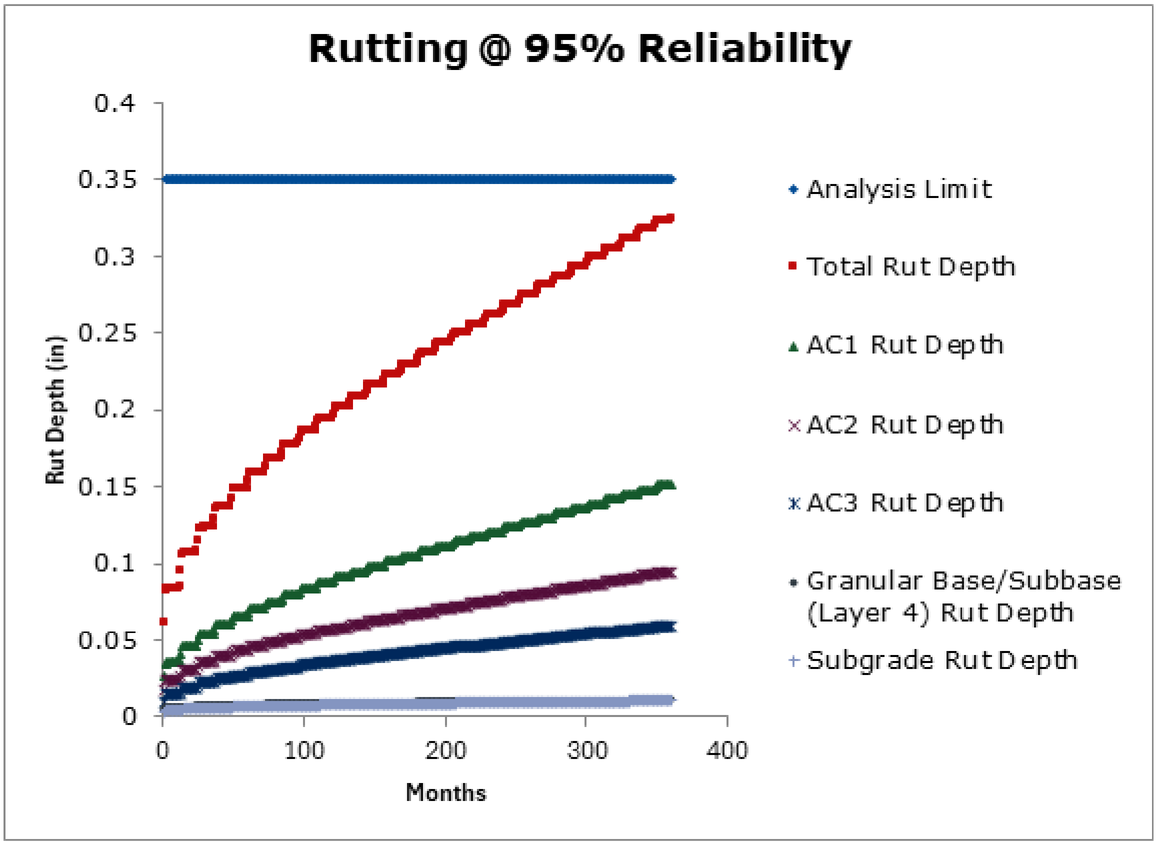


Figure C.9. TxME Predicted Rutting Life for the Proposed Perpetual Pavement Structure.

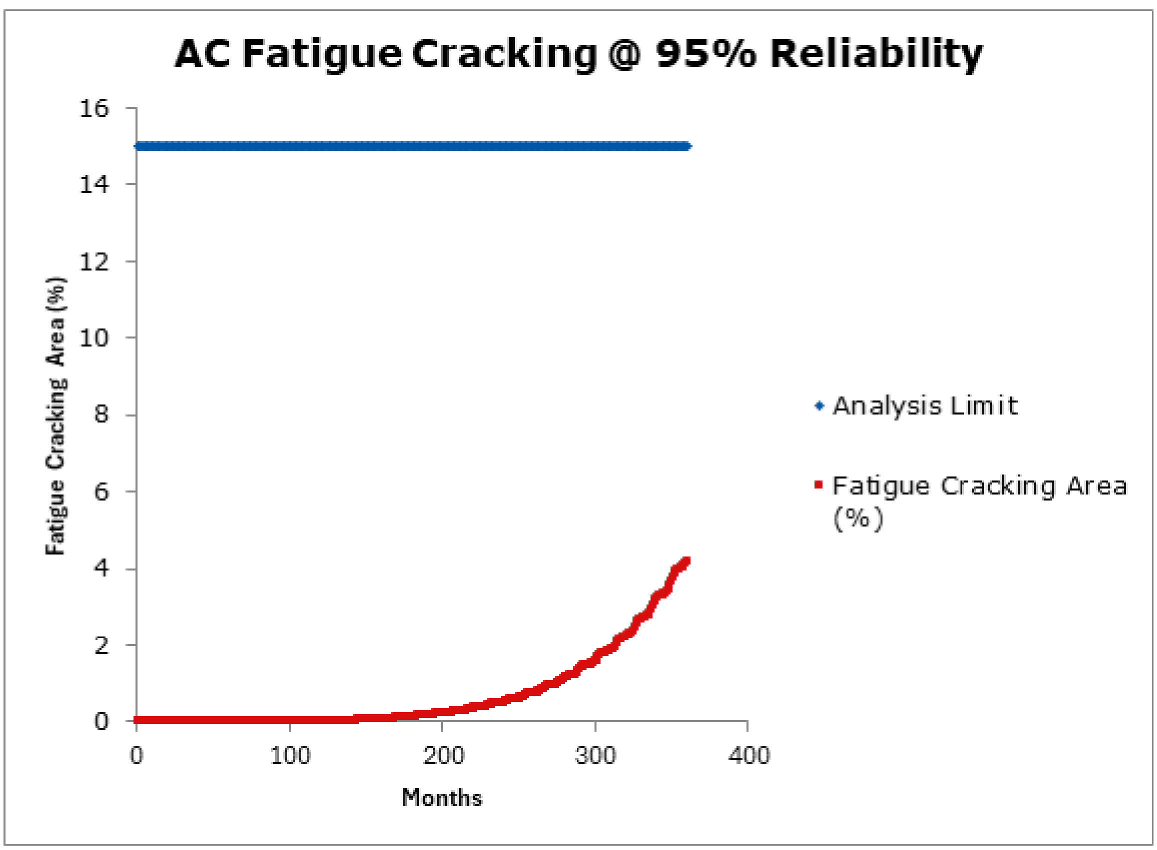


Figure C.10. TxME Predicted Cracking Life for the Proposed Perpetual Pavement Structure.

One of the many capabilities that the TxME allows designers to evaluate is the impact of incorporating RAP and RAS into the pavement structure. In this case, recycled materials were added to the Type B base and RBL layers, which is an acceptable approach since the fatigue model initiates cracking at the lowest AC layer. Figure C.11 shows the predicted impact of only using 15% RAP, while Figure C.12 demonstrates the impact of adding 15% RAP and 3% RAS. In both cases, the incorporation of recycled materials significantly reduces the life, causing fatigue cracking to exceed the allowable 15% limit.

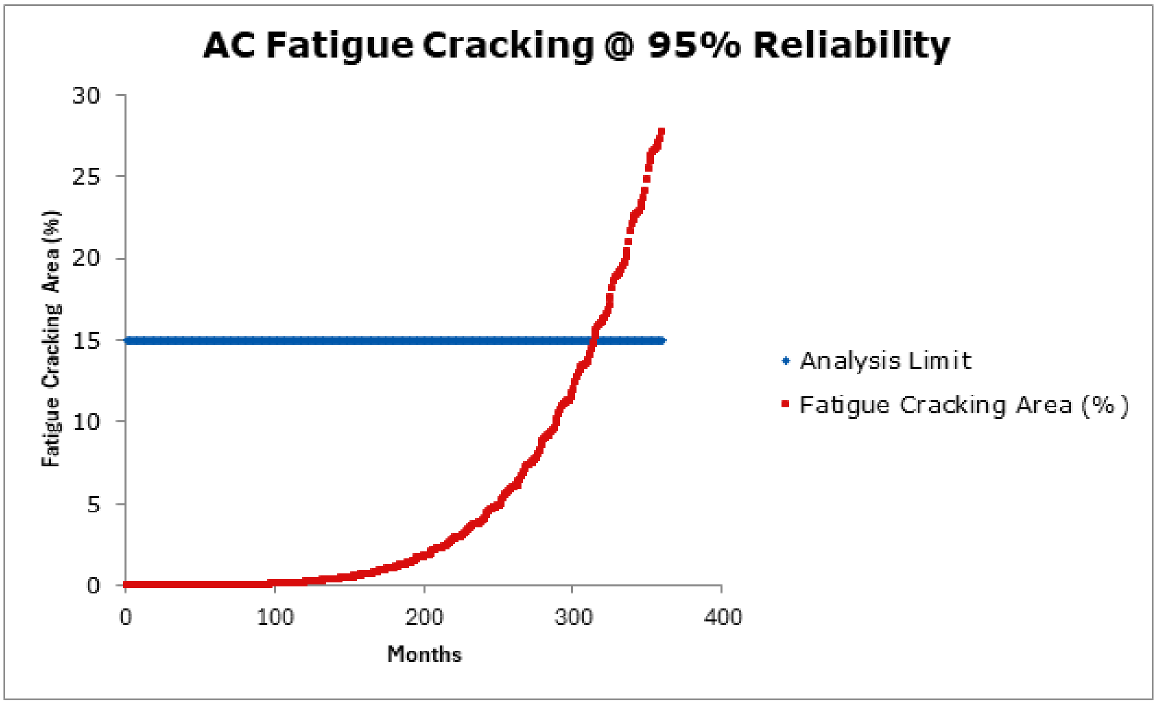


Figure C.11. TxME Predicted Cracking Life for the Proposed Perpetual Pavement Structure with 15% RAP Introduced to the Type B and RBL Layer.

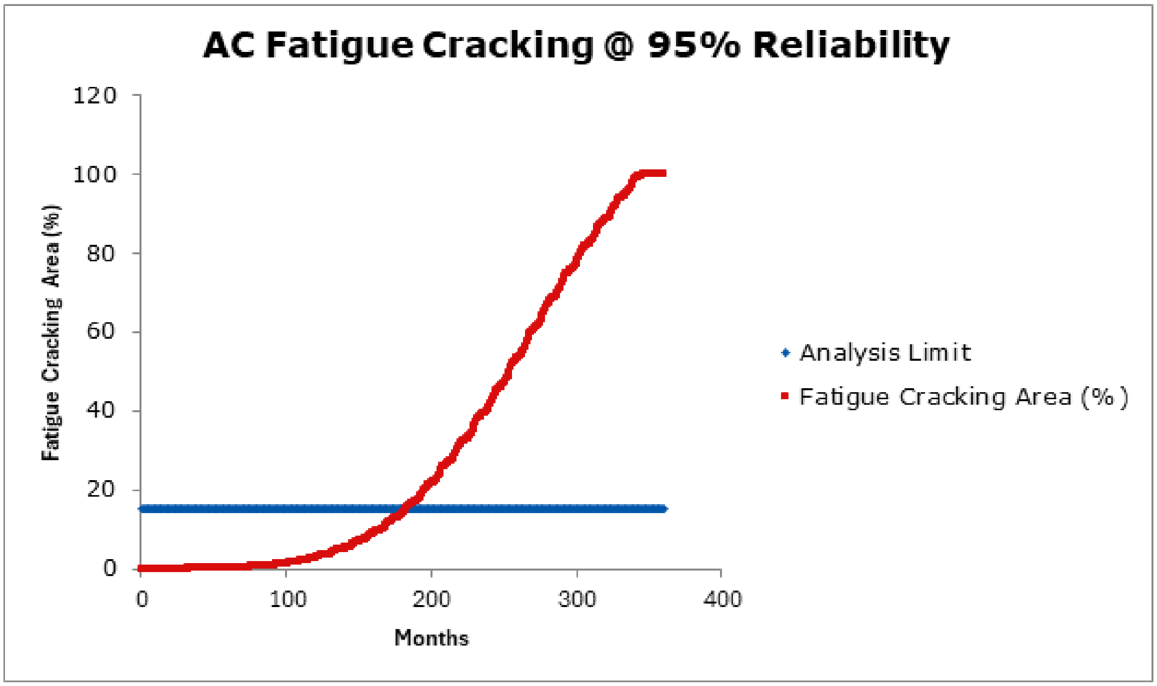


Figure C.12 TxME Predicted Cracking Life for the Proposed Perpetual Pavement Structure with 15% RAP and 3% RAS Introduced to the Type B and RBL Layer.

References

1) Craus, J., R. Yuce, and C.L. Monismith. "Fatigue Behavior of Thin Asphalt Concrete Layers in Flexible Pavement Structures," *Proceedings, Association of Asphalt Paving Technologies*, Vol. 53, pp. 559–582, 1984.
2) Fernando, E., J. Oh, C. Estakhri, and S. Nazarian. "Verification of the Load Thickness Design Curves in the Modified Triaxial Design Method", TTI Report 4519-1, June 2008.
3) Zhou, F., E. Fernando, and T. Scullion. "Development, Calibration, And Validation of Performance Prediction Models For The Texas M-E Flexible Pavement Design System", TTI Report 0-5798-2, August 2010.
4) Hu, S., F. Zhou, and T. Scullion. "Development of Texas Mechanistic-Empirical Flexible Pavement Design System (TxME)", TTI Report 0-6622-2, January 2014.
5) Hu, S., A. Rahman, J. Zhang, F. Zhou, and T. Scullion. "Implementation of Texas Mechanistic Empirical Flexible Pavement Design System (TxME)", TTI Report 5-6622-01-R1, February 2019.