



TxACOL Workshop

Texas Asphalt Concrete Overlay Design and Analysis System

5-5123-03-P1

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General Information

lide2

- Two workshops were held respectively on Aug. 25 at Paris, Tx and on Oct. 6 at Austin, Tx
- More than 30 representatives from TxDOT attended
- Introduction of TxACOL software, key input parameters, and related lab and field tests were presented
- Attendees practiced the software step by step

TxACOL

Workshop

Presentation Outline

Slide 3

- Introduction
- Program training and exercises
- Key inputs for existing pavement and field testing
- Key inputs for asphalt overlay

Expected Learning Outcomes

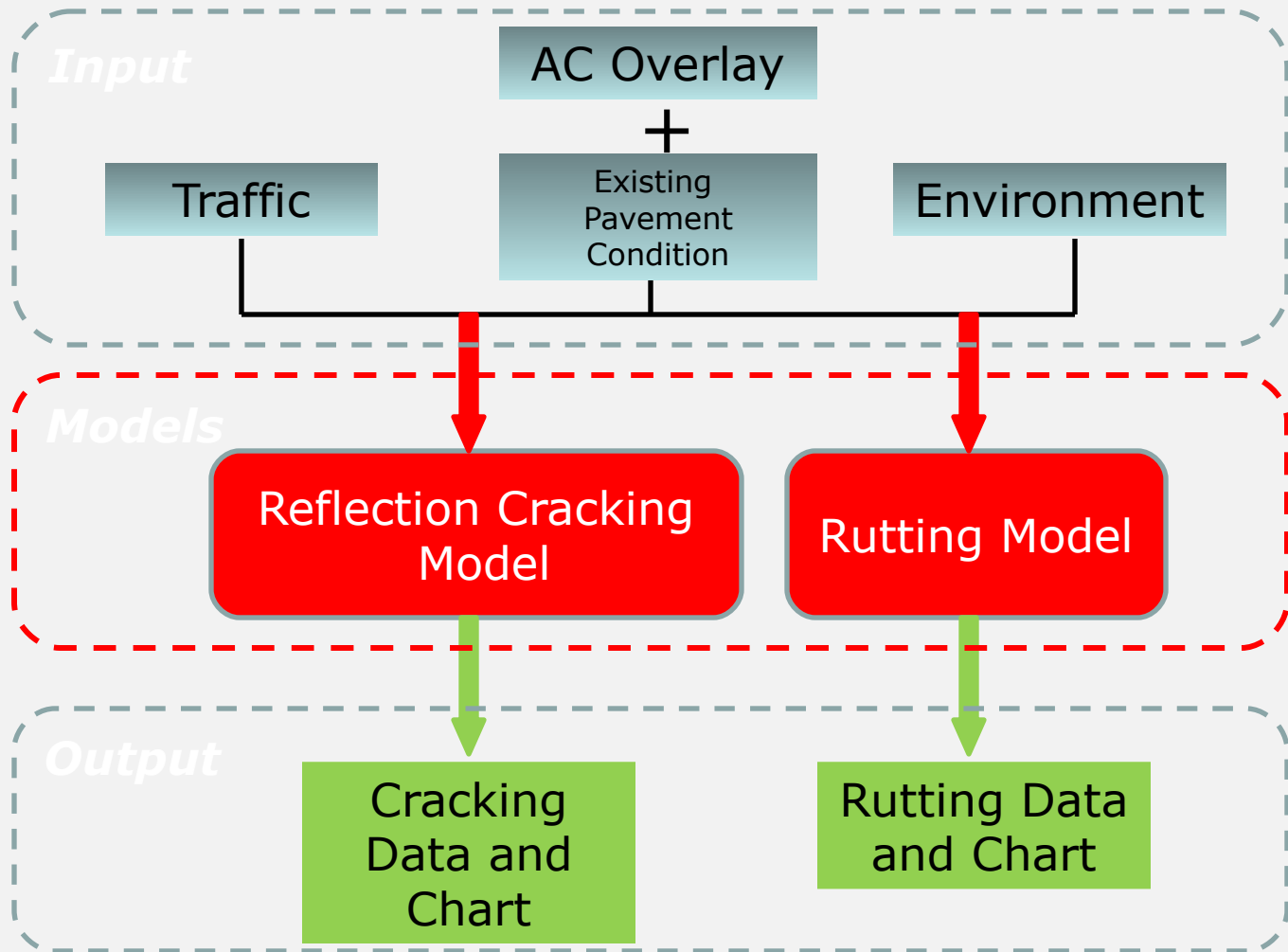
- Be able to perform program installation and un-installation
- Be familiar with creating, editing, saving, and running a project file
- Know how to design an asphalt overlay using the TxACOL program
- Understand Key input parameters and the requested lab or field test

Presentation Outline

lide5

- Introduction
- Program training and exercises
- Key inputs for existing pavement and field testing
- Key inputs for asphalt overlay

TxACOL Flowchart



TxACOL Features

lide7

- M-E program
- User-friendly interface
- Short running time
- Default values provided in the software
- Traffic input is compatible to the current pavement design software FPS19W

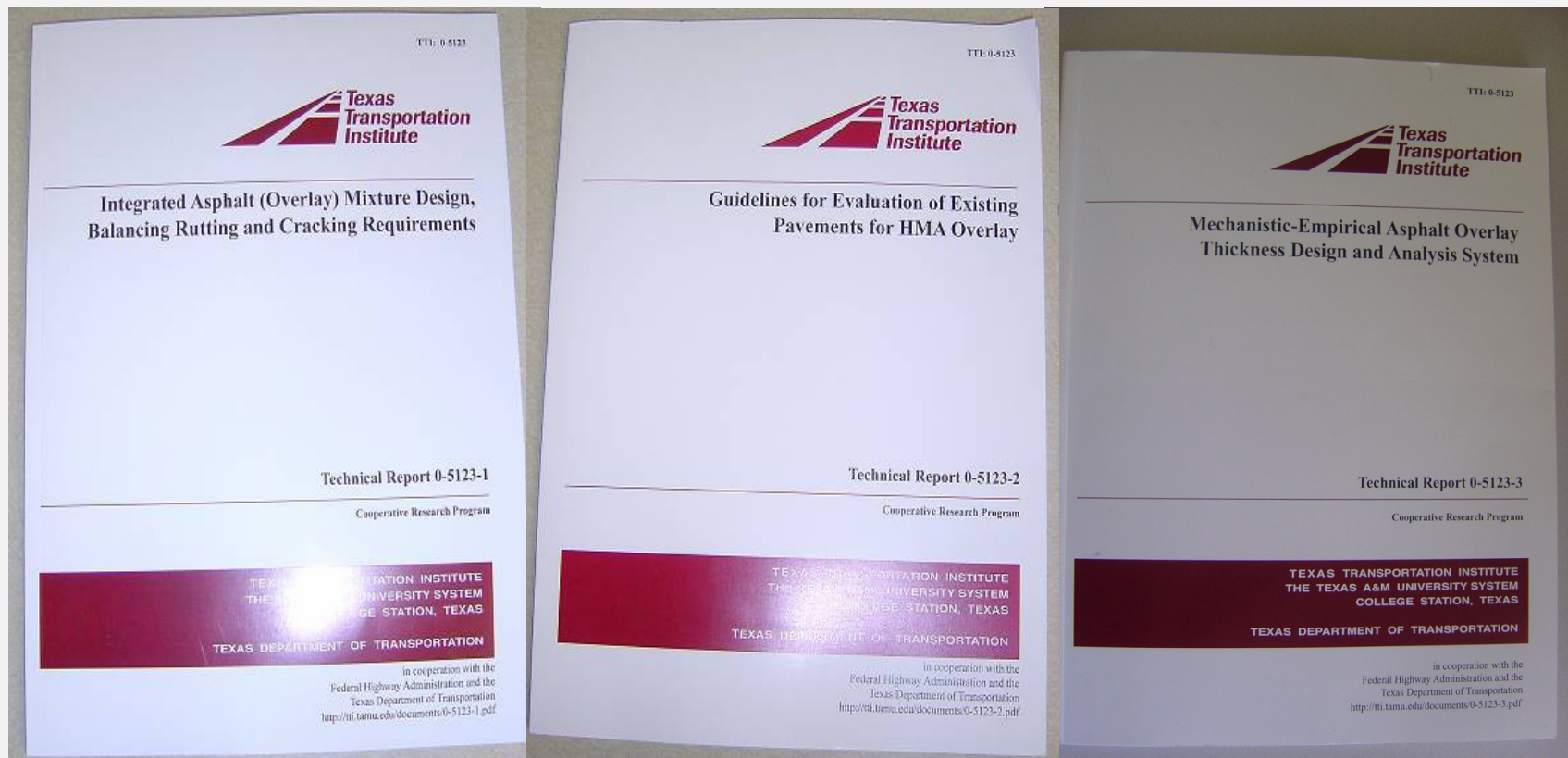
TxACOL Features

(Continued)

- Pavement temperature is automatically predicted from EICM model
- Rutting and cracking are analyzed simultaneously
- Output is in Excel format and can be easily incorporated into electronic documents and reports

TxACOL Technical Background

Slide 9



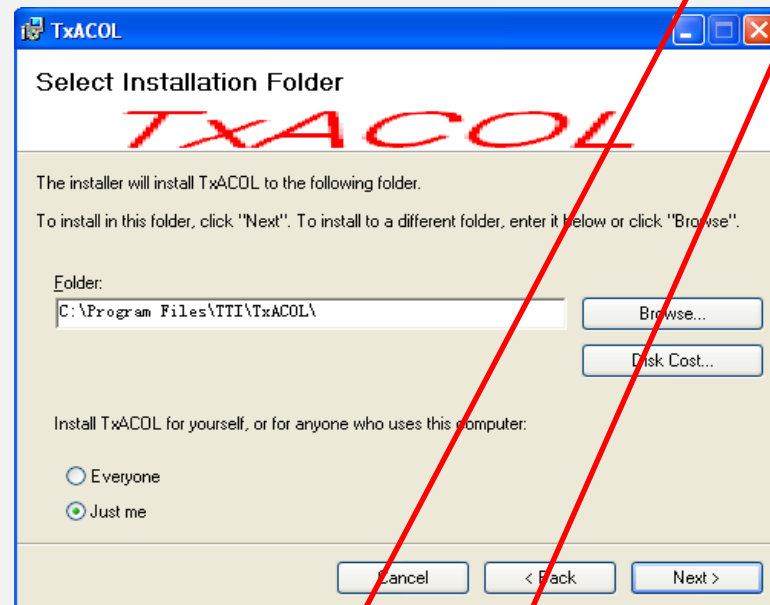
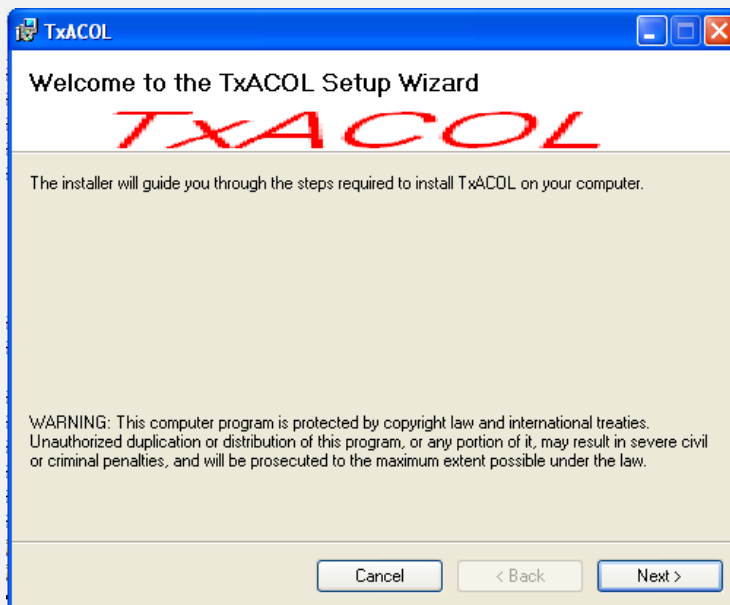
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How to Install

lide10

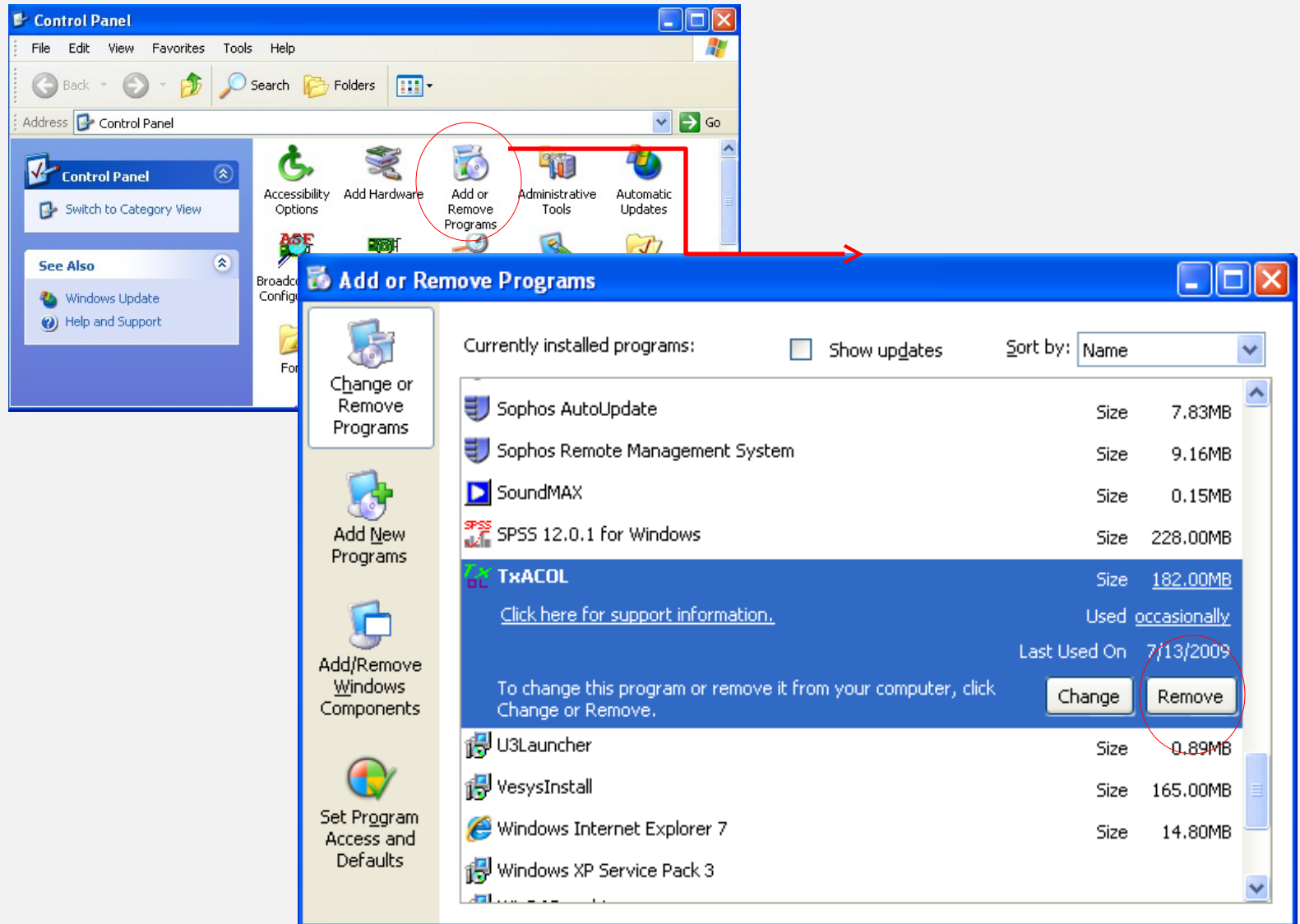
- Double click "Setup.exe" file
- If this is the first installation, the following screens will appear:



Choose your favorite installation folder here

How to Uninstall

lide11



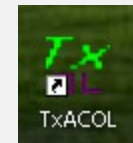
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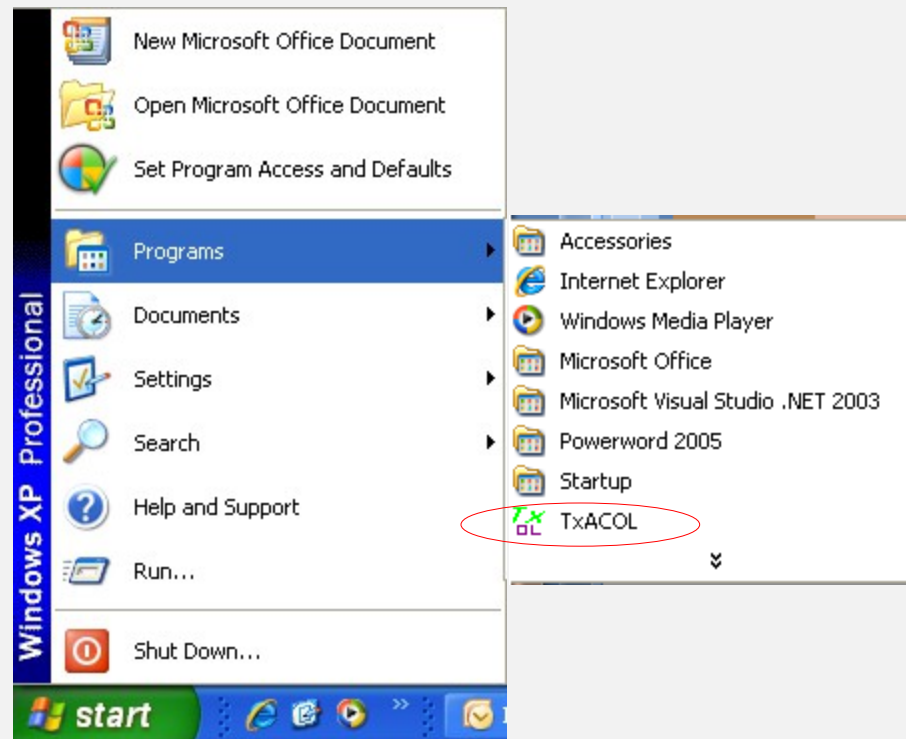
Launch the Program

lide12

Double click the icon



or

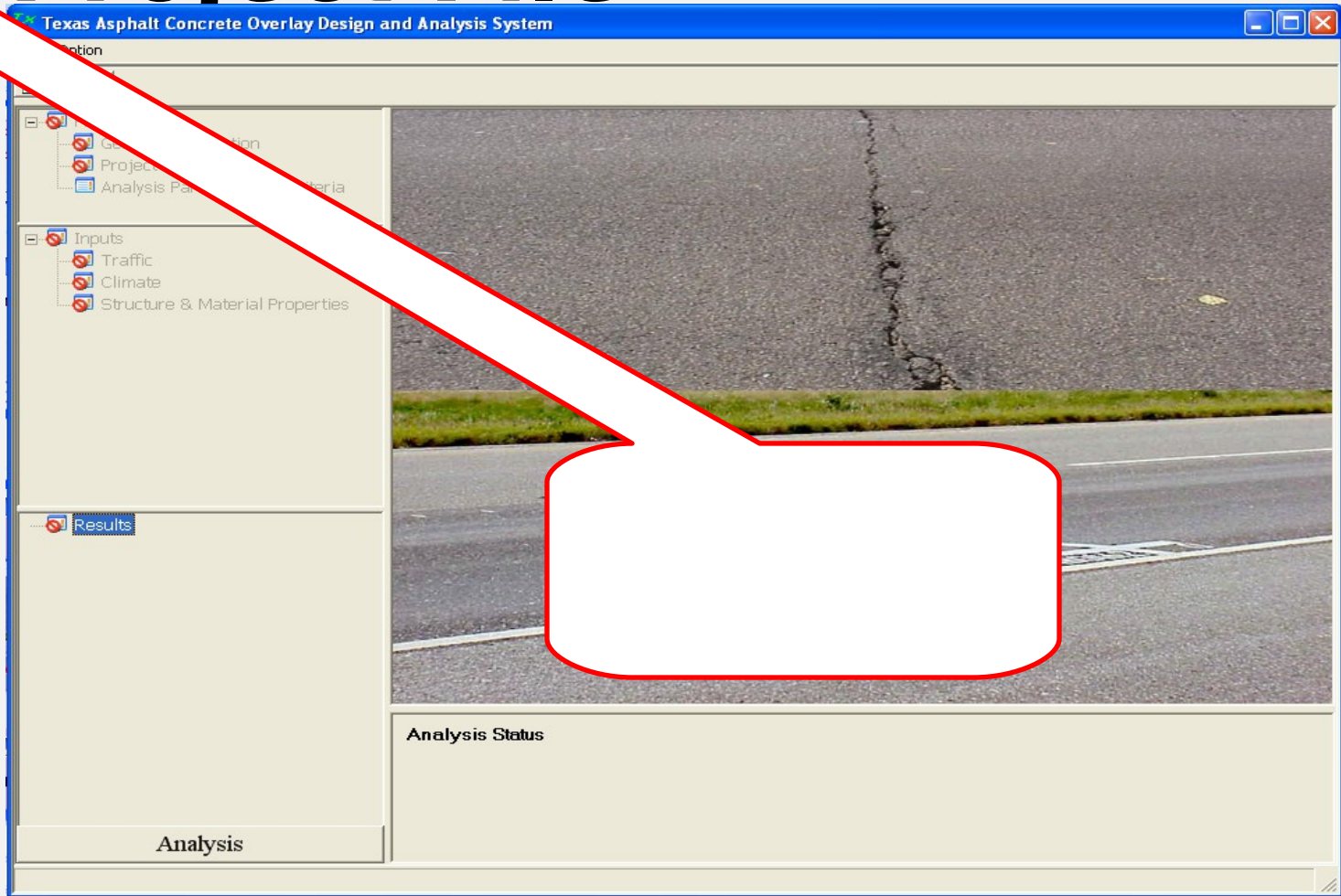


Presentation Outline

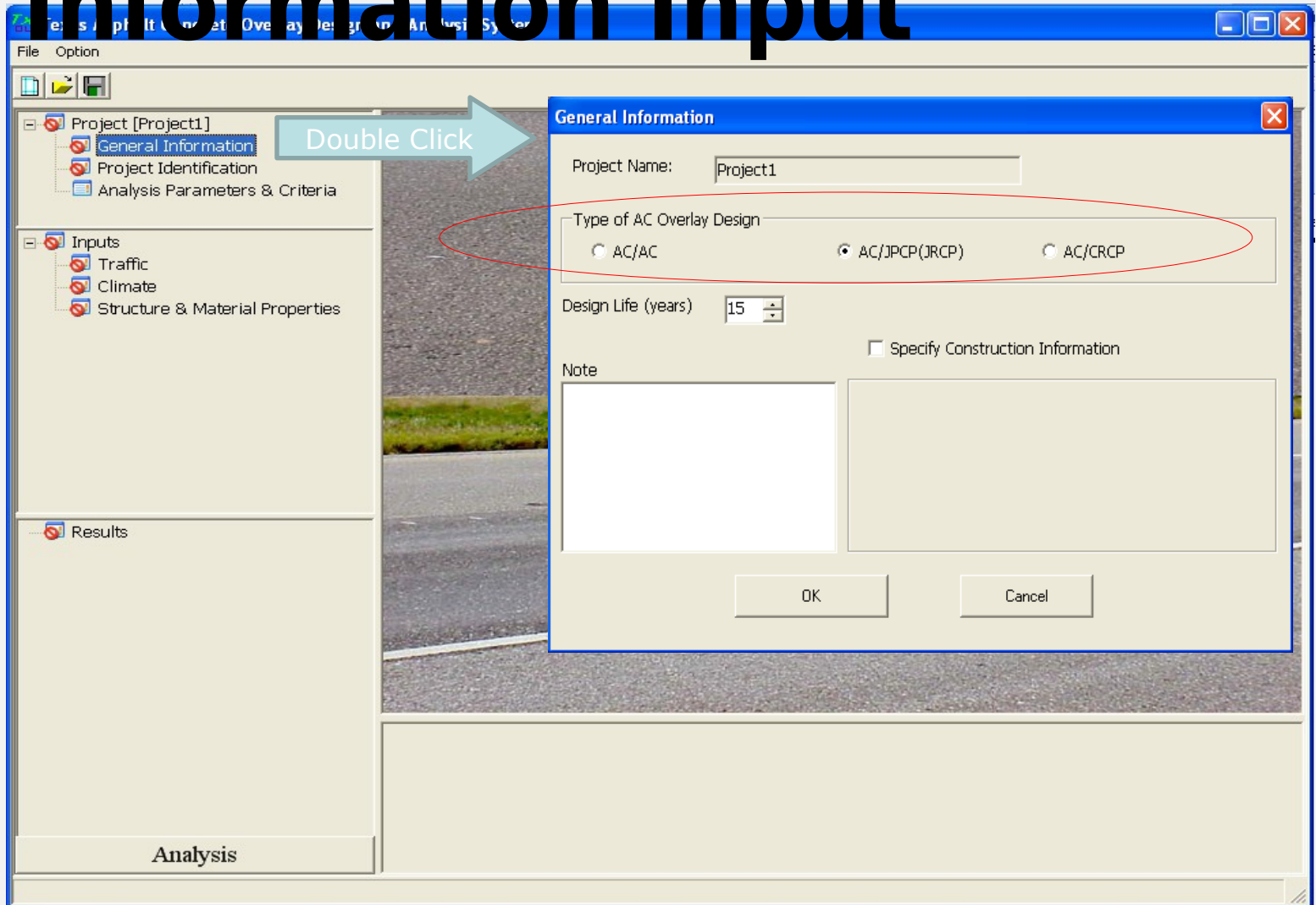
Slide 13

- Introduction
- Program training and exercises
- Key inputs for existing pavement and field testing
- Key inputs for asphalt overlay

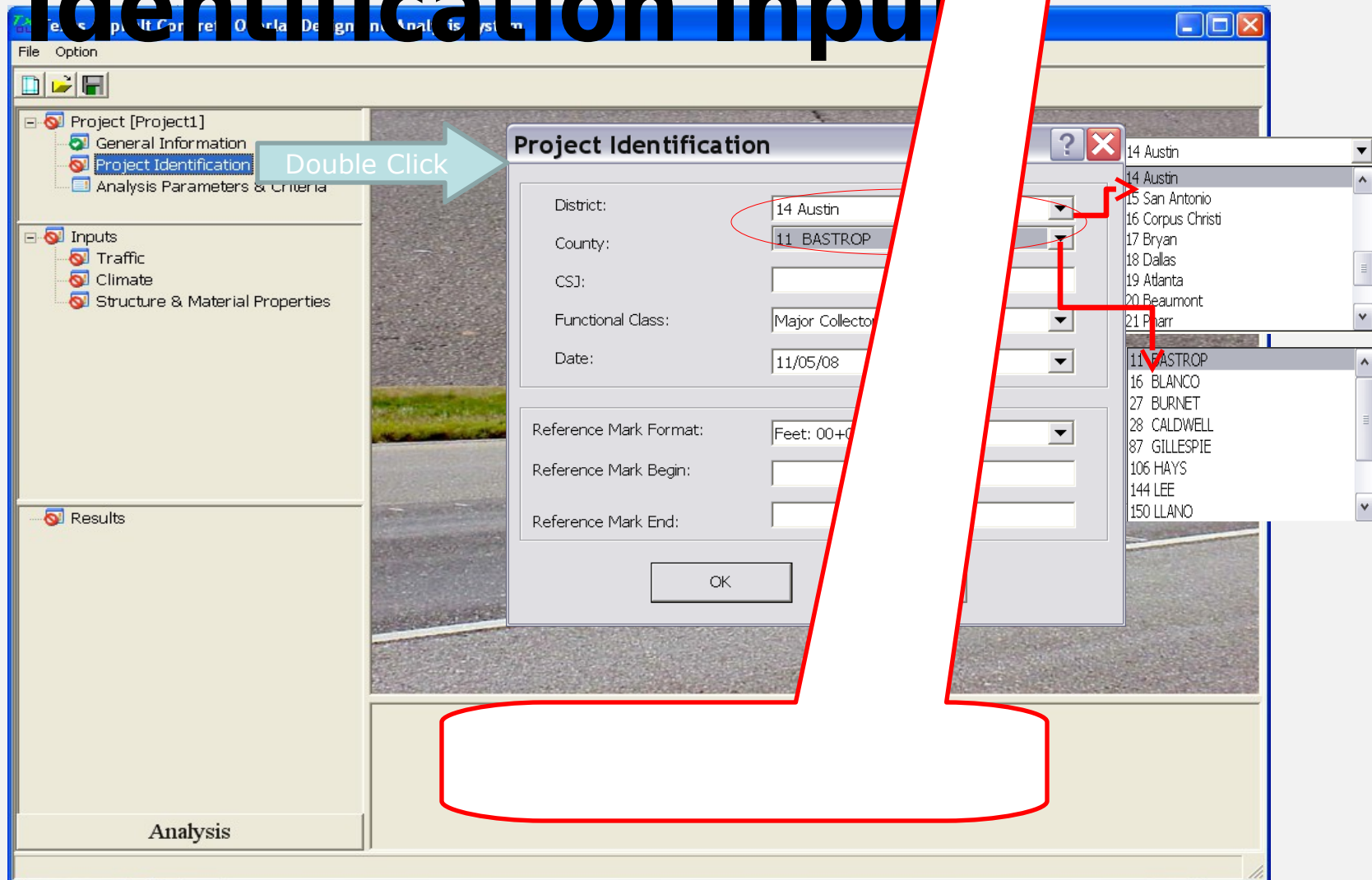
Step 1: Create a New Project File



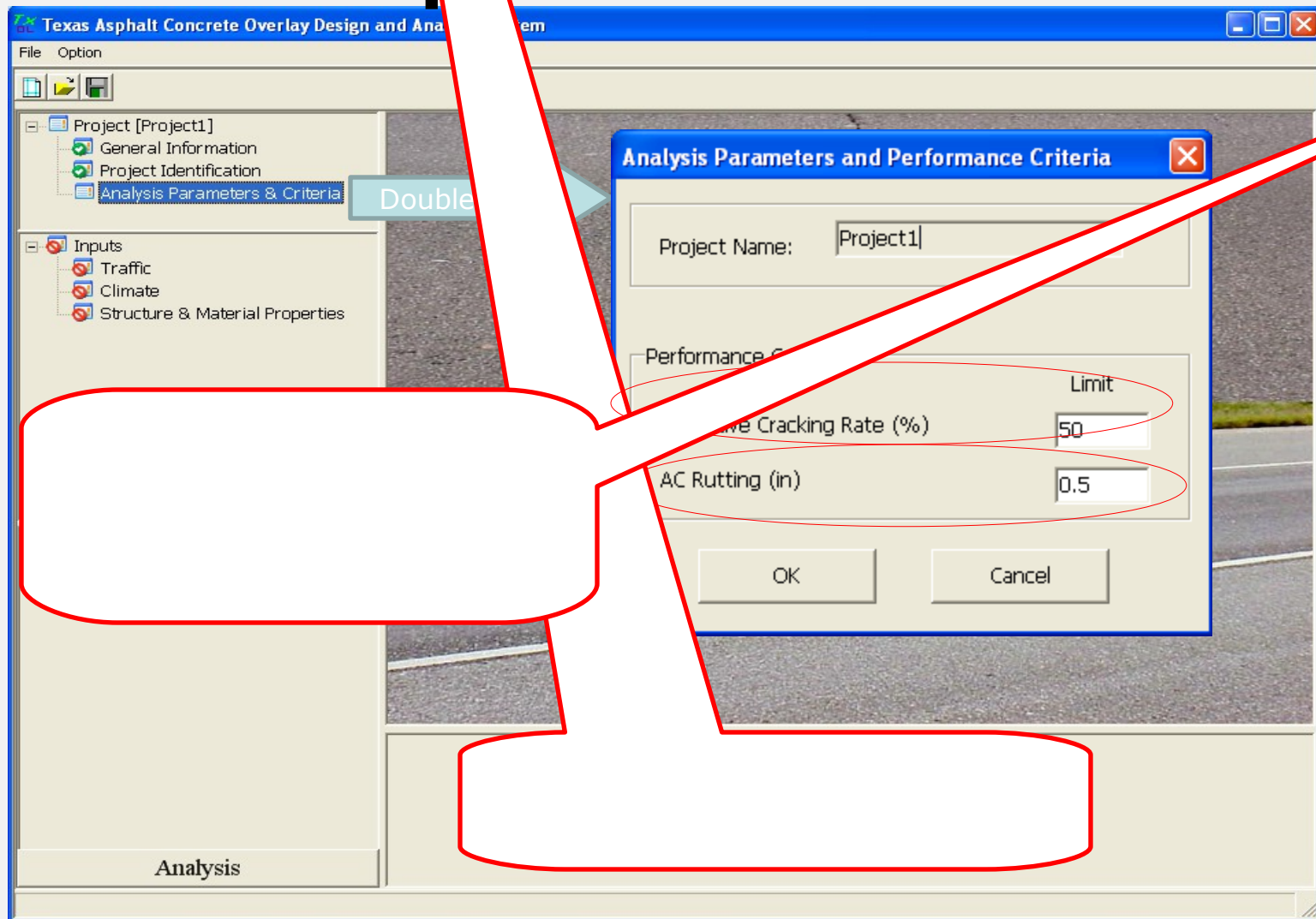
Step 2: General Information Input



Step 3: Project Identification Input



Step 4: Analysis Parameters & Criteria Input



Step 5: Traffic Input

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Texas Asphalt Concrete Overlay Design and Analysis System

File Option

Project [Project1]
 General Information
 Project Identification
 Analysis Parameters & Criteria

Inputs
 Traffic
 Climate
 Structure & Material Properties

Results

Traffic Load (ESALs) Input

Single Axle with Dual Tires (18 kip, 100psi)

AC Overlay

Existing Pavement

ADT-Beginning (Veh/Day): 2000

ADT-End 20 YR (Veh/Day): 3500

18 kip ESALs 20 YR (1 DIR) (millions): 10.0

Operation Speed (mph): 60

OK Cancel

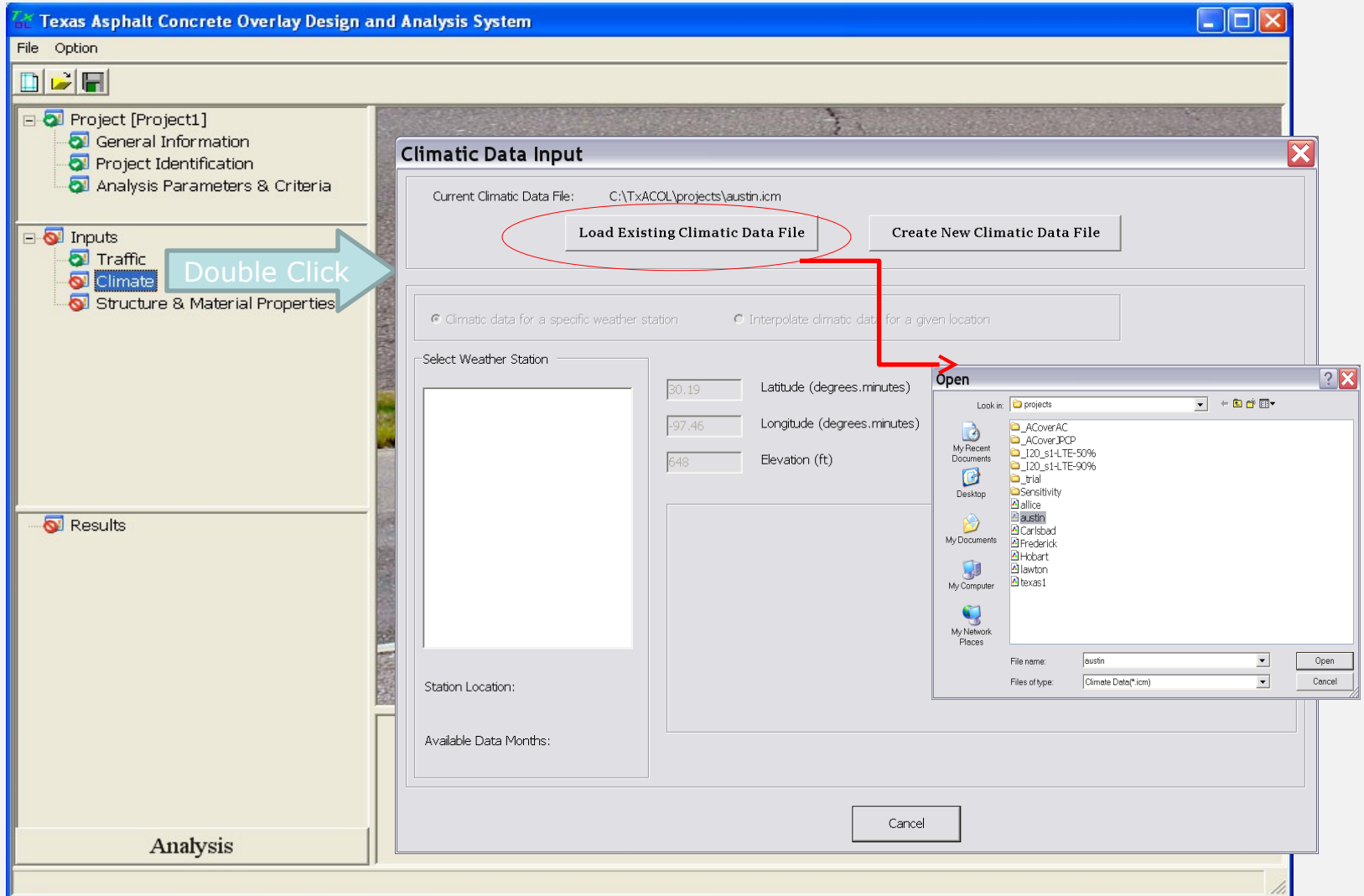
Analysis

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Step 6: Climate Input

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The screenshot displays the **Texas Asphalt Concrete Overlay Design and Analysis System** software interface. The main window has a menu bar with **File** and **Option**. On the left, a project tree shows **Project [Project1]** with sub-items: **General Information**, **Project Identification**, **Analysis Parameters & Criteria**, **Inputs**, and **Results**. The **Inputs** folder is expanded, showing **Traffic**, **Climate** (highlighted with a blue arrow and the text "Double Click"), and **Structure & Material Properties**.

The **Climate Data Input** dialog box is open, showing the **Current Climatic Data File:** **C:\TxACOL\projects\Austin.icm**. It has two buttons: **Load Existing Climatic Data File** (circled in red) and **Create New Climatic Data File**. Below these are two radio buttons: **Climatic data for a specific weather station** (selected) and **Interpolate climatic data for a given location**. The **Select Weather Station** section includes input fields for **Latitude (degrees.minutes)** (30.19), **Longitude (degrees.minutes)** (-97.46), and **Elevation (ft)** (548). There are also fields for **Station Location:** and **Available Data Months:**. A **Cancel** button is at the bottom.

A red arrow points from the **Load Existing Climatic Data File** button to a file selection window. This window shows the **Look in:** **projects** folder, listing various files and folders. The **File name:** is **austin** and the **Files of type:** is **Climate Data (*.icm)**. The **Open** button is highlighted.

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Analysis

Step 7: Climate Input (Continued)

Project [Project1]

- General Information
- Project Identification
- Analysis Parameters & Criteria

Inputs

- Traffic
- Climate** (Double Click)
- Structure & Material Properties

Results

Analysis

Climatic Data Input

Current Climatic Data File: C:\TxACOL\projects\Austin.icm

Load Existing Climatic Data File | Create New Climatic Data File

☐ Climatic data for a specific weather station
☒ Interpolate climatic data for a given location

Select Weather Station

- ABILENE, TX
- ALICE, TX
- AMARILLO, TX
- ANGLETON/LAKE JACKSON, TX
- ARLINGTON, TX
- AUSTIN/CITY, TX
- AUSTIN/BERGSTROM, TX
- BEAUMONT/PORT ARTHUR, TX
- BORGER, TX
- BROWNSVILLE, TX
- BURNET, TX
- CHILDRESS, TX
- COLLEGE STATION, TX
- CONROE, TX
- CORSICANA, TX
- CORPUS CHRISTI, TX
- COTULLA, TX

Station Location:
CAMP MABRY ARMY NATL GRDB

Available Data Months: 116

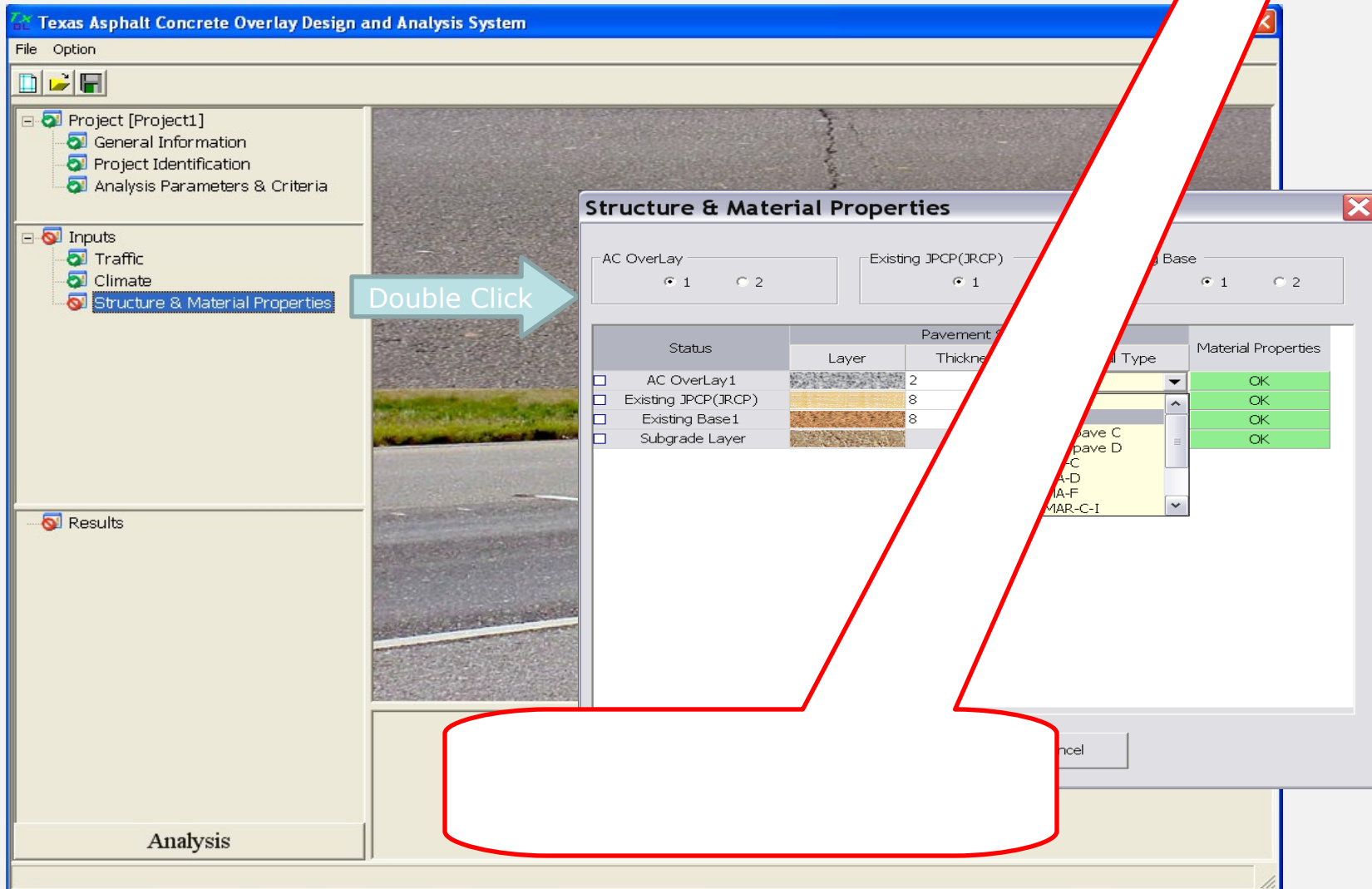
Latitude (degrees.minutes): 30.19
 Longitude (degrees.minutes): -97.46
 Elevation (ft): 648

☒ #1 0.0 miles, AUSTIN/CITY, TX, CAMP MABRY ARMY NATL GRDB, Lat. 30.19, Lon. -97.46, Ele. 648, Months. 116
☒ #2 10.5 miles, AUSTIN/BERGSTROM, TX, AUSTIN-BERGSTROM INTL APT, Lat. 30.11, Lon. -97.41, Ele. 658, Months. 100
☒ #3 40.0 miles, BURNET, TX, BURNET MUNI CRADDOCK FIELD, Lat. 30.44, Lon. -98.14, Ele. 1275, Months. 114
☐ #4 44.8 miles, NEW BRAUNFELS, TX, NEW BRAUNFELS MUNICIPAL AP, Lat. 29.43, Lon. -98.03, Ele. 632, Months. 116
☐ #5 68.4 miles, SAN ANTONIO, TX, INTERNATIONAL AIRPORT, Lat. 29.32, Lon. -98.28, Ele. 818, Months. 116
☐ #6 79.8 miles, SAN ANTONIO, TX, STINSON MUNICIPAL AIRPORT, Lat. 29.2, Lon. -98.28, Ele. 579, Months. 94

Generate | Cancel

Step 8: Structure Input

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Structure & Material Properties

AC OverLay: ☒ 1 ☐ 2

Existing JPCP(JRCP): ☒ 1 ☐ 2

Existing Base: ☒ 1 ☐ 2

Status	Layer	Pavement Type	Thickness	Material Properties
<input type="checkbox"/>	AC OverLay1	2		OK
<input type="checkbox"/>	Existing JPCP(JRCP)	8		OK
<input type="checkbox"/>	Existing Base1	8		OK
<input type="checkbox"/>	Subgrade Layer			OK

Material Properties: OK, OK, OK, OK

Analysis

Step 9: Structure (Continued)

Structure & Material Properties

AC OverLay: ☒ 1 ☐ 2 Existing JPCP(JRCP): ☒ 1 ☐ 2 Existing Base: ☐ 0 ☒ 1 ☐ 2

Status	Layer	Thickness	Material Type	Material Properties
<input type="checkbox"/>	AC OverLay1	2	Type D	OK
<input type="checkbox"/>	Existing JPCP(JRCP)	8	Existing JPCP	OK
<input type="checkbox"/>	Existing Base1	8	Granular Base	OK
<input type="checkbox"/>	Subgrade Layer		Subgrade	OK

OK Cancel

AC OverLay1

Material Type: Thickness(inch): Thermal Coefficient of Expansion (1e-6 in/in/F): Poisson Ratio:

Superpave PG Binder Grading

High Temp (C)	Low Temp (C)
64	-22
70	-28
76	

Material Performance Properties

Fracture Properties Rutting Properties

Modulus Input: ☒ Level 3 (Default Value) ☐ Level 2 (Witczak Model) ☐ Level 1 (Test Data)

Default Value |

No Input Needed.

OK Cancel

Existing JPCP(JRCP)

Material Type: Thickness(inch): Poisson Ratio: Thermal Coefficient of Expansion (1e-6 in/in/F):

General Properties

Joint/Crack Spacing (ft): Modulus (ksi): Load Transfer Efficiency (%):

OK Cancel

Existing Base1

Material Type: Thickness(inch): Poisson Ratio:

☐ Level 2: Typical design value ☒ Level 1: Monthly design value

Modulus Input

Month	Modulus (ksi)
Jan.	
Feb.	
Mar.	
Apr.	
May	
June	
July	
Aug.	
Sep.	
Oct.	
Nov.	
Dec.	

OK Cancel

Subgrade Layer

Material Type: Thickness(inch): Poisson Ratio:

☒ Level 2: Typical design value ☐ Level 1: Monthly design value

Modulus Input

Typical Modulus (ksi):

OK Cancel

Step 10: AC Material Properties Input

Level 3 Input

Level 1 Input

AC OverLay1

Material Type: Thickness(inch):

Thermal Coefficient of Expansion (1e-6 in/in/F): Poisson Ratio:

Superpave PG Binder Grading

High Temp (C)	Low Temp (C)	
	-22	-28
64		
70		
76		

Modulus Input

☒ Level 3 (Default Value) ☐ Level 2 (Witczak Model) ☐ Level 1 (Test Data)

Default Value

No Input Needed.

Material Performance Properties

AC OverLay1

Material Type: Thickness(inch):

Thermal Coefficient of Expansion (1e-6 in/in/F): Poisson Ratio:

Superpave PG Binder Grading

High Temp (C)	Low Temp (C)	
	-22	-28
64		
70		
76		

Modulus Input

☐ Level 3 (Default Value) ☐ Level 2 (Witczak Model) ☒ Level 1 (Test Data)

Test Data

Dynamic Modulus (E*) (ksi)

Number of Temperatures: Number of frequencies:

Temperature (F)	Frequency (Hz)					
	25	10	5	1	0.5	0.1
14						
40						
70						
100						
130						

You can import or export dynamic modulus here

Step 11: Fracture and Rutting Properties Input

Fracture Properties Rutting Properties

Fracture Property Data

Number of Temperatures:

Temperature (F)	A	n
77	2.0865e-8	4.3475

OK Cancel

Rutting Property Data

Number of Temperatures:

Temperature (F)	alpha	mu
104	0.7609	0.7265

OK Cancel

Step 12: Existing Layer Properties Input

Existing AC

Existing PCC

Existing AC

Material Type: **Existing AC** Thickness(inch): **8**

Thermal Coefficient of Expansion (1e-6 in/in/F): **13.5** Poisson Ratio: **0.35**

Main Cracking Pattern

Cracking Type

- ☐ Alligator Cracking
- ☐ Longitudinal Cracking
- ☒ Transverse Cracking
- ☐ Block Cracking

Transverse Cracking Options

- ☒ Severity Level
- ☐ LTE Value (%)

Severity Level

- ☐ Low
- ☒ Medium
- ☐ High

Crack Spacing (ft) **15**

FWD Backcalculated Modulus

No. of Temperatures **1**

Temperature(°F)	Modulus(ksi)
77	500

OK Cancel

Existing JPCP(JRCP)

Material Type: **Existing JPCP**

Thickness(inch): **8** Poisson Ratio: **0.15**

Thermal Coefficient of Expansion (1e-6 in/in/F): **5.5**

General Properties

Joint/Crack Spacing (ft) **15**

Modulus (ksi) **4000**

Load Transfer Efficiency (%) **70**

OK Cancel

The default values are different between JPCP and CRCP

Step 13: Base Layer

Properties Input

Granular Base

Stabilized Base

Existing Base 1 [X]

Material Type:

Thickness(inch): Poisson Ratio:

☒ Level 2: Typical design value ☐ Level 1: Monthly design value

Modulus Input

Typical Modulus (ksi)

OK Cancel

Existing Base 1 [X]

Material Type:

Thickness(inch): Poisson Ratio:

Mechanical Strength Properties

Modulus (ksi)

OK Cancel

Step 14: Subgrade Properties Input

Level 2

Level 1

Subgrade Layer [X]

Material Type:

Thickness(inch): Poisson Ratio:

☒ Level 2: Typical design value
 ☐ Level 1: Monthly design value

Modulus Input

Typical Modulus (ksi)

OK Cancel

Subgrade Layer [X]

Material Type:

Thickness(inch): Poisson Ratio:

☐ Level 2: Typical design value
 ☒ Level 1: Monthly design value

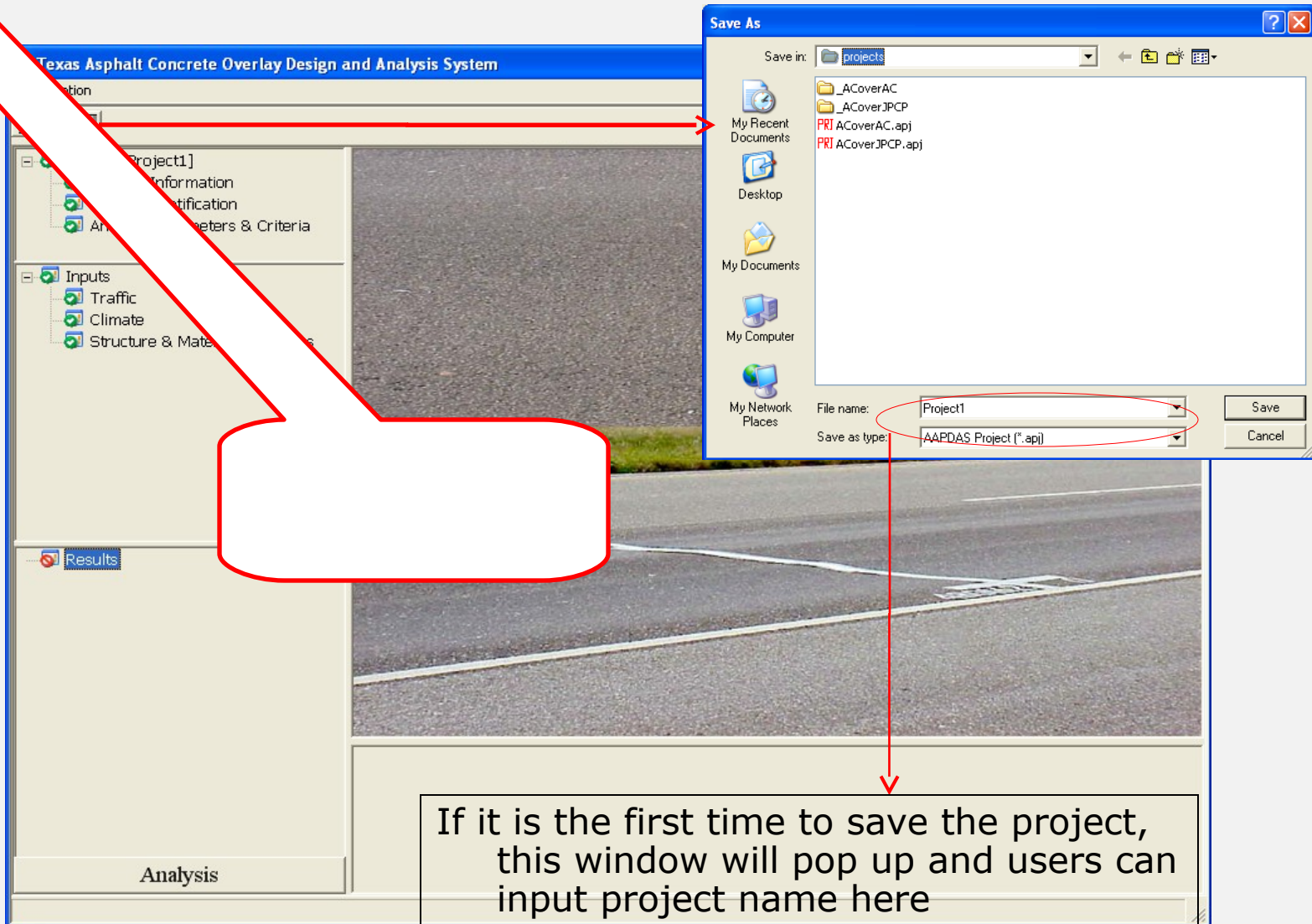
Modulus Input

Month	Modulus (ksi)
Jan.	<input type="text" value="4"/>
Feb.	<input type="text" value="4"/>
Mar.	<input type="text" value="4"/>
Apr.	<input type="text" value="4"/>
May	<input type="text" value="4"/>
June	<input type="text" value="4"/>
July	<input type="text" value="4"/>
Aug.	<input type="text" value="4"/>
Sep.	<input type="text" value="4"/>
Oct.	<input type="text" value="4"/>
Nov.	<input type="text" value="4"/>
Dec.	<input type="text" value="4"/>

OK Cancel

Step 15: Save the Project File

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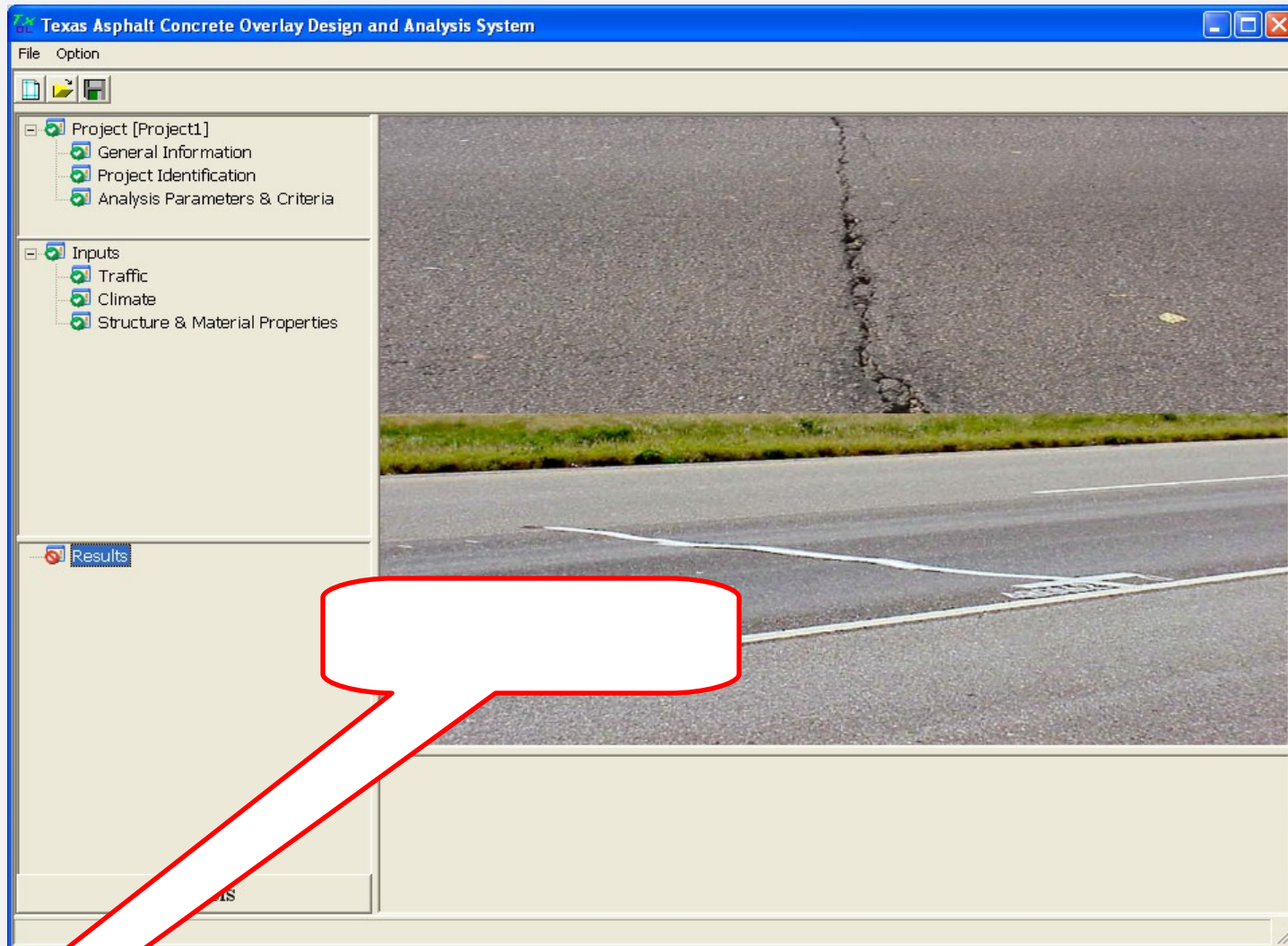


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Step 16: Run Analysis

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Example 1 (Paris Workshop)

- AC over AC
- Design life: 10 years
- District: Paris, Lamar
- Traffic: 5 million ESALs for 20 years
- Location: latitude $33^{\circ}39'$, longitude $-95^{\circ}33'$, and elevation 600 ft

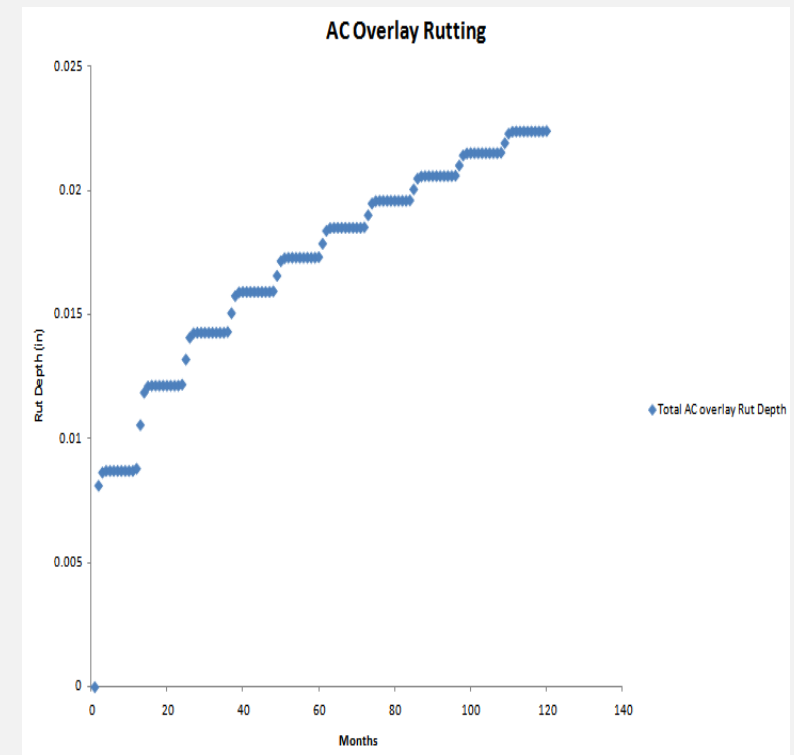
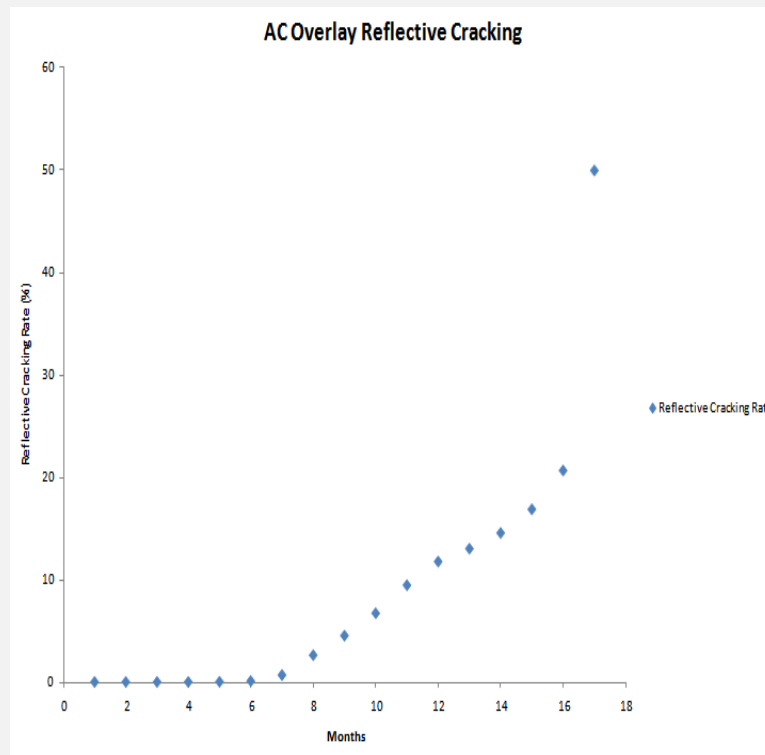
Example 1 (Paris Workshop) (Continued)

- Layer thickness
 - AC overlay: 2 inches; Existing AC: 3 inches; Base: 6 inches
- AC overlay property
 - Mix type: Type D; Binder type: PG 76-22
 - Modulus Input Level: Level 3-default values
 - Fracture properties and Rutting properties: default values
- Existing AC layer property
 - Transverse cracking, medium severity, cracking space: 15 ft
 - FWD modulus @ 77 °F: 500 ksi
- Base
 - Type: CTB, Modulus: 200 ksi
- Subgrade

Example 1 (Paris Workshop) Result

Cracking

Rutting



Example 1 (Austin Workshop)

- Overlay Type: AC over JPCP
- Design or Analysis Life: 15 years
- District: Austin; County: Travis
- Analysis Parameters & Criteria:
 - Reflective Cracking Rate Limit: 50%
 - AC Rutting: 0.5 inch
- Traffic: ADT-Beginning: 20000; ADT-End: 35000; ESALs: 5.0 million; Speed: 60 mph
- Weather Station: Austin/City, Tx

Example 1 (Austin Workshop) (Continued)

- Layer thickness
 - AC overlay: 2.5 inches; Existing JPCP: 9 inches; Base: 4 inches
- AC overlay property
 - Mix type: Type D; Binder type: PG 76-22
 - Modulus Input Level: Level 3-default values
 - Fracture properties and Rutting properties: default values
- Existing JPCP property
 - Modulus: 4000 ksi, cracking space: 15 ft, LTE: 70%
- Base
 - Type: Granular base, Modulus: 50 ksi
- Subgrade
 - Modulus: By default

Exercise 1

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- Use “New” function
- Change the previous example to 2-lift overlays
- The top overlay is the same Type D mix, but its thickness reduces to 1.5 inches
- The bottom overlay is 1 inch CAM mix with a PG76-22 binder
- All the other inputs are kept the same as Example 1

Exercise 2

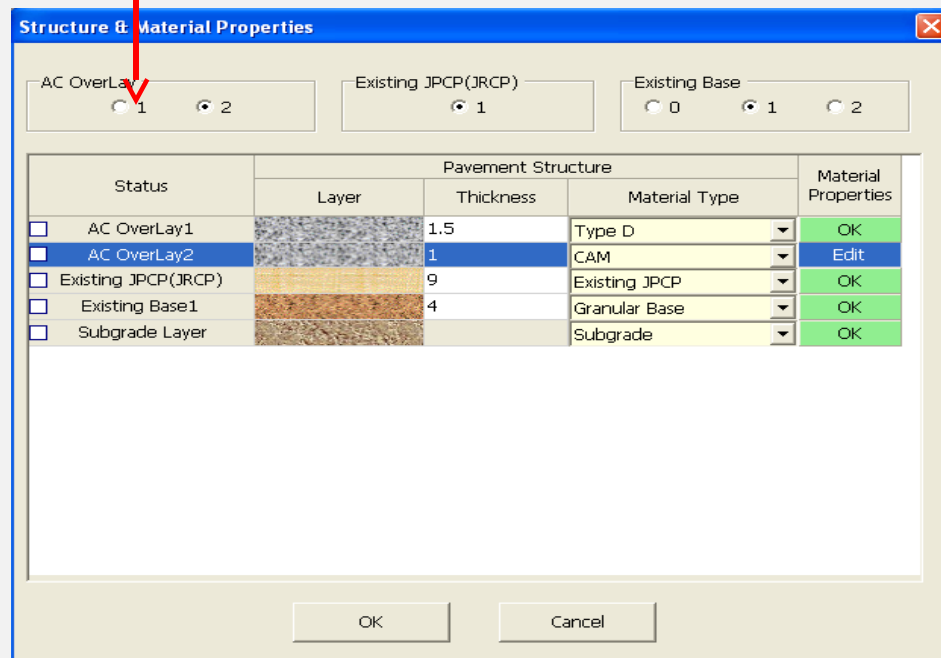
Slide 36

- Use "Save as" function
- Change the previous exercise back to one lift overlay
- Select overlay mix: SMA-D with a PG76-22 binder
- Keep all the other inputs the same as Example 1


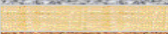
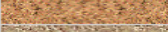


Exercise 2_Hint

Slide 37

- Use "save as" function
- Click radio button "1" to remove an overlay (Remember: choose/highlight one overlay first)



The dialog box is titled "Structure & Material Properties". It contains three radio button groups at the top: "AC Overlay" (with options 1 and 2), "Existing JPCP(JRCP)" (with option 1), and "Existing Base" (with options 0, 1, and 2). Below these is a table with the following columns: "Status", "Layer", "Thickness", "Material Type", and "Material Properties".

Status	Layer	Thickness	Material Type	Material Properties
<input type="checkbox"/> AC Overlay1		1.5	Type D	OK
<input checked="" type="checkbox"/> AC Overlay2		1	CAM	Edit
<input type="checkbox"/> Existing JPCP(JRCP)		9	Existing JPCP	OK
<input type="checkbox"/> Existing Base1		4	Granular Base	OK
<input type="checkbox"/> Subgrade Layer			Subgrade	OK

At the bottom of the dialog box are "OK" and "Cancel" buttons.

Summary for Different Overlay Mixes

2.5 inches Type D

After 52 months, Reflective Cracking Rate reaches 50%.

Rut depth reaches 0.084 inches after 15 years (180 months).

1.5 inches Type D + 1 inch CAM

After 129 months, Reflective Cracking Rate reaches 50%.

Rut depth reaches 0.3 inches after 15 years (180 months).

2.5 inches SMA

After 129 months, Reflective Cracking Rate reaches 50%.

Rut depth reaches 0.08 inches after 15 years (180 months).

Example 2 - Overlay Thickness Design

- Overlay Type: AC over JPCP
- Design Life: 10 years
- District: Wichita Falls; County: Cooke
- Analysis Parameters & Criteria:
 - Reflective Cracking Rate Limit: 50%
 - AC Rutting: 0.5 inch
- Traffic: ADT-Beginning: 19350; ADT-End: 28800; ESALs: 4.5 million; Speed: 60 mph
- Weather Station: Wichita Falls, Tx

Example 2 - Overlay Thickness Design (Continued)

Slide 40

- Layer thickness
 - AC overlay: Unknown; Existing JPCP: 8 inches; Base: 4 inches
- AC overlay property
 - Mix type: Type D; Binder type: PG 76-22
 - Modulus Input Level: Level 3-default values
 - Fracture properties and Rutting properties: default values
- Existing JPCP property
 - Modulus: 4000 ksi, joint space: 15 ft, LTE: 70%
- Base
 - Type: Granular base, Modulus: 30 ksi
- Subgrade
 - Modulus: By default

Trial Thicknesses During Design

- Overlay thickness trial 1: 2 inches

After 15 months, Reflective Cracking Rate reaches 50%.

Rut depth reaches 0.05 inches after 15 years (180 months).

- Overlay thickness trial 2: 4 inches

After 162 months, Reflective Cracking Rate reaches 50%.

Rut depth reaches 0.077 inches after 15 years (180 months).

Trial Thicknesses During Design (Continued)

- Overlay thickness trial 3: 3.5 inches

After 100 months, Reflective Cracking Rate reaches 50%.

Rut depth reaches 0.07 inches after 15 years (180 months).

- Obviously for all these cases, the rutting problem is not significant. To meet the 10 years design life requirement, a 4 inches overlay is recommended

Exercise 3

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- Change the existing JPCP's LTE to 50%
- Keep the other inputs the same as Example 2
- The recommended overlay thickness=?

Answer to Exercise 3

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5 inches

- Trial 1: 4 inches, 69 months
- Trial 2: 5 inches, 148 months
- Trial 3: 4.5 inches, 105 months

Tips and Reminders

Slide 45

- Accept default values if you don't have specific test results
- Use climatic interpolation function when there is no existing weather station available in this area
- Use "save as" to reduce some input work
- Save the project file before clicking "Analysis" button
- Do not move or rename the project file manually

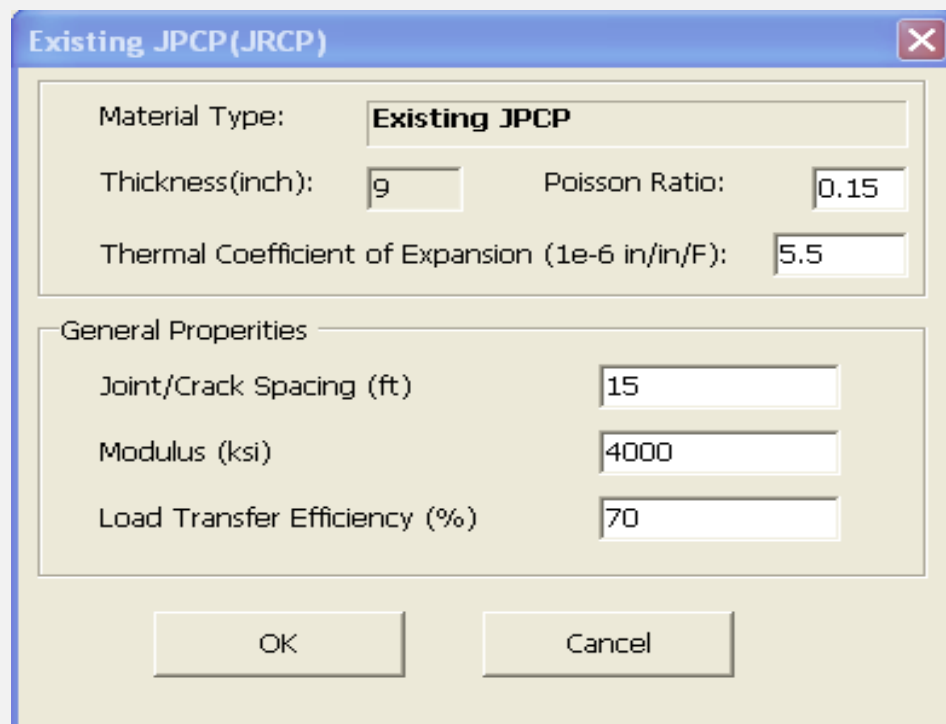
Presentation Outline

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- Introduction
- Program training and exercises
- Key inputs for existing pavement and field testing
- Key inputs for overlays and lab

Key Input Parameters for Existing Pavements

- Existing pavements
 - 1) Layer modulus and 2) Joints/cracks LTE
- Field testing
 - FWD
 - RDD



Existing JPCP (JRCPP)

Material Type: **Existing JPCP**

Thickness(inch): **9** Poisson Ratio: **0.15**

Thermal Coefficient of Expansion (1e-6 in/in/F): **5.5**

General Properties

Joint/Crack Spacing (ft) **15**

Modulus (ksi) **4000**

Load Transfer Efficiency (%) **70**

OK Cancel

JPCP Pavement Evaluation

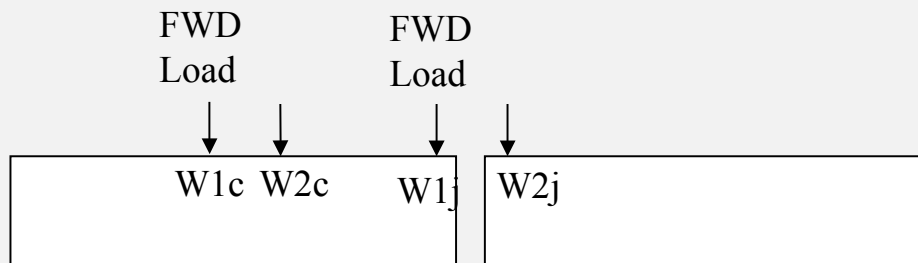
- For Layer modulus backcalculation
 - center slab
 - 30 drops per section (max spacing: 0.1 mile)
- For LTE
 - joint measurements
 - FWD
 - RDD

FWD Backcalculated Modulus

- In Texas, "MODULUS 6.0" is commonly used for modulus backcalculation

TTI MODULUS ANALYSIS SYSTEM (SUMMARY REPORT)														(Version 6.0)	
District:20 (Beaumont) County :122 (JASPER) Highway/Road: US0096			Pavement: 10.00 Base: 10.00 Subbase: 0.00 Subgrade: 97.98(by DB)							MODULI RANGE(psi)		Poisson Ratio Values H1: v = 0.20 H2: v = 0.35 H3: v = 0.00 H4: v = 0.35			
										Minimum	Maximum				
										340,000	5,500,000				
										10,000	550,000				
											5,000				
Station	Load (lbs)	Measured Deflection (mils):					Calculated Moduli values (ksi):					Absolute	Dpth to		
		R1	R2	R3	R4	R5	R6	R7	SURF(E1)	BASE(E2)	SUBB(E3)	SUBG(E4)	ERR/Sens	Bedrock	
0.000	11,070	4.55	4.01	3.55	3.00	2.52	1.96	1.59	3457.9	315.2	0.0	10.8	1.20	147.5	
0.197	11,098	3.63	3.18	2.80	2.27	1.87	1.46	1.17	5165.5	163.8	0.0	16.0	0.92	137.0	
0.399	11,051	4.20	3.72	3.25	2.65	2.21	1.80	1.42	3383.0	340.2	0.0	12.4	0.75	130.4	
0.595	11,035	7.87	7.20	6.61	5.60	4.69	3.57	2.70	3037.8	81.1	0.0	5.8	2.53	125.1	
0.797	10,880	5.10	4.41	3.86	3.12	2.54	1.95	1.50	3324.7	114.5	0.0	11.9	1.01	123.3	
0.994	10,943	4.64	4.18	3.78	3.16	2.68	2.01	1.49	5458.4	59.1	0.0	10.8	1.96	102.6	
1.200	10,975	6.05	5.27	4.56	3.61	2.76	1.89	1.20	2825.1	13.6	0.0	13.6	2.77	81.5	
1.393	11,154	2.85	2.35	1.94	1.52	1.20	0.86	0.67	3437.5	316.6	0.0	28.1	1.11	91.5	
1.601	10,876	4.72	4.09	3.54	2.91	2.37	1.80	1.34	3609.0	125.2	0.0	12.8	0.97	104.2	
1.798	11,074	4.40	4.11	3.96	3.35	2.89	2.24	1.69	5500.0	71.7	0.0	10.4	5.29	108.7	
1.995	10,979	3.49	3.04	2.66	2.26	1.92	1.56	1.28	3816.0	550.0	0.0	13.5	0.52	145.0	
2.197	10,864	4.88	4.12	3.60	2.68	2.11	1.59	1.09	2649.9	103.6	0.0	15.3	1.46	92.3	
2.399	11,051	3.67	3.24	2.89	2.39	2.03	1.61	1.24	4262.8	401.1	0.0	13.3	1.04	111.1	
2.588	10,721	4.50	4.02	3.60	3.04	2.40	1.91	1.43	5065.9	60.5	0.0	11.8	1.39	103.7	
2.789	10,947	2.69	2.17	1.78	1.36	1.06	0.74	0.59	3183.2	318.3	0.0	32.0	1.47	84.6	
2.999	10,832	4.28	3.81	3.36	2.72	2.24	1.73	1.44	4323.0	131.4	0.0	13.0	1.04	149.4	
3.200	10,947	2.44	2.03	1.64	1.22	0.93	0.66	0.52	4492.1	149.8	0.0	37.8	0.83	88.9	
3.401	11,066	2.41	2.00	1.69	1.29	0.98	0.83	0.68	5500.0	82.2	0.0	36.6	3.86	300.0	
3.610	11,039	2.97	2.39	2.01	1.52	1.17	0.84	0.62	3135.3	267.4	0.0	28.8	1.44	95.6	
3.612	10,900	3.16	2.43	1.78	1.31	0.98	0.70	0.50	1743.7	289.0	0.0	35.5	1.48	86.9	
3.796	11,051	1.79	1.41	1.13	0.80	0.58	0.39	0.31	5304.9	148.2	0.0	64.4	1.46	73.5	
4.000	10,939	3.06	2.66	2.30	1.72	1.42	1.01	0.81	5500.0	27.2	0.0	26.9	2.19	96.4	
4.194	10,943	2.55	2.21	1.83	1.55	1.22	0.99	0.85	4423.2	547.7	0.0	23.3	0.99	300.0	
4.399	10,892	3.08	2.66	2.30	1.74	1.41	1.03	0.73	5500.0	31.5	0.0	26.1	1.84	89.1	
4.600	10,880	2.70	2.30	1.99	1.65	1.34	1.06	0.87	4273.2	550.0	0.0	21.1	0.50	138.1	
4.801	10,983	3.06	2.61	2.30	1.90	1.56	1.30	1.10	4096.2	550.0	0.0	17.3	1.22	300.0	
4.998	10,876	2.80	2.26	1.98	1.52	1.17	0.90	0.75	3419.0	363.8	0.0	26.5	1.48	130.8	
5.199	10,816	2.99	2.57	2.31	1.79	1.41	1.17	0.95	5500.0	103.0	0.0	22.4	2.83	149.6	
5.400	10,896	3.28	2.91	2.48	1.95	1.64	1.30	1.08	4512.2	259.3	0.0	18.0	1.34	168.8	
5.602	10,991	2.20	1.85	1.56	1.24	1.05	0.81	0.69	5500.0	144.2	0.0	36.5	6.64	118.9	
5.799	10,717	2.87	2.49	2.15	1.79	1.62	1.11	0.85	4369.7	517.6	0.0	18.2	2.95	300.0	
6.000	10,689	3.24	2.89	2.49	2.01	1.59	1.29	0.99	5161.6	176.3	0.0	18.0	1.00	109.2	
6.204	10,705	3.24	2.69	2.35	1.90	1.51	1.16	0.96	3345.8	364.2	0.0	19.4	1.18	129.3	
6.401	10,816	3.76	3.24	2.83	2.30	1.91	1.41	1.09	4500.3	152.8	0.0	16.1	1.62	109.5	
Mean:		3.62	3.13	2.73	2.20	1.79	1.37	1.06	4199.3	232.1	0.0	21.3	1.77	118.0	
Std. Dev:		1.21	1.14	1.08	0.93	0.79	0.61	0.45	1017.8	169.7	0.0	11.6	1.31	36.3	
Var Coeff(%):		33.41	36.37	39.42	42.28	44.08	44.39	42.60	24.2	73.1	0.0	54.2	73.72	30.7	

FWD Based LTE at Joints/Cracks



$$LTE = (W2j/W1j) / (W2c/W1c)$$

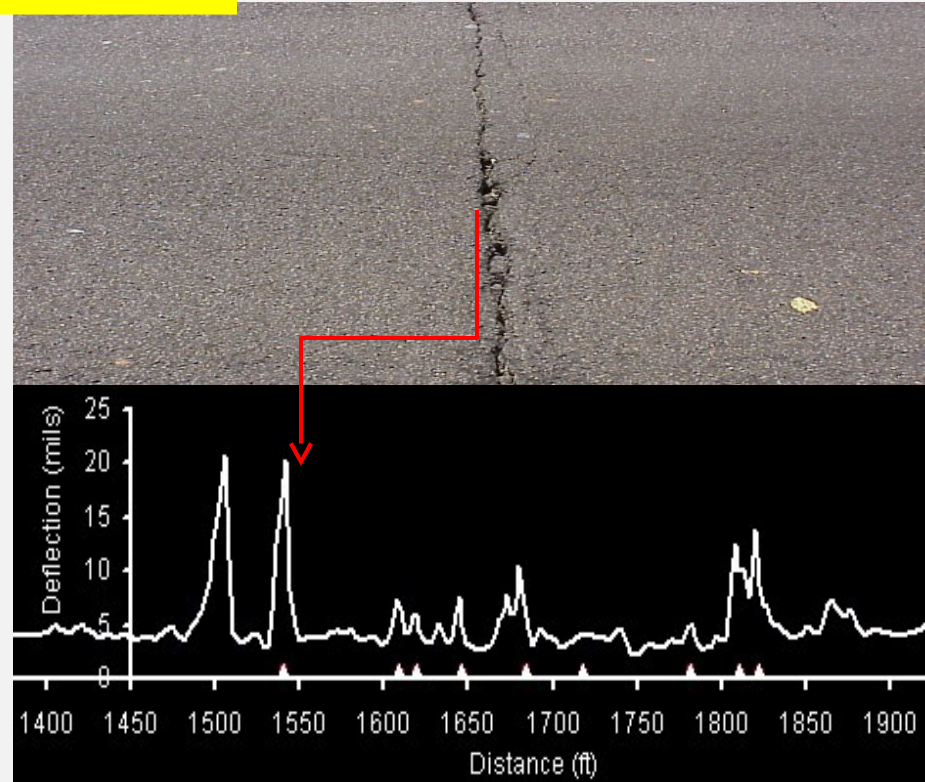


Near the slab center

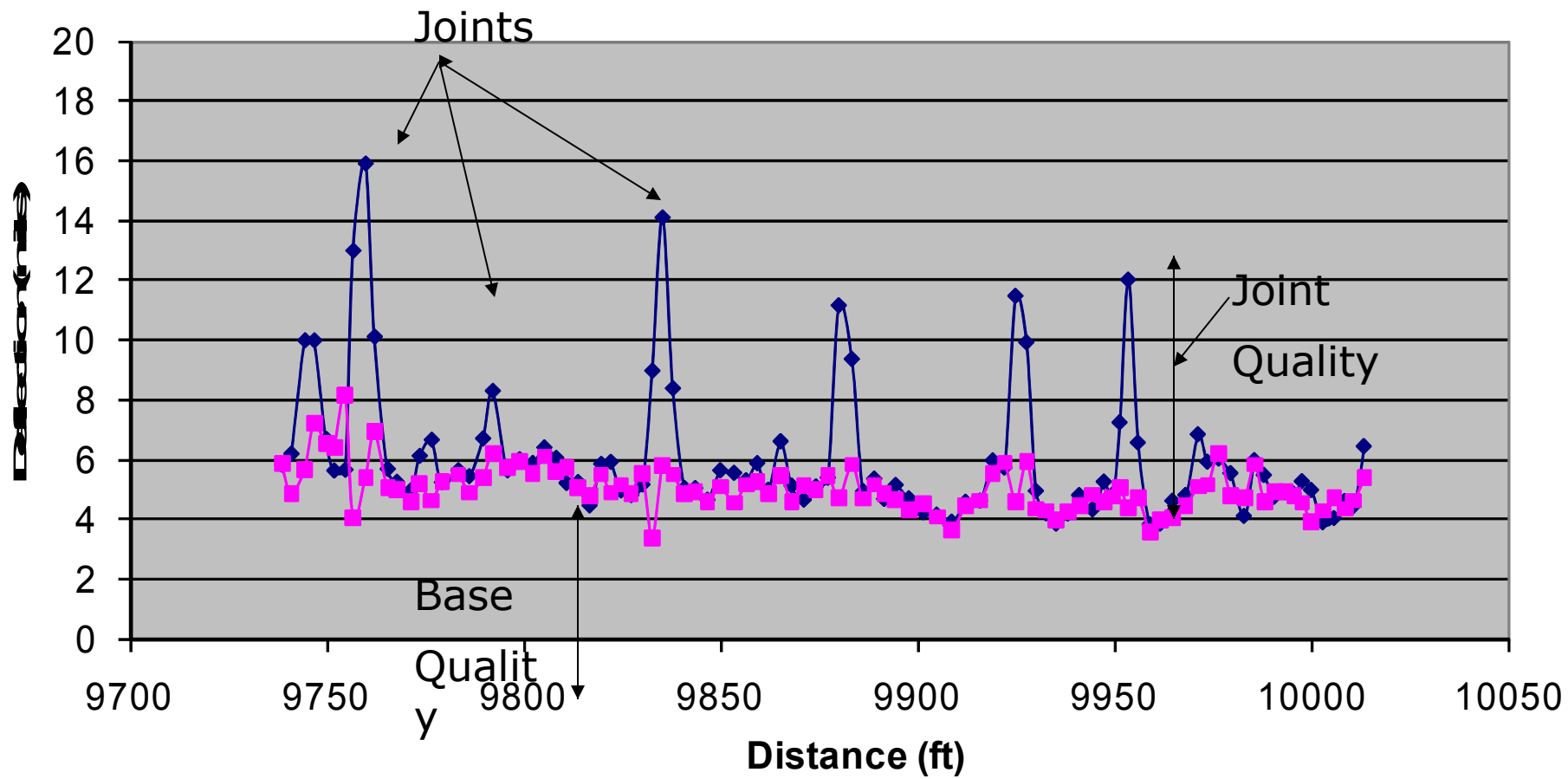


Near the joint/crack

RDD Based LTE Evaluation



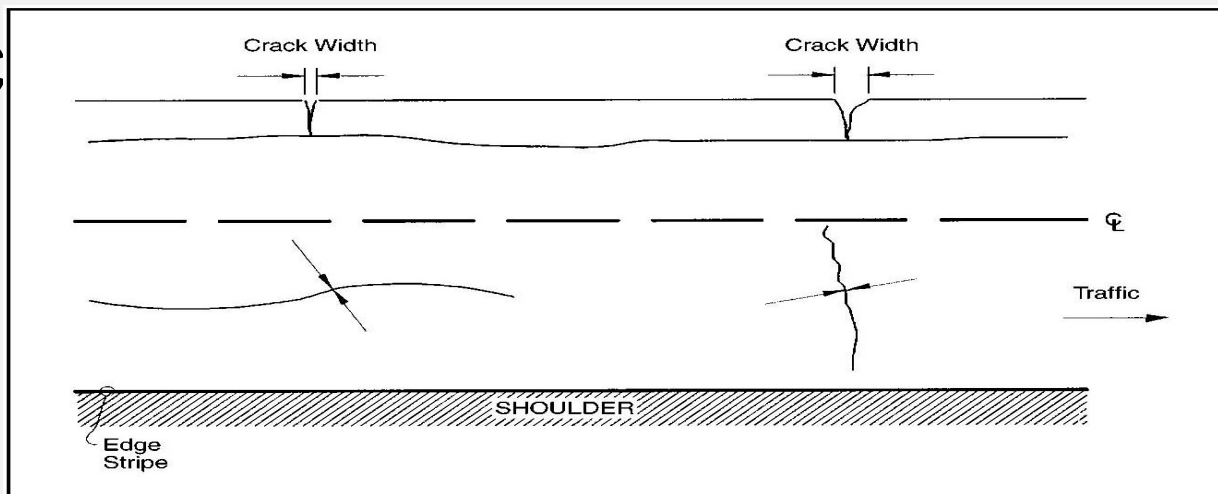
RDD Raw Data



Flexible Pavement Evaluation

- For layer modulus backcalculation
 - 30 drops per section (max spacing 0.1 mile)
- For LTE evaluation
 - FWD based, similar to JPCP

– C



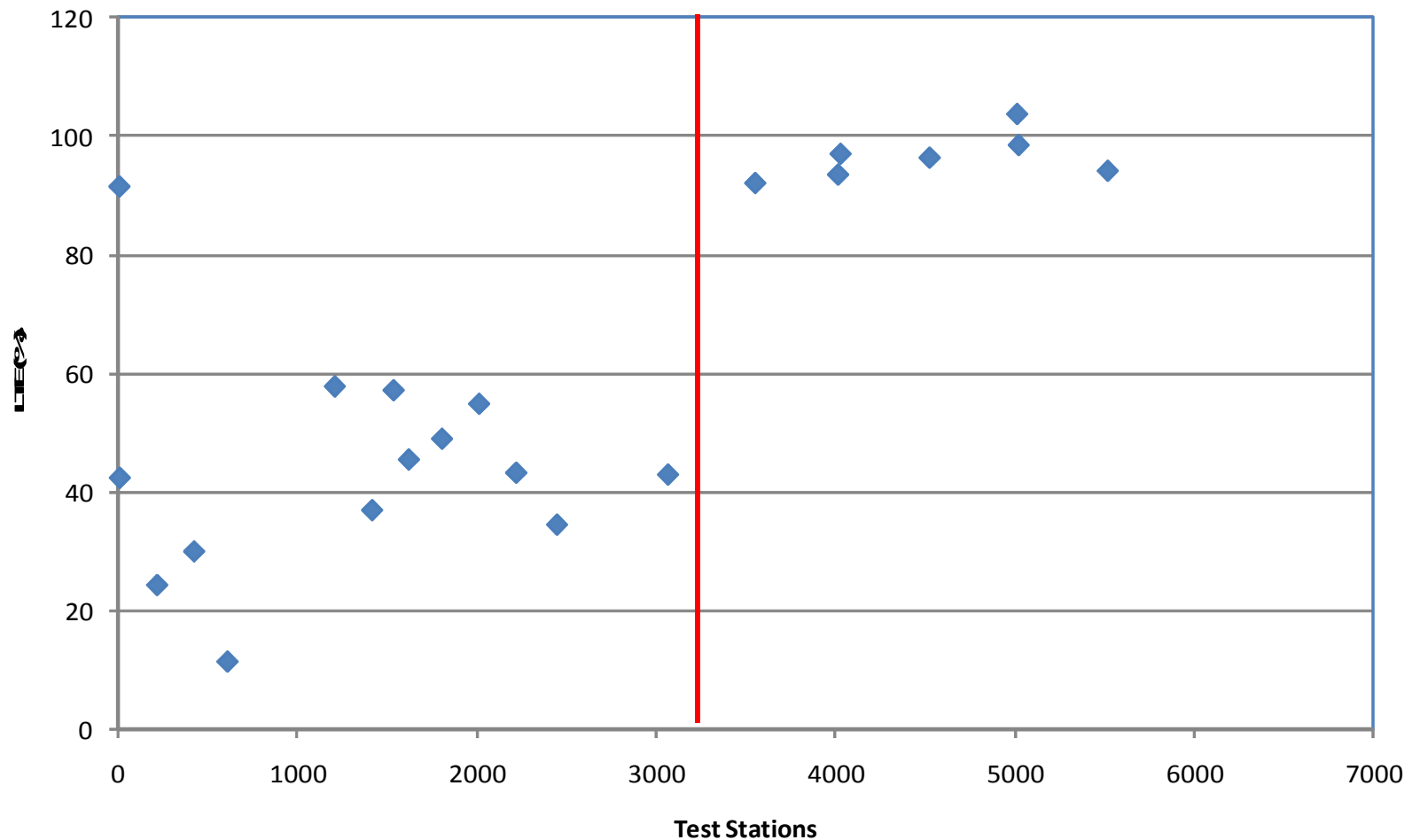


FWD Based L^TE ment



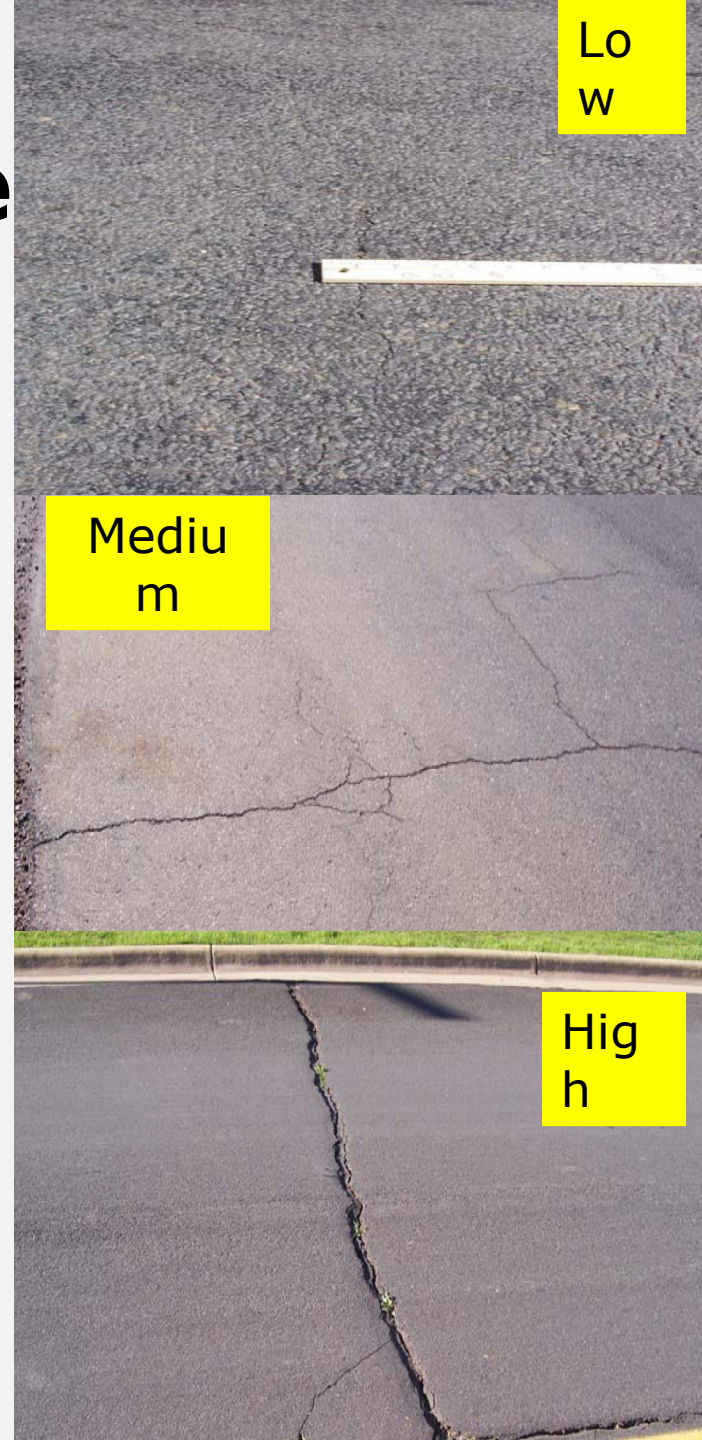
		Load	Measured	Deflection (mils):			
		Station	(lbs)	R1	R2	R1/R2	LTE (%)
1/2	Center	0	10,359	9.45	4.15	0.439153	86
	Crack	21	10,284	10.03	3.79	0.377866	
3	Center	67	10,355	7.31	3.55	0.485636	73
	Crack	84	10,312	10.31	3.68	0.356935	
4	Center	99	10,244	6.56	3.34	0.509146	81
	Crack	112	10,189	10.49	4.34	0.413727	
5	Center	136	9,795	9.04	5.14	0.568584	67
	Crack	153	10,288	11.52	4.41	0.382813	
6	Center	169	10,300	8.48	4.07	0.479953	124
	Crack	182	10,395	6.36	3.77	0.592767	
7	Center	196	10,153	10.19	5.63	0.552502	89
	Crack	207	10,343	8.87	4.35	0.490417	
8	Center	222	10,228	9.73	5.33	0.54779	65
	Crack	231	10,113	11.72	4.2	0.358362	
9	Center	248	10,077	11.04	5.7	0.516304	80
	Crack	262	10,153	10.57	4.39	0.415326	
10	Center	290	10,145	7.09	3.41	0.480959	95
	Crack	304	10,161	8.3	3.78	0.455422	
11	Center	325	10,252	6.8	3.82	0.561765	75
	Crack	338	10,330	10.40	4.43	0.434254	

FWD Based LTE Measurement



Flexible Pavement- Severity Level Base LTE

- Low severity crack: LTE=85%
 - Crack width < 1/8"
- Medium severity crack: LTE=70%
 - 1/8" < Crack width < 1/4" or any crack (< 1/4") with adjacent random low severity cracking
- High severity crack: LTE=55%
 - Crack width > 1/4" or any crack (< 1/4") with adjacent random medium to high severity cracking



Low

Medium

High

Presentation Outline

Slide 57

- Introduction
- Program training and exercises
- Key inputs for existing pavement and field testing
- Key inputs for asphalt overlays

Key Inputs for Asphalt Overlays Level 1

1. Dynamic modulus $|E^*|$
2. Fracture properties (A and n)
3. Rutting properties (a and μ)

Dynamic Modulus $|E^*|$

Slide 59

- Test equipment



Sample size:
4" diameter by 6"
high

Replicates: 3

Dynamic Modulus $|E^*|$ (Continued)

- 5 test temperatures:
14, 40, 70, 100, and 130°F
- 6 loading frequencies:
25, 10, 5, 1, 0.5, and 0.1Hz

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

	25Hz	10Hz	5Hz	1Hz	0.5Hz	0.1Hz
14°F	2346.7	2307.4	2175	1810	1682	1378
40°F	1843	1687	1498	1080	916	619
70°F	820	597	467	280	223	139

Dynamic Modulus $|E^*|$

Slide 61

- Input interface in the program

AC OverLay1

Material Type: **Type D** Thickness(inch): **2.5**

Thermal Coefficient of Expansion (1e-6 in/in/F): **13.5** Poisson Ratio: **0.35**

Superpave PG Binder Grading

High Temp (C)	Low Temp (C)	
	-22	-28
64		
70		
76		

Modulus Input

☐ Level 3 (Default Value) ☐ Level 2 (Witczak Model) ☒ Level 1 (Test Data)

Test Data

Dynamic Modulus (E^* ,ksi)

Number of Temperatures: **5** Number of frequencies: **6**

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

Import Export

Material Performance Properties

Fracture Properties

Rutting Properties

OK Cancel

Fracture Properties: A & n

- Fracture model

Model Calibration

AC Rutting | AC Crack Propagation | Reflective Cracking

$$\Delta C = k_1 \Delta N_i A K_{bend}^n + k_2 \Delta N_i A K_{shear}^n + k_3 A K_{thermal}^n$$

ΔC = crack length increment
 ΔN = daily load repetitions, ESALs
 K_{bend} = stress intensity factor caused by bending traffic load
 K_{shear} = stress intensity factor caused by shearing traffic load
 $K_{thermal}$ = stress intensity factor caused by daily temperature variation
 A, n = cracking properties, determined by overlay tester
 k_1, k_2, k_3 = calibration factors

☐ Special Analysis
☒ State Calibration

Calibration Factors

k1:
 k2:
 k3:

OK Cancel

Fracture Properties A & n (Continued)

- Test equipment: Overlay Tester

Step 1: Modulus Test

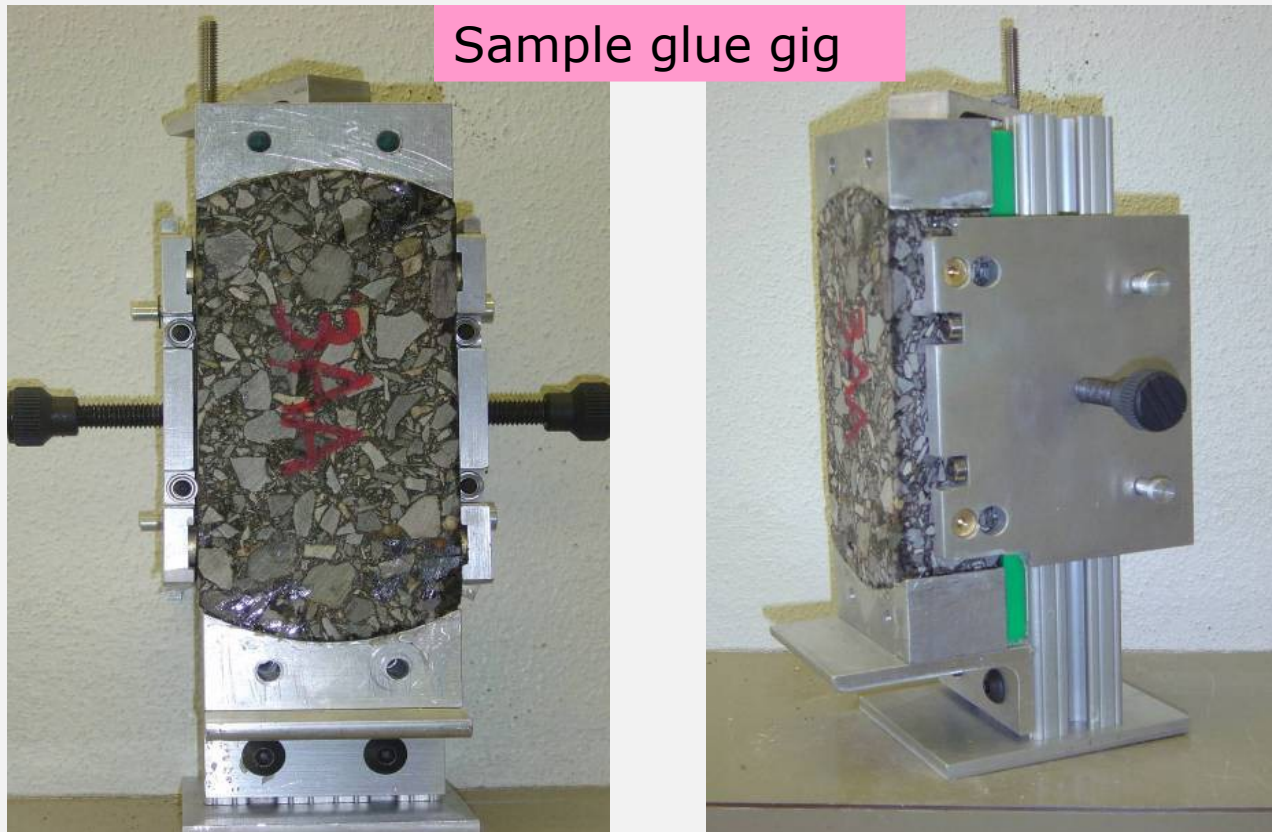
Step 2: Cracking test to obtain A, n

Three replicates required



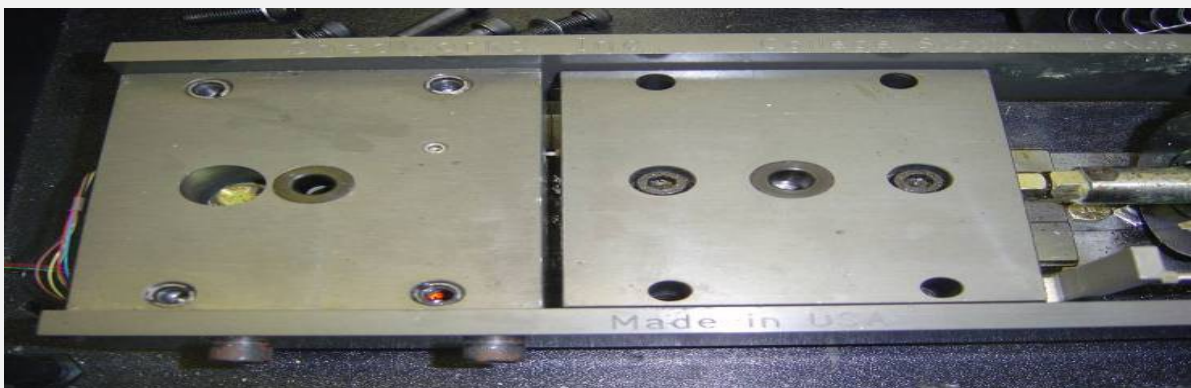
Fracture Properties A & n (Continued)

- Modulus test –preparing samples



Fracture Properties A & n (Continued)

- Modulus test – installing new base plates



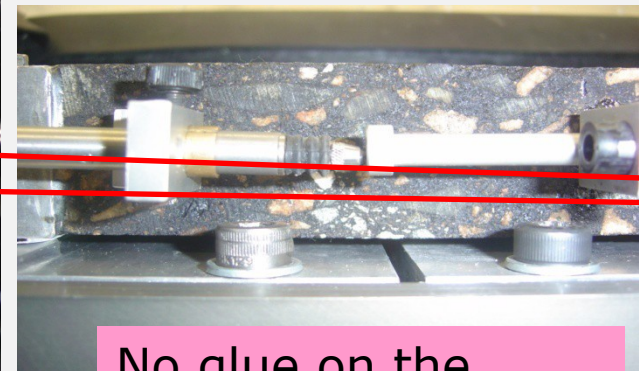
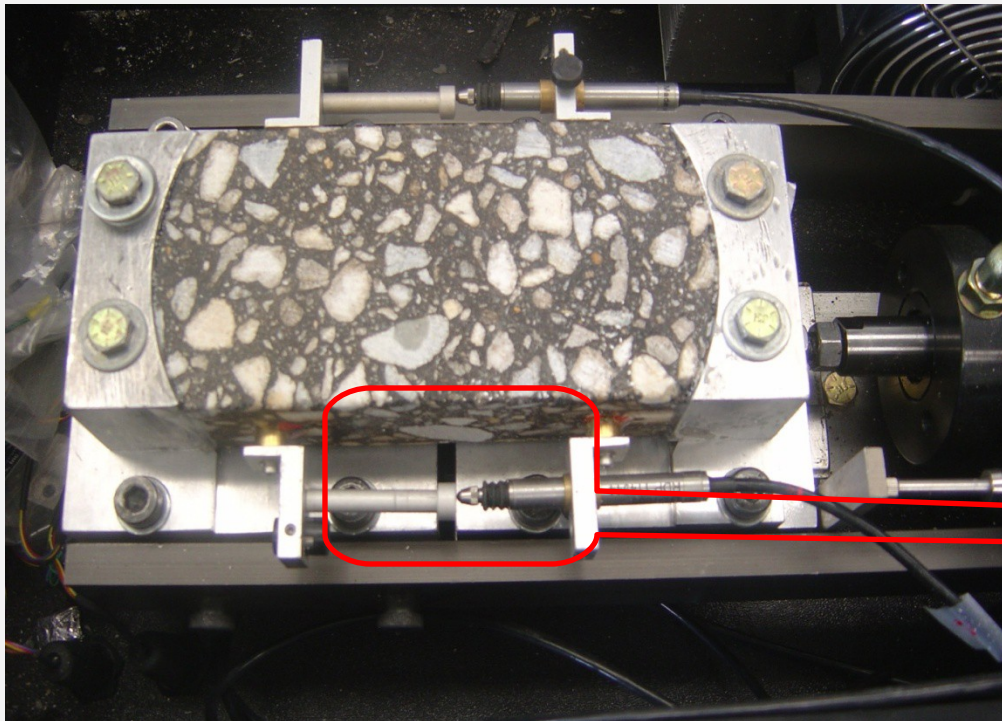
Regular
OT
Machine



OT-E*
System

Fracture Properties A & n (Continued)

- Modulus test – mounting

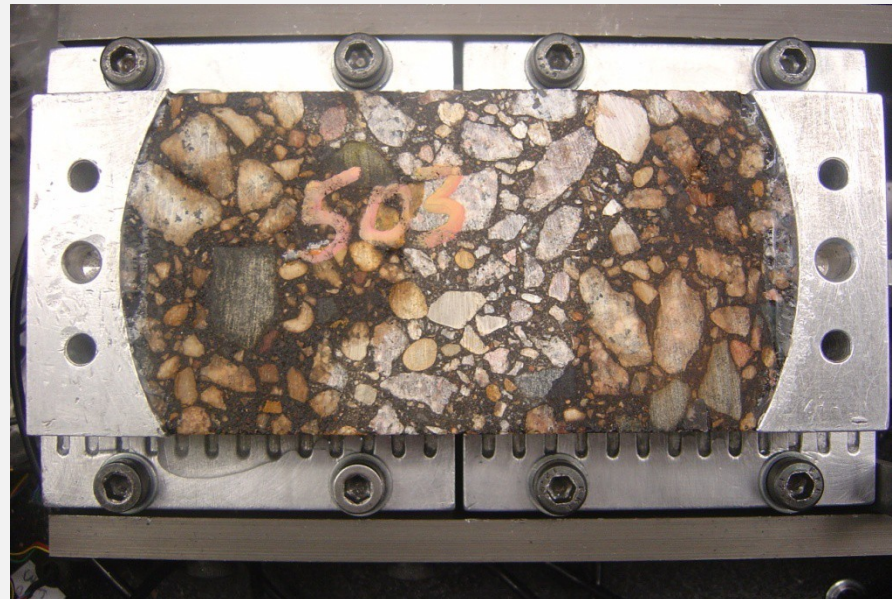


No glue on the bottom.

Fracture Properties A & n (Continued)

- Cracking test

Same as regular OT test except with a smaller opening displacement: 0.017"



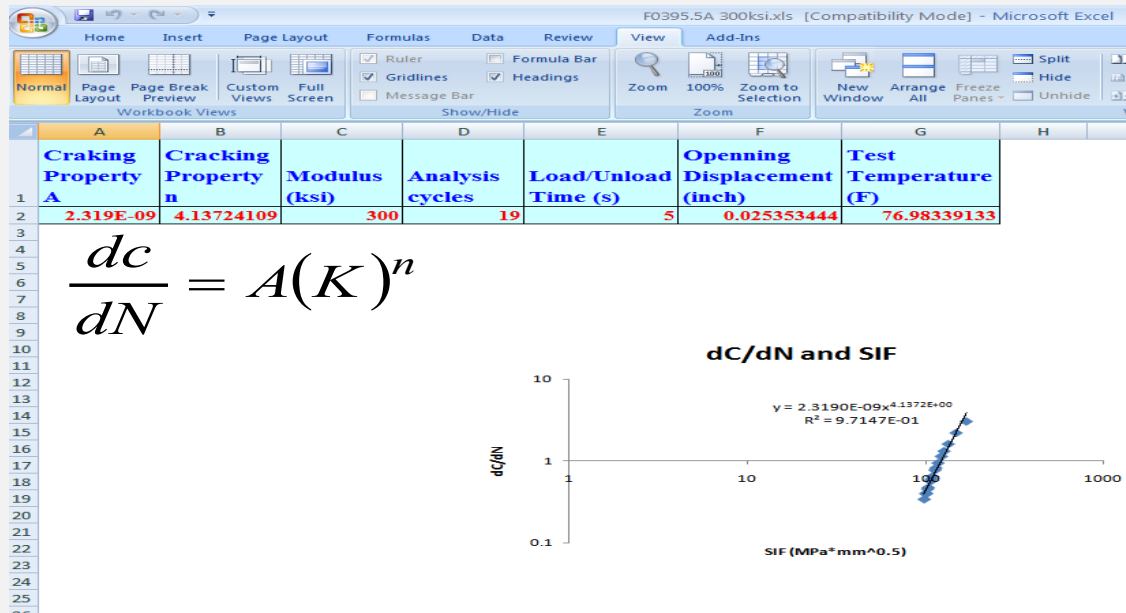
Fracture Properties A & n (Continued)

- Excel macro to determine A & n

Modulus Input

Sample Modulus (ksi)

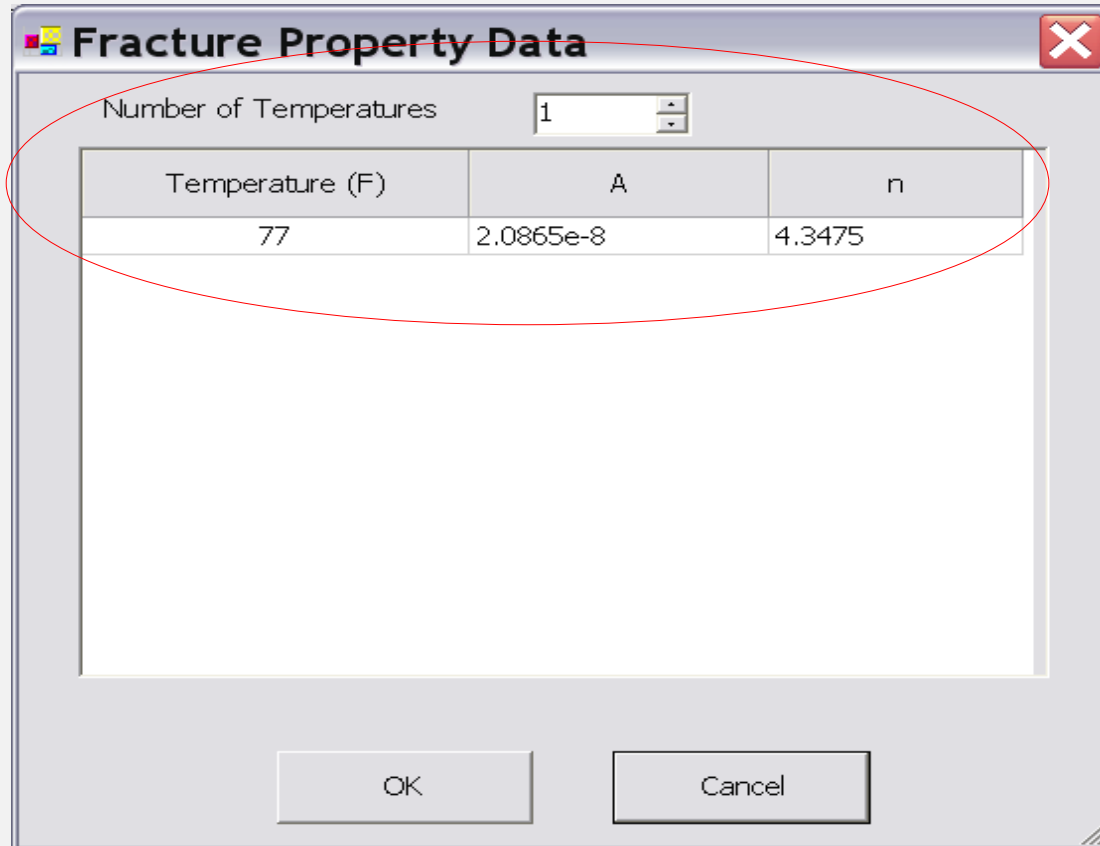
Input



Output

Fracture Properties: A & n

- Input interface in the program



Fracture Property Data

Number of Temperatures: 1

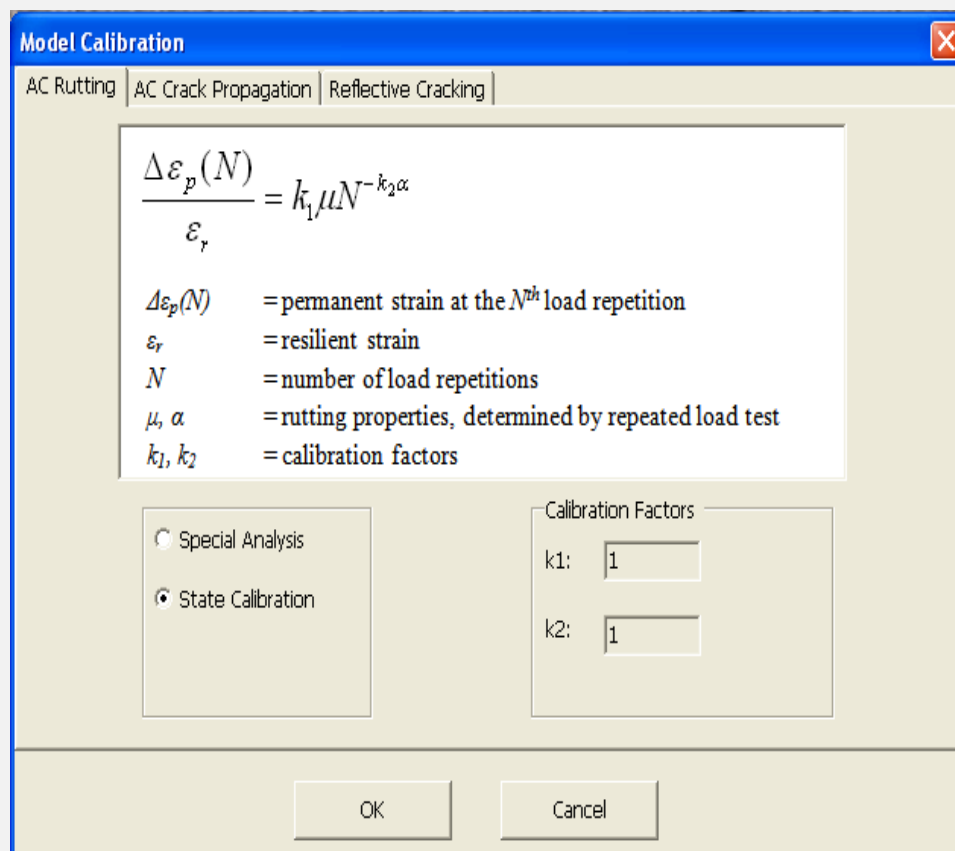
Temperature (F)	A	n
77	2.0865e-8	4.3475

OK Cancel

Rutting Properties α & μ

Slide 70

- Rutting model



Model Calibration

AC Rutting | AC Crack Propagation | Reflective Cracking

$$\frac{\Delta \varepsilon_p(N)}{\varepsilon_r} = k_1 \mu N^{-k_2 \alpha}$$

$\Delta \varepsilon_p(N)$ = permanent strain at the N^{th} load repetition
 ε_r = resilient strain
 N = number of load repetitions
 μ, α = rutting properties, determined by repeated load test
 k_1, k_2 = calibration factors

☐ Special Analysis
☒ State Calibration

Calibration Factors

k1:

k2:

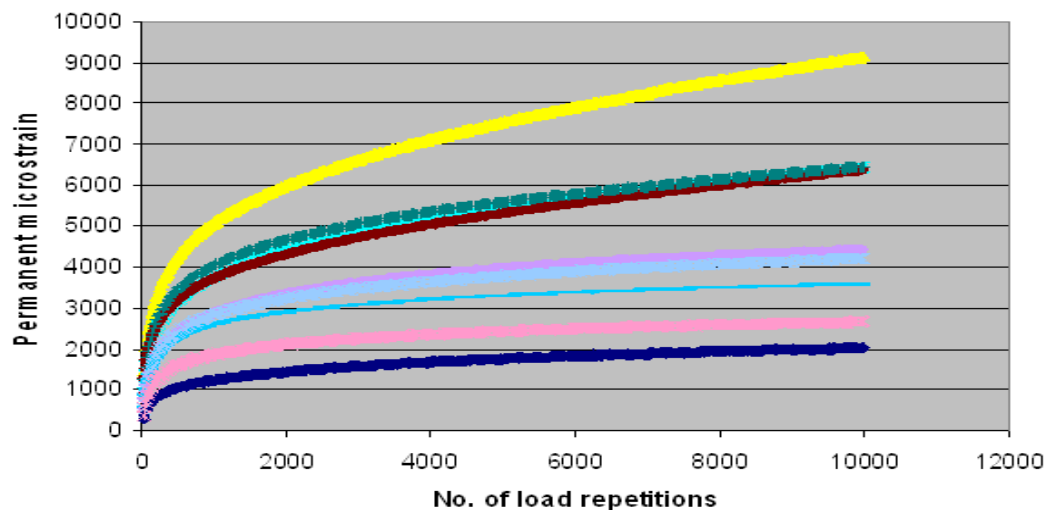
OK Cancel

TxACOL

Workshop

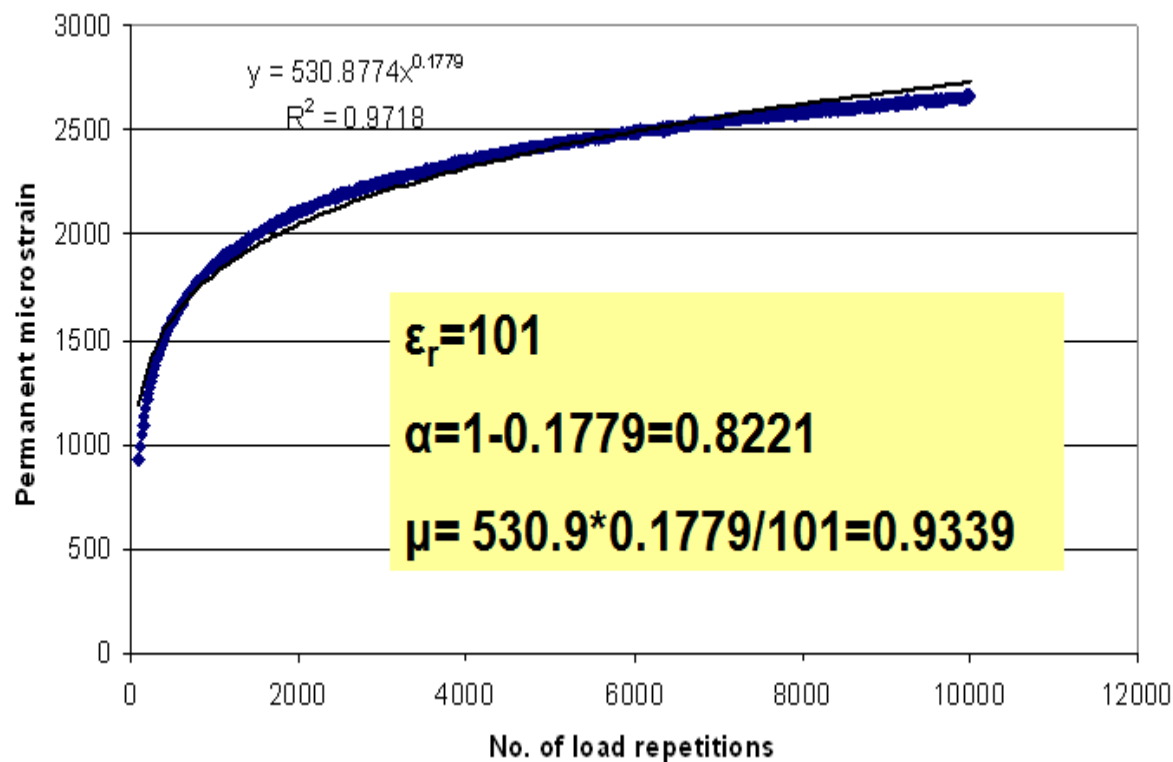
Rutting property α & μ (Continued)

- Test equipment: same as $|E^*|$ test
- Test conditions
 - 10,000 load repetitions
 - 0.1s loading + 0.9s rest
 - 2 replicates required



Rutting Properties: α & μ (Continued)

- α & μ determination method

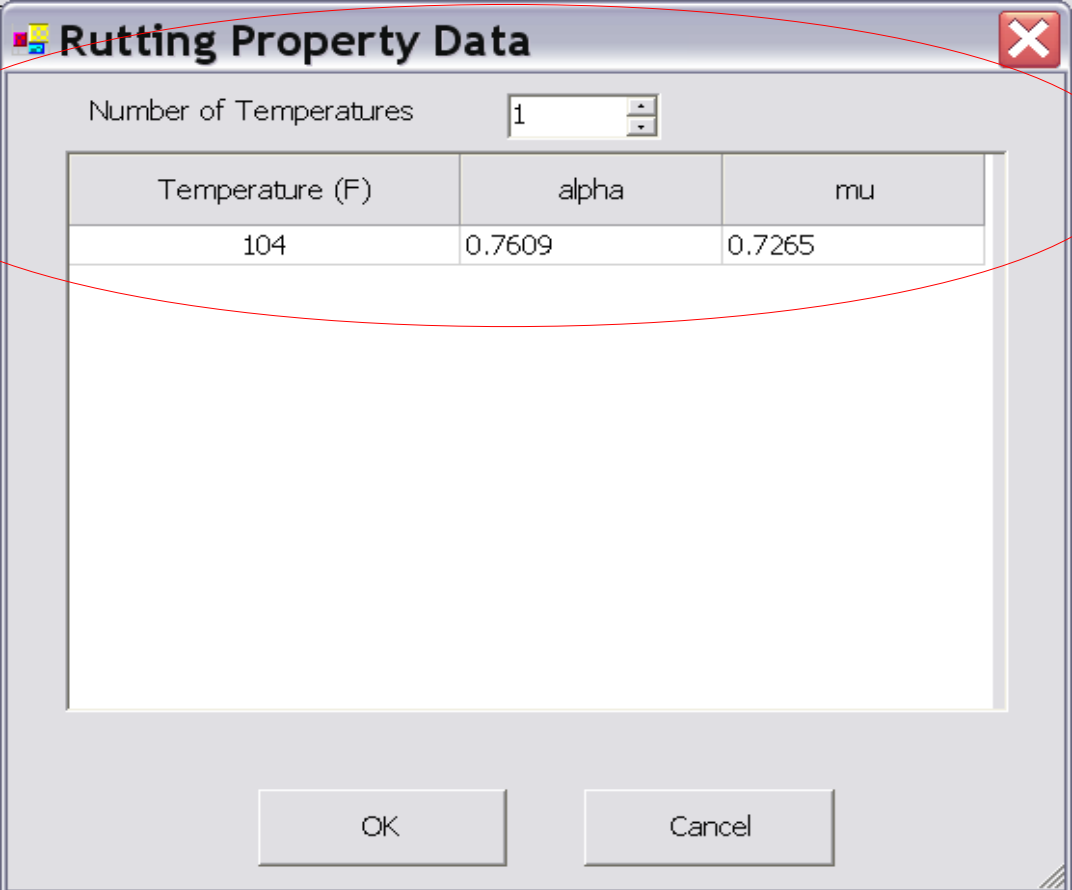


$$\mu = \frac{ab}{\epsilon_r}$$

$$\alpha = 1 - b$$

Rutting Properties: α & μ (Continued)

- Input interface in the program



Rutting Property Data

Number of Temperatures: 1

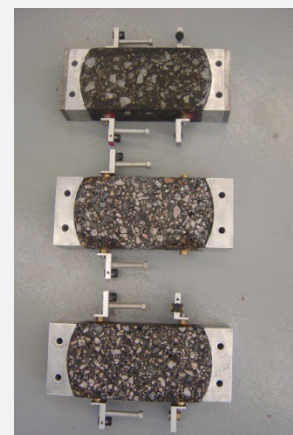
Temperature (F)	alpha	mu
104	0.7609	0.7265

OK Cancel

Lab Test Summary

Slide 74

- Dynamic modulus $|E^*|$ test 3 replicates
- Rutting properties (α & μ) test 2 replicates
- Cracking properties (A & n) test 3 replicates



Questions?

Assistance needed?

Slide 76

- Contact TTI research team:
 - by email
 - Sheng Hu: S-hu@ttimail.tamu.edu
 - Fujie Zhou: F-zhou@ttimail.tamu.edu
 - Tom Scullion: T-scullyon@tamu.edu
 - by phone
 - Sheng Hu: 979-845-9767
 - Fujie Zhou: 979-458-3965
 - Tom Scullion: 979-845-9913

Thank you!

APPENDIX

Handouts for Austin Workshop

Example 1

- Overlay Type: AC over JPCP
- Design or Analysis Life: 15 years
- District: Austin; County: Travis
- Analysis Parameters & Criteria:
 - Reflective Cracking Rate Limit: 50%
 - AC Rutting: 0.5 inch
- Traffic:
 - ADT-Beginning: 20000; ADT-End: 35000; ESALs: 5.0 million; Speed: 60 mph
- Weather Station: Austin/City, Tx
- Layer thickness
 - AC overlay: 2.5 inches
 - Existing JPCP: 9 inches
 - Base: 4 inches
- AC overlay property
 - Mix type: Type D; Binder type: PG 76-22
 - Modulus Input Level: Level 3-default values
 - Fracture properties and Rutting properties: default values
- Existing JPCP property
 - Modulus: 4000 ksi, cracking space: 15 ft, LTE: 70%
- Base
 - Type: Granular base, Modulus: 50 ksi
- Subgrade
 - Modulus: By default

Analysis Result:

2.5 inches Type D

After **52** months, Reflective Cracking Rate reaches 50%.

Rut depth reaches **0.084** inches after 15 years (180 months).

Exercise 1

- Overlay Type: AC over JPCP
- Design or Analysis Life: 15 years
- District: Austin; County: Travis
- Analysis Parameters & Criteria:
 - Reflective Cracking Rate Limit: 50%
 - AC Rutting: 0.5 inch
- Traffic:
 - ADT-Beginning: 20000; ADT-End: 35000; ESALs: 5.0 million; Speed: 60 mph
- Weather Station: Austin/City, Tx
- Layer thickness
 - AC overlay 1: 1.5 inches
 - AC overlay 2: 1 inches
 - Existing JPCP: 9 inches
 - Base: 4 inches
- AC overlay 1 property
 - Mix type: Type D; Binder type: PG 76-22
 - Modulus Input Level: Level 3-default values
 - Fracture properties and Rutting properties: default values
- AC overlay 2 property
 - Mix type: CAM; Binder type: PG 76-22
 - Modulus Input Level: Level 3-default values
 - Fracture properties and Rutting properties: default values
- Existing JPCP property
 - Modulus: 4000 ksi, cracking space: 15 ft, LTE: 70%
- Base
 - Type: Granular base, Modulus: 50 ksi
- Subgrade
 - Modulus: By default

Analysis Result: (Please fill in the blanks):

1.5 inches Type D +1 inch CAM

After months, Reflective Cracking Rate reaches 50%.

Rut depth reaches inches after 15 years (180 months).

Exercise 2

- Use “Save as” function
- Change the previous exercise back to one lift overlay
- Select overlay mix: SMA-D with a PG76-22 binder
- Keep all the other inputs the same as Example 1

Analysis Result: (Please fill in the blanks):

2.5 inches SMA

After months, Reflective Cracking Rate **reaches** 50%.

Rut depth reaches inches after 15 years (180 months).

Example 2: US82 Overlay Thickness Design

- Overlay Type: AC over JPCP
- Design Life: 10 years
- District: Wichita Falls; County: Cooke
- Analysis Parameters & Criteria:
 - Reflective Cracking Rate Limit: 50%
 - AC Rutting: 0.5 inch
- Traffic
 - ADT-Beginning: 19350; ADT-End: 28800; ESALs: 4.5 million; Speed: 60 mph
- Weather Station: Wichita Falls, TX
- Layer thickness
 - AC overlay: **Using trial thickness**
 - Existing JPCP: 8 inches
 - Base: 4 inches
- AC overlay property
 - Mix type: Type D; Binder type: PG 76-22
 - Modulus Input Level: Level 3-default values
 - Fracture properties and Rutting properties: default values
- Existing JPCP property
 - Modulus: 4000 ksi, joint space: 15 ft, LTE: 70%
- Base
 - Type: Granular base, Modulus: 30 ksi
- Subgrade
 - Modulus: By default

The recommended overlay thickness=?

Answer :

4 inches

- Trial 1: **2** inches, **15** months
- Trial 2: **4** inches, **162** months
- Trial 3: **3.5** inches, **100** months

Exercise 3

- Change the existing JPCP's LTE to **50%**
- Keep the other inputs the same as Example 2
- The recommended overlay thickness=?

Answer (Please fill in the blanks):

inches

- Trial 1: 4 inches, months
- Trial 2: 5 inches, months
- Trial 3: 4.5 inches, months