HMEC

Highway Materials Engineering Course

PARTICIPANT WORKBOOK

Mechanistic Empirical Pavement Design Guide

MODULE

E

U.S.Department of Transportation
Federal Highway Administration

Table of Contents

About This Workbook

This workbook has been developed as a resource for participants. This workbook can be used during the training session to follow along with the instructor and take notes, as well as for reference after the module has ended.

Course Overview

The Federal Highway Administration (FHWA) Highway Materials Engineering Course (HMEC) is a comprehensive multi-week training event that consists of eight content “modules” that provide students with the knowledge to develop materials specifications and guidance, make effective acceptance decisions, and design, construct, and maintain assets with a long service life. Modules range in duration for the number of days they take to complete. The modules are:

- Module A: Quality Assurance
- Module B: Soils and Foundations
- Module C: Steel, Welding, and Coatings
- Module D: Aggregates for Transportation Construction Projects
- Module E: Mechanistic Empirical Pavement Design Guide
- Module F: Asphalt Materials and Paving Mixtures
- Module G: Portland Cement Concrete
- Module H: Evaluating Recycled Materials for Beneficial Uses in Transportation

Introduction

Module E: Mechanistic Empirical Pavement Design Guide (MEPDG) is the fifth module in the HMEC. Although other modules and workshops are presented on this topic, Module E provides content that is specific to materials engineers. Participants will be given the information that they need to more proficiently and actively review agency- and consultant-generated pavement designs to ensure their alignment with the appropriate materials designs. Participants who do not normally review pavement design, or only perform a cursory review, will learn how to review pavement design with more knowledge of what they are looking at, and how the material design selected by the designer may impact the ultimate pavement service life. This was not done before the advent of the MEPDG approach.

Module E Overview

Below is a visual overview of all of the lessons covered in this module:

Web-based Training (WBT)

- 1 Intro to Web-based Training

Instructor-led Training (ILT)

- 2 Project Level, Traffic, and Climate Inputs
- 3 Materials Inputs
- 4 Flexible Pavement Design
- 5 Rigid Pavement Design
- 6 Hot Topics
- **Review and Final Assessment**

Module Goals

The goals for this module are as follows:

- Explain the principles of the Mechanistic-Empirical Pavement Design Guide (MEPDG) approach and how it differs from empirical methods used in the past
- Explain the interactions between various input parameters, materials properties, pavement layers, and design features as they relate to predicted pavement performance
- Identify the material property inputs to the Pavement ME Design software and how to get them from the laboratory, material catalogs, or national sources of input values
- Analyze the sensitivity of various materials inputs to understand their impact on predicted pavement performance
- Describe the relationship between the Pavement ME Design software inputs and predicted performance and note any known limitations in the software prediction models, particularly those that relate to materials
- Explain the difference between level 1, 2, and 3 inputs and their impact on the design/performance

Learning Outcomes

Lesson 1: Introduction

- LO 1.1: List the basic factors required in designing a pavement structure
- LO 1.2: Compare mixture design and pavement design related to materials in terms of predicted pavement performance
- LO 1.3: Distinguish between empirical and mechanistic empirical design methods
- LO 1.4: List the factors that may affect the predicted performance of pavements in Pavement ME Design
- LO 1.5: Describe the steps of a Pavement ME Design analysis
- LO 1.6: Describe the iterative design process used with Pavement ME Design software
- LO 1.7: Describe the performance parameters analyzed by Pavement ME Design software
- LO 1.8: Explain how pavement prediction models from Pavement ME Design are being incorporated into the evaluation of asphalt and concrete paving mixtures
- LO 1.9: Using an example, identify important considerations for pavement design

Lesson 2: Project Level, Traffic, and Climate Inputs
- LO 2.1: Explain the approach to setting appropriate performance thresholds in the Pavement ME Design software through consultation with the individual agency’s pavement policy
- LO 2.2: Identify the approach for setting the trial pavement structure
- LO 2.3: Explain why the Pavement ME Design offers input options to the user and provide examples of the differences between input levels
- LO 2.4: Select traffic inputs that are commensurate with the roadway functional class
- LO 2.5: List options for selecting weather stations and depth to groundwater table

Lesson 3: Materials Inputs
- LO 3.1: Identify the properties of unbound materials for use in pavement structural design
- LO 3.2: Determine properties of untreated granular layers
- LO 3.3: Determine properties of treated/stabilized base and subbase layers
- LO 3.4: Identify properties required for different input levels for asphalt layers
- LO 3.5: Identify properties required for different input levels for concrete layers
- LO 3.6: Distinguish differing inputs and features of CRCP versus JPCP
- LO 3.7: Define the materials properties for assessing the existing pavement as part of a rehabilitation pavement design
- LO 3.8: Define design reliability
- LO 3.9: Name five aspects of variability in the factors that affect pavement performance

Lesson 4: Flexible Pavement Design
- LO 4.1: Perform an evaluation of completed Pavement ME Design new flexible pavement designs
- LO 4.2: Perform an evaluation of completed Pavement ME Design rehabilitation flexible pavement designs

Lesson 5: Rigid Pavement Design
- LO 5.1: Perform an evaluation of a completed Pavement ME Design new rigid pavement design
- LO 5.2: Perform an evaluation of a completed Pavement ME Design rehabilitation rigid pavement design

Lesson 6: Hot Topics
- LO 6.1: Describe the challenges of pavement analysis and design
- LO 6.2: Evaluate the limitations of the Pavement ME Design software for pavement design or rehabilitation
- LO 6.3: Discuss emerging trends, new technology, and issues related to pavement design

ILT Instruction Icons

The following icons are used on the slides as a cue to the instructor and participants:

Icon	Icon Name	Typical Use
⏰	Timer	▪ Call out the estimated time for the lesson
⚠ ℹ	Important Information	▪ Call out important information.
Q&A	Q & A	▪ Check for understanding or agreement. ▪ Survey participants. ▪ Solicit feedback.
⤡	Breakout/Small Group Exercise	▪ Break participants into groups. ▪ Provide directions for exercise.
🎥	Video/Sound	▪ Show a video.
📓	Reference	▪ Reference another document or resource.
🔗	Links	▪ Share a Web link for additional resources.
✎	Whiteboard	▪ Draw or document something on a whiteboard or easel pad.

Icon	Icon Name	Typical Use
SAFETY	Safety	▪ Call out important safety information.
COMMON ERROR	Common Error	▪ Call out a system or process that is often misused.

Slide 1

ILT

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Highway Materials Engineering Course

Lesson 2: Project Level, Traffic, and Climate Inputs

Mechanistic Empirical Pavement Design Guide (MEPDG)

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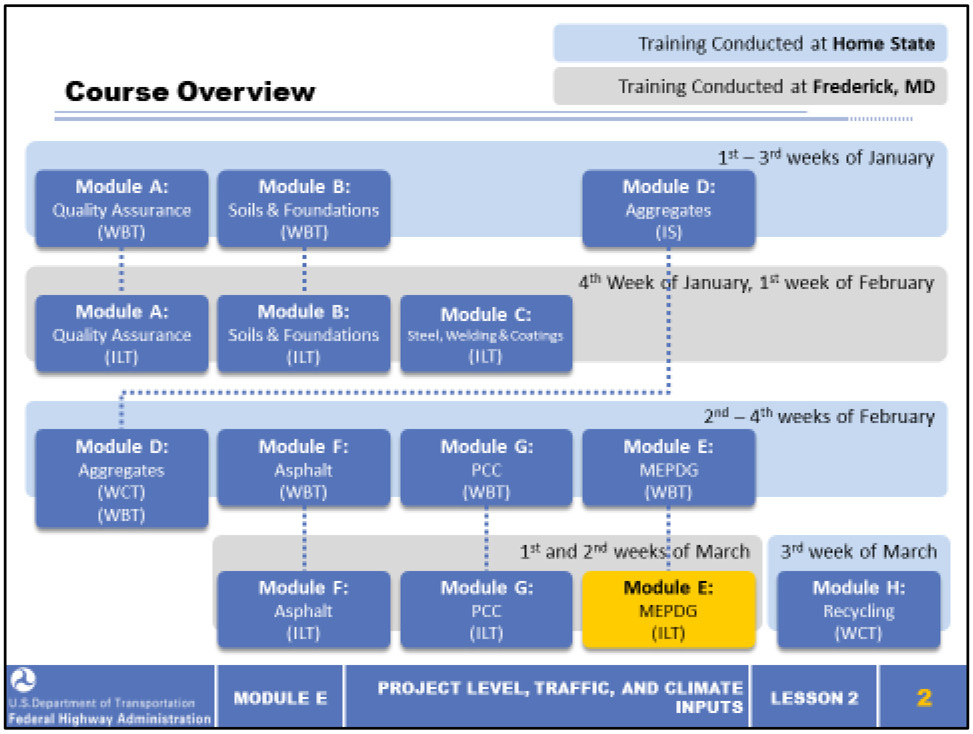
Federal Highway Administration

MODULE

E

Slide 2



Training Conducted at **Home State**

Training Conducted at **Frederick, MD**

Course Overview

1st – 3rd weeks of January

Module A: Quality Assurance (WBT)

Module B: Soils & Foundations (WBT)

Module D: Aggregates (IS)

4th Week of January, 1st week of February

Module A: Quality Assurance (ILT)

Module B: Soils & Foundations (ILT)

Module C: Steel, Welding & Coatings (ILT)

2nd – 4th weeks of February

Module D: Aggregates (WCT) (WBT)

Module F: Asphalt (WBT)

Module G: PCC (WBT)

Module E: MEPDG (WBT)

1st and 2nd weeks of March

Module F: Asphalt (ILT)

Module G: PCC (ILT)

Module E: MEPDG (ILT)

3rd week of March

Module H: Recycling (WCT)

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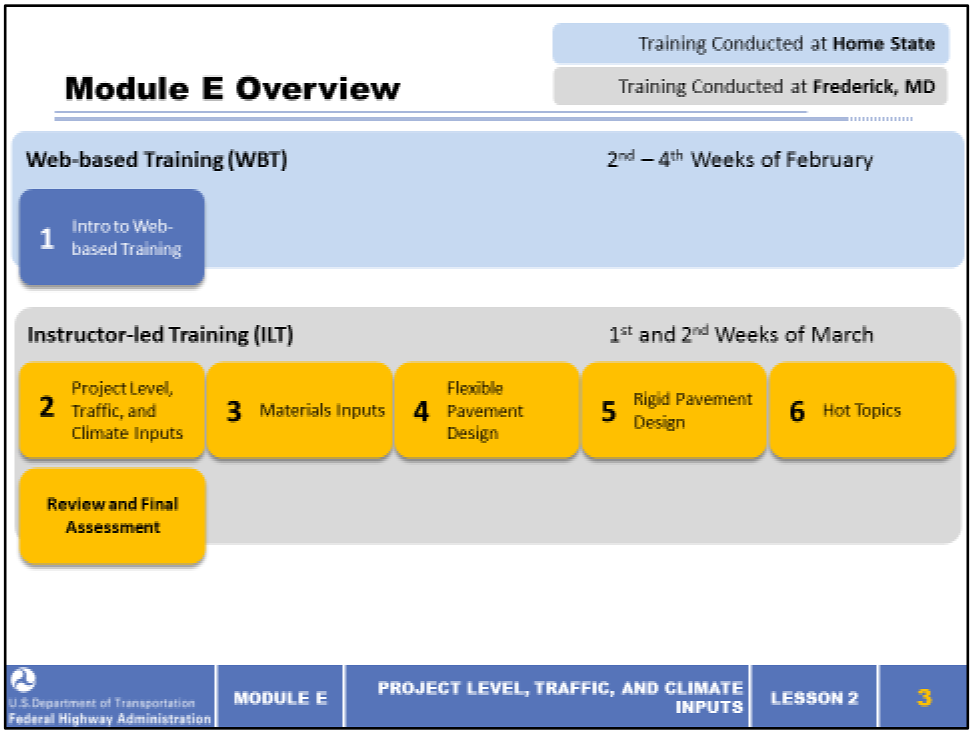
Federal Highway Administration

MODULE E | PROJECT LEVEL, TRAFFIC, AND CLIMATE INPUTS | LESSON 2 | 2

Slide 3



Training Conducted at **Home State**

Training Conducted at **Frederick, MD**

Module E Overview

Web-based Training (WBT) — 2^{nd} – 4^{th} Weeks of February

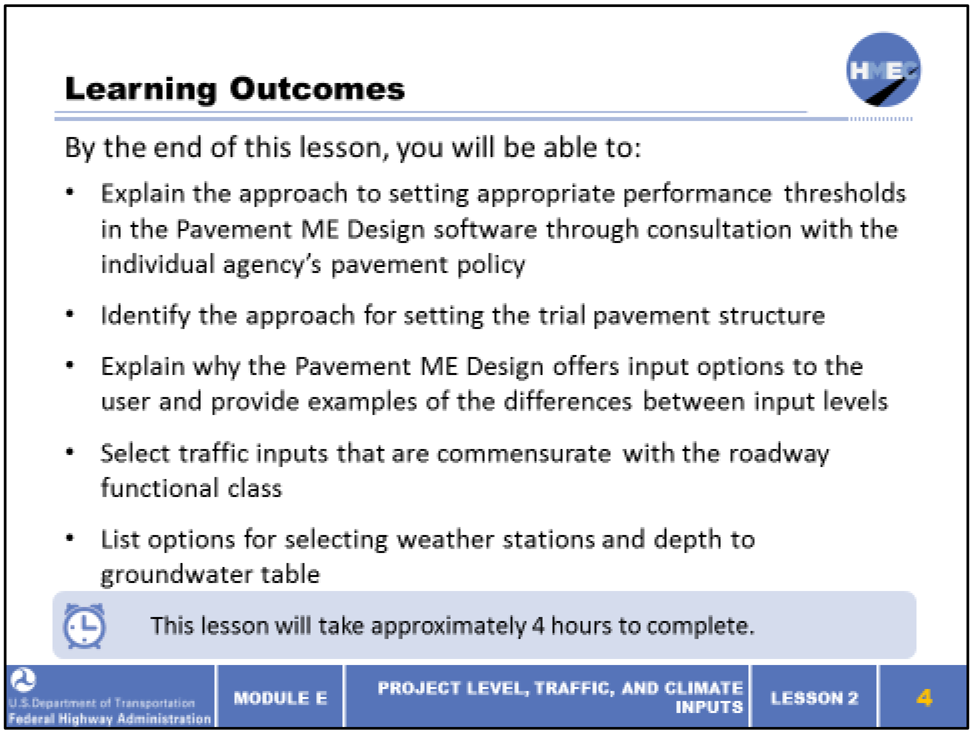
- 1 Intro to Web-based Training

Instructor-led Training (ILT) — 1^{st} and 2^{nd} Weeks of March

- 2 Project Level, Traffic, and Climate Inputs
- 3 Materials Inputs
- 4 Flexible Pavement Design
- 5 Rigid Pavement Design
- 6 Hot Topics
- **Review and Final Assessment**

U.S. Department of Transportation Federal Highway Administration | MODULE E | PROJECT LEVEL, TRAFFIC, AND CLIMATE INPUTS | LESSON 2 | 3

Slide 4



Learning Outcomes

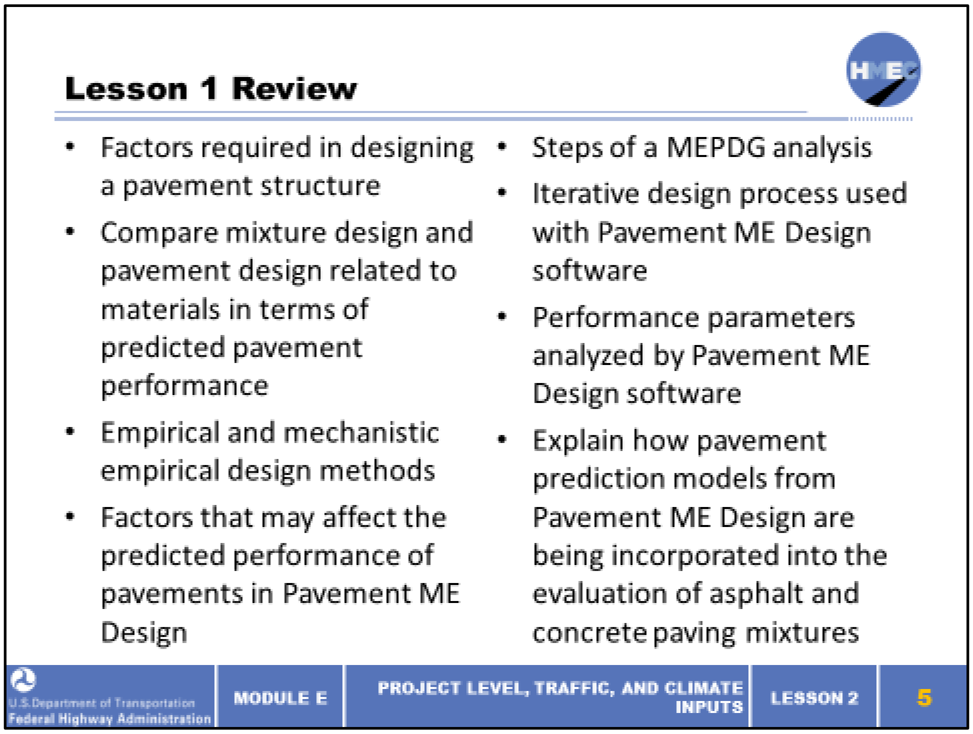
By the end of this lesson, you will be able to:

- Explain the approach to setting appropriate performance thresholds in the Pavement ME Design software through consultation with the individual agency's pavement policy
- Identify the approach for setting the trial pavement structure
- Explain why the Pavement ME Design offers input options to the user and provide examples of the differences between input levels
- Select traffic inputs that are commensurate with the roadway functional class
- List options for selecting weather stations and depth to groundwater table

This lesson will take approximately 4 hours to complete.

U.S. Department of Transportation
Federal Highway Administration
MODULE E
PROJECT LEVEL, TRAFFIC, AND CLIMATE INPUTS
LESSON 2
4

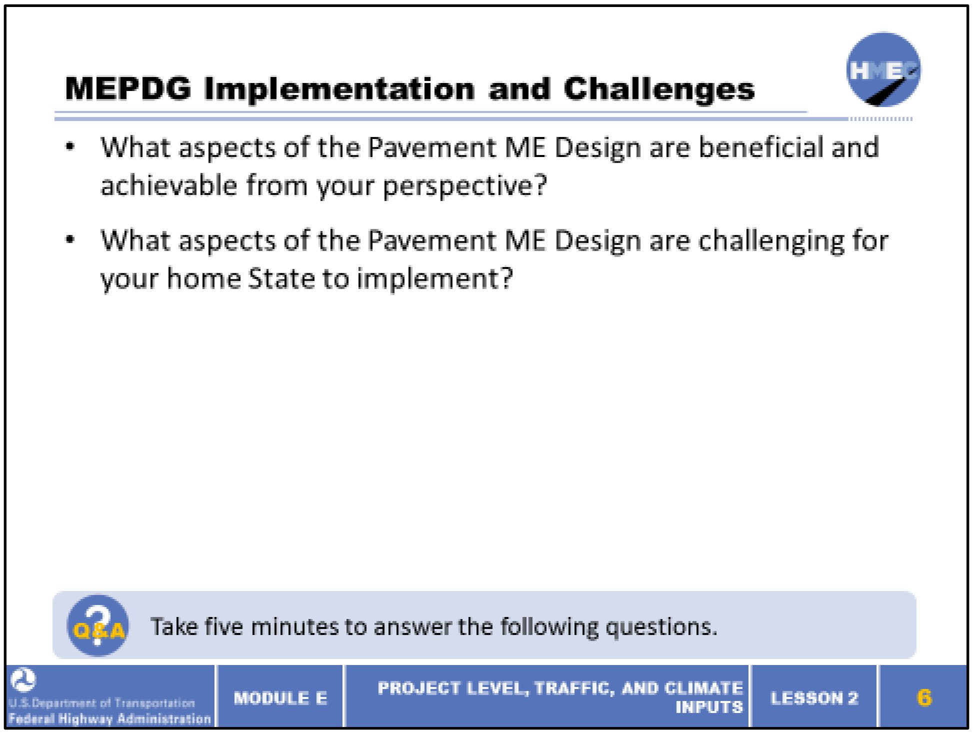
Slide 5



Lesson 1 Review

- Factors required in designing a pavement structure
- Compare mixture design and pavement design related to materials in terms of predicted pavement performance
- Empirical and mechanistic empirical design methods
- Factors that may affect the predicted performance of pavements in Pavement ME Design
- Steps of a MEPDG analysis
- Iterative design process used with Pavement ME Design software
- Performance parameters analyzed by Pavement ME Design software
- Explain how pavement prediction models from Pavement ME Design are being incorporated into the evaluation of asphalt and concrete paving mixtures

Slide 6



MEPDG Implementation and Challenges

- What aspects of the Pavement ME Design are beneficial and achievable from your perspective?
- What aspects of the Pavement ME Design are challenging for your home State to implement?

Take five minutes to answer the following questions.

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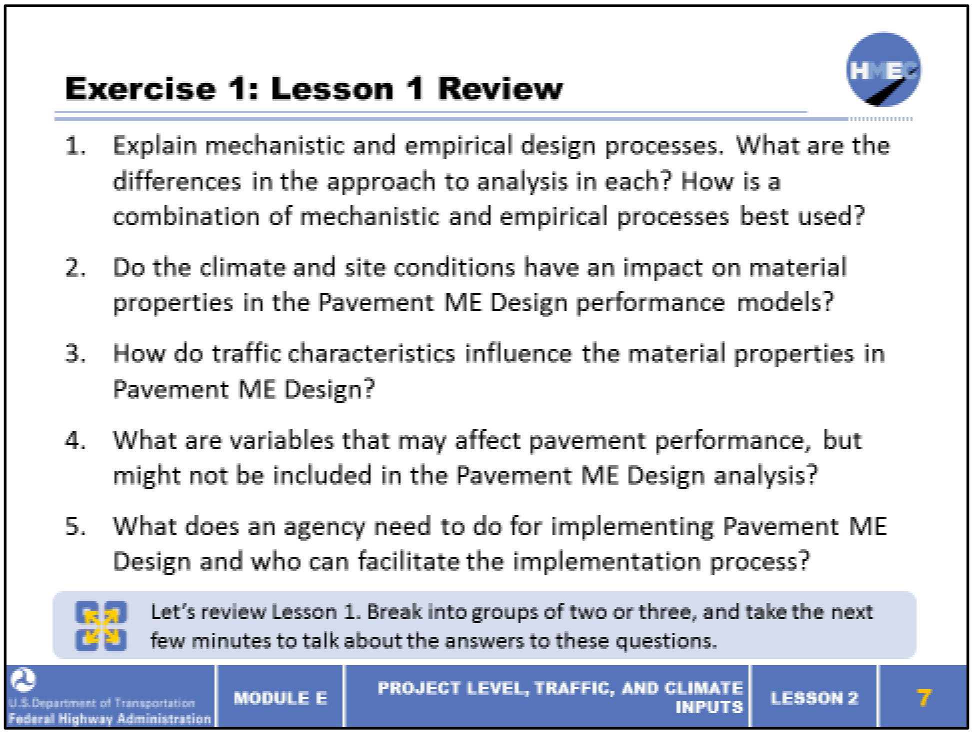
Slide 7



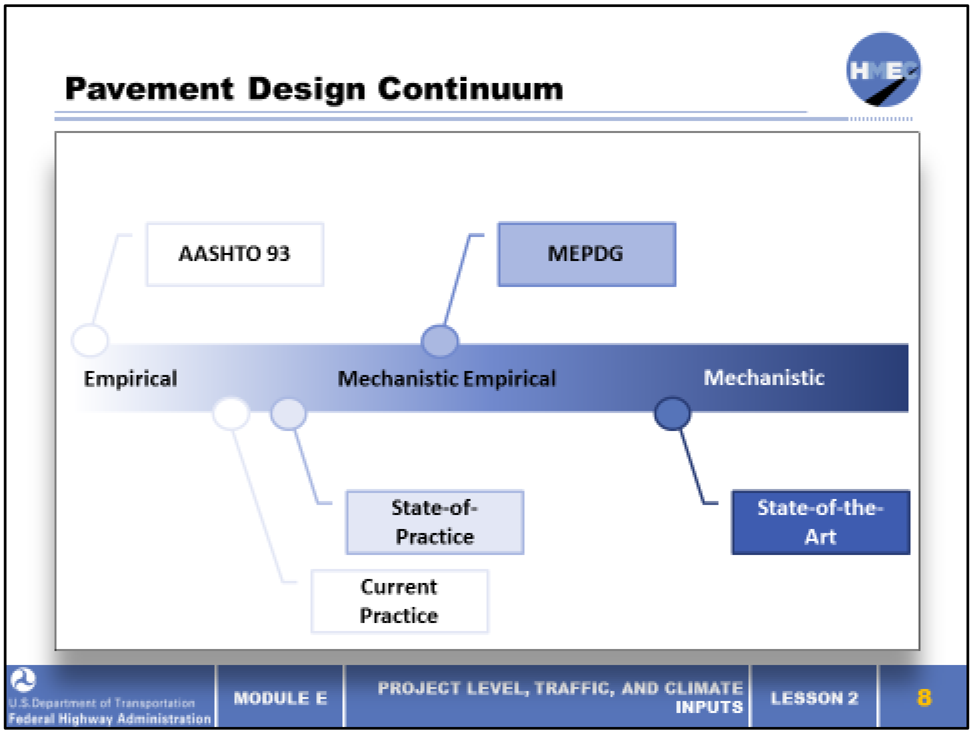
Exercise 1: Lesson 1 Review

1. Explain mechanistic and empirical design processes. What are the differences in the approach to analysis in each? How is a combination of mechanistic and empirical processes best used?
2. Do the climate and site conditions have an impact on material properties in the Pavement ME Design performance models?
3. How do traffic characteristics influence the material properties in Pavement ME Design?
4. What are variables that may affect pavement performance, but might not be included in the Pavement ME Design analysis?
5. What does an agency need to do for implementing Pavement ME Design and who can facilitate the implementation process?

Let's review Lesson 1. Break into groups of two or three, and take the next few minutes to talk about the answers to these questions.

U.S. Department of Transportation Federal Highway Administration | MODULE E | PROJECT LEVEL, TRAFFIC, AND CLIMATE INPUTS | LESSON 2 | 7

Slide 8



Pavement Design Continuum

AASHTO 93

MEPDG

Empirical

Mechanistic Empirical

Mechanistic

State-of-Practice

State-of-the-Art

Current Practice

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MODULE E

PROJECT LEVEL, TRAFFIC, AND CLIMATE INPUTS

LESSON 2

8

This continuum qualitatively summarizes pavement design practice as it exists today. Note the distance between the current practice and state-of-practice and between the state-of-practice and state-of-the-art. Most agencies (approximately 90%) currently use AASHTO-based empirical design procedures (72, 86, or 93). The state-of-practice is the most advanced practice being used by DOTs at this point (some use mechanistic empirical design). The state-of-the-art is where current research activities in pavement design are leading us.

Recall the empirical design (such as the AASHTO 1993 version) is based on statistical models from road tests. Then, mechanistic empirical design includes the calculation of stresses/strains combined with empirical pavement performance models, like the MEPDG approach.

Finally, a mechanistic design would include mechanistic-based pavement performance models and is the area in the continuum where researchers are pushing forward toward for the future of pavement design.

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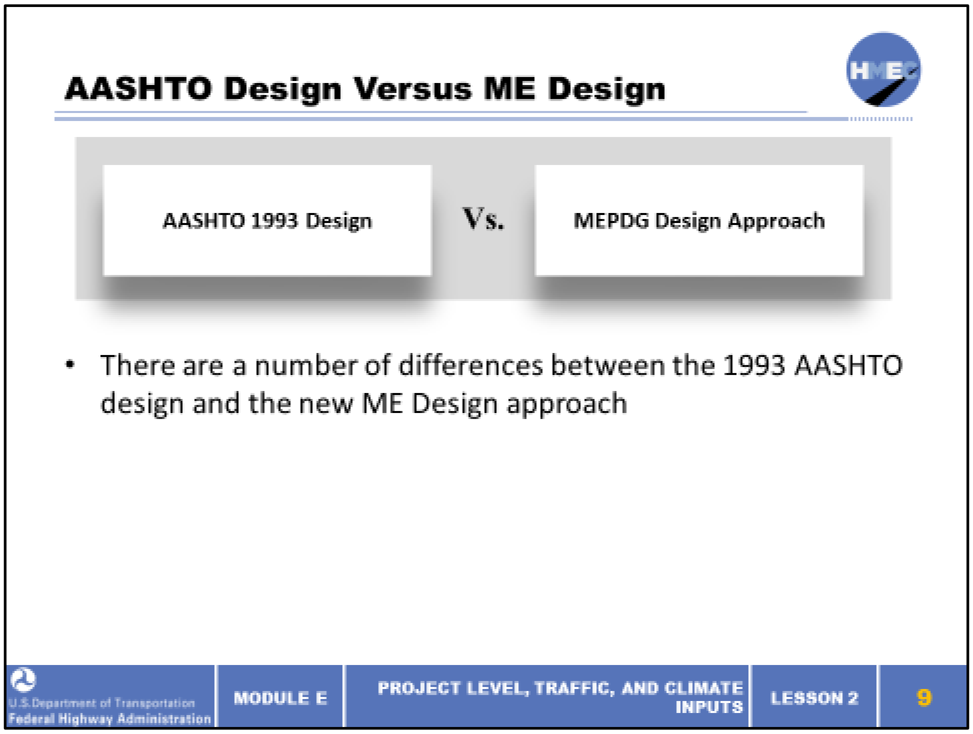
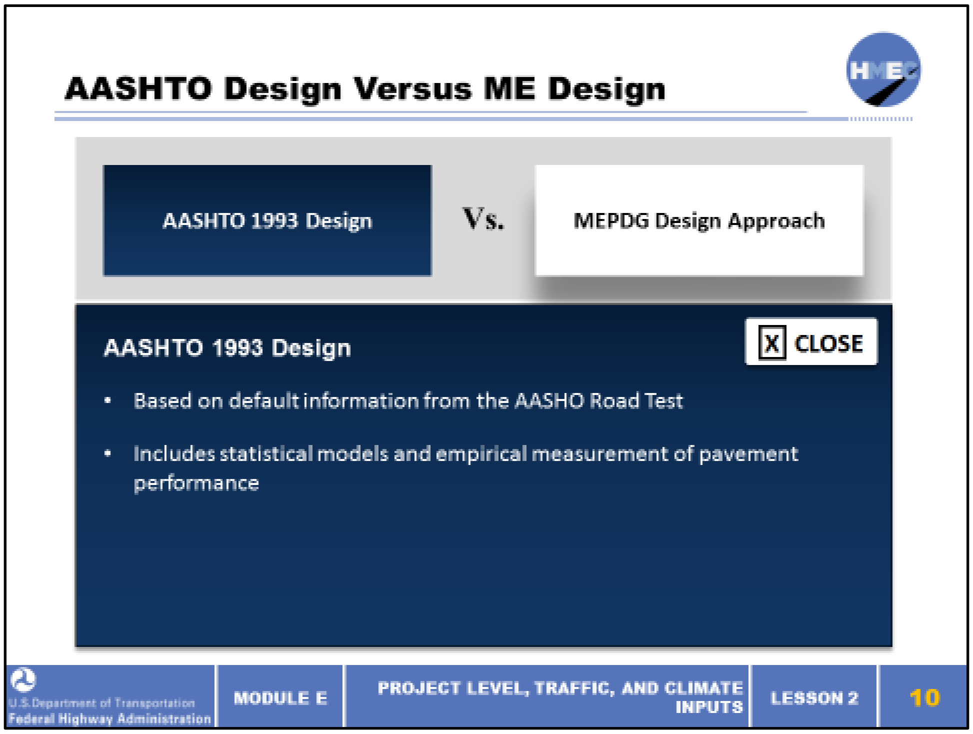


AASHTO Design Versus ME Design

AASHTO 1993 Design Vs. MEPDG Design Approach

- There are a number of differences between the 1993 AASHTO design and the new ME Design approach

Slide 10



AASHTO Design Versus ME Design

AASHTO 1993 Design Vs. MEPDG Design Approach

AASHTO 1993 Design

☒ CLOSE

- Based on default information from the AASHO Road Test
- Includes statistical models and empirical measurement of pavement performance

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Federal Highway Administration
MODULE E
PROJECT LEVEL, TRAFFIC, AND CLIMATE INPUTS
LESSON 2
10

The AASHTO 1993 design is based on field measurements and observations taken from the AASHO Road Test, which were then used to create empirical models including statistical correlations. The AASHTO 1993 design further refined the statistical models and empirical measurements for use as inputs in the estimation of pavement performance and calculation of required pavement layer thicknesses.

One of the major differences in the two approaches is how the traffic loads are characterized. The AASHTO 1993 design is still founded on the traffic loads originally modeled from the AASHO Road Test.

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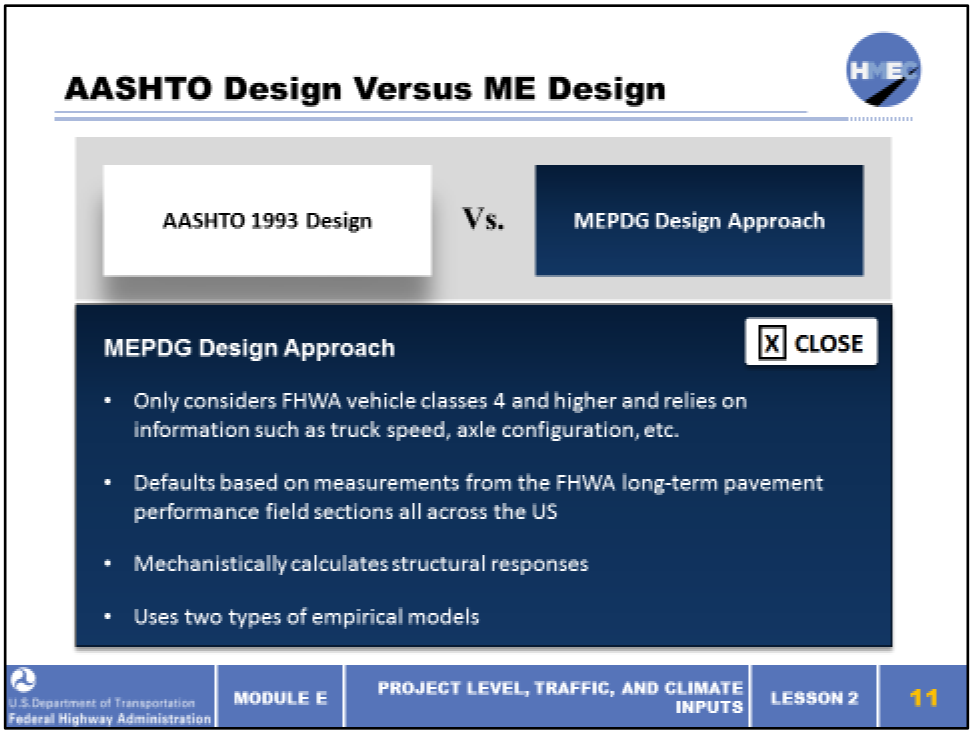
Slide 11



AASHTO Design Versus ME Design

AASHTO 1993 Design

Vs.

MEPDG Design Approach

MEPDG Design Approach

☒ CLOSE

- Only considers FHWA vehicle classes 4 and higher and relies on information such as truck speed, axle configuration, etc.
- Defaults based on measurements from the FHWA long-term pavement performance field sections all across the US
- Mechanistically calculates structural responses
- Uses two types of empirical models

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Federal Highway Administration

MODULE E

PROJECT LEVEL, TRAFFIC, AND CLIMATE INPUTS

LESSON 2

11

One of the major differences in design approach lies in how traffic loads are characterized. The ME approach only considers FHWA vehicle classes 4 and higher and relies on information such as truck speed, axle configuration, etc.

ME design defaults are based on measurements from the FHWA long-term pavement performance field sections all across the United States.

Structural responses (stresses, strains, and deflections) are mechanistically-calculated in ME design and are based on material properties, environmental conditions, and loading characteristics.

There are two types of empirical models used in the MEPDG. One model predicts the distress directly (e.g., rutting model for flexible pavements, and faulting for rigid pavements). A second model predicts the damage, which is then calibrated against measured field distress (for example, fatigue cracking for flexible pavements and punch outs for continuously reinforced rigid pavements).

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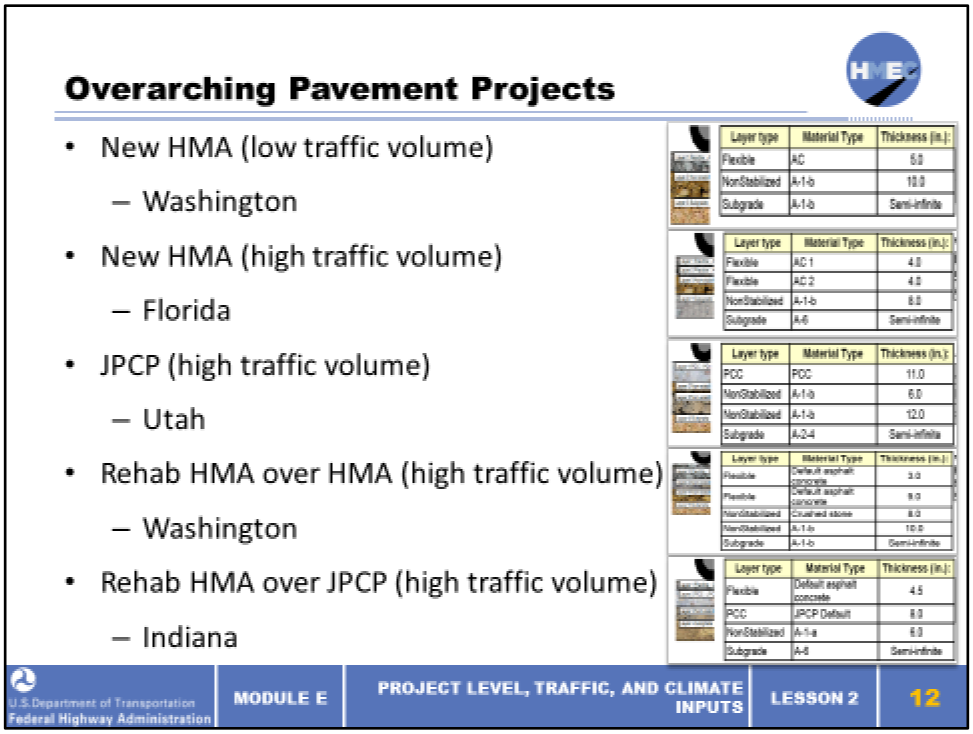
Slide 12



Overarching Pavement Projects

- New HMA (low traffic volume)
  - Washington
- New HMA (high traffic volume)
  - Florida
- JPCP (high traffic volume)
  - Utah
- Rehab HMA over HMA (high traffic volume)
  - Washington
- Rehab HMA over JPCP (high traffic volume)
  - Indiana

Layer type	Material Type	Thickness (in.):
Flexible	AC	5.0
NonStabilized	A-1-b	10.0
Subgrade	A-1-b	Semi-infinite

Layer type	Material Type	Thickness (in.):
Flexible	AC 1	4.0
Flexible	AC 2	4.0
NonStabilized	A-1-b	8.0
Subgrade	A-6	Semi-infinite

Layer type	Material Type	Thickness (in.):
PCC	PCC	11.0
NonStabilized	A-1-b	6.0
NonStabilized	A-1-b	12.0
Subgrade	A-2-4	Semi-infinite

Layer type	Material Type	Thickness (in.):
Flexible	Default asphalt concrete	3.0
Flexible	Default asphalt concrete	9.0
NonStabilized	Crushed stone	8.0
NonStabilized	A-1-b	10.0
Subgrade	A-1-b	Semi-infinite

Layer type	Material Type	Thickness (in.):
Flexible	Default asphalt concrete	4.5
PCC	JPCP Default	8.0
NonStabilized	A-1-a	6.0
Subgrade	A-6	Semi-infinite

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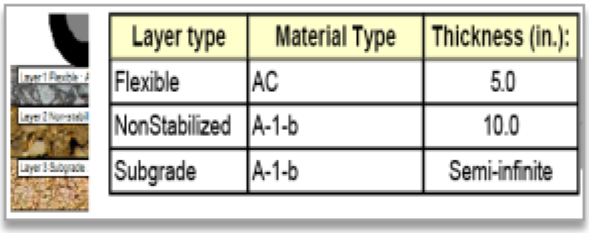
Federal Highway Administration

MODULE E

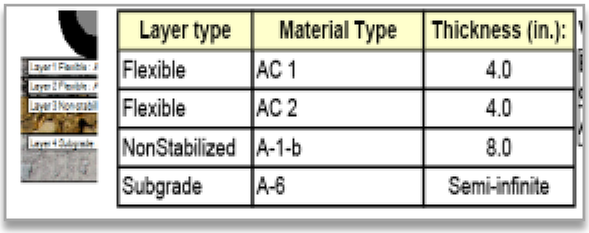
PROJECT LEVEL, TRAFFIC, AND CLIMATE INPUTS

LESSON 2

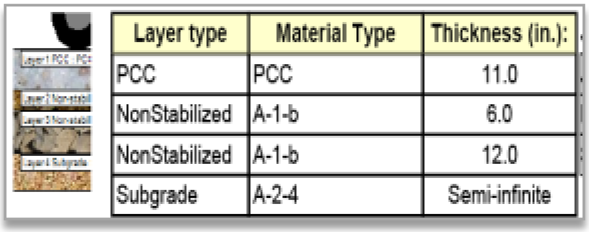
12



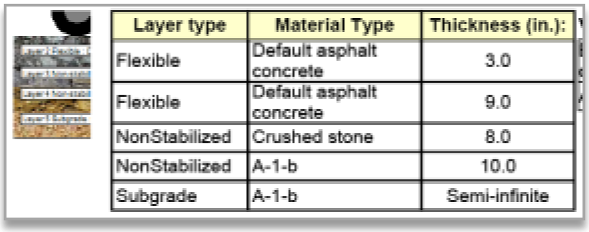
Layer type	Material Type	Thickness (in.):
Flexible	AC	5.0
NonStabilized	A-1-b	10.0
Subgrade	A-1-b	Semi-infinite



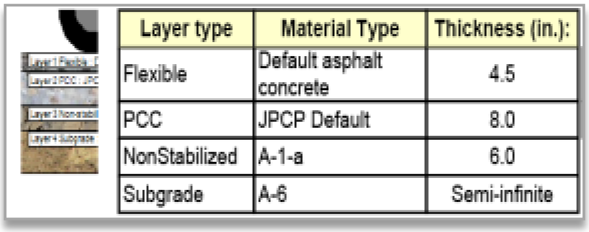
Layer type	Material Type	Thickness (in.):
Flexible	AC 1	4.0
Flexible	AC 2	4.0
NonStabilized	A-1-b	8.0
Subgrade	A-6	Semi-infinite



Layer type	Material Type	Thickness (in.):
PCC	PCC	11.0
NonStabilized	A-1-b	6.0
NonStabilized	A-1-b	12.0
Subgrade	A-2-4	Semi-infinite



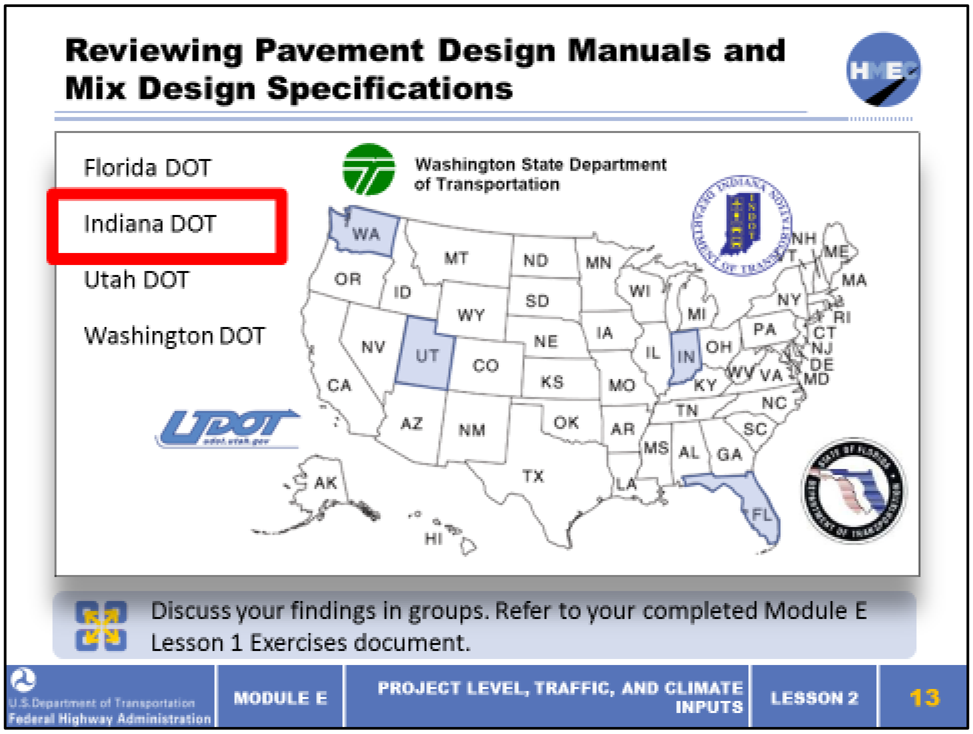
Layer type	Material Type	Thickness (in.):
Flexible	Default asphalt concrete	3.0
Flexible	Default asphalt concrete	9.0
NonStabilized	Crushed stone	8.0
NonStabilized	A-1-b	10.0
Subgrade	A-1-b	Semi-infinite



Layer type	Material Type	Thickness (in.):
Flexible	Default asphalt concrete	4.5
PCC	JPCP Default	8.0
NonStabilized	A-1-a	6.0
Subgrade	A-6	Semi-infinite

These sample pavement projects were selected from LTPP sections nearby or in each of these States and were intended to represent a range of pavement design types and truck traffic volumes. In this module, we will focus primarily on these types of pavement designs, although we will also explore the CRCP pavement later on in Lesson 5.

Slide 13



Reviewing Pavement Design Manuals and Mix Design Specifications

Florida DOT

Indiana DOT

Utah DOT

Washington DOT

Washington State Department of Transportation

Discuss your findings in groups. Refer to your completed Module E Lesson 1 Exercises document.

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MODULE E

PROJECT LEVEL, TRAFFIC, AND CLIMATE INPUTS

LESSON 2

13

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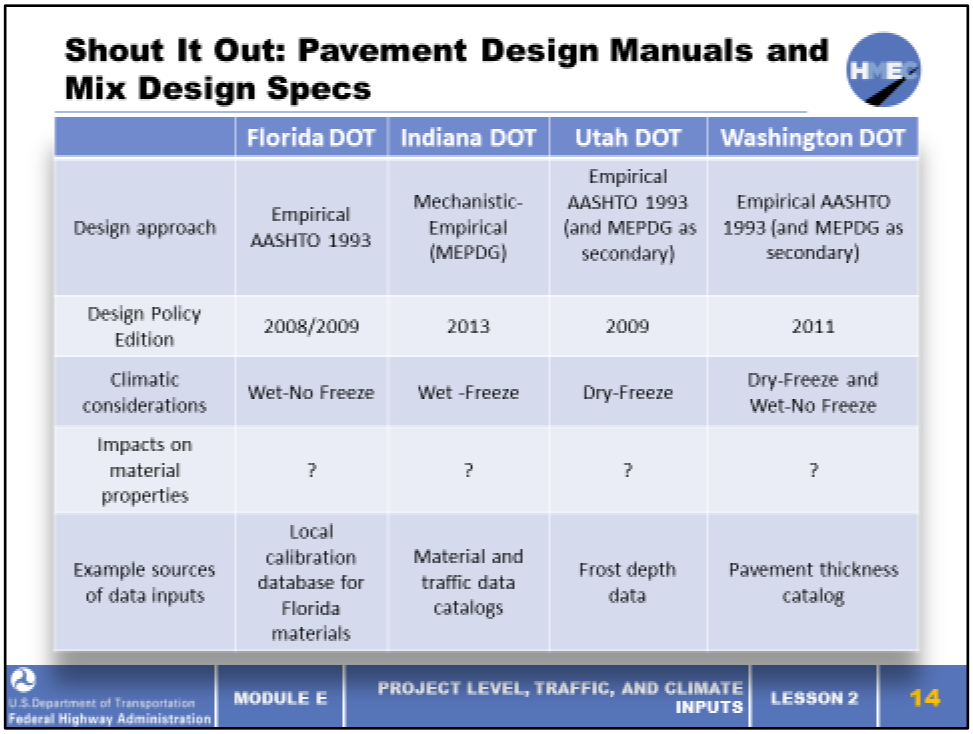
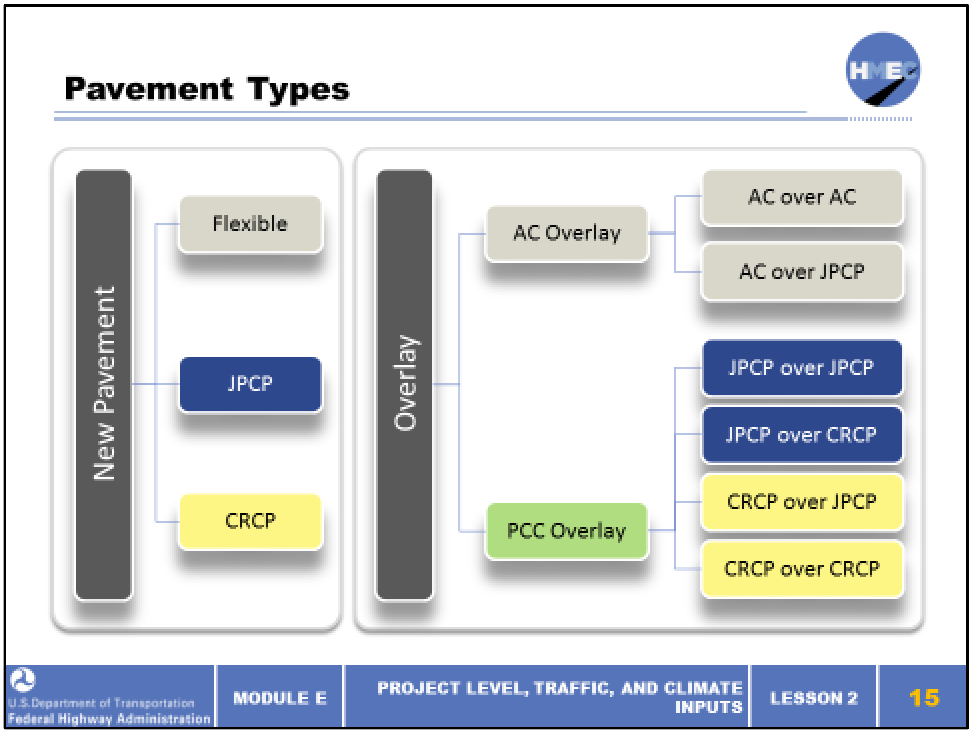
Slide 14



Shout It Out: Pavement Design Manuals and Mix Design Specs

	Florida DOT	Indiana DOT	Utah DOT	Washington DOT
Design approach	Empirical AASHTO 1993	Mechanistic-Empirical (MEPDG)	Empirical AASHTO 1993 (and MEPDG as secondary)	Empirical AASHTO 1993 (and MEPDG as secondary)
Design Policy Edition	2008/2009	2013	2009	2011
Climatic considerations	Wet-No Freeze	Wet -Freeze	Dry-Freeze	Dry-Freeze and Wet-No Freeze
Impacts on material properties	?	?	?	?
Example sources of data inputs	Local calibration database for Florida materials	Material and traffic data catalogs	Frost depth data	Pavement thickness catalog

Slide 15



Pavement Types

New Pavement
- Flexible
- JPCP
- CRCP

Overlay
- AC Overlay
  - AC over AC
  - AC over JPCP
- PCC Overlay
  - JPCP over JPCP
  - JPCP over CRCP
  - CRCP over JPCP
  - CRCP over CRCP

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MODULE E
PROJECT LEVEL, TRAFFIC, AND CLIMATE INPUTS
LESSON 2
15

This slide shows both the new flexible and new rigid pavement types that can be analyzed in the Pavement ME Design software. The right side of the slide introduces the types of overlays (of existing flexible or existing rigid pavements) that can be analyzed in the software.

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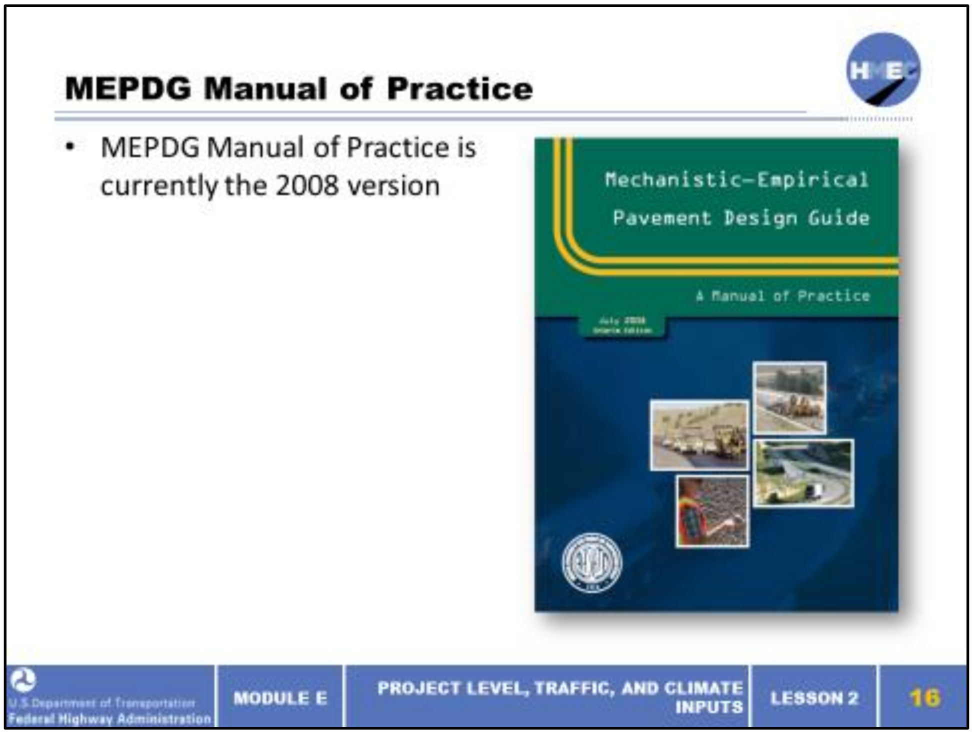


MEPDG Manual of Practice

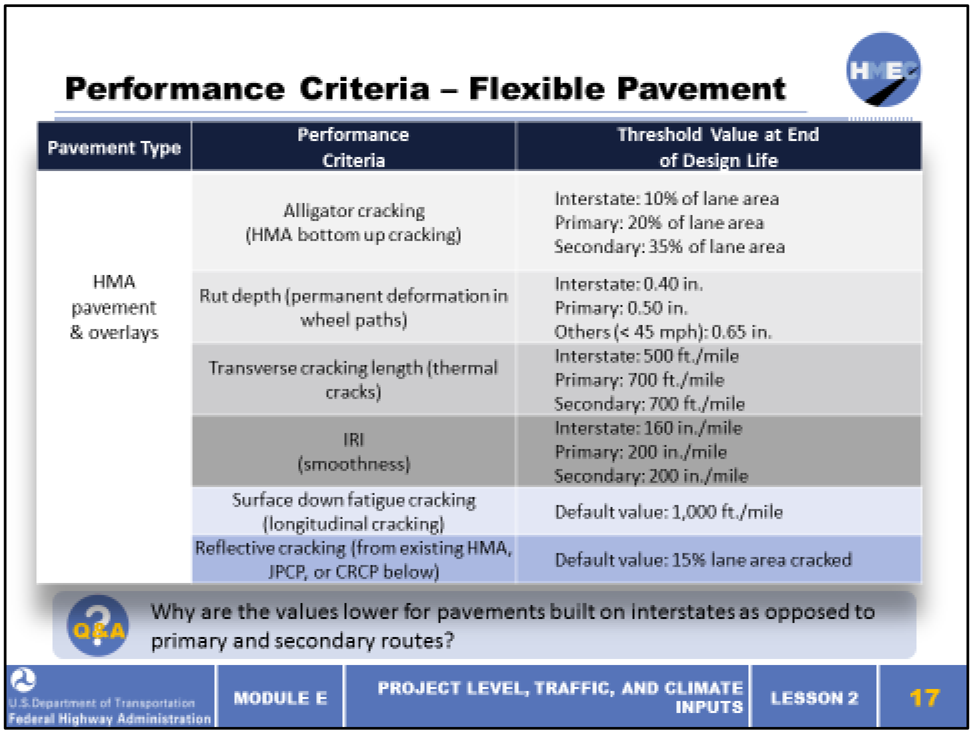
- MEPDG Manual of Practice is currently the 2008 version

Mechanistic-Empirical
Pavement Design Guide
A Manual of Practice

U.S. Department of Transportation Federal Highway Administration | MODULE E | PROJECT LEVEL, TRAFFIC, AND CLIMATE INPUTS | LESSON 2 | 16

The MEPDG Manual of Practice is currently still the 2008 version.

Slide 17



Performance Criteria – Flexible Pavement

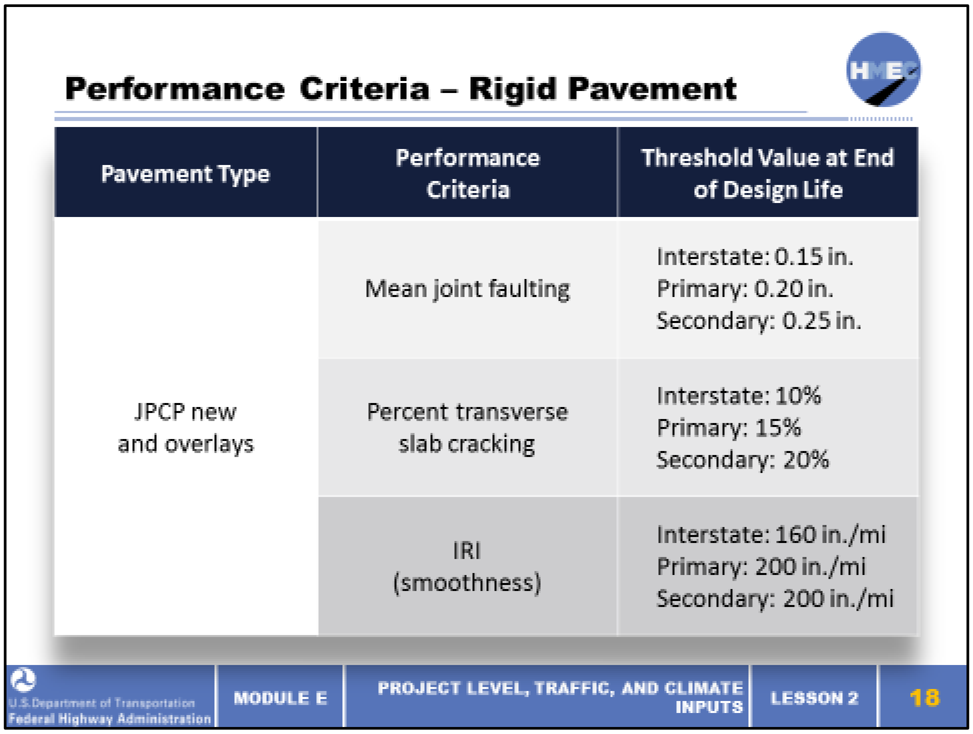
Pavement Type	Performance Criteria	Threshold Value at End of Design Life
HMA pavement & overlays	Alligator cracking (HMA bottom up cracking)	Interstate: 10% of lane area Primary: 20% of lane area Secondary: 35% of lane area
	Rut depth (permanent deformation in wheel paths)	Interstate: 0.40 in. Primary: 0.50 in. Others (< 45 mph): 0.65 in.
	Transverse cracking length (thermal cracks)	Interstate: 500 ft./mile Primary: 700 ft./mile Secondary: 700 ft./mile
	IRI (smoothness)	Interstate: 160 in./mile Primary: 200 in./mile Secondary: 200 in./mile
	Surface down fatigue cracking (longitudinal cracking)	Default value: 1,000 ft./mile
	Reflective cracking (from existing HMA, JPCP, or CRCP below)	Default value: 15% lane area cracked

Q&A Why are the values lower for pavements built on interstates as opposed to primary and secondary routes?

These values are based on the functional classification of the roadway. This table introduces the performance criteria (damage types) and the recommended terminal distress threshold values for flexible pavements and flexible overlays of existing flexible pavements.

The threshold values increase as you go from an interstate type pavement down to a secondary roadway because you are willing to allow more damage to build up before you are in need of scheduling pavement repairs. Part of the reason is that vehicles travel much faster speeds on interstate facilities (so there is a safety element) and also, it costs both the users and the agencies much more $ to set up a work zone on an interstate to make pavement repairs, as opposed to on the lower functional class roadways.

Slide 18



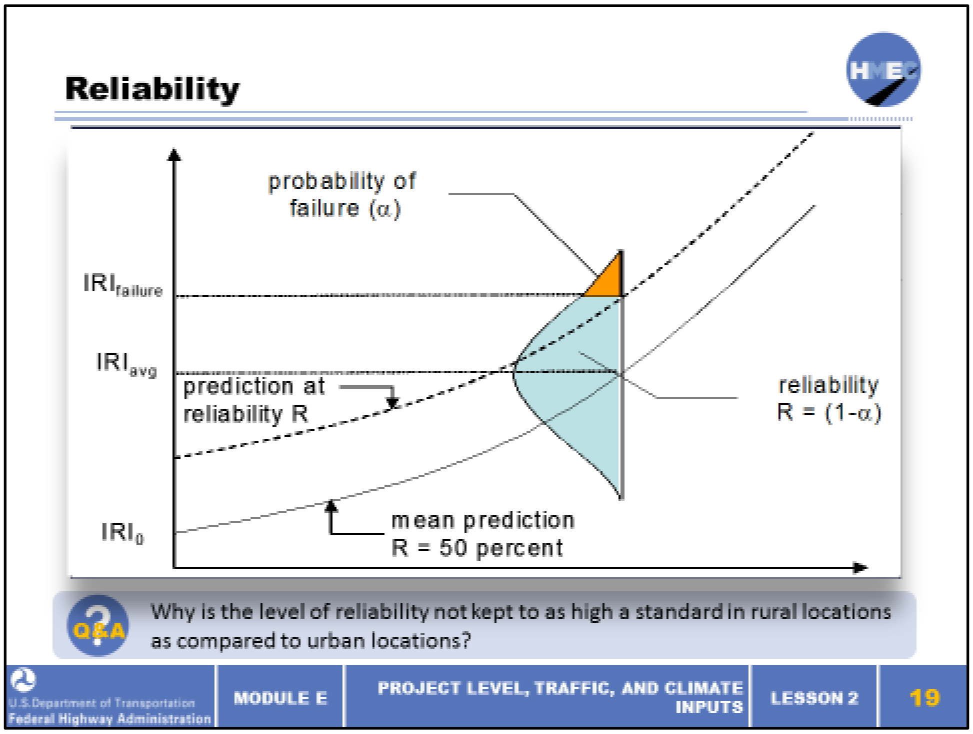
Performance Criteria – Rigid Pavement

Pavement Type	Performance Criteria	Threshold Value at End of Design Life
JPCP new and overlays	Mean joint faulting	Interstate: 0.15 in. Primary: 0.20 in. Secondary: 0.25 in.
	Percent transverse slab cracking	Interstate: 10% Primary: 15% Secondary: 20%
	IRI (smoothness)	Interstate: 160 in./mi Primary: 200 in./mi Secondary: 200 in./mi

U.S. Department of Transportation Federal Highway Administration | MODULE E | PROJECT LEVEL, TRAFFIC, AND CLIMATE INPUTS | LESSON 2 | 18

Again, these values are based on the functional classification of the roadway. This table introduces the performance criteria (damage types) and the recommended terminal distress threshold values for rigid pavements, primarily faulting, percent of slabs transverse cracked, and ride quality (International Roughness Index, IRI). The same trend is noted here in terms of how the threshold values increase with the drop in roadway facility level.

Slide 19



Reliability

probability of failure (α)
IRI_failure
IRI_avg
prediction at reliability R
reliability R = (1-α)
IRI_0
mean prediction R = 50 percent

Q&A Why is the level of reliability not kept to as high a standard in rural locations as compared to urban locations?

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Reliability is defined as the probability that the predicted performance indicator of the trial design will not exceed the design criteria within the design-analysis period.

The table shows that not only will the level of reliability (out of 100%) change with a road’s functional classification but also with its location (urban versus rural).

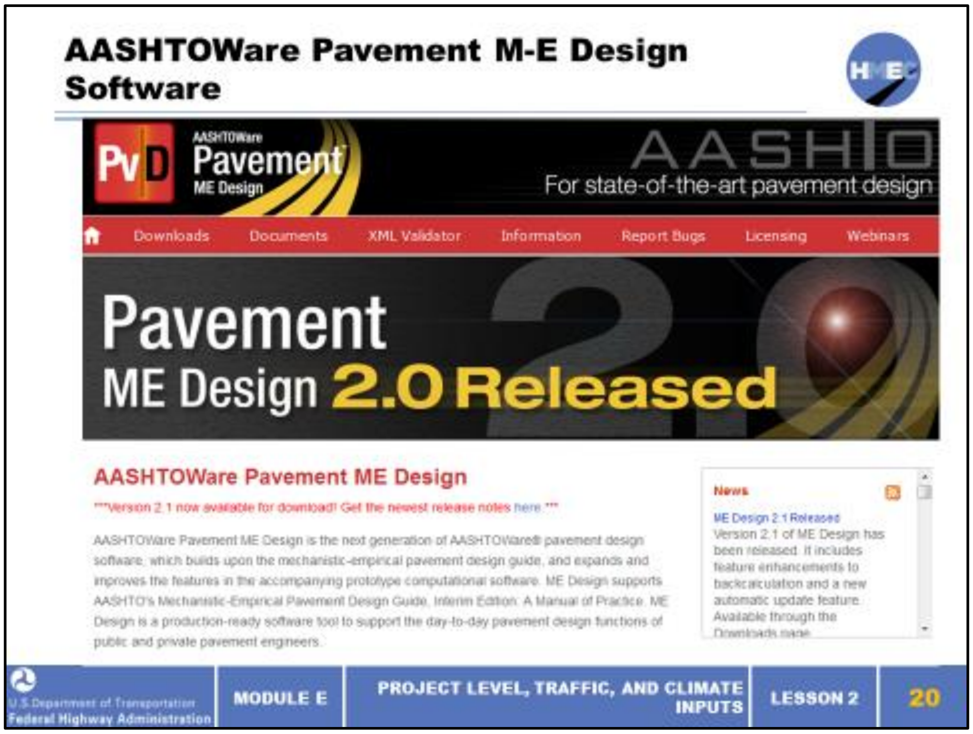
A good way to look at it is to show that 100% - the reliability selected = the risk that a designer is willing to take on a project not reaching its full design life.

The trial design is evaluated for adequacy against user input performance criteria and reliability values through the prediction of distresses and smoothness. If the design does not meet the desired performance criteria at the specified reliability, it is revised and the evaluation process is repeated as necessary.

For example, a design reliability of 90% represents the probability (9 out of 10 projects) that the mean faulting for the project will not exceed the faulting criteria.

Reliability can be selected as a lower value for pavements designed in rural locations since generally they carry less traffic volumes. However, it should be noted that high level reliability is also very conservative in design and tends to result in over-thick pavements. (See graph from the MEPDG Manual of Practice)

Slide 20



AASHTOWare Pavement M-E Design Software

AASHTOWare Pavement ME Design

Version 2.1 now available for download! Get the newest release notes here.

AASHTOWare Pavement ME Design is the next generation of AASHTOWare® pavement design software, which builds upon the mechanistic-empirical pavement design guide, and expands and improves the features in the accompanying prototype computational software. ME Design supports AASHTO's Mechanistic-Empirical Pavement Design Guide, Interim Edition: A Manual of Practice. ME Design is a production-ready software tool to support the day-to-day pavement design functions of public and private pavement engineers.

News

ME Design 2.1 Released

Version 2.1 of ME Design has been released. It includes feature enhancements to backcalculation and a new automatic update feature. Available through the Downloads page

U.S. Department of Transportation
Federal Highway Administration
MODULE E
PROJECT LEVEL, TRAFFIC, AND CLIMATE INPUTS
LESSON 2
20

The AASHTOWare Pavement ME Design Software can be downloaded (with a license) from the AASHTO website and its various release versions are noted in the “News” section on the right-hand side of the screen.

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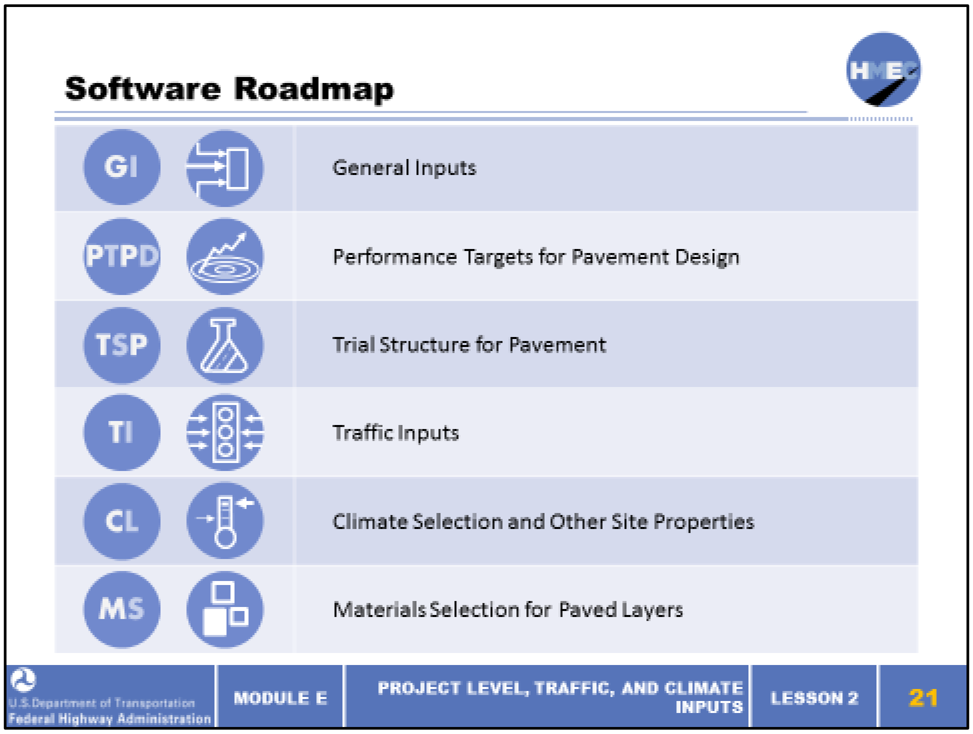
Slide 21



Software Roadmap

GI	General Inputs
PTPD	Performance Targets for Pavement Design
TSP	Trial Structure for Pavement
TI	Traffic Inputs
CL	Climate Selection and Other Site Properties
MS	Materials Selection for Paved Layers

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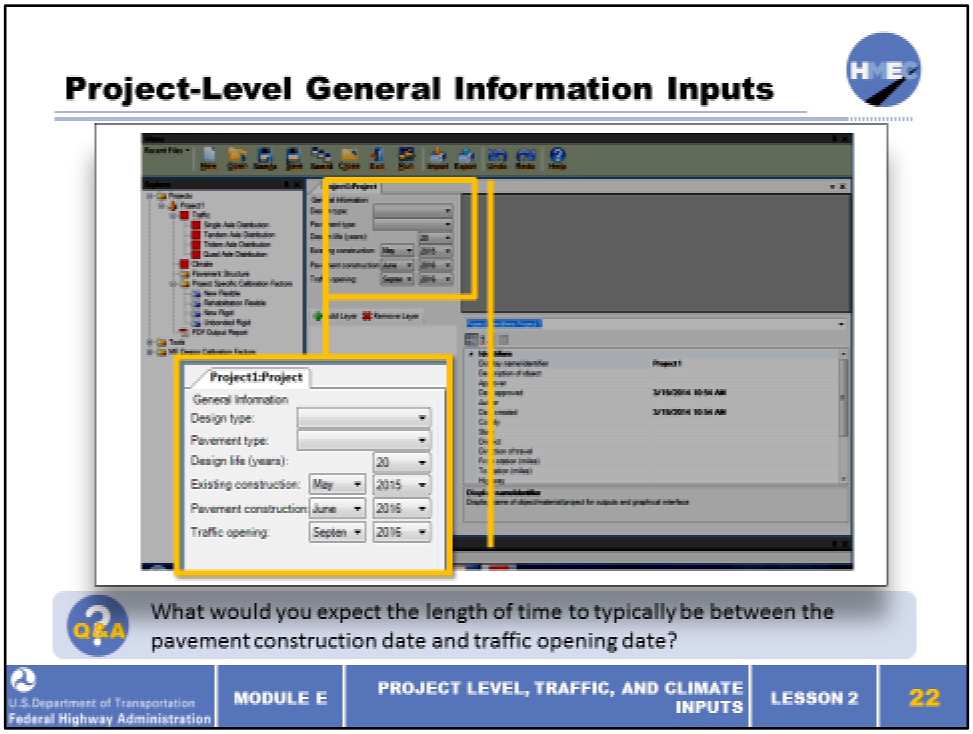
Federal Highway Administration
MODULE E
PROJECT LEVEL, TRAFFIC, AND CLIMATE INPUTS
LESSON 2
21

The AASHTOWare Pavement ME Design Software has six main data entry windows: General inputs, Performance Targets for Pavement Design, Trial Structure for Pavement, Traffic Inputs, Climate Selection and Other Site Properties, and Materials Selection for Paved Layers. Each data entry window provides space to enter data inputs. These will be covered in detail throughout Lessons 2 and 3.

Slide 22



Project-Level General Information Inputs

What would you expect the length of time to typically be between the pavement construction date and traffic opening date?

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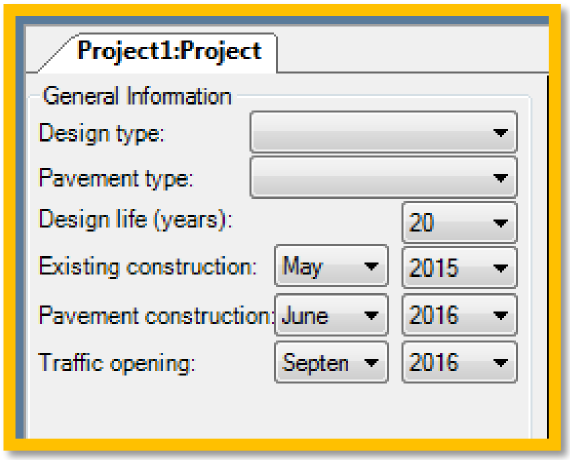
PROJECT LEVEL, TRAFFIC, AND CLIMATE INPUTS
LESSON 2
22



General Information

Design type:

Pavement type:

Design life (years): 20

Existing construction: May 2015

Pavement construction: June 2016

Traffic opening: Septen 2016

The different parts of the General Information to the analysis tool include design life, type of pavement (flexible, rigid, composite), type of design (new versus rehabilitation), and key dates in the phases of the design.

The design life does not consider the potential for intermediate pavement light maintenance or repairs, nor preservation treatments, over the pavement’s service.

Existing construction is defined as the last time the pavement underwent construction or major rehabilitation.

Pavement construction is the date at which the final surface (either asphalt or concrete) will be placed.

Traffic opening is the date at which the maintenance and protection of traffic (effectively, the work zone) will be taken up and traffic will be permitted on the final pavement surface.

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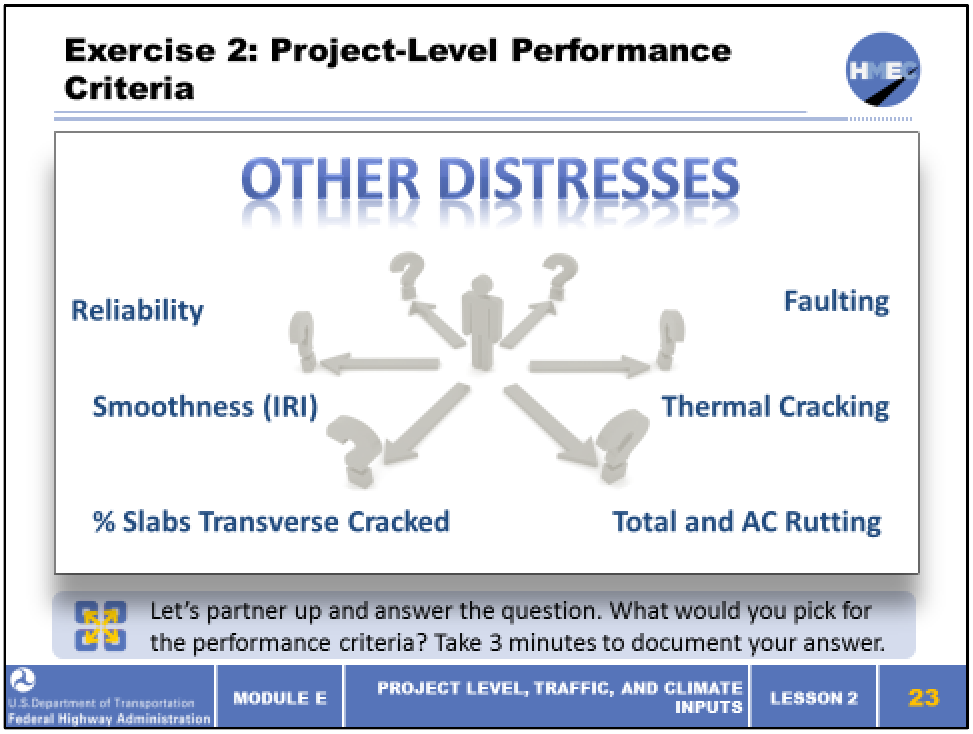
Slide 23



Exercise 2: Project-Level Performance Criteria

OTHER DISTRESSES

Reliability

Faulting

Smoothness (IRI)

Thermal Cracking

% Slabs Transverse Cracked

Total and AC Rutting

Let's partner up and answer the question. What would you pick for the performance criteria? Take 3 minutes to document your answer.

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PROJECT LEVEL, TRAFFIC, AND CLIMATE INPUTS
LESSON 2
23

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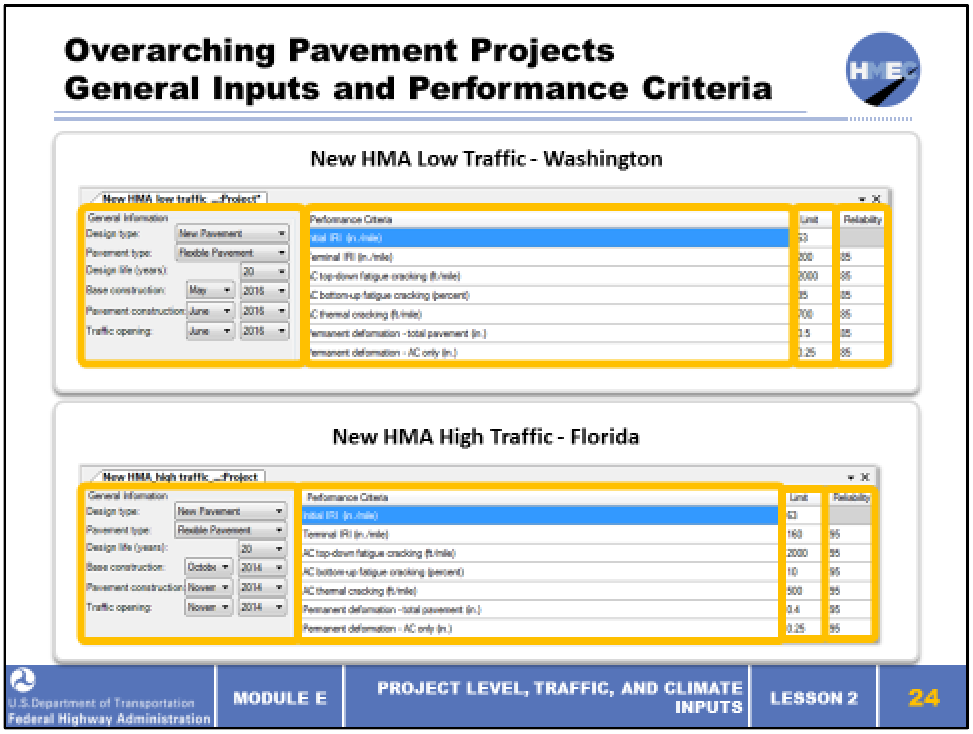
Slide 24



Overarching Pavement Projects General Inputs and Performance Criteria

New HMA Low Traffic - Washington

General Information
Design type: New Pavement
Pavement type: Flexible Pavement
Design life (years): 20
Base construction: May 2016
Pavement construction: June 2016
Traffic opening: June 2016

Performance Criteria	Limit	Reliability
otal IRI (in./mile)	63	
erminal IRI (in./mile)	200	85
C top-down fatigue cracking (ft/mile)	2000	85
C bottom-up fatigue cracking (percent)	35	85
C thermal cracking (ft/mile)	700	85
ermanent deformation - total pavement (in.)	1.5	85
ermanent deformation - AC only (in.)	0.25	85

New HMA High Traffic - Florida

General Information
Design type: New Pavement
Pavement type: Flexible Pavement
Design life (years): 20
Base construction: Octobe 2014
Pavement construction: Novem 2014
Traffic opening: Novem 2014

Performance Criteria	Limit	Reliability
Initial IRI (in./mile)	63	
Terminal IRI (in./mile)	160	95
AC top-down fatigue cracking (ft/mile)	2000	95
AC bottom-up fatigue cracking (percent)	10	95
AC thermal cracking (ft/mile)	500	95
Permanent deformation - total pavement (in.)	0.4	95
Permanent deformation - AC only (in.)	0.25	95

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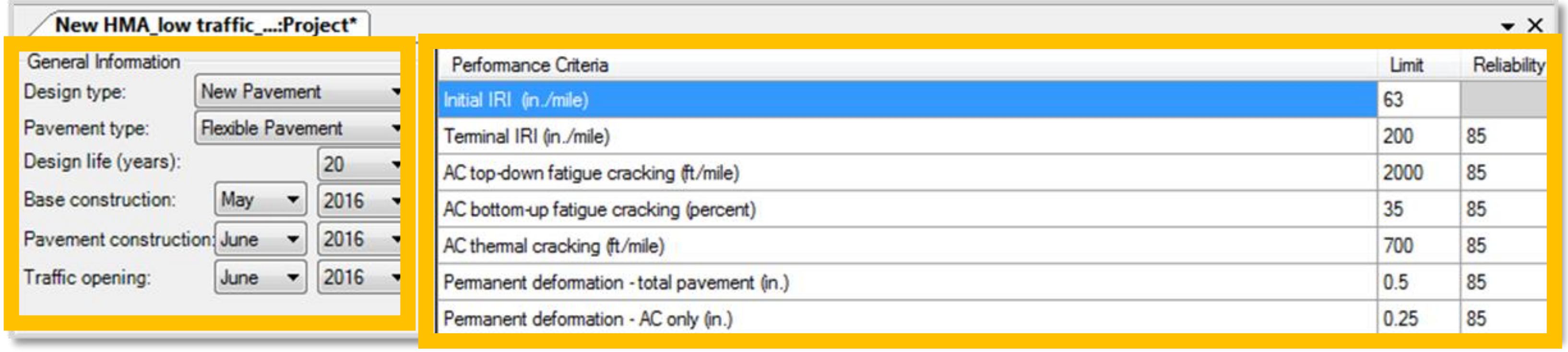
MODULE E | PROJECT LEVEL, TRAFFIC, AND CLIMATE INPUTS | LESSON 2 | 24

New HMA Low Traffic – Washington



General Information
Design type: New Pavement
Pavement type: Flexible Pavement
Design life (years): 20
Base construction: May 2016
Pavement construction: June 2016
Traffic opening: June 2016

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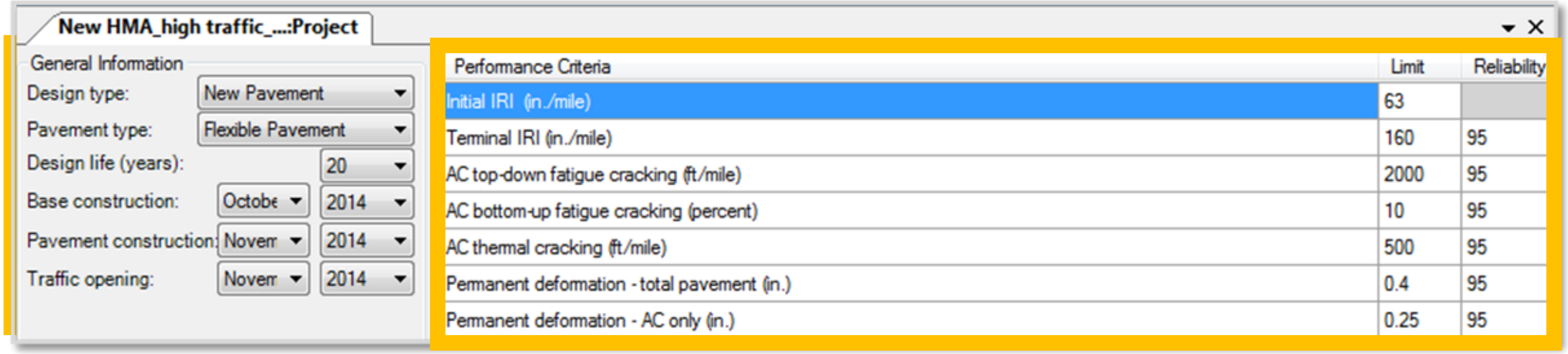
AC thermal cracking (ft/mile)	700	85
Permanent deformation - total pavement (in.)	0.5	85
Permanent deformation - AC only (in.)	0.25	85

New HMA High Traffic – Florida



General Information
Design type: New Pavement
Pavement type: Flexible Pavement
Design life (years): 20
Base construction: Octobe 2014
Pavement construction: Noverr 2014
Traffic opening: Noverr 2014

Performance Criteria	Limit	Reliability
Initial IRI (in./mile)	63	
Terminal IRI (in./mile)	160	95
AC top-down fatigue cracking (ft/mile)	2000	95
AC bottom-up fatigue cracking (percent)	10	95
AC thermal cracking (ft/mile)	500	95
Permanent deformation - total pavement (in.)	0.4	95
Permanent deformation - AC only (in.)	0.25	95

WSDOT has for the past 40 years (or more) used the perpetual pavement concepts (50 year pavement designs) to design pavements. About 99 percent of our pavements crack from the top down. The beauty of this is for rehab the pavement tells us what is needed for mill and fill purposes. For most of our rehab jobs we simply core the cracks and find that normally a 0.15' (1.8 inch) inlay is sufficient. We continue to get pavements with long life even on mill and fill projects and do not spend an enormous amount of time with pavement design for rehabilitation projects.

The user can define when the base is constructed (in a new pavement section) as well as when the final surface pavement lift is completed, and finally when the traffic is permitted to commence on the new pavement (usually the same month as the final surface pavement lift was placed in the case of flexible pavements).

The list of distresses are presented next and then the user must input the target distress threshold values in the Limit column. These values should not be exceeded by the predicted distresses or else the trial pavement structure or materials should be altered in an attempt to improve pavement performance and meet the design life. The final column is the Reliability level for the trial design and the value entered is reflective of the roadway's functional class.

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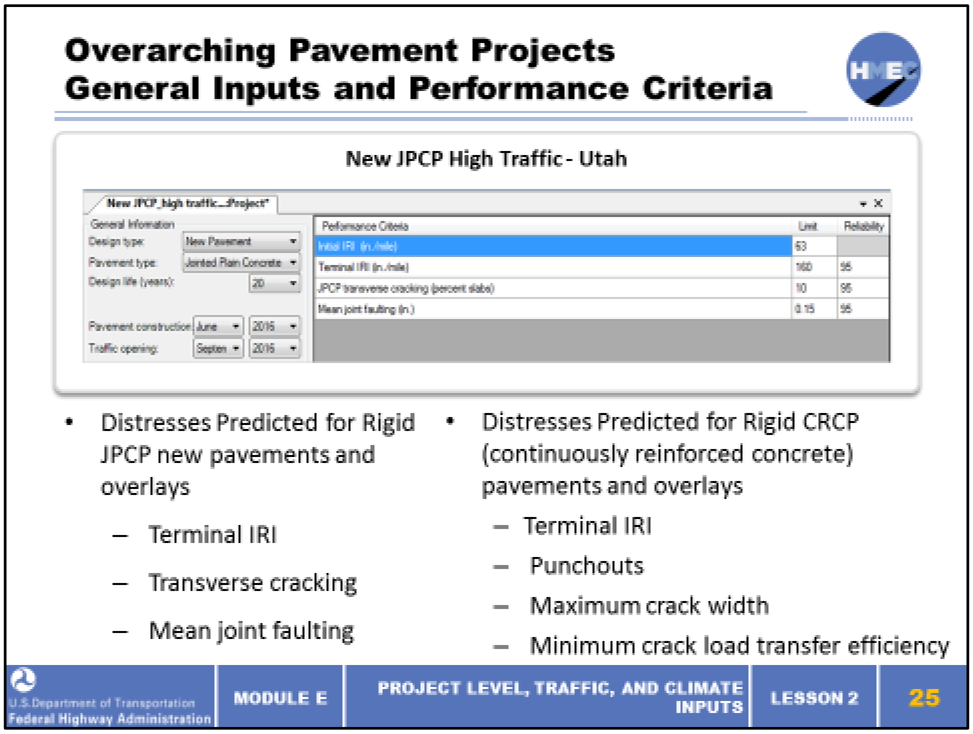
Slide 25



Overarching Pavement Projects General Inputs and Performance Criteria

New JPCP High Traffic - Utah

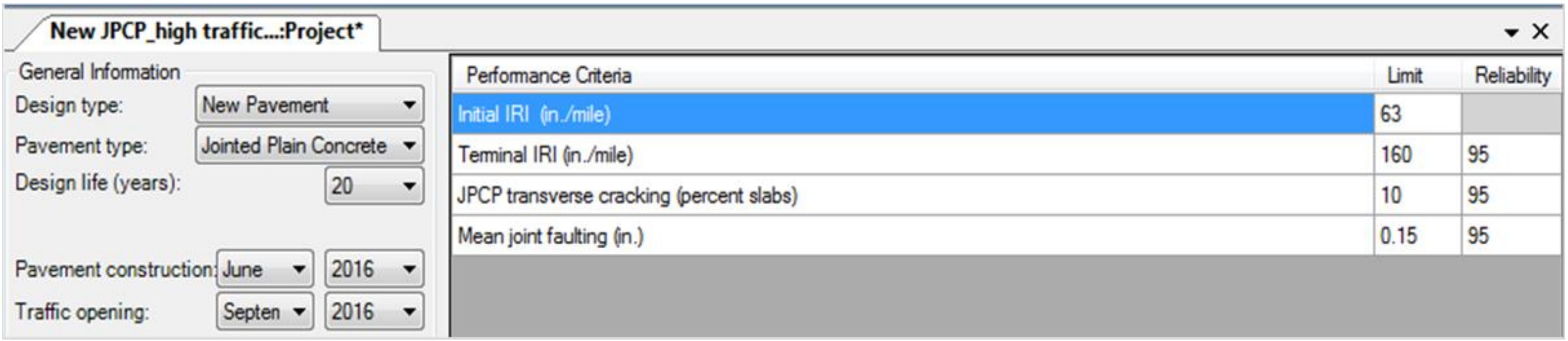
General Information

- Design type: New Pavement
- Pavement type: Jointed Plain Concrete
- Design life (years): 20
- Pavement construction: June 2016
- Traffic opening: Septem 2016

Performance Criteria	Limit	Reliability
Initial IRI (in./mile)	63	
Terminal IRI (in./mile)	160	95
JPCP transverse cracking (percent slabs)	10	95
Mean joint faulting (in.)	0.15	95

- Distresses Predicted for Rigid JPCP new pavements and overlays
  - Terminal IRI
  - Transverse cracking
  - Mean joint faulting
- Distresses Predicted for Rigid CRCP (continuously reinforced concrete) pavements and overlays
  - Terminal IRI
  - Punchouts
  - Maximum crack width
  - Minimum crack load transfer efficiency

New JPCP High Traffic – Utah



General Information

Design type: New Pavement

Pavement type: Jointed Plain Concrete

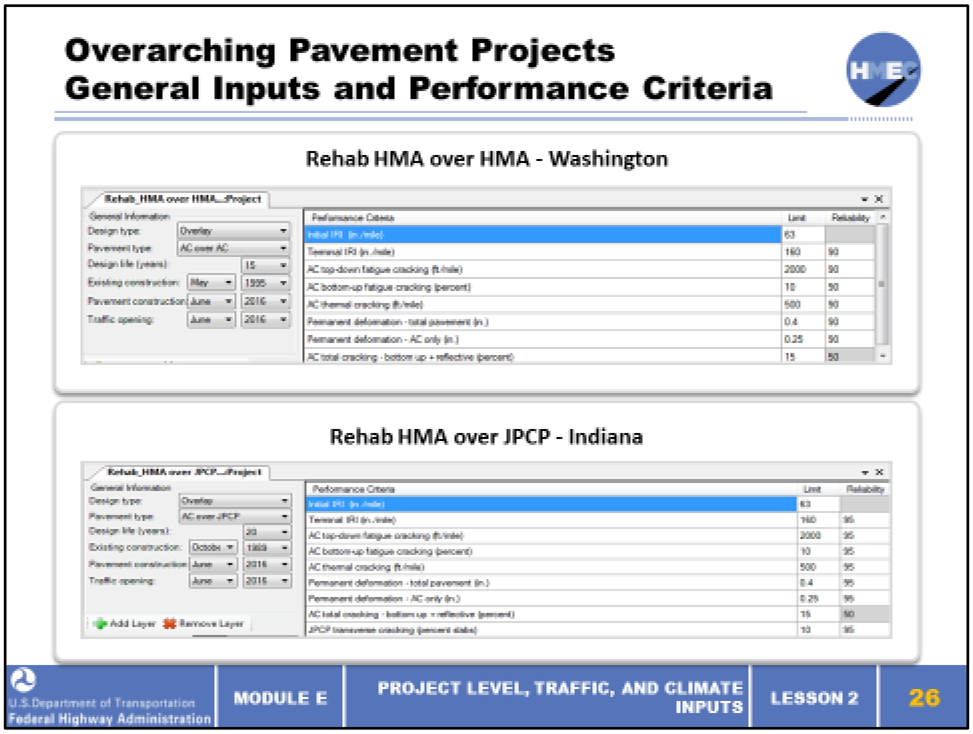
Design life (years): 20

Pavement construction: June 2016

Traffic opening: Septen 2016

Performance Criteria	Limit	Reliability
Initial IRI (in./mile)	63	
Terminal IRI (in./mile)	160	95
JPCP transverse cracking (percent slabs)	10	95
Mean joint faulting (in.)	0.15	95

Slide 26



Overarching Pavement Projects General Inputs and Performance Criteria

Rehab HMA over HMA - Washington

Rehab_HMA over HMA...Project

General Information

Design type: Overlay
Pavement type: AC over AC
Design life (years): 15
Existing construction: May 1995
Pavement construction: June 2016
Traffic opening: June 2016

Performance Criteria	Limit	Reliability
Initial IRI (in./mile)	63	
Terminal IRI (in./mile)	160	90
AC top-down fatigue cracking (ft/mile)	2000	90
AC bottom-up fatigue cracking (percent)	10	90
AC thermal cracking (ft/mile)	500	90
Permanent deformation - total pavement (in.)	0.4	90
Permanent deformation - AC only (in.)	0.25	90
AC total cracking - bottom up + reflective (percent)	15	50

Rehab HMA over JPCP - Indiana

Rehab_HMA over JPCP...Project

General Information

Design type: Overlay
Pavement type: AC over JPCP
Design life (years): 20
Existing construction: Octobe 1989
Pavement construction: June 2016
Traffic opening: June 2016

Performance Criteria	Limit	Reliability
Initial IRI (in./mile)	63	
Terminal IRI (in./mile)	160	95
AC top-down fatigue cracking (ft/mile)	2000	95
AC bottom-up fatigue cracking (percent)	10	95
AC thermal cracking (ft/mile)	500	95
Permanent deformation - total pavement (in.)	0.4	95
Permanent deformation - AC only (in.)	0.25	95
AC total cracking - bottom up + reflective (percent)	15	50
JPCP transverse cracking (percent slabs)	10	95

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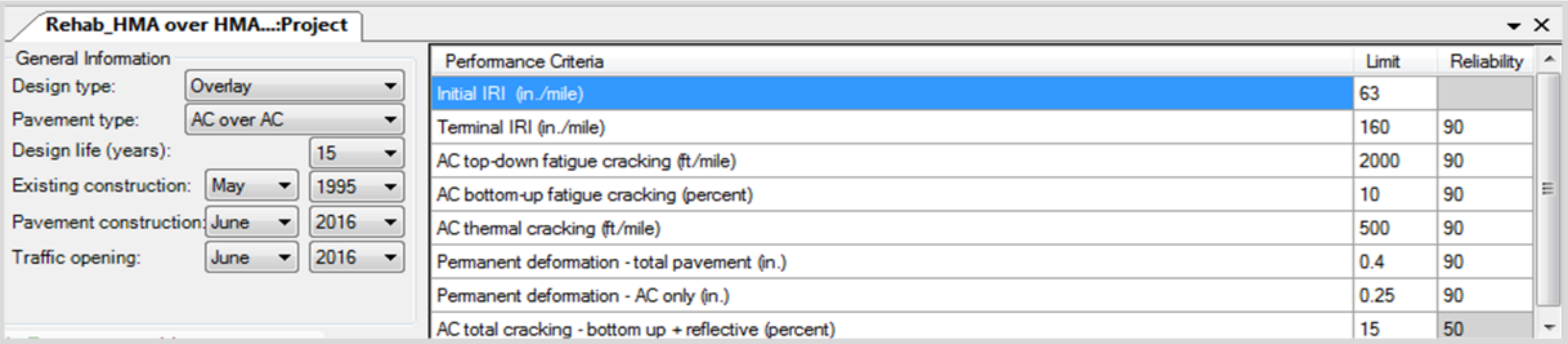
MODULE E | PROJECT LEVEL, TRAFFIC, AND CLIMATE INPUTS | LESSON 2 | 26

Rehab HMA over HMA – Washington



General Information

Design type: Overlay
Pavement type: AC over AC
Design life (years): 15
Existing construction: May 1995
Pavement construction: June 2016
Traffic opening: June 2016

Performance Criteria	Limit	Reliability
Initial IRI (in./mile)	63	
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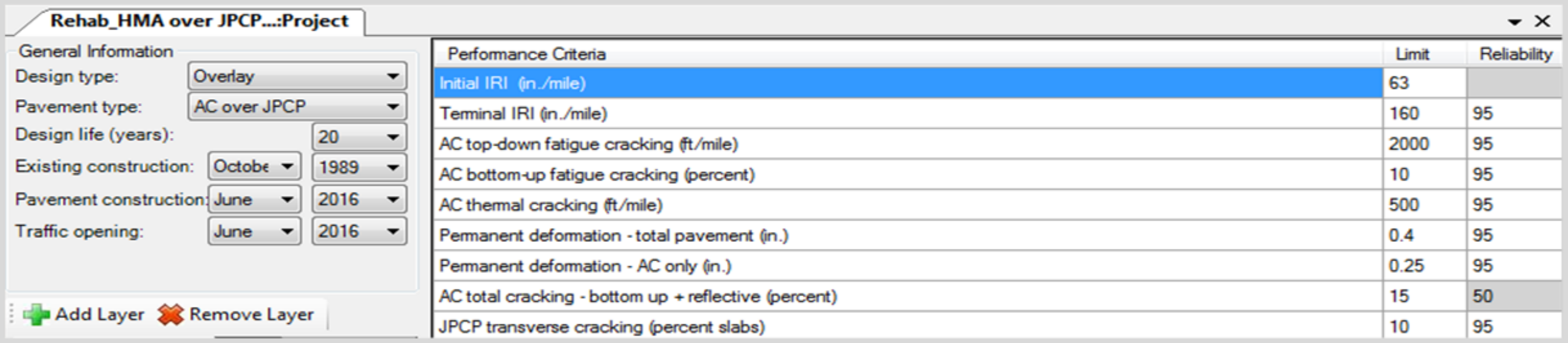
AC top-down fatigue cracking (ft/mile)	2000	90
AC bottom-up fatigue cracking (percent)	10	90
AC thermal cracking (ft/mile)	500	90
Permanent deformation - total pavement (in.)	0.4	90
Permanent deformation - AC only (in.)	0.25	90
AC total cracking - bottom up + reflective (percent)	15	50

Rehab HMA over JPCP – Indiana



General Information

Design type: Overlay
Pavement type: AC over JPCP
Design life (years): 20
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Permanent deformation - total pavement (in.)	0.4	95
Permanent deformation - AC only (in.)	0.25	95
AC total cracking - bottom up + reflective (percent)	15	50
JPCP transverse cracking (percent slabs)	10	95

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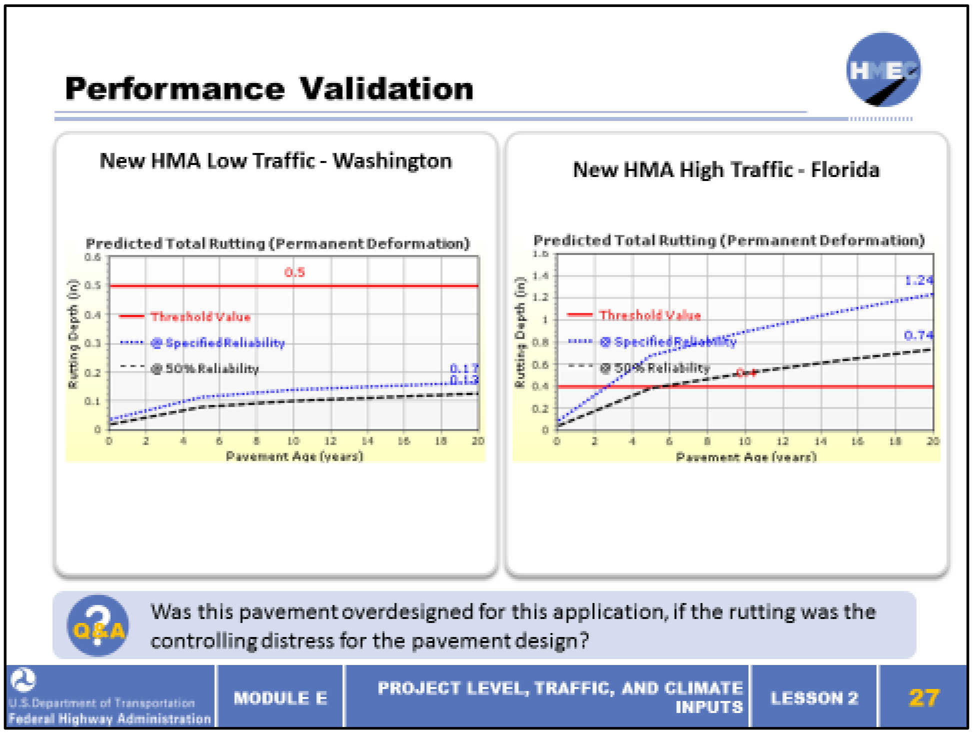
Slide 27



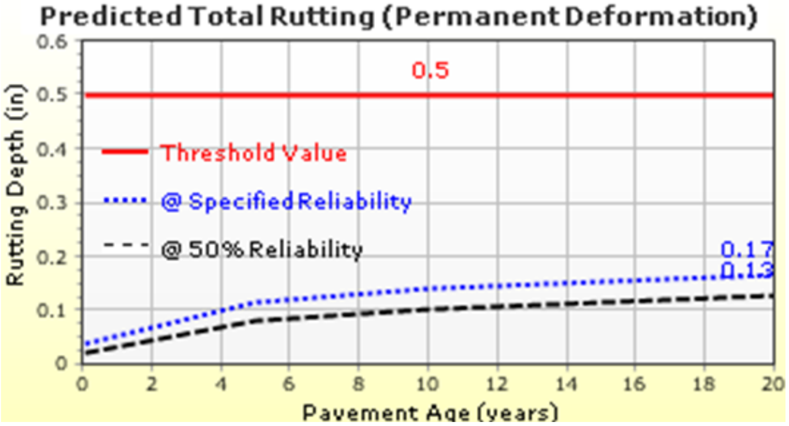
Performance Validation

New HMA Low Traffic - Washington

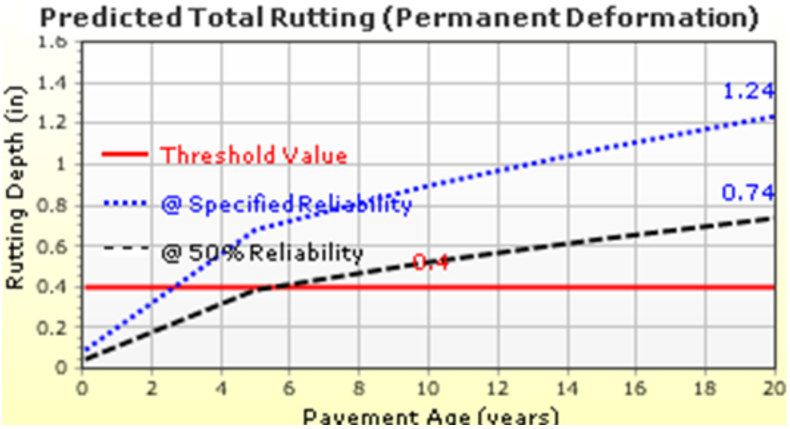
New HMA High Traffic - Florida

Was this pavement overdesigned for this application, if the rutting was the controlling distress for the pavement design?

New HMA Low Traffic – Washington



New HMA High Traffic – Florida



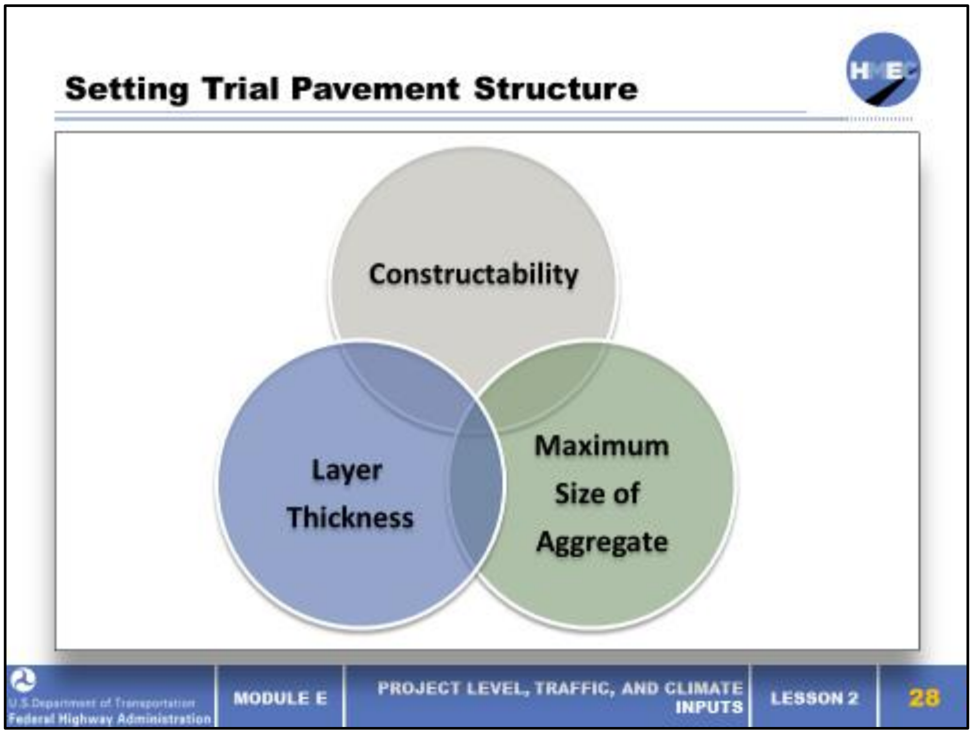
This slide shows how to read an example of a plot generated from Pavement ME Design. Explain fail/pass concept.

In order to verify whether the trial design will perform sufficiently over the intended design life (meaning, the life over which no major reconstruction or rehabilitation is required), there are plots generated automatically by the software that allow the user to look at the amount of specific distress predicted with pavement age. The plots of damage with time are generated for both the 50% reliability design level and for the specific reliability (anywhere between 80% and 99%) level. The threshold value is indicated by a red flat line paralleling the X-axis.

50% reliability means average performance. That means that half of the time, the expected performance is exceeded.

In the case of the new flexible pavement subjected to low truck traffic volumes in Washington State, the total amount of rutting predicted did not exceed the threshold value of 0.5 in. This was both at the 50% reliability level and at the specified reliability level (85%). This means that the trial design has passed, with respect to rutting performance.

Slide 28



Setting Trial Pavement Structure

Constructability

Layer Thickness

Maximum Size of Aggregate

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There are several considerations that go into the establishment of the trial design structure. The layer thickness is the actual factor that we are interested in inputting; however, it has to be selected keeping in mind its relationship to constructability in the field and the maximum size of aggregate selected for the mix design.

The trial pavement structure cannot be selected in isolation; the asphalt or concrete mixture and construction specifications do play a part in pavement design and must be consulted when performing pavement design in the new Pavement ME Design software. There are issues to keep in mind such as the relationship between the concrete pavement thickness and the dowel bar diameter (to be sure there is sufficient cover above and below the dowel). Another example is the relationship between the maximum aggregate size and asphalt layer thickness. The asphalt layer must be thick enough to act as a unit: Thickness > 3 times the (Maximum Aggregate Size of HMA Mixture Used).

Constructability is also a factor and some States (such as Pennsylvania) may have minimum layer thicknesses they will permit in design, similar to the previous AASHTO design approach.

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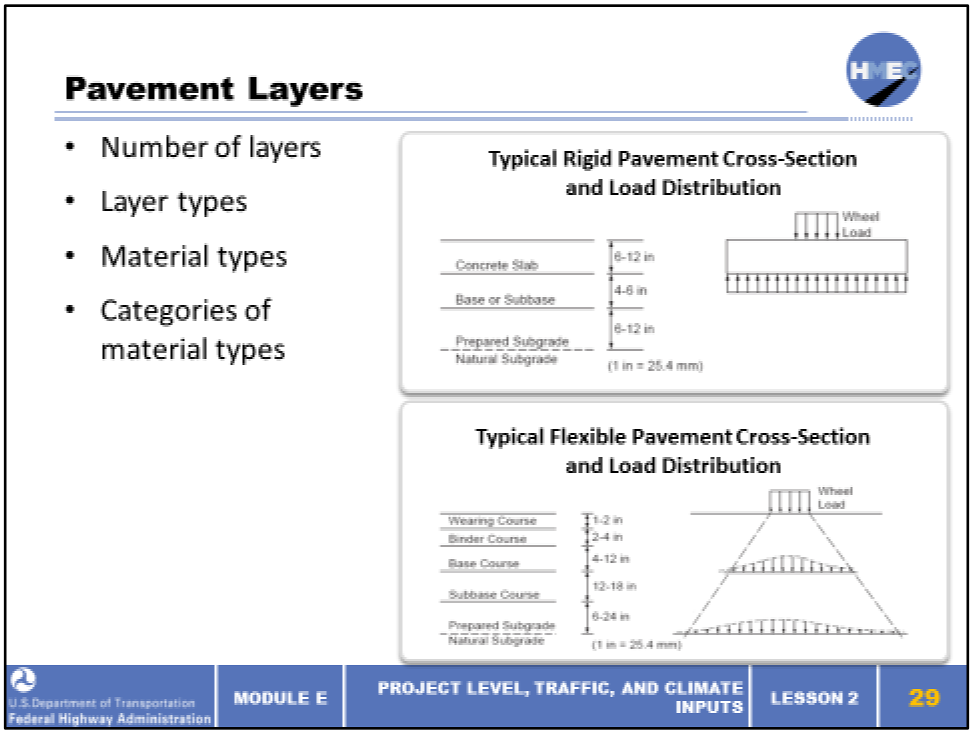
Slide 29



Pavement Layers

- Number of layers
- Layer types
- Material types
- Categories of material types

Typical Rigid Pavement Cross-Section and Load Distribution

Wheel Load
Concrete Slab
Base or Subbase
Prepared Subgrade
Natural Subgrade
6-12 in
4-6 in
6-12 in
(1 in = 25.4 mm)

Typical Flexible Pavement Cross-Section and Load Distribution

Wheel Load
Wearing Course
Binder Course
Base Course
Subbase Course
Prepared Subgrade
Natural Subgrade
1-2 in
2-4 in
4-12 in
12-18 in
6-24 in
(1 in = 25.4 mm)

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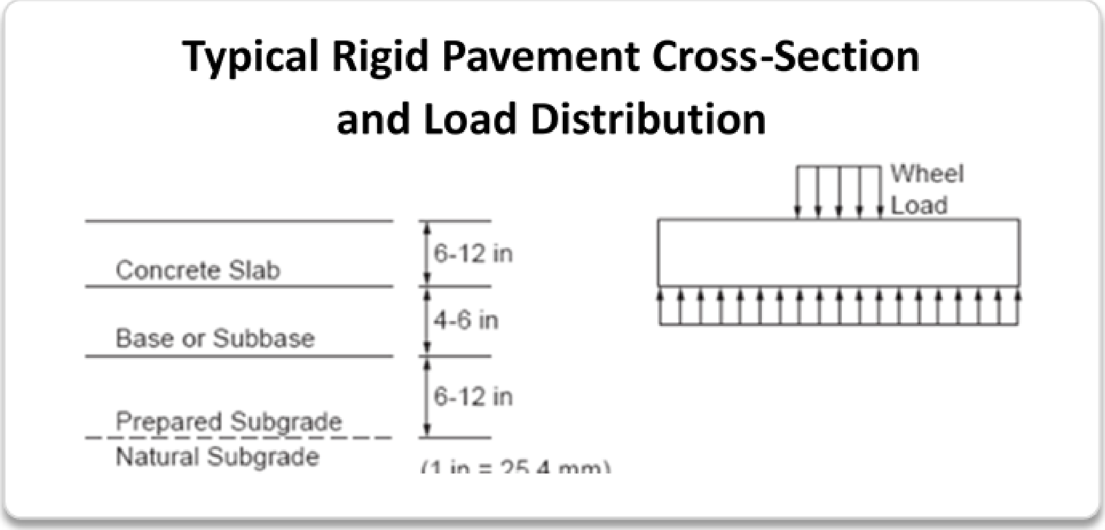
Federal Highway Administration

MODULE E

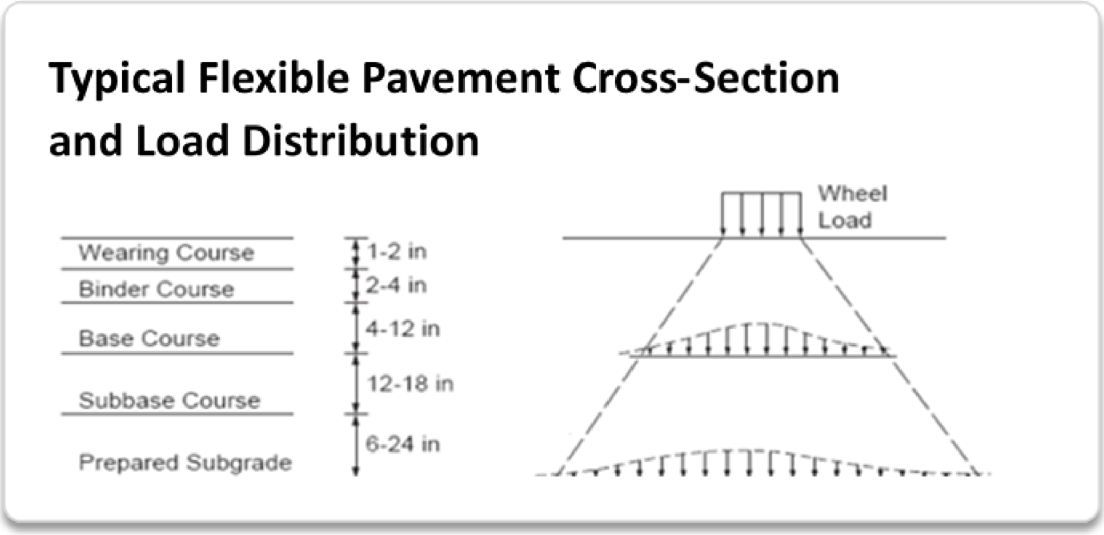
PROJECT LEVEL, TRAFFIC, AND CLIMATE INPUTS

LESSON 2

29



Typical Rigid Pavement Cross-Section and Load Distribution



Typical Flexible Pavement Cross-Section and Load Distribution

The figures in the slide show what is the expectation in the software of typical pavement structural profiles and the way the load distribution is translated through a rigid versus flexible pavement. They also provide typical layer thicknesses for each layer.

Reference: http://satheshkumar.puzl.com/puzl/files/727/26273/510e2a9031a1d.pdf

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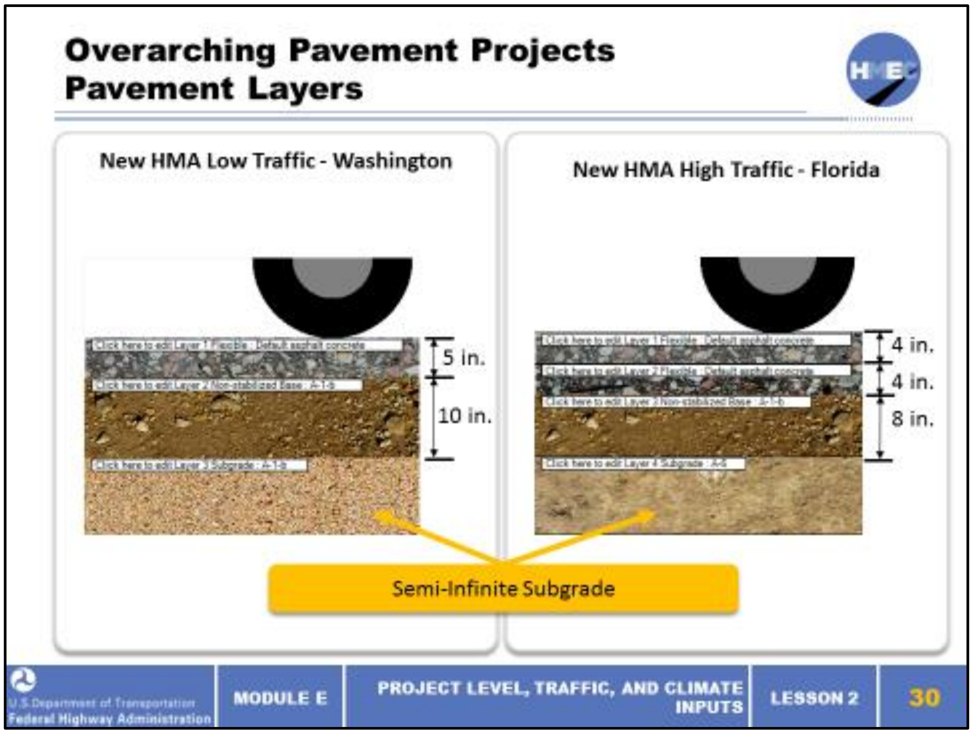
Slide 30



Overarching Pavement Projects Pavement Layers

New HMA Low Traffic - Washington

New HMA High Traffic - Florida

Click here to edit Layer 1 Flexible : Default asphalt concrete
Click here to edit Layer 2 Non-stabilized Base : A-1-b
Click here to edit Layer 3 Subgrade : A-1-b
5 in.
10 in.
Click here to edit Layer 1 Flexible : Default asphalt concrete
Click here to edit Layer 2 Flexible : Default asphalt concrete
Click here to edit Layer 3 Non-stabilized Base : A-1-b
Click here to edit Layer 4 Subgrade : A-6
4 in.
4 in.
8 in.

Semi-Infinite Subgrade

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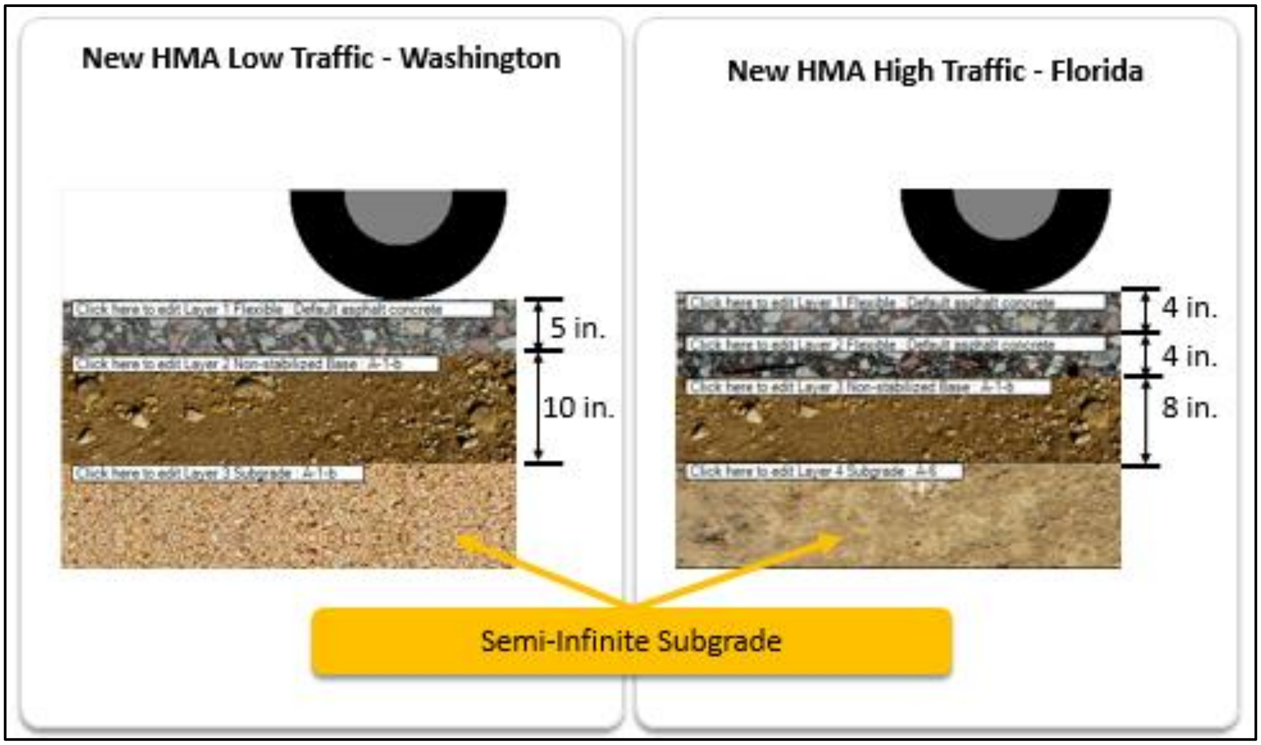
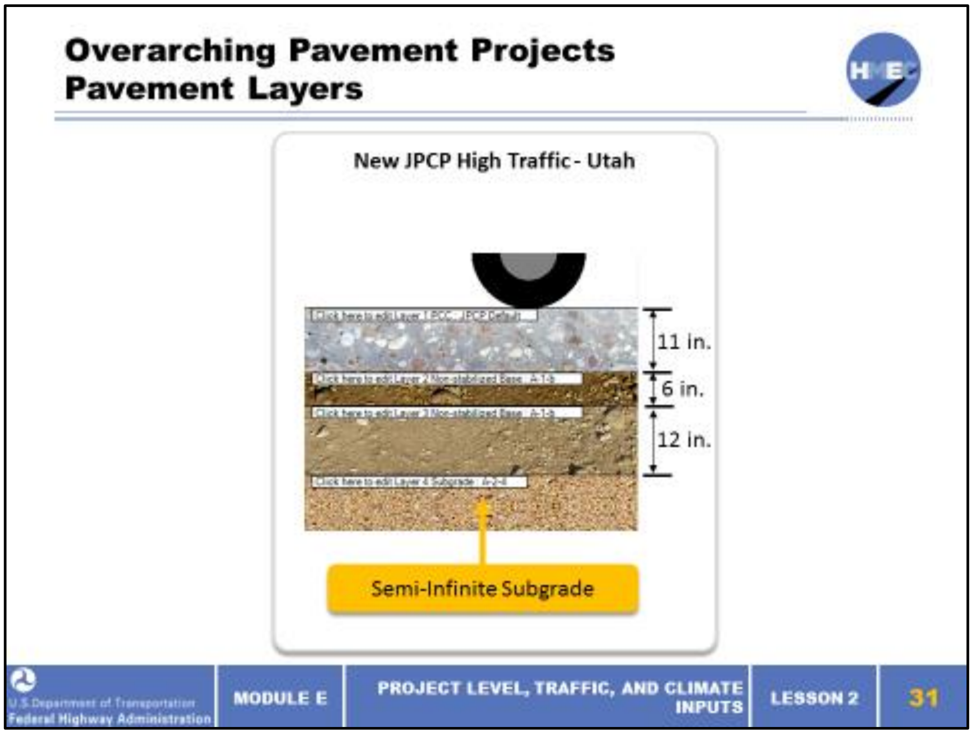
MODULE E | PROJECT LEVEL, TRAFFIC, AND CLIMATE INPUTS | LESSON 2 | 30


New HMA Low Traffic - Washington
Click here to edit Layer 1 Flexible : Default asphalt concrete
Click here to edit Layer 2 Non-stabilized Base : A-1-b
Click here to edit Layer 3 Subgrade : A-1-b
5 in.
10 in.
New HMA High Traffic - Florida
Click here to edit Layer 1 Flexible : Default asphalt concrete
Click here to edit Layer 2 Flexible : Default asphalt concrete
Click here to edit Layer 3 Non-stabilized Base : A-1-b
Click here to edit Layer 4 Subgrade : A-6
4 in.
4 in.
8 in.
Semi-Infinite Subgrade

This slide shows the two new flexible pavement structural profiles. Point out the various layers and layer thicknesses. These are all based on LTPP field sections in the region.

Slide 31



Overarching Pavement Projects
Pavement Layers

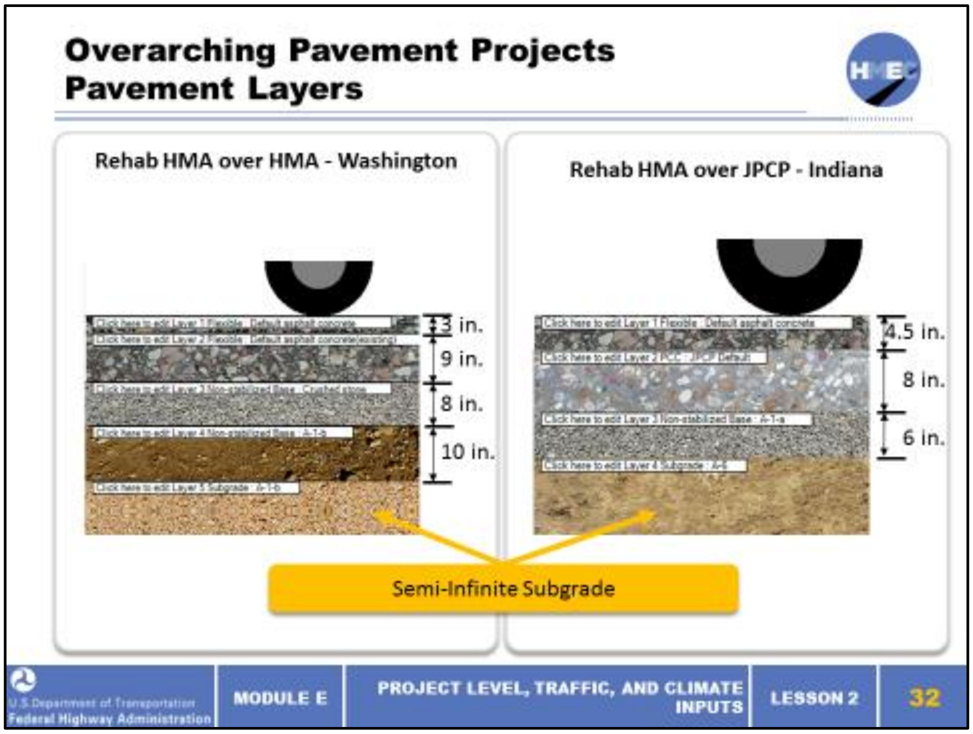
New JPCP High Traffic - Utah

Click here to edit Layer 1 PCC : JPCP Default
Click here to edit Layer 2 Non-stabilized Base : A-1-b
Click here to edit Layer 3 Non-stabilized Base : A-1-b
Click here to edit Layer 4 Subgrade : A-2-4
11 in.
6 in.
12 in.
Semi-Infinite Subgrade

U.S. Department of Transportation Federal Highway Administration | MODULE E | PROJECT LEVEL, TRAFFIC, AND CLIMATE INPUTS | LESSON 2 | 31

This slide shows the new rigid pavement structural profile. Point out the various layers and layer thicknesses. These are all based on LTPP field sections in the region.

Slide 32



Overarching Pavement Projects Pavement Layers

Rehab HMA over HMA - Washington

Rehab HMA over JPCP - Indiana

Click here to edit Layer 1 Flexible : Default asphalt concrete
Click here to edit Layer 2 Flexible : Default asphalt concrete(existing)
Click here to edit Layer 3 Non-stabilized Base : Crushed stone
Click here to edit Layer 4 Non-stabilized Base : A-1-b
Click here to edit Layer 5 Subgrade : A-1-b
3 in.
9 in.
8 in.
10 in.
Click here to edit Layer 1 Flexible : Default asphalt concrete
Click here to edit Layer 2 PCC : JPCP Default
Click here to edit Layer 3 Non-stabilized Base : A-1-a
Click here to edit Layer 4 Subgrade : A-6
4.5 in.
8 in.
6 in.

Semi-Infinite Subgrade

U.S. Department of Transportation Federal Highway Administration | MODULE E | PROJECT LEVEL, TRAFFIC, AND CLIMATE INPUTS | LESSON 2 | 32

This slide shows the two AC overlay rehabilitated pavement structural profiles (one over existing asphalt, one over existing concrete). Point out the various layers and layer thicknesses. These are all based on LTPP field sections in the region.

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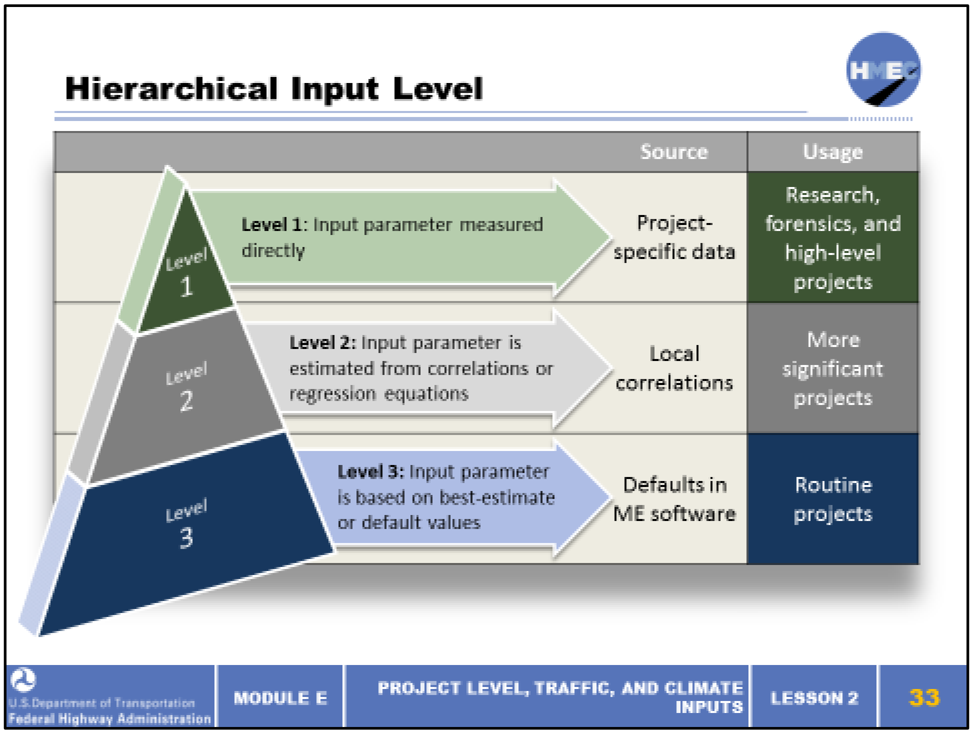
Slide 33



Hierarchical Input Level

	Source	Usage
Level 1: Input parameter measured directly	Project-specific data	Research, forensics, and high-level projects
Level 2: Input parameter is estimated from correlations or regression equations	Local correlations	More significant projects
Level 3: Input parameter is based on best-estimate or default values	Defaults in ME software	Routine projects

HMEC
Level 1
Level 2
Level 3
U.S. Department of Transportation Federal Highway Administration
MODULE E
PROJECT LEVEL, TRAFFIC, AND CLIMATE INPUTS
LESSON 2
33

The best quality inputs available for pavement sections were used to calibrate the Pavement ME Design and to determine the standard error of each prediction model.

The hierarchical input concept or approach provides the designer with flexibility in obtaining the inputs for a design project based on the importance of the project and the available resources.

In a way the numbering of the levels may confuse some of the participants because the Level 1 is actually the most "accurate" input level. One way to explain this would be to tell participants to think of the levels in terms of a competition (so, #1 is the top, #2 is second-best, and #3 is last position).

For many of the inputs, the default values are perfectly adequate, while project-specific inputs are highly desirable for some of the inputs.

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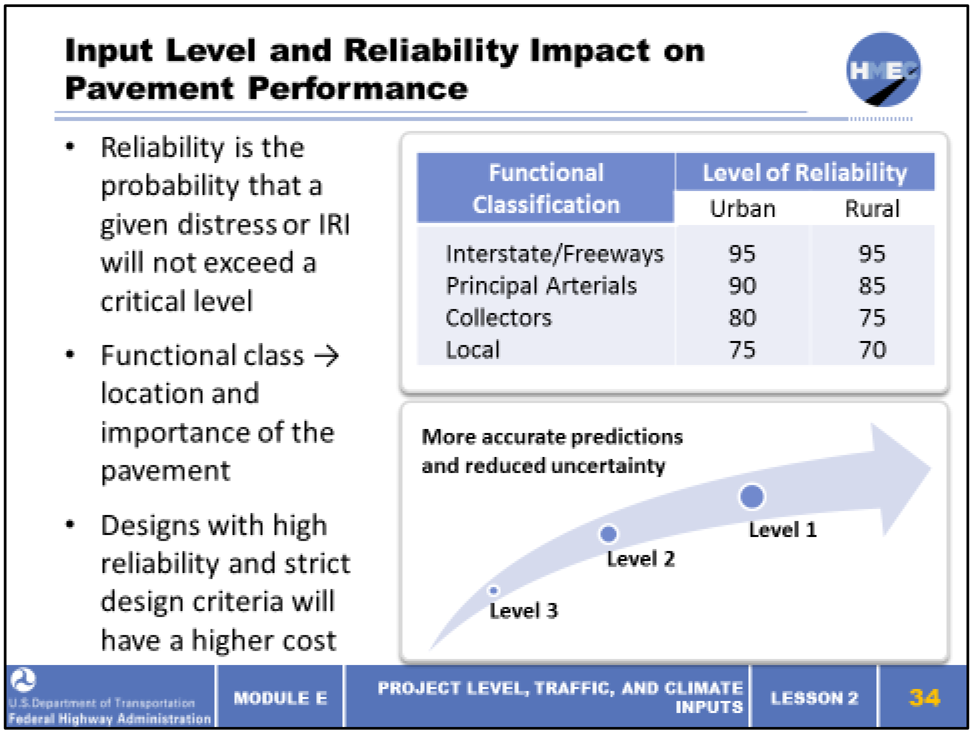
Slide 34



Input Level and Reliability Impact on Pavement Performance

- Reliability is the probability that a given distress or IRI will not exceed a critical level
- Functional class → location and importance of the pavement
- Designs with high reliability and strict design criteria will have a higher cost

Functional Classification	Level of Reliability	
	Urban	Rural
Interstate/Freeways	95	95
Principal Arterials	90	85
Collectors	80	75
Local	75	70

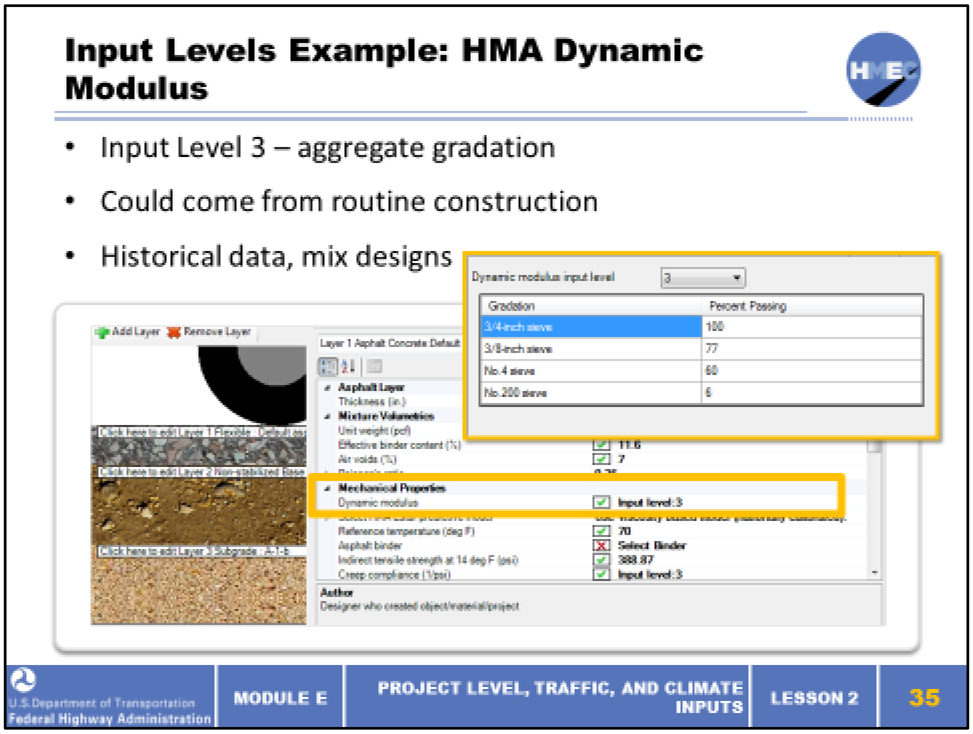
More accurate predictions and reduced uncertainty

Reliability is the probability that a given distress or IRI will not exceed a critical level.

Higher traffic volumes may indicate that a higher reliability is desired, such as on a freeway versus a lower volume county arterial, thus, the functional classification of the roadway may sway the reliability in terms of the location and importance of the pavement being designed. This takes into consideration locations where the user delays and work zone costs are higher risk and higher cost.

Designs with high reliability and strict design criteria will have a higher cost.

Slide 35



Input Levels Example: HMA Dynamic Modulus

- Input Level 3 – aggregate gradation
- Could come from routine construction
- Historical data, mix designs

Dynamic modulus input level: 3

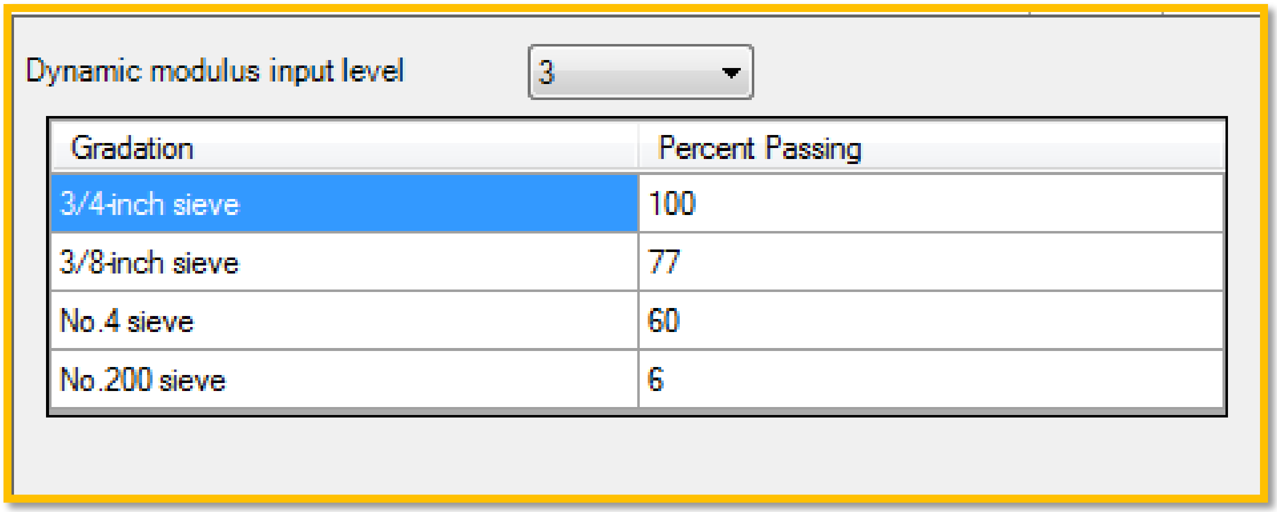
Gradation	Percent Passing
3/4-inch sieve	100
3/8-inch sieve	77
No.4 sieve	60
No.200 sieve	6

Layer 1 Asphalt Concrete Default

Asphalt Layer
Thickness (in.)
Mixture Volumetrics
Unit weight (pcf)
Effective binder content (%): ☑ 11.6
Air voids (%): ☑ 7
Mechanical Properties
Dynamic modulus: ☑ Input level:3
Reference temperature (deg F): ☑ 70
Asphalt binder: ☒ Select Binder
Indirect tensile strength at 14 deg F (psi): ☑ 388.87
Creep compliance (1/psi): ☑ Input level:3

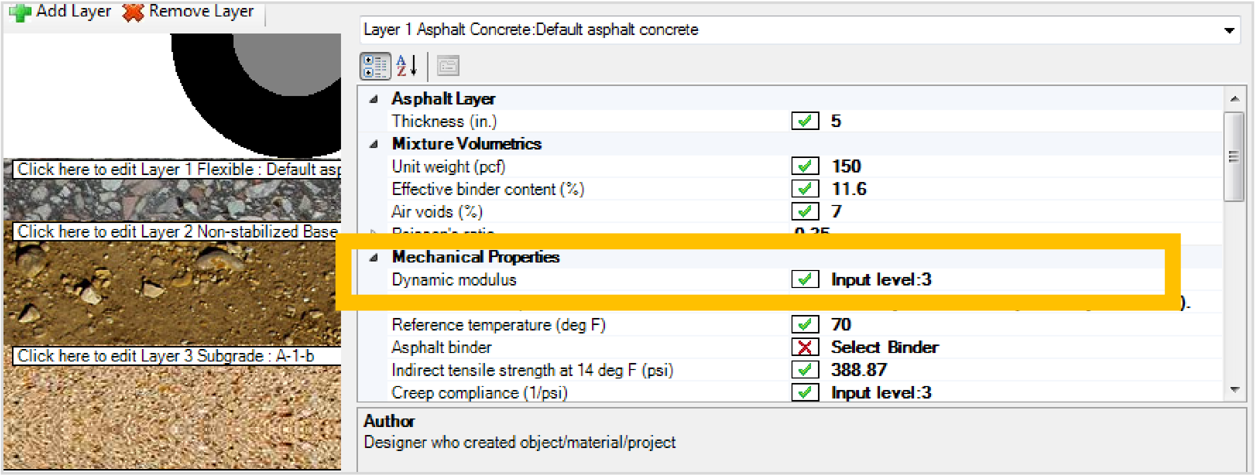
Author
Designer who created object/material/project

Add Layer
Remove Layer
Click here to edit Layer 1 Flexible : Default as
Click here to edit Layer 2 Non-stabilized Base
Click here to edit Layer 3 Subgrade : A-1-b



Dynamic modulus input level: 3

Gradation	Percent Passing
3/4-inch sieve	100
3/8-inch sieve	77
No.4 sieve	60
No.200 sieve	6


Add Layer
Remove Layer
Click here to edit Layer 1 Flexible : Default asp
Click here to edit Layer 2 Non-stabilized Base
Click here to edit Layer 3 Subgrade : A-1-b

Layer 1 Asphalt Concrete:Default asphalt concrete

Asphalt Layer

Thickness (in.)	✓	5

Mixture Volumetrics

Unit weight (pcf)	✓	150
Effective binder content (%)	✓	11.6
Air voids (%)	✓	7

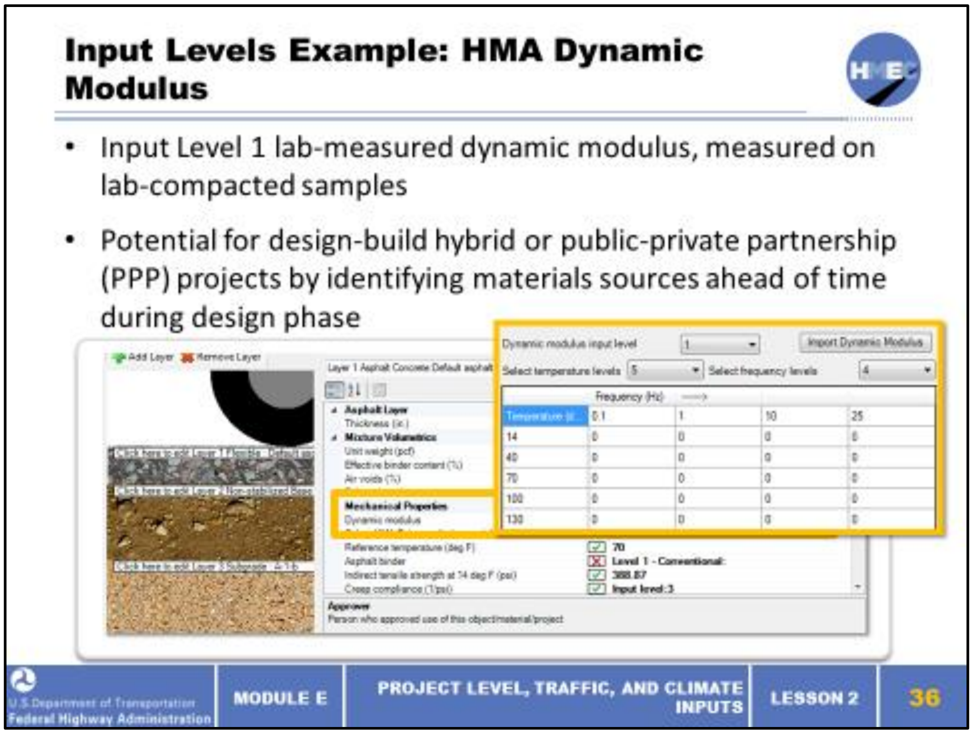
Mechanical Properties

Dynamic modulus	✓	Input level:3
Reference temperature (deg F)	✓	70
Asphalt binder	✗	Select Binder
Indirect tensile strength at 14 deg F (psi)	✓	388.87
Creep compliance (1/psi)	✓	Input level:3

Author
Designer who created object/material/project

This slide presents the inputting of Level 3 asphalt materials inputs, demonstrated directly from the software, specifically the dynamic modulus. In the Level 3 input case, the dropdown menu brings the user to a screen for an asphalt mix where the aggregate percent passing is input for key sieves, as per the Witczak dynamic modulus equation, which we will cover in more depth in Lesson 4.

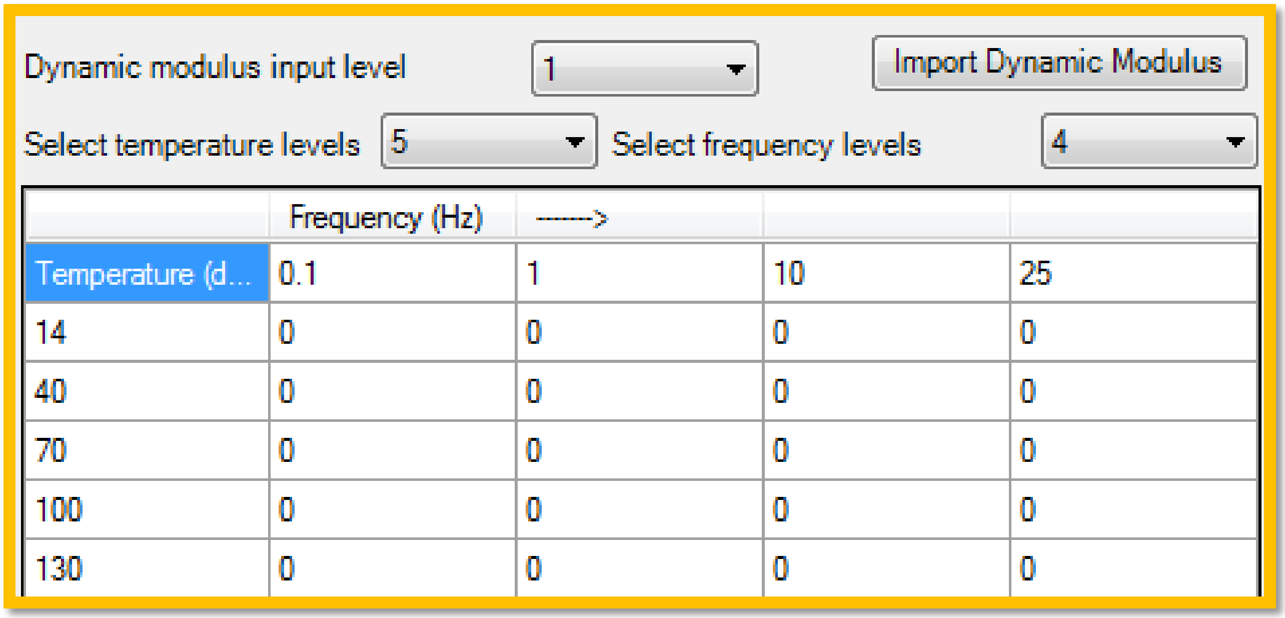
Slide 36



Input Levels Example: HMA Dynamic Modulus

- Input Level 1 lab-measured dynamic modulus, measured on lab-compacted samples
- Potential for design-build hybrid or public-private partnership (PPP) projects by identifying materials sources ahead of time during design phase

U.S. Department of Transportation Federal Highway Administration | MODULE E | PROJECT LEVEL, TRAFFIC, AND CLIMATE INPUTS | LESSON 2 | 36

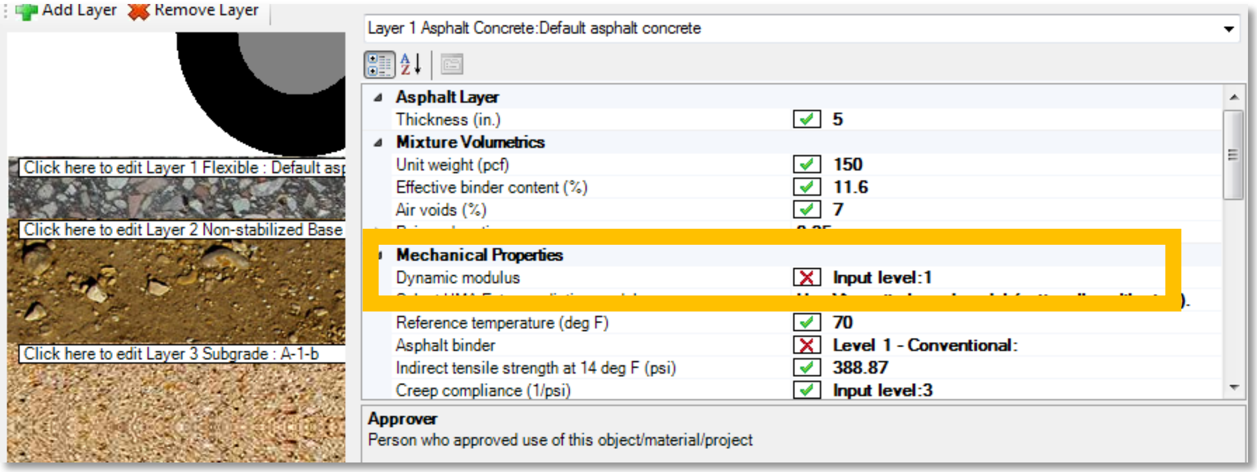


Dynamic modulus input level: 1

Select temperature levels: 5

Select frequency levels: 4

	Frequency (Hz)	------->		
Temperature (d...	0.1	1	10	25
14	0	0	0	0
40	0	0	0	0
70	0	0	0	0
100	0	0	0	0
130	0	0	0	0


Add Layer
Remove Layer
Click here to edit Layer 1 Flexible : Default asp
Click here to edit Layer 2 Non-stabilized Base
Click here to edit Layer 3 Subgrade : A-1-b

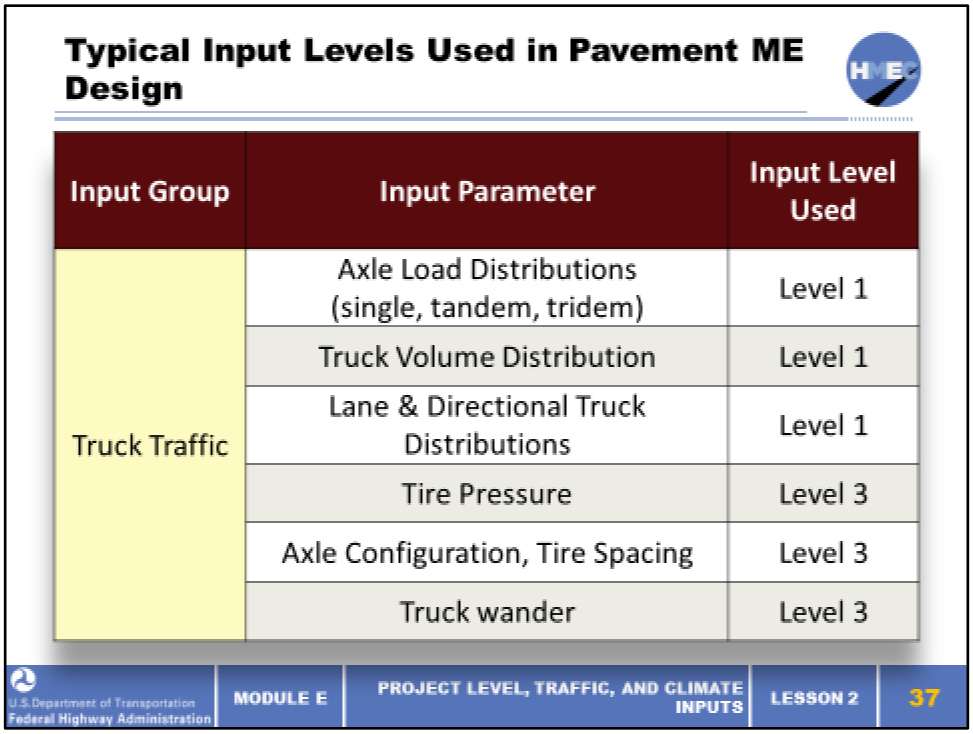
Layer 1 Asphalt Concrete:Default asphalt concrete

Asphalt Layer	
Thickness (in.)	☑ 5
Mixture Volumetrics	
Unit weight (pcf)	☑ 150
Effective binder content (%)	☑ 11.6
Air voids (%)	☑ 7
Mechanical Properties	
Dynamic modulus	☒ Input level:1
Reference temperature (deg F)	☑ 70
Asphalt binder	☒ Level 1 - Conventional:
Indirect tensile strength at 14 deg F (psi)	☑ 388.87
Creep compliance (1/psi)	☑ Input level:3

Approver
Person who approved use of this object/material/project

This slide presents the inputting of Level 1 asphalt materials inputs, demonstrated directly from the software. In the Level 1 input case, the dropdown menu brings the user to a screen for an asphalt mix where the laboratory data from the dynamic modulus test are input. The test data can be input for up to five temperature levels and up to six frequency levels. We will cover the dynamic modulus in more depth in Lesson 4.

Slide 37



Typical Input Levels Used in Pavement ME Design

Input Group	Input Parameter	Input Level Used
Truck Traffic	Axle Load Distributions (single, tandem, tridem)	Level 1
	Truck Volume Distribution	Level 1
	Lane & Directional Truck Distributions	Level 1
	Tire Pressure	Level 3
	Axle Configuration, Tire Spacing	Level 3
	Truck wander	Level 3

Overview of each level of data for traffic parameters.

The point here is to get a more detailed design that will withstand the known and projected types of traffic and loadings on a pavement. Level 1 inputs would be worth the investment to gather from weigh-in-motion (WIM) stations, etc., such as for the top three parameters listed in the table. For other inputs that may not be as influential in the pavement prediction models, and that are relatively consistent factors (e.g., tire pressure and spacing, truck wander, axle configuration), it is perhaps less important to attempt to measure these parameters in the field.

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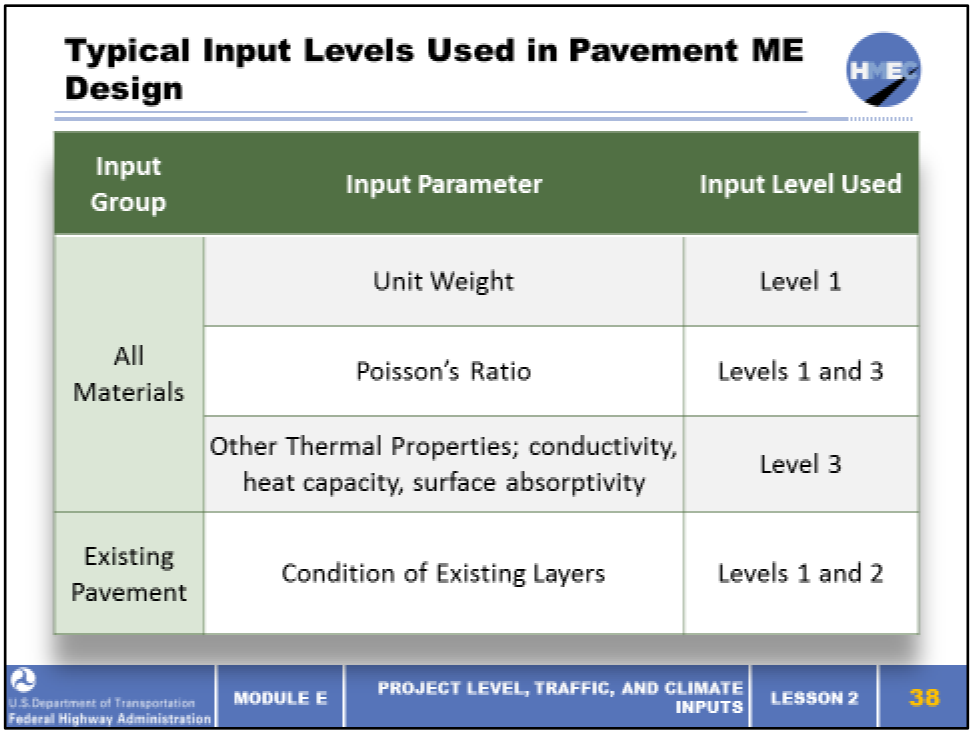
Slide 38



Typical Input Levels Used in Pavement ME Design

Input Group	Input Parameter	Input Level Used
All Materials	Unit Weight	Level 1
	Poisson's Ratio	Levels 1 and 3
	Other Thermal Properties; conductivity, heat capacity, surface absorptivity	Level 3
Existing Pavement	Condition of Existing Layers	Levels 1 and 2

Overview of some levels of data for climate and other parameters.

The point here is to that sensitivity analysis research was conducted by NCHRP 1-47 project and indicated that some parameters are less influential on pavement performance predictions than others. The "Other Thermal Properties; conductivity, heat capacity" don't have a large effect on predictions, and thus are kept at Level 3. NOTE: some input parameters that were deemed "sensitive" in the NCHRP 1-47A study may only be an artifact of the model, and not an intended sensitive input factor.

Overall, it is best for software users to follow the AASHTO MEPDG Manual of Practice.

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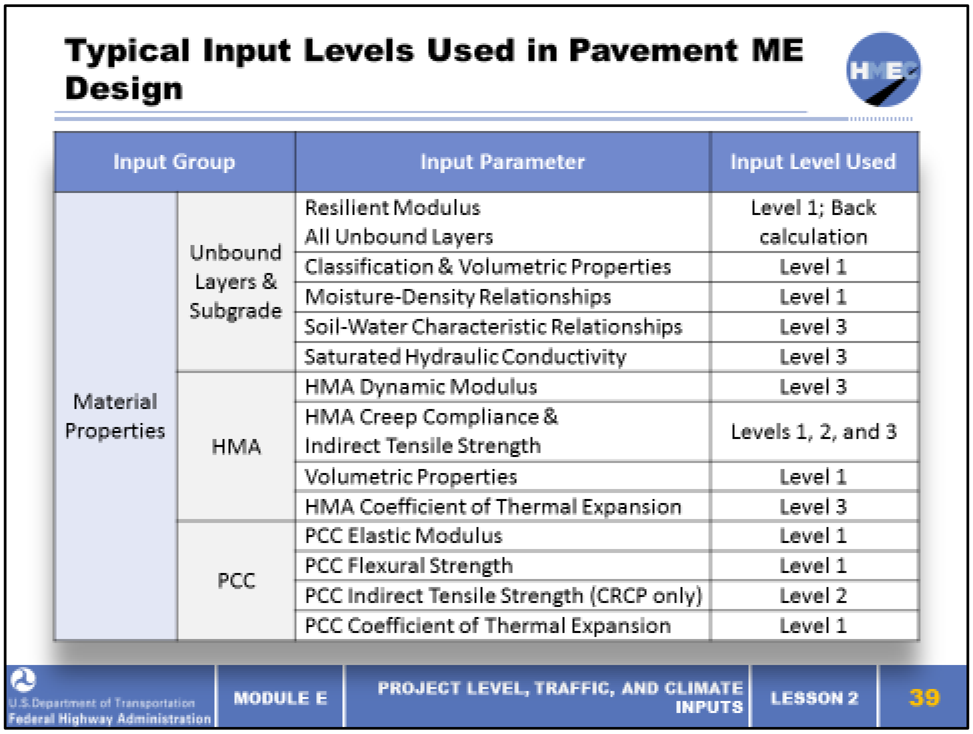
Slide 39



Typical Input Levels Used in Pavement ME Design

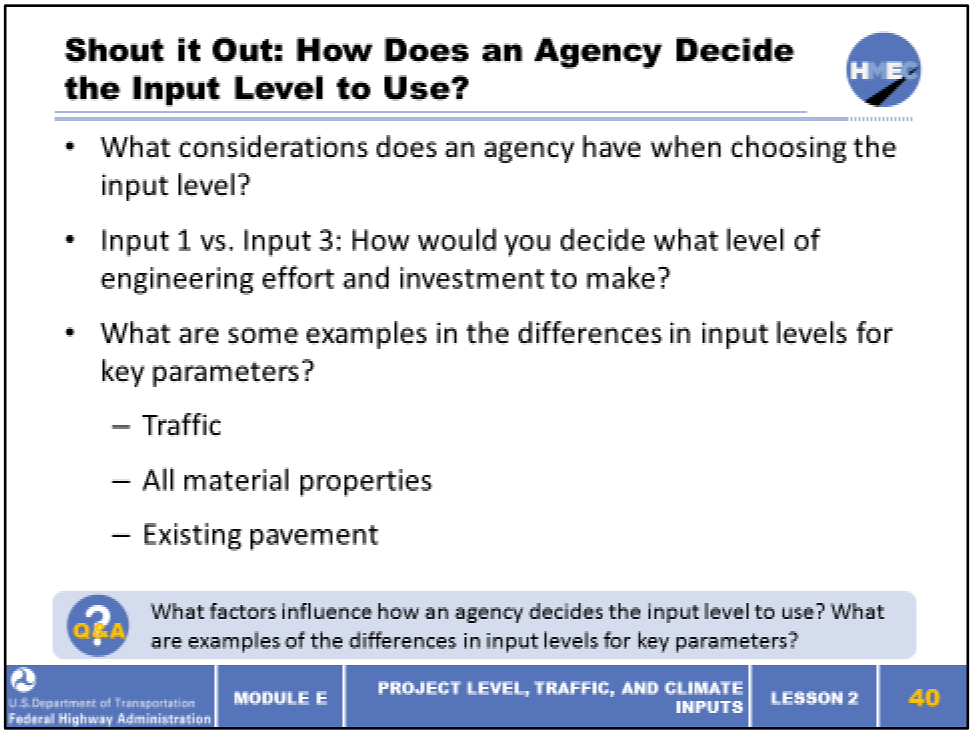
Input Group		Input Parameter	Input Level Used
Material Properties	Unbound Layers & Subgrade	Resilient Modulus All Unbound Layers	Level 1; Back calculation
		Classification & Volumetric Properties	Level 1
		Moisture-Density Relationships	Level 1
		Soil-Water Characteristic Relationships	Level 3
		Saturated Hydraulic Conductivity	Level 3
	HMA	HMA Dynamic Modulus	Level 3
		HMA Creep Compliance & Indirect Tensile Strength	Levels 1, 2, and 3
		Volumetric Properties	Level 1
		HMA Coefficient of Thermal Expansion	Level 3
	PCC	PCC Elastic Modulus	Level 1
		PCC Flexural Strength	Level 1
		PCC Indirect Tensile Strength (CRCP only)	Level 2
		PCC Coefficient of Thermal Expansion	Level 1

U.S. Department of Transportation Federal Highway Administration | MODULE E | PROJECT LEVEL, TRAFFIC, AND CLIMATE INPUTS | LESSON 2 | 39

Overview of some levels of data for material property parameters.

The point here is to that sensitivity analysis research was conducted by NCHRP 1-47 project and indicated that some parameters are less influential on pavement performance predictions than others. Some parameters are just too expensive (test equipment, volume of material needed, personnel expertise required) or too time-intensive to consistently gather Level 1 inputs for and thus were calibrated and are generally used as Level 3 values (e.g., HMA CTE, HMA dynamic modulus, etc.).

Slide 40

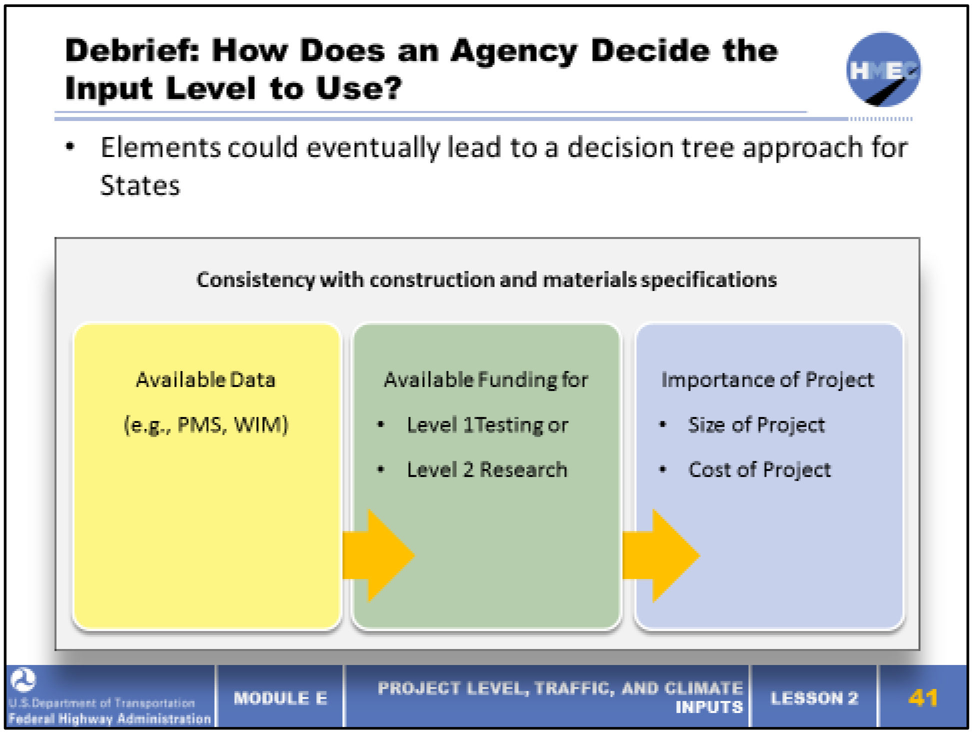


Shout it Out: How Does an Agency Decide the Input Level to Use?

- What considerations does an agency have when choosing the input level?
- Input 1 vs. Input 3: How would you decide what level of engineering effort and investment to make?
- What are some examples in the differences in input levels for key parameters?
  - Traffic
  - All material properties
  - Existing pavement

Q&A What factors influence how an agency decides the input level to use? What are examples of the differences in input levels for key parameters?

Slide 41



Debrief: How Does an Agency Decide the Input Level to Use?

- Elements could eventually lead to a decision tree approach for States

Consistency with construction and materials specifications

Available Data

(e.g., PMS, WIM)

Available Funding for

- Level 1Testing or
- Level 2 Research

Importance of Project

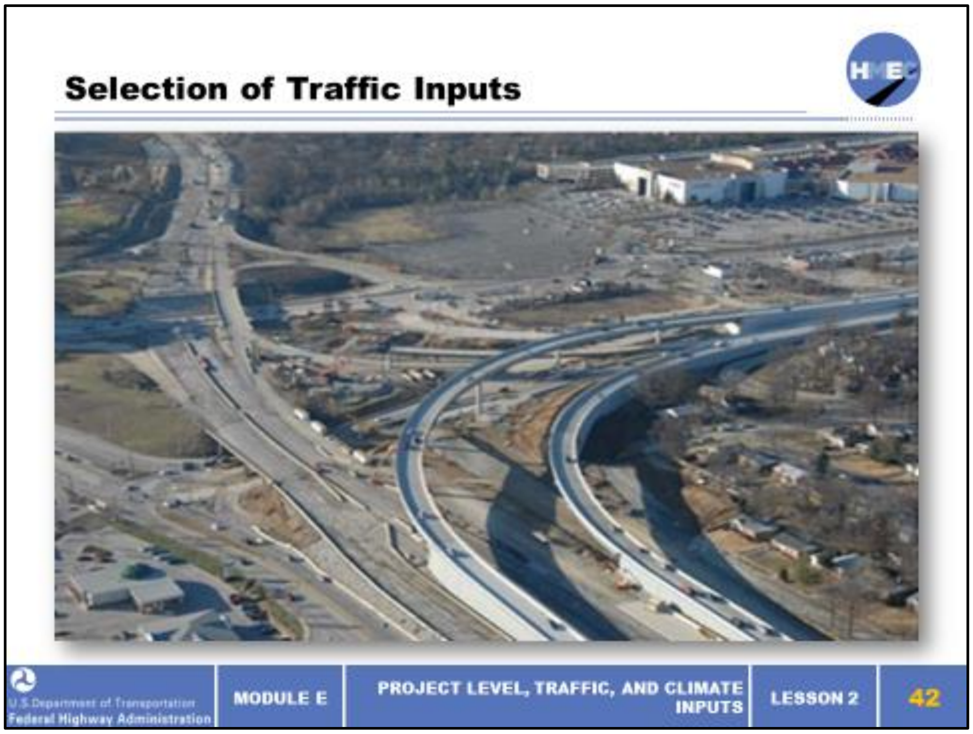
- Size of Project
- Cost of Project

U.S. Department of Transportation Federal Highway Administration | MODULE E | PROJECT LEVEL, TRAFFIC, AND CLIMATE INPUTS | LESSON 2 | 41

Philosophy that the level of engineering effort should be consistent with the relative importance, size, and cost of the project.

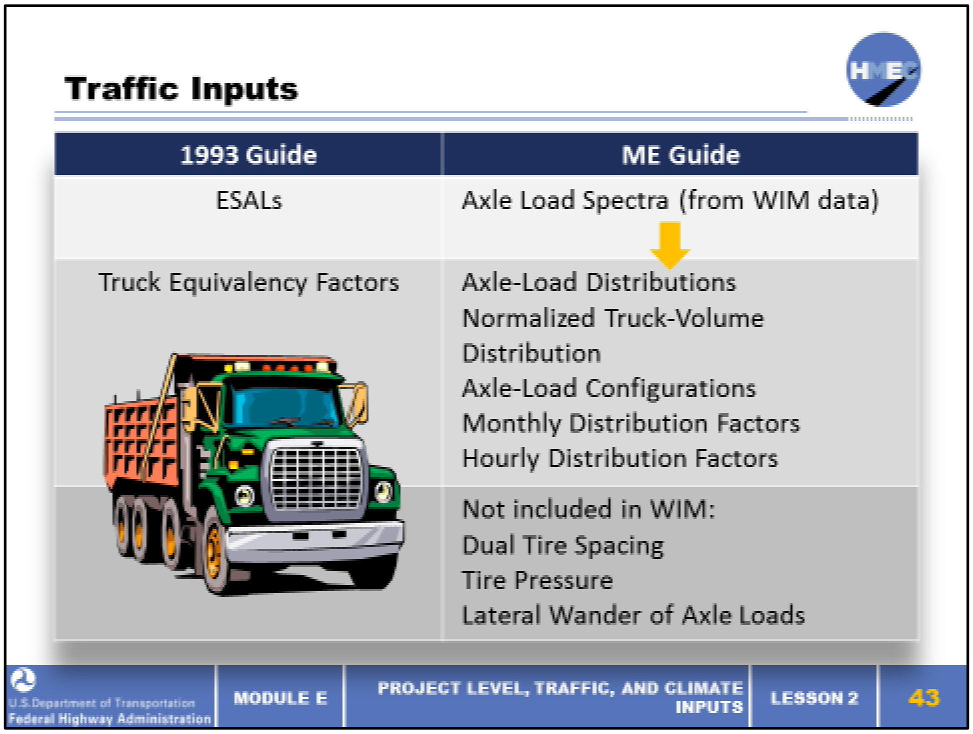
Consider:
• Available data on the performance of pavements and mixes (through pavement management system);
• Available traffic data from weigh-in-motion or other traffic data collection sources; and
• Available funding/capital to collect Level 1 inputs as testing is expensive; if an agency wants Level 2 inputs, need to fund a research project to determine the correlations.

Slide 42



Selection of Traffic Inputs

Slide 43



Traffic Inputs

1993 Guide	ME Guide
ESALs	Axle Load Spectra (from WIM data)
Truck Equivalency Factors	Axle-Load Distributions Normalized Truck-Volume Distribution Axle-Load Configurations Monthly Distribution Factors Hourly Distribution Factors
	Not included in WIM: Dual Tire Spacing Tire Pressure Lateral Wander of Axle Loads

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The Pavement ME Design looks at FHWA class 4 vehicles and larger.

Traffic characterization consists of estimating the axle load distributions applied to the pavement structure (refer to subsection 8.1). The MEPDG does not use equivalent single axle loads (ESAL) and does not require the development of load equivalency factors.

The axle-load spectra are obtained from processing WIM data.

- Axle-load distributions (single, tandem, tridem, quads)
- Axle-load configurations (axle spacing and wheelbase)

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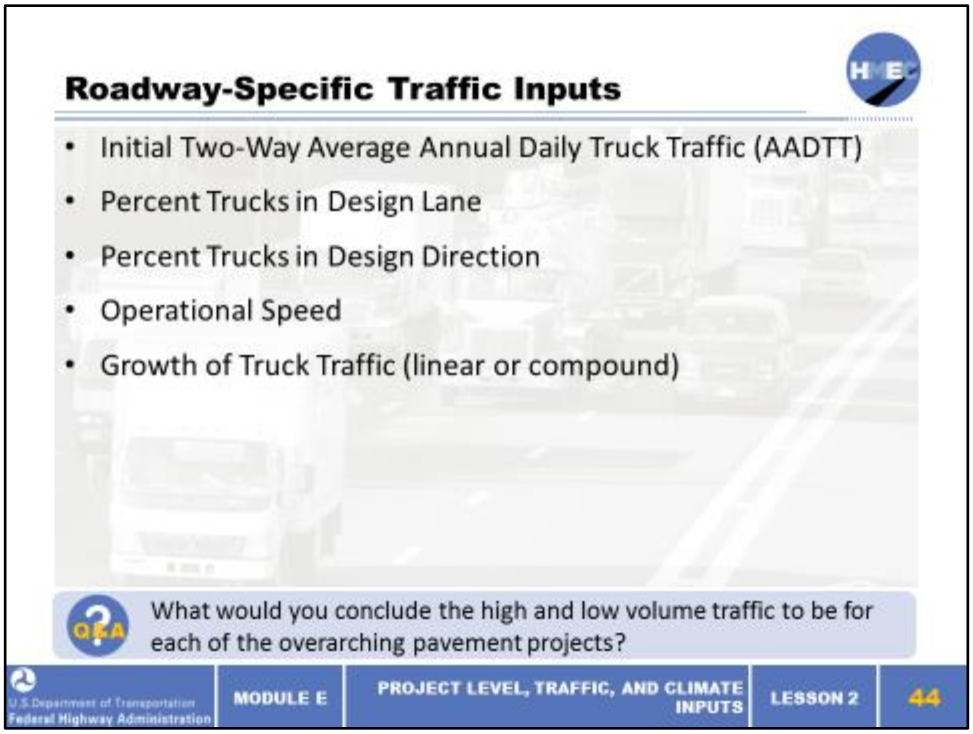
Slide 44



Roadway-Specific Traffic Inputs

- Initial Two-Way Average Annual Daily Truck Traffic (AADTT)
- Percent Trucks in Design Lane
- Percent Trucks in Design Direction
- Operational Speed
- Growth of Truck Traffic (linear or compound)

Q&A What would you conclude the high and low volume traffic to be for each of the overarching pavement projects?

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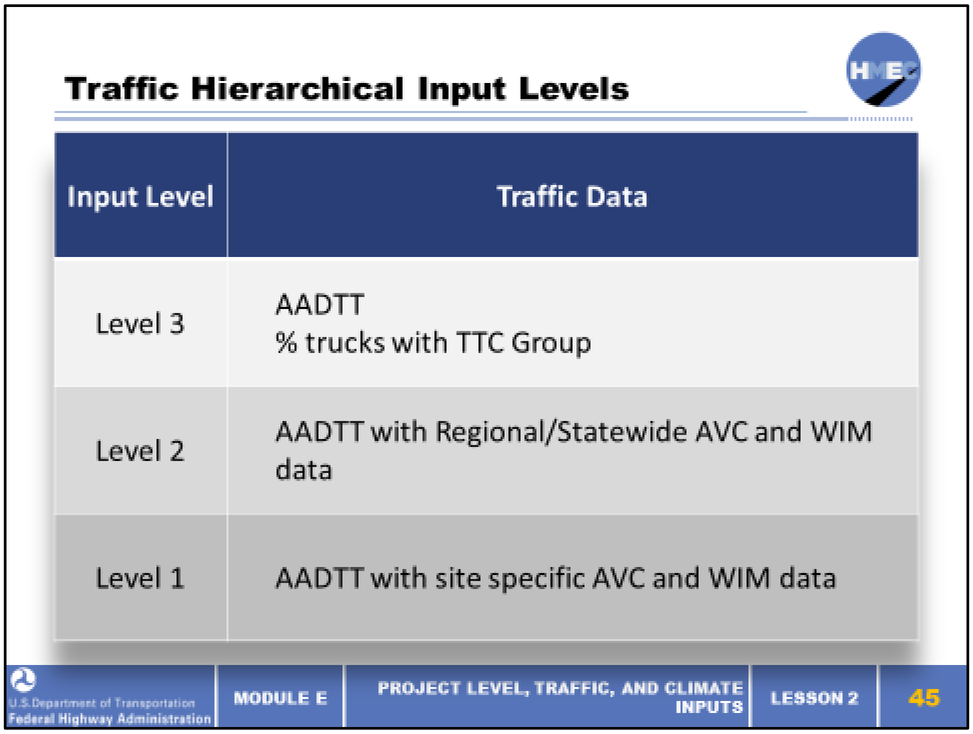
Slide 45



Traffic Hierarchical Input Levels

Input Level	Traffic Data
Level 3	AADTT % trucks with TTC Group
Level 2	AADTT with Regional/Statewide AVC and WIM data
Level 1	AADTT with site specific AVC and WIM data

Traffic is most important for designs with higher volumes, and this is something for the participants to be aware of since it would also require closer attention to materials inputs. Consider, the approach in Superpave for selecting a mix design is currently based on ESALs. How do we relate the two? A sliding scale may be used or some States have come up with materials catalogs.

As stated, three hierarchical input levels are used in the traffic module.

Levels 1 and 2 are based on AVC and WIM measurements, either segment specific or regional average values; whereas Level 3 inputs are based on nationally developed default distributions for truck class volumes and axle load distributions.

The national default values (Level 3) are dependent on the functional classification of the roadway and vehicle count data to identify gross truck class distributions.

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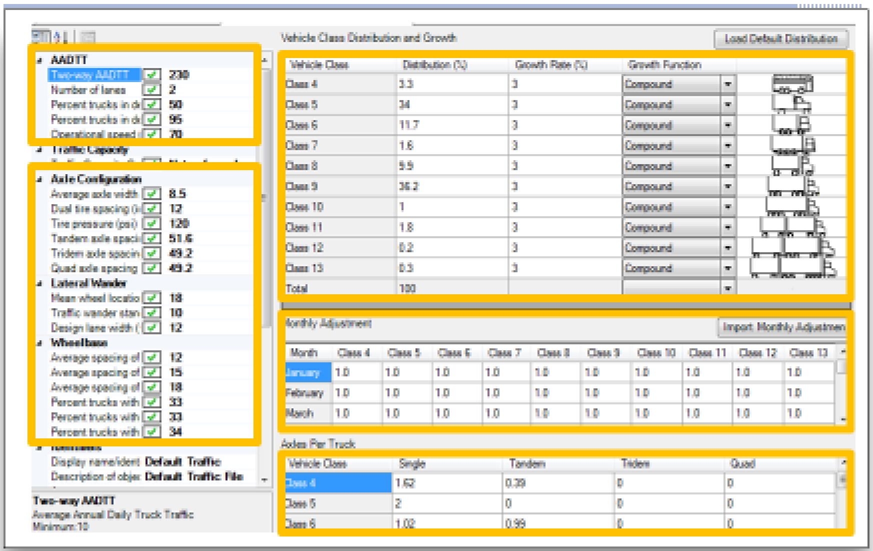
Slide 46

Pavement ME Design Traffic Input



AADTT

Two-way AADTT	230
Number of lanes	2
Percent trucks in d	50
Percent trucks in d	95
Operational speed (	70

Traffic Capacity

Axle Configuration

Average axle width	8.5
Dual tire spacing (i	12
Tire pressure (psi)	120
Tandem axle spaci	51.6
Tridem axle spacin	49.2
Quad axle spacing	49.2

Lateral Wander

Mean wheel locatio	18
Traffic wander stan	10
Design lane width (	12

Wheelbase

Average spacing of	12
Average spacing of	15
Average spacing of	18
Percent trucks with	33
Percent trucks with	33
Percent trucks with	34

Display name/ident	Default Traffic
Description of objec	Default Traffic File

Two-way AADTT
Average Annual Daily Truck Traffic
Minimum:10

Vehicle Class Distribution and Growth

Vehicle Class	Distribution (%)	Growth Rate (%)	Growth Function
Class 4	3.3	3	Compound
Class 5	34	3	Compound
Class 6	11.7	3	Compound
Class 7	1.6	3	Compound
Class 8	9.9	3	Compound
Class 9	36.2	3	Compound
Class 10	1	3	Compound
Class 11	1.8	3	Compound
Class 12	0.2	3	Compound
Class 13	0.3	3	Compound
Total	100		

Monthly Adjustment

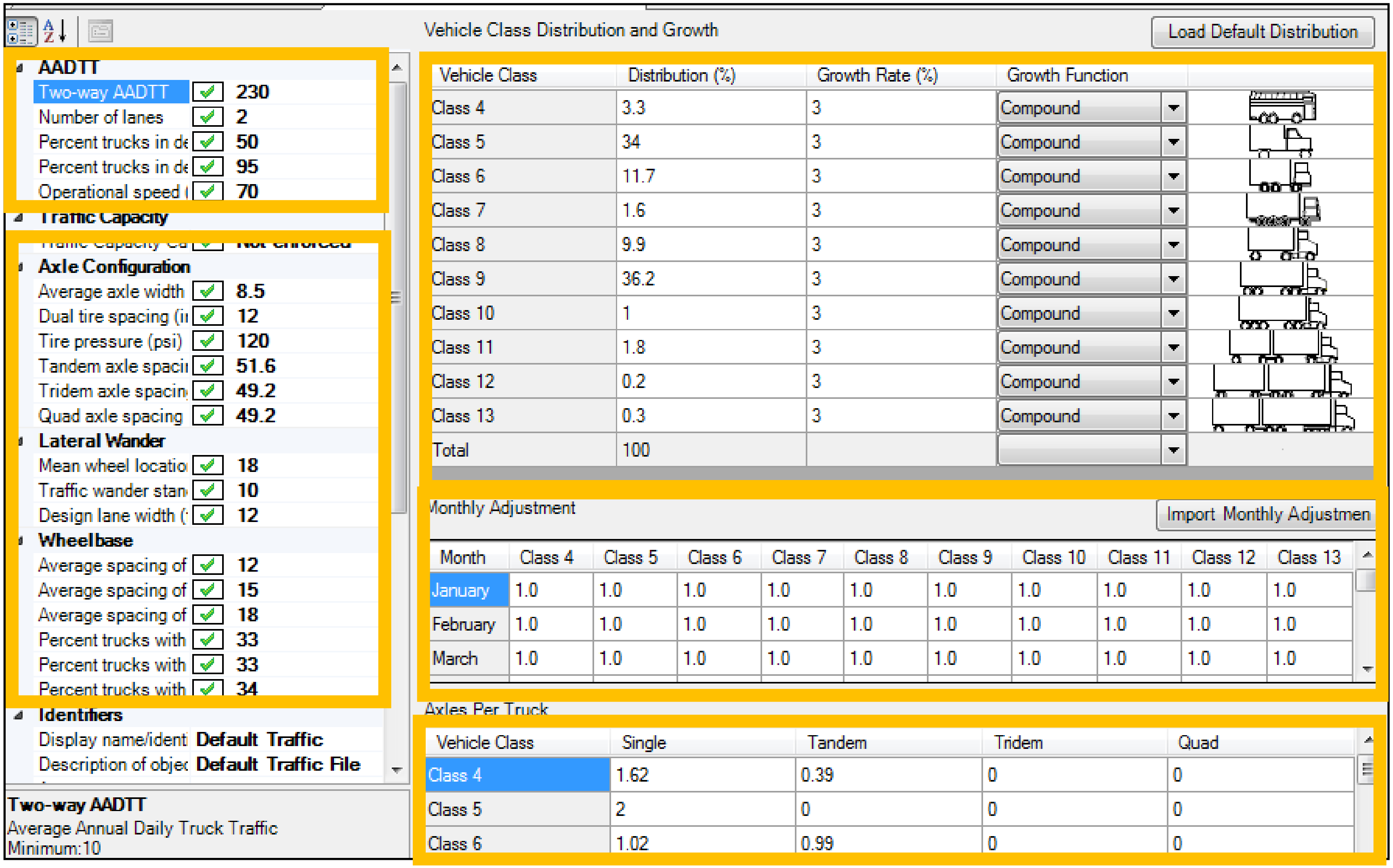
Month	Class 4	Class 5	Class 6	Class 7	Class 8	Class 9	Class 10	Class 11	Class 12	Class 13
January	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
February	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
March	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Axles Per Truck

Vehicle Class	Single	Tandem	Tridem	Quad
Class 4	1.62	0.39	0	0
Class 5	2	0	0	0
Class 6	1.02	0.99	0	0

U.S. Department of Transportation
Federal Highway Administration

MODULE E | PROJECT LEVEL, TRAFFIC, AND CLIMATE INPUTS | LESSON 2 | 46



AADTT

Two-way AADTT	☑	230
Number of lanes	☑	2
Percent trucks in de	☑	50
Percent trucks in de	☑	95
Operational speed (	☑	70

Traffic Capacity

Traffic Capacity Ca	☑	Not enforced

Axle Configuration

Average axle width	☑	8.5
Dual tire spacing (in	☑	12
Tire pressure (psi)	☑	120
Tandem axle spacii	☑	51.6
Tridem axle spacin	☑	49.2
Quad axle spacing	☑	49.2

Lateral Wander

Mean wheel locatio	☑	18
Traffic wander stan	☑	10
Design lane width (	☑	12

Wheelbase

Average spacing of	☑	12
Average spacing of	☑	15
Average spacing of	☑	18
Percent trucks with	☑	33
Percent trucks with	☑	33
Percent trucks with	☑	34

Identifiers

Display name/ident	Default Traffic
Description of objec	Default Traffic File

Two-way AADTT
Average Annual Daily Truck Traffic
Minimum:10

Vehicle Class Distribution and Growth

Vehicle Class	Distribution (%)	Growth Rate (%)	Growth Function
Class 4	3.3	3	Compound
Class 5	34	3	Compound
Class 6	11.7	3	Compound
Class 7	1.6	3	Compound
Class 8	9.9	3	Compound
Class 9	36.2	3	Compound
Class 10	1	3	Compound
Class 11	1.8	3	Compound
Class 12	0.2	3	Compound
Class 13	0.3	3	Compound
Total	100		

Monthly Adjustment

Month	Class 4	Class 5	Class 6	Class 7	Class 8	Class 9	Class 10	Class 11	Class 12	Class 13
January	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
February	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
March	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Axles Per Truck

Vehicle Class	Single	Tandem	Tridem	Quad
Class 4	1.62	0.39	0	0
Class 5	2	0	0	0
Class 6	1.02	0.99	0	0

This is a screen capture of the various segments in the software where all of these different truck traffic inputs are entered. It is intended to generally introduce what the Pavement ME Design traffic input screens look like.

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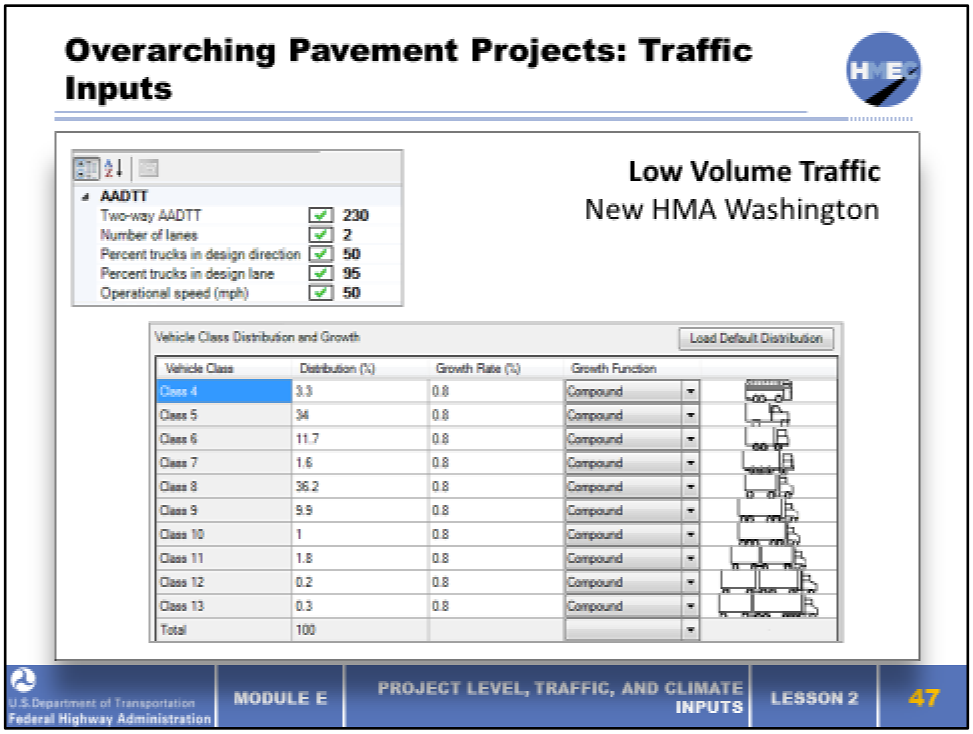
Slide 47



Overarching Pavement Projects: Traffic Inputs

Low Volume Traffic

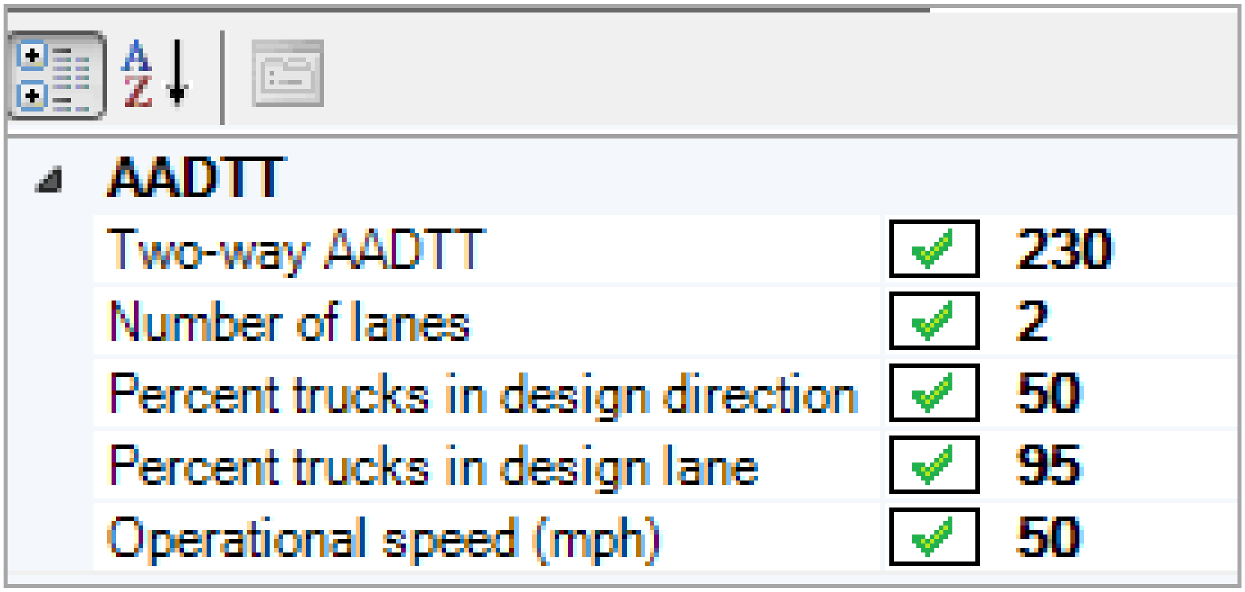
New HMA Washington

AADTT

Two-way AADTT	☑	230
Number of lanes	☑	2
Percent trucks in design direction	☑	50
Percent trucks in design lane	☑	95
Operational speed (mph)	☑	50

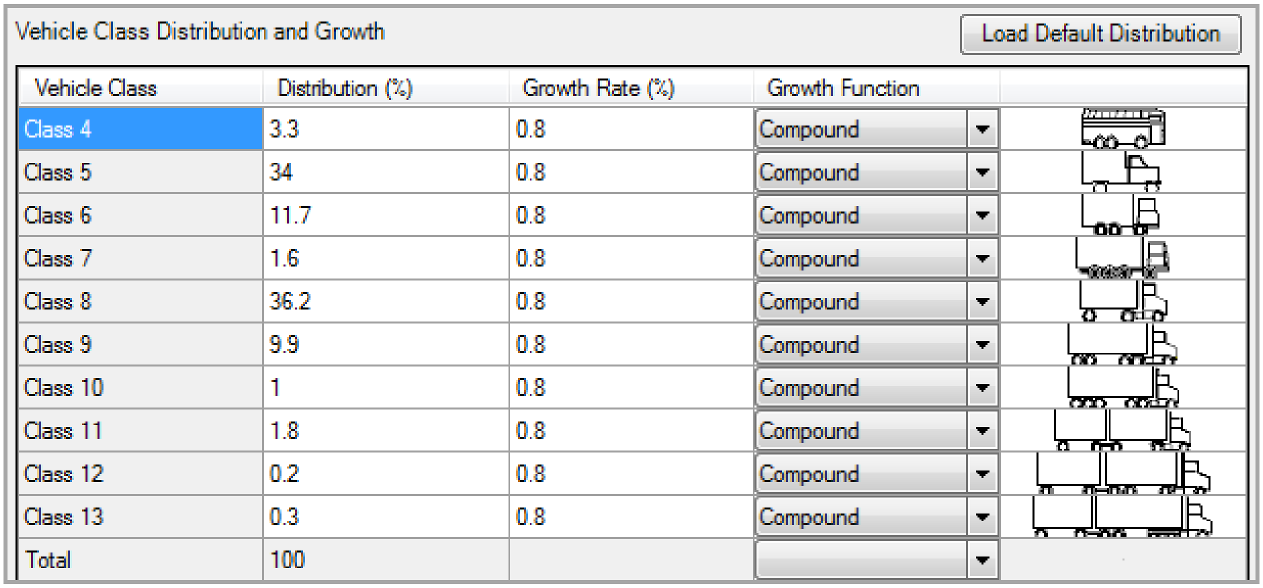
Vehicle Class Distribution and Growth

Vehicle Class	Distribution (%)	Growth Rate (%)	Growth Function
Class 4	3.3	0.8	Compound
Class 5	34	0.8	Compound
Class 6	11.7	0.8	Compound
Class 7	1.6	0.8	Compound
Class 8	36.2	0.8	Compound
Class 9	9.9	0.8	Compound
Class 10	1	0.8	Compound
Class 11	1.8	0.8	Compound
Class 12	0.2	0.8	Compound
Class 13	0.3	0.8	Compound
Total	100		



AADTT

Two-way AADTT	☑	230
Number of lanes	☑	2
Percent trucks in design direction	☑	50
Percent trucks in design lane	☑	95
Operational speed (mph)	☑	50


Vehicle Class Distribution and Growth
Load Default Distribution

Vehicle Class	Distribution (%)	Growth Rate (%)	Growth Function
Class 4	3.3	0.8	Compound
Class 5	34	0.8	Compound
Class 6	11.7	0.8	Compound
Class 7	1.6	0.8	Compound
Class 8	36.2	0.8	Compound
Class 9	9.9	0.8	Compound
Class 10	1	0.8	Compound
Class 11	1.8	0.8	Compound
Class 12	0.2	0.8	Compound
Class 13	0.3	0.8	Compound
Total	100		

You are looking at a screen capture of key traffic inputs for low volume road sample project. The top box is the AADTT input section, which defines the volume annually of heavy vehicle classes, along with the percent of those trucks in the design lane and design direction. The number of lanes is also input in this screen, and it should be noted that in Pavement ME Design you are only analyzing a design in one direction, so the number of lanes are in one direction. The operational speed is also input in miles per hour.

The second input box shows the Vehicle Class Distribution and Growth inputs. The distribution is the percentage of each of the FHWA's nine heavy vehicle types (from buses which are Class 4 to double trailers with the most axles are Class 13). The distribution shown is typical for a low volume rural road. You can see that the growth rate percentage of heavy trucks is then entered in the next column, followed by the type of growth (either None, Linear, or Compound). In this case, compound growth was selected which may be indicative of major land use changes in the area or significant development expected over the duration of the pavement's design life period.

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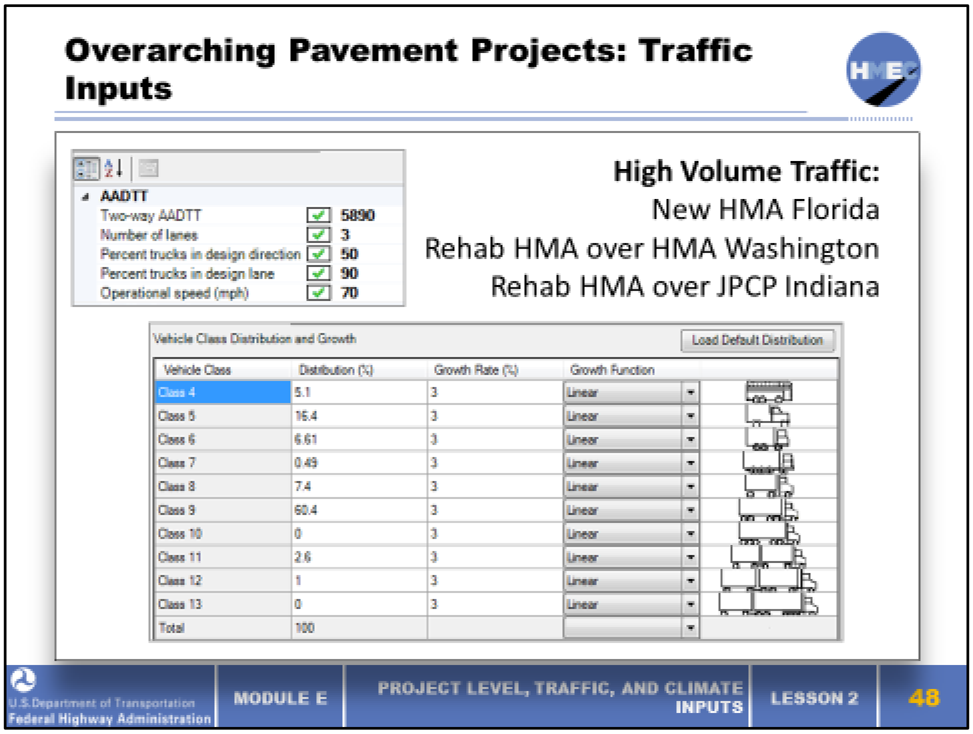
Slide 48



Overarching Pavement Projects: Traffic Inputs

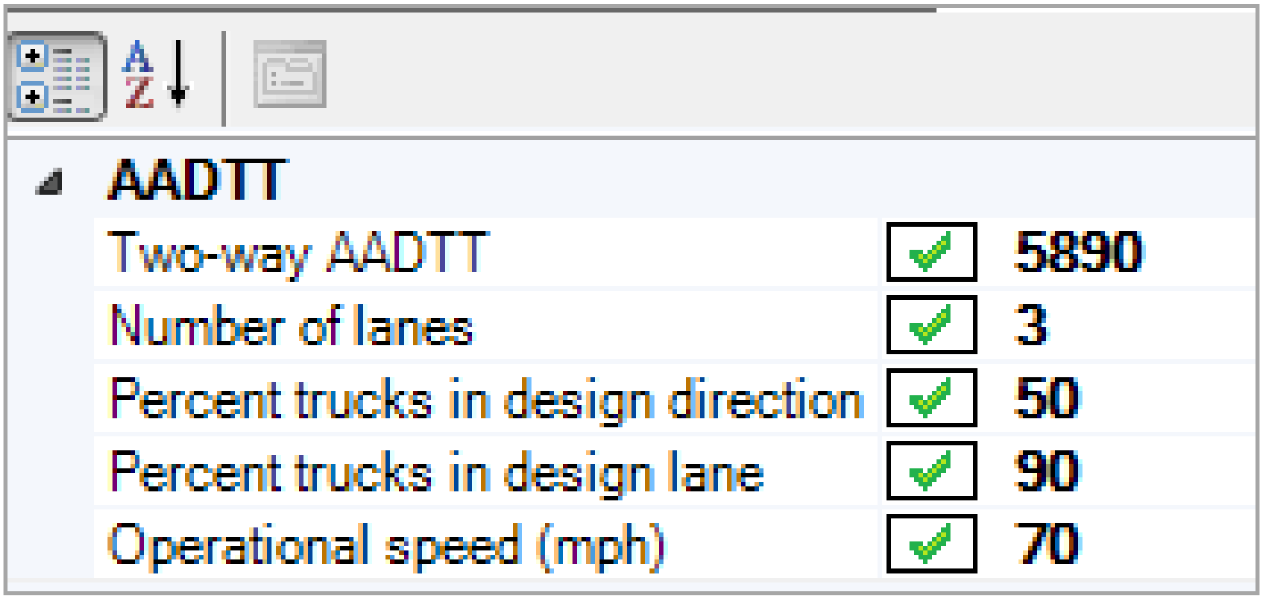
- AADTT
  - Two-way AADTT ☑ 5890
  - Number of lanes ☑ 3
  - Percent trucks in design direction ☑ 50
  - Percent trucks in design lane ☑ 90
  - Operational speed (mph) ☑ 70

High Volume Traffic:
New HMA Florida
Rehab HMA over HMA Washington
Rehab HMA over JPCP Indiana

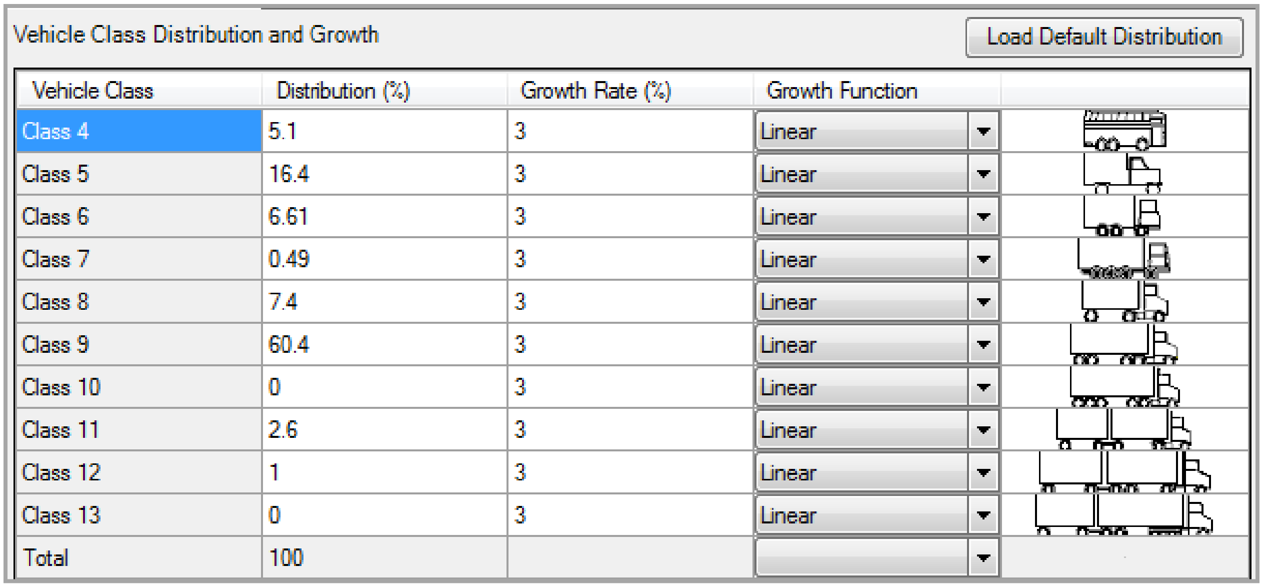
Vehicle Class Distribution and Growth

Vehicle Class	Distribution (%)	Growth Rate (%)	Growth Function
Class 4	5.1	3	Linear
Class 5	16.4	3	Linear
Class 6	6.61	3	Linear
Class 7	0.49	3	Linear
Class 8	7.4	3	Linear
Class 9	60.4	3	Linear
Class 10	0	3	Linear
Class 11	2.6	3	Linear
Class 12	1	3	Linear
Class 13	0	3	Linear
Total	100		

U.S. Department of Transportation
Federal Highway Administration
MODULE E
PROJECT LEVEL, TRAFFIC, AND CLIMATE INPUTS
LESSON 2



- AADTT
  - Two-way AADTT ☑ 5890
  - Number of lanes ☑ 3
  - Percent trucks in design direction ☑ 50
  - Percent trucks in design lane ☑ 90
  - Operational speed (mph) ☑ 70


Vehicle Class Distribution and Growth
Load Default Distribution

Vehicle Class	Distribution (%)	Growth Rate (%)	Growth Function
Class 4	5.1	3	Linear
Class 5	16.4	3	Linear
Class 6	6.61	3	Linear
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Class 10	0	3	Linear
Class 11	2.6	3	Linear
Class 12	1	3	Linear
Class 13	0	3	Linear
Total	100		

You are looking at a screen capture of key traffic inputs for high volume road sample project. The top box is the AADTT input section, which defines the volume annually of heavy vehicle classes, along with the percent of those trucks in the design lane and design direction. The number of lanes is also input in this screen, and it should be noted that in Pavement ME Design you are only analyzing a design in one direction, so the number of lanes are in one direction. The operational speed is also input in miles per hour.

The second input box shows the Vehicle Class Distribution and Growth inputs. The distribution is the percentage of each of the FHWA's nine heavy vehicle types (from buses which are Class 4 to double trailers with the most axles are Class 13). The distribution shown is typical for a high volume freeway or major arterial. You can see that the growth rate percentage of heavy trucks is then entered in the next column, followed by the type of growth (either None, Linear, or Compound). In this case, linear growth was selected which may be indicative of steady population and economic growth expected over the duration of the pavement's design life period.

Slide 49

Selection of Climate Inputs

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Federal Highway Administration

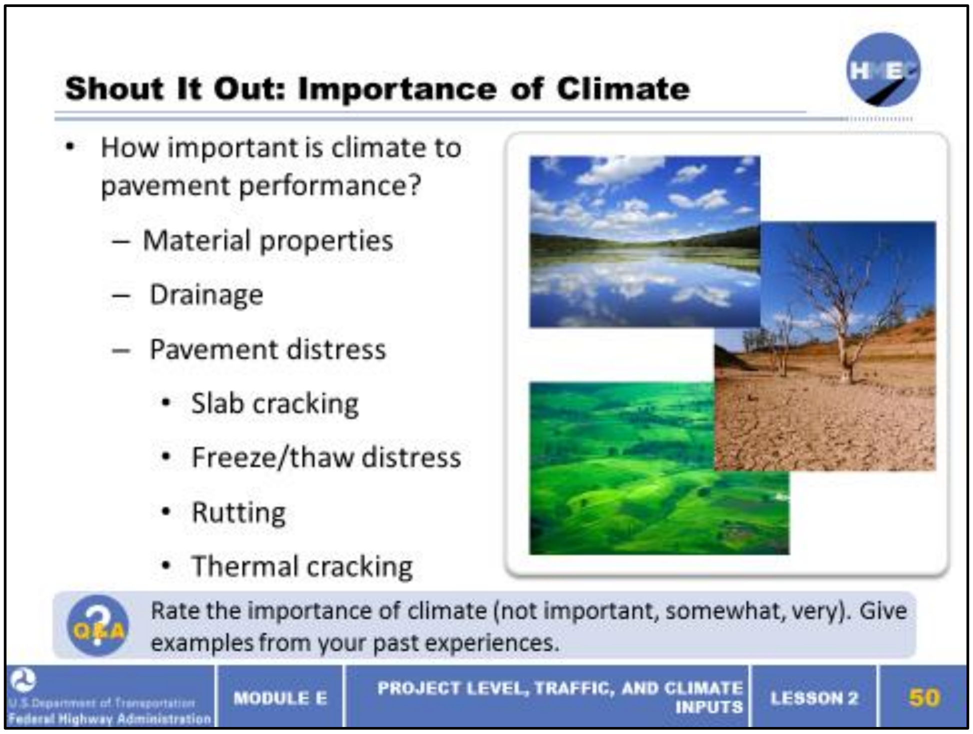
MODULE E

PROJECT LEVEL, TRAFFIC, AND CLIMATE INPUTS

LESSON 2

49

Slide 50



Shout It Out: Importance of Climate

- How important is climate to pavement performance?
  - Material properties
  - Drainage
  - Pavement distress
    - Slab cracking
    - Freeze/thaw distress
    - Rutting
    - Thermal cracking

Rate the importance of climate (not important, somewhat, very). Give examples from your past experiences.

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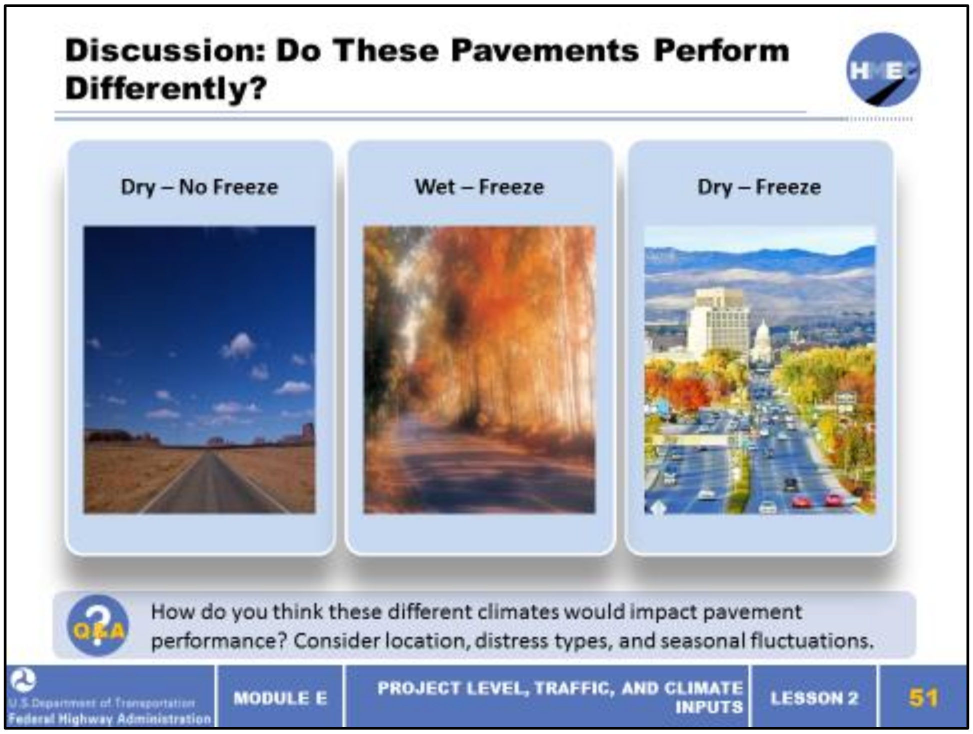
The climate data inputs to the Pavement ME Design models will indirectly trigger the IRI (roughness) of the pavement; for example, any prolonged rainfall events or shallow groundwater table may cause faulting to occur in concrete pavements due to eroding of the base layer and this would impact the ride quality of the pavement. Something similar could happen in asphalt pavements but rutting or fatigue cracking might not exceed the threshold criteria for each of the individual distresses but the combination of both could increase the IRI to above its threshold level.

Slide 51



Discussion: Do These Pavements Perform Differently?

Dry – No Freeze

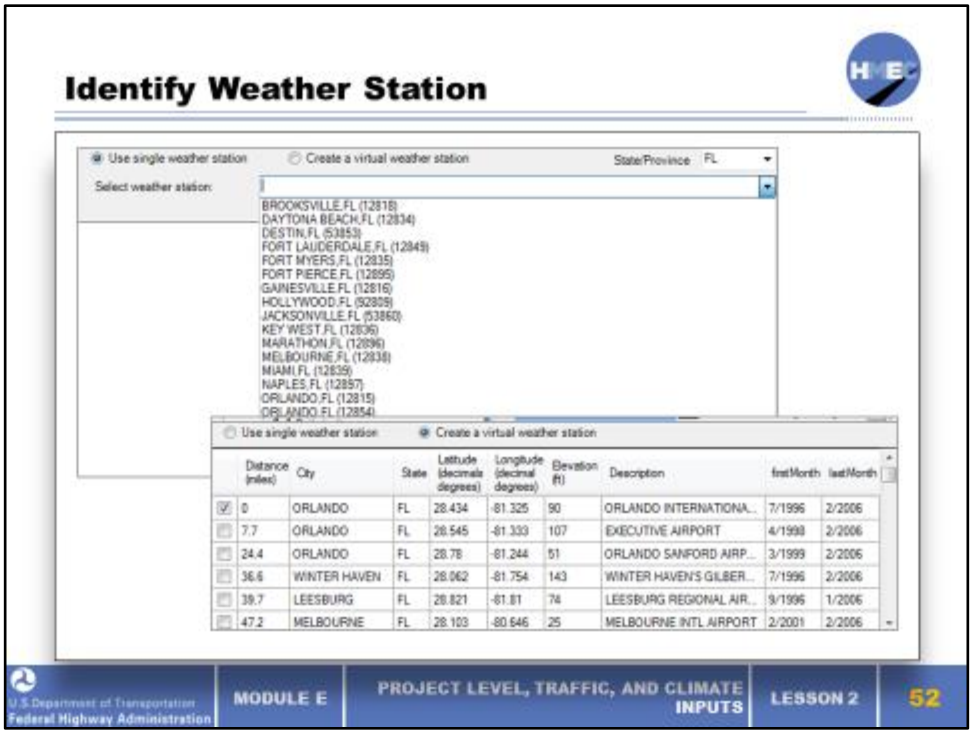
Wet – Freeze

Dry – Freeze

How do you think these different climates would impact pavement performance? Consider location, distress types, and seasonal fluctuations.

Think about how climate impacts material properties and pavement performance.

Slide 52



Identify Weather Station

● Use single weather station ○ Create a virtual weather station State/Province FL

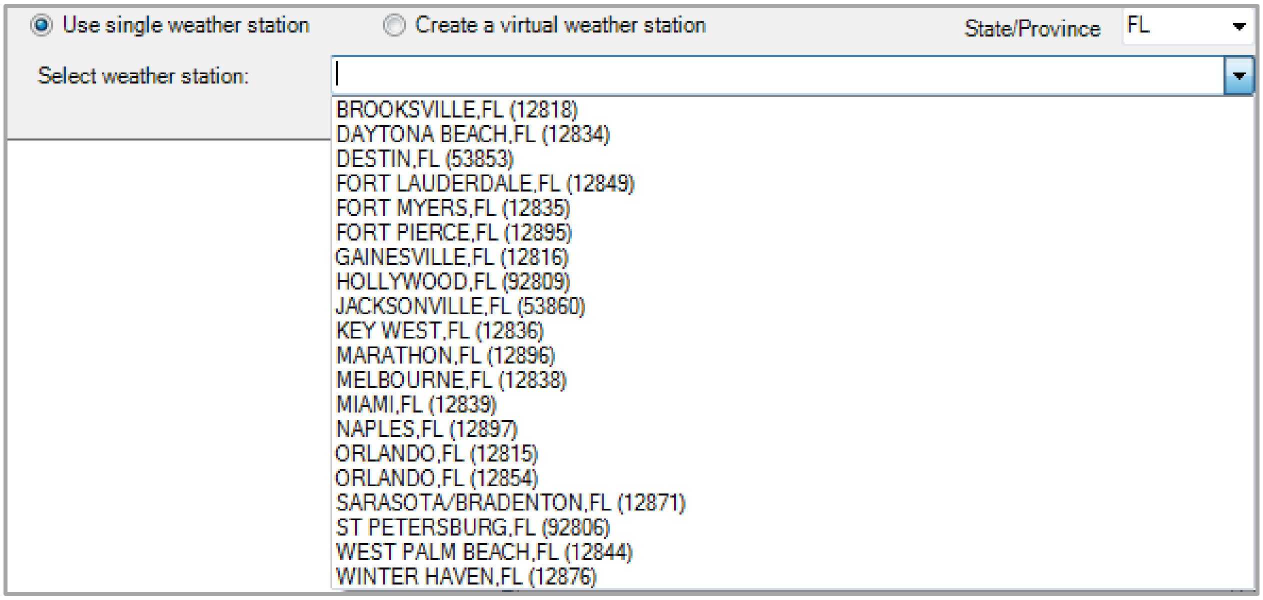
Select weather station:

BROOKSVILLE,FL (12818)
DAYTONA BEACH,FL (12834)
DESTIN,FL (53853)
FORT LAUDERDALE,FL (12849)
FORT MYERS,FL (12835)
FORT PIERCE,FL (12895)
GAINESVILLE,FL (12816)
HOLLYWOOD,FL (92809)
JACKSONVILLE,FL (53860)
KEY WEST,FL (12836)
MARATHON,FL (12896)
MELBOURNE,FL (12838)
MIAMI,FL (12839)
NAPLES,FL (12897)
ORLANDO,FL (12815)
ORLANDO,FL (12854)

○ Use single weather station ● Create a virtual weather station

	Distance (miles)	City	State	Latitude (decimals degrees)	Longitude (decimal degrees)	Elevation (ft)	Description	firstMonth	lastMonth
☑	0	ORLANDO	FL	28.434	-81.325	90	ORLANDO INTERNATIONA...	7/1996	2/2006
☐	7.7	ORLANDO	FL	28.545	-81.333	107	EXECUTIVE AIRPORT	4/1998	2/2006
☐	24.4	ORLANDO	FL	28.78	-81.244	51	ORLANDO SANFORD AIRP...	3/1999	2/2006
☐	36.6	WINTER HAVEN	FL	28.062	-81.754	143	WINTER HAVEN'S GILBER...	7/1996	2/2006
☐	39.7	LEESBURG	FL	28.821	-81.81	74	LEESBURG REGIONAL AIR...	9/1996	1/2006
☐	47.2	MELBOURNE	FL	28.103	-80.646	25	MELBOURNE INTL AIRPORT	2/2001	2/2006

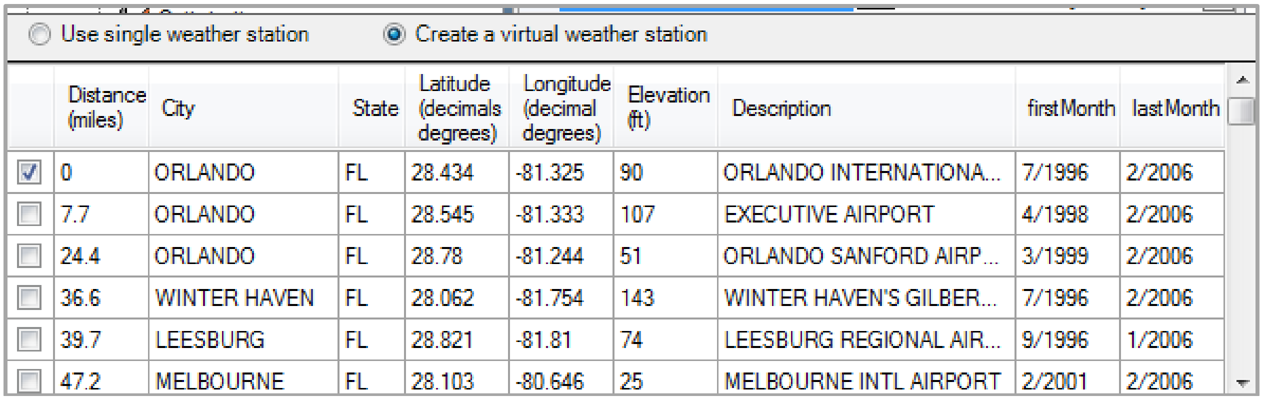
U.S. Department of Transportation
Federal Highway Administration
MODULE E
PROJECT LEVEL, TRAFFIC, AND CLIMATE INPUTS
LESSON 2
52



● Use single weather station ○ Create a virtual weather station State/Province FL

Select weather station:

BROOKSVILLE,FL (12818)
DAYTONA BEACH,FL (12834)
DESTIN,FL (53853)
FORT LAUDERDALE,FL (12849)
FORT MYERS,FL (12835)
FORT PIERCE,FL (12895)
GAINESVILLE,FL (12816)
HOLLYWOOD,FL (92809)
JACKSONVILLE,FL (53860)
KEY WEST,FL (12836)
MARATHON,FL (12896)
MELBOURNE,FL (12838)
MIAMI,FL (12839)
NAPLES,FL (12897)
ORLANDO,FL (12815)
ORLANDO,FL (12854)
SARASOTA/BRADENTON,FL (12871)
ST PETERSBURG,FL (92806)
WEST PALM BEACH,FL (12844)
WINTER HAVEN,FL (12876)



○ Use single weather station ● Create a virtual weather station

	Distance (miles)	City	State	Latitude (decimals degrees)	Longitude (decimal degrees)	Elevation (ft)	Description	firstMonth	lastMonth
☑	0	ORLANDO	FL	28.434	-81.325	90	ORLANDO INTERNATIONA...	7/1996	2/2006
☐	7.7	ORLANDO	FL	28.545	-81.333	107	EXECUTIVE AIRPORT	4/1998	2/2006
☐	24.4	ORLANDO	FL	28.78	-81.244	51	ORLANDO SANFORD AIRP...	3/1999	2/2006
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☐	39.7	LEESBURG	FL	28.821	-81.81	74	LEESBURG REGIONAL AIR...	9/1996	1/2006
☐	47.2	MELBOURNE	FL	28.103	-80.646	25	MELBOURNE INTL AIRPORT	2/2001	2/2006

There are two options for identifying a weather station.

Option A: Select a single specific weather station by name from given list.

Option B: Interpolate climatic data for a location by selecting multiple by entering:

- Latitude (degrees, minutes);
- Longitude (degrees, minutes); and
- Elevation (ft.).

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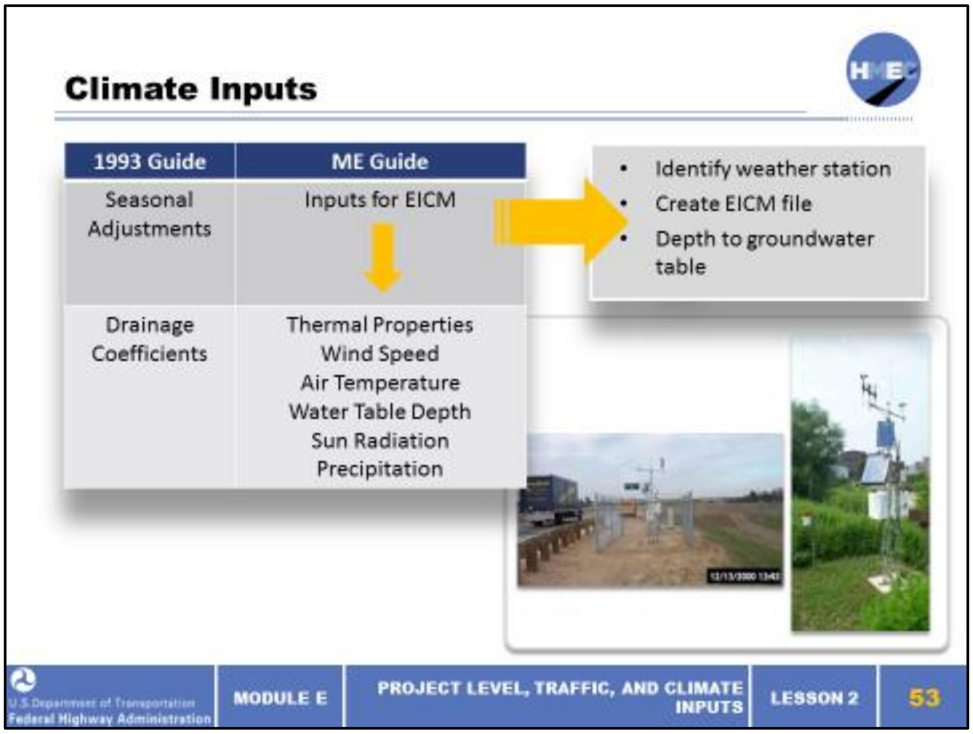
Slide 53



Climate Inputs

1993 Guide	ME Guide
Seasonal Adjustments	Inputs for EICM
Drainage Coefficients	Thermal Properties Wind Speed Air Temperature Water Table Depth Sun Radiation Precipitation

- Identify weather station
- Create EICM file
- Depth to groundwater table

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This slide shows how the previous AASHTO 1993 guide considered the influence of climate with resilient modulus adjustments and drainage coefficients. Pavement ME Design uses the Enhanced Integrated Climatic Model (EICM) to provide more robust climate inputs for the pavement analysis.

In the 1993 guide, seasonal adjustments to soil resilient modulus are made using the effective resilient modulus concept (ur tables). Drainage coefficient tables for unbound material layers are indicated with mi values for various drainage conditions (excellent to poor) and saturation levels (percent of time spent approaching saturation).

Detailed climatic data are required for predicting pavement distress with the Pavement ME Design software and include data such as hourly temperature, precipitation, wind speed, relative humidity, and cloud cover. These data are used to predict the temperature and moisture content in each of the pavement layers, as well as provide some of the inputs to the site factor parameter for the smoothness prediction models.

EICM is used to predict hourly temperature profile through the pavement structure based on historical hourly climatic data.

Climatic inputs are essentially used by the program to predict the temperature and moisture profiles in the pavement over the design life. Further, this prediction is used to determine the modulus of the pavement materials as they change over the design life.

All of the climate data needed by the Pavement ME Design are available from weather stations, generally located at airfields around the US. The Pavement ME Design has an extensive number of weather stations embedded in its software for ease of use and implementation.

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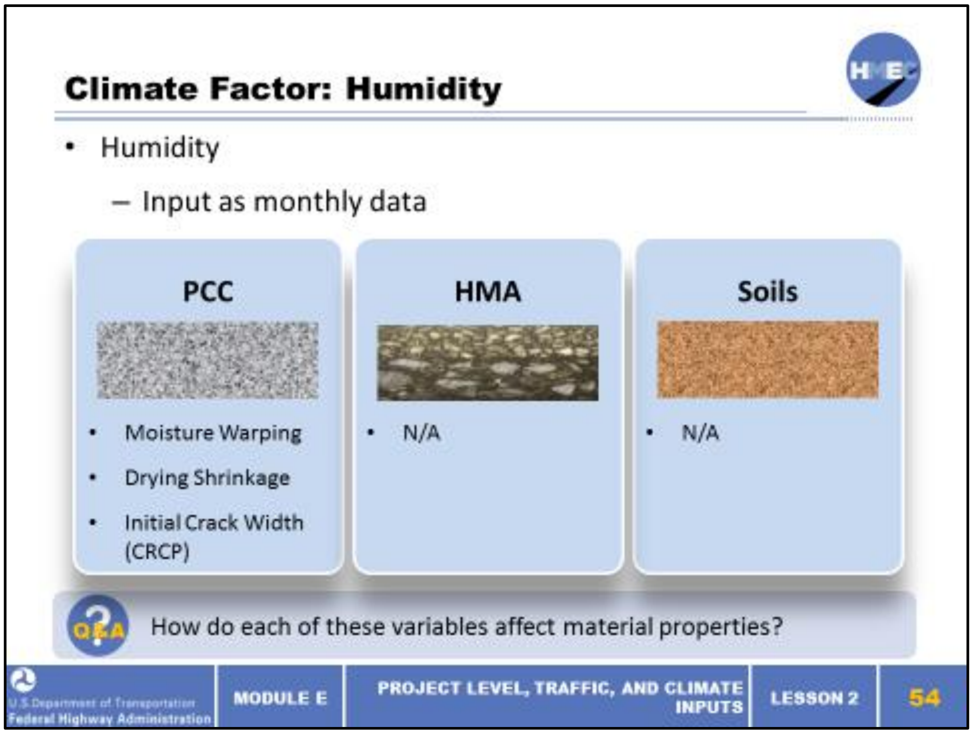
Slide 54



Climate Factor: Humidity

- Humidity
  - Input as monthly data

PCC

- Moisture Warping
- Drying Shrinkage
- Initial Crack Width (CRCP)

HMA

- N/A

Soils

- N/A

Q&A How do each of these variables affect material properties?

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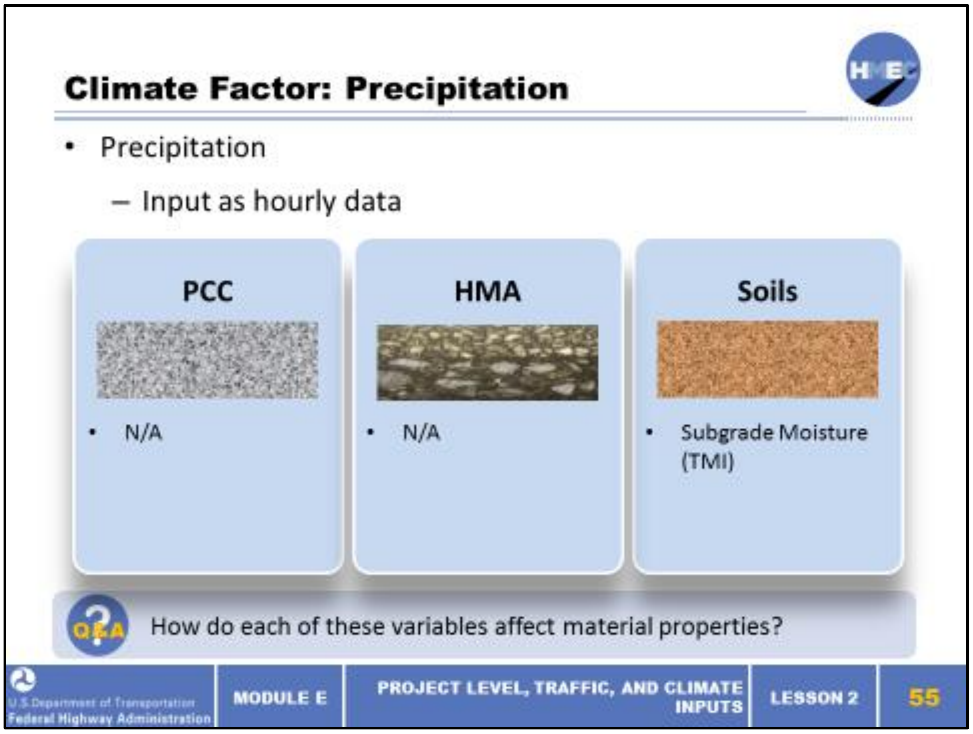
Humidity is provided by the EICM in monthly humidity measurements. Humidity affects concrete pavement in a few key ways: moisture warping, drying shrinkage, and initial crack width.

Slide 55



Climate Factor: Precipitation

- Precipitation
  - Input as hourly data

PCC

- N/A

HMA

- N/A

Soils

- Subgrade Moisture (TMI)

How do each of these variables affect material properties?

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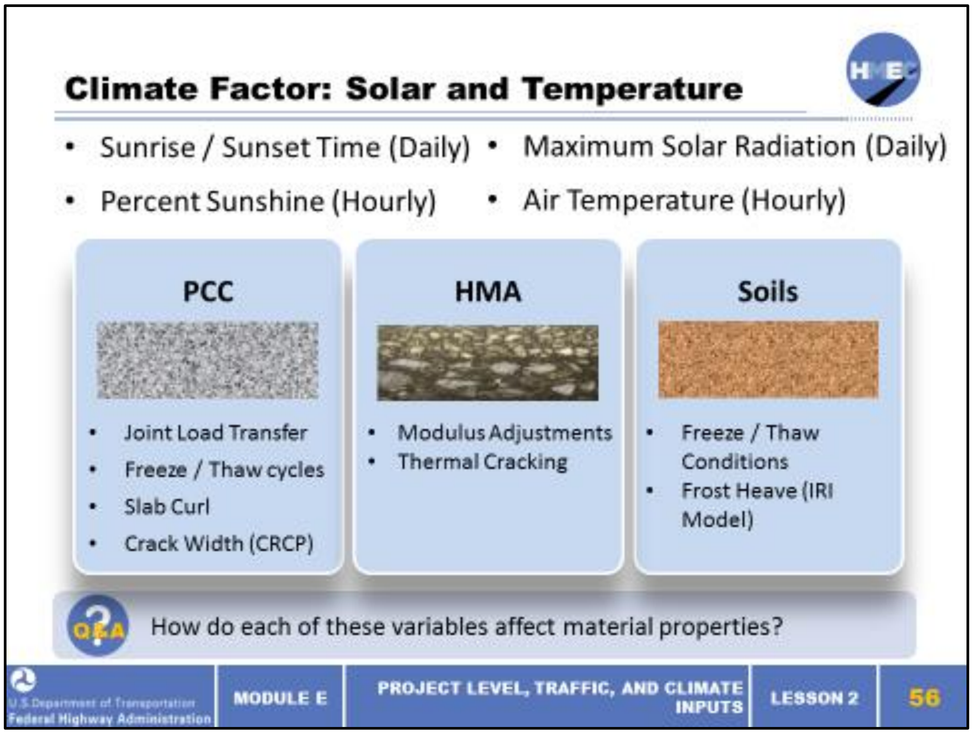
Precipitation is provided by the EICM in hourly humidity measurements. Precipitation is not modeled as influential in the Pavement ME Design software (although in reality, it does impact the HMA mixture performance sometimes significantly in the field). However, it does influence the subgrade moisture through the Thornthwaite moisture index (TMI).

Slide 56



Climate Factor: Solar and Temperature

- Sunrise / Sunset Time (Daily)
- Maximum Solar Radiation (Daily)
- Percent Sunshine (Hourly)
- Air Temperature (Hourly)

PCC

- Joint Load Transfer
- Freeze / Thaw cycles
- Slab Curl
- Crack Width (CRCP)

HMA

- Modulus Adjustments
- Thermal Cracking

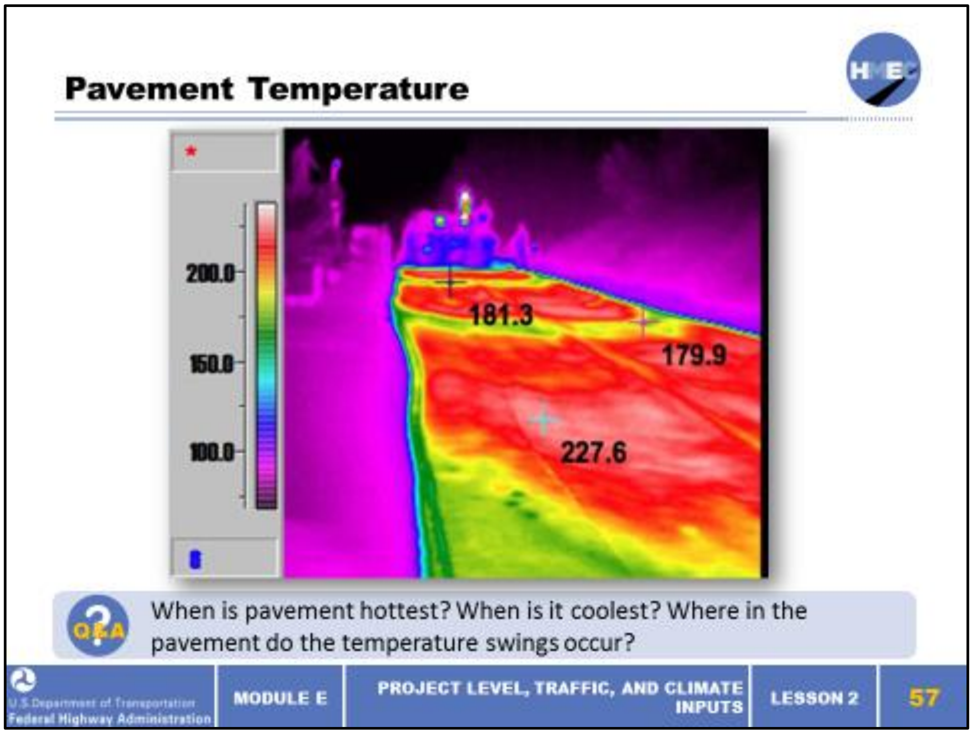
Soils

- Freeze / Thaw Conditions
- Frost Heave (IRI Model)

How do each of these variables affect material properties?

To show the influence of climate on the properties of the materials.

Slide 57



Pavement Temperature

200.0
150.0
100.0
181.3
179.9
227.6

Q&A When is pavement hottest? When is it coolest? Where in the pavement do the temperature swings occur?

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Temperature variation hourly will influence the material properties and responses to loading. This is the essence of “climate loading” in a pavement that is the output provided by the EICM.

Note that this picture is a temperature profile during the placement of an asphalt lift and not typical in service pavement temperatures.

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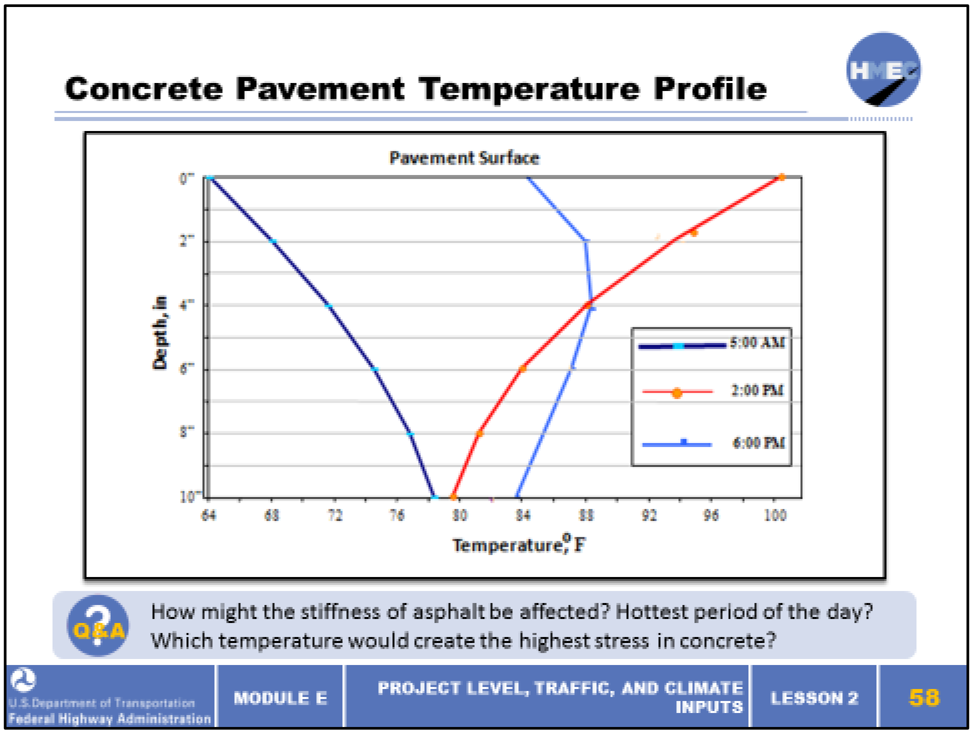
Slide 58

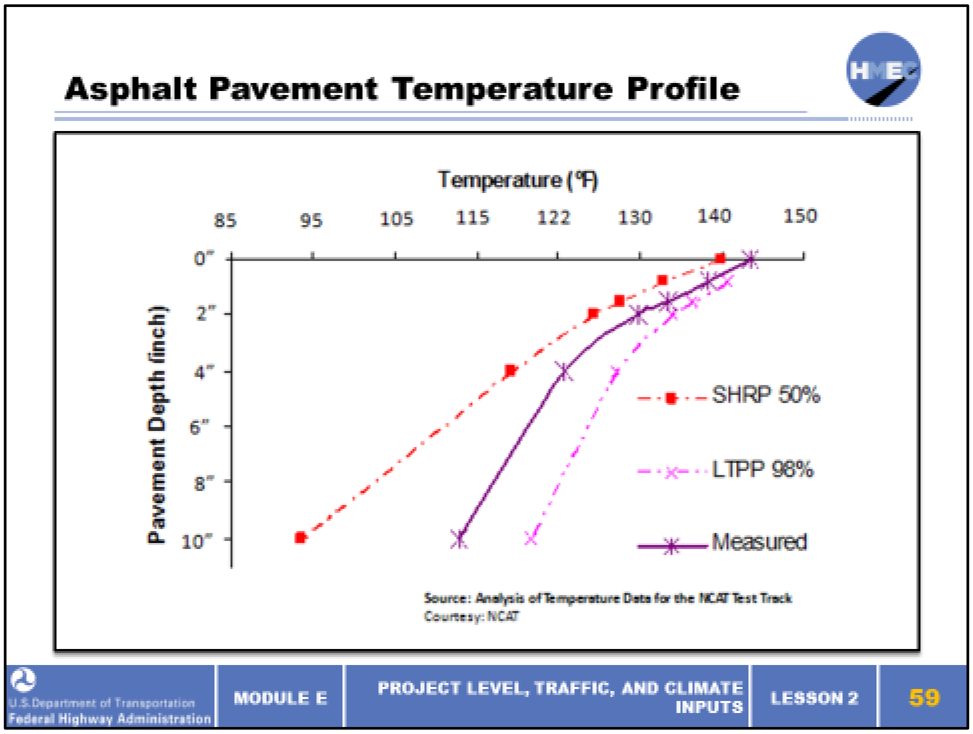


Concrete Pavement Temperature Profile

Q&A How might the stiffness of asphalt be affected? Hottest period of the day? Which temperature would create the highest stress in concrete?

This slide presents the temperature profile within a concrete pavement. The temperature in degrees Fahrenheit is shown on the X-axis and the depth down within the concrete pavement structure is shown on the Y-axis. Three different temperature schemata are shown that represent the distributions at three different times of day. The dark blue trend is at 5:00 a.m., the red trend is at 2:00 p.m., and the light blue trend is at 6:00 p.m.

Slide 59



Asphalt Pavement Temperature Profile

Source: Analysis of Temperature Data for the NCAT Test Track
Courtesy: NCAT

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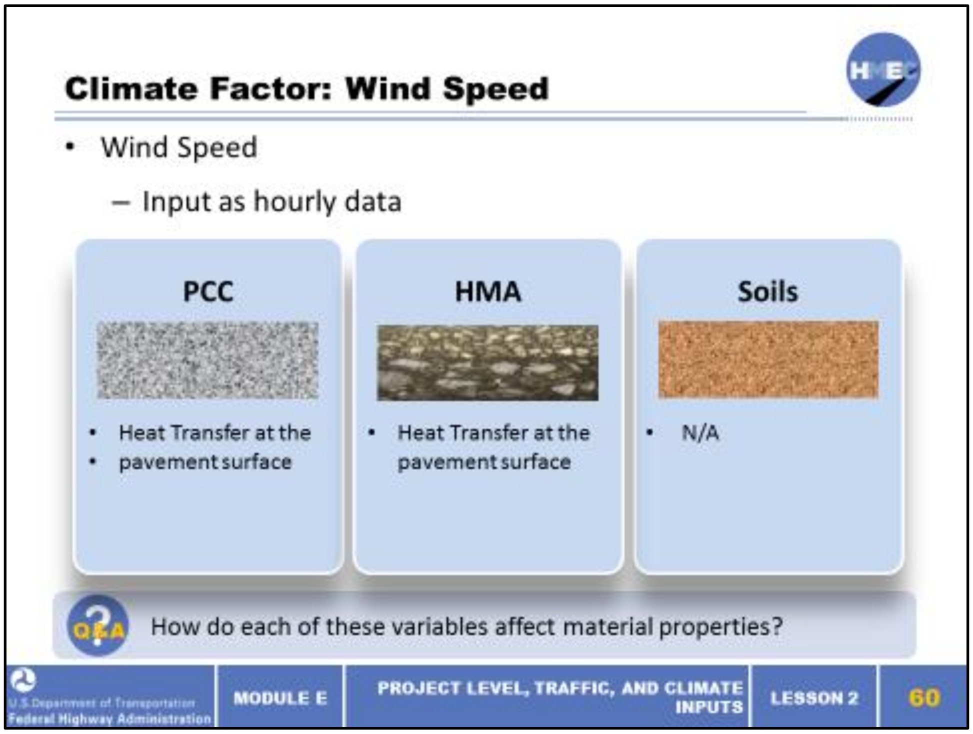
For different methods of measuring the temperature profile, at varying levels of accuracy, the distribution of temperature through the pavement does vary somewhat in terms of its magnitude; however, the trends of how the temperature is represented through the depth of the pavement are relatively consistent.

Slide 60



Climate Factor: Wind Speed

- Wind Speed
  - Input as hourly data

PCC

- Heat Transfer at the
- pavement surface

HMA

- Heat Transfer at the pavement surface

Soils

- N/A

How do each of these variables affect material properties?

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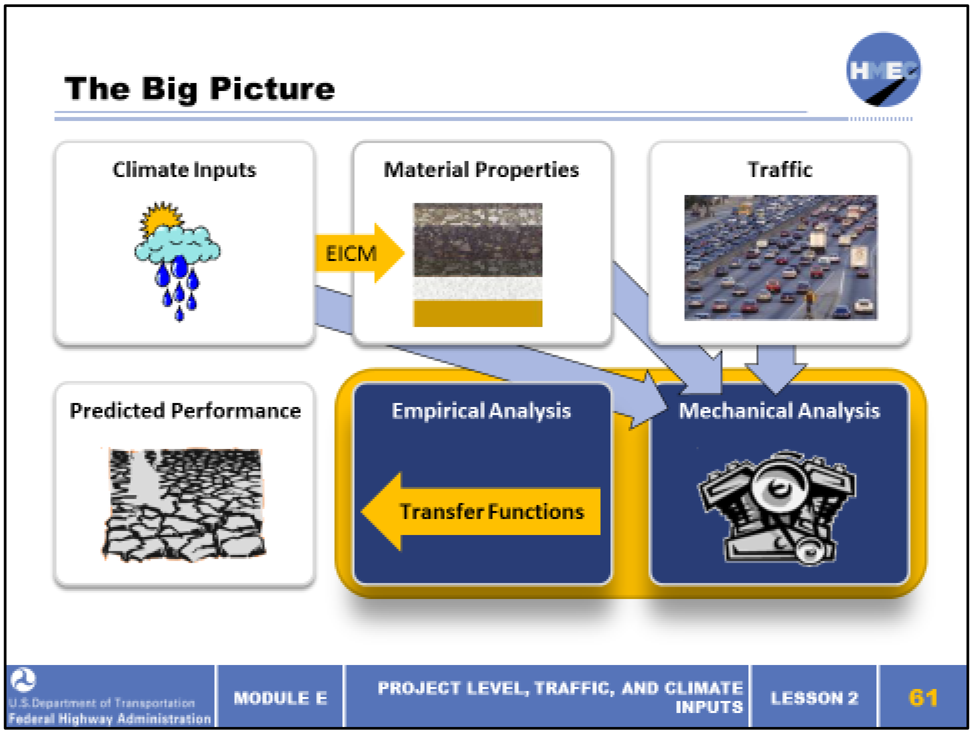
The wind speed can affect the amount of heat transfer at the surface of the asphalt or concrete pavement.

Slide 61



The Big Picture

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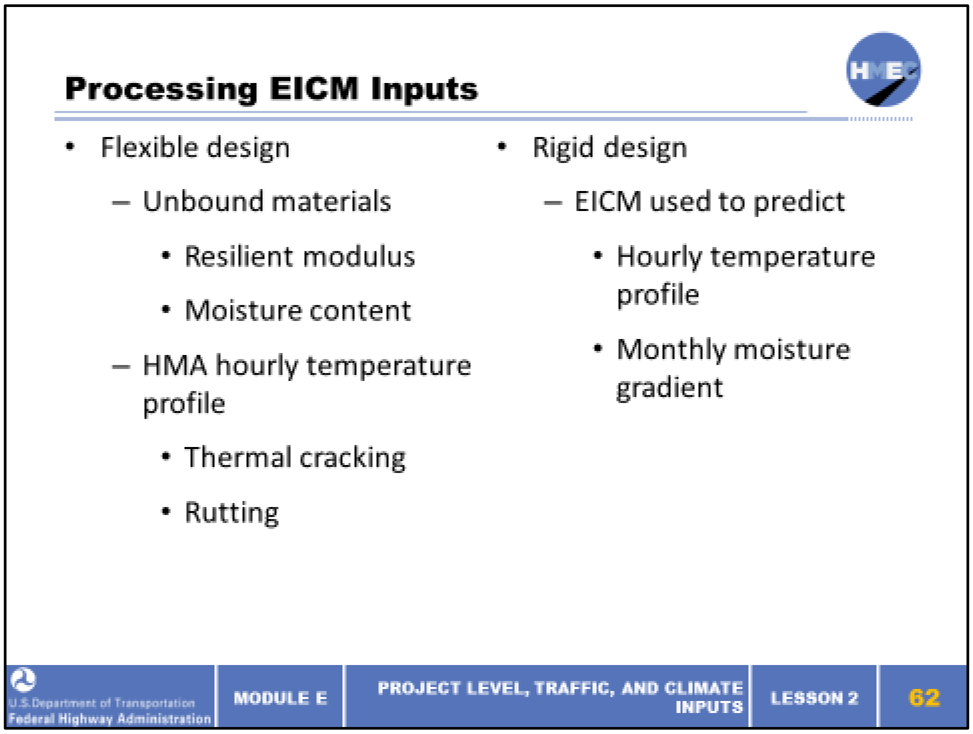
Slide 62



Processing EICM Inputs

- Flexible design
  - Unbound materials
    - Resilient modulus
    - Moisture content
  - HMA hourly temperature profile
    - Thermal cracking
    - Rutting
- Rigid design
  - EICM used to predict
    - Hourly temperature profile
    - Monthly moisture gradient

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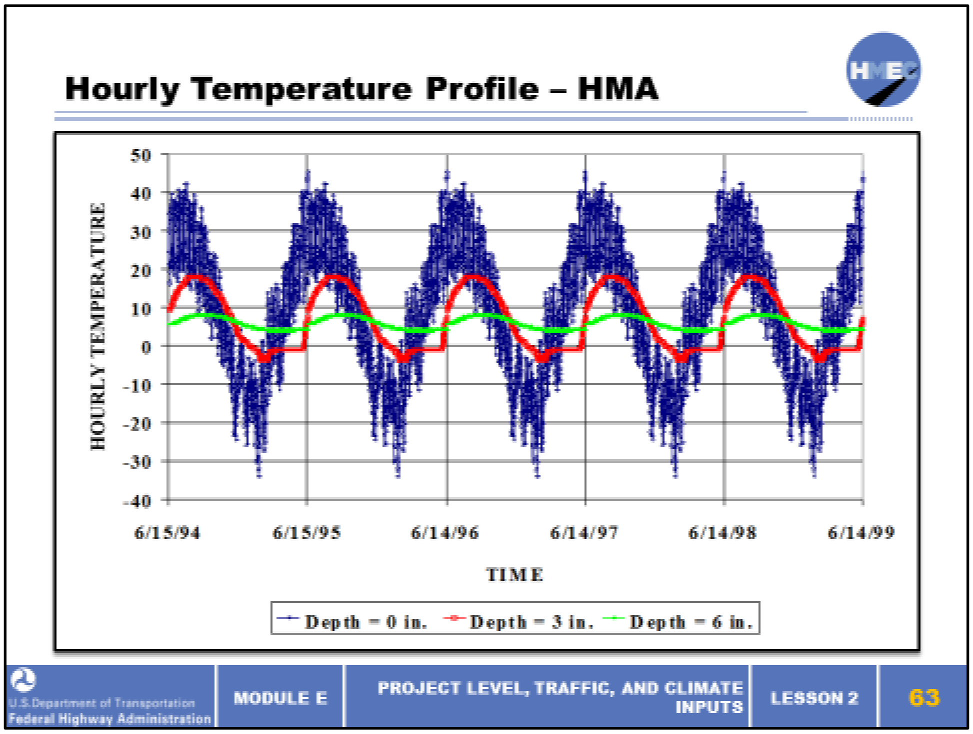
The Enhanced Integrated Climatic Model (EICM) is the built-in model that converts raw climate data into "environmental loading," which greatly influences in a composite manner each material's mechanical responses. In the ICM module, the materials passing #200 and plasticity index (PI) directly influence the predicted IRI (roughness) in the results. Even when the Pavement ME Design users don't select the ICM, the software models will take those two values in order to predict the IRI.

Slide 63



Hourly Temperature Profile – HMA

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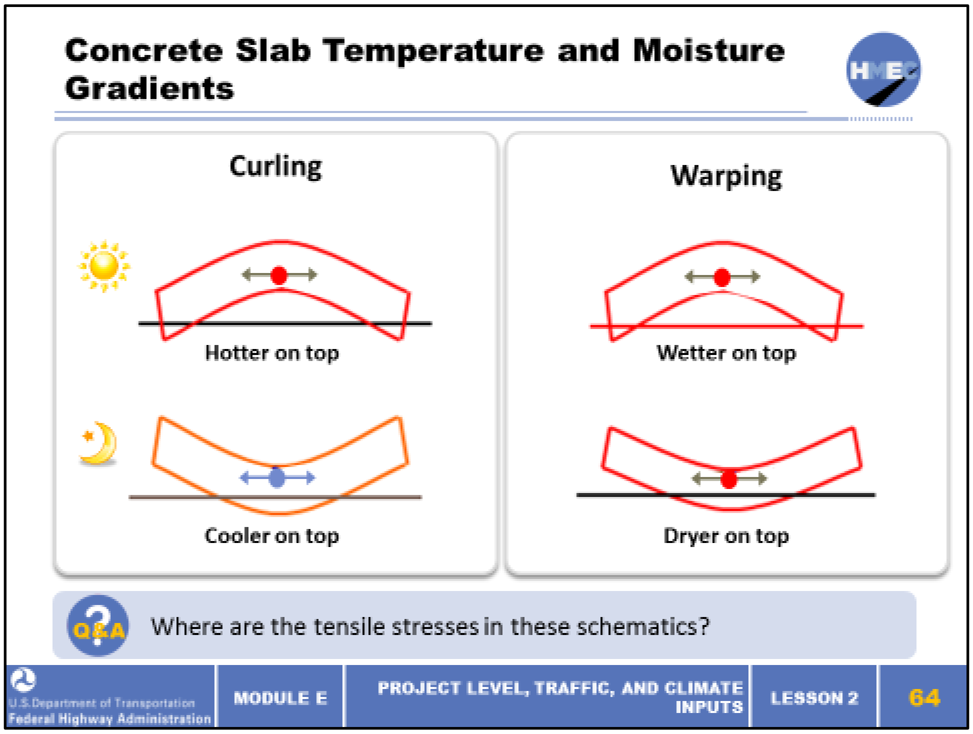
MODULE E | PROJECT LEVEL, TRAFFIC, AND CLIMATE INPUTS | LESSON 2 | 63

This figure shows that there are greater temperature fluctuations near the surface of an asphalt layer as compare to further down in the layer. These temperature effects directly impact the modulus of the material.

Slide 64



Concrete Slab Temperature and Moisture Gradients

Curling

Hotter on top

Cooler on top

Warping

Wetter on top

Dryer on top

Q&A Where are the tensile stresses in these schematics?

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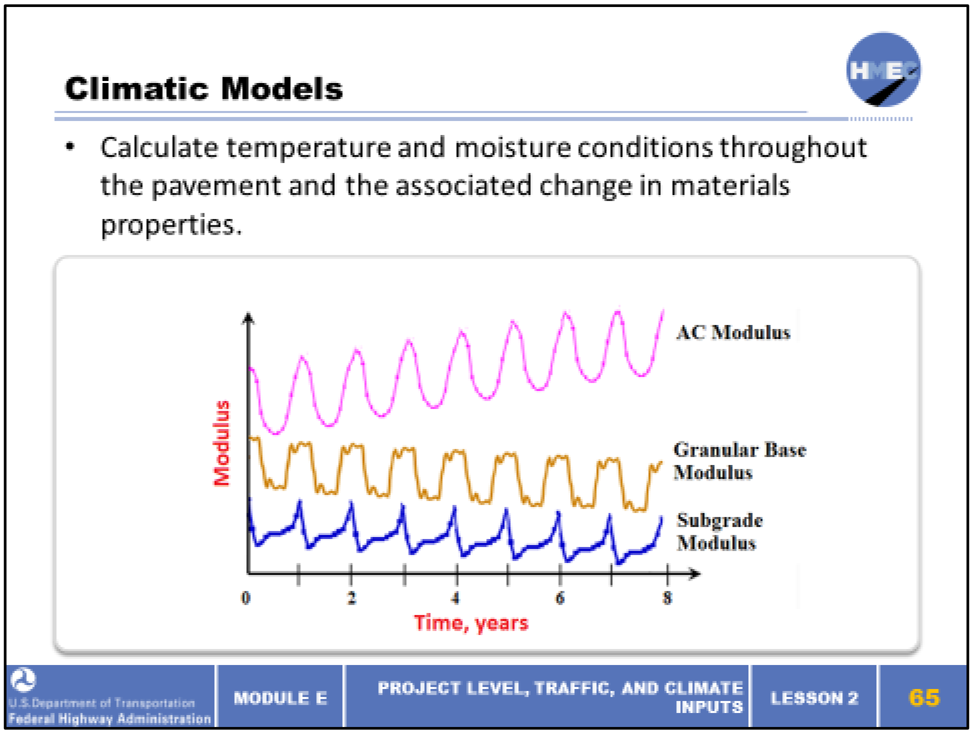
Both daytime (positive) and nighttime (negative) thermal gradient probability distributions are obtained for each month in each year over the intended design life analyzed in the Pavement ME Design.

At the critical times, the stresses are additive. However, one condition will typically predominate the other.

In addition, both temperature gradients (e.g., from a sudden intense rainfall in the middle of a hot sunny afternoon) and moisture gradients (e.g., dew or frost at the surface of a pavement in the mornings during certain seasons in certain locations) do cause rigid pavement to warp and curl.

Slide 65



Climatic Models

- Calculate temperature and moisture conditions throughout the pavement and the associated change in materials properties.

There is a lot happening in the pavement structure over time. The Pavement ME Design models are capable of calculating the changes in moisture and temperature at critical locations over time and calculate the associated changes in materials properties.

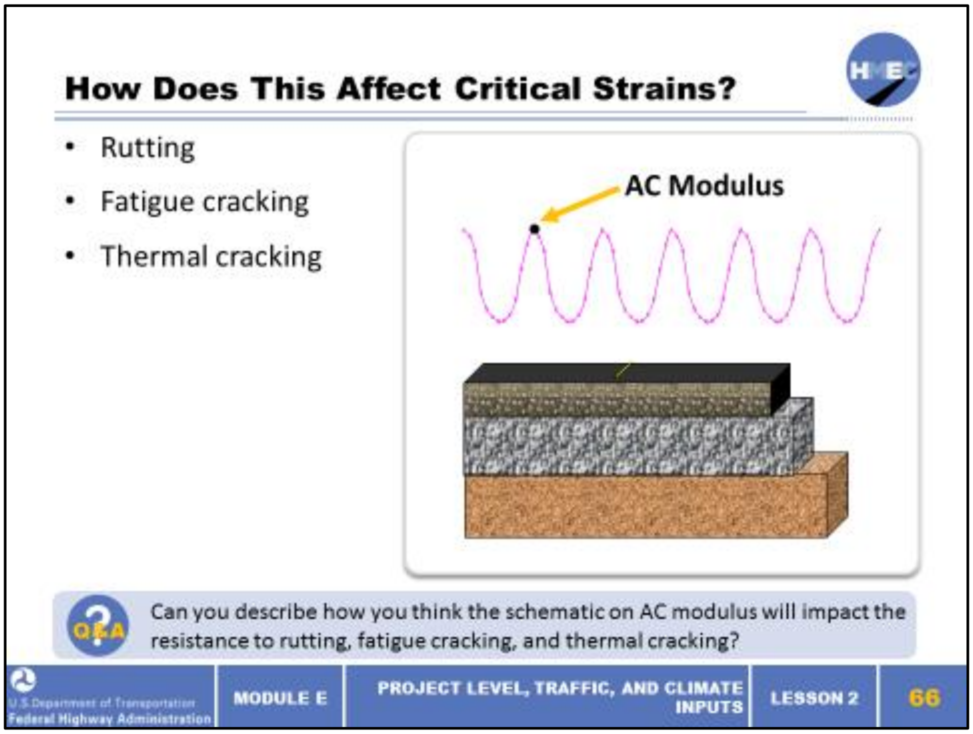
In addition to the annual cyclical changes in modulus for each of the pavement layer materials, there is also a change over time in the modulus with aging. The magnitude of the change in modulus depends on the material type and location.

For example, a granular base modulus may decrease over time due to water infiltration and/or contamination of the base.

The subgrade modulus will likely decrease over time due to consolidation, infiltration of groundwater or other drainage problems, etc.

The asphalt modulus will increase over time due to stiffening through the aging process.

Slide 66



How Does This Affect Critical Strains?

- Rutting
- Fatigue cracking
- Thermal cracking

Can you describe how you think the schematic on AC modulus will impact the resistance to rutting, fatigue cracking, and thermal cracking?

Relate the impact of climate loading on critical pavement responses (tensile strain at bottom of asphalt layer, compressive strain at top of subgrade layer).

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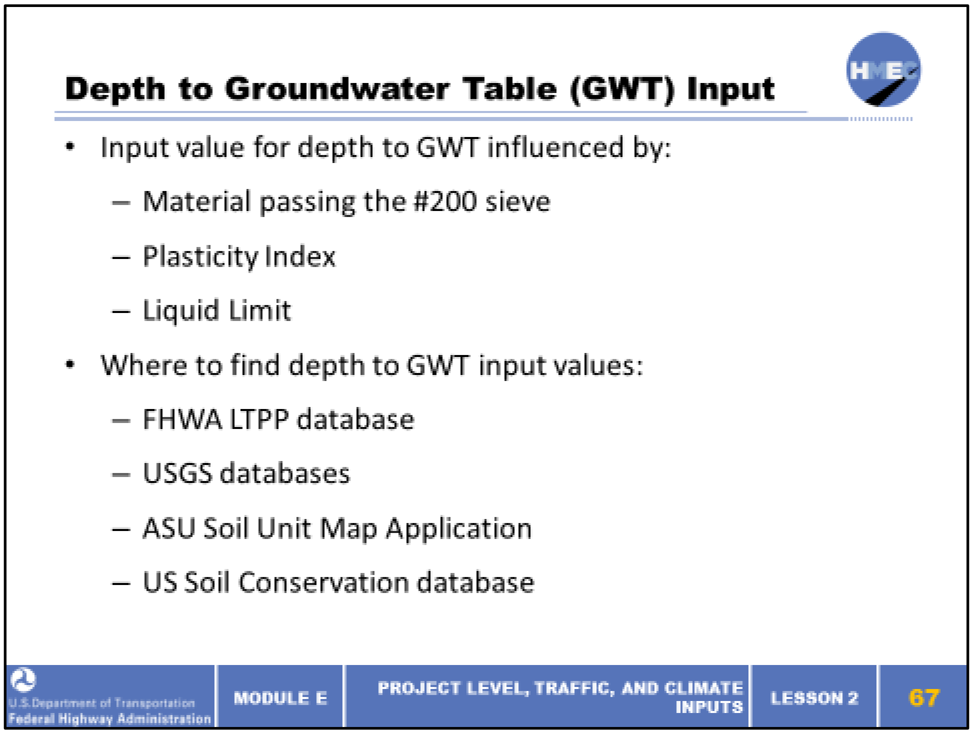
Slide 67



Depth to Groundwater Table (GWT) Input

- Input value for depth to GWT influenced by:
  - Material passing the #200 sieve
  - Plasticity Index
  - Liquid Limit
- Where to find depth to GWT input values:
  - FHWA LTPP database
  - USGS databases
  - ASU Soil Unit Map Application
  - US Soil Conservation database

Introduction of sources of climate information for use as inputs to the Pavement ME Design.

You can use FHWA LTPP database or ASU Soil Unit Map tool for finding soil types and properties per any location in the US and depth to GWT information, also potentially more detailed information in the US Soil Conservation or USGS databases or comparable.

In the Pavement ME Design software, the seasonal average depth to GWT is not provided along with the climate data summary from the EICM and must be input by the user. However, the software does provide a default value of depth to GWT (5.34 ft.) for users.

The NCHRP Project 1-47 Final Report was consulted to determine the extent of sensitivity of the depth to GWT on pavement performance predictions (Schwartz et al., 2011). Three groundwater table depths of two, seven, and 12 ft. were explored in the research report. The authors concluded that depth to GWT is considered insensitive for flexible, JPCP, and CRCP pavements.

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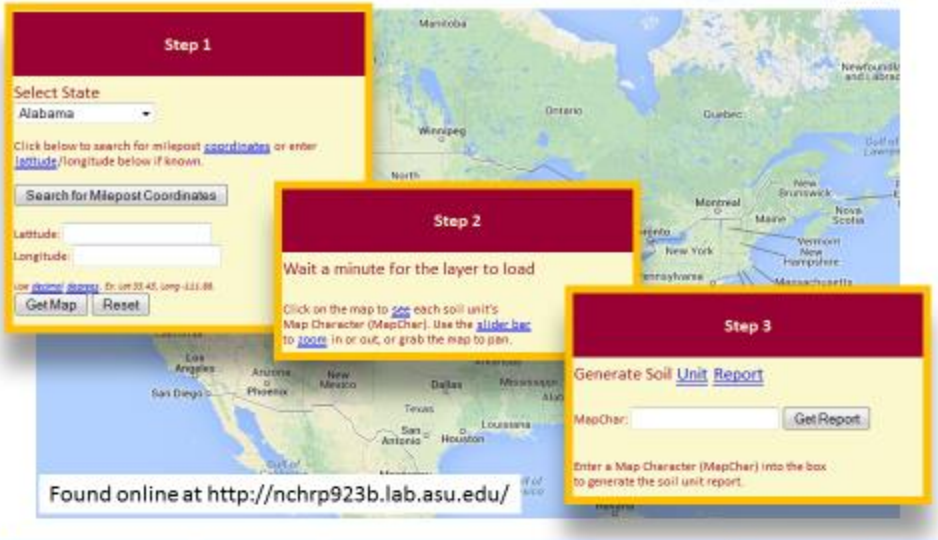
Slide 68

ASU Soil Unit Map Application



Step 1

Select State

Click below to search for milepost coordinates or enter latitude/longitude below if known.

Use decimal degrees. Ex: Lat 33.45, Long -111.88

Step 2

Wait a minute for the layer to load

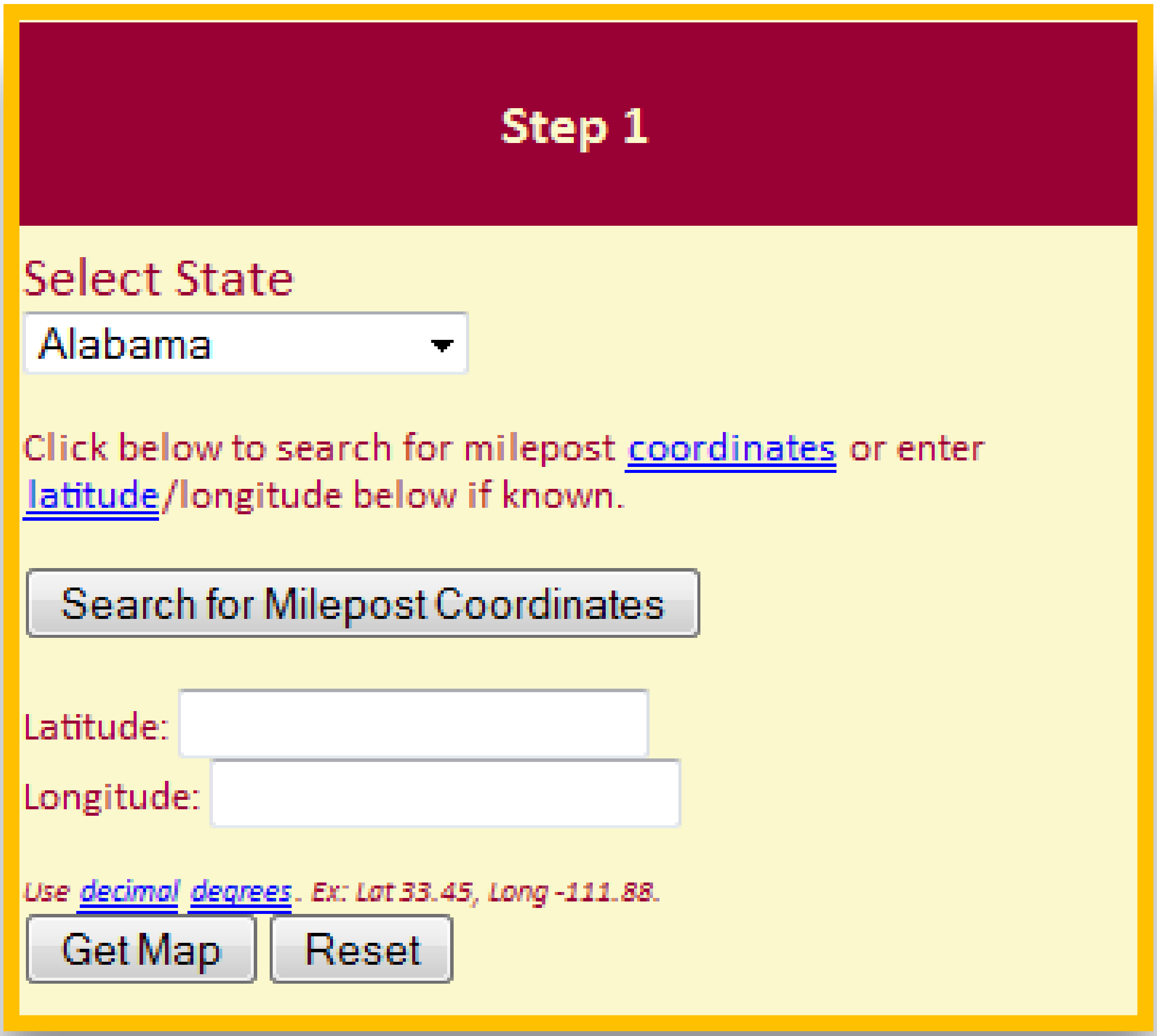
Click on the map to see each soil unit's Map Character (MapChar). Use the slider bar to zoom in or out, or grab the map to pan.

Step 3

Generate Soil Unit Report

Enter a Map Character (MapChar) into the box to generate the soil unit report.

Found online at http://nchrp923b.lab.asu.edu/



Step 1

Select State

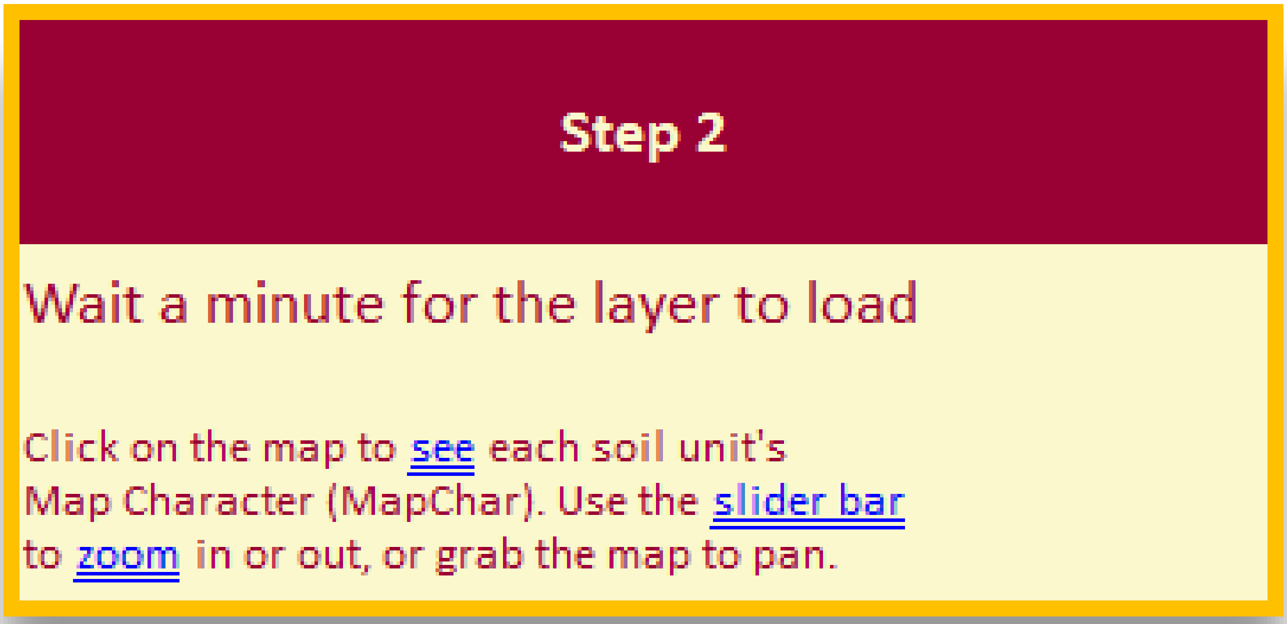
Alabama

Click below to search for milepost coordinates or enter latitude/longitude below if known.

Latitude:

Longitude:

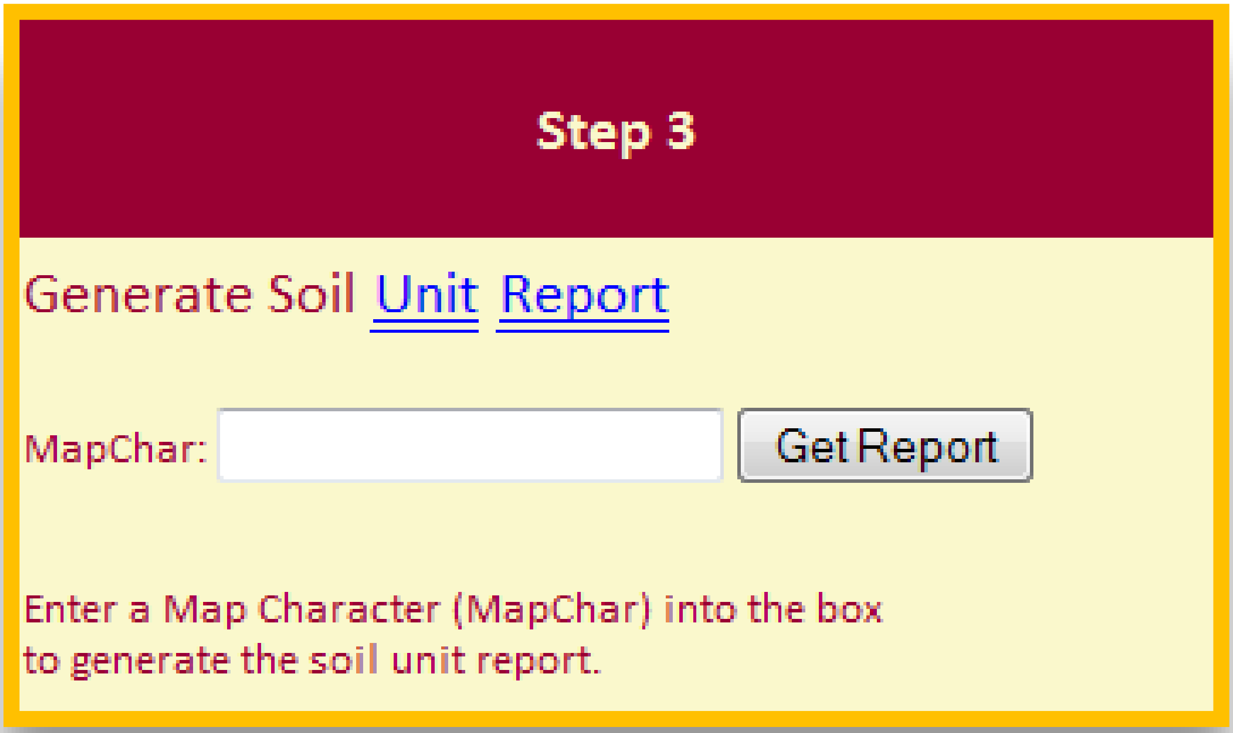
Use decimal degrees. Ex: Lat 33.45, Long -111.88.



Step 2

Wait a minute for the layer to load

Click on the map to see each soil unit's
Map Character (MapChar). Use the slider bar
to zoom in or out, or grab the map to pan.



Step 3

Generate Soil Unit Report

Enter a Map Character (MapChar) into the box
to generate the soil unit report.

Can use ASU Soil Unit Map tool for finding soil types and properties per any location in the US and depth to GWT information, also potentially more detailed information in the US Soil Conservation or USGS databases or comparable.

Reference: http://nchrp923b.lab.asu.edu/

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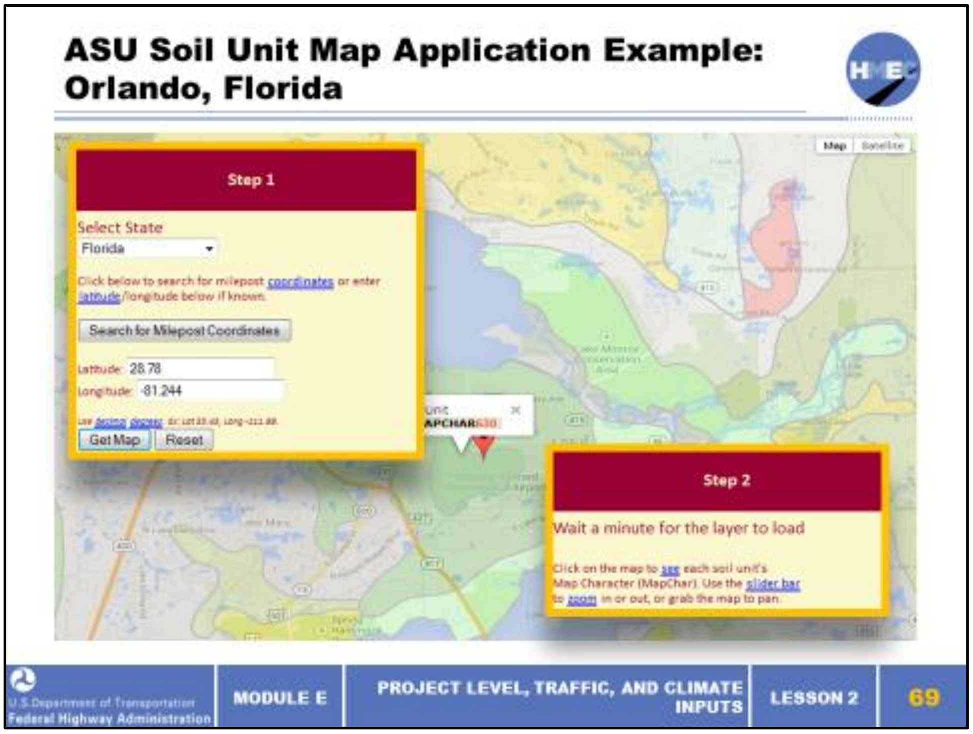
Slide 69



ASU Soil Unit Map Application Example: Orlando, Florida

Step 1

Select State

Florida

Click below to search for milepost coordinates or enter latitude/longitude below if known.

Latitude: 28.78

Longitude: -81.244

Use decimal degrees: ex: Lat 33.43, Long -111.88.

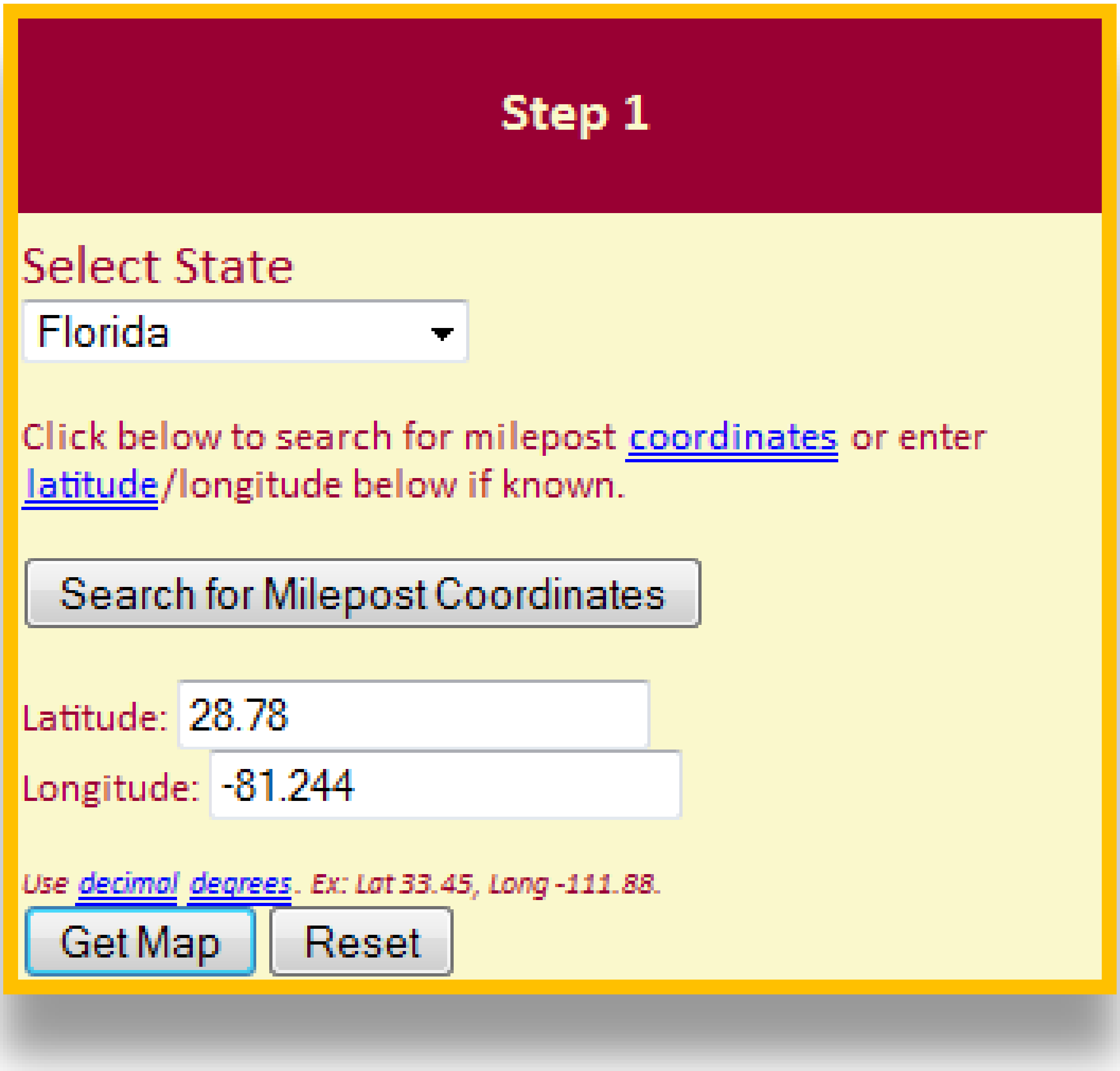
Step 2

Wait a minute for the layer to load

Click on the map to see each soil unit's Map Character (MapChar). Use the slider bar to zoom in or out, or grab the map to pan.

HMEC
Map
Satellite
Search for Milepost Coordinates
Get Map
Reset
Unit
APCHAR630
U.S. Department of Transportation
Federal Highway Administration

MODULE E | PROJECT LEVEL, TRAFFIC, AND CLIMATE INPUTS | LESSON 2 | 69



Select State

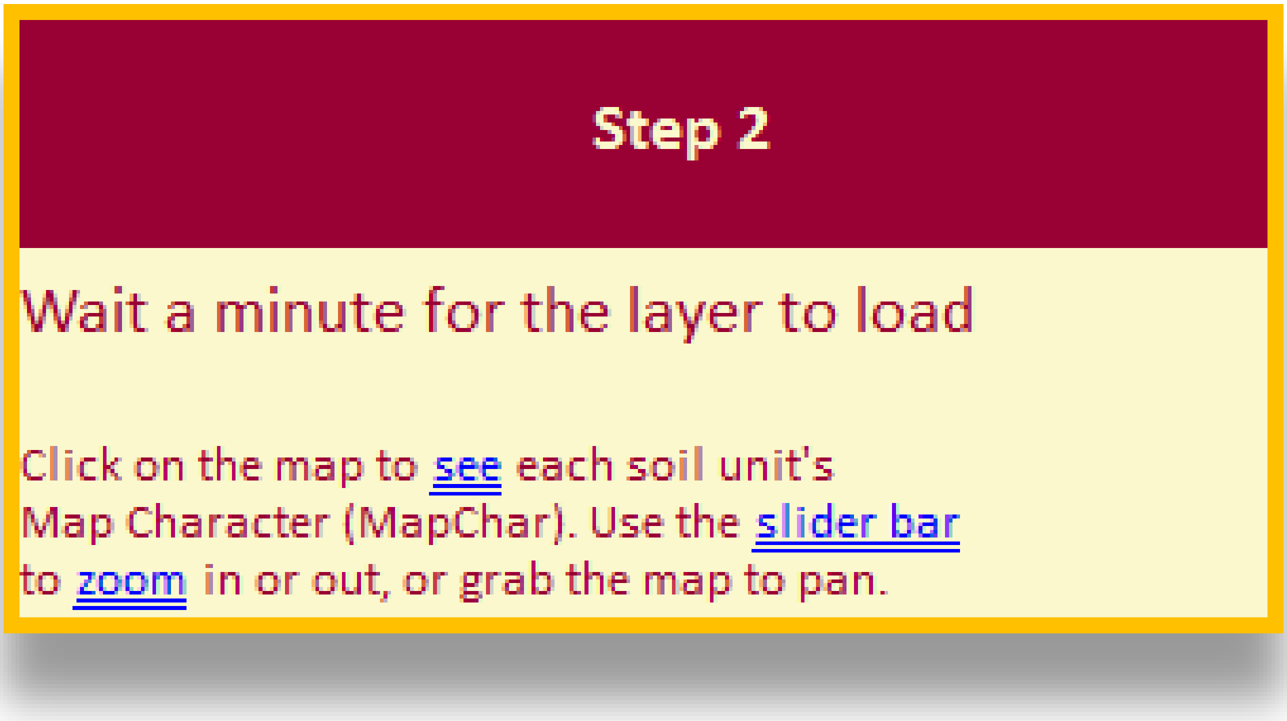
Florida

Click below to search for milepost coordinates or enter latitude/longitude below if known.

Latitude: 28.78

Longitude: -81.244

Use decimal degrees. Ex: Lat 33.45, Long -111.88.



Step 2

Wait a minute for the layer to load

Click on the map to see each soil unit's
Map Character (MapChar). Use the slider bar
to zoom in or out, or grab the map to pan.

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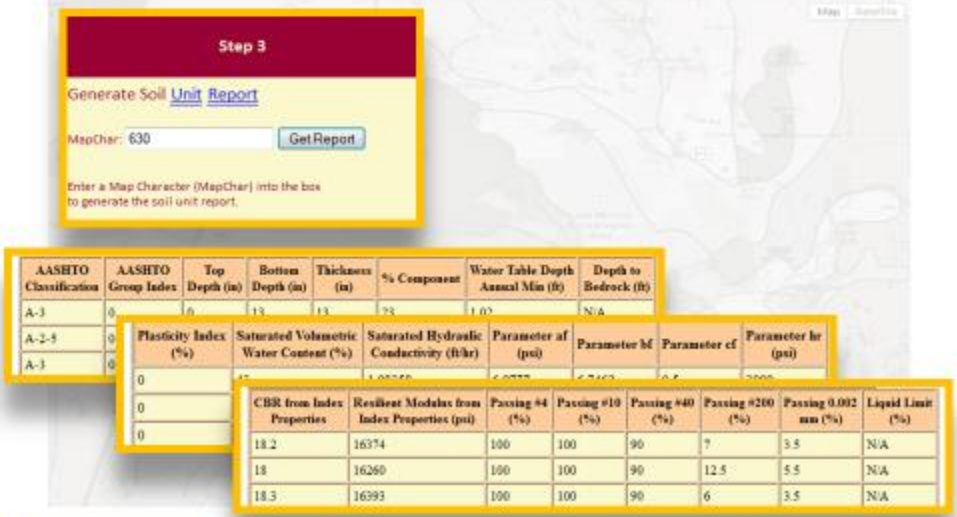
Slide 70

ASU Soil Unit Map Application Example: Orlando, Florida



Step 3

Generate Soil Unit Report

MapChar: 630

Enter a Map Character (MapChar) into the box to generate the soil unit report.

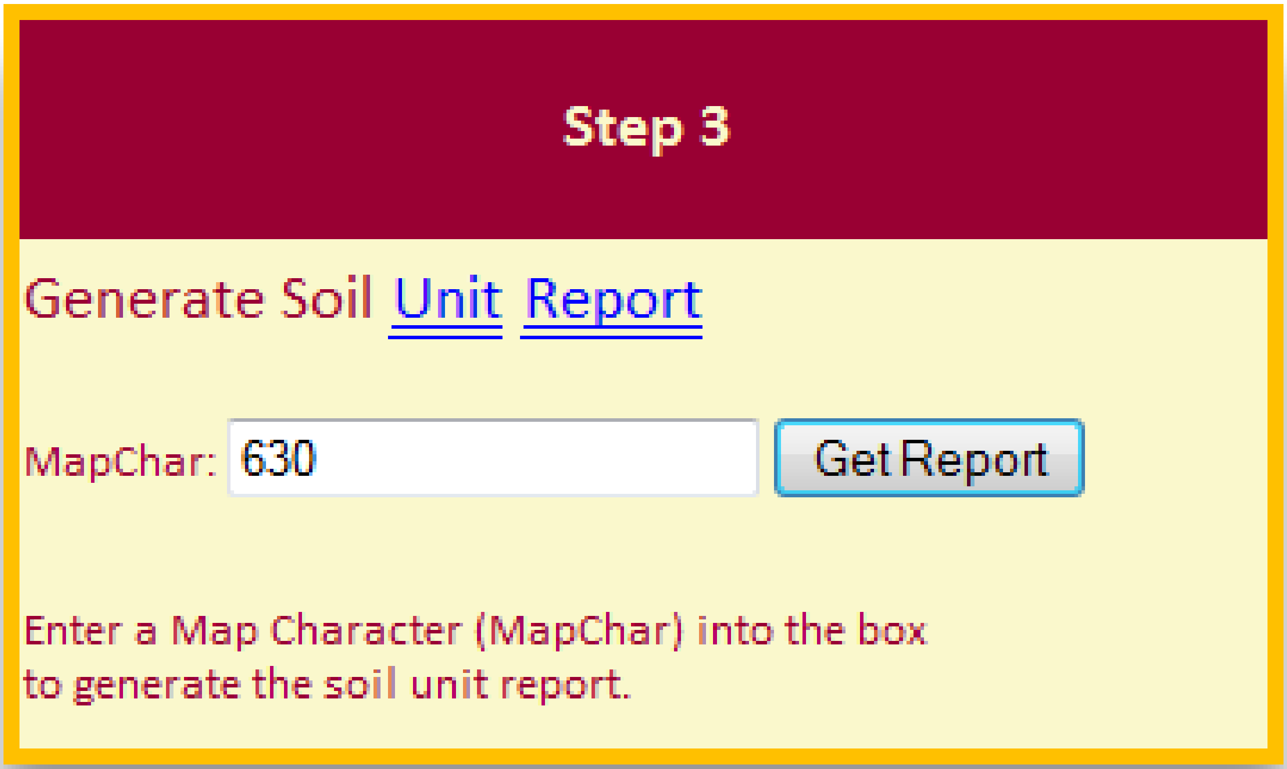
AASHTO Classification	AASHTO Group Index	Top Depth (in)	Bottom Depth (in)	Thickness (in)	% Component	Water Table Depth Annual Min (ft)	Depth to Bedrock (ft)
A-3	0	0	13	13	23	1.02	N/A
A-2-5	0						
A-3	0						

Plasticity Index (%)	Saturated Volumetric Water Content (%)	Saturated Hydraulic Conductivity (ft/hr)	Parameter af (psi)	Parameter bf	Parameter cf	Parameter hr (psi)
0						
0						
0						

CBR from Index Properties	Resilient Modulus from Index Properties (psi)	Passing #4 (%)	Passing #10 (%)	Passing #40 (%)	Passing #200 (%)	Passing 0.002 mm (%)	Liquid Limit (%)
18.2	16374	100	100	90	7	3.5	N/A
18	16260	100	100	90	12.5	5.5	N/A
18.3	16393	100	100	90	6	3.5	N/A

U.S. Department of Transportation
Federal Highway Administration

MODULE E | PROJECT LEVEL, TRAFFIC, AND CLIMATE INPUTS | LESSON 2 | 70

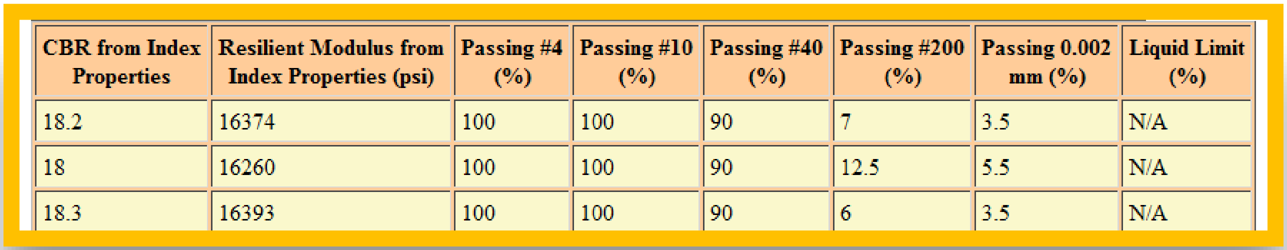


Step 3

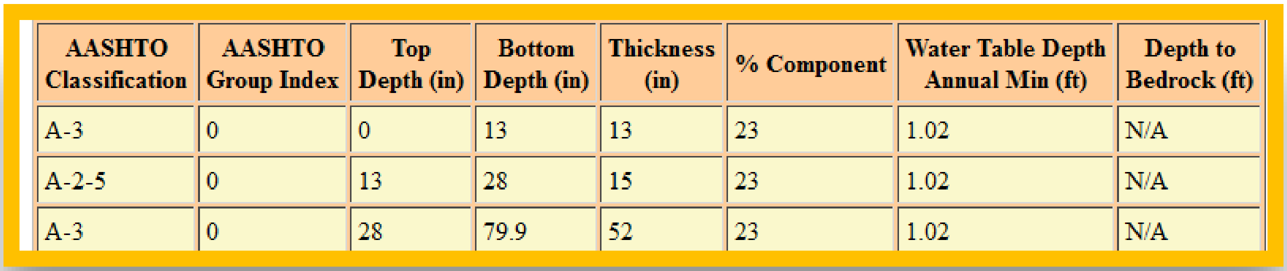
Generate Soil Unit Report

MapChar: 630

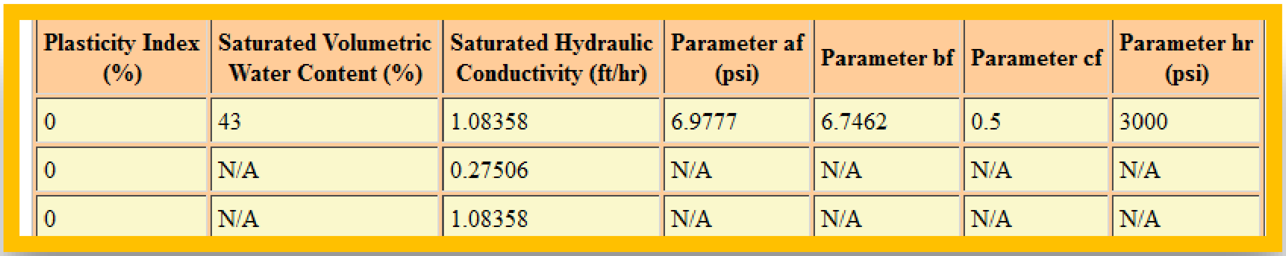
Enter a Map Character (MapChar) into the box to generate the soil unit report.



CBR from Index Properties	Resilient Modulus from Index Properties (psi)	Passing #4 (%)	Passing #10 (%)	Passing #40 (%)	Passing #200 (%)	Passing 0.002 mm (%)	Liquid Limit (%)
18.2	16374	100	100	90	7	3.5	N/A
18	16260	100	100	90	12.5	5.5	N/A
18.3	16393	100	100	90	6	3.5	N/A



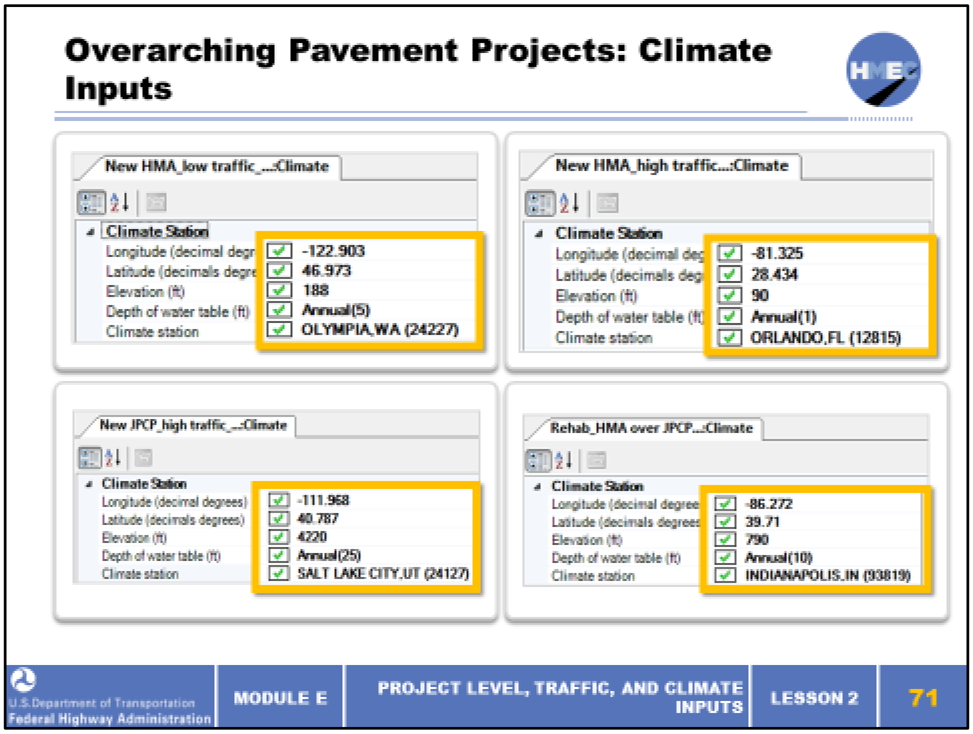
AASHTO Classification	AASHTO Group Index	Top Depth (in)	Bottom Depth (in)	Thickness (in)	% Component	Water Table Depth Annual Min (ft)	Depth to Bedrock (ft)
A-3	0	0	13	13	23	1.02	N/A
A-2-5	0	13	28	15	23	1.02	N/A
A-3	0	28	79.9	52	23	1.02	N/A



Plasticity Index (%)	Saturated Volumetric Water Content (%)	Saturated Hydraulic Conductivity (ft/hr)	Parameter af (psi)	Parameter bf	Parameter cf	Parameter hr (psi)
0	43	1.08358	6.9777	6.7462	0.5	3000
0	N/A	0.27506	N/A	N/A	N/A	N/A
0	N/A	1.08358	N/A	N/A	N/A	N/A

The ASU soil unit map application provides input values for soil type, thickness, water table depth annual minimum, depth to bedrock, CBR, resilient modulus, gradation, liquid limit, plastic index, etc. These were gathered for the Florida sample pavement project.

Slide 71



Overarching Pavement Projects: Climate Inputs

New HMA_low traffic_...:Climate

Climate Station		
Longitude (decimal degr	☑	-122.903
Latitude (decimals degre	☑	46.973
Elevation (ft)	☑	188
Depth of water table (ft)	☑	Annual(5)
Climate station	☑	OLYMPIA,WA (24227)

New HMA_high traffic...:Climate

Climate Station		
Longitude (decimal deg	☑	-81.325
Latitude (decimals deg	☑	28.434
Elevation (ft)	☑	90
Depth of water table (ft)	☑	Annual(1)
Climate station	☑	ORLANDO,FL (12815)

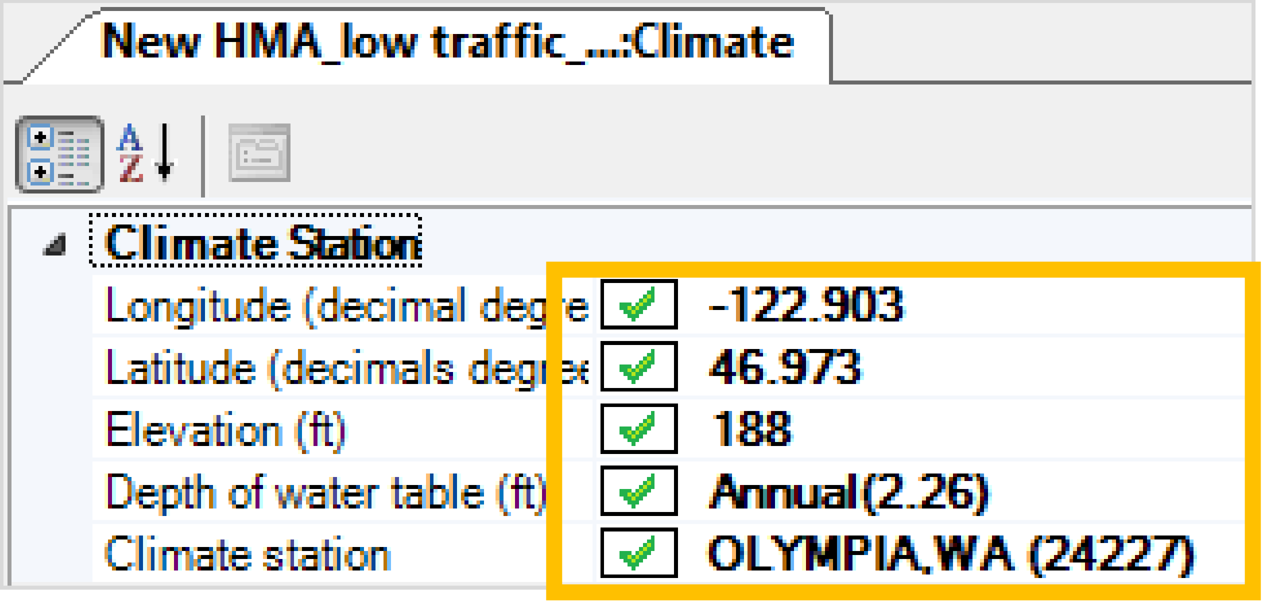
New JPCP_high traffic_...:Climate

Climate Station		
Longitude (decimal degrees)	☑	-111.968
Latitude (decimals degrees)	☑	40.787
Elevation (ft)	☑	4220
Depth of water table (ft)	☑	Annual(25)
Climate station	☑	SALT LAKE CITY,UT (24127)

Rehab_HMA over JPCP...:Climate

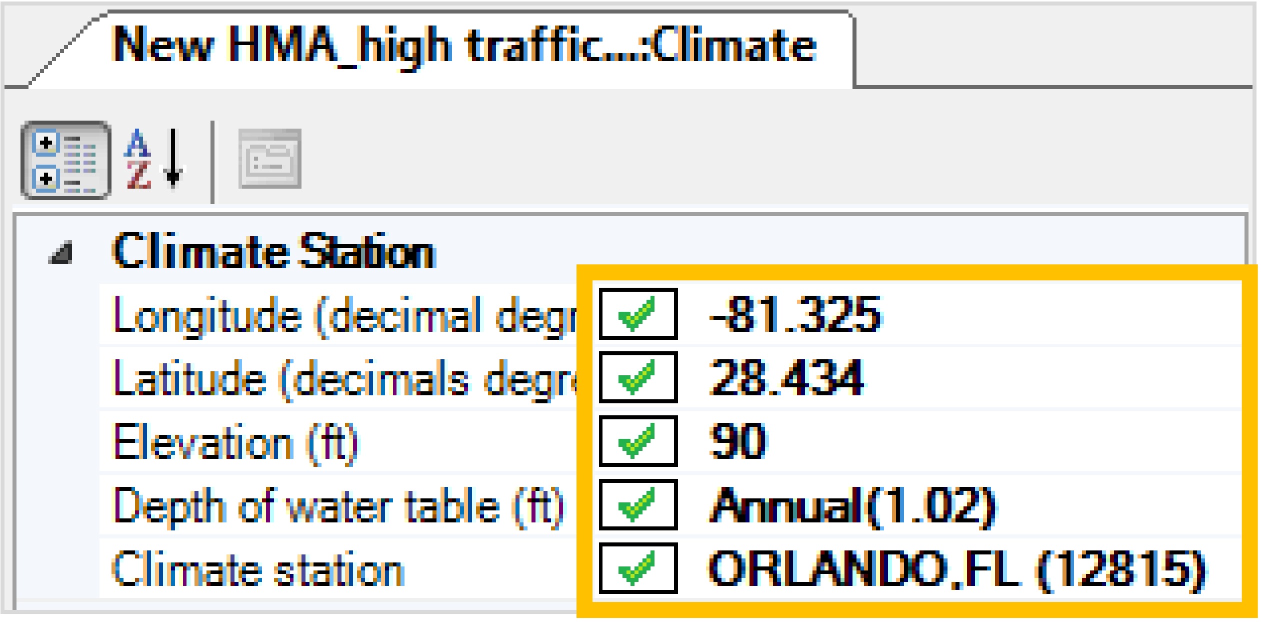
Climate Station		
Longitude (decimal degree	☑	-86.272
Latitude (decimals degree	☑	39.71
Elevation (ft)	☑	790
Depth of water table (ft)	☑	Annual(10)
Climate station	☑	INDIANAPOLIS,IN (93819)

U.S. Department of Transportation Federal Highway Administration | MODULE E | PROJECT LEVEL, TRAFFIC, AND CLIMATE INPUTS | LESSON 2 | 71



New HMA_low traffic_...:Climate

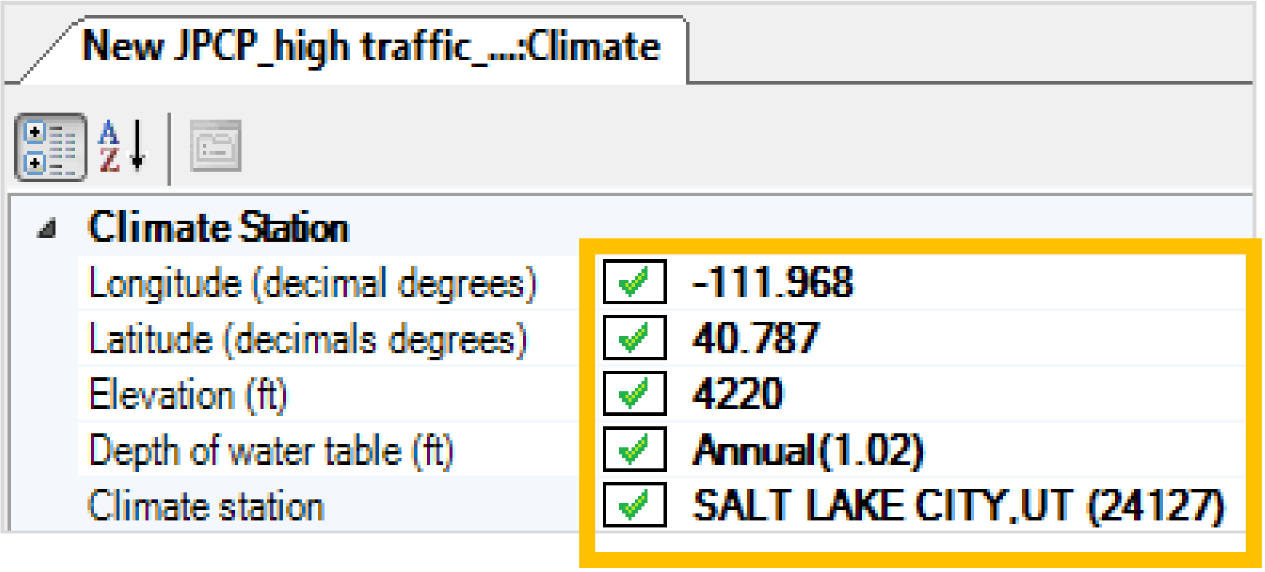
Climate Station		
Longitude (decimal deg e	☑	-122.903
Latitude (decimals degr e	☑	46.973
Elevation (ft)	☑	188
Depth of water table (ft)	☑	Annual(2.26)
Climate station	☑	OLYMPIA,WA (24227)



New HMA_high traffic...:Climate

Climate Station

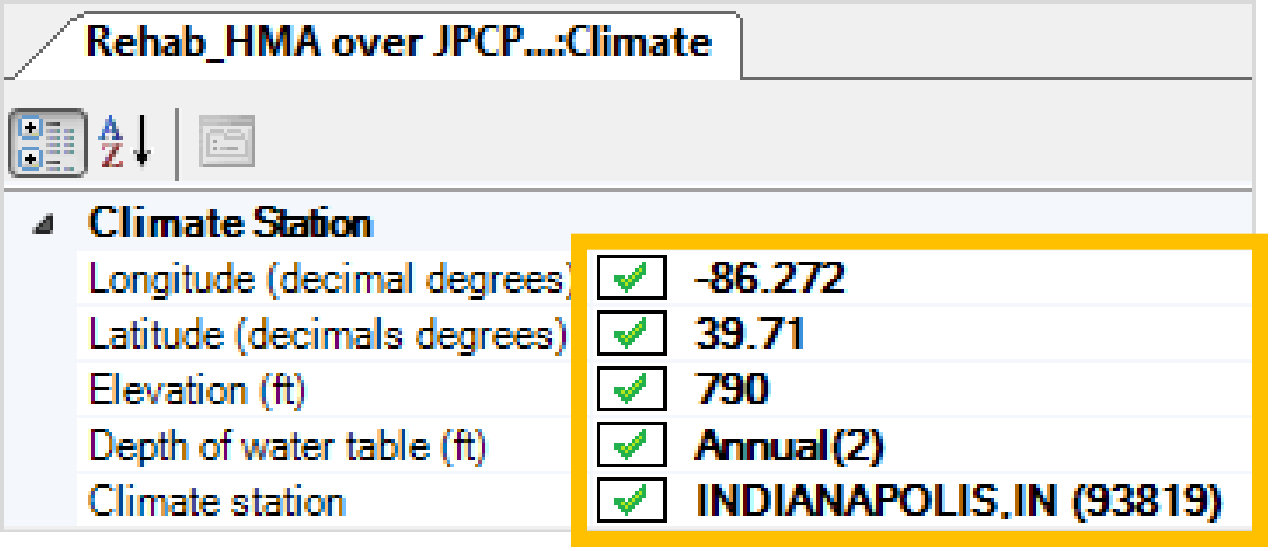
Longitude (decimal degr	✓	-81.325
Latitude (decimals degr	✓	28.434
Elevation (ft)	✓	90
Depth of water table (ft)	✓	Annual(1.02)
Climate station	✓	ORLANDO,FL (12815)



New JPCP_high traffic_...:Climate

Climate Station

Longitude (decimal degrees)	✓	-111.968
Latitude (decimals degrees)	✓	40.787
Elevation (ft)	✓	4220
Depth of water table (ft)	✓	Annual(1.02)
Climate station	✓	SALT LAKE CITY,UT (24127)



Rehab_HMA over JPCP...:Climate

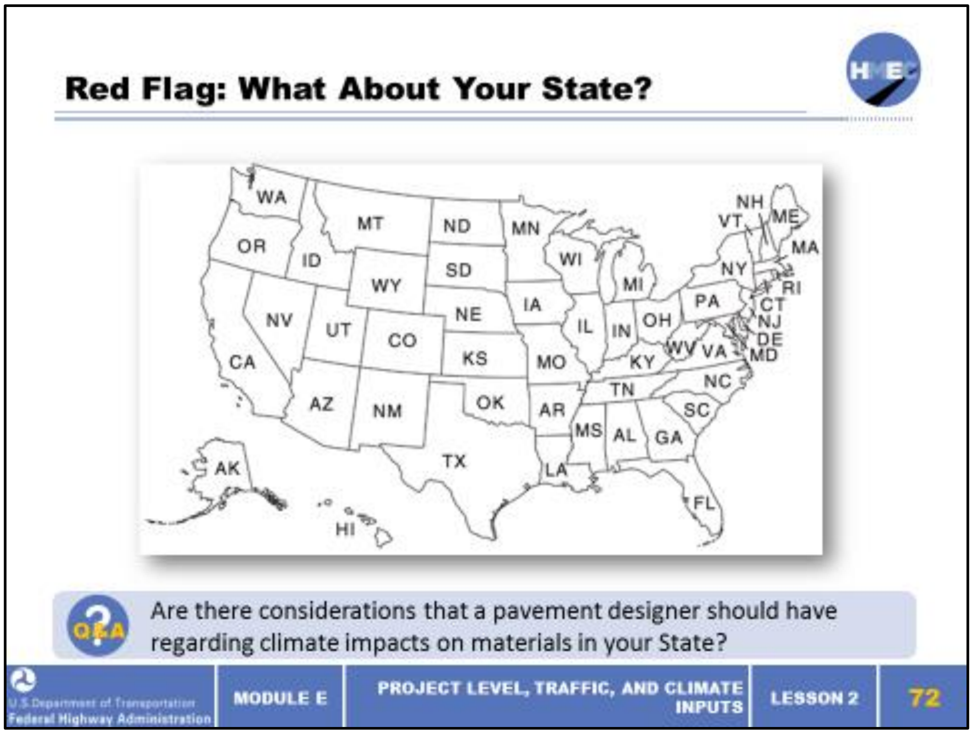
Climate Station

Longitude (decimal degrees)	☑	-86.272
Latitude (decimals degrees)	☑	39.71
Elevation (ft)	☑	790
Depth of water table (ft)	☑	Annual(2)
Climate station	☑	INDIANAPOLIS,IN (93819)

Using provided scenario and given data sets, select the weather data set for the four overarching pavement project sites. This slide presents the latitude and longitude for each of the four sites, which we define as Olympia, Washington; Orlando, Florida; Salt Lake City, Utah; and, Indianapolis, Indiana. One can see from the individual screen captures from Pavement ME Design that the elevation is quite different in each of the four locations. The climate stations in the Pavement ME Design that are uploaded (along with all of the EICM climate input descriptors, which are not shown on the main input screens but can be requested via a "Climate Summary" tab on a separate page) and each one has been assigned its own five-digit numerical descriptor within the software itself.

The depth to groundwater table input for the files comes from the ASU Soil Unit Map Application, but it should be noted that this may result in a more conservative design being required, due to the difference mentioned in the previous slide.

Slide 72


WA
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NV
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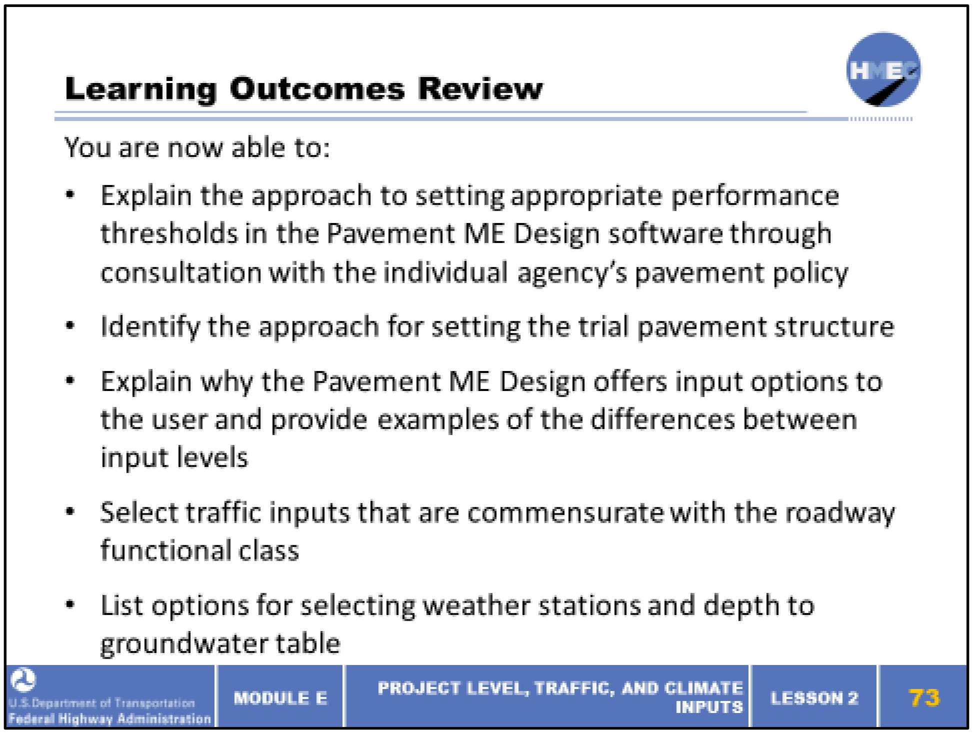
OK
TX
MN
IA
MO
AR
LA
WI
IL
MS
MI
IN
KY
TN
AL
OH
GA
FL
WV
VA
NC
SC
PA
NY
VT
NH
ME
MA
RI
CT
NJ
DE
MD
AK
HI

Red Flag: What About Your State?

Are there considerations that a pavement designer should have regarding climate impacts on materials in your State?

U.S. Department of Transportation Federal Highway Administration | MODULE E | PROJECT LEVEL, TRAFFIC, AND CLIMATE INPUTS | LESSON 2 | 72

Slide 73



Learning Outcomes Review

You are now able to:

- Explain the approach to setting appropriate performance thresholds in the Pavement ME Design software through consultation with the individual agency's pavement policy
- Identify the approach for setting the trial pavement structure
- Explain why the Pavement ME Design offers input options to the user and provide examples of the differences between input levels
- Select traffic inputs that are commensurate with the roadway functional class
- List options for selecting weather stations and depth to groundwater table

Slide 1

HMEC

Highway Materials Engineering Course

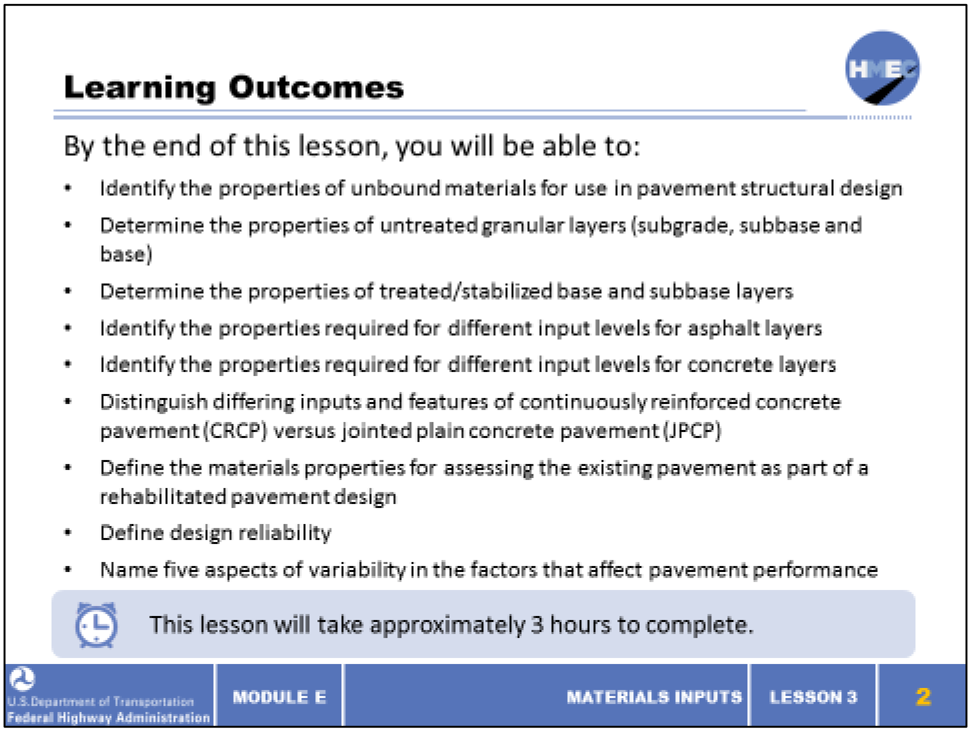
Lesson 3: Materials Inputs

Mechanistic Empirical Pavement Design Guide (MEPDG)

U.S. Department of Transportation
Federal Highway Administration

MODULE E

Slide 2



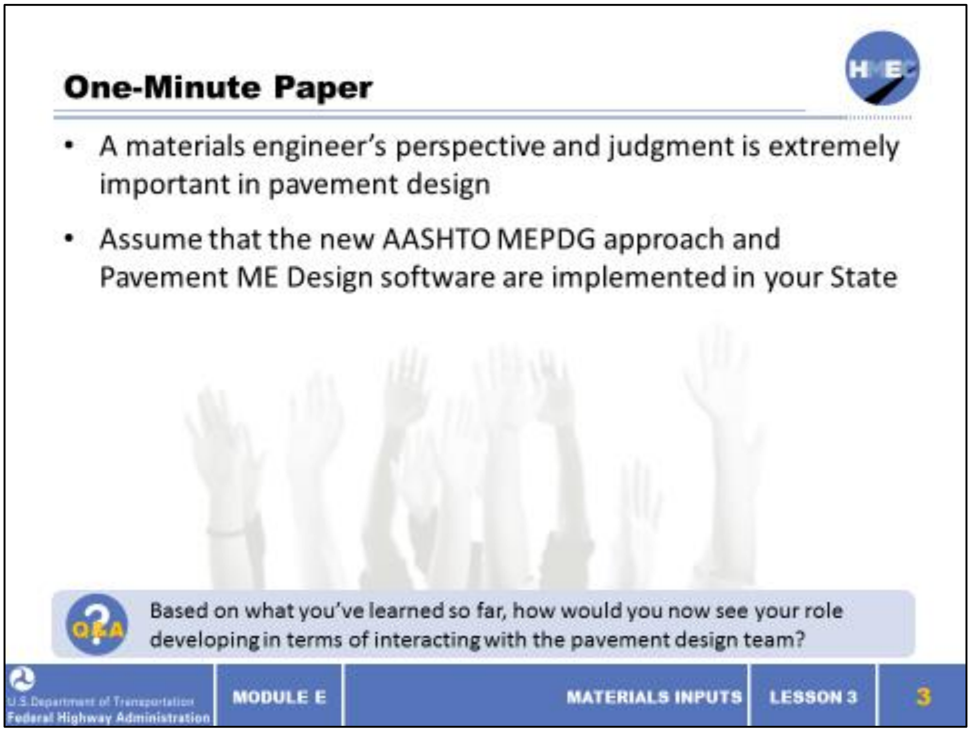
Learning Outcomes

By the end of this lesson, you will be able to:

- Identify the properties of unbound materials for use in pavement structural design
- Determine the properties of untreated granular layers (subgrade, subbase and base)
- Determine the properties of treated/stabilized base and subbase layers
- Identify the properties required for different input levels for asphalt layers
- Identify the properties required for different input levels for concrete layers
- Distinguish differing inputs and features of continuously reinforced concrete pavement (CRCP) versus jointed plain concrete pavement (JPCP)
- Define the materials properties for assessing the existing pavement as part of a rehabilitated pavement design
- Define design reliability
- Name five aspects of variability in the factors that affect pavement performance

This lesson will take approximately 3 hours to complete.

Slide 3



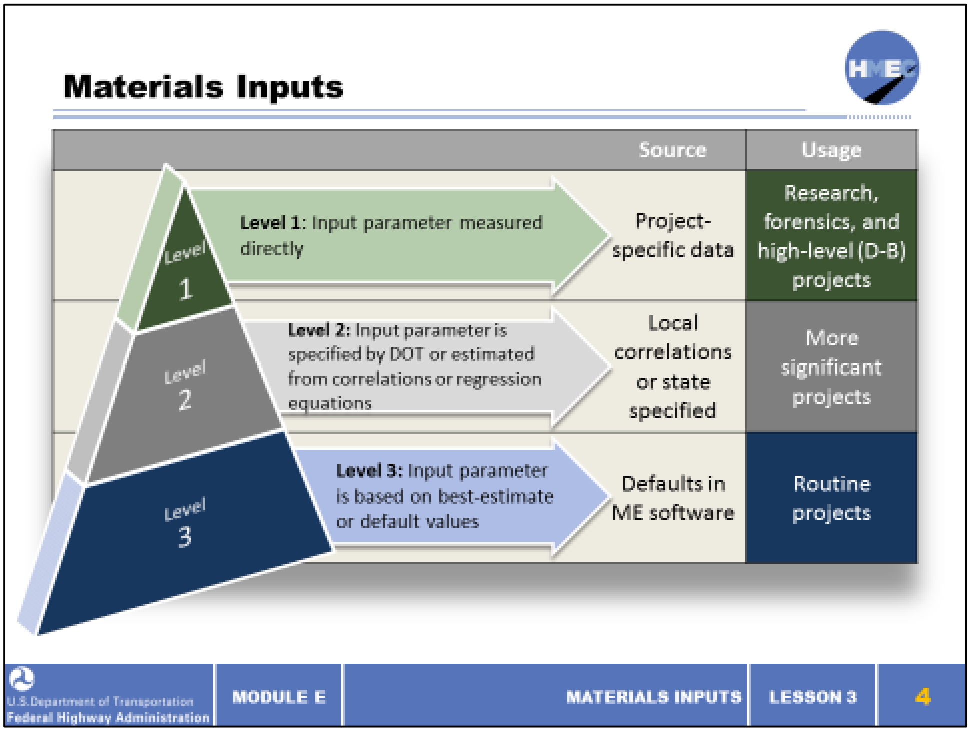
One-Minute Paper

- A materials engineer's perspective and judgment is extremely important in pavement design
- Assume that the new AASHTO MEPDG approach and Pavement ME Design software are implemented in your State

Based on what you've learned so far, how would you now see your role developing in terms of interacting with the pavement design team?

HMEC
Q&A
U.S. Department of Transportation
Federal Highway Administration
MODULE E
MATERIALS INPUTS
LESSON 3
3

Slide 4

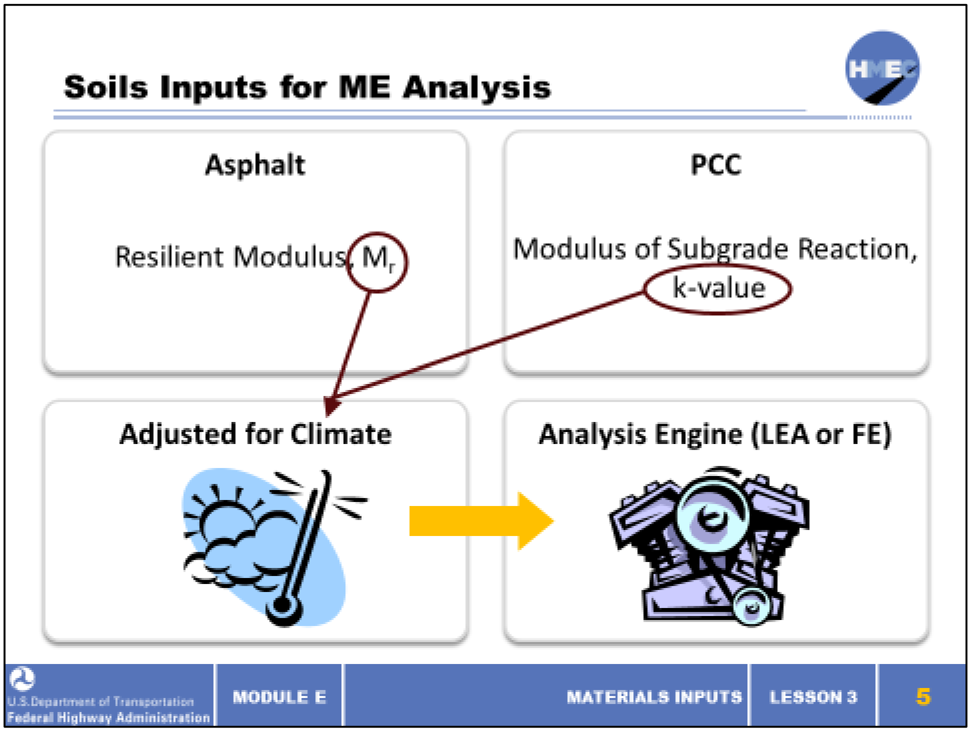


Materials Inputs

	Source	Usage
Level 1: Input parameter measured directly	Project-specific data	Research, forensics, and high-level (D-B) projects
Level 2: Input parameter is specified by DOT or estimated from correlations or regression equations	Local correlations or state specified	More significant projects
Level 3: Input parameter is based on best-estimate or default values	Defaults in ME software	Routine projects

Level 1
Level 2
Level 3
HMEC
U.S. Department of Transportation
Federal Highway Administration
MODULE E
MATERIALS INPUTS
LESSON 3
4

Slide 5



Soils Inputs for ME Analysis

Asphalt

Resilient Modulus, M_r

PCC

Modulus of Subgrade Reaction, k-value

Adjusted for Climate

Analysis Engine (LEA or FE)

HMEC
U.S. Department of Transportation
Federal Highway Administration
MODULE E
MATERIALS INPUTS
LESSON 3
5

The support provided by the subgrade is represented differently in the Pavement ME Design software based on whether you are designing a flexible or rigid pavement. The layered elastic analysis (LEA) design analysis will need a resilient modulus (M_r) value for unbound material and soils in a flexible pavement. The resilient modulus is a measure of the stiffness of the unbound layer or sublayer.

The finite element (FE) analysis will require a modulus of subgrade reaction (k) value for unbound materials in a rigid pavement. The k-value is a dynamic modulus of subgrade reaction for each month of the design analysis period for these layers. The effective k-value, therefore, essentially represents the compressibility of underlying layers (i.e., unbound base, subbase, and subgrade layers) upon which the upper-bound layers and existing hot mix asphalt (HMA) or Portland cement concrete (PCC) layer is constructed.

There are different ways to get to a resilient modulus value and a k-value depending on what level of input you are using.

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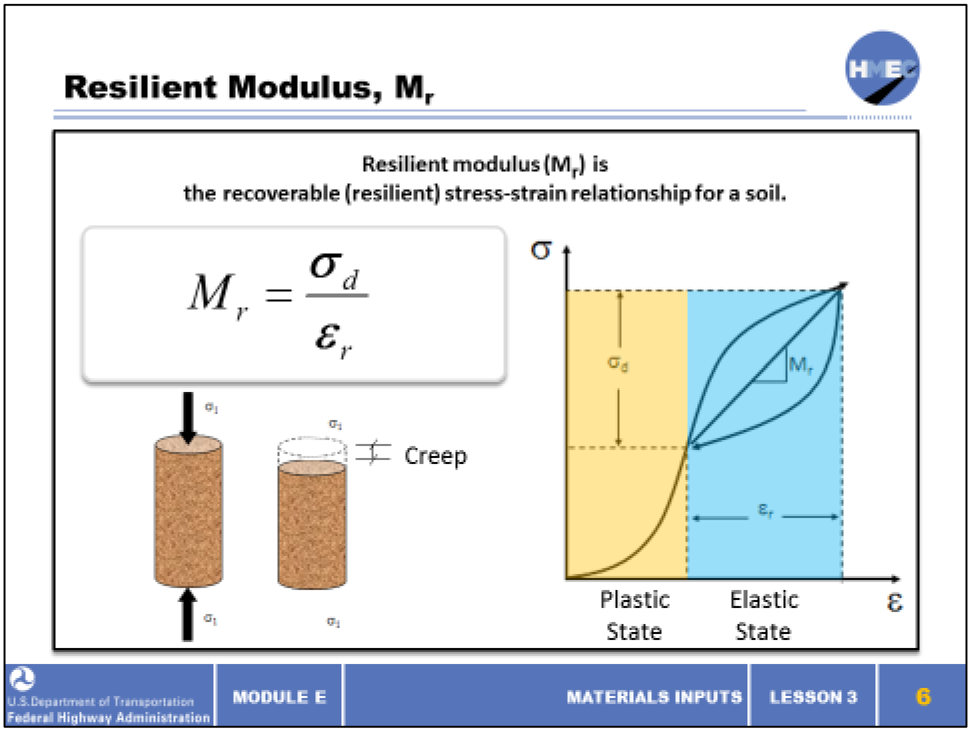
Slide 6



Resilient Modulus, M_r

Resilient modulus (M_r) is
the recoverable (resilient) stress-strain relationship for a soil.

$$M_r = \frac{\sigma_d}{\varepsilon_r}$$

The resilient modulus is a ratio of the deviator stress over the recoverable portion of the strain.

Take a soil sample and place a load on it. We will look at how the stress-strain relationship develops. The sample will deform (strain) under the pressure of the load. The general stress-strain curve will look like the one on the screen. When the load is removed, the sample will recover most of its original length. The length that is not recovered is referred to as the non-recoverable strain or creep.

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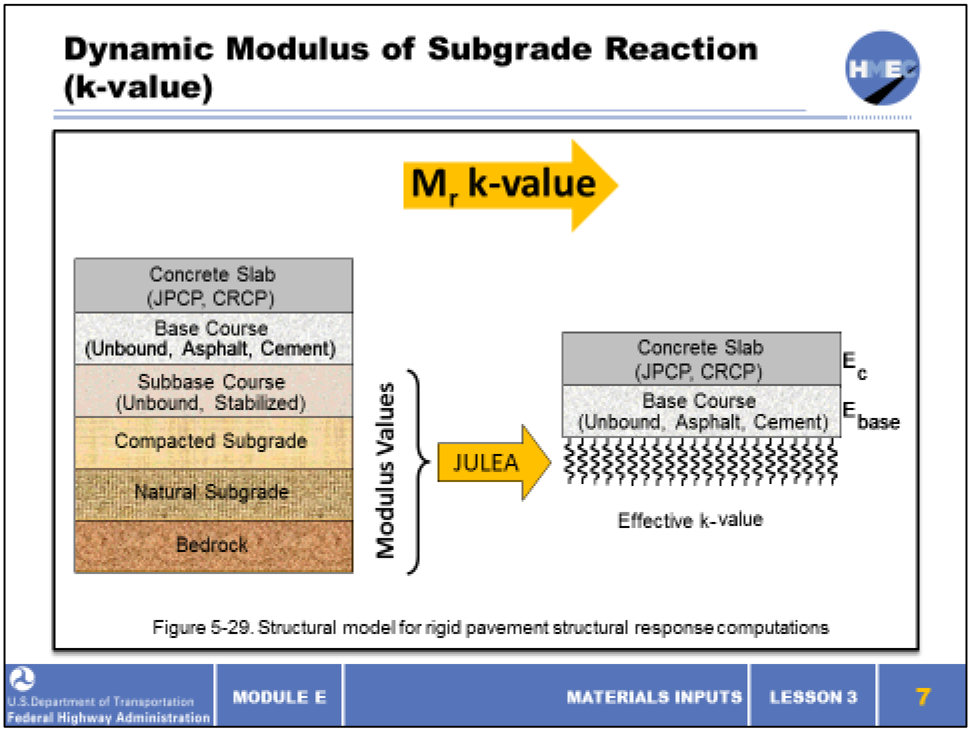
Slide 7



Dynamic Modulus of Subgrade Reaction (k-value)

M_r k-value
Concrete Slab (JPCP, CRCP)
Base Course (Unbound, Asphalt, Cement)
Subbase Course (Unbound, Stabilized)
Compacted Subgrade
Natural Subgrade
Bedrock
Modulus Values
JULEA
Concrete Slab (JPCP, CRCP)
E_c
Base Course (Unbound, Asphalt, Cement)
E_{base}
Effective k-value

Figure 5-29. Structural model for rigid pavement structural response computations

U.S. Department of Transportation Federal Highway Administration | MODULE E | MATERIALS INPUTS | LESSON 3 | 7

For new rigid pavements, there are only two levels of inputs for soils and unbound bases (Levels 2 and 3). The design guide will convert the layer thicknesses and M_r to an effective modulus of subgrade reaction (k). The resilient modulus is converted to a k-value internally within the software for evaluating rigid pavements. The subgrade modulus is modeled as elastic springs in rigid pavements. The stiffness of the elastic springs is also called subgrade reaction.

JULEA = Jacob Uzan Layered Elastic Analysis computational approach.

The subgrade reaction may be determined in the following ways:

- Provide resilient modulus inputs of the existing unbound sublayers, including the subgrade soil similar to new design. The Pavement ME Design software will back calculate an effective single dynamic modulus of subgrade reaction (k-value) for each month of the design analysis period for these layers. The effective k-value, therefore, essentially represents the compressibility of underlying layers (i.e., unbound base, subbase, and subgrade layers) upon which the upper-bound layers and existing HMA or PCC layer is constructed. These monthly values will be used in design of the rehabilitation alternative.

- Measure the top of slab deflections with a falling weight deflectometer (FWD) and conduct a back-calculation process to establish the mean k-value during a given month. Enter this mean value and the month of testing into the DARWin-ME. This entered k-value will remain for that month throughout the analysis period, but the k-value for other months will vary according to moisture movement and frost depth in the pavement.

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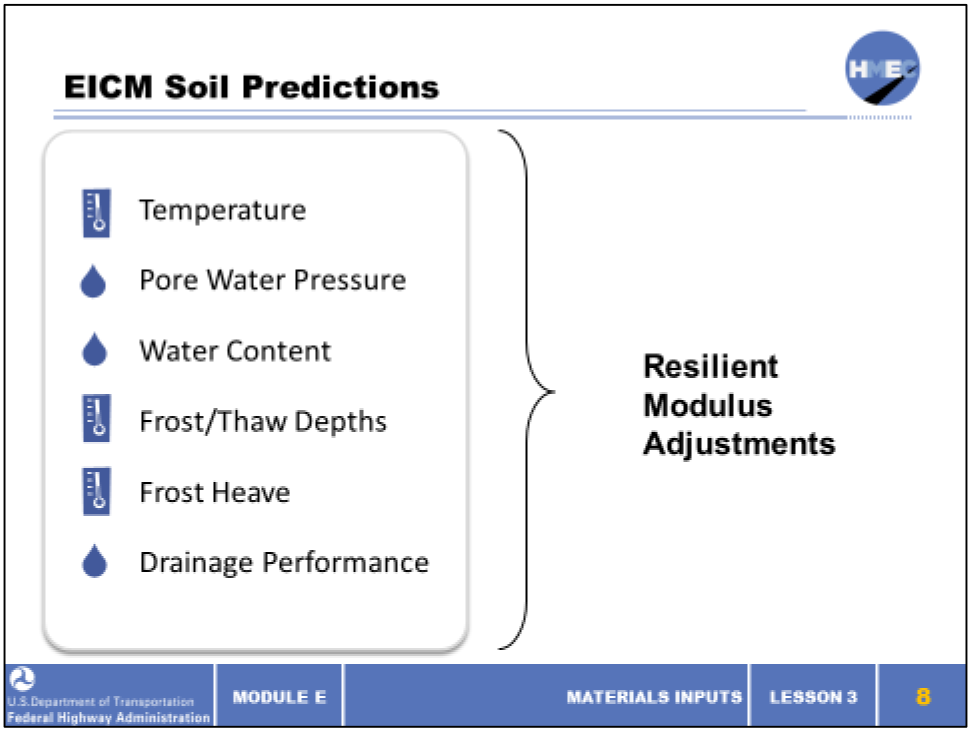
Slide 8



EICM Soil Predictions

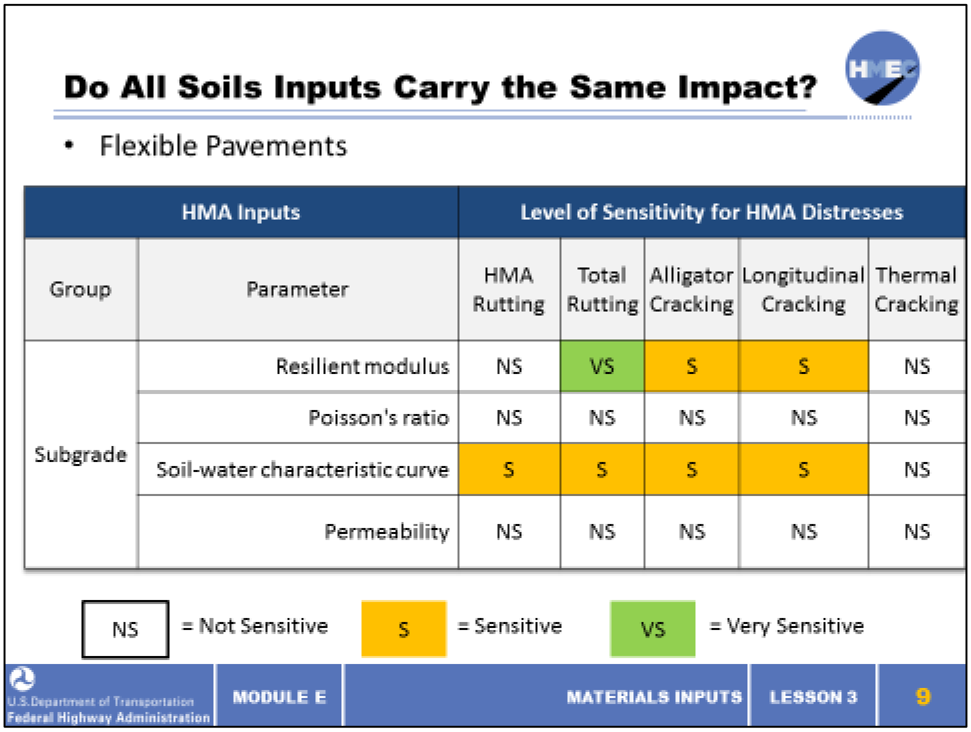
- Temperature
- Pore Water Pressure
- Water Content
- Frost/Thaw Depths
- Frost Heave
- Drainage Performance

Resilient Modulus Adjustments

U.S. Department of Transportation Federal Highway Administration | MODULE E | MATERIALS INPUTS | LESSON 3 | 8

In unbound materials, these properties are predicted by the various models in the EICM. They are then used to adjust the resilient modulus of the soil accordingly throughout the life of the design pavement being analyzed.

Slide 9



Do All Soils Inputs Carry the Same Impact?

- Flexible Pavements

HMA Inputs		Level of Sensitivity for HMA Distresses				
Group	Parameter	HMA Rutting	Total Rutting	Alligator Cracking	Longitudinal Cracking	Thermal Cracking
Subgrade	Resilient modulus	NS	VS	S	S	NS
	Poisson's ratio	NS	NS	NS	NS	NS
	Soil-water characteristic curve	S	S	S	S	NS
	Permeability	NS	NS	NS	NS	NS

NS = Not Sensitive S = Sensitive VS = Very Sensitive

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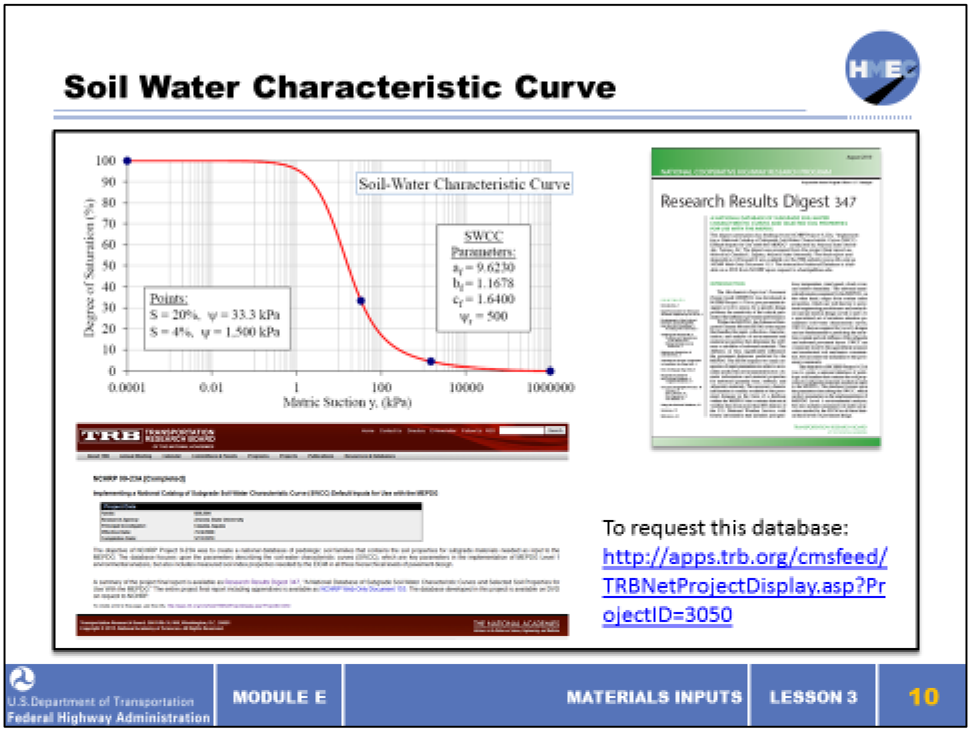
MODULE E
MATERIALS INPUTS
LESSON 3
9

The resilient modulus is most influential for the structural responses, consistent with pavement design theory. The soil-water characteristic curve is also sensitive for all but thermal cracking.

Slide 10



Soil Water Characteristic Curve

To request this database:
http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=3050

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Federal Highway Administration
MODULE E
MATERIALS INPUTS
LESSON 3
10

The SWCC is defined as the relationship between soil water content and soil matric suction. The water content refers to either the volumetric water content (ratio of volume of water to the volume of solids) or the degree of saturation (percentage of voids filled with water), depending upon the intended use of the SWCC relationship. For engineering purposes, the degree of saturation (percentage of voids filled with water) is commonly used. The soil suction corresponds to the matric suction (ua − uw), which is the difference between the pore-air pressure and the pore-water pressure.

The model implemented in the Pavement ME Design software is represented as a sigmoidal function with four fitting parameters.

Pavement ME incorporates the effects of environmental conditions such as precipitation and temperature in the determination of changes of unbound material properties during the life of the pavement structure. This model makes use of unsaturated soil principles, which in turn requires the input of the SWCC.

To aid in the implementation of the MEPDG, an alternative way to determine the SWCC via laboratory testing, is a method that estimates or derives the SWCC based on well-known soil index properties. The NCHRP 9-23A (RRD 347) project entitled "A National Catalog of Subgrade Soil-Water Characteristic Curve (SWCC) Default Inputs and Selected Soil Properties for Use with the ME-PDG" was carried out at Arizona State University in 2010. The objective of this project was the creation of a national database of pedologic soil families that reflected the input soil properties for subgrade materials needed in the implementation of the approved AASHTO MEPDG (Darter et al., 2006). The database focuses upon the soil water characteristic curve parameters, which are key parameters in the implementation of Level 1 environmental analysis as well as measured soil index properties needed in all hierarchical levels of the climatic/environmental engine of the guide, the "Enhanced Integrated Climatic Model (EICM)."

To request this database:
http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=3050

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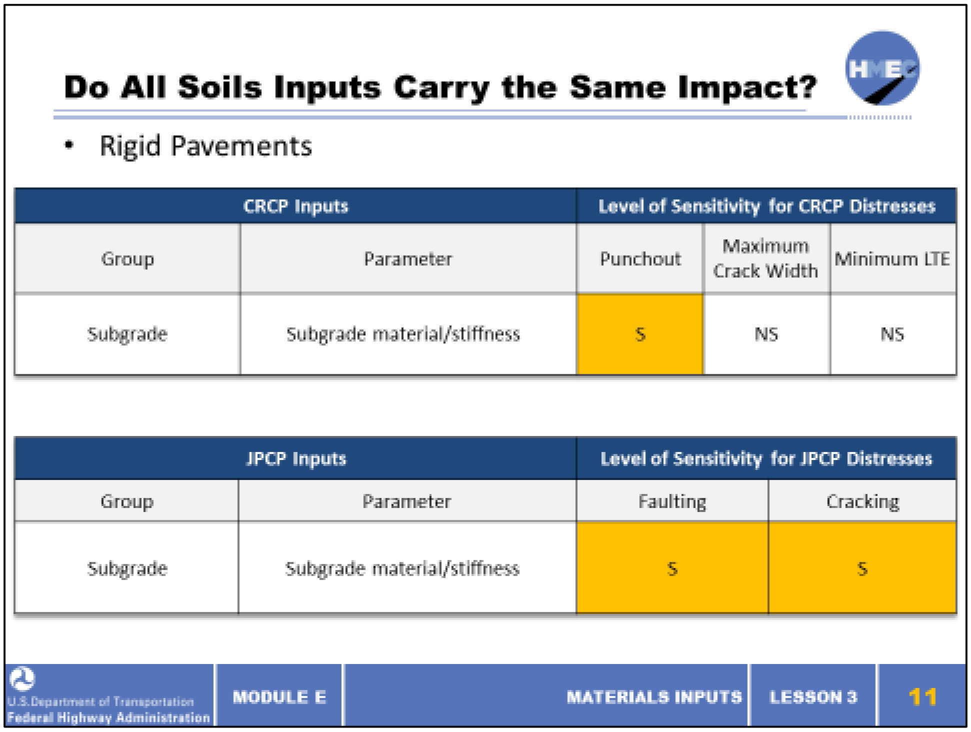
Slide 11



Do All Soils Inputs Carry the Same Impact?

- Rigid Pavements

CRCP Inputs		Level of Sensitivity for CRCP Distresses		
Group	Parameter	Punchout	Maximum Crack Width	Minimum LTE
Subgrade	Subgrade material/stiffness	S	NS	NS

JPCP Inputs		Level of Sensitivity for JPCP Distresses	
Group	Parameter	Faulting	Cracking
Subgrade	Subgrade material/stiffness	S	S

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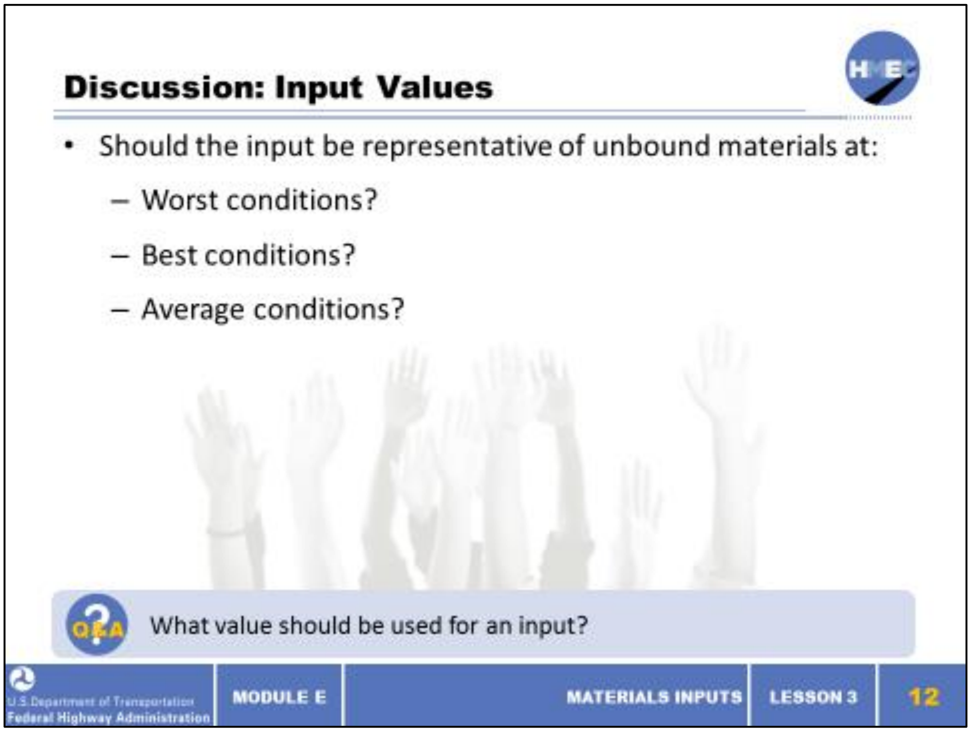
The subgrade material type and stiffness is most influential for the structural responses, consistent with pavement design theory.

Slide 12



Discussion: Input Values

- Should the input be representative of unbound materials at:
  - Worst conditions?
  - Best conditions?
  - Average conditions?

What value should be used for an input?

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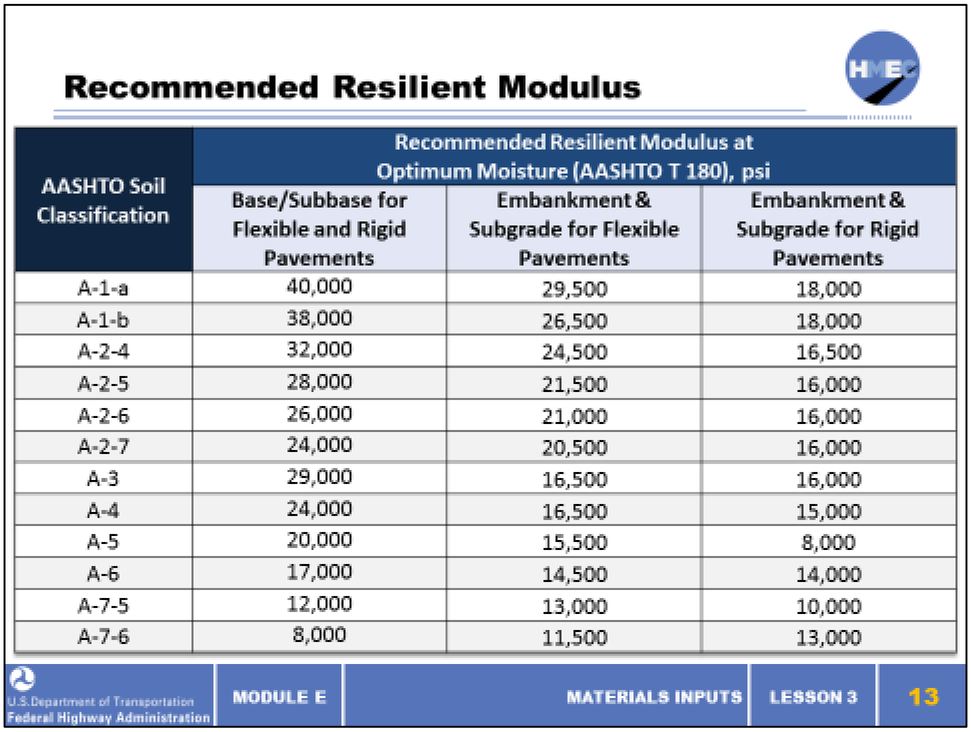
Consider what we've covered so far in this lesson and the impact different properties have on pavement performance.

Slide 13



Recommended Resilient Modulus

AASHTO Soil Classification	Recommended Resilient Modulus at Optimum Moisture (AASHTO T 180), psi		
	Base/Subbase for Flexible and Rigid Pavements	Embankment & Subgrade for Flexible Pavements	Embankment & Subgrade for Rigid Pavements
A-1-a	40,000	29,500	18,000
A-1-b	38,000	26,500	18,000
A-2-4	32,000	24,500	16,500
A-2-5	28,000	21,500	16,000
A-2-6	26,000	21,000	16,000
A-2-7	24,000	20,500	16,000
A-3	29,000	16,500	16,000
A-4	24,000	16,500	15,000
A-5	20,000	15,500	8,000
A-6	17,000	14,500	14,000
A-7-5	12,000	13,000	10,000
A-7-6	8,000	11,500	13,000

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If you don’t have the modulus values, they can be entered by using the suggested values from the MEPDG Manual of Practice. These values can be taken from a State DOT materials catalog and from the Arizona State University interactive soil unit map application.

The different MR values for different layers and pavement type in this Table reflect the stress-dependent material properties.

The inputs for soil resilient moduli can be variable in pavement design and have relatively high coefficients of variation, as described in NCHRP Research Results Digest 308. The resilient modulus tables in the MEPDG Manual of Practice (2008) presented the recommended resilient modulus at optimum moisture for each of the AASHTO soil classes.

Different stiffness values are recommended for the same material, depending on the intended use of the material in the design of the pavement. For example, if a DOT plans to use an A-2-4 soil (perhaps it is the local source for construction projects in an area) as a base layer for a pavement design, then the A-2-4 must pass (or be compacted to) a stiffness value of 32,000 psi in order to effectively dissipate the load stresses induced and protect the subgrade and perform reliably.

However, if the A-2-4 is being used as an embankment or subgrade layer in a rigid pavement, then it is in a position further down deep into the pavement’s layered system and will not need to be compacted or strengthened to the same level of stiffness as when it’s being used as a base. Instead, it would just need to pass with a modulus of 16,500psi.

This table shows the recommended resilient modulus input at optimum density and moisture, but the standard deviation should also be considered when picking the most appropriate resilient modulus default value for your design. It should be noted that these values vary with pavement type (flexible versus rigid) for a number of reasons, such as the greater dependence on subgrade stiffness in the performance of rigid pavements versus flexible pavements (in which there are more layers above the subgrade which provide intermediate support and dissipation of stresses through the entire pavement system).

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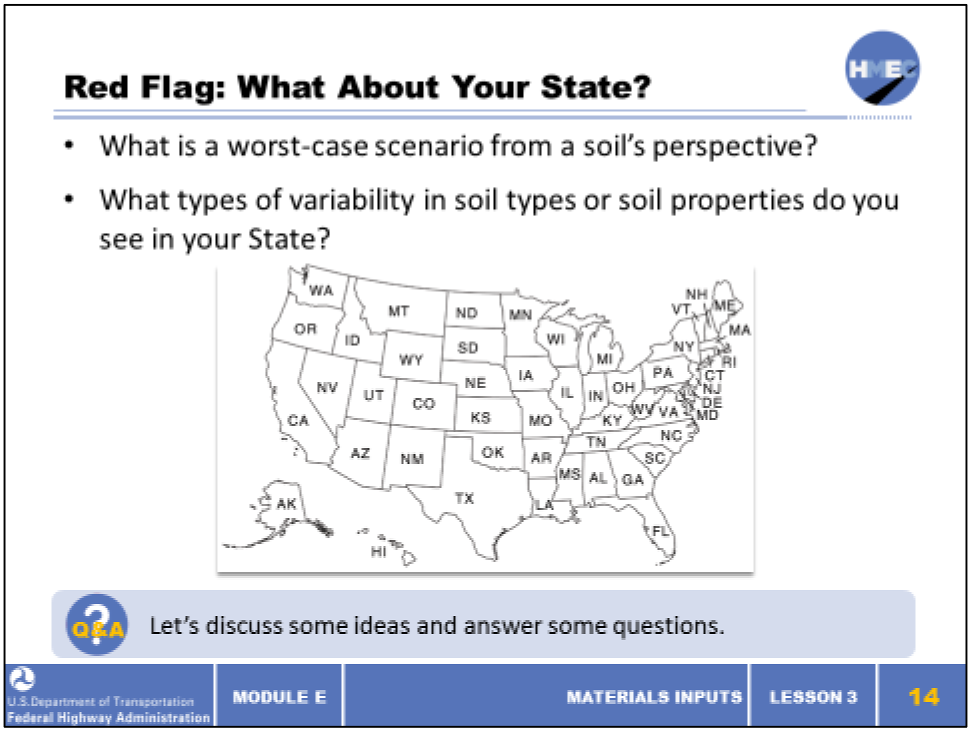
Slide 14



Red Flag: What About Your State?

- What is a worst-case scenario from a soil's perspective?
- What types of variability in soil types or soil properties do you see in your State?

WA
OR
CA
NV
ID
MT
WY
UT
AZ
CO
NM
ND
SD
NE
KS
OK
TX
MN
IA
MO
AR
LA
WI
IL
MS
MI
IN
KY
TN
AL
OH
WV
VA
NC
SC
GA
FL
PA
NY
VT
NH
ME
MA
RI
CT
NJ
DE
MD
AK
HI
Q&A

Let's discuss some ideas and answer some questions.

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Federal Highway Administration
MODULE E
MATERIALS INPUTS
LESSON 3
14

Thinking of your own State, answer the following questions.

- What is a worst-case scenario from a soil's perspective?
- What types of variability in soil types or soil properties do you see in your State?

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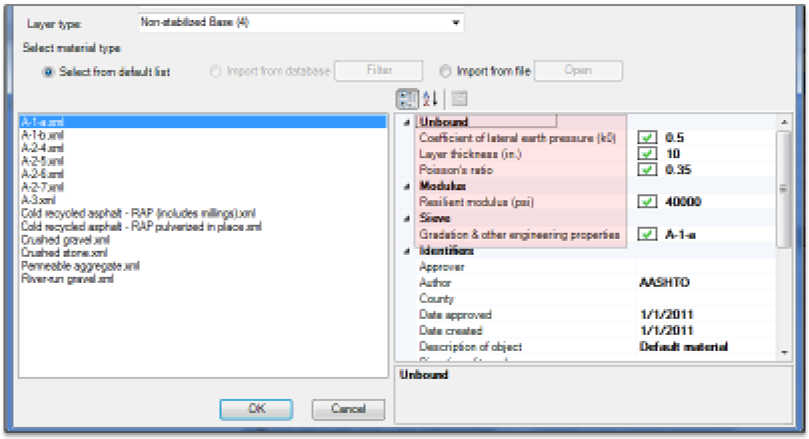
Slide 15

Untreated Granular Layers: Properties



Layer type: Non-stabilized Base (4)

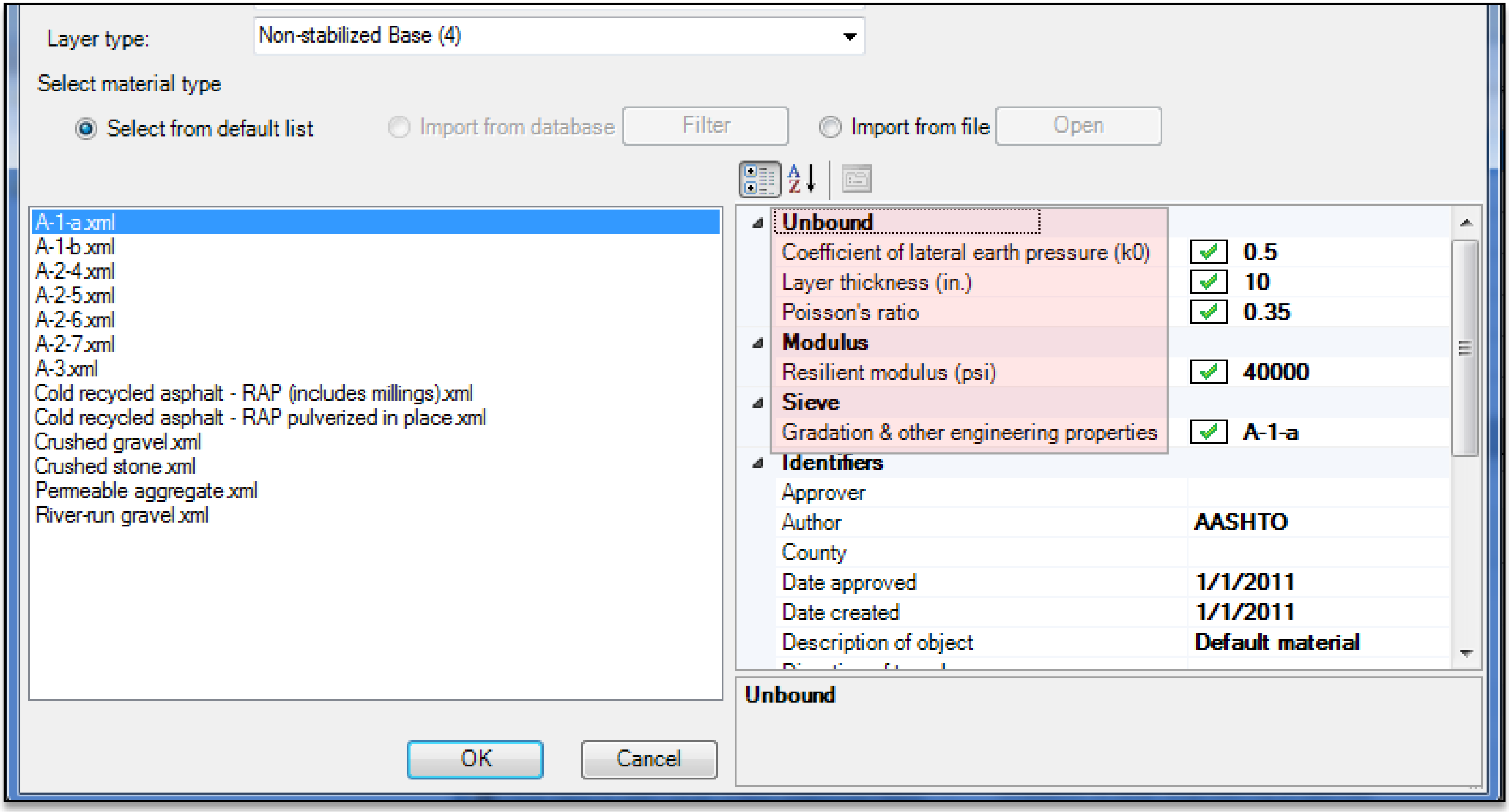
Select material type

● Select from default list ○ Import from database ○ Import from file

A-1-a.xml
A-1-b.xml
A-2-4.xml
A-2-5.xml
A-2-6.xml
A-2-7.xml
A-3.xml
Cold recycled asphalt - RAP (includes millings).xml
Cold recycled asphalt - RAP pulverized in place.xml
Crushed gravel.xml
Crushed stone.xml
Permeable aggregate.xml
River-run gravel.xml

Unbound	
Coefficient of lateral earth pressure (k0)	☑ 0.5
Layer thickness (in.)	☑ 10
Poisson's ratio	☑ 0.35
Modulus	
Resilient modulus (psi)	☑ 40000
Sieve	
Gradation & other engineering properties	☑ A-1-a
Identifiers	
Approver	
Author	AASHTO
County	
Date approved	1/1/2011
Date created	1/1/2011
Description of object	Default material

Unbound



Layer type: Non-stabilized Base (4)

Select material type

● Select from default list ○ Import from database Filter ○ Import from file Open

- A-1-a.xml
- A-1-b.xml
- A-2-4.xml
- A-2-5.xml
- A-2-6.xml
- A-2-7.xml
- A-3.xml
- Cold recycled asphalt - RAP (includes millings).xml
- Cold recycled asphalt - RAP pulverized in place.xml
- Crushed gravel.xml
- Crushed stone.xml
- Permeable aggregate.xml
- River-run gravel.xml

Unbound		
Coefficient of lateral earth pressure (k0)	✓	**0.5**
Layer thickness (in.)	✓	**10**
Poisson's ratio	✓	**0.35**
Modulus		
Resilient modulus (psi)	✓	**40000**
Sieve		
Gradation & other engineering properties	✓	**A-1-a**
Identifiers		
Approver		
Author		**AASHTO**
County		
Date approved		**1/1/2011**
Date created		**1/1/2011**
Description of object		**Default material**

Unbound

Point out the untreated granular layers properties that are entered into the software.

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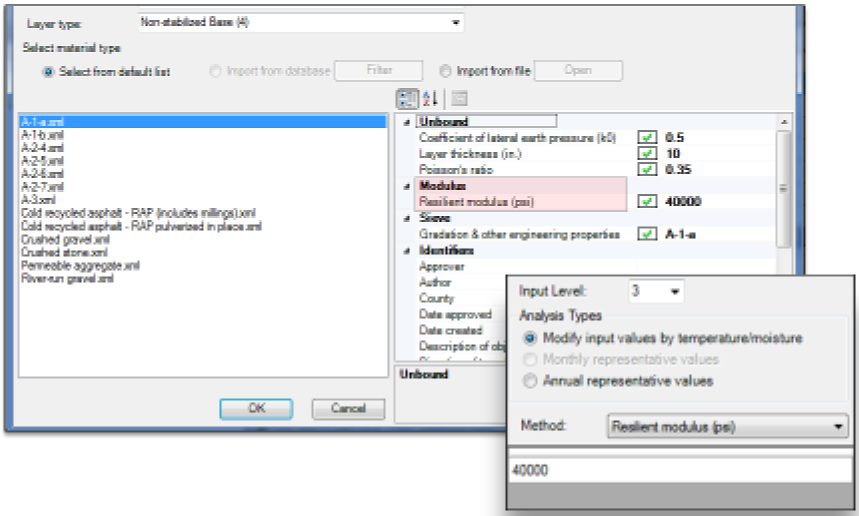
Slide 16

Untreated Granular Layers: Modulus



Layer type: Non-stabilized Base (4)

Select material type

● Select from default list ○ Import from database ○ Import from file

A-1-a.xml
A-1-b.xml
A-2-4.xml
A-2-5.xml
A-2-6.xml
A-2-7.xml
A-3.xml
Cold recycled asphalt - RAP (includes millings).xml
Cold recycled asphalt - RAP pulverized in place.xml
Crushed gravel.xml
Crushed stone.xml
Permeable aggregate.xml
River-run gravel.xml

Unbound

Coefficient of lateral earth pressure (k0)	☑	0.5
Layer thickness (in.)	☑	10
Poisson's ratio	☑	0.35
Modulus		
Resilient modulus (psi)	☑	40000
Sieve		
Gradation & other engineering properties	☑	A-1-a
Identifiers		
Approver		
Author		
County		
Date approved		
Date created		
Description of obj		

Unbound

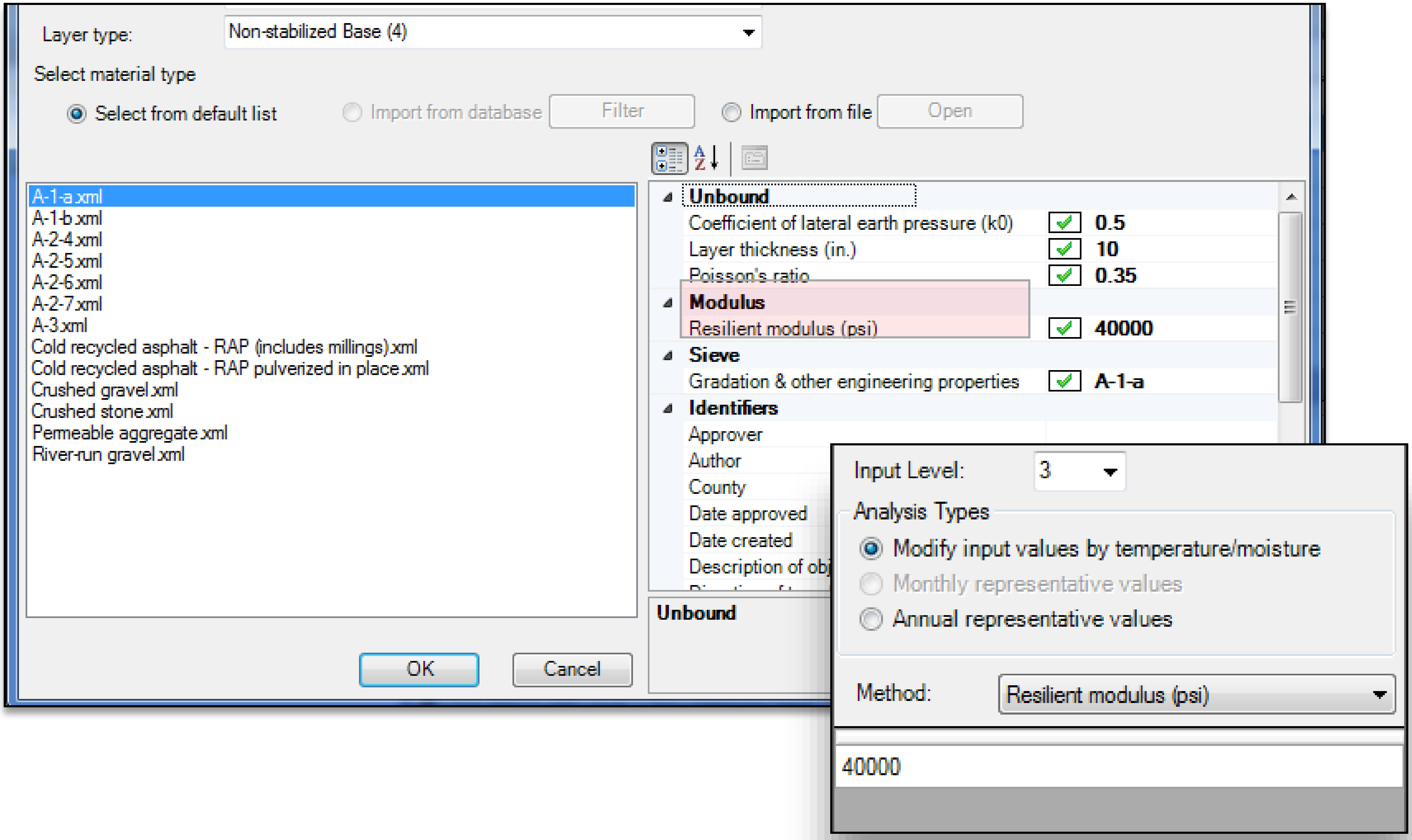
Input Level: 3

Analysis Types

● Modify input values by temperature/moisture
○ Monthly representative values
○ Annual representative values

Method: Resilient modulus (psi)

40000



Layer type: Non-stabilized Base (4)

Select material type

● Select from default list ○ Import from database ○ Import from file

A-1-a.xml
A-1-b.xml
A-2-4.xml
A-2-5.xml
A-2-6.xml
A-2-7.xml
A-3.xml
Cold recycled asphalt - RAP (includes millings).xml
Cold recycled asphalt - RAP pulverized in place.xml
Crushed gravel.xml
Crushed stone.xml
Permeable aggregate.xml
River-run gravel.xml

Unbound

Coefficient of lateral earth pressure (k0)	☑	**0.5**
Layer thickness (in.)	☑	**10**
Poisson's ratio	☑	**0.35**

Modulus

Resilient modulus (psi)	☑	**40000**

Sieve

Gradation & other engineering properties	☑	**A-1-a**

Identifiers

Approver
Author
County
Date approved
Date created
Description of obj

Unbound

Input Level: 3

Analysis Types

● Modify input values by temperature/moisture
○ Monthly representative values
○ Annual representative values

Method: Resilient modulus (psi)

40000

The resilient modulus is converted to a k-value internally within the software for evaluating rigid pavements. The resilient modulus values at the time of construction for the same AASHTO soil classification are different under flexible and rigid pavements because stress-state under these pavements is different. Soils are stress-dependent and the resilient modulus will change with changing stress state.

The resilient modulus for the unbound layers and foundation may also be estimated from the California bearing ratio (CBR) test (AASHTO T 193) or the R-value test (AASHTO T 190).

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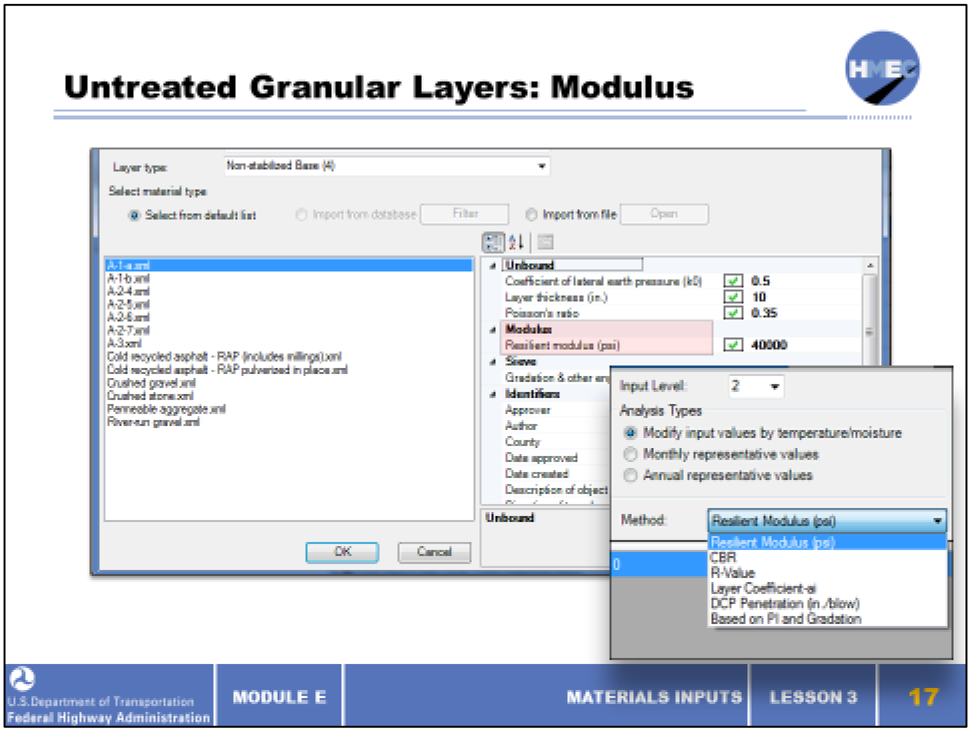
Slide 17



Untreated Granular Layers: Modulus

Layer type: Non-stabilized Base (4)

Select material type

● Select from default list ○ Import from database ○ Import from file

A-1-a.xml
A-1-b.xml
A-2-4.xml
A-2-5.xml
A-2-6.xml
A-2-7.xml
A-3.xml
Cold recycled asphalt - RAP (includes millings).xml
Cold recycled asphalt - RAP pulverized in place.xml
Crushed gravel.xml
Crushed stone.xml
Permeable aggregate.xml
River-run gravel.xml

Unbound
Coefficient of lateral earth pressure (k0) ☑ 0.5
Layer thickness (in.) ☑ 10
Poisson's ratio ☑ 0.35
Modulus
Resilient modulus (psi) ☑ 40000
Sieve
Gradation & other en
Identifiers
Approver
Author
County
Date approved
Date created
Description of object

Unbound

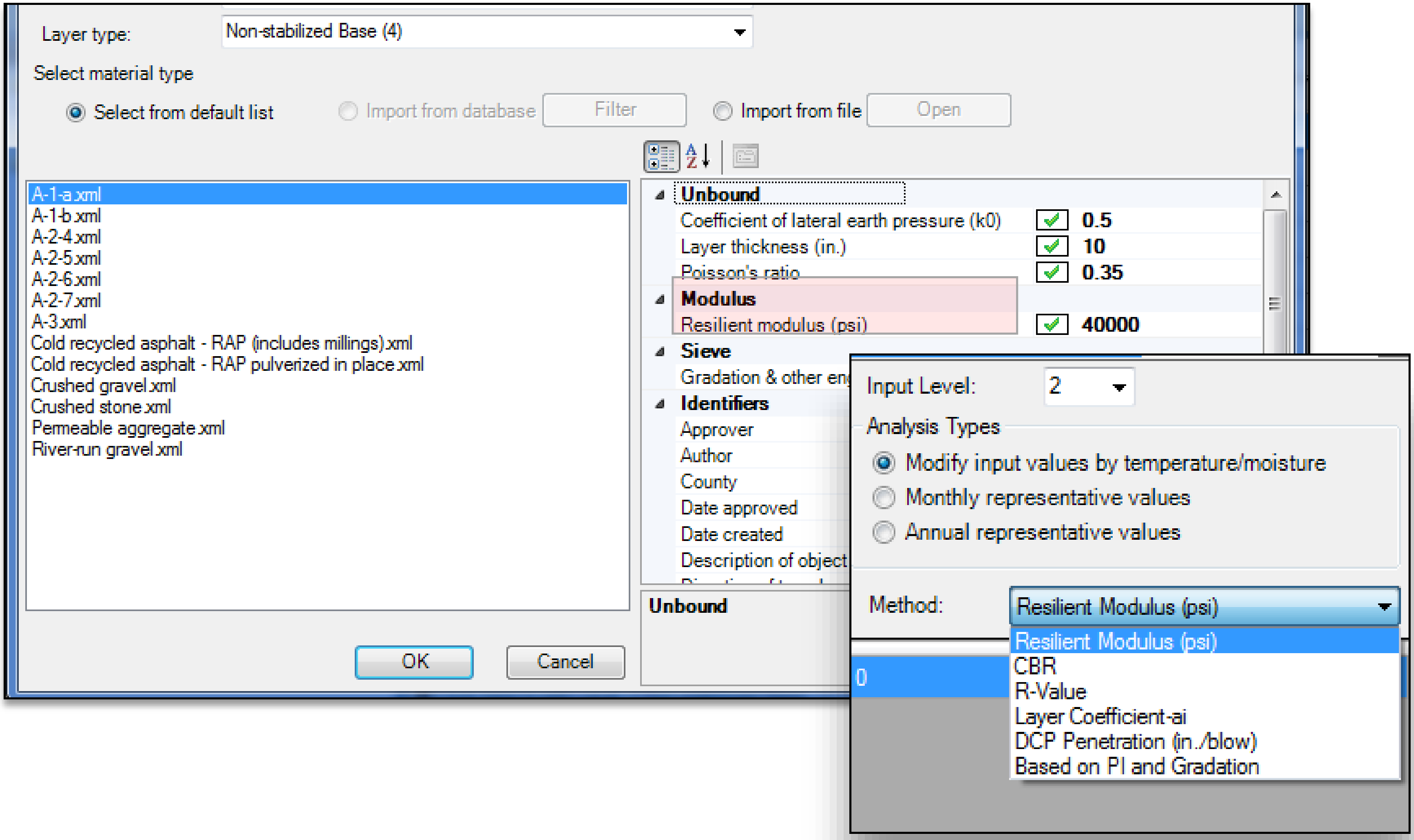
Input Level: 2

Analysis Types
● Modify input values by temperature/moisture
○ Monthly representative values
○ Annual representative values

Method: Resilient Modulus (psi)

Filter
Open
OK
Cancel
Resilient Modulus (psi)
CBR
R-Value
Layer Coefficient-ai
DCP Penetration (in./blow)
Based on PI and Gradation
0
HMEC
U.S.Department of Transportation
Federal Highway Administration

–



Layer type: Non-stabilized Base (4)

Select material type

● Select from default list ○ Import from database ○ Import from file

- A-1-a.xml
- A-1-b.xml
- A-2-4.xml
- A-2-5.xml
- A-2-6.xml
- A-2-7.xml
- A-3.xml
- Cold recycled asphalt - RAP (includes millings).xml
- Cold recycled asphalt - RAP pulverized in place.xml
- Crushed gravel.xml
- Crushed stone.xml
- Permeable aggregate.xml
- River-run gravel.xml

Unbound

Coefficient of lateral earth pressure (k0)	✓	0.5
Layer thickness (in.)	✓	10
Poisson's ratio	✓	0.35

Modulus

Resilient modulus (psi)	✓	40000

Sieve

Gradation & other en

Identifiers

- Approver
- Author
- County
- Date approved
- Date created
- Description of object

Unbound

Input Level: 2

Analysis Types

● Modify input values by temperature/moisture
○ Monthly representative values
○ Annual representative values

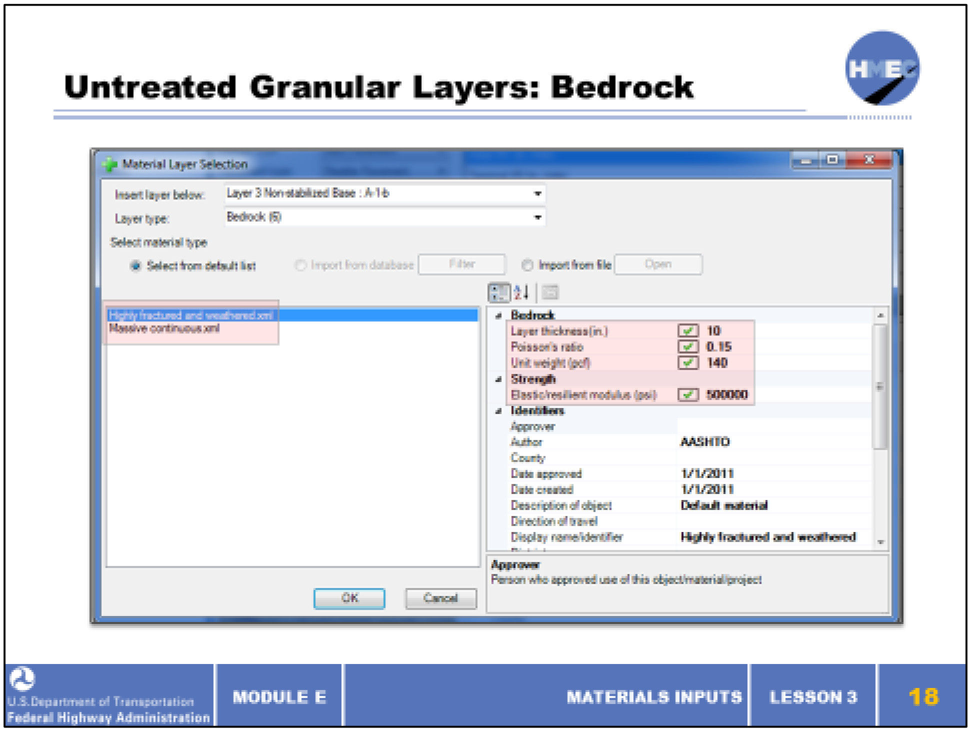
Method: Resilient Modulus (psi)

- Resilient Modulus (psi)
- CBR
- R-Value
- Layer Coefficient-ai
- DCP Penetration (in./blow)
- Based on PI and Gradation

0

In this case, the Level 2 inputs come from correlations based on laboratory or field data, but are not specific to the project site per se.

Slide 18



Untreated Granular Layers: Bedrock

Material Layer Selection

Insert layer below: Layer 3 Non-stabilized Base : A-1-b

Layer type: Bedrock (6)

Select material type

● Select from default list ○ Import from database ○ Import from file

Highly fractured and weathered.xml
Massive continuous.xml

Bedrock

Layer thickness(in.)	☑	10
Poisson's ratio	☑	0.15
Unit weight (pcf)	☑	140

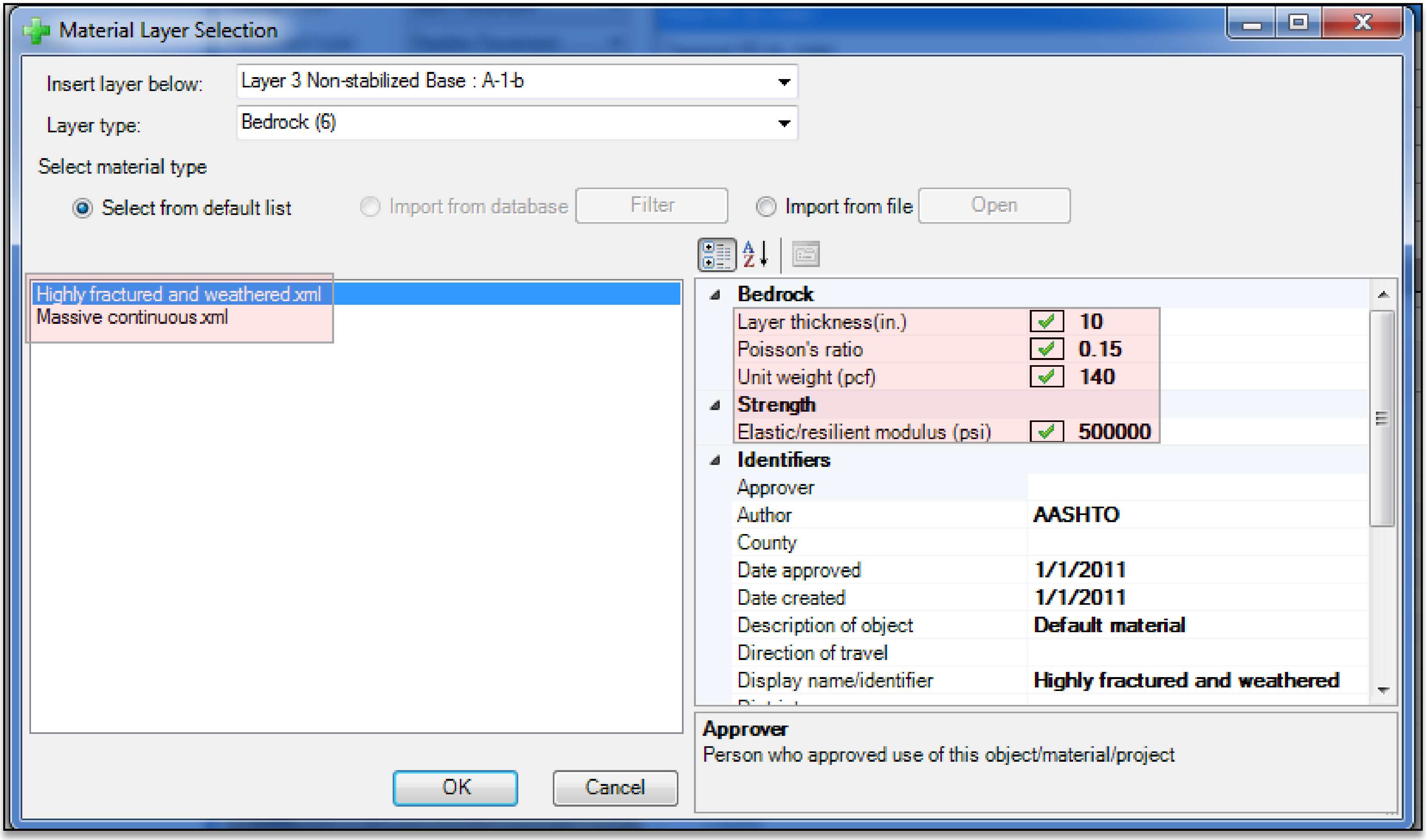
Strength

Elastic/resilient modulus (psi)	☑	500000

Identifiers

Approver	
Author	AASHTO
County	
Date approved	1/1/2011
Date created	1/1/2011
Description of object	Default material
Direction of travel	
Display name/identifier	Highly fractured and weathered

Approver
Person who approved use of this object/material/project



Insert layer below: Layer 3 Non-stabilized Base : A-1-b

Layer type: Bedrock (6)

Select material type

● Select from default list ○ Import from database ○ Import from file

Highly fractured and weathered.xml
Massive continuous.xml

Bedrock		
Layer thickness(in.)	✓	10
Poisson's ratio	✓	0.15
Unit weight (pcf)	✓	140
Strength		
Elastic/resilient modulus (psi)	✓	500000
Identifiers		
Approver		
Author		AASHTO
County		
Date approved		1/1/2011
Date created		1/1/2011
Description of object		Default material
Direction of travel		
Display name/identifier		Highly fractured and weathered

Approver
Person who approved use of this object/material/project

Bedrock is most influential on rigid pavements because if bedrock is within 10 feet of the pavement’s surface, it will confine the material (subgrade) and will produce a higher k-value.
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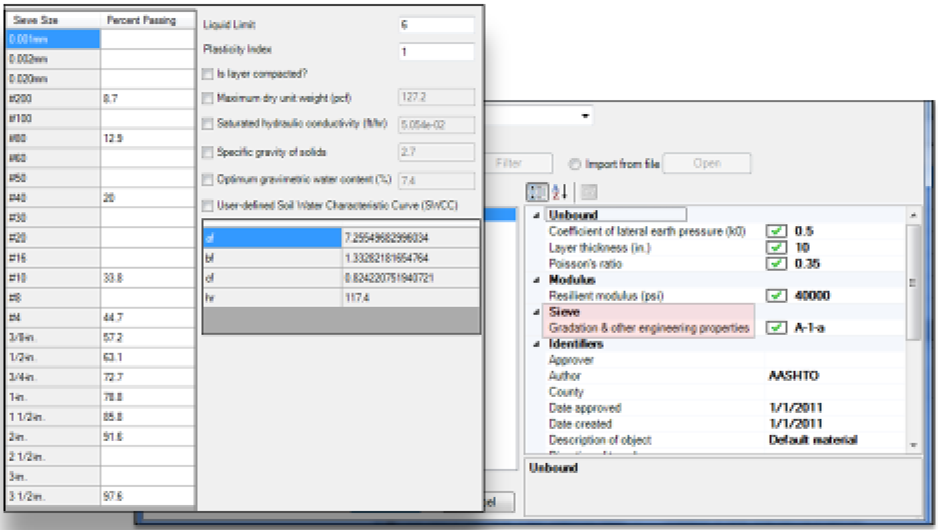
Slide 19

Untreated Granular Layers: Sieve Analysis



Sieve Size	Percent Passing
0.001mm	
0.002mm	
0.020mm	
#200	8.7
#100	
#80	12.9
#60	
#50	
#40	20
#30	
#20	
#16	
#10	33.8
#8	
#4	44.7
3/8in.	57.2
1/2in.	63.1
3/4in.	72.7
1in.	78.8
1 1/2in.	85.8
2in.	91.6
2 1/2in.	
3in.	
3 1/2in.	97.6

Liquid Limit: 6

Plasticity Index: 1

☐ Is layer compacted?

☐ Maximum dry unit weight (pcf): 127.2

☐ Saturated hydraulic conductivity (ft/hr): 5.054e-02

☐ Specific gravity of solids: 2.7

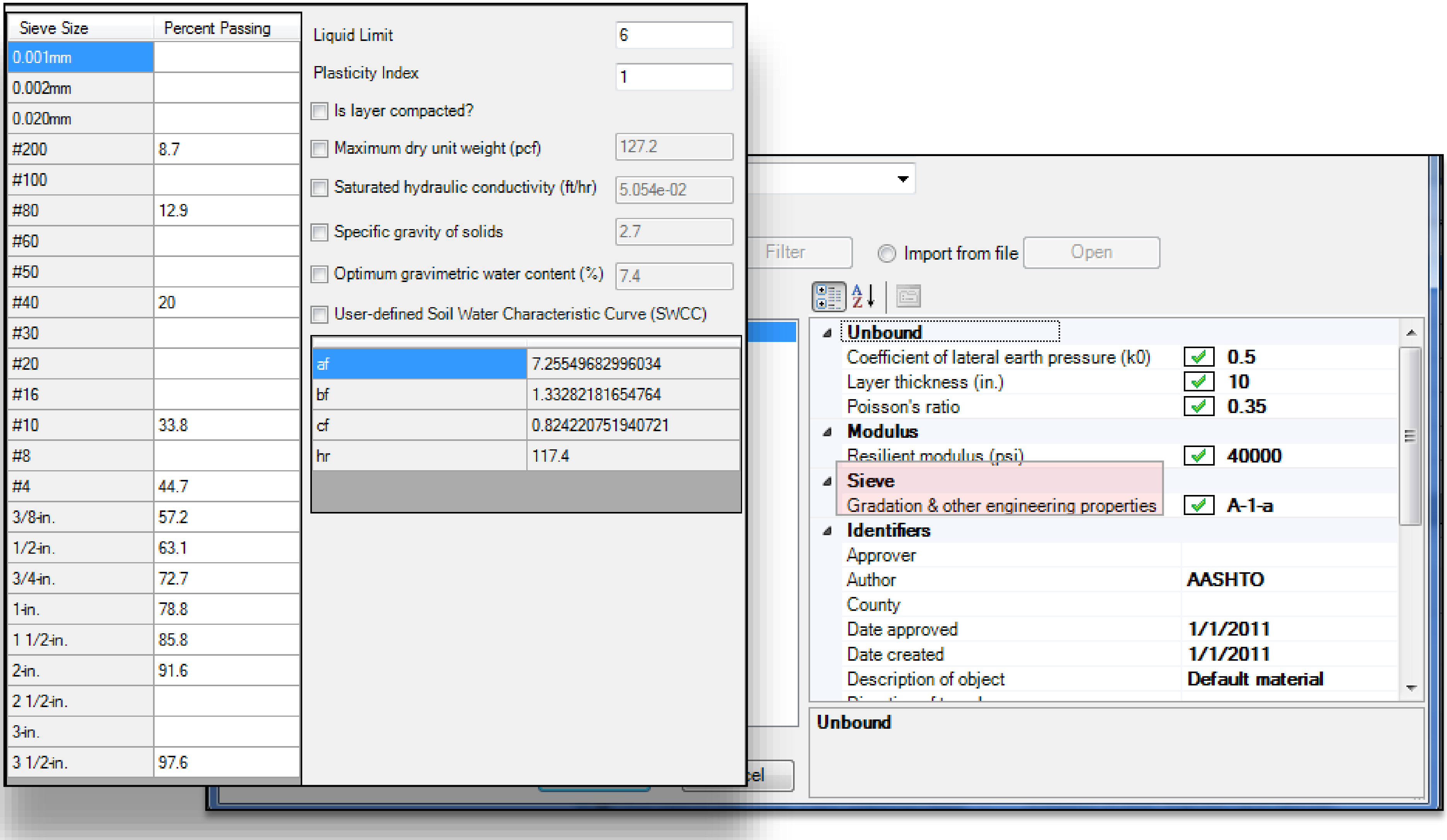
☐ Optimum gravimetric water content (%): 7.4

☐ User-defined Soil Water Characteristic Curve (SWCC)

af	7.25549682996034
bf	1.33282181654764
cf	0.824220751940721
hr	117.4

Unbound		
Coefficient of lateral earth pressure (k0)	☑	0.5
Layer thickness (in.)	☑	10
Poisson's ratio	☑	0.35
Modulus		
Resilient modulus (psi)	☑	40000
Sieve		
Gradation & other engineering properties	☑	A-1-a
Identifiers		
Approver		
Author		AASHTO
County		
Date approved		1/1/2011
Date created		1/1/2011
Description of object		Default material

Unbound



Sieve Size	Percent Passing
0.001mm	
0.002mm	
0.020mm	
#200	8.7
#100	
#80	12.9
#60	
#50	
#40	20
#30	
#20	
#16	
#10	33.8
#8	
#4	44.7
3/8-in.	57.2
1/2-in.	63.1
3/4-in.	72.7
1-in.	78.8
1 1/2-in.	85.8
2-in.	91.6
2 1/2-in.	
3-in.	
3 1/2-in.	97.6

Liquid Limit	6
Plasticity Index	1
☐ Is layer compacted?	
☐ Maximum dry unit weight (pcf)	127.2
☐ Saturated hydraulic conductivity (ft/hr)	5.054e-02
☐ Specific gravity of solids	2.7
☐ Optimum gravimetric water content (%)	7.4
☐ User-defined Soil Water Characteristic Curve (SWCC)	

af	7.25549682996034
bf	1.33282181654764
cf	0.824220751940721
hr	117.4

Unbound	
Coefficient of lateral earth pressure (k0)	✓ **0.5**
Layer thickness (in.)	✓ **10**
Poisson's ratio	✓ **0.35**
Modulus	
Resilient modulus (psi)	✓ **40000**
Sieve	
Gradation & other engineering properties	✓ **A-1-a**
Identifiers	
Approver	
Author	**AASHTO**
County	
Date approved	**1/1/2011**
Date created	**1/1/2011**
Description of object	**Default material**

Unbound

The sieve gradation can be input for each soil layer, as well as key properties like the liquid limit (LL), plasticity index (PI), and the soil water characteristic curve (SWCC).

These values can be taken from a State DOT materials catalog and from the Arizona State University interactive soil unit map application.

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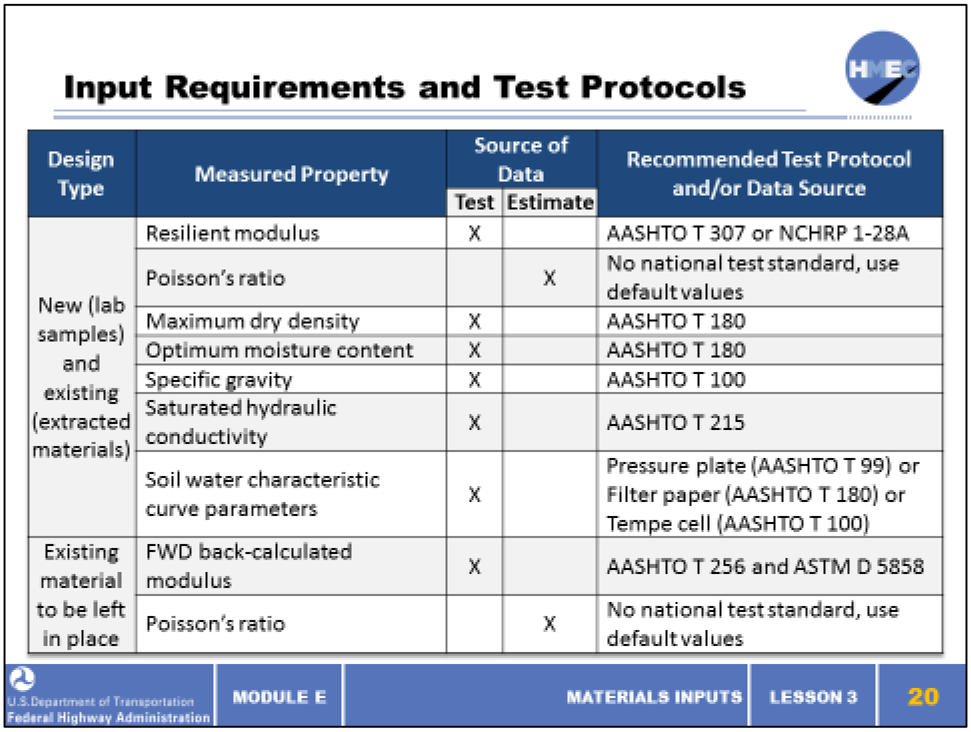
Slide 20



Input Requirements and Test Protocols

Design Type	Measured Property	Source of Data		Recommended Test Protocol and/or Data Source
		Test	Estimate	
New (lab samples) and existing (extracted materials)	Resilient modulus	X		AASHTO T 307 or NCHRP 1-28A
	Poisson's ratio		X	No national test standard, use default values
	Maximum dry density	X		AASHTO T 180
	Optimum moisture content	X		AASHTO T 180
	Specific gravity	X		AASHTO T 100
	Saturated hydraulic conductivity	X		AASHTO T 215
	Soil water characteristic curve parameters	X		Pressure plate (AASHTO T 99) or Filter paper (AASHTO T 180) or Tempe cell (AASHTO T 100)
Existing material to be left in place	FWD back-calculated modulus	X		AASHTO T 256 and ASTM D 5858
	Poisson's ratio		X	No national test standard, use default values

U.S. Department of Transportation
Federal Highway Administration

MODULE E

MATERIALS INPUTS

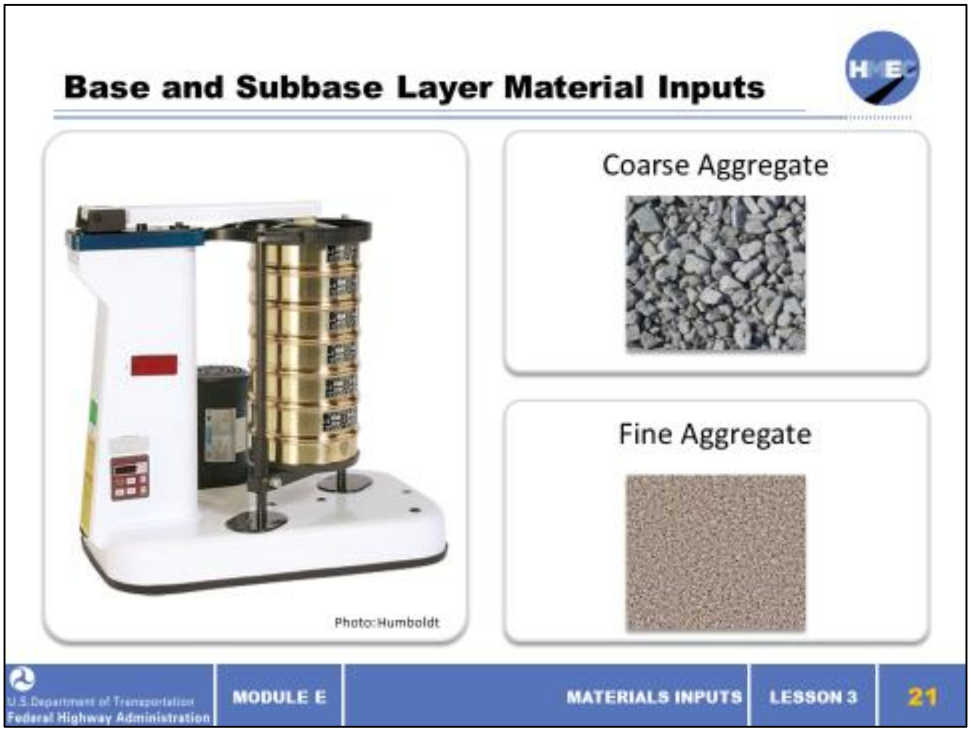
LESSON 3

20

Most of the soil or unbound material properties can be tested in the lab and have an AASHTO standard, with the exception of Poisson's ratio.

There are two options for test methods that yield the resilient modulus:
(1) Regression coefficients k_1, k_2, k_3 for the generalized constitutive model that defines resilient modulus as a function of stress state and regressed from laboratory resilient modulus tests.
(2) Determine the average design resilient modulus for the expected in-place stress state from laboratory resilient modulus tests.

Slide 21



Base and Subbase Layer Material Inputs

Coarse Aggregate

Fine Aggregate

Photo: Humboldt

U.S. Department of Transportation
Federal Highway Administration

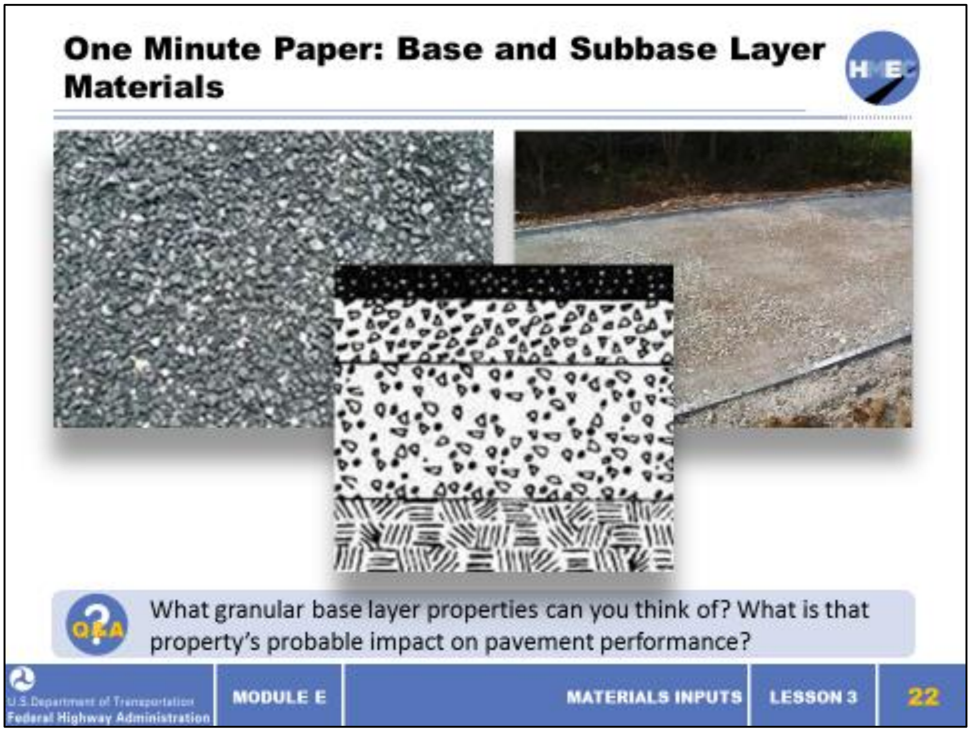
MODULE E

MATERIALS INPUTS

LESSON 3

21

Slide 22



One Minute Paper: Base and Subbase Layer Materials

Q&A What granular base layer properties can you think of? What is that property's probable impact on pavement performance?

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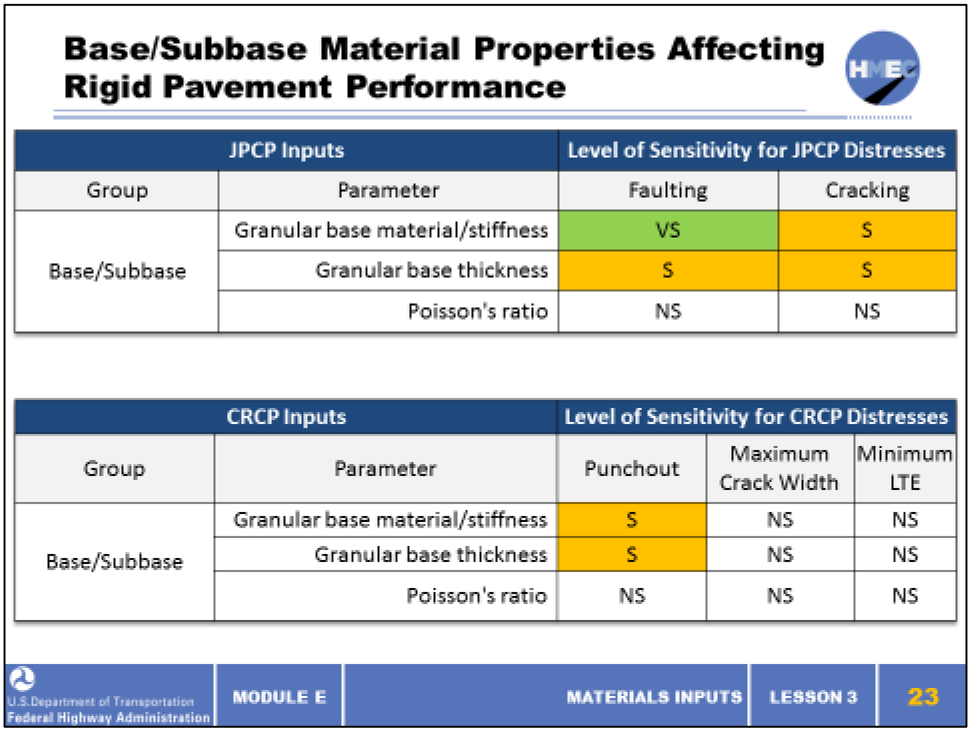
MATERIALS INPUTS
LESSON 3
22

Slide 23



Base/Subbase Material Properties Affecting Rigid Pavement Performance

JPCP Inputs		Level of Sensitivity for JPCP Distresses	
Group	Parameter	Faulting	Cracking
Base/Subbase	Granular base material/stiffness	VS	S
	Granular base thickness	S	S
	Poisson's ratio	NS	NS

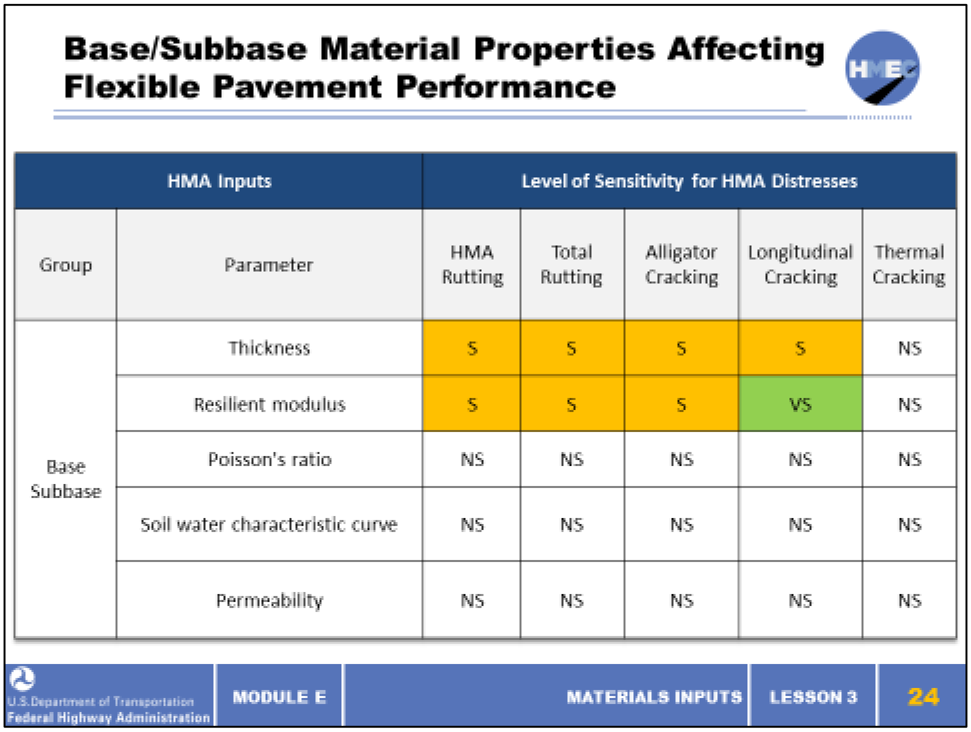
CRCP Inputs		Level of Sensitivity for CRCP Distresses		
Group	Parameter	Punchout	Maximum Crack Width	Minimum LTE
Base/Subbase	Granular base material/stiffness	S	NS	NS
	Granular base thickness	S	NS	NS
	Poisson's ratio	NS	NS	NS

U.S. Department of Transportation Federal Highway Administration | MODULE E | MATERIALS INPUTS | LESSON 3 | 23

The base or subbase layer stiffness is the most sensitive parameter for JPCP faulting and cracking. The thickness of the subbase/base layer is also sensitive for both. This makes sense in that it is a jointed system.

In the case of CRC pavements, the punchout model is the only one that is sensitive to base layer characteristics, specifically the stiffness and thickness.

Slide 24



Base/Subbase Material Properties Affecting Flexible Pavement Performance

HMA Inputs		Level of Sensitivity for HMA Distresses				
Group	Parameter	HMA Rutting	Total Rutting	Alligator Cracking	Longitudinal Cracking	Thermal Cracking
Base Subbase	Thickness	S	S	S	S	NS
	Resilient modulus	S	S	S	VS	NS
	Poisson's ratio	NS	NS	NS	NS	NS
	Soil water characteristic curve	NS	NS	NS	NS	NS
	Permeability	NS	NS	NS	NS	NS

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Federal Highway Administration

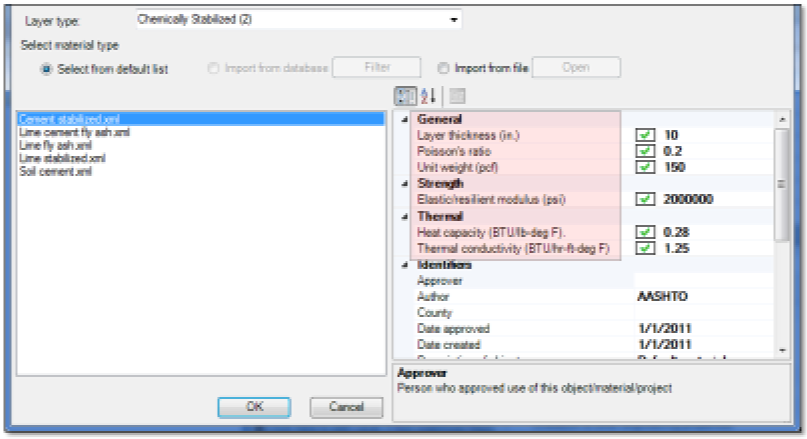
MODULE E | MATERIALS INPUTS | LESSON 3 | 24

Similar to the case of rigid pavements, the thickness and stiffness of the base layer are most influential on all of the structural-related distresses predicted.

In areas where the program is not sensitive to certain inputs, default values are used.

Slide 25

Treated/Stabilized Base and Subbase Layers: Properties



Layer type: Chemically Stabilized (2)

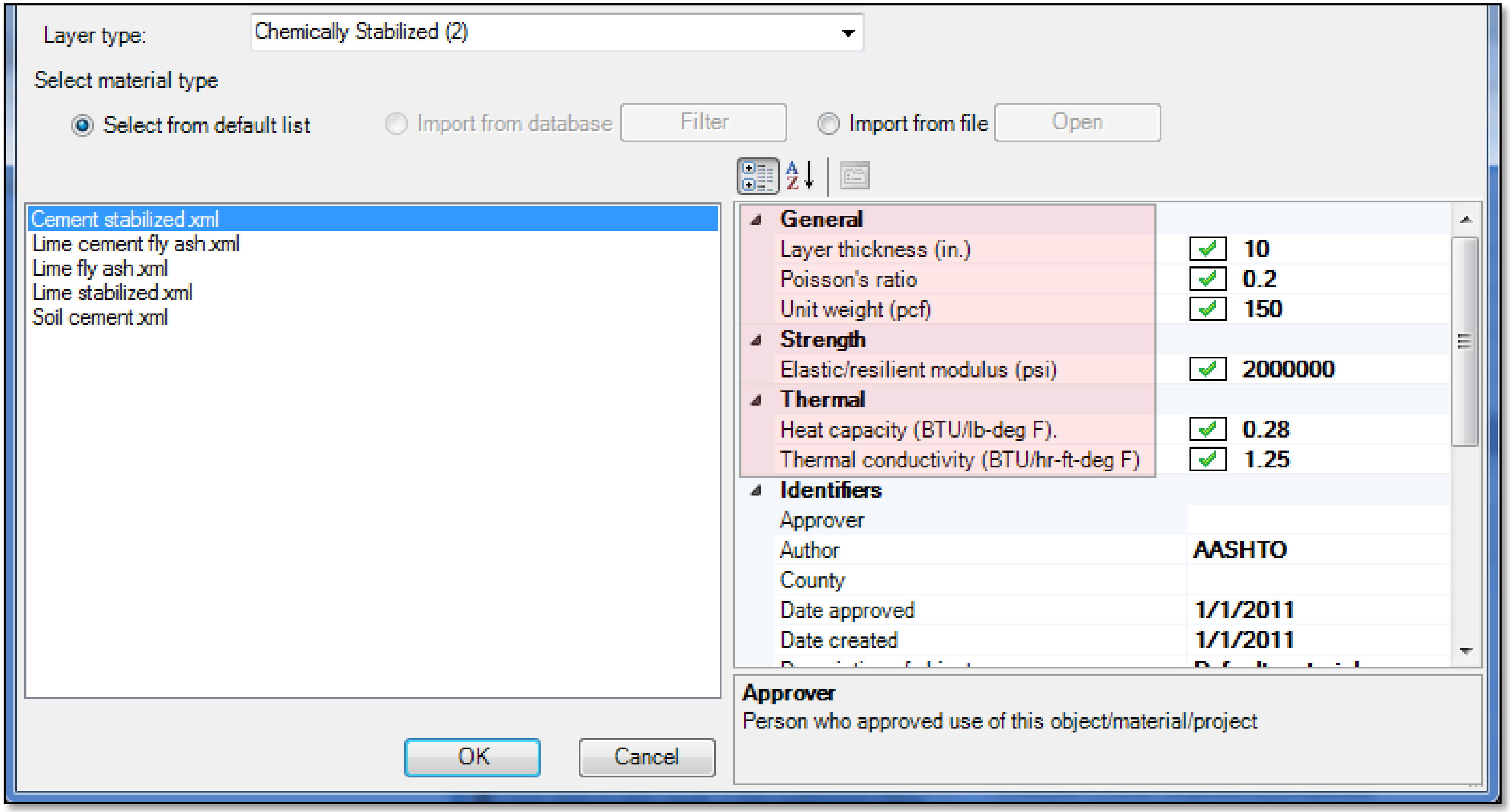
Select material type

● Select from default list ○ Import from database ○ Import from file

Cement stabilized.xml
Lime cement fly ash.xml
Lime fly ash.xml
Lime stabilized.xml
Soil cement.xml

General	
Layer thickness (in.)	☑ 10
Poisson's ratio	☑ 0.2
Unit weight (pcf)	☑ 150
Strength	
Elastic/resilient modulus (psi)	☑ 2000000
Thermal	
Heat capacity (BTU/lb-deg F).	☑ 0.28
Thermal conductivity (BTU/hr-ft-deg F)	☑ 1.25
Identifiers	
Approver	
Author	AASHTO
County	
Date approved	1/1/2011
Date created	1/1/2011

Approver
Person who approved use of this object/material/project



Layer type: Chemically Stabilized (2)

Select material type

● Select from default list ○ Import from database ○ Import from file

- Cement stabilized.xml
- Lime cement fly ash.xml
- Lime fly ash.xml
- Lime stabilized.xml
- Soil cement.xml

General	
Layer thickness (in.)	☑ 10
Poisson's ratio	☑ 0.2
Unit weight (pcf)	☑ 150
Strength	
Elastic/resilient modulus (psi)	☑ 2000000
Thermal	
Heat capacity (BTU/lb-deg F).	☑ 0.28
Thermal conductivity (BTU/hr-ft-deg F)	☑ 1.25
Identifiers	
Approver	
Author	AASHTO
County	
Date approved	1/1/2011
Date created	1/1/2011

Approver
Person who approved use of this object/material/project

Chemically-stabilized materials to choose from include soil cement, lime, cement, lime cement fly ash, and lime fly ash.

It should be noted that a chemically stabilized soil is not the same as a soil treatment. A soil treatment is a modified soil, but will not exhibit the stiffness properties equivalent to a chemically stabilized soil. In the case of a soil treatment, the input should be the same as that of an untreated natural soil but with a higher modulus.

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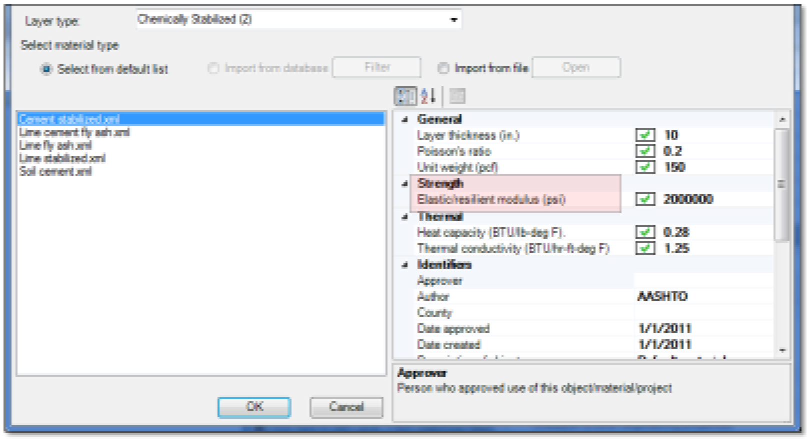
Slide 26

Treated/Stabilized Base and Subbase Layers: Strength



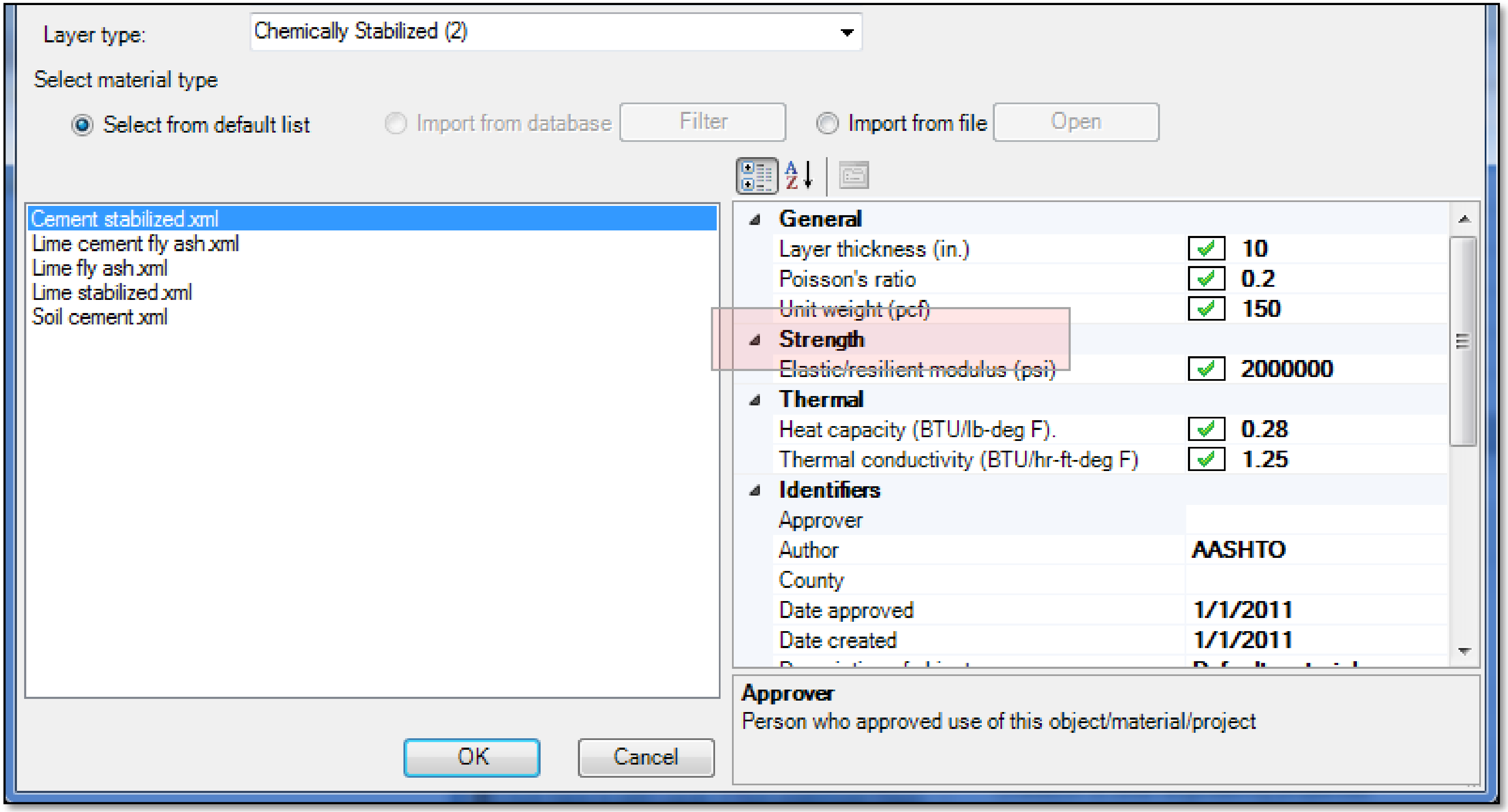
Layer type: Chemically Stabilized (2)

● Select from default list

- Cement stabilized.xml
- Lime cement fly ash.xml
- Lime fly ash.xml
- Lime stabilized.xml
- Soil cement.xml

General		
Layer thickness (in.)	☑	10
Poisson's ratio	☑	0.2
Unit weight (pcf)	☑	150
Strength		
Elastic/resilient modulus (psi)	☑	2000000
Thermal		
Heat capacity (BTU/lb-deg F)	☑	0.28
Thermal conductivity (BTU/hr-ft-deg F)	☑	1.25
Identifiers		
Approver		
Author		AASHTO
County		
Date approved		1/1/2011
Date created		1/1/2011

Approver
Person who approved use of this object/material/project



Layer type: Chemically Stabilized (2)

Select material type

● Select from default list ○ Import from database ○ Import from file

- Cement stabilized.xml
- Lime cement fly ash.xml
- Lime fly ash.xml
- Lime stabilized.xml
- Soil cement.xml

General		
Layer thickness (in.)	☑	10
Poisson's ratio	☑	0.2
Unit weight (pcf)	☑	150
Strength		
Elastic/resilient modulus (psi)	☑	2000000
Thermal		
Heat capacity (BTU/lb-deg F).	☑	0.28
Thermal conductivity (BTU/hr-ft-deg F)	☑	1.25
Identifiers		
Approver		
Author		AASHTO
County		
Date approved		1/1/2011
Date created		1/1/2011

Approver
Person who approved use of this object/material/project

Strength of the treated subbase or base layer is the most influential input as described in the NCHRP RRD 372 report. Strength property can be input either as an elastic or a resilient modulus value.

The distinction between stabilized or strengthened base layers is made in this screen. The consideration is important for establishing the layer structure for categorizing as a concrete base layer or unbound material in the MEPDG.

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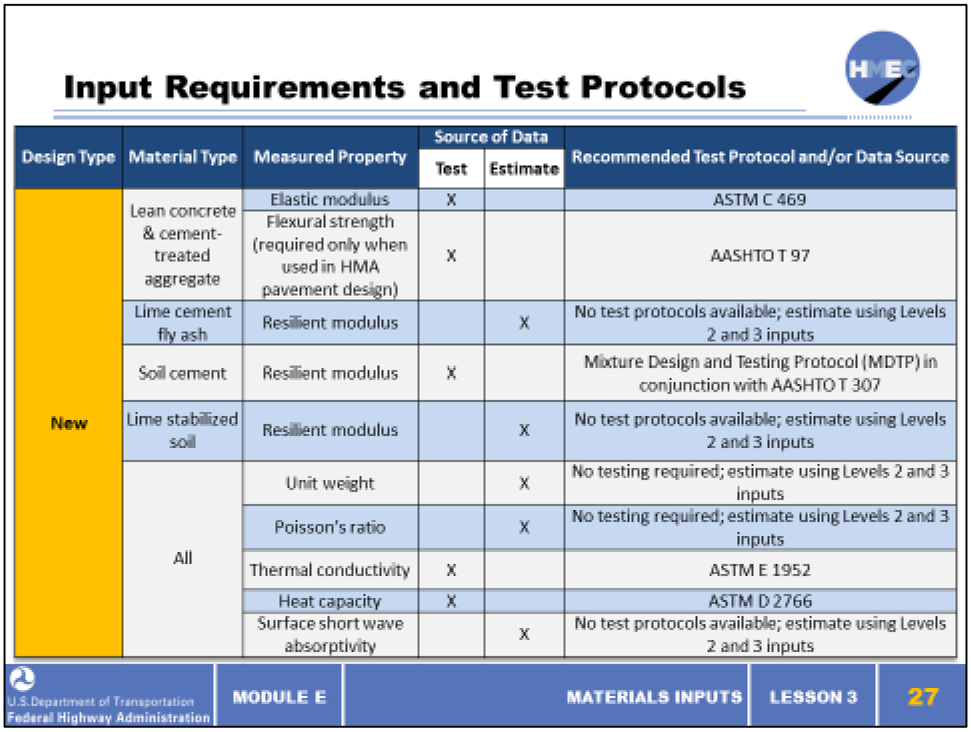
Slide 27



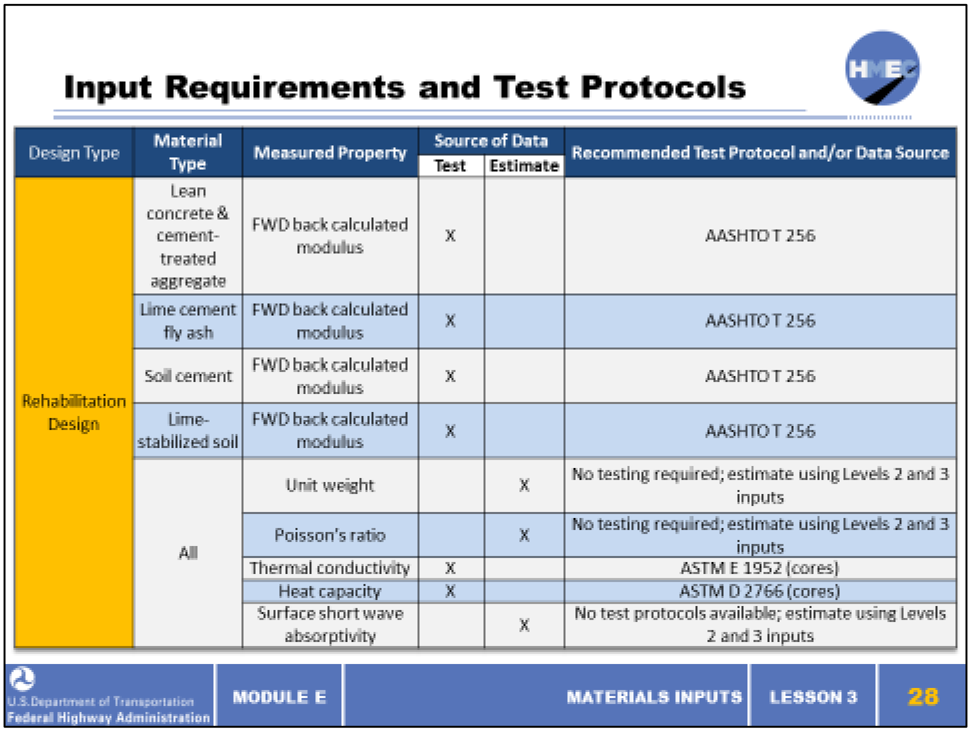
Input Requirements and Test Protocols

Design Type	Material Type	Measured Property	Source of Data: Test	Source of Data: Estimate	Recommended Test Protocol and/or Data Source
New	Lean concrete & cement-treated aggregate	Elastic modulus	X		ASTM C 469
		Flexural strength (required only when used in HMA pavement design)	X		AASHTO T 97
	Lime cement fly ash	Resilient modulus		X	No test protocols available; estimate using Levels 2 and 3 inputs
	Soil cement	Resilient modulus	X		Mixture Design and Testing Protocol (MDTP) in conjunction with AASHTO T 307
	Lime stabilized soil	Resilient modulus		X	No test protocols available; estimate using Levels 2 and 3 inputs
	All	Unit weight		X	No testing required; estimate using Levels 2 and 3 inputs
		Poisson's ratio		X	No testing required; estimate using Levels 2 and 3 inputs
		Thermal conductivity	X		ASTM E 1952
		Heat capacity	X		ASTM D 2766
		Surface short wave absorptivity		X	No test protocols available; estimate using Levels 2 and 3 inputs

U.S. Department of Transportation Federal Highway Administration | MODULE E | MATERIALS INPUTS | LESSON 3 | 27

This table shows that there is more variability in terms of whether the treated base layer properties can be tested in the lab and have an AASHTO standard. No testing is required for Poisson's ratio.

Slide 28



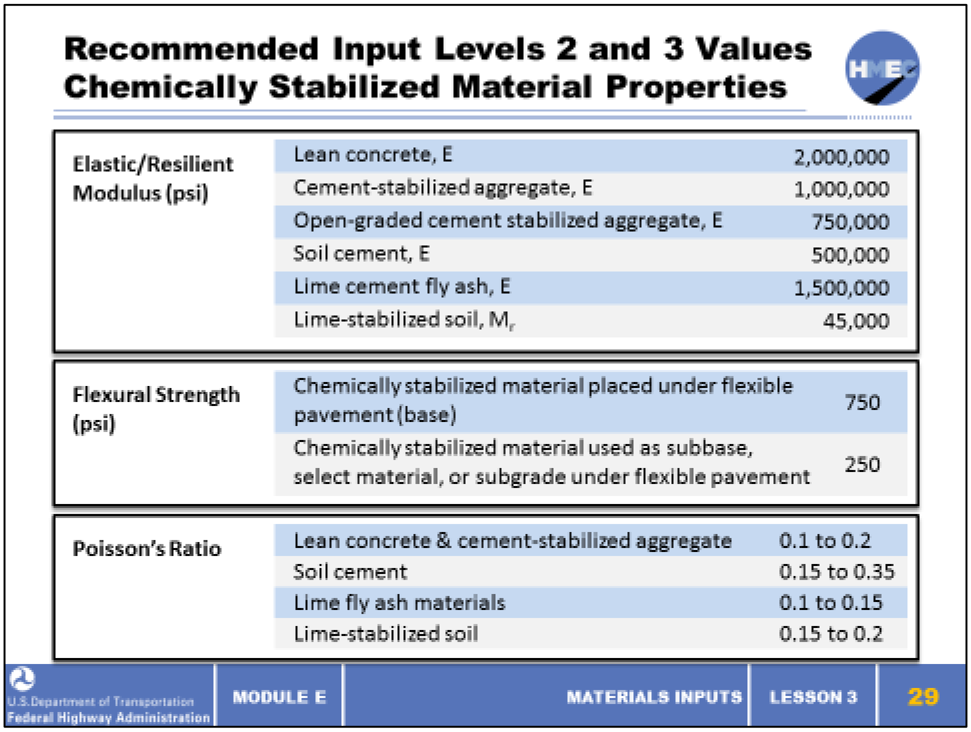
Input Requirements and Test Protocols

Design Type	Material Type	Measured Property	Source of Data		Recommended Test Protocol and/or Data Source
			Test	Estimate	
Rehabilitation Design	Lean concrete & cement-treated aggregate	FWD back calculated modulus	X		AASHTO T 256
	Lime cement fly ash	FWD back calculated modulus	X		AASHTO T 256
	Soil cement	FWD back calculated modulus	X		AASHTO T 256
	Lime-stabilized soil	FWD back calculated modulus	X		AASHTO T 256
	All	Unit weight		X	No testing required; estimate using Levels 2 and 3 inputs
		Poisson's ratio		X	No testing required; estimate using Levels 2 and 3 inputs
		Thermal conductivity	X		ASTM E 1952 (cores)
		Heat capacity	X		ASTM D 2766 (cores)
		Surface short wave absorptivity		X	No test protocols available; estimate using Levels 2 and 3 inputs

U.S. Department of Transportation Federal Highway Administration | MODULE E | MATERIALS INPUTS | LESSON 3 | 28

This table shows that most of the properties come from field testing using the falling weight deflectometer (FWD) to back calculate for the treated base layer modulus and have an AASHTO standard. No testing is required for Poisson's ratio or unit weight.

Slide 29

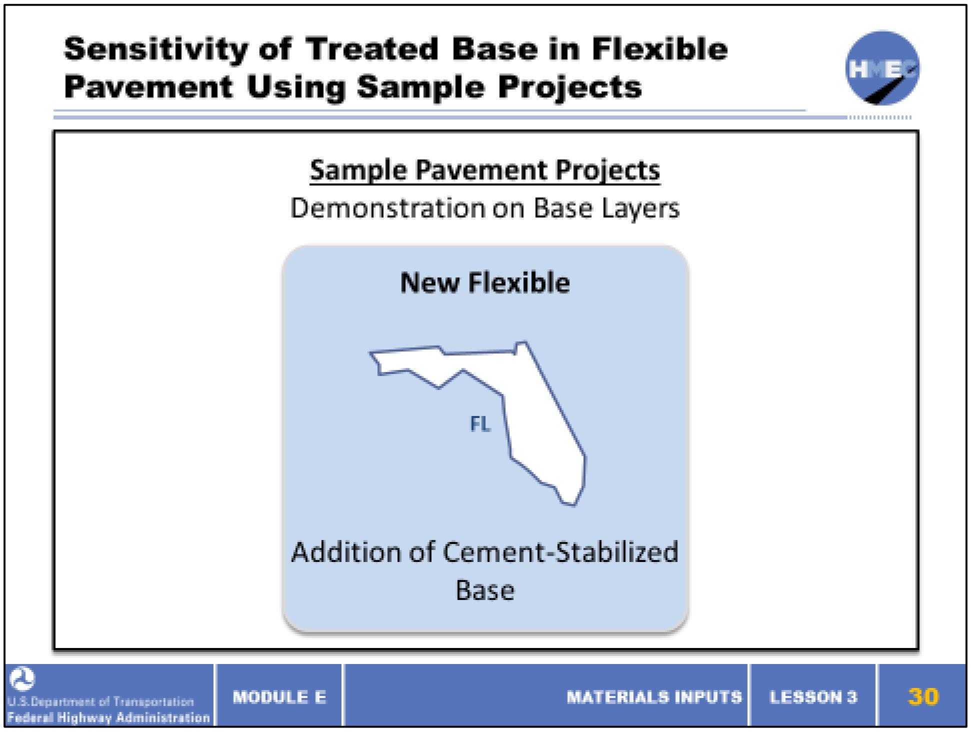


Recommended Input Levels 2 and 3 Values Chemically Stabilized Material Properties

Elastic/Resilient Modulus (psi)	Lean concrete, E	2,000,000
	Cement-stabilized aggregate, E	1,000,000
	Open-graded cement stabilized aggregate, E	750,000
	Soil cement, E	500,000
	Lime cement fly ash, E	1,500,000
	Lime-stabilized soil, M_r	45,000
Flexural Strength (psi)	Chemically stabilized material placed under flexible pavement (base)	750
	Chemically stabilized material used as subbase, select material, or subgrade under flexible pavement	250
Poisson's Ratio	Lean concrete & cement-stabilized aggregate	0.1 to 0.2
	Soil cement	0.15 to 0.35
	Lime fly ash materials	0.1 to 0.15
	Lime-stabilized soil	0.15 to 0.2

This is helpful for a starting point when there is not existing information in a given State to start doing trial designs.

Slide 30



Sensitivity of Treated Base in Flexible Pavement Using Sample Projects

Sample Pavement Projects

Demonstration on Base Layers

New Flexible

FL

Addition of Cement-Stabilized Base

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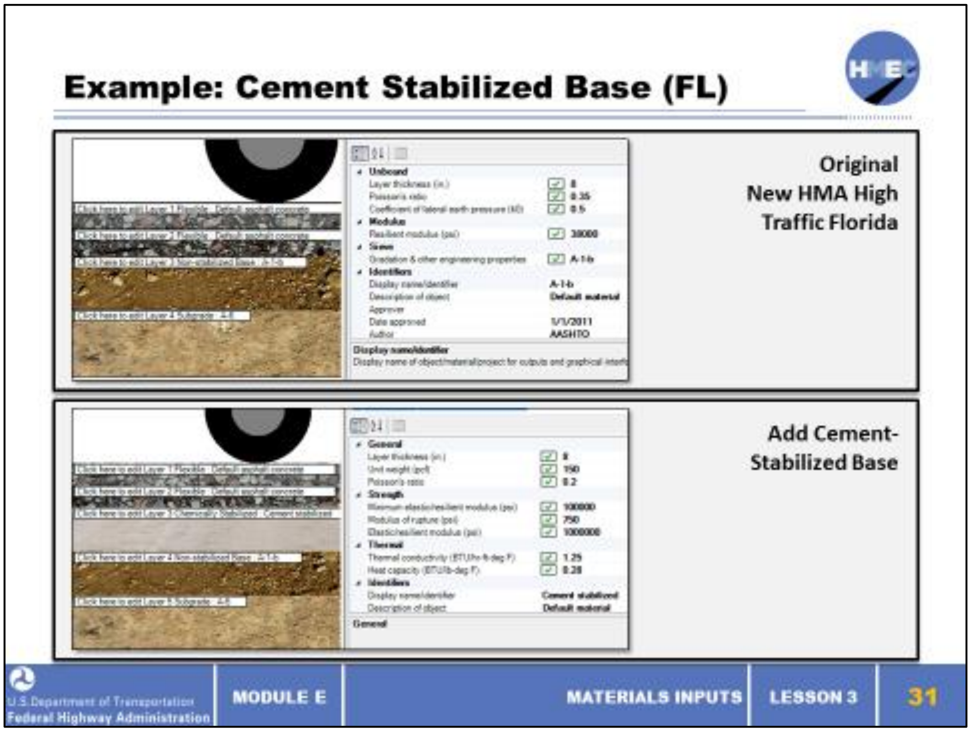
MODULE E
MATERIALS INPUTS
LESSON 3
30

This screen shows how a Florida project will be used to demonstrate the input of treated versus untreated base layers. The results will be covered later in Lesson 4.

Slide 31



Example: Cement Stabilized Base (FL)

Original New HMA High Traffic Florida

Click here to edit Layer 1 Flexible : Default asphalt concrete
Click here to edit Layer 2 Flexible : Default asphalt concrete
Click here to edit Layer 3 Non-stabilized Base : A-1-b
Click here to edit Layer 4 Subgrade : A-6

Unbound	
Layer thickness (in.)	☑ 8
Poisson's ratio	☑ 0.35
Coefficient of lateral earth pressure (k0)	☑ 0.5
Modulus	
Resilient modulus (psi)	☑ 38000
Sieve	
Gradation & other engineering properties	☑ A-1-b
Identifiers	
Display name/identifier	A-1-b
Description of object	**Default material**
Approver	
Date approved	1/1/2011
Author	AASHTO

Display name/identifier
Display name of object/material/project for outputs and graphical interf

Add Cement-Stabilized Base

Click here to edit Layer 1 Flexible : Default asphalt concrete
Click here to edit Layer 2 Flexible : Default asphalt concrete
Click here to edit Layer 3 Chemically Stabilized : Cement stabilized
Click here to edit Layer 4 Non-stabilized Base : A-1-b
Click here to edit Layer 5 Subgrade : A-6

General	
Layer thickness (in.)	☑ 8
Unit weight (pcf)	☑ 150
Poisson's ratio	☑ 0.2
Strength	
Minimum elastic/resilient modulus (psi)	☑ 100000
Modulus of rupture (psi)	☑ 750
Elastic/resilient modulus (psi)	☑ 1000000
Thermal	
Thermal conductivity (BTU/hr-ft-deg F)	☑ 1.25
Heat capacity (BTU/lb-deg F)	☑ 0.28
Identifiers	
Display name/identifier	**Cement stabilized**
Description of object	**Default material**

General

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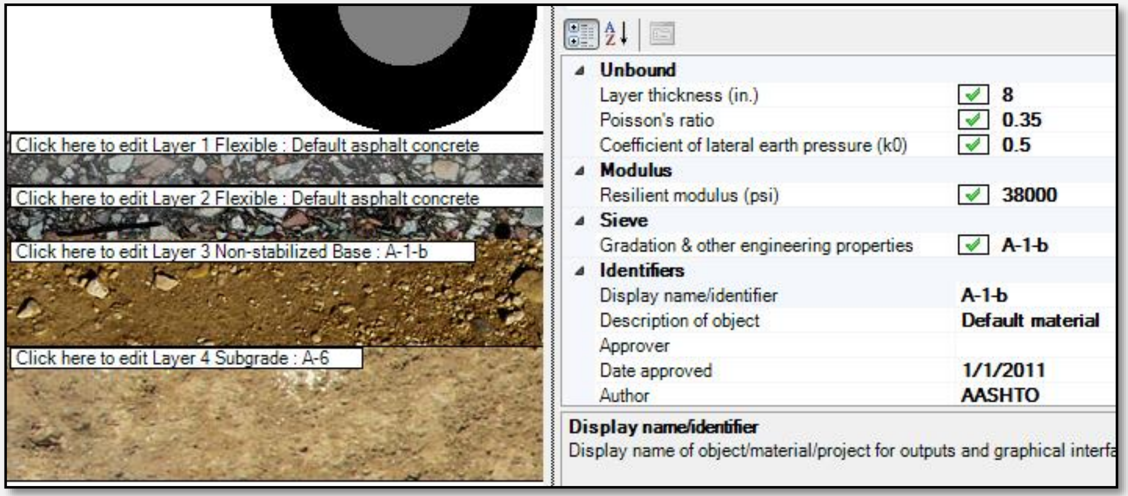
Federal Highway Administration
MODULE E
MATERIALS INPUTS
LESSON 3
31

Original New HMA High Traffic Florida

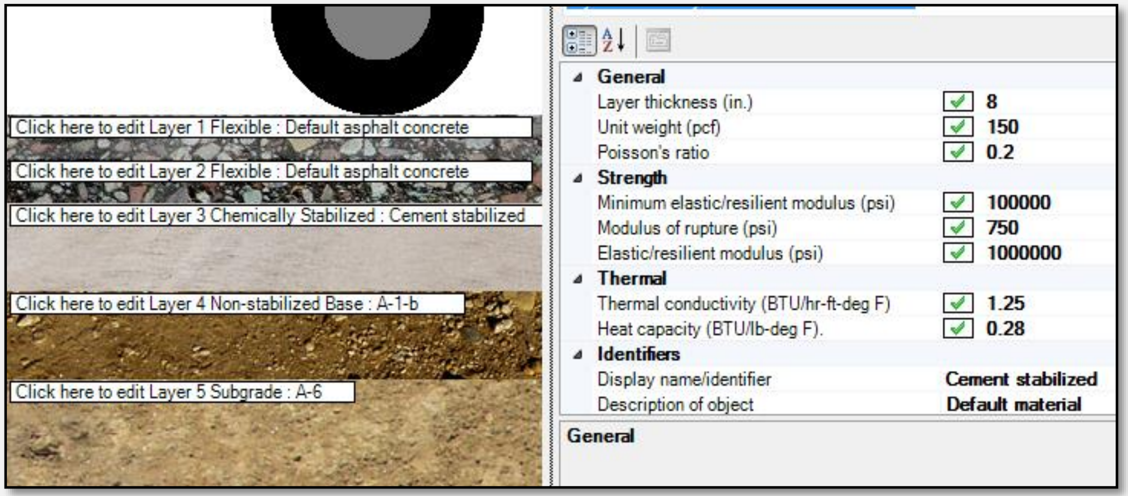


Click here to edit Layer 1 Flexible : Default asphalt concrete
Click here to edit Layer 2 Flexible : Default asphalt concrete
Click here to edit Layer 3 Non-stabilized Base : A-1-b
Click here to edit Layer 4 Subgrade : A-6

Unbound	
Layer thickness (in.)	☑ 8
Poisson's ratio	☑ 0.35
Coefficient of lateral earth pressure (k0)	☑ 0.5
Modulus	
Resilient modulus (psi)	☑ 38000
Sieve	
Gradation & other engineering properties	☑ A-1-b
Identifiers	
Display name/identifier	A-1-b
Description of object	Default material
Approver	
Date approved	1/1/2011
Author	AASHTO

Display name/identifier
Display name of object/material/project for outputs and graphical interfa

Add Cement-Stabilized Base



Click here to edit Layer 1 Flexible : Default asphalt concrete
Click here to edit Layer 2 Flexible : Default asphalt concrete
Click here to edit Layer 3 Chemically Stabilized : Cement stabilized
Click here to edit Layer 4 Non-stabilized Base : A-1-b
Click here to edit Layer 5 Subgrade : A-6

General	
Layer thickness (in.)	☑ 8
Unit weight (pcf)	☑ 150
Poisson's ratio	☑ 0.2
Strength	
Minimum elastic/resilient modulus (psi)	☑ 100000
Modulus of rupture (psi)	☑ 750
Elastic/resilient modulus (psi)	☑ 1000000
Thermal	
Thermal conductivity (BTU/hr-ft-deg F)	☑ 1.25
Heat capacity (BTU/lb-deg F).	☑ 0.28
Identifiers	
Display name/identifier	Cement stabilized
Description of object	Default material

General

It should be noted that an asphalt-treated base is not an option in Pavement ME Design software. A minimum of two unbound layers is necessary to model moisture and drainage in the software. Results will be shown later.

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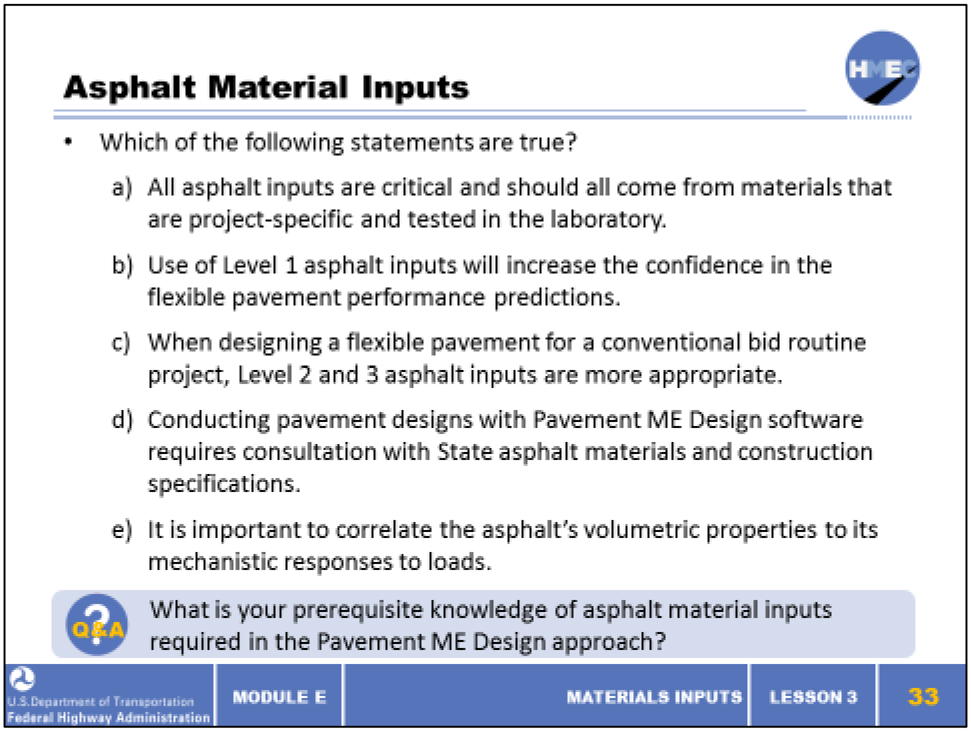
Slide 32

Asphalt Material Inputs

Slide 33

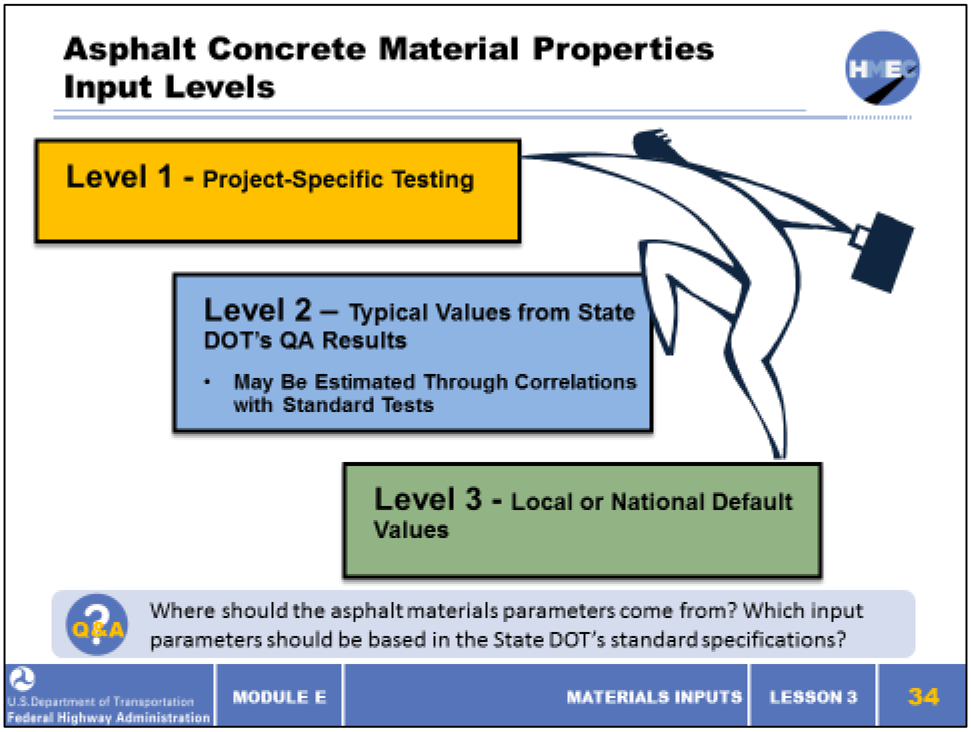


Asphalt Material Inputs

- Which of the following statements are true?
  - a) All asphalt inputs are critical and should all come from materials that are project-specific and tested in the laboratory.
  - b) Use of Level 1 asphalt inputs will increase the confidence in the flexible pavement performance predictions.
  - c) When designing a flexible pavement for a conventional bid routine project, Level 2 and 3 asphalt inputs are more appropriate.
  - d) Conducting pavement designs with Pavement ME Design software requires consultation with State asphalt materials and construction specifications.
  - e) It is important to correlate the asphalt's volumetric properties to its mechanistic responses to loads.

Q&A What is your prerequisite knowledge of asphalt material inputs required in the Pavement ME Design approach?

Slide 34



Asphalt Concrete Material Properties Input Levels

Level 1 - Project-Specific Testing

Level 2 – Typical Values from State DOT's QA Results

- May Be Estimated Through Correlations with Standard Tests

Level 3 - Local or National Default Values

Where should the asphalt materials parameters come from? Which input parameters should be based in the State DOT's standard specifications?

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MATERIALS INPUTS
LESSON 3
34

The general approach for determining design inputs for materials in the Pavement ME Design process for characterizing the paving materials and foundation should be consistent with the relative importance, size, and cost of the design project.

Input Level 1 involves comprehensive laboratory tests. In contrast, Level 3 requires the designer to estimate the most appropriate design input value of the material property based on experience with little or no testing.

Level 2 inputs come from typical values from the State DOT's QA programs but should not be based on the minimum requirements in the specifications. It depends what the DOT specification can achieve and should represent typical values (from QA test samples) found for the materials in a particular State. They can also estimate through correlations with other material properties that are commonly measured in the laboratory or field.

Regardless of the selected input level, the program runs the same analysis.

Level 2 and 3 inputs come from routine construction projects in which the contractors are not known during the design process. The input parameters should be based strongly on the State

DOT’s standard specifications. Level 1 can be used for design-build projects in which the contractor and possibly the material sources may be known during the design process.

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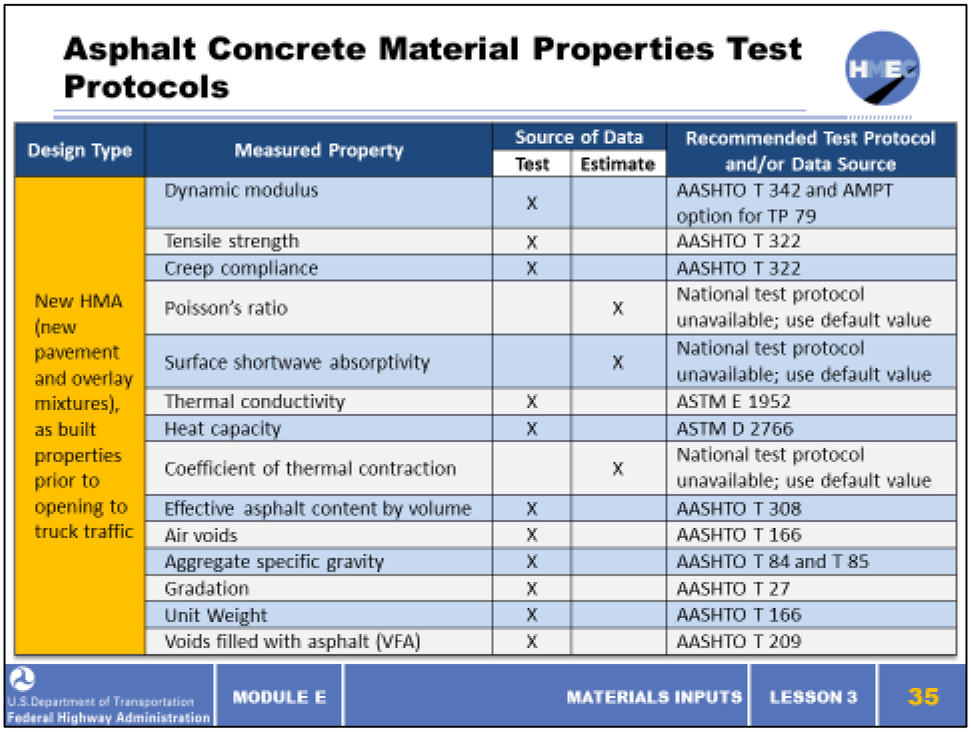
Slide 35



Asphalt Concrete Material Properties Test Protocols

Design Type	Measured Property	Source of Data		Recommended Test Protocol and/or Data Source
		Test	Estimate	
New HMA (new pavement and overlay mixtures), as built properties prior to opening to truck traffic	Dynamic modulus	X		AASHTO T 342 and AMPT option for TP 79
	Tensile strength	X		AASHTO T 322
	Creep compliance	X		AASHTO T 322
	Poisson's ratio		X	National test protocol unavailable; use default value
	Surface shortwave absorptivity		X	National test protocol unavailable; use default value
	Thermal conductivity	X		ASTM E 1952
	Heat capacity	X		ASTM D 2766
	Coefficient of thermal contraction		X	National test protocol unavailable; use default value
	Effective asphalt content by volume	X		AASHTO T 308
	Air voids	X		AASHTO T 166
	Aggregate specific gravity	X		AASHTO T 84 and T 85
	Gradation	X		AASHTO T 27
	Unit Weight	X		AASHTO T 166
	Voids filled with asphalt (VFA)	X		AASHTO T 209

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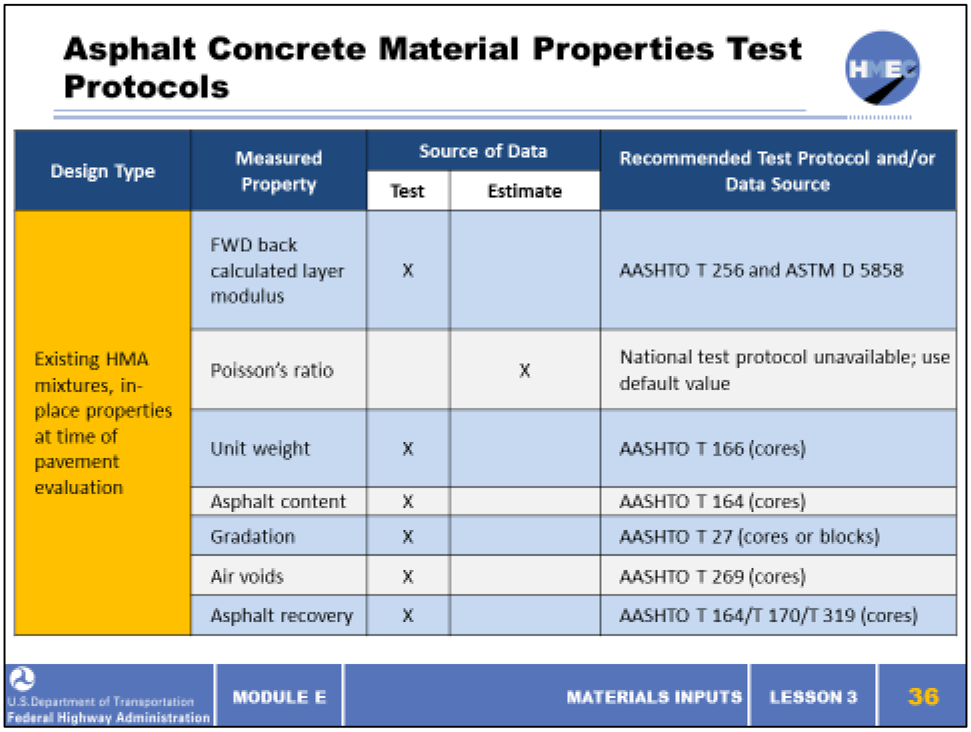
Test methods are available for all of the asphalt material properties except three: Poisson's ratio, surface shortwave absorptivity, and coefficient of thermal contraction.

Slide 36



Asphalt Concrete Material Properties Test Protocols

Design Type	Measured Property	Source of Data		Recommended Test Protocol and/or Data Source
		Test	Estimate	
Existing HMA mixtures, in-place properties at time of pavement evaluation	FWD back calculated layer modulus	X		AASHTO T 256 and ASTM D 5858
	Poisson's ratio		X	National test protocol unavailable; use default value
	Unit weight	X		AASHTO T 166 (cores)
	Asphalt content	X		AASHTO T 164 (cores)
	Gradation	X		AASHTO T 27 (cores or blocks)
	Air voids	X		AASHTO T 269 (cores)
	Asphalt recovery	X		AASHTO T 164/T 170/T 319 (cores)

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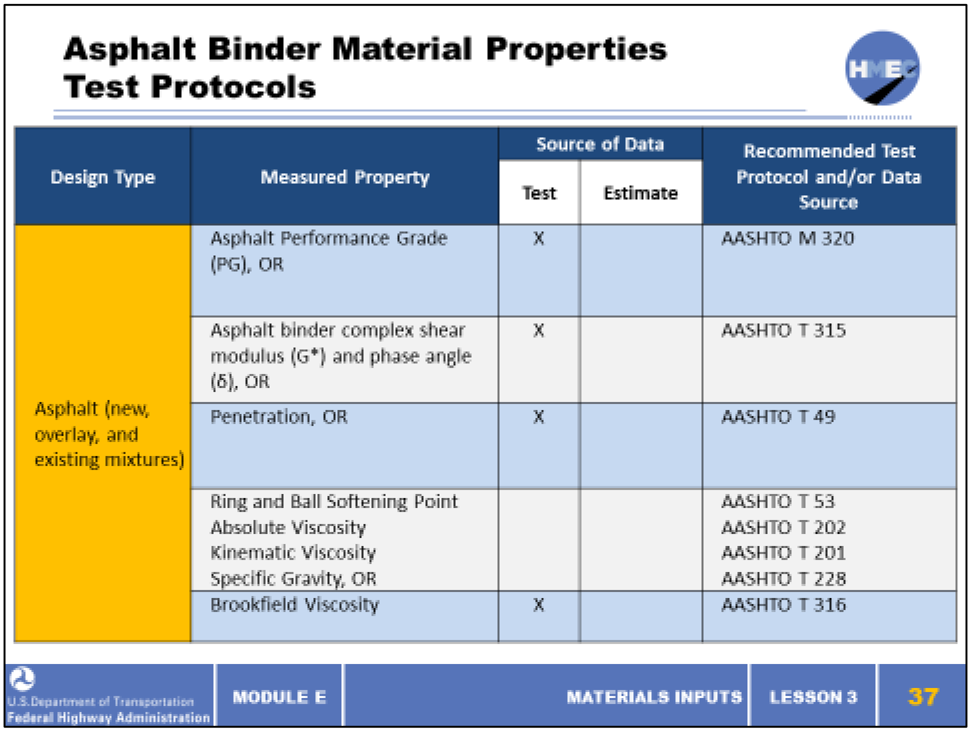
Field or lab test methods are available for all of the asphalt material properties except one: Poisson's ratio. Testing is done either by using the falling weight deflectometer or by taking cores and bringing them back to the lab for testing.

Slide 37



Asphalt Binder Material Properties Test Protocols

Design Type	Measured Property	Source of Data		Recommended Test Protocol and/or Data Source
		Test	Estimate	
Asphalt (new, overlay, and existing mixtures)	Asphalt Performance Grade (PG), OR	X		AASHTO M 320
	Asphalt binder complex shear modulus (G*) and phase angle (δ), OR	X		AASHTO T 315
	Penetration, OR	X		AASHTO T 49
	Ring and Ball Softening Point Absolute Viscosity Kinematic Viscosity Specific Gravity, OR			AASHTO T 53 AASHTO T 202 AASHTO T 201 AASHTO T 228
	Brookfield Viscosity	X		AASHTO T 316

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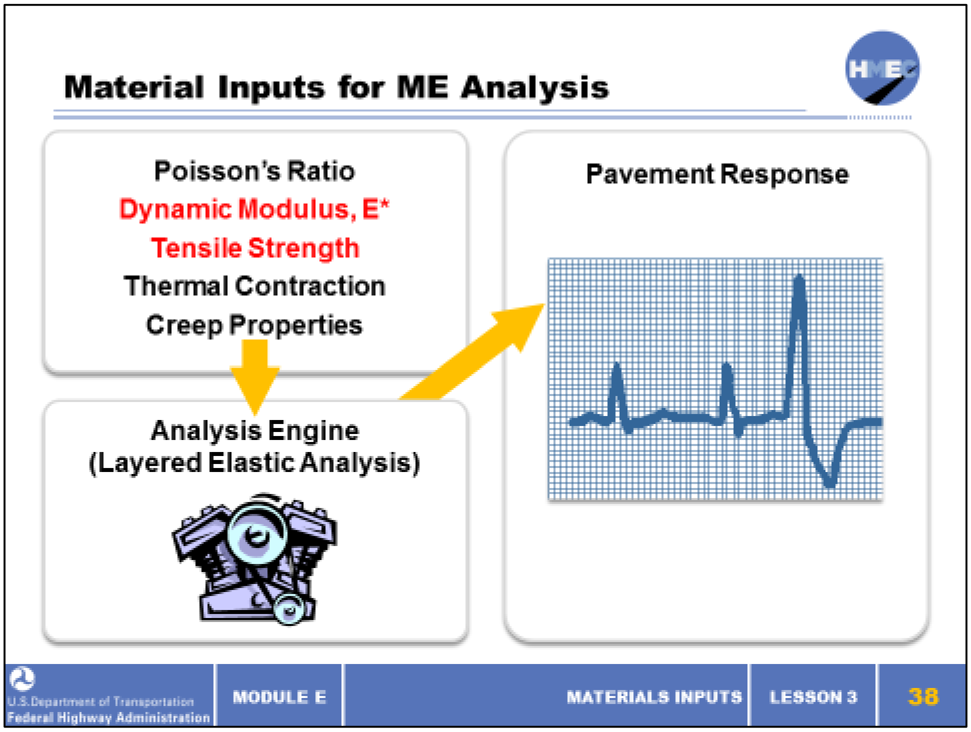
Lab test methods are available for all of the asphalt binder properties. Testing can be done for existing asphalt layers by taking cores and bringing them back to the lab for binder extraction and testing.

Slide 38



Material Inputs for ME Analysis

Poisson's Ratio
Dynamic Modulus, E*
Tensile Strength
Thermal Contraction
Creep Properties

Analysis Engine
(Layered Elastic Analysis)

Pavement Response

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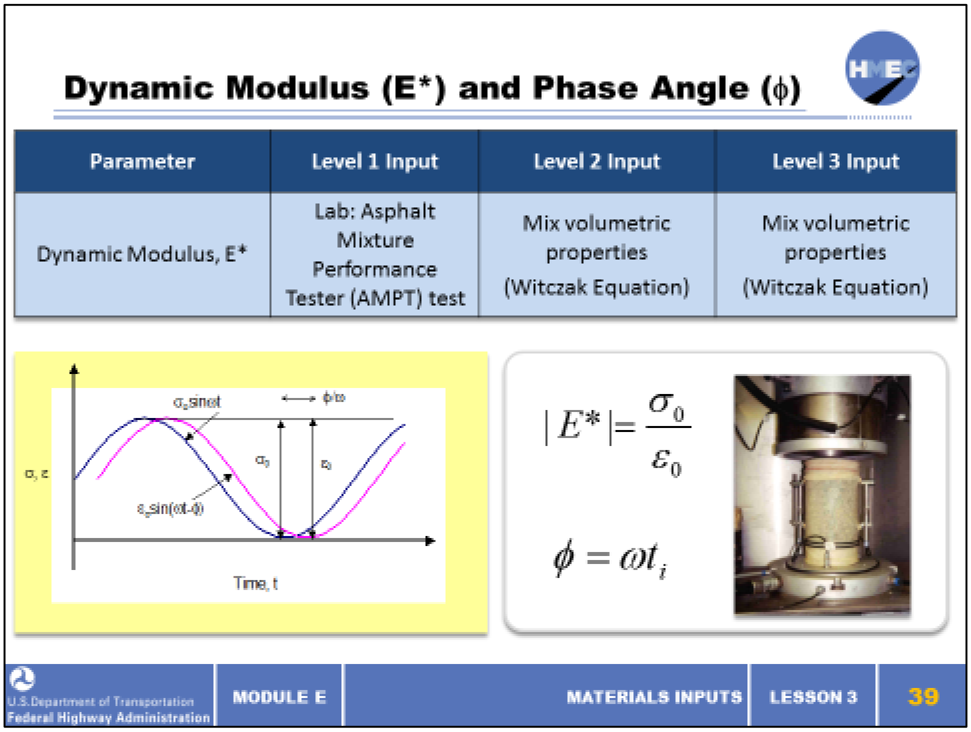
MODULE E
MATERIALS INPUTS
LESSON 3
38

Dynamic modulus is a key input to calculating pavement response.

Slide 39



Dynamic Modulus (E*) and Phase Angle (ϕ)

Parameter	Level 1 Input	Level 2 Input	Level 3 Input
Dynamic Modulus, E*	Lab: Asphalt Mixture Performance Tester (AMPT) test	Mix volumetric properties (Witczak Equation)	Mix volumetric properties (Witczak Equation)

$\sigma_0 \sin\omega t$
ϕ/ω
σ, ε
σ_0
ε_0
$\varepsilon_0 \sin(\omega t-\phi)$
Time, t

$$|E^*| = \frac{\sigma_0}{\varepsilon_0}$$

$$\phi = \omega t_i$$

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MODULE E MATERIALS INPUTS LESSON 3 39

Dynamic modulus and phase angle represent the stiffness of asphalt mix in response to a dynamic loading from standing traffic loading to highway speeds and at a range of temperatures experienced in the field. This material property addresses both fatigue cracking and rutting in flexible pavements.

All asphaltic materials are highly sensitive to temperature and the rate of loading. Because asphalt is a viscoelastic-plastic material, the modulus of an asphalt mix may approach that of an unbound granular material at high temperatures and long loading rates (i.e., slow speed of passing vehicles). In contrast, at cold temperatures and very short load rates, the material will tend to behave in a pure elastic mode and have modulus values that approach that of PCC material. In the MEPDG, the methodology for asphaltic mixtures will take into account the range of temperatures expected in the design period. The use of an asphalt master curve is based on time-temperature superposition principles.

Note that the higher the level of input, the more aggressive the testing program needs to be as described earlier.

The approach for Level 1 inputs is the development of a master curve and shift factors for each asphalt mixture used by an agency. Master curves involve time-temperature superposition. First, a standard reference temperature (usually 70 °F) is selected. Then, dynamic modulus tests at various temperatures are shifted with respect to time to form the master curve describing the time dependency of the material. The amount of shifting at each temperature required to form the master curve describes its temperature dependency.

For the Level 2 and Level 3 analyses, the master curves are developed directly from the dynamic modulus predictive equation. The Witczak's predictive equation was originally developed through the NCHPR Project 1-47A. The original model was based on a non-linear regression analysis and incorporated mixture volumetrics and aggregate gradation to predict the dynamic modulus of mixtures. This model was later reformulated to include binder stiffness data (NCHRP 1-40D). The dynamic modulus predictive equation is one of the most comprehensive mixture stiffness models available to the profession today. This model can predict the dynamic modulus of asphalt mixtures over a range of temperatures, rates of loading, and aging conditions from information that is readily available from material specifications or volumetric design of the mixture. Major inputs are bitumen viscosity, loading rate, mixture air void content, mixture effective bitumen content, and mixture aggregate gradation.

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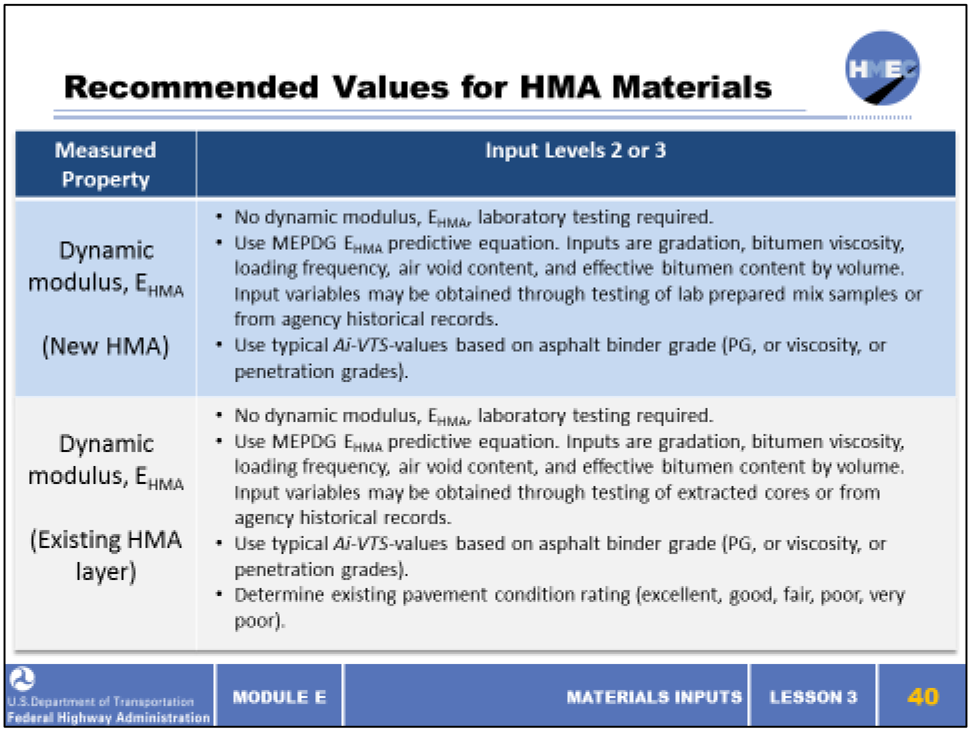
Slide 40



Recommended Values for HMA Materials

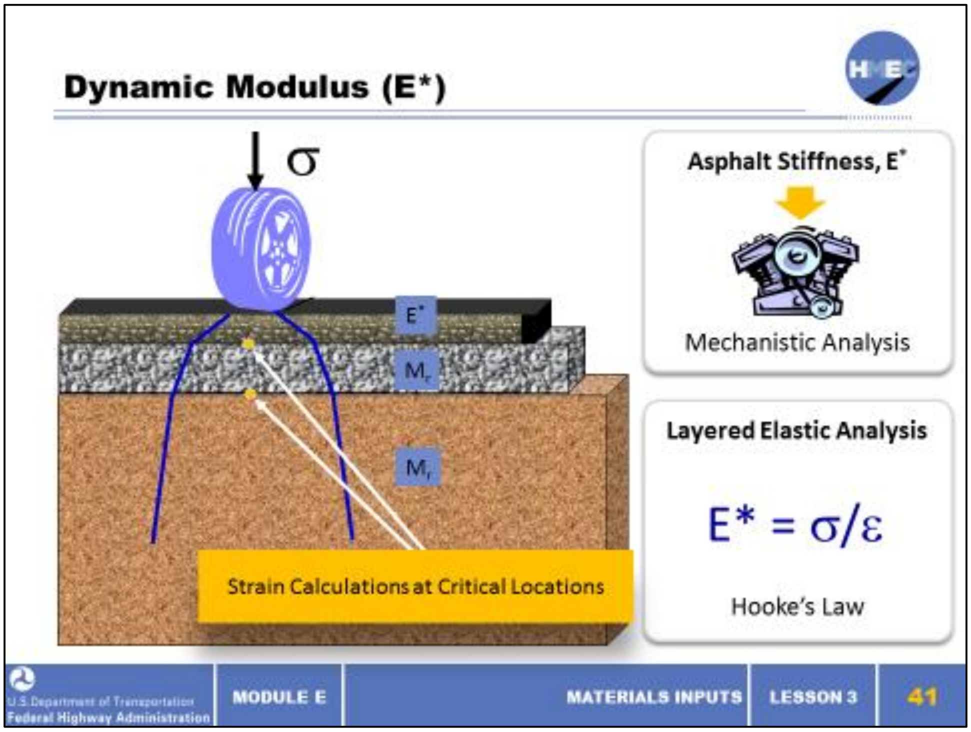
Measured Property	Input Levels 2 or 3
Dynamic modulus, E_{HMA} (New HMA)	• No dynamic modulus, E_{HMA}, laboratory testing required. • Use MEPDG E_{HMA} predictive equation. Inputs are gradation, bitumen viscosity, loading frequency, air void content, and effective bitumen content by volume. Input variables may be obtained through testing of lab prepared mix samples or from agency historical records. • Use typical *Ai-VTS*-values based on asphalt binder grade (PG, or viscosity, or penetration grades).
Dynamic modulus, E_{HMA} (Existing HMA layer)	• No dynamic modulus, E_{HMA}, laboratory testing required. • Use MEPDG E_{HMA} predictive equation. Inputs are gradation, bitumen viscosity, loading frequency, air void content, and effective bitumen content by volume. Input variables may be obtained through testing of extracted cores or from agency historical records. • Use typical *Ai-VTS*-values based on asphalt binder grade (PG, or viscosity, or penetration grades). • Determine existing pavement condition rating (excellent, good, fair, poor, very poor).

U.S. Department of Transportation Federal Highway Administration | MODULE E | MATERIALS INPUTS | LESSON 3 | 40

When an agency has limited or no testing capabilities, it is recommended that Level 2 and 3 inputs are used, and these are provided as recommended values from the MEPDG Manual of Practice.

For Level 2 and 3, the dynamic modulus could also come from representative samples of a material that meets the State DOT spec and was tested in the laboratory. The representative samples are a reflection of the State DOT's specs (as taken from testing materials from the as-built projects).

Slide 41



Dynamic Modulus (E*)

Strain Calculations at Critical Locations

Asphalt Stiffness, E*

Mechanistic Analysis

Layered Elastic Analysis

$$E^* = \sigma/\varepsilon$$

Hooke's Law

U.S. Department of Transportation Federal Highway Administration | MODULE E | MATERIALS INPUTS | LESSON 3 | 41

With those two variables known (stress and dynamic modulus of the asphalt layer), we can solve for the strain at critical locations in the pavement structure using the layered elastic analysis engine built into the software.

LEA is founded on Hooke's Law.

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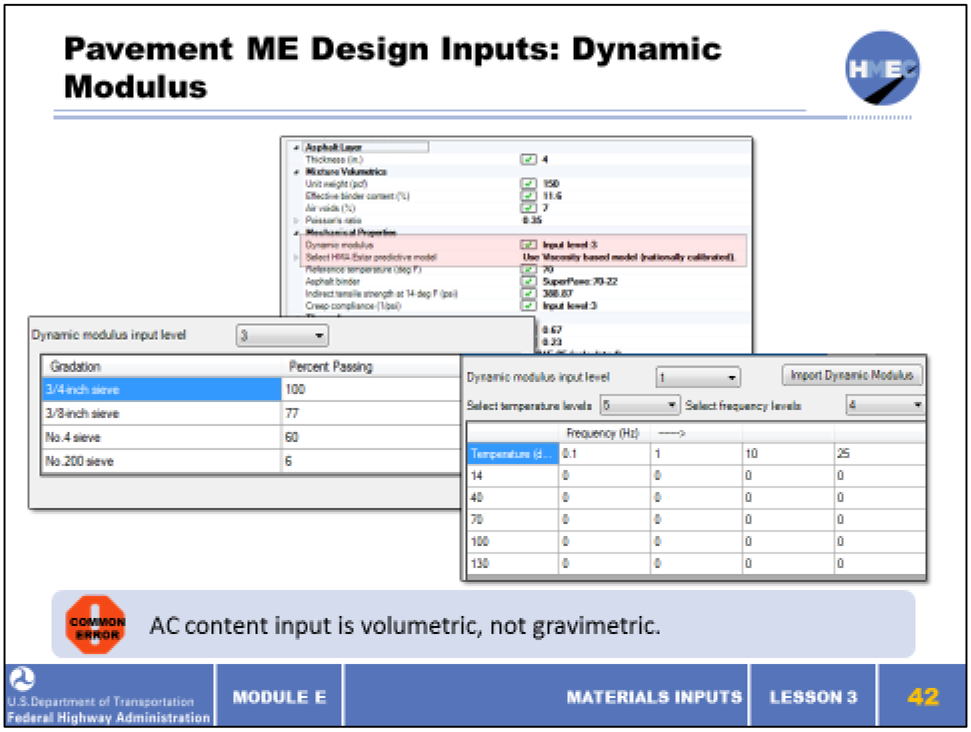
Slide 42



Pavement ME Design Inputs: Dynamic Modulus

Asphalt Layer

Thickness (in.)	☑ 4
Mixture Volumetrics	
Unit weight (pcf)	☑ 150
Effective binder content (%)	☑ 11.6
Air voids (%)	☑ 7
Poisson's ratio	0.35
Mechanical Properties	
Dynamic modulus	☑ Input level 3
Select HMA Estar predictive model	Use Viscosity based model (nationally calibrated).
Reference temperature (deg F)	☑ 70
Asphalt binder	☑ SuperPave: 70-22
Indirect tensile strength at 14 deg F (psi)	☑ 388.87
Creep compliance (1/psi)	☑ Input level 3
	0.67
	0.23

Dynamic modulus input level 3

Gradation	Percent Passing
3/4-inch sieve	100
3/8-inch sieve	77
No.4 sieve	60
No.200 sieve	6

Dynamic modulus input level 1

Import Dynamic Modulus

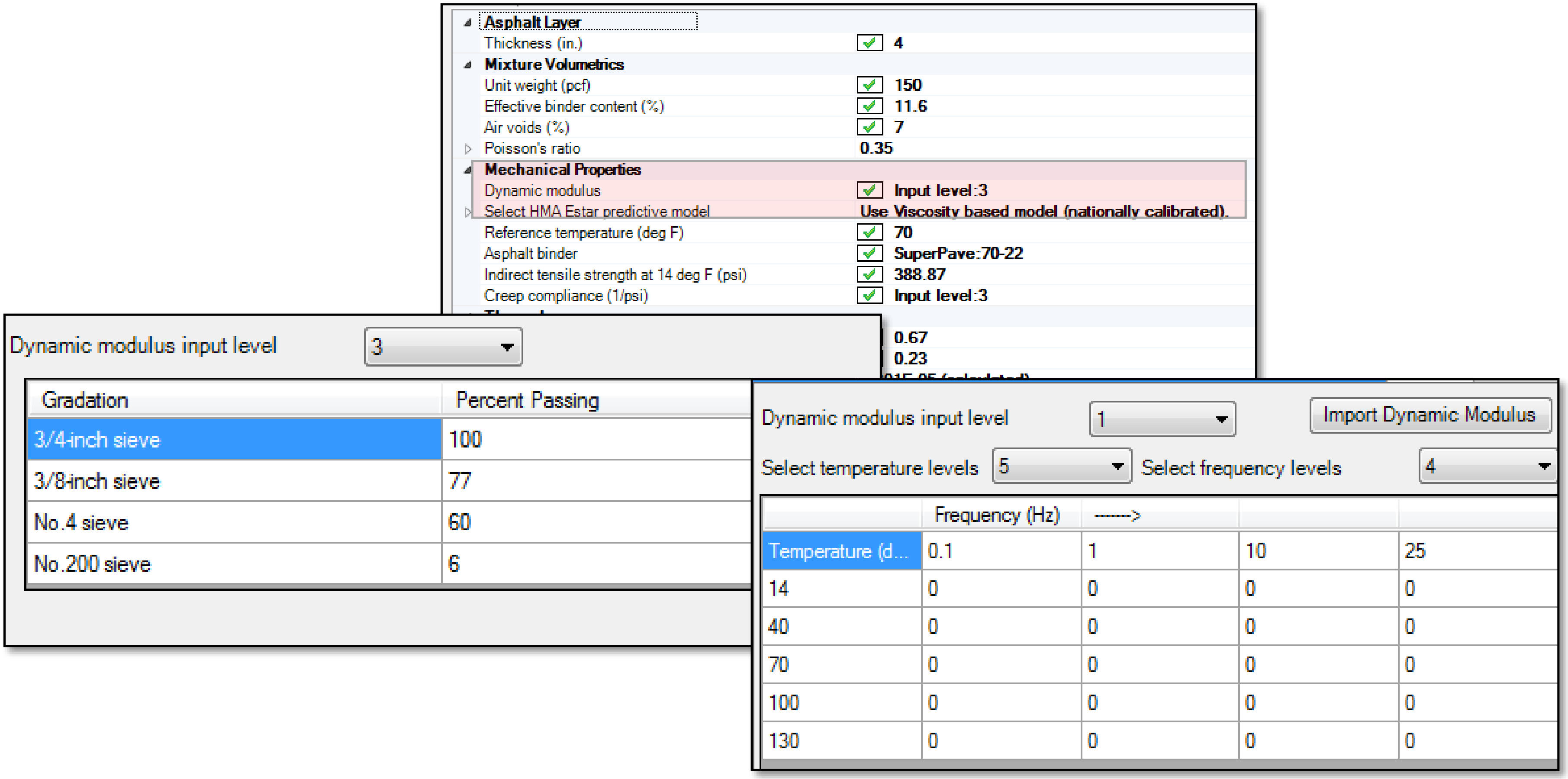
Select temperature levels 5

Select frequency levels 4

	Frequency (Hz)	---->		
Temperature (d...	0.1	1	10	25
14	0	0	0	0
40	0	0	0	0
70	0	0	0	0
100	0	0	0	0
130	0	0	0	0

COMMON ERROR

AC content input is volumetric, not gravimetric.



Asphalt Layer	
Thickness (in.)	☑ **4**
Mixture Volumetrics	
Unit weight (pcf)	☑ **150**
Effective binder content (%)	☑ **11.6**
Air voids (%)	☑ **7**
Poisson's ratio	**0.35**
Mechanical Properties	
Dynamic modulus	☑ **Input level:3**
Select HMA Estar predictive model	**Use Viscosity based model (nationally calibrated).**
Reference temperature (deg F)	☑ **70**
Asphalt binder	☑ **SuperPave:70-22**
Indirect tensile strength at 14 deg F (psi)	☑ **388.87**
Creep compliance (1/psi)	☑ **Input level:3**
	0.67
	0.23

Dynamic modulus input level: 3

Gradation	Percent Passing
3/4-inch sieve	100
3/8-inch sieve	77
No.4 sieve	60
No.200 sieve	6

Dynamic modulus input level: 1

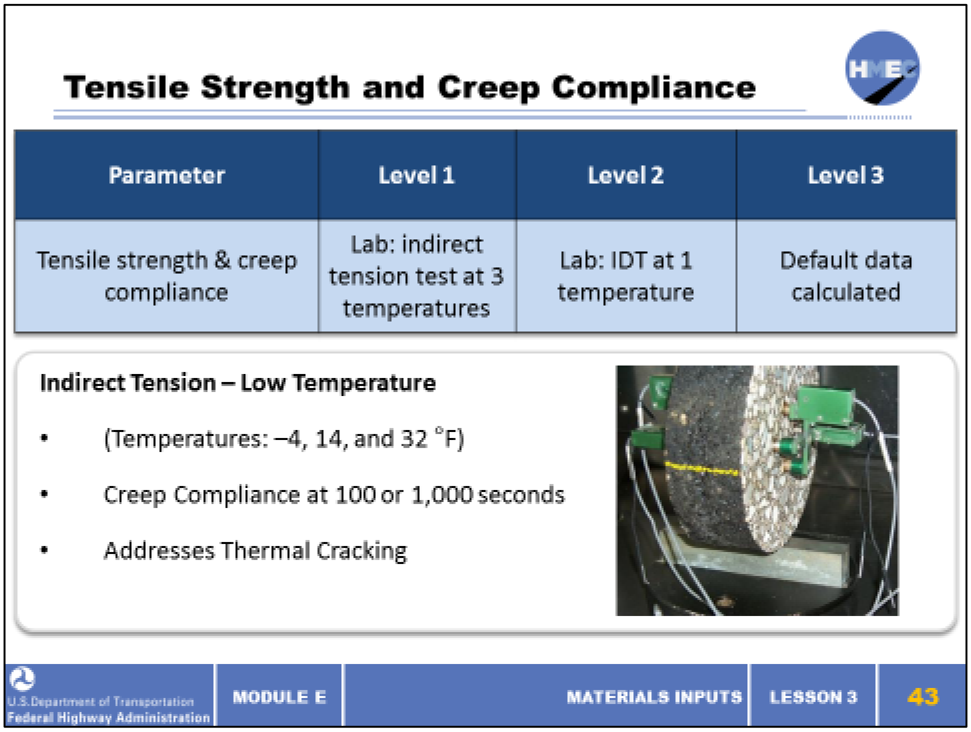
Select temperature levels: 5

Select frequency levels: 4

	Frequency (Hz)	------->		
Temperature (d...	0.1	1	10	25
14	0	0	0	0
40	0	0	0	0
70	0	0	0	0
100	0	0	0	0
130	0	0	0	0

Same information for Level 2 and 3 inputs for dynamic modulus.

Slide 43



Tensile Strength and Creep Compliance

Parameter	Level 1	Level 2	Level 3
Tensile strength & creep compliance	Lab: indirect tension test at 3 temperatures	Lab: IDT at 1 temperature	Default data calculated

Indirect Tension – Low Temperature

- (Temperatures: –4, 14, and 32 °F)
- Creep Compliance at 100 or 1,000 seconds
- Addresses Thermal Cracking

U.S. Department of Transportation
Federal Highway Administration
MODULE E
MATERIALS INPUTS
LESSON 3
43

The thermal cracking indirect tension test (IDT) will test an asphalt specimen to determine at what temperature and load it will fail. This test is directly used in the thermal cracking predictions.

Correlations between binder properties are used as an indirect Level 2 characterization of the materials.

The design guide software computes the coefficient of thermal contraction, internally using the HMAC volumetric properties such as voids in the mineral aggregate (VMA) and the thermal contraction coefficient for the aggregates.

Represents tensile strength of asphalt and low-temperature mix behavior and details of the testing include:

- Tensile strength at 14 °F;
- Creep compliance curves at –4, 14, and 32 °F; and
- Coefficient of thermal contraction.

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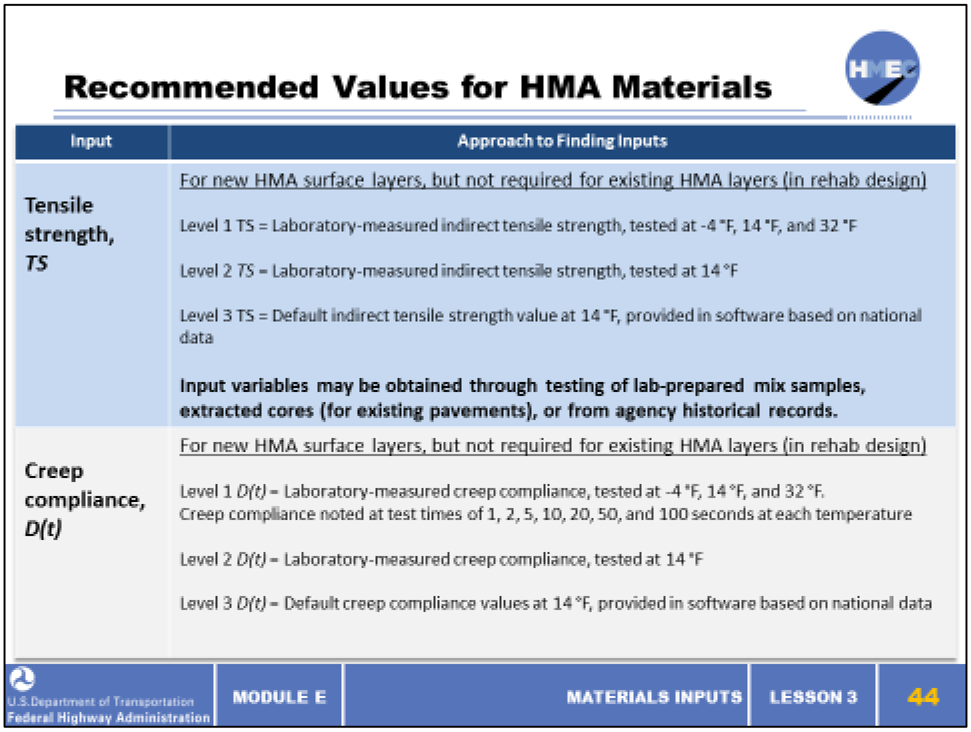
Slide 44



Recommended Values for HMA Materials

Input	Approach to Finding Inputs
Tensile strength, *TS*	For new HMA surface layers, but not required for existing HMA layers (in rehab design) Level 1 TS = Laboratory-measured indirect tensile strength, tested at -4 °F, 14 °F, and 32 °F Level 2 *TS* = Laboratory-measured indirect tensile strength, tested at 14 °F Level 3 TS = Default indirect tensile strength value at 14 °F, provided in software based on national data **Input variables may be obtained through testing of lab-prepared mix samples, extracted cores (for existing pavements), or from agency historical records.**
Creep compliance, *D(t)*	For new HMA surface layers, but not required for existing HMA layers (in rehab design) Level 1 *D(t)* = Laboratory-measured creep compliance, tested at -4 °F, 14 °F, and 32 °F. Creep compliance noted at test times of 1, 2, 5, 10, 20, 50, and 100 seconds at each temperature Level 2 *D(t)* = Laboratory-measured creep compliance, tested at 14 °F Level 3 *D(t)* = Default creep compliance values at 14 °F, provided in software based on national data

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MODULE E MATERIALS INPUTS LESSON 3 44

When an agency has limited or no testing capabilities, it is recommended that Level 2 and 3 inputs are used and these are provided as recommended values from the MEPDG Manual of Practice.

The MEPDG Manual of Practice provides the regression equations provided, and historical mixture data can be used in the equations or an agency can develop a materials catalog based on typical mixture data gathered over time.

Tensile strength: You need to measure the following parameters to get the tensile strength—as-constructed HMA air voids, as-constructed voids filled with asphalt, asphalt penetration at 77 °F, and asphalt viscosity temperature susceptibility (VTS) intercept.

Equation: TS (psi) = 7416.712-114.016*Va-0.304*Va2-122.592*VFA+0.704*VFA2 +405.71*Log10 (Pen77)-2039.296*log10 (A)

Creep compliance: You need to define the following parameters to get the creep compliance of asphalt—time in months of expected age of the HMA, as-constructed HMA air voids, as-constructed voids filled with asphalt, asphalt penetration at 77 °F, and the temperature at which creep compliance is measured.

Equation: D (t) = D1*tm
Log(D1) = -8.524+0.01306*T+0.7957*log10(Va) +2.0103*log10(VFA)-1.923*log10(A)
m = 1.1628-0.00185*T-0.04596*Va-0.00247*Pen77+0.001683*T*(Pen77)^0.4605

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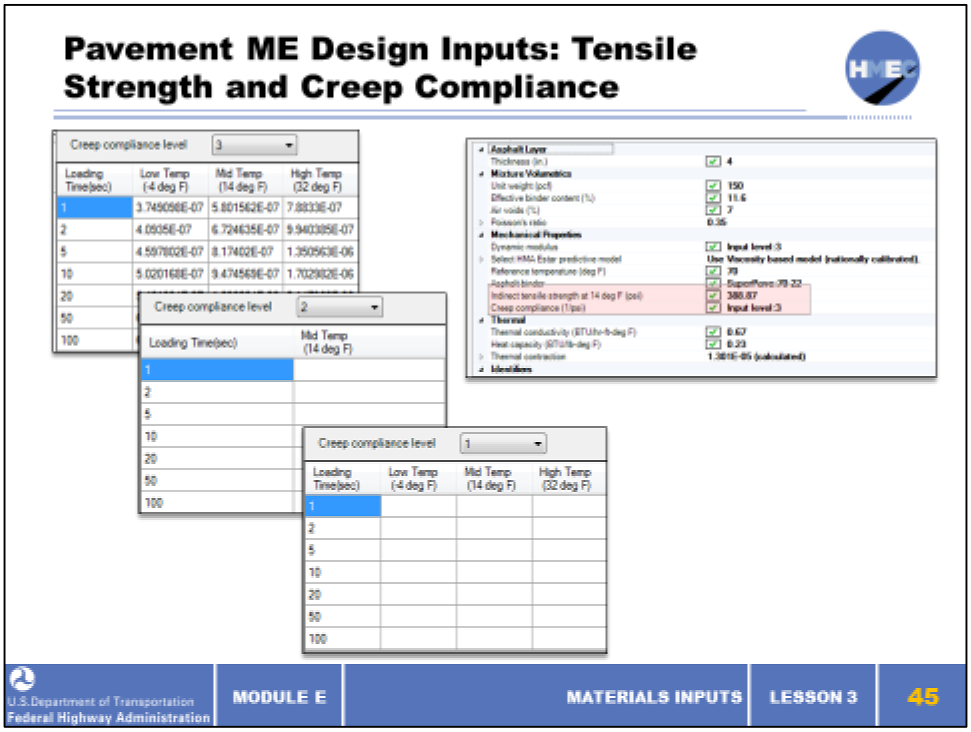
Slide 45



Pavement ME Design Inputs: Tensile Strength and Creep Compliance

Creep compliance level: 3

Loading Time(sec)	Low Temp (-4 deg F)	Mid Temp (14 deg F)	High Temp (32 deg F)
1	3.749098E-07	5.801562E-07	7.8833E-07
2	4.0935E-07	6.724635E-07	9.940385E-07
5	4.597802E-07	8.17402E-07	1.350563E-06
10	5.020168E-07	9.474569E-07	1.702982E-06
20			
50			
100			

Creep compliance level: 2

Loading Time(sec)	Mid Temp (14 deg F)
1	
2	
5	
10	
20	
50	
100	

Creep compliance level: 1

Loading Time(sec)	Low Temp (-4 deg F)	Mid Temp (14 deg F)	High Temp (32 deg F)
1			
2			
5			
10			
20			
50			
100			

Asphalt Layer

Thickness (in.)	☑ 4
Mixture Volumetrics	
Unit weight (pcf)	☑ 150
Effective binder content (%)	☑ 11.6
Air voids (%)	☑ 7
Poisson's ratio	0.35
Mechanical Properties	
Dynamic modulus	☑ Input level 3
Select HMA Estar predictive model	Use Viscosity based model (nationally calibrated).
Reference temperature (deg F)	☑ 70
Asphalt binder	☑ SuperPave:70-22
Indirect tensile strength at 14 deg F (psi)	☑ 388.87
Creep compliance (1/psi)	☑ Input level 3
Thermal	
Thermal conductivity (BTU/hr-ft-deg F)	☑ 0.67
Heat capacity (BTU/lb-deg F)	☑ 0.23
Thermal contraction	1.381E-05 (calculated)
Identifiers	

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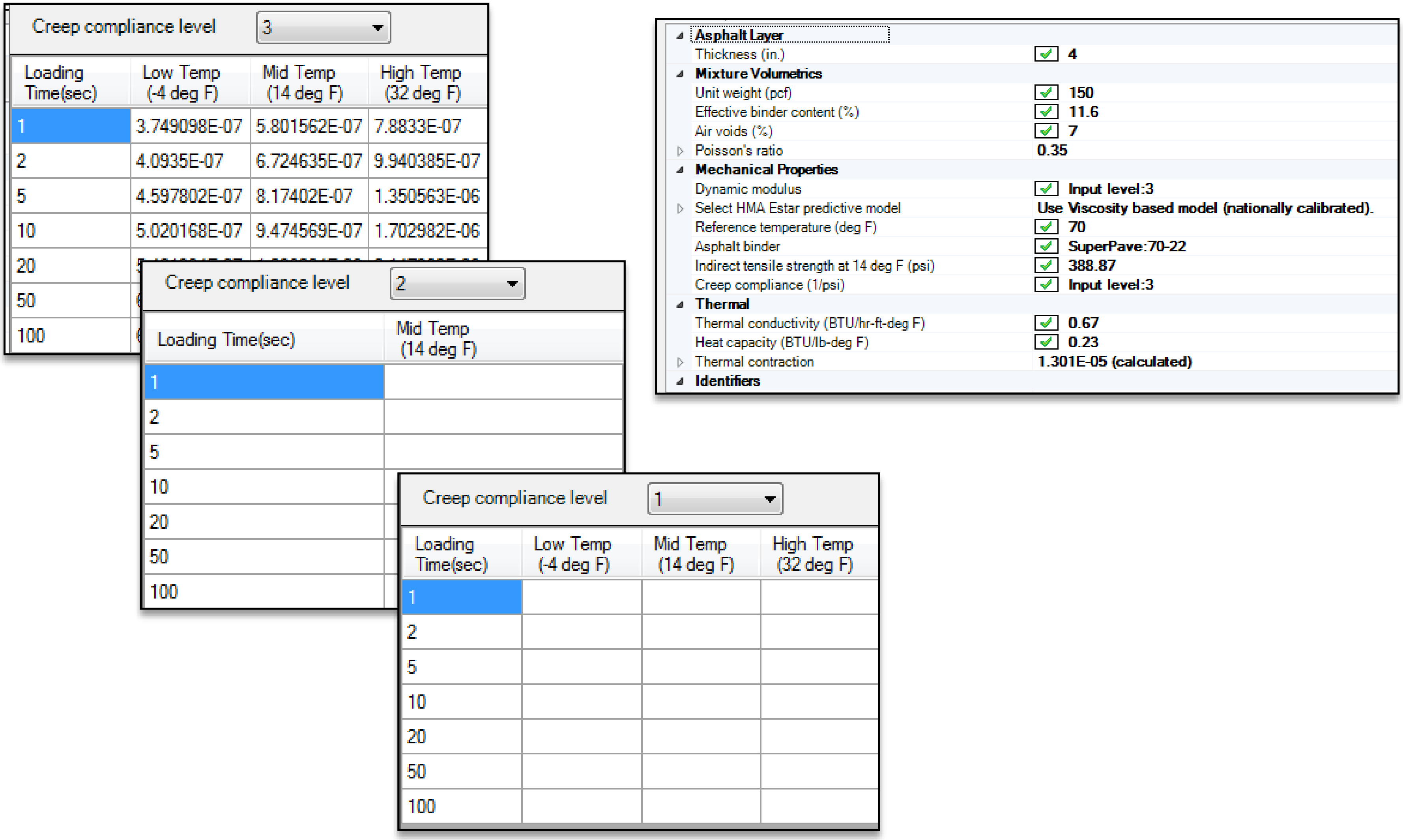
MODULE E | MATERIALS INPUTS | LESSON 3 | 45



Creep compliance level: 3

Loading Time(sec)	Low Temp (-4 deg F)	Mid Temp (14 deg F)	High Temp (32 deg F)
1	3.749098E-07	5.801562E-07	7.8833E-07
2	4.0935E-07	6.724635E-07	9.940385E-07
5	4.597802E-07	8.17402E-07	1.350563E-06
10	5.020168E-07	9.474569E-07	1.702982E-06
20			
50			
100			

Creep compliance level: 2

Loading Time(sec)	Mid Temp (14 deg F)
1	
2	
5	
10	
20	
50	
100	

Creep compliance level: 1

Loading Time(sec)	Low Temp (-4 deg F)	Mid Temp (14 deg F)	High Temp (32 deg F)
1			
2			
5			
10			
20			
50			
100			

Asphalt Layer	
Thickness (in.)	✓ **4**
Mixture Volumetrics	
Unit weight (pcf)	✓ **150**
Effective binder content (%)	✓ **11.6**
Air voids (%)	✓ **7**
Poisson's ratio	**0.35**
Mechanical Properties	
Dynamic modulus	✓ **Input level:3**
Select HMA Estar predictive model	**Use Viscosity based model (nationally calibrated).**
Reference temperature (deg F)	✓ **70**
Asphalt binder	✓ **SuperPave:70-22**
Indirect tensile strength at 14 deg F (psi)	✓ **388.87**
Creep compliance (1/psi)	✓ **Input level:3**
Thermal	
Thermal conductivity (BTU/hr-ft-deg F)	✓ **0.67**
Heat capacity (BTU/lb-deg F)	✓ **0.23**
Thermal contraction	**1.301E-05 (calculated)**
Identifiers	

Difference between input Levels 1 and 2 is the number of test temperatures. Level 3 inputs are default values from the national calibration conducted under NCHRP Project 1-37.

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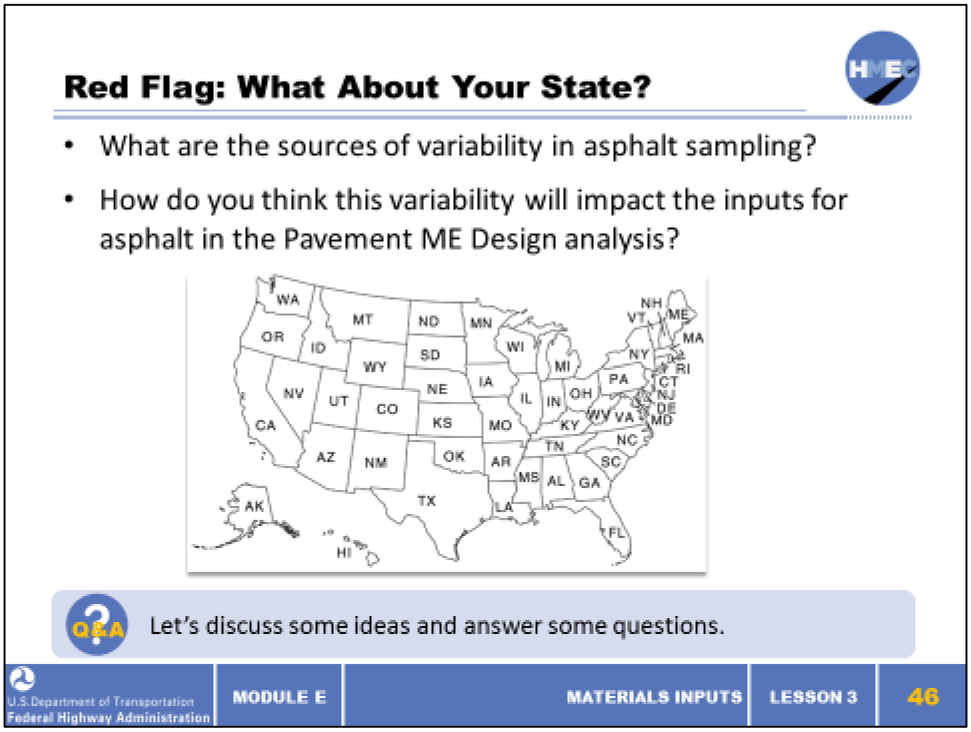
Slide 46



Red Flag: What About Your State?

- What are the sources of variability in asphalt sampling?
- How do you think this variability will impact the inputs for asphalt in the Pavement ME Design analysis?

WA
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HMEC

Q&A Let's discuss some ideas and answer some questions.

U.S. Department of Transportation Federal Highway Administration | MODULE E | MATERIALS INPUTS | LESSON 3 | 46

- What are the sources of variability in asphalt sampling?
- How do you think this variability will impact the inputs for asphalt in the Pavement ME Design analysis?

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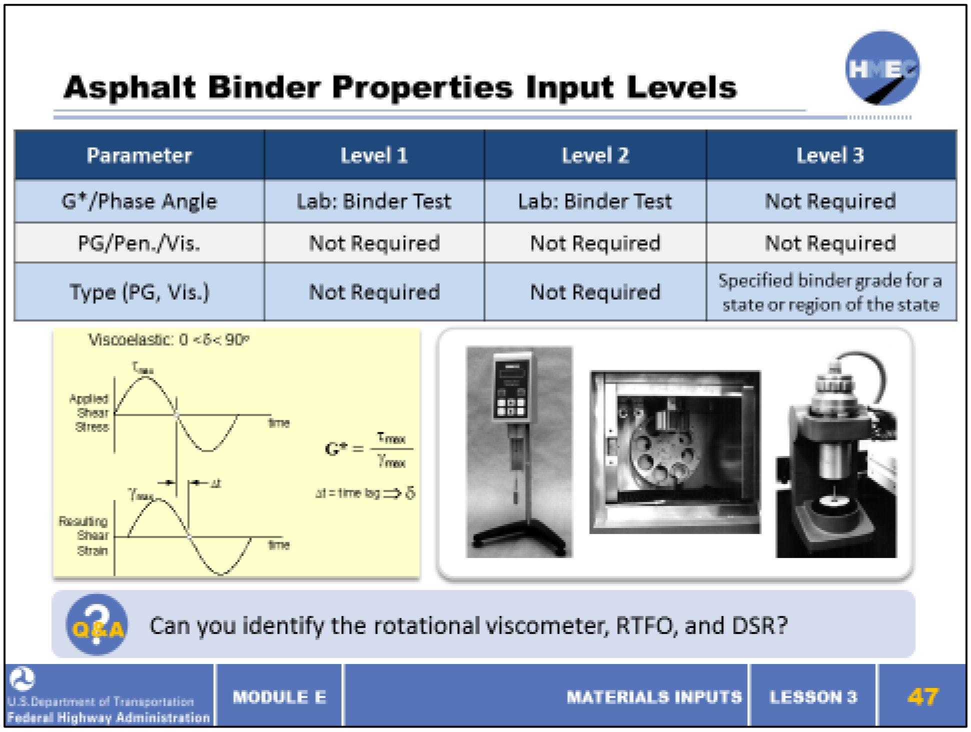
Slide 47



Asphalt Binder Properties Input Levels

Parameter	Level 1	Level 2	Level 3
G*/Phase Angle	Lab: Binder Test	Lab: Binder Test	Not Required
PG/Pen./Vis.	Not Required	Not Required	Not Required
Type (PG, Vis.)	Not Required	Not Required	Specified binder grade for a state or region of the state

Viscoelastic: 0 <δ< 90°
τ_{max}
Applied Shear Stress
time
γ_{max}
Δt
Resulting Shear Strain
time
$G^* = \frac{\tau_{max}}{\gamma_{max}}$
Δt = time lag ⇒ δ
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Federal Highway Administration
MODULE E
MATERIALS INPUTS
LESSON 3
47

Can you identify the rotational viscometer, RTFO, and DSR?

Rotational viscometer: It addresses rutting potential of binders. It is used in calculation of A (regression intercept) and VTS (regression slope). Rotational viscosity is used to evaluate high temperature workability of binders. A rotational coaxial cylinder viscometer, such as the Brookfield apparatus, is used rather than a capillary viscometer. Some asphalt technologists refer to this measure as "Brookfield viscosity. “

Dynamic Shear Rheometer (DSR): This test method covers the determination of the dynamic shear modulus and phase angle of asphalt binder when tested in dynamic (oscillatory) shear using parallel plate test geometry. It addresses binder strength and resistance to shearing.

Short-term binder aging: All binder data should be input after rolling thin film oven (RTFO) aging (versus pressure aging vessel, PAV, or original binder properties). Mix design or plant specimens information is made from RTFO aged as well. RTFO simulates aging in the construction process. Input levels for Binder and E* are related. For example, when Level 1 is selected for Modulus then the user has to fill in a matrix of E* values at a number of temperatures and load frequencies. To characterize the binder, when Level 1 is selected for E*, then G* and delta are necessary.

Level 1: Shear stiffness G* and phase angle (δ) at multiple temperatures at a frequency of ω = 10 radians/sec
Level 2: Same as Level 1
Level 3: Default A-VTS viscosity temperature susceptibility parameters based on Superpave Performance Grade (PG)

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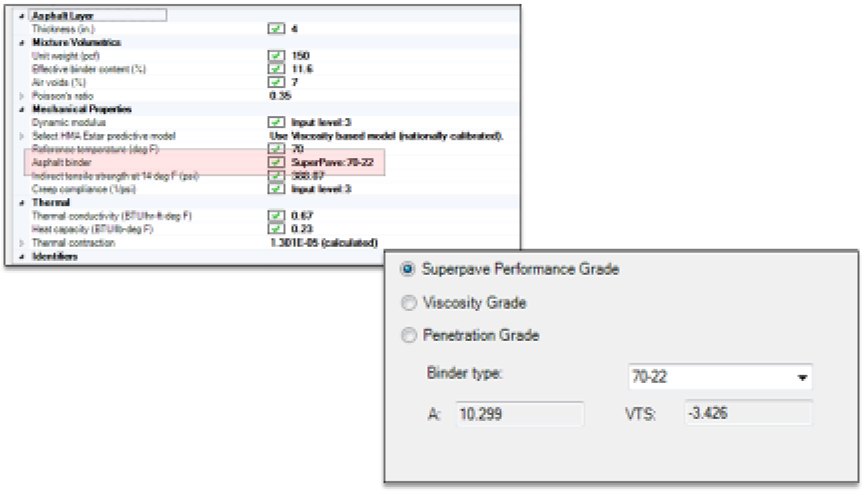
Slide 48

Pavement ME Design Inputs: Binder Properties



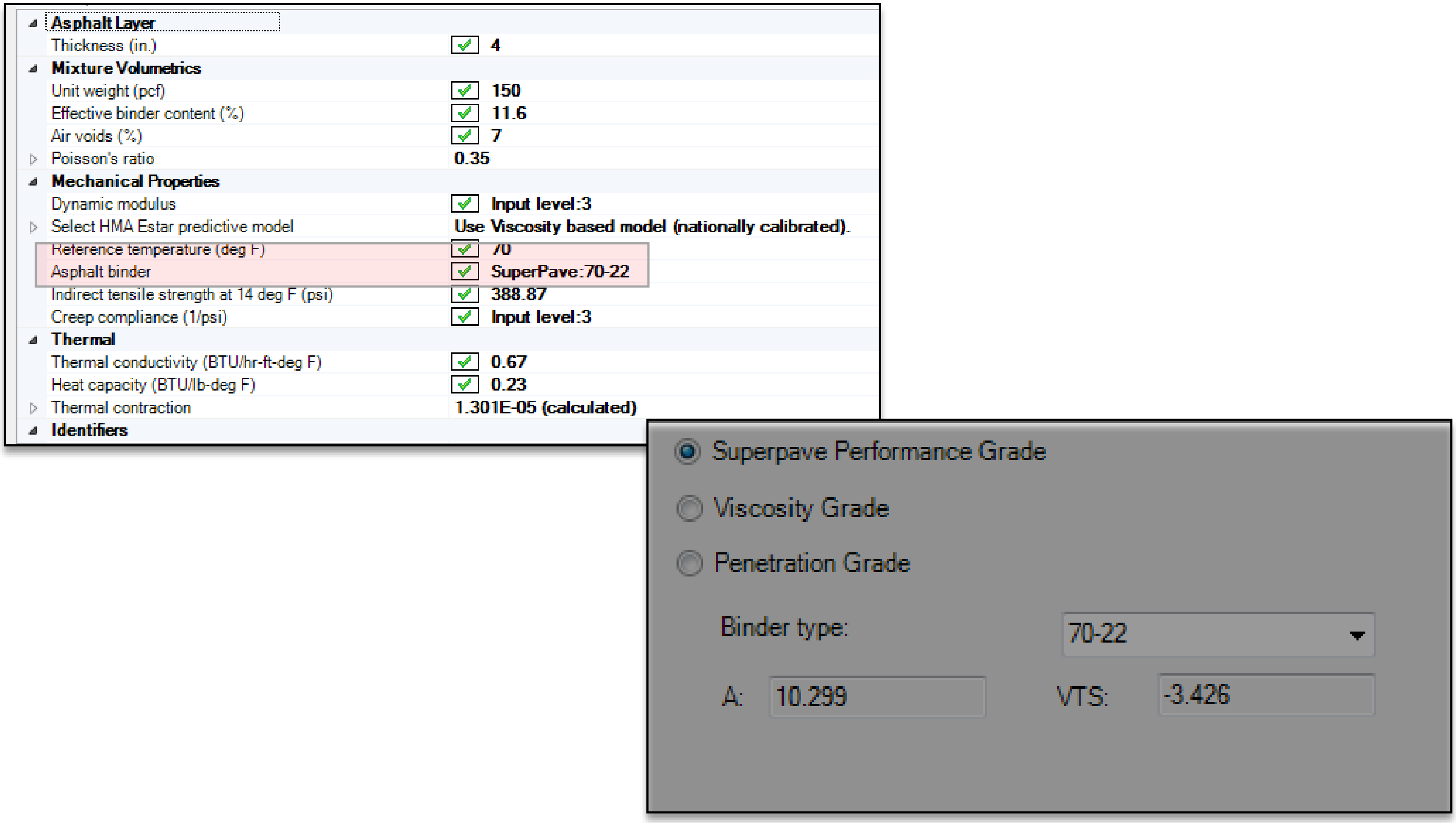
Asphalt Layer		
Thickness (in.)	☑	4
Mixture Volumetrics		
Unit weight (pcf)	☑	150
Effective binder content (%)	☑	11.6
Air voids (%)	☑	7
Poisson's ratio		0.35
Mechanical Properties		
Dynamic modulus	☑	Input level: 3
Select HMA Estar predictive model		Use Viscosity based model (nationally calibrated).
Reference temperature (deg F)	☑	70
Asphalt binder	☑	SuperPave: 70-22
Indirect tensile strength at 14 deg F (psi)	☑	388.87
Creep compliance (1/psi)	☑	Input level: 3
Thermal		
Thermal conductivity (BTU/hr-ft-deg F)	☑	0.67
Heat capacity (BTU/lb-deg F)	☑	0.23
Thermal contraction		1.301E-05 (calculated)
Identifiers		

● Superpave Performance Grade
○ Viscosity Grade
○ Penetration Grade

Binder type: 70-22

A: 10.299 VTS: -3.426

U.S. Department of Transportation Federal Highway Administration | MODULE E | MATERIALS INPUTS | LESSON 3 | 48



Asphalt Layer	
Thickness (in.)	☑ 4
Mixture Volumetrics	
Unit weight (pcf)	☑ 150
Effective binder content (%)	☑ 11.6
Air voids (%)	☑ 7
Poisson's ratio	0.35
Mechanical Properties	
Dynamic modulus	☑ Input level:3
Select HMA Estar predictive model	Use Viscosity based model (nationally calibrated).
Reference temperature (deg F)	☑ 70
Asphalt binder	☑ SuperPave:70-22
Indirect tensile strength at 14 deg F (psi)	☑ 388.87
Creep compliance (1/psi)	☑ Input level:3
Thermal	
Thermal conductivity (BTU/hr-ft-deg F)	☑ 0.67
Heat capacity (BTU/lb-deg F)	☑ 0.23
Thermal contraction	1.301E-05 (calculated)
Identifiers	

● Superpave Performance Grade
○ Viscosity Grade
○ Penetration Grade

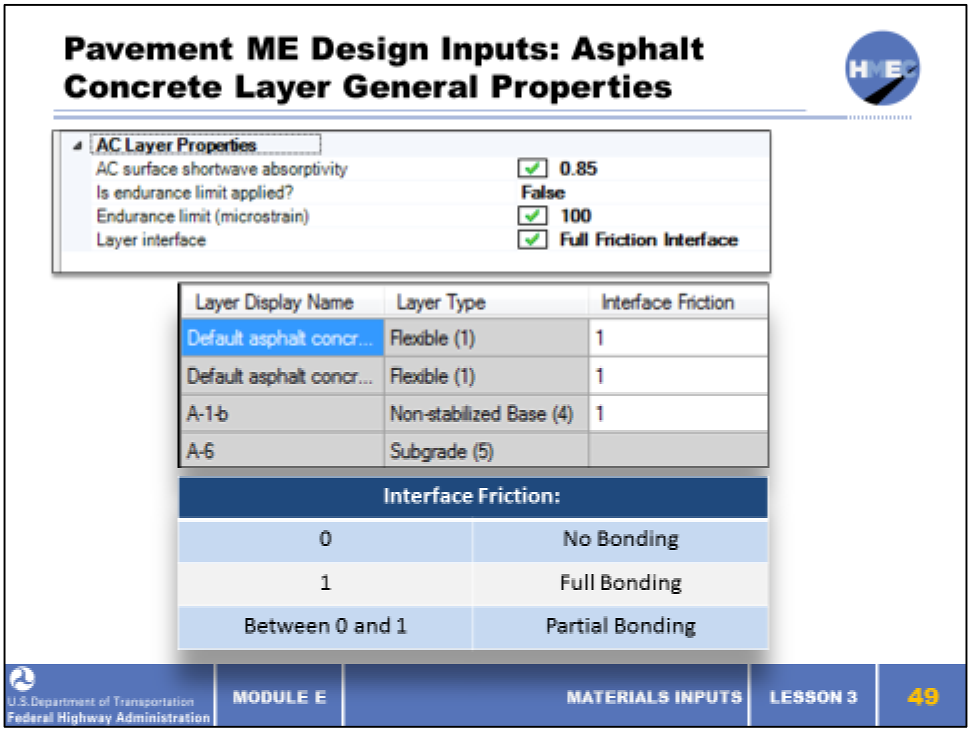
Binder type: 70-22

A: 10.299

VTS: -3.426

Level 1 and 2 asphalt binder inputs require either Superpave or conventional asphalt binder test data. Level 3 requires the user to select a binder grade.

Slide 49



Pavement ME Design Inputs: Asphalt Concrete Layer General Properties

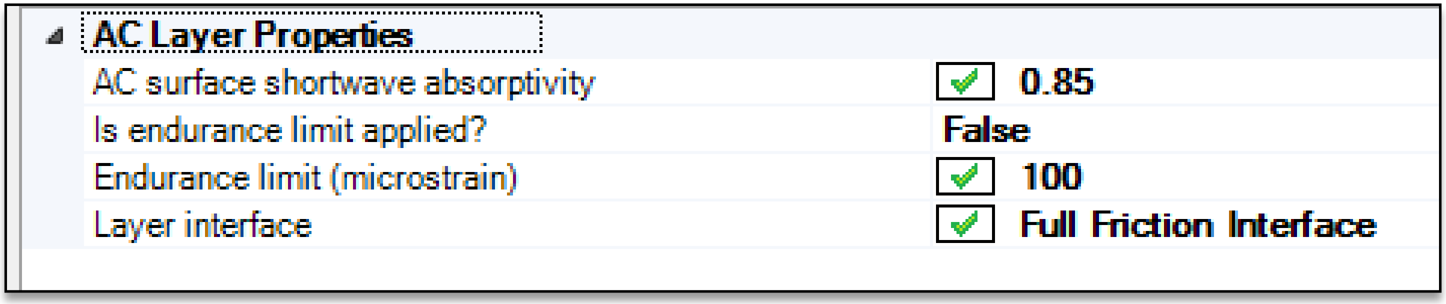
AC Layer Properties

AC surface shortwave absorptivity	☑ 0.85
Is endurance limit applied?	**False**
Endurance limit (microstrain)	☑ 100
Layer interface	☑ Full Friction Interface

Layer Display Name	Layer Type	Interface Friction
Default asphalt concr...	Flexible (1)	1
Default asphalt concr...	Flexible (1)	1
A-1-b	Non-stabilized Base (4)	1
A-6	Subgrade (5)	

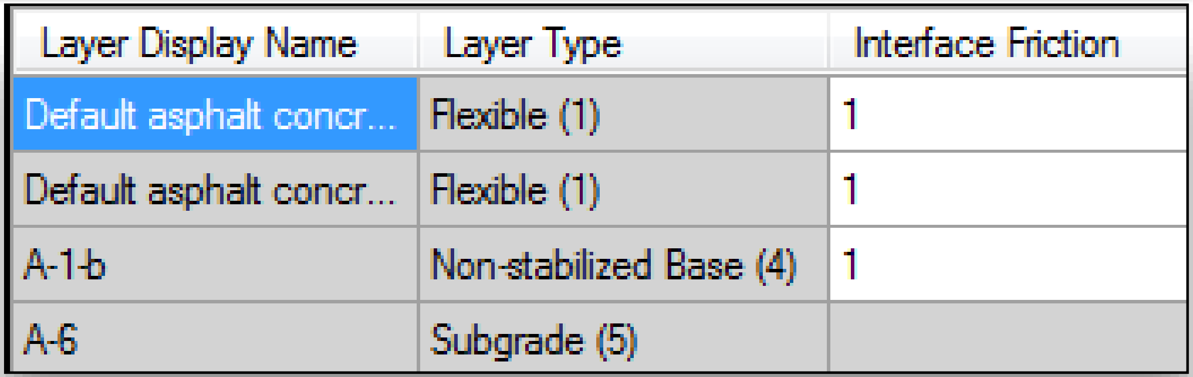
Interface Friction:	
0	No Bonding
1	Full Bonding
Between 0 and 1	Partial Bonding

U.S. Department of Transportation
Federal Highway Administration
MODULE E
MATERIALS INPUTS
LESSON 3
49



AC Layer Properties

AC surface shortwave absorptivity	☑ 0.85
Is endurance limit applied?	False
Endurance limit (microstrain)	☑ 100
Layer interface	☑ Full Friction Interface



Layer Display Name	Layer Type	Interface Friction
Default asphalt concr...	Flexible (1)	1
Default asphalt concr...	Flexible (1)	1
A-1-b	Non-stabilized Base (4)	1
A-6	Subgrade (5)	

Interface Friction:	
0	No Bonding
1	Full Bonding
Between 0 and 1	Partial Bonding

Asphalt concrete (AC) surface absorptivity: This dimensionless parameter defines the fraction of available solar energy absorbed by the pavement surface.

Layer interface indicates the adhesion bonding of two layers at their interface.

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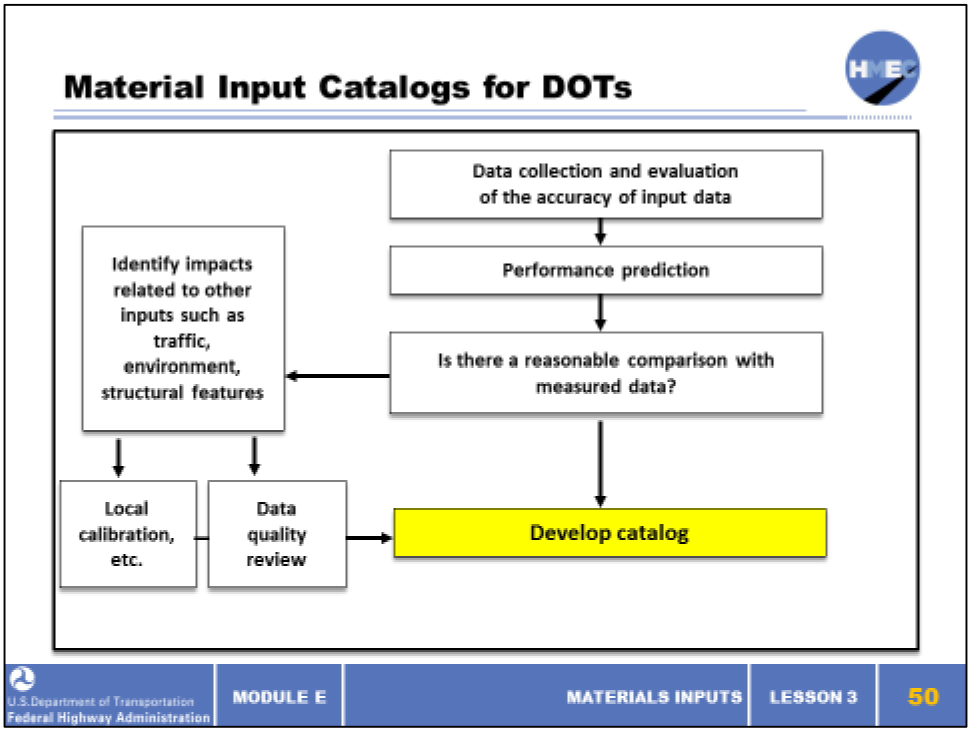
Slide 50



Material Input Catalogs for DOTs

Data collection and evaluation of the accuracy of input data

Performance prediction

Is there a reasonable comparison with measured data?

Identify impacts related to other inputs such as traffic, environment, structural features

Local calibration, etc.

Data quality review

Develop catalog

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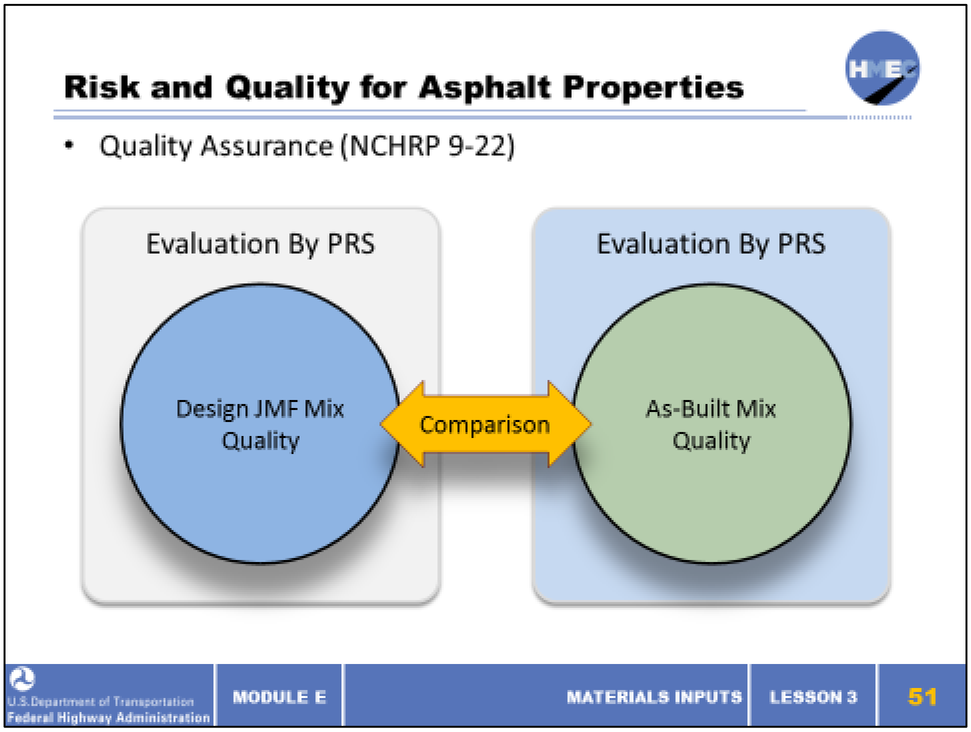
MODULE E
MATERIALS INPUTS
LESSON 3
50

A flowchart outlining the general process for a DOT to develop a Materials Inputs Catalog is presented in this slide. The process would start with some research into the types of inputs that would be sensitive for pavements in a particular state or in various regions of a state.

The next step would be to collect data on these inputs and do some initial analysis to determine the accuracy of the input data collected. The preliminary analyses would be evaluated in terms of their performance predictions and possibly compare that with past field pavement performance history found in a state’s pavement management databases.

In the event that trial designs using the developed material inputs catalog don't produce reasonable designs as compared to a DOT’s past experience, then additional steps should be taken to investigate whether the inconsistencies are stemming from materials inputs, or perhaps from traffic, environment, or other structural inputs that could be influencing the results. Examples of these additional steps could be additional quality review on the gathered material input data, performing local calibration (if not previously done), etc. After these steps are conducted (if necessary), the materials catalog can be developed for general use, but it should be mentioned that each project is unique and should be considered in the design phase and again prior to construction to ensure the materials assumed are still valid.

Slide 51



Risk and Quality for Asphalt Properties

- Quality Assurance (NCHRP 9-22)

This screen shows the overall concepts behind the QRSS approach on potential applications connecting materials testing and acceptance to pavement design performance predictions.

These come from the project NCHRP 9-22 Beta Testing and Validation of HMA PRS, in which the predicted performance (using Pavement ME Design models) of the as-designed mixture (designed by either the contractor or the State DOT) is compared to the predicted performance of the as-built mix (produced at the contractor's plant during production).

The lab tests can be run to determine the gradation, air voids, asphalt content, and specific gravities—or one can run the Dynamic Modulus test on the HMA instead of the gradation, which gives a more detailed assessment of the mixture's performance potential at the mix design and production stage prior to construction.

The advancement of the volumetrics-based procedure developed in NCHRP 9-22 led to the development of a field-based procedure in a follow-on NCHRP Project 9-22A Evaluation of the Quality-Related Specification Software (QRSS) Version 1.0.

It is an example of how risk and quality in the sampling process, as well as the impact of asphalt production properties, can affect pavement distress predictions. A field-based procedure (like that of NCHRP Project 9-22A) allows for the as-design mix was compared to the predicted performance of the as-built mix (sampled at the contractor's plant during production, and considering in situ construction properties such as density). This approach can account for variability in the mixture since it is based on evaluating material in a lot-by-lot (and sublots) basis, as opposed to the averages used in the Pavement ME Design.

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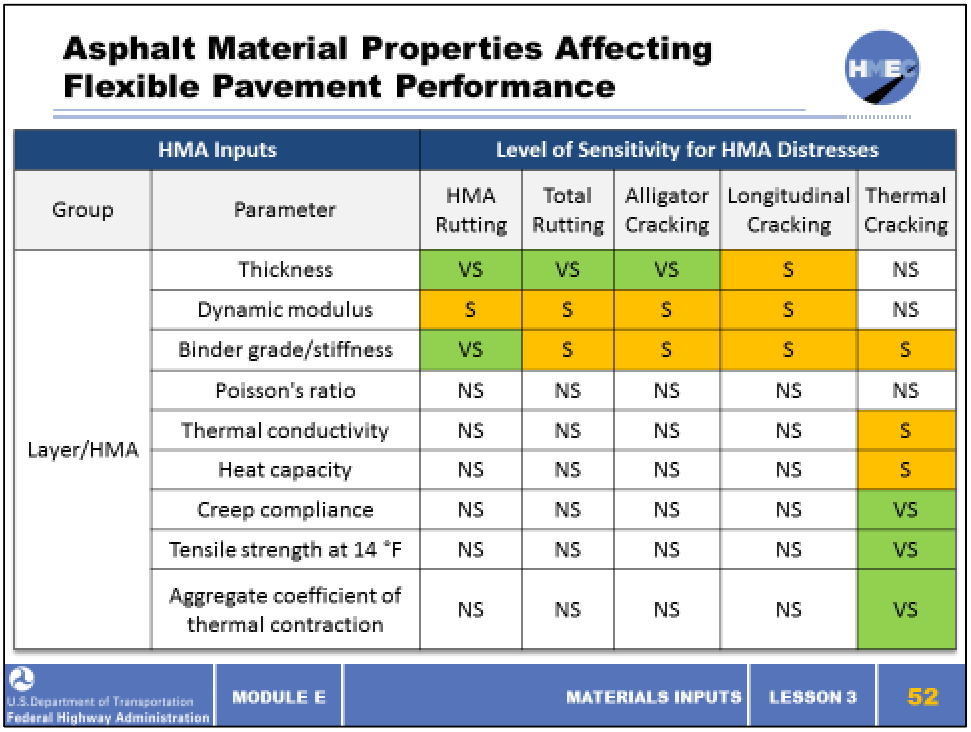
Slide 52



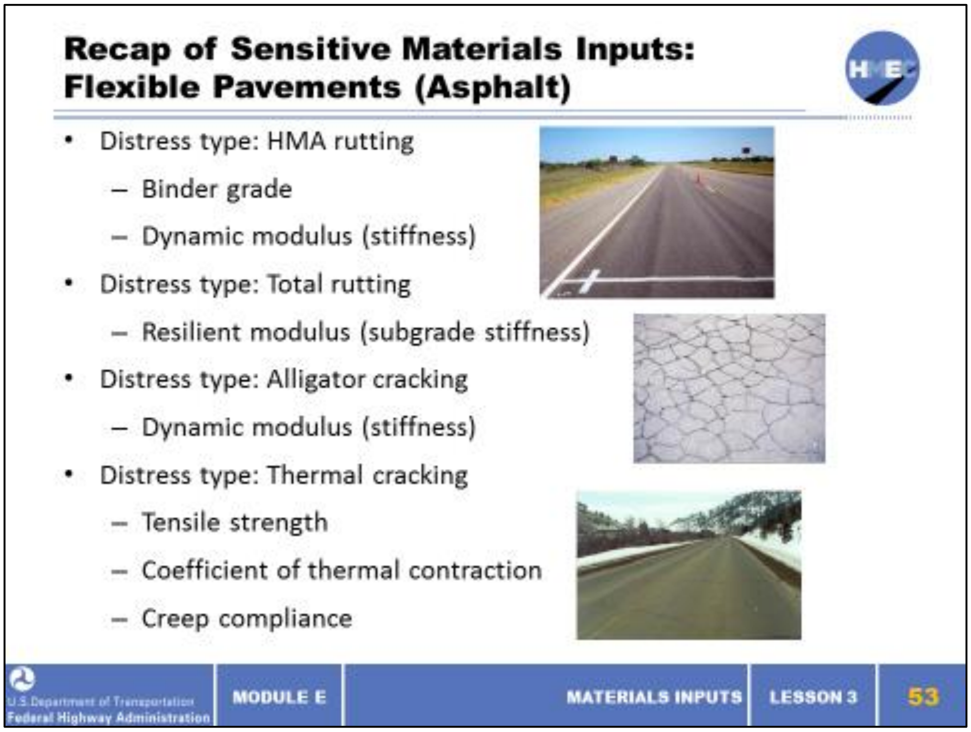
Asphalt Material Properties Affecting Flexible Pavement Performance

HMA Inputs		Level of Sensitivity for HMA Distresses				
Group	Parameter	HMA Rutting	Total Rutting	Alligator Cracking	Longitudinal Cracking	Thermal Cracking
Layer/HMA	Thickness	VS	VS	VS	S	NS
	Dynamic modulus	S	S	S	S	NS
	Binder grade/stiffness	VS	S	S	S	S
	Poisson's ratio	NS	NS	NS	NS	NS
	Thermal conductivity	NS	NS	NS	NS	S
	Heat capacity	NS	NS	NS	NS	S
	Creep compliance	NS	NS	NS	NS	VS
	Tensile strength at 14 °F	NS	NS	NS	NS	VS
	Aggregate coefficient of thermal contraction	NS	NS	NS	NS	VS

U.S. Department of Transportation
Federal Highway Administration
MODULE E
MATERIALS INPUTS
LESSON 3
52

The asphalt layer's dynamic modulus and thickness are most influential on the structurally based pavement distresses (rutting and fatigue cracking); however, the low-temperature properties (tensile strength, coefficient of thermal contraction, and creep compliance) are most sensitive for thermal cracking distress.

Slide 53



Recap of Sensitive Materials Inputs: Flexible Pavements (Asphalt)

- Distress type: HMA rutting
  - Binder grade
  - Dynamic modulus (stiffness)
- Distress type: Total rutting
  - Resilient modulus (subgrade stiffness)
- Distress type: Alligator cracking
  - Dynamic modulus (stiffness)
- Distress type: Thermal cracking
  - Tensile strength
  - Coefficient of thermal contraction
  - Creep compliance

U.S. Department of Transportation
Federal Highway Administration

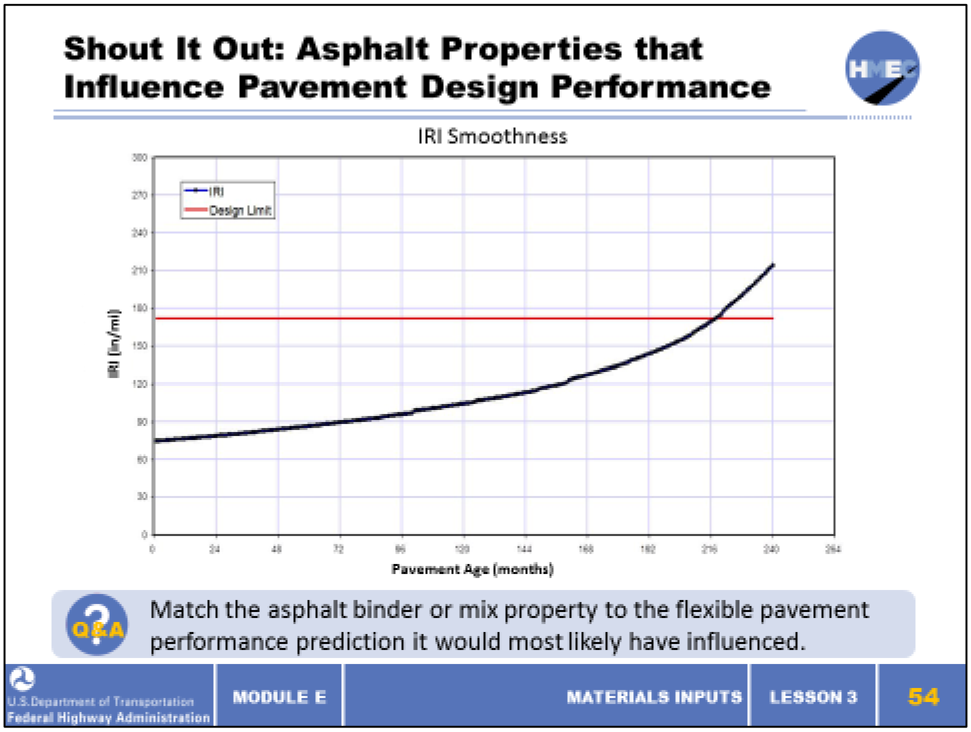
MODULE E

MATERIALS INPUTS

LESSON 3

53

Slide 54



Shout It Out: Asphalt Properties that Influence Pavement Design Performance

Match the asphalt binder or mix property to the flexible pavement performance prediction it would most likely have influenced.

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MODULE E | MATERIALS INPUTS | LESSON 3 | 54

Slide 55

Concrete Material Inputs

U.S. Department of Transportation
Federal Highway Administration

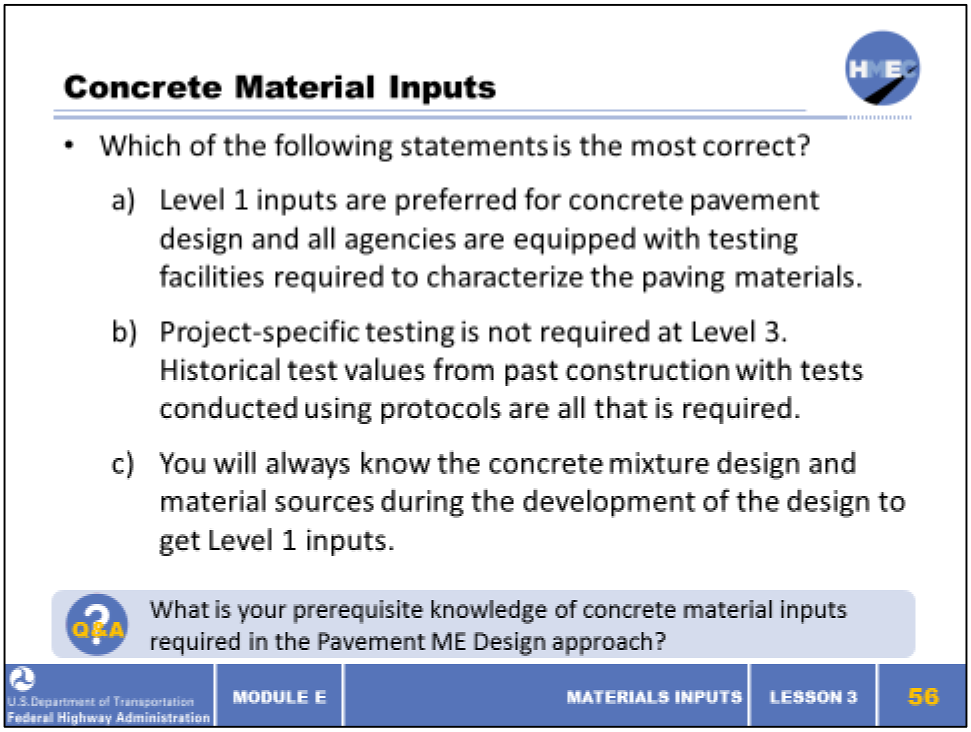
MODULE E

MATERIALS INPUTS

LESSON 3

55

Slide 56



Concrete Material Inputs

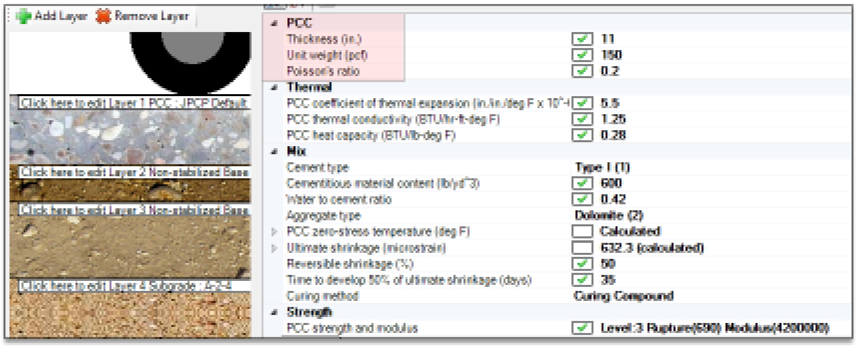
- Which of the following statements is the most correct?
  - a) Level 1 inputs are preferred for concrete pavement design and all agencies are equipped with testing facilities required to characterize the paving materials.
  - b) Project-specific testing is not required at Level 3. Historical test values from past construction with tests conducted using protocols are all that is required.
  - c) You will always know the concrete mixture design and material sources during the development of the design to get Level 1 inputs.

Q&A What is your prerequisite knowledge of concrete material inputs required in the Pavement ME Design approach?

U.S. Department of Transportation Federal Highway Administration | MODULE E | MATERIALS INPUTS | LESSON 3 | 56

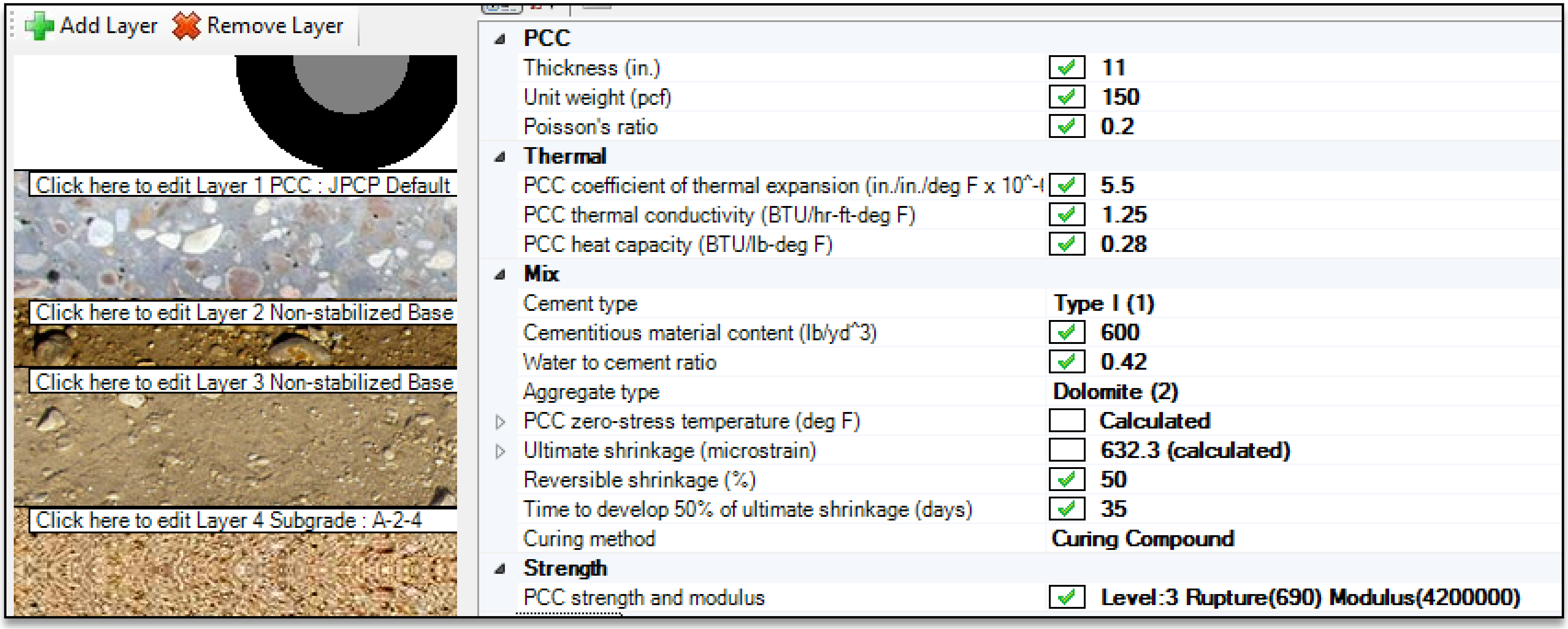
Slide 57

Portland Cement Concrete (PCC) Material Inputs


Add Layer
Remove Layer
Click here to edit Layer 1 PCC : JPCP Default
Click here to edit Layer 2 Non-stabilized Base
Click here to edit Layer 3 Non-stabilized Base
Click here to edit Layer 4 Subgrade : A-2-4

PCC	
Thickness (in.)	☑ 11
Unit weight (pcf)	☑ 150
Poisson's ratio	☑ 0.2
Thermal	
PCC coefficient of thermal expansion (in./in./deg F x 10^-6)	☑ 5.5
PCC thermal conductivity (BTU/hr-ft-deg F)	☑ 1.25
PCC heat capacity (BTU/lb-deg F)	☑ 0.28
Mix	
Cement type	Type I (1)
Cementitious material content (lb/yd^3)	☑ 600
Water to cement ratio	☑ 0.42
Aggregate type	Dolomite (2)
PCC zero-stress temperature (deg F)	☐ Calculated
Ultimate shrinkage (microstrain)	☐ 632.3 (calculated)
Reversible shrinkage (%)	☑ 50
Time to develop 50% of ultimate shrinkage (days)	☑ 35
Curing method	Curing Compound
Strength	
PCC strength and modulus	☑ Level:3 Rupture(690) Modulus(4200000)

PCC Materials	Level 3 µtypical
PCC Slabs (newly constructed or existing)	0.20
Fractured Slab	
Crack/Seat	0.20
Break/Seat	0.20
Rubbilized	0.30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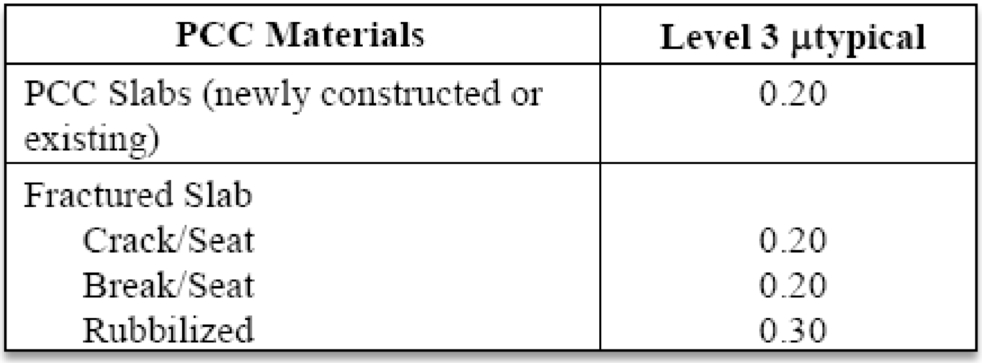
Click here to edit Layer 2 Non-stabilized Base
Click here to edit Layer 3 Non-stabilized Base
Click here to edit Layer 4 Subgrade : A-2-4

PCC		
Thickness (in.)	☑	**11**
Unit weight (pcf)	☑	**150**
Poisson's ratio	☑	**0.2**
Thermal		
PCC coefficient of thermal expansion (in./in./deg F x 10^-	☑	**5.5**
PCC thermal conductivity (BTU/hr-ft-deg F)	☑	**1.25**
PCC heat capacity (BTU/lb-deg F)	☑	**0.28**
Mix		
Cement type		**Type I (1)**
Cementitious material content (lb/yd^3)	☑	**600**
Water to cement ratio	☑	**0.42**
Aggregate type		**Dolomite (2)**
PCC zero-stress temperature (deg F)	☐	**Calculated**
Ultimate shrinkage (microstrain)	☐	**632.3 (calculated)**
Reversible shrinkage (%)	☑	**50**
Time to develop 50% of ultimate shrinkage (days)	☑	**35**
Curing method		**Curing Compound**
Strength		
PCC strength and modulus	☑	**Level:3 Rupture(690) Modulus(4200000)**



PCC Materials	Level 3 µtypical
PCC Slabs (newly constructed or existing)	0.20
Fractured Slab Crack/Seat Break/Seat Rubbilized	 0.20 0.20 0.30

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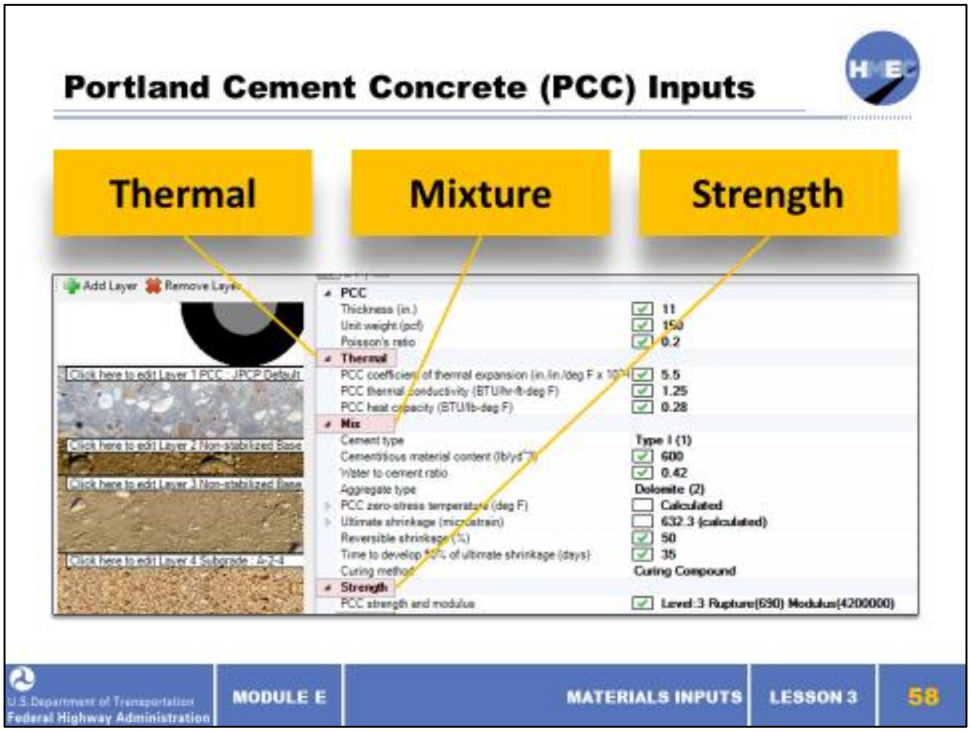
Slide 58



Portland Cement Concrete (PCC) Inputs

Thermal **Mixture** **Strength**

Add Layer
Remove Layer
Click here to edit Layer 1 PCC : JPCP Default
Click here to edit Layer 2 Non-stabilized Base
Click here to edit Layer 3 Non-stabilized Base
Click here to edit Layer 4 Subgrade : A-2-4

PCC		
Thickness (in.)	☑	11
Unit weight (pcf)	☑	150
Poisson's ratio	☑	0.2
Thermal		
PCC coefficient of thermal expansion (in./in./deg F x 10^-6)	☑	5.5
PCC thermal conductivity (BTU/hr-ft-deg F)	☑	1.25
PCC heat capacity (BTU/lb-deg F)	☑	0.28
Mix		
Cement type		Type I (1)
Cementitious material content (lb/yd^3)	☑	600
Water to cement ratio	☑	0.42
Aggregate type		Dolomite (2)
PCC zero-stress temperature (deg F)	☐	Calculated
Ultimate shrinkage (microstrain)	☐	632.3 (calculated)
Reversible shrinkage (%)	☑	50
Time to develop 50% of ultimate shrinkage (days)	☑	35
Curing method		Curing Compound
Strength		
PCC strength and modulus	☑	Level:3 Rupture(690) Modulus(4200000)

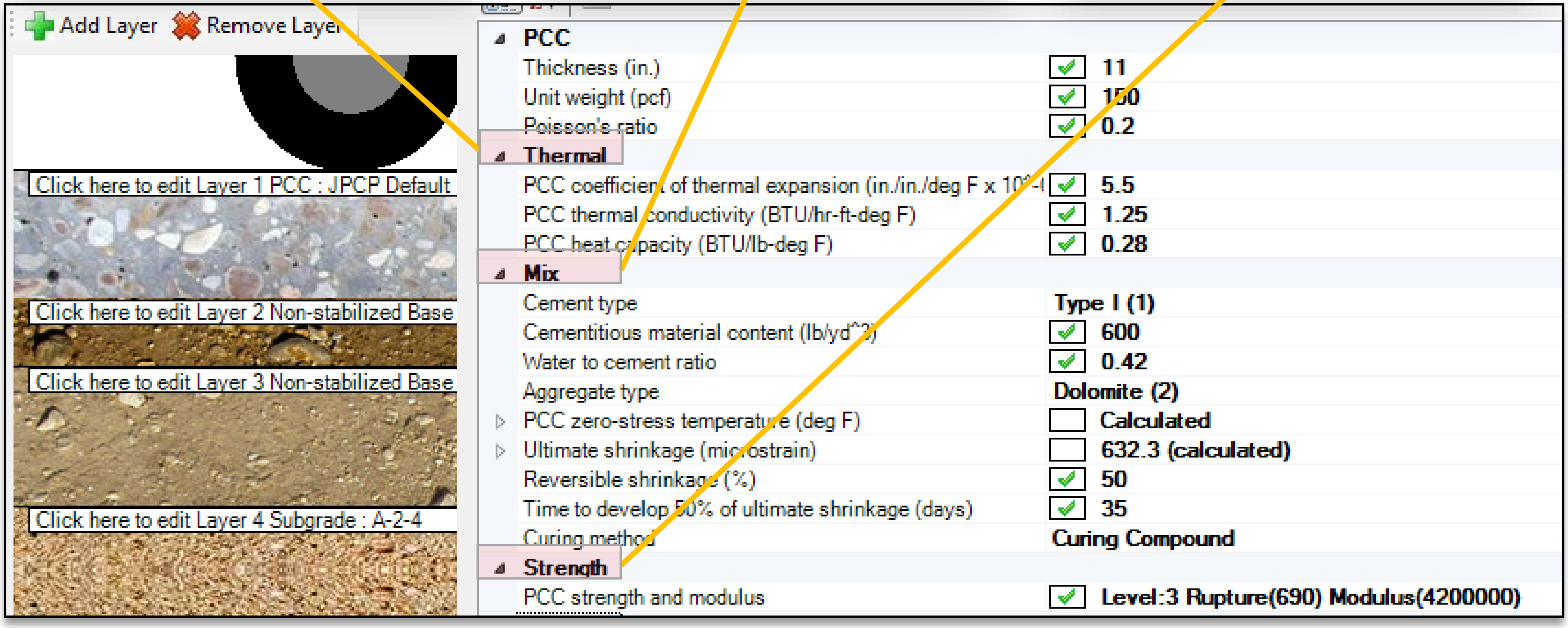
U.S. Department of Transportation
Federal Highway Administration

MODULE E MATERIALS INPUTS LESSON 3 58

Thermal

Mixture

Strength


Add Layer
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Click here to edit Layer 1 PCC : JPCP Default
Click here to edit Layer 2 Non-stabilized Base
Click here to edit Layer 3 Non-stabilized Base
Click here to edit Layer 4 Subgrade : A-2-4

PCC		
Thickness (in.)	☑	11
Unit weight (pcf)	☑	150
Poisson's ratio	☑	0.2
Thermal		
PCC coefficient of thermal expansion (in./in./deg F x 10^-	☑	5.5
PCC thermal conductivity (BTU/hr-ft-deg F)	☑	1.25
PCC heat capacity (BTU/lb-deg F)	☑	0.28
Mix		
Cement type		Type I (1)
Cementitious material content (lb/yd^3)	☑	600
Water to cement ratio	☑	0.42
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PCC zero-stress temperature (deg F)	☐	Calculated
Ultimate shrinkage (microstrain)	☐	632.3 (calculated)
Reversible shrinkage (%)	☑	50
Time to develop 50% of ultimate shrinkage (days)	☑	35
Curing method		Curing Compound
Strength		
PCC strength and modulus	☑	Level:3 Rupture(690) Modulus(4200000)

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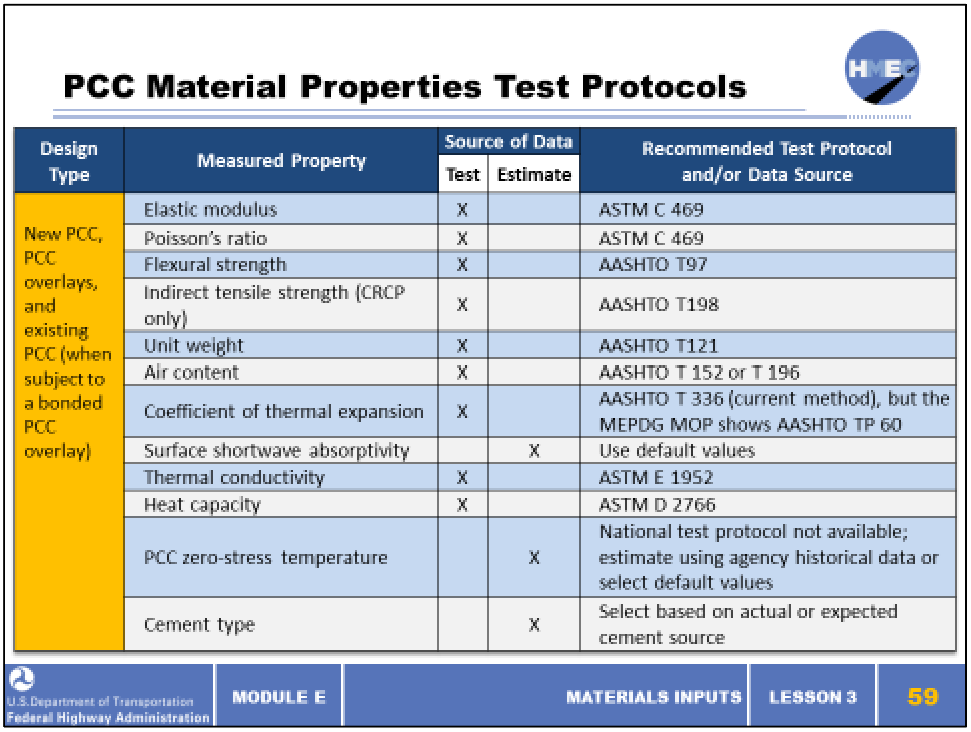
Slide 59



PCC Material Properties Test Protocols

Design Type	Measured Property	Source of Data		Recommended Test Protocol and/or Data Source
		Test	Estimate	
New PCC, PCC overlays, and existing PCC (when subject to a bonded PCC overlay)	Elastic modulus	X		ASTM C 469
	Poisson's ratio	X		ASTM C 469
	Flexural strength	X		AASHTO T97
	Indirect tensile strength (CRCP only)	X		AASHTO T198
	Unit weight	X		AASHTO T121
	Air content	X		AASHTO T 152 or T 196
	Coefficient of thermal expansion	X		AASHTO T 336 (current method), but the MEPDG MOP shows AASHTO TP 60
	Surface shortwave absorptivity		X	Use default values
	Thermal conductivity	X		ASTM E 1952
	Heat capacity	X		ASTM D 2766
	PCC zero-stress temperature		X	National test protocol not available; estimate using agency historical data or select default values
	Cement type		X	Select based on actual or expected cement source

U.S. Department of Transportation Federal Highway Administration | MODULE E | MATERIALS INPUTS | LESSON 3 | 59

Lab test methods are available for nearly all of the concrete material properties. Estimates must be done for surface shortwave absorptivity, PCC zero-stress temperature, and cement type. Testing can be done for existing concrete layers by taking cores, bringing them back to the lab for testing.

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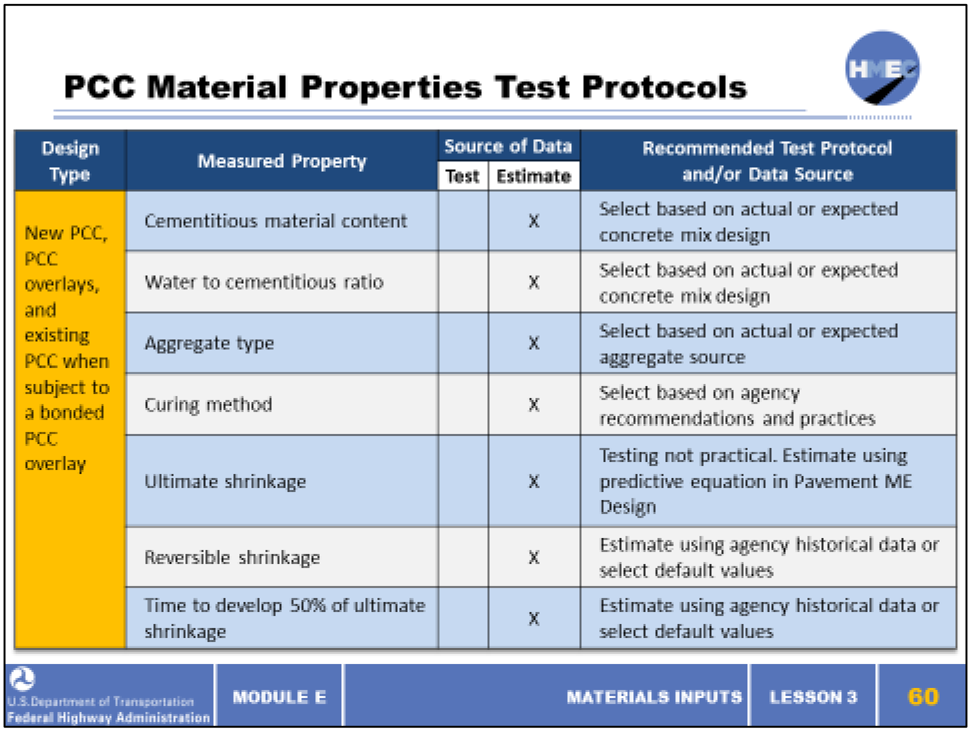
Slide 60

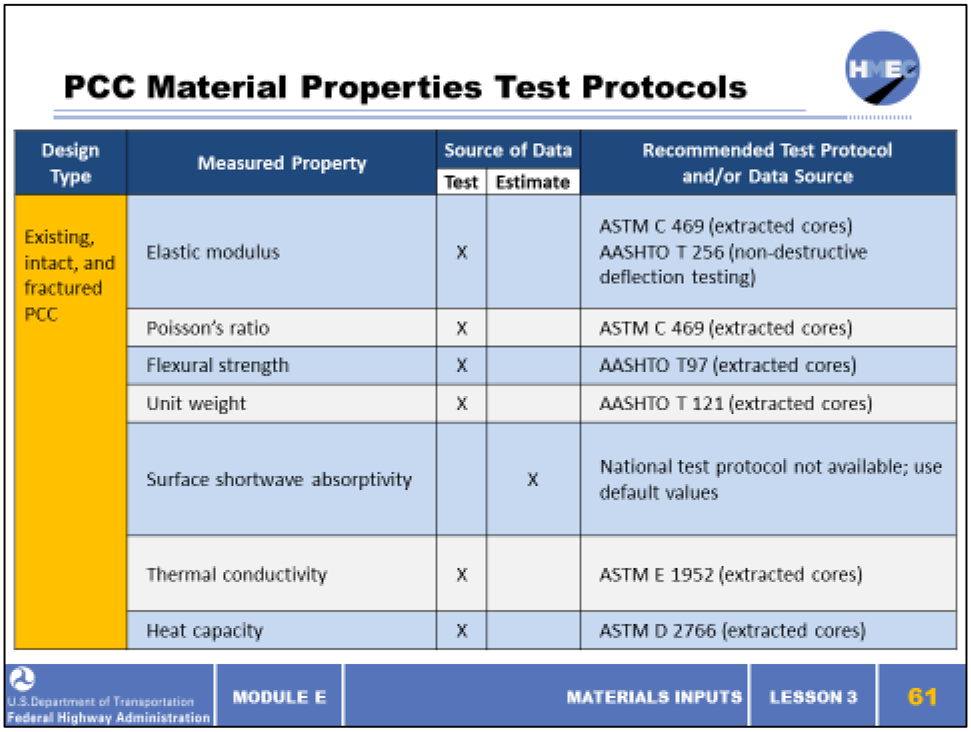


PCC Material Properties Test Protocols

Design Type	Measured Property	Source of Data		Recommended Test Protocol and/or Data Source
		Test	Estimate	
New PCC, PCC overlays, and existing PCC when subject to a bonded PCC overlay	Cementitious material content		X	Select based on actual or expected concrete mix design
	Water to cementitious ratio		X	Select based on actual or expected concrete mix design
	Aggregate type		X	Select based on actual or expected aggregate source
	Curing method		X	Select based on agency recommendations and practices
	Ultimate shrinkage		X	Testing not practical. Estimate using predictive equation in Pavement ME Design
	Reversible shrinkage		X	Estimate using agency historical data or select default values
	Time to develop 50% of ultimate shrinkage		X	Estimate using agency historical data or select default values

U.S. Department of Transportation Federal Highway Administration | MODULE E | MATERIALS INPUTS | LESSON 3 | 60

Slide 61



PCC Material Properties Test Protocols

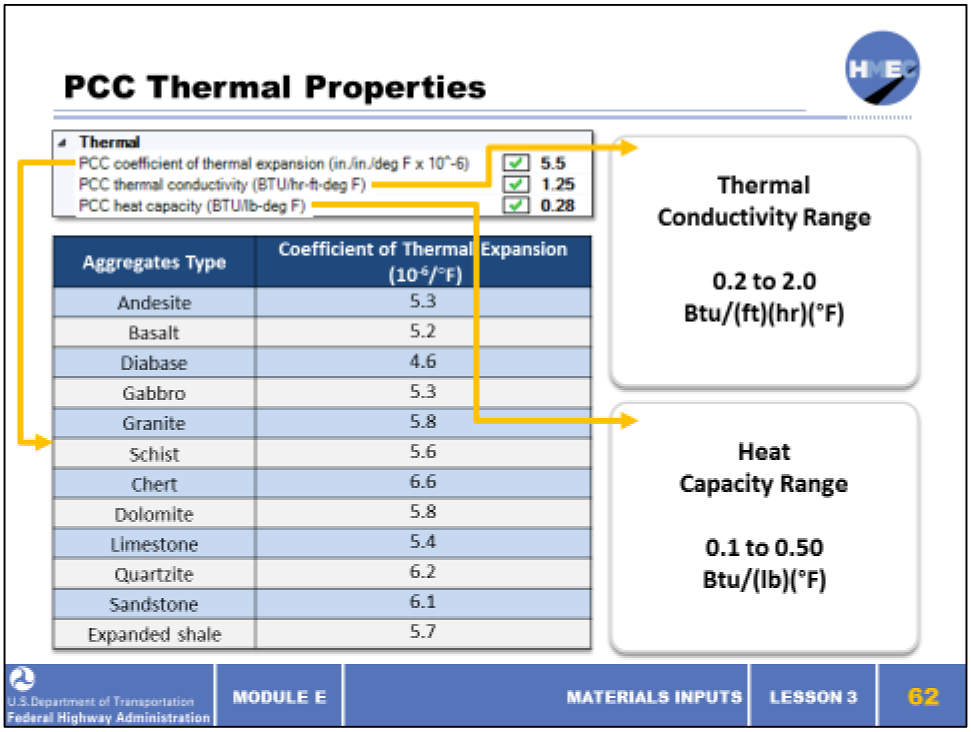
Design Type	Measured Property	Source of Data		Recommended Test Protocol and/or Data Source
		Test	Estimate	
Existing, intact, and fractured PCC	Elastic modulus	X		ASTM C 469 (extracted cores) AASHTO T 256 (non-destructive deflection testing)
	Poisson's ratio	X		ASTM C 469 (extracted cores)
	Flexural strength	X		AASHTO T97 (extracted cores)
	Unit weight	X		AASHTO T 121 (extracted cores)
	Surface shortwave absorptivity		X	National test protocol not available; use default values
	Thermal conductivity	X		ASTM E 1952 (extracted cores)
	Heat capacity	X		ASTM D 2766 (extracted cores)

U.S. Department of Transportation Federal Highway Administration | MODULE E | MATERIALS INPUTS | LESSON 3 | 61

The purpose of the screen is to introduce the test methods required for Level 1 inputs of existing concrete material properties for rehabilitation designs of existing rigid pavements.

Lab test methods are available for nearly all of the existing concrete material properties. Estimates must be done for surface shortwave absorptivity.

Slide 62



PCC Thermal Properties

Thermal

PCC coefficient of thermal expansion (in./in./deg F x 10^-6) ☑ 5.5

PCC thermal conductivity (BTU/hr-ft-deg F) ☑ 1.25

PCC heat capacity (BTU/lb-deg F) ☑ 0.28

Aggregates Type	Coefficient of Thermal Expansion (10^{-6}/°F)
Andesite	5.3
Basalt	5.2
Diabase	4.6
Gabbro	5.3
Granite	5.8
Schist	5.6
Chert	6.6
Dolomite	5.8
Limestone	5.4
Quartzite	6.2
Sandstone	6.1
Expanded shale	5.7

Thermal Conductivity Range

0.2 to 2.0 Btu/(ft)(hr)(°F)

Heat Capacity Range

0.1 to 0.50 Btu/(lb)(°F)

U.S. Department of Transportation
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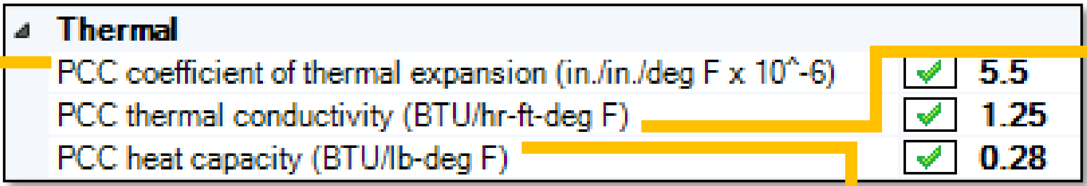
MODULE E MATERIALS INPUTS LESSON 3 62



Thermal

PCC coefficient of thermal expansion (in./in./deg F x 10^-6)	☑	5.5
PCC thermal conductivity (BTU/hr-ft-deg F)	☑	1.25
PCC heat capacity (BTU/lb-deg F)	☑	0.28

Aggregates Type	Coefficient of Thermal Expansion (10^{-6}/°F)
Andesite	5.3
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Gabbro	5.3
Granite	5.8
Schist	5.6
Chert	6.6
Dolomite	5.8
Limestone	5.4
Quartzite	6.2
Sandstone	6.1
Expanded shale	5.7

Thermal Conductivity Range
0.2 to 2.0
Btu/(ft)(hr)(°F)

Heat Capacity Range
0.1 to 0.50
Btu/(lb)(°F)

Thermal conductivity typical values for concrete range from 0.2 to 2.0 Btu/ (ft) (hr) (°F). Use default value set in program: 1.25 Btu/ (ft) (hr) (°F).

Heat capacity typical values for concrete range from 0.1 to 0.50 Btu/(lb)(°F).Use default value set in program: 0.28 BTU/lb.-°F

It should be noted that the CTE values presented on this slide are uncorrected values. Therefore, it is recommended that the CTE values be corrected and that a recalibrated model should be used.

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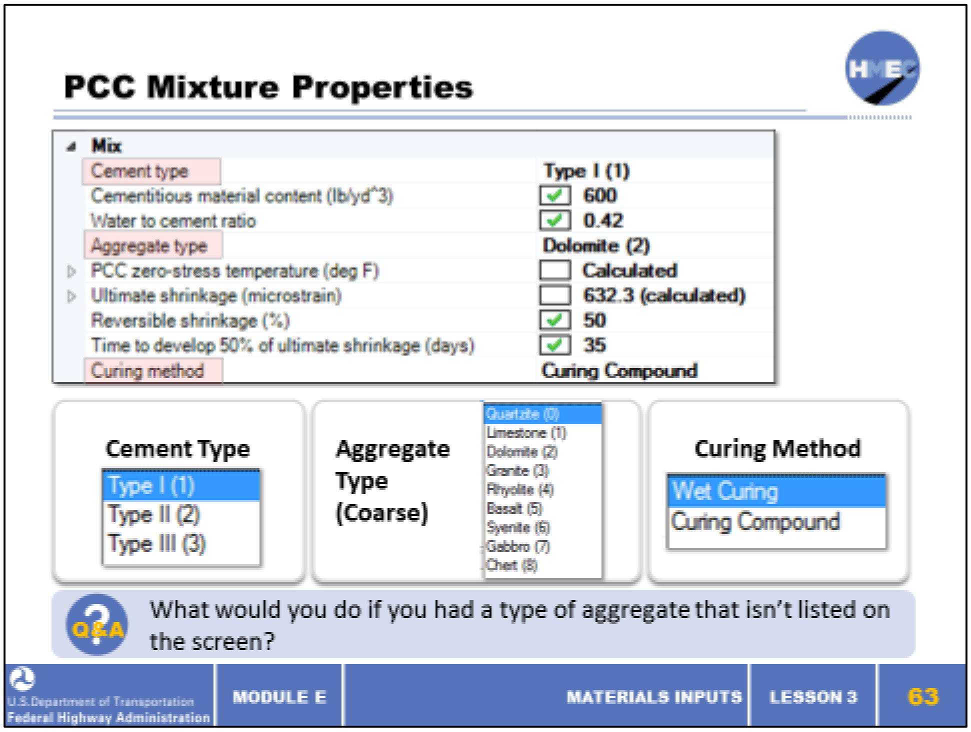
Slide 63



PCC Mixture Properties

Mix

Cement type	Type I (1)
Cementitious material content (lb/yd^3)	☑ 600
Water to cement ratio	☑ 0.42
Aggregate type	Dolomite (2)
▷ PCC zero-stress temperature (deg F)	☐ Calculated
▷ Ultimate shrinkage (microstrain)	☐ 632.3 (calculated)
Reversible shrinkage (%)	☑ 50
Time to develop 50% of ultimate shrinkage (days)	☑ 35
Curing method	Curing Compound

Cement Type

- Type I (1)
- Type II (2)
- Type III (3)

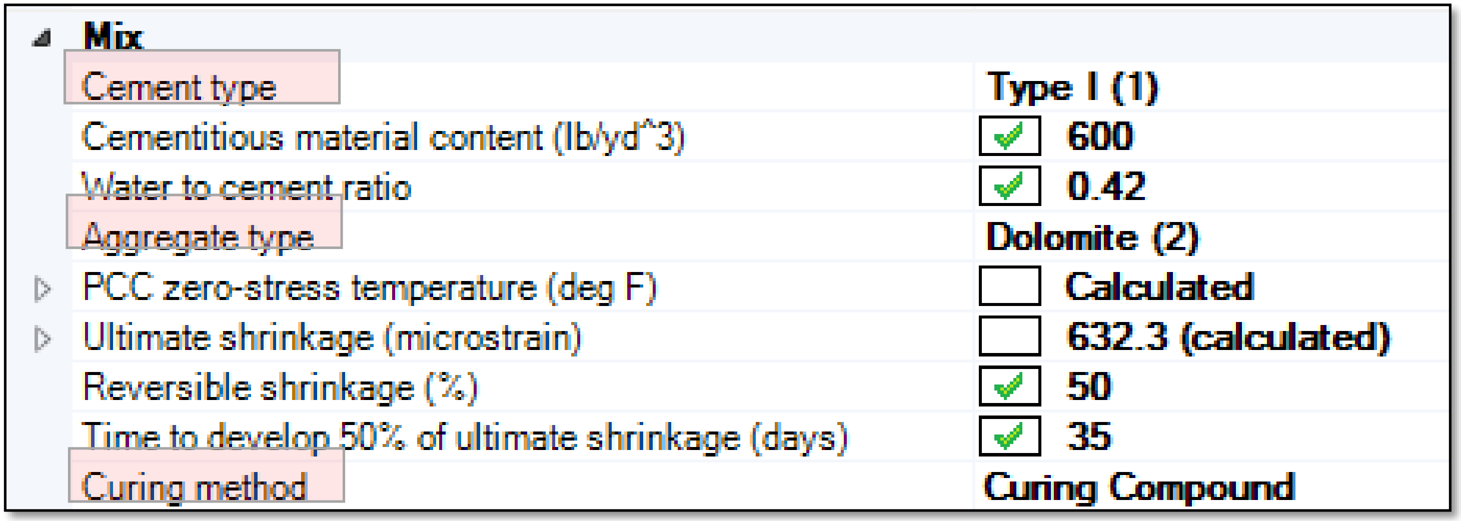
Aggregate Type (Coarse)

- Quartzite (0)
- Limestone (1)
- Dolomite (2)
- Granite (3)
- Rhyolite (4)
- Basalt (5)
- Syenite (6)
- Gabbro (7)
- Chert (8)

Curing Method

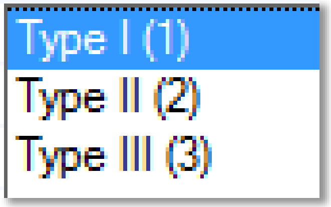
- Wet Curing
- Curing Compound

Q&A What would you do if you had a type of aggregate that isn't listed on the screen?



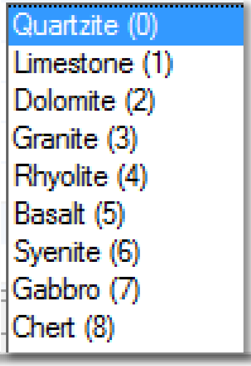
Mix		
Cement type		Type I (1)
Cementitious material content (lb/yd^3)	☑	600
Water to cement ratio	☑	0.42
Aggregate type		Dolomite (2)
PCC zero-stress temperature (deg F)	☐	Calculated
Ultimate shrinkage (microstrain)	☐	632.3 (calculated)
Reversible shrinkage (%)	☑	50
Time to develop 50% of ultimate shrinkage (days)	☑	35
Curing method		Curing Compound

Cement Type



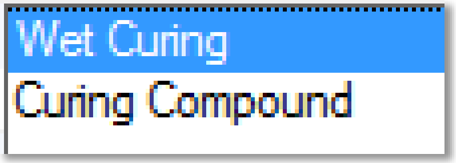
- Type I (1)
- Type II (2)
- Type III (3)

Aggregate Type (Coarse)



- Quartzite (0)
- Limestone (1)
- Dolomite (2)
- Granite (3)
- Rhyolite (4)
- Basalt (5)
- Syenite (6)
- Gabbro (7)
- Chert (8)

Curing Method



- Wet Curing
- Curing Compound

The main three inputs for the PCC mixes include the cement type, aggregate type, and curing method proposed.

The cement type and coarse aggregate type will influence the CTE, as shown by a researcher at the University of Arkansas and FHWA.

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Slide 64

Red Flag: What About Your State?

- Where do you foresee conflicts between the concrete mix specifications and the types of inputs required by Pavement ME Design?
- What level of risk would result due to how the specifications versus the inputs compare?

Q&A Consider your State and answer the questions on this screen.

- Where do you foresee conflicts between the concrete mix specifications and the types of inputs required by Pavement ME Design?
- What level of risk would result due to how the specifications versus the inputs compare?

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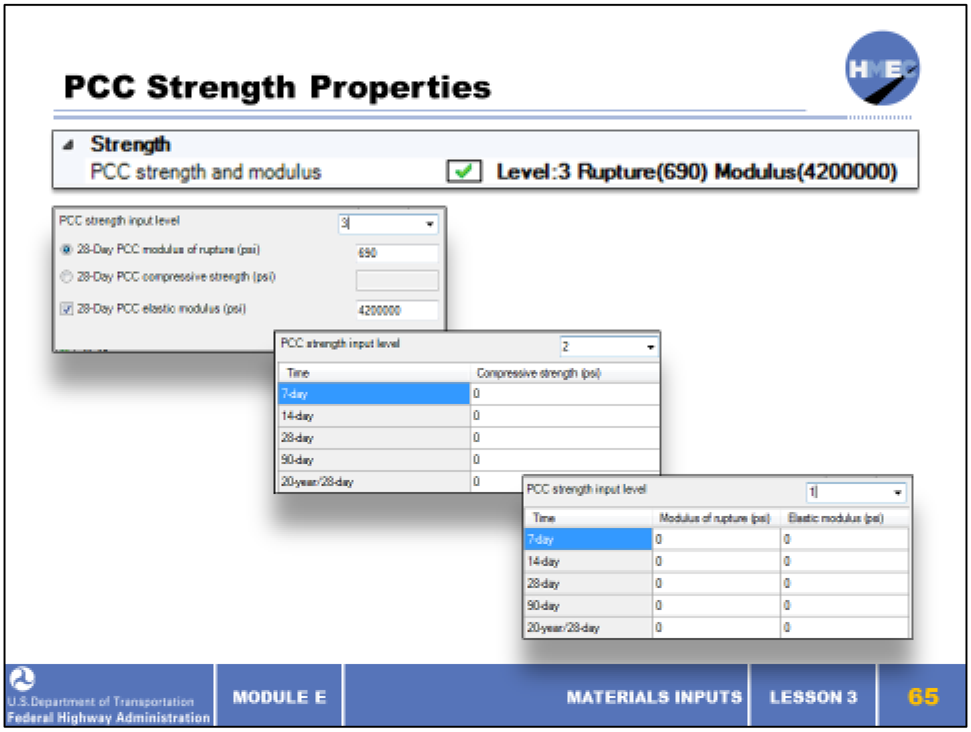
Slide 65



PCC Strength Properties

Strength

PCC strength and modulus ✓ **Level:3 Rupture(690) Modulus(4200000)**

PCC strength input level: 3

● 28-Day PCC modulus of rupture (psi): 690

○ 28-Day PCC compressive strength (psi):

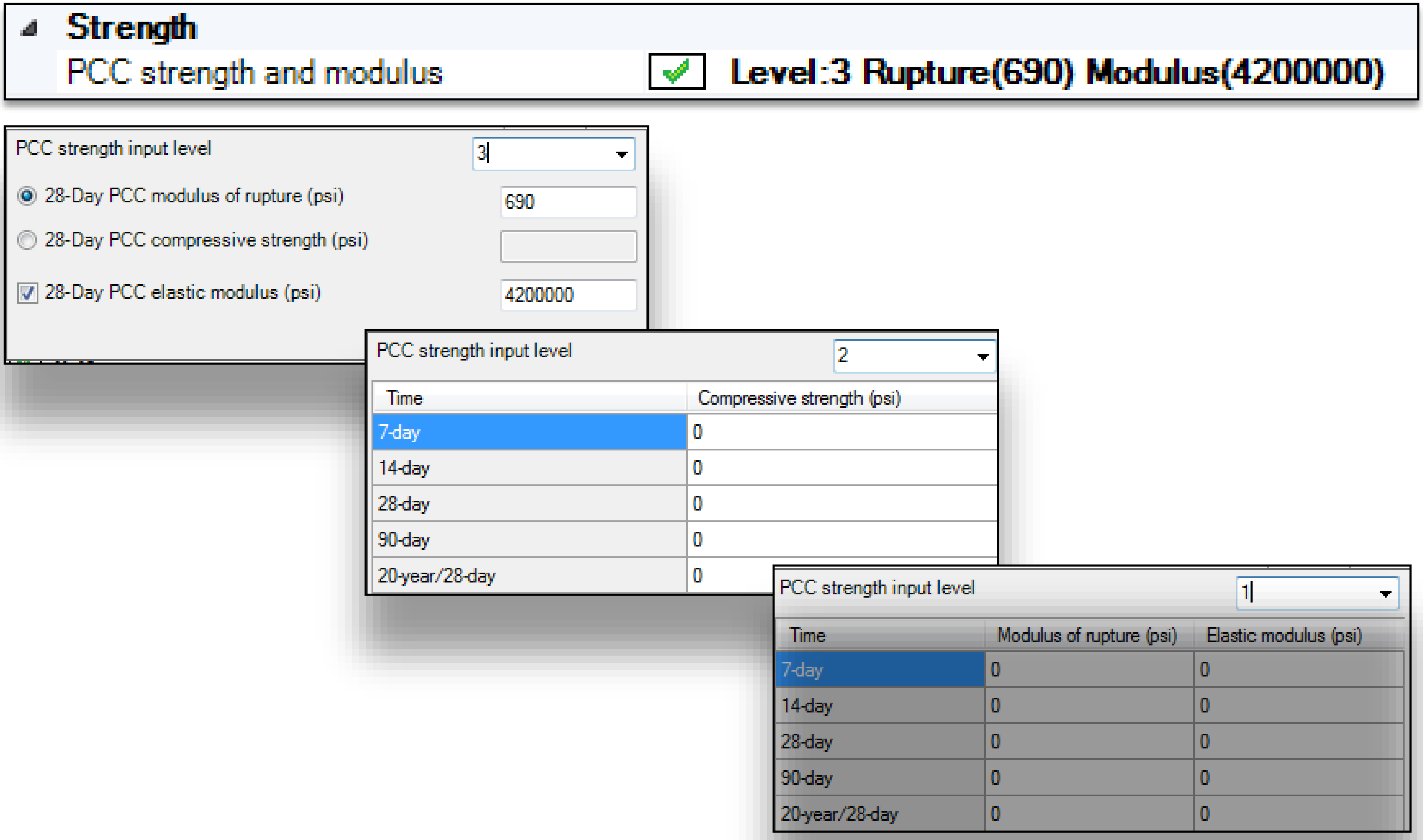
☑ 28-Day PCC elastic modulus (psi): 4200000

PCC strength input level: 2

Time	Compressive strength (psi)
7-day	0
14-day	0
28-day	0
90-day	0
20-year/28-day	0

PCC strength input level: 1

Time	Modulus of rupture (psi)	Elastic modulus (psi)
7-day	0	0
14-day	0	0
28-day	0	0
90-day	0	0
20-year/28-day	0	0



Strength

PCC strength and modulus ✓ **Level:3 Rupture(690) Modulus(4200000)**

PCC strength input level: 3

● 28-Day PCC modulus of rupture (psi): 690

○ 28-Day PCC compressive strength (psi):

☑ 28-Day PCC elastic modulus (psi): 4200000

PCC strength input level: 2

Time	Compressive strength (psi)
7-day	0
14-day	0
28-day	0
90-day	0
20-year/28-day	0

PCC strength input level: 1

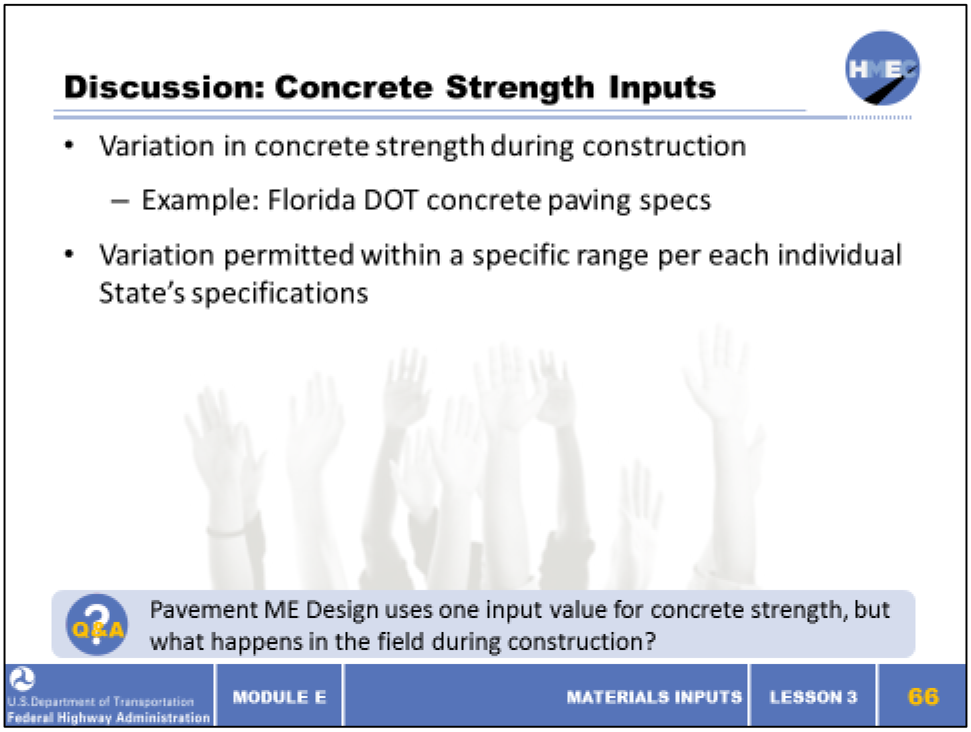
Time	Modulus of rupture (psi)	Elastic modulus (psi)
7-day	0	0
14-day	0	0
28-day	0	0
90-day	0	0
20-year/28-day	0	0

Note that the 20-year/28-day value may be something that you do not have. It is a long-term data from some sort of field testing. If you do not have any information on your moduli after 20 years in service, then the recommended values for the 20-year/28-day ratios are provided in the NCHRP 1-37A report Part 2 Design Inputs.

Chapter 2 Material Characterization include:

- For MOE, the max value for 20-year/28-day is 1.20.
- For compressive strength, the max value for 20-year/28-day is 1.35.
- For MOR, the max value for 20-year/28-day is 1.20.

Slide 66



Discussion: Concrete Strength Inputs

- Variation in concrete strength during construction
  - Example: Florida DOT concrete paving specs
- Variation permitted within a specific range per each individual State's specifications

Q&A Pavement ME Design uses one input value for concrete strength, but what happens in the field during construction?

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The variation should be represented by representative samples observed in the particular state DOT's specification using average values from the field data. This is an important point in that specification value could be much lower than what has been constructed in the field and the materials engineers would need to know and give this information to the designers to do a longer-lasting pavement design. Unless a DOT has historical data, a designer would not know what values to use. Therefore the best avenue may be to use the minimum design strength. In a design-build situation, there would be more control over what the contractor is going to produce ahead of time, and the variation would be expected to be much lower in materials samples.

The reality is that there is variation in concrete strength during construction (e.g., the Florida DOT concrete paving specs allow for a minimum 28-day compressive strength between 3,000 and 4,400 psi), which is permitted within a specific range per each individual State's specifications. For initial design, the user should be specifying the design strength, not using what the contractor actually provides, unless this is used to compute PRS pay factors or for forensic purposes.

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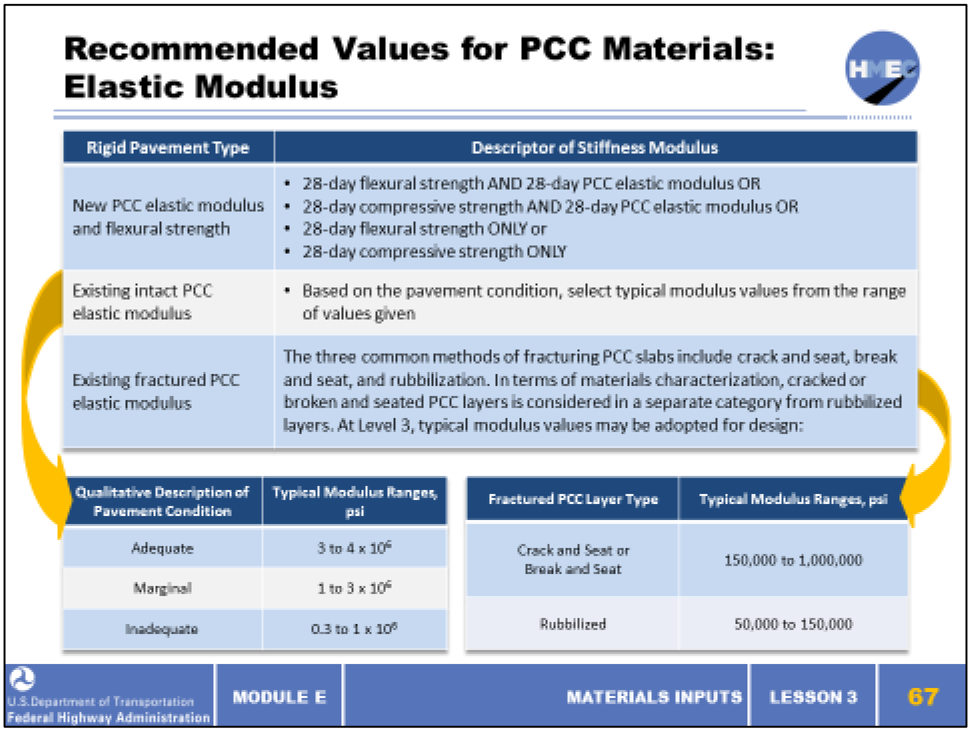
Slide 67



Recommended Values for PCC Materials: Elastic Modulus

Rigid Pavement Type	Descriptor of Stiffness Modulus
New PCC elastic modulus and flexural strength	• 28-day flexural strength AND 28-day PCC elastic modulus OR • 28-day compressive strength AND 28-day PCC elastic modulus OR • 28-day flexural strength ONLY or • 28-day compressive strength ONLY
Existing intact PCC elastic modulus	• Based on the pavement condition, select typical modulus values from the range of values given
Existing fractured PCC elastic modulus	The three common methods of fracturing PCC slabs include crack and seat, break and seat, and rubbilization. In terms of materials characterization, cracked or broken and seated PCC layers is considered in a separate category from rubbilized layers. At Level 3, typical modulus values may be adopted for design:

Qualitative Description of Pavement Condition	Typical Modulus Ranges, psi
Adequate	3 to 4×10^6
Marginal	1 to 3×10^6
Inadequate	0.3 to 1×10^6

Fractured PCC Layer Type	Typical Modulus Ranges, psi
Crack and Seat or Break and Seat	150,000 to 1,000,000
Rubbilized	50,000 to 150,000

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This information gives participants values to start within the absence of testing equipment and Level 1 inputs.

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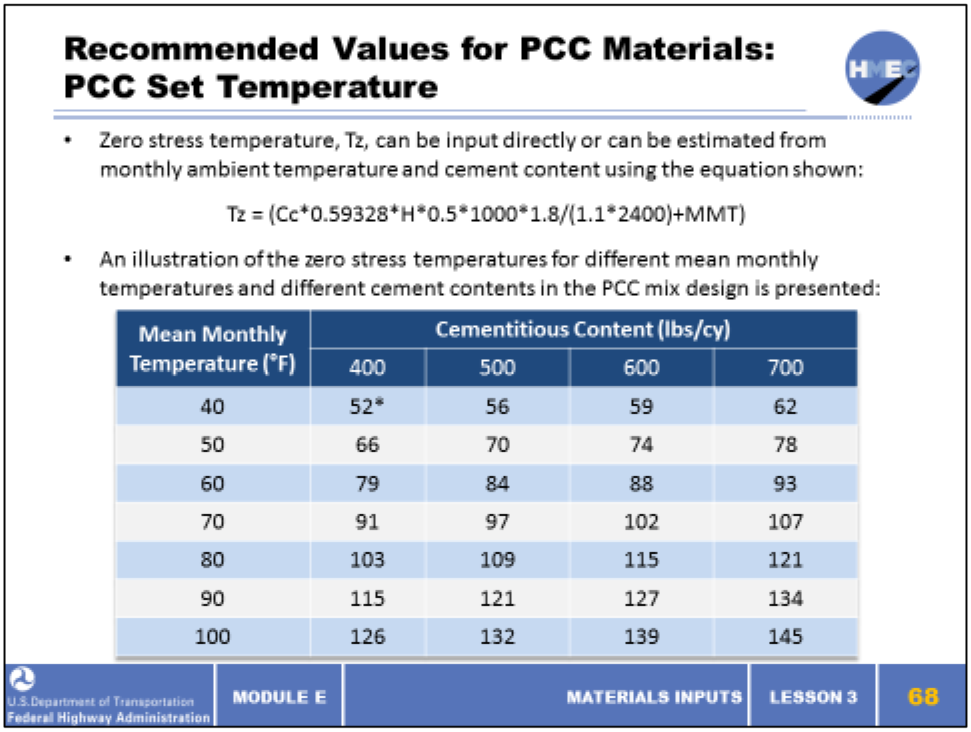
Slide 68



Recommended Values for PCC Materials: PCC Set Temperature

- Zero stress temperature, Tz, can be input directly or can be estimated from monthly ambient temperature and cement content using the equation shown:

$$Tz = (Cc*0.59328*H*0.5*1000*1.8/(1.1*2400)+MMT)$$

- An illustration of the zero stress temperatures for different mean monthly temperatures and different cement contents in the PCC mix design is presented:

Mean Monthly Temperature (°F)	Cementitious Content (lbs/cy)			
	400	500	600	700
40	52*	56	59	62
50	66	70	74	78
60	79	84	88	93
70	91	97	102	107
80	103	109	115	121
90	115	121	127	134
100	126	132	139	145

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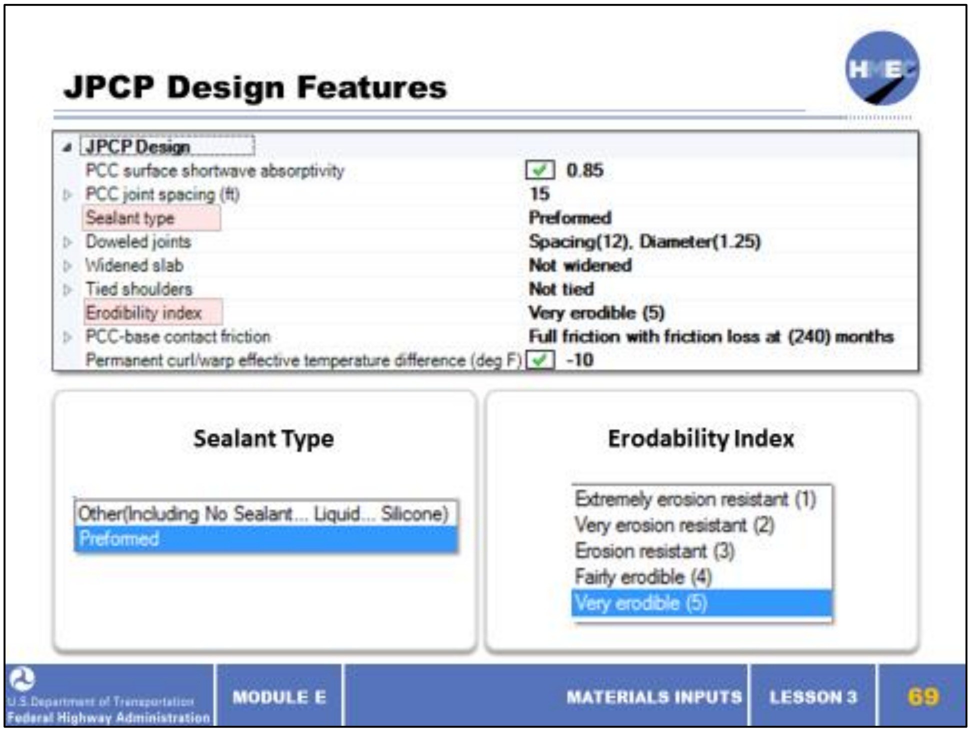
$T_z = (C_c*0.59328*H*0.5*1000*1.8/(1.1*2400)+MMT)$
Where:
T_z = PCC set temperature (allowable range: 70 to 212 °F)
C_C = Cementitious content, lb/yd^3
H = -0.0787+0.007*MMT-0.00003*MMT^2
MMT = Mean monthly temperature for month of construction, °F

Slide 69



JPCP Design Features

JPCP Design

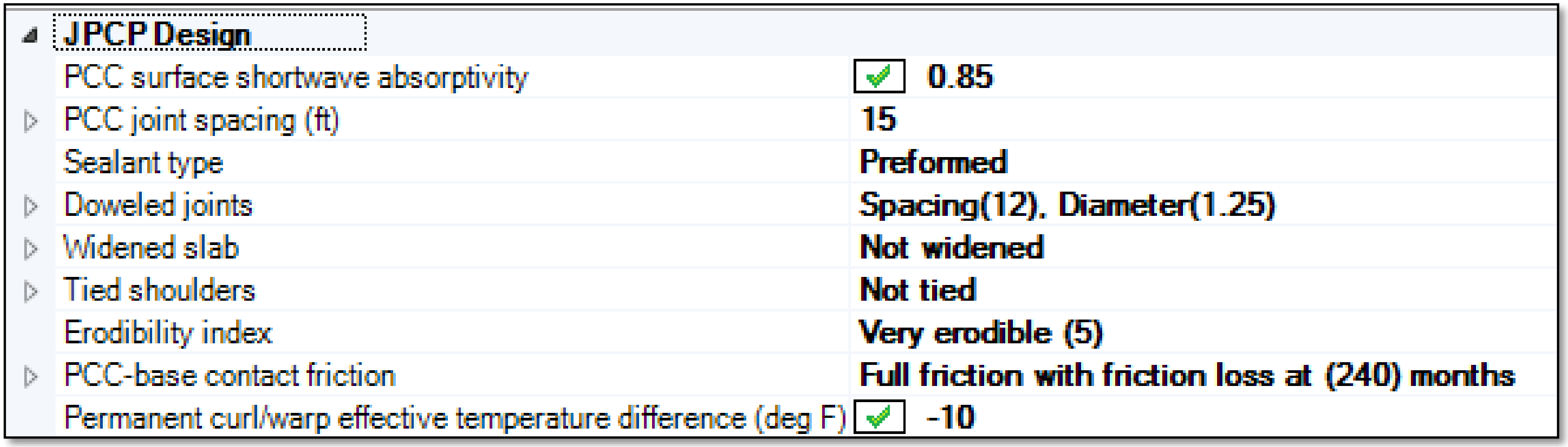
PCC surface shortwave absorptivity	☑ 0.85
PCC joint spacing (ft)	15
Sealant type	Preformed
Doweled joints	Spacing(12), Diameter(1.25)
Widened slab	Not widened
Tied shoulders	Not tied
Erodibility index	Very erodible (5)
PCC-base contact friction	Full friction with friction loss at (240) months
Permanent curl/warp effective temperature difference (deg F)	☑ -10

Sealant Type

- Other(Including No Sealant... Liquid... Silicone)
- Preformed

Erodability Index

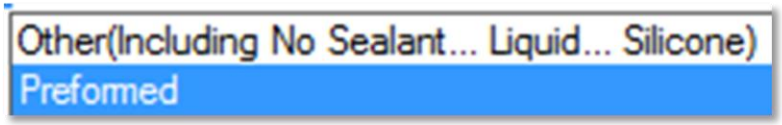
- Extremely erosion resistant (1)
- Very erosion resistant (2)
- Erosion resistant (3)
- Fairly erodible (4)
- Very erodible (5)



JPCP Design

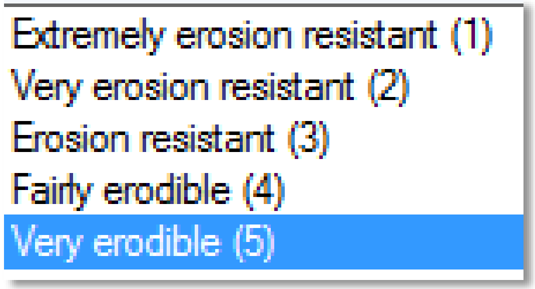
PCC surface shortwave absorptivity	✓ 0.85
PCC joint spacing (ft)	15
Sealant type	Preformed
Doweled joints	Spacing(12), Diameter(1.25)
Widened slab	Not widened
Tied shoulders	Not tied
Erodibility index	Very erodible (5)
PCC-base contact friction	Full friction with friction loss at (240) months
Permanent curl/warp effective temperature difference (deg F)	✓ -10

Sealant Type



Other(Including No Sealant... Liquid... Silicone)
Preformed

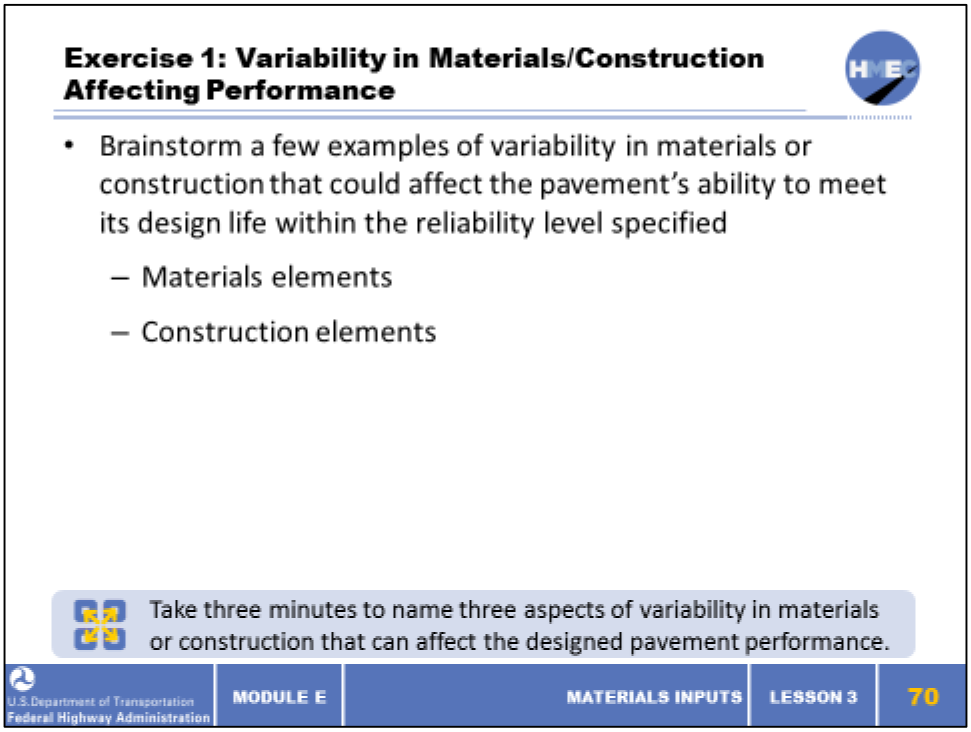
Erodibility Index



Extremely erosion resistant (1)
Very erosion resistant (2)
Erosion resistant (3)
Fairly erodible (4)
Very erodible (5)

The design feature inputs for JPCP include key parameters such as the joint spacing, sealant type, presence of widened slab and dowels, shoulder ties, and erodibility index.

Slide 70



Exercise 1: Variability in Materials/Construction Affecting Performance

- Brainstorm a few examples of variability in materials or construction that could affect the pavement's ability to meet its design life within the reliability level specified
  - Materials elements
  - Construction elements

Take three minutes to name three aspects of variability in materials or construction that can affect the designed pavement performance.

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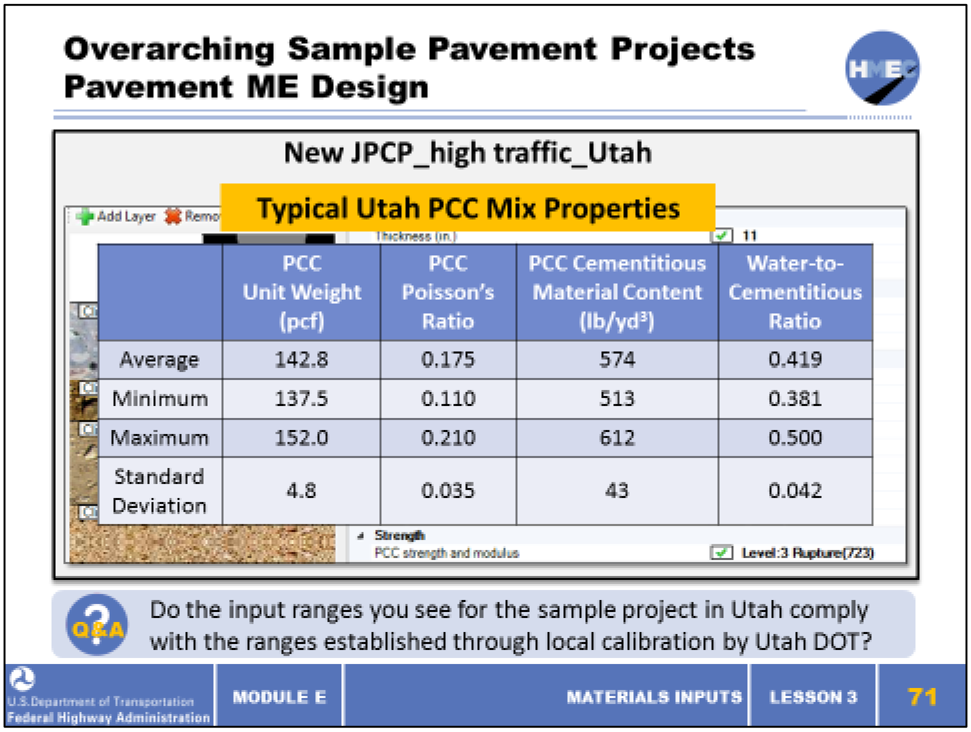
MODULE E
MATERIALS INPUTS
LESSON 3
70

Slide 71



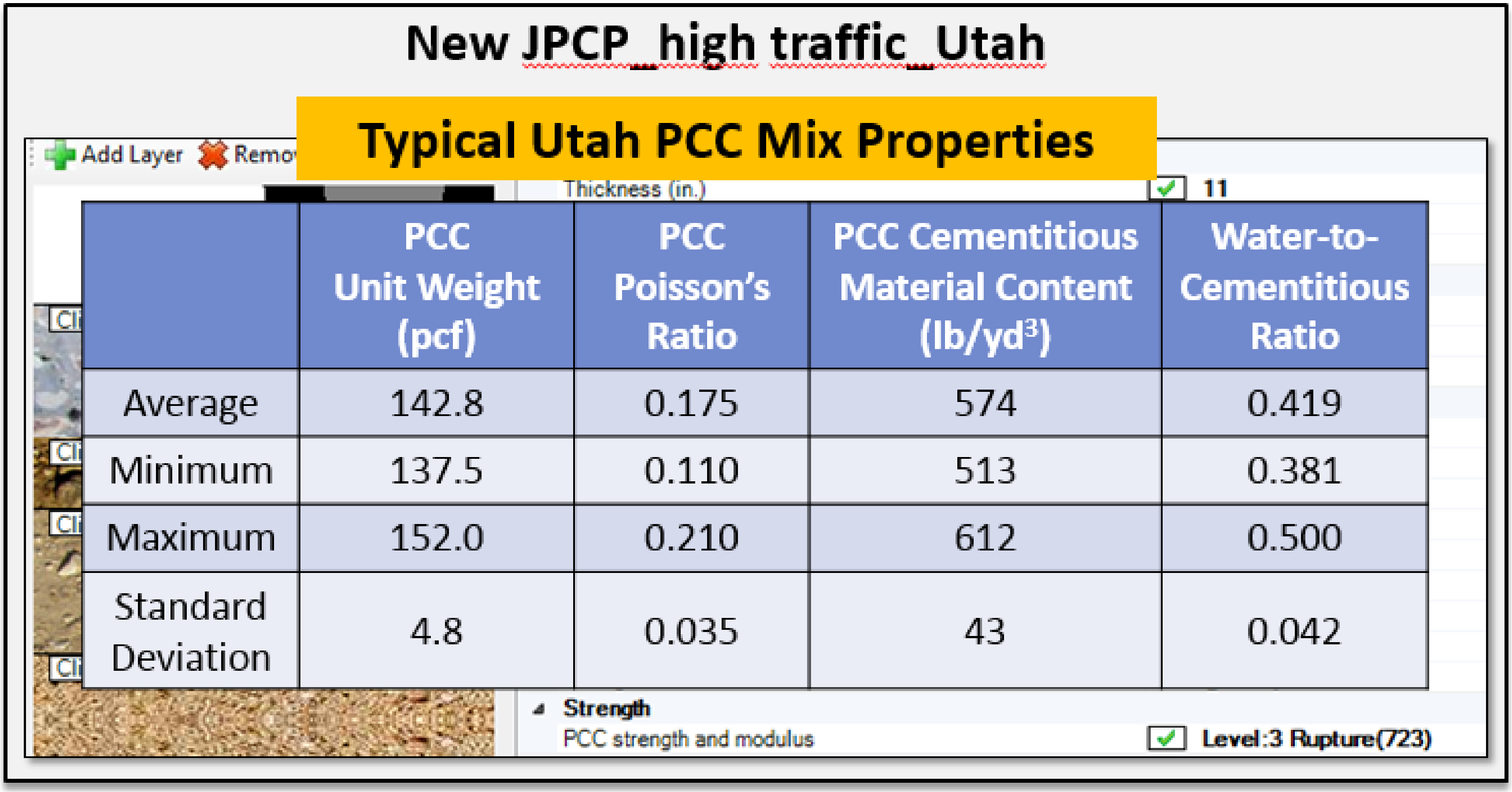
Overarching Sample Pavement Projects Pavement ME Design

New JPCP_high traffic_Utah

Typical Utah PCC Mix Properties

	PCC Unit Weight (pcf)	PCC Poisson's Ratio	PCC Cementitious Material Content (lb/yd³)	Water-to-Cementitious Ratio
Average	142.8	0.175	574	0.419
Minimum	137.5	0.110	513	0.381
Maximum	152.0	0.210	612	0.500
Standard Deviation	4.8	0.035	43	0.042

Q&A Do the input ranges you see for the sample project in Utah comply with the ranges established through local calibration by Utah DOT?



New JPCP_high traffic_Utah

Typical Utah PCC Mix Properties

Thickness (in.) ☑ 11

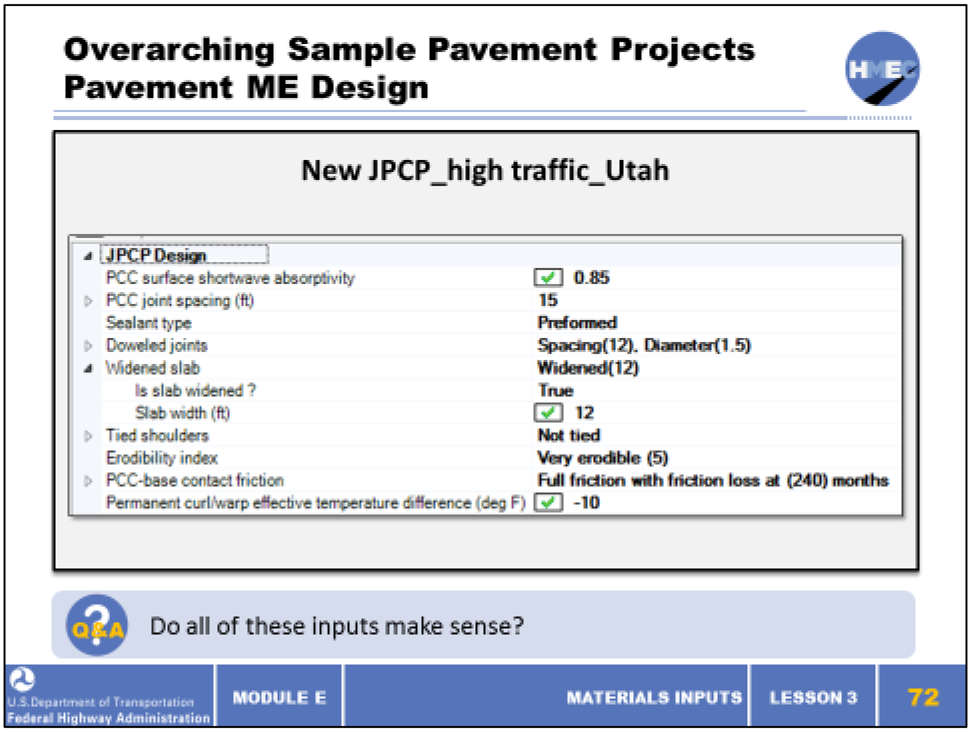
	PCC Unit Weight (pcf)	PCC Poisson's Ratio	PCC Cementitious Material Content (lb/yd^3)	Water-to-Cementitious Ratio
Average	142.8	0.175	574	0.419
Minimum	137.5	0.110	513	0.381
Maximum	152.0	0.210	612	0.500
Standard Deviation	4.8	0.035	43	0.042

Strength

PCC strength and modulus ☑ Level:3 Rupture(723)

Level 3 inputs for rigid pavement PCC properties are shown.

Slide 72



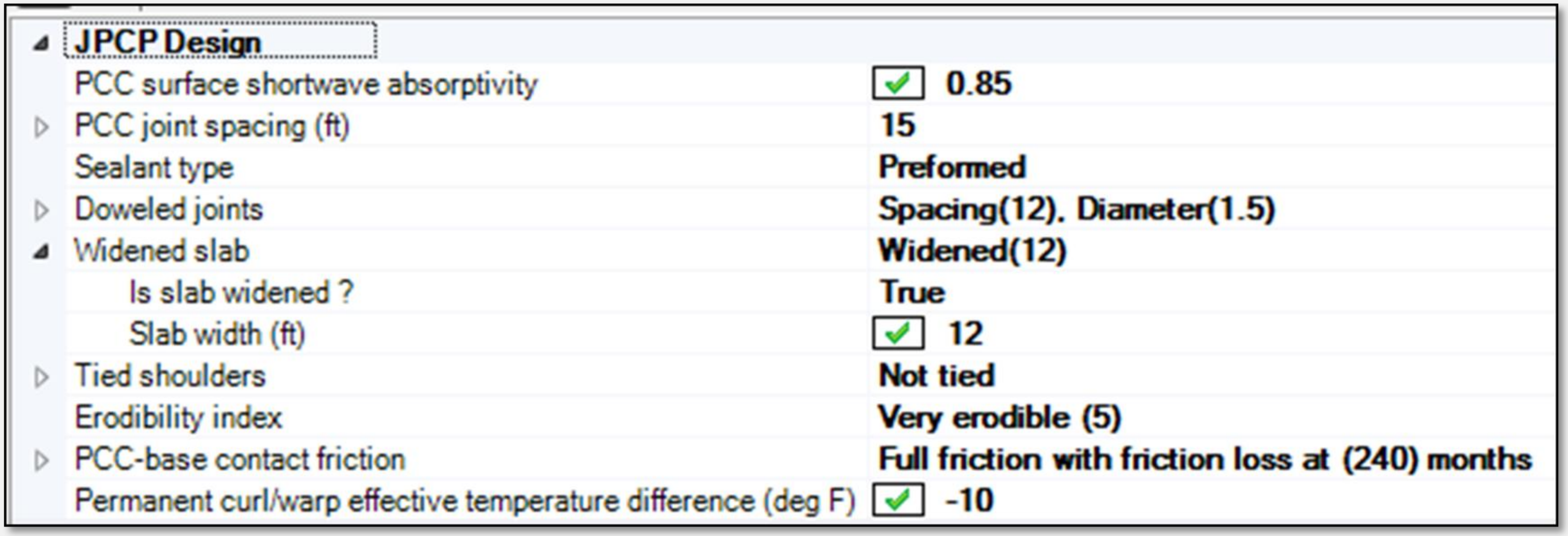
Overarching Sample Pavement Projects Pavement ME Design

New JPCP_high traffic_Utah

JPCP Design	
PCC surface shortwave absorptivity	☑ 0.85
PCC joint spacing (ft)	15
Sealant type	Preformed
Doweled joints	Spacing(12), Diameter(1.5)
Widened slab	Widened(12)
Is slab widened ?	True
Slab width (ft)	☑ 12
Tied shoulders	Not tied
Erodibility index	Very erodible (5)
PCC-base contact friction	Full friction with friction loss at (240) months
Permanent curl/warp effective temperature difference (deg F)	☑ -10

Q&A Do all of these inputs make sense?

New JPCP_high traffic_Utah



JPCP Design

PCC surface shortwave absorptivity	☑ 0.85
PCC joint spacing (ft)	15
Sealant type	Preformed
Doweled joints	Spacing(12), Diameter(1.5)
Widened slab	Widened(12)
Is slab widened ?	True
Slab width (ft)	☑ 12
Tied shoulders	Not tied
Erodibility index	Very erodible (5)
PCC-base contact friction	Full friction with friction loss at (240) months
Permanent curl/warp effective temperature difference (deg F)	☑ -10

The design properties for the sample pavement design project in Utah are shown and will be demonstrated as part of Lesson 5.

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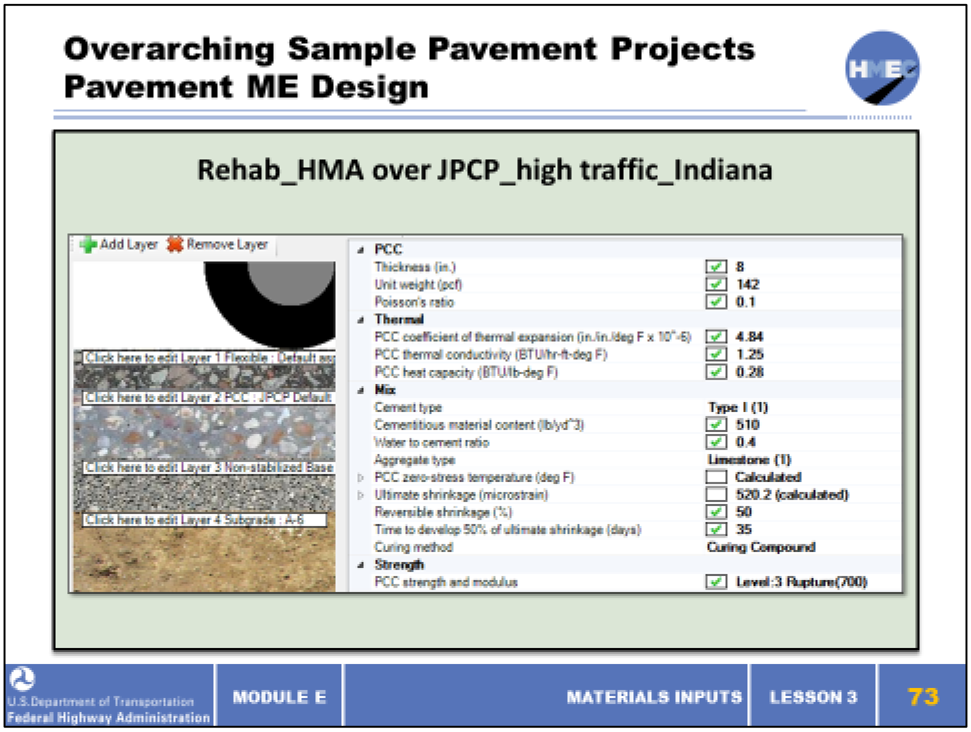

Overarching Sample Pavement Projects Pavement ME Design

Rehab_HMA over JPCP_high traffic_Indiana

Add Layer
Remove Layer
Click here to edit Layer 1 Flexible : Default asp
Click here to edit Layer 2 PCC : JPCP Default
Click here to edit Layer 3 Non-stabilized Base
Click here to edit Layer 4 Subgrade : A-6

PCC		
Thickness (in.)	☑	8
Unit weight (pcf)	☑	142
Poisson's ratio	☑	0.1
Thermal		
PCC coefficient of thermal expansion (in./in./deg F x 10^-6)	☑	4.84
PCC thermal conductivity (BTU/hr-ft-deg F)	☑	1.25
PCC heat capacity (BTU/lb-deg F)	☑	0.28
Mix		
Cement type		Type I (1)
Cementitious material content (lb/yd^3)	☑	510
Water to cement ratio	☑	0.4
Aggregate type		Limestone (1)
PCC zero-stress temperature (deg F)	☐	Calculated
Ultimate shrinkage (microstrain)	☐	520.2 (calculated)
Reversible shrinkage (%)	☑	50
Time to develop 50% of ultimate shrinkage (days)	☑	35
Curing method		Curing Compound
Strength		
PCC strength and modulus	☑	Level:3 Rupture(700)

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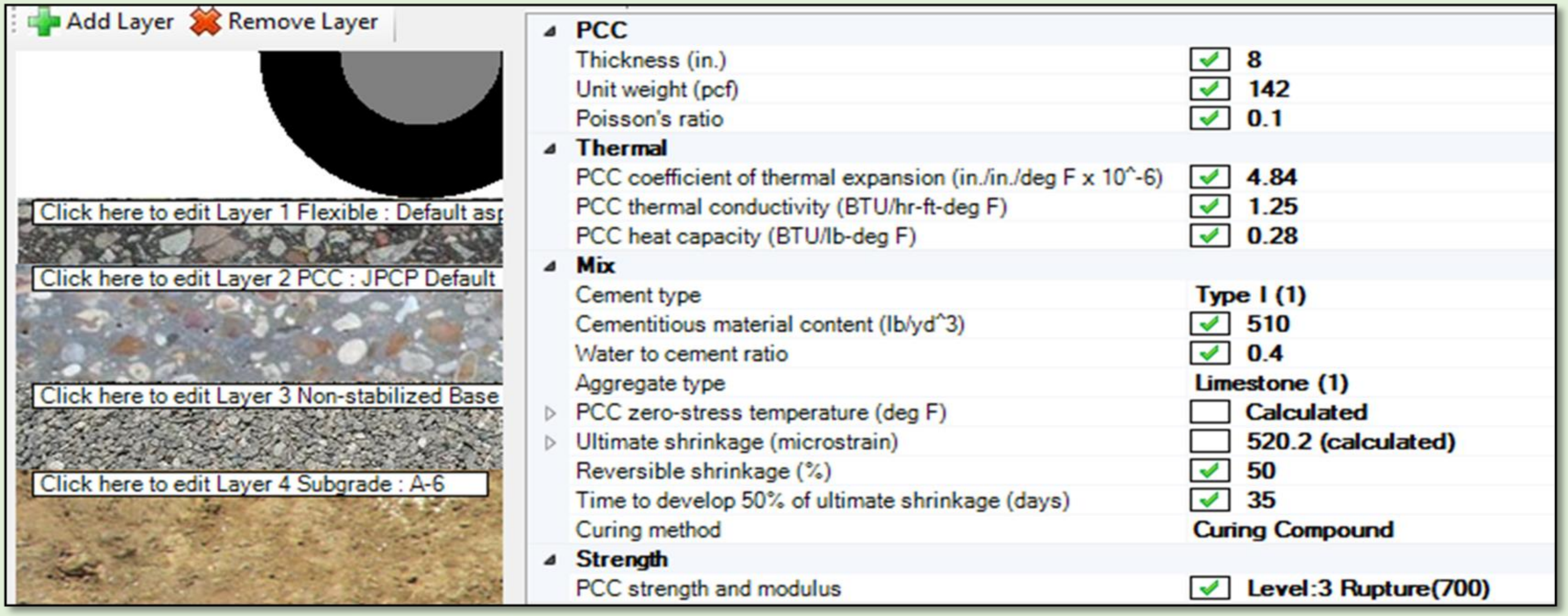
MODULE E

MATERIALS INPUTS

LESSON 3

73

Rehab_HMA over JPCP_high traffic_Indiana


Add Layer
Remove Layer
Click here to edit Layer 1 Flexible : Default asp
Click here to edit Layer 2 PCC : JPCP Default
Click here to edit Layer 3 Non-stabilized Base
Click here to edit Layer 4 Subgrade : A-6

PCC		
Thickness (in.)	☑	**8**
Unit weight (pcf)	☑	**142**
Poisson's ratio	☑	**0.1**
Thermal		
PCC coefficient of thermal expansion (in./in./deg F x 10^-6)	☑	**4.84**
PCC thermal conductivity (BTU/hr-ft-deg F)	☑	**1.25**
PCC heat capacity (BTU/lb-deg F)	☑	**0.28**
Mix		
Cement type		**Type I (1)**
Cementitious material content (lb/yd^3)	☑	**510**
Water to cement ratio	☑	**0.4**
Aggregate type		**Limestone (1)**
PCC zero-stress temperature (deg F)	☐	**Calculated**
Ultimate shrinkage (microstrain)	☐	**520.2 (calculated)**
Reversible shrinkage (%)	☑	**50**
Time to develop 50% of ultimate shrinkage (days)	☑	**35**
Curing method		**Curing Compound**
Strength		
PCC strength and modulus	☑	**Level:3 Rupture(700)**

One can see that the PCC properties are exactly the same as in the case of the new rigid pavement. A designer would have to access construction and plant records from the original PCC construction to get these inputs. FWD or other testing would be used to get a back calculation of the existing pavement's modulus.

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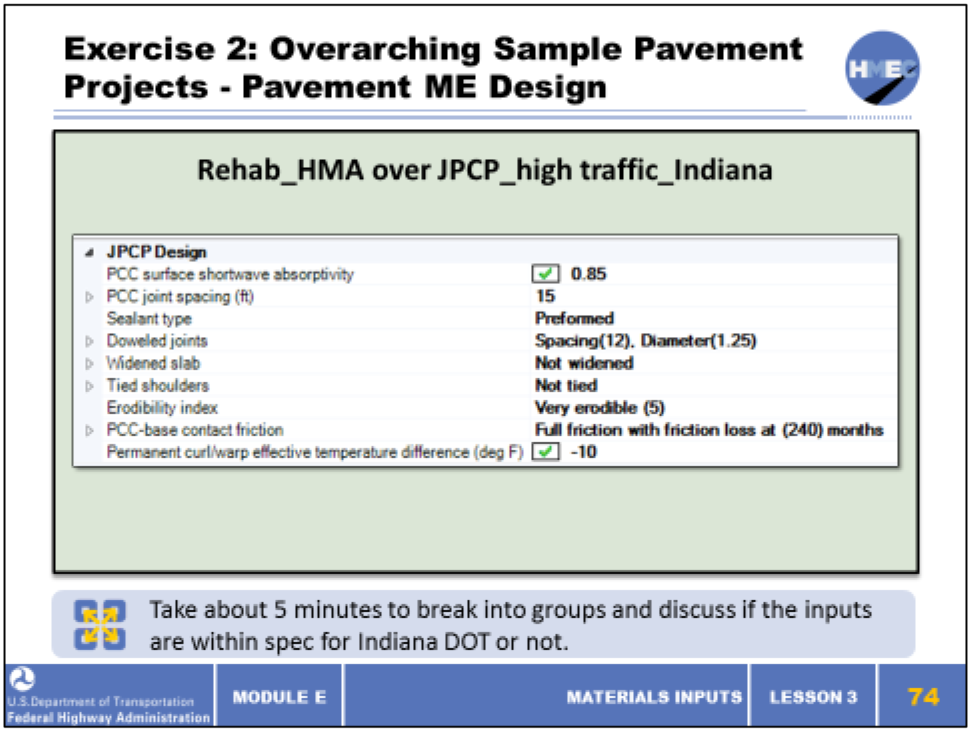

Exercise 2: Overarching Sample Pavement Projects - Pavement ME Design

Rehab_HMA over JPCP_high traffic_Indiana

JPCP Design	
PCC surface shortwave absorptivity	☑ 0.85
PCC joint spacing (ft)	15
Sealant type	Preformed
Doweled joints	Spacing(12), Diameter(1.25)
Widened slab	Not widened
Tied shoulders	Not tied
Erodibility index	Very erodible (5)
PCC-base contact friction	Full friction with friction loss at (240) months
Permanent curl/warp effective temperature difference (deg F)	☑ -10

Take about 5 minutes to break into groups and discuss if the inputs are within spec for Indiana DOT or not.

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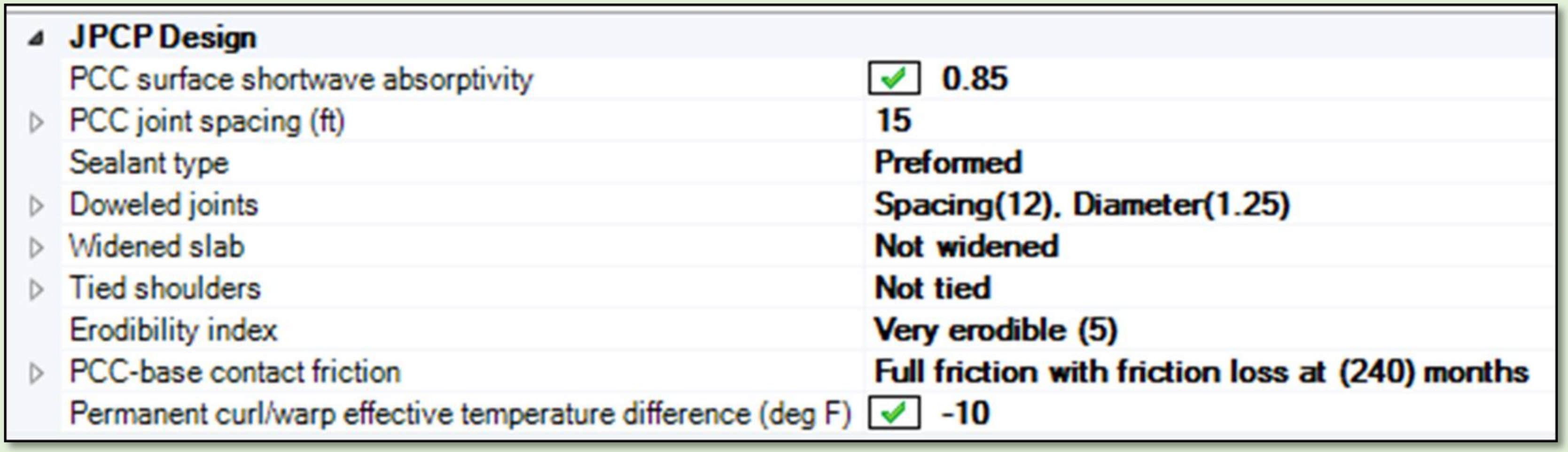
MODULE E
MATERIALS INPUTS
LESSON 3
74

Rehab_HMA over JPCP_high traffic_Indiana



JPCP Design

PCC surface shortwave absorptivity	☑ 0.85
PCC joint spacing (ft)	15
Sealant type	Preformed
Doweled joints	Spacing(12), Diameter(1.25)
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Erodibility index	Very erodible (5)
PCC-base contact friction	Full friction with friction loss at (240) months
Permanent curl/warp effective temperature difference (deg F)	☑ -10

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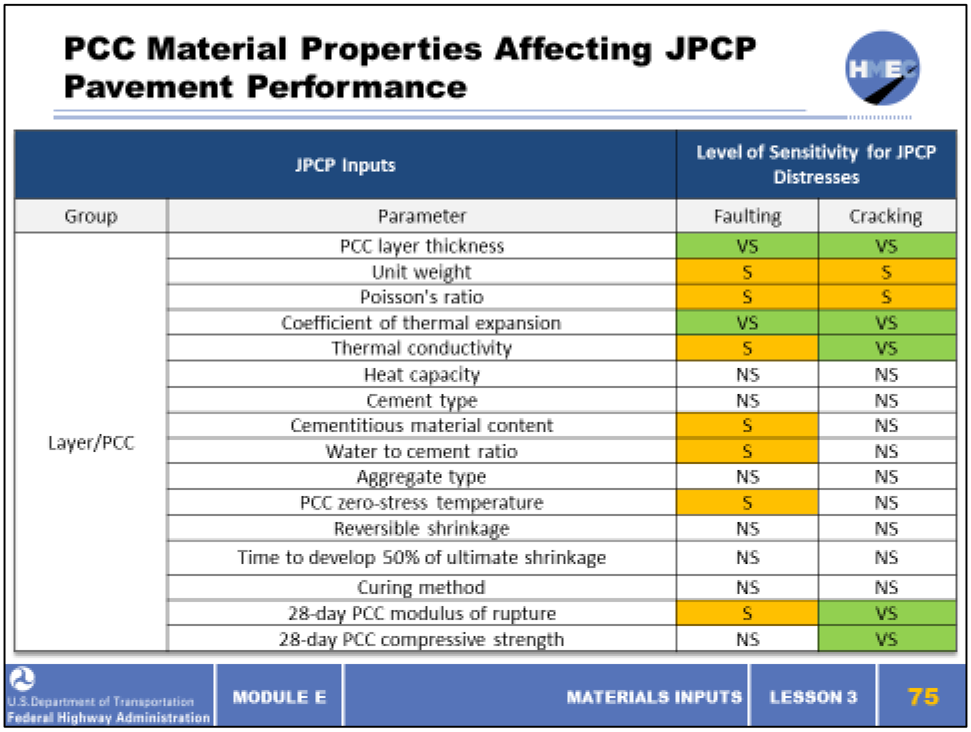

PCC Material Properties Affecting JPCP Pavement Performance

JPCP Inputs		Level of Sensitivity for JPCP Distresses	
Group	Parameter	Faulting	Cracking
Layer/PCC	PCC layer thickness	VS	VS
	Unit weight	S	S
	Poisson's ratio	S	S
	Coefficient of thermal expansion	VS	VS
	Thermal conductivity	S	VS
	Heat capacity	NS	NS
	Cement type	NS	NS
	Cementitious material content	S	NS
	Water to cement ratio	S	NS
	Aggregate type	NS	NS
	PCC zero-stress temperature	S	NS
	Reversible shrinkage	NS	NS
	Time to develop 50% of ultimate shrinkage	NS	NS
	Curing method	NS	NS
	28-day PCC modulus of rupture	S	VS
	28-day PCC compressive strength	NS	VS

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MODULE E

MATERIALS INPUTS

LESSON 3

75

The principal concrete material properties that affect concrete pavement performance include MR, E, and thermal coefficient.

Other sensitive factors include the thickness (which is a pavement design factor, not a materials factor).

Notes on the high sensitivity of the coefficient of thermal expansion, and thermal conductivity: While the predicted pavement performance may be show high sensitivity to some of the parameters, those results should be considered with caution in that the models were calibrated using default values and the actual effects of those parameters on pavement performance are generally unknown.

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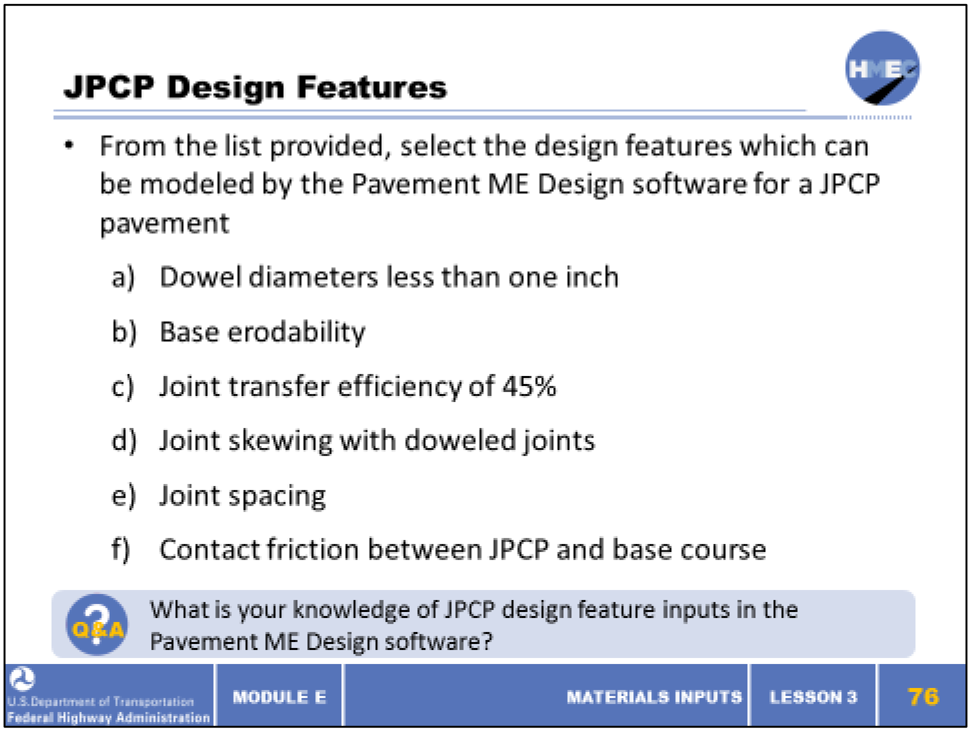
Slide 76



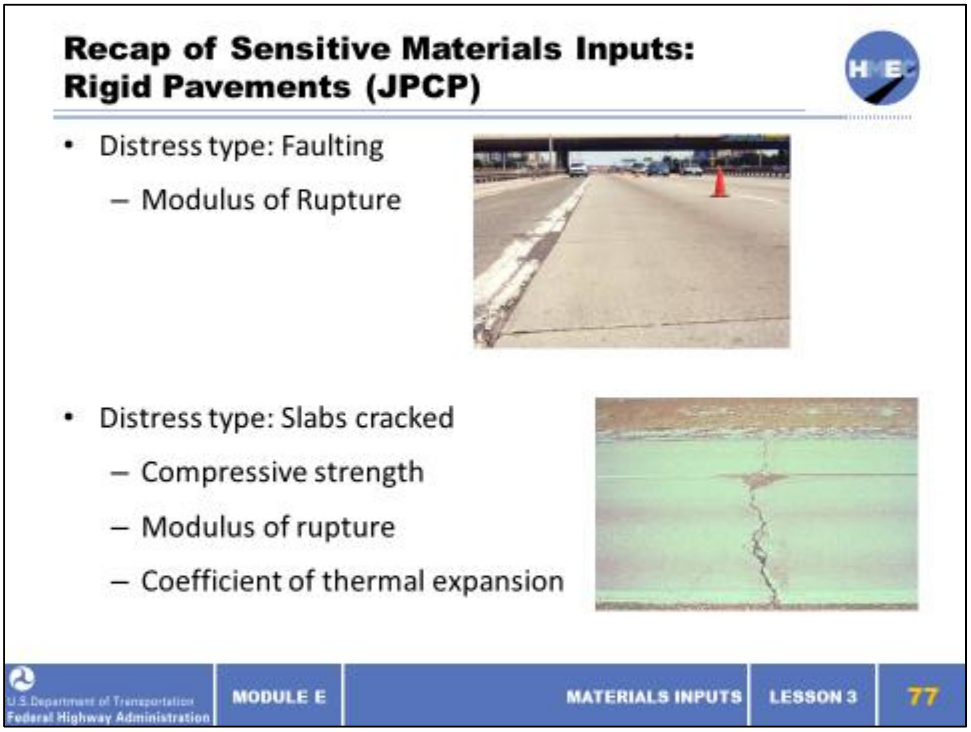
JPCP Design Features

- From the list provided, select the design features which can be modeled by the Pavement ME Design software for a JPCP pavement
  a) Dowel diameters less than one inch
  b) Base erodability
  c) Joint transfer efficiency of 45%
  d) Joint skewing with doweled joints
  e) Joint spacing
  f) Contact friction between JPCP and base course

Q&A What is your knowledge of JPCP design feature inputs in the Pavement ME Design software?

The purpose of the screen is to gauge the participants' post-requisite knowledge. This is a post-knowledge multiple choice question given to the participants before the content is delivered.

Slide 77



Recap of Sensitive Materials Inputs: Rigid Pavements (JPCP)

- Distress type: Faulting
  - Modulus of Rupture
- Distress type: Slabs cracked
  - Compressive strength
  - Modulus of rupture
  - Coefficient of thermal expansion

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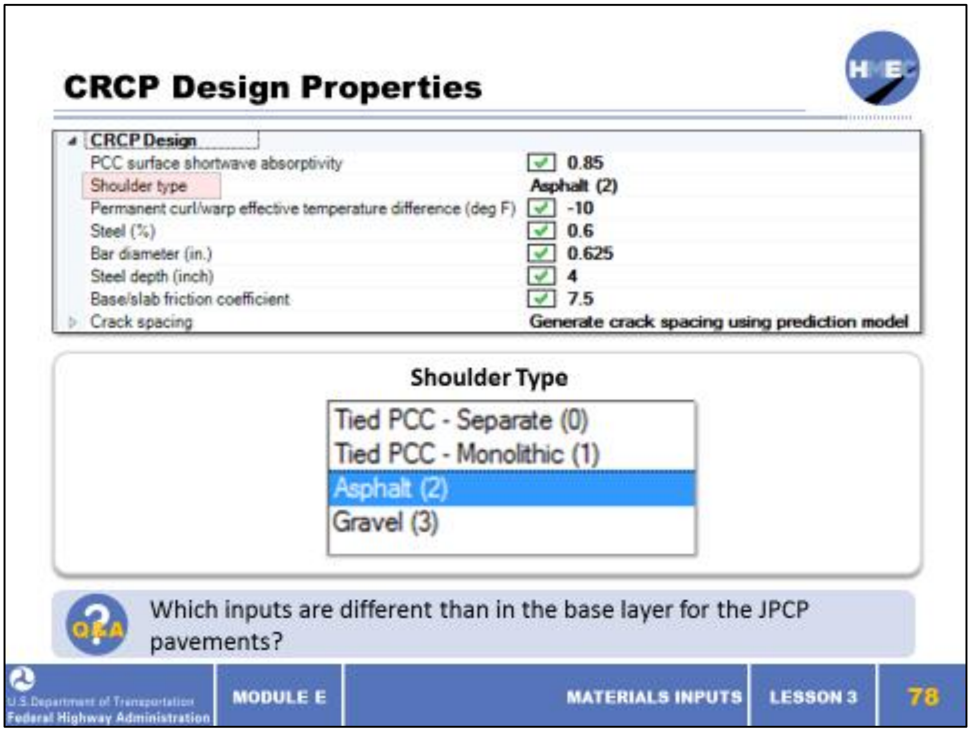
These are the inputs that are most of interest to a pavement designer seeking input from a materials engineer in his/her agency.

Slide 78



CRCP Design Properties

CRCP Design	
PCC surface shortwave absorptivity	☑ 0.85
Shoulder type	Asphalt (2)
Permanent curl/warp effective temperature difference (deg F)	☑ -10
Steel (%)	☑ 0.6
Bar diameter (in.)	☑ 0.625
Steel depth (inch)	☑ 4
Base/slab friction coefficient	☑ 7.5
Crack spacing	Generate crack spacing using prediction model

Shoulder Type

- Tied PCC - Separate (0)
- Tied PCC - Monolithic (1)
- Asphalt (2)
- Gravel (3)

Which inputs are different than in the base layer for the JPCP pavements?

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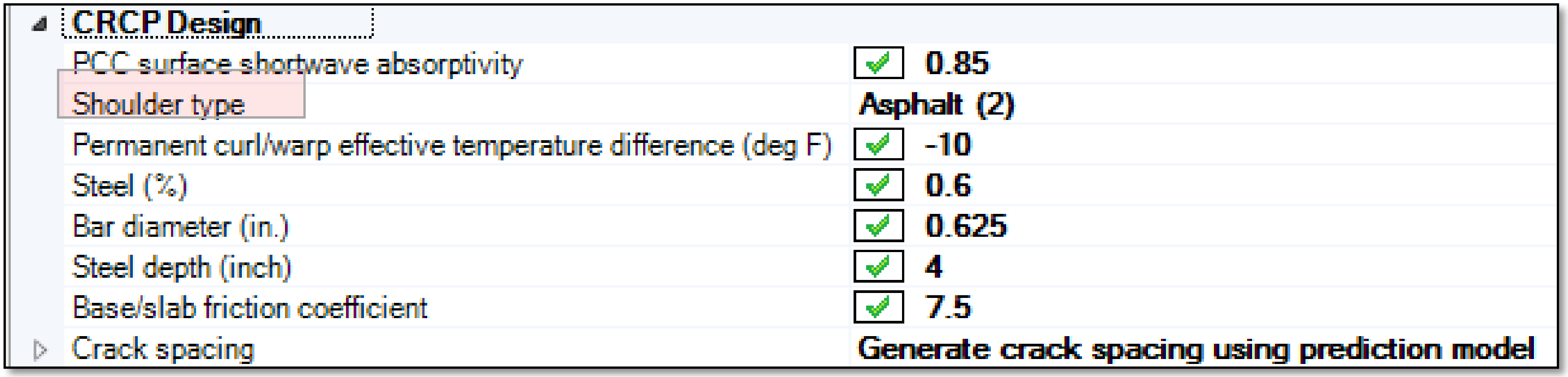
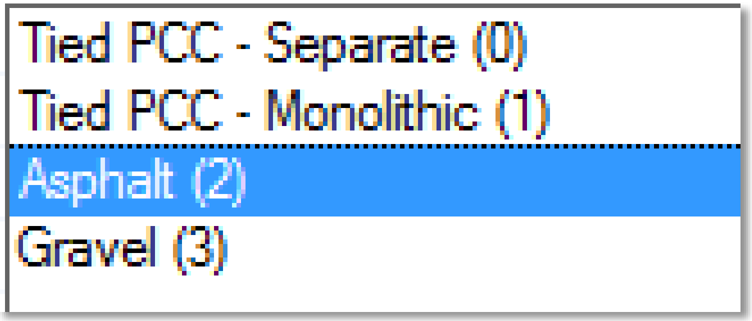
MATERIALS INPUTS
LESSON 3
78



CRCP Design	
PCC surface shortwave absorptivity	☑ 0.85
Shoulder type	**Asphalt (2)**
Permanent curl/warp effective temperature difference (deg F)	☑ -10
Steel (%)	☑ 0.6
Bar diameter (in.)	☑ 0.625
Steel depth (inch)	☑ 4
Base/slab friction coefficient	☑ 7.5
Crack spacing	**Generate crack spacing using prediction model**

Shoulder Type



- Tied PCC - Separate (0)
- Tied PCC - Monolithic (1)
- Asphalt (2)
- Gravel (3)

Additional items include the shoulder type, percentage, and depth of steel in the slab, bar diameter, base/slab friction coefficient, and the crack spacing.

Both JPCP and CRCP can have stabilized bases. The options are always the same as the ones for flex pavements: cement stabilized, lime cement fly ash, lime fly ash, lime stabilized, and soil cement stabilized. However, the base/slab friction coefficient is only an input for CRCP pavements and not for JPCP.

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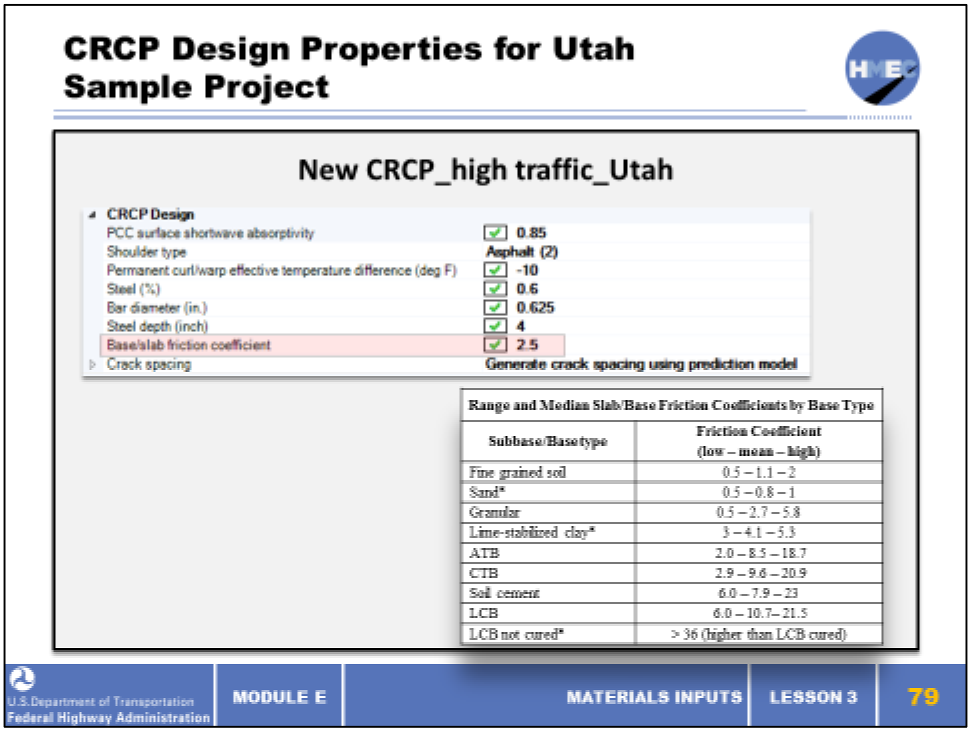


CRCP Design Properties for Utah Sample Project

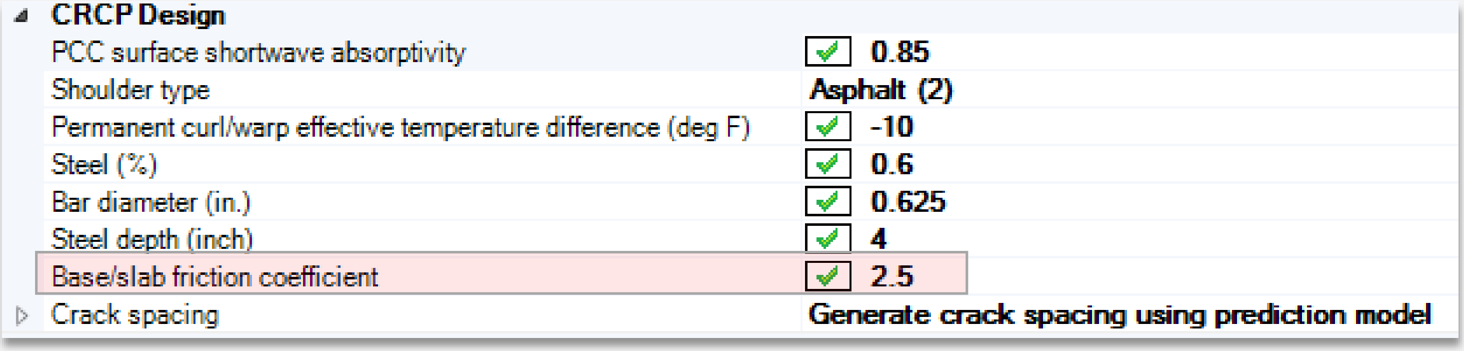
New CRCP_high traffic_Utah

CRCP Design	
PCC surface shortwave absorptivity	☑ 0.85
Shoulder type	Asphalt (2)
Permanent curl/warp effective temperature difference (deg F)	☑ -10
Steel (%)	☑ 0.6
Bar diameter (in.)	☑ 0.625
Steel depth (inch)	☑ 4
Base/slab friction coefficient	☑ 2.5
Crack spacing	Generate crack spacing using prediction model

Range and Median Slab/Base Friction Coefficients by Base Type

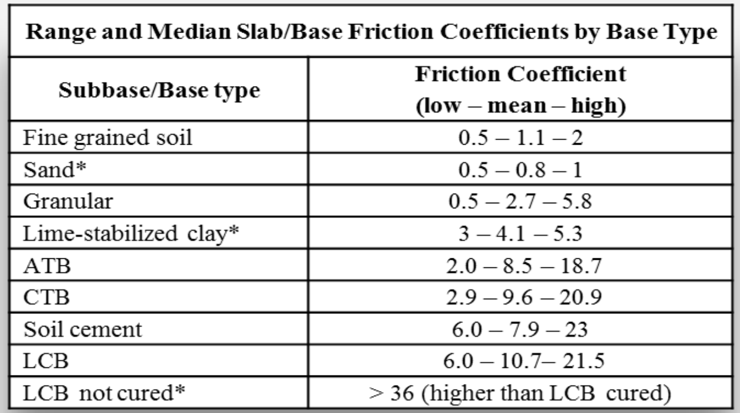
Subbase/Basetype	Friction Coefficient (low – mean – high)
Fine grained soil	0.5 – 1.1 – 2
Sand*	0.5 – 0.8 – 1
Granular	0.5 – 2.7 – 5.8
Lime-stabilized clay*	3 – 4.1 – 5.3
ATB	2.0 – 8.5 – 18.7
CTB	2.9 – 9.6 – 20.9
Soil cement	6.0 – 7.9 – 23
LCB	6.0 – 10.7– 21.5
LCB not cured*	> 36 (higher than LCB cured)

New CRCP_high traffic_Utah



CRCP Design

PCC surface shortwave absorptivity	☑ 0.85
Shoulder type	Asphalt (2)
Permanent curl/warp effective temperature difference (deg F)	☑ -10
Steel (%)	☑ 0.6
Bar diameter (in.)	☑ 0.625
Steel depth (inch)	☑ 4
Base/slab friction coefficient	☑ 2.5
Crack spacing	Generate crack spacing using prediction model



Range and Median Slab/Base Friction Coefficients by Base Type

Subbase/Base type	Friction Coefficient (low – mean – high)
Fine grained soil	0.5 – 1.1 – 2
Sand*	0.5 – 0.8 – 1
Granular	0.5 – 2.7 – 5.8
Lime-stabilized clay*	3 – 4.1 – 5.3
ATB	2.0 – 8.5 – 18.7
CTB	2.9 – 9.6 – 20.9
Soil cement	6.0 – 7.9 – 23
LCB	6.0 – 10.7– 21.5
LCB not cured*	> 36 (higher than LCB cured)

This section will be demonstrated as part of the Lesson 5 module. The base/slab friction coefficient varies by base type and the MEPDG MOP provides typical average values. This input is in fact only an input for the CRCP design and is not a base layer input for JPCP.

The screen includes the table of ranges for the base/slab friction coefficient, which is an input option for base layer only with the CRCP design properties.
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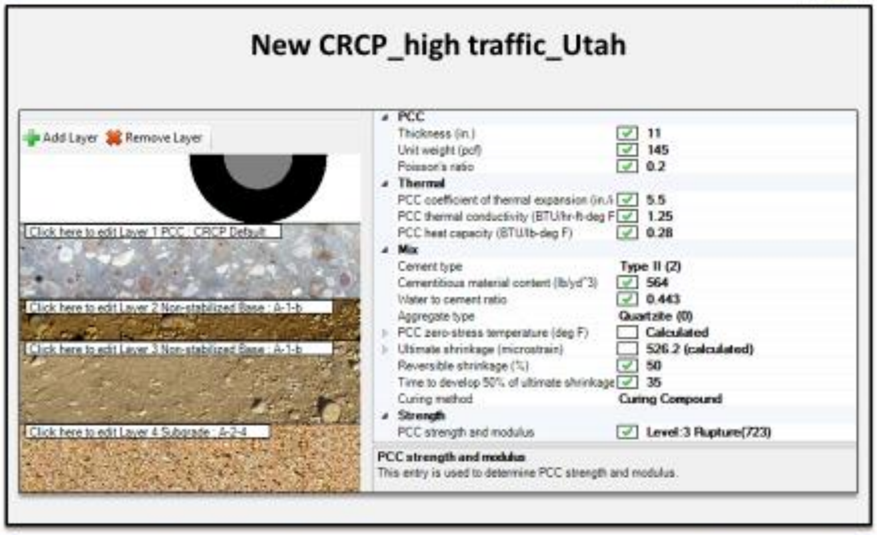
Slide 80

CRCP Concrete Mix Properties



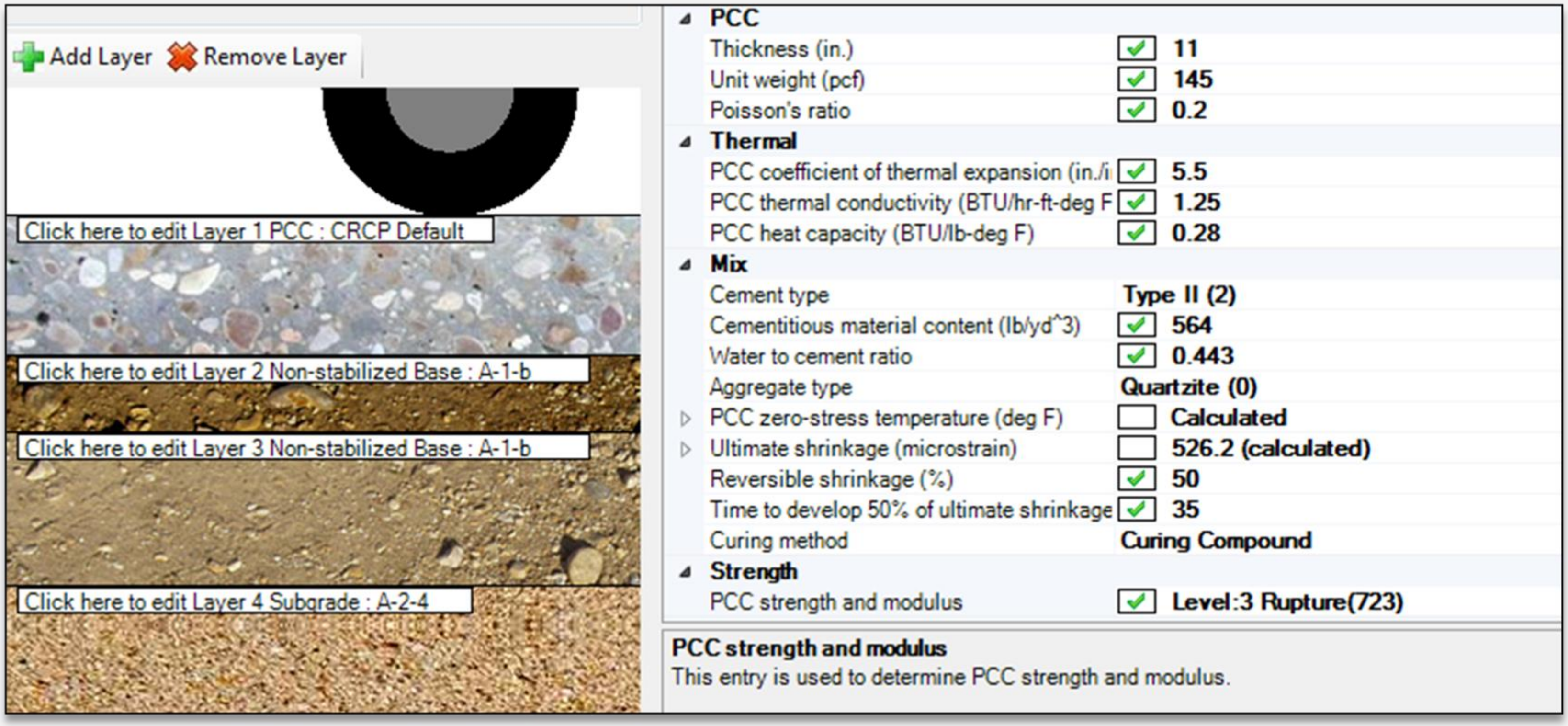
New CRCP_high traffic_Utah

Add Layer
Remove Layer
Click here to edit Layer 1 PCC : CRCP Default
Click here to edit Layer 2 Non-stabilized Base : A-1-b
Click here to edit Layer 3 Non-stabilized Base : A-1-b
Click here to edit Layer 4 Subgrade : A-2-4

PCC		
Thickness (in.)	☑	11
Unit weight (pcf)	☑	145
Poisson's ratio	☑	0.2
Thermal		
PCC coefficient of thermal expansion (in./i	☑	5.5
PCC thermal conductivity (BTU/hr-ft-deg F	☑	1.25
PCC heat capacity (BTU/lb-deg F)	☑	0.28
Mix		
Cement type		Type II (2)
Cementitious material content (lb/yd^3)	☑	564
Water to cement ratio	☑	0.443
Aggregate type		Quartzite (0)
PCC zero-stress temperature (deg F)	☐	Calculated
Ultimate shrinkage (microstrain)	☐	526.2 (calculated)
Reversible shrinkage (%)	☑	50
Time to develop 50% of ultimate shrinkage	☑	35
Curing method		Curing Compound
Strength		
PCC strength and modulus	☑	Level:3 Rupture(723)

PCC strength and modulus
This entry is used to determine PCC strength and modulus.

New CRCP_high traffic_Utah



Click here to edit Layer 1 PCC : CRCP Default

Click here to edit Layer 2 Non-stabilized Base : A-1-b

Click here to edit Layer 3 Non-stabilized Base : A-1-b

Click here to edit Layer 4 Subgrade : A-2-4

PCC		
Thickness (in.)	☑	11
Unit weight (pcf)	☑	145
Poisson's ratio	☑	0.2
Thermal		
PCC coefficient of thermal expansion (in./i	☑	5.5
PCC thermal conductivity (BTU/hr-ft-deg F	☑	1.25
PCC heat capacity (BTU/lb-deg F)	☑	0.28
Mix		
Cement type		Type II (2)
Cementitious material content (lb/yd^3)	☑	564
Water to cement ratio	☑	0.443
Aggregate type		Quartzite (0)
PCC zero-stress temperature (deg F)	☐	Calculated
Ultimate shrinkage (microstrain)	☐	526.2 (calculated)
Reversible shrinkage (%)	☑	50
Time to develop 50% of ultimate shrinkage	☑	35
Curing method		Curing Compound
Strength		
PCC strength and modulus	☑	Level:3 Rupture(723)

PCC strength and modulus
This entry is used to determine PCC strength and modulus.

Both JPCP and CRCP have the same inputs for materials properties of the concrete mixtures.

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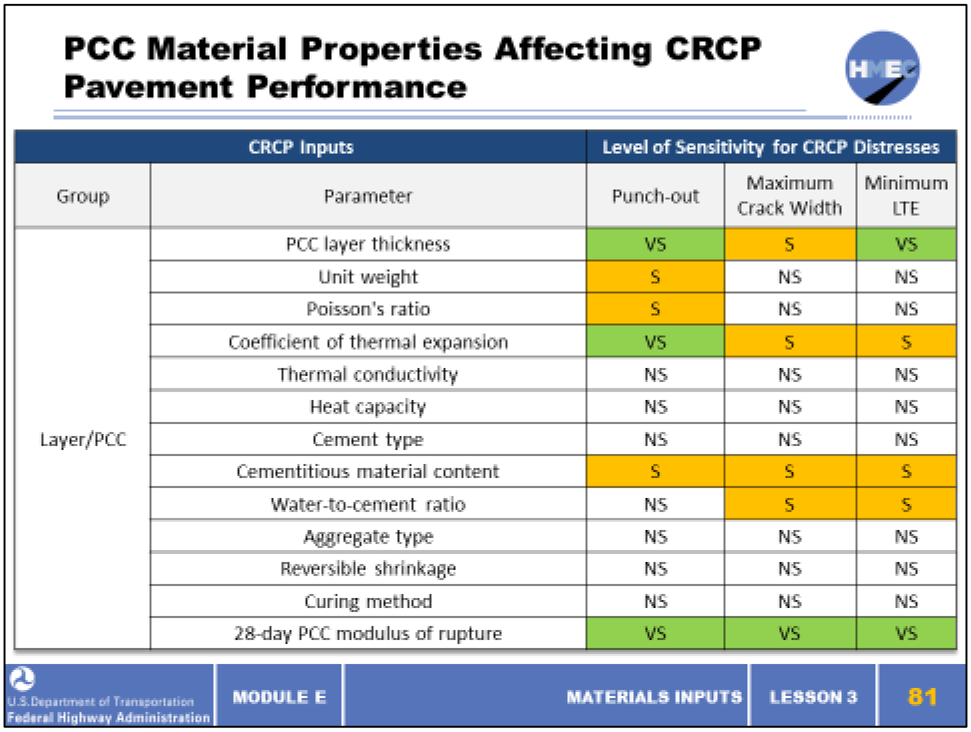
Slide 81



PCC Material Properties Affecting CRCP Pavement Performance

CRCP Inputs		Level of Sensitivity for CRCP Distresses		
Group	Parameter	Punch-out	Maximum Crack Width	Minimum LTE
Layer/PCC	PCC layer thickness	VS	S	VS
	Unit weight	S	NS	NS
	Poisson's ratio	S	NS	NS
	Coefficient of thermal expansion	VS	S	S
	Thermal conductivity	NS	NS	NS
	Heat capacity	NS	NS	NS
	Cement type	NS	NS	NS
	Cementitious material content	S	S	S
	Water-to-cement ratio	NS	S	S
	Aggregate type	NS	NS	NS
	Reversible shrinkage	NS	NS	NS
	Curing method	NS	NS	NS
	28-day PCC modulus of rupture	VS	VS	VS

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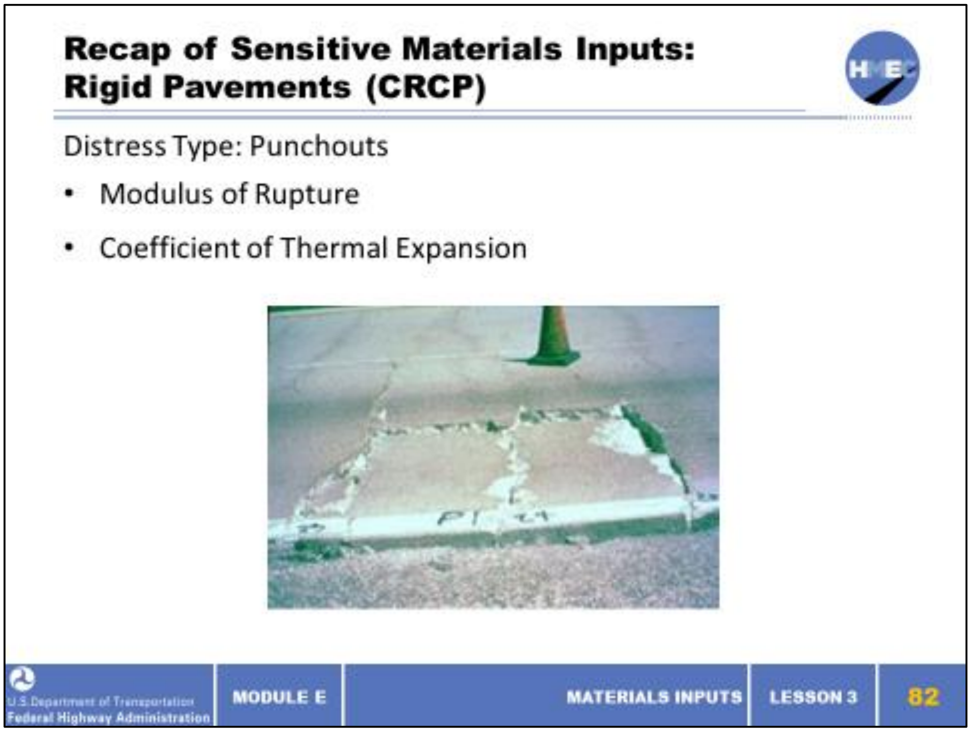
MODULE E
MATERIALS INPUTS
LESSON 3
81

The most sensitive factors are the thickness, coefficient of thermal expansion, and the modulus of rupture.

Slide 82



Recap of Sensitive Materials Inputs: Rigid Pavements (CRCP)

Distress Type: Punchouts

- Modulus of Rupture
- Coefficient of Thermal Expansion

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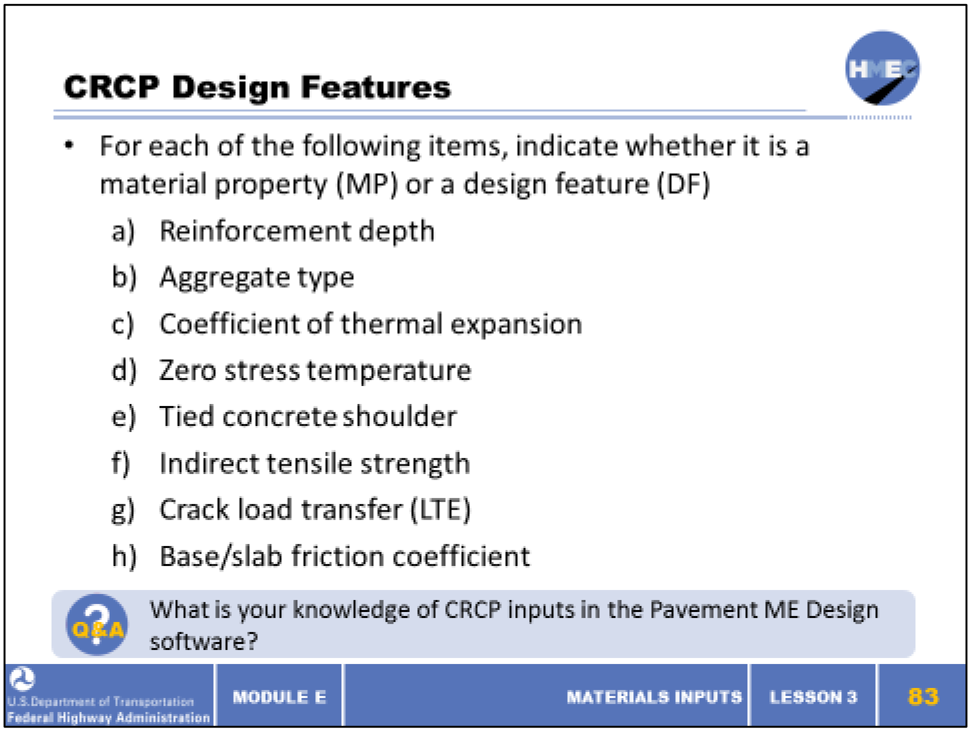
Federal Highway Administration

MODULE E | MATERIALS INPUTS | LESSON 3 | 82

These are the inputs that are most of interest to a pavement designer seeking input from a materials engineer in his/her agency.

Slide 83



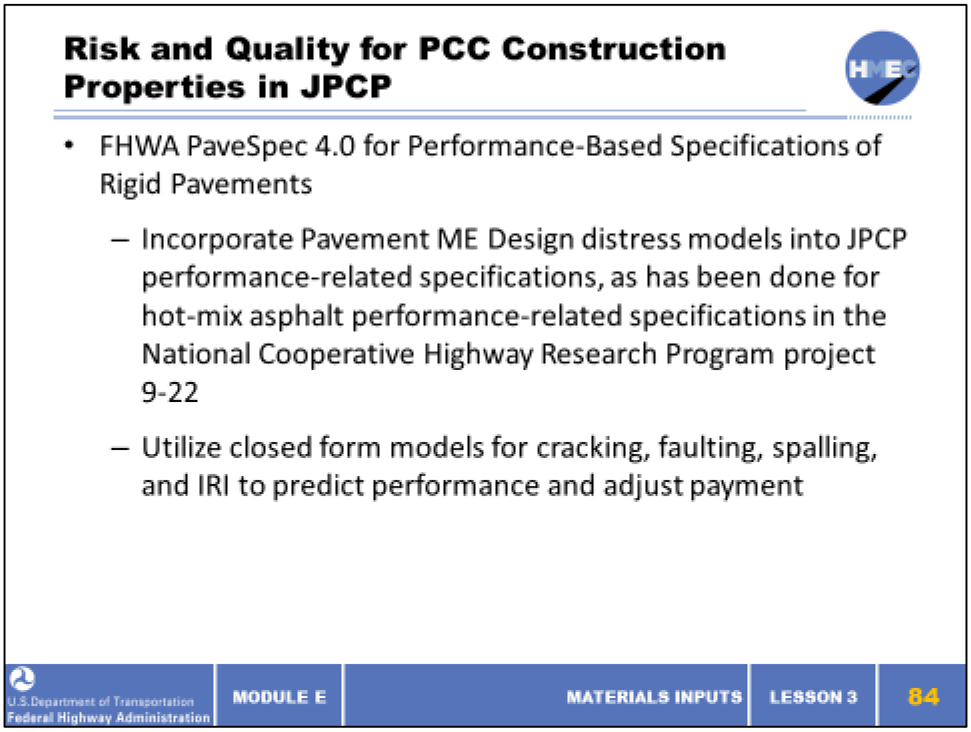
CRCP Design Features

- For each of the following items, indicate whether it is a material property (MP) or a design feature (DF)
  a) Reinforcement depth
  b) Aggregate type
  c) Coefficient of thermal expansion
  d) Zero stress temperature
  e) Tied concrete shoulder
  f) Indirect tensile strength
  g) Crack load transfer (LTE)
  h) Base/slab friction coefficient

Q&A What is your knowledge of CRCP inputs in the Pavement ME Design software?

U.S. Department of Transportation Federal Highway Administration | MODULE E | MATERIALS INPUTS | LESSON 3 | 83

Slide 84



Risk and Quality for PCC Construction Properties in JPCP

- FHWA PaveSpec 4.0 for Performance-Based Specifications of Rigid Pavements
  - Incorporate Pavement ME Design distress models into JPCP performance-related specifications, as has been done for hot-mix asphalt performance-related specifications in the National Cooperative Highway Research Program project 9-22
  - Utilize closed form models for cracking, faulting, spalling, and IRI to predict performance and adjust payment

U.S. Department of Transportation Federal Highway Administration | MODULE E | MATERIALS INPUTS | LESSON 3 | 84

This is a performance-based specification program that was developed with the Pavement ME Design predictive models for concrete pavement distresses.

The following are the key project objectives for FHWA:

- Incorporating Mechanistic-Empirical Pavement Design Guide (MEPDG) models in jointed plain concrete pavement (JPCP) performance-related specifications (PRS).
- Providing assistance to State highway agencies in developing and using Level 1 and Level 2 PRS.
- Developing a plan for State-wide implementation of PRS.

Slide 85

Material Inputs for Pavement Rehabilitation

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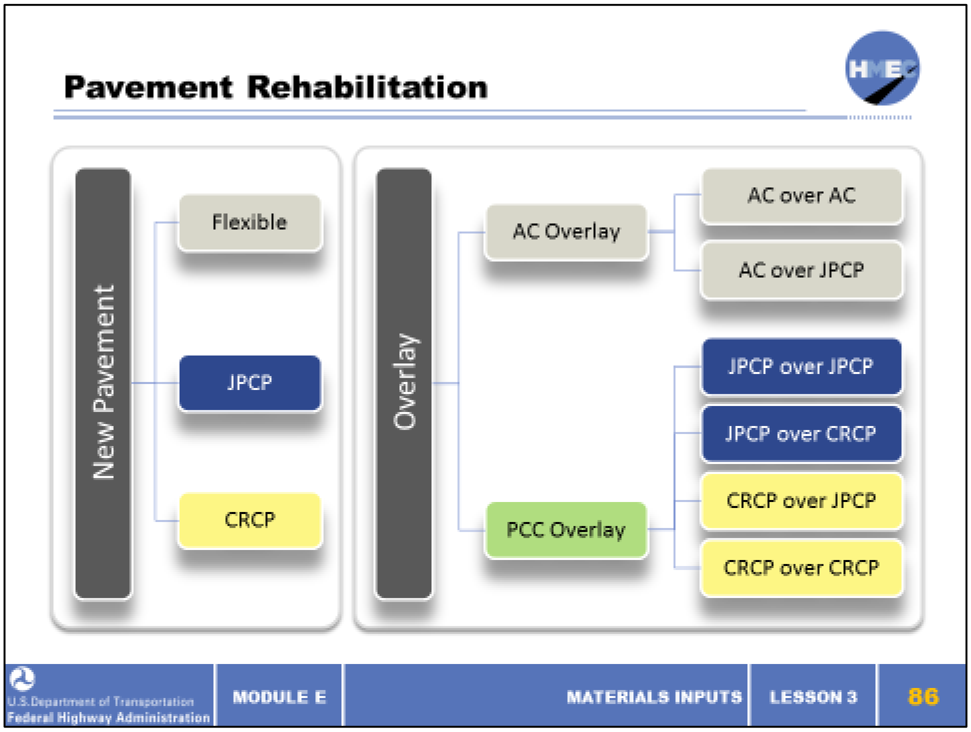
MODULE E

MATERIALS INPUTS

LESSON 3

This purpose of this screen is to transition to the section on material inputs for pavement rehabilitation and concept of reliability.

Slide 86



Pavement Rehabilitation

New Pavement
- Flexible
- JPCP
- CRCP

Overlay
- AC Overlay
  - AC over AC
  - AC over JPCP
- PCC Overlay
  - JPCP over JPCP
  - JPCP over CRCP
  - CRCP over JPCP
  - CRCP over CRCP

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Federal Highway Administration
MODULE E
MATERIALS INPUTS
LESSON 3
86

Rehabilitated pavements can feature either asphalt concrete (AC) or Portland cement concrete (PCC) overlays.

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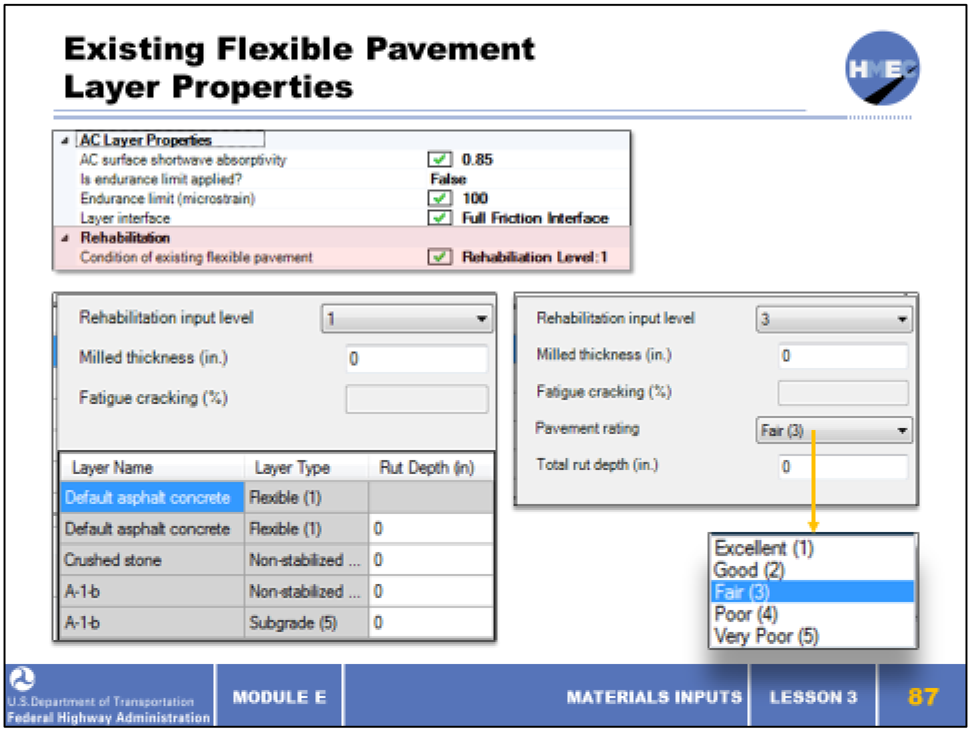
Slide 87



Existing Flexible Pavement Layer Properties

AC Layer Properties	
AC surface shortwave absorptivity	☑ 0.85
Is endurance limit applied?	False
Endurance limit (microstrain)	☑ 100
Layer interface	☑ Full Friction Interface
Rehabilitation	
Condition of existing flexible pavement	☑ Rehabiliation Level:1

Rehabilitation input level: 1

Milled thickness (in.): 0

Fatigue cracking (%):

Layer Name	Layer Type	Rut Depth (in)
Default asphalt concrete	Flexible (1)	
Default asphalt concrete	Flexible (1)	0
Crushed stone	Non-stabilized ...	0
A-1-b	Non-stabilized ...	0
A-1-b	Subgrade (5)	0

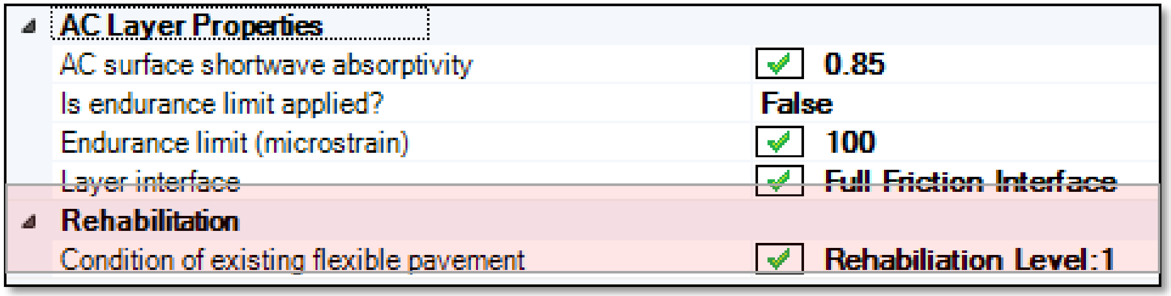
Rehabilitation input level: 3

Milled thickness (in.): 0

Fatigue cracking (%):

Pavement rating: Fair (3)

Total rut depth (in.): 0

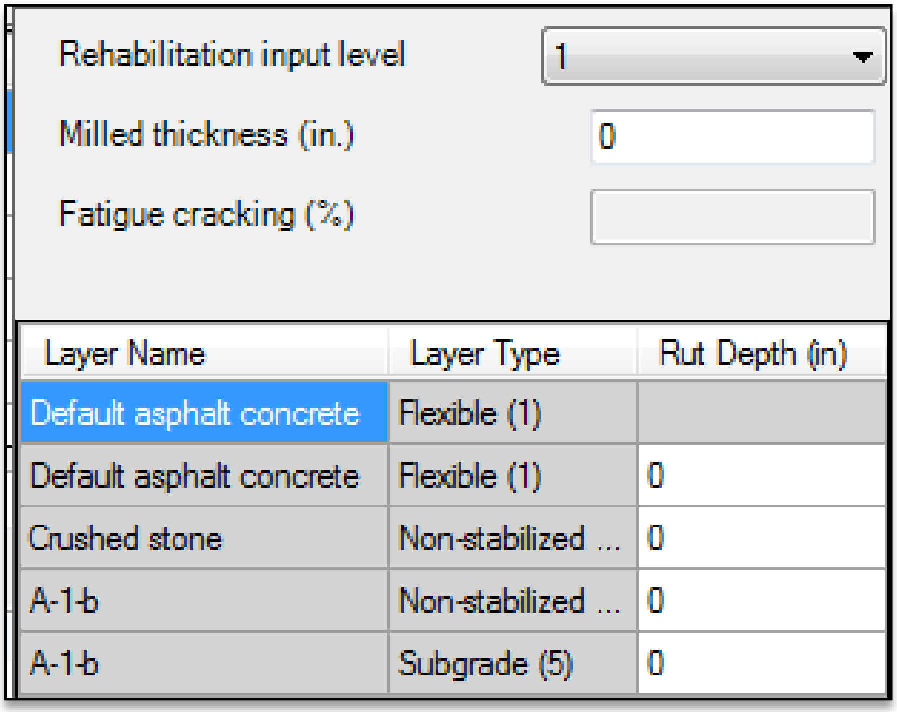


AC Layer Properties

AC surface shortwave absorptivity	✓ 0.85
Is endurance limit applied?	False
Endurance limit (microstrain)	✓ 100
Layer interface	✓ Full Friction Interface

Rehabilitation

Condition of existing flexible pavement	✓ Rehabiliation Level:1

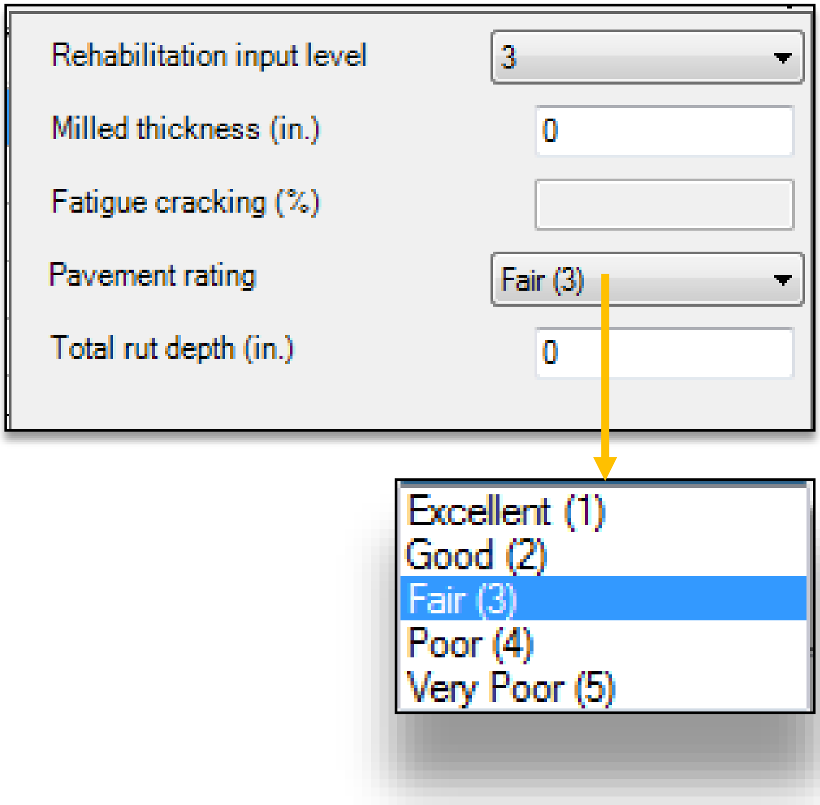


Rehabilitation input level: 1

Milled thickness (in.): 0

Fatigue cracking (%):

Layer Name	Layer Type	Rut Depth (in)
Default asphalt concrete	Flexible (1)	
Default asphalt concrete	Flexible (1)	0
Crushed stone	Non-stabilized ...	0
A-1-b	Non-stabilized ...	0
A-1-b	Subgrade (5)	0



Rehabilitation input level: 3

Milled thickness (in.): 0

Fatigue cracking (%):

Pavement rating: Fair (3)

Total rut depth (in.): 0

This presents the definition of existing asphalt material properties and conditions, as part of a rehabilitated flexible pavement design.

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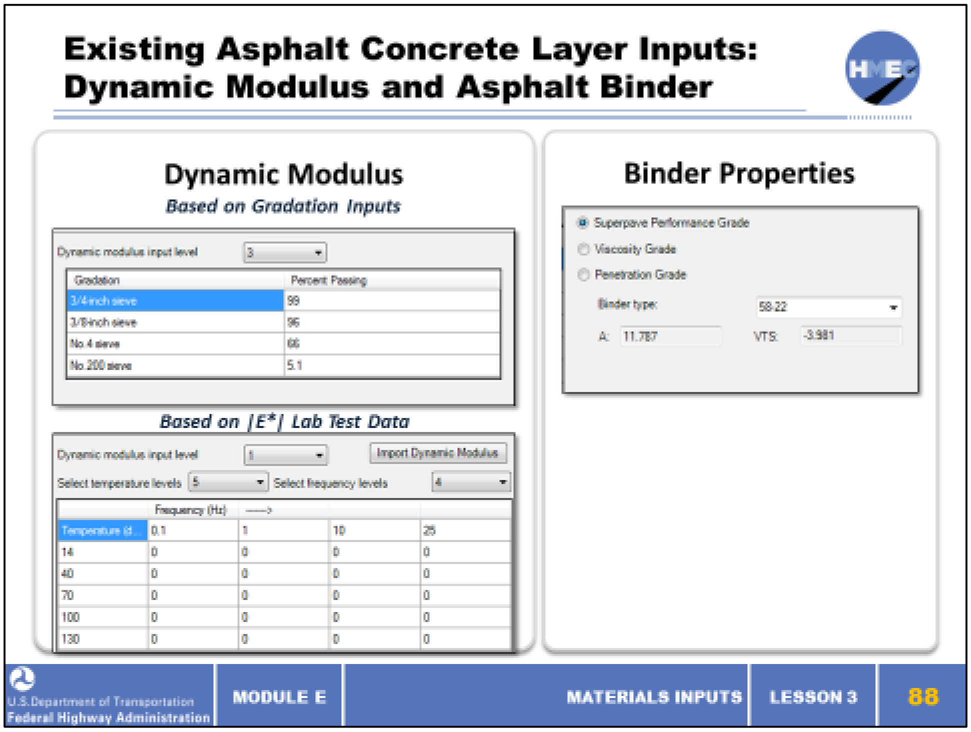
Slide 88



Existing Asphalt Concrete Layer Inputs: Dynamic Modulus and Asphalt Binder

Dynamic Modulus

Based on Gradation Inputs

Dynamic modulus input level: 3

Gradation	Percent Passing
3/4-inch sieve	99
3/8-inch sieve	96
No.4 sieve	66
No.200 sieve	5.1

Based on |E| Lab Test Data*

Dynamic modulus input level: 1

Select temperature levels: 5

Select frequency levels: 4

	Frequency (Hz)	——>		
Temperature (d...	0.1	1	10	25
14	0	0	0	0
40	0	0	0	0
70	0	0	0	0
100	0	0	0	0
130	0	0	0	0

Binder Properties

● Superpave Performance Grade
○ Viscosity Grade
○ Penetration Grade

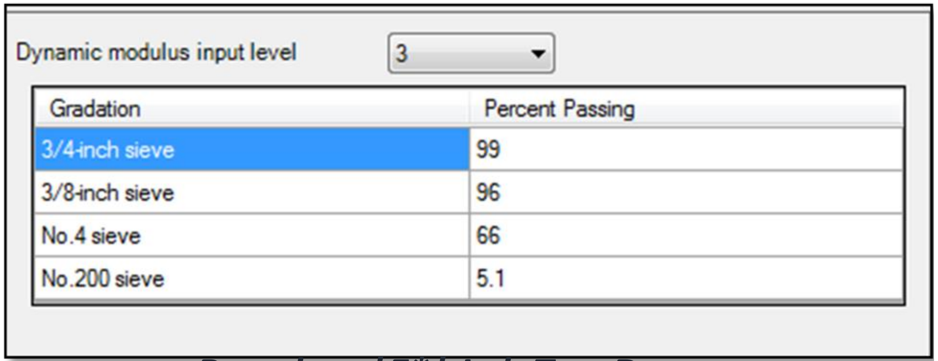
Binder type: 58-22

A: 11.787

VTS: -3.981

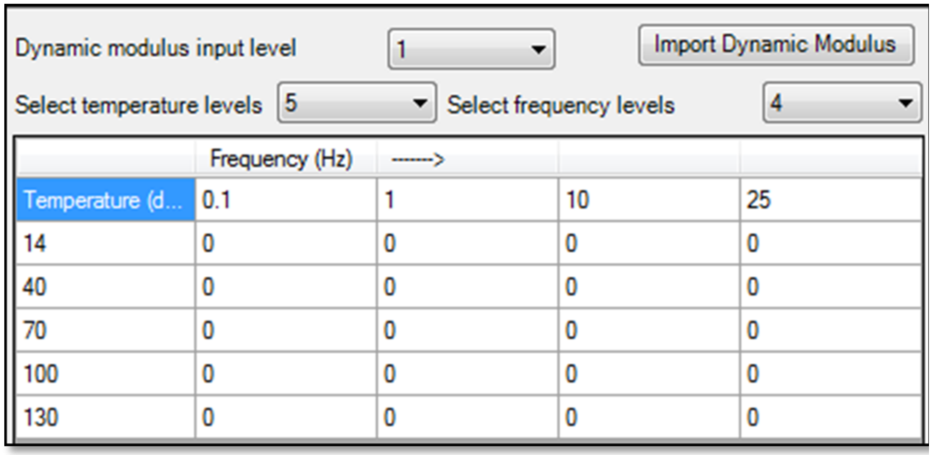
Dynamic Modulus

Based on Gradation Inputs


Dynamic modulus input level: 3

Gradation	Percent Passing
3/4-inch sieve	99
3/8-inch sieve	96
No.4 sieve	66
No.200 sieve	5.1

Based on |E| Lab Test Data*



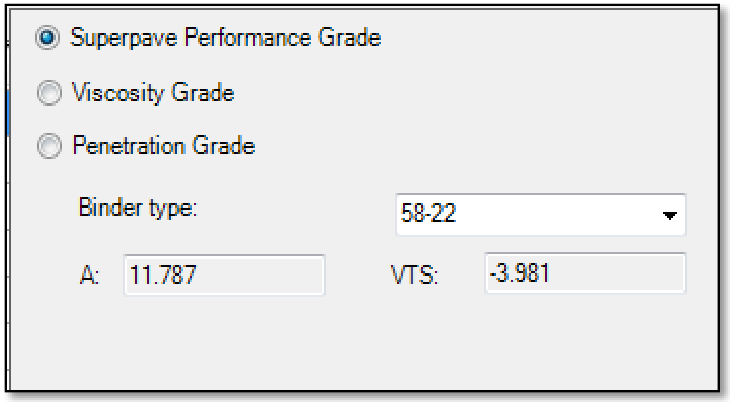
Dynamic modulus input level: 1

Select temperature levels: 5

Select frequency levels: 4

	Frequency (Hz)	------->		
Temperature (d...	0.1	1	10	25
14	0	0	0	0
40	0	0	0	0
70	0	0	0	0
100	0	0	0	0
130	0	0	0	0

Binder Properties


● Superpave Performance Grade

○ Viscosity Grade

○ Penetration Grade

Binder type: 58-22

A: 11.787

VTS: -3.981

Some laboratory tests (from AASHTO) allow for taking cores from the existing pavement and run an extraction to get the binder grade of the existing asphalt layer.

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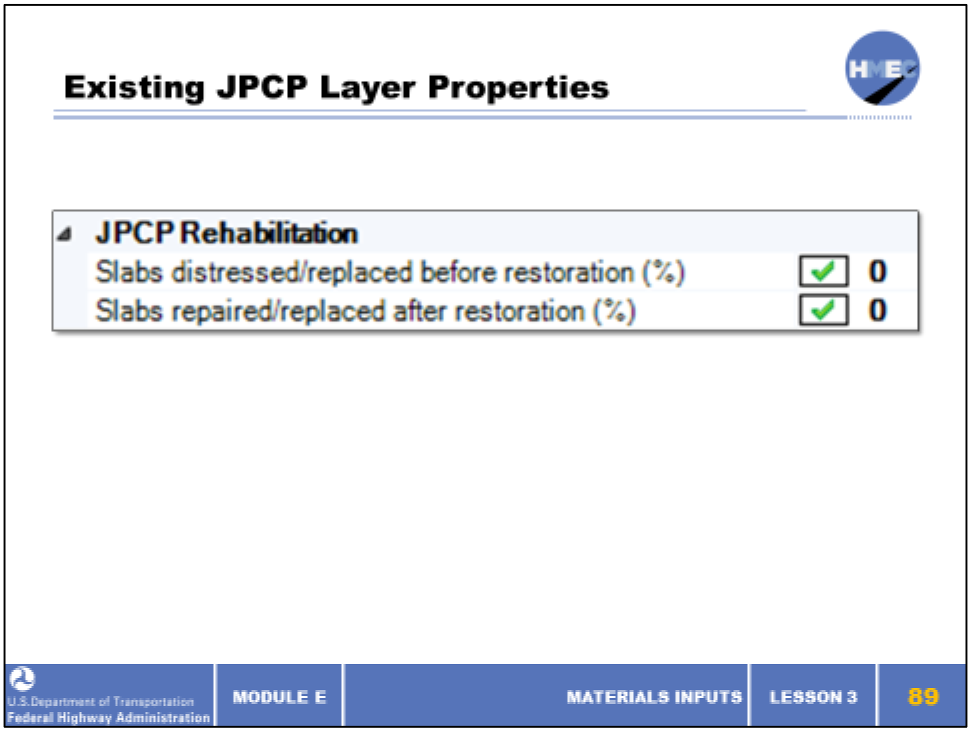
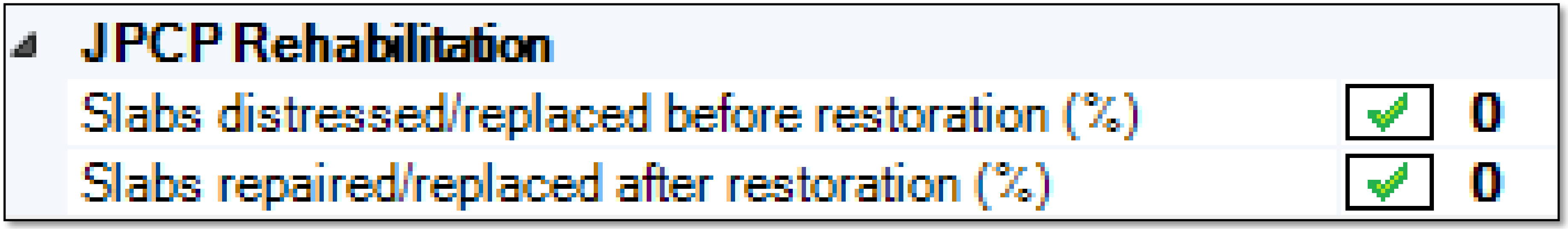
Slide 89



Existing JPCP Layer Properties

JPCP Rehabilitation

Slabs distressed/replaced before restoration (%)	☑	0
Slabs repaired/replaced after restoration (%)	☑	0



JPCP Rehabilitation

Slabs distressed/replaced before restoration (%)	✓	0
Slabs repaired/replaced after restoration (%)	✓	0

In theory, you’d want the amount before. The amount after should be 0% so that all damage is fixed prior to the placement of an overlay. However, it may depend on constructability issues and the maintenance budget.

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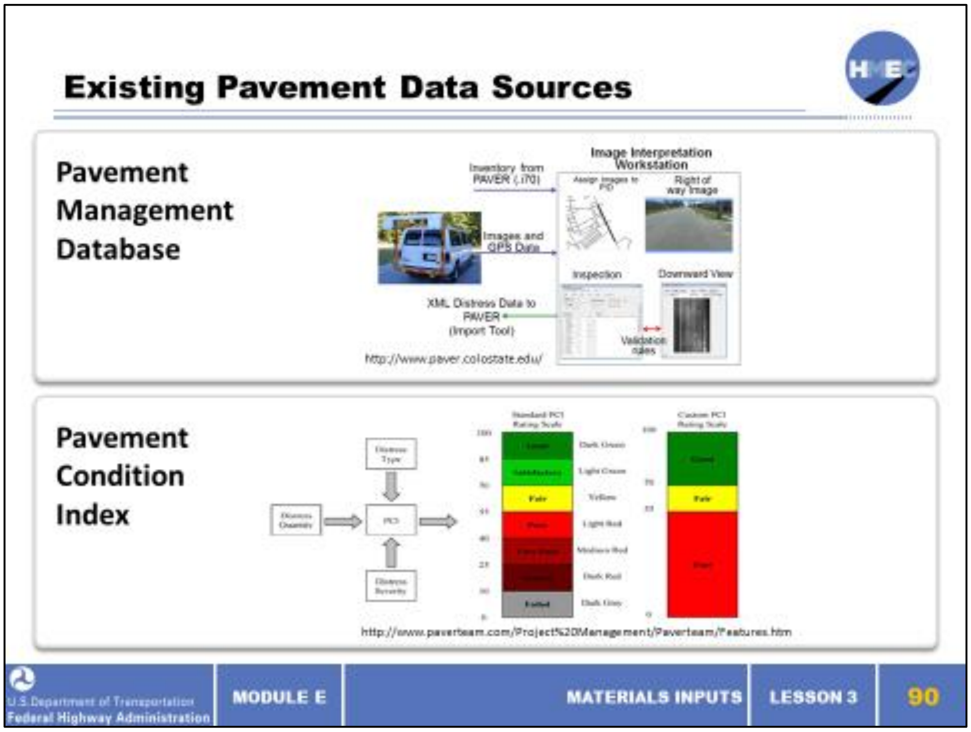
Slide 90



Existing Pavement Data Sources

Pavement Management Database

Inventory from PAVER (.i70)
Images and GPS Data
Image Interpretation Workstation
Assign images to PID
Right of way Image
Inspection
Downward View
Validation rules
XML Distress Data to PAVER (Import Tool)

http://www.paver.colostate.edu/

Pavement Condition Index

Distress Type
Distress Quantity
PCI
Distress Severity
Standard PCI Rating Scale
100
85
70
55
40
25
10
0
Good
Satisfactory
Fair
Poor
Very Poor
Serious
Failed
Dark Green
Light Green
Yellow
Light Red
Medium Red
Dark Red
Dark Gray
Custom PCI Rating Scale
100
70
55
0
Good
Fair
Poor

http://www.paverteam.com/Project%20Management/Paverteam/Features.htm

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Federal Highway Administration
MODULE E
MATERIALS INPUTS
LESSON 3
90

Pavement Management Database

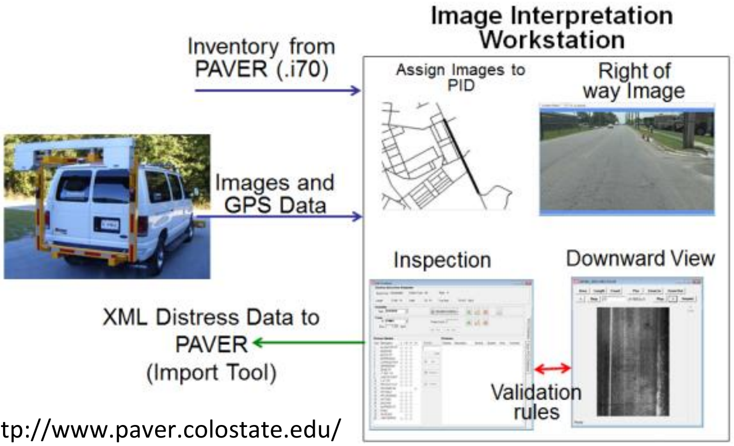
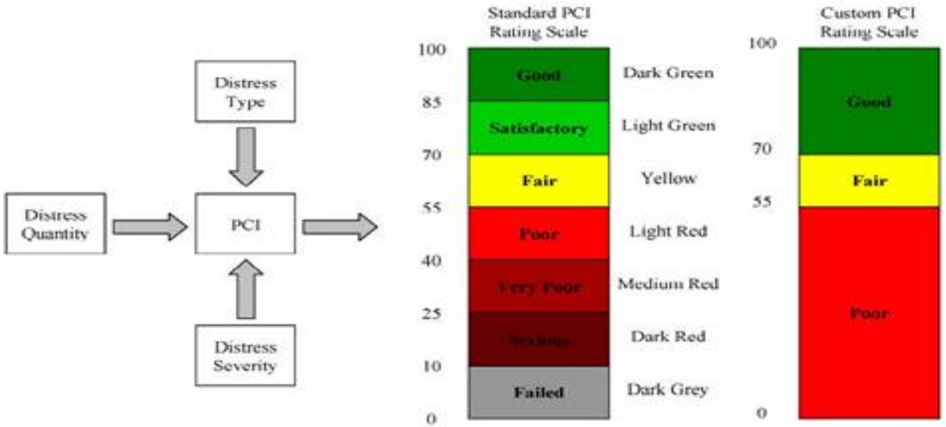


Image Interpretation Workstation
Inventory from PAVER (.i70)
Assign Images to PID
Right of way Image
Images and GPS Data
Inspection
Downward View
XML Distress Data to PAVER (Import Tool)
Validation rules

http://www.paver.colostate.edu/

Pavement Condition Index



http://www.paverteam.com/Project%20Management/Paverteam/Features.htm

There are many potential sources of data for existing pavements when considering a rehabilitation design. Here are two examples of potential sources of data:

One source is the data provided in pavement management database (such as the PaveView used by New Jersey DOT). Note that it is critical for you to be aware that there should be material quality checks performed on the information included in pavement management databases.

Another source is the data provided by doing pavement condition index (such as the MicroPaver developed by USACE and used by many county and perhaps some State DOT transportation officials).

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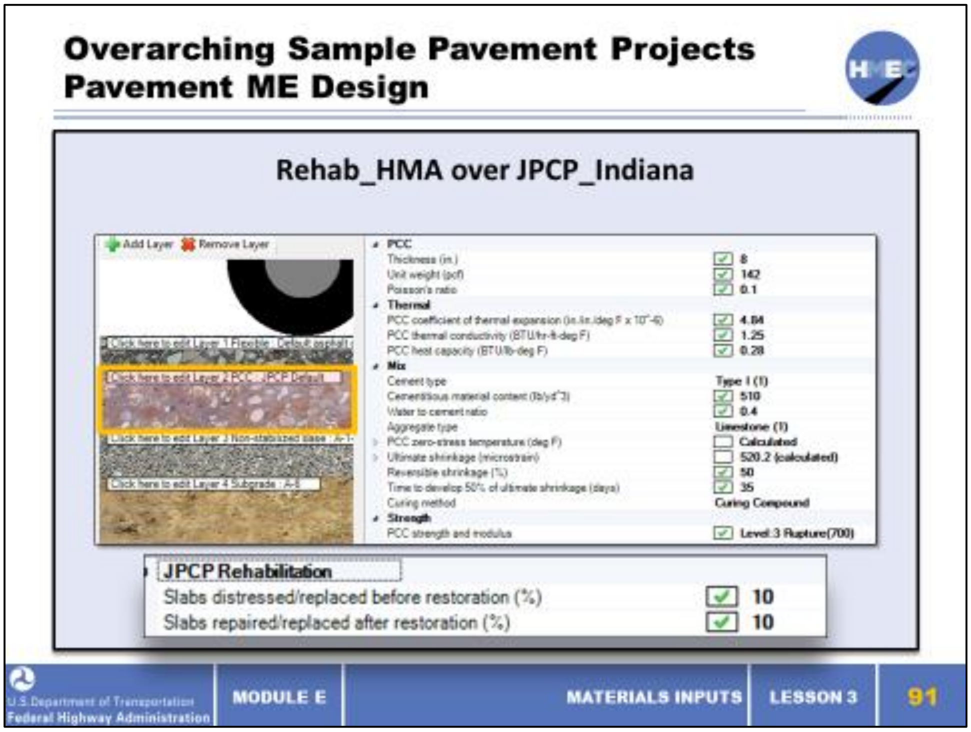
Slide 91


HMEC
Add Layer
Remove Layer
Click here to edit Layer 1 Flexible : Default asphalt c
Click here to edit Layer 2 PCC : JPCP Default
Click here to edit Layer 3 Non-stabilized base : A-1-
Click here to edit Layer 4 Subgrade : A-6

Overarching Sample Pavement Projects Pavement ME Design

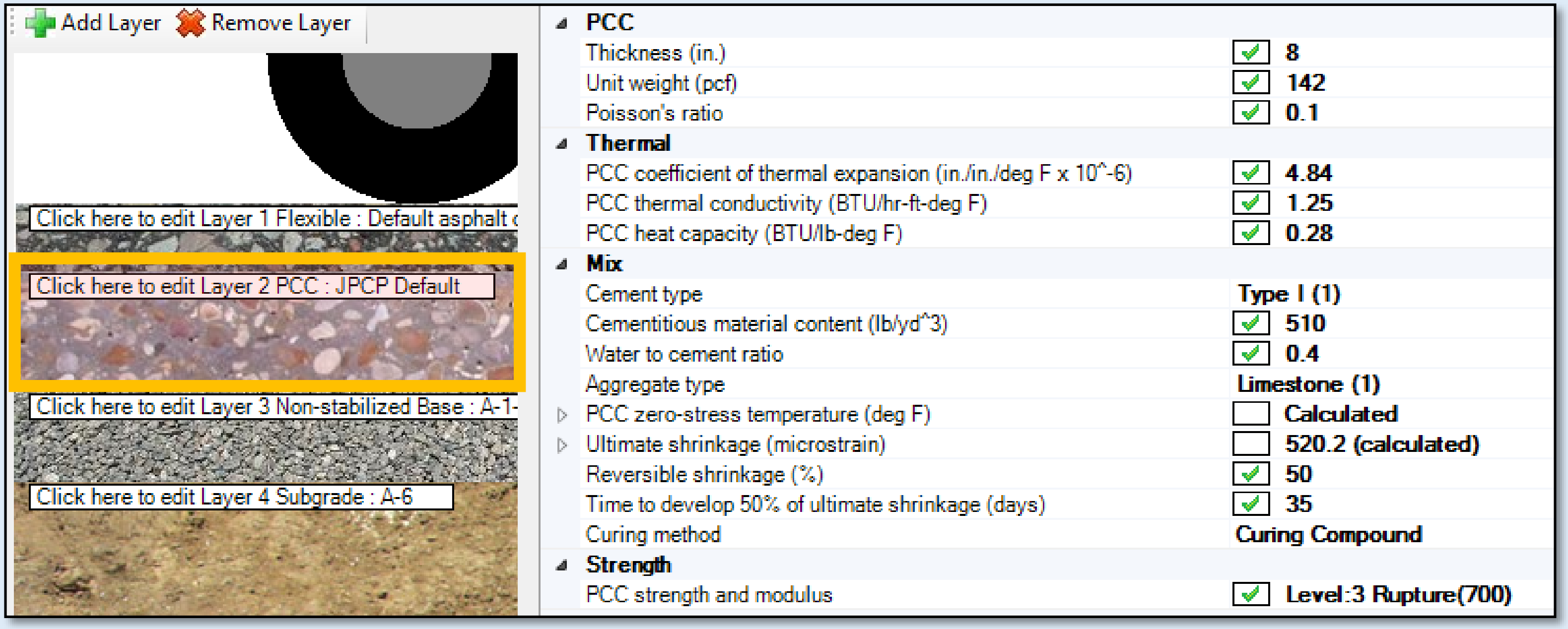
Rehab_HMA over JPCP_Indiana

PCC	
Thickness (in.)	☑ 8
Unit weight (pcf)	☑ 142
Poisson's ratio	☑ 0.1
Thermal	
PCC coefficient of thermal expansion (in./in./deg F x 10^-6)	☑ 4.84
PCC thermal conductivity (BTU/hr-ft-deg F)	☑ 1.25
PCC heat capacity (BTU/lb-deg F)	☑ 0.28
Mix	
Cement type	Type I (1)
Cementitious material content (lb/yd^3)	☑ 510
Water to cement ratio	☑ 0.4
Aggregate type	Limestone (1)
PCC zero-stress temperature (deg F)	☐ Calculated
Ultimate shrinkage (microstrain)	☐ 520.2 (calculated)
Reversible shrinkage (%)	☑ 50
Time to develop 50% of ultimate shrinkage (days)	☑ 35
Curing method	Curing Compound
Strength	
PCC strength and modulus	☑ Level:3 Rupture(700)

JPCP Rehabilitation	
Slabs distressed/replaced before restoration (%)	☑ 10
Slabs repaired/replaced after restoration (%)	☑ 10

U.S. Department of Transportation
Federal Highway Administration
MODULE E
MATERIALS INPUTS
LESSON 3
91

Rehab_HMA over JPCP_Indiana



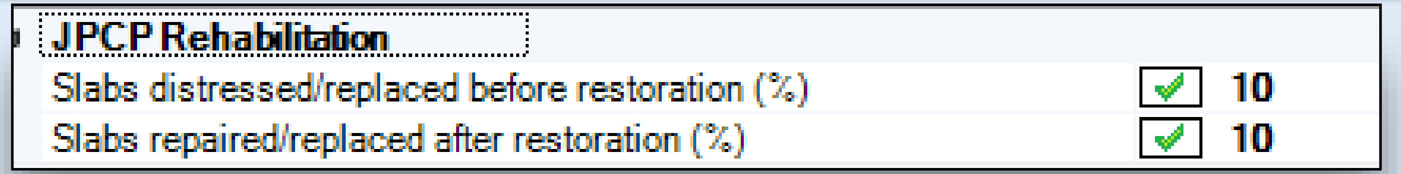
Click here to edit Layer 1 Flexible : Default asphalt

Click here to edit Layer 2 PCC : JPCP Default

Click here to edit Layer 3 Non-stabilized Base : A-1-

Click here to edit Layer 4 Subgrade : A-6

PCC		
Thickness (in.)	☑	8
Unit weight (pcf)	☑	142
Poisson's ratio	☑	0.1
Thermal		
PCC coefficient of thermal expansion (in./in./deg F x 10^-6)	☑	4.84
PCC thermal conductivity (BTU/hr-ft-deg F)	☑	1.25
PCC heat capacity (BTU/lb-deg F)	☑	0.28
Mix		
Cement type		Type I (1)
Cementitious material content (lb/yd^3)	☑	510
Water to cement ratio	☑	0.4
Aggregate type		Limestone (1)
PCC zero-stress temperature (deg F)	☐	Calculated
Ultimate shrinkage (microstrain)	☐	520.2 (calculated)
Reversible shrinkage (%)	☑	50
Time to develop 50% of ultimate shrinkage (days)	☑	35
Curing method		Curing Compound
Strength		
PCC strength and modulus	☑	Level:3 Rupture(700)



JPCP Rehabilitation		
Slabs distressed/replaced before restoration (%)	☑	10
Slabs repaired/replaced after restoration (%)	☑	10

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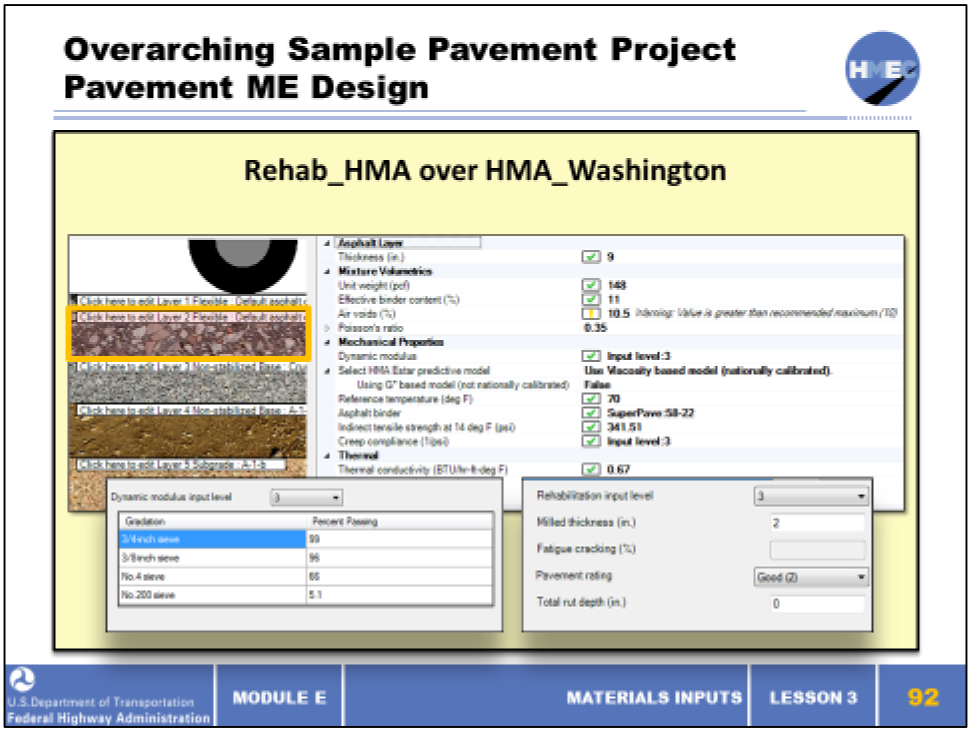
Slide 92



Overarching Sample Pavement Project Pavement ME Design

Rehab_HMA over HMA_Washington

Click here to edit Layer 1 Flexible : Default asphalt
Click here to edit Layer 2 Flexible : Default asphalt
Click here to edit Layer 3 Non-stabilized Base :
Click here to edit Layer 4 Non-stabilized Base : A-1-
Click here to edit Layer 5 Subgrade : A-1-b

Asphalt Layer	
Thickness (in.)	☑ 9
Mixture Volumetrics	
Unit weight (pcf)	☑ 148
Effective binder content (%)	☑ 11
Air voids (%)	☐ 10.5 *[illegible]: Value is greater than recommended maximum (10)*
Poisson's ratio	0.35
Mechanical Properties	
Dynamic modulus	☑ Input level:3
Select HMA Estar predictive model	Use Viscosity based model (nationally calibrated).
Using G* based model (not nationally calibrated)	False
Reference temperature (deg F)	☑ 70
Asphalt binder	☑ SuperPave:58-22
Indirect tensile strength at 14 deg F (psi)	☑ 341.51
Creep compliance (1/psi)	☑ Input level:3
Thermal	
Thermal conductivity (BTU/hr-ft-deg F)	☑ 0.67

Dynamic modulus input level: 3

Gradation	Percent Passing
3/4-inch sieve	99
3/8-inch sieve	96
No.4 sieve	66
No.200 sieve	5.1

Rehabilitation input level: 3

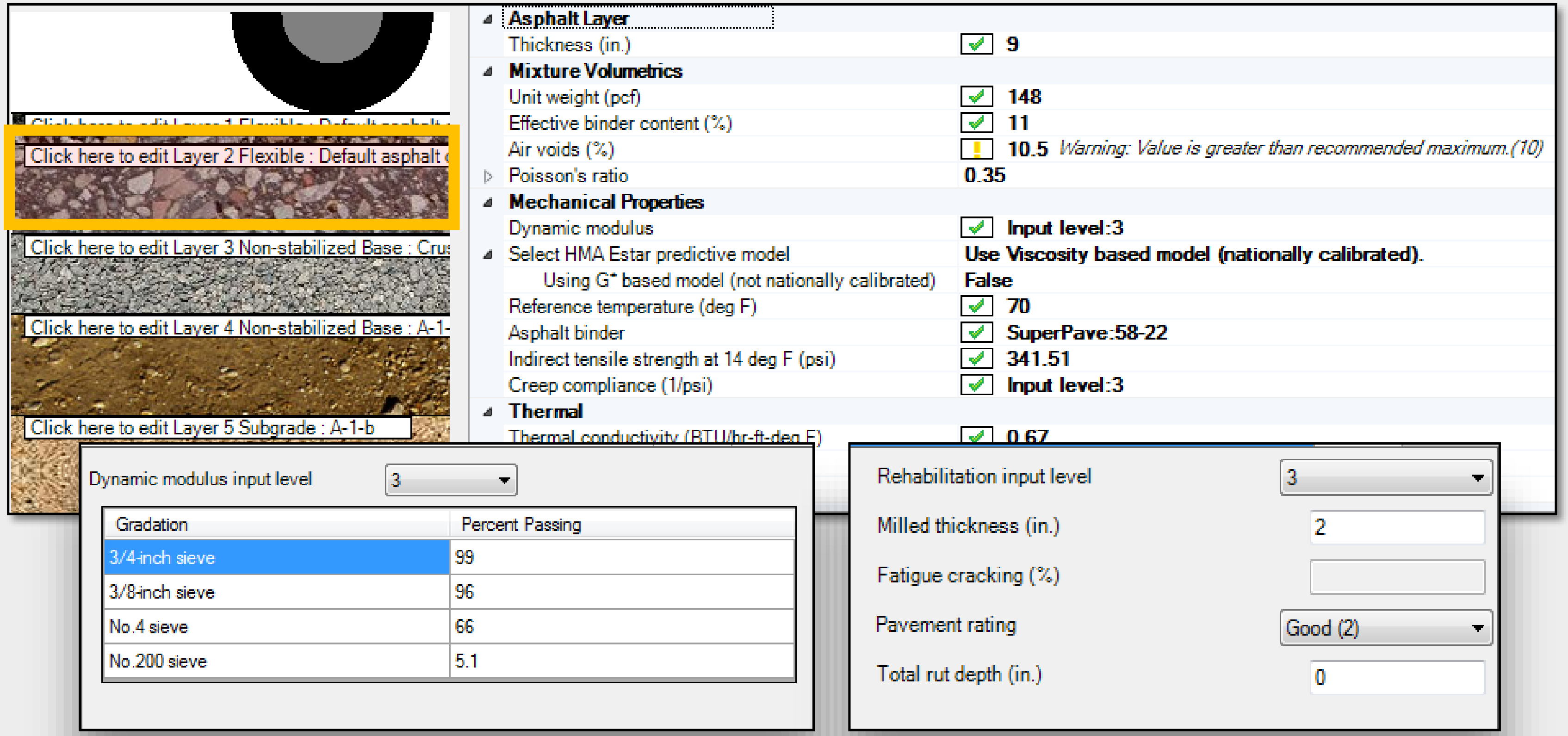
Milled thickness (in.): 2

Fatigue cracking (%):

Pavement rating: Good (2)

Total rut depth (in.): 0

Rehab_HMA over HMA_Washington



Click here to edit Layer 2 Flexible : Default asphalt

Click here to edit Layer 3 Non-stabilized Base : Cru

Click here to edit Layer 4 Non-stabilized Base : A-1-

Click here to edit Layer 5 Subgrade : A-1-b

Asphalt Layer		
Thickness (in.)	✓	**9**
Mixture Volumetrics		
Unit weight (pcf)	✓	**148**
Effective binder content (%)	✓	**11**
Air voids (%)	!	**10.5** *Warning: Value is greater than recommended maximum.(10)*
Poisson's ratio		**0.35**
Mechanical Properties		
Dynamic modulus	✓	**Input level:3**
Select HMA Estar predictive model		**Use Viscosity based model (nationally calibrated).**
Using G* based model (not nationally calibrated)		**False**
Reference temperature (deg F)	✓	**70**
Asphalt binder	✓	**SuperPave:58-22**
Indirect tensile strength at 14 deg F (psi)	✓	**341.51**
Creep compliance (1/psi)	✓	**Input level:3**
Thermal		
Thermal conductivity (BTU/hr-ft-deg F)	✓	**0.67**

Dynamic modulus input level: 3

Gradation	Percent Passing
3/4-inch sieve	99
3/8-inch sieve	96
No.4 sieve	66
No.200 sieve	5.1

Rehabilitation input level: 3

Milled thickness (in.): 2

Fatigue cracking (%):

Pavement rating: Good (2)

Total rut depth (in.): 0

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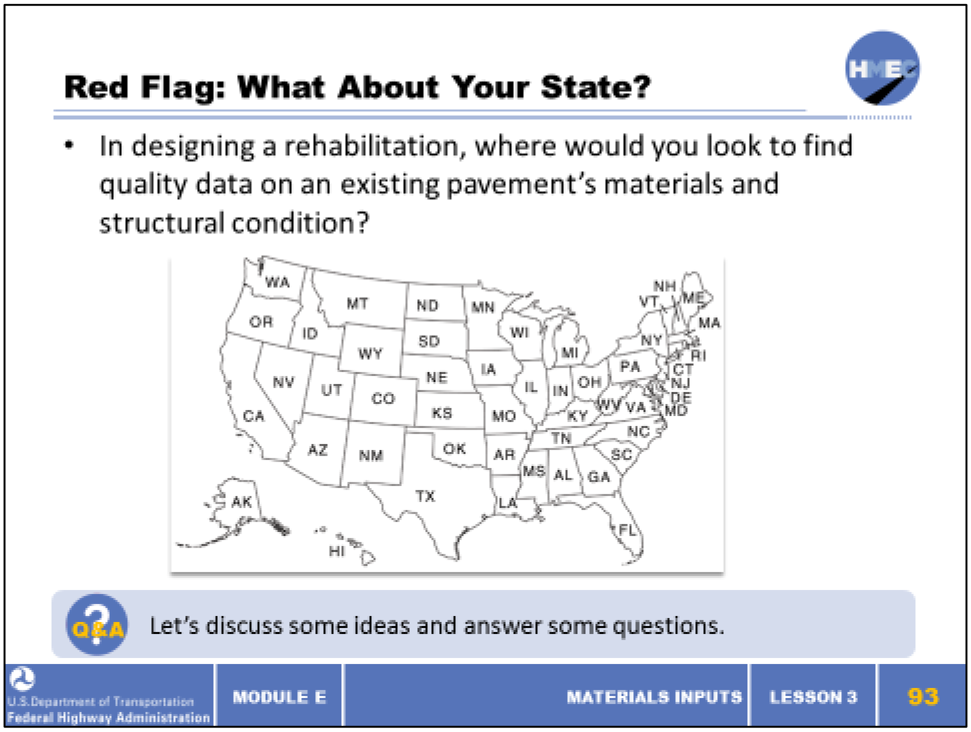
Slide 93



Red Flag: What About Your State?

- In designing a rehabilitation, where would you look to find quality data on an existing pavement's materials and structural condition?

HMEC
WA
OR
CA
NV
ID
MT
WY
UT
AZ
CO
NM
ND
SD
NE
KS
OK
TX
MN
IA
MO
AR
LA
WI
IL
MI
IN
OH
KY
TN
MS
AL
GA
FL
SC
NC
VA
WV
PA
NY
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NH
ME
MA
RI
CT
NJ
DE
MD
AK
HI
Q&A

Let's discuss some ideas and answer some questions.

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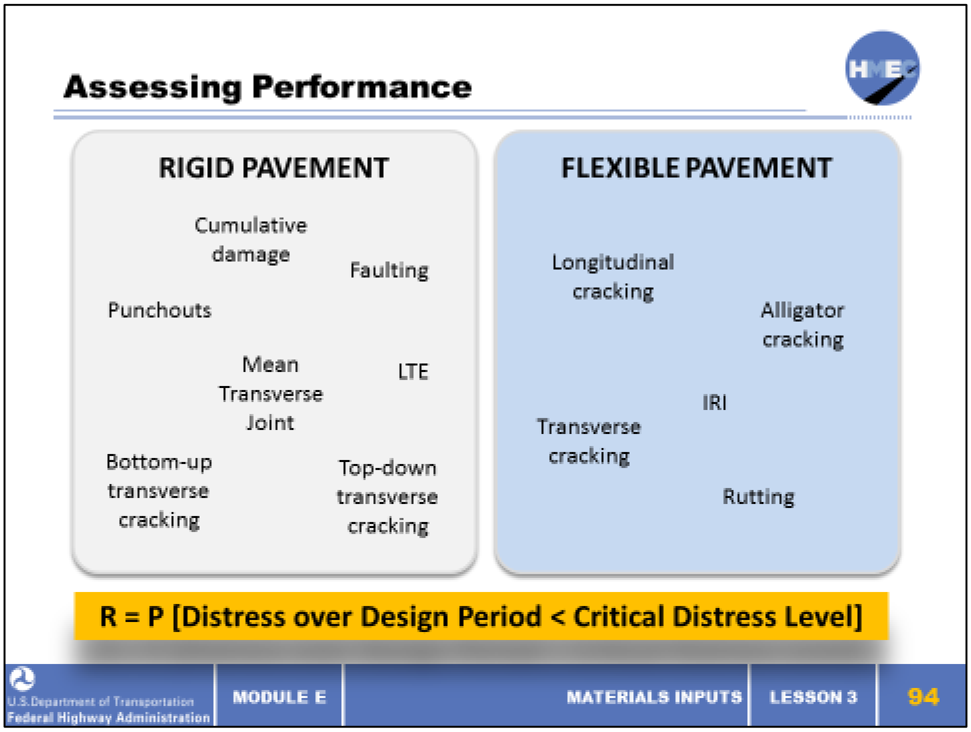
MODULE E | MATERIALS INPUTS | LESSON 3 | 93

Slide 94



Assessing Performance

RIGID PAVEMENT

Cumulative damage

Faulting

Punchouts

Mean Transverse Joint

LTE

Bottom-up transverse cracking

Top-down transverse cracking

FLEXIBLE PAVEMENT

Longitudinal cracking

Alligator cracking

IRI

Transverse cracking

Rutting

R = P [Distress over Design Period < Critical Distress Level]

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Design performance criteria and design reliability greatly affect the determination of an adequately-performing pavement.

Reliability is the probability that the predicted performance indicator of the trial design will not exceed the design criteria within the design-analysis period. The design criteria and design reliability levels could be selected in balance with each other. A low level of distress should not be selected in conjunction with a high level of reliability because this may make it impossible or costly to obtain an adequate design. A designer may specify the desired level of reliability for each distress type and smoothness.

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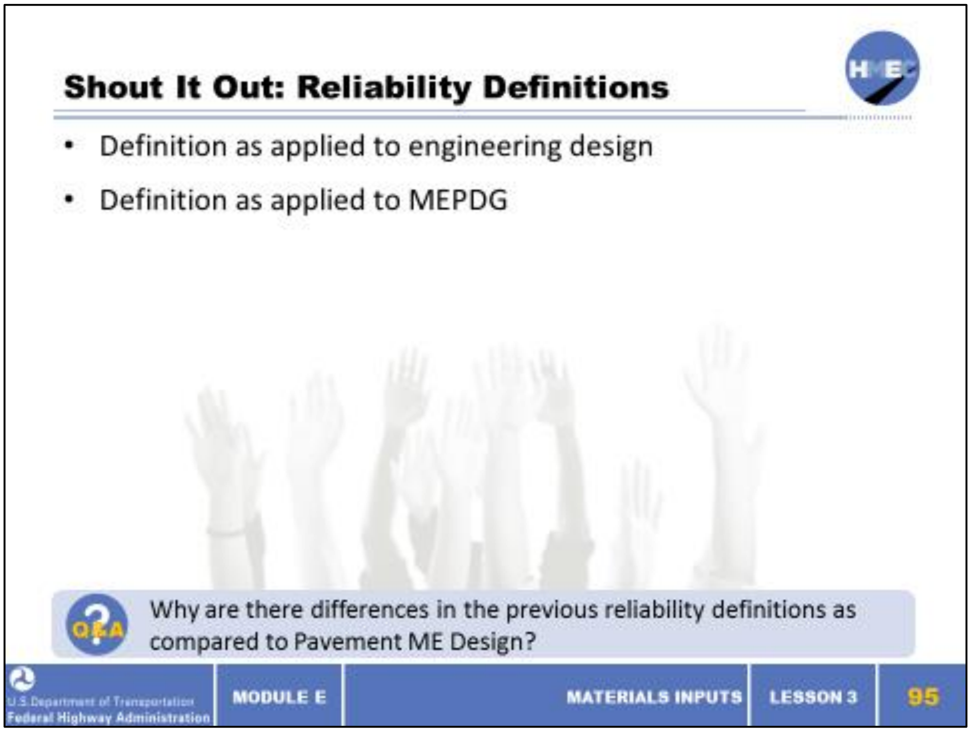
Slide 95



Shout It Out: Reliability Definitions

- Definition as applied to engineering design
- Definition as applied to MEPDG

Why are there differences in the previous reliability definitions as compared to Pavement ME Design?

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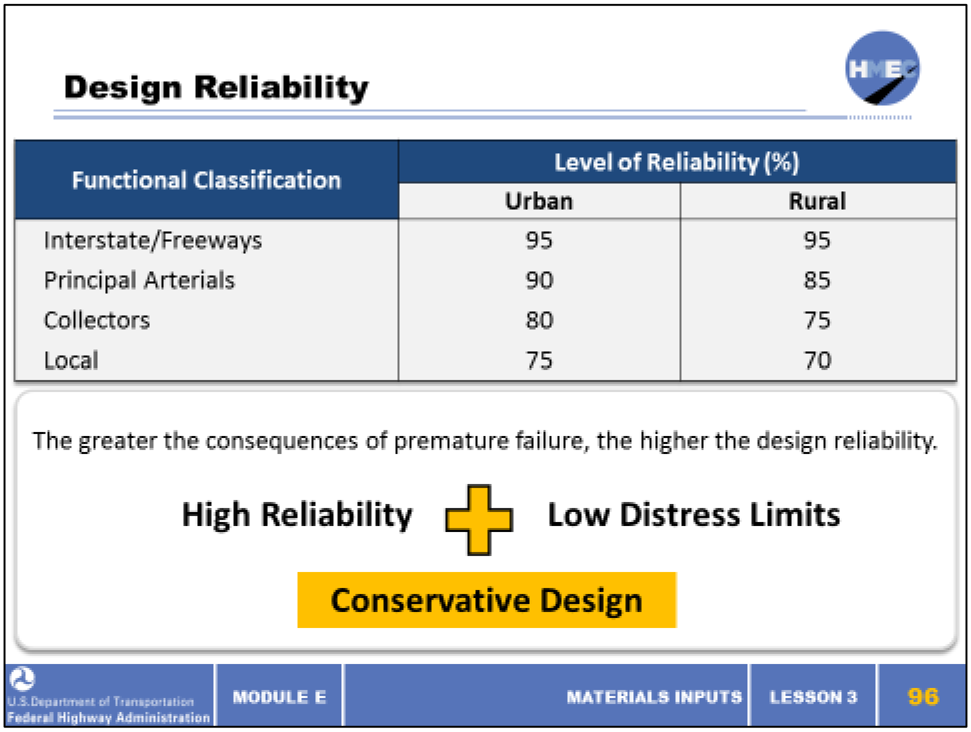
Slide 96



Design Reliability

Functional Classification	Level of Reliability (%)	
	Urban	Rural
Interstate/Freeways	95	95
Principal Arterials	90	85
Collectors	80	75
Local	75	70

The greater the consequences of premature failure, the higher the design reliability.

High Reliability + **Low Distress Limits**

Conservative Design

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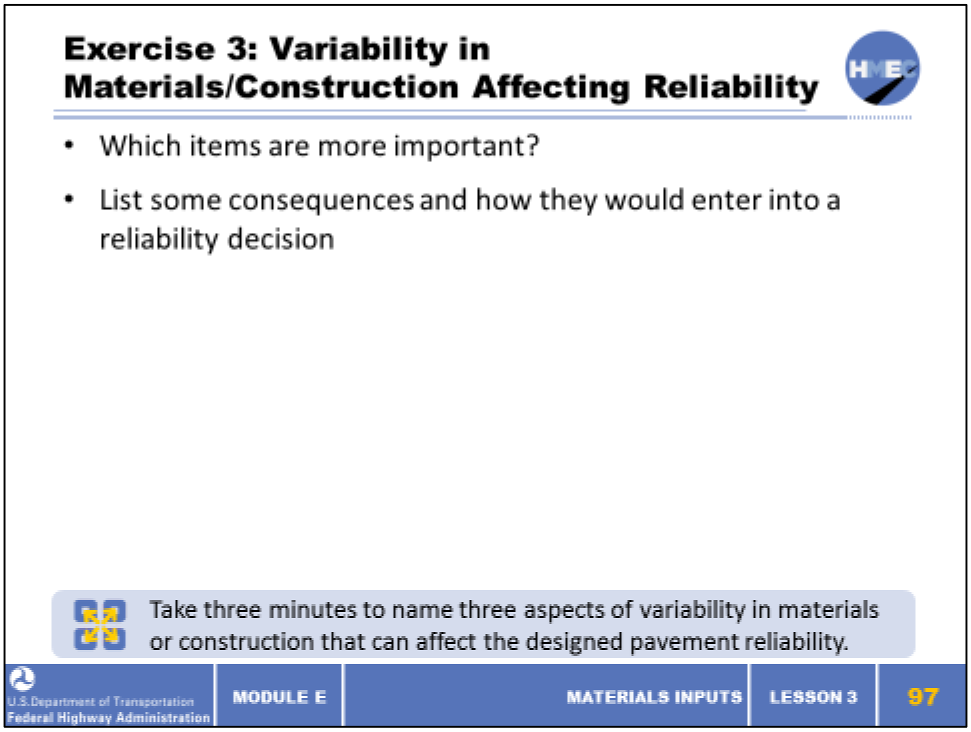
Reliability has been incorporated in the Pavement ME Design in a consistent and uniform fashion for all pavement types. A designer may specify the desired level of reliability for each distress type and smoothness. The level of design reliability could be based on the general consequence of reaching the terminal condition earlier than the design life. Design reliability levels selected may vary by distress type and IRI or may remain constant for each. Reliability could be selected based on the type of distress and the standard error of the distress prediction model. In all cases, engineering judgment and experience should be used when selecting a particular reliability value. Since reliability can significantly impact the pavement predictions, it is advisable that all stakeholders are consulted before selecting a value.

Slide 97



Exercise 3: Variability in Materials/Construction Affecting Reliability

- Which items are more important?
- List some consequences and how they would enter into a reliability decision

Take three minutes to name three aspects of variability in materials or construction that can affect the designed pavement reliability.

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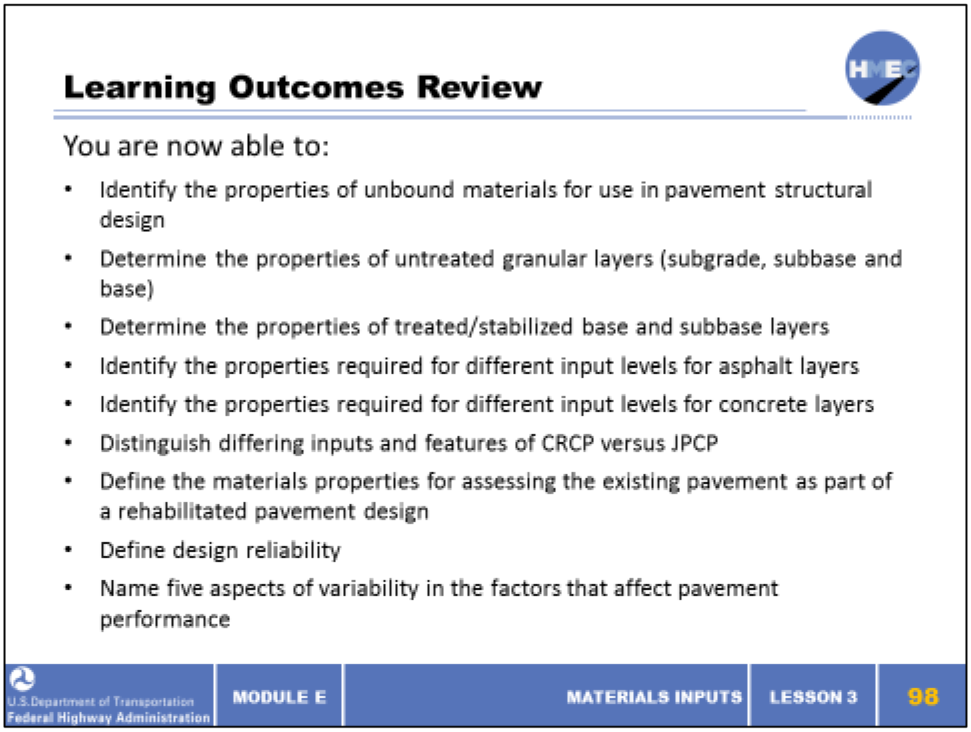
MODULE E MATERIALS INPUTS LESSON 3 97

Slide 98



Learning Outcomes Review

You are now able to:

- Identify the properties of unbound materials for use in pavement structural design
- Determine the properties of untreated granular layers (subgrade, subbase and base)
- Determine the properties of treated/stabilized base and subbase layers
- Identify the properties required for different input levels for asphalt layers
- Identify the properties required for different input levels for concrete layers
- Distinguish differing inputs and features of CRCP versus JPCP
- Define the materials properties for assessing the existing pavement as part of a rehabilitated pavement design
- Define design reliability
- Name five aspects of variability in the factors that affect pavement performance

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MATERIALS INPUTS
LESSON 3
98

Slide 1

ILT

HMEC

Highway Materials Engineering Course

Lesson 4: Flexible Pavement Design

Mechanistic Empirical Pavement Design Guide (MEPDG)

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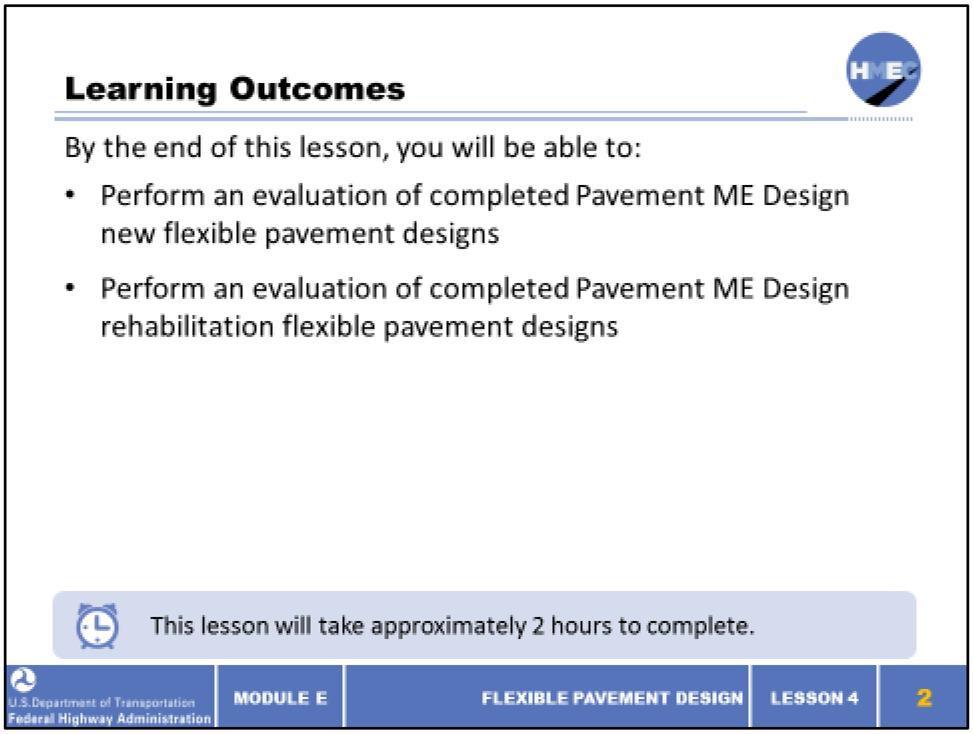
MODULE

E

Slide 2



Learning Outcomes

By the end of this lesson, you will be able to:

- Perform an evaluation of completed Pavement ME Design new flexible pavement designs
- Perform an evaluation of completed Pavement ME Design rehabilitation flexible pavement designs

This lesson will take approximately 2 hours to complete.

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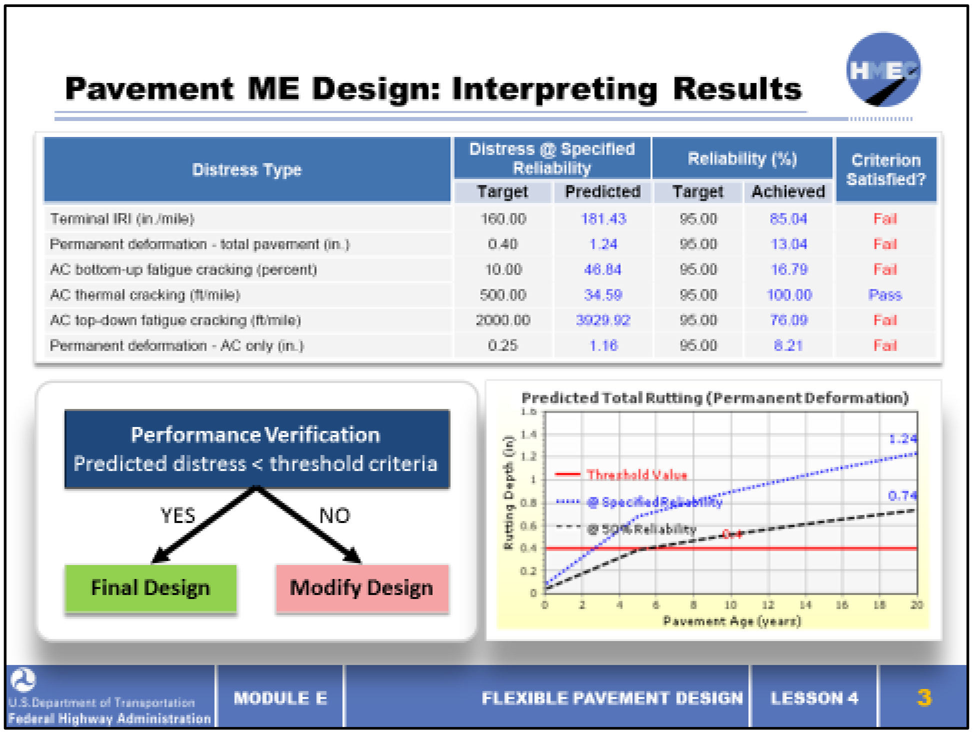
The Pavement ME Design has dual purposes, both as a pavement analysis tool to be used in academic exercises and as a pavement design tool for practitioners. Input for pavement analysis is project-specific, while inputs for pavement design would be primarily taken from the values from mix designs and what DOTs specify in their specifications. This is because when agencies design a pavement two years prior to construction, an agency doesn’t really don't know who the contractor is that will get the job and what specific mix design that the contractor will use in the JMF. Therefore, the inputs should be representative samples of an agency’s historic sample data that will reflect the strength of the DOT’s specification.

Slide 3



Pavement ME Design: Interpreting Results

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	181.43	95.00	85.04	Fail
Permanent deformation - total pavement (in.)	0.40	1.24	95.00	13.04	Fail
AC bottom-up fatigue cracking (percent)	10.00	46.84	95.00	16.79	Fail
AC thermal cracking (ft/mile)	500.00	34.59	95.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	2000.00	3929.92	95.00	76.09	Fail
Permanent deformation - AC only (in.)	0.25	1.16	95.00	8.21	Fail

Performance Verification
Predicted distress < threshold criteria

YES → Final Design

NO → Modify Design

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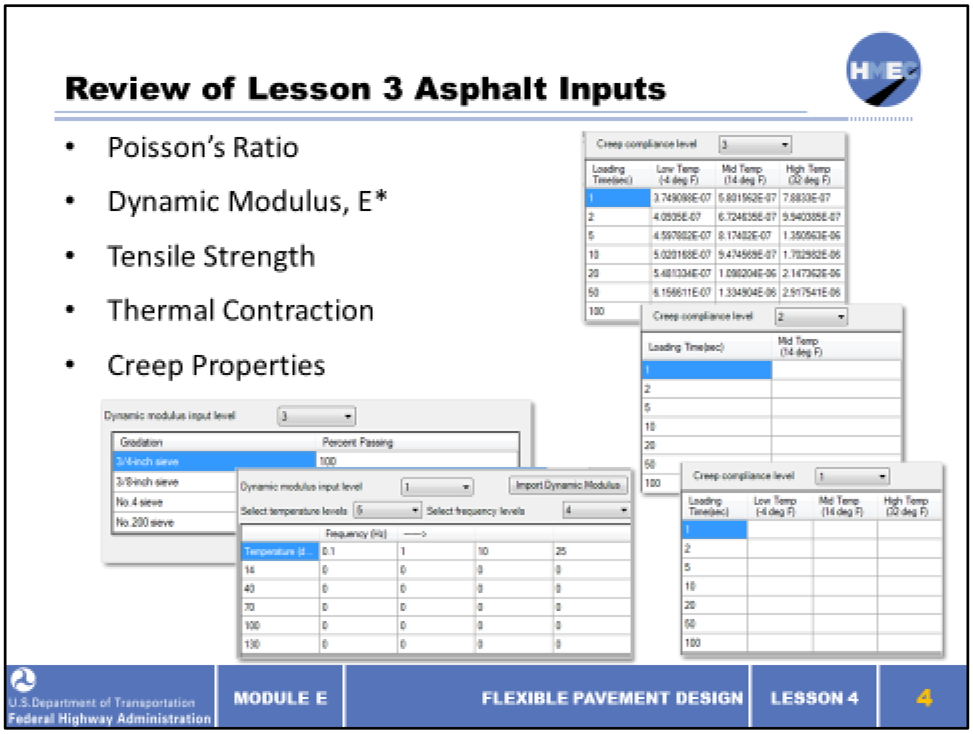
Federal Highway Administration
MODULE E
FLEXIBLE PAVEMENT DESIGN
LESSON 4
3

Slide 4



Review of Lesson 3 Asphalt Inputs

- Poisson’s Ratio
- Dynamic Modulus, E*
- Tensile Strength
- Thermal Contraction
- Creep Properties

Creep compliance level: 3

Loading Time(sec)	Low Temp (-4 deg F)	Mid Temp (14 deg F)	High Temp (32 deg F)
1	3.749098E-07	5.801962E-07	7.88833E-07
2	4.0935E-07	6.724035E-07	9.940385E-07
5	4.597802E-07	8.17402E-07	1.350963E-06
10	5.020168E-07	9.474569E-07	1.702982E-06
20	5.481334E-07	1.098204E-06	2.147362E-06
50	6.156611E-07	1.334904E-06	2.917541E-06
100			

Creep compliance level: 2

Loading Time(sec)	Mid Temp (14 deg F)
1	
2	
5	
10	
20	
50	
100	

Creep compliance level: 1

Loading Time(sec)	Low Temp (-4 deg F)	Mid Temp (14 deg F)	High Temp (32 deg F)
1			
2			
5			
10			
20			
50			
100			

Dynamic modulus input level: 3

Gradation	Percent Passing
3/4-inch sieve	100
3/8-inch sieve	
No.4 sieve	
No.200 sieve	

Dynamic modulus input level: 1

Select temperature levels: 6

Select frequency levels: 4

	Frequency (Hz)	⟶		
Temperature (d...	0.1	1	10	25
14	0	0	0	0
40	0	0	0	0
70	0	0	0	0
100	0	0	0	0
130	0	0	0	0

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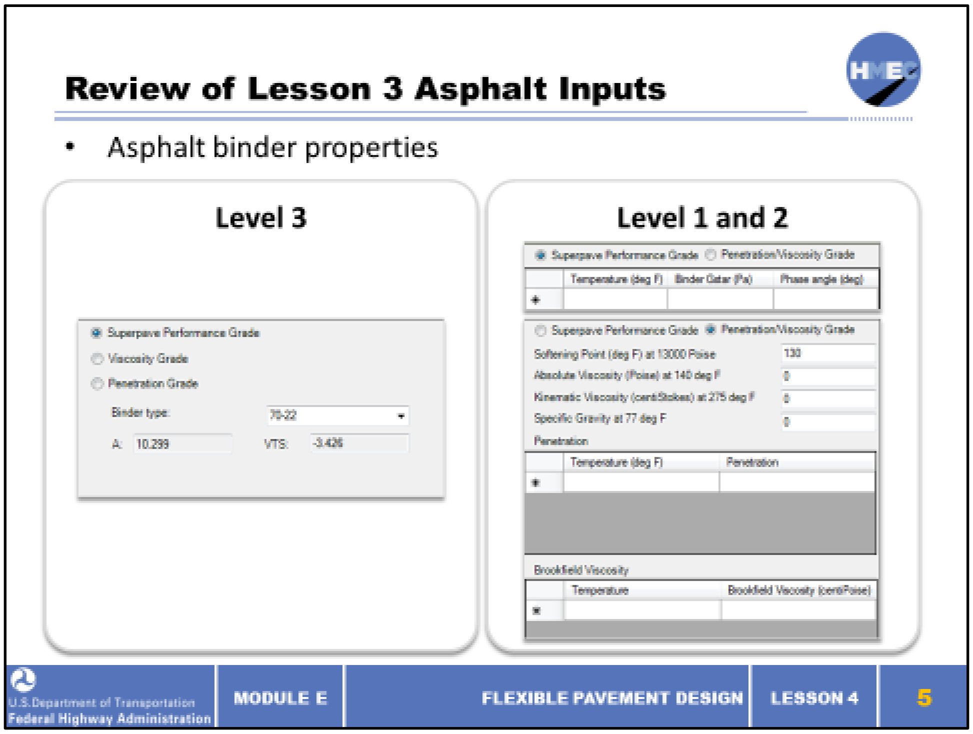
FLEXIBLE PAVEMENT DESIGN
LESSON 4
4

In this screen, the asphalt inputs required in the Pavement ME Design software are reviewed.

Slide 5



Review of Lesson 3 Asphalt Inputs

- Asphalt binder properties

Level 3

● Superpave Performance Grade
○ Viscosity Grade
○ Penetration Grade

Binder type: 70-22

A: 10.299 VTS: -3.426

Level 1 and 2

● Superpave Performance Grade ○ Penetration/Viscosity Grade

	Temperature (deg F)	Binder Gstar (Pa)	Phase angle (deg)
*			

○ Superpave Performance Grade ● Penetration/Viscosity Grade

Softening Point (deg F) at 13000 Poise: 130
Absolute Viscosity (Poise) at 140 deg F: 0
Kinematic Viscosity (centiStokes) at 275 deg F: 0
Specific Gravity at 77 deg F: 0

Penetration

	Temperature (deg F)	Penetration
*		

Brookfield Viscosity

	Temperature	Brookfield Viscosity (centiPoise)
*		

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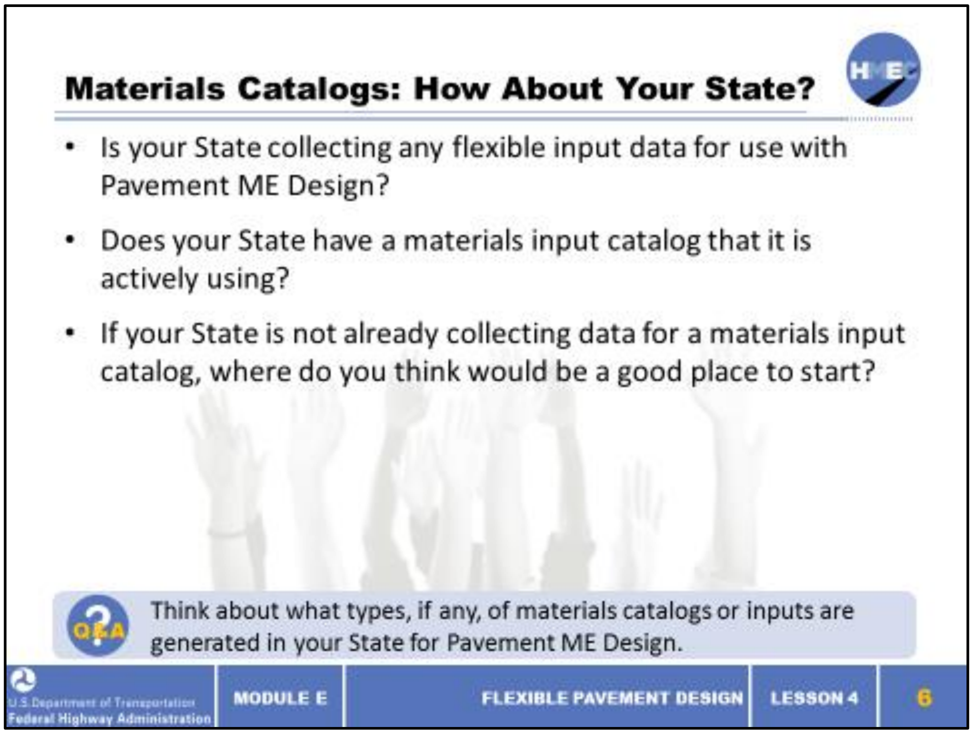
MODULE E
FLEXIBLE PAVEMENT DESIGN
LESSON 4
5

In this screen, the binder inputs required in the Pavement ME Design software are reviewed.

Slide 6



Materials Catalogs: How About Your State?

- Is your State collecting any flexible input data for use with Pavement ME Design?
- Does your State have a materials input catalog that it is actively using?
- If your State is not already collecting data for a materials input catalog, where do you think would be a good place to start?

Think about what types, if any, of materials catalogs or inputs are generated in your State for Pavement ME Design.

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RRD 372 Sensitivity Tables (Flexible Pavements)

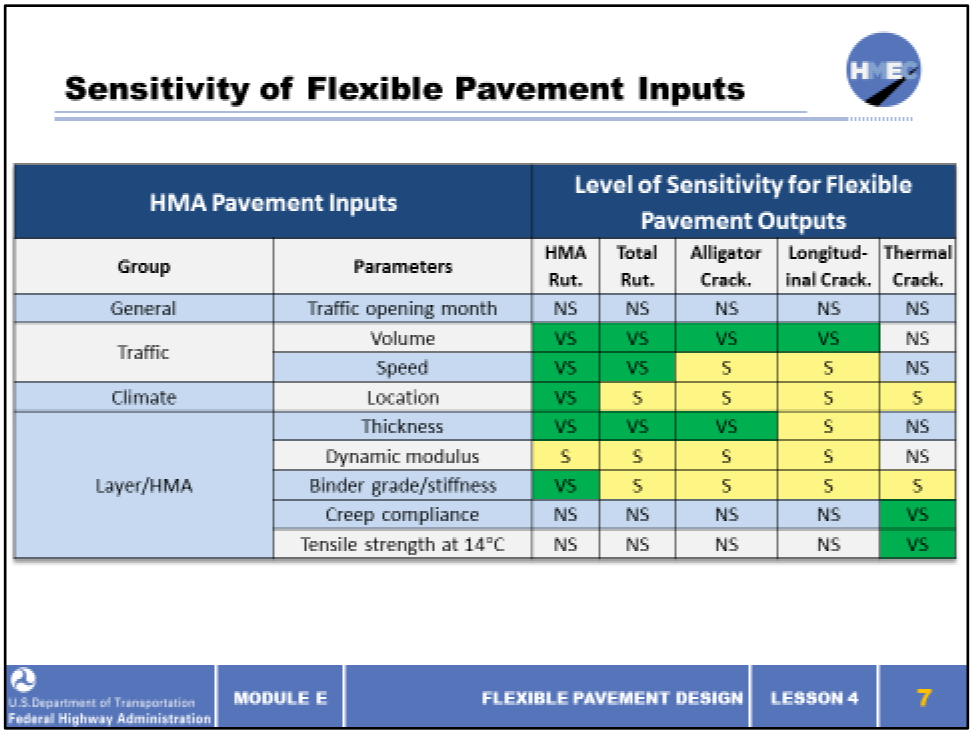
Inputs affecting HMA pavements

HMA Pavement Inputs		Level of Sensitivity for Flexible Pavement Outputs				
Group	**Parameters**	**HMA Rutting**	**Total Rutting**	**Alligator Cracking**	**Longitudinal Cracking**	**Thermal Cracking**
General	Traffic opening month	NS	NS	NS	NS	NS
Traffic	Volume	VS	VS	VS	VS	NS
	Speed	VS	VS	S	S	NS
Climate	Location	VS	S	S	S	S
	Depth to groundwater table	NS	S	NS	NS	NS
Layer/General	Surface shortwave absorptivity	VS	VS	S	VS	NS
Layer/HMA	Thickness	VS	VS	VS	S	NS
	Dynamic modulus	S	S	S	S	NS
	Binder grade/stiffness	VS	S	S	S	S
	Poisson's ratio	NS	NS	NS	NS	NS
	Thermal conductivity	NS	NS	NS	NS	S
	Heat capacity	NS	NS	NS	NS	S
	Creep compliance	NS	NS	NS	NS	VS
	Tensile strength at 14°C	NS	NS	NS	NS	VS
	Aggregate coefficient of thermal contraction	NS	NS	NS	NS	VS
Layer/Base (Subbase)	Thickness	S	S	S	S	NS
	Resilient modulus	S	S	S	VS	NS
	Poisson's ratio	NS	NS	NS	NS	NS
	Soil-water characteristic curve	NS	NS	NS	NS	NS

	Permeability	NS	NS	NS	NS	NS
	Compacted/uncompacted	NS	NS	NS	NS	NS
Layer/Subgrade	Resilient modulus	NS	VS	S	S	NS
	Poission's ratio	NS	NS	NS	NS	NS
	Soil-water characteristic curve	S	S	S	S	NS
	Permeability	NS	NS	NS	NS	NS
	Compacted/uncompacted	NS	NS	NS	NS	NS
HMA/HMA (Rehab)	Milled AC thickness	NS	NS	NS	NS	NS
	Existing AC thickness (after milling)	S	S	S	S	NS
	Existing AC binder grade	S	S	S	S	NS
	Pavement rating	VS	S	VS	VS	NS
	Total rutting	VS	VS	NS	NS	NS
HMA/JPCP (Rehab)	Existing PCC modulus of rupture	NS	NS	NS	NS	NS
	Percent slaps cracked/repaired	NS	NS	NS	NS	NS
	Monthly modulus of subgrade reaction	NS	NS	NS	NS	NS
	Month for measuring modulus	NS	NS	NS	NS	NS

Very Sensitive	Sensitive

Slide 7



Sensitivity of Flexible Pavement Inputs

HMA Pavement Inputs		Level of Sensitivity for Flexible Pavement Outputs				
Group	Parameters	HMA Rut.	Total Rut.	Alligator Crack.	Longitud-inal Crack.	Thermal Crack.
General	Traffic opening month	NS	NS	NS	NS	NS
Traffic	Volume	VS	VS	VS	VS	NS
	Speed	VS	VS	S	S	NS
Climate	Location	VS	S	S	S	S
Layer/HMA	Thickness	VS	VS	VS	S	NS
	Dynamic modulus	S	S	S	S	NS
	Binder grade/stiffness	VS	S	S	S	S
	Creep compliance	NS	NS	NS	NS	VS
	Tensile strength at 14°C	NS	NS	NS	NS	VS

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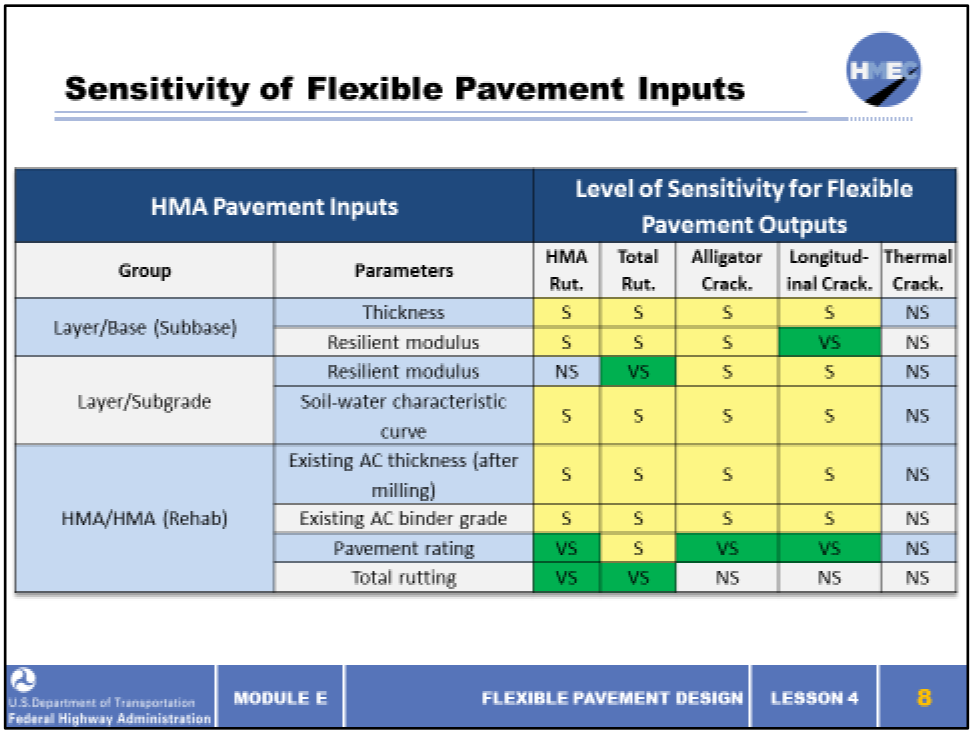
MODULE E FLEXIBLE PAVEMENT DESIGN LESSON 4 7

The information is needed to consider the changes to materials inputs.

Slide 8



Sensitivity of Flexible Pavement Inputs

HMA Pavement Inputs		Level of Sensitivity for Flexible Pavement Outputs				
Group	Parameters	HMA Rut.	Total Rut.	Alligator Crack.	Longitudinal Crack.	Thermal Crack.
Layer/Base (Subbase)	Thickness	S	S	S	S	NS
	Resilient modulus	S	S	S	VS	NS
Layer/Subgrade	Resilient modulus	NS	VS	S	S	NS
	Soil-water characteristic curve	S	S	S	S	NS
HMA/HMA (Rehab)	Existing AC thickness (after milling)	S	S	S	S	NS
	Existing AC binder grade	S	S	S	S	NS
	Pavement rating	VS	S	VS	VS	NS
	Total rutting	VS	VS	NS	NS	NS

It should be noted that there are many important parameters that are important to HMA over JPCP rehab designs but did not show sensitivity because of current limitations in the Pavement ME Design models, such as:

- Existing PCC modulus of rupture,
- Percent slaps cracked/repaired,
- Monthly modulus of subgrade reaction, and
- Month for measuring modulus

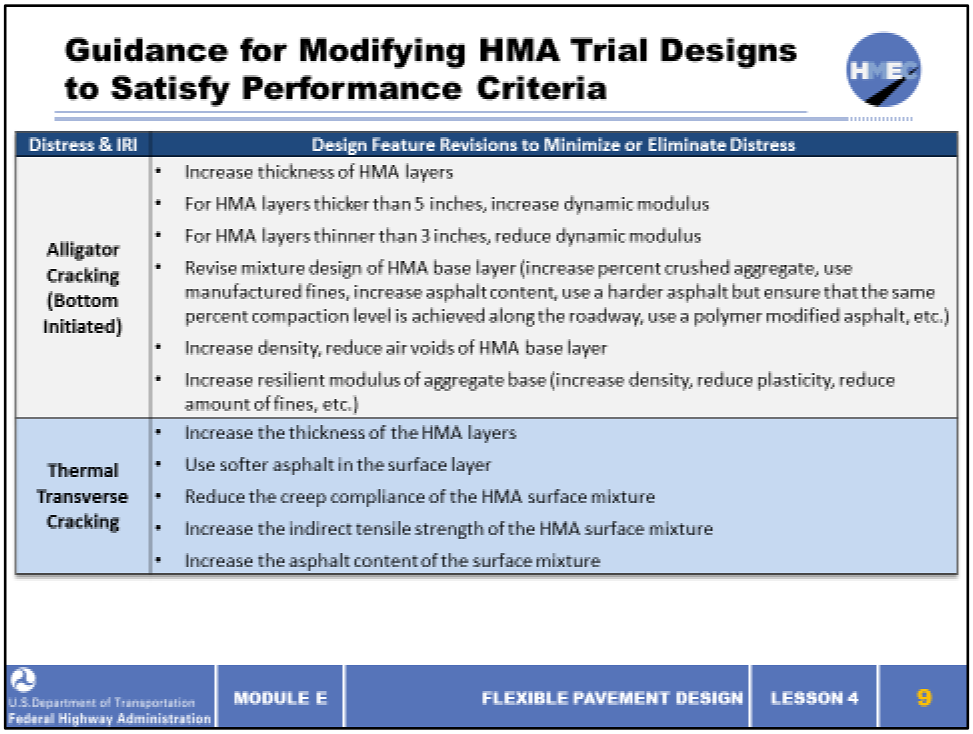
The same point applies to Milled AC Thickness, in HMA over HMA rehab designs.

Suggested Alterations to Pavement Design (JPCP)

Guidance for Modifying JPCP Trial Designs to Satisfy Performance Criteria (Taken from the AASHTO MEPDG Manual of Practice, 2008)

Distress & IRI	Modifications to Minimize or Eliminate
Joint Crack Width	• Build JPCP to set at lower temperature (cool PCC, place cooler temperatures). • Reduce drying shrinkage of PCC (increase aggregate size, decrease w/c ratio, decrease cement content). • Decrease joint spacing. • Reduce PCC coefficient of thermal expansion.
Joint LTE	• Use mechanical load transfer devices (dowels). • Increase diameter of dowels. • Reduce joint crack width (see joint crack width recommendations). • Increase aggregate size.
Joint Faulting	• Increase slab thickness. • Reduce joint width over analysis period. • Increase erosion resistance of base (specific recommendations for each type of base). • Minimize permanent curl/warp through curing procedures that eliminate built-in temperature gradient. • PCC tied shoulder. • Widened slab (by 1 to 2 ft.).
Slab Cracking	• Increase slab thickness. • Increase PCC strength. • Minimize permanent curl/warp through curing procedures that eliminate built-in temperature gradient. • PCC tied shoulder (separate placement or monolithic placement better). • Widened slab (1 to 2 ft.). • Use PCC with lower coefficient of thermal expansion.
IRI JPCP	• Require more stringent smoothness criteria and greater incentives.

Slide 9



Guidance for Modifying HMA Trial Designs to Satisfy Performance Criteria

Distress & IRI	Design Feature Revisions to Minimize or Eliminate Distress
Alligator Cracking (Bottom Initiated)	• Increase thickness of HMA layers • For HMA layers thicker than 5 inches, increase dynamic modulus • For HMA layers thinner than 3 inches, reduce dynamic modulus • Revise mixture design of HMA base layer (increase percent crushed aggregate, use manufactured fines, increase asphalt content, use a harder asphalt but ensure that the same percent compaction level is achieved along the roadway, use a polymer modified asphalt, etc.) • Increase density, reduce air voids of HMA base layer • Increase resilient modulus of aggregate base (increase density, reduce plasticity, reduce amount of fines, etc.)
Thermal Transverse Cracking	• Increase the thickness of the HMA layers • Use softer asphalt in the surface layer • Reduce the creep compliance of the HMA surface mixture • Increase the indirect tensile strength of the HMA surface mixture • Increase the asphalt content of the surface mixture

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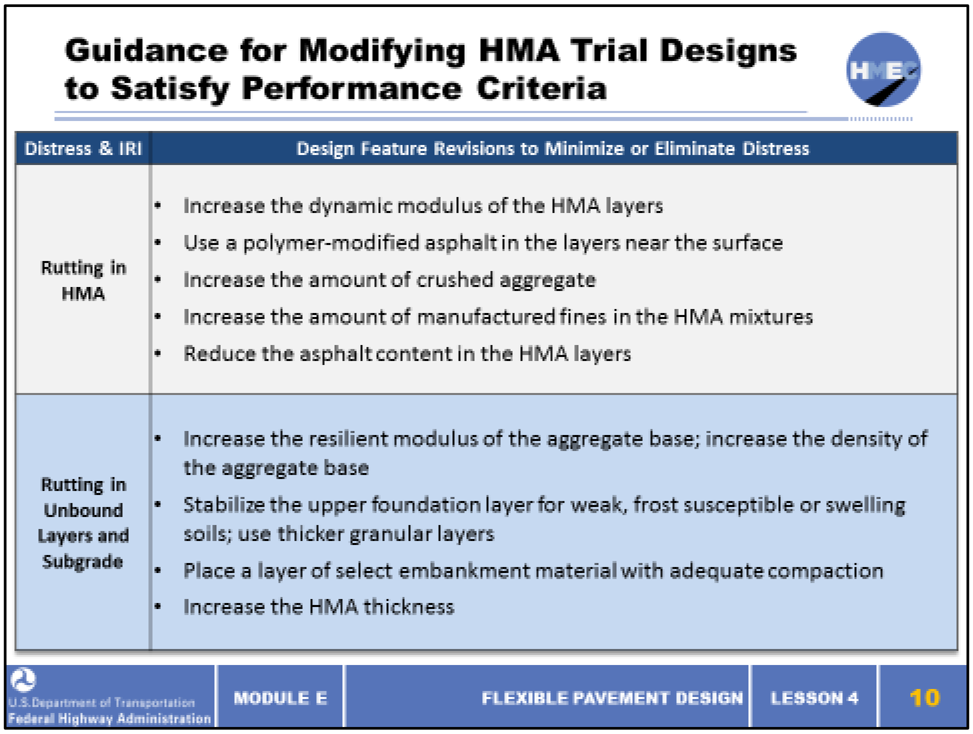
This shows that for alligator (traditional fatigue) cracking or thermal cracking, there are at least four alterations that you can make to decrease the amount of each of these distresses.

For alligator cracking, there are different recommendations regarding dynamic modulus (increasing versus decreasing it) based on the total HMA thickness (in terms of total asphalt thickness). For example, a designer would want the thin asphalt layers to have more flex in them (rather than behave more brittle).

Slide 10



Guidance for Modifying HMA Trial Designs to Satisfy Performance Criteria

Distress & IRI	Design Feature Revisions to Minimize or Eliminate Distress
Rutting in HMA	• Increase the dynamic modulus of the HMA layers • Use a polymer-modified asphalt in the layers near the surface • Increase the amount of crushed aggregate • Increase the amount of manufactured fines in the HMA mixtures • Reduce the asphalt content in the HMA layers
Rutting in Unbound Layers and Subgrade	• Increase the resilient modulus of the aggregate base; increase the density of the aggregate base • Stabilize the upper foundation layer for weak, frost susceptible or swelling soils; use thicker granular layers • Place a layer of select embankment material with adequate compaction • Increase the HMA thickness

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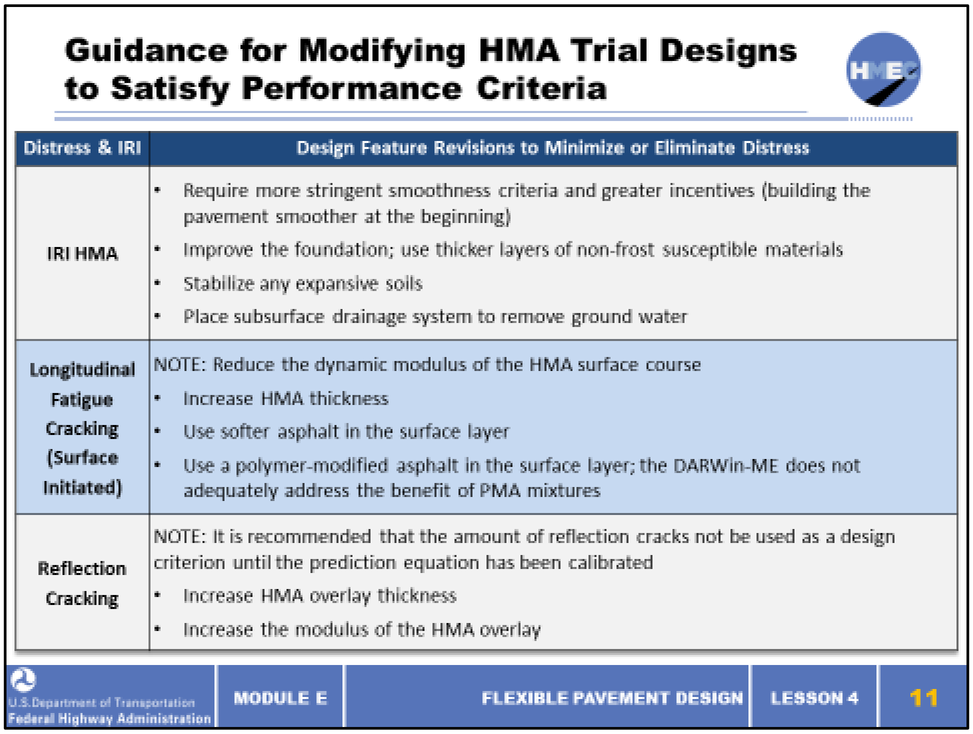
MODULE E | FLEXIBLE PAVEMENT DESIGN | LESSON 4 | 10

This shows that for rutting in the asphalt surface or total rutting in a flexible (new or overlay) pavement, there are at least four alterations that you can make to decrease the amount of each of these distresses.

Slide 11



Guidance for Modifying HMA Trial Designs to Satisfy Performance Criteria

Distress & IRI	Design Feature Revisions to Minimize or Eliminate Distress
IRI HMA	• Require more stringent smoothness criteria and greater incentives (building the pavement smoother at the beginning) • Improve the foundation; use thicker layers of non-frost susceptible materials • Stabilize any expansive soils • Place subsurface drainage system to remove ground water
Longitudinal Fatigue Cracking (Surface Initiated)	NOTE: Reduce the dynamic modulus of the HMA surface course • Increase HMA thickness • Use softer asphalt in the surface layer • Use a polymer-modified asphalt in the surface layer; the DARWin-ME does not adequately address the benefit of PMA mixtures
Reflection Cracking	NOTE: It is recommended that the amount of reflection cracks not be used as a design criterion until the prediction equation has been calibrated • Increase HMA overlay thickness • Increase the modulus of the HMA overlay

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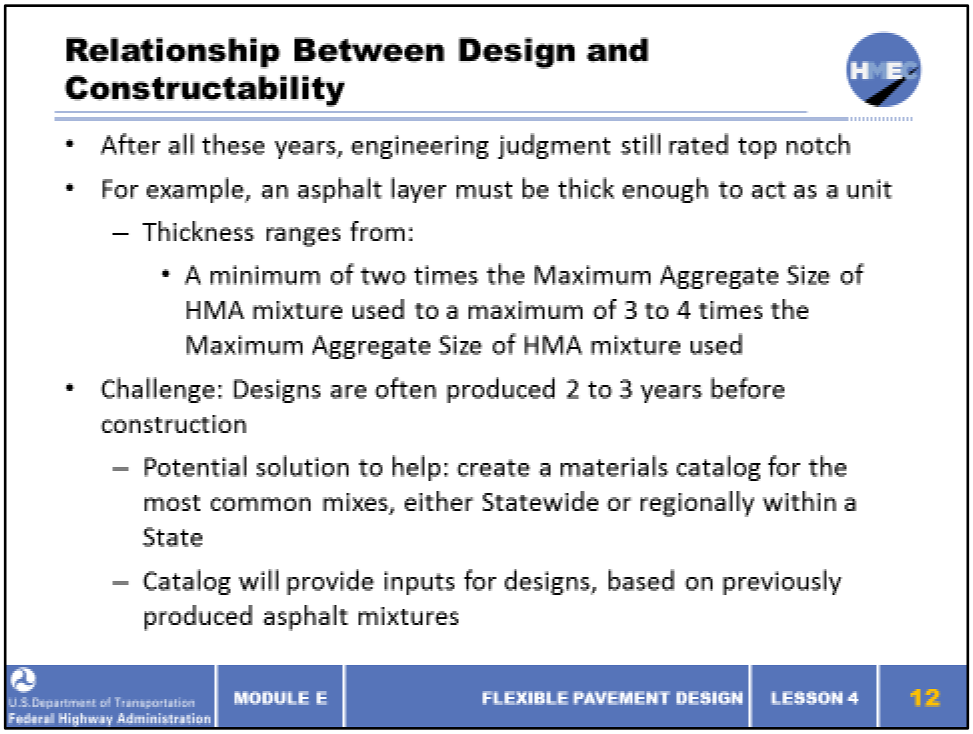
MODULE E | FLEXIBLE PAVEMENT DESIGN | LESSON 4 | 11

This shows that for IRI, longitudinal cracking, or reflection cracking in a flexible (new or overlay) pavement, there are at least two alterations that you can make to (a) improve rideability or (b) decrease the amount of each of these distresses.

Slide 12



Relationship Between Design and Constructability

- After all these years, engineering judgment still rated top notch
- For example, an asphalt layer must be thick enough to act as a unit
  - Thickness ranges from:
    - A minimum of two times the Maximum Aggregate Size of HMA mixture used to a maximum of 3 to 4 times the Maximum Aggregate Size of HMA mixture used
- Challenge: Designs are often produced 2 to 3 years before construction
  - Potential solution to help: create a materials catalog for the most common mixes, either Statewide or regionally within a State
  - Catalog will provide inputs for designs, based on previously produced asphalt mixtures

U.S. Department of Transportation Federal Highway Administration | MODULE E | FLEXIBLE PAVEMENT DESIGN | LESSON 4 | 12

Information needed to consider the changes to materials inputs:

Design versus constructability: If you design without considering carefully whether the design is viable for the construction conditions, then its service life is doomed from the start, e.g., engineering judgment is as important as it ever was and the “push button, give me an answer” nature of the Pavement ME Design still requires the engineer to use good engineering common sense. Coordination with the construction engineers is key.

The size of the State will influence the generation of a materials catalog, Statewide versus regionally. It also depends on the number of quarries and PG suppliers in the State.

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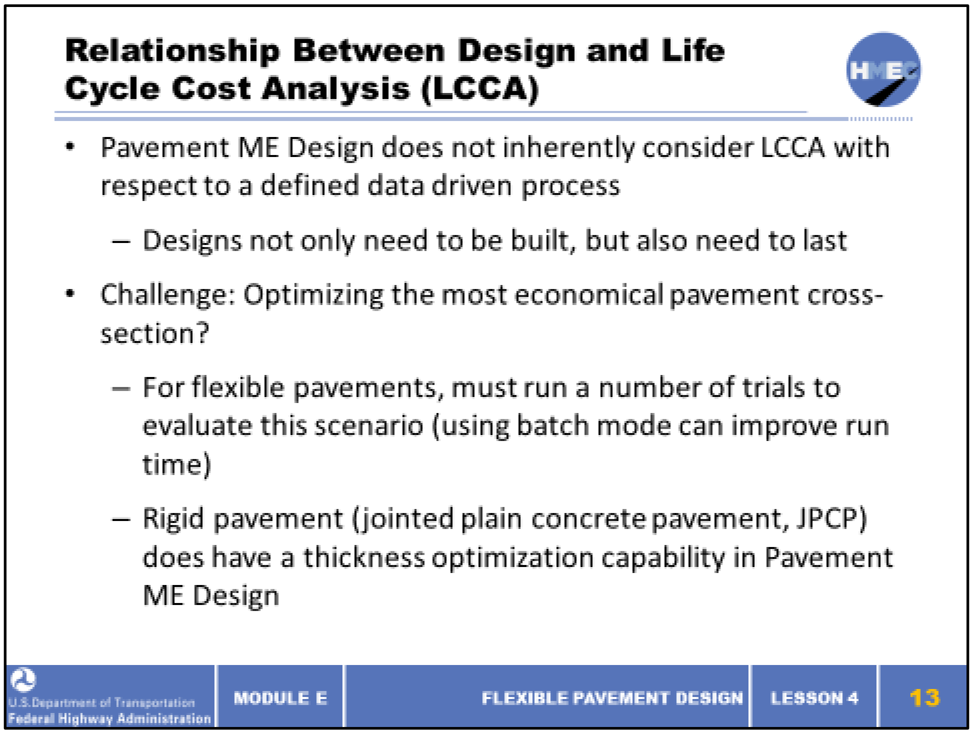
Slide 13

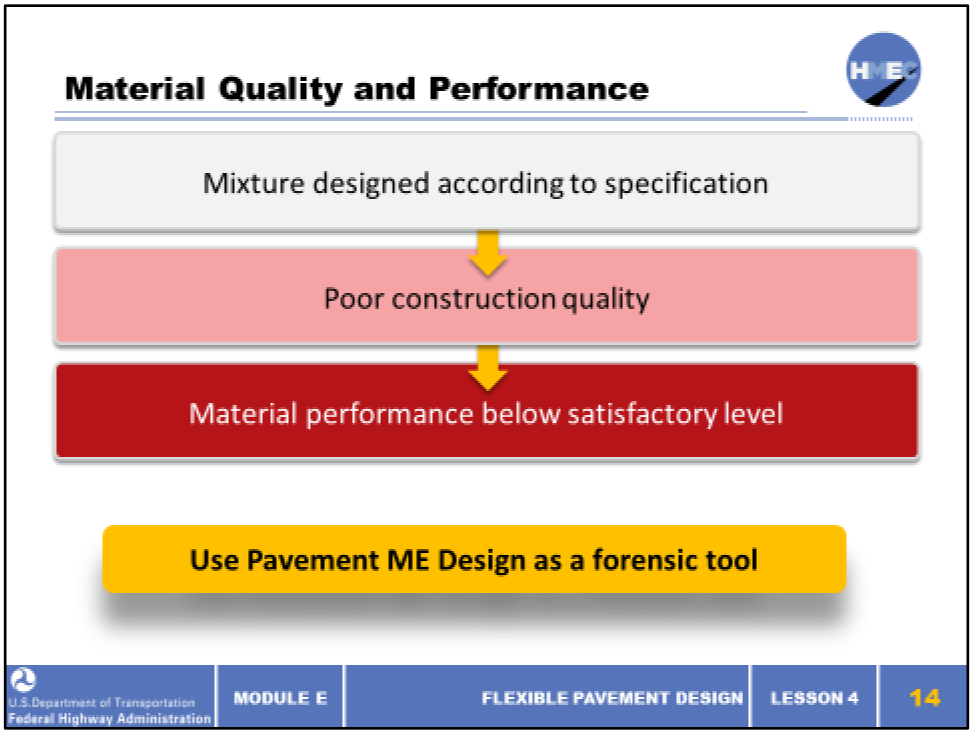


Relationship Between Design and Life Cycle Cost Analysis (LCCA)

- Pavement ME Design does not inherently consider LCCA with respect to a defined data driven process
  - Designs not only need to be built, but also need to last
- Challenge: Optimizing the most economical pavement cross-section?
  - For flexible pavements, must run a number of trials to evaluate this scenario (using batch mode can improve run time)
  - Rigid pavement (jointed plain concrete pavement, JPCP) does have a thickness optimization capability in Pavement ME Design

Hundreds of trials would have to be run for each combination of thickness and material properties to try and determine the most economical pavement cross-section for a given location. However, it is critical that engineering judgment be used to perform reality checks on designs in that they are consistent with constructability requirements.

Slide 14



Material Quality and Performance

Mixture designed according to specification

Poor construction quality

Material performance below satisfactory level

Use Pavement ME Design as a forensic tool

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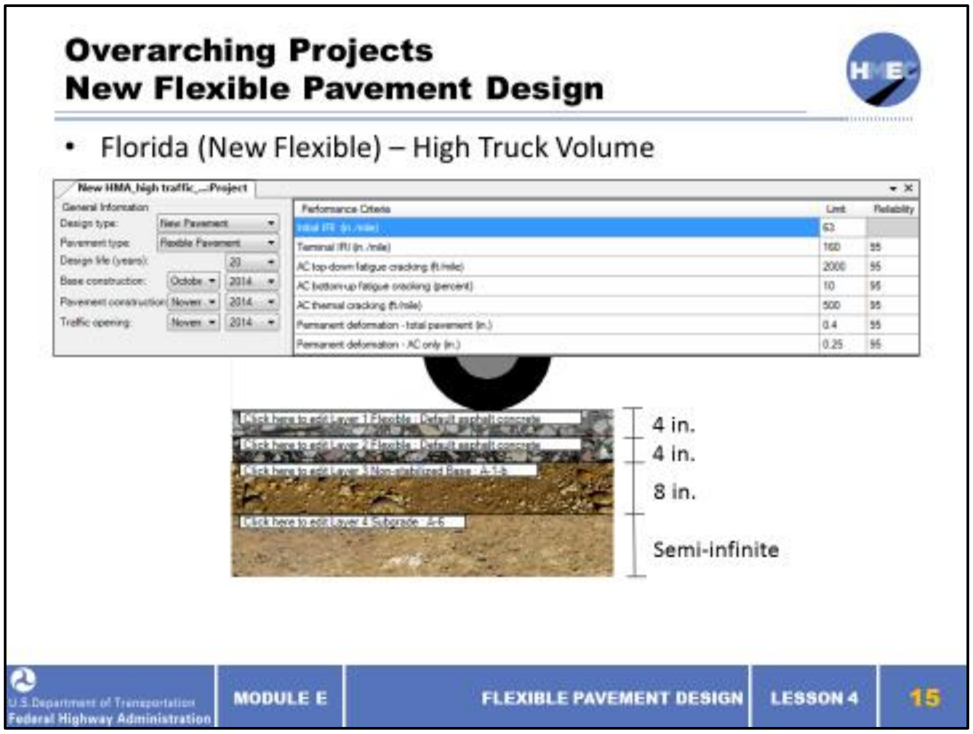
Poor construction quality results in greater variability in material properties and road performance.

Variability in mix properties like E* exist in real life, but in Pavement ME Design, we can only model it by creating multiple runs changing one parameter at a time incrementally and noting the impacts on the distress predictions on the performance criteria.

Slide 15



Overarching Projects
New Flexible Pavement Design

- Florida (New Flexible) – High Truck Volume

New HMA_high traffic_...:Project

General Information

Design type: New Pavement

Pavement type: Flexible Pavement

Design life (years): 20

Base construction: Octobe 2014

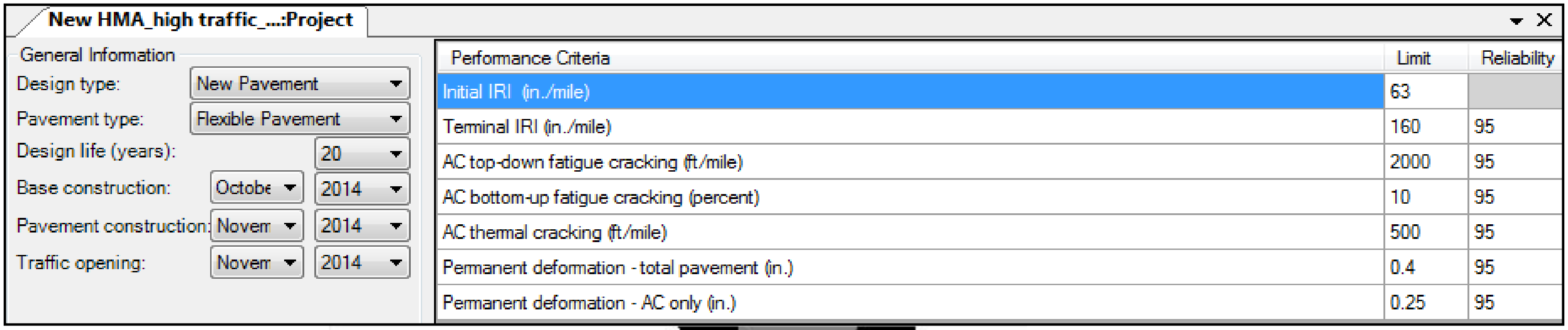
Pavement construction: Novem 2014

Traffic opening: Novem 2014

Performance Criteria	Limit	Reliability
Initial IRI (in./mile)	63	
Terminal IRI (in./mile)	160	95
AC top-down fatigue cracking (ft/mile)	2000	95
AC bottom-up fatigue cracking (percent)	10	95
AC thermal cracking (ft/mile)	500	95
Permanent deformation - total pavement (in.)	0.4	95
Permanent deformation - AC only (in.)	0.25	95

Click here to edit Layer 1 Flexible : Default asphalt concrete
Click here to edit Layer 2 Flexible : Default asphalt concrete
Click here to edit Layer 3 Non-stabilized Base : A-1-b
Click here to edit Layer 4 Subgrade : A-6
4 in.
4 in.
8 in.
Semi-infinite
U.S. Department of Transportation
Federal Highway Administration
MODULE E
FLEXIBLE PAVEMENT DESIGN
LESSON 4
15

- Florida (New Flexible) – High Truck Volume



New HMA_high traffic_...:Project

General Information

Design type: New Pavement
Pavement type: Flexible Pavement
Design life (years): 20
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Permanent deformation - total pavement (in.)	0.4	95
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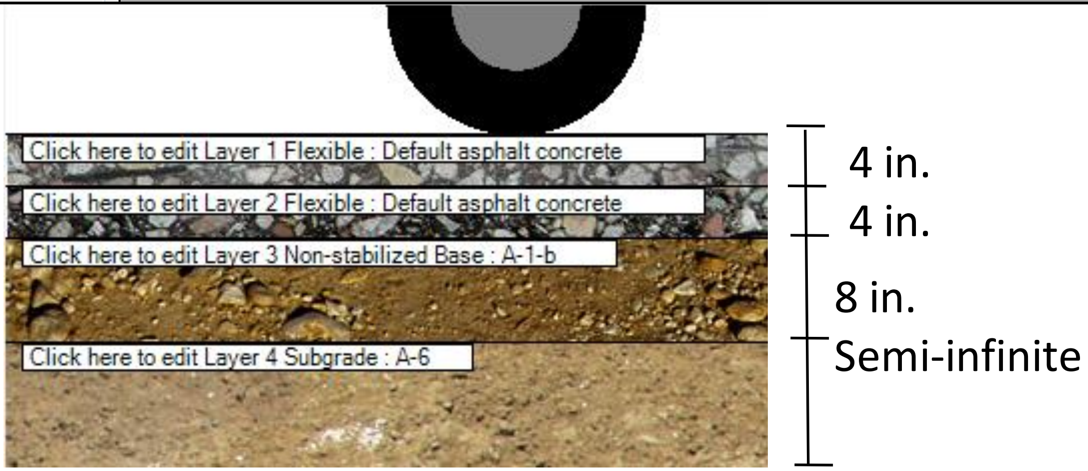
Click here to edit Layer 1 Flexible : Default asphalt concrete
Click here to edit Layer 2 Flexible : Default asphalt concrete
Click here to edit Layer 3 Non-stabilized Base : A-1-b
Click here to edit Layer 4 Subgrade : A-6
4 in.
4 in.
8 in.
Semi-infinite

Perform an evaluation of completed Pavement ME Design new flexible pavement designs, including critical analysis of pavement performance and suggested design alterations.

The summary of materials input data (and other design input data) are presented following this slide. This screen reviews with participants the pavement structure and performance criteria used for an interstate (based on the recommended values from the MEPDG Manual of Practice), design life, and material layers for the Florida sample section.

The DOT departmental policy should be used to select the performance criteria, as opposed to being limited to a very strict pre-set of values.

For example, Indiana adopted a maximum IRI of 160 inch/mile because it is the State DOT policy. If a higher IRI value than this were permitted, then the pavement condition would be flagged as having potential safety issues. Some State DOTs have performance criteria for IRI and other distresses based on other reasons. Overall, the idea is that there is no general rule toward applying the performance criteria threshold.

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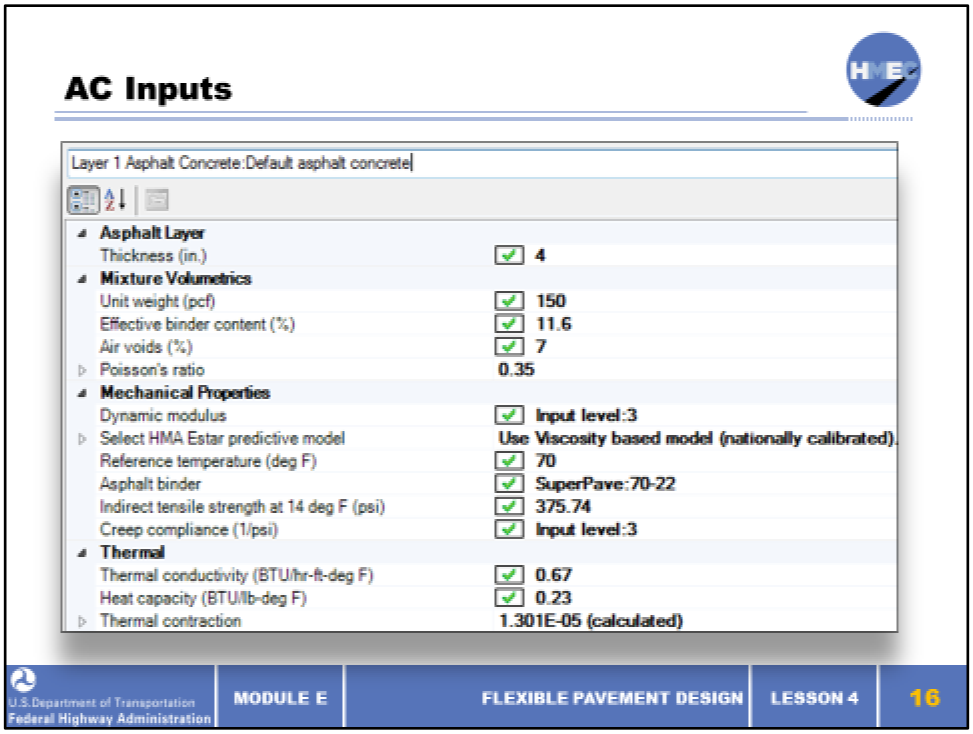
Slide 16



AC Inputs

Layer 1 Asphalt Concrete:Default asphalt concrete

Asphalt Layer	
Thickness (in.)	☑ 4
Mixture Volumetrics	
Unit weight (pcf)	☑ 150
Effective binder content (%)	☑ 11.6
Air voids (%)	☑ 7
Poisson's ratio	0.35
Mechanical Properties	
Dynamic modulus	☑ Input level:3
Select HMA Estar predictive model	Use Viscosity based model (nationally calibrated).
Reference temperature (deg F)	☑ 70
Asphalt binder	☑ SuperPave:70-22
Indirect tensile strength at 14 deg F (psi)	☑ 375.74
Creep compliance (1/psi)	☑ Input level:3
Thermal	
Thermal conductivity (BTU/hr-ft-deg F)	☑ 0.67
Heat capacity (BTU/lb-deg F)	☑ 0.23
Thermal contraction	1.301E-05 (calculated)

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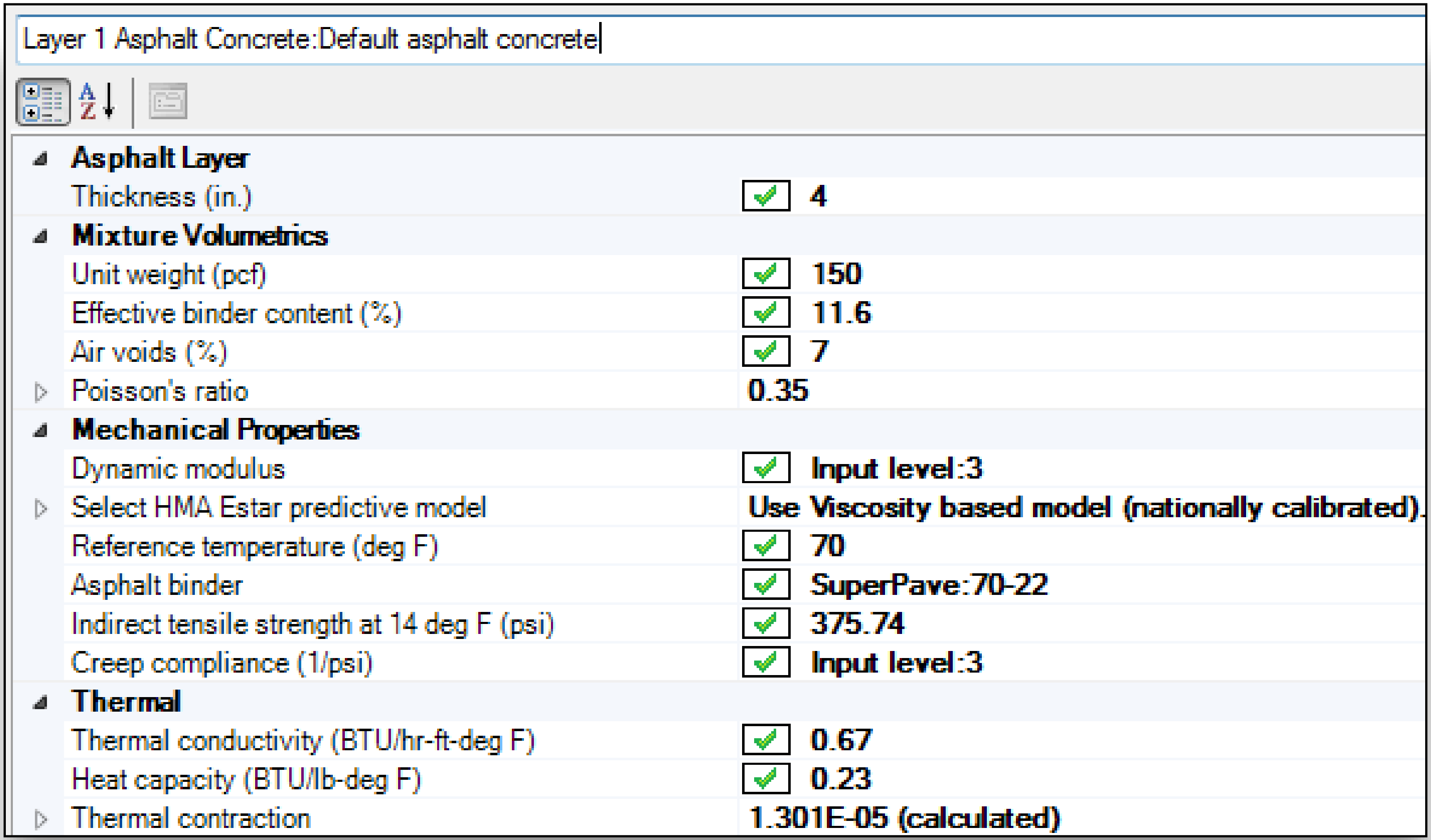
Federal Highway Administration

MODULE E FLEXIBLE PAVEMENT DESIGN LESSON 4 16



Layer 1 Asphalt Concrete:Default asphalt concrete

Asphalt Layer	
Thickness (in.)	☑ 4
Mixture Volumetrics	
Unit weight (pcf)	☑ 150
Effective binder content (%)	☑ 11.6
Air voids (%)	☑ 7
Poisson's ratio	0.35
Mechanical Properties	
Dynamic modulus	☑ Input level:3
Select HMA Estar predictive model	Use Viscosity based model (nationally calibrated).
Reference temperature (deg F)	☑ 70
Asphalt binder	☑ SuperPave:70-22
Indirect tensile strength at 14 deg F (psi)	☑ 375.74
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Thermal	
Thermal conductivity (BTU/hr-ft-deg F)	☑ 0.67
Heat capacity (BTU/lb-deg F)	☑ 0.23
Thermal contraction	1.301E-05 (calculated)

Perform an evaluation of completed Pavement ME Design new flexible pavement designs, including critical analysis of pavement performance and suggested design alterations.

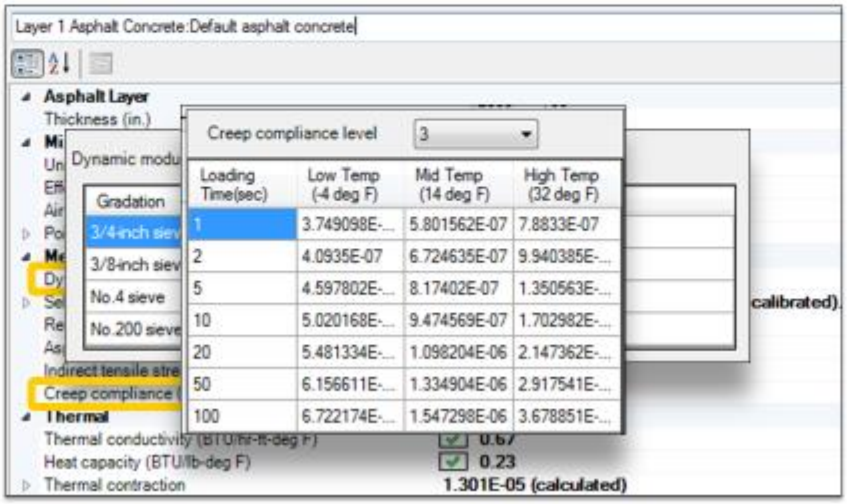
This screen reviews the material properties for the asphalt surface layer for the Florida sample section.

It should be noted that in Florida, most interstates would be required to have an open-graded friction course always placed as the surface layer. However, the ME Design software is not yet calibrated to fully predict for the majority of mixture types used for the top layer (commonly referred to as wearing courses) in flexible pavements. While the Pavement ME Design software was calibrated using a range of dense-graded surface mixes, it is not yet calibrated to fully reflect the performance for certain wearing courses such as stone matrix asphalt (SMA) and open-graded friction courses (OGFC).

This should be a cautionary note to materials engineers and designers, a challenge of reflecting construction reality within the context of design modeling.

Slide 17

AC Properties – Mechanical Responses



Layer 1 Asphalt Concrete:Default asphalt concrete

Asphalt Layer

Thickness (in.)

Dynamic modu

Gradation
3/4-inch siev
3/8-inch siev
No.4 sieve
No.200 sieve

Indirect tensile stre

Creep compliance (

Thermal

Thermal conductivity (BTU/hr-ft-deg F) ☑ 0.67

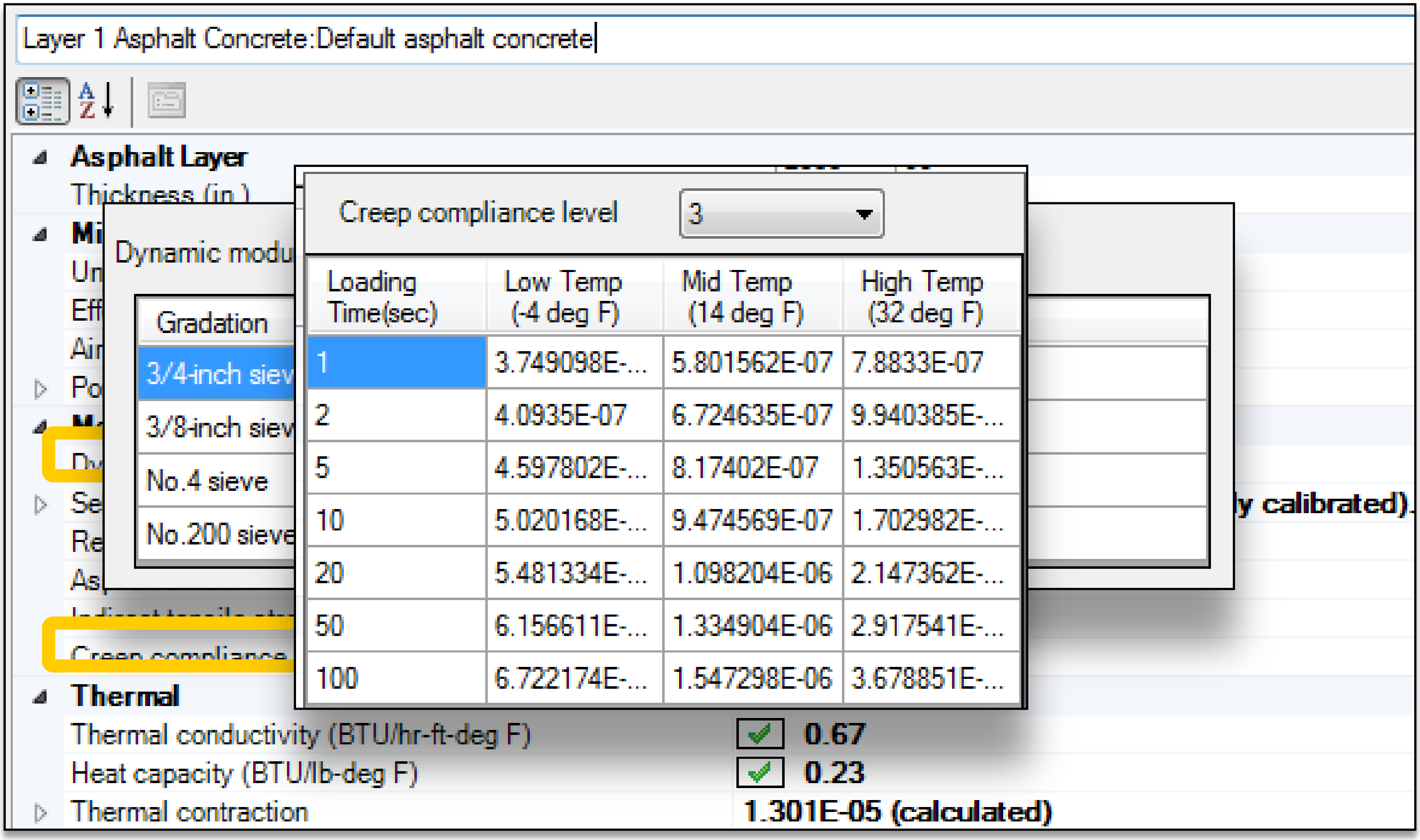
Heat capacity (BTU/lb-deg F) ☑ 0.23

Thermal contraction 1.301E-05 (calculated)

calibrated).

Creep compliance level: 3

Loading Time(sec)	Low Temp (-4 deg F)	Mid Temp (14 deg F)	High Temp (32 deg F)
1	3.749098E-...	5.801562E-07	7.8833E-07
2	4.0935E-07	6.724635E-07	9.940385E-...
5	4.597802E-...	8.17402E-07	1.350563E-...
10	5.020168E-...	9.474569E-07	1.702982E-...
20	5.481334E-...	1.098204E-06	2.147362E-...
50	6.156611E-...	1.334904E-06	2.917541E-...
100	6.722174E-...	1.547298E-06	3.678851E-...



Layer 1 Asphalt Concrete:Default asphalt concrete

Asphalt Layer

Thickness (in.)

Dynamic modu

Gradation
3/4-inch siev
3/8-inch siev
No.4 sieve
No.200 sieve

Creep compliance level 3

Loading Time(sec)	Low Temp (-4 deg F)	Mid Temp (14 deg F)	High Temp (32 deg F)
1	3.749098E-...	5.801562E-07	7.8833E-07
2	4.0935E-07	6.724635E-07	9.940385E-...
5	4.597802E-...	8.17402E-07	1.350563E-...
10	5.020168E-...	9.474569E-07	1.702982E-...
20	5.481334E-...	1.098204E-06	2.147362E-...
50	6.156611E-...	1.334904E-06	2.917541E-...
100	6.722174E-...	1.547298E-06	3.678851E-...

Thermal

Thermal conductivity (BTU/hr-ft-deg F)	✓ 0.67
Heat capacity (BTU/lb-deg F)	✓ 0.23
Thermal contraction	1.301E-05 (calculated)

Perform an evaluation of completed Pavement ME Design new flexible pavement designs, including critical analysis of pavement performance and suggested design alterations.

This screen reviews with participants the material properties for the asphalt surface layer for the Florida sample section—the Level 3 inputs properties for low-temperature performance and dynamic modulus, volumetric properties, etc.

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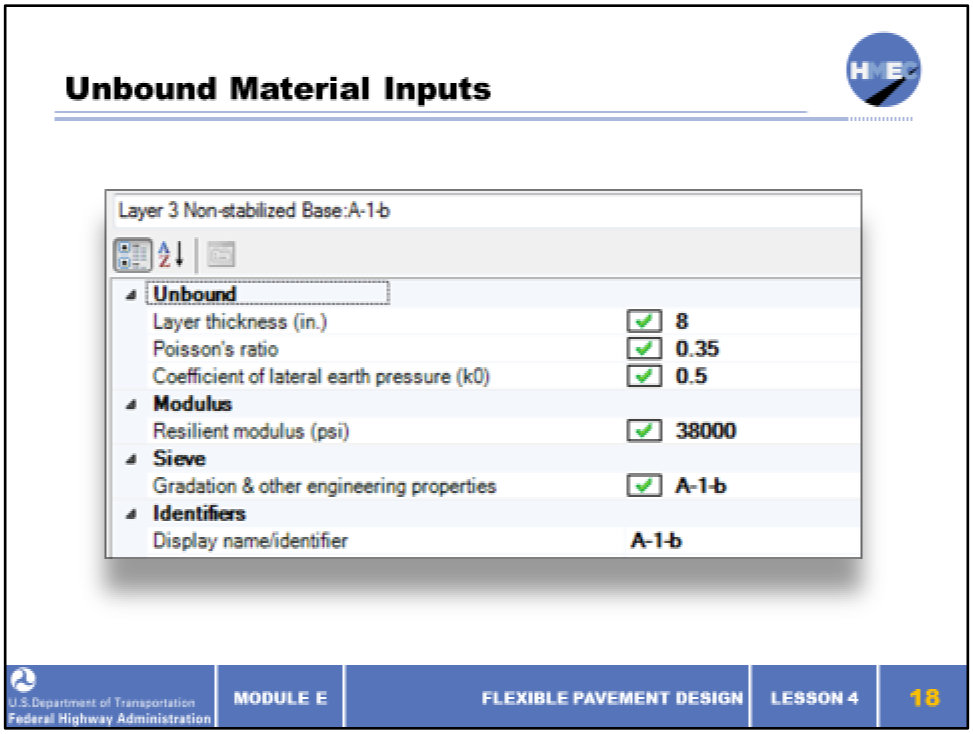
Slide 18



Unbound Material Inputs

Layer 3 Non-stabilized Base:A-1-b

Unbound	
Layer thickness (in.)	☑ **8**
Poisson's ratio	☑ **0.35**
Coefficient of lateral earth pressure (k0)	☑ **0.5**
Modulus	
Resilient modulus (psi)	☑ **38000**
Sieve	
Gradation & other engineering properties	☑ **A-1-b**
Identifiers	
Display name/identifier	**A-1-b**

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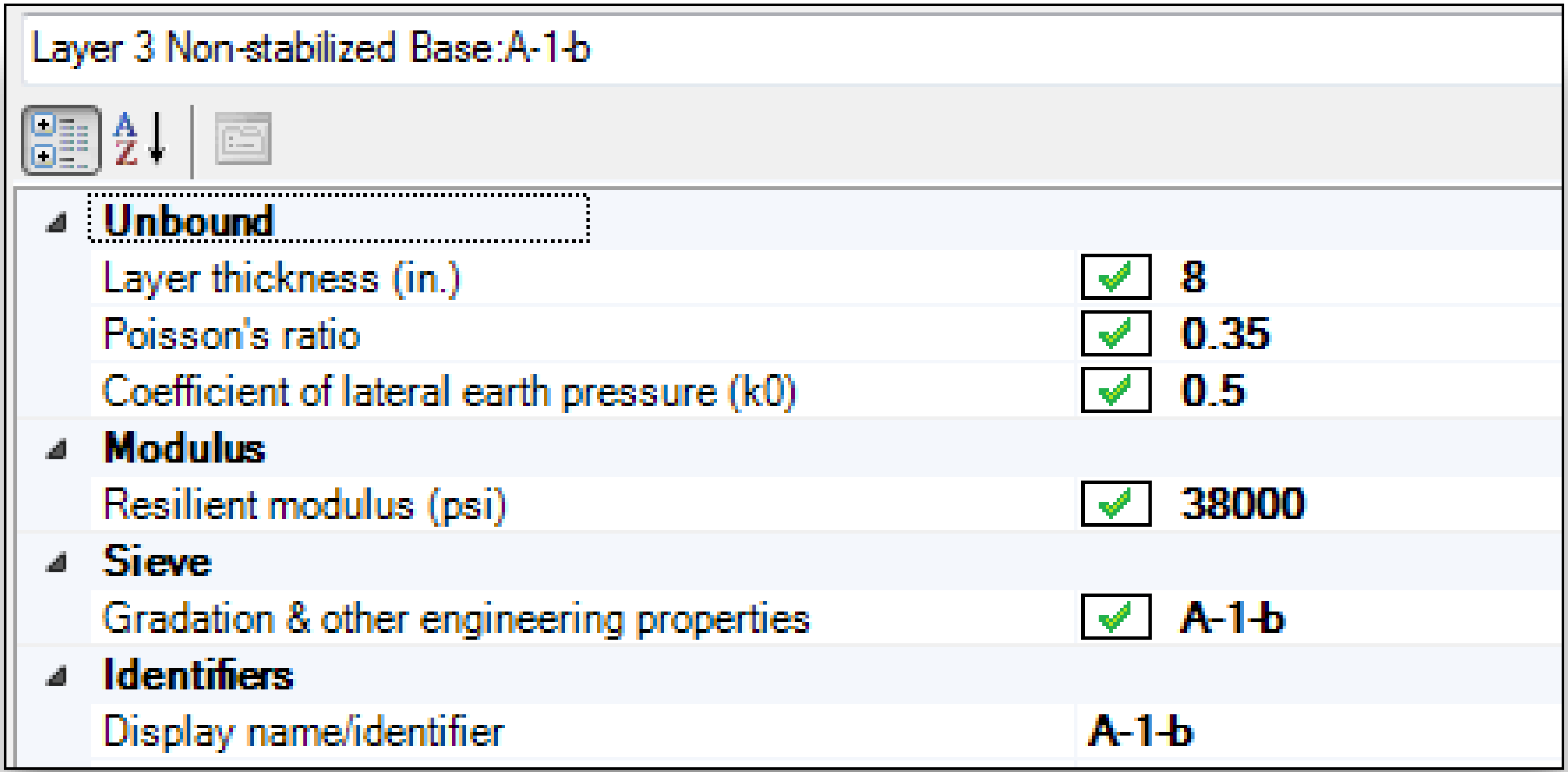
MODULE E
FLEXIBLE PAVEMENT DESIGN
LESSON 4
18



Layer 3 Non-stabilized Base:A-1-b

Unbound

Layer thickness (in.)	✓	8
Poisson's ratio	✓	0.35
Coefficient of lateral earth pressure (k0)	✓	0.5

Modulus

Resilient modulus (psi)	✓	38000

Sieve

Gradation & other engineering properties	✓	A-1-b

Identifiers

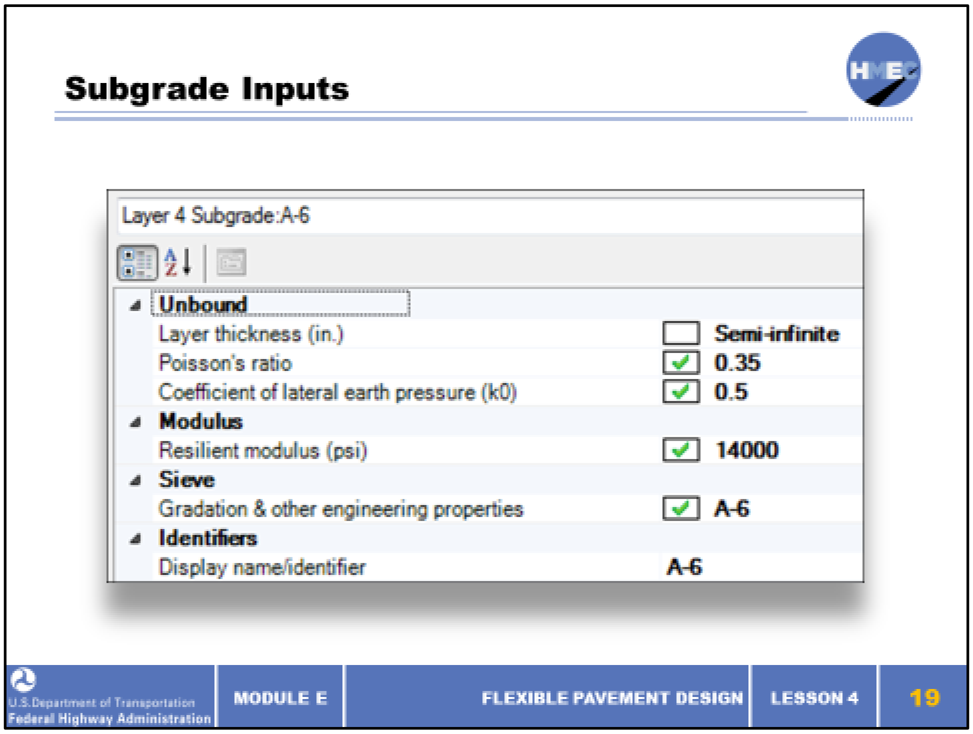
Display name/identifier	A-1-b

Perform an evaluation of completed Pavement ME Design new flexible pavement designs, including critical analysis of pavement performance and suggested design alterations.

This screen reviews the material properties for the unstabilized aggregate base layer for the Florida sample section.

It should be noted that in Florida, oftentimes the DOT uses a limerock base, which has high strength and can account for the thinner asphalt sections. This is part of how FDOT optimizes costs in their flexible pavement designs.

Slide 19



Subgrade Inputs

Layer 4 Subgrade:A-6

Unbound

Layer thickness (in.)	☐	**Semi-infinite**
Poisson's ratio	☑	**0.35**
Coefficient of lateral earth pressure (k0)	☑	**0.5**

Modulus

Resilient modulus (psi)	☑	**14000**

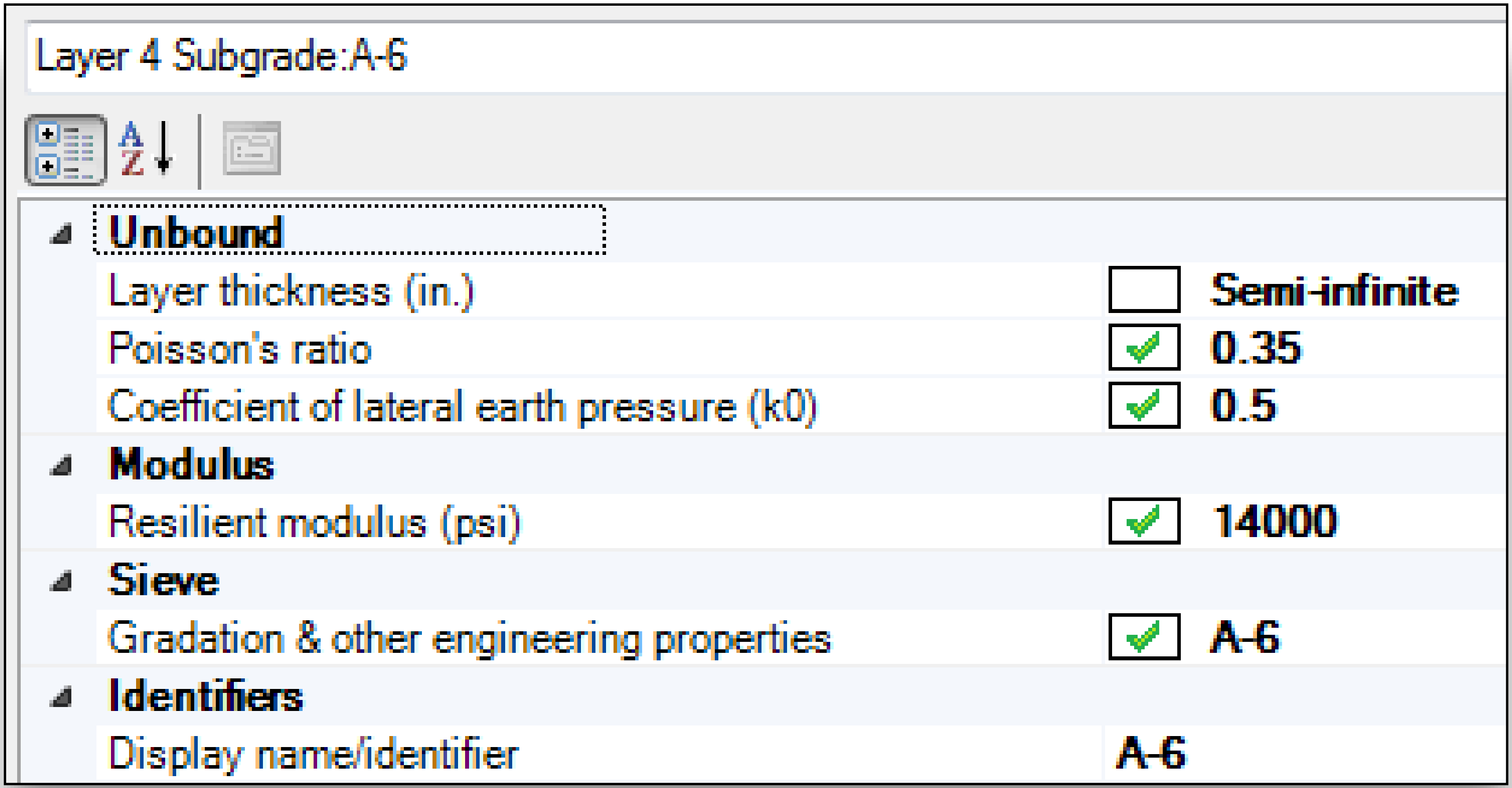
Sieve

Gradation & other engineering properties	☑	**A-6**

Identifiers

Display name/identifier	**A-6**

U.S. Department of Transportation
Federal Highway Administration
MODULE E
FLEXIBLE PAVEMENT DESIGN
LESSON 4
19



Layer 4 Subgrade:A-6

Unbound

Layer thickness (in.)	☐	**Semi-infinite**
Poisson's ratio	☑	**0.35**
Coefficient of lateral earth pressure (k0)	☑	**0.5**

Modulus

Resilient modulus (psi)	☑	**14000**

Sieve

Gradation & other engineering properties	☑	**A-6**

Identifiers

Display name/identifier	**A-6**

Perform an evaluation of completed Pavement ME Design new flexible pavement designs, including critical analysis of pavement performance and suggested design alterations.

This screen reviews the material properties for the subgrade layer for the Florida sample section.

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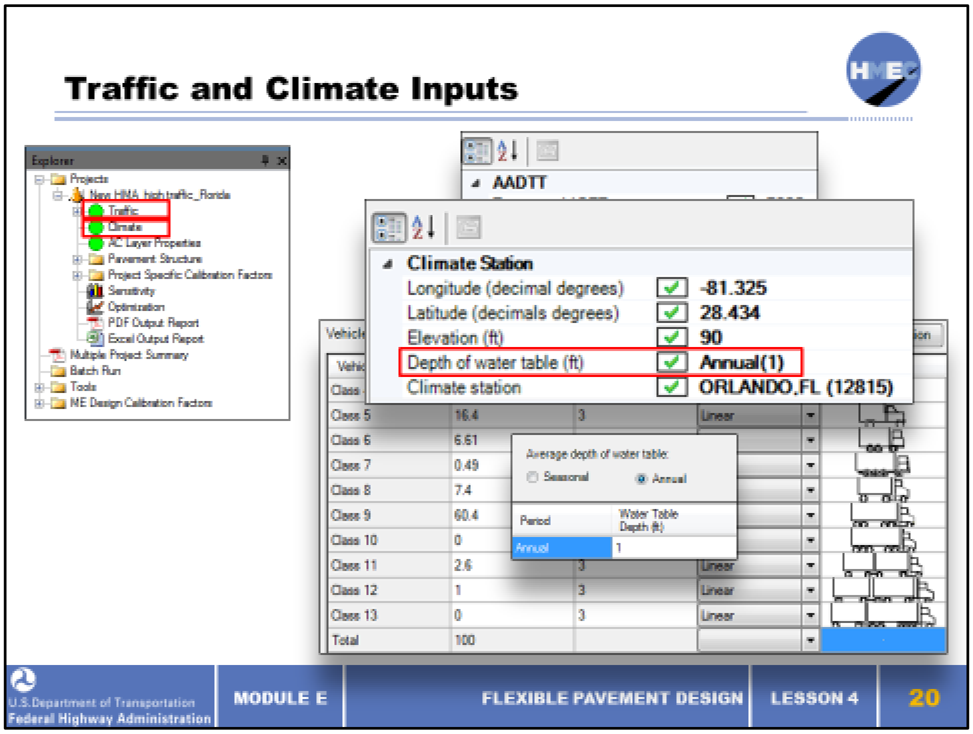
Slide 20



Traffic and Climate Inputs

Climate Station

Longitude (decimal degrees) ✓ -81.325

Latitude (decimals degrees) ✓ 28.434

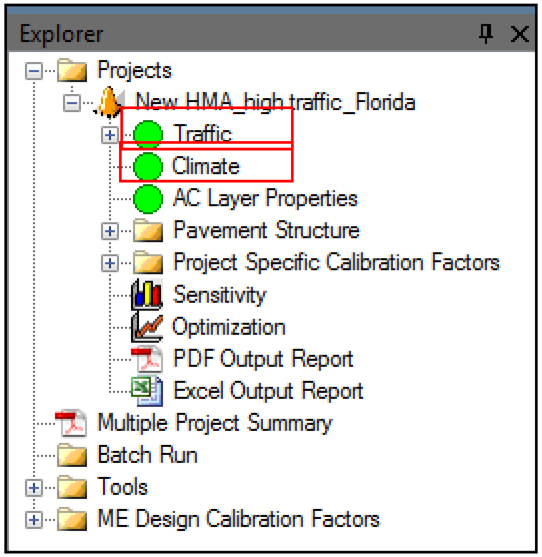
Elevation (ft) ✓ 90

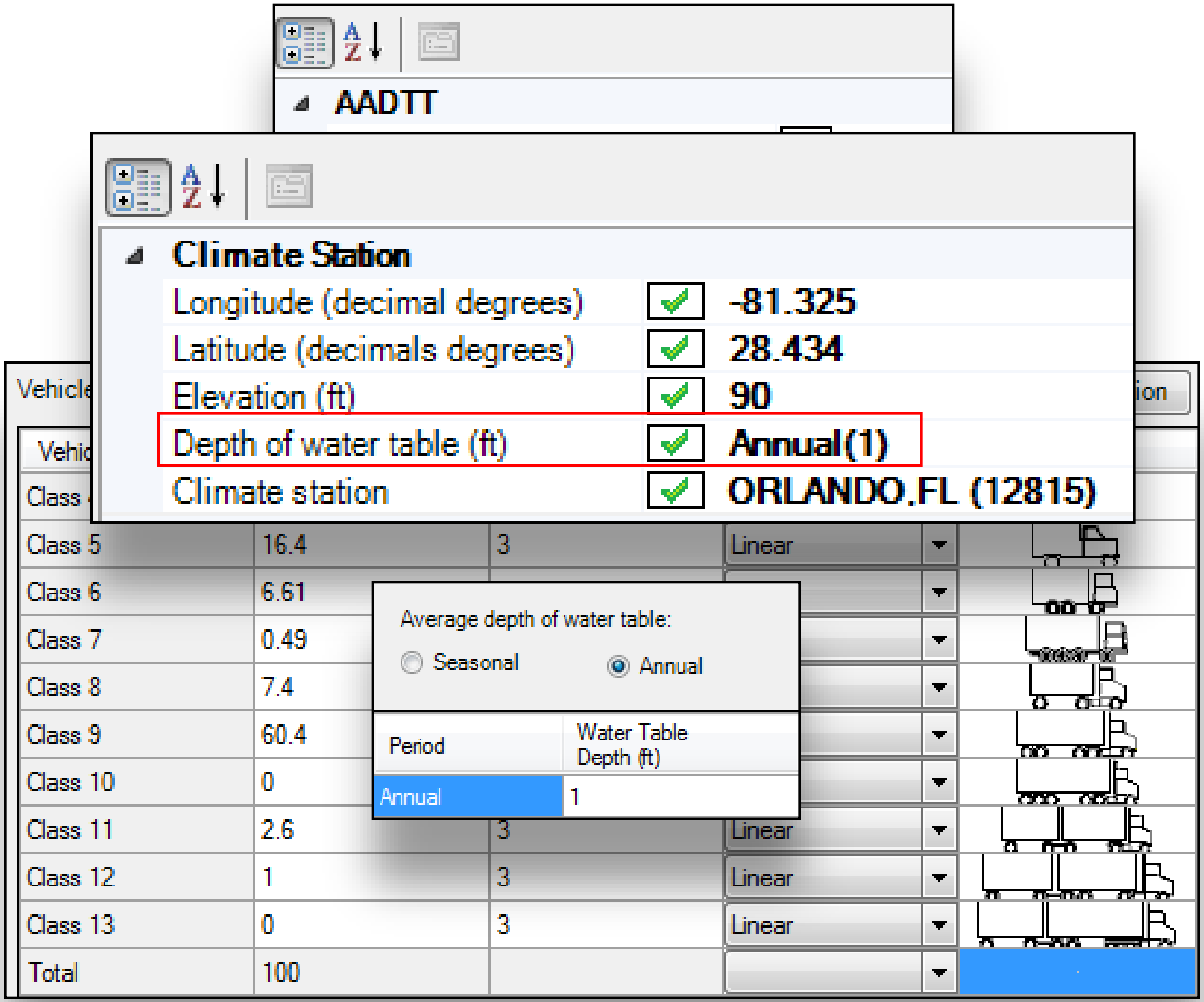
Depth of water table (ft) ✓ Annual(1)

Climate station ✓ ORLANDO,FL (12815)

Average depth of water table: ○ Seasonal ● Annual

Period	Water Table Depth (ft)
Annual	1





Climate Station

Longitude (decimal degrees)	✓	-81.325
Latitude (decimals degrees)	✓	28.434
Elevation (ft)	✓	90
Depth of water table (ft)	✓	Annual(1)
Climate station	✓	ORLANDO,FL (12815)

Average depth of water table:

○ Seasonal ● Annual

Period	Water Table Depth (ft)
Annual	1

Vehic			
Class			
Class 5	16.4	3	Linear
Class 6	6.61		
Class 7	0.49		
Class 8	7.4		
Class 9	60.4		
Class 10	0		
Class 11	2.6	3	Linear
Class 12	1	3	Linear
Class 13	0	3	Linear
Total	100		

Perform an evaluation of completed Pavement ME Design new flexible pavement designs, including critical analysis of pavement performance and suggested design alterations.

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Slide 21

AASHTOWare
Pavement
ME Design
PvD
AASHTO

Software Demonstration for Flexible Pavement

Start Demonstration

New Flexible Pavement Example

U.S. Department of Transportation Federal Highway Administration | MODULE E | FLEXIBLE PAVEMENT DESIGN | LESSON 4 | 21

Start Demonstration

New Flexible Pavement Example

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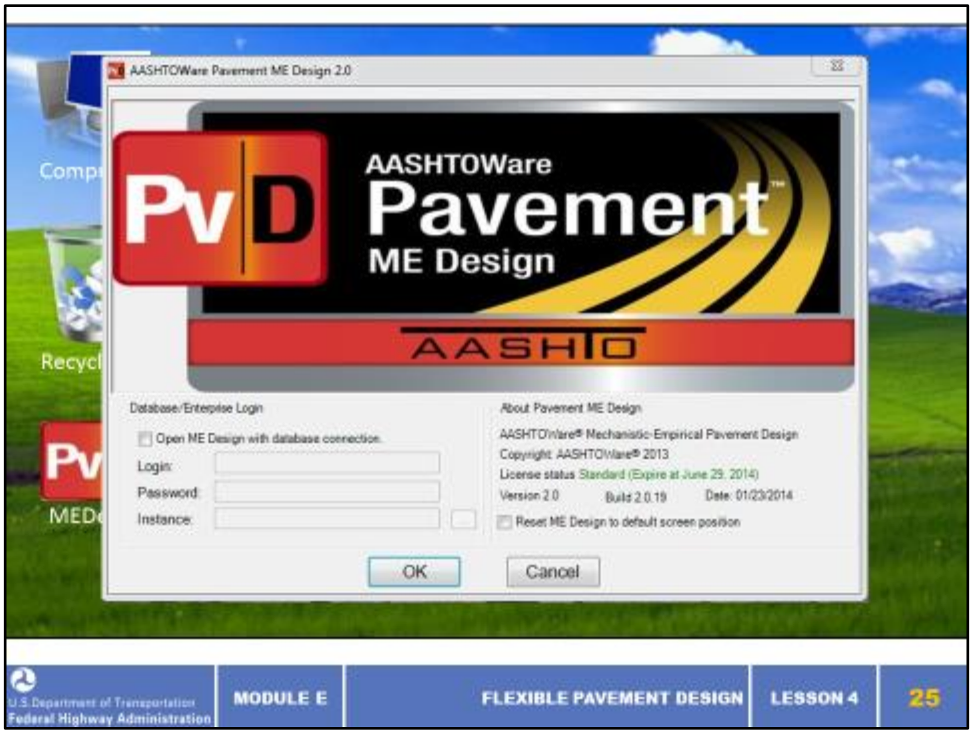
Slide 22



Database/Enterprise Login

☐ Open ME Design with database connection.

Login:
Password:
Instance:

About Pavement ME Design

AASHTOWare® Mechanistic-Empirical Pavement Design
Copyright: AASHTOWare® 2013
License status: Standard (Expire at June 29, 2014)
Version 2.0 Build 2.0.19 Date: 01/23/2014

☐ Reset ME Design to default screen position

Select the AASHTO Ware Pavement ME Design icon to launch the software. Select OK.

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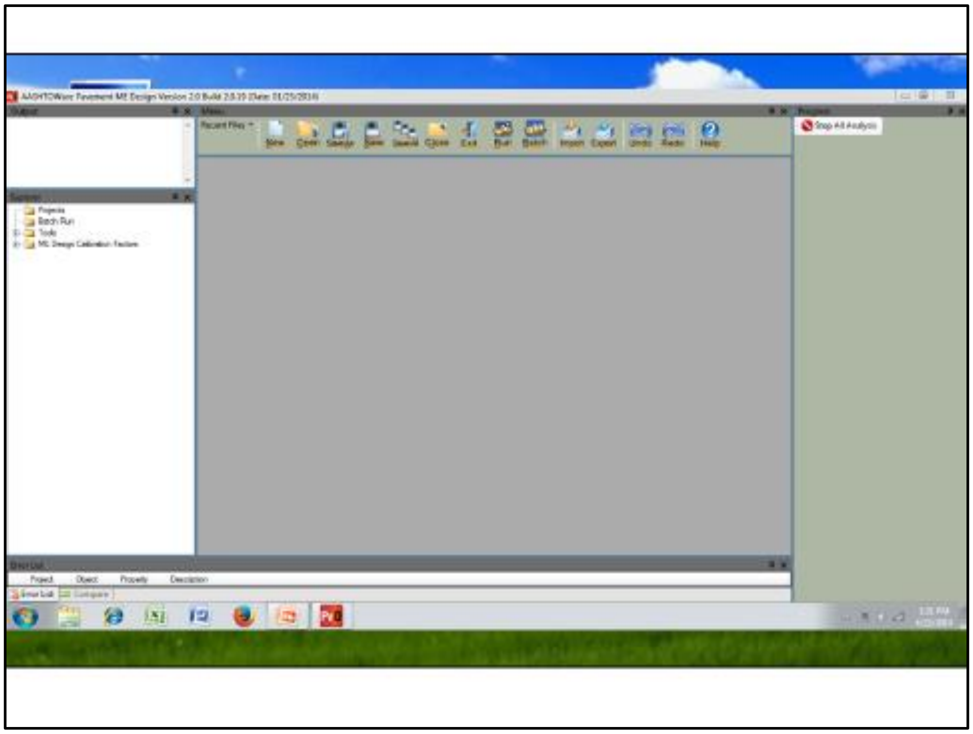
Slide 23



Select New.

This window will appear after the new icon is clicked on.

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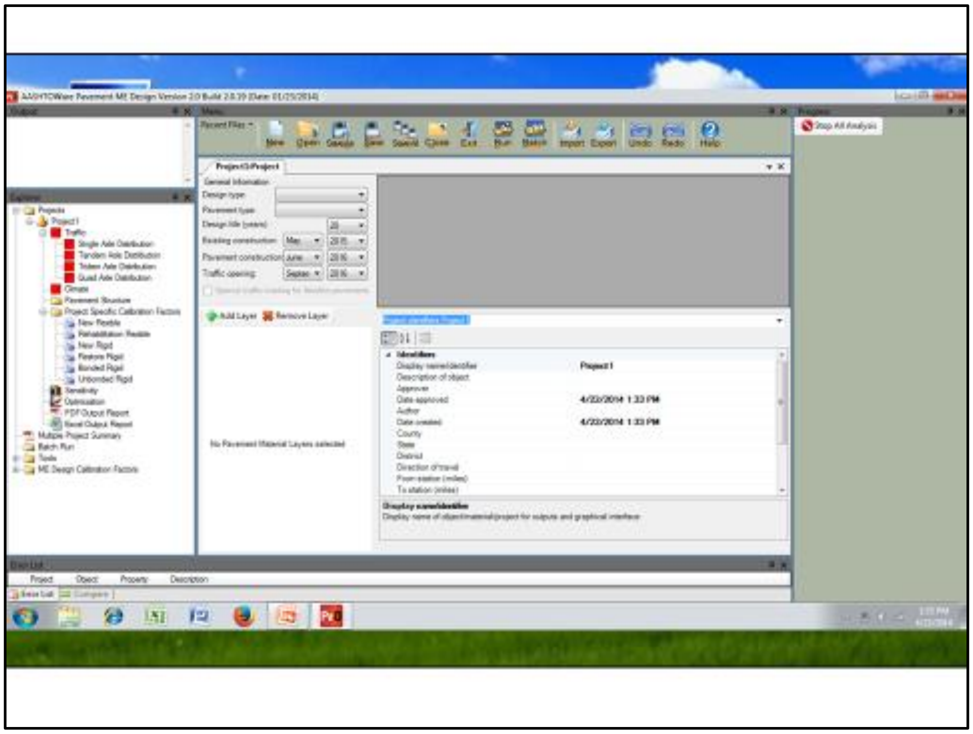
Slide 24



General Information
Design type:
Pavement type:
Design life (years): 20
Existing construction: May 2015
Pavement construction: June 2016
Traffic opening: September 2016

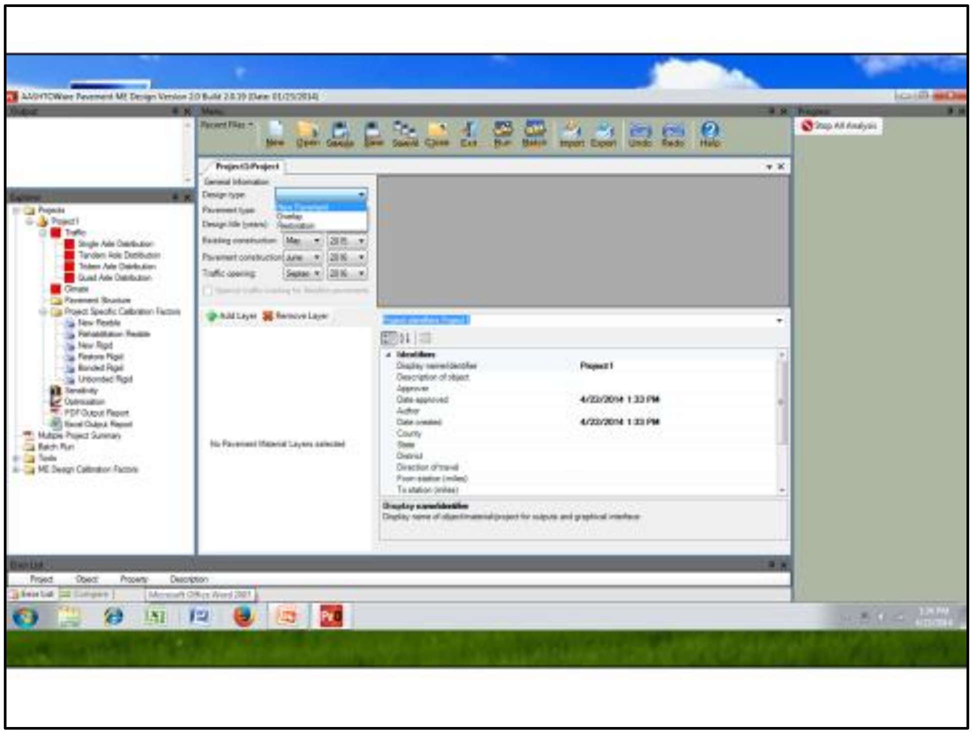
No Pavement Material Layers selected

Identifiers
Display name/identifier: Project1
Description of object:
Approver:
Date approved: 4/22/2014 1:33 PM
Author:
Date created: 4/22/2014 1:33 PM
County:
State:
District:
Direction of travel:
From station (miles):
To station (miles):

Display name/identifier
Display name of object/material/project for outputs and graphical interface

Select Design Type.

Slide 25



Design type:
Pavement type:
Design life (years):
Existing construction: May 2015
Pavement construction: June 2016
Traffic opening: Septem 2016

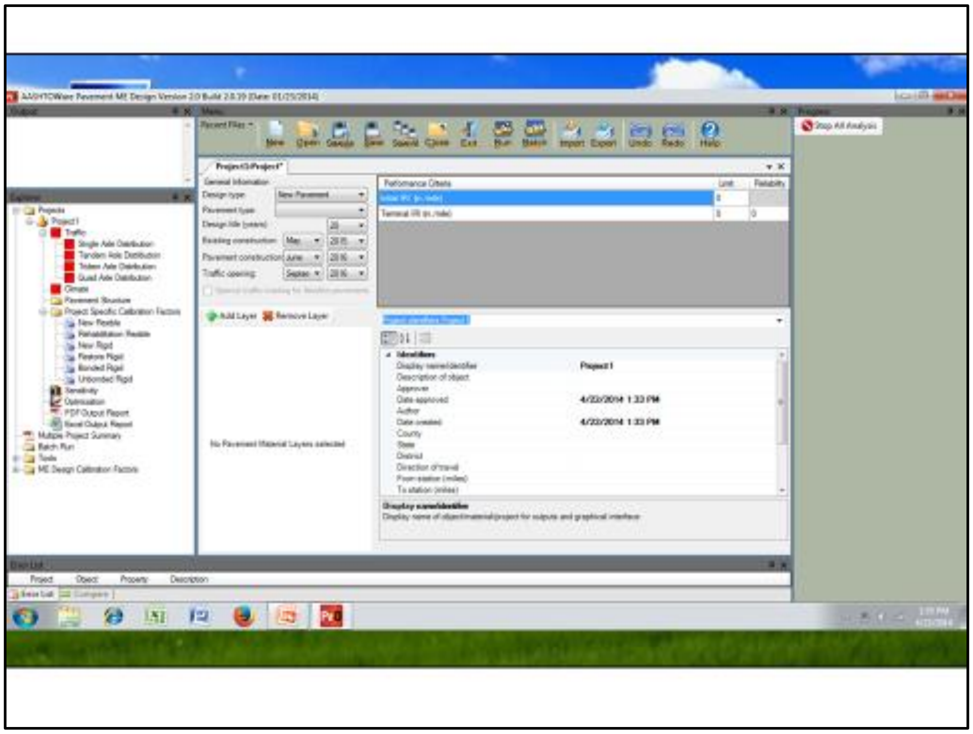
No Pavement Material Layers selected

Display name/identifier: Project1
Description of object:
Approver:
Date approved: 4/22/2014 1:33 PM
Author:
Date created: 4/22/2014 1:33 PM
County:
State:
District:
Direction of travel:
From station (miles):
To station (miles):

Display name/identifier
Display name of object/material/project for outputs and graphical interface.

Select New Pavement.

Slide 26



AASHTOWare Pavement ME Design Version 2.0 Build 2.0.19 (Date: 01/25/2014)

Design type: New Pavement

Pavement type:

No Pavement Material Layers selected

Display name/identifier: Project1

Date approved: 4/22/2014 1:33 PM

Date created: 4/22/2014 1:33 PM

Select Pavement Type.

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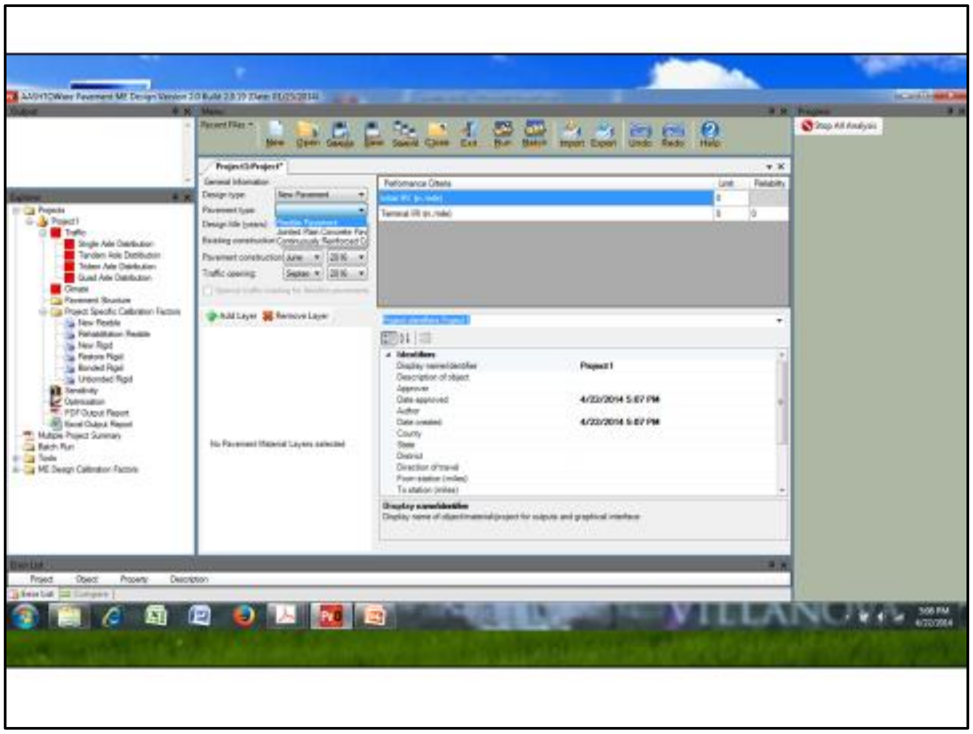
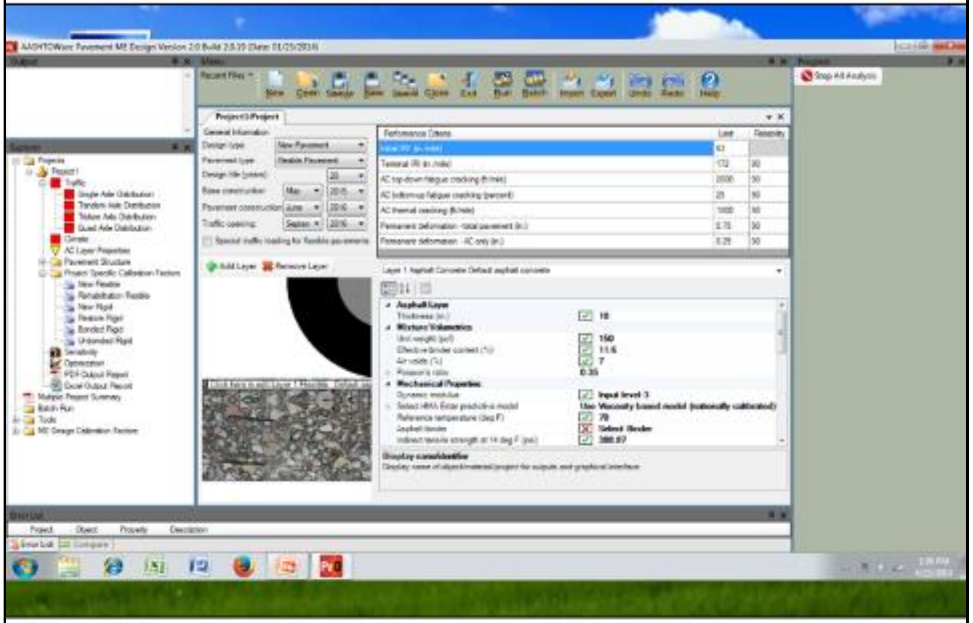
Slide 27



Select Flexible Pavement.

Slide 28



AASHTOWare Pavement ME Design Version 2.0 Build 2.0.19 (Date: 01/25/2014)

General Information

Design type	New Pavement
Pavement type	Flexible Pavement
Design life (years)	20
Base construction	May 2015
Pavement construction	June 2016
Traffic opening	September 2016

☐ Special traffic loading for flexible pavements

Performance Criteria	Limit	Reliability
Initial IRI (in./mile)	63	
Terminal IRI (in./mile)	172	90
AC top-down fatigue cracking (ft/mile)	2000	90
AC bottom-up fatigue cracking (percent)	25	90
AC thermal cracking (ft/mile)	1000	90
Permanent deformation - total pavement (in.)	0.75	90
Permanent deformation - AC only (in.)	0.25	90

Layer 1 Asphalt Concrete: Default asphalt concrete

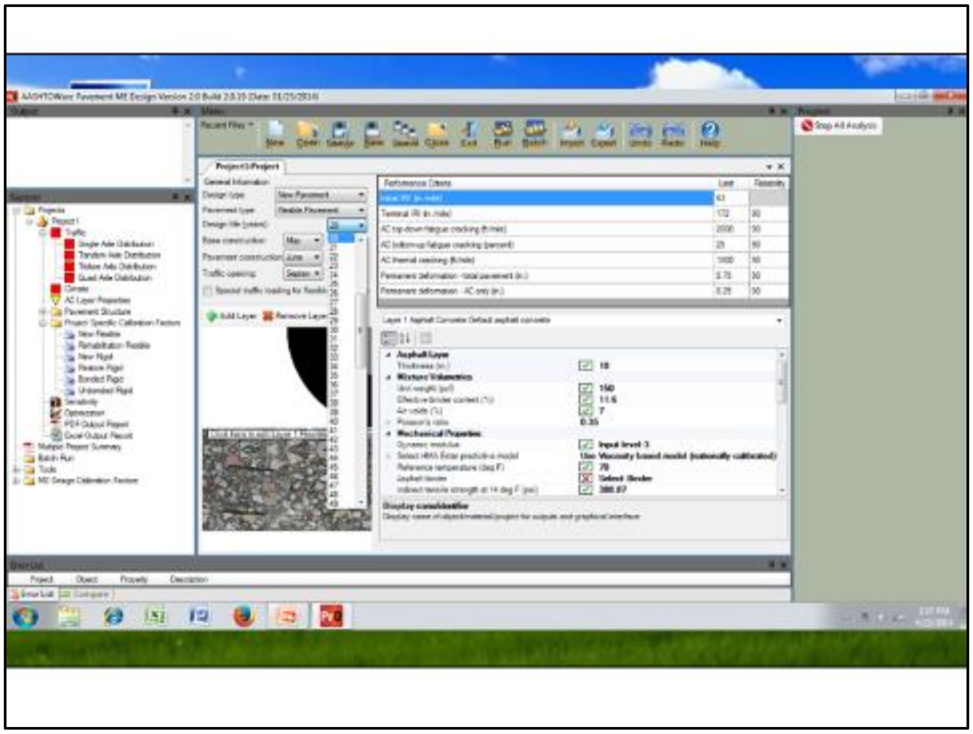
Asphalt Layer	
Thickness (in.)	☑ 10
Mixture Volumetrics	
Unit weight (pcf)	☑ 150
Effective binder content (%)	☑ 11.6
Air voids (%)	☑ 7
Poisson's ratio	0.35
Mechanical Properties	
Dynamic modulus	☑ Input level 3
Select HMA Estar predictive model	Use Viscosity based model (nationally calibrated)
Reference temperature (deg F)	☑ 70
Asphalt binder	☒ Select Binder
Indirect tensile strength at 14 deg F (psi)	☑ 380.87

Display name/identifier

Display name of object/material/project for outputs and graphical interface

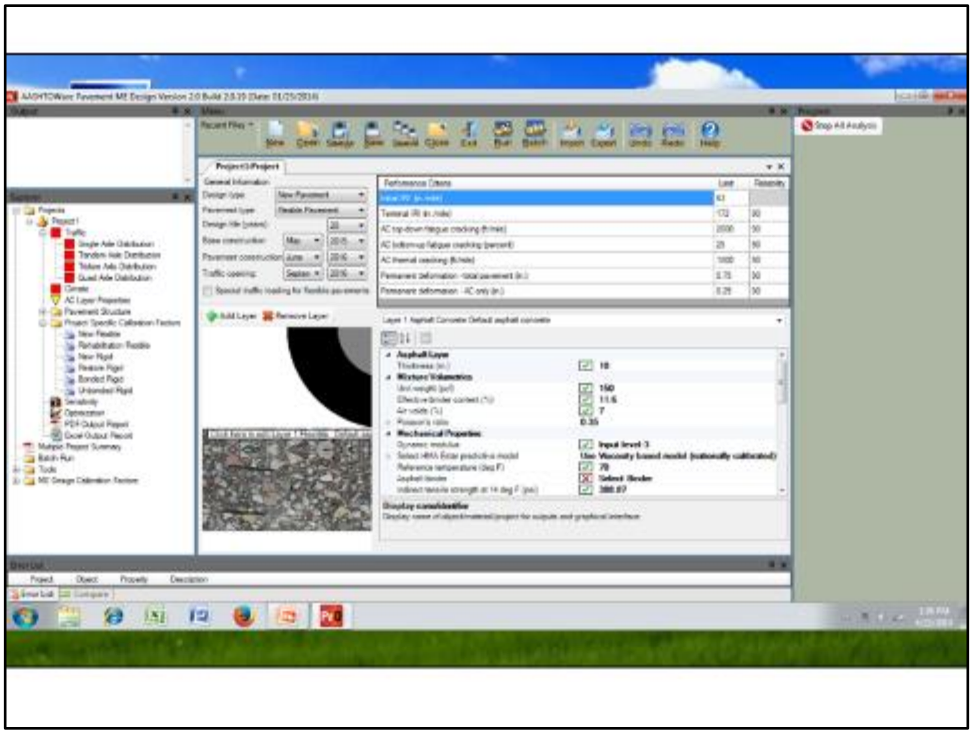
Select Design Life (Years).

Slide 29



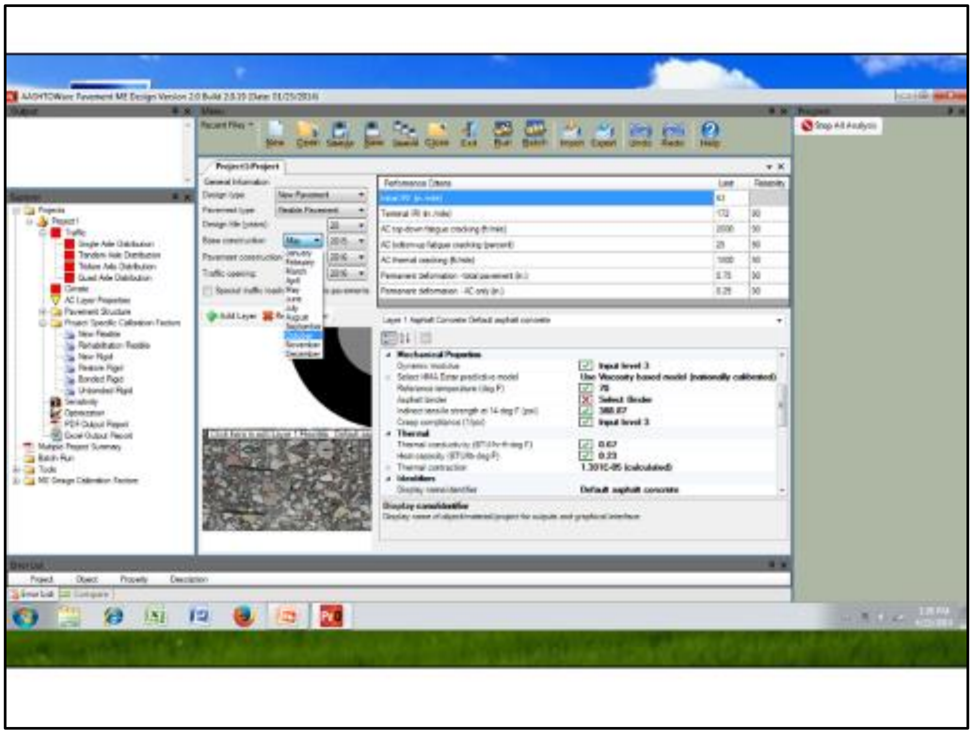
Select 20 years from the Design Life field.

Slide 30



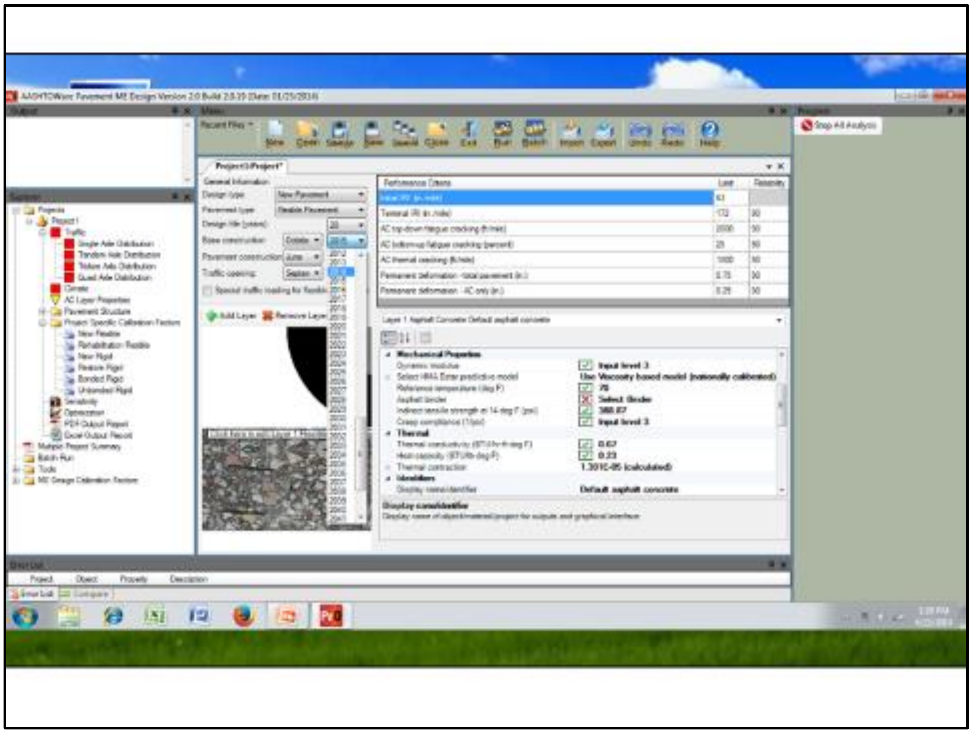
Select Base Construction Month.

Slide 31



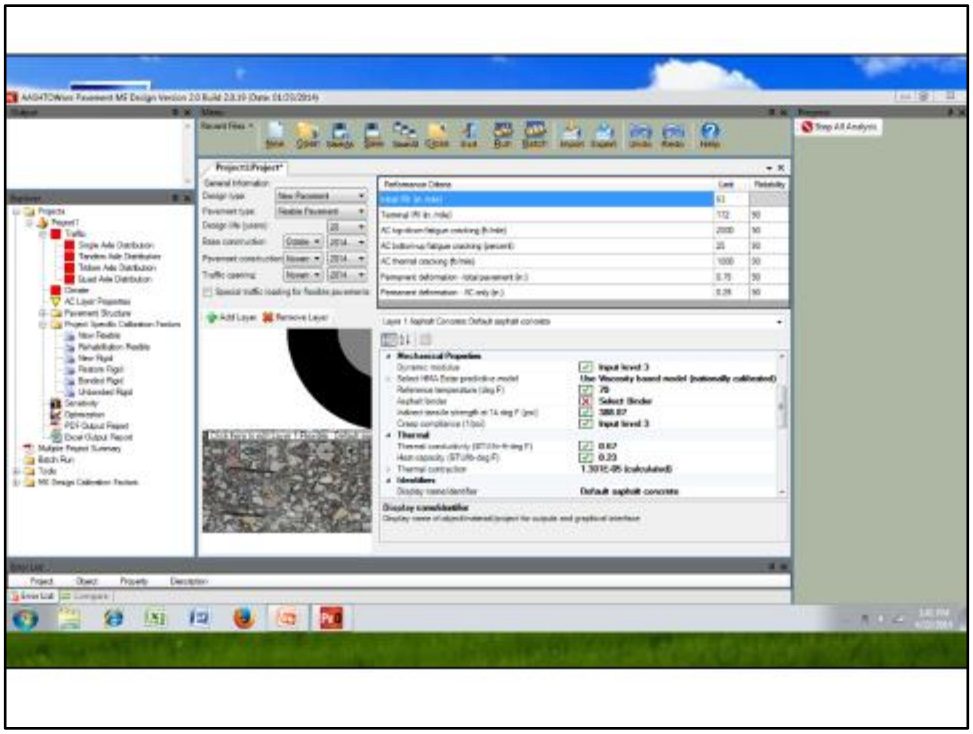
Select October as the Base Construction Month.

Slide 32



Select 2014 from the Base Construction Year field.

Slide 33

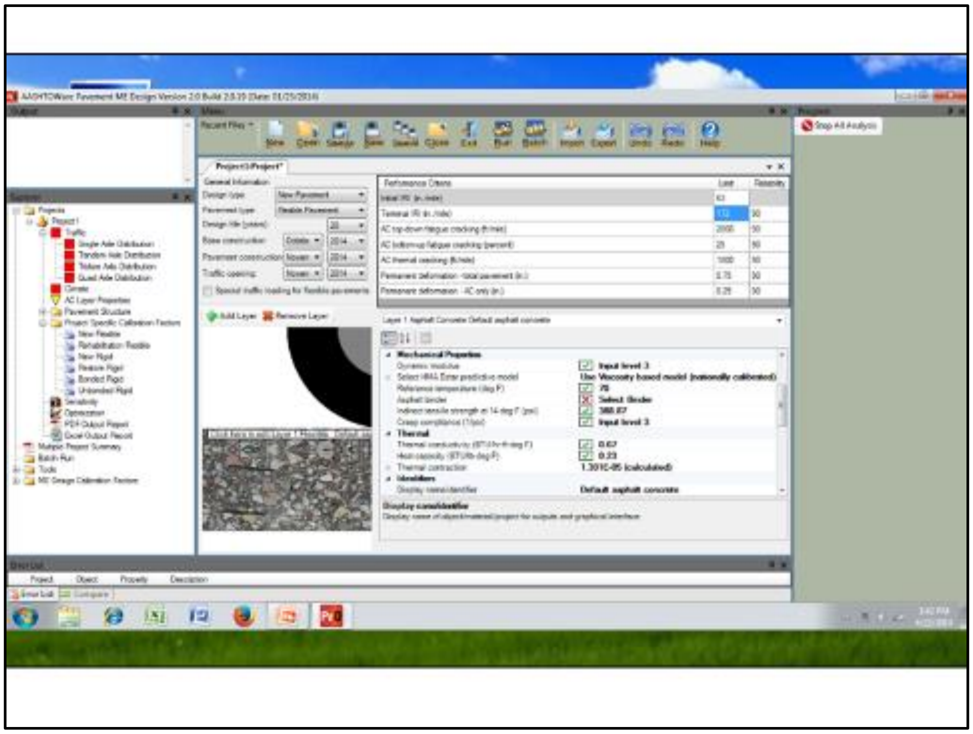


General Information
Design type: New Pavement
Pavement type: Flexible Pavement
Design life (years): 20
Base construction: October 2014
Pavement construction: November 2014
Traffic opening: November 2014

Performance Criteria	Limit	Reliability
Initial IRI (in./mile)	63	
Terminal IRI (in./mile)	172	50
AC top-down fatigue cracking (ft/mile)	2000	50
AC bottom-up fatigue cracking (percent)	25	50
AC thermal cracking (ft/mile)	1000	50
Permanent deformation - total pavement (in.)	0.75	50
Permanent deformation - AC only (in.)	0.25	50

In the same manner as for the base construction, change the dates for Pavement Construction and Traffic Opening.

Slide 34



General Information

Design type: New Pavement

Pavement type: Flexible Pavement

Design life (years): 20

Base construction: October 2014

Pavement construction: November 2014

Traffic opening: November 2014

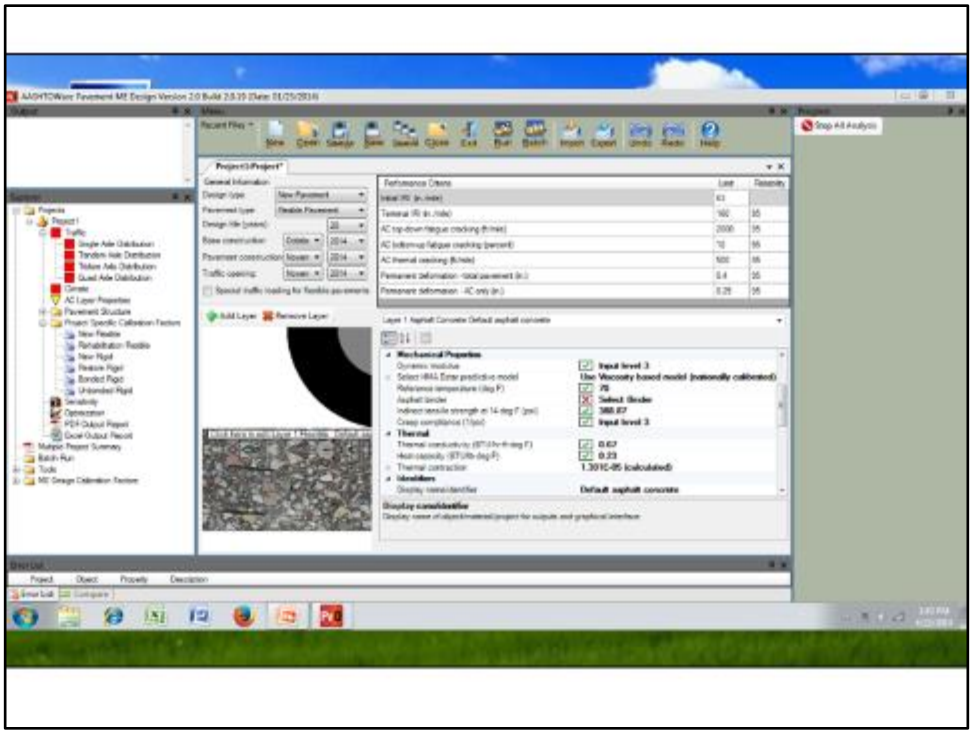
☐ Special traffic loading for flexible pavements

Performance Criteria	Limit	Reliability
Initial IRI (in./mile)	63	
Terminal IRI (in./mile)	172	50
AC top-down fatigue cracking (ft/mile)	2000	50
AC bottom-up fatigue cracking (percent)	25	50
AC thermal cracking (ft/mile)	1000	50
Permanent deformation - total pavement (in.)	0.75	50
Permanent deformation - AC only (in.)	0.25	50

Layer 1 Asphalt Concrete:Default asphalt concrete

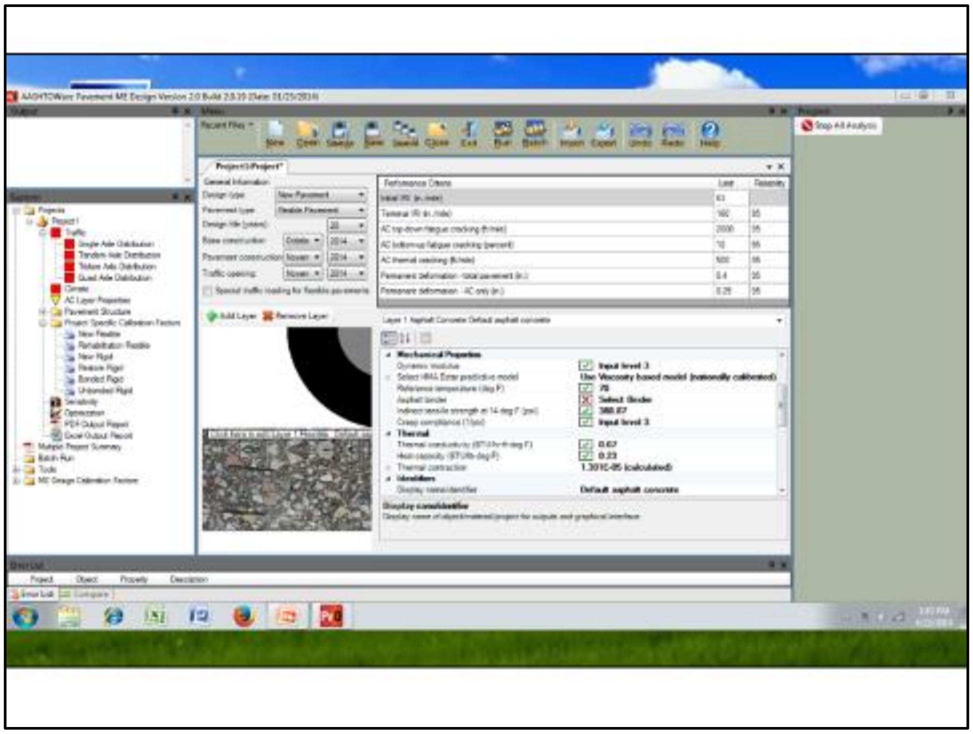
Change the Performance Criteria thresholds.

Slide 35



Change the Performance Criteria thresholds.

Slide 36



Select Add Layer.

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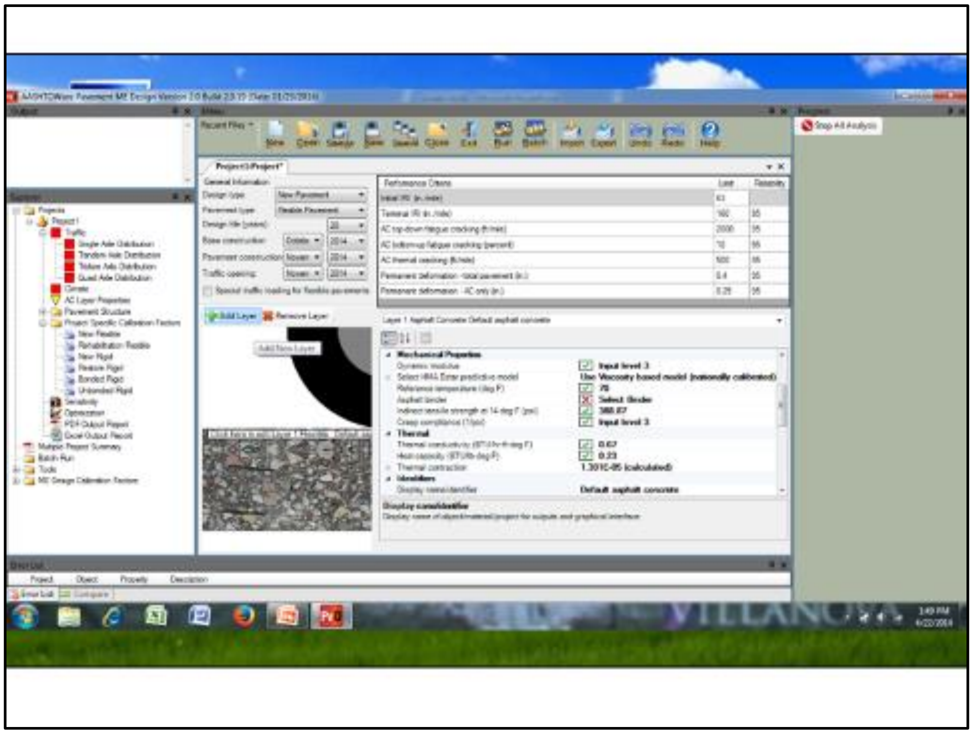
Slide 37



Start building your structure.

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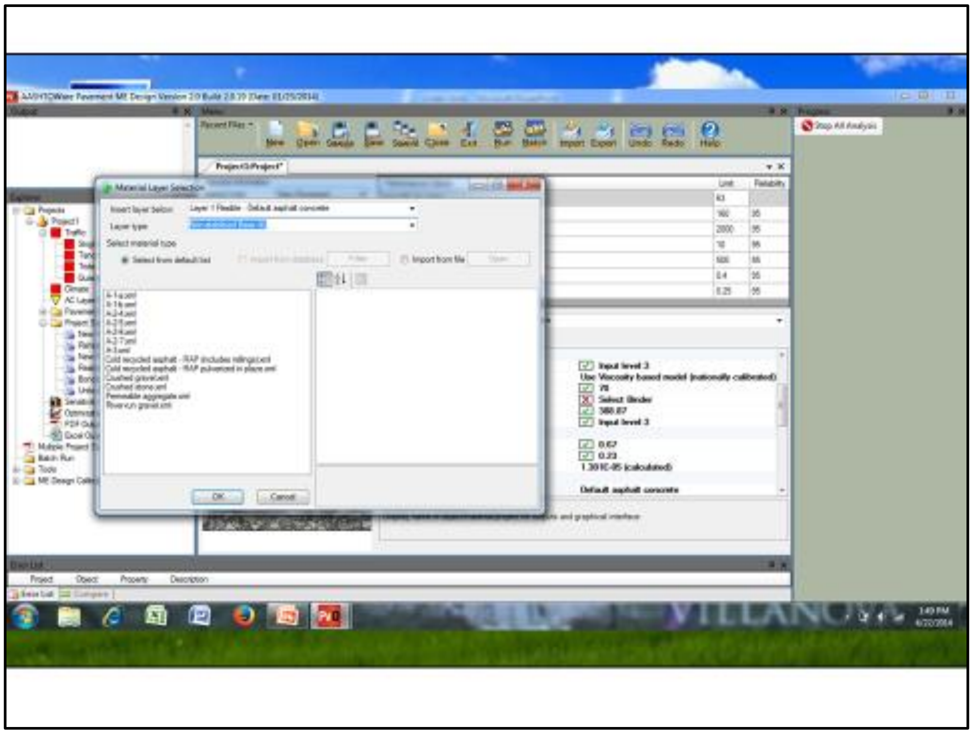
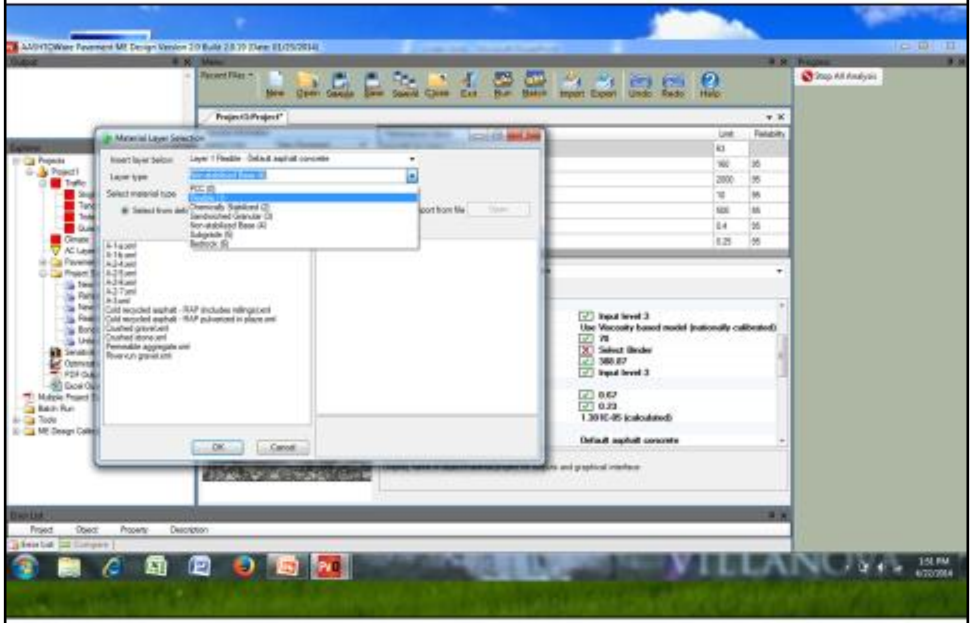
Slide 38



A-1-a.xml
A-1-b.xml
A-2-4.xml
A-2-5.xml
A-2-6.xml
A-2-7.xml
A-3.xml
Cold recycled asphalt - RAP includes millings.xml
Cold recycled asphalt - RAP pulverized in place.xml
Crushed gravel.xml
Crushed stone.xml
Permeable aggregate.xml
River-run gravel.xml

This window will pop up giving you the option to select the Layer Type

Slide 39



Insert layer below: Layer 1 Flexible : Default asphalt concrete

Layer type: Non-stabilized Base (4)

Select Flexible.

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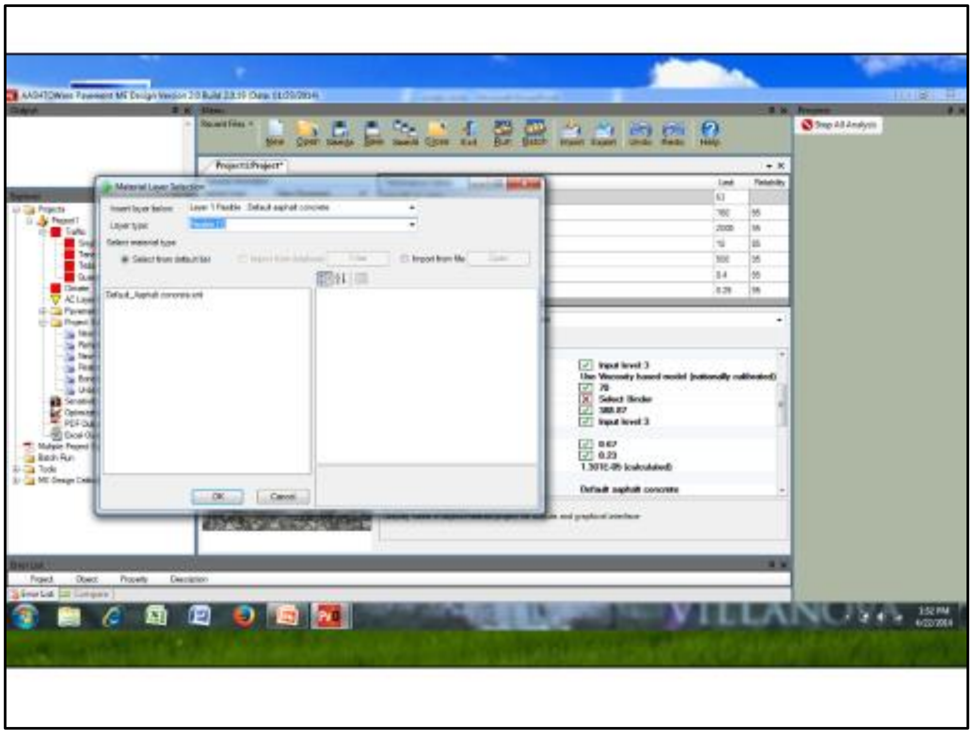
Slide 40



Material Layer Selection

Insert layer below: Layer 1 Flexible : Default asphalt concrete

Layer type: Flexible

Select material type

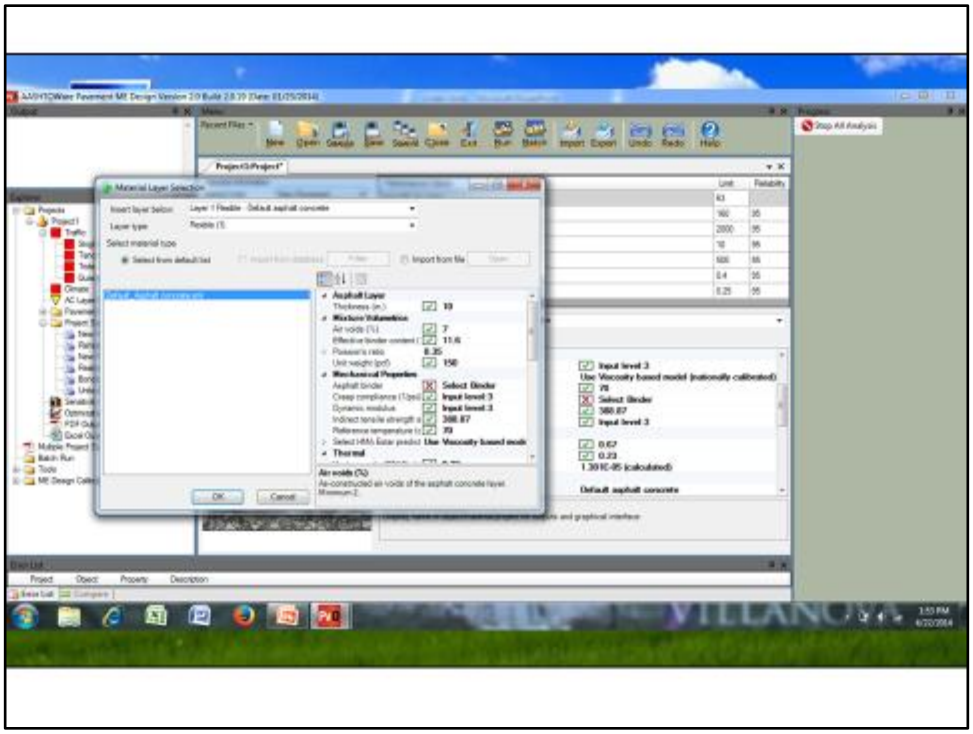
● Select from default list

☐ Import from file

Default_Asphalt concrete.xml

Select Default Asphalt concrete.xml.

Slide 41



Insert layer below: Layer 1 Flexible : Default asphalt concrete

Layer type: Flexible (1)

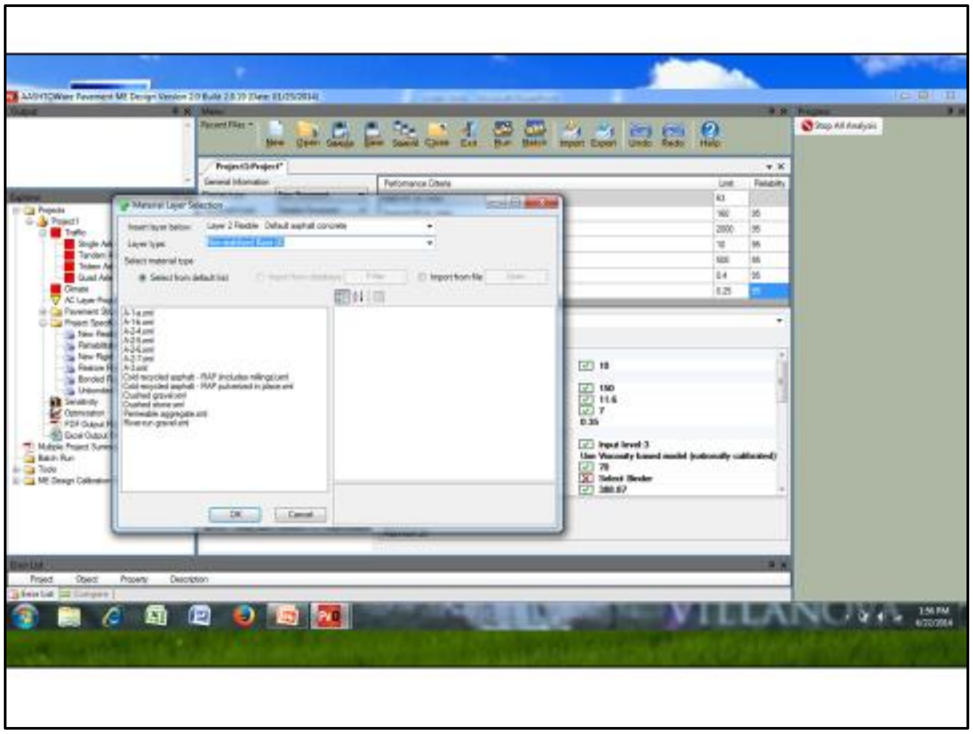
Default asphalt concrete

- Asphalt Layer
  - Thickness (in.): 10
- Mixture Volumetrics
  - Air voids (%): 7
  - Effective binder content (: 11.6
  - Poisson's ratio: 0.35
  - Unit weight (pcf): 150
- Mechanical Properties
  - Asphalt binder: Select Binder
  - Creep compliance (1/psi): Input level 3
  - Dynamic modulus: Input level 3
  - Indirect tensile strength a: 388.87
  - Reference temperature (: 70
  - Select HMA Estar predict: Use Viscosity based mode
- Thermal

Air voids (%)
As-constructed air voids of the asphalt concrete layer. Minimum 2.

Select OK.

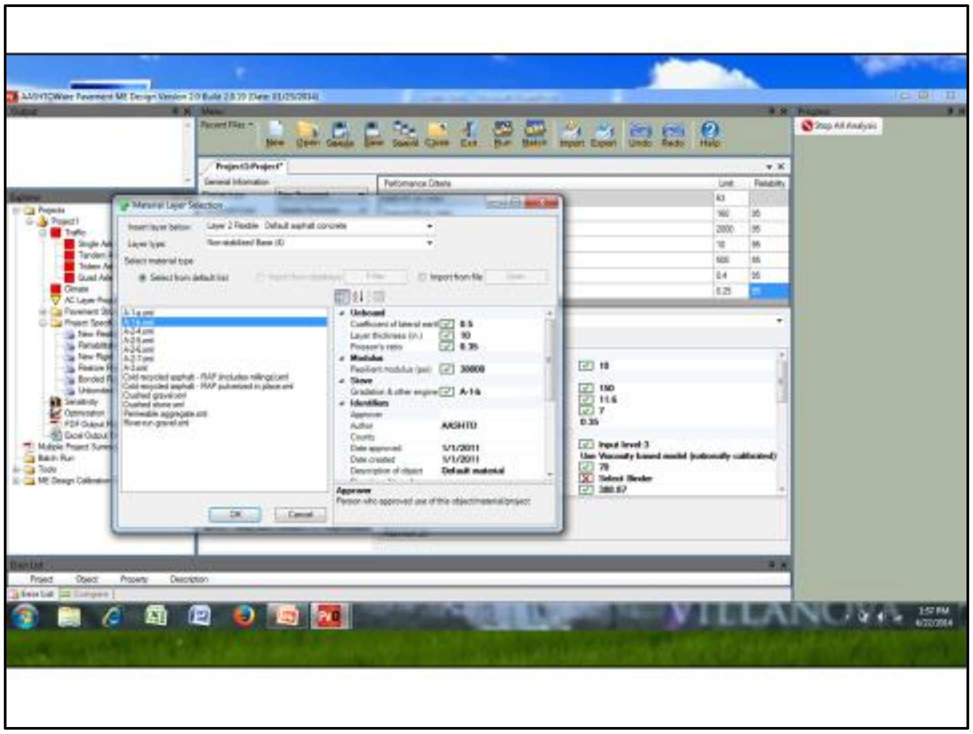
Slide 42



Insert layer below: Layer 2 Flexible : Default asphalt concrete

Repeat the same process to add the remaining layers. Select Add Layer and choose Non-stabilized Base.

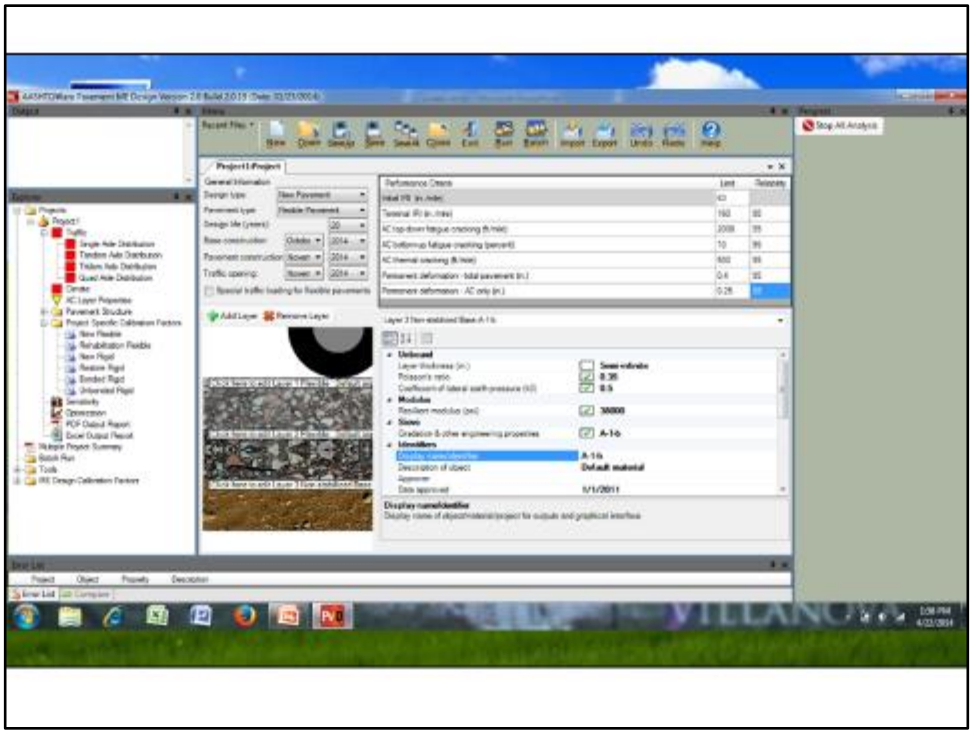
Slide 43



Select A-1-b.xml and then select OK.

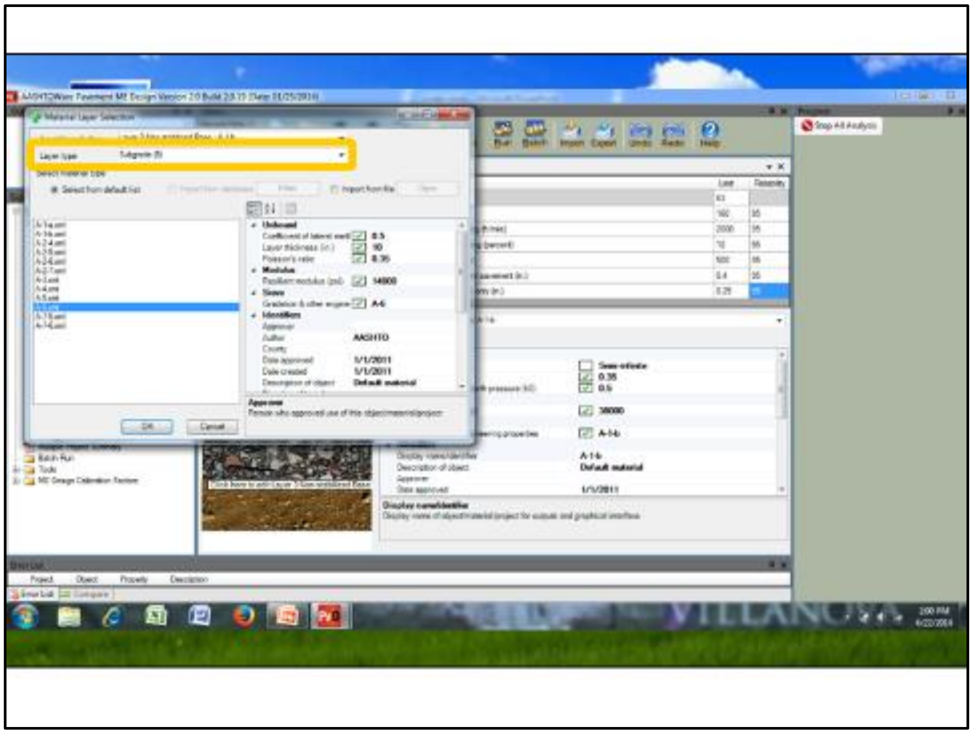
Notes: On screen – AASHTOWare Pavement ME Design new project screen

Slide 44



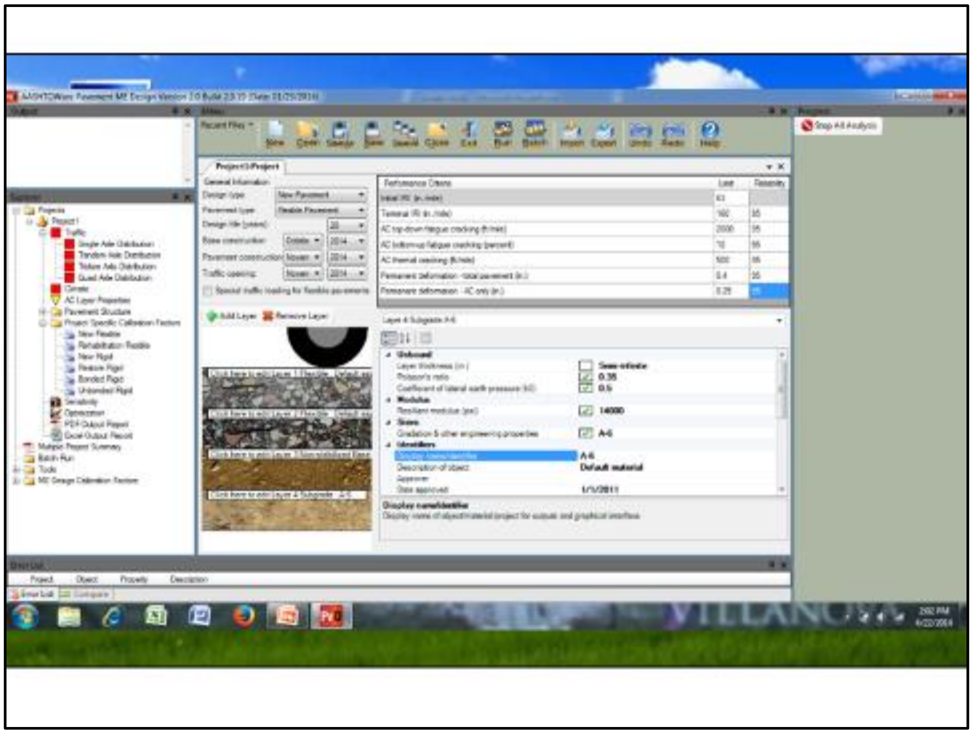
We’ll add another layer. Select Add Layer.

Slide 45



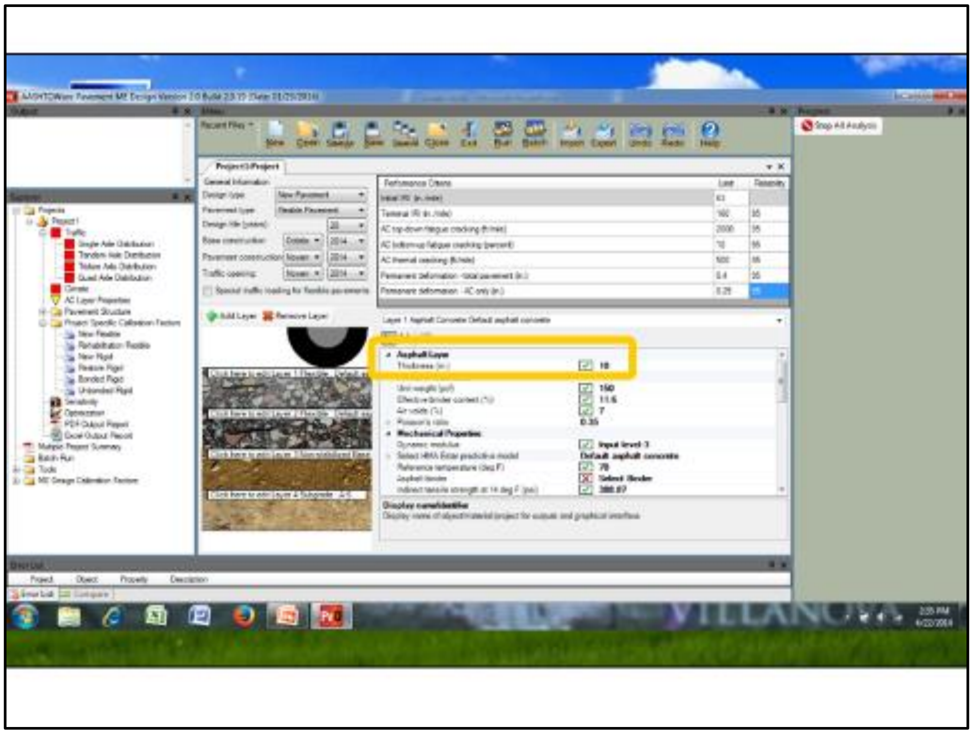
Select Layer Type of Subgrade. Select A-6 as the material. Then, select OK to add this layer.

Slide 46



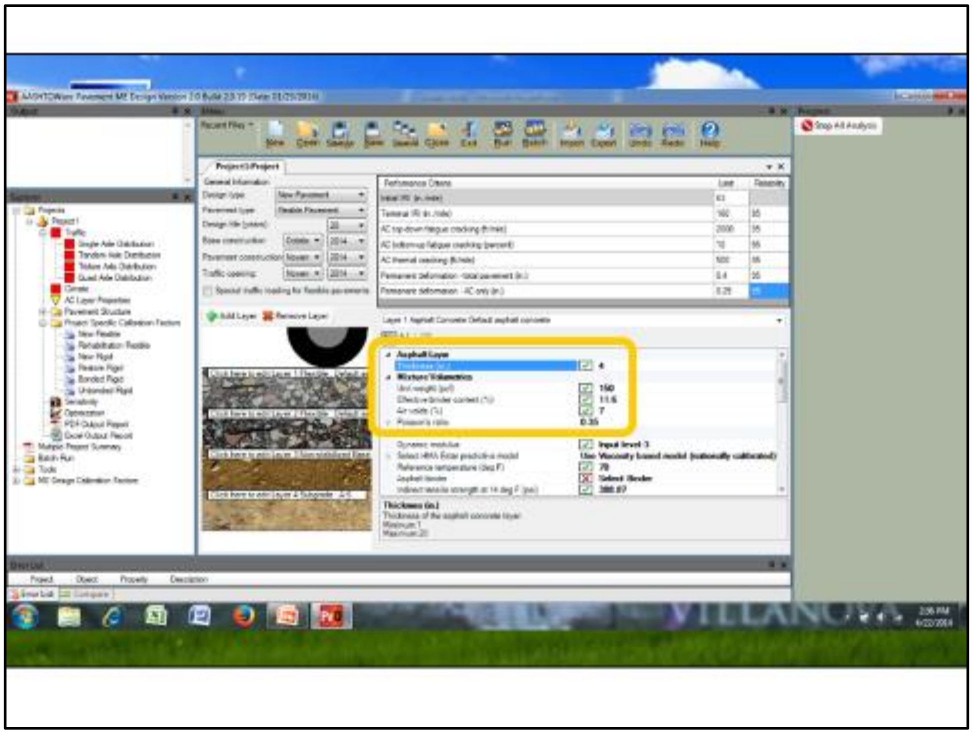
Now we can go back to each layer and adjust thicknesses and properties.

Slide 47



Now we can input thickness and material properties for the first layer. First, we’ll change the Thickness to 4 inches.

Slide 48



Asphalt Layer
Thickness (in.) 4
Mixture Volumetrics
Unit weight (pcf) 150
Effective binder content (%) 11.6
Air voids (%) 7
Poisson's ratio 0.35

Note the Thickness is now 4 inches.

The mixture volumetrics will not be changed for this example.

Select the Dynamic Modulus to input Level 3 values. Go to the next screen.

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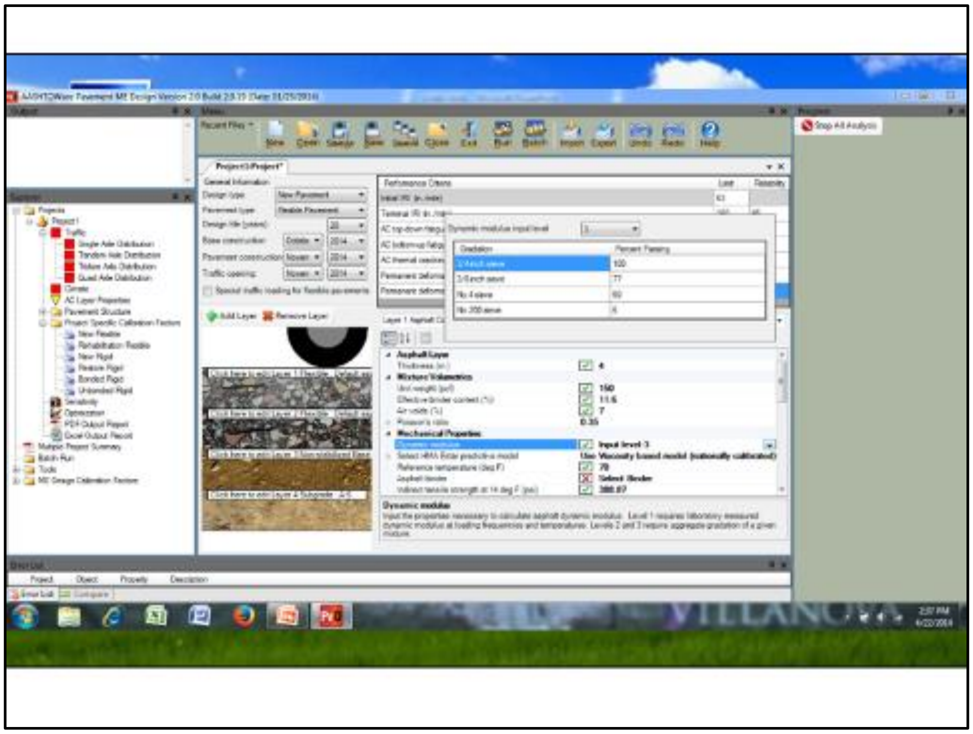
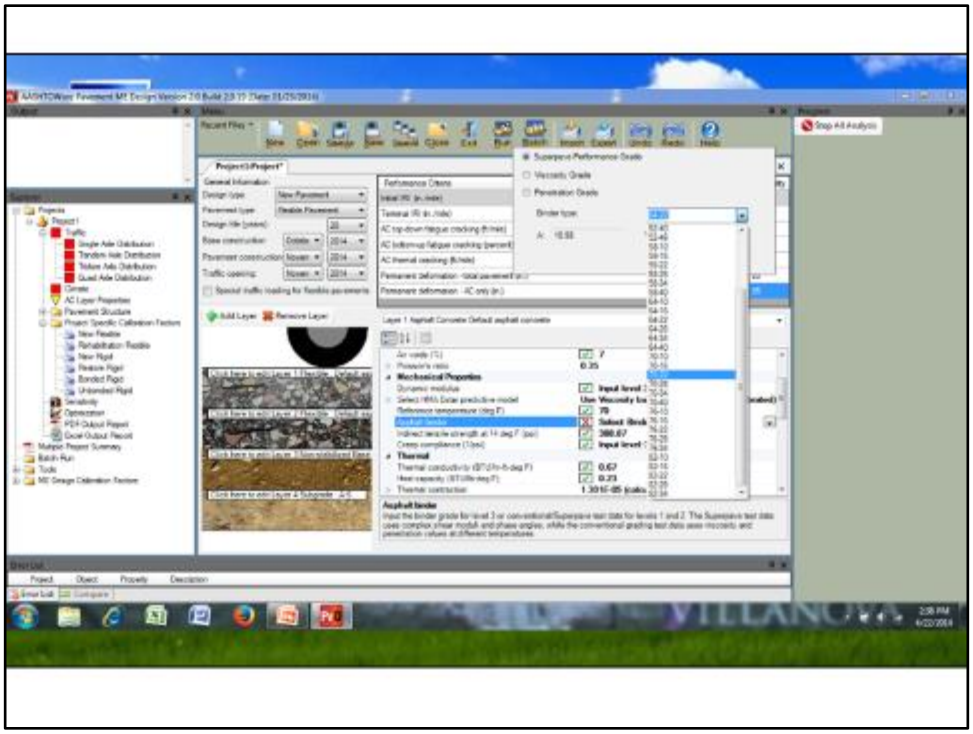
Slide 49



Now you can input Level 3 values for Dynamic Modulus.

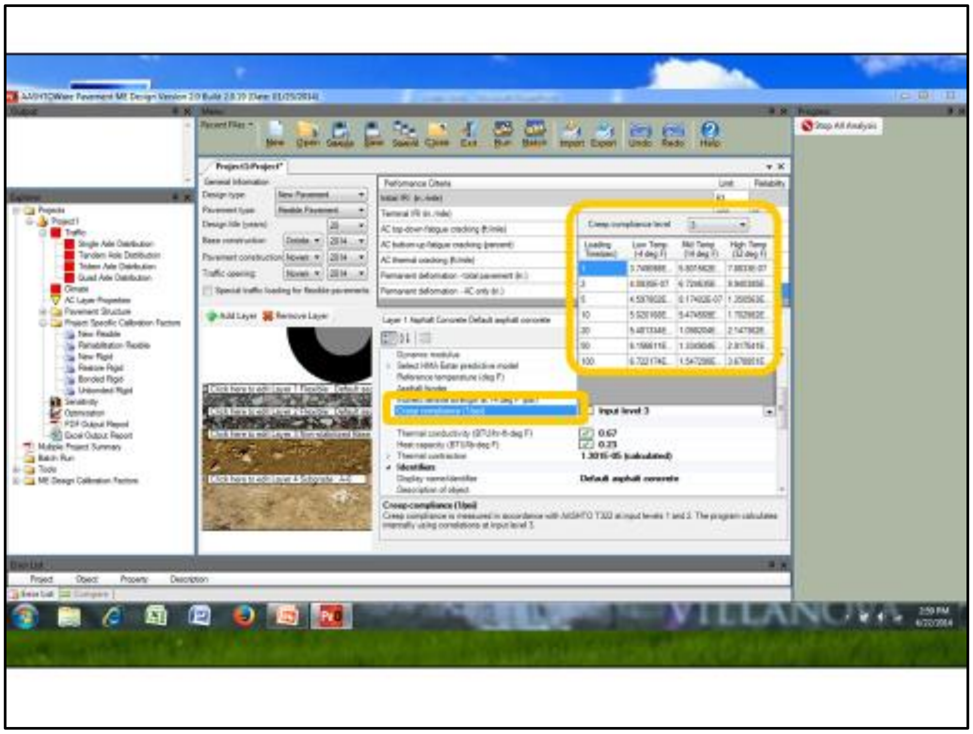
Next we are going to choose the Asphalt Binder.

Slide 50



Select PG70-22 from the Asphalt Binder list.

Slide 51



Creep compliance level: 3

Input level 3

Thermal conductivity (BTU/hr-ft-deg F): 0.67

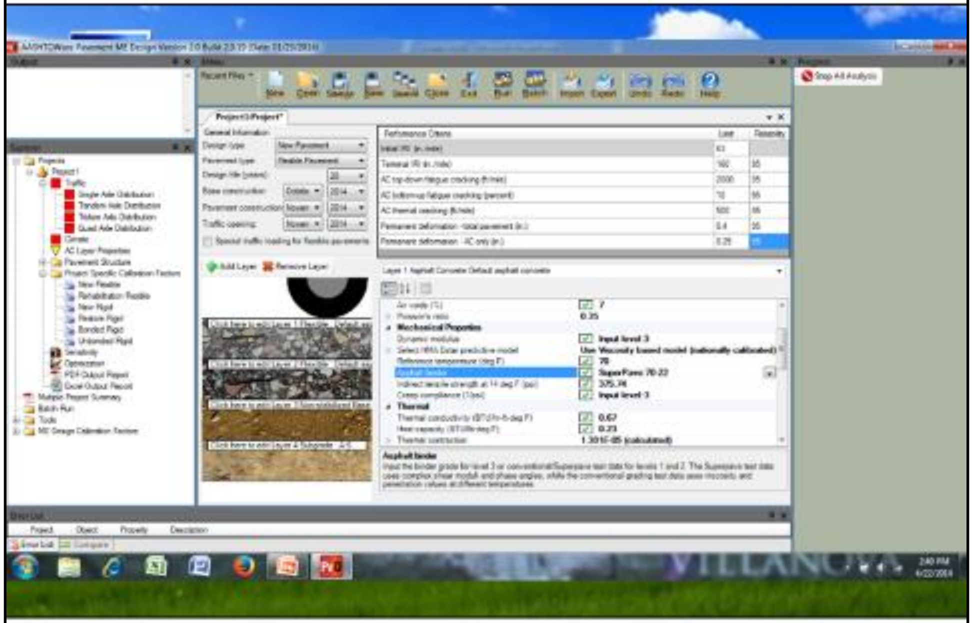
Heat capacity (BTU/lb-deg F): 0.23

Display name/identifier: Default asphalt concrete

Creep compliance (1/psi)
Creep compliance is measured in accordance with AASHTO T322 at input levels 1 and 2. The program calculates internally using correlations at input level 3.

Select Creep Compliance to accept Level 3 default values.

Slide 52

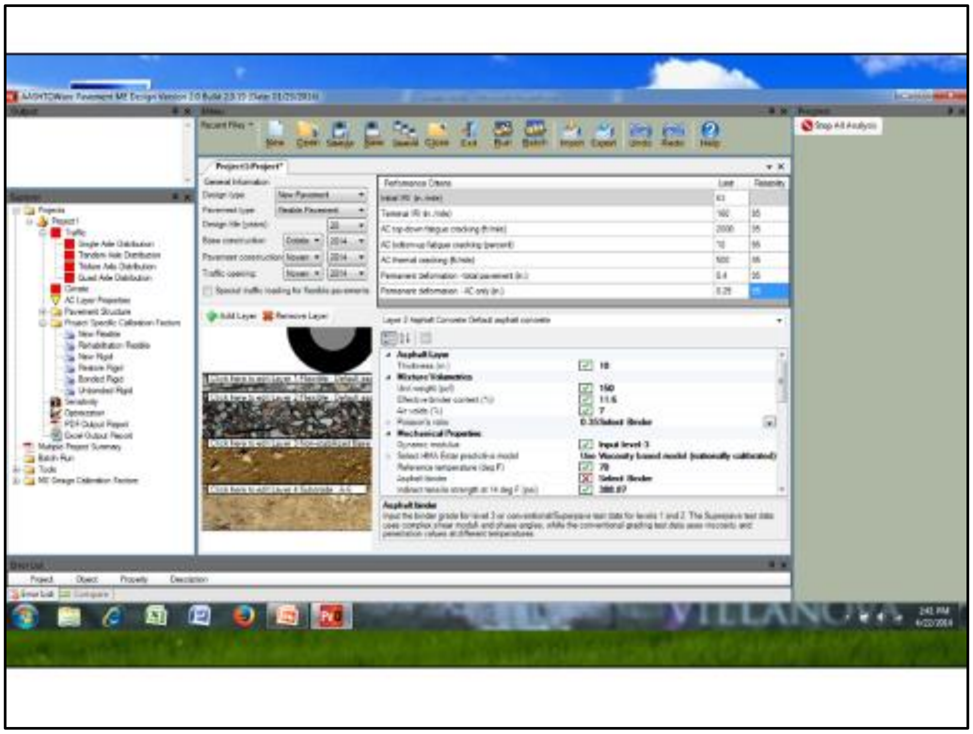


Layer 1 Asphalt Concrete Default asphalt concrete

Air voids (%) 7
Poisson's ratio 0.35
Mechanical Properties
Dynamic modulus Input level 3
Select HMA Estar predictive model Use Viscosity based model (nationally calibrated)
Reference temperature (deg F) 70
Asphalt binder SuperPave 70-22
Indirect tensile strength at 14 deg F (psi) 375.74
Creep compliance (1/psi) Input level 3
Thermal
Thermal conductivity (BTU/hr-ft-deg F) 0.67
Heat capacity (BTU/lb-deg F) 0.23
Thermal contraction 1.301E-05 (calculated)

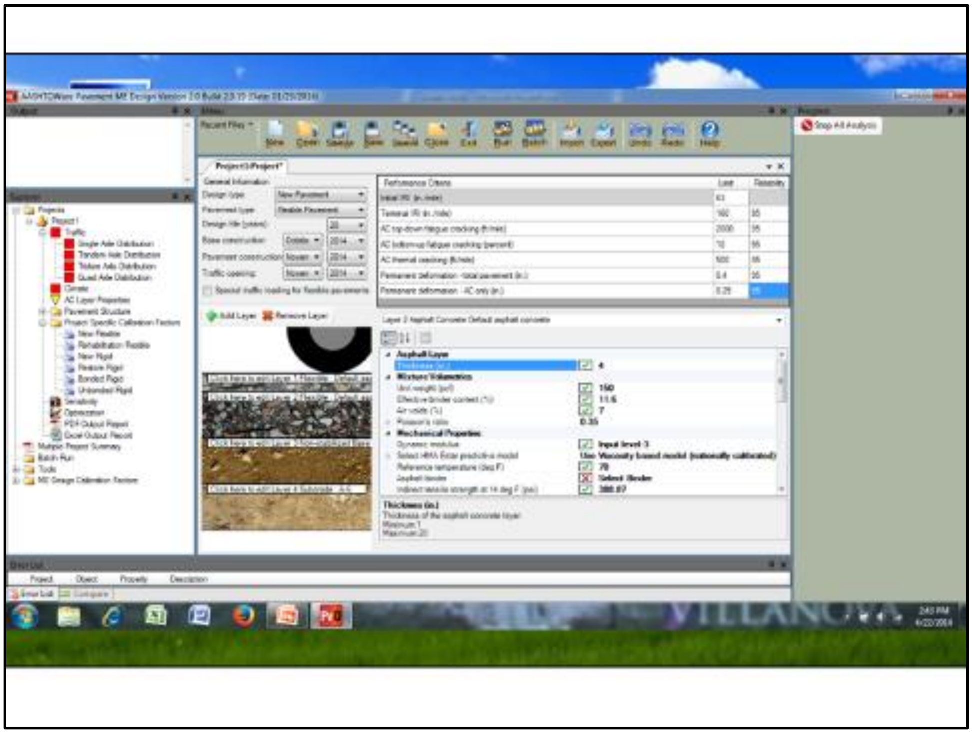
Everything else is default for Layer 1.

Slide 53



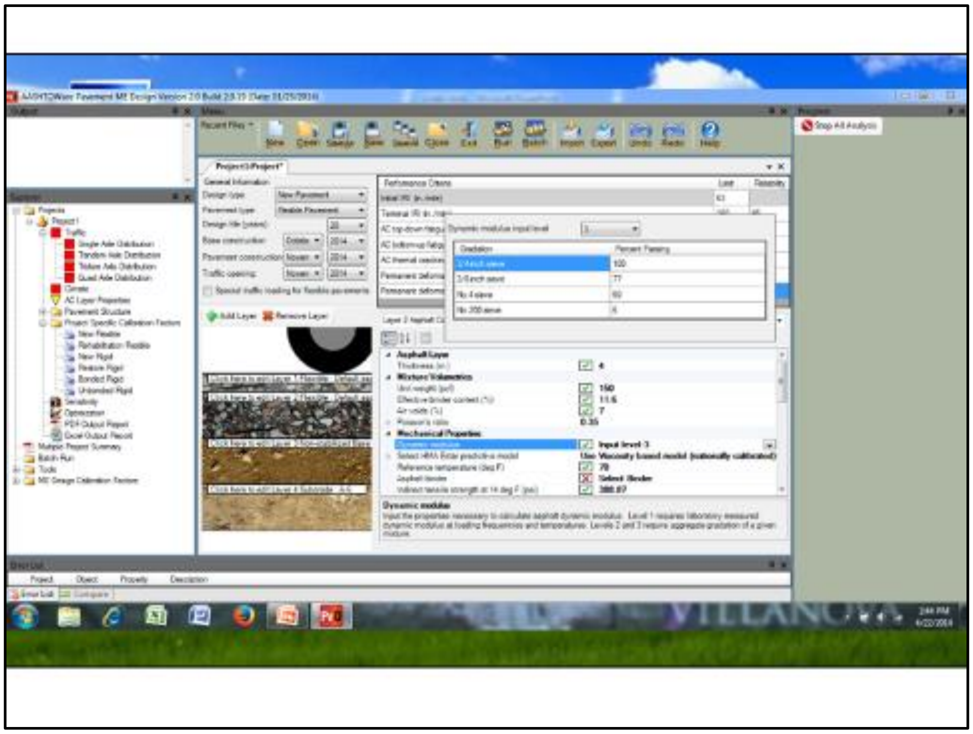
Now we can input thickness and material properties for Layer 2. First select Layer 2; then we'll change the Thickness to 4 inches by selecting Thickness.

Slide 54



Now we can input thickness and material properties for Layer 2. First select Layer 2, then we'll change the Thickness to 4 inches by selecting Thickness.

Slide 55



Dynamic modulus input level: 3

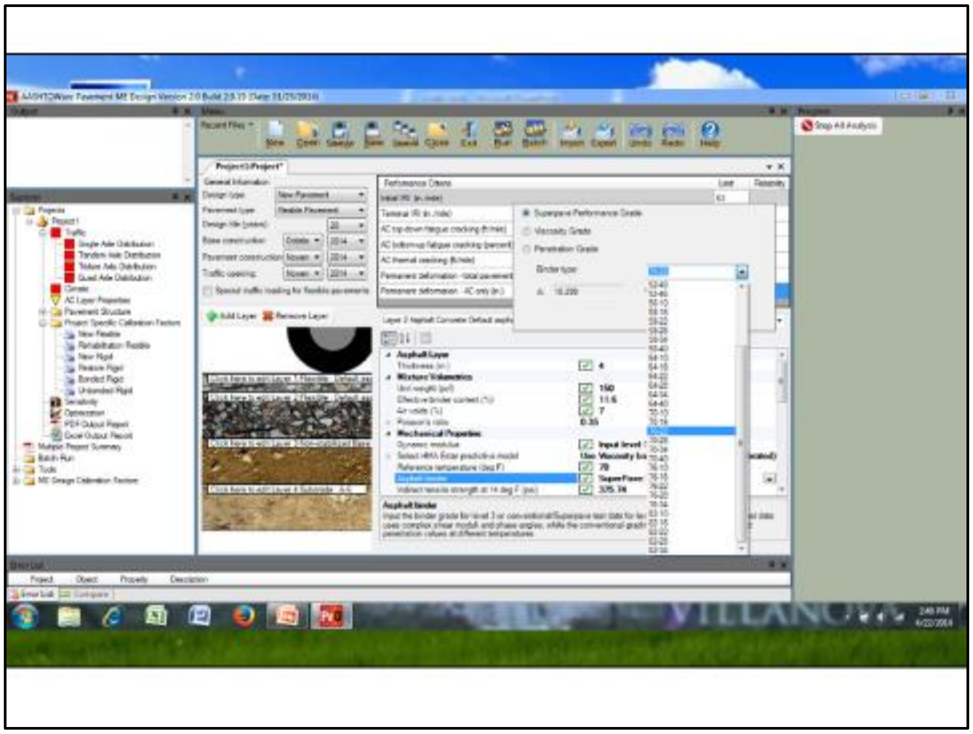
Gradation	Percent Passing
3/4-inch sieve	100
3/8-inch sieve	77
No. 4 sieve	60
No. 200 sieve	6

Asphalt Layer	
Thickness (in.)	4
Mixture Volumetrics	
Unit weight (pcf)	150
Effective binder content (%)	11.6
Air voids (%)	7
Poisson's ratio	0.35
Mechanical Properties	
Dynamic modulus	Input level 3
Select HMA Ebar predictive model	Use Viscosity based model (nationally calibrated)
Reference temperature (deg F)	70
Asphalt binder	Select Binder
Indirect tensile strength at 14 deg F (psi)	380.87

Dynamic modulus
Input the properties necessary to calculate asphalt dynamic modulus. Level 1 requires laboratory measured dynamic modulus at loading frequencies and temperatures. Levels 2 and 3 require aggregate gradation of a given mixture.

Select Dynamic Modulus to input Level 3 values.

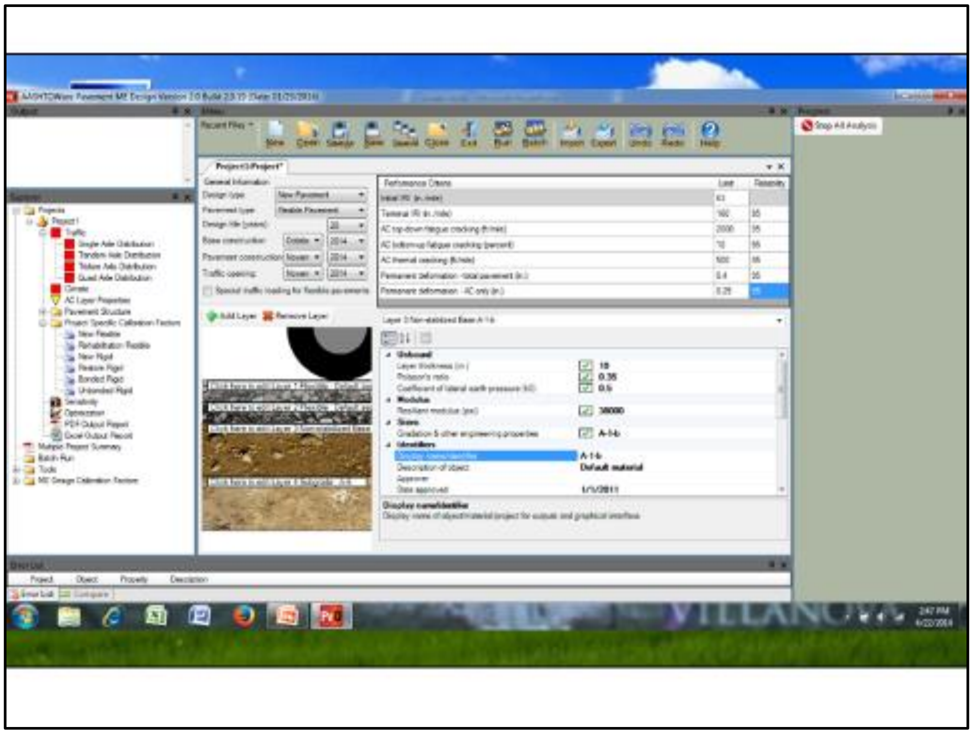
Slide 56



Select Asphalt Binder to choose PG70-22.

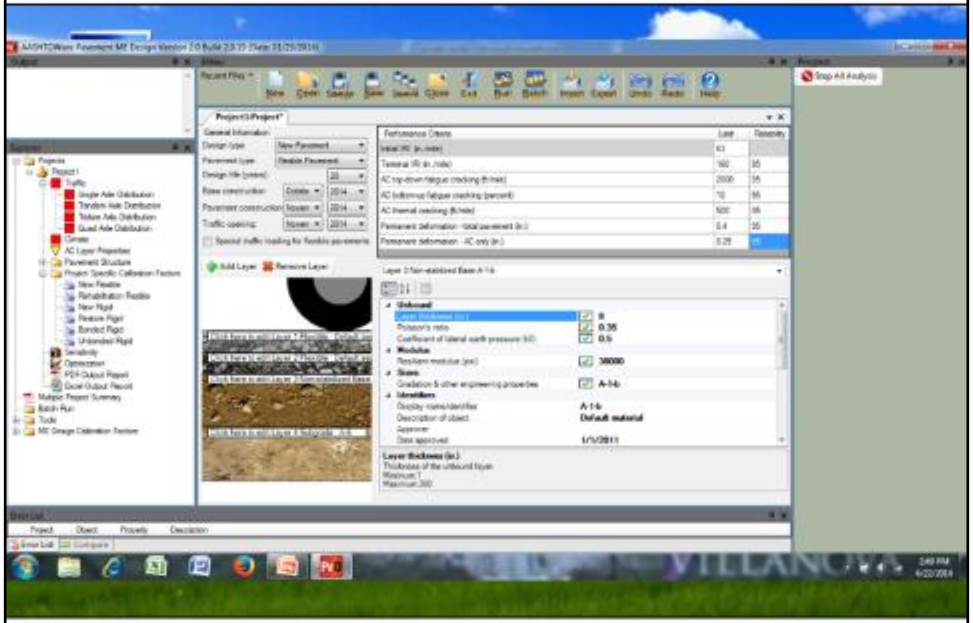
Everything else is default.

Slide 57



Select Layer 3.

Slide 58

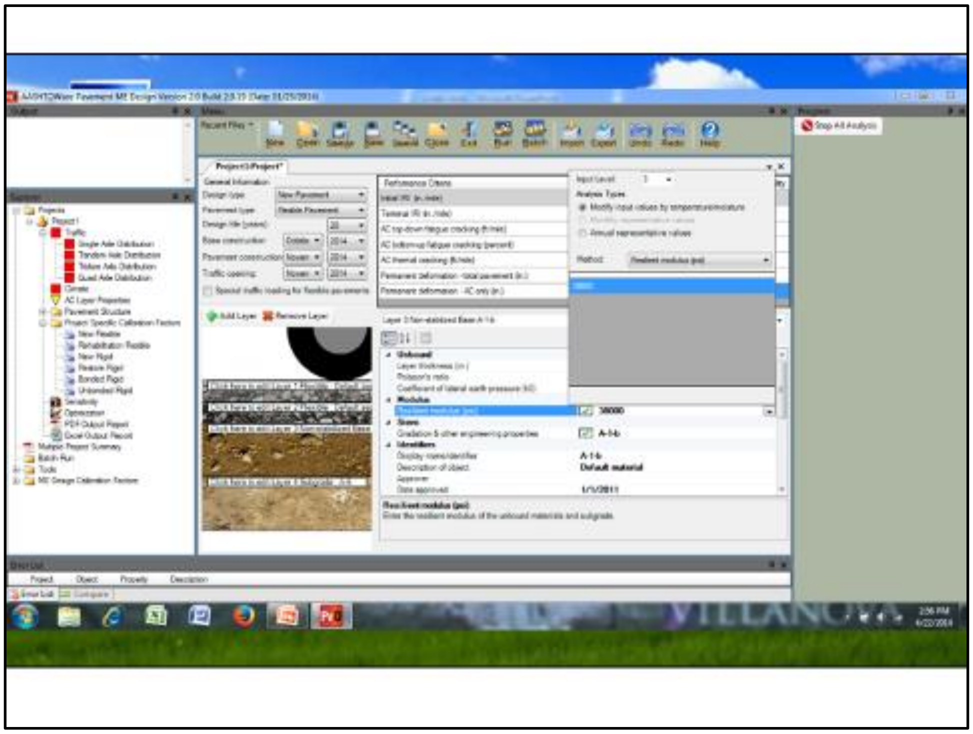

Layer 3 Non-stabilized Base:A-1-b

Unbound
Layer thickness (in.) 8
Poisson's ratio 0.35
Coefficient of lateral earth pressure (k0) 0.5
Modulus
Resilient modulus (psi) 38000
Sieve
Gradation & other engineering properties A-1-b
Identifiers
Display name/identifier A-1-b
Description of object **Default material**
Approver
Date approved 1/1/2011

Layer thickness (in.)
Thickness of the unbound layer
Minimum:1
Maximum:300

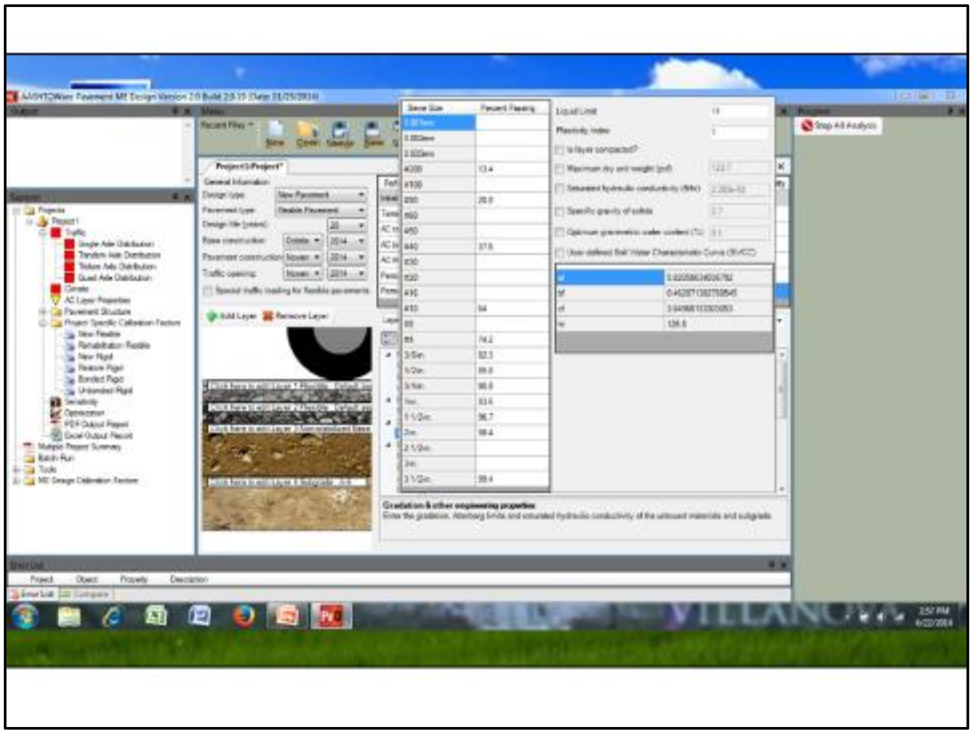
Now we can input thickness and material properties for Layer 3. Change the Thickness to 8 inches by selecting Thickness.

Slide 59



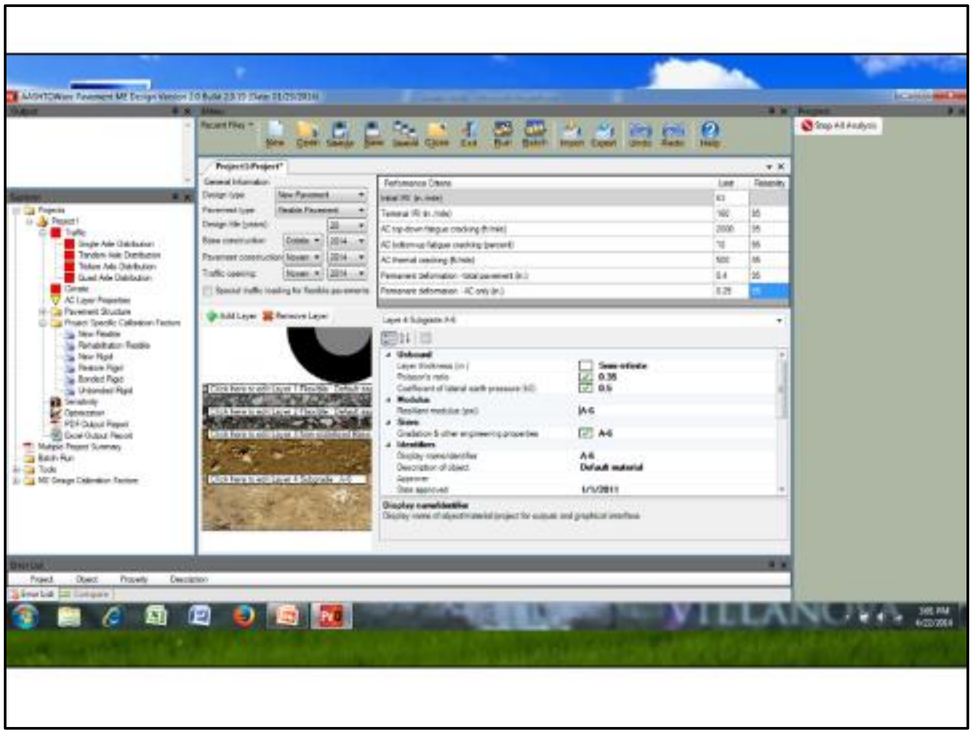
Select Resilient Modulus to accept Level 3 values.

Slide 60



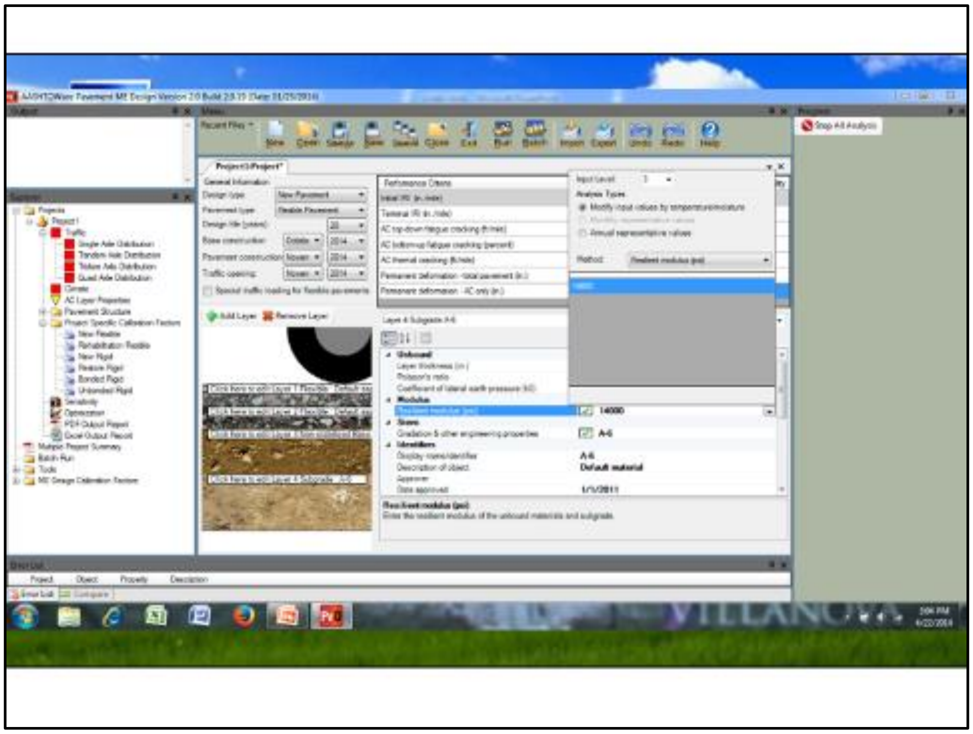
Select Gradation and Other Engineering Properties to accept default values.

Slide 61



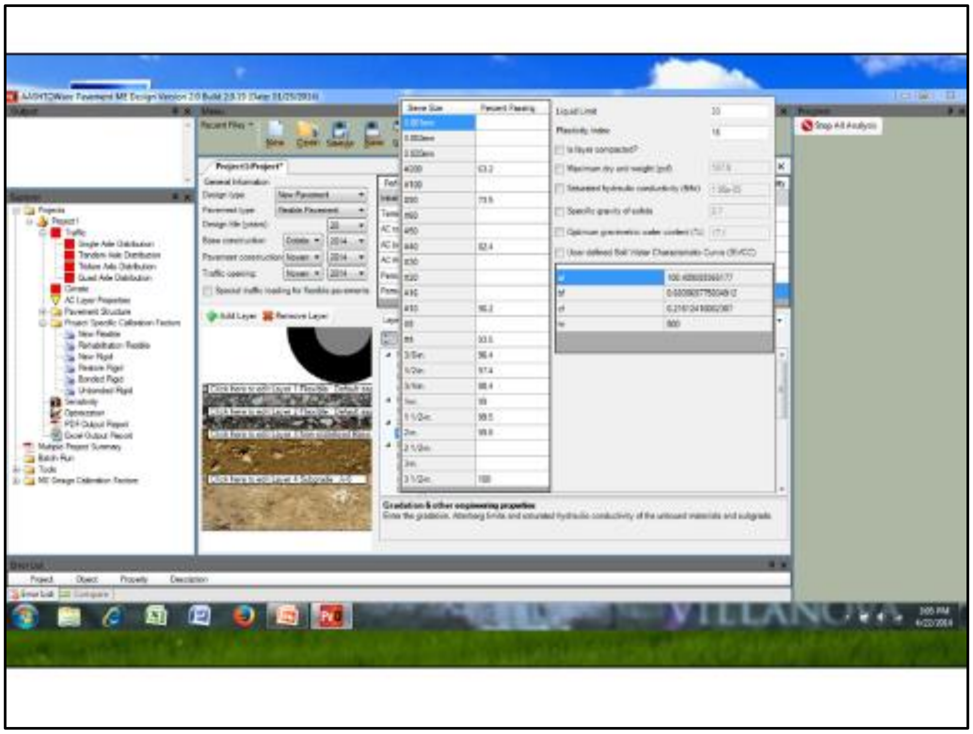
Select Layer 4.

Slide 62



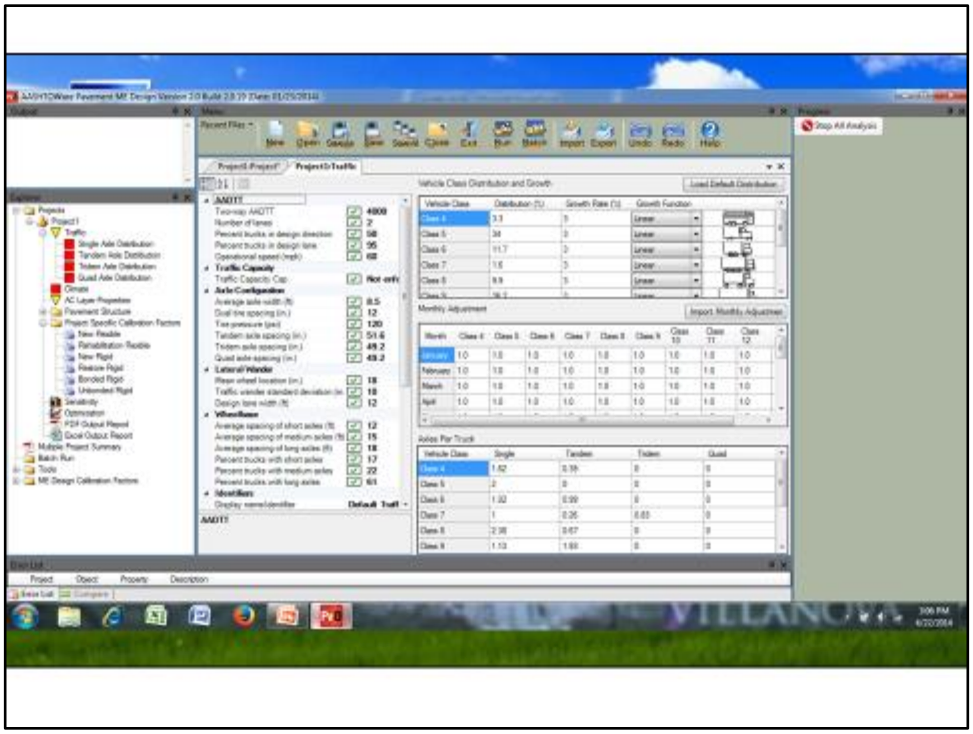
Select Resilient Modulus to accept Level 3 values.

Slide 63



Select Gradation and Other Engineering Properties to accept default values.

Slide 64



Select Traffic to input traffic data.

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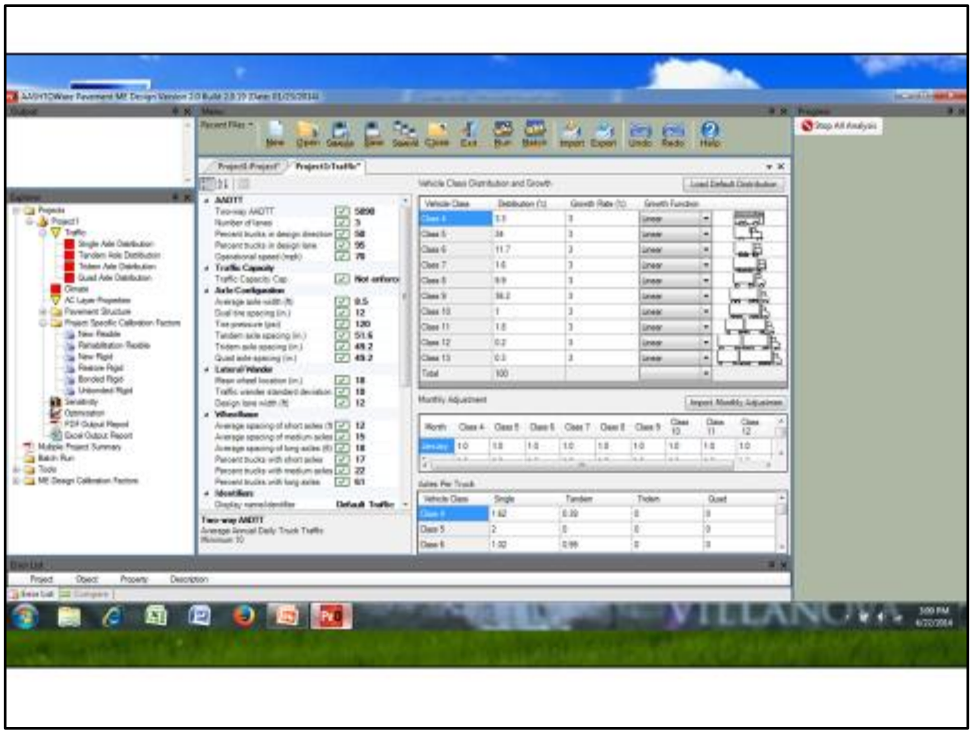
Slide 65



AADTT
- Two-way AADTT: 5890
- Number of lanes: 3
- Percent trucks in design direction: 50
- Percent trucks in design lane: 95
- Operational speed (mph): 70

Traffic Capacity
- Traffic Capacity Cap: Not enforced

Axle Configuration
- Average axle width (ft): 8.5
- Dual tire spacing (in.): 12
- Tire pressure (psi): 120
- Tandem axle spacing (in.): 51.6
- Tridem axle spacing (in.): 49.2
- Quad axle spacing (in.): 49.2

Lateral Wander
- Mean wheel location (in.): 18
- Traffic wander standard deviation (in.): 10
- Design lane width (ft): 12

Wheelbase
- Average spacing of short axles (ft): 12
- Average spacing of medium axles (ft): 15
- Average spacing of long axles (ft): 18
- Percent trucks with short axles: 17
- Percent trucks with medium axles: 22
- Percent trucks with long axles: 61

Identifiers
- Display name/identifier: Default Traffic

Two-way AADTT
Average Annual Daily Truck Traffic
Minimum: 10

Vehicle Class Distribution and Growth

Vehicle Class	Distribution (%)	Growth Rate (%)	Growth Function
Class 4	3.3	3	Linear
Class 5	34	3	Linear
Class 6	11.7	3	Linear
Class 7	1.6	3	Linear
Class 8	9.9	3	Linear
Class 9	36.2	3	Linear
Class 10	1	3	Linear
Class 11	1.8	3	Linear
Class 12	0.2	3	Linear
Class 13	0.3	3	Linear
Total	100		

Monthly Adjustment

Month	Class 4	Class 5	Class 6	Class 7	Class 8	Class 9	Class 10	Class 11	Class 12
January	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Axles Per Truck

Vehicle Class	Single	Tandem	Tridem	Quad
Class 4	1.62	0.39	0	0
Class 5	2	0	0	0
Class 6	1.02	0.99	0	0

Change Traffic Data accordingly.

Select Vehicle Class.

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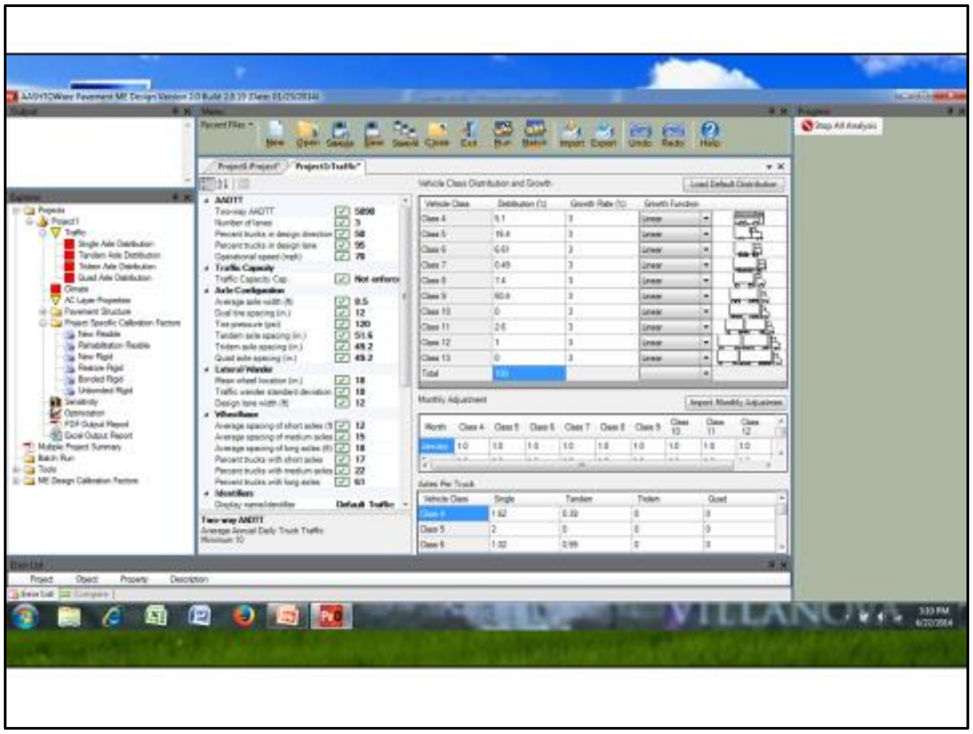
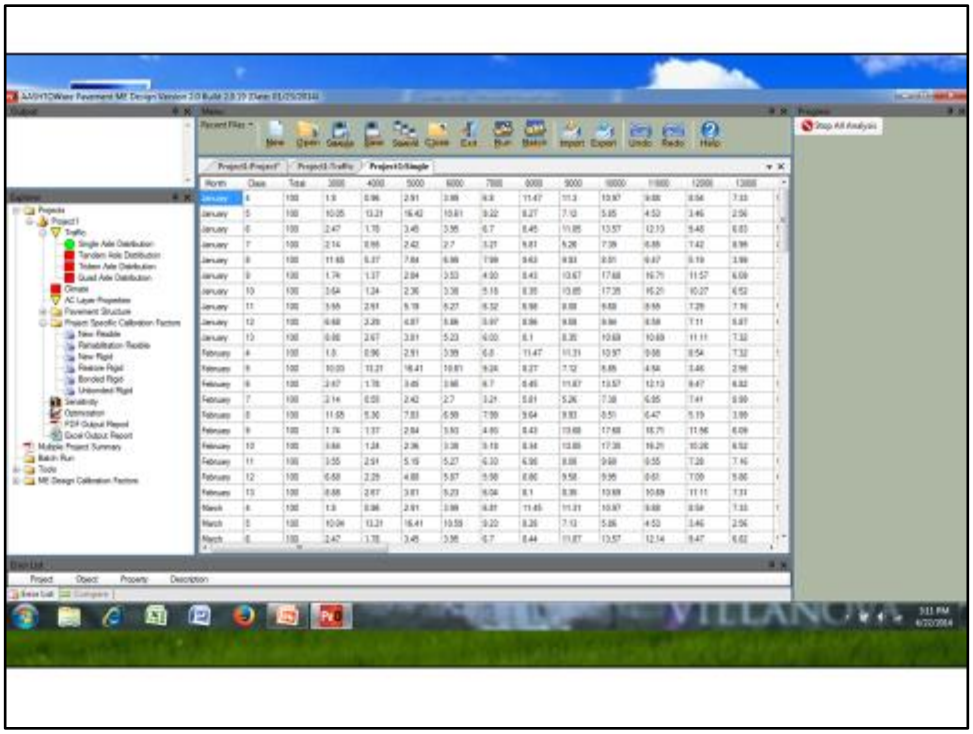
Slide 66



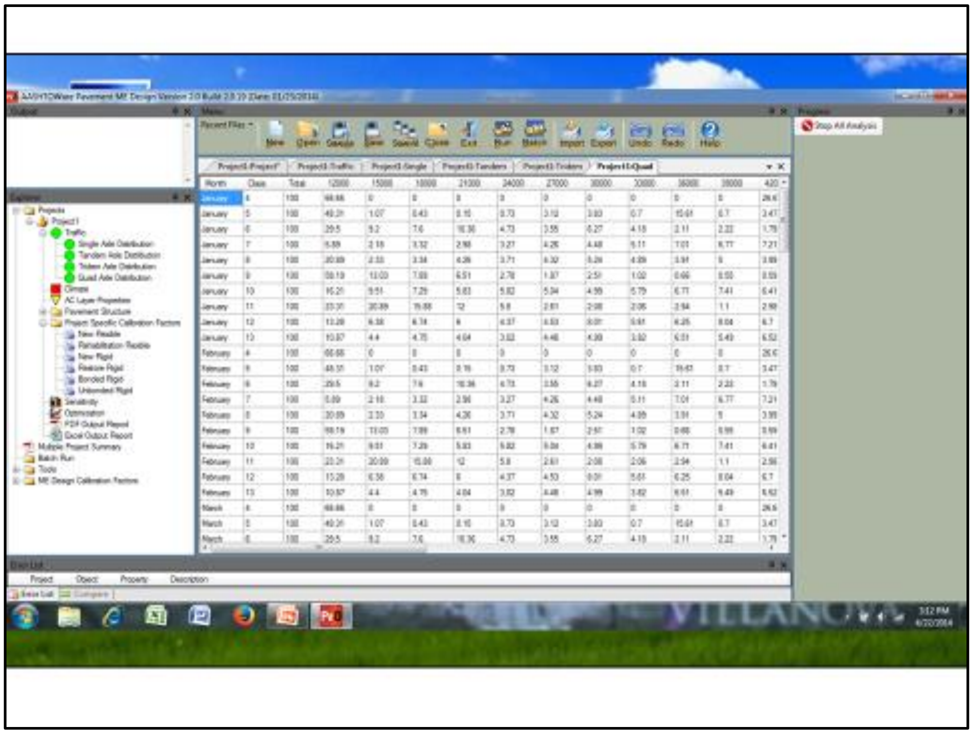
Adjust Distribution, Growth Rate, and Growth Function to represent high-traffic conditions.

Slide 67



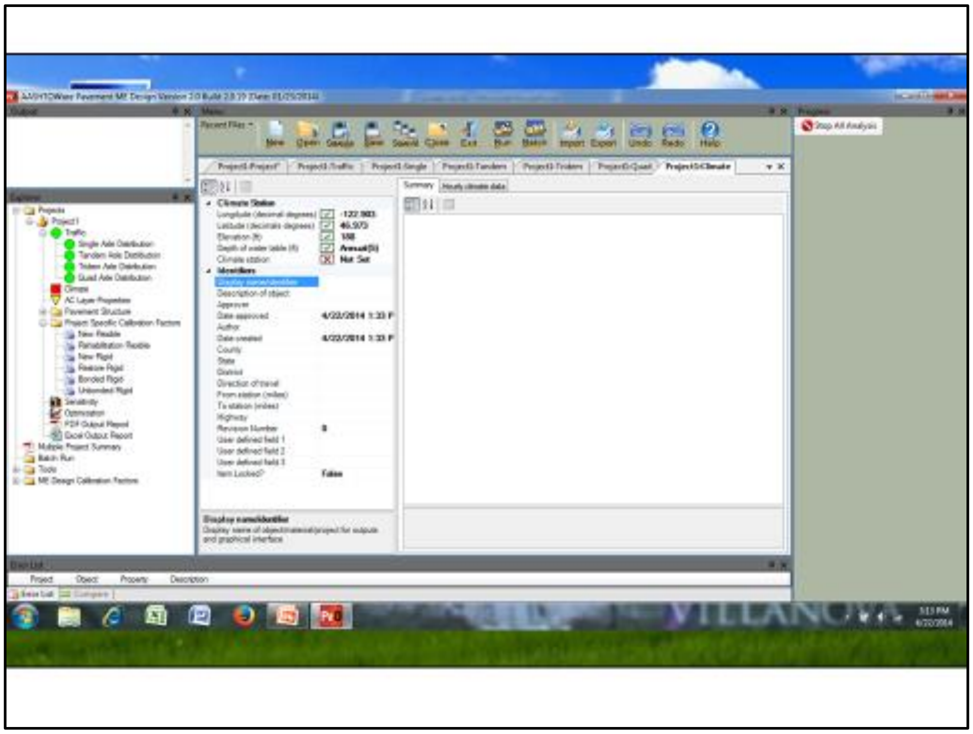
Select Single Axle Distribution to turn it green (accepting default values).

Slide 68



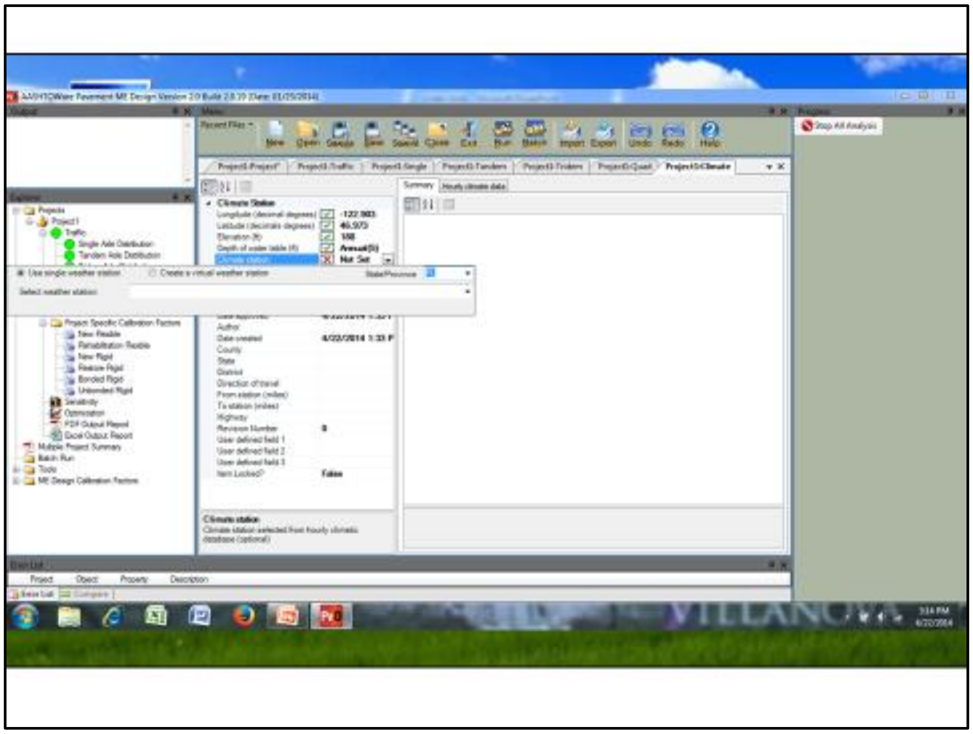
Select the Other Axle Distributions to turn them green (accepting default values).

Slide 69



Select Climate.

Slide 70



Select Climate Station.

Select FL for Florida.

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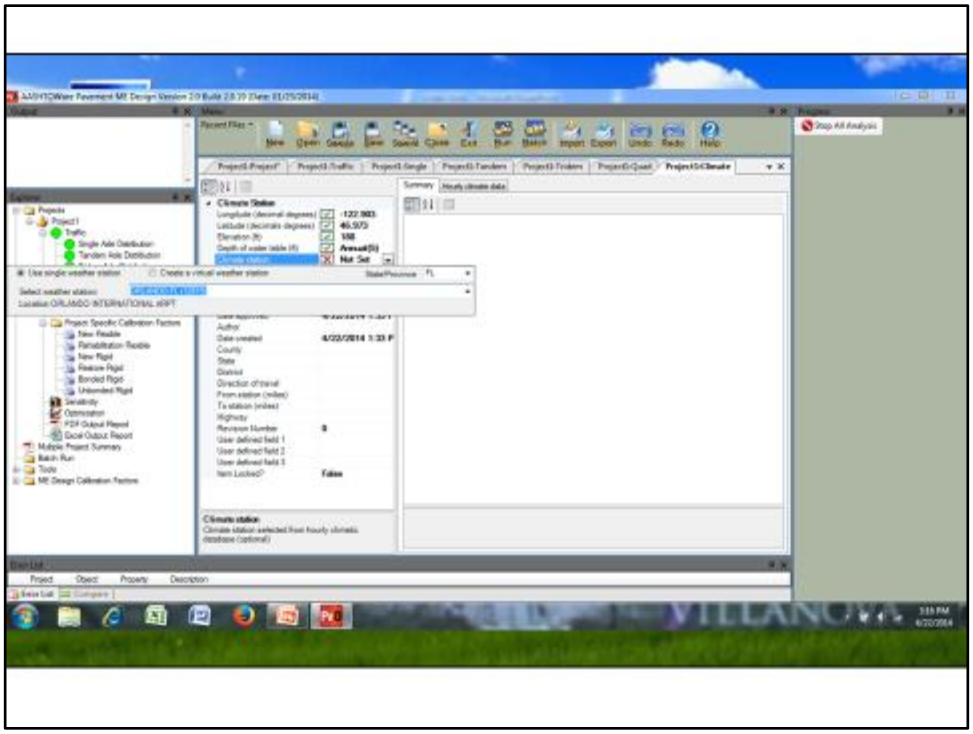
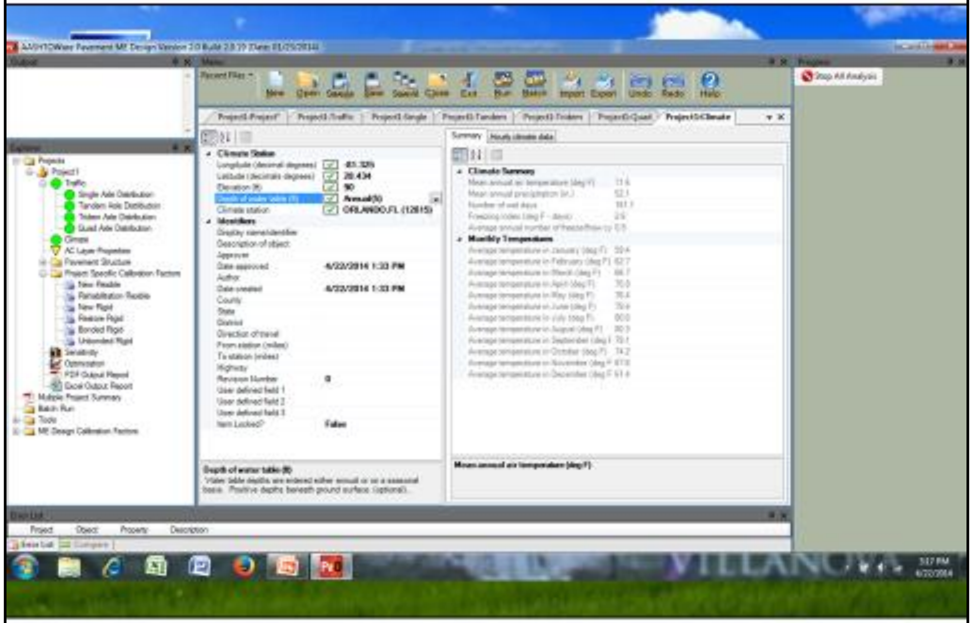
Slide 71



Select Weather Station.

Select Orlando.

Slide 72

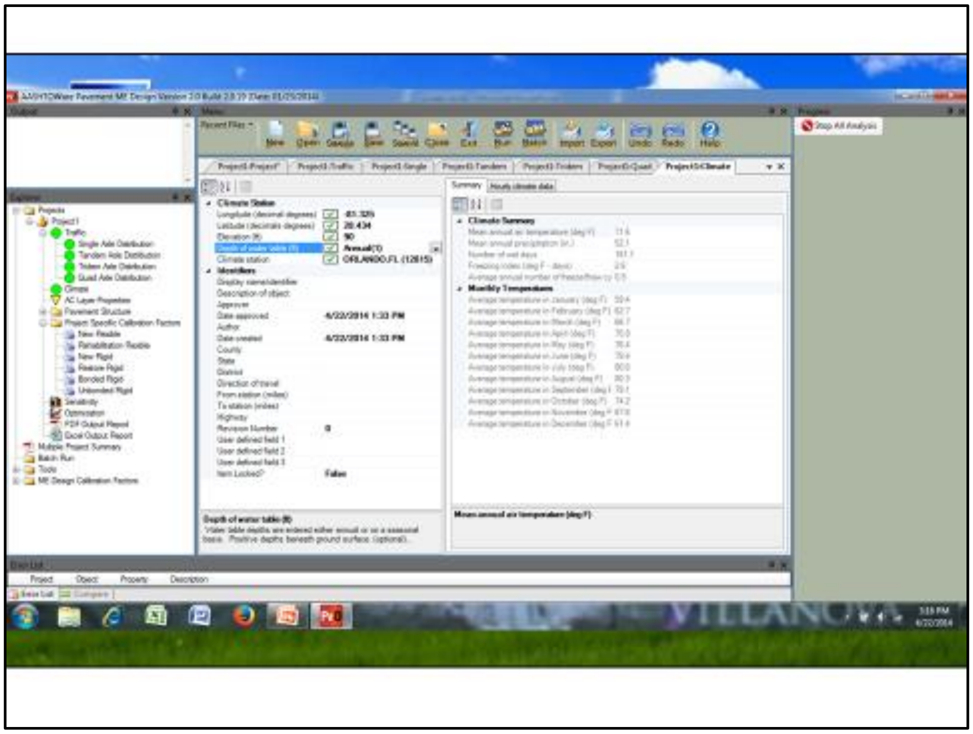


Climate Station
Longitude (decimal degrees) -81.325
Latitude (decimals degrees) 28.434
Elevation (ft) 90
Depth of water table (ft) Annual(5)
Climate station ORLANDO,FL (12815)
Identifiers
Date approved 4/22/2014 1:33 PM
Date created 4/22/2014 1:33 PM
Revision Number 0
Item Locked? False

Depth of water table (ft)
Water table depths are entered either annual or on a seasonal basis. Positive depths beneath ground surface. (optional).

Select Depth of Water Table.

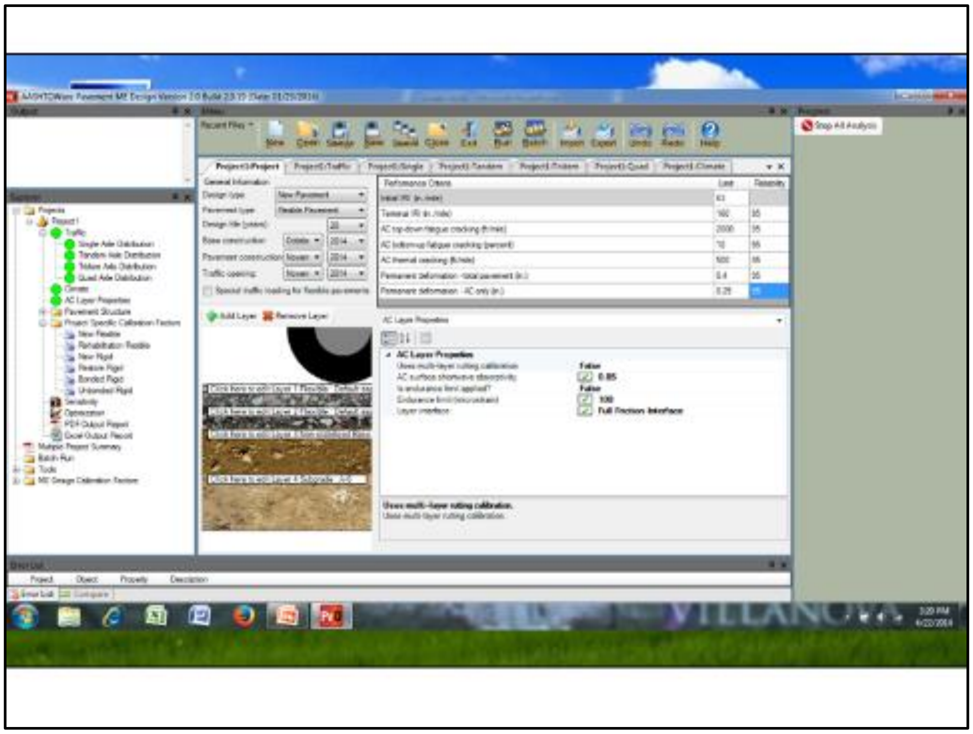
Slide 73



Input 1 for Water Table Depth.

Select outside of the Depth of Water Table window to accept the input.

Slide 74



General Information
Design type: New Pavement
Pavement type: Flexible Pavement
Design life (years): 20
Base construction: October 2014
Pavement construction: November 2014
Traffic opening: November 2014
☐ Special traffic loading for flexible pavements

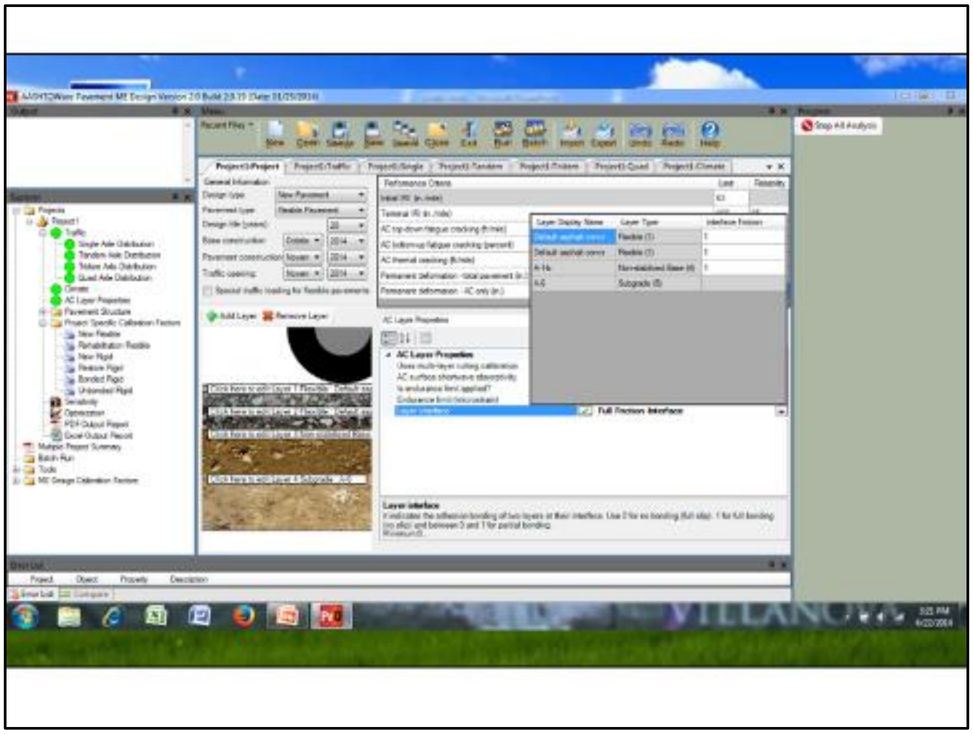
Performance Criteria	Limit	Reliability
Initial IRI (in./mile)	63	
Terminal IRI (in./mile)	[illegible]	[illegible]
AC top-down fatigue cracking (ft/mile)	2000	[illegible]
AC bottom-up fatigue cracking (percent)	[illegible]	[illegible]
AC thermal cracking (ft/mile)	[illegible]	[illegible]
Permanent deformation - total pavement (in.)	0.4	[illegible]
Permanent deformation - AC only (in.)	0.25	[illegible]

AC Layer Properties
Uses multi-layer rutting calibration: False
AC surface shortwave absorptivity: 0.85
Is endurance limit applied?: False
Endurance limit (microstrain): 100
Layer interface: Full Friction Interface

Uses multi-layer rutting calibration.
Uses multi-layer rutting calibration.

Select AC Layer Properties.

Slide 75



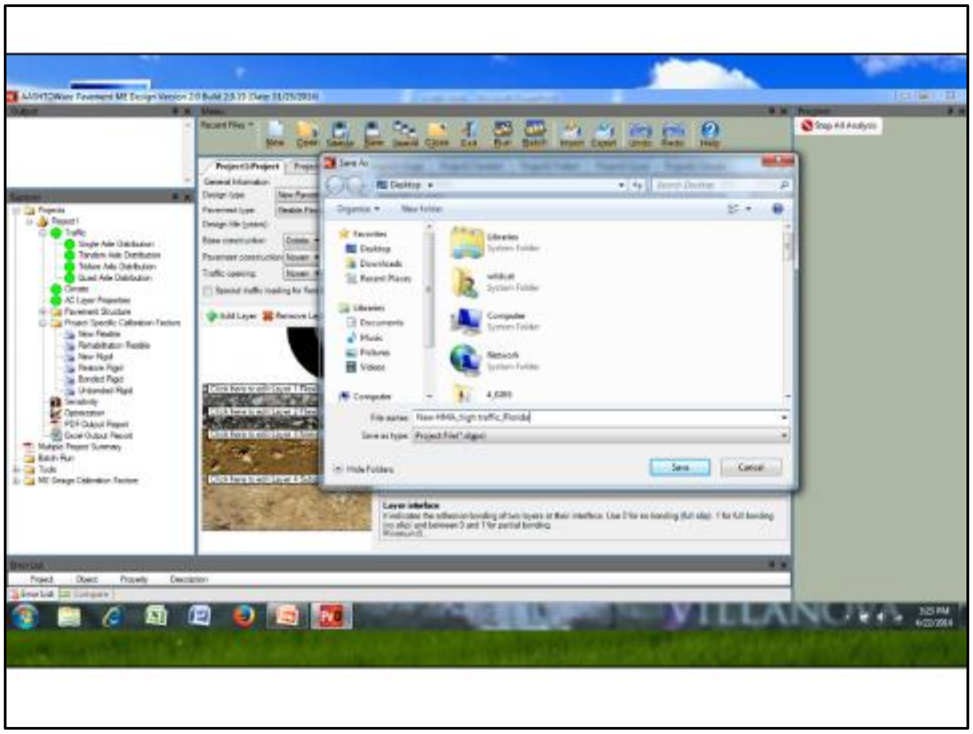
Layer Display Name	Layer Type	Interface Friction
Default asphalt concrete	Flexible (1)	1
Default asphalt concrete	Flexible (1)	1
A-1-b	Non-stabilized Base (4)	1
A-6	Subgrade (5)	

Layer Interface: Full Friction Interface

Layer interface
It indicates the adhesion bonding of two layers at their interface. Use 0 for no bonding (full slip), 1 for full bonding (no slip) and between 0 and 1 for partial bonding.

Select Layer Interface to check and accept default values.

Slide 76



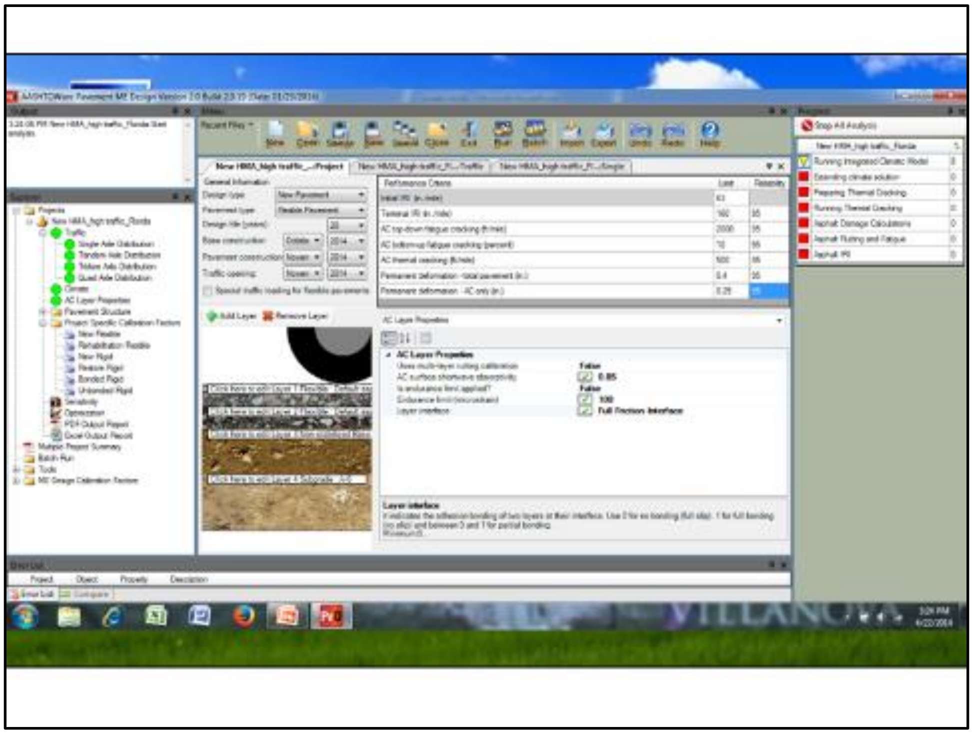
File name: New HMA_high traffic_Florida

Save as type: Project File(*.dgpx)

Select Save.

Then, name your project.

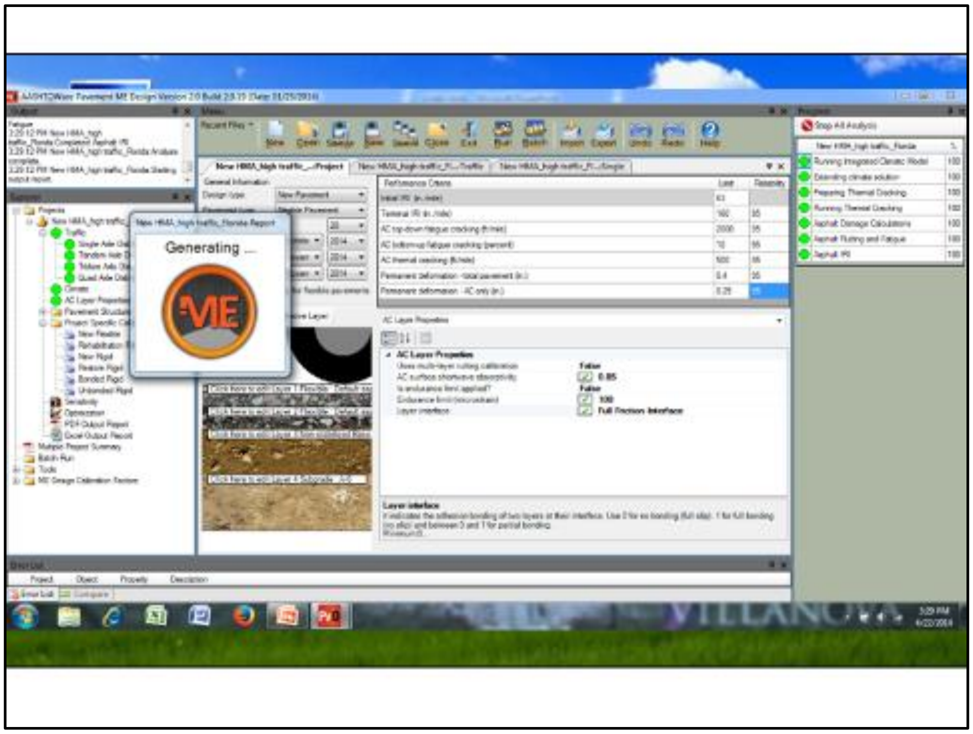
Slide 77



Select Run.

Analysis progress will display on the right-hand side of the screen.

Slide 78



When the analysis is complete, the software will generate the output (PDF and Excel).

Slide 79

Software Demonstration for Flexible Pavement

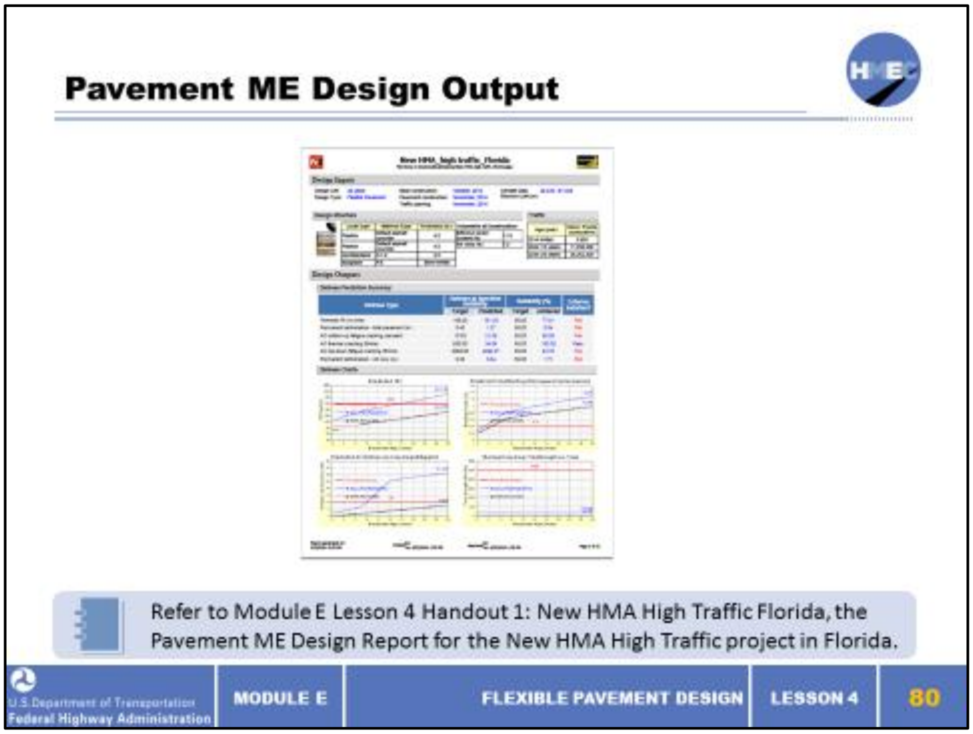
AASHTOWare Pavement ME Design

AASHTO

End Demonstration

New Flexible Pavement Example

Slide 80



Pavement ME Design Output

Refer to Module E Lesson 4 Handout 1: New HMA High Traffic Florida, the Pavement ME Design Report for the New HMA High Traffic project in Florida.

Perform an evaluation of Pavement ME Design new flexible pavement design and suggest design alterations based on material properties to consider and try when the pavement's intended service life is not met. This screen capture shows what the Pavement ME Design software pulls up automatically in Excel or PDF format for users.

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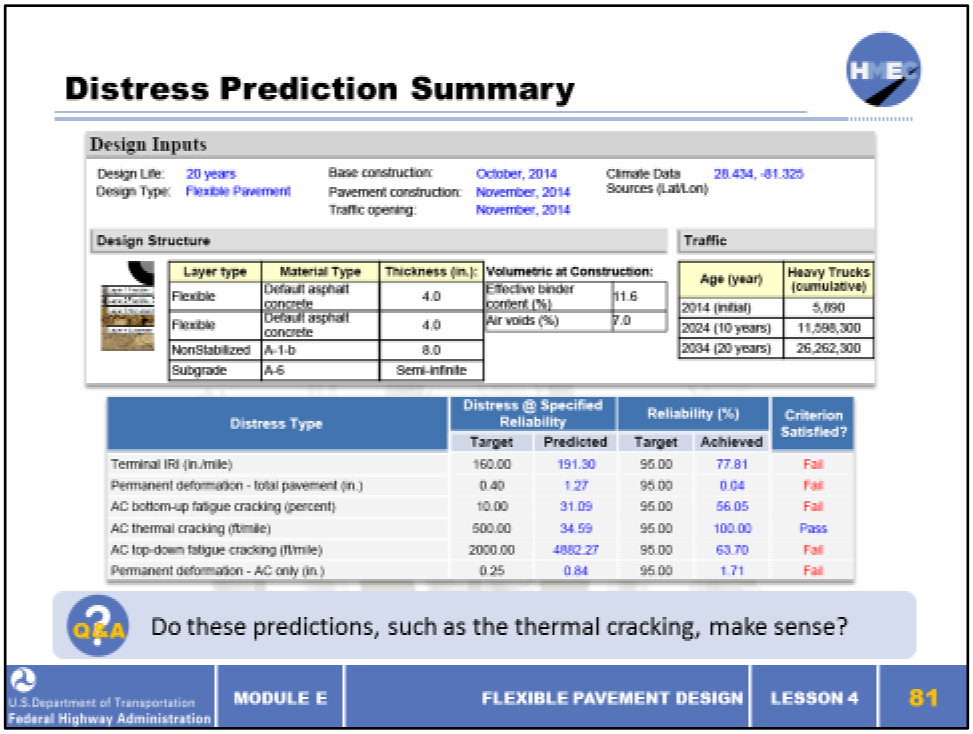
Slide 81



Distress Prediction Summary

Design Inputs

Design Life: 20 years
Design Type: Flexible Pavement

Base construction: October, 2014
Pavement construction: November, 2014
Traffic opening: November, 2014

Climate Data Sources (Lat/Lon): 28.434, -81.325

Design Structure

Layer type	Material Type	Thickness (in.):
Flexible	Default asphalt concrete	4.0
Flexible	Default asphalt concrete	4.0
NonStabilized	A-1-b	8.0
Subgrade	A-6	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	11.6
Air voids (%)	7.0

Traffic

Age (year)	Heavy Trucks (cumulative)
2014 (initial)	5,890
2024 (10 years)	11,598,300
2034 (20 years)	26,262,300

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	191.30	95.00	77.81	Fail
Permanent deformation - total pavement (in.)	0.40	1.27	95.00	0.04	Fail
AC bottom-up fatigue cracking (percent)	10.00	31.09	95.00	56.05	Fail
AC thermal cracking (ft/mile)	500.00	34.59	95.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	2000.00	4882.27	95.00	63.70	Fail
Permanent deformation - AC only (in.)	0.25	0.84	95.00	1.71	Fail

Q&A Do these predictions, such as the thermal cracking, make sense?

U.S. Department of Transportation Federal Highway Administration | MODULE E | FLEXIBLE PAVEMENT DESIGN | LESSON 4 | 81

It can be clearly observed from the output table that every distress was exceeded except for the thermal cracking.

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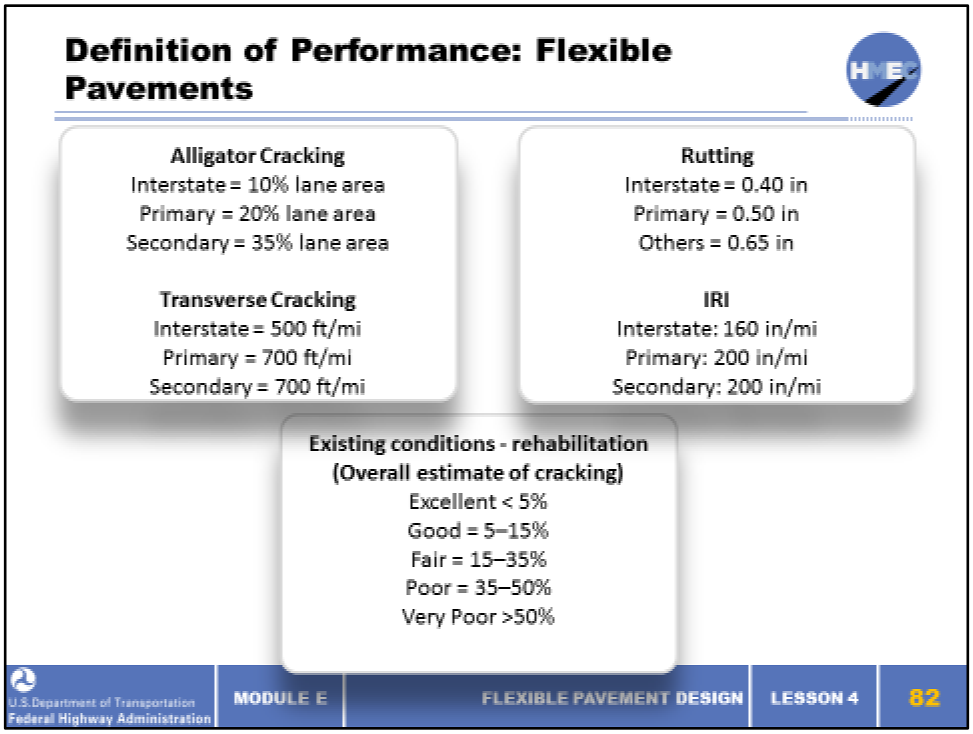
Slide 82



Definition of Performance: Flexible Pavements

Alligator Cracking
Interstate = 10% lane area
Primary = 20% lane area
Secondary = 35% lane area

Transverse Cracking
Interstate = 500 ft/mi
Primary = 700 ft/mi
Secondary = 700 ft/mi

Rutting
Interstate = 0.40 in
Primary = 0.50 in
Others = 0.65 in

IRI
Interstate: 160 in/mi
Primary: 200 in/mi
Secondary: 200 in/mi

Existing conditions - rehabilitation
(Overall estimate of cracking)
Excellent < 5%
Good = 5–15%
Fair = 15–35%
Poor = 35–50%
Very Poor >50%

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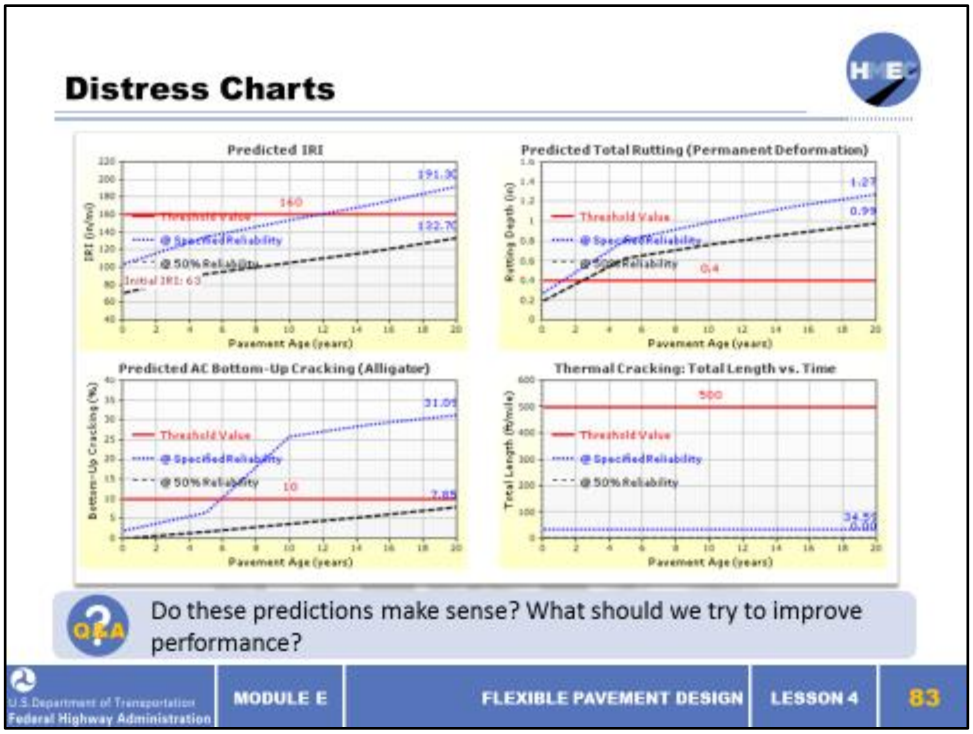
MODULE E
FLEXIBLE PAVEMENT DESIGN
LESSON 4
82

The failure parameters provided in the MEPDG Manual of Practice are provided for flexible pavements, to be used in defining terminal performance, for the major distresses included in the Pavement ME Design tool.

It should be noted that for IRI, the minimum construction smoothness specifications can negate the starting point for IRI predictions at higher reliability levels. For example, Missouri requires a maximum IRI of 80 inches/mile for new asphalt and concrete pavement; therefore, we would never have an initial IRI over 100 as is shown in this design at 95% reliability.

Slide 83



Distress Charts

Do these predictions make sense? What should we try to improve performance?

It can be clearly observed from the output table that every distress was exceeded except for the thermal cracking.

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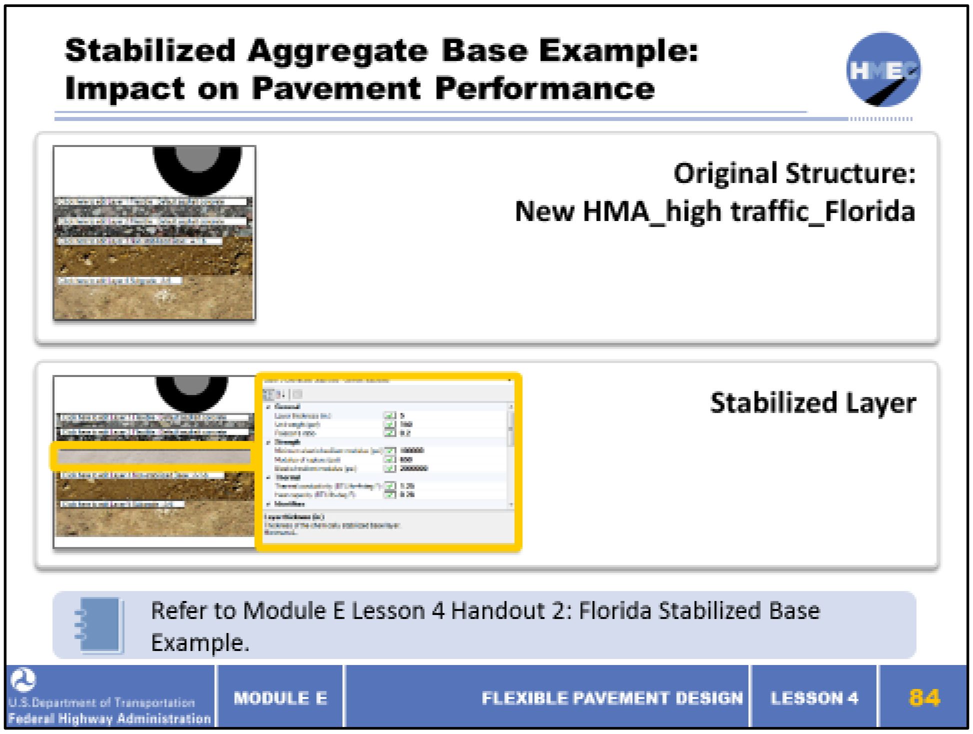
Slide 84



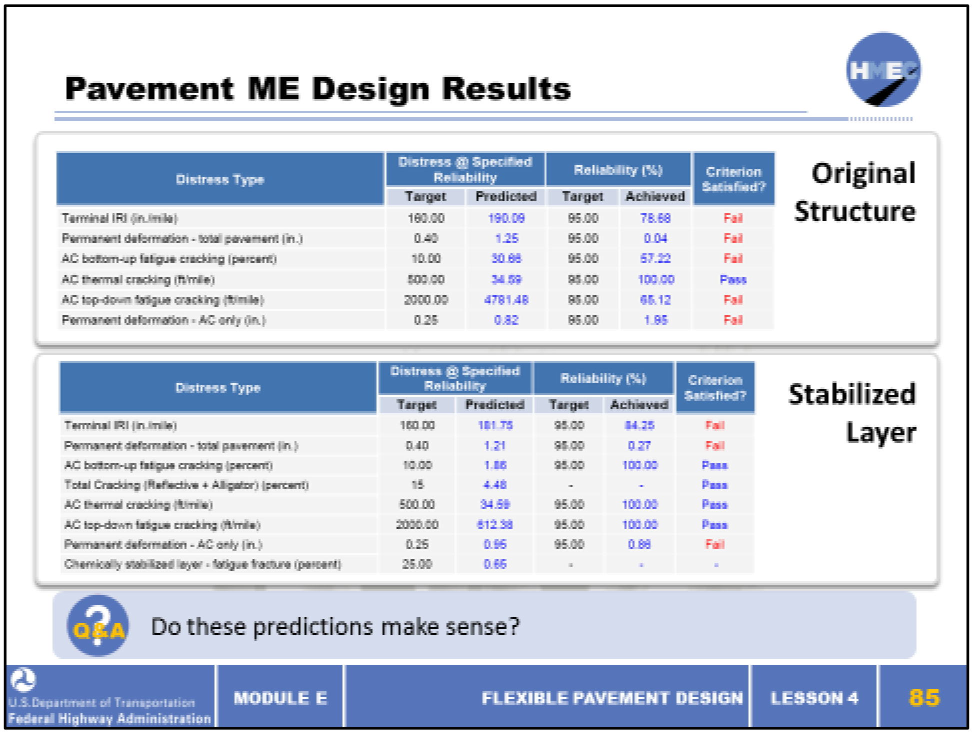
Stabilized Aggregate Base Example: Impact on Pavement Performance

Original Structure:
New HMA_high traffic_Florida

Stabilized Layer

Refer to Module E Lesson 4 Handout 2: Florida Stabilized Base Example.

Slide 85



Pavement ME Design Results

Original Structure

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	190.09	95.00	78.68	Fail
Permanent deformation - total pavement (in.)	0.40	1.25	95.00	0.04	Fail
AC bottom-up fatigue cracking (percent)	10.00	30.86	95.00	57.22	Fail
AC thermal cracking (ft/mile)	500.00	34.59	95.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	2000.00	4781.48	95.00	65.12	Fail
Permanent deformation - AC only (in.)	0.25	0.82	95.00	1.85	Fail

Stabilized Layer

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	181.75	95.00	84.25	Fail
Permanent deformation - total pavement (in.)	0.40	1.21	95.00	0.27	Fail
AC bottom-up fatigue cracking (percent)	10.00	1.86	95.00	100.00	Pass
Total Cracking (Reflective + Alligator) (percent)	15	4.48	-	-	Pass
AC thermal cracking (ft/mile)	500.00	34.59	95.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	2000.00	612.38	95.00	100.00	Pass
Permanent deformation - AC only (in.)	0.25	0.95	95.00	0.88	Fail
Chemically stabilized layer - fatigue fracture (percent)	25.00	0.65	-	-	-

Q&A Do these predictions make sense?

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First we look at the original structure’s results, then the narration brings in the results from the new trial run.

It can be clearly observed from the output table that the alligator and top-down fatigue cracking performance improved, as did the IRI although to a lesser degree.

However, when observing the effects of the change on rutting, the addition of a chemically stabilized material (CSM) layer did not appear to induce any major improvement in the resistance to rutting.

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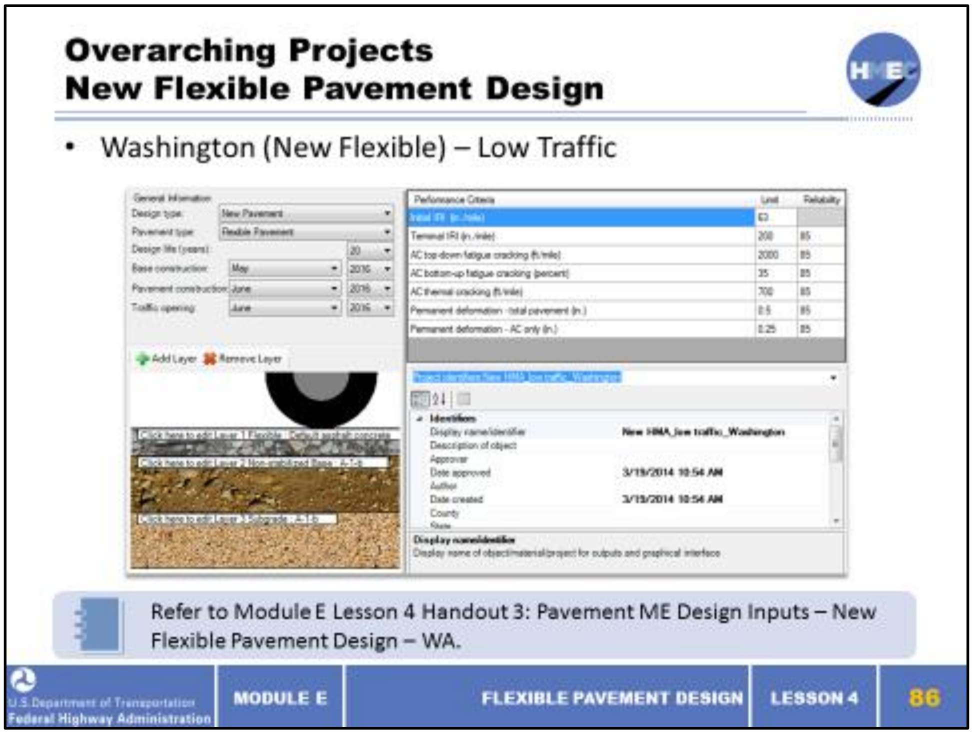
Slide 86



Overarching Projects New Flexible Pavement Design

- Washington (New Flexible) – Low Traffic

General Information
Design type: New Pavement
Pavement type: Flexible Pavement
Design life (years): 20
Base construction: May 2016
Pavement construction: June 2016
Traffic opening: June 2016

Performance Criteria	Limit	Reliability
Initial IRI (in./mile)	63	
Terminal IRI (in./mile)	200	85
AC top-down fatigue cracking (ft/mile)	2000	85
AC bottom-up fatigue cracking (percent)	35	85
AC thermal cracking (ft/mile)	700	85
Permanent deformation - total pavement (in.)	0.5	85
Permanent deformation - AC only (in.)	0.25	85

Project identifier: New HMA_low traffic_Washington

Identifiers
Display name/identifier: New HMA_low traffic_Washington
Description of object
Approver
Date approved: 3/19/2014 10:54 AM
Author
Date created: 3/19/2014 10:54 AM
County
State

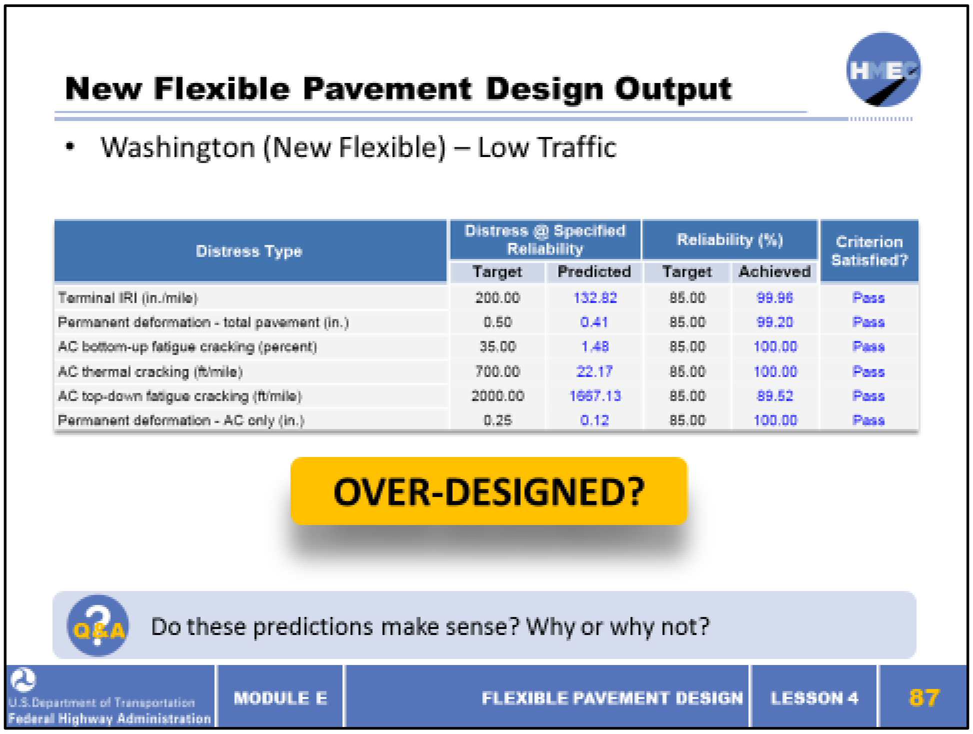
Display name/identifier
Display name of object/material/project for outputs and graphical interface

Add Layer
Remove Layer
Click here to edit Layer 1 Flexible : Default asphalt concrete
Click here to edit Layer 2 Non-stabilized Base : A-1-b
Click here to edit Layer 3 Subgrade : A-1-b

Refer to Module E Lesson 4 Handout 3: Pavement ME Design Inputs – New Flexible Pavement Design – WA.

Software demonstration. Perform an evaluation of completed Pavement ME Design new flexible pavement designs, including critical analysis of pavement performance and suggested design alterations.

Slide 87



New Flexible Pavement Design Output

- Washington (New Flexible) – Low Traffic

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	200.00	132.82	85.00	99.96	Pass
Permanent deformation - total pavement (in.)	0.50	0.41	85.00	99.20	Pass
AC bottom-up fatigue cracking (percent)	35.00	1.48	85.00	100.00	Pass
AC thermal cracking (ft/mile)	700.00	22.17	85.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	2000.00	1667.13	85.00	89.52	Pass
Permanent deformation - AC only (in.)	0.25	0.12	85.00	100.00	Pass

OVER-DESIGNED?

Q&A Do these predictions make sense? Why or why not?

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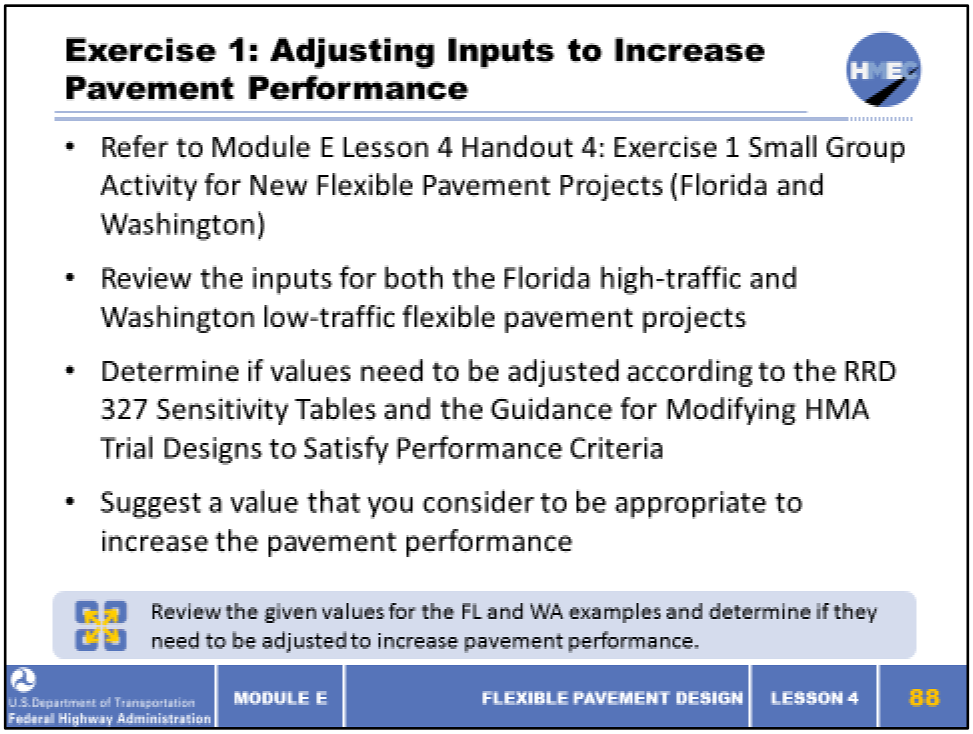
It can be clearly observed from the output table that no distresses exceeded the performance threshold criteria for the lower functional class roadway. It calls into question: Was the pavement overdesigned in some way? Can we optimize it better in terms of making a more cost-efficient design?

How did we factor in variability in the materials used in the design? What if we tried to factor in material variability, even though design reliability is lower (85%)?

Slide 88



Exercise 1: Adjusting Inputs to Increase Pavement Performance

- Refer to Module E Lesson 4 Handout 4: Exercise 1 Small Group Activity for New Flexible Pavement Projects (Florida and Washington)
- Review the inputs for both the Florida high-traffic and Washington low-traffic flexible pavement projects
- Determine if values need to be adjusted according to the RRD 327 Sensitivity Tables and the Guidance for Modifying HMA Trial Designs to Satisfy Performance Criteria
- Suggest a value that you consider to be appropriate to increase the pavement performance

Review the given values for the FL and WA examples and determine if they need to be adjusted to increase pavement performance.

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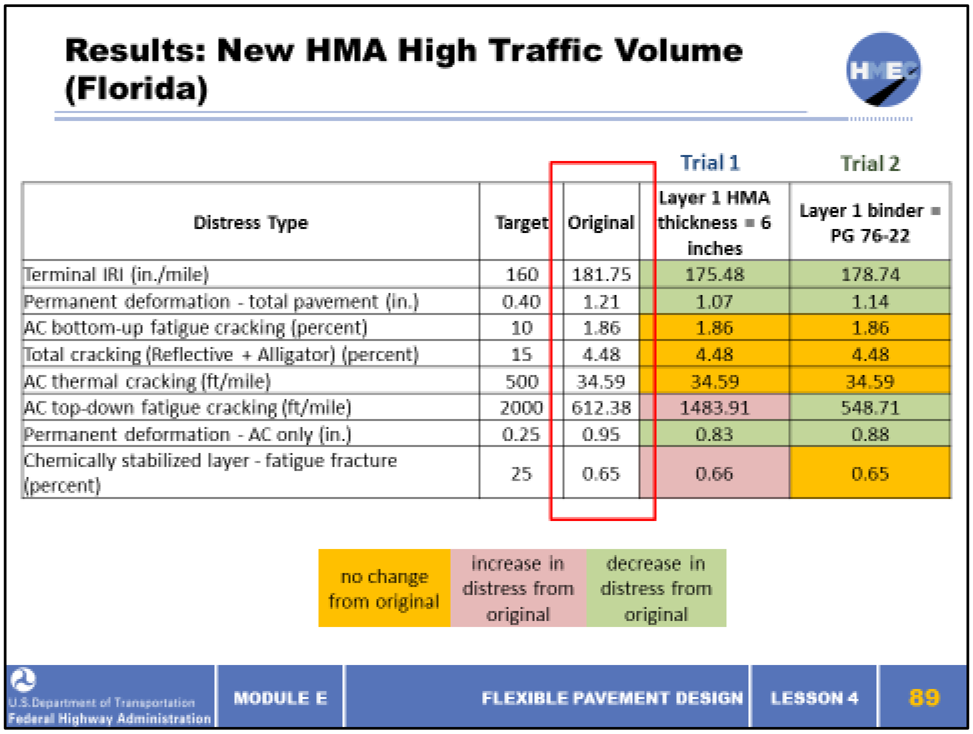
Slide 89



Results: New HMA High Traffic Volume (Florida)

Distress Type	Target	Original	Trial 1 Layer 1 HMA thickness = 6 inches	Trial 2 Layer 1 binder = PG 76-22
Terminal IRI (in./mile)	160	181.75	175.48	178.74
Permanent deformation - total pavement (in.)	0.40	1.21	1.07	1.14
AC bottom-up fatigue cracking (percent)	10	1.86	1.86	1.86
Total cracking (Reflective + Alligator) (percent)	15	4.48	4.48	4.48
AC thermal cracking (ft/mile)	500	34.59	34.59	34.59
AC top-down fatigue cracking (ft/mile)	2000	612.38	1483.91	548.71
Permanent deformation - AC only (in.)	0.25	0.95	0.83	0.88
Chemically stabilized layer - fatigue fracture (percent)	25	0.65	0.66	0.65

no change from original

increase in distress from original

decrease in distress from original

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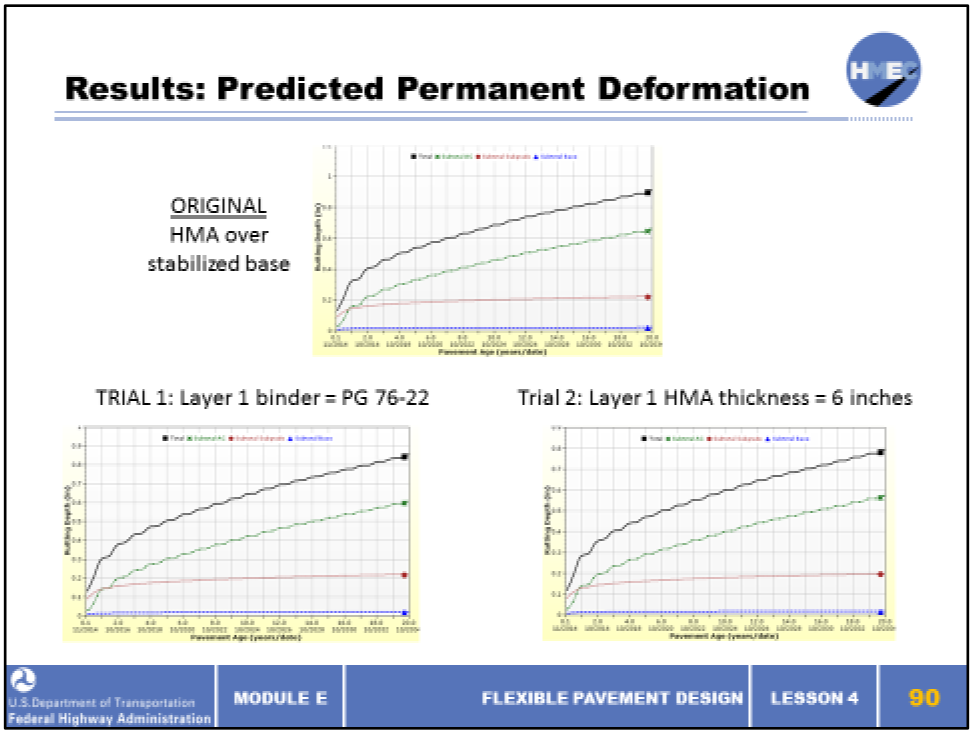
This table shows the results of two Trials on the Florida high-volume pavement with a cement-stabilized base.

The first trial altered the HMA top layer’s thickness from 4” to 6” and the effect was sufficient to reduce the rutting in the subgrade and HMA somewhat, as compared to the original. However, in doing so, there was a major increase in top-down fatigue cracking which resulted as a side effect of the improvement to rutting.

The second trial altered the HMA top layer’s high-temperature binder grade from 70 to 76 and the effect was sufficient to reduce the rutting in the HMA somewhat, as compared to the original.

Slide 90



Results: Predicted Permanent Deformation

ORIGINAL
HMA over
stabilized base

TRIAL 1: Layer 1 binder = PG 76-22

Trial 2: Layer 1 HMA thickness = 6 inches

U.S. Department of Transportation
Federal Highway Administration

MODULE E

FLEXIBLE PAVEMENT DESIGN

LESSON 4

90

These plots show the rutting predicted for the Original structure as well as the two trials described in the previous slide.

The plots indicate the Total rutting (black line), and rutting in each of the individual layers: subgrade (red line), base (blue line), and asphalt surface (green line).

The results show that there is some change in rutting performance by increasing the thickness, or by increasing the high temperature grade of the asphalt surface layer. However, the improvement is not significant and indicates that other alterations to either the pavement's materials or structure will be necessary to achieve the 20 year design life.

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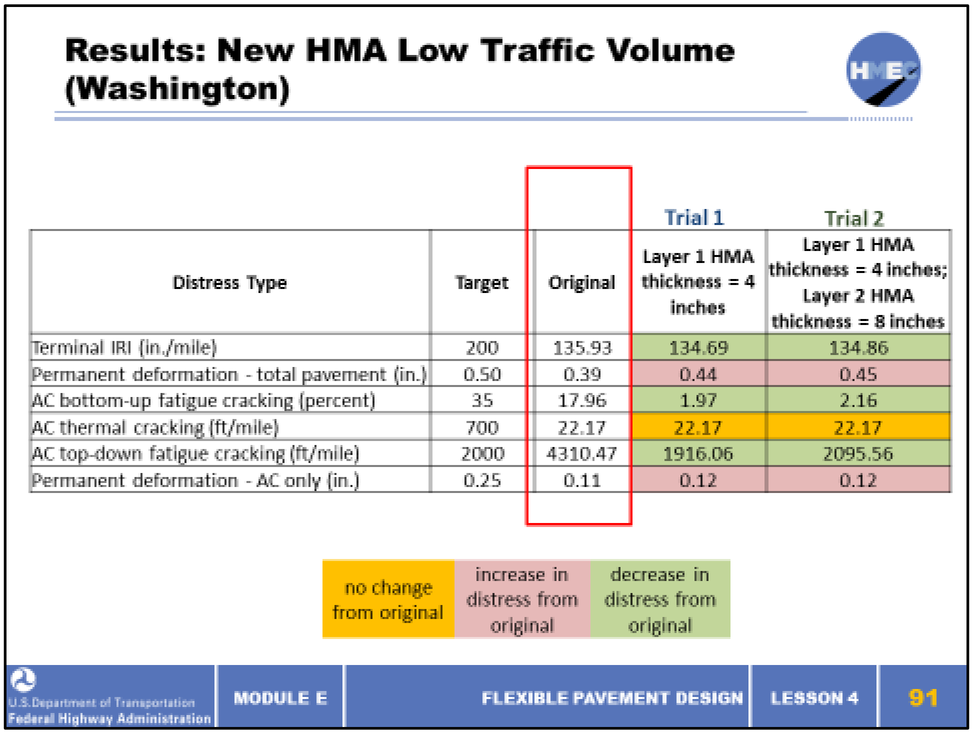
Slide 91



Results: New HMA Low Traffic Volume (Washington)

			Trial 1	Trial 2
Distress Type	Target	Original	Layer 1 HMA thickness = 4 inches	Layer 1 HMA thickness = 4 inches; Layer 2 HMA thickness = 8 inches
Terminal IRI (in./mile)	200	135.93	🟩 134.69	🟩 134.86
Permanent deformation - total pavement (in.)	0.50	0.39	🟥 0.44	🟥 0.45
AC bottom-up fatigue cracking (percent)	35	17.96	🟩 1.97	🟩 2.16
AC thermal cracking (ft/mile)	700	22.17	🟨 22.17	🟨 22.17
AC top-down fatigue cracking (ft/mile)	2000	4310.47	🟩 1916.06	🟩 2095.56
Permanent deformation - AC only (in.)	0.25	0.11	🟥 0.12	🟥 0.12

🟨	🟥	🟩
no change from original	increase in distress from original	decrease in distress from original

U.S. Department of Transportation Federal Highway Administration | MODULE E | FLEXIBLE PAVEMENT DESIGN | LESSON 4 | 91

This table shows the results of two Trials on the Washington low-volume pavement which was believed to be overdesigned and we were looking for ways to optimize the pavement structure while economizing at the same time.

The first trial altered the HMA top layer's thickness down to 4" and the effect was that there was a slight increase in rutting, mostly in the subgrade, as compared to the Original.

The second trial altered the HMA top layer's thickness down to 4" AND the granular base layer's thickness down to 8" and the effect was nearly identical to that in Trial 1.

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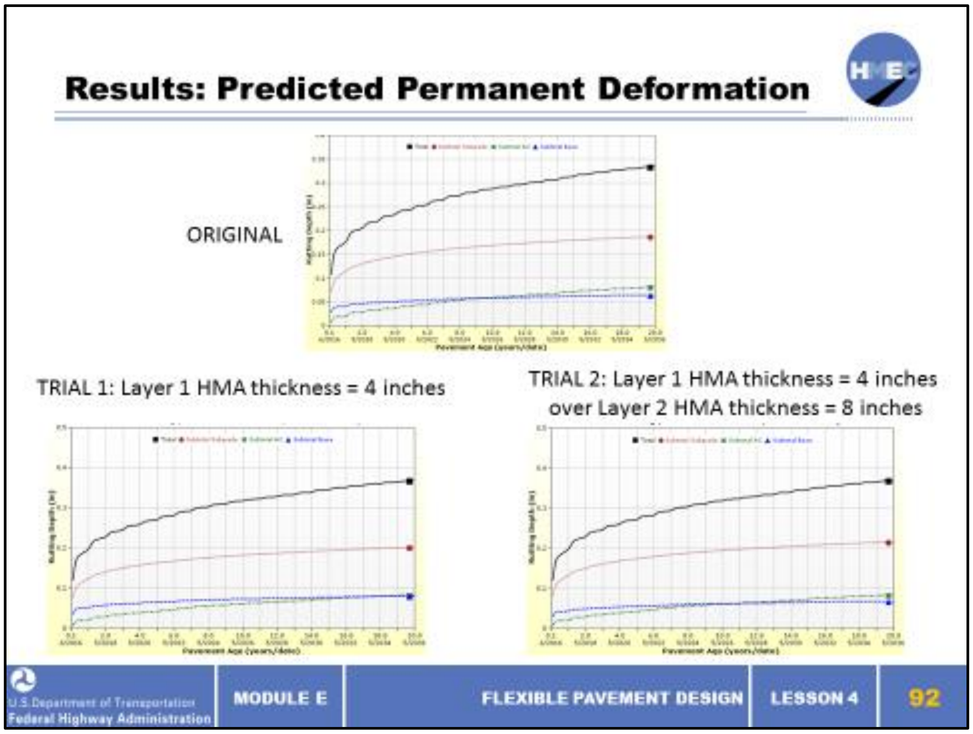
Slide 92



Results: Predicted Permanent Deformation

ORIGINAL

TRIAL 1: Layer 1 HMA thickness = 4 inches

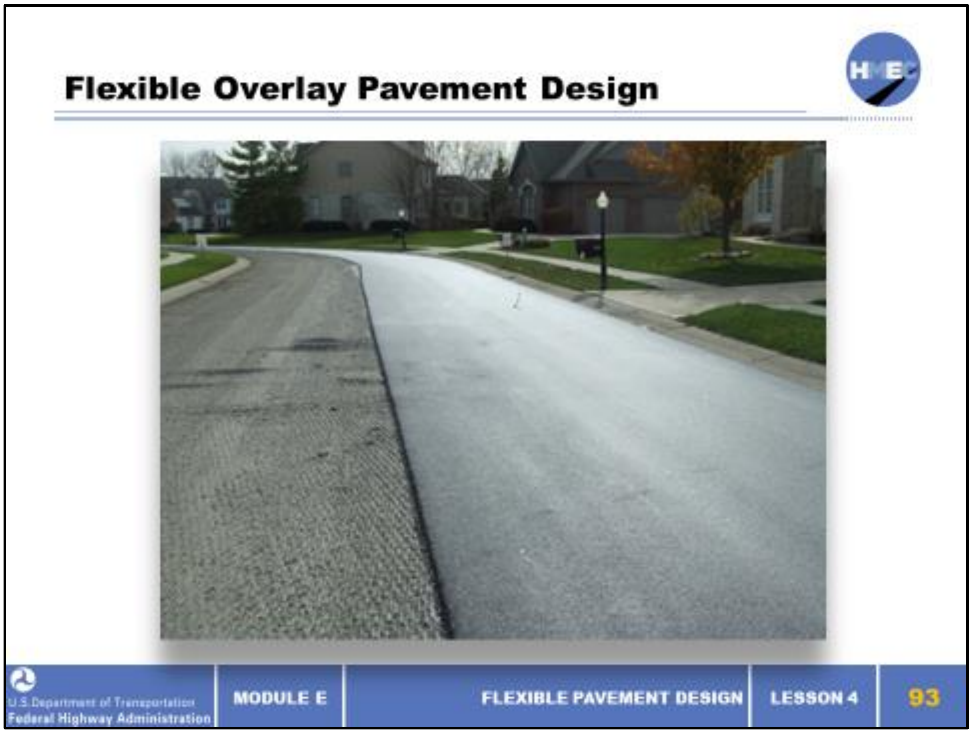
TRIAL 2: Layer 1 HMA thickness = 4 inches
over Layer 2 HMA thickness = 8 inches

These plots show the rutting predicted for the Original structure as well as the two trials described in the previous slide.

The plots indicate the Total rutting (black line), and rutting in each of the individual layers: subgrade (red line), base (blue line), and asphalt surface (green line).

The results show that there is very little change in performance by slimming down the structure by several inches, thereby saving $$ and not at the expense of performance over the 20-year design life. In this way, we were able to optimize the pavement and save the Washington DOT money and materials resources.

Slide 93



Flexible Overlay Pavement Design

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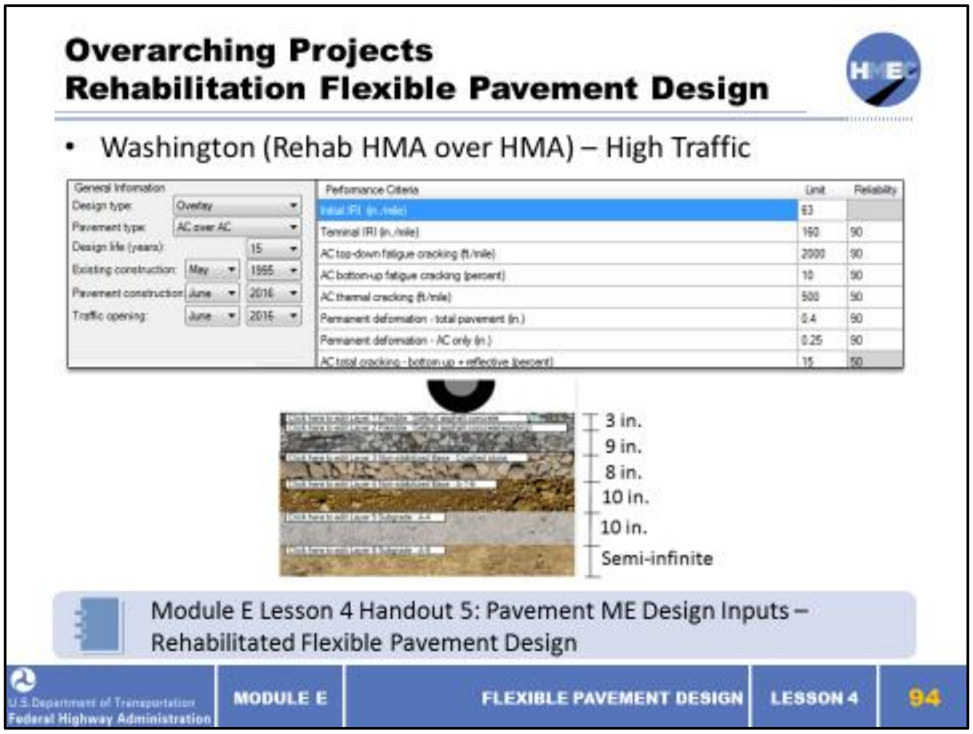
MODULE E | FLEXIBLE PAVEMENT DESIGN | LESSON 4 | 93

Slide 94



Overarching Projects
Rehabilitation Flexible Pavement Design

- Washington (Rehab HMA over HMA) – High Traffic

General Information

Design type: Overlay

Pavement type: AC over AC

Design life (years): 15

Existing construction: May 1995

Pavement construction: June 2016

Traffic opening: June 2016

Performance Criteria	Limit	Reliability
Initial IRI (in./mile)	63	
Terminal IRI (in./mile)	160	90
AC top-down fatigue cracking (ft/mile)	2000	90
AC bottom-up fatigue cracking (percent)	10	90
AC thermal cracking (ft/mile)	500	90
Permanent deformation - total pavement (in.)	0.4	90
Permanent deformation - AC only (in.)	0.25	90
AC total cracking - bottom up + reflective (percent)	15	50

Module E Lesson 4 Handout 5: Pavement ME Design Inputs – Rehabilitated Flexible Pavement Design

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Federal Highway Administration
MODULE E
FLEXIBLE PAVEMENT DESIGN
LESSON 4
94

Perform an evaluation of completed Pavement ME Design rehabilitated flexible pavement design, including critical analysis of pavement performance and suggested design alterations.

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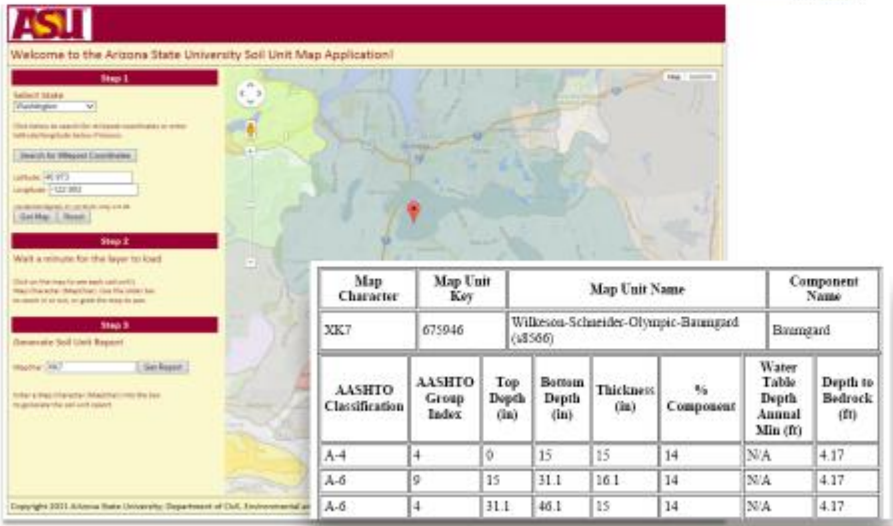
Slide 95

Soil Characterization



Welcome to the Arizona State University Soil Unit Map Application!

Select State: Washington

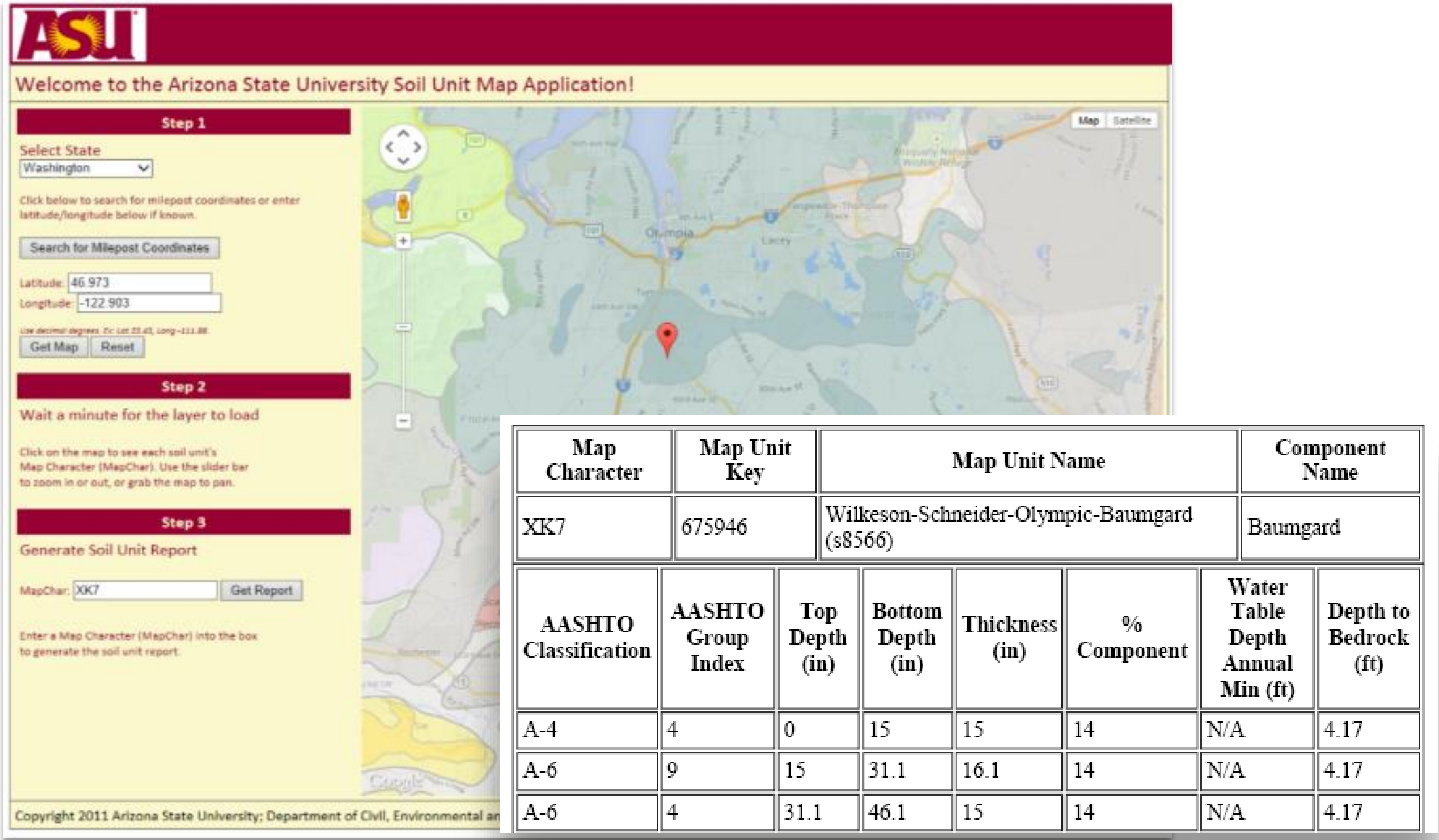
Step 2: Wait a minute for the layer to load

Step 3: Generate Soil Unit Report

MapChar: XK7

Map Character	Map Unit Key	Map Unit Name	Component Name
XK7	675946	Wilkeson-Schneider-Olympic-Baumgard (s8566)	Baumgard

AASHTO Classification	AASHTO Group Index	Top Depth (in)	Bottom Depth (in)	Thickness (in)	% Component	Water Table Depth Annual Min (ft)	Depth to Bedrock (ft)
A-4	4	0	15	15	14	N/A	4.17
A-6	9	15	31.1	16.1	14	N/A	4.17
A-6	4	31.1	46.1	15	14	N/A	4.17



Welcome to the Arizona State University Soil Unit Map Application!

Step 1

Select State

Washington

Click below to search for milepost coordinates or enter latitude/longitude below if known.

Search for Milepost Coordinates

Latitude: 46.973

Longitude: -122.903

Use decimal degrees. Ex: Lat 33.43, Long -111.88.

Get Map Reset

Step 2

Wait a minute for the layer to load

Click on the map to see each soil unit's Map Character (MapChar). Use the slider bar to zoom in or out, or grab the map to pan.

Step 3

Generate Soil Unit Report

MapChar: XK7 Get Report

Enter a Map Character (MapChar) into the box to generate the soil unit report.

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Map Character	Map Unit Key	Map Unit Name	Component Name
XK7	675946	Wilkeson-Schneider-Olympic-Baumgard (s8566)	Baumgard

AASHTO Classification	AASHTO Group Index	Top Depth (in)	Bottom Depth (in)	Thickness (in)	% Component	Water Table Depth Annual Min (ft)	Depth to Bedrock (ft)
A-4	4	0	15	15	14	N/A	4.17
A-6	9	15	31.1	16.1	14	N/A	4.17
A-6	4	31.1	46.1	15	14	N/A	4.17

This screen will remind participants where to get the subgrade-related information from in case those are not available (from previous testing).

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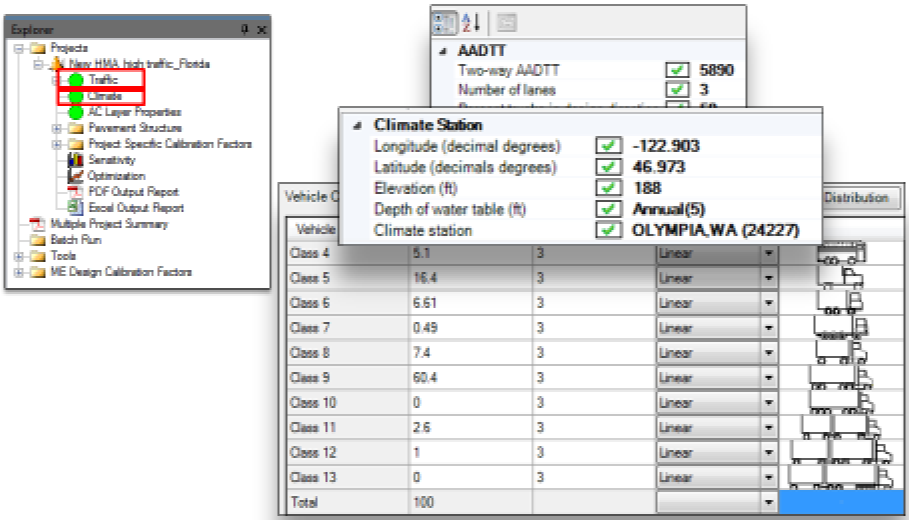
Slide 96

Traffic and Climate Inputs



AADTT

Two-way AADTT ✓ 5890

Number of lanes ✓ 3

Climate Station

Longitude (decimal degrees) ✓ -122.903

Latitude (decimals degrees) ✓ 46.973

Elevation (ft) ✓ 188

Depth of water table (ft) ✓ Annual(5)

Climate station ✓ OLYMPIA,WA (24227)

Vehicle			
Class 4	5.1	3	Linear
Class 5	16.4	3	Linear
Class 6	6.61	3	Linear
Class 7	0.49	3	Linear
Class 8	7.4	3	Linear
Class 9	60.4	3	Linear
Class 10	0	3	Linear
Class 11	2.6	3	Linear
Class 12	1	3	Linear
Class 13	0	3	Linear
Total	100		

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MODULE E | FLEXIBLE PAVEMENT DESIGN | LESSON 4 | 96

Perform an evaluation of completed Pavement ME Design rehabilitated flexible pavement designs, including critical analysis of pavement performance and suggested design alterations.

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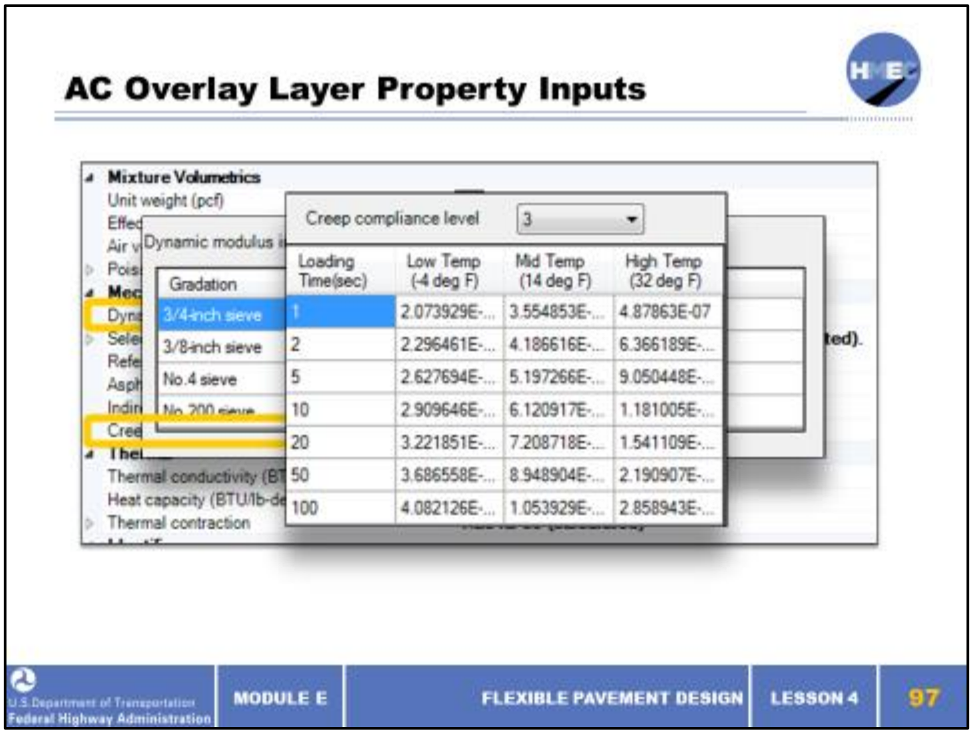
Slide 97



AC Overlay Layer Property Inputs

Creep compliance level: 3

Loading Time(sec)	Low Temp (-4 deg F)	Mid Temp (14 deg F)	High Temp (32 deg F)
1	2.073929E-...	3.554853E-...	4.87863E-07
2	2.296461E-...	4.186616E-...	6.366189E-...
5	2.627694E-...	5.197266E-...	9.050448E-...
10	2.909646E-...	6.120917E-...	1.181005E-...
20	3.221851E-...	7.208718E-...	1.541109E-...
50	3.686558E-...	8.948904E-...	2.190907E-...
100	4.082126E-...	1.053929E-...	2.858943E-...

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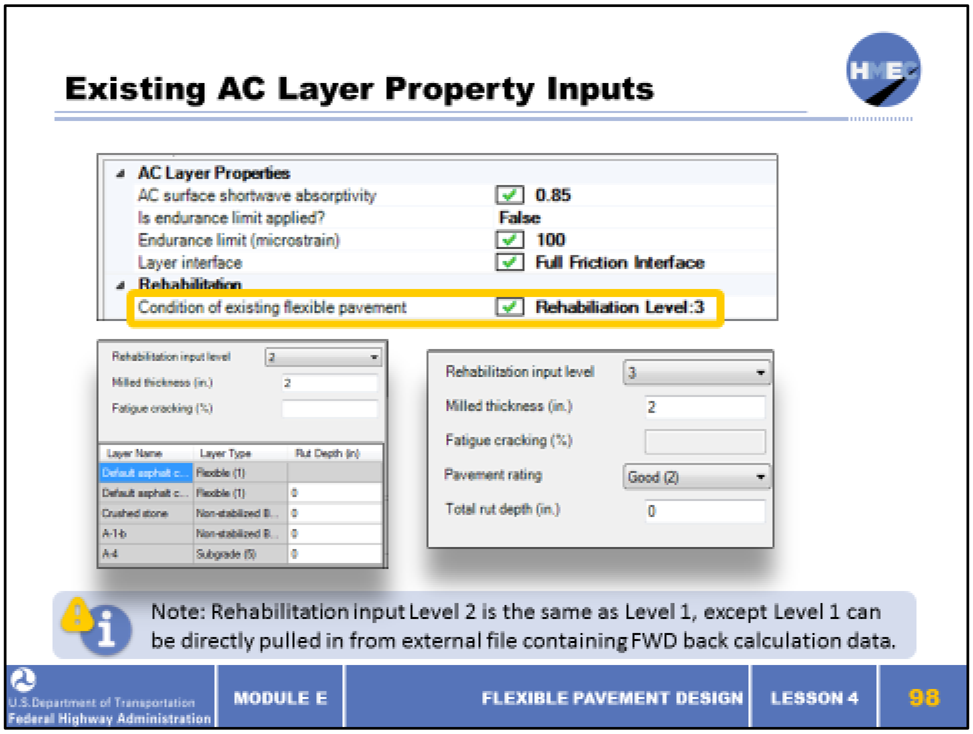
MODULE E FLEXIBLE PAVEMENT DESIGN LESSON 4 97

Perform an evaluation of completed Pavement ME Design rehabilitated flexible pavement designs, including critical analysis of pavement performance and suggested design alterations.

Slide 98



Existing AC Layer Property Inputs

AC Layer Properties

AC surface shortwave absorptivity	☑ 0.85
Is endurance limit applied?	False
Endurance limit (microstrain)	☑ 100
Layer interface	☑ Full Friction Interface

Rehabilitation

Condition of existing flexible pavement	☑ Rehabiliation Level:3

Rehabilitation input level: 2
Milled thickness (in.): 2
Fatigue cracking (%):

Layer Name	Layer Type	Rut Depth (in)
Default asphalt c...	Flexible (1)	
Default asphalt c...	Flexible (1)	0
Crushed stone	Non-stabilized B...	0
A-1-b	Non-stabilized B...	0
A-4	Subgrade (5)	0

Rehabilitation input level: 3
Milled thickness (in.): 2
Fatigue cracking (%):
Pavement rating: Good (2)
Total rut depth (in.): 0

Note: Rehabilitation input Level 2 is the same as Level 1, except Level 1 can be directly pulled in from external file containing FWD back calculation data.

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Federal Highway Administration
MODULE E
FLEXIBLE PAVEMENT DESIGN
LESSON 4
98

Perform an evaluation of completed Pavement ME Design rehabilitated flexible pavement designs, including critical analysis of pavement performance and suggested design alterations.

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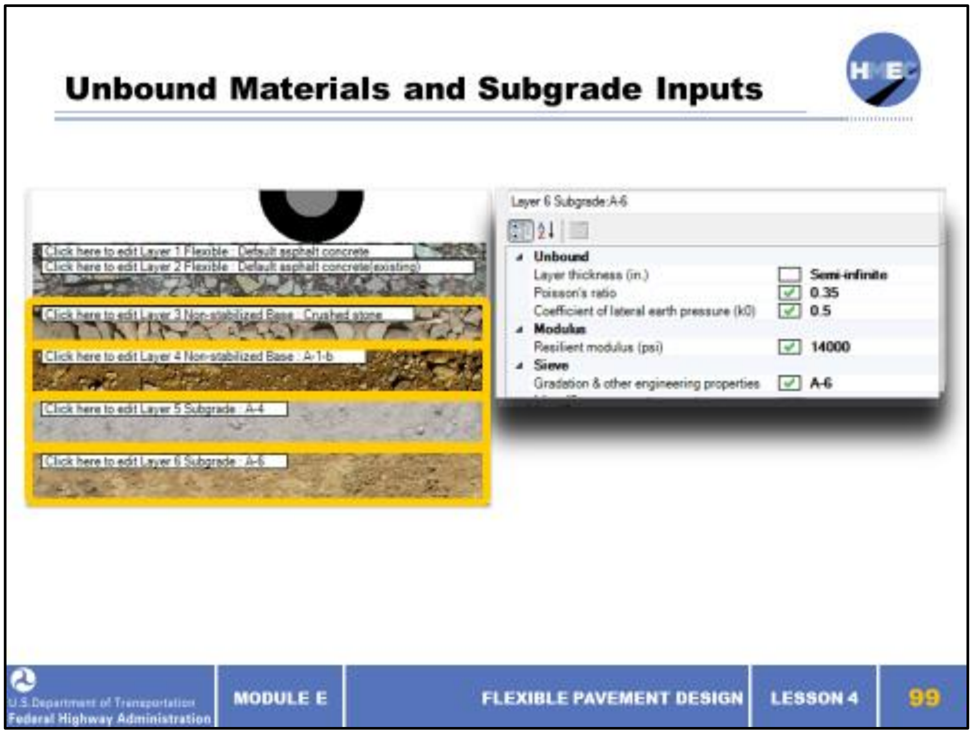
Slide 99



Unbound Materials and Subgrade Inputs

Click here to edit Layer 1 Flexible : Default asphalt concrete
Click here to edit Layer 2 Flexible : Default asphalt concrete(existing)
Click here to edit Layer 3 Non-stabilized Base : Crushed stone
Click here to edit Layer 4 Non-stabilized Base : A-1-b
Click here to edit Layer 5 Subgrade : A-4
Click here to edit Layer 6 Subgrade : A-6

Layer 6 Subgrade:A-6

Unbound		
Layer thickness (in.)	☐	**Semi-infinite**
Poisson's ratio	☑	**0.35**
Coefficient of lateral earth pressure (k0)	☑	**0.5**
Modulus		
Resilient modulus (psi)	☑	**14000**
Sieve		
Gradation & other engineering properties	☑	**A-6**

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Federal Highway Administration
MODULE E
FLEXIBLE PAVEMENT DESIGN
LESSON 4
99

Perform an evaluation of completed Pavement ME Design new flexible pavement designs, including critical analysis of pavement performance and suggested design alterations.

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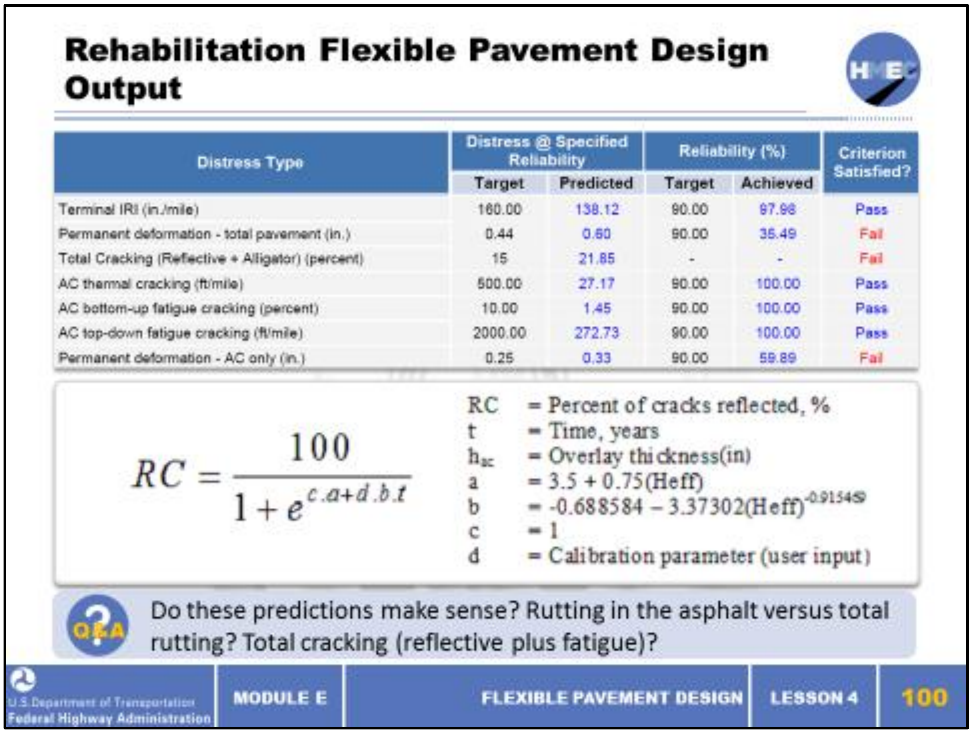
Slide 100



Rehabilitation Flexible Pavement Design Output

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	138.12	90.00	97.98	Pass
Permanent deformation - total pavement (in.)	0.44	0.60	90.00	35.49	Fail
Total Cracking (Reflective + Alligator) (percent)	15	21.85	-	-	Fail
AC thermal cracking (ft/mile)	500.00	27.17	90.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	10.00	1.45	90.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	2000.00	272.73	90.00	100.00	Pass
Permanent deformation - AC only (in.)	0.25	0.33	90.00	59.89	Fail

$$RC = \frac{100}{1 + e^{c.a + d.b.t}}$$

RC = Percent of cracks reflected, %
t = Time, years
h_{ac} = Overlay thickness(in)
a = 3.5 + 0.75(Heff)
b = $-0.688584 - 3.37302(\text{Heff})^{-0.915459}$
c = 1
d = Calibration parameter (user input)

Q&A Do these predictions make sense? Rutting in the asphalt versus total rutting? Total cracking (reflective plus fatigue)?

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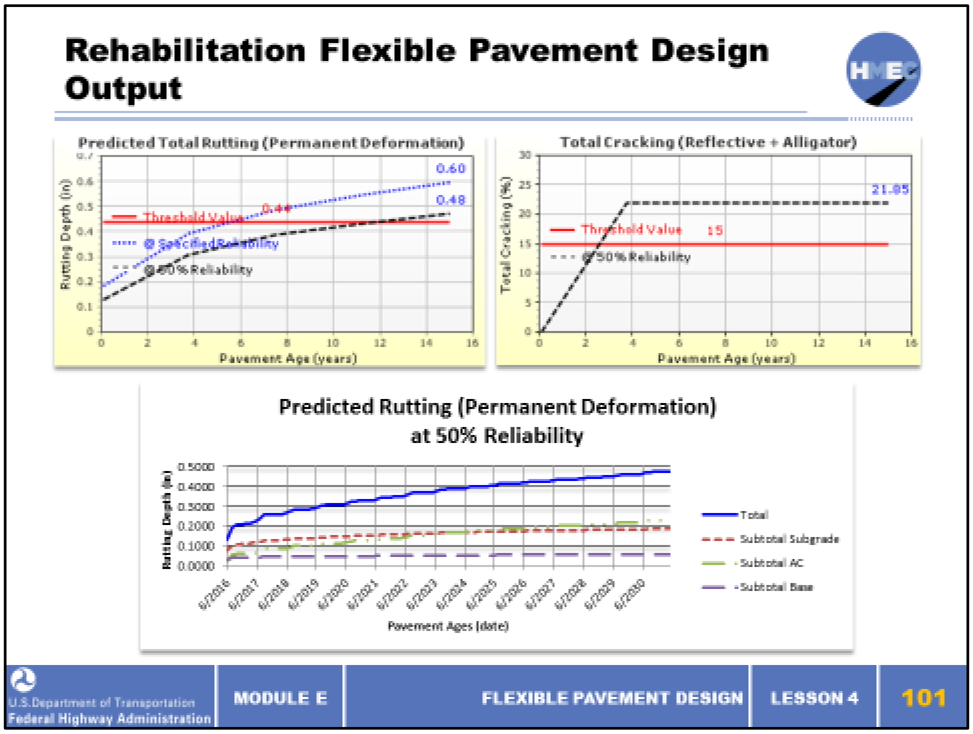
It can be clearly observed from the output table that rutting and total cracking fail the performance criteria, but IRI, TC, and other cracking pass. Note that the total cracking is only predicted at 50% reliability and cannot be run at any higher level of reliability at this time.

Slide 101



Rehabilitation Flexible Pavement Design Output

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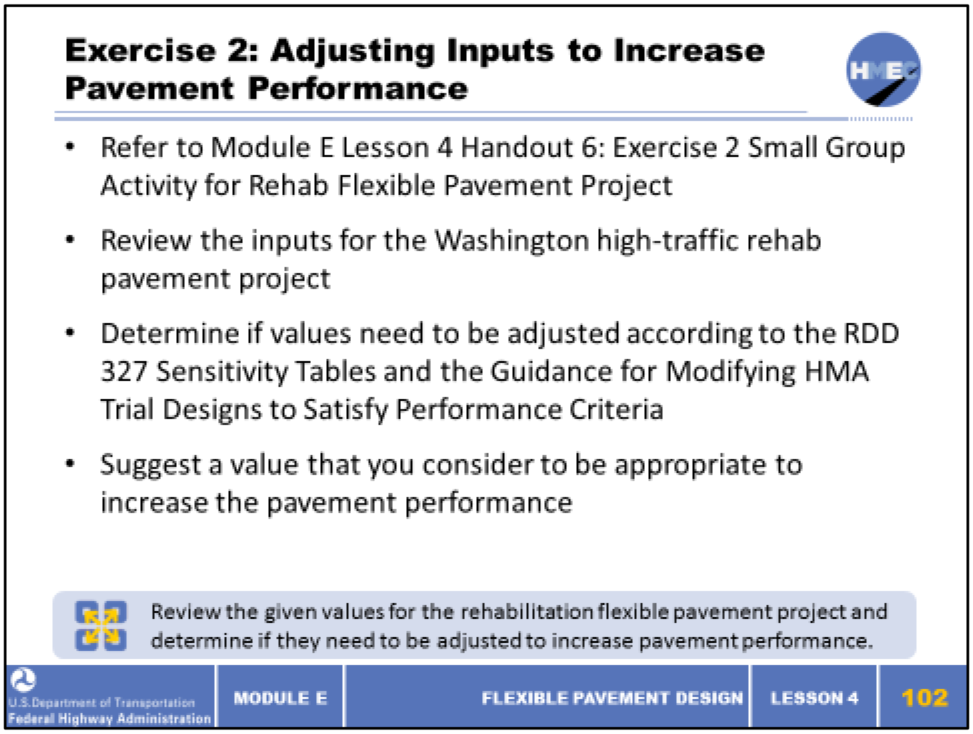
MODULE E | FLEXIBLE PAVEMENT DESIGN | LESSON 4 | 101

The predicted rutting at 50% reliability does not exceed the performance criteria of 0.4 inches until about 12 years, which is a good performance for an overlay. However, at the 90% reliability level, the threshold is exceeded at six years, which is sooner than desired for going out to do further repairs.

Predicted Total Rutting (Permanent Deformation): The rutting can be further studied in terms of the source, by observing the rutting at 50% reliability in each layer. This plot shows that the majority of rutting early on is in the subgrade (the red dashed trend) and that at about eight years of life, the instability rutting (rutting in the AC, shown by the green larger dashed trend) overtakes the rutting in the subgrade.

Total Cracking (Reflective + Alligator): The reflective cracking model in the Pavement ME Design current version is a placeholder and will be replaced (estimated to be) in Summer 2015 It is only capable of predicting 50% reliability at this time. According to the figure, the cracking would reflect through for this pavement at year three and accumulate to about 22% lane area cracked.

Slide 102



Exercise 2: Adjusting Inputs to Increase Pavement Performance

- Refer to Module E Lesson 4 Handout 6: Exercise 2 Small Group Activity for Rehab Flexible Pavement Project
- Review the inputs for the Washington high-traffic rehab pavement project
- Determine if values need to be adjusted according to the RDD 327 Sensitivity Tables and the Guidance for Modifying HMA Trial Designs to Satisfy Performance Criteria
- Suggest a value that you consider to be appropriate to increase the pavement performance

Review the given values for the rehabilitation flexible pavement project and determine if they need to be adjusted to increase pavement performance.

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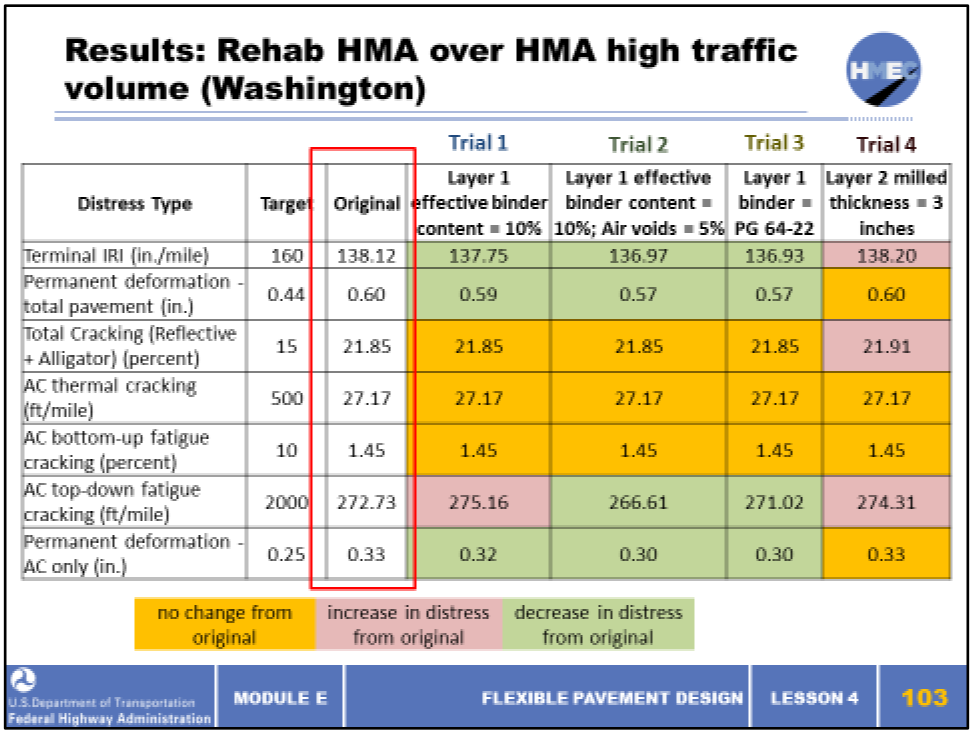
Slide 103



Results: Rehab HMA over HMA high traffic volume (Washington)

Distress Type	Target	Original	Trial 1 Layer 1 effective binder content = 10%	Trial 2 Layer 1 effective binder content = 10%; Air voids = 5%	Trial 3 Layer 1 binder = PG 64-22	Trial 4 Layer 2 milled thickness = 3 inches
Terminal IRI (in./mile)	160	138.12	137.75	136.97	136.93	138.20
Permanent deformation - total pavement (in.)	0.44	0.60	0.59	0.57	0.57	0.60
Total Cracking (Reflective + Alligator) (percent)	15	21.85	21.85	21.85	21.85	21.91
AC thermal cracking (ft/mile)	500	27.17	27.17	27.17	27.17	27.17
AC bottom-up fatigue cracking (percent)	10	1.45	1.45	1.45	1.45	1.45
AC top-down fatigue cracking (ft/mile)	2000	272.73	275.16	266.61	271.02	274.31
Permanent deformation - AC only (in.)	0.25	0.33	0.32	0.30	0.30	0.33

no change from original | increase in distress from original | decrease in distress from original

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This table shows the results of four Trials on the rehabilitation design for Washington high-volume flexible pavement.

The first trial altered the HMA top layer's AC content to 10% and the effect was that there was a slight improvement in rutting but almost imperceptible, as compared to the Original.

The second trial altered the HMA top layer's AC content 10% and the air void content to 5% and the effect was nearly identical to that in Trial 1.

The third trial increased the HMA top layer's high temperature binder grade from a 58 to a 64 and the effect was that there was a slight improvement in rutting, as compared to the original.

The fourth trial increased the milling depth into the existing HMA pavement from 2" to 3" and the effect was negative and resulted in a slight increase in rutting and in IRI.

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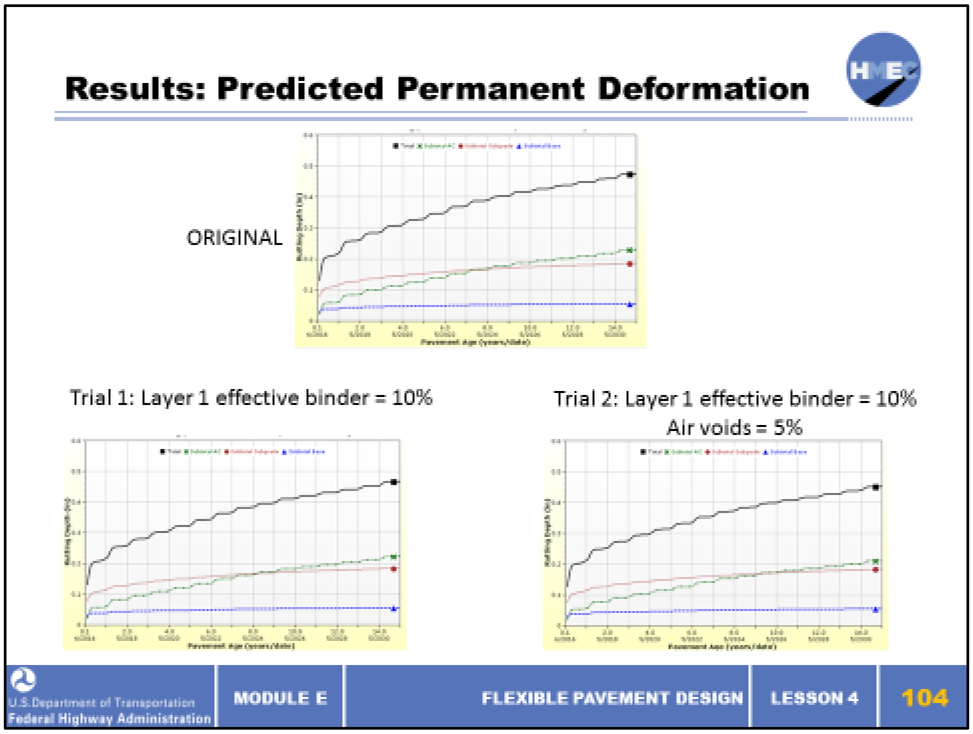
Slide 104



Results: Predicted Permanent Deformation

ORIGINAL

Trial 1: Layer 1 effective binder = 10%

Trial 2: Layer 1 effective binder = 10%
Air voids = 5%

These plots show the rutting predicted for the original flexible pavement rehab structure as well as the two first trials described in the previous slide.

The plots indicate the Total rutting (black line), and rutting in each of the individual layers: subgrade (red line), base (blue line), and asphalt surface (green line).

The results show that there is very little change in performance by changing the binder content and by also decreasing the air voids.

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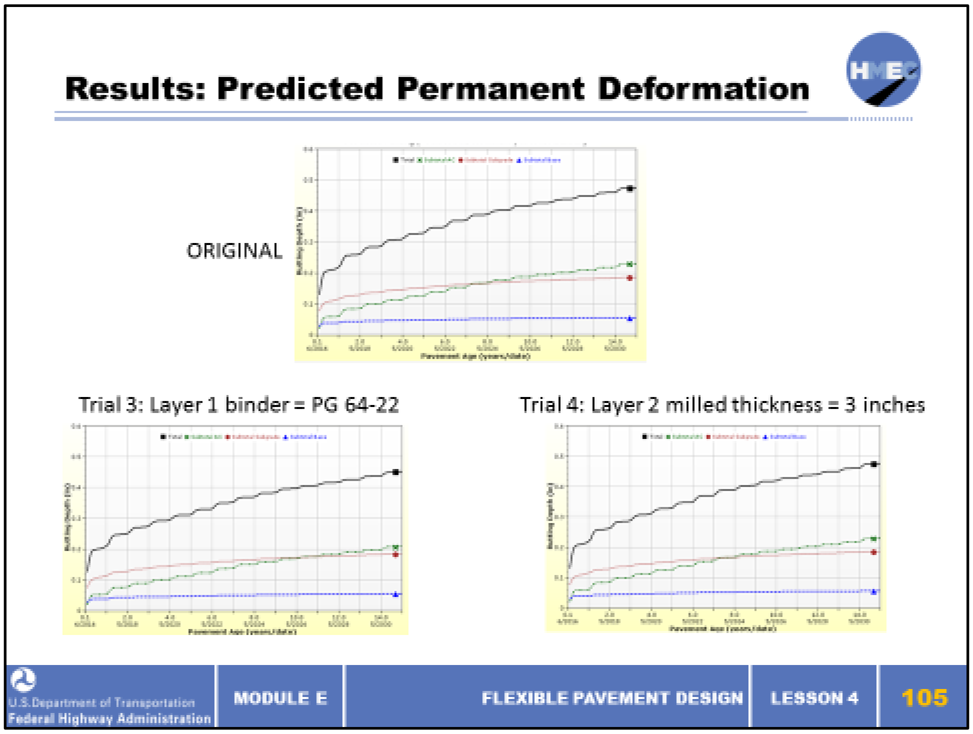
Slide 105



Results: Predicted Permanent Deformation

ORIGINAL

Trial 3: Layer 1 binder = PG 64-22

Trial 4: Layer 2 milled thickness = 3 inches

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MODULE E

FLEXIBLE PAVEMENT DESIGN

LESSON 4

105

These plots show the rutting predicted for the Original flexible pavement rehab structure as well as the second two trials described in a previous slide.

The plots indicate the Total rutting (black line), and rutting in each of the individual layers: subgrade (red line), base (blue line), and asphalt surface (green line).

The results show that there is very little change in performance by changing the binder high temperature grade (from 58 to 64) although a slight improvement was noticed in AC rutting. In terms of the increase in milling thickness in the existing AC prior to placement of the HMA overlay, increasing the milling depth by 1 inch did not appear to have any impact at all and may have slightly increased rutting in the AC.

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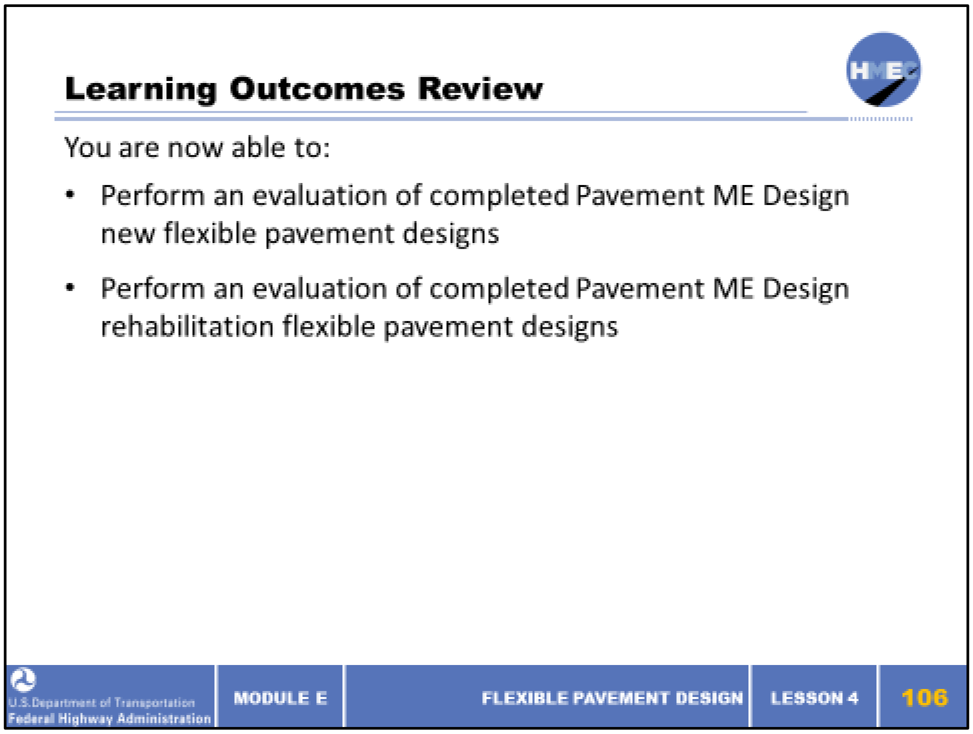
Slide 106



Learning Outcomes Review

You are now able to:

- Perform an evaluation of completed Pavement ME Design new flexible pavement designs
- Perform an evaluation of completed Pavement ME Design rehabilitation flexible pavement designs

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Slide 1

HMEC

Highway Materials Engineering Course

Lesson 5: Rigid Pavement Design

Mechanistic Empirical Pavement Design Guide (MEPDG)

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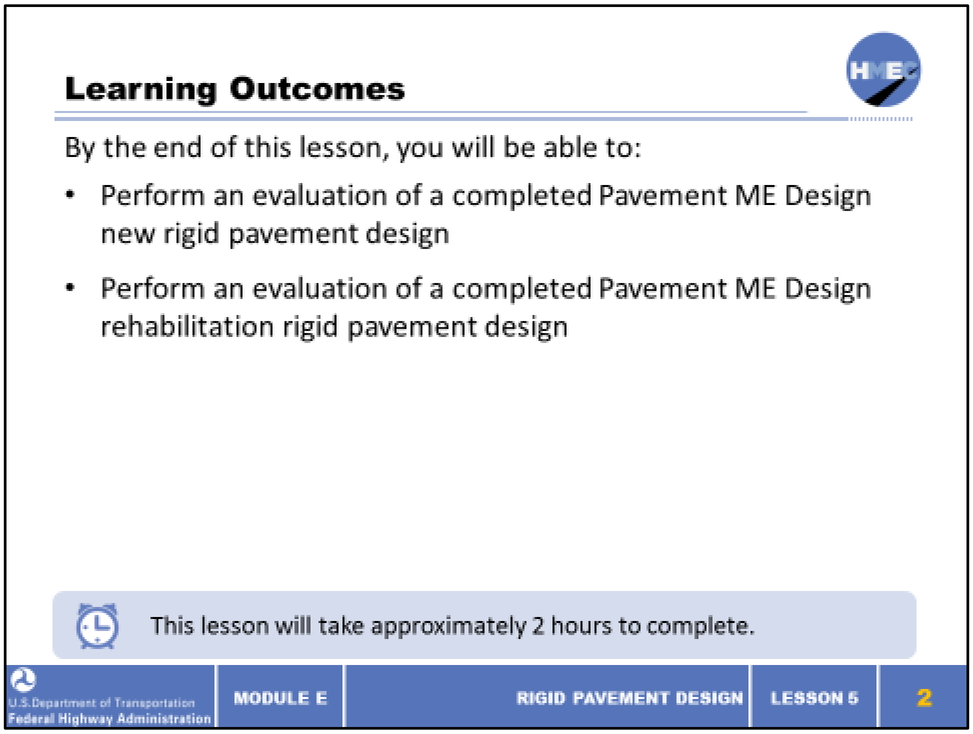
Slide 2



Learning Outcomes

By the end of this lesson, you will be able to:

- Perform an evaluation of a completed Pavement ME Design new rigid pavement design
- Perform an evaluation of a completed Pavement ME Design rehabilitation rigid pavement design

This lesson will take approximately 2 hours to complete.

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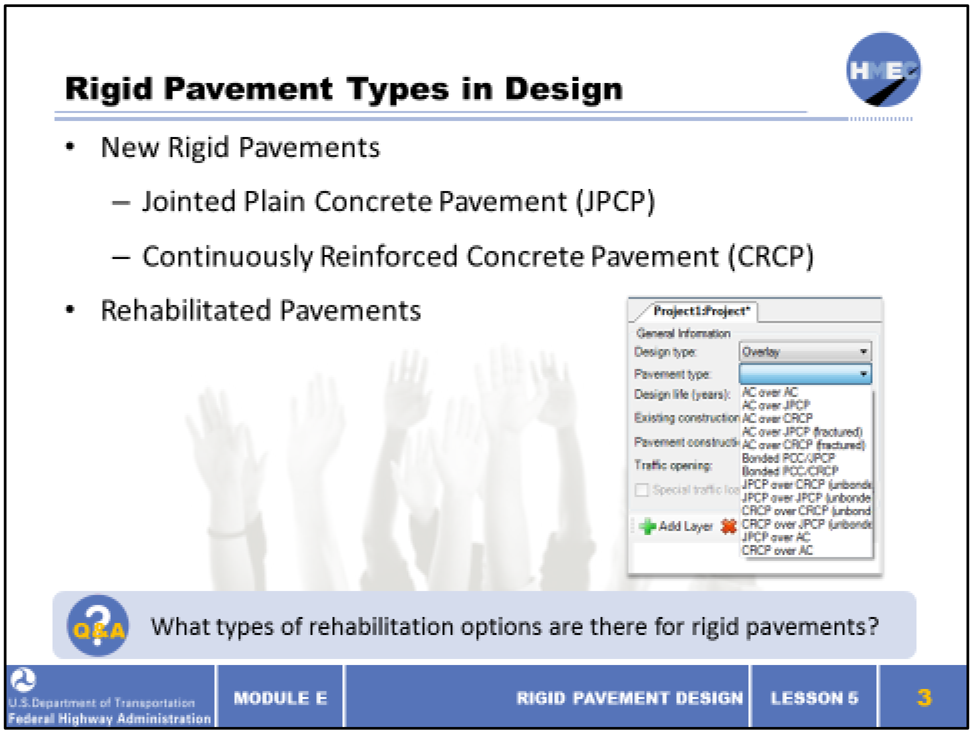
MODULE E | RIGID PAVEMENT DESIGN | LESSON 5 | 2

Slide 3



Rigid Pavement Types in Design

- New Rigid Pavements
  - Jointed Plain Concrete Pavement (JPCP)
  - Continuously Reinforced Concrete Pavement (CRCP)
- Rehabilitated Pavements

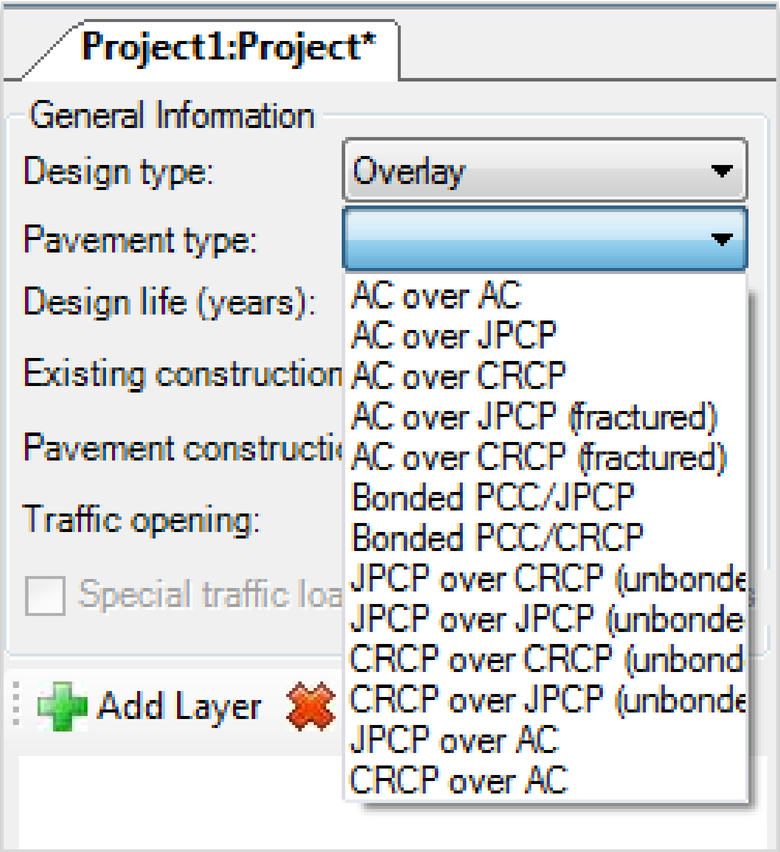
Project1:Project*

General Information

Design type: Overlay

Pavement type:

Q&A What types of rehabilitation options are there for rigid pavements?


Project1:Project*
General Information
Design type:
Overlay
Pavement type:
Design life (years):
Existing construction
Pavement constructi
Traffic opening:
☐ Special traffic loa
Add Layer
AC over AC
AC over JPCP
AC over CRCP
AC over JPCP (fractured)
AC over CRCP (fractured)
Bonded PCC/JPCP
Bonded PCC/CRCP
JPCP over CRCP (unbonde
JPCP over JPCP (unbonde
CRCP over CRCP (unbond
CRCP over JPCP (unbonde
JPCP over AC
CRCP over AC

There are a number of rigid pavement types that can be evaluated in the Pavement ME Design software.

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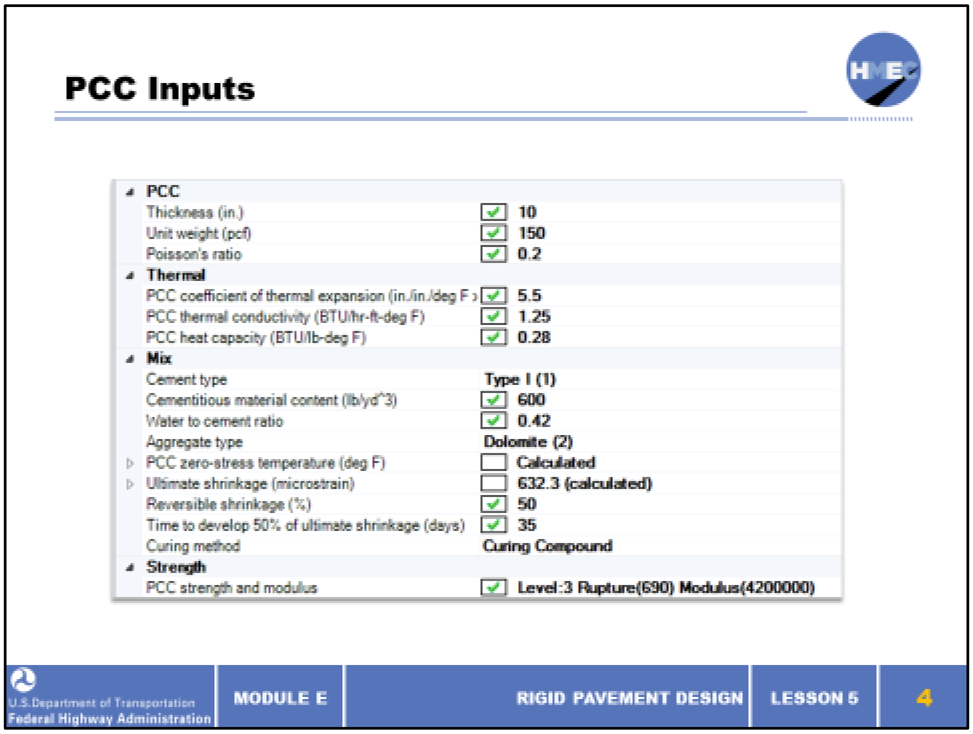
Slide 4



PCC Inputs

PCC	
Thickness (in.)	☑ 10
Unit weight (pcf)	☑ 150
Poisson's ratio	☑ 0.2
Thermal	
PCC coefficient of thermal expansion (in./in./deg F ›	☑ 5.5
PCC thermal conductivity (BTU/hr-ft-deg F)	☑ 1.25
PCC heat capacity (BTU/lb-deg F)	☑ 0.28
Mix	
Cement type	Type I (1)
Cementitious material content (lb/yd^3)	☑ 600
Water to cement ratio	☑ 0.42
Aggregate type	Dolomite (2)
PCC zero-stress temperature (deg F)	☐ Calculated
Ultimate shrinkage (microstrain)	☐ 632.3 (calculated)
Reversible shrinkage (%)	☑ 50
Time to develop 50% of ultimate shrinkage (days)	☑ 35
Curing method	Curing Compound
Strength	
PCC strength and modulus	☑ Level:3 Rupture(690) Modulus(4200000)

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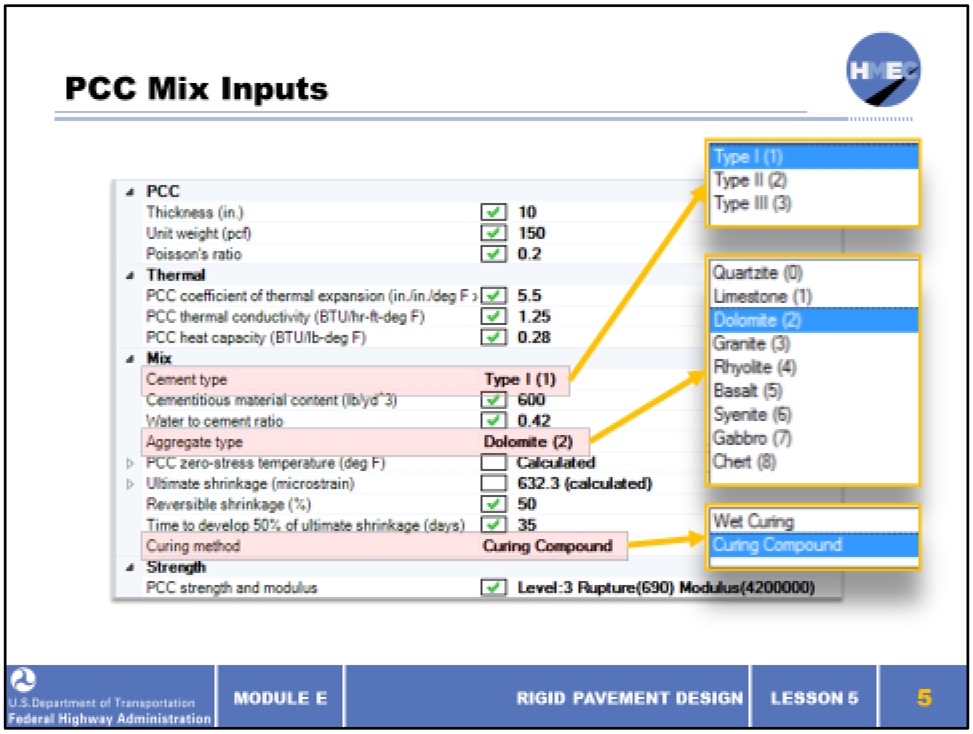
MODULE E
RIGID PAVEMENT DESIGN
LESSON 5
4

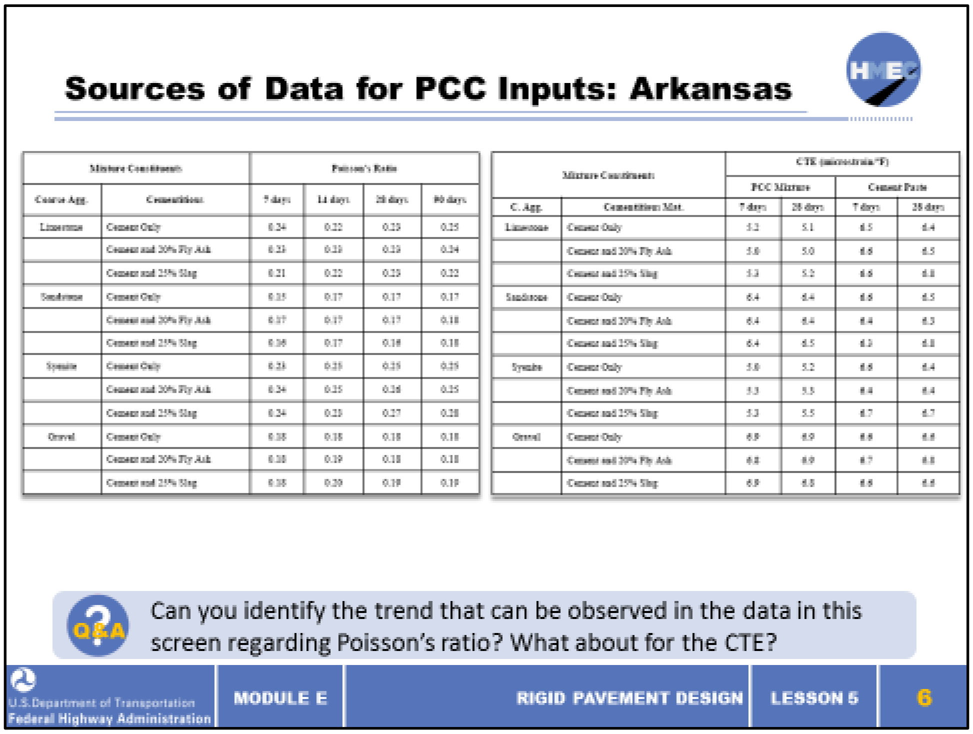
Slide 5



PCC Mix Inputs

PCC		
Thickness (in.)	☑	10
Unit weight (pcf)	☑	150
Poisson's ratio	☑	0.2
Thermal		
PCC coefficient of thermal expansion (in./in./deg F x	☑	5.5
PCC thermal conductivity (BTU/hr-ft-deg F)	☑	1.25
PCC heat capacity (BTU/lb-deg F)	☑	0.28
Mix		
Cement type		Type I (1)
Cementitious material content (lb/yd^3)	☑	600
Water to cement ratio	☑	0.42
Aggregate type		Dolomite (2)
PCC zero-stress temperature (deg F)	☐	Calculated
Ultimate shrinkage (microstrain)	☐	632.3 (calculated)
Reversible shrinkage (%)	☑	50
Time to develop 50% of ultimate shrinkage (days)	☑	35
Curing method		Curing Compound
Strength		
PCC strength and modulus	☑	Level:3 Rupture(690) Modulus(4200000)

Slide 6



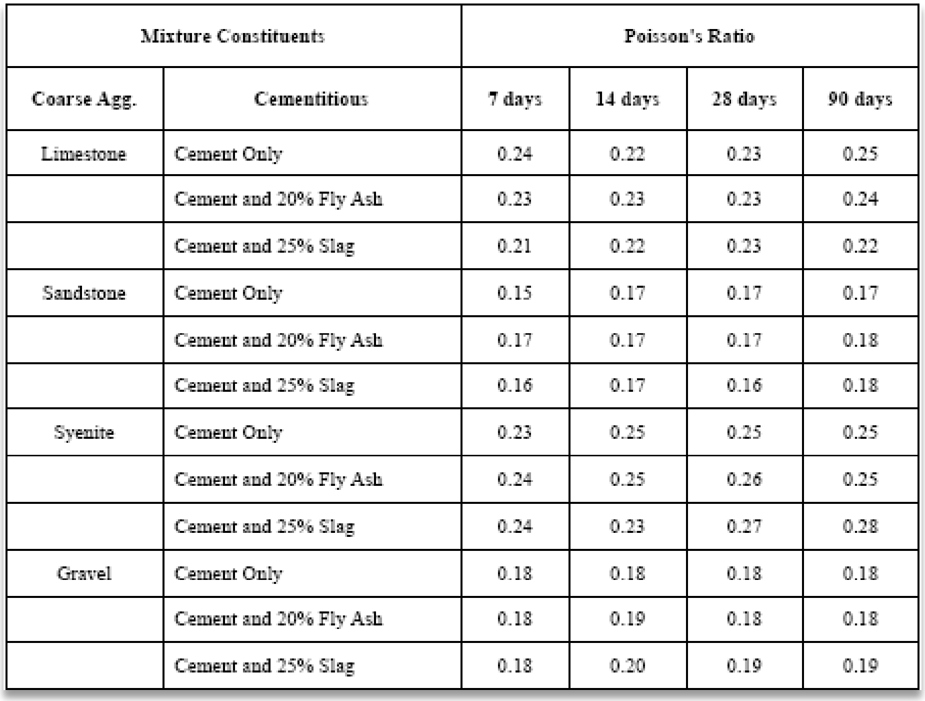
Sources of Data for PCC Inputs: Arkansas

Mixture Constituents		Poisson's Ratio			
Coarse Agg.	Cementitious	7 days	14 days	28 days	90 days
Limestone	Cement Only	0.24	0.22	0.23	0.25
	Cement and 20% Fly Ash	0.23	0.23	0.23	0.24
	Cement and 25% Slag	0.21	0.22	0.23	0.22
Sandstone	Cement Only	0.15	0.17	0.17	0.17
	Cement and 20% Fly Ash	0.17	0.17	0.17	0.18
	Cement and 25% Slag	0.16	0.17	0.18	0.18
Syenite	Cement Only	0.23	0.25	0.25	0.25
	Cement and 20% Fly Ash	0.24	0.25	0.26	0.25
	Cement and 25% Slag	0.24	0.23	0.27	0.28
Gravel	Cement Only	0.18	0.18	0.18	0.18
	Cement and 20% Fly Ash	0.18	0.19	0.18	0.18
	Cement and 25% Slag	0.18	0.20	0.19	0.19

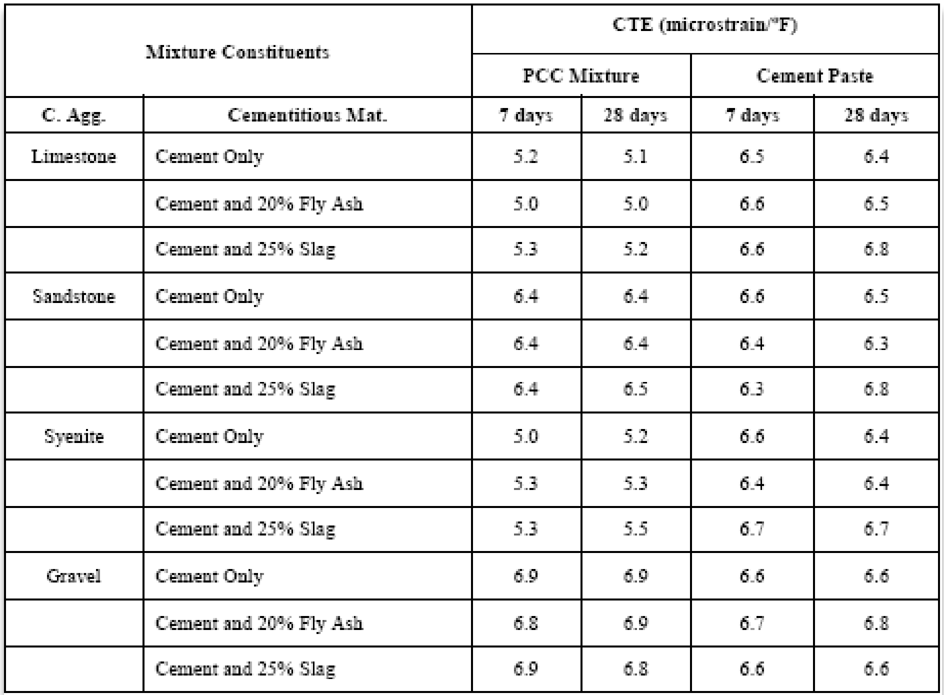
Mixture Constituents		CTE (microstrain/°F)			
		PCC Mixture		Cement Paste	
C. Agg.	Cementitious Mat.	7 days	28 days	7 days	28 days
Limestone	Cement Only	5.2	5.1	6.5	6.4
	Cement and 20% Fly Ash	5.0	5.0	6.8	6.5
	Cement and 25% Slag	5.3	5.2	6.6	6.8
Sandstone	Cement Only	6.4	6.4	6.6	6.5
	Cement and 20% Fly Ash	6.4	6.4	6.4	6.3
	Cement and 25% Slag	6.4	6.5	6.3	6.8
Syenite	Cement Only	5.0	5.2	6.6	6.4
	Cement and 20% Fly Ash	5.3	5.3	6.4	6.4
	Cement and 25% Slag	5.3	5.5	6.7	6.7
Gravel	Cement Only	6.9	6.9	6.6	6.6
	Cement and 20% Fly Ash	6.8	6.9	6.7	6.8
	Cement and 25% Slag	6.9	6.8	6.6	6.6

Q&A

Can you identify the trend that can be observed in the data in this screen regarding Poisson's ratio? What about for the CTE?



Mixture Constituents		Poisson's Ratio			
Coarse Agg.	**Cementitious**	**7 days**	**14 days**	**28 days**	**90 days**
Limestone	Cement Only	0.24	0.22	0.23	0.25
	Cement and 20% Fly Ash	0.23	0.23	0.23	0.24
	Cement and 25% Slag	0.21	0.22	0.23	0.22
Sandstone	Cement Only	0.15	0.17	0.17	0.17
	Cement and 20% Fly Ash	0.17	0.17	0.17	0.18
	Cement and 25% Slag	0.16	0.17	0.16	0.18
Syenite	Cement Only	0.23	0.25	0.25	0.25
	Cement and 20% Fly Ash	0.24	0.25	0.26	0.25
	Cement and 25% Slag	0.24	0.23	0.27	0.28
Gravel	Cement Only	0.18	0.18	0.18	0.18
	Cement and 20% Fly Ash	0.18	0.19	0.18	0.18
	Cement and 25% Slag	0.18	0.20	0.19	0.19



Mixture Constituents		CTE (microstrain/°F)			
		PCC Mixture		**Cement Paste**	
C. Agg.	**Cementitious Mat.**	**7 days**	**28 days**	**7 days**	**28 days**
Limestone	Cement Only	5.2	5.1	6.5	6.4
	Cement and 20% Fly Ash	5.0	5.0	6.6	6.5
	Cement and 25% Slag	5.3	5.2	6.6	6.8
Sandstone	Cement Only	6.4	6.4	6.6	6.5
	Cement and 20% Fly Ash	6.4	6.4	6.4	6.3
	Cement and 25% Slag	6.4	6.5	6.3	6.8
Syenite	Cement Only	5.0	5.2	6.6	6.4
	Cement and 20% Fly Ash	5.3	5.3	6.4	6.4
	Cement and 25% Slag	5.3	5.5	6.7	6.7
Gravel	Cement Only	6.9	6.9	6.6	6.6
	Cement and 20% Fly Ash	6.8	6.9	6.7	6.8
	Cement and 25% Slag	6.9	6.8	6.6	6.6

Arkansas DOT regionally has only four types of aggregates from quarries in its State. The table on the left shows the measured coefficient of thermal expansion (CTE) for mixes and cement paste. The results for the CTE of Portland cement concrete (PCC) mixture are a reflection of the change in coarse aggregate type. The results for the cement paste represent a combination of the effects of the cement type and fine aggregate (which in Arkansas consists also of fly ash and slag). The results in the table showed that the CTE doesn’t change with age for the four main types of aggregates in Arkansas.

The second table (right) shows the same mixture constituents for the common concrete mixtures in Arkansas and observes the impacts of age on the measured Poisson’s ratio. The table shows that the Poisson’s ratio varies with aggregate type and indicates that the national default values may not be the best reflection of performance. This demonstrates the importance of doing laboratory testing for Level 2 or 3 inputs for local calibration.

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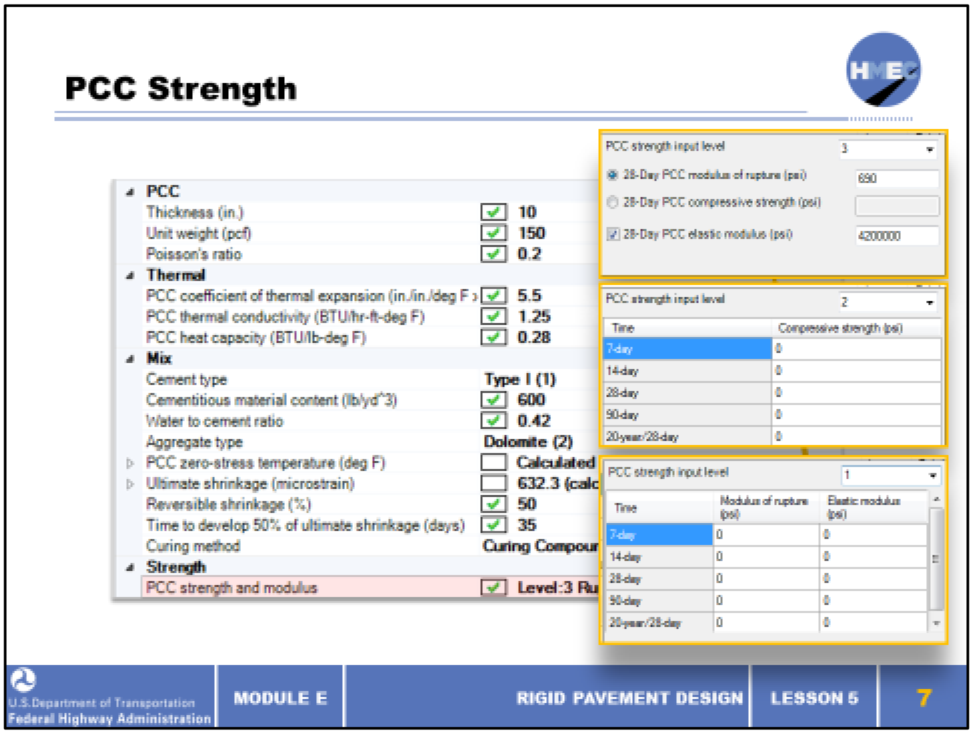
Slide 7



PCC Strength

PCC		
Thickness (in.)	☑	10
Unit weight (pcf)	☑	150
Poisson's ratio	☑	0.2
Thermal		
PCC coefficient of thermal expansion (in./in./deg F x	☑	5.5
PCC thermal conductivity (BTU/hr-ft-deg F)	☑	1.25
PCC heat capacity (BTU/lb-deg F)	☑	0.28
Mix		
Cement type		Type I (1)
Cementitious material content (lb/yd^3)	☑	600
Water to cement ratio	☑	0.42
Aggregate type		Dolomite (2)
PCC zero-stress temperature (deg F)	☐	Calculated
Ultimate shrinkage (microstrain)	☐	632.3 (calc
Reversible shrinkage (%)	☑	50
Time to develop 50% of ultimate shrinkage (days)	☑	35
Curing method		Curing Compour
Strength		
PCC strength and modulus	☑	Level:3 Ru

PCC strength input level: 3

● 28-Day PCC modulus of rupture (psi): 690

○ 28-Day PCC compressive strength (psi):

☑ 28-Day PCC elastic modulus (psi): 4200000

PCC strength input level: 2

Time	Compressive strength (psi)
7-day	0
14-day	0
28-day	0
90-day	0
20-year/28-day	0

PCC strength input level: 1

Time	Modulus of rupture (psi)	Elastic modulus (psi)
7-day	0	0
14-day	0	0
28-day	0	0
90-day	0	0
20-year/28-day	0	0

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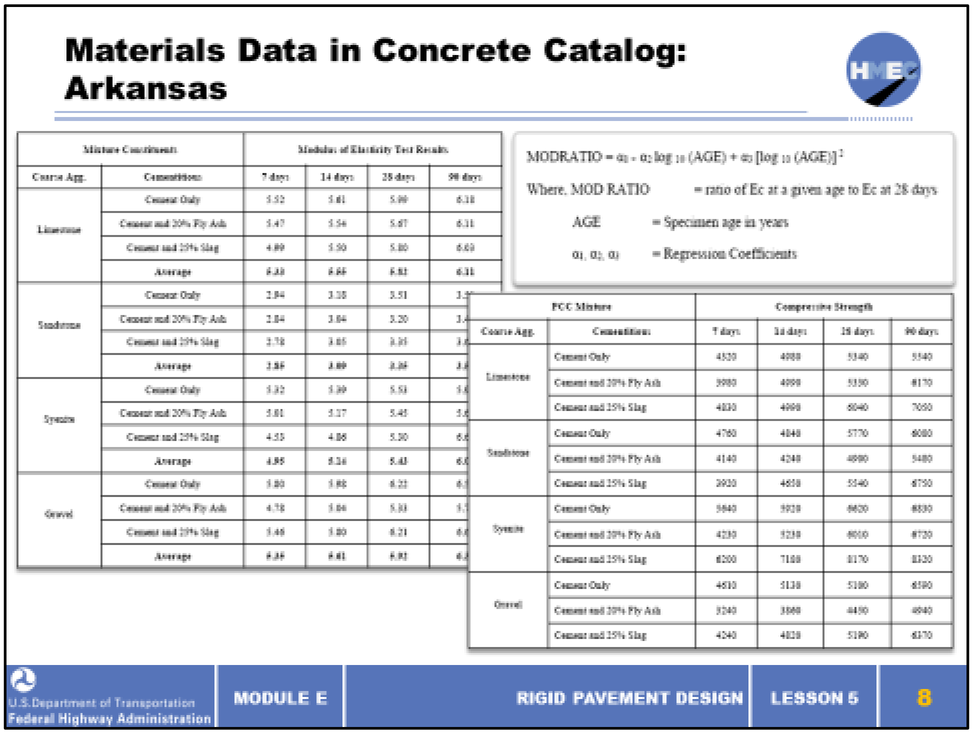
Federal Highway Administration
MODULE E
RIGID PAVEMENT DESIGN
LESSON 5
7

The strength and modulus can be input at three different levels, as seen to the right (Level 3 at top, down to Level 1 requirements at the bottom).

Slide 8



Materials Data in Concrete Catalog: Arkansas

$$MODRATIO = \alpha_1 + \alpha_2 \log_{10}(AGE) + \alpha_3 [\log_{10}(AGE)]^2$$

Where, MOD RATIO = ratio of Ec at a given age to Ec at 28 days

AGE = Specimen age in years

$\alpha_1, \alpha_2, \alpha_3$ = Regression Coefficients

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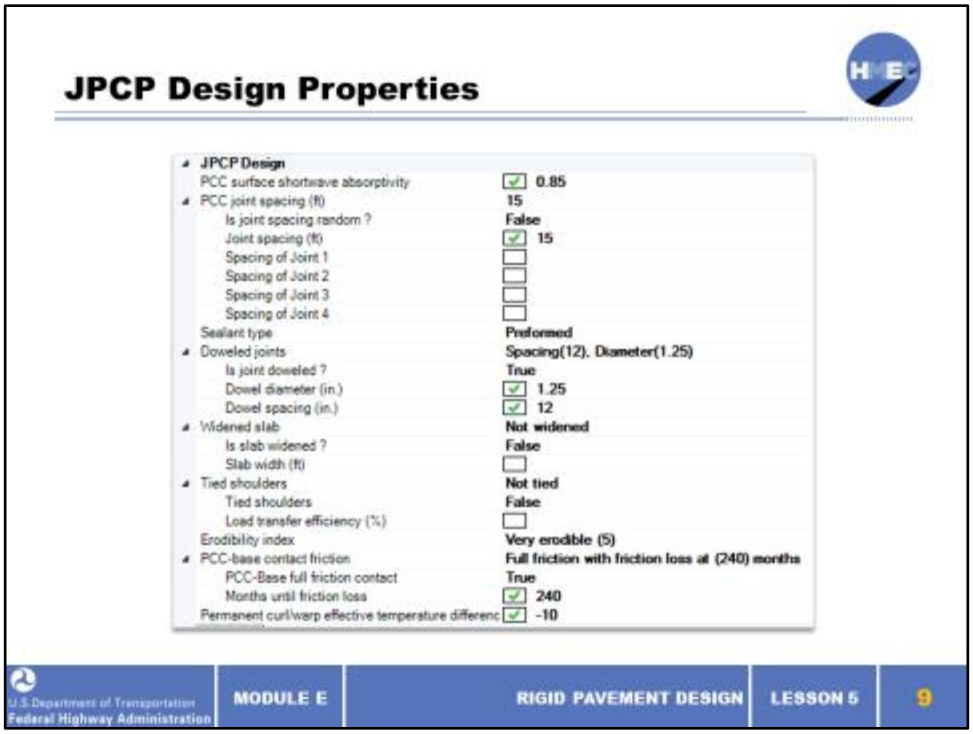
The table on the left compares modulus of elasticity (in units of million psi) measured at the four key points in time with the mixture constituents showed in the previous example.

The table on the right compares compressive strength (in units of psi) measured at the four key points in time with the mixture constituents showed in the previous example.

For a Level 1 input of modulus of elasticity, the MEPDG requires the construction of a modulus gain curve to predict the modulus of elasticity at any age of concrete based on the regression model form. The regression model equation represented in the equation on the screen has three regression coefficients—α1, α2, α3—which are optimized using regression analysis.

Slide 9



JPCP Design Properties

JPCP Design	
PCC surface shortwave absorptivity	☑ 0.85
PCC joint spacing (ft)	15
Is joint spacing random ?	False
Joint spacing (ft)	☑ 15
Spacing of Joint 1	☐
Spacing of Joint 2	☐
Spacing of Joint 3	☐
Spacing of Joint 4	☐
Sealant type	Preformed
Doweled joints	Spacing(12), Diameter(1.25)
Is joint doweled ?	True
Dowel diameter (in.)	☑ 1.25
Dowel spacing (in.)	☑ 12
Widened slab	Not widened
Is slab widened ?	False
Slab width (ft)	☐
Tied shoulders	Not tied
Tied shoulders	False
Load transfer efficiency (%)	☐
Erodibility index	Very erodible (5)
PCC-base contact friction	Full friction with friction loss at (240) months
PCC-Base full friction contact	True
Months until friction loss	☑ 240
Permanent curl/warp effective temperature differenc	☑ -10

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Federal Highway Administration

MODULE E

RIGID PAVEMENT DESIGN

LESSON 5

9

The properties of the slab, joints, and interaction with substrate layers are defined in the software.

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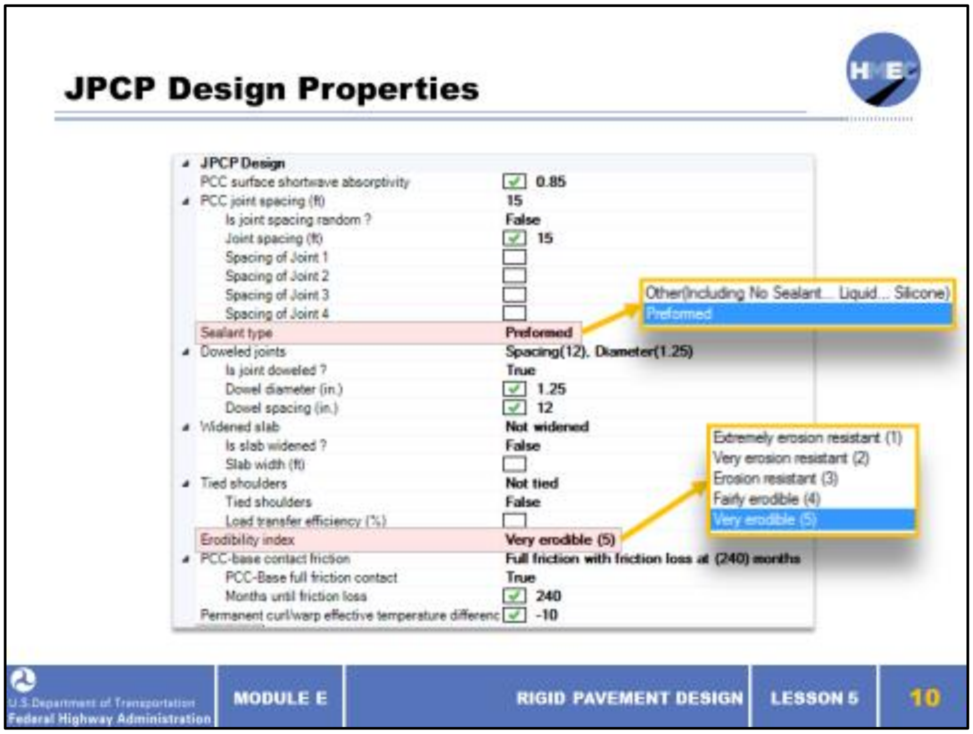
Slide 10

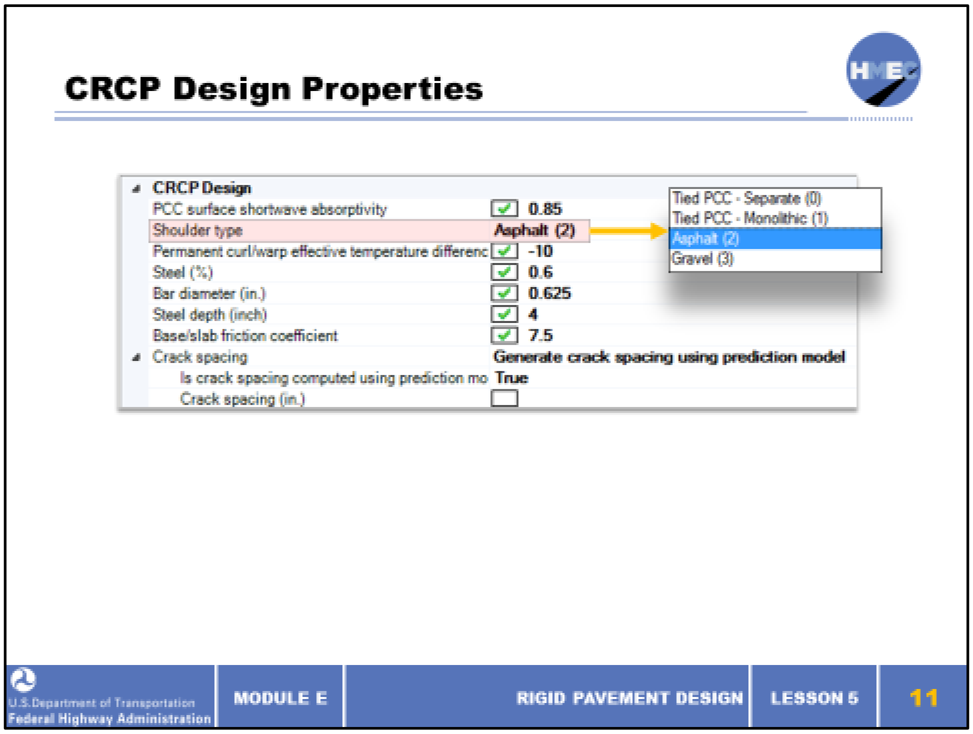


JPCP Design Properties

JPCP Design	
PCC surface shortwave absorptivity	☑ 0.85
PCC joint spacing (ft)	15
Is joint spacing random ?	False
Joint spacing (ft)	☑ 15
Spacing of Joint 1	☐
Spacing of Joint 2	☐
Spacing of Joint 3	☐
Spacing of Joint 4	☐
Sealant type	Preformed
Doweled joints	Spacing(12), Diameter(1.25)
Is joint doweled ?	True
Dowel diameter (in.)	☑ 1.25
Dowel spacing (in.)	☑ 12
Widened slab	Not widened
Is slab widened ?	False
Slab width (ft)	☐
Tied shoulders	Not tied
Tied shoulders	False
Load transfer efficiency (%)	☐
Erodibility index	Very erodible (5)
PCC-base contact friction	Full friction with friction loss at (240) months
PCC-Base full friction contact	True
Months until friction loss	☑ 240
Permanent curl/warp effective temperature differenc	☑ -10

Other(Including No Sealant... Liquid... Silicone)
Preformed
Extremely erosion resistant (1)
Very erosion resistant (2)
Erosion resistant (3)
Fairly erodible (4)
Very erodible (5)

Slide 11



CRCP Design Properties

CRCP Design
PCC surface shortwave absorptivity ☑ 0.85
Shoulder type **Asphalt (2)**
Permanent curl/warp effective temperature differenc ☑ -10
Steel (%) ☑ 0.6
Bar diameter (in.) ☑ 0.625
Steel depth (inch) ☑ 4
Base/slab friction coefficient ☑ 7.5
Crack spacing **Generate crack spacing using prediction model**
Is crack spacing computed using prediction mo **True**
Crack spacing (in.) ☐

Tied PCC - Separate (0)
Tied PCC - Monolithic (1)
Asphalt (2)
Gravel (3)
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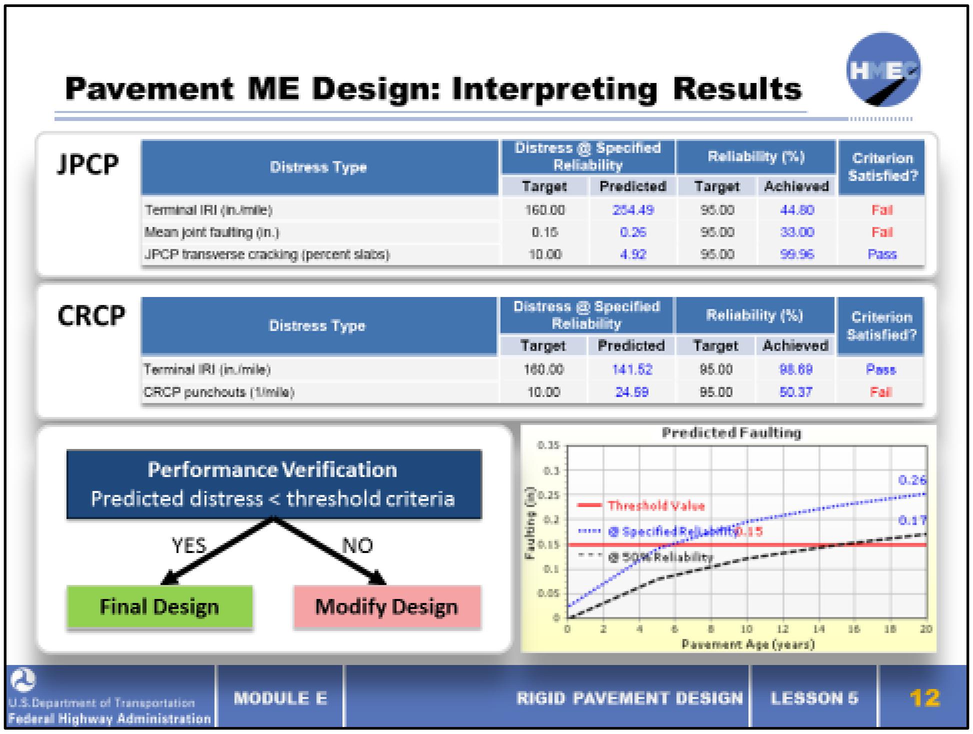
MODULE E
RIGID PAVEMENT DESIGN
LESSON 5
11

This screen highlights the input selections for shoulder type.

Slide 12



Pavement ME Design: Interpreting Results

JPCP

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	254.49	95.00	44.80	Fail
Mean joint faulting (in.)	0.15	0.26	95.00	33.00	Fail
JPCP transverse cracking (percent slabs)	10.00	4.92	95.00	99.96	Pass

CRCP

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	141.52	95.00	98.69	Pass
CRCP punchouts (1/mile)	10.00	24.59	95.00	50.37	Fail

Performance Verification
Predicted distress < threshold criteria

YES → Final Design

NO → Modify Design

Predicted Faulting

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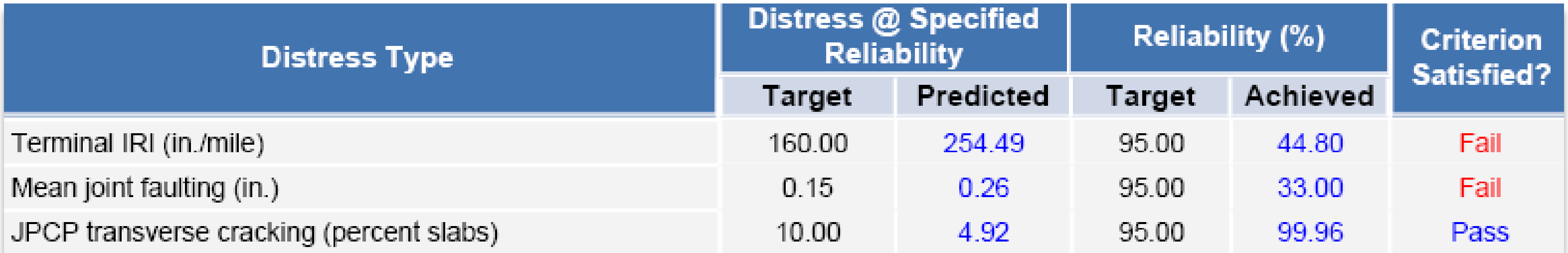
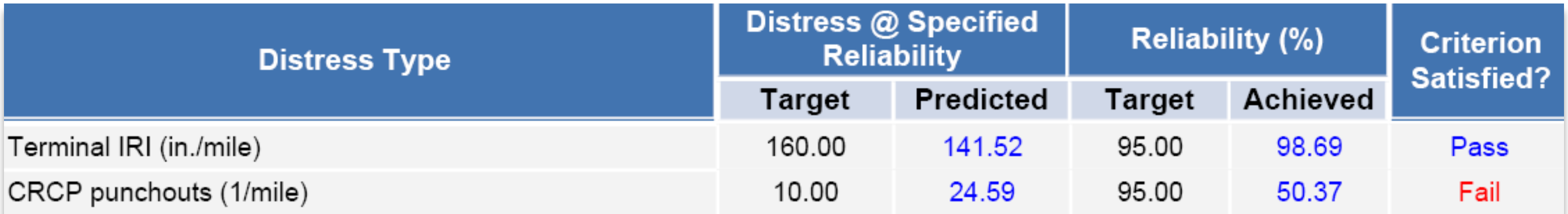
MODULE E | RIGID PAVEMENT DESIGN | LESSON 5 | 12

JPCP



Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	254.49	95.00	44.80	Fail
Mean joint faulting (in.)	0.15	0.26	95.00	33.00	Fail
JPCP transverse cracking (percent slabs)	10.00	4.92	95.00	99.96	Pass

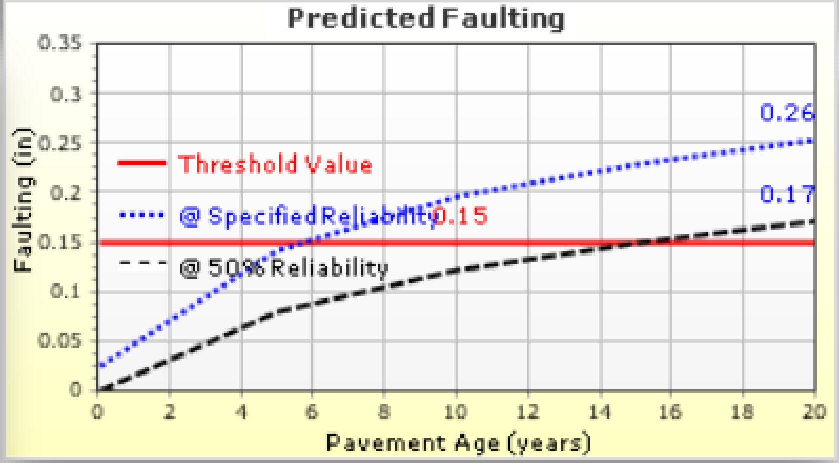
CRCP



Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	141.52	95.00	98.69	Pass
CRCP punchouts (1/mile)	10.00	24.59	95.00	50.37	Fail

Final Design

Modify Design



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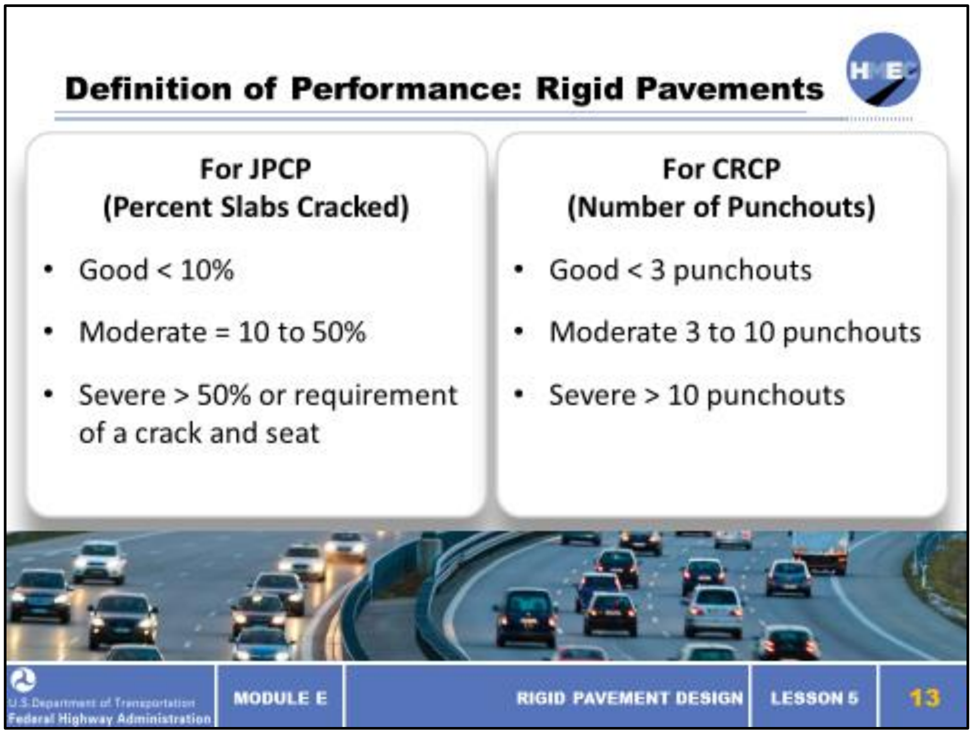
Slide 13



Definition of Performance: Rigid Pavements

For JPCP
(Percent Slabs Cracked)

- Good < 10%
- Moderate = 10 to 50%
- Severe > 50% or requirement of a crack and seat

For CRCP
(Number of Punchouts)

- Good < 3 punchouts
- Moderate 3 to 10 punchouts
- Severe > 10 punchouts

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Federal Highway Administration
MODULE E
RIGID PAVEMENT DESIGN
LESSON 5
13

These categories are used for evaluating existing pavements in a rehabilitation design situation.

RRD 372 Sensitivity Tables (Rigid Pavements – JPCP)

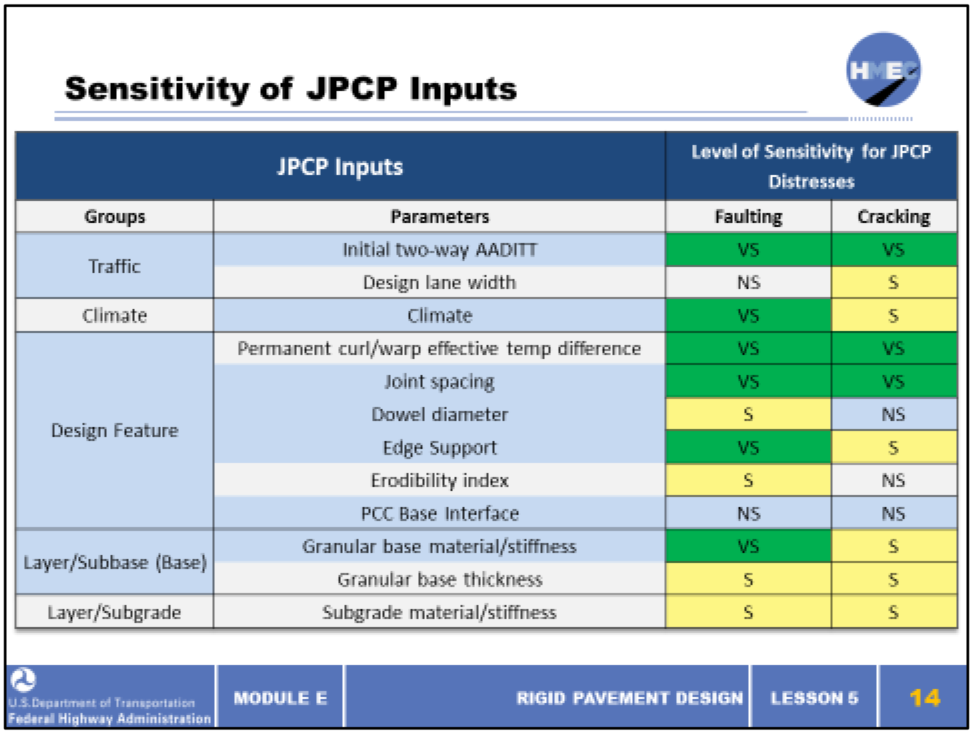
Inputs affecting JPCP pavements

JPCP Inputs		Level of Sensitivity for JPCP Distresses	
Groups	**Parameters**	**Faulting**	**Cracking**
Traffic	Initial two-way AADTT	VS	VS
	Design lane width	NS	S
Climate	Climate	VS	S
Design Feature	Permanent curl/warp effective temp difference	VS	VS
	Joint spacing	VS	VS
	Sealant type	NS	NS
	Dowel diameter	S	NS
	Dowel spacing	NS	NS
	Edge Support	VS	S
	Erodibility index	S	NS
	PCC Base Interface	NS	NS
Layer/General	Surface shortwave absorptivity	VS	VS
Layer/PCC	PCC layer thickness	VS	VS
	Unit weight	S	S
	Poisson’s ratio	S	S
	Coefficient of thermal expansion	VS	VS
	Thermal conductivity	S	VS
	Heat capacity	NS	NS
	Cement type	NS	NS

	Cementitious material content	S	NS
	Water/cement ratio	S	NS
	Aggregate type	NS	NS
	PCC zero-stress temperature	S	NS
	Reversible shrinkage	NS	NS
	Time to develop 50% of ultimate shrinkage	NS	NS
	Curing method	NS	NS
	28-day PCC modulus of rupture	S	VS
	28-day PCC compressive strength	NS	VS
Layer/Subbase (Base)	Granular base material/stiffness	VS	S
	Granular base thickness	S	S
	Poisson's ratio	NS	NS
Layer/Subgrade	Subgrade material/stiffness	S	S
	Poisson's ratio	NS	NS
	Compacted or uncompacted	NS	NS
JPCP/HMA (Rehab)	HMA milled thickness	NS	NS
	Pavement rating	S	S
	Monthly modulus of subgrade reaction measured	S	S
	Month for measuring modulus	S	S

Very Sensitive	Sensitive

Slide 14



Sensitivity of JPCP Inputs

JPCP Inputs		Level of Sensitivity for JPCP Distresses	
Groups	**Parameters**	**Faulting**	**Cracking**
Traffic	Initial two-way AADITT	VS	VS
	Design lane width	NS	S
Climate	Climate	VS	S
Design Feature	Permanent curl/warp effective temp difference	VS	VS
	Joint spacing	VS	VS
	Dowel diameter	S	NS
	Edge Support	VS	S
	Erodibility index	S	NS
	PCC Base Interface	NS	NS
Layer/Subbase (Base)	Granular base material/stiffness	VS	S
	Granular base thickness	S	S
Layer/Subgrade	Subgrade material/stiffness	S	S

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MODULE E | RIGID PAVEMENT DESIGN | LESSON 5 | 14

This is the table from the NCHRP 1-47 (RRD 372) report that shows the information on the factors which are most sensitive for jointed rigid pavement performance.

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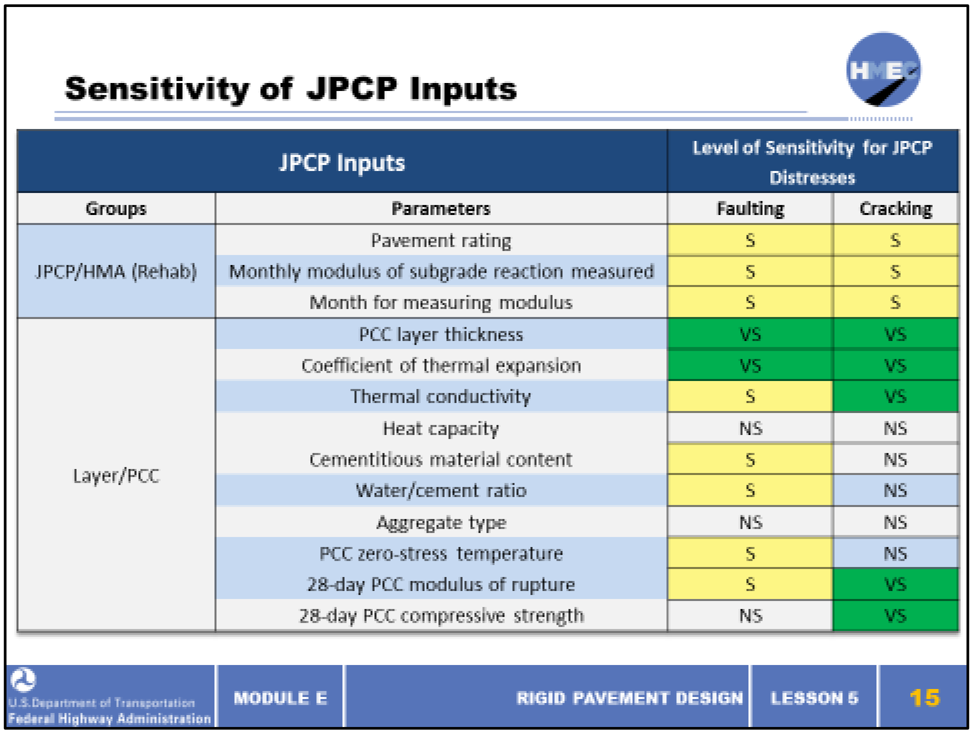
Slide 15



Sensitivity of JPCP Inputs

JPCP Inputs		Level of Sensitivity for JPCP Distresses	
Groups	Parameters	Faulting	Cracking
JPCP/HMA (Rehab)	Pavement rating	S	S
	Monthly modulus of subgrade reaction measured	S	S
	Month for measuring modulus	S	S
Layer/PCC	PCC layer thickness	VS	VS
	Coefficient of thermal expansion	VS	VS
	Thermal conductivity	S	VS
	Heat capacity	NS	NS
	Cementitious material content	S	NS
	Water/cement ratio	S	NS
	Aggregate type	NS	NS
	PCC zero-stress temperature	S	NS
	28-day PCC modulus of rupture	S	VS
	28-day PCC compressive strength	NS	VS

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MODULE E | RIGID PAVEMENT DESIGN | LESSON 5 | 15

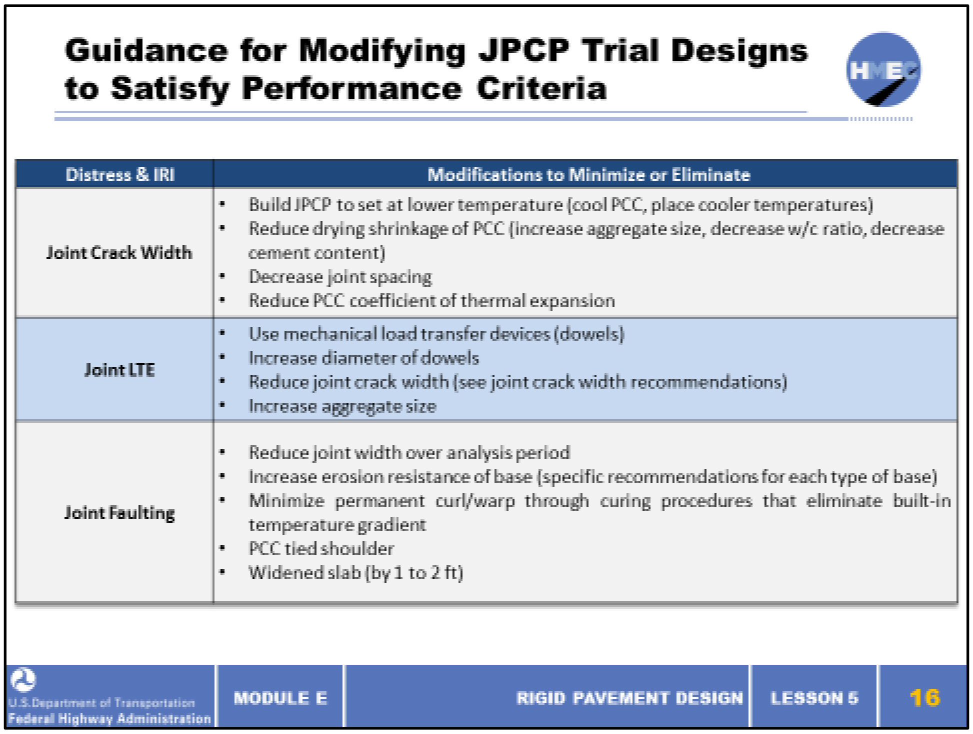
This is the table continued (from the NCHRP 1-47 (RRD 372) report) that shows more information on the factors which are most sensitive for jointed rigid pavement performance.

Suggested Alterations to Pavement Design (JPCP)

Guidance for Modifying JPCP Trial Designs to Satisfy Performance Criteria (Taken from the AASHTO MEPDG Manual of Practice, 2008)

Distress & IRI	Modifications to Minimize or Eliminate
Joint Crack Width	• Build JPCP to set at lower temperature (cool PCC, place cooler temperatures). • Reduce drying shrinkage of PCC (increase aggregate size, decrease w/c ratio, decrease cement content). • Decrease joint spacing. • Reduce PCC coefficient of thermal expansion.
Joint LTE	• Use mechanical load transfer devices (dowels). • Increase diameter of dowels. • Reduce joint crack width (see joint crack width recommendations). • Increase aggregate size.
Joint Faulting	• Increase slab thickness. • Reduce joint width over analysis period. • Increase erosion resistance of base (specific recommendations for each type of base). • Minimize permanent curl/warp through curing procedures that eliminate built-in temperature gradient. • PCC tied shoulder. • Widened slab (by 1 to 2 ft).
Slab Cracking	• Increase slab thickness. • Increase PCC strength. • Minimize permanent curl/warp through curing procedures that eliminate built-in temperature gradient. • PCC tied shoulder (separate placement or monolithic placement better). • Widened slab (1 to 2 ft). • Use PCC with lower coefficient of thermal expansion.
IRI JPCP	• Require more stringent smoothness criteria and greater incentives.

Slide 16



Guidance for Modifying JPCP Trial Designs to Satisfy Performance Criteria

Distress & IRI	Modifications to Minimize or Eliminate
Joint Crack Width	• Build JPCP to set at lower temperature (cool PCC, place cooler temperatures) • Reduce drying shrinkage of PCC (increase aggregate size, decrease w/c ratio, decrease cement content) • Decrease joint spacing • Reduce PCC coefficient of thermal expansion
Joint LTE	• Use mechanical load transfer devices (dowels) • Increase diameter of dowels • Reduce joint crack width (see joint crack width recommendations) • Increase aggregate size
Joint Faulting	• Reduce joint width over analysis period • Increase erosion resistance of base (specific recommendations for each type of base) • Minimize permanent curl/warp through curing procedures that eliminate built-in temperature gradient • PCC tied shoulder • Widened slab (by 1 to 2 ft)

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MODULE E RIGID PAVEMENT DESIGN LESSON 5 16

The screen provides the following distresses: joint crack width, joint load transfer efficiency (LTE), and joint faulting, and at least four alterations that you can make to decrease the amount of each of these distresses. For example, increasing the diameter of dowels or providing tied shoulders and/or a widened slab are both options used effectively to reduce joint faulting. However, increasing the slab thickness is one example of an option that would not be effective in minimizing the amount of faulting at joints.

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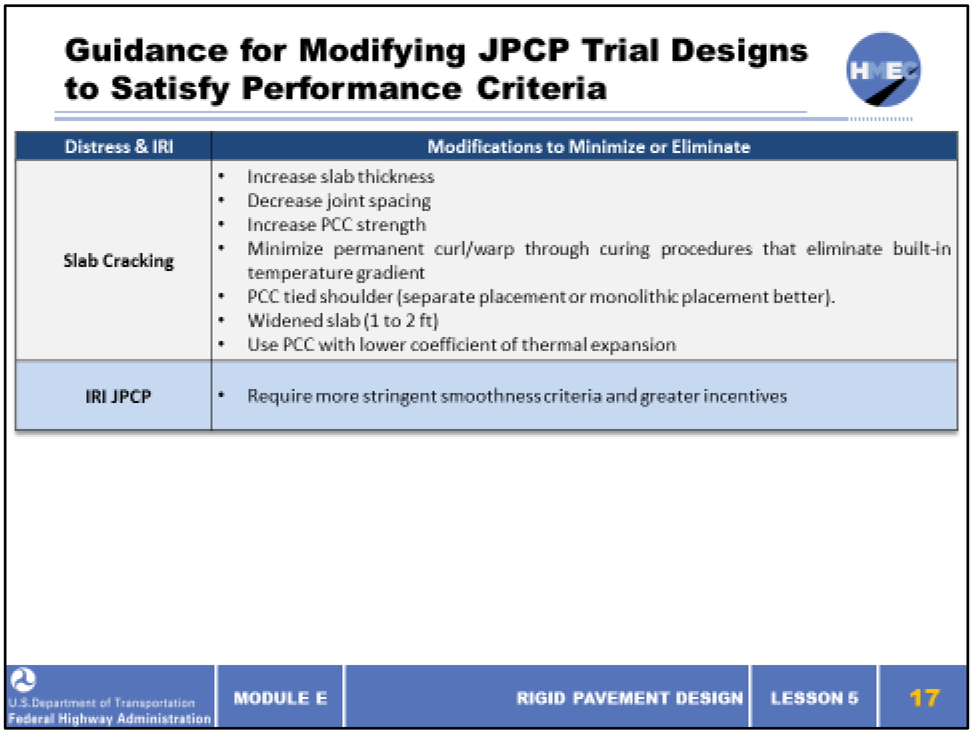
Slide 17



Guidance for Modifying JPCP Trial Designs to Satisfy Performance Criteria

Distress & IRI	Modifications to Minimize or Eliminate
Slab Cracking	• Increase slab thickness • Decrease joint spacing • Increase PCC strength • Minimize permanent curl/warp through curing procedures that eliminate built-in temperature gradient • PCC tied shoulder (separate placement or monolithic placement better). • Widened slab (1 to 2 ft) • Use PCC with lower coefficient of thermal expansion
IRI JPCP	• Require more stringent smoothness criteria and greater incentives

U.S. Department of Transportation
Federal Highway Administration
MODULE E
RIGID PAVEMENT DESIGN
LESSON 5
17

This shows that for crack width in the jointed pavement surface there are at least four alterations that you can make to decrease the amount of each of these distresses.

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RRD 372 Sensitivity Tables (Rigid Pavements – CRCP)

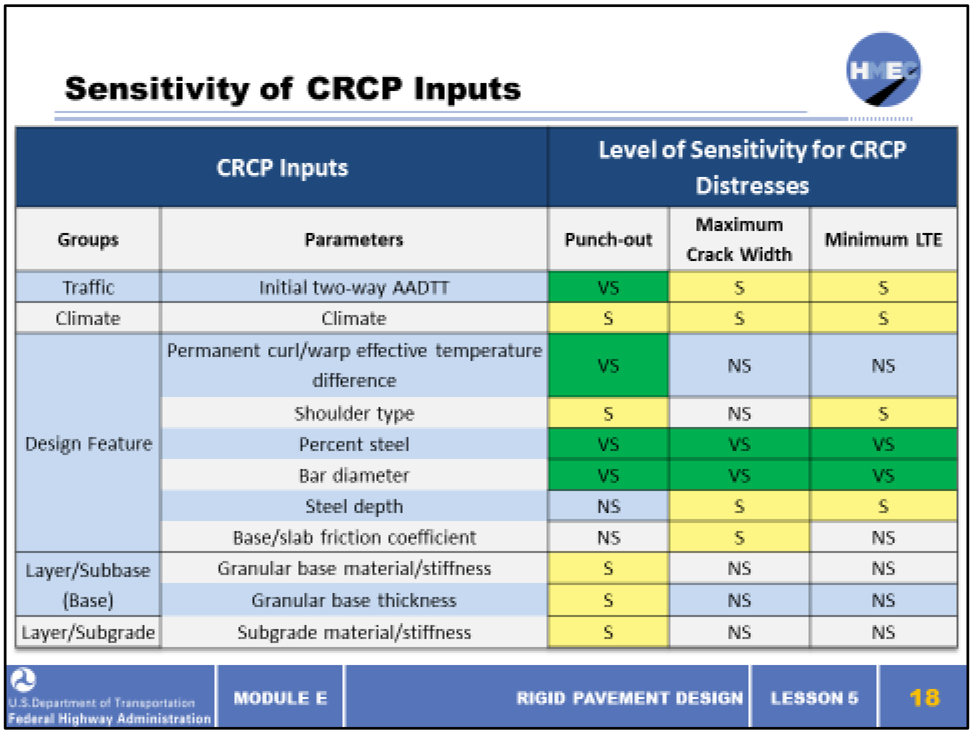
Inputs affecting CRCP pavements

CRCP Inputs		Level of Sensitivity for CRCP Distresses		
Groups	**Parameters**	**Punch-out**	**Maximum Crack Width**	**Minimum LTE**
Traffic	Initial two-way AADTT	VS	S	S
Climate	Climate	S	S	S
Design Feature	Permanent curl/warp effective temperature difference	VS	NS	NS
	Shoulder type	S	NS	S
	Percent steel	VS	VS	VS
	Bar diameter	VS	VS	VS
	Steel depth	NS	S	S
	Base/slab friction coefficient	NS	S	NS
Layer/General	Surface shortwave absorptivity	NS	NS	NS
Layer/PCC	PCC layer thickness	VS	S	VS
	Unit weight	S	NS	NS
	Poisson’s ratio	S	NS	NS
	Coefficient of thermal expansion	VS	S	S
	Thermal conductivity	NS	NS	NS
	Heat capacity	NS	NS	NS
	Cement type	NS	NS	NS
	Cementitious material content	S	S	S
	Water/cement ratio	NS	S	S

	Aggregate type	NS	NS	NS
	Reversible shrinkage	NS	NS	NS
	Curing method	NS	NS	NS
	28-day PCC modulus of rupture	VS	VS	VS
Layer/Subbase (Base)	Granular base material/stiffness	S	NS	NS
	Granular base thickness	S	NS	NS
	Poisson's ratio	NS	NS	NS
	Compacted or uncompacted	NS	NS	NS
Layer/Subgrade	Subgrade material/stiffness	S	NS	NS
	Poisson's ratio	NS	NS	NS
	Compacted or uncompacted	NS	NS	NS

Very Sensitive	Sensitive

Slide 18



Sensitivity of CRCP Inputs

CRCP Inputs		Level of Sensitivity for CRCP Distresses		
Groups	**Parameters**	**Punch-out**	**Maximum Crack Width**	**Minimum LTE**
Traffic	Initial two-way AADTT	VS	S	S
Climate	Climate	S	S	S
Design Feature	Permanent curl/warp effective temperature difference	VS	NS	NS
	Shoulder type	S	NS	S
	Percent steel	VS	VS	VS
	Bar diameter	VS	VS	VS
	Steel depth	NS	S	S
	Base/slab friction coefficient	NS	S	NS
Layer/Subbase (Base)	Granular base material/stiffness	S	NS	NS
	Granular base thickness	S	NS	NS
Layer/Subgrade	Subgrade material/stiffness	S	NS	NS

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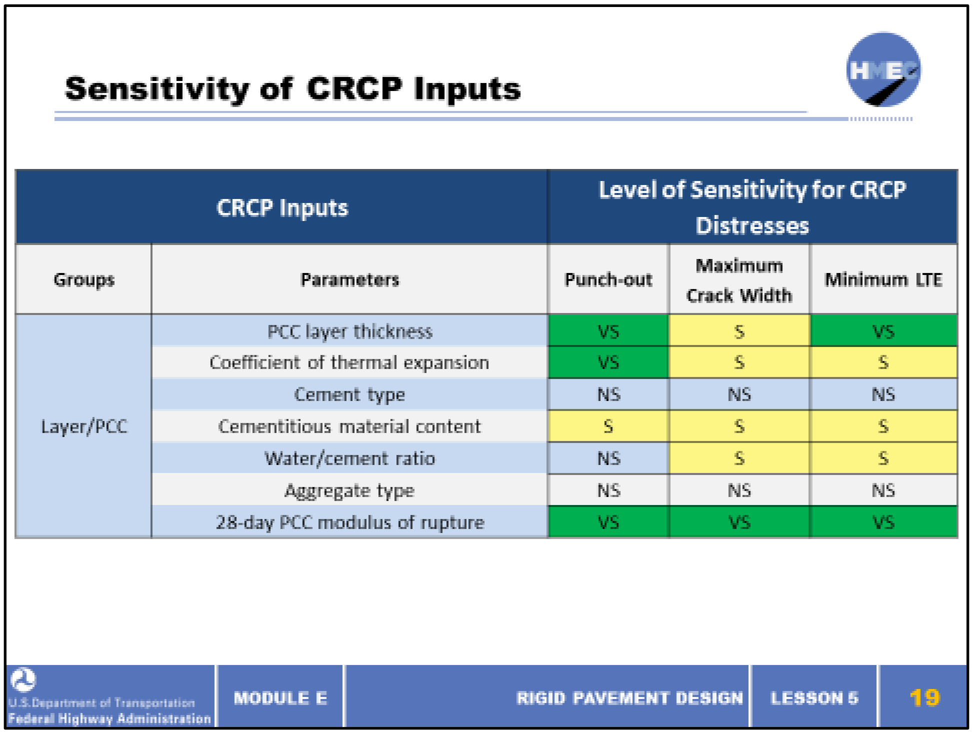
MODULE E | RIGID PAVEMENT DESIGN | LESSON 5 | 18

This is the table from the NCHRP 1-47 (RRD 372) report that shows the information on the factors which are most sensitive for continuously-reinforced rigid pavement performance.

Slide 19



Sensitivity of CRCP Inputs

CRCP Inputs		Level of Sensitivity for CRCP Distresses		
Groups	Parameters	Punch-out	Maximum Crack Width	Minimum LTE
Layer/PCC	PCC layer thickness	VS	S	VS
	Coefficient of thermal expansion	VS	S	S
	Cement type	NS	NS	NS
	Cementitious material content	S	S	S
	Water/cement ratio	NS	S	S
	Aggregate type	NS	NS	NS
	28-day PCC modulus of rupture	VS	VS	VS

U.S. Department of Transportation
Federal Highway Administration
MODULE E
RIGID PAVEMENT DESIGN
LESSON 5
19

This is the table continued (from the NCHRP 1-47 (RRD 372) report) that shows more information on the factors which are most sensitive for continuously-reinforced rigid pavement performance.

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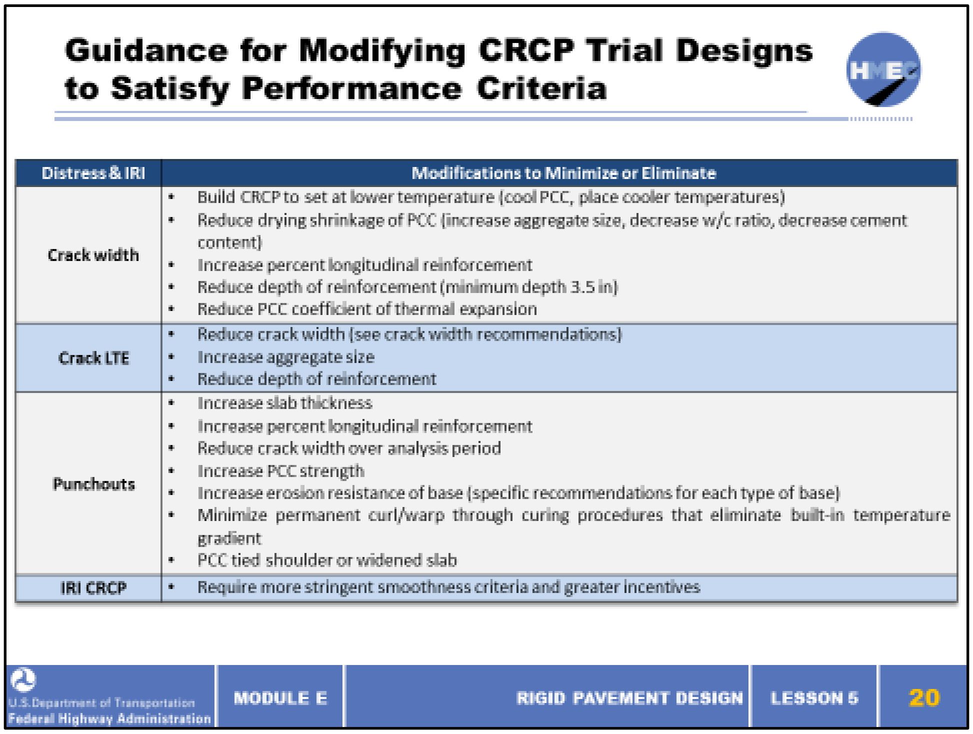
Suggested Alterations to Pavement Design (CRCP)

Guidance for Modifying CRCP Trial Designs to Satisfy Performance Criteria (Taken from the AASHTO MEPDG Manual of Practice, 2008)

Distress & IRI	Modifications to Minimize or Eliminate
Crack width	• Build CRCP to set at lower temperature (cool PCC, place cooler temperatures). • Reduce drying shrinkage of PCC (increase aggregate size, decrease w/c ratio, decrease cement content). • Increase percent longitudinal reinforcement. • Reduce depth of reinforcement (minimum depth 3.5 in). • Reduce PCC coefficient of thermal expansion.
Crack LTE	• Reduce crack width (see crack width recommendations). • Increase aggregate size. • Reduce depth of reinforcement.
Punchouts	• Increase slab thickness. • Increase percent longitudinal reinforcement. • Reduce crack width over analysis period. • Increase PCC strength. • Increase erosion resistance of base (specific recommendations for each type of base). • Minimize permanent curl/warp through curing procedures that eliminate built-in temperature gradient. • PCC tied shoulder or widened slab.
IRI CRCP	• Require more stringent smoothness criteria and greater incentives.

Slide 20



Guidance for Modifying CRCP Trial Designs to Satisfy Performance Criteria

Distress & IRI	Modifications to Minimize or Eliminate
Crack width	• Build CRCP to set at lower temperature (cool PCC, place cooler temperatures) • Reduce drying shrinkage of PCC (increase aggregate size, decrease w/c ratio, decrease cement content) • Increase percent longitudinal reinforcement • Reduce depth of reinforcement (minimum depth 3.5 in) • Reduce PCC coefficient of thermal expansion
Crack LTE	• Reduce crack width (see crack width recommendations) • Increase aggregate size • Reduce depth of reinforcement
Punchouts	• Increase slab thickness • Increase percent longitudinal reinforcement • Reduce crack width over analysis period • Increase PCC strength • Increase erosion resistance of base (specific recommendations for each type of base) • Minimize permanent curl/warp through curing procedures that eliminate built-in temperature gradient • PCC tied shoulder or widened slab
IRI CRCP	• Require more stringent smoothness criteria and greater incentives

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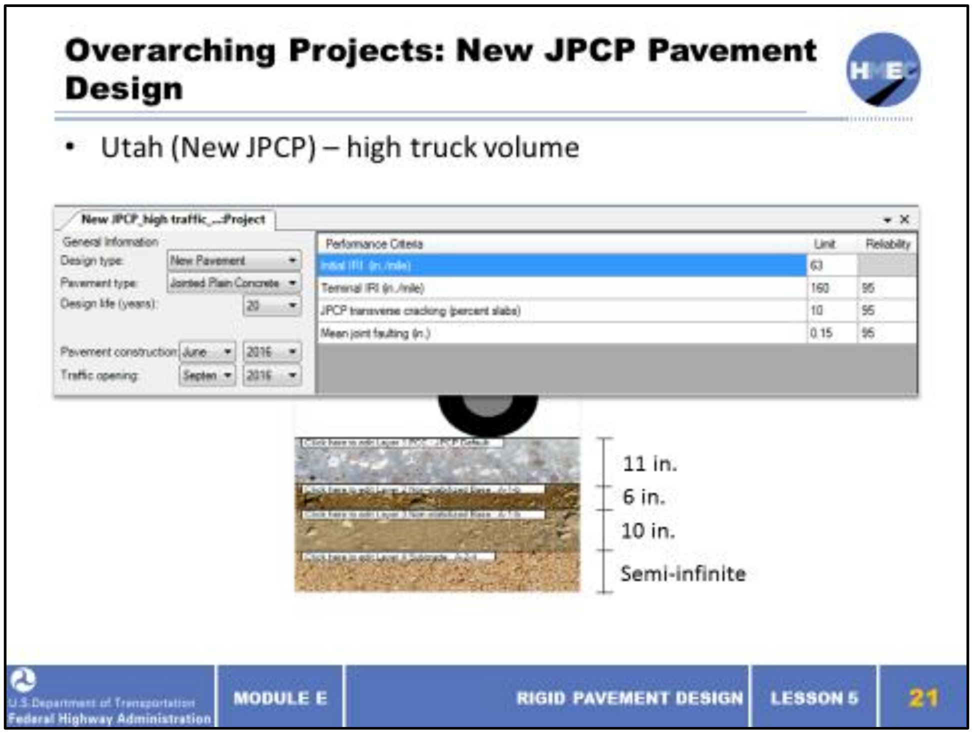
MODULE E | RIGID PAVEMENT DESIGN | LESSON 5 | 20

Slide 21



Overarching Projects: New JPCP Pavement Design

- Utah (New JPCP) – high truck volume

New JPCP_high traffic_...Project

General Information

Design type: New Pavement

Pavement type: Jointed Plain Concrete

Design life (years): 20

Pavement construction: June 2016

Traffic opening: Septen 2016

Performance Criteria	Limit	Reliability
Initial IRI (in./mile)	63	
Terminal IRI (in./mile)	160	95
JPCP transverse cracking (percent slabs)	10	95
Mean joint faulting (in.)	0.15	95

11 in.

6 in.

10 in.

Semi-infinite

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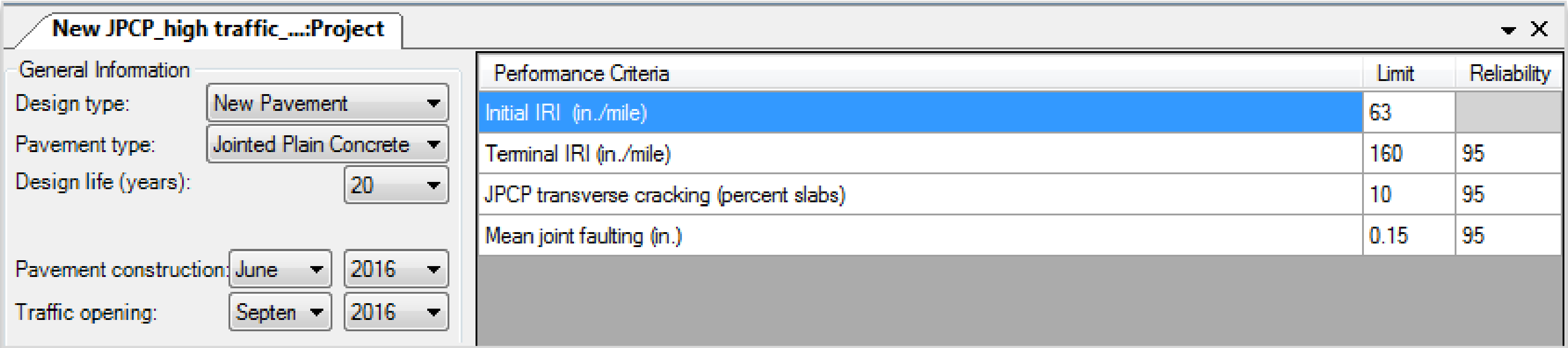
Federal Highway Administration
MODULE E
RIGID PAVEMENT DESIGN
LESSON 5
21



New JPCP_high traffic_...:Project

General Information

Design type: New Pavement

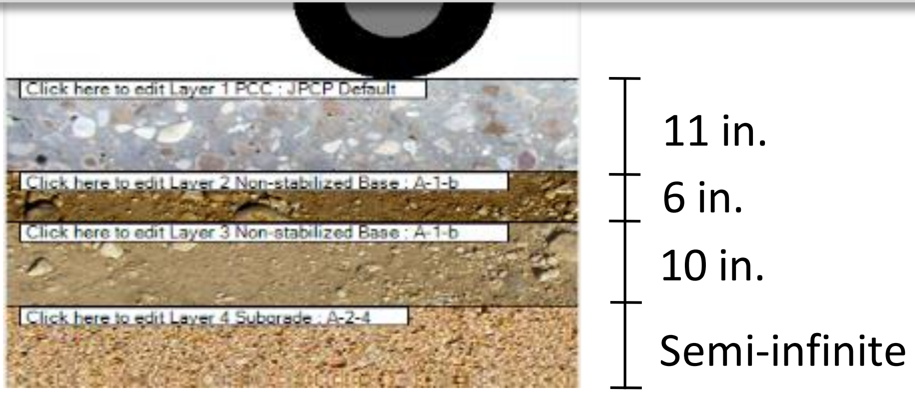
Pavement type: Jointed Plain Concrete

Design life (years): 20

Pavement construction: June 2016

Traffic opening: Septen 2016

Performance Criteria	Limit	Reliability
Initial IRI (in./mile)	63	
Terminal IRI (in./mile)	160	95
JPCP transverse cracking (percent slabs)	10	95
Mean joint faulting (in.)	0.15	95


Click here to edit Layer 1 PCC : JPCP Default
Click here to edit Layer 2 Non-stabilized Base : A-1-b
Click here to edit Layer 3 Non-stabilized Base : A-1-b
Click here to edit Layer 4 Subgrade : A-2-4
11 in.
6 in.
10 in.
Semi-infinite

Slide 22

Software Demonstration for Rigid Pavement

AASHTOWare Pavement ME Design

Start Demonstration

New Rigid Pavement Example

Start Demonstration

New Rigid Pavement Example

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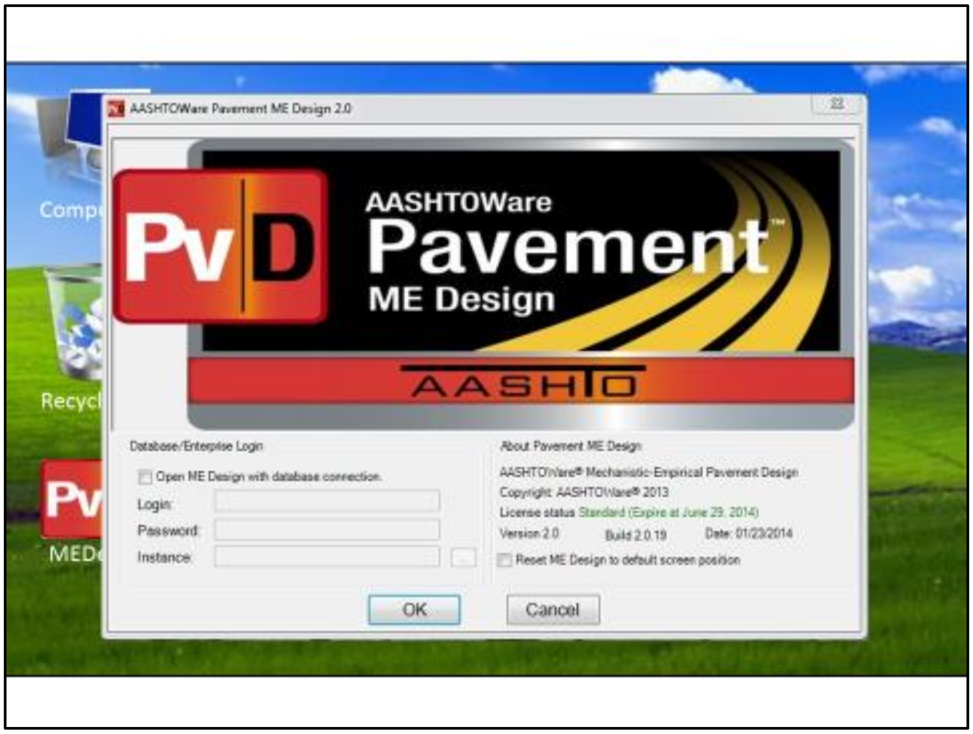
Slide 23



Database/Enterprise Login

☐ Open ME Design with database connection.

Login:

Password:

Instance:

About Pavement ME Design

AASHTOWare® Mechanistic-Empirical Pavement Design

Copyright: AASHTOWare® 2013

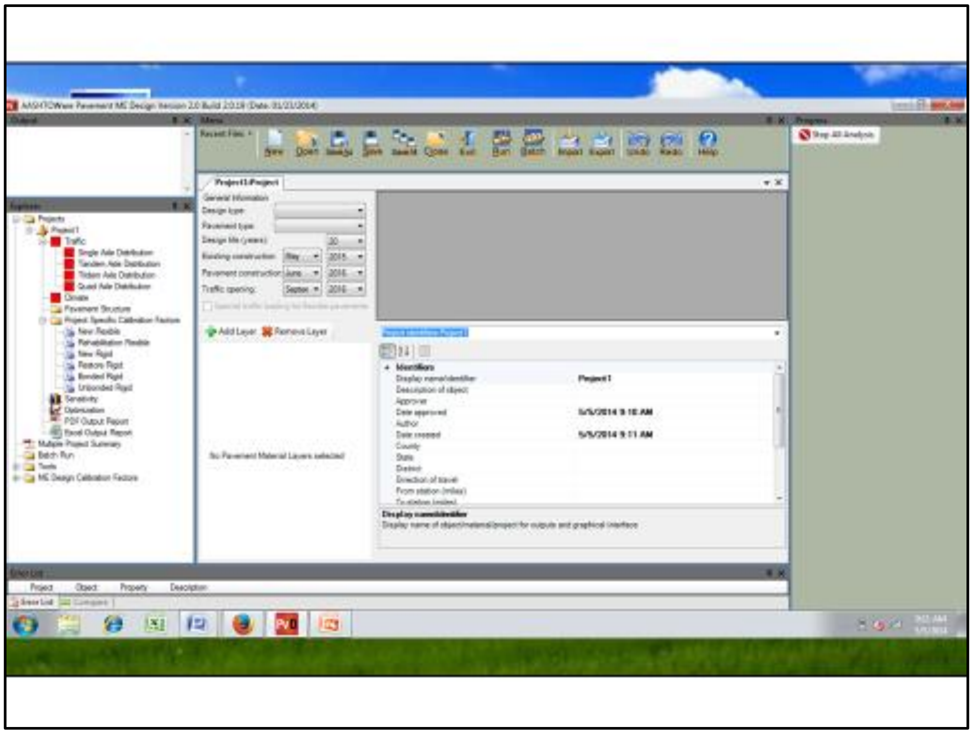
License status Standard (Expire at June 29, 2014)

Version 2.0 Build 2.0.19 Date: 01/23/2014

☐ Reset ME Design to default screen position

Select the AASHTO Ware Pavement ME Design icon to launch the software. Select OK.

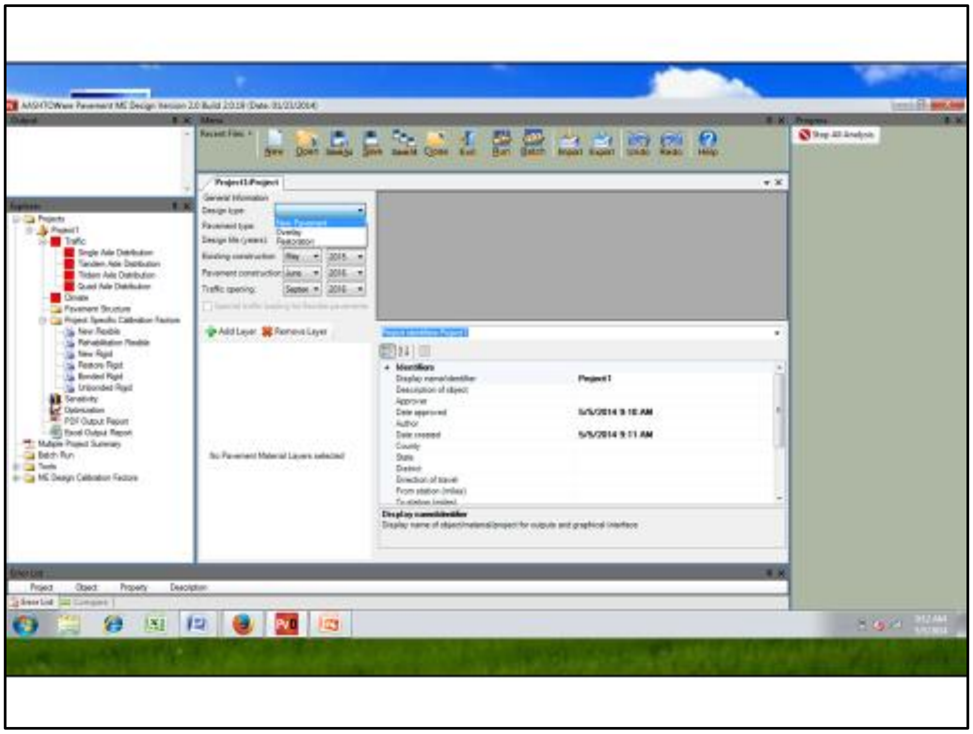
Slide 24



Select New.

This window will appear after the new icon is clicked on.

Slide 25

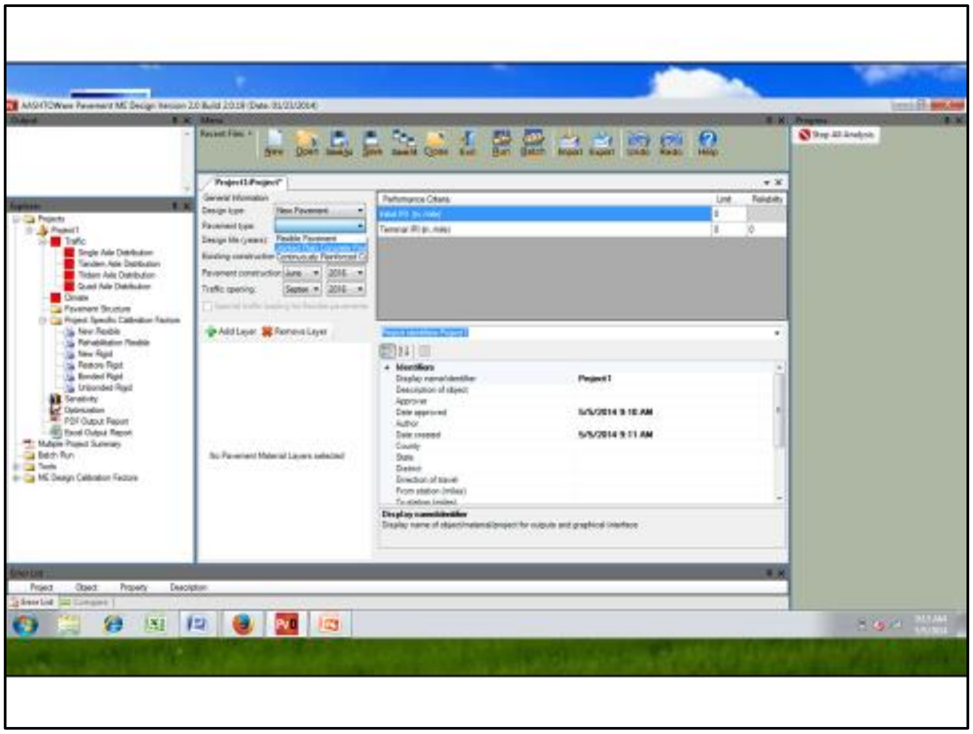


General information
Design type: New Pavement / Overlay / Restoration
Pavement construction: June 2016
Traffic opening: Septem 2016

Identifiers
Display name/identifier: Project1
Description of object:
Approver:
Date approved: 5/5/2014 9:10 AM
Author:
Date created: 5/5/2014 9:11 AM
County:

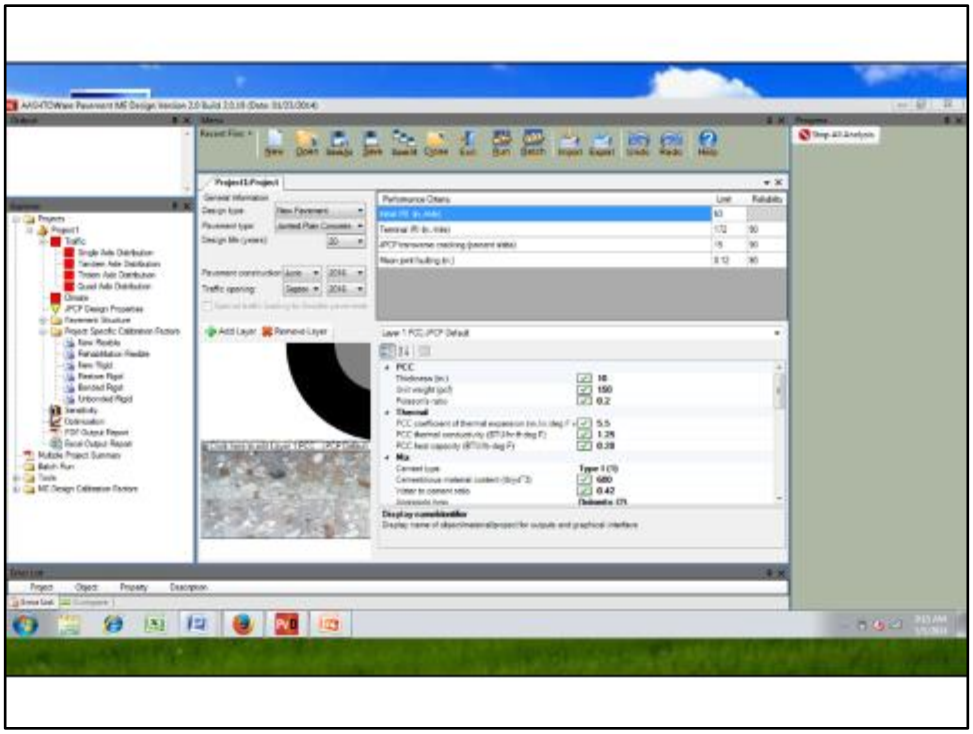
Select Design Type and select New Pavement.

Slide 26



Select Pavement Type and select Jointed Plain Concrete Pavement.

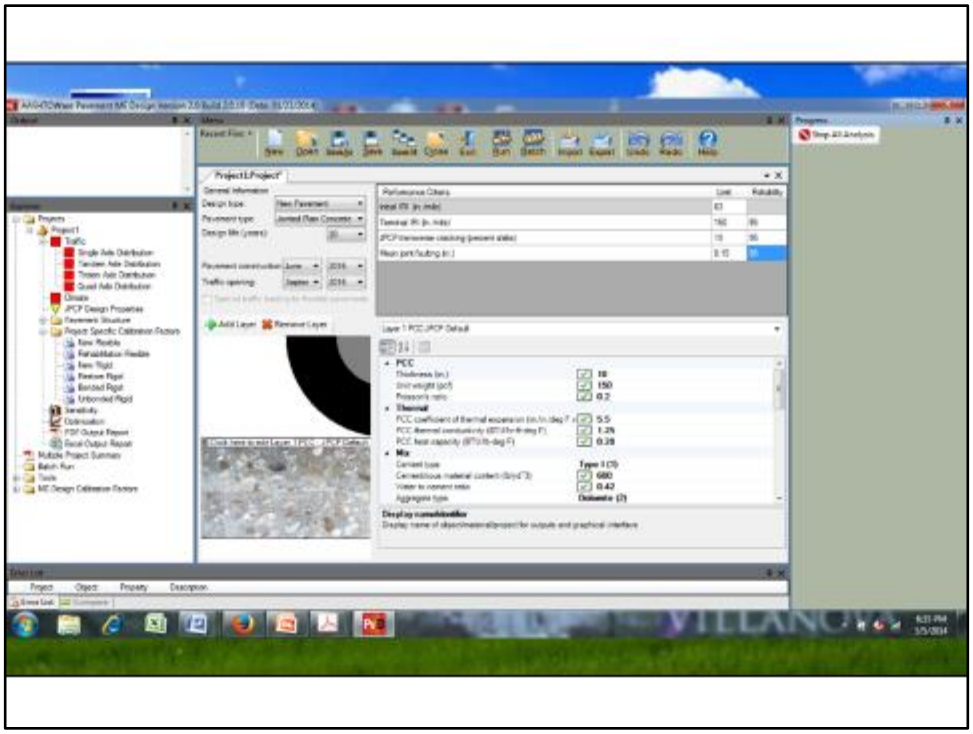
Slide 27



Performance Criteria	Limit	Reliability
Initial IRI (in./mile)	63	
Terminal IRI (in./mile)	172	90
JPCP transverse cracking (percent slabs)	15	90
Mean joint faulting (in.)	0.12	90

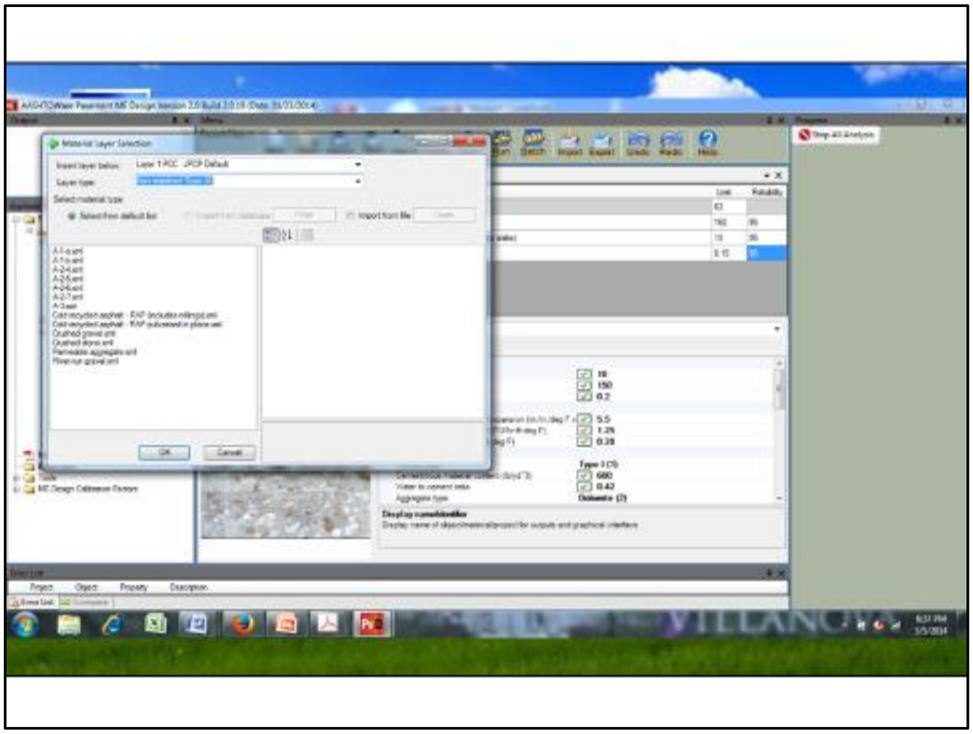
Change Threshold Criteria and Reliability.

Slide 28



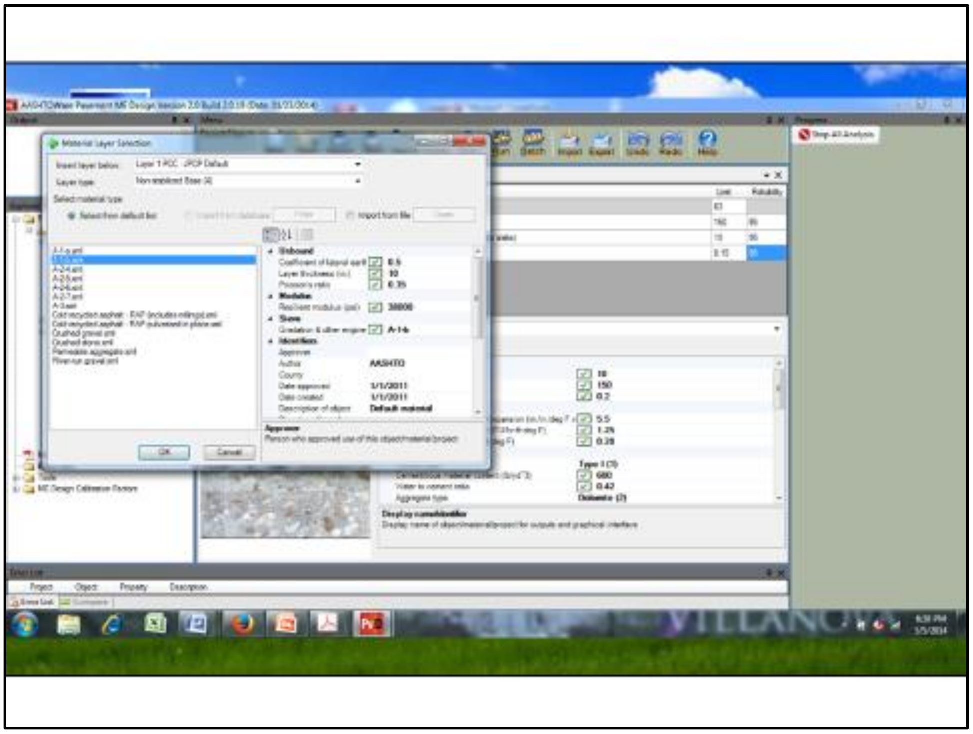
Select Add Layer to build the pavement structure.

Slide 29



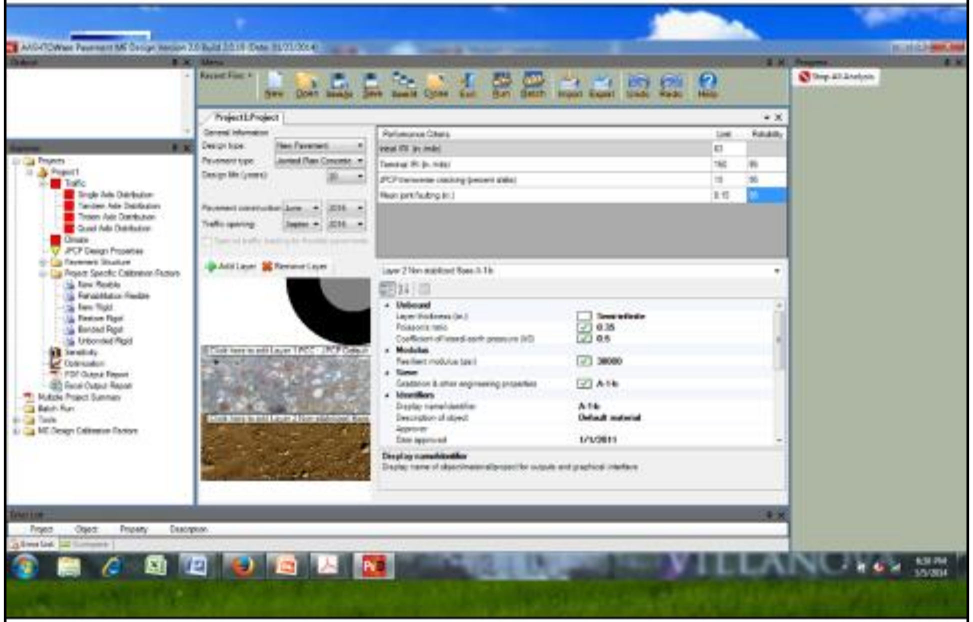
Select the appropriate base layer: A-1-b.xml.

Slide 30



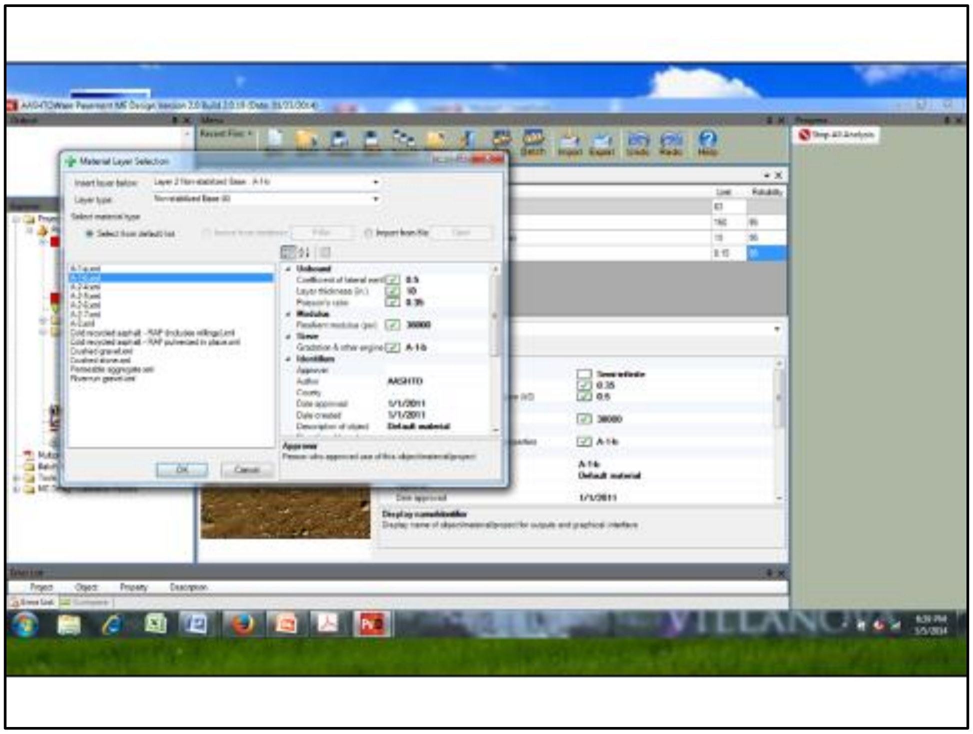
Select OK.

Slide 31



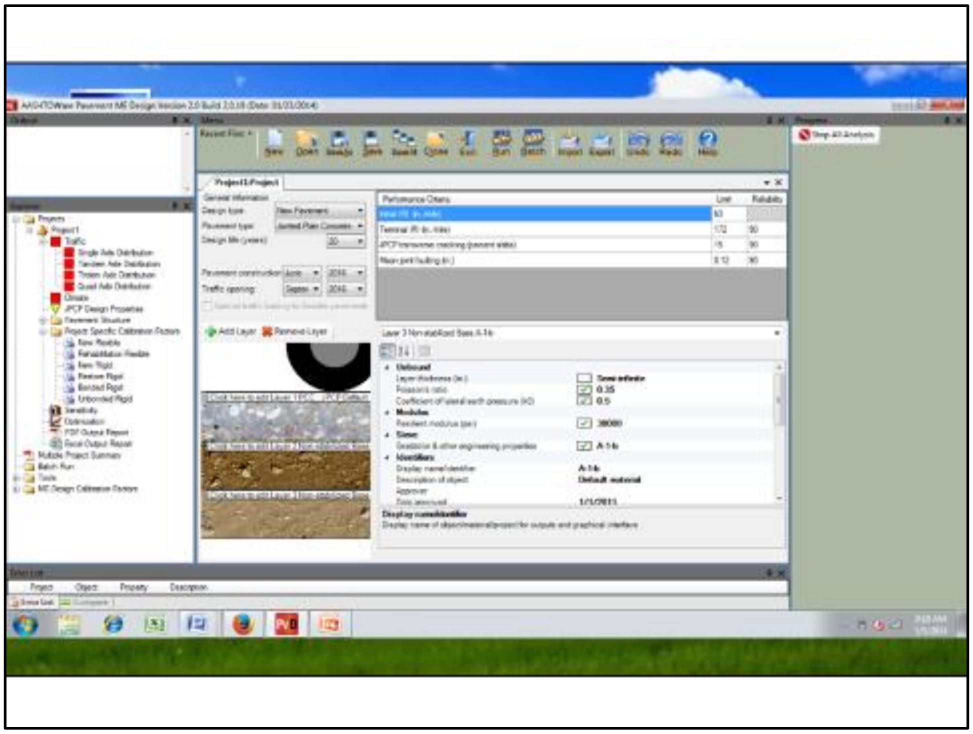
Select Add Layer to add a subbase (A-1-b.xml).

Slide 32



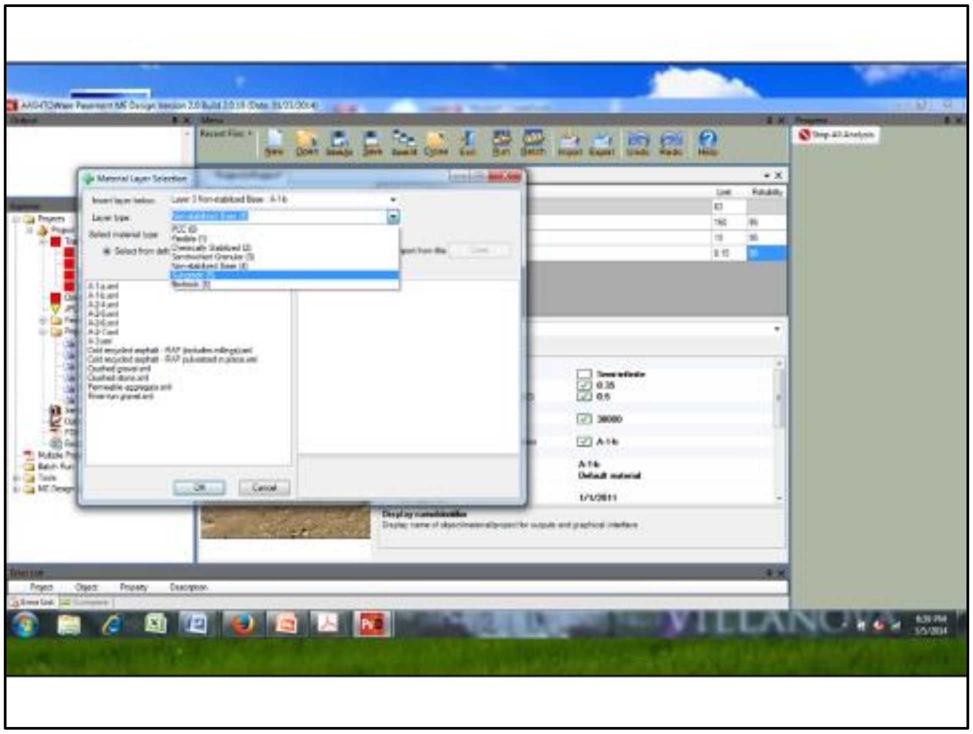
Select OK.

Slide 33



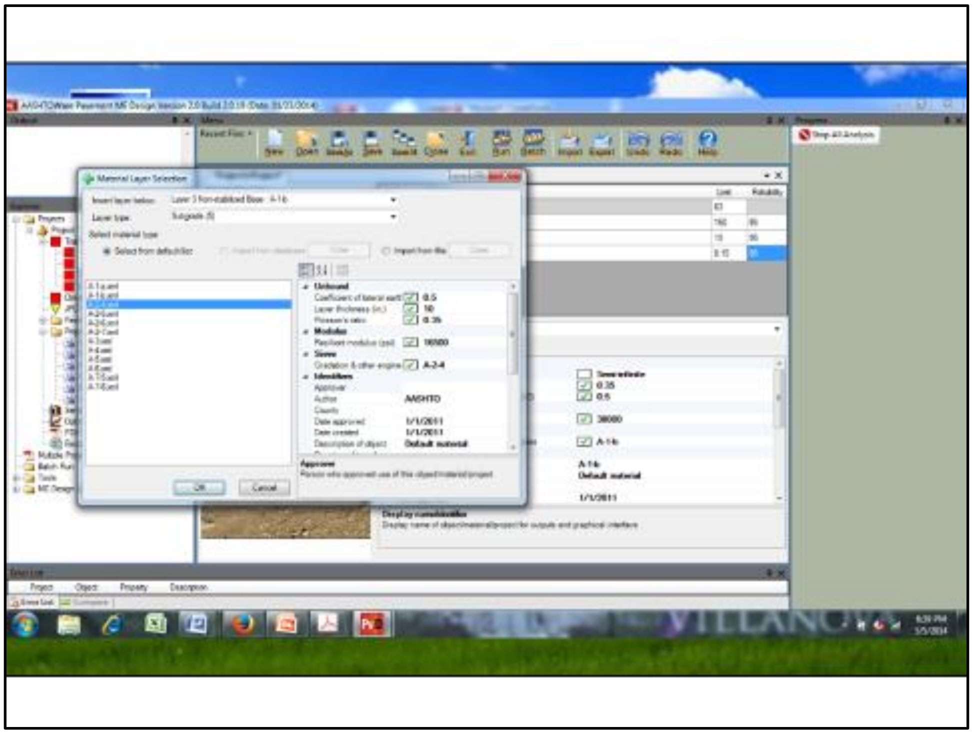
Select Add Layer to add the subgrade (A-2-4.xml).

Slide 34



Select Subgrade as layer type.

Slide 35



Insert layer below: Layer 3 Non-stabilized Base: A-1-b

Layer type: Subgrade (5)

Unbound
Coefficient of lateral earth ☑ 0.5
Layer thickness (in.) ☑ 10
Poisson's ratio ☑ 0.35

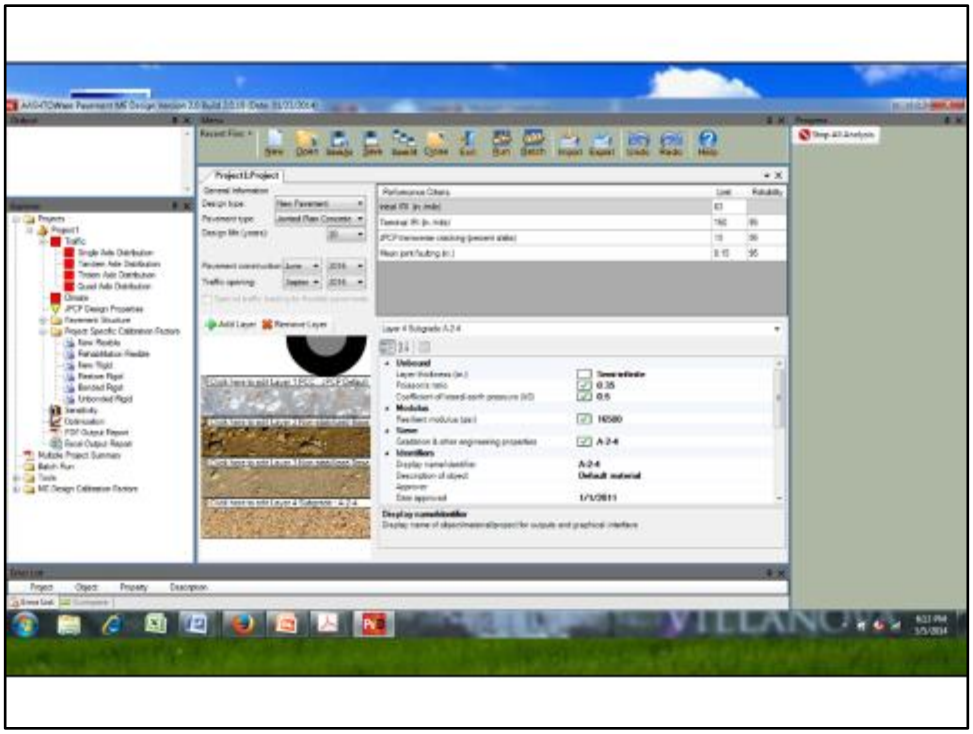
Modulus
Resilient modulus (psi) ☑ 16500

Sieve
Gradation & other engine ☑ A-2-4

Identifiers
Author AASHTO
Date approved 1/1/2011
Date created 1/1/2011
Description of object Default material

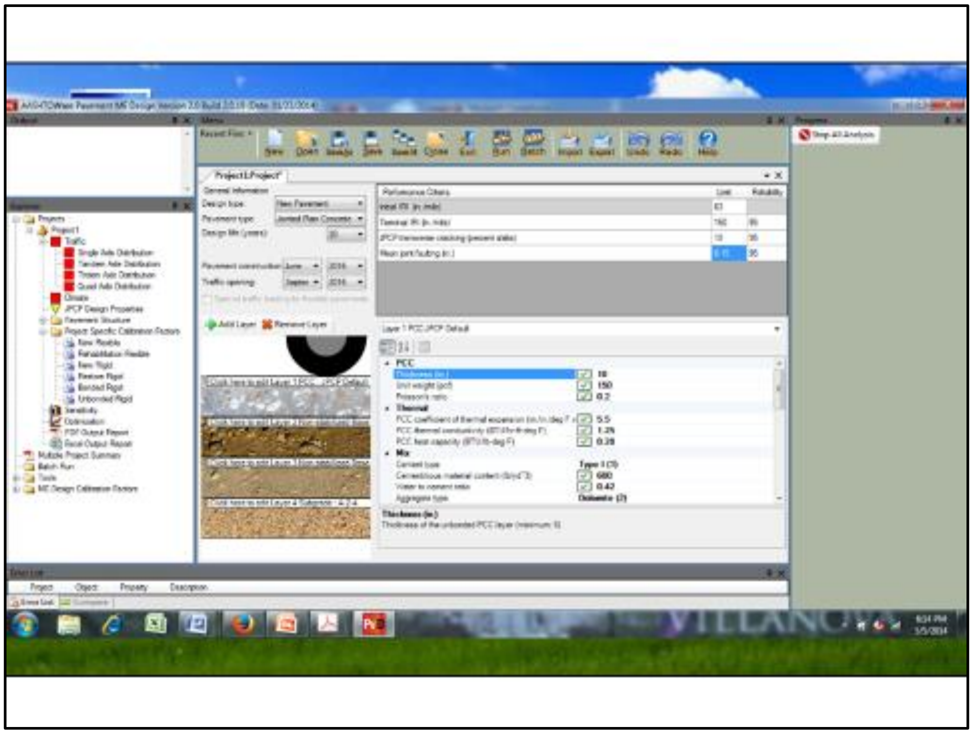
Select A-2-4.xml and select OK.

Slide 36



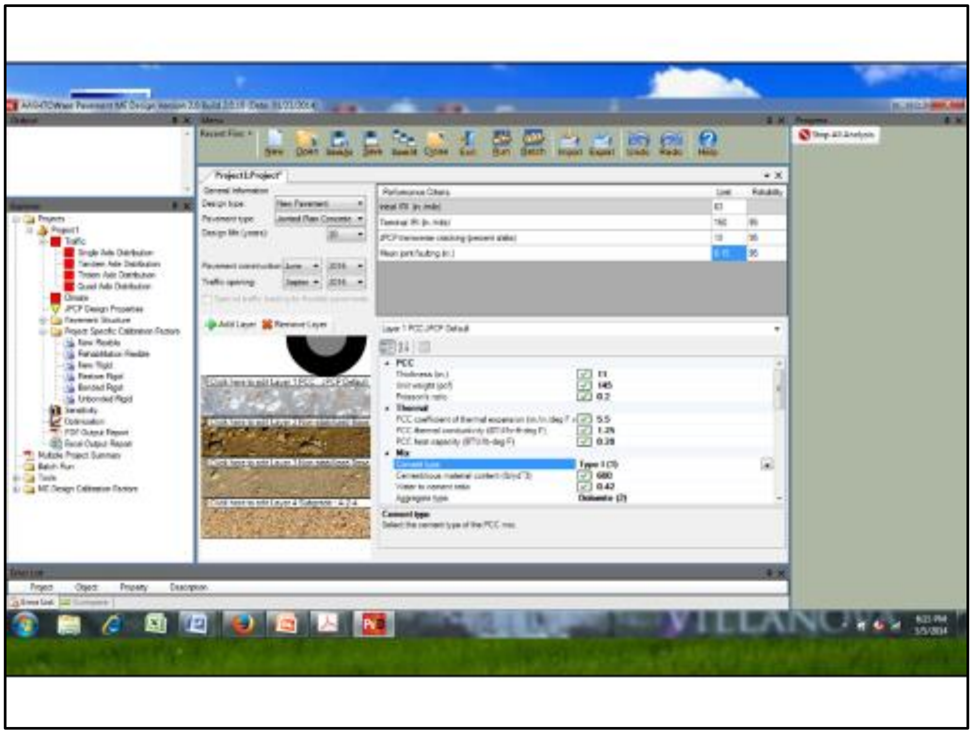
Now you can select each layer to adjust thicknesses and material properties. Select Layer 1 (shown on the next screen).

Slide 37



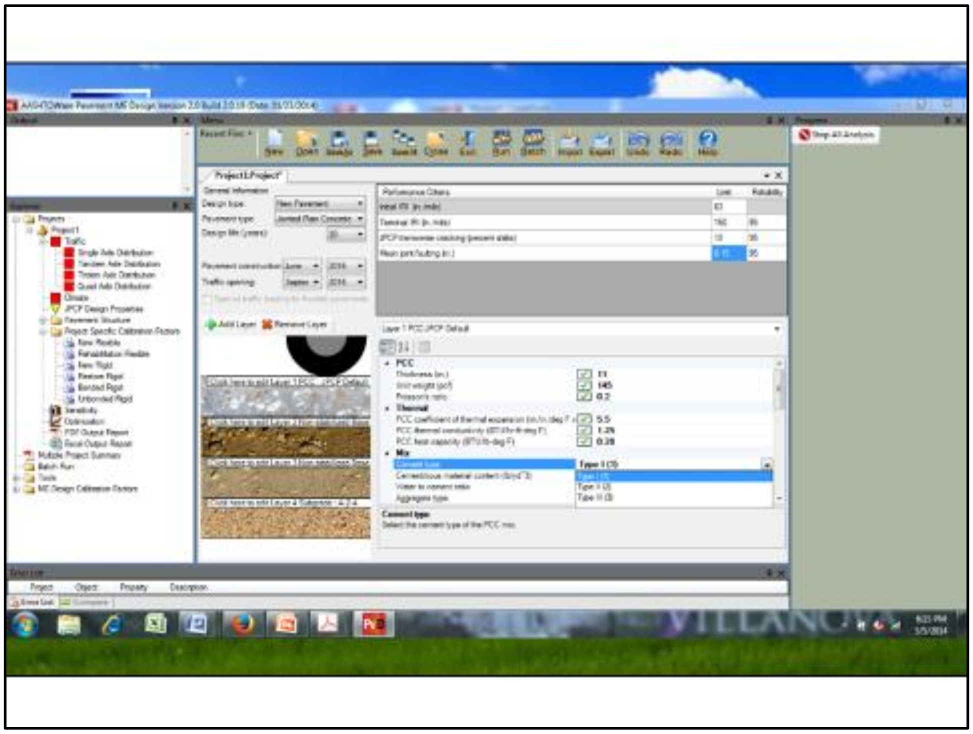
Select each parameter to change its value when necessary.

Slide 38



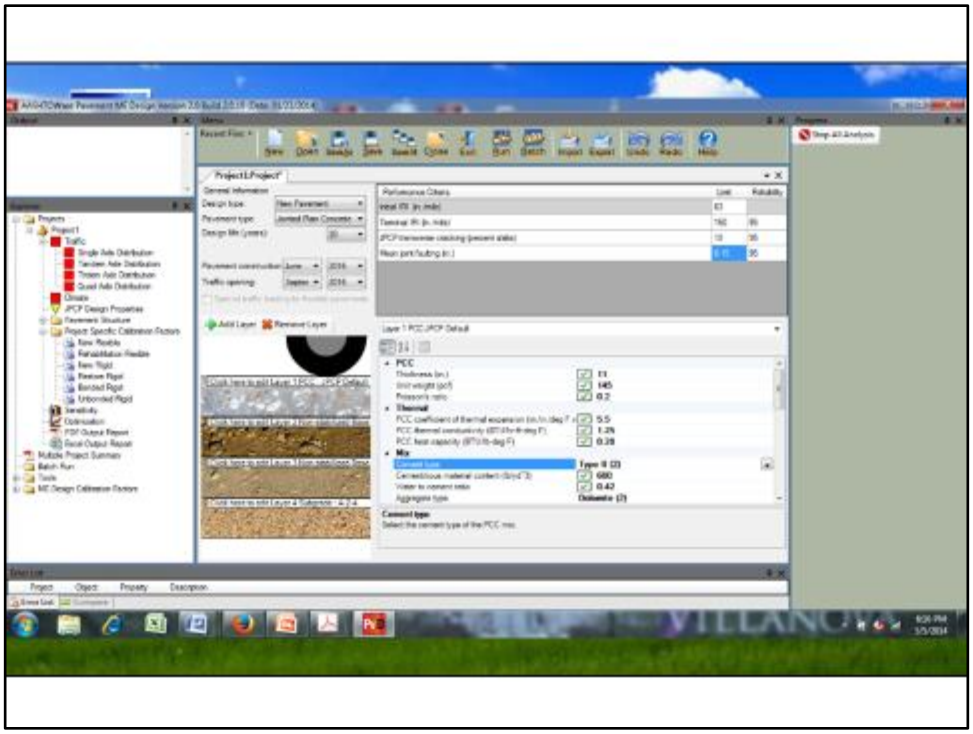
Select Cement Type to select the appropriate material.

Slide 39



Select Type II (shown on next screen).

Slide 40



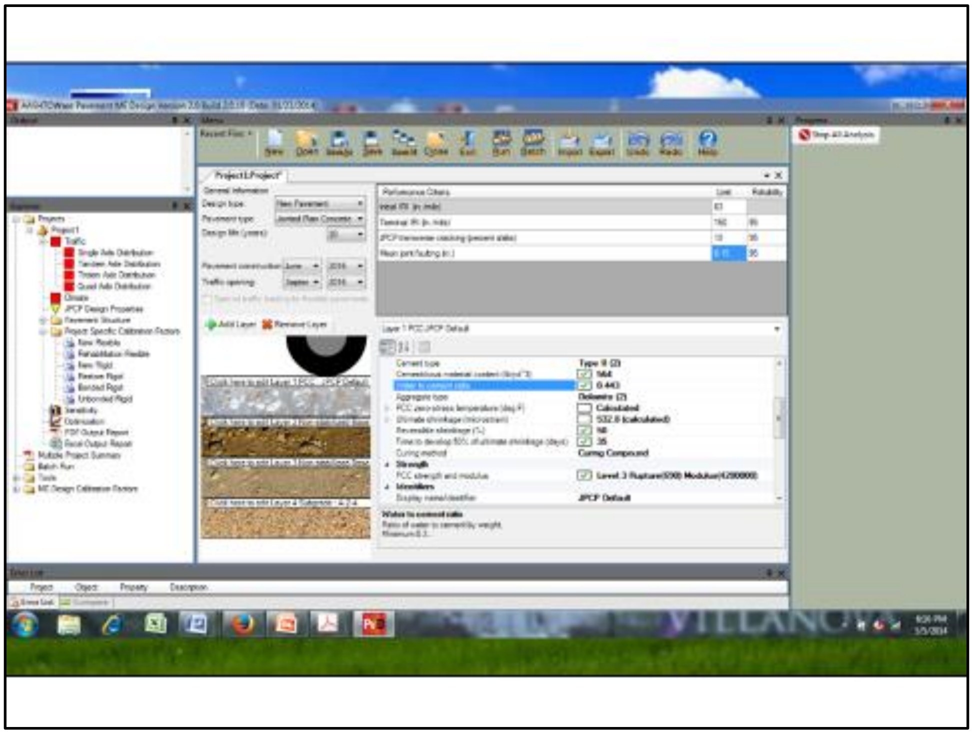
Layer 1 PCC JPCP Default

PCC
Thickness (in.) 11
Unit weight (pcf) 145
Poisson's ratio 0.2
Thermal
PCC coefficient of thermal expansion 5.5
PCC thermal conductivity 1.25
PCC heat capacity 0.28
Mix
Cement type Type II (2)
Cementitious material content 600
Water to cement ratio 0.42
Aggregate type Dolomite (2)

Cement type
Select the cement type of the PCC mix.

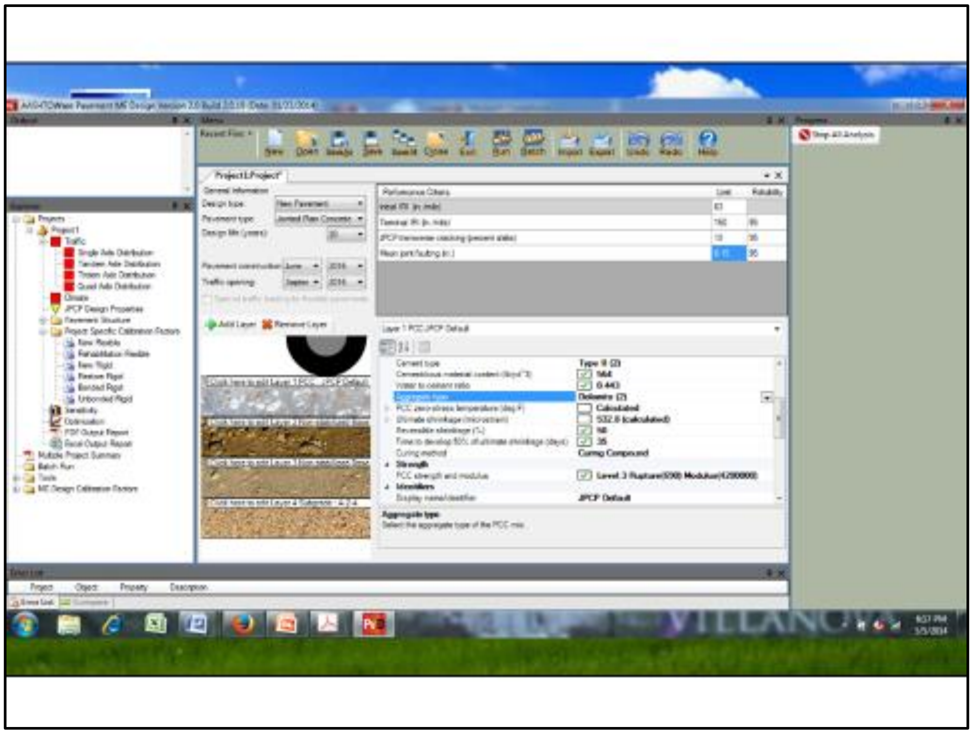
This screen shows Type II selected.

Slide 41



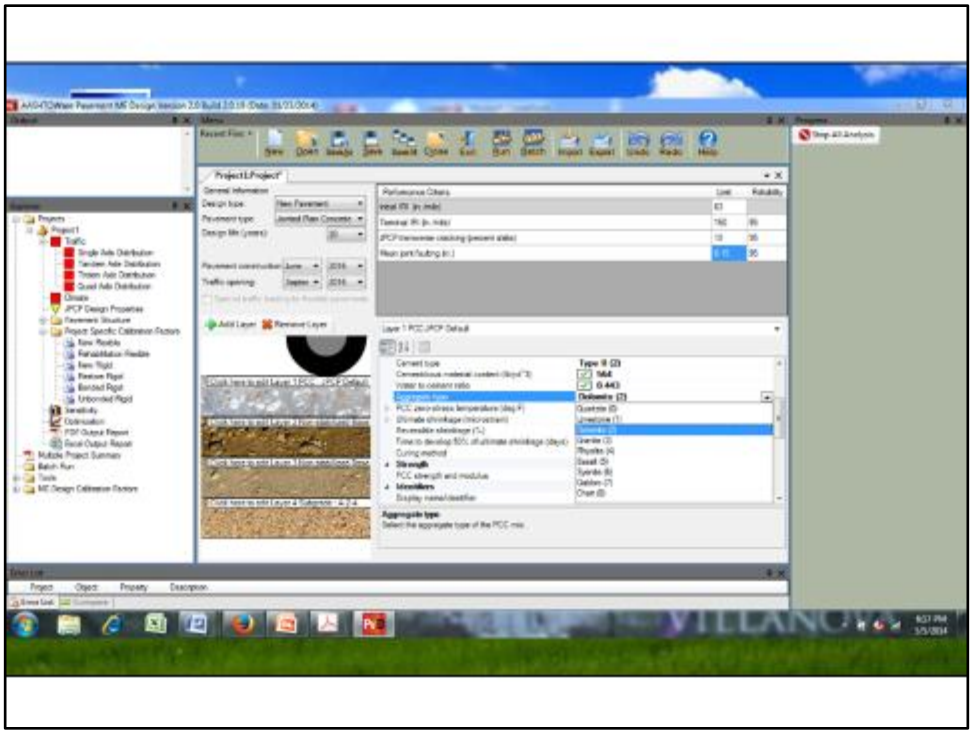
Update Cementitious Material Content and Water to Cement Ratio.

Slide 42



Select Aggregate Type (shown on the next screen).

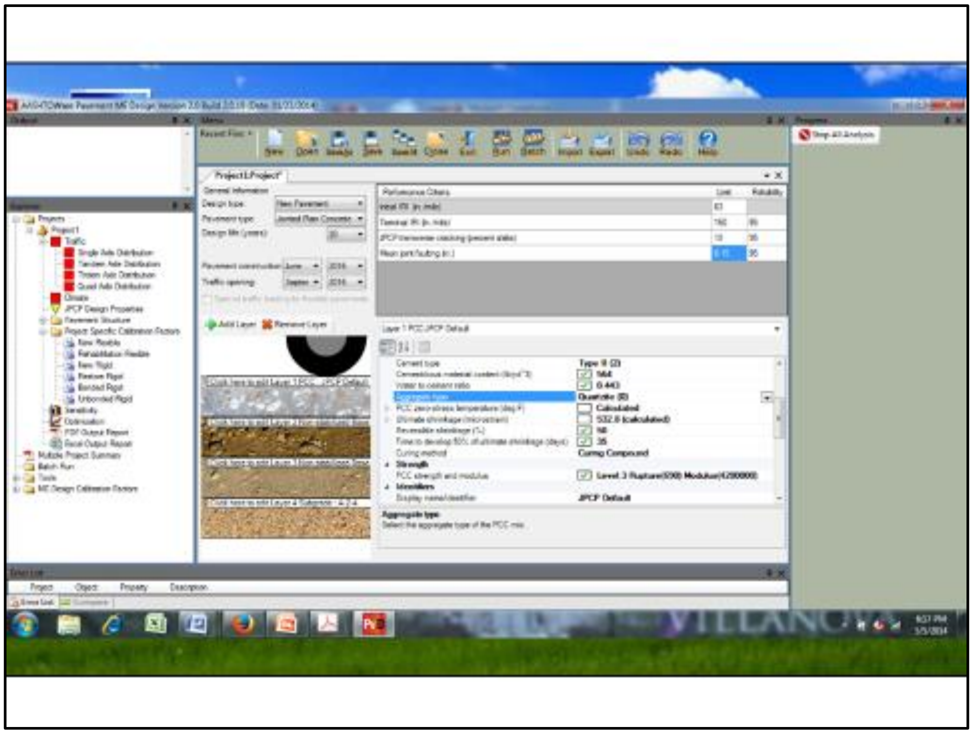
Slide 43



Select Quartzite (shown on the next screen).

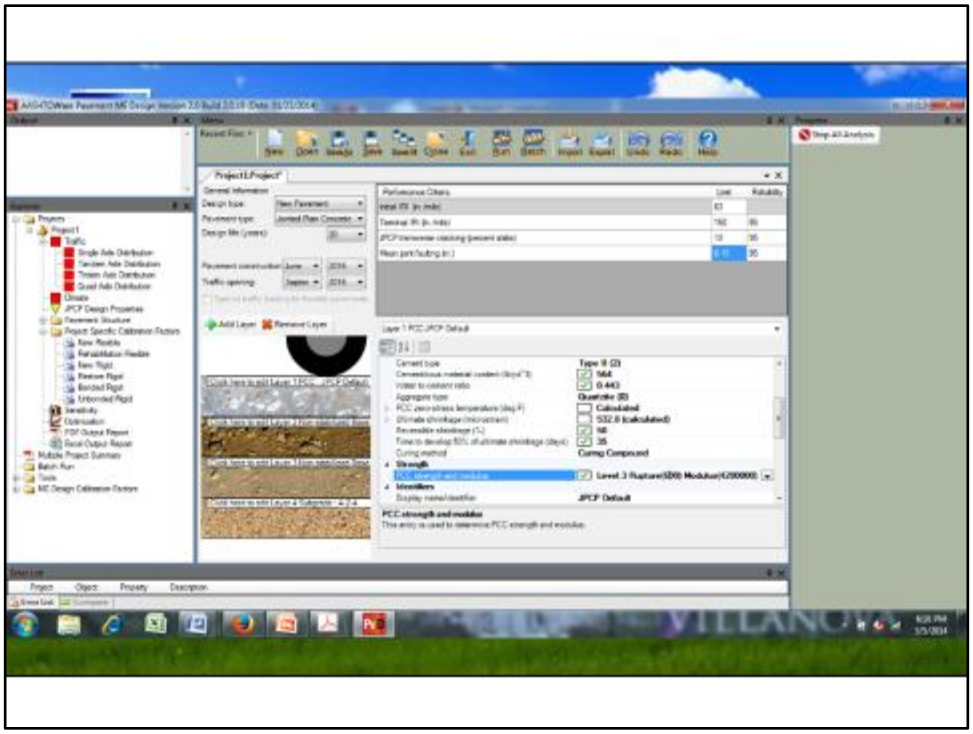
It should be noted that the type of aggregate is for information purposes only, changing the input has no impact on the design. However, the type of coarse aggregate has a significant impact on the PCC CTE value.

Slide 44



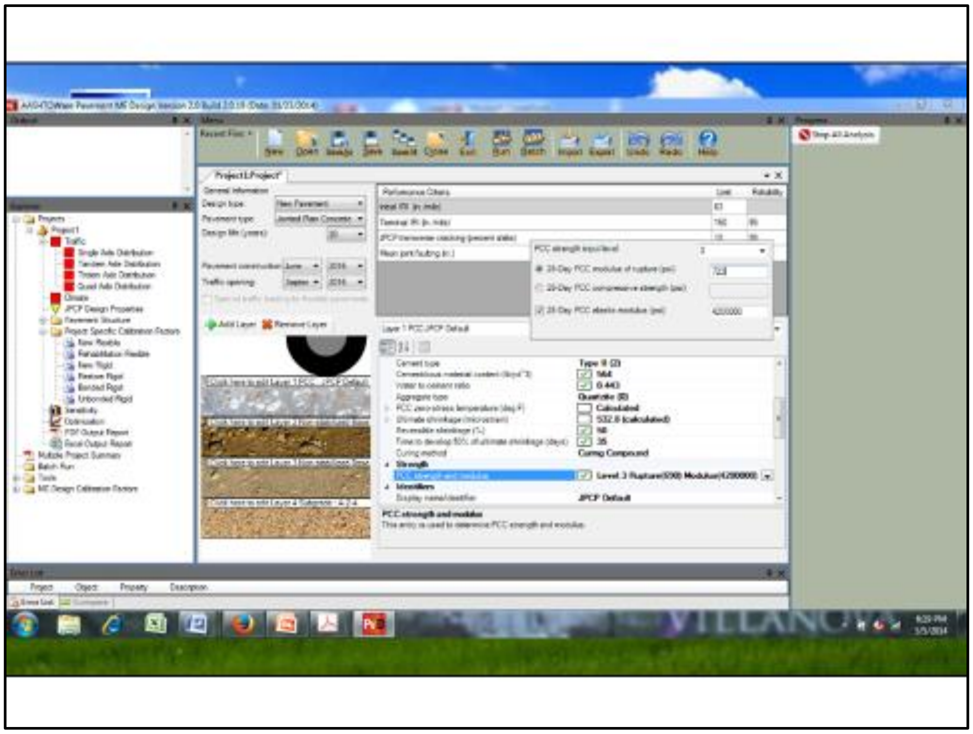
This screen shows Quartzite selected.

Slide 45



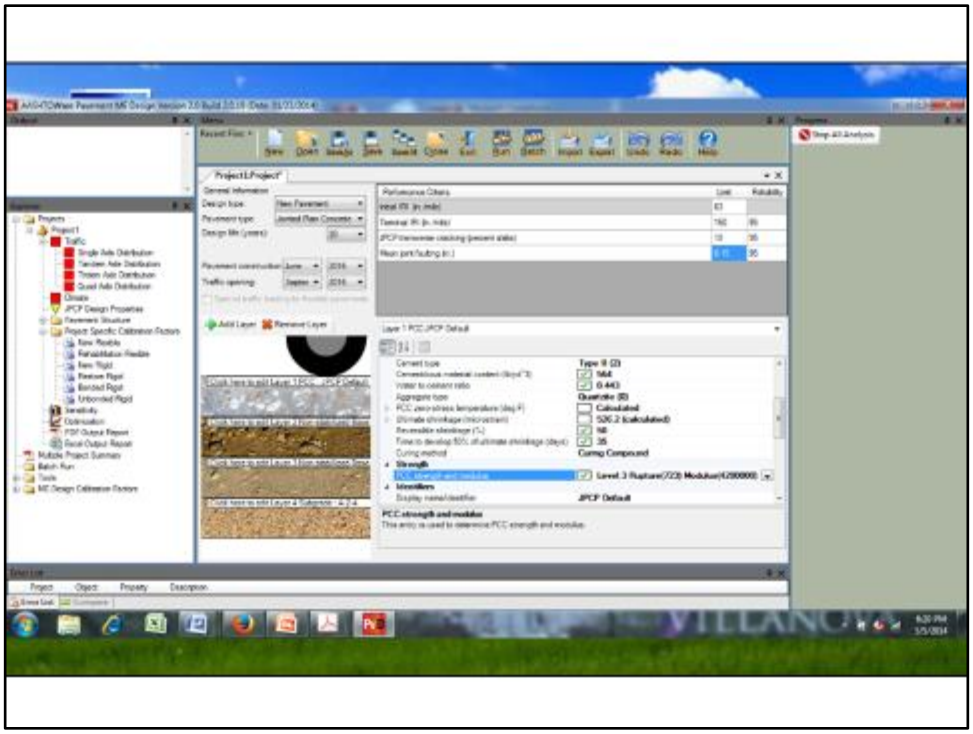
Select PCC Strength and Modulus.

Slide 46



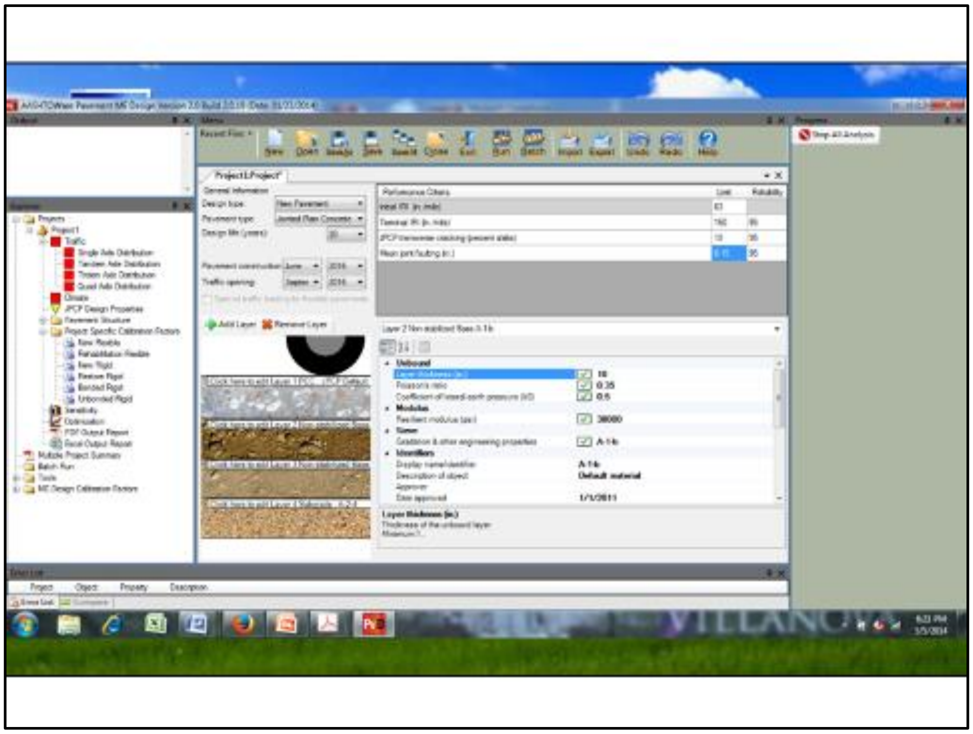
Change Modulus of Rupture to 723.

Slide 47



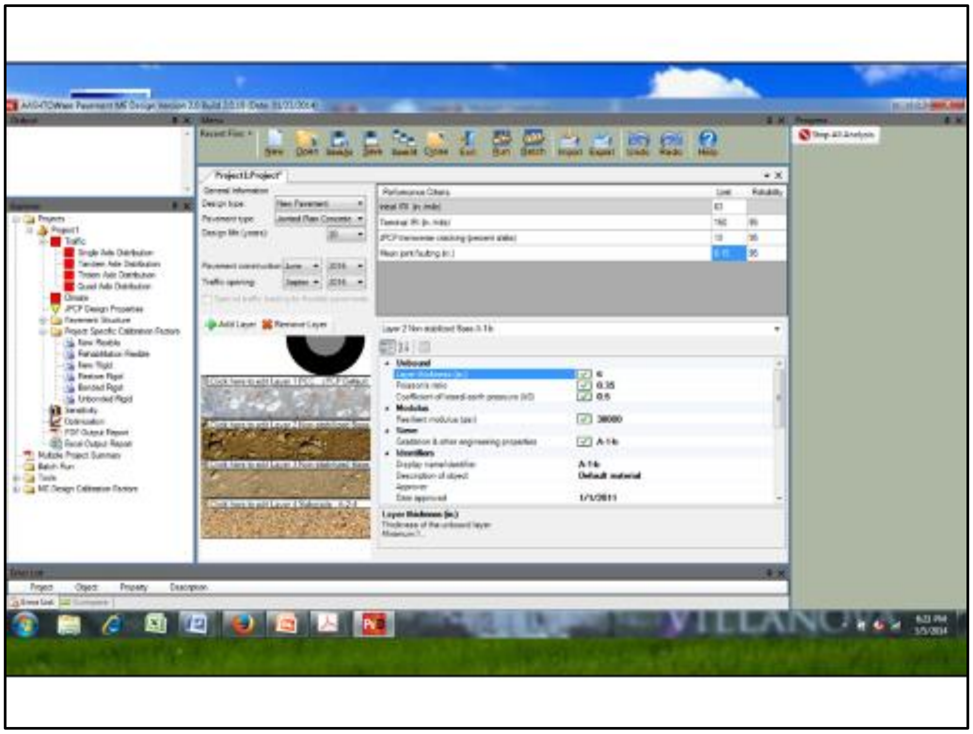
Select Layer 2.

Slide 48



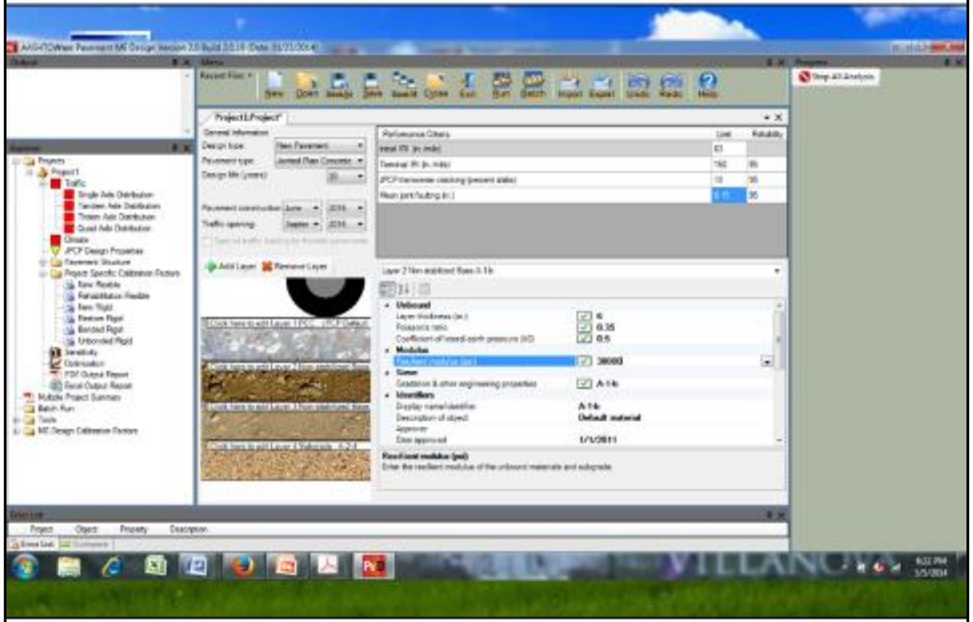
Adjust Layer Thickness (shown on the next screen).

Slide 49



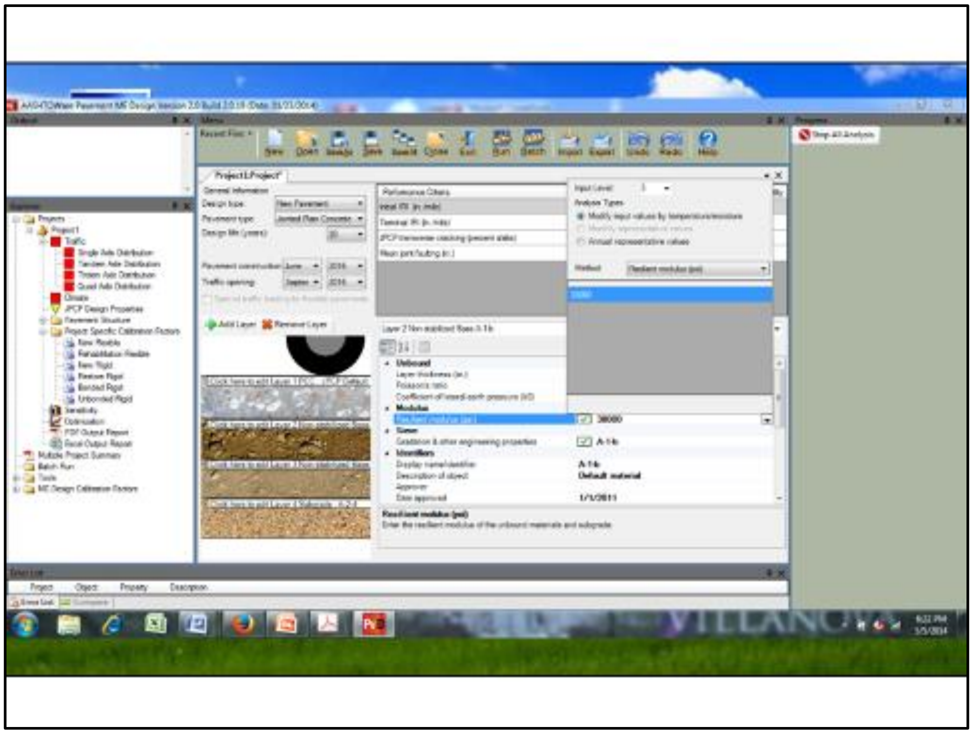
This screen shows the Layer Thickness that has been adjusted.

Slide 50



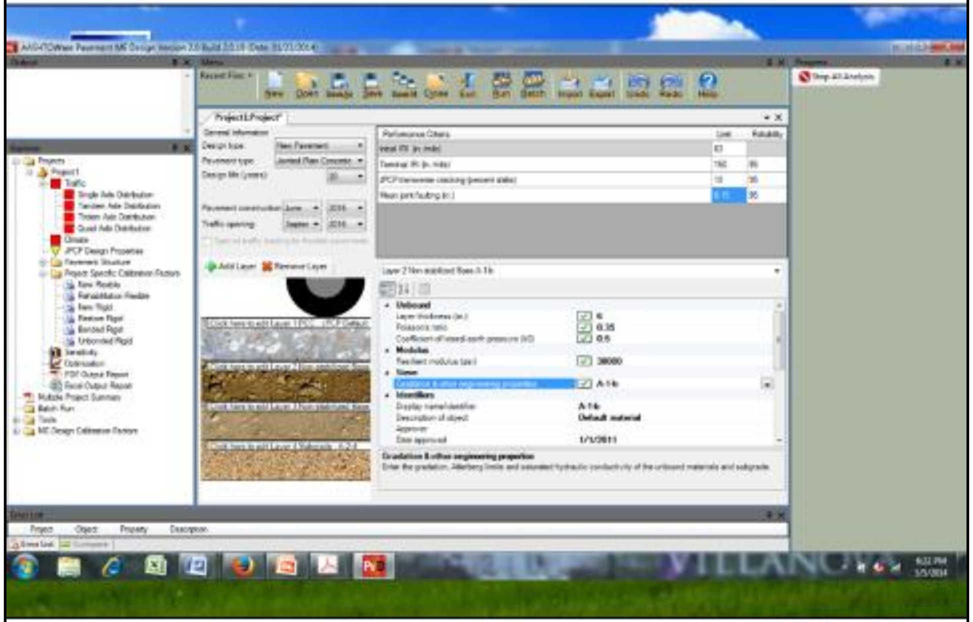
Select Resilient Modulus.

Slide 51



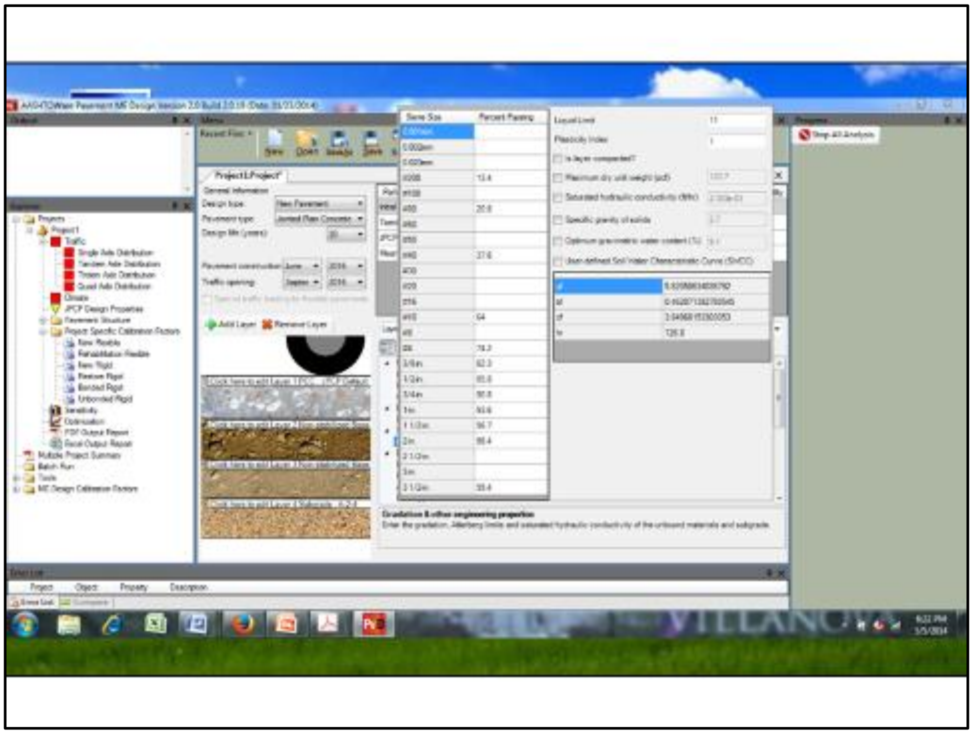
Accept default values as Level 3.

Slide 52



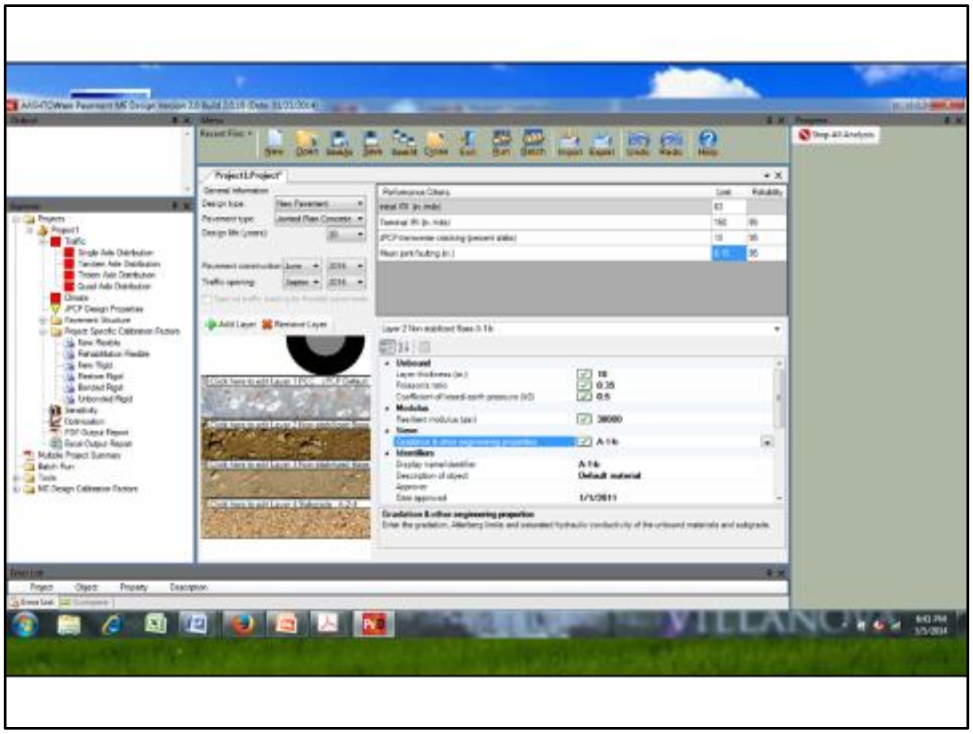
Select Gradation and Other Engineering Properties (shown on the next screen

Slide 53



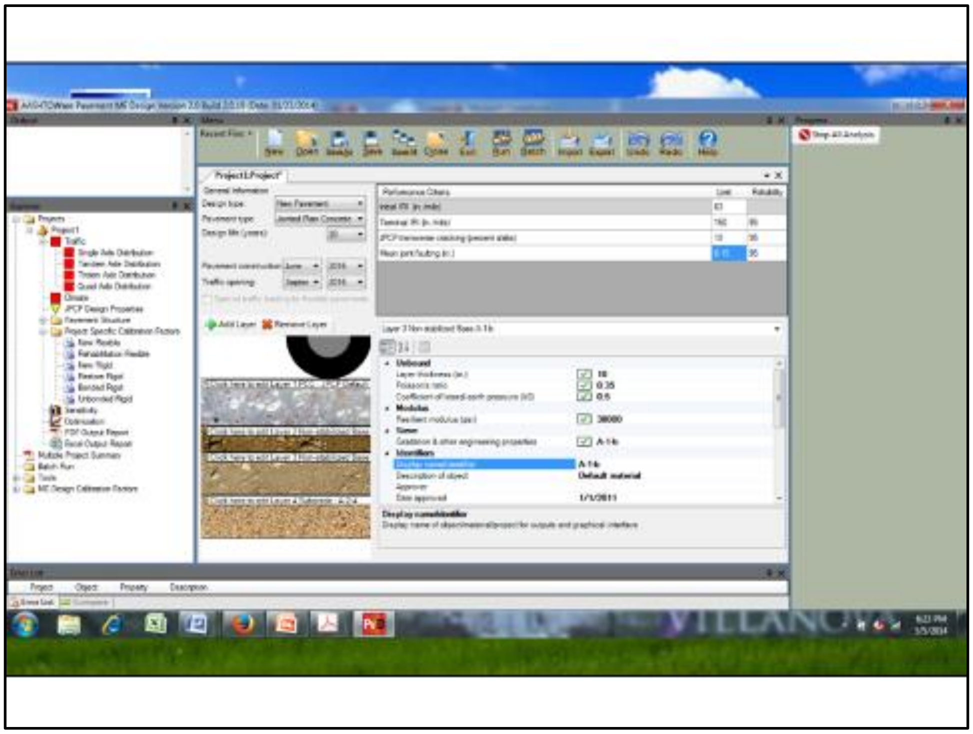
Accept default values.

Slide 54



Select Layer 3 (shown on the next screen).

Slide 55



This screen shows Layer 3 selected.

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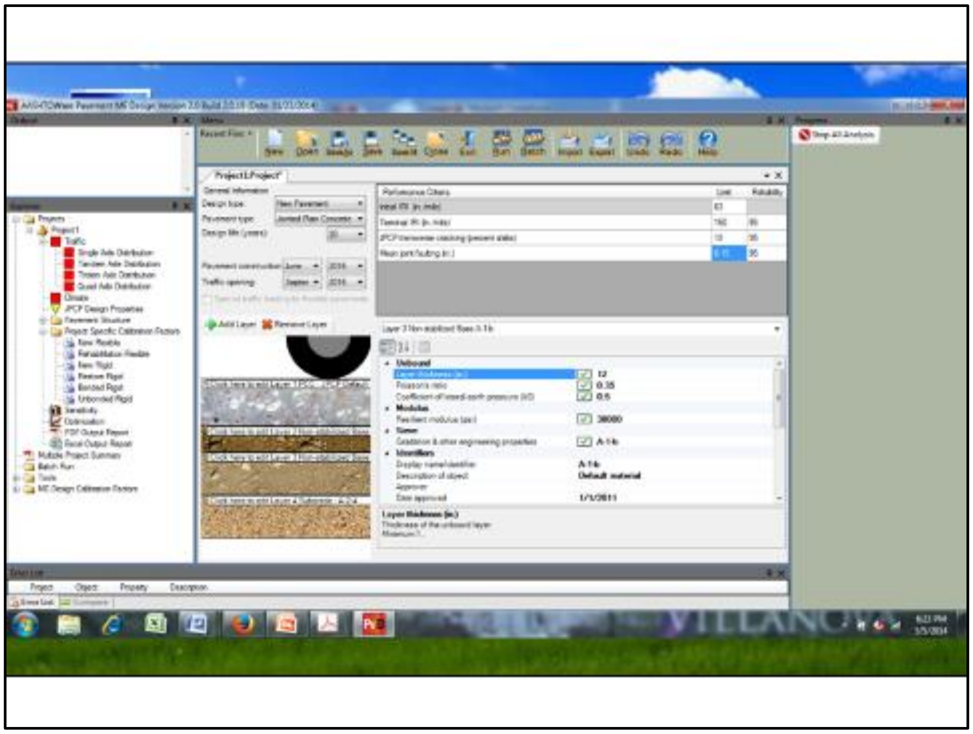
Slide 56



Layer 3 Non-stabilized Base:A-1-b

Unbound

Layer thickness (in.)	☑ 12
Poisson's ratio	☑ 0.35
Coefficient of lateral earth pressure (k0)	☑ 0.5

Modulus

Resilient modulus (psi)	☑ 38000

Sieve

Gradation & other engineering properties	☑ A-1-b

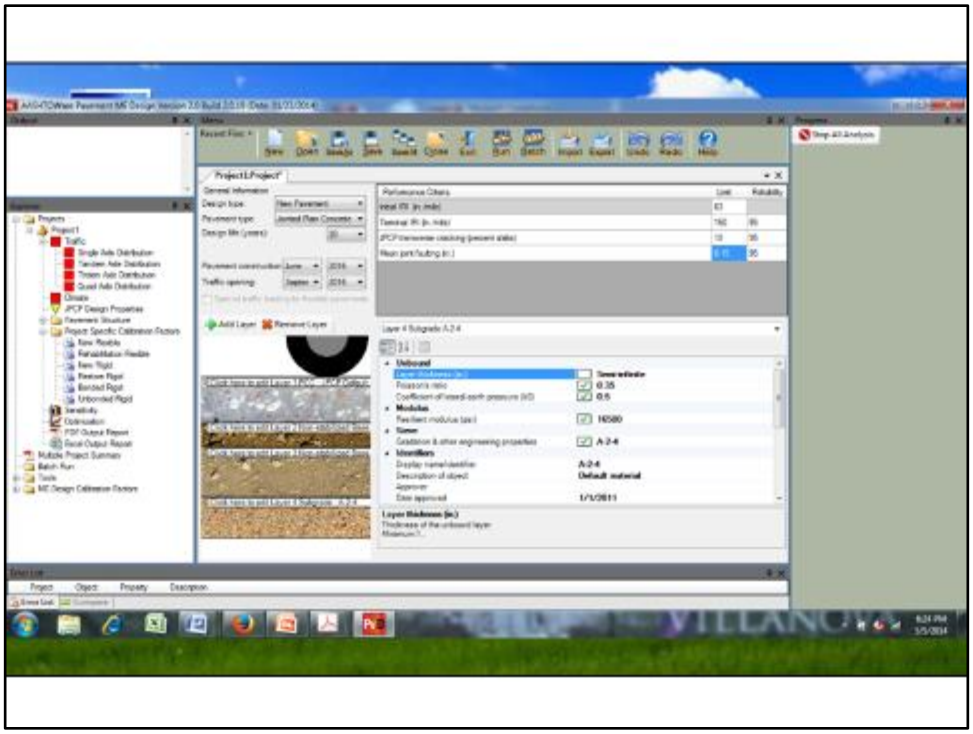
Identifiers

Display name/identifier	A-1-b
Description of object	Default material
Approver	
Date approved	1/1/2011

Layer thickness (in.)
Thickness of the unbound layer

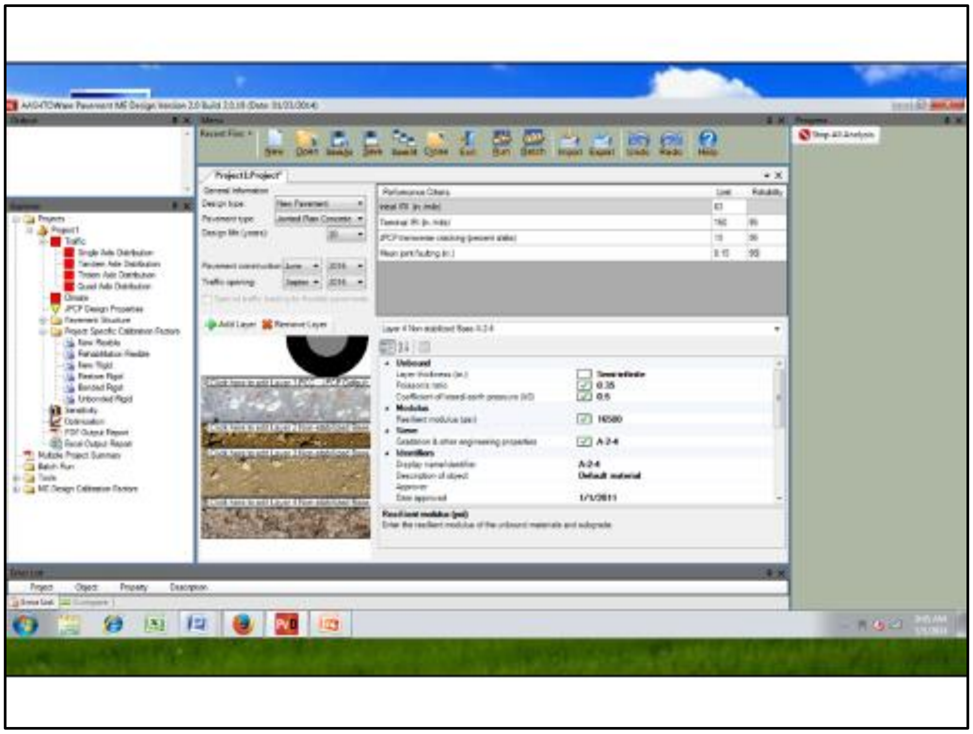
Adjust Layer Thickness and leave other inputs as default.

Slide 57



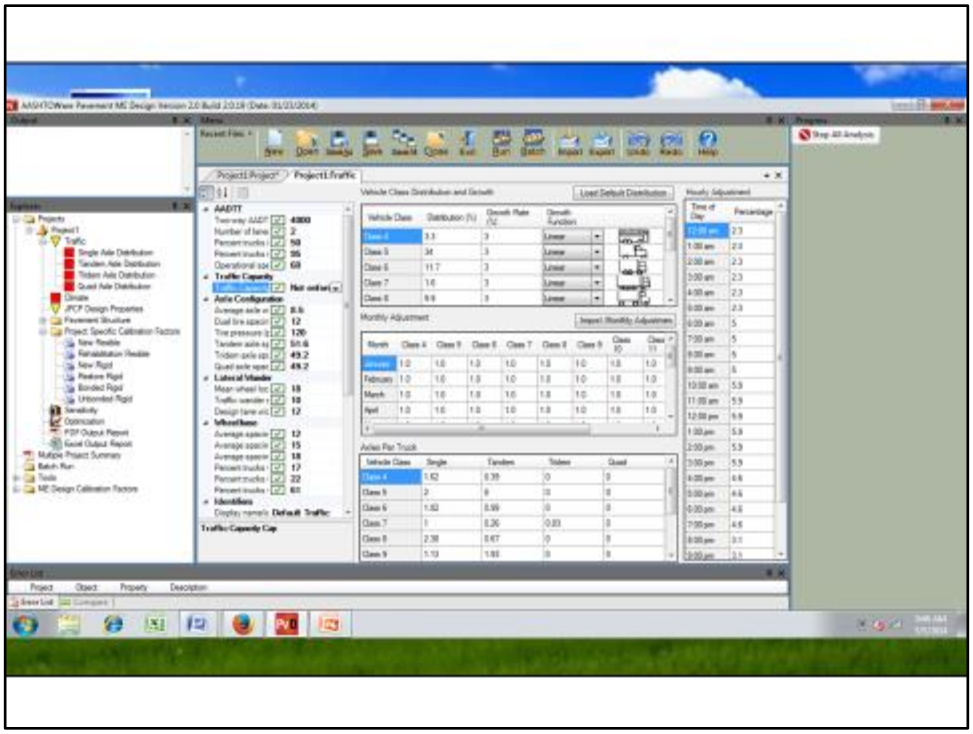
Select Layer 4 and then accept default values.

Slide 58



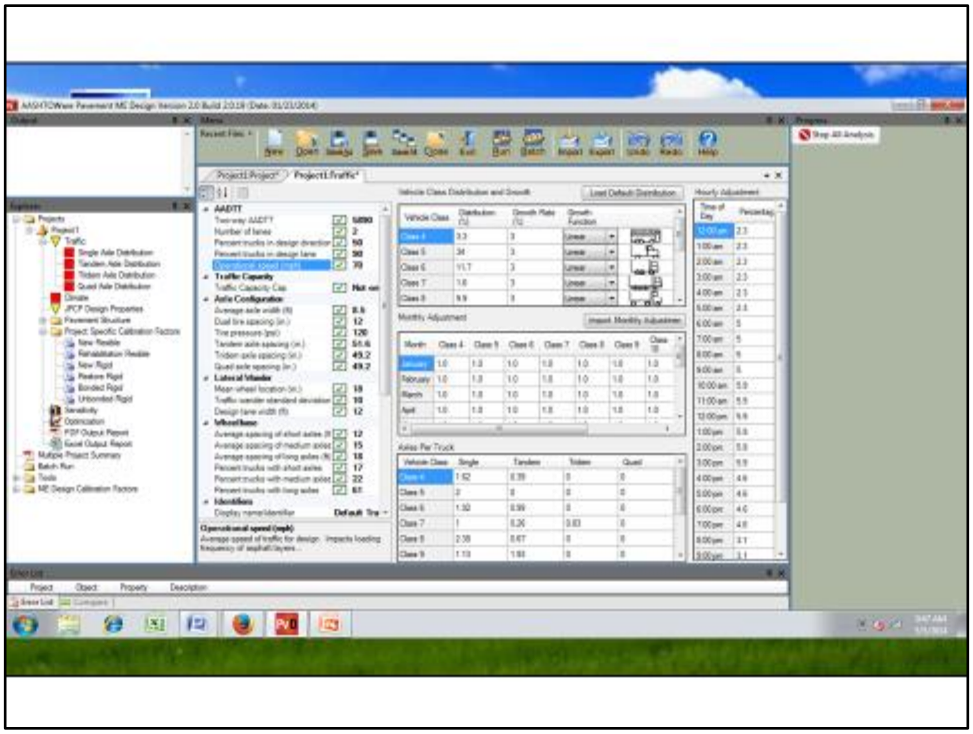
Select Traffic.

Slide 59



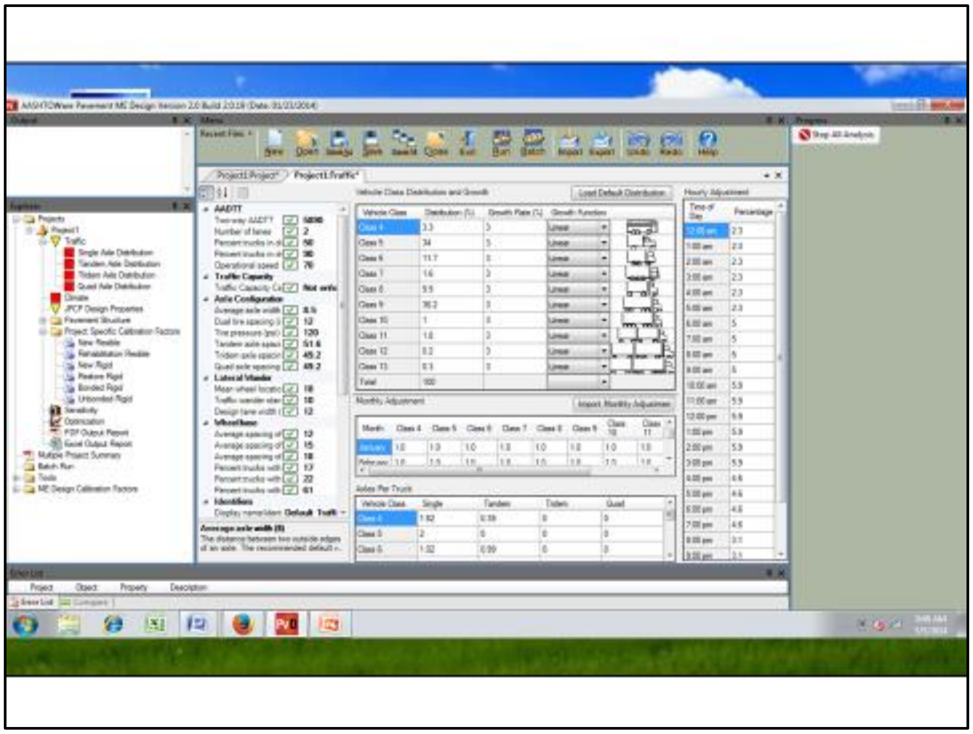
Adjust AADTT values.

Slide 60



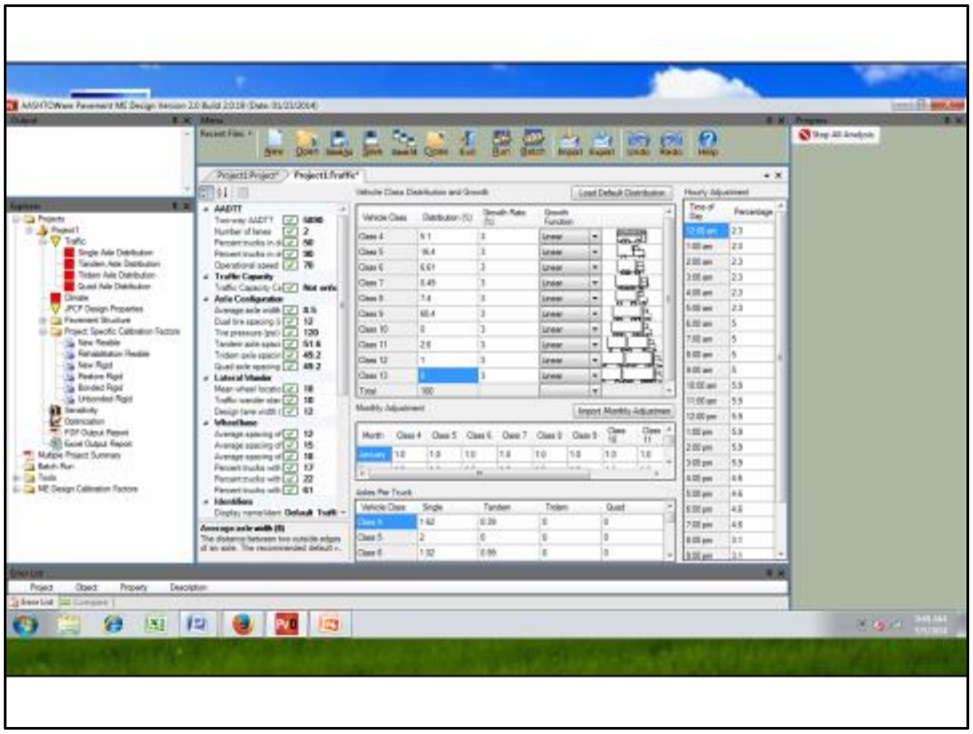
Select Vehicle Class Distribution and Growth.

Side 61



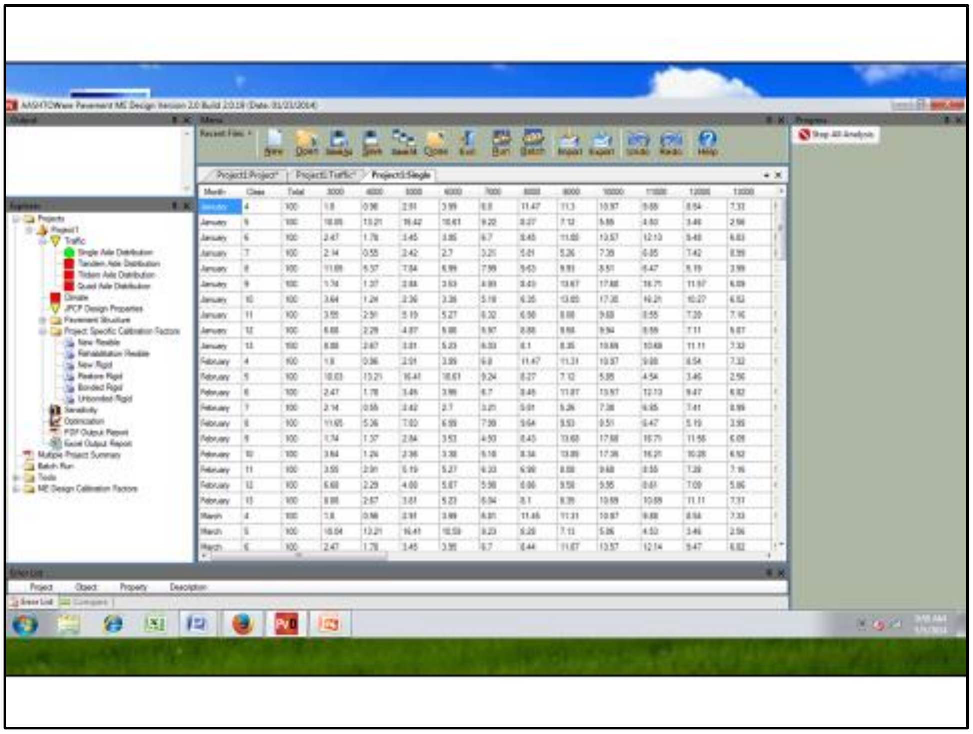
Adjust Distribution (shown on the next screen).

Slide 62



This screen shows Distribution that has been adjusted.

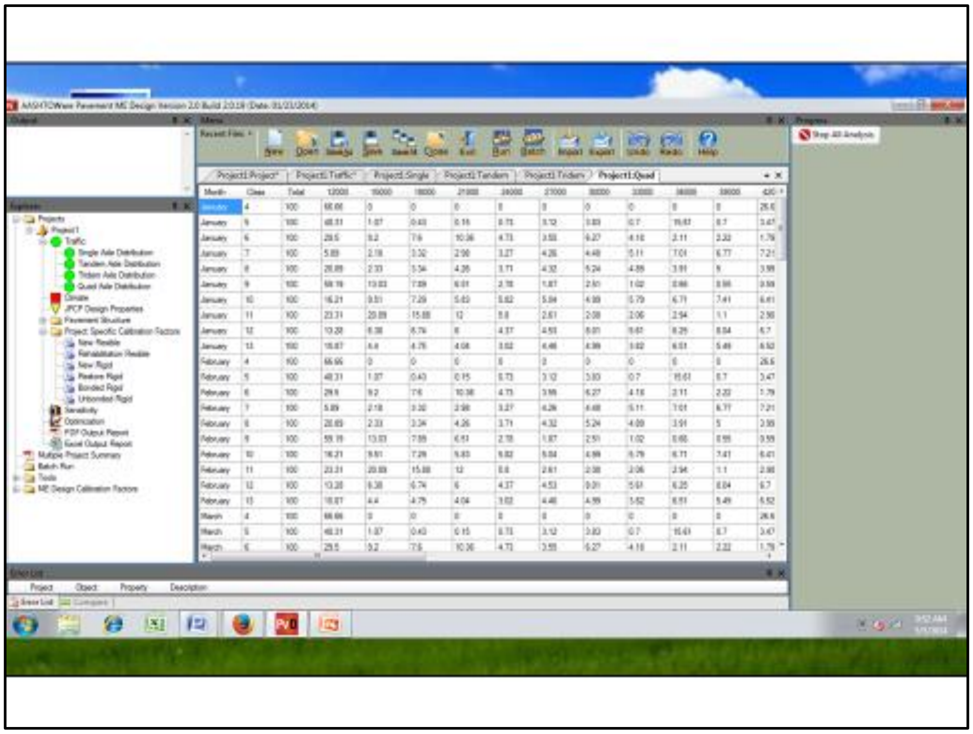
Slide 63



Double-click on each Axle Distribution under the Traffic to accept the default values.

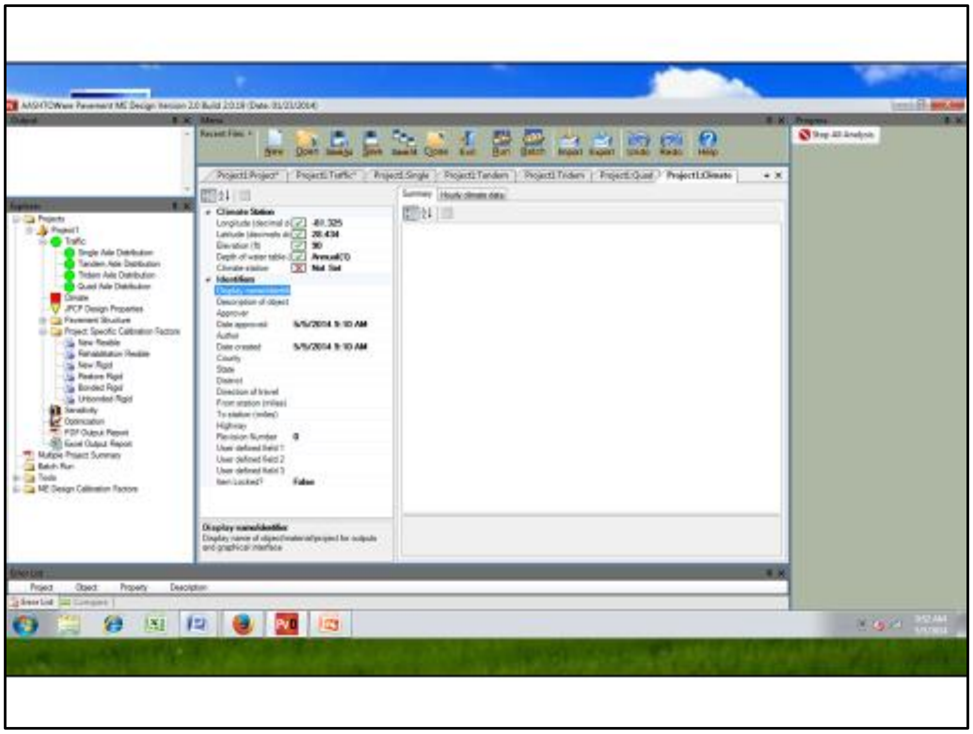
The icon next to each Distribution will turn green (shown on the next screen).

Slide 64



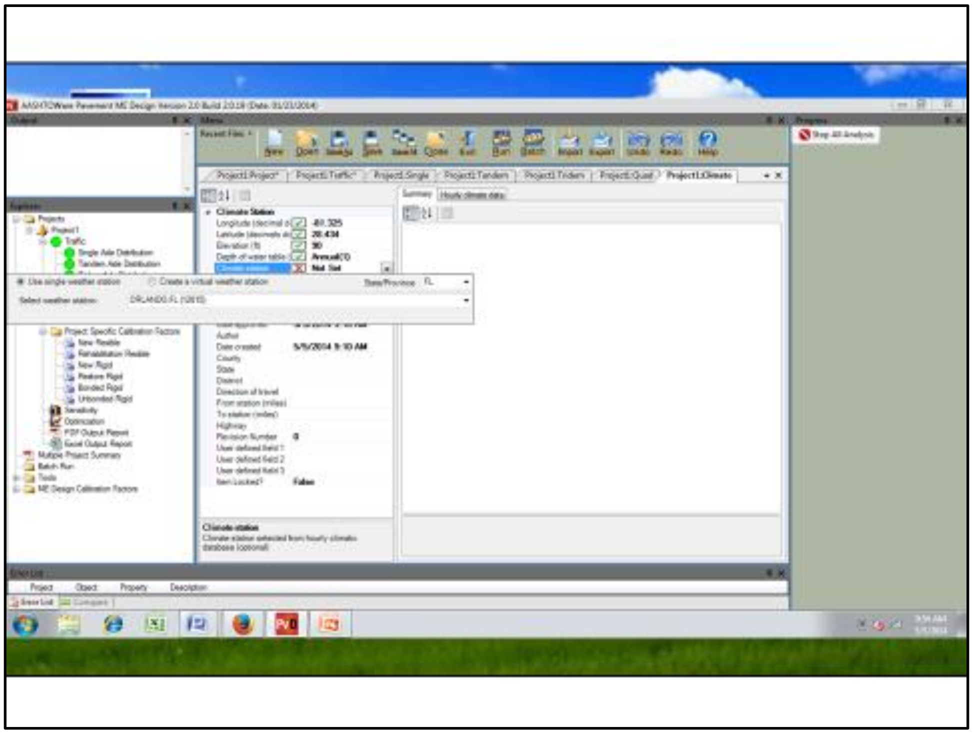
This screen shows the green circles next to each distribution in the Traffic.

Slide 65



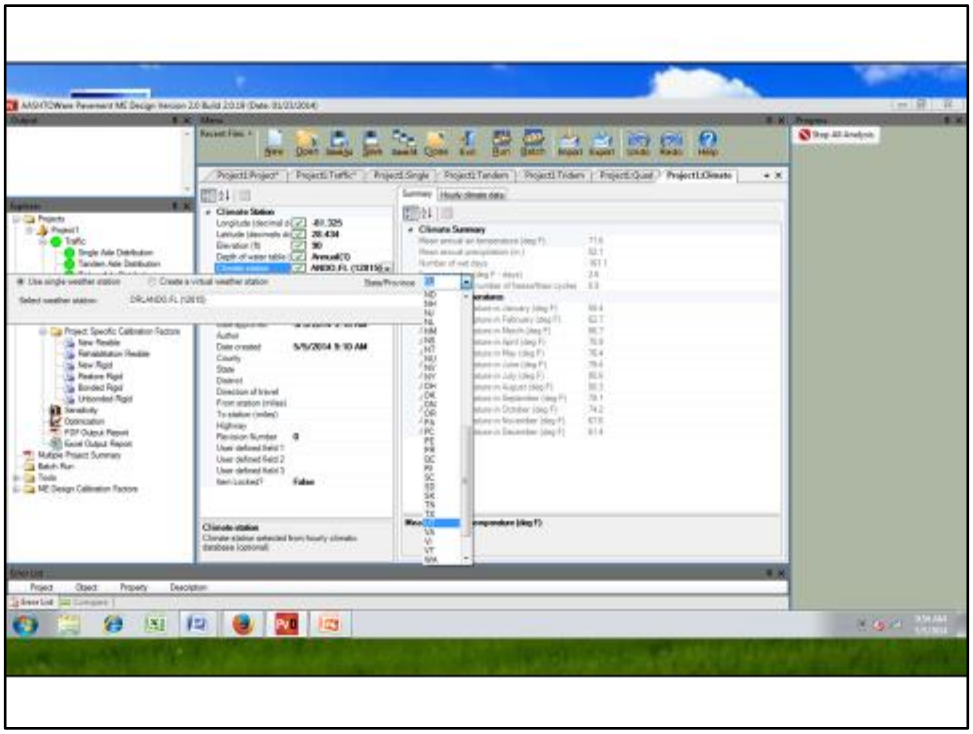
Select Climate.

Slide 66



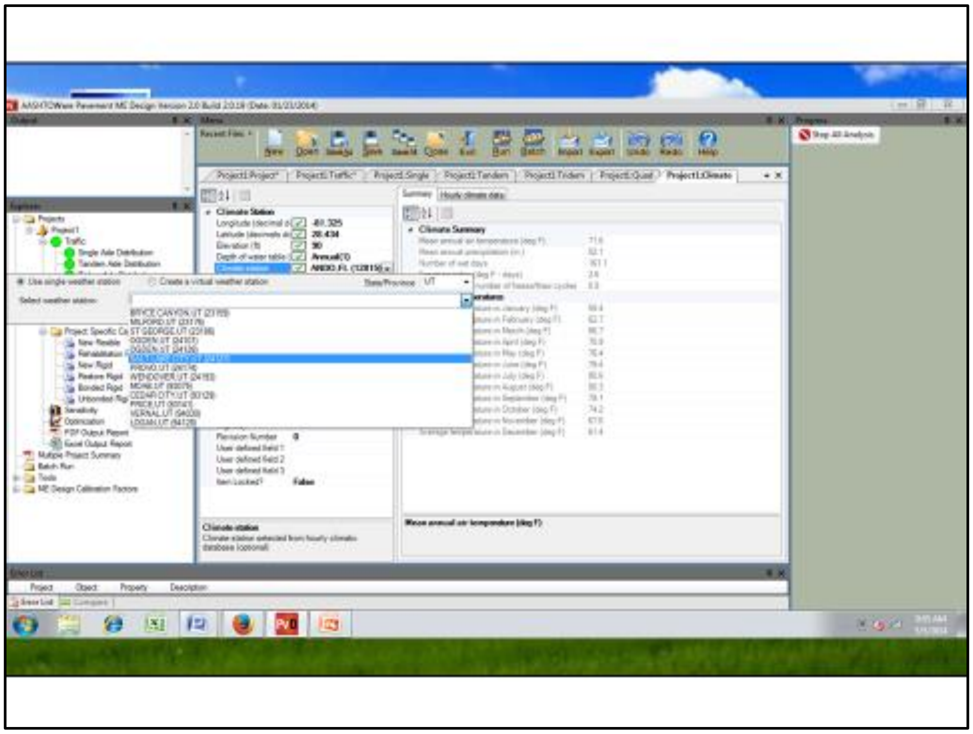
Select Climate Station. Then select State/Province to select a State.

Slide 67



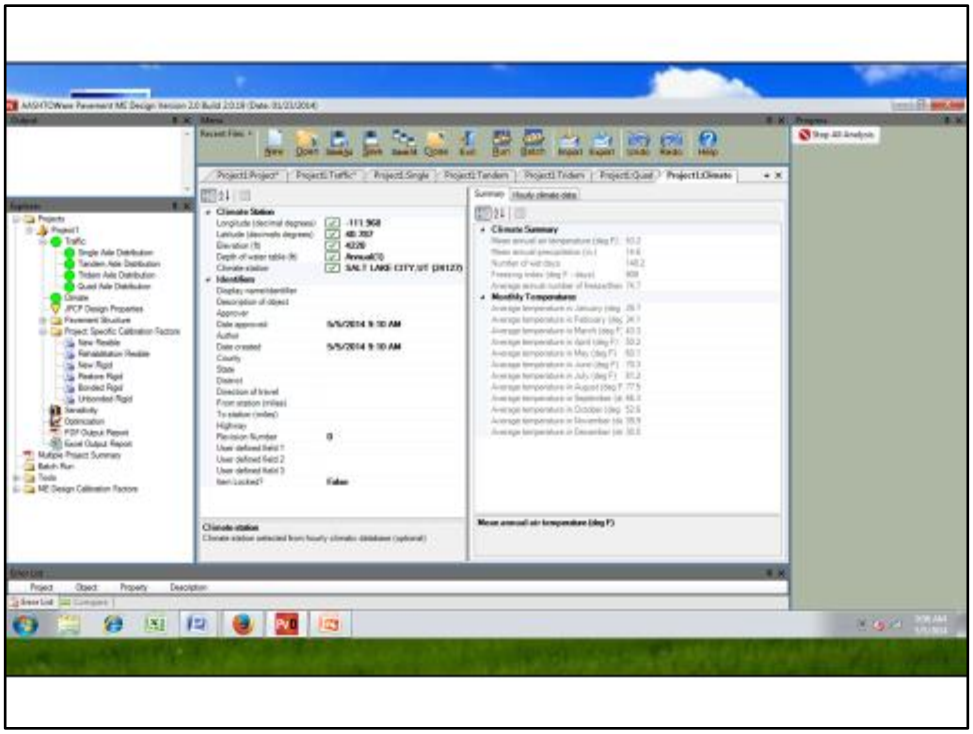
Select Utah.

Slide 68



Select Weather Station and select Salt Lake City.

Slide 69

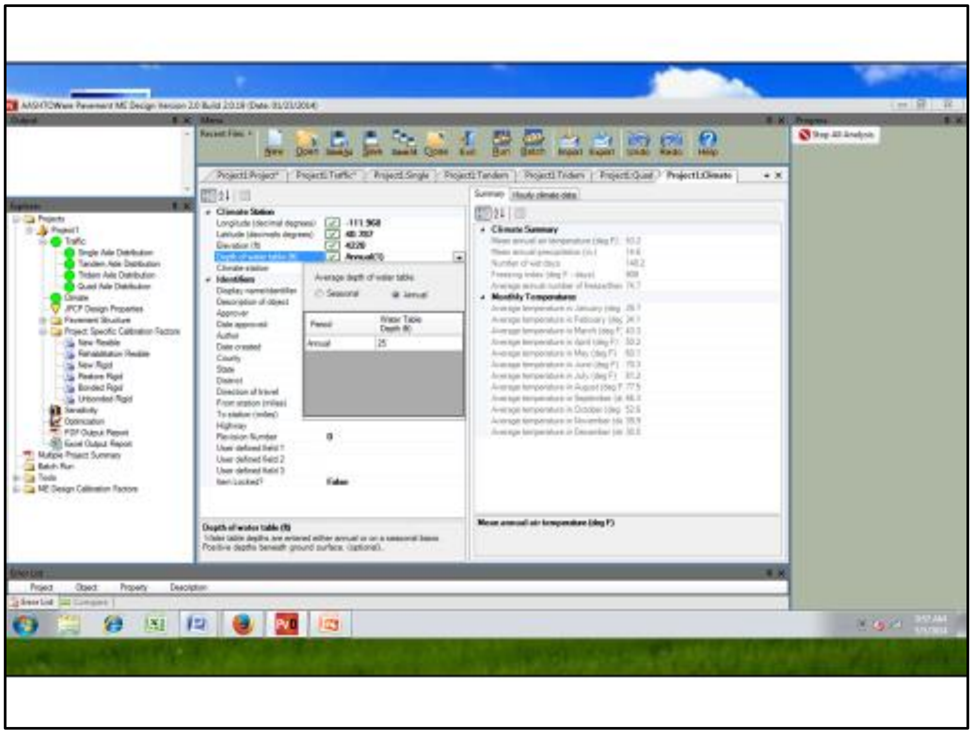


Climate Station
Longitude (decimal degrees) ☑ -111.968
Latitude (decimals degrees) ☑ 40.787
Elevation (ft) ☑ 4226
Depth of water table (ft) ☑ Annual(3)
Climate station ☑ SALT LAKE CITY,UT (24127)
Identifiers
Date approved 5/5/2014 9:10 AM
Date created 5/5/2014 9:10 AM
Revision Number 0
Item Locked? False

Climate station
Climate station selected from hourly climatic database (optional)

Select Depth of Water Table.

Slide 70



Climate Station
Longitude (decimal degrees) ☑ -111.968
Latitude (decimals degrees) ☑ 40.787
Elevation (ft) ☑ 4226
Depth of water table (ft) ☑ Annual(1)

Average depth of water table
○ Seasonal ● Annual

Period	Water Table Depth (ft)
Annual	25

Revision Number 0
Item Locked? False

Depth of water table (ft)
Water table depths are entered either annual or on a seasonal basis. Positive depths beneath ground surface. (optional).

Input the new value of 25 feet (shown on the next screen).

From NCHRP 1-37A Report: The water table represents the line below which soils are completely saturated. It is measured from the top of the subgrade. Water may seep upward from a high groundwater table due to capillary suction or vapor movements, or it may flow laterally from the pavement edges and side ditches. Therefore, adequate side ditches with flow lines beneath the pavement structure are necessary.

The groundwater table depth is intended to be either the best estimate of the annual average depth or the seasonal average depth (a value for each of the four seasons of the year). At input Level 1, it could be determined from profile characterization borings prior to design. At input Level 3, an estimate of the annual average value or the seasonal averages can be provided. A potential source to obtain Level 3 estimates is the county soil reports produced by the National Resources Conservation Service.

It is important to recognize that this parameter plays a significant role in the overall accuracy of the foundation/pavement moisture contents and hence, equilibrium modulus values. Every attempt should be made to characterize it as accurately as possible.

http://www.state.nj.us/transportation/eng/documents/RDM/sec10.shtm

Road ditches are channels adjacent to the roadway used to intercept runoff and groundwater occurring from areas within and adjacent to the right-of-way and to carry this flow to drainage structures or to natural waterways.

If water table is less than 5 feet below the top of the subgrade, then frost susceptibility is a concern.

For example, if the ditch line is 6 feet, the water table is suppressed, therefore, even when the geotech report shows the water table as 2 feet, but because of the pavement is in fill section and the ditch line is 6 feet, then the water table depth should be 6 feet.

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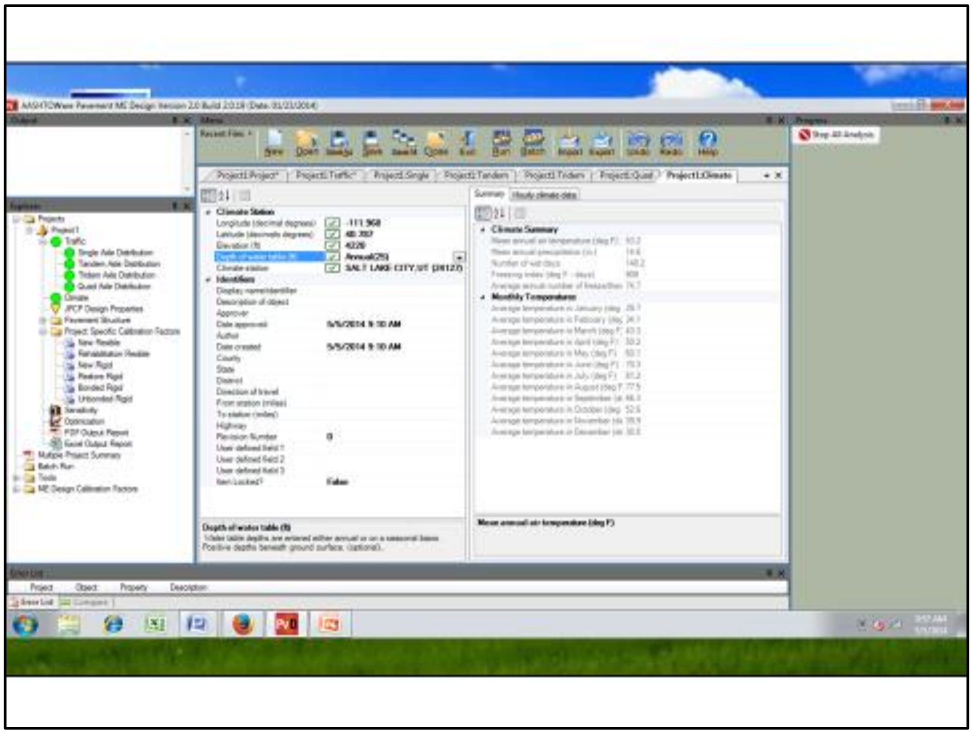
Slide 71



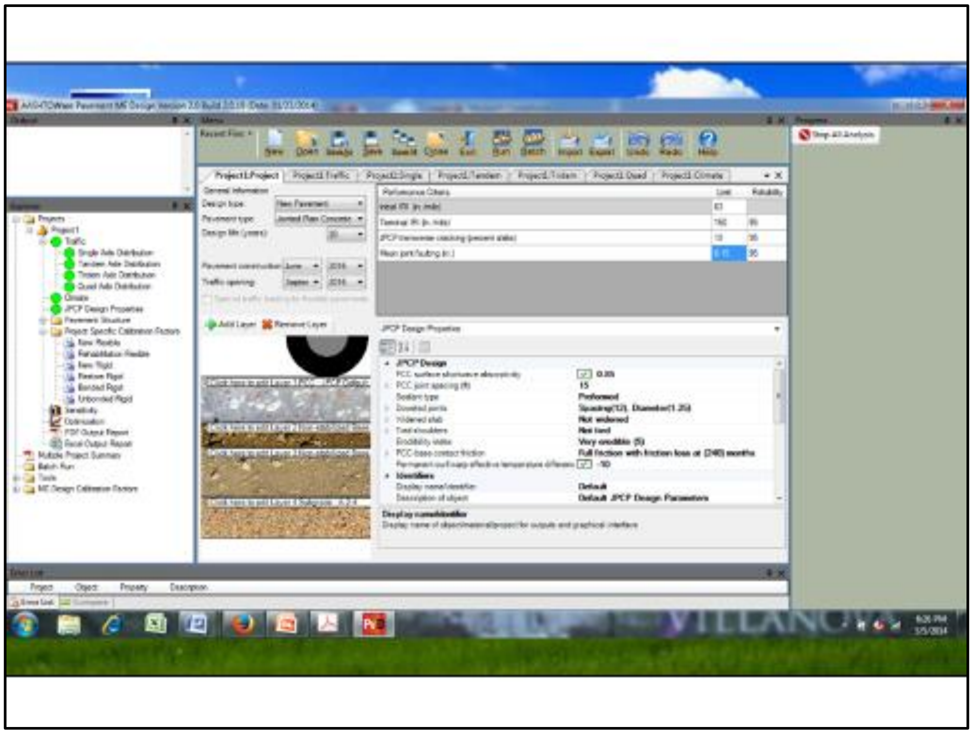
Climate Station		
Longitude (decimal degrees)	☑	-111.968
Latitude (decimals degrees)	☑	40.787
Elevation (ft)	☑	4228
Depth of water table (ft)	☑	Annual(25)
Climate station	☑	SALT LAKE CITY, UT (24127)
Identifiers		
Display name/identifier		
Description of object		
Approver		
Date approved		5/5/2014 9:10 AM
Author		
Date created		5/5/2014 9:10 AM
County		
State		
District		
Direction of travel		
From station (miles)		
To station (miles)		
Highway		
Revision Number		0
User defined field 1		
User defined field 2		
User defined field 3		
Item Locked?		False

Depth of water table (ft)
Water table depths are entered either annual or on a seasonal basis. Positive depths beneath ground surface. (optional).

Mean annual air temperature (deg F)

This screen shows the new value for Depth of Water Table (ft).

Slide 72



JPCP Design

PCC surface shortwave absorptivity: 0.85

PCC joint spacing (ft): 15

Sealant type: Preformed

Doweled joints: Spacing(12), Diameter(1.25)

Widened slab: Not widened

Tied shoulders: Not tied

Erodibility index: Very erodible (5)

PCC-base contact friction: Full friction with friction loss at (240) months

Permanent curl/warp effective temperature difference: -10

Identifiers

Display name/identifier: Default

Description of object: Default JPCP Design Parameters

Select JPCP Design Properties.

It should be noted that the thickness depends on constructability. Contractors can construct only in 0.5-inch increments. Also, the size of the dowel bars should be designed based on local practices. JPCP that is 7 inches thick cannot use 1.5-inch dowel to negate the faulting failure.

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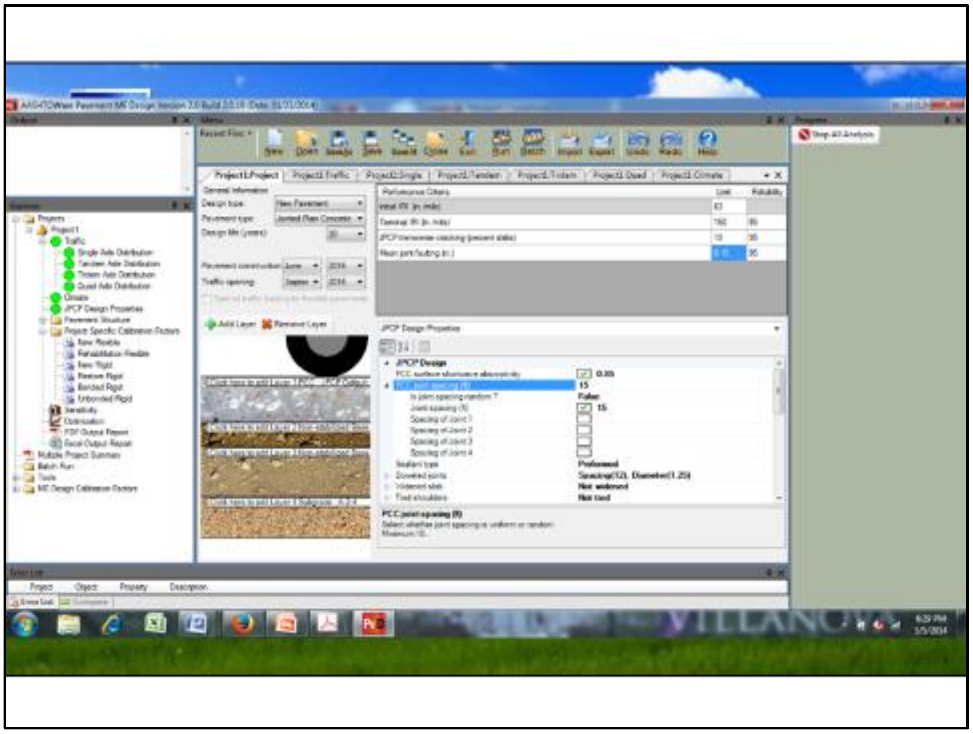
Slide 73



Select the small arrow next to PCC joint spacing to change it to 18 feet (shown on the next screen).

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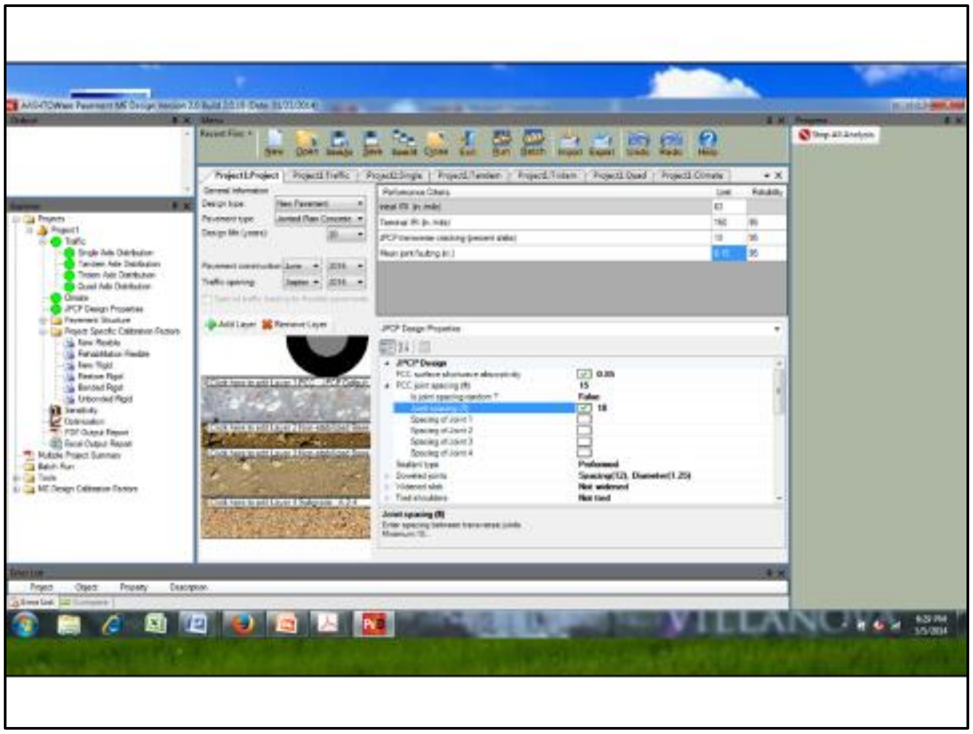
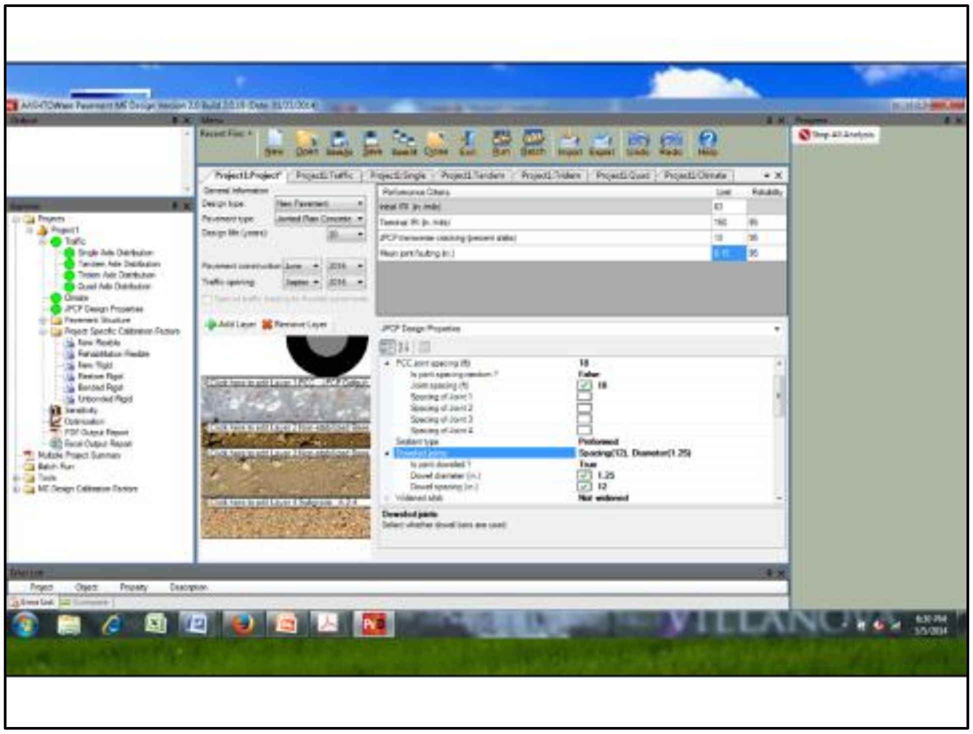
Slide 74



This screen shows PCC joint spacing of 18 feet.

Slide 75



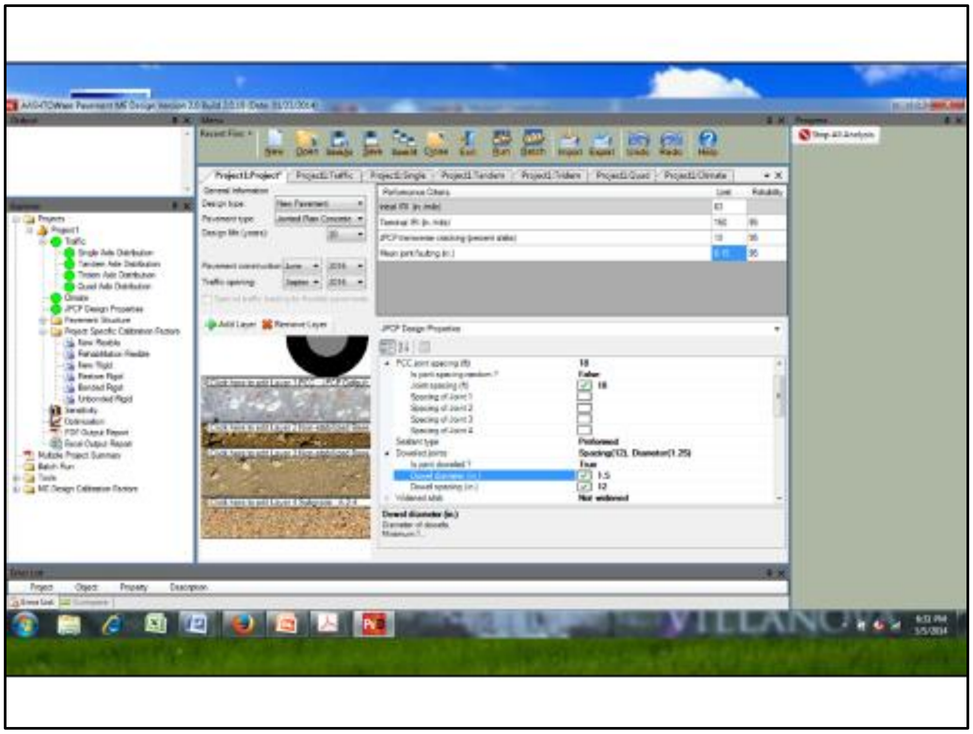
JPCP Design Properties

- PCC joint spacing (ft): 18
  - Is joint spacing random?: False
  - Joint spacing (ft): ☑ 18
  - Spacing of Joint 1: ☐
  - Spacing of Joint 2: ☐
  - Spacing of Joint 3: ☐
  - Spacing of Joint 4: ☐
- Sealant type: Preformed
- Doweled joints: Spacing(12), Diameter(1.25)
  - Is joint doweled?: True
  - Dowel diameter (in.): ☑ 1.25
  - Dowel spacing (in.): ☑ 12
- Widened slab: Not widened

Doweled joints
Select whether dowel bars are used

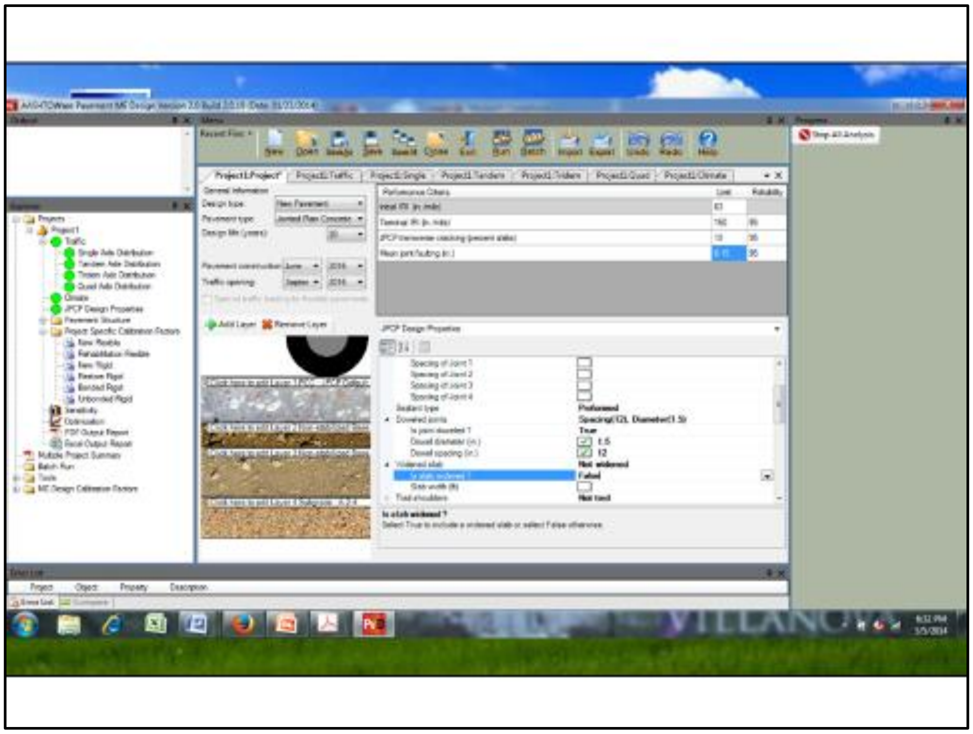
Select the small arrow next to Doweled Joints to change inputs (shown on the next screen).

Slide 76



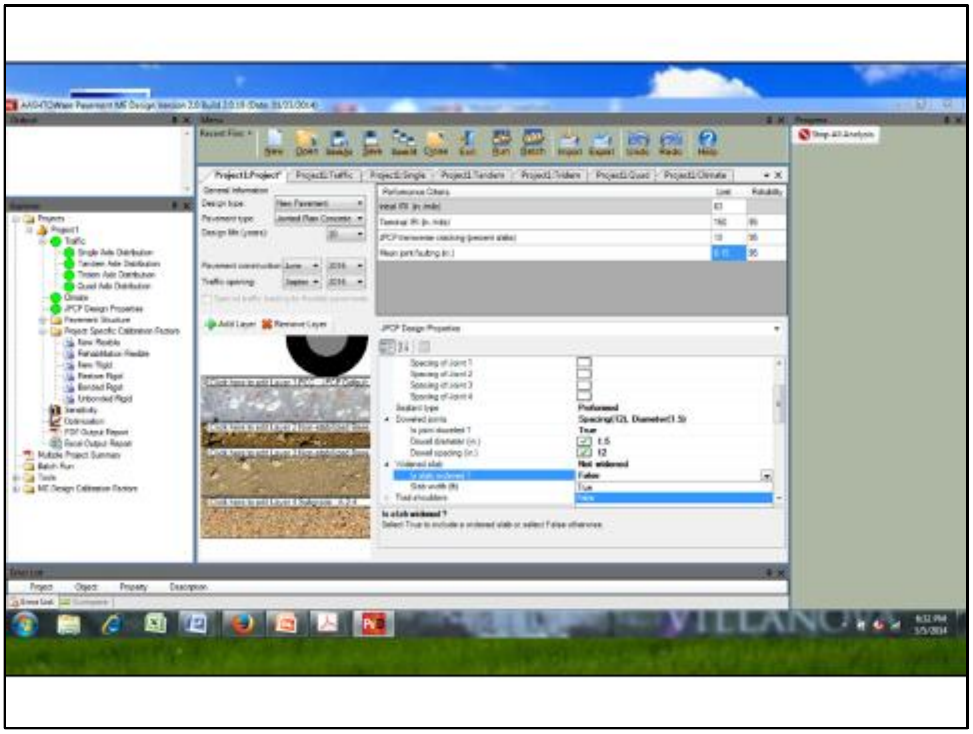
This screen shows the Doweled Joints inputs.

Slide 77



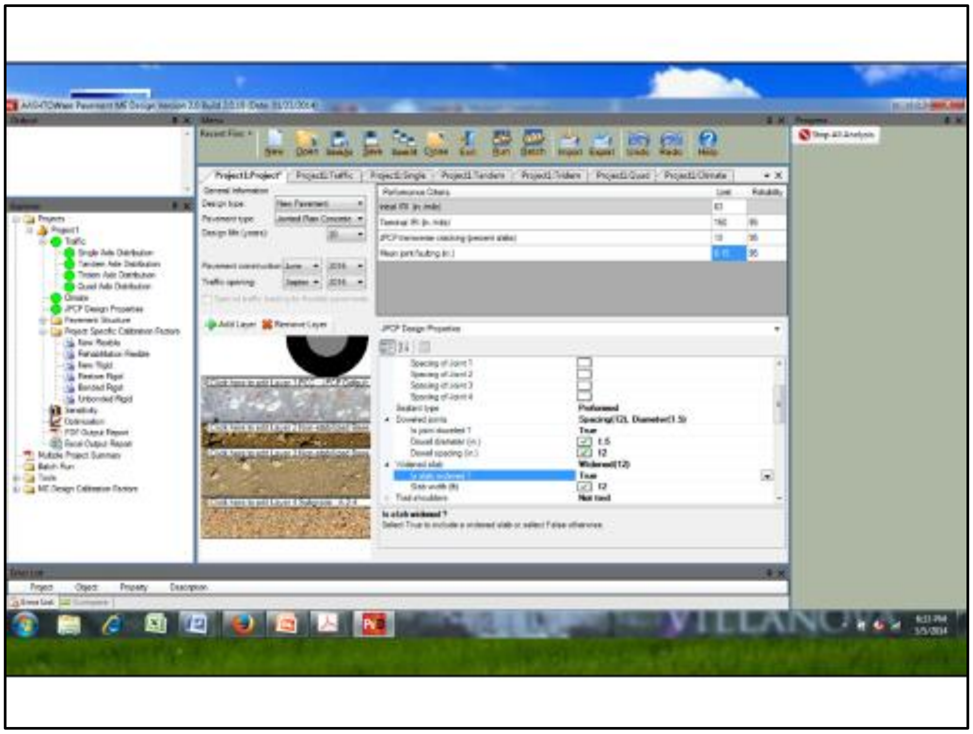
Select the small arrow next to Widened Slab to change inputs (shown on the next screen).

Slide 78



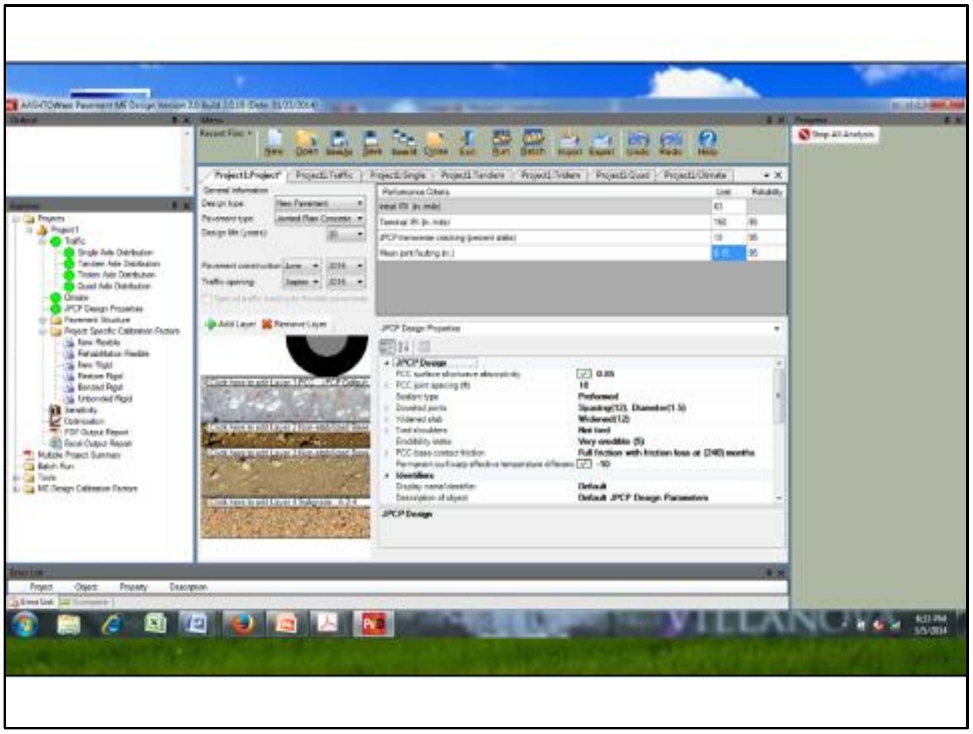
Select True (shown on the next screen).

Slide 79



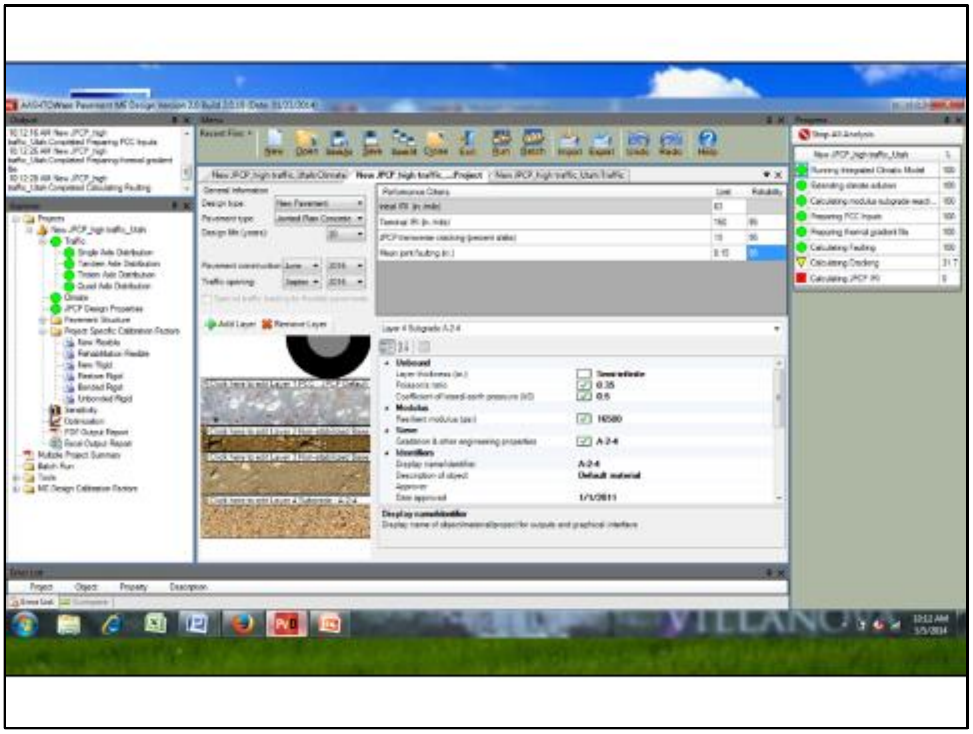
This screen shows that True has been selected.

Slide 80



Leave remaining values as default.

Slide 81



Save the project by selecting Save. Select Run to run the analysis.

Slide 82

Software Demonstration for Rigid Pavement

PvD
AASHTOWare
Pavement
ME Design
AASHTO

End Demonstration

New Rigid Pavement Example

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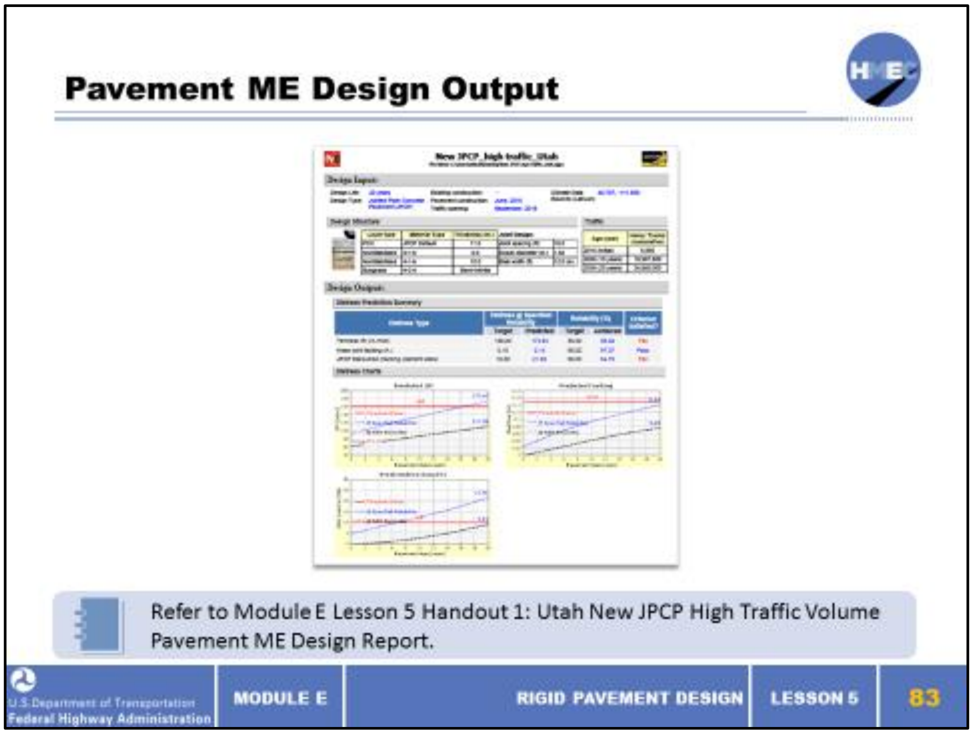
Federal Highway Administration
MODULE E
RIGID PAVEMENT DESIGN
LESSON 5
82

Slide 83



Pavement ME Design Output

Refer to Module E Lesson 5 Handout 1: Utah New JPCP High Traffic Volume Pavement ME Design Report.

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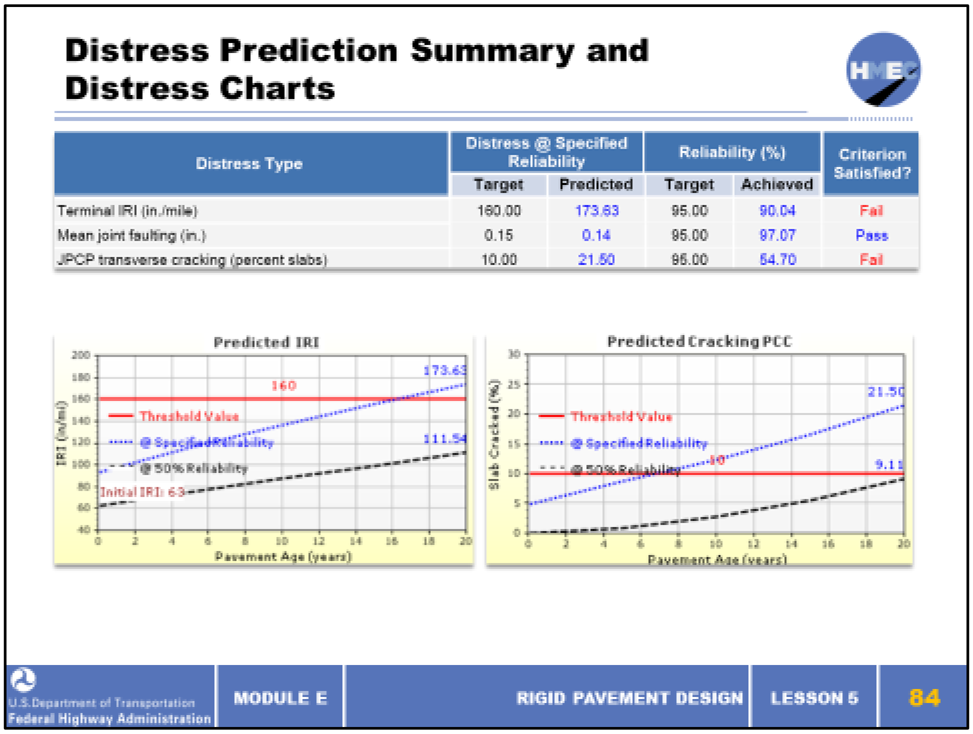
MODULE E
RIGID PAVEMENT DESIGN
LESSON 5
83

Perform an evaluation of Pavement ME Design new rigid pavement design and suggest design alterations based on material properties, to consider and try when the pavement's intended service life is not met. This screen capture shows what the Pavement ME Design software pulls up automatically in an Excel or PDF format for users.

Slide 84



Distress Prediction Summary and Distress Charts

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	173.63	95.00	90.04	Fail
Mean joint faulting (in.)	0.15	0.14	95.00	97.07	Pass
JPCP transverse cracking (percent slabs)	10.00	21.50	95.00	54.70	Fail

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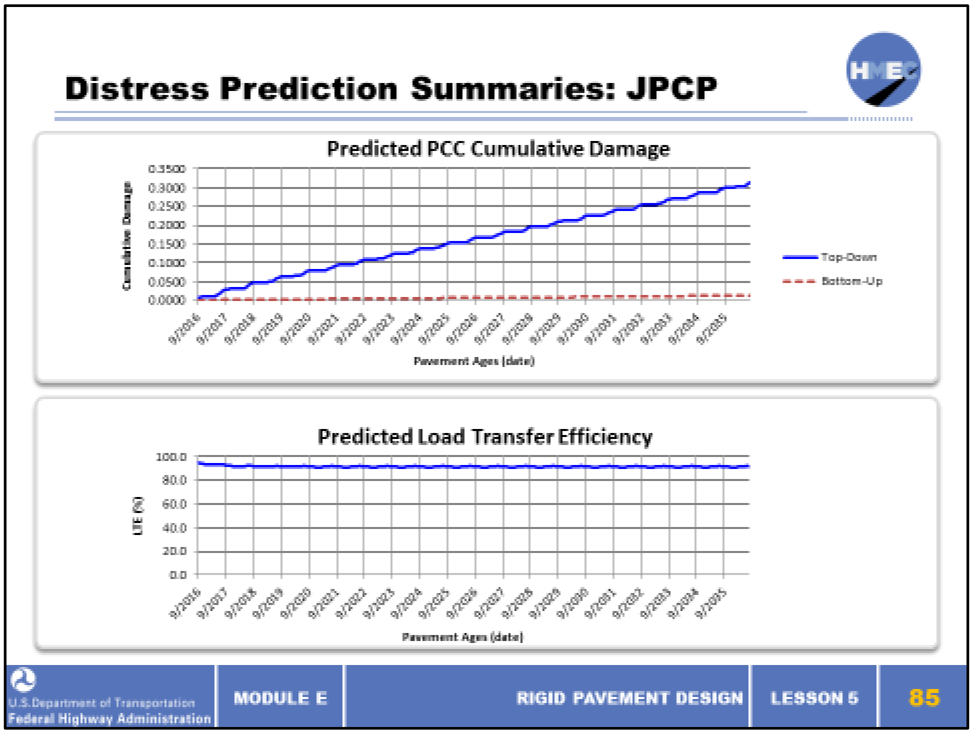
RIGID PAVEMENT DESIGN
LESSON 5
84

The purpose of the screen is to help participants interpret output from the new rigid pavement analysis (JPCP).

The cracking predicted at reliability level (95%) failed the threshold at seven years; however, at 50% reliability, it made it to 20 years. The IRI tracks closely with the cracking although because the faulting did not fail, the IRI threshold is exceeded much later than for the transverse cracking.

In terms of the IRI, the minimum construction smoothness specifications can take precedence over the starting point recommended from the MEPDG Manual of Practice for a starting point for the IRI predictions at higher reliability levels, as in the case of flexible pavements.

Slide 85



Distress Prediction Summaries: JPCP

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Federal Highway Administration | MODULE E | RIGID PAVEMENT DESIGN | LESSON 5 | 85

The purpose of the screen is to help participants interpret output from the new rigid pavement analysis (JPCP), beyond just the plots to introduce again the LTE and cumulative damage output.

The cumulative damage (both bottom-up and top-down) can be observed in the output of the Pavement ME Design software, along with the load transfer efficiency of the dowels. There is relatively minor damage occurring from the bottom-up; however, there is a steady increase in damage over time from the top down. The load transfer efficiency remains very good over the life of the pavement (doesn’t dip below 90%), which is a positive performance factor for the trial design and may further explain the minimal impact of faulting.

When comparing the top-down and bottom-up cracking trends, we can look back at rigid pavement behavior. Basically at nighttime, the bottom portion of the surface layer is hotter than the upper portion. This reduces the top-down FC life of the pavement. The opposite occurs during the day. In addition, it is very dry in Utah, and as a result, the shrinkage rate at the surface of the rigid pavement is much more pronounced than at the bottom of the pavement. This will also accelerate the development of fatigue cracks at the surface of the concrete pavement.

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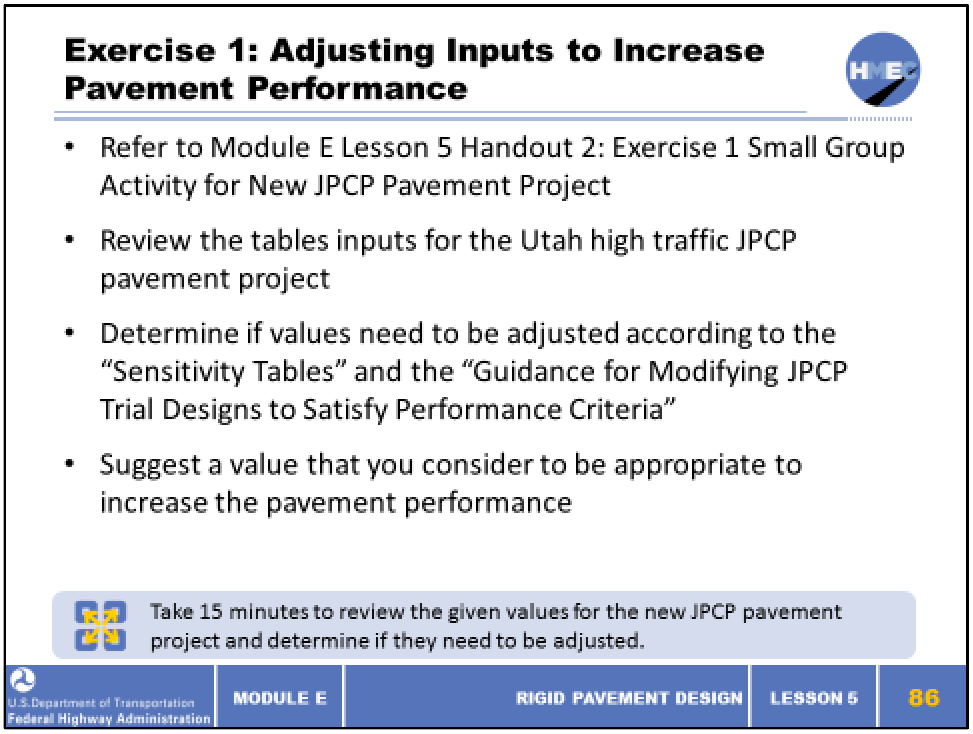
Slide 86



Exercise 1: Adjusting Inputs to Increase Pavement Performance

- Refer to Module E Lesson 5 Handout 2: Exercise 1 Small Group Activity for New JPCP Pavement Project
- Review the tables inputs for the Utah high traffic JPCP pavement project
- Determine if values need to be adjusted according to the "Sensitivity Tables" and the "Guidance for Modifying JPCP Trial Designs to Satisfy Performance Criteria"
- Suggest a value that you consider to be appropriate to increase the pavement performance

Take 15 minutes to review the given values for the new JPCP pavement project and determine if they need to be adjusted.

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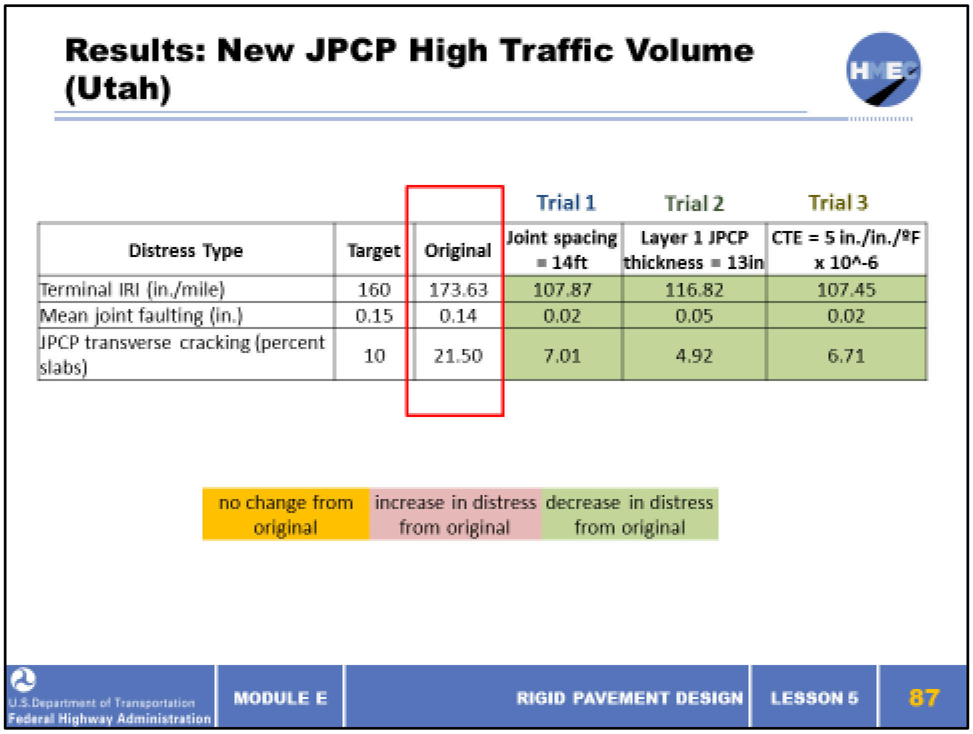
MODULE E | RIGID PAVEMENT DESIGN | LESSON 5 | 86

Slide 87



Results: New JPCP High Traffic Volume (Utah)

			Trial 1	Trial 2	Trial 3
Distress Type	Target	Original	Joint spacing = 14ft	Layer 1 JPCP thickness = 13in	CTE = 5 in./in./ºF x 10^-6
Terminal IRI (in./mile)	160	173.63	107.87	116.82	107.45
Mean joint faulting (in.)	0.15	0.14	0.02	0.05	0.02
JPCP transverse cracking (percent slabs)	10	21.50	7.01	4.92	6.71

no change from original	increase in distress from original	decrease in distress from original

U.S. Department of Transportation Federal Highway Administration MODULE E RIGID PAVEMENT DESIGN LESSON 5 87

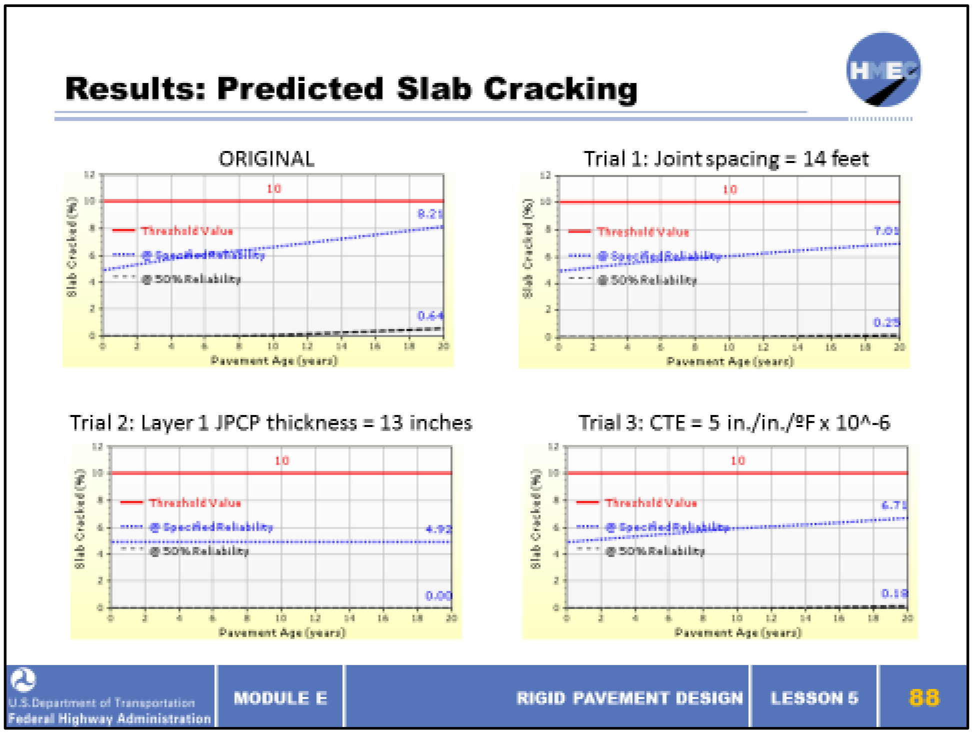
This table shows the results of three Trials on the new design for Utah high-volume rigid pavement

The first trial decreased the rigid pavement joint spacing down to 14-ft and the effect was that there was improvement in all distresses, as compared to the Original.

The second trial increased the JPCP thickness to 13 inches and the effect was more pronounced in terms of reducing distresses.

The third trial decreased the coefficient of thermal expansion CTE of the JPCP to 5.0 and the resulting impact on distresses is nearly identical to that of Trial 1 and improved performance.

Slide 88



Results: Predicted Slab Cracking

ORIGINAL

Trial 1: Joint spacing = 14 feet

Trial 2: Layer 1 JPCP thickness = 13 inches

Trial 3: CTE = 5 in./in./ºF x 10^-6

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MODULE E

RIGID PAVEMENT DESIGN

LESSON 5

88

These plots show the percentage of slab cracking predicted for the Original JPCP pavement structure as well as the three trials described in the previous slide.

The plots indicate the amount of slab cracking predicted at 50% reliability (black line), the threshold criteria for slab cracking (red line), and the amount of slab cracking predicted at the specified reliability of 95% (blue line).

The results show that there is significant improvement in cracking by increasing the thickness of the JPCP layer. A modest improvement in cracking was observed with the use of a lower CTE value and shorter joint spacing.

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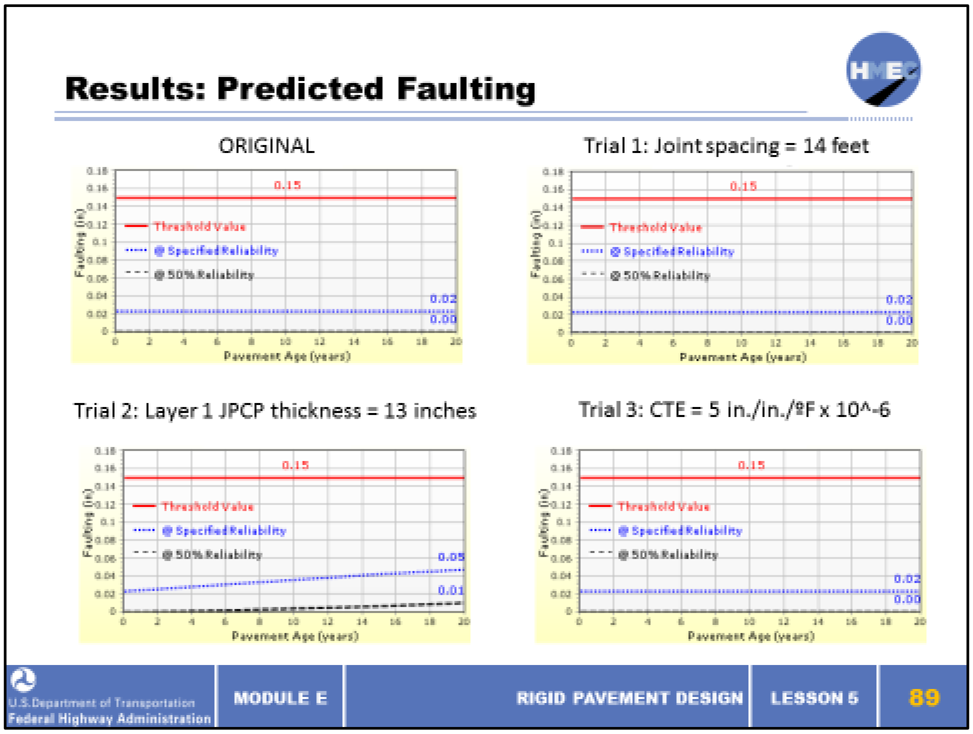
Slide 89



Results: Predicted Faulting

ORIGINAL

Trial 1: Joint spacing = 14 feet

Trial 2: Layer 1 JPCP thickness = 13 inches

Trial 3: CTE = 5 in./in./ºF x 10^-6

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MODULE E | RIGID PAVEMENT DESIGN | LESSON 5 | 89

These plots show the amount of faulting (in inches) predicted for the Original JPCP pavement structure as well as the three trials described in a previous slide.

The plots indicate the amount of faulting predicted at 50% reliability (black line), the threshold criteria for faulting (red line), and the amount of faulting predicted at the specified reliability of 95% (blue line).

The results show that there is a slight increase in faulting when the JPCP layer thickness increased. No change in performance was observed with the use of a lower CTE value or shorter joint spacing.

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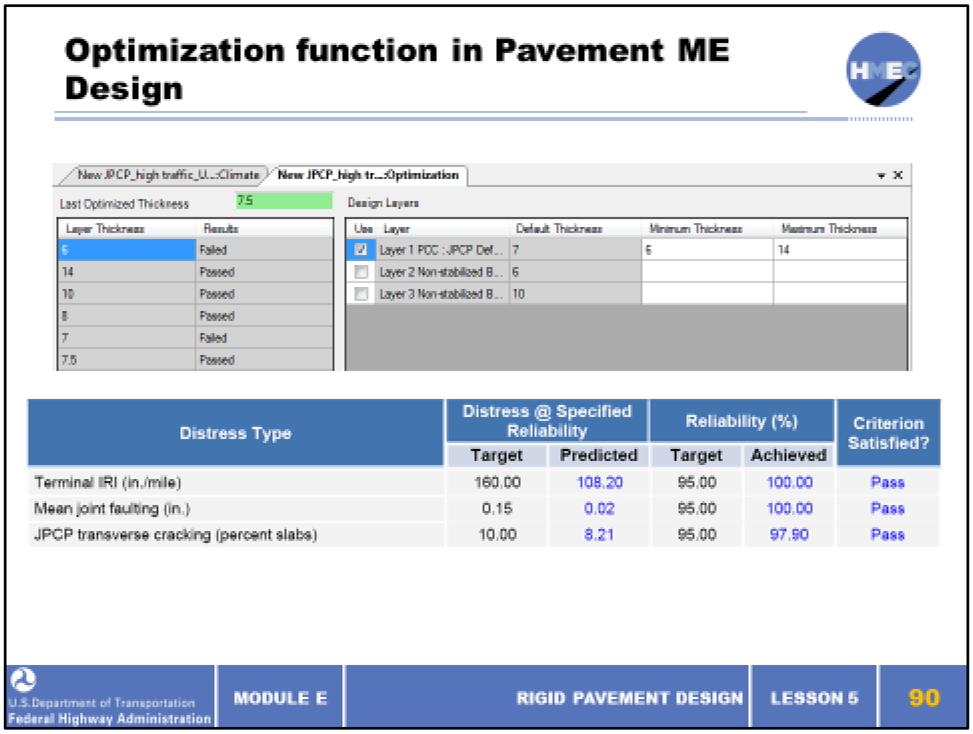
Slide 90



Optimization function in Pavement ME Design

New JPCP_high traffic_U...:Climate | New JPCP_high tr...:Optimization

Last Optimized Thickness: 7.5

Layer Thickness	Results
6	Failed
14	Passed
10	Passed
8	Passed
7	Failed
7.5	Passed

Design Layers

Use	Layer	Default Thickness	Minimum Thickness	Maximum Thickness
☑	Layer 1 PCC : JPCP Def...	7	6	14
☐	Layer 2 Non-stabilized B...	6		
☐	Layer 3 Non-stabilized B...	10		

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	108.20	95.00	100.00	Pass
Mean joint faulting (in.)	0.15	0.02	95.00	100.00	Pass
JPCP transverse cracking (percent slabs)	10.00	8.21	95.00	97.90	Pass

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MODULE E | RIGID PAVEMENT DESIGN | LESSON 5 | 90

The purpose of this screen is to introduce the optimization function available in the pavement ME design software. This is available for JPCP pavements only.

The optimization was performed after changing the slab width to 13 feet first. The output was from using 8-inch PCC. The optimization function works by the user selecting a parameter to optimize on (a layer thickness) and a range of values (max and min) to calculate the pavement performance. The optimization ceases once all performance criteria are satisfied (all pass)

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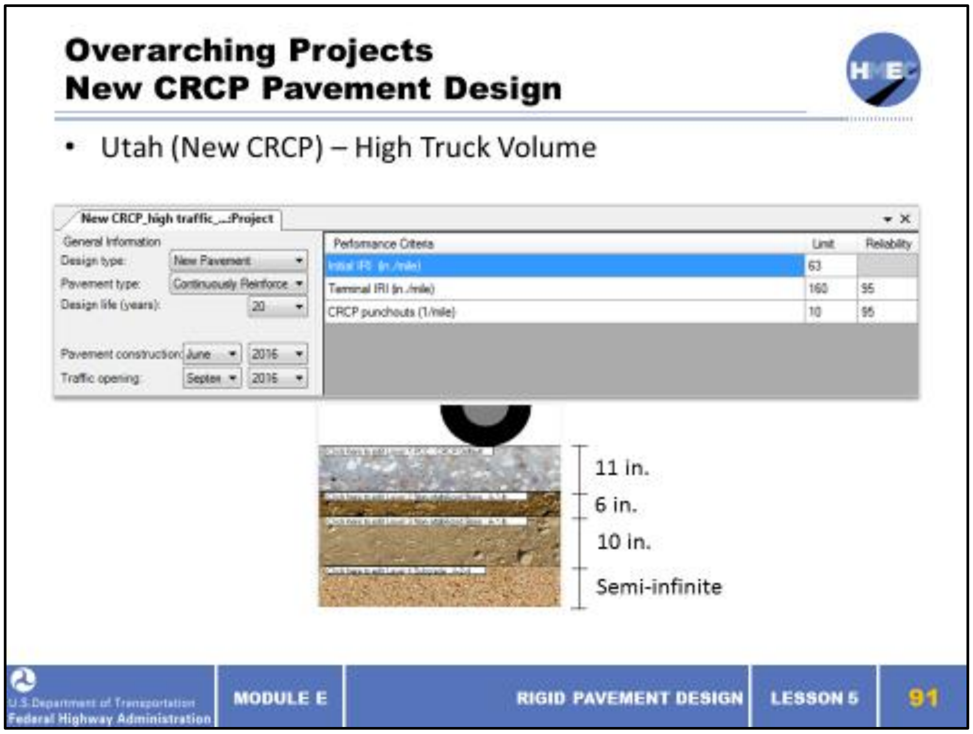
Slide 91



Overarching Projects
New CRCP Pavement Design

- Utah (New CRCP) – High Truck Volume

New CRCP_high traffic_...:Project

General Information

Design type: New Pavement

Pavement type: Continuously Reinforce

Design life (years): 20

Pavement construction: June 2016

Traffic opening: Septem 2016

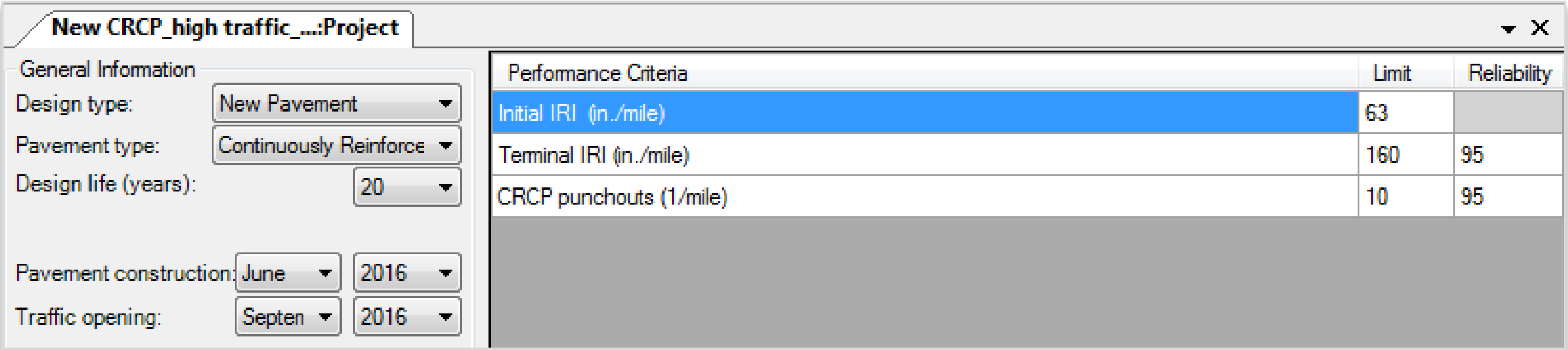
Performance Criteria	Limit	Reliability
Initial IRI (in./mile)	63	
Terminal IRI (in./mile)	160	95
CRCP punchouts (1/mile)	10	95

11 in.

6 in.

10 in.

Semi-infinite



New CRCP_high traffic_...:Project

General Information

Design type: New Pavement

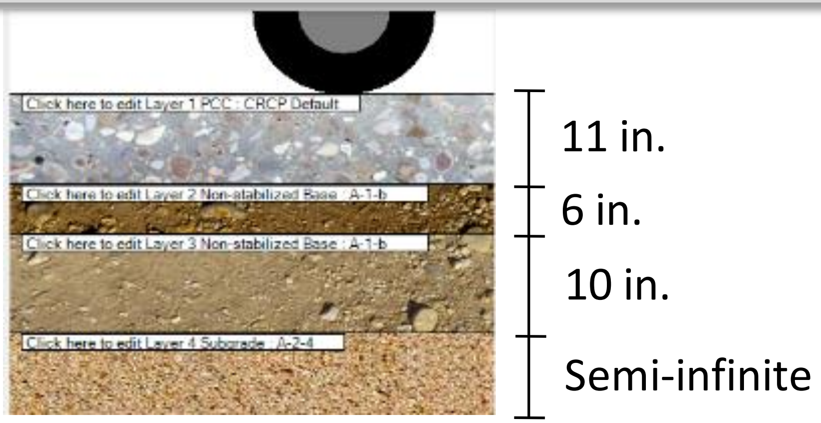
Pavement type: Continuously Reinforce

Design life (years): 20

Pavement construction: June 2016

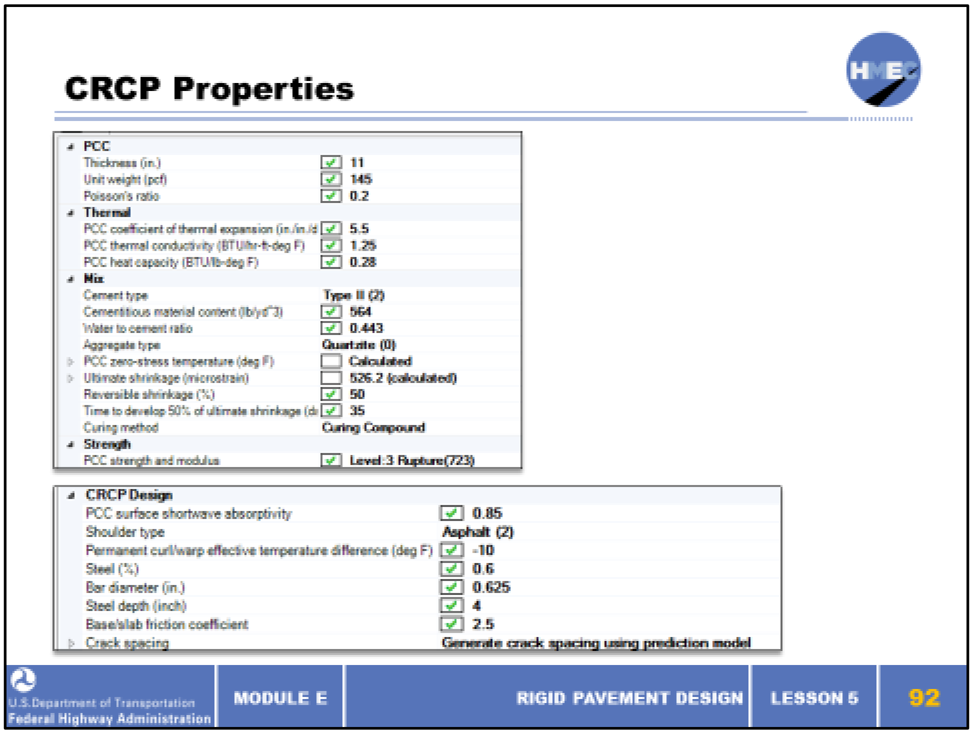
Traffic opening: Septen 2016

Performance Criteria	Limit	Reliability
Initial IRI (in./mile)	63	
Terminal IRI (in./mile)	160	95
CRCP punchouts (1/mile)	10	95


Click here to edit Layer 1 PCC : CRCP Default
Click here to edit Layer 2 Non-stabilized Base : A-1-b
Click here to edit Layer 3 Non-stabilized Base : A-1-b
Click here to edit Layer 4 Subgrade : A-2-4
11 in.
6 in.
10 in.
Semi-infinite

The purpose of the screen is to reintroduce the sample pavement project in order to set up the software demonstration.

Slide 92



CRCP Properties

PCC		
Thickness (in.)	☑	11
Unit weight (pcf)	☑	145
Poisson's ratio	☑	0.2
Thermal		
PCC coefficient of thermal expansion (in./in./d	☑	5.5
PCC thermal conductivity (BTU/hr-ft-deg F)	☑	1.25
PCC heat capacity (BTU/lb-deg F)	☑	0.28
Mix		
Cement type		Type II (2)
Cementitious material content (lb/yd^3)	☑	564
Water to cement ratio	☑	0.443
Aggregate type		Quartzite (0)
PCC zero-stress temperature (deg F)	☐	Calculated
Ultimate shrinkage (microstrain)	☐	526.2 (calculated)
Reversible shrinkage (%)	☑	50
Time to develop 50% of ultimate shrinkage (d	☑	35
Curing method		Curing Compound
Strength		
PCC strength and modulus	☑	Level:3 Rupture(723)

CRCP Design		
PCC surface shortwave absorptivity	☑	0.85
Shoulder type		Asphalt (2)
Permanent curl/warp effective temperature difference (deg F)	☑	-10
Steel (%)	☑	0.6
Bar diameter (in.)	☑	0.625
Steel depth (inch)	☑	4
Base/slab friction coefficient	☑	2.5
Crack spacing		Generate crack spacing using prediction model

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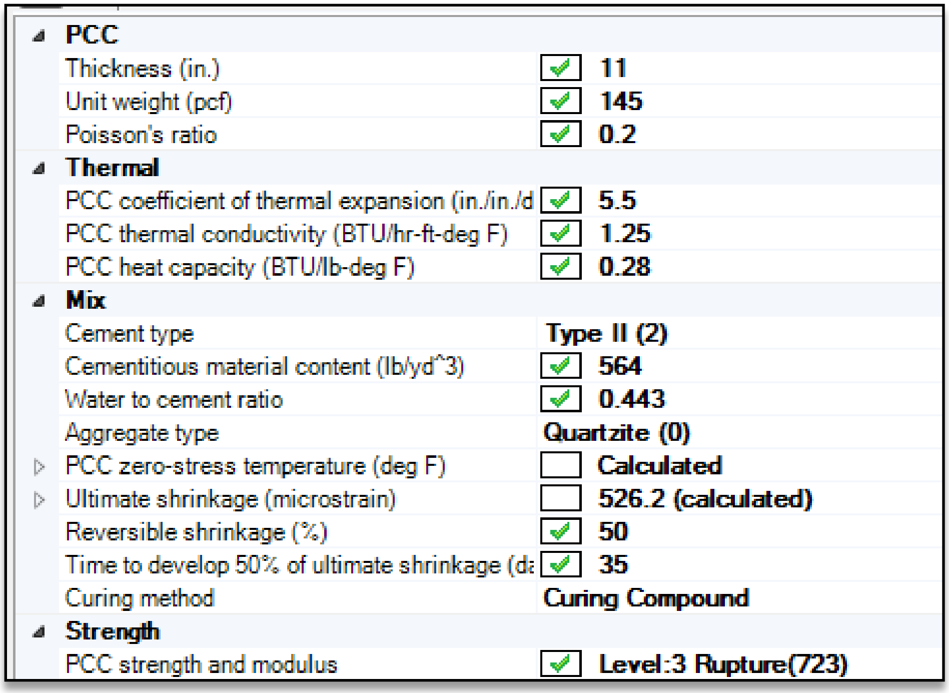
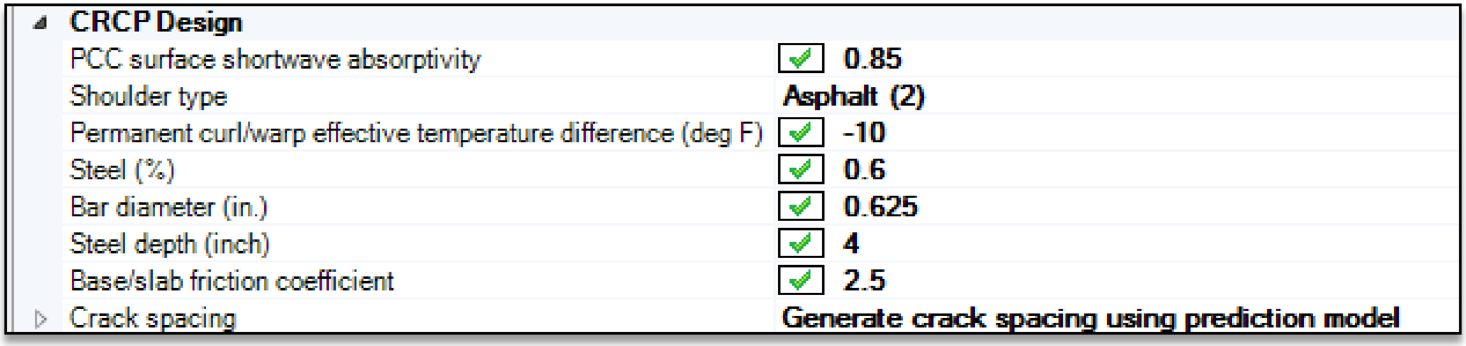
MODULE E
RIGID PAVEMENT DESIGN
LESSON 5
92



PCC		
Thickness (in.)	☑	11
Unit weight (pcf)	☑	145
Poisson's ratio	☑	0.2
Thermal		
PCC coefficient of thermal expansion (in./in./d	☑	5.5
PCC thermal conductivity (BTU/hr-ft-deg F)	☑	1.25
PCC heat capacity (BTU/lb-deg F)	☑	0.28
Mix		
Cement type		Type II (2)
Cementitious material content (lb/yd^3)	☑	564
Water to cement ratio	☑	0.443
Aggregate type		Quartzite (0)
▷ PCC zero-stress temperature (deg F)	☐	Calculated
▷ Ultimate shrinkage (microstrain)	☐	526.2 (calculated)
Reversible shrinkage (%)	☑	50
Time to develop 50% of ultimate shrinkage (da	☑	35
Curing method		Curing Compound
Strength		
PCC strength and modulus	☑	Level:3 Rupture(723)



CRCP Design		
PCC surface shortwave absorptivity	☑	0.85
Shoulder type		Asphalt (2)
Permanent curl/warp effective temperature difference (deg F)	☑	-10
Steel (%)	☑	0.6
Bar diameter (in.)	☑	0.625
Steel depth (inch)	☑	4
Base/slab friction coefficient	☑	2.5
▷ Crack spacing		Generate crack spacing using prediction model

The properties of the slab, joints, and interaction with substrate layers is defined in the software for the Utah sample CRCP pavement project.

The only difference between the Utah sample project and this one is that the first demonstration was for a JPCP in Utah and this surface was simply switched to be a CRCP.

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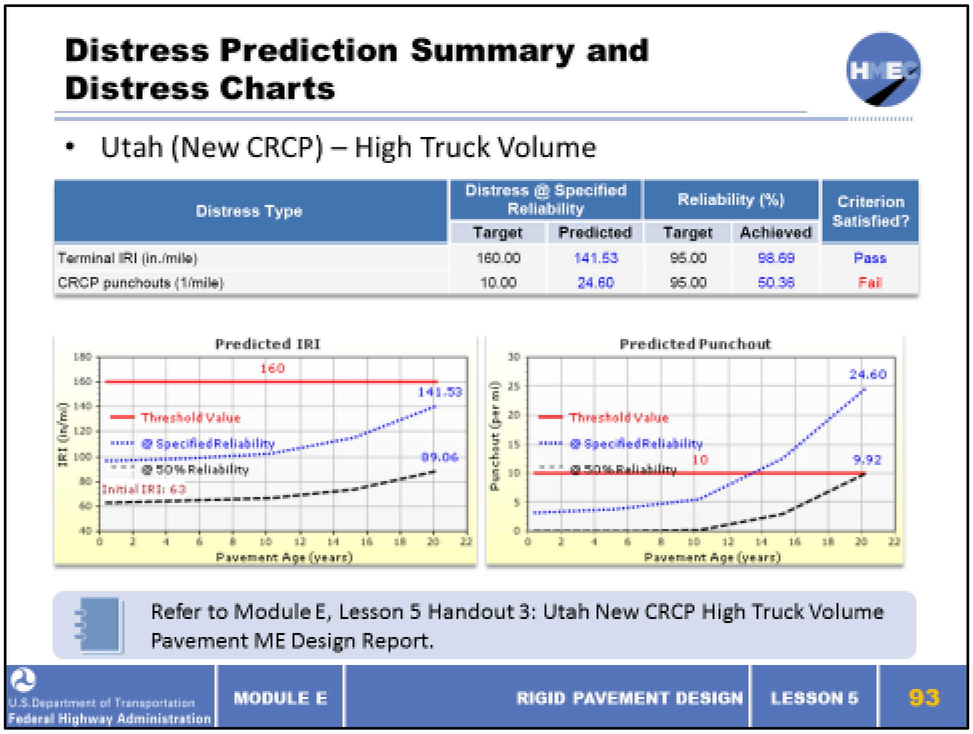
Slide 93



Distress Prediction Summary and Distress Charts

- Utah (New CRCP) – High Truck Volume

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	141.53	95.00	98.69	Pass
CRCP punchouts (1/mile)	10.00	24.60	95.00	50.36	Fail

Refer to Module E, Lesson 5 Handout 3: Utah New CRCP High Truck Volume Pavement ME Design Report.

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The purpose of the screen is to help participants interpret output from the new rigid pavement analysis (CRCP).

The number of punchouts predicted at reliability level (95%) failed the threshold at 14 years; however, at 50% reliability, it made it to 20 years. The IRI tracks with the punchout trend, but the IRI threshold is not exceeded even at 95% reliability.

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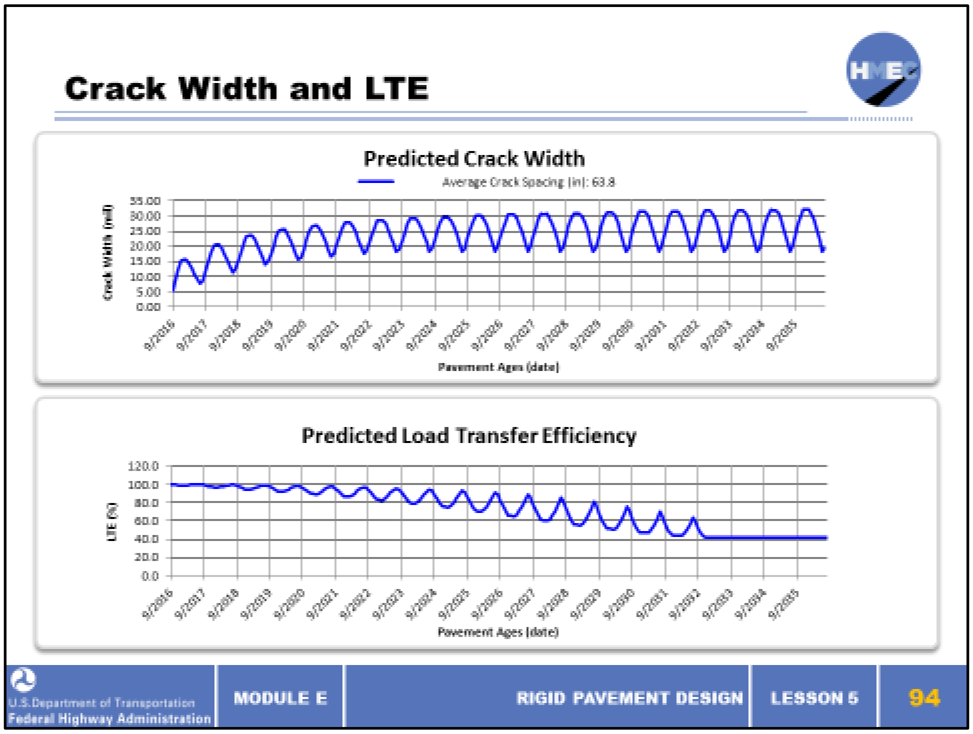
Slide 94



Crack Width and LTE

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MODULE E | RIGID PAVEMENT DESIGN | LESSON 5 | 94

The purpose of the screen is to help participants interpret output from the new rigid pavement analysis (CRCP) beyond just the plots, to introduce again the LTE and predicted crack width output.

The crack width can be observed in the output of the Pavement ME Design software. The average crack spacing computes at approximately 64 inches, and the crack width increases linearly from 5 millinches (mils) to a maximum of 30 mils over the course of 10 years and then stabilizes after 10 years of service life.

The load transfer efficiency decreases linearly after the first two years of pavement life until it reaches a minimum level of 40% efficiency after 15 years in service.

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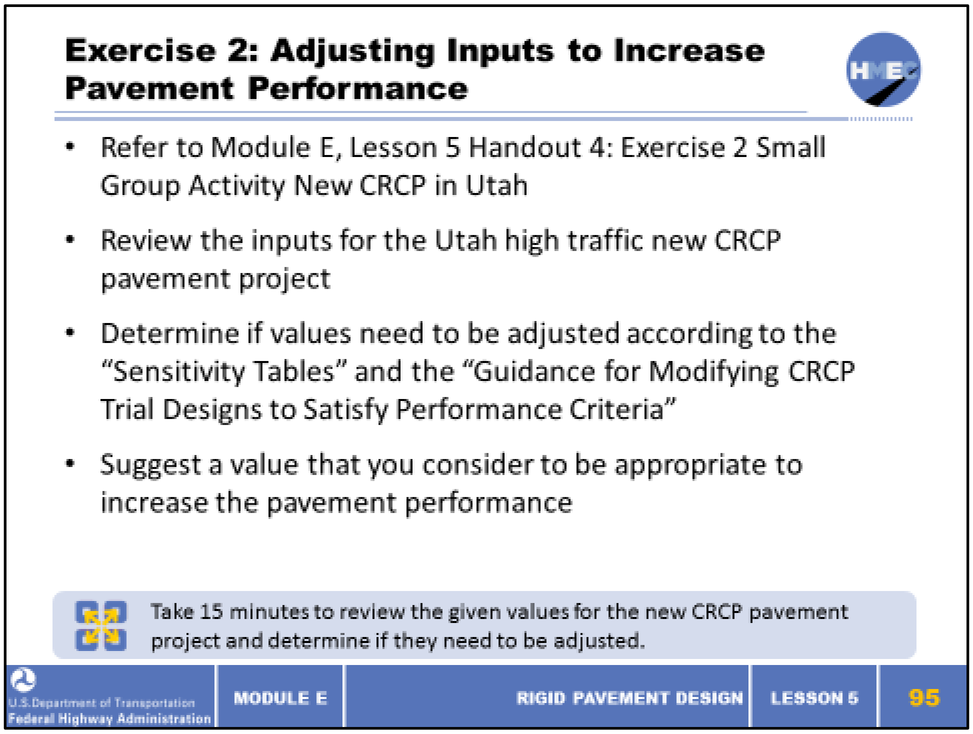
Slide 95



Exercise 2: Adjusting Inputs to Increase Pavement Performance

- Refer to Module E, Lesson 5 Handout 4: Exercise 2 Small Group Activity New CRCP in Utah
- Review the inputs for the Utah high traffic new CRCP pavement project
- Determine if values need to be adjusted according to the “Sensitivity Tables” and the “Guidance for Modifying CRCP Trial Designs to Satisfy Performance Criteria”
- Suggest a value that you consider to be appropriate to increase the pavement performance

Take 15 minutes to review the given values for the new CRCP pavement project and determine if they need to be adjusted.

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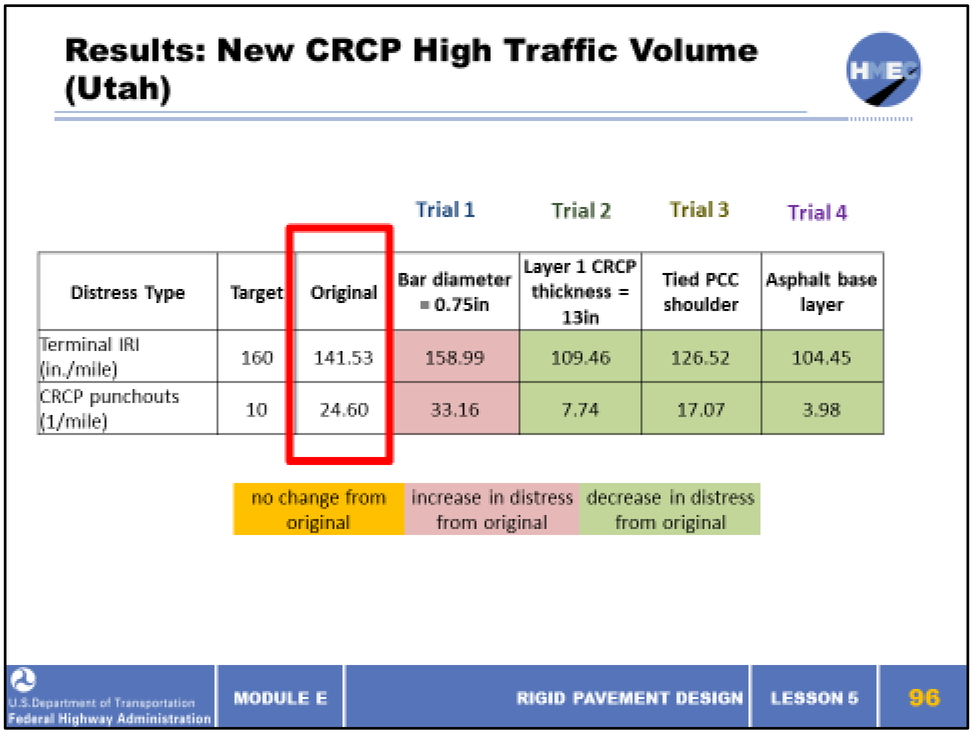
MODULE E
RIGID PAVEMENT DESIGN
LESSON 5
95

Slide 96



Results: New CRCP High Traffic Volume (Utah)

			Trial 1	Trial 2	Trial 3	Trial 4
Distress Type	Target	Original	Bar diameter = 0.75in	Layer 1 CRCP thickness = 13in	Tied PCC shoulder	Asphalt base layer
Terminal IRI (in./mile)	160	141.53	158.99	109.46	126.52	104.45
CRCP punchouts (1/mile)	10	24.60	33.16	7.74	17.07	3.98

🟨	🟥	🟩
no change from original	increase in distress from original	decrease in distress from original

U.S. Department of Transportation Federal Highway Administration | MODULE E | RIGID PAVEMENT DESIGN | LESSON 5 | 96

This table shows the results of four Trials on the new design for Utah high-volume CRC rigid pavement

The first trial increased the CRC's reinforcement bar diameter to 0.75 inches and the effect was negative in that there was a marked increase in IRI and in the number of punchouts, as compared to the Original.

The second trial increased the CRC thickness to 13 inches and the effect was more pronounced in terms of reducing distresses, as compared to the Original.

The third trial changed from an Asphalt shoulder to a tied PCC separated shoulder and was sufficient in decreasing the number of punchouts and the IRI and improved performance.

The fourth trial changed from a 6-inch non-stabilized base (A-1-b) to a 5-inch asphalt base. This change resulted in a significant reduction in terminal IRI and number of punchouts compared to the original design.

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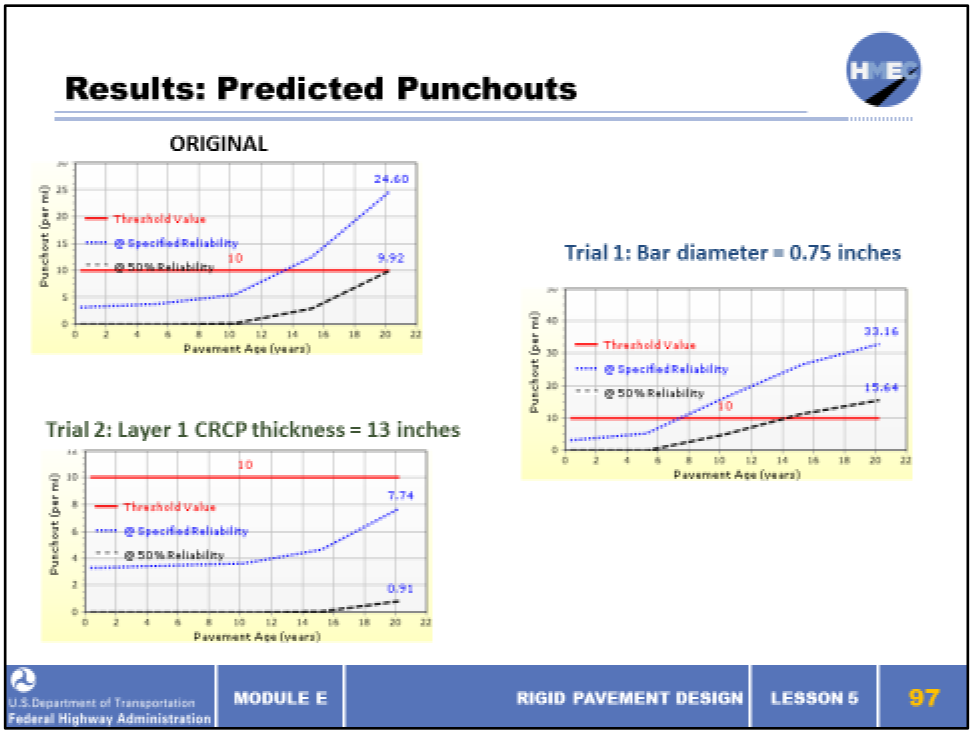
Slide 97



Results: Predicted Punchouts

ORIGINAL

Trial 1: Bar diameter = 0.75 inches

Trial 2: Layer 1 CRCP thickness = 13 inches

U.S. Department of Transportation
Federal Highway Administration

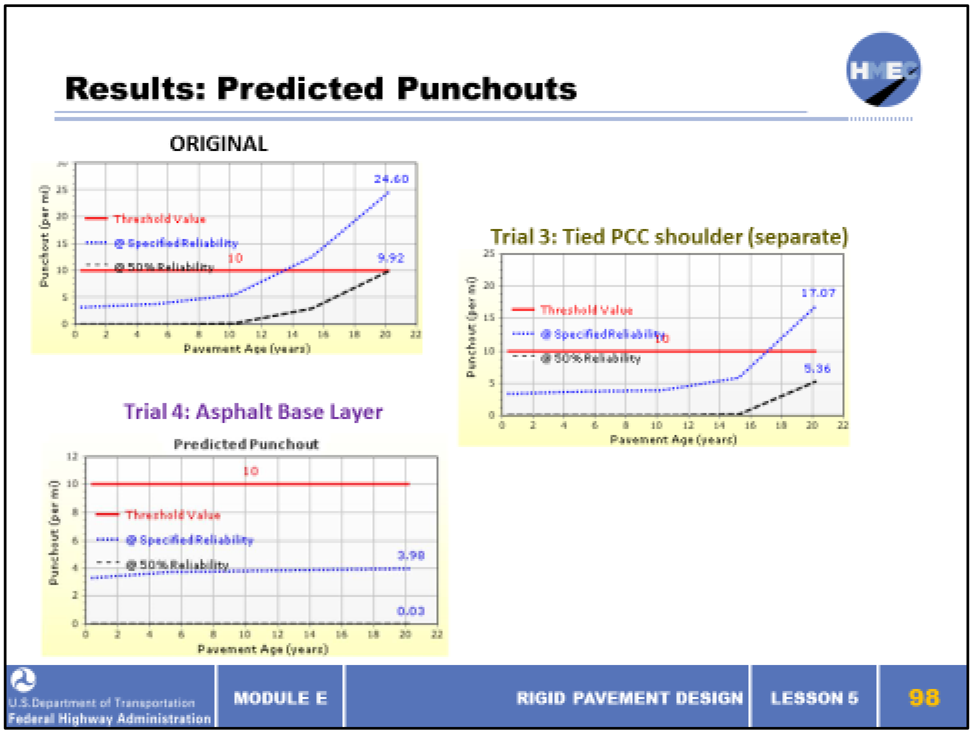
MODULE E | RIGID PAVEMENT DESIGN | LESSON 5 | 97

These plots show the number of punchouts predicted for the original CRCP pavement structure as well as the four trials described in a previous slide.

The plots indicate the number of punchouts predicted at 50% reliability (black line), the threshold criteria for punchouts (red line), and the number of punchouts predicted at the specified reliability of 95% (blue line).

The results show that there is significant improvement in decreasing the number of punchouts by increasing the thickness of the CRCP layer. A modest improvement in the number of punchouts was observed with the use of a tied PCC separated shoulder. However, the use of a larger reinforcement bar diameter (0.75") actually made the punchout problem worse and increased the number of punchouts by about 30%.

Slide 98



Results: Predicted Punchouts

ORIGINAL

Trial 3: Tied PCC shoulder (separate)

Trial 4: Asphalt Base Layer

Predicted Punchout

U.S. Department of Transportation
Federal Highway Administration

MODULE E

RIGID PAVEMENT DESIGN

LESSON 5

98

These plots show the number of punchouts predicted for the original CRCP pavement structure as well as the four trials described in a previous slide.

The plots indicate the number of punchouts predicted at 50% reliability (black line), the threshold criteria for punchouts (red line), and the number of punchouts predicted at the specified reliability of 95% (blue line).

The results show that there is significant improvement in decreasing the number of punchouts by increasing the thickness of the CRCP layer. A modest improvement in the number of punchouts was observed with the use of a tied PCC separated shoulder. However, the use of a larger reinforcement bar diameter (0.75") actually made the punchout problem worse and increased the number of punchouts by about 30%. Substituting 6 inches of the non-stabilized base (A-1-b) with a 5-inch asphalt layer significantly decreased the predicted number of punchouts.

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Slide 99

Rehabilitation of Rigid Pavements

The purpose of this screen is to transition to the section on pavement rehabilitation design of rigid pavements.

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Slide 100

Software Demonstration for Rigid Pavement

PvD AASHTOWare Pavement ME Design AASHTO

Start Demonstration

Flexible Overlay over a Jointed Rigid Pavement Example

Start Demonstration

Flexible Overlay over a Jointed Rigid Pavement Example

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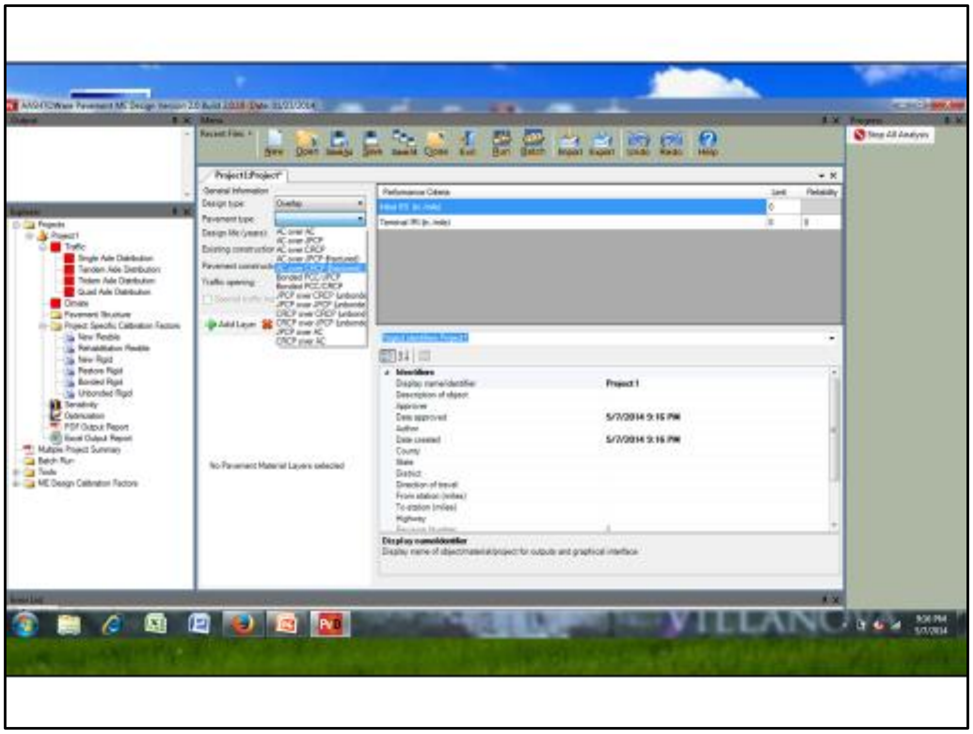
Slide 101



Design type: Overlay

No Pavement Material Layers selected

Display name/identifier: Project 1

Date approved: 5/7/2014 9:16 PM

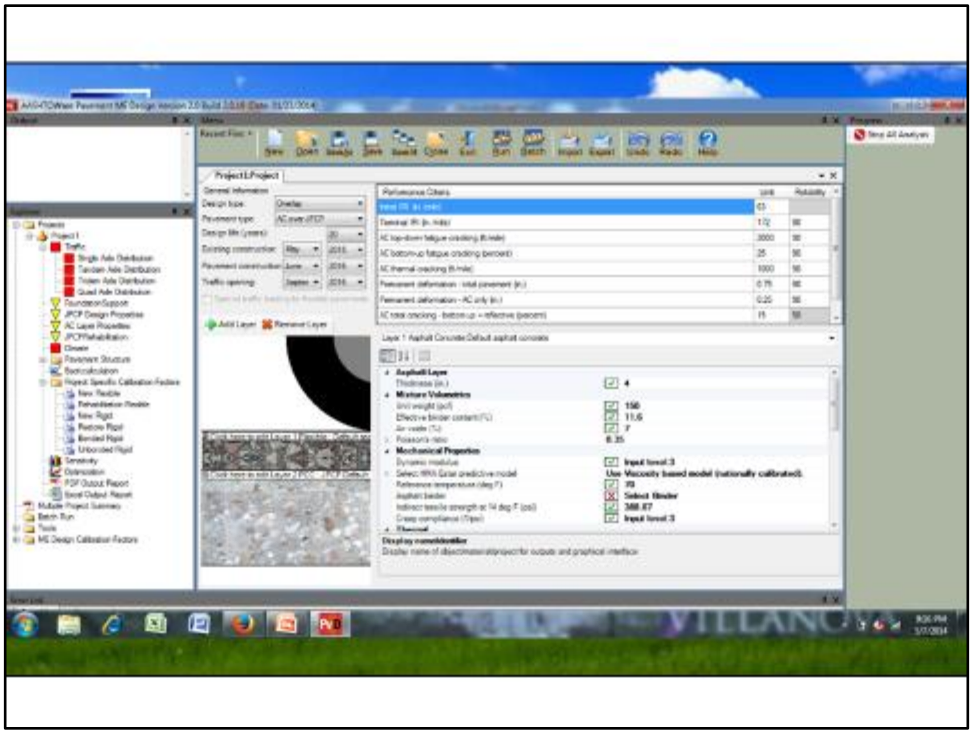
Date created: 5/7/2014 9:16 PM

Display name/identifier

Display name of object/material/project for outputs and graphical interface

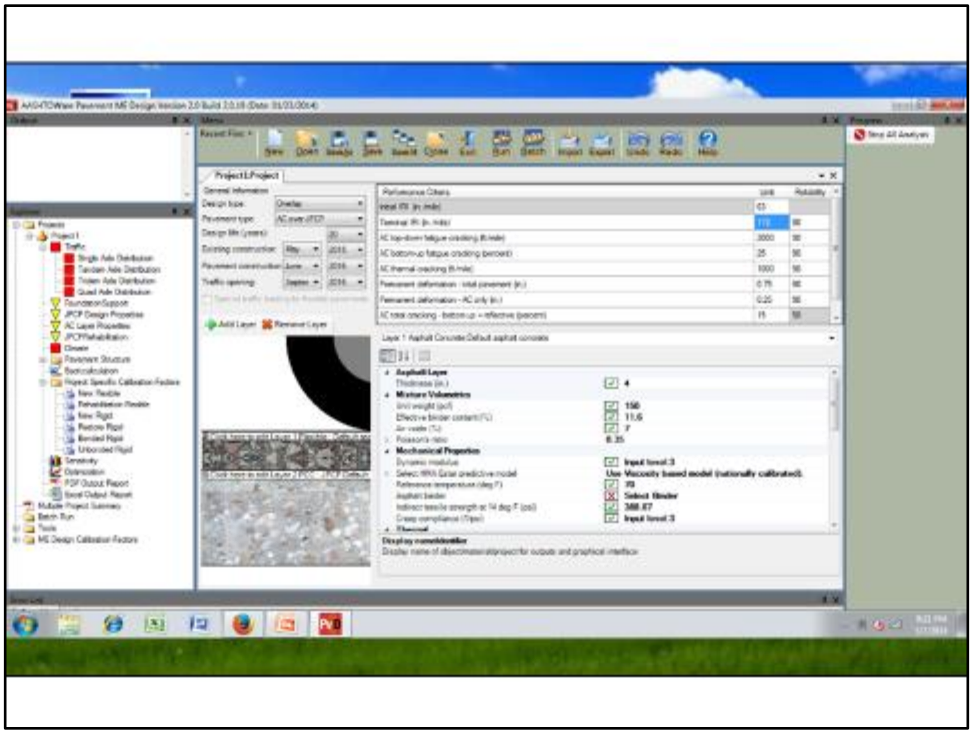
Select Project Type. Then, select AC over JPCP (shown on the next screen).

Slide 102



This screen shows the AC over JPCP pavement type selected.

Slide 103



Change Performance Criteria limit and reliability.

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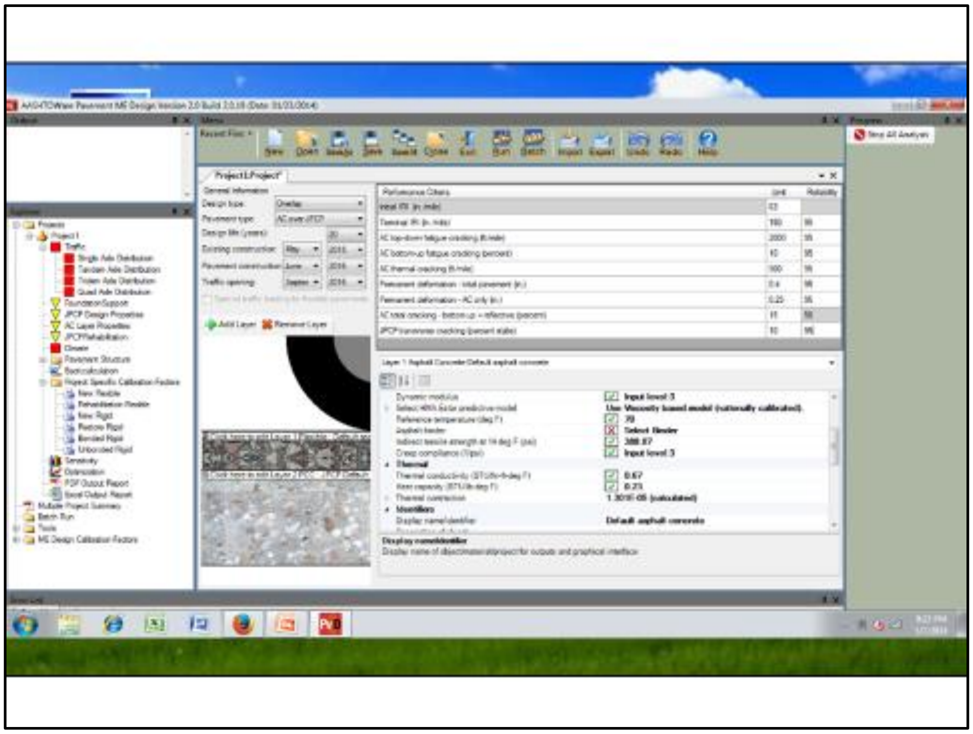
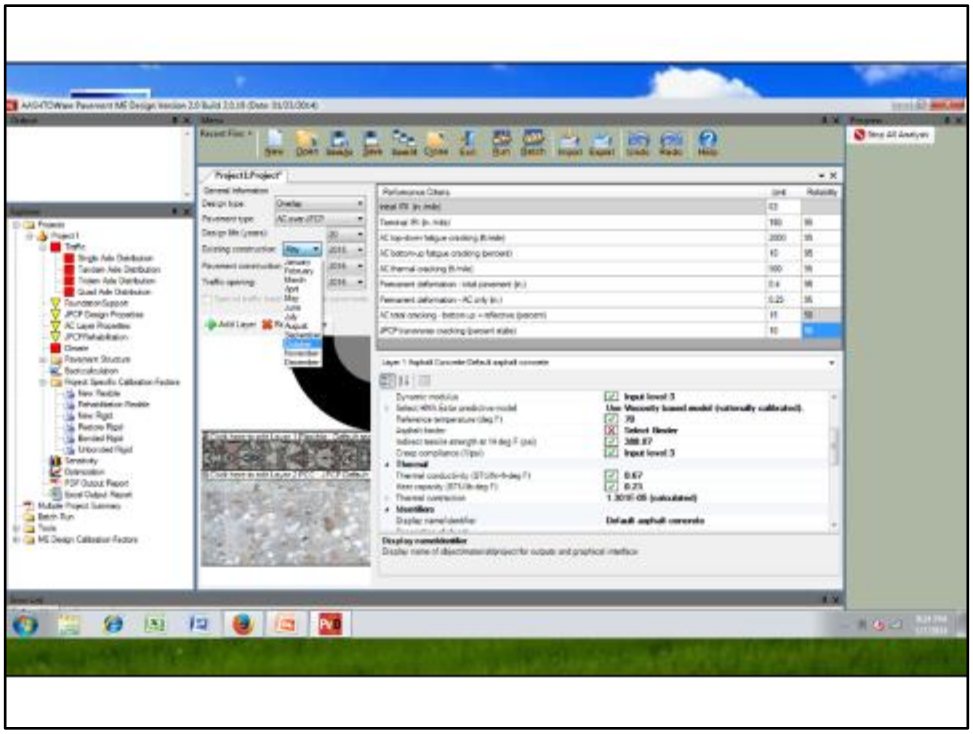
Slide 104



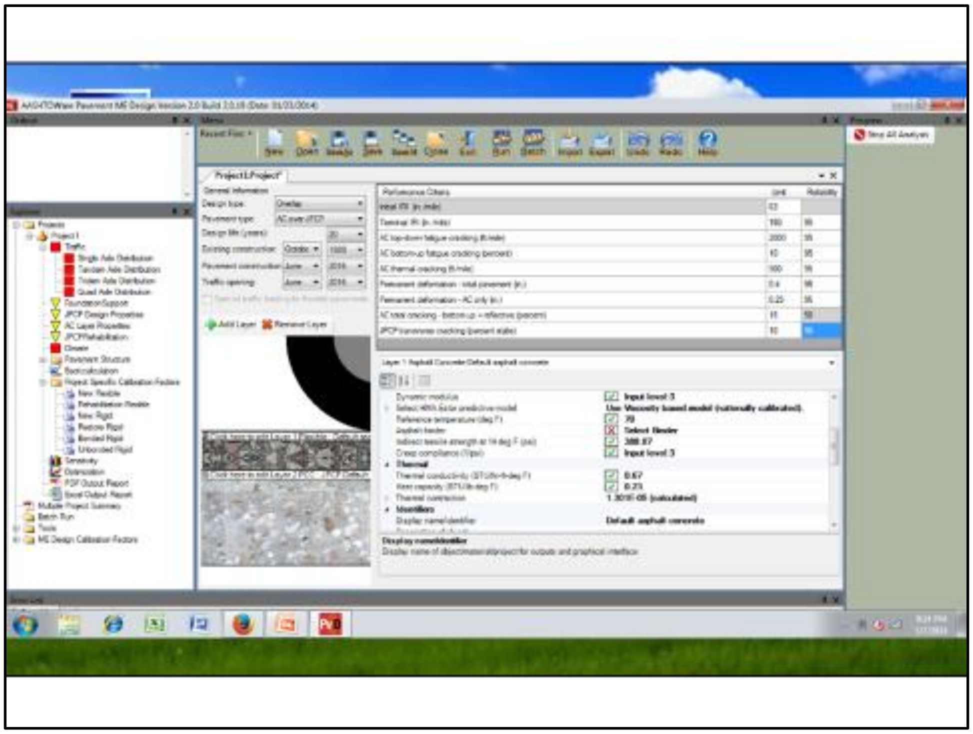
The reliability was changed from the default to a more suitable reliability value for a freeway/interstate, functionally classed roadway. It should be noted as well that the maximum reliability that one can place on AC total cracking (reflective + bottom-up) is 50% reliability, which is a limitation of the software at this time with the placeholder reflective cracking model.

Slide 105



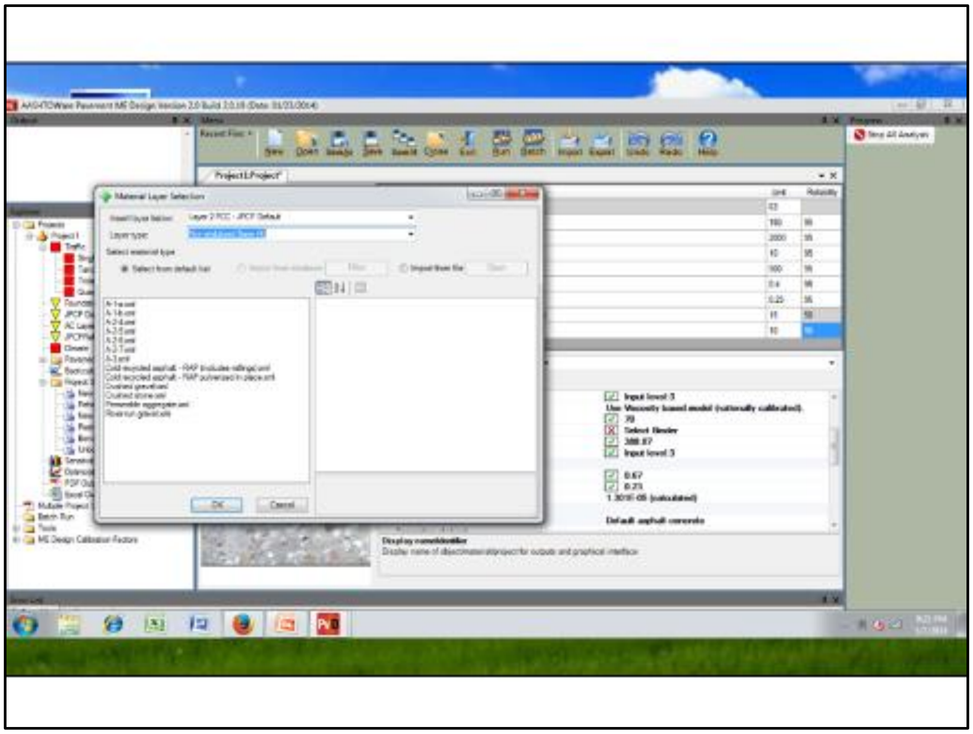
Select the Existing Construction month to change it.

Slide 106



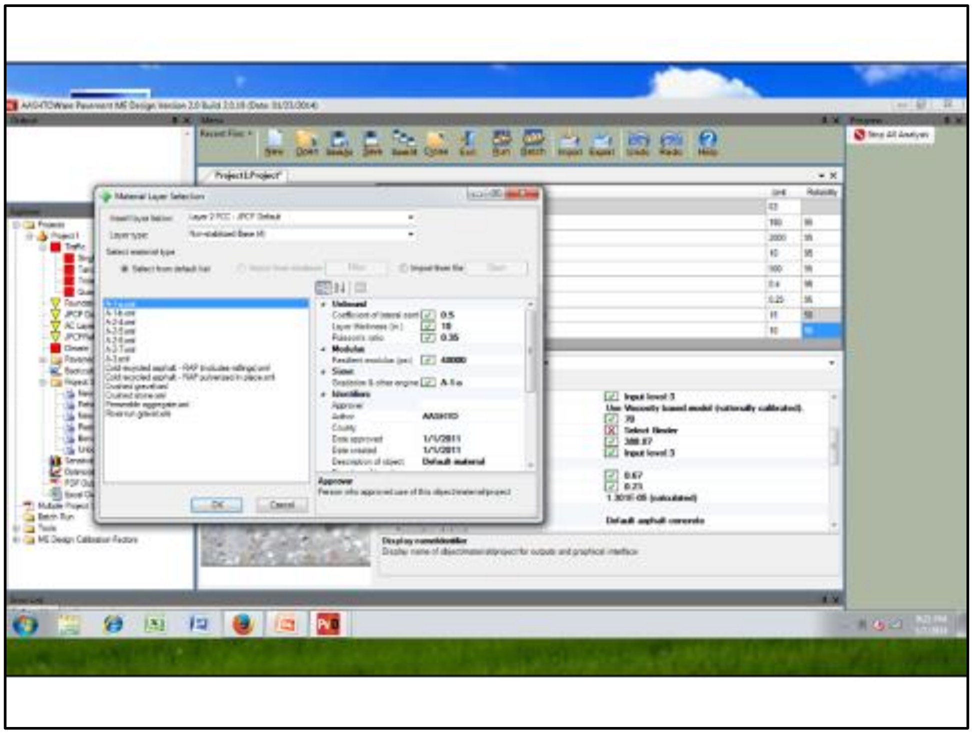
Select Add Layer (shown on the next screen).

Slide 107



This screen shows the information that pops up when Add Layer is selected.

Slide 108



Select A-1-a.xml and then select OK.

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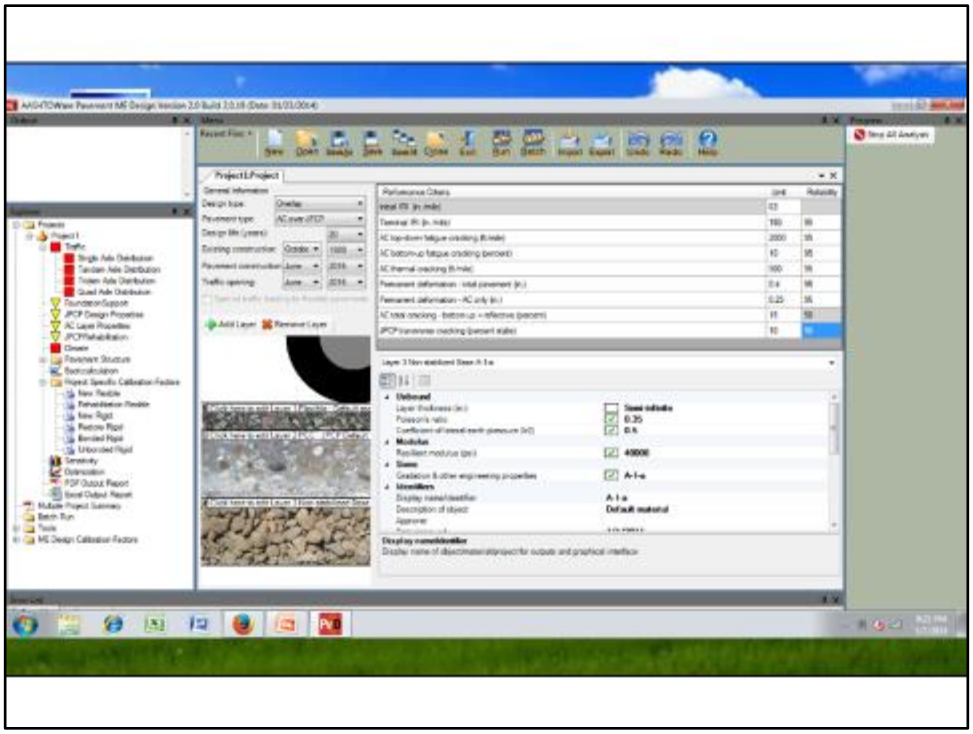
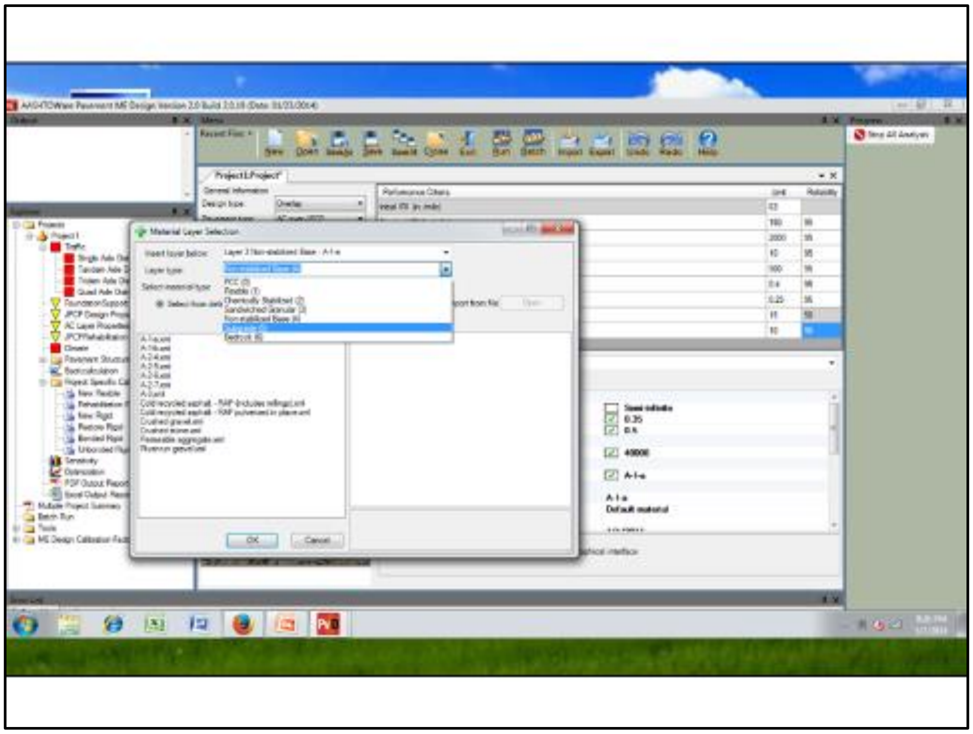
Slide 109



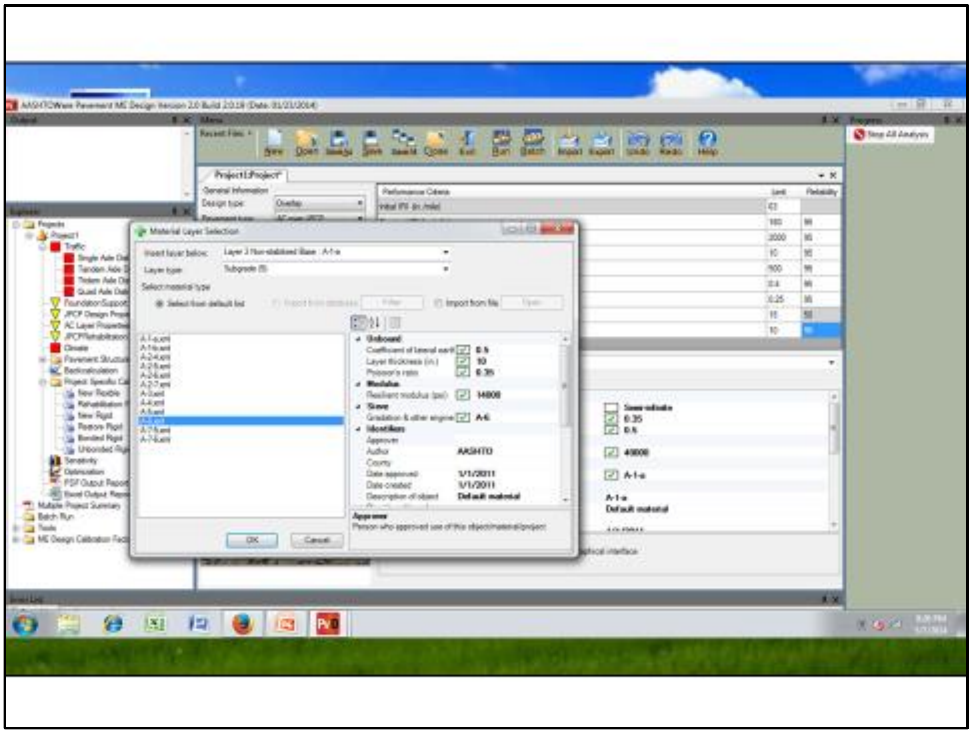
Select Add Layer.

Slide 110



Select Layer Type to change it to Subgrade.

Slide 111



Insert layer below: Layer 3 Non-stabilized Base : A-1-a

Layer type: Subgrade (5)

Coefficient of lateral earth ☑ 0.5

Layer thickness (in.) ☑ 10

Poisson's ratio ☑ 0.35

Resilient modulus (psi) ☑ 14000

Gradation & other engine ☑ A-6

Author AASHTO

Date approved 1/1/2011

Date created 1/1/2011

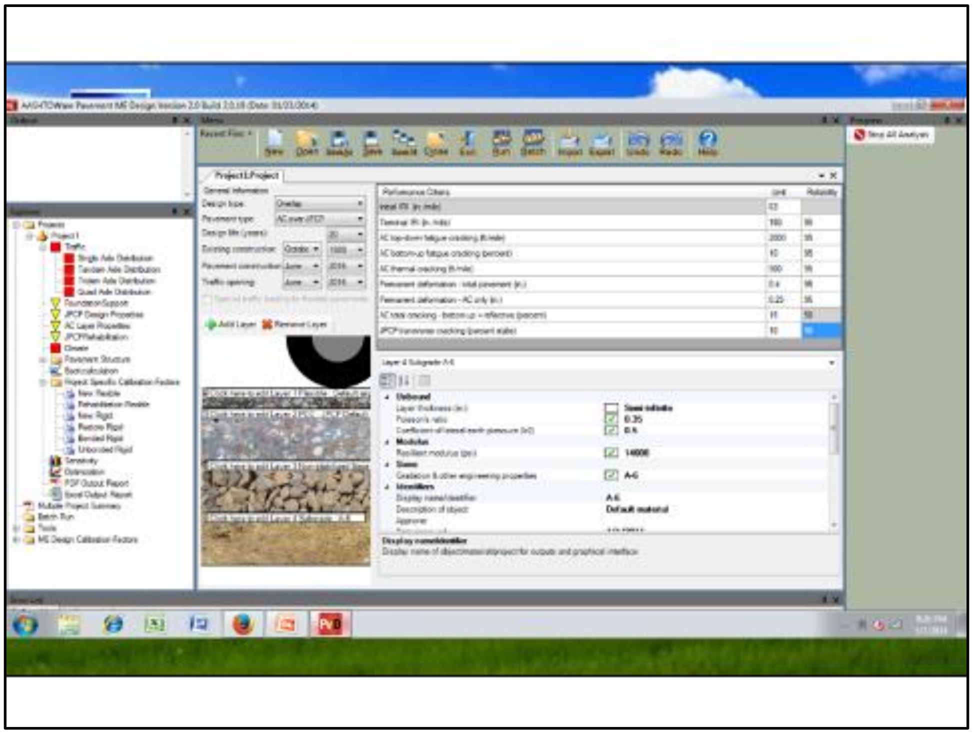
Description of object Default material

Approver

Person who approved use of this object/material/project

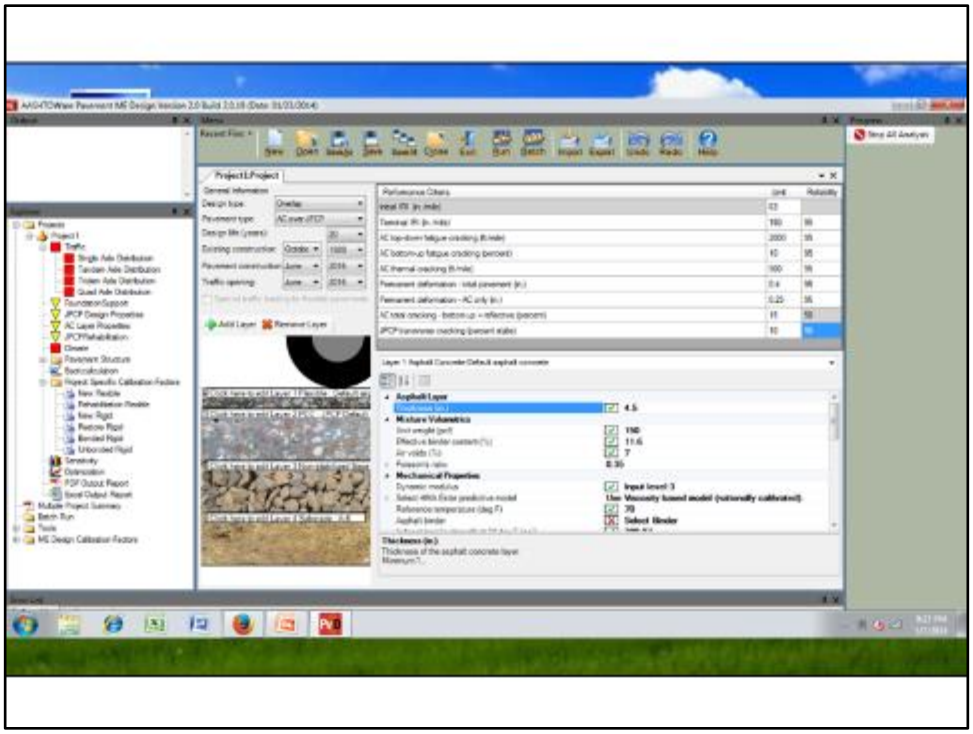
Select A-6.xml and Select OK.

Slide 112



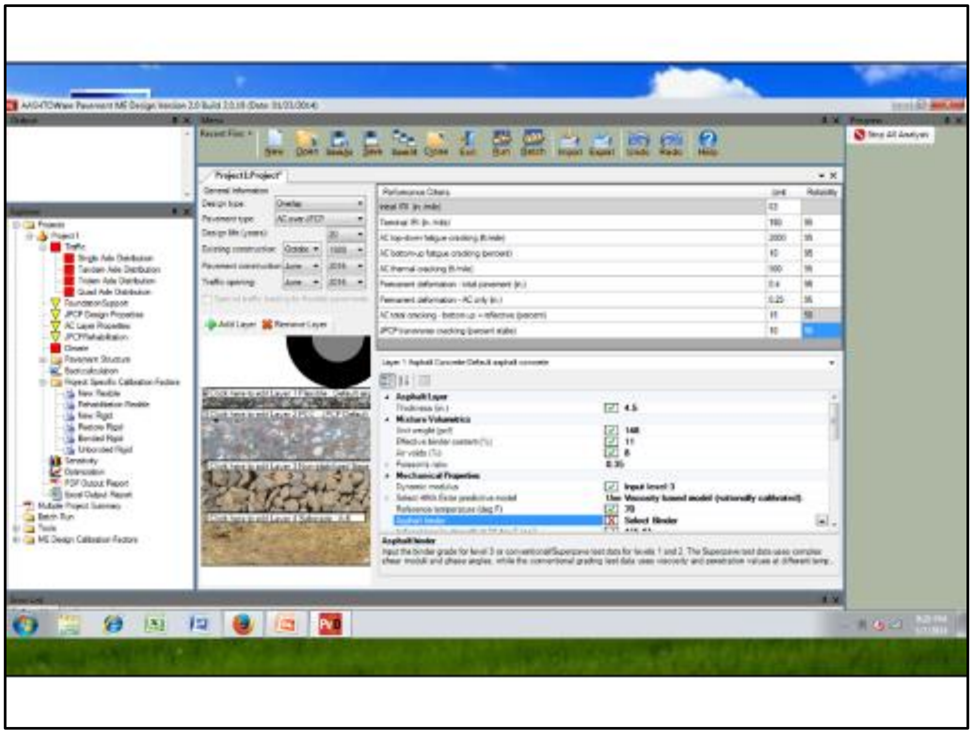
Select Layer 1 (shown on the next screen).

Slide 113



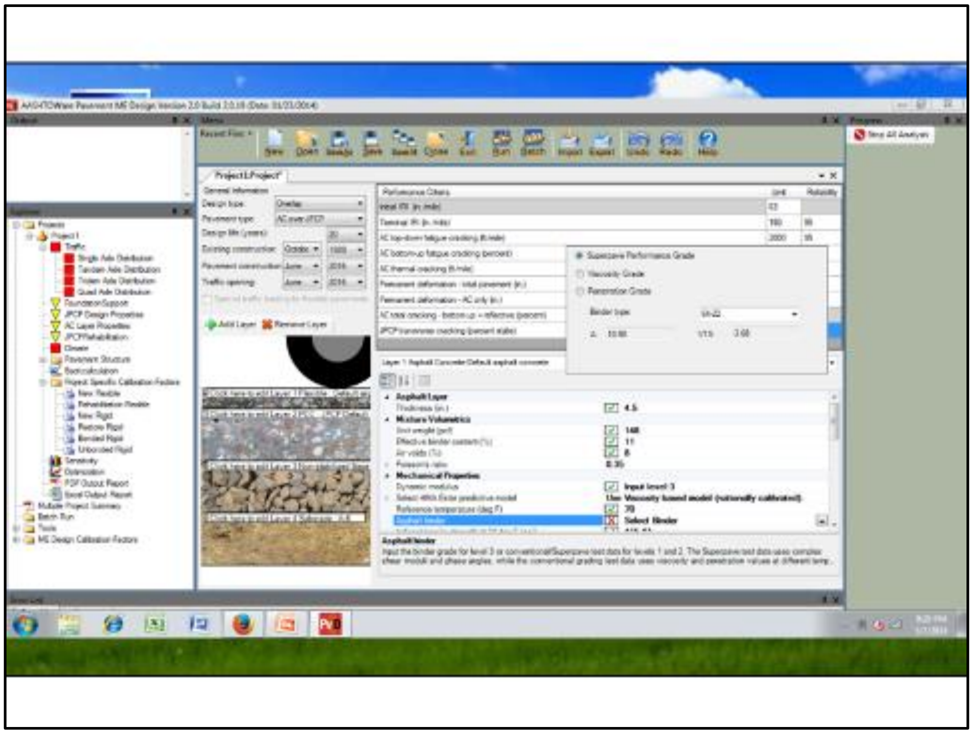
Select Thickness to adjust it. Select the other properties to adjust them as well.

Slide 114



Select Asphalt Binder (shown on the next screen).

Slide 115



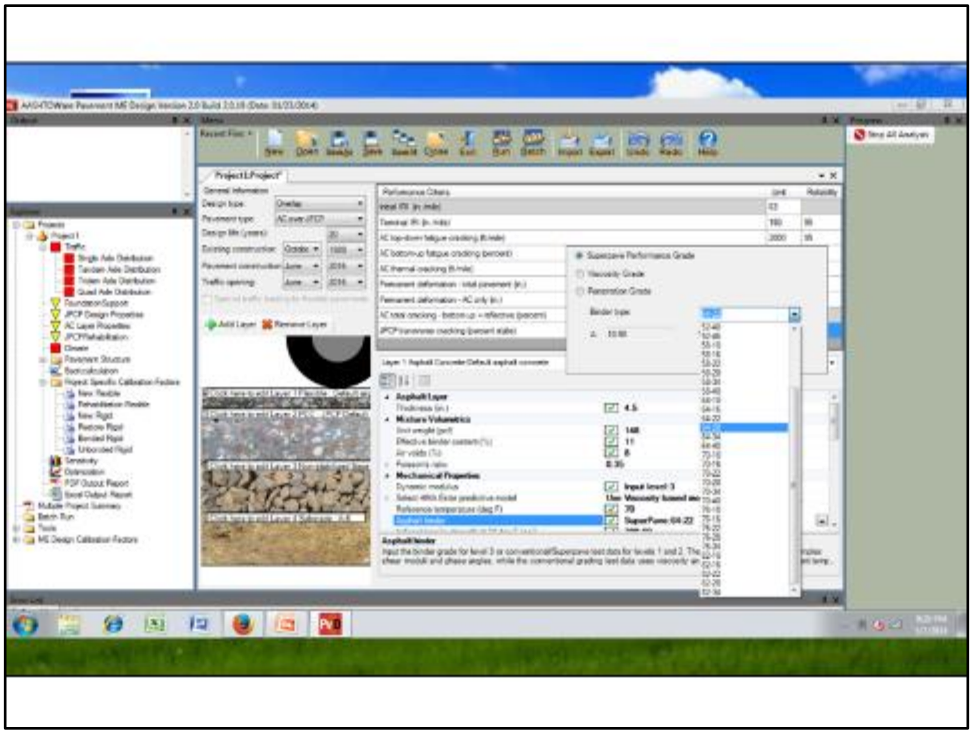
○ Superpave Performance Grade
○ Viscosity Grade
○ Penetration Grade

Asphalt Layer
Thickness (in.) ☑ 4.5
Mixture Volumetrics
Unit weight (pcf) ☑ 148
Effective binder content (%) ☑ 11
Air voids (%) ☑ 8
Poisson's ratio 0.35
Mechanical Properties
Dynamic modulus ☑ Input level 3
Select HMA Gstar predictive model Use Viscosity based model (nationally calibrated)
Reference temperature (deg F) ☑ 70
Asphalt binder ☒ Select Binder

Asphalt binder
Input the binder grade for level 3 or conventional/Superpave test data for levels 1 and 2. The Superpave test data uses complex shear moduli and phase angles, while the conventional grading test data uses viscosity and penetration values at different temp...

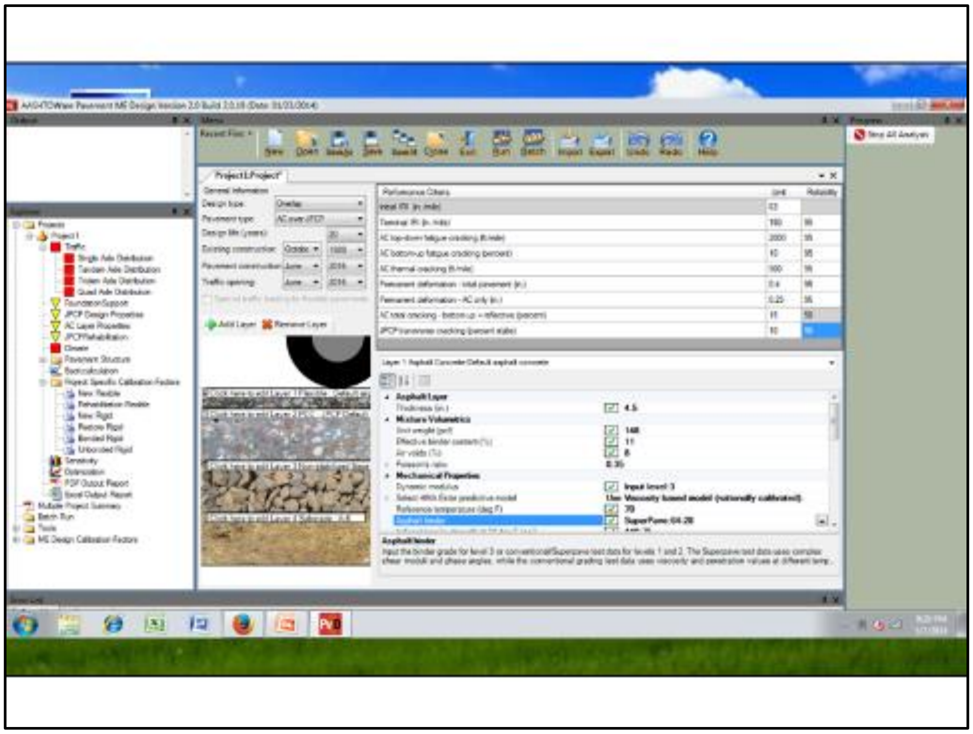
This screen shows the information that pops up when Asphalt Binder is selected.

Slide 116



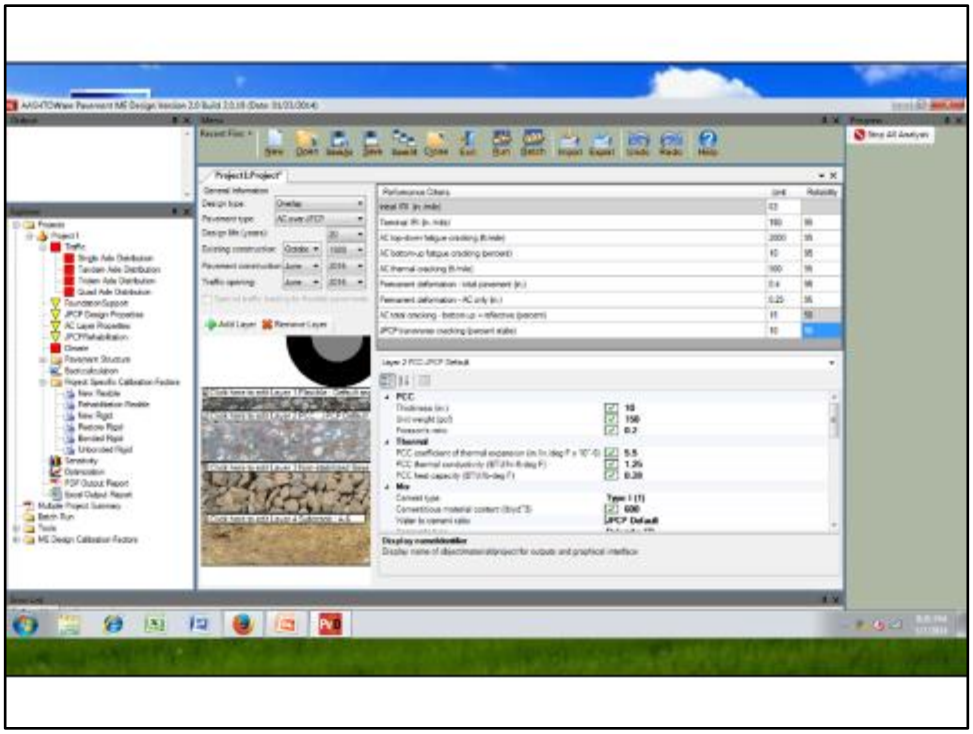
Select 64-28 (shown on the next screen).

Slide 117



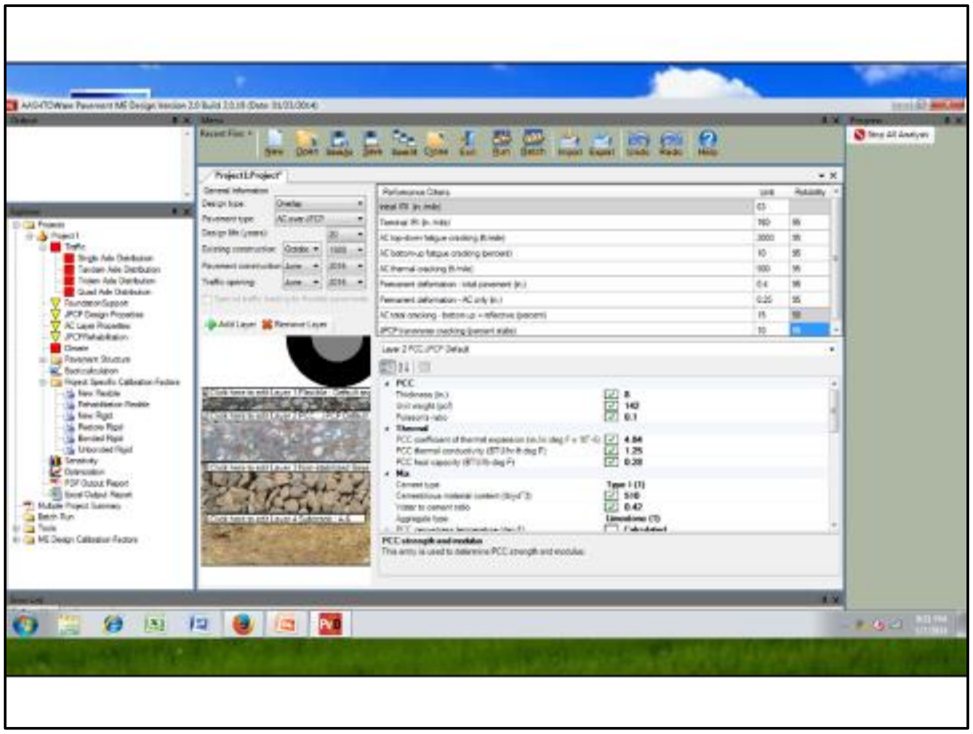
Select Layer 2.

Slide 118



Adjust Properties (shown on the next screen).

Slide 119



Layer 2 PCC:JPCP Default

PCC
Thickness (in.) 8
Unit weight (pcf) 142
Poisson's ratio 0.1

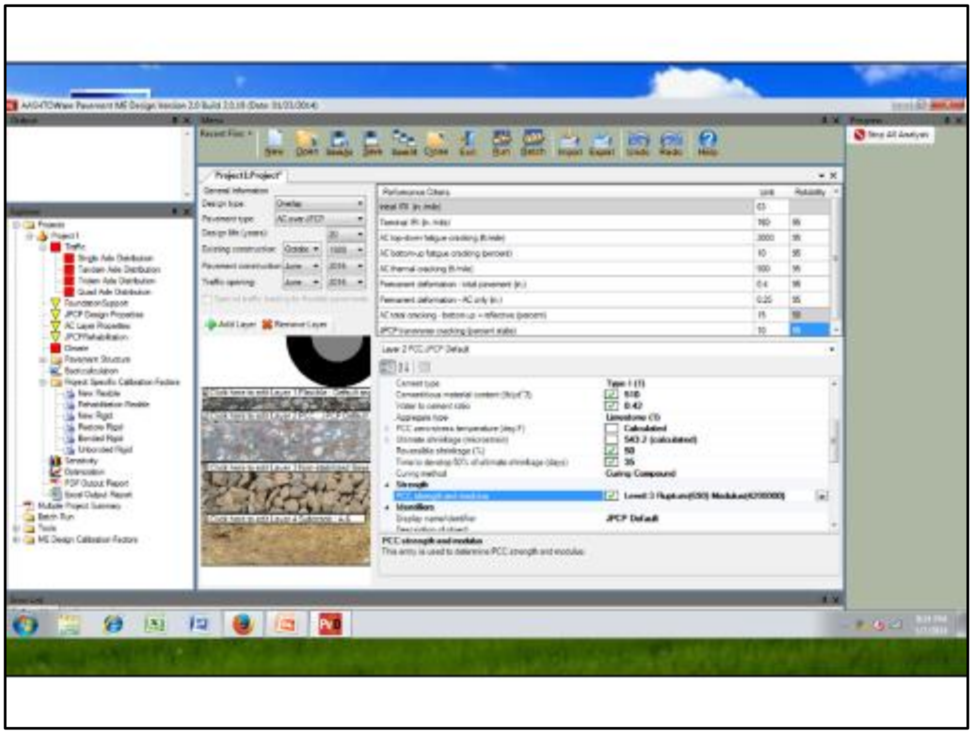
Thermal
PCC coefficient of thermal expansion (in./in./deg F x 10^-6) 4.84
PCC thermal conductivity (BTU/hr-ft-deg F) 1.25
PCC heat capacity (BTU/lb-deg F) 0.28

Mix
Cement type Type I (1)
Cementitious material content (lb/yd^3) 516
Water to cement ratio 0.42
Aggregate type Limestone (1)

PCC strength and modulus
This entry is used to determine PCC strength and modulus.

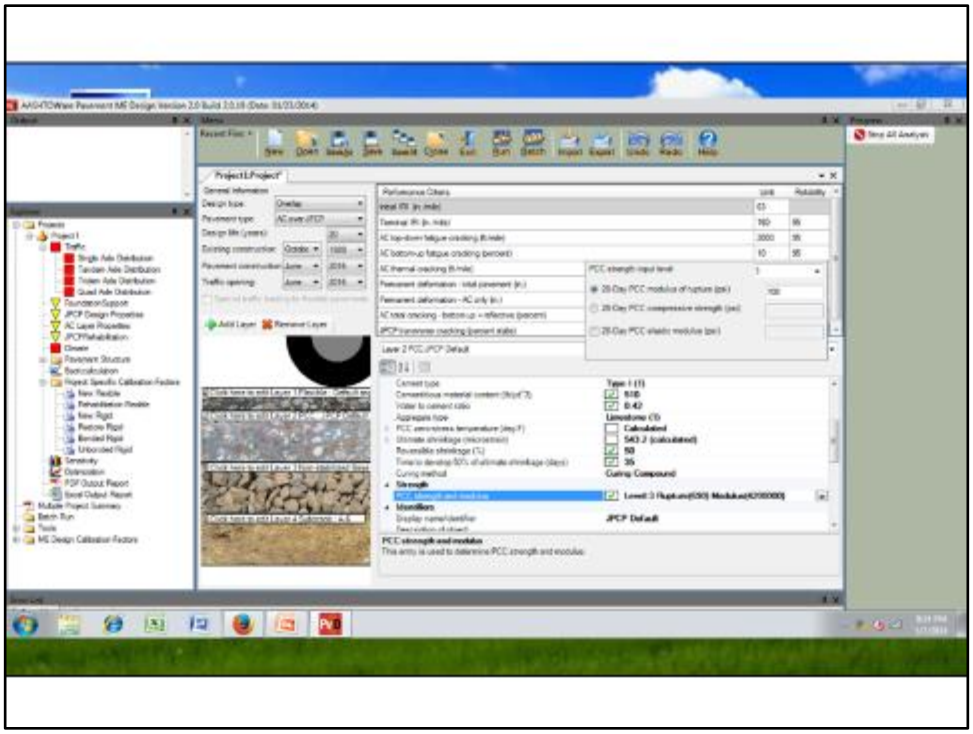
This screen shows the adjusted properties.

Slide 120



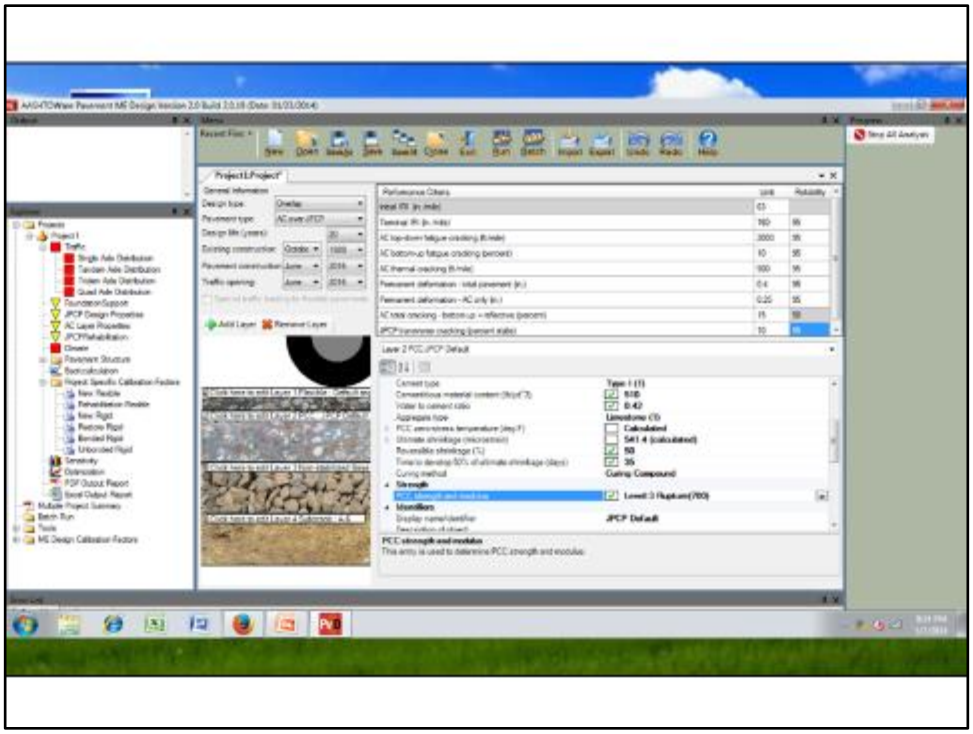
Select PCC Strength and Modulus (shown on the next screen

Slide 121



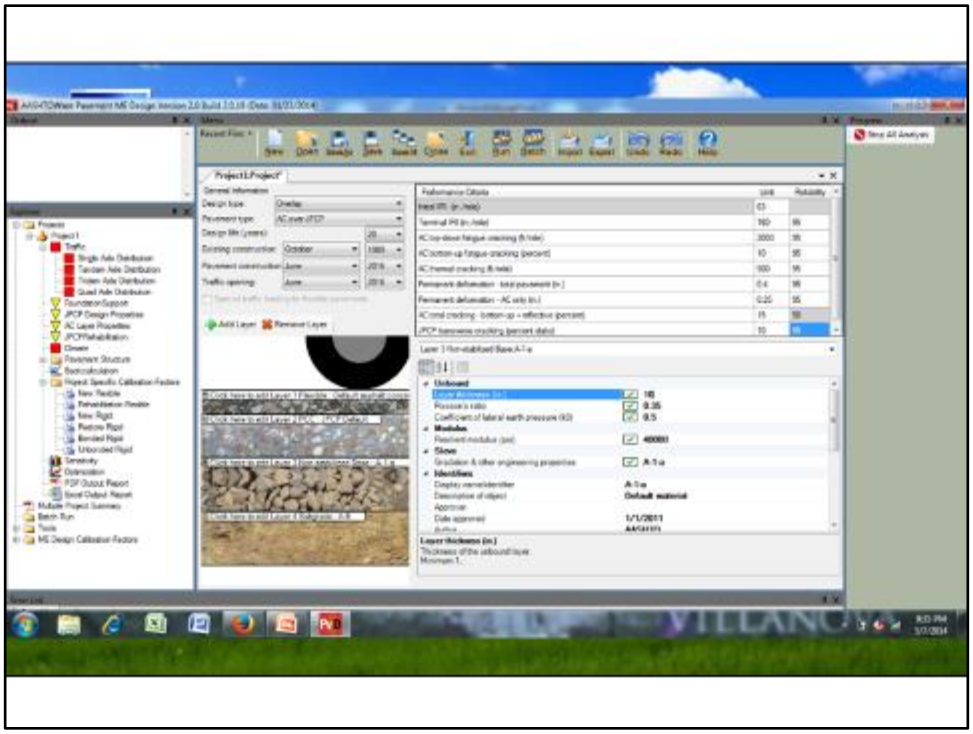
Update value to 700 psi (shown on the next screen).

Slide 122



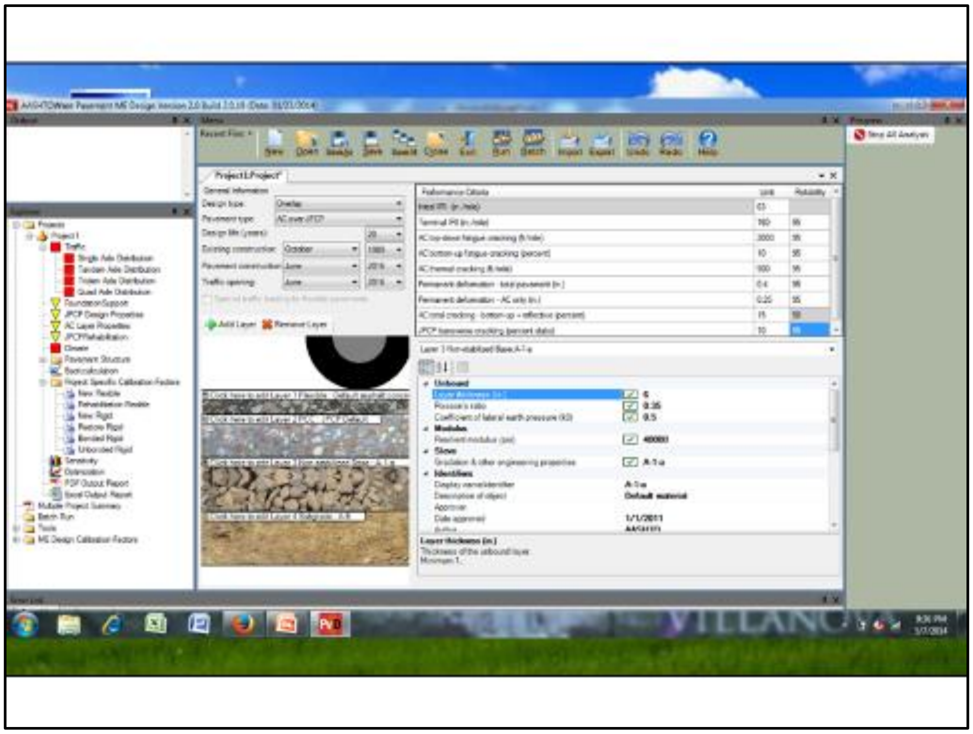
Select Layer 3.

Slide 123



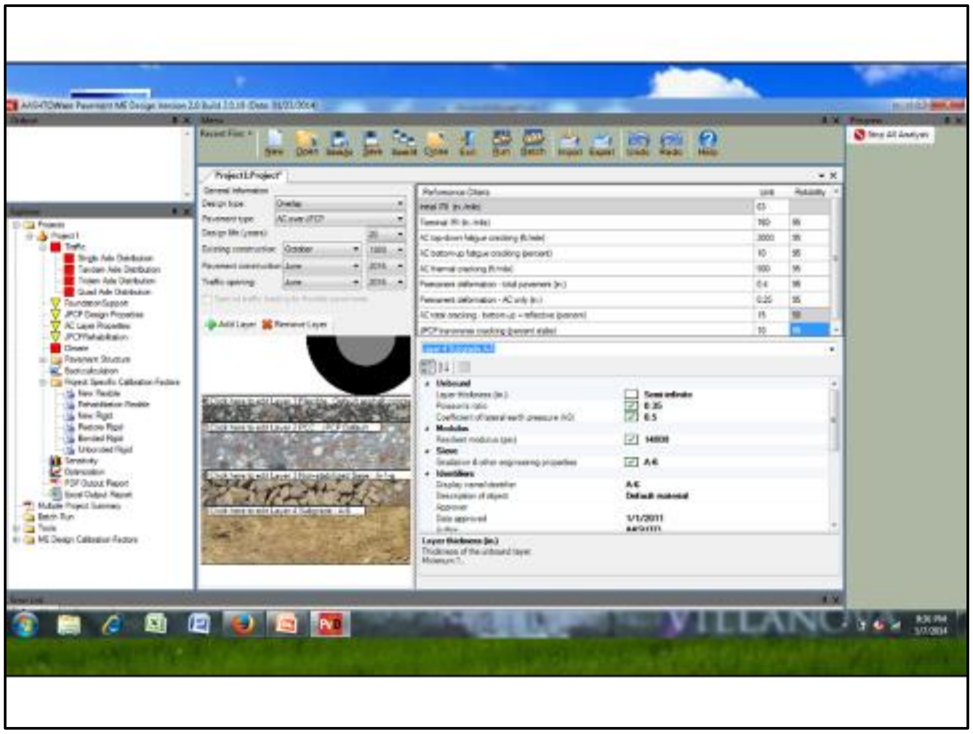
Adjust Layer Thickness.

Slide 124



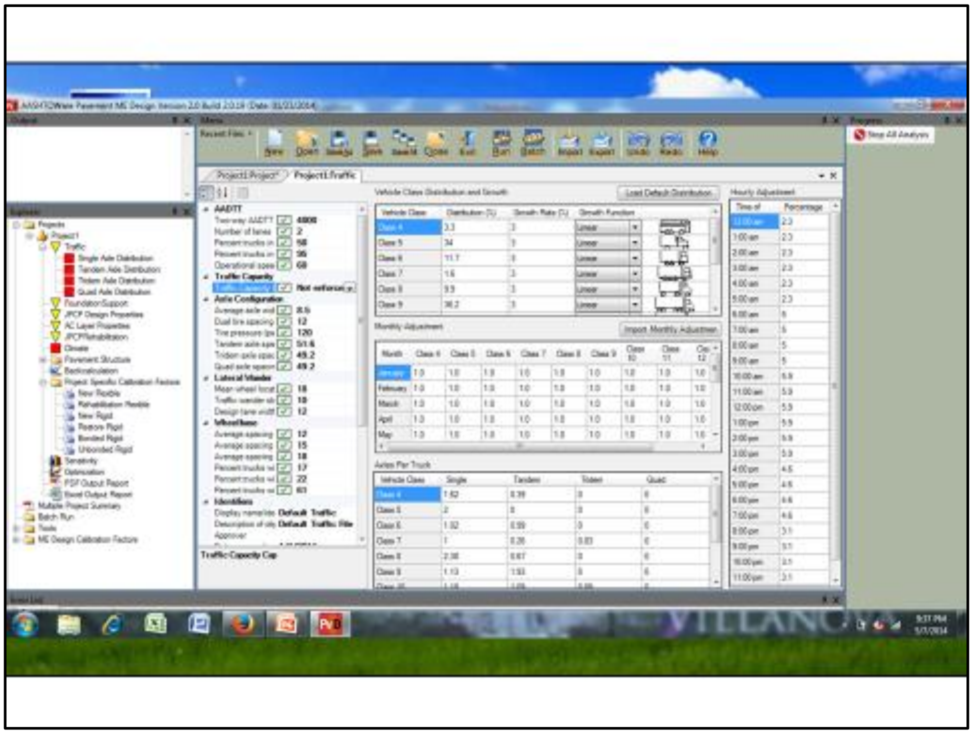
Select Layer 4 (shown on the next screen).

Slide 125



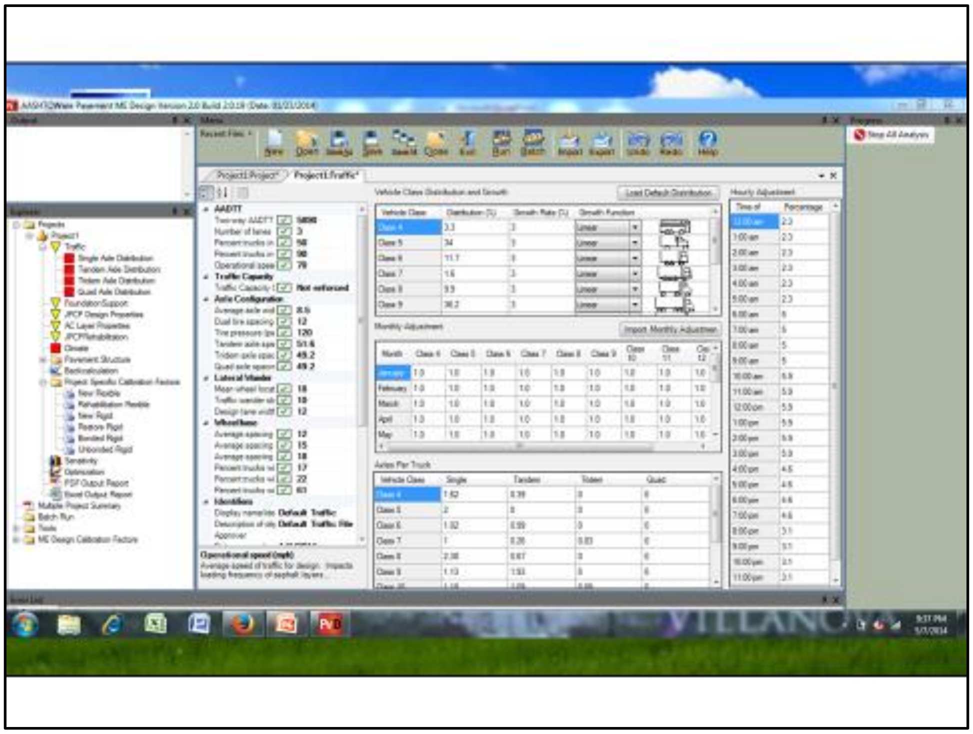
Select Traffic (shown on the next screen).

Slide 126



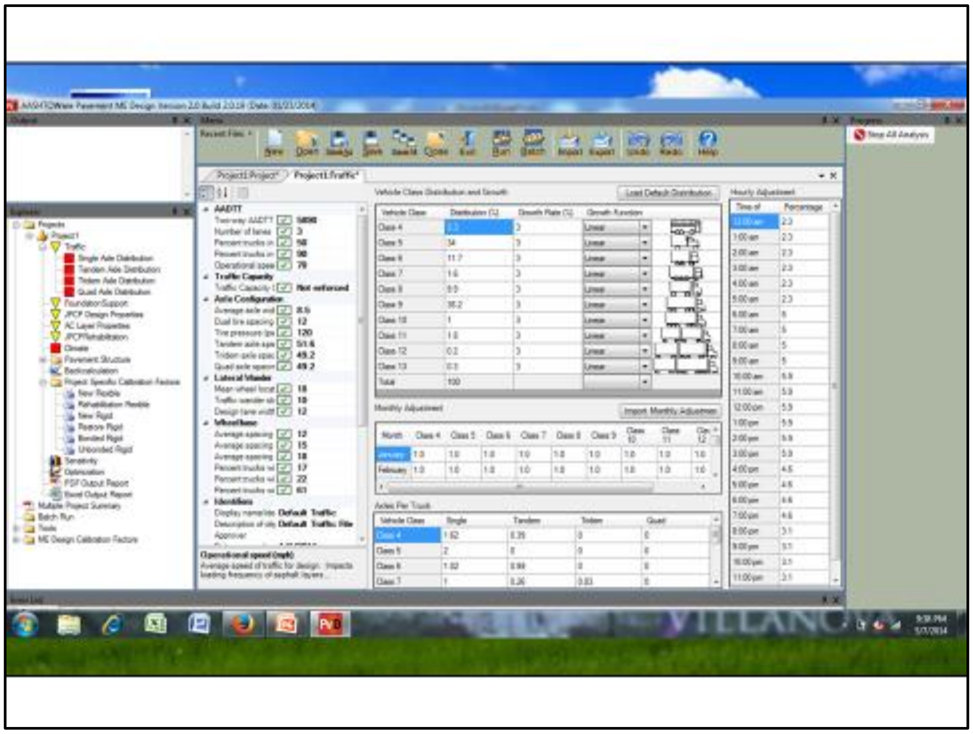
Select AADTT (shown on the next screen).

Slide 127



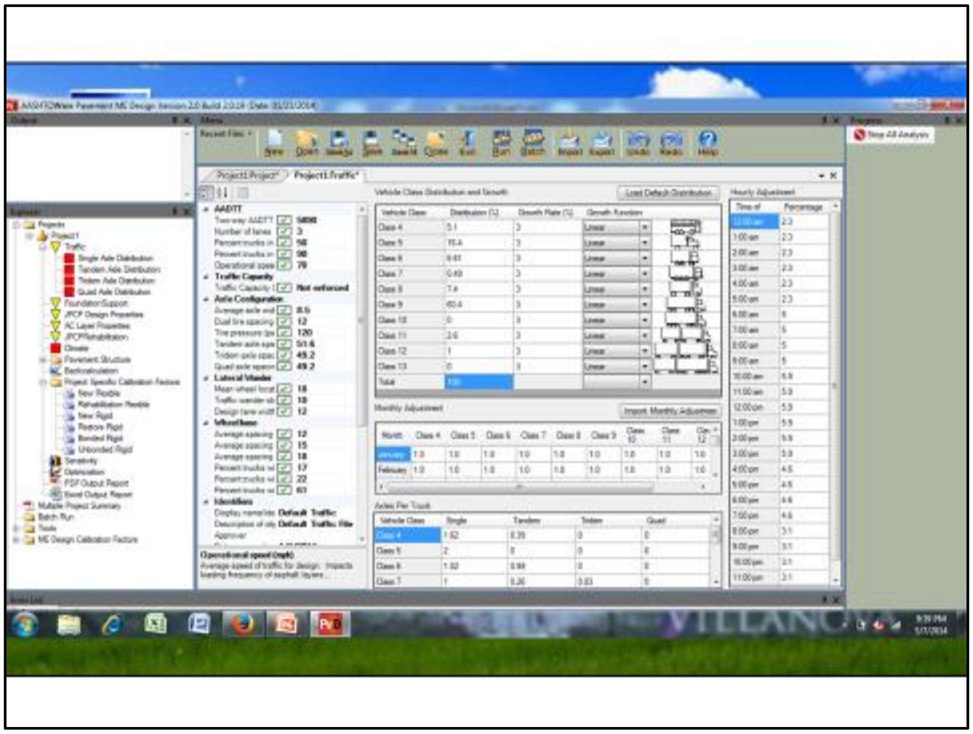
Select Vehicle Class Distribution and Growth (shown on the next screen).

Slide 128



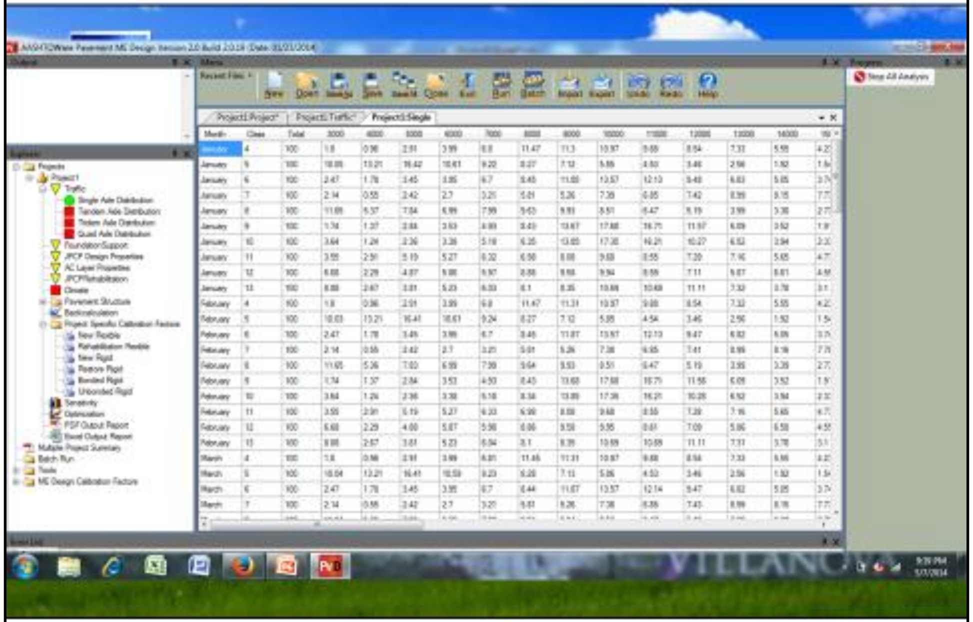
Select Adjust Distribution (%) (shown on the next screen).

Slide 129



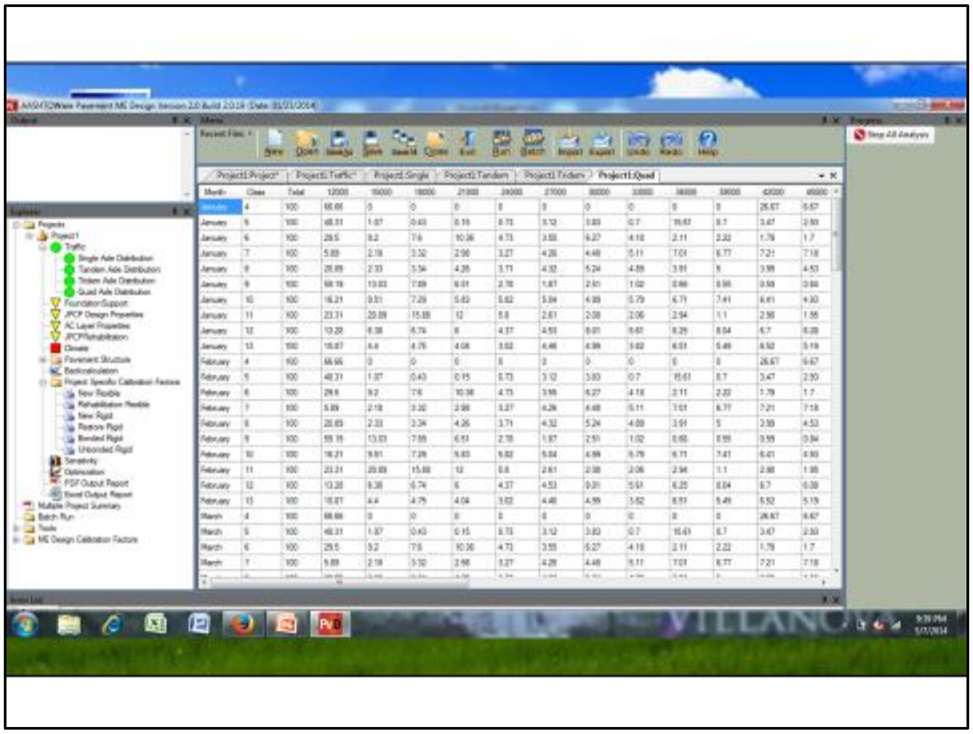
Double-click on Single Axle Distribution to accept default values.

Slide 130



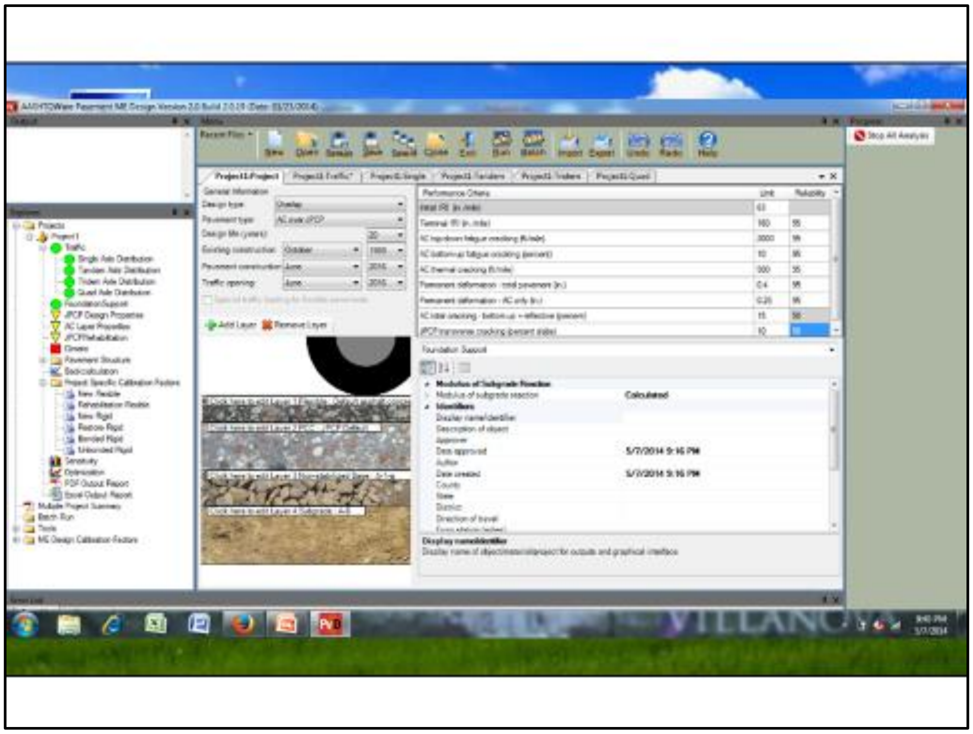
Double-click on the Other Distributions to accept default values (shown on the next screen).

Slide 131



Select Foundation Support (shown on the next screen).

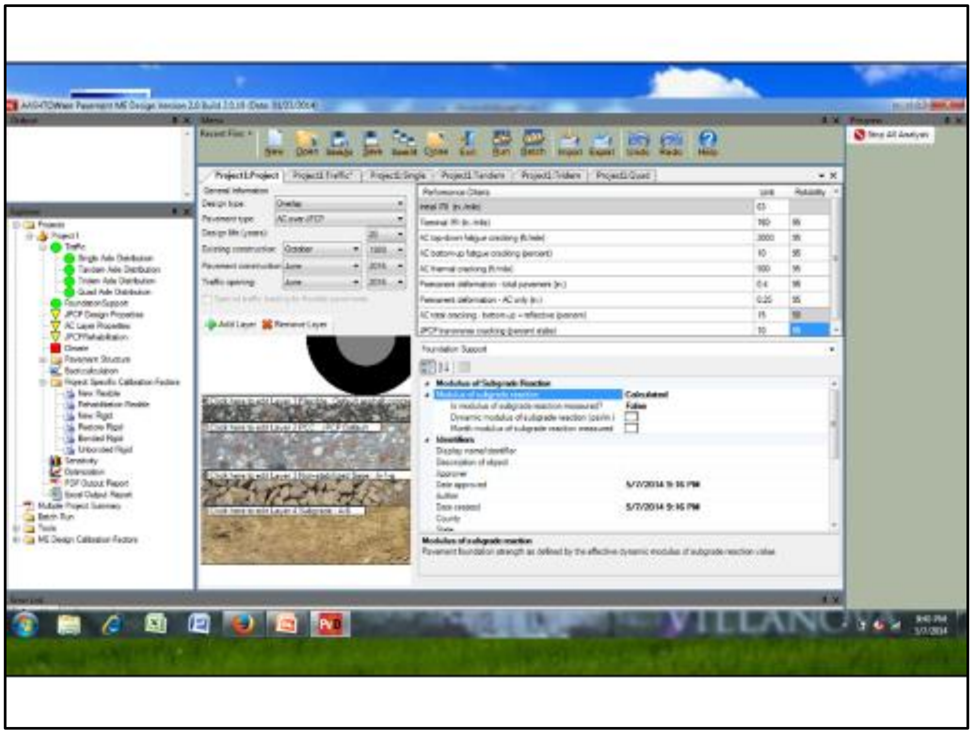
Slide 132



Select the small arrow next to Modulus of Subgrade Reaction (shown on the next screen).

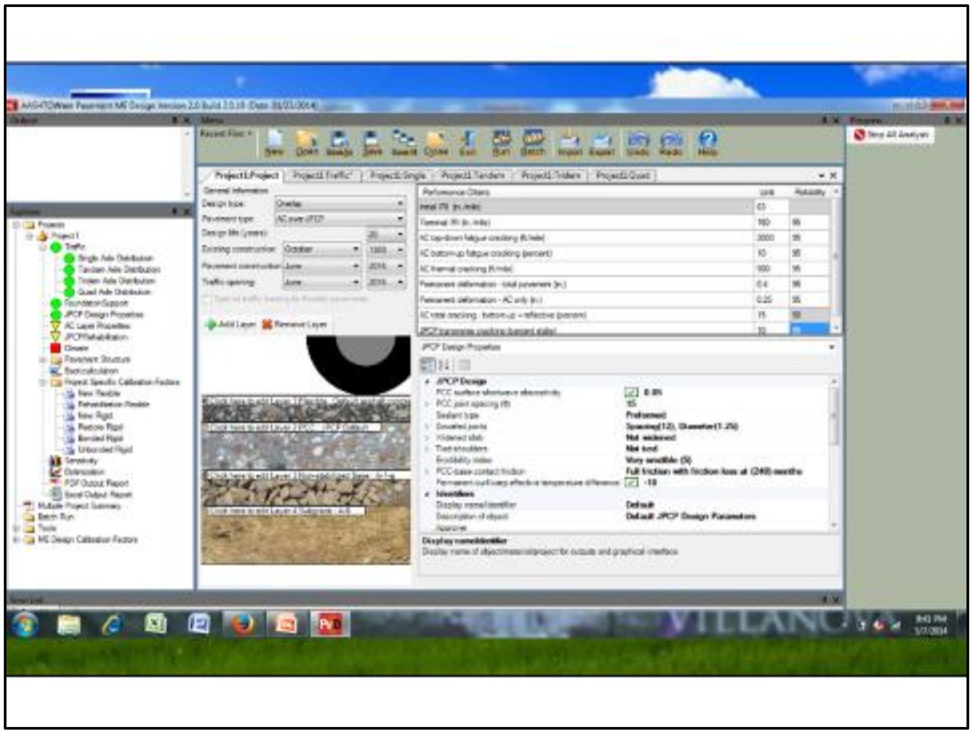
There are input options for directly inputting the falling weight deflectometer (FWD) backcalculated data for the existing pavement foundation support. This is something that can be used as part of a rehabilitation design.

Slide 133



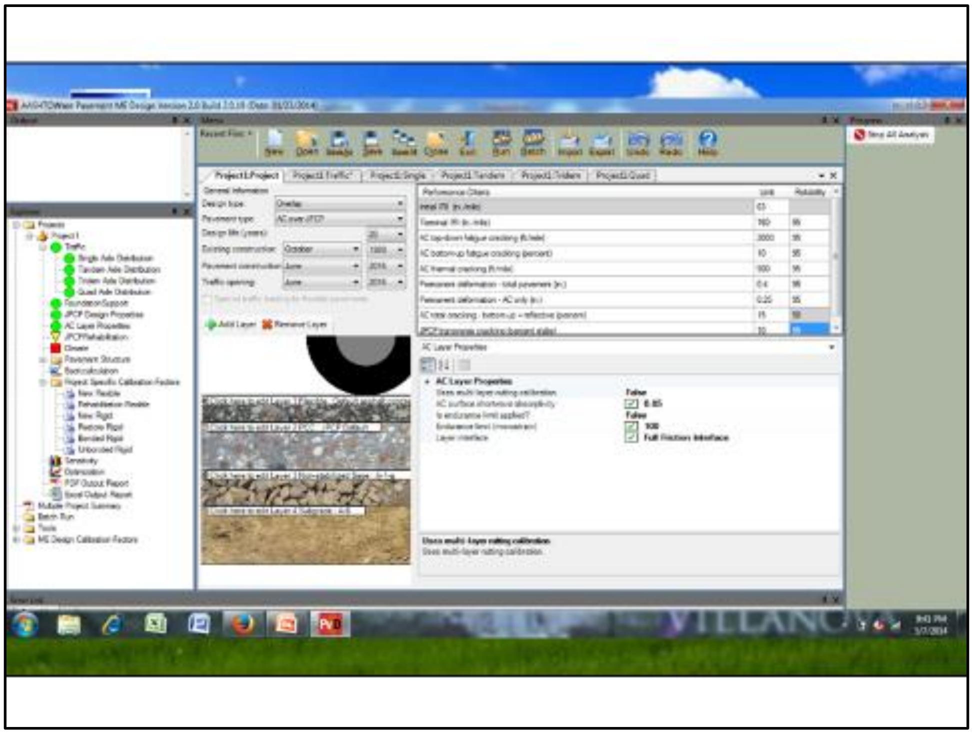
Select JPCP Design Properties (shown on the next screen).

Slide 134



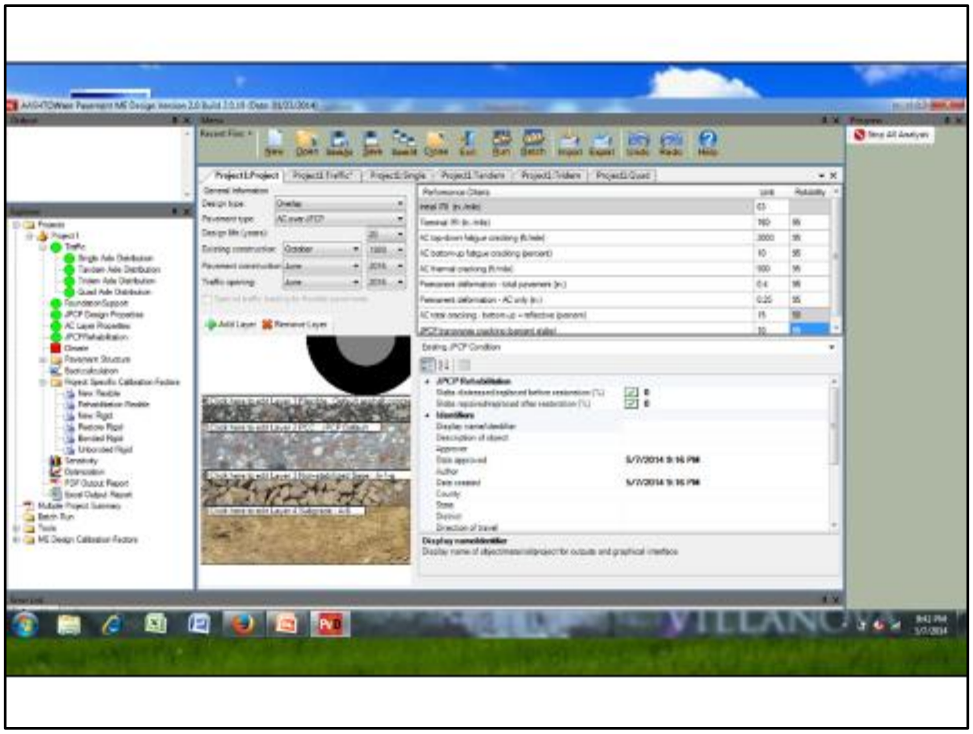
Select AC Layer Properties (shown on the next screen).

Slide 135



Select JPCP Rehabilitation (shown on the next screen).

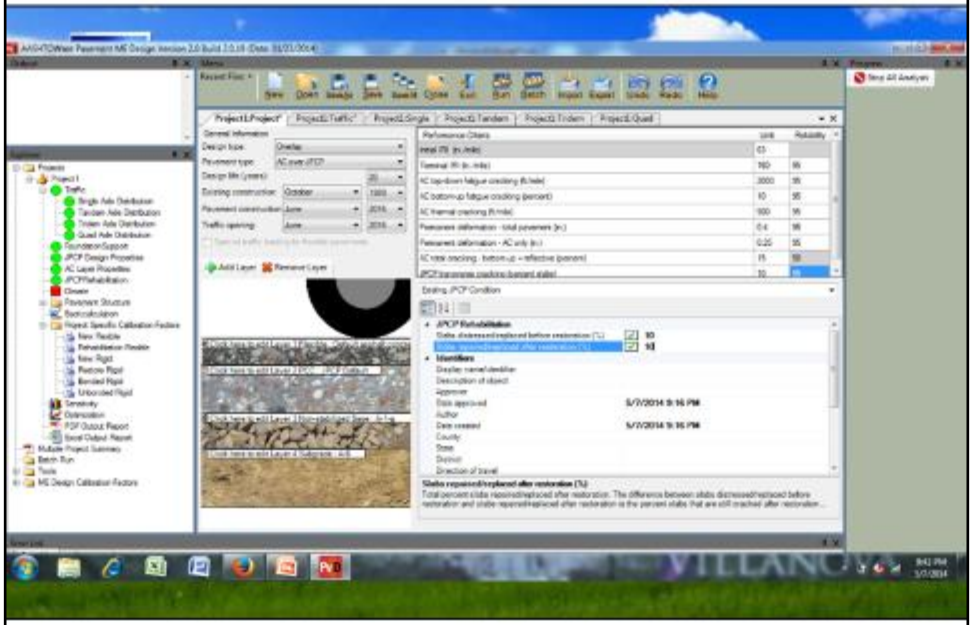
Slide 136



Change values (shown on the next screen).

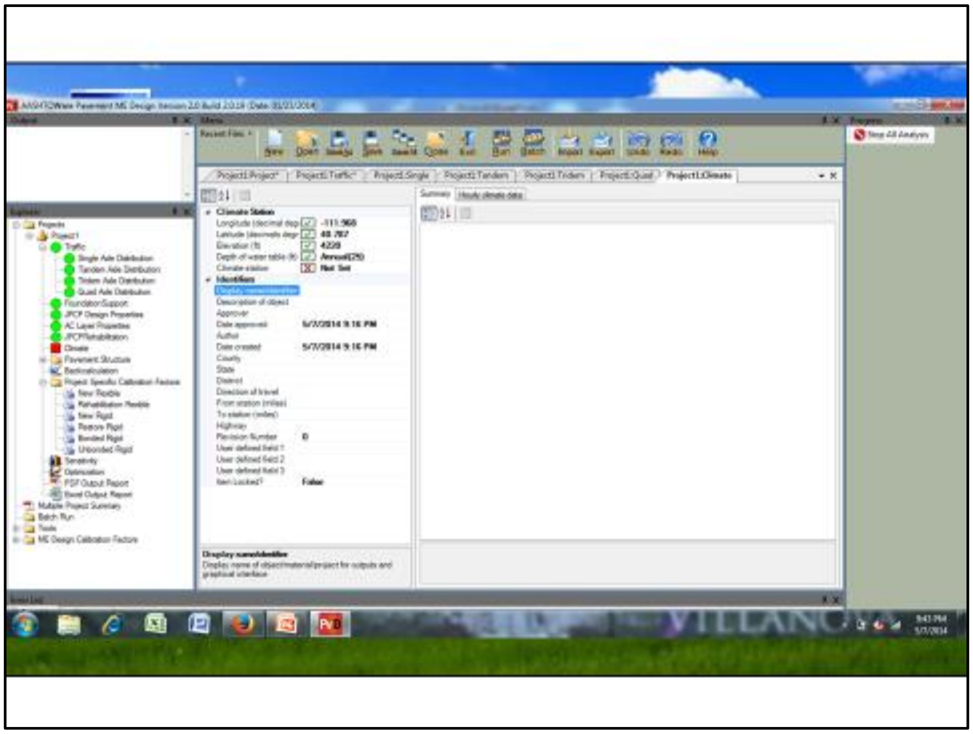
One of the important inputs when describing the condition of an existing concrete prior to repair is to identify the percentage of cracks prior to repair and also the percentage of cracks still left after repairs have been made. This sets the appropriate starting point for the degradation rate used as part of the pavement performance prediction models.

Slide 137



Select Climate.

Slide 138



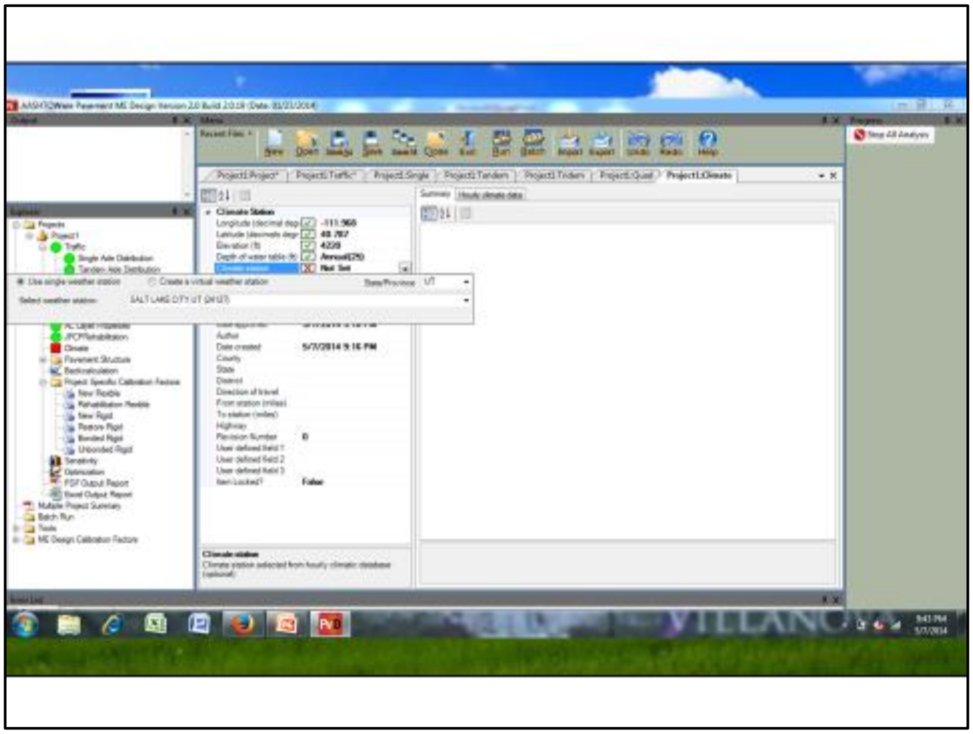
Climate Station		
Longitude (decimal deg	☑	-111.968
Latitude (decimals degr	☑	40.787
Elevation (ft)	☑	4229
Depth of water table (ft)	☑	Annual(25)
Climate station	☒	Not Set
Identifiers		
Display name/identifier		
Description of object		
Approver		
Date approved		5/7/2014 9:16 PM
Author		
Date created		5/7/2014 9:16 PM
County		
State		
District		
Direction of travel		
From station (miles)		
To station (miles)		
Highway		
Revision Number		0
User defined field 1		
User defined field 2		
User defined field 3		
Item Locked?		False

Display name/identifier

Display name of object/material/project for outputs and graphical interface

Select Climate Station (shown on the next screen).

Slide 139


Climate Station
Longitude (decimal deg) -111.968
Latitude (decimals deg) 40.787
Elevation (ft) 4229
Depth of water table (ft) Annual(25)
Climate station Not Set
● Use single weather station ○ Create a virtual weather station State/Province UT
Select weather station: SALT LAKE CITY UT (24127)
Date created 5/7/2014 9:16 PM
Revision Number 0
Item Locked? False

Select State/Province (shown on the next screen).

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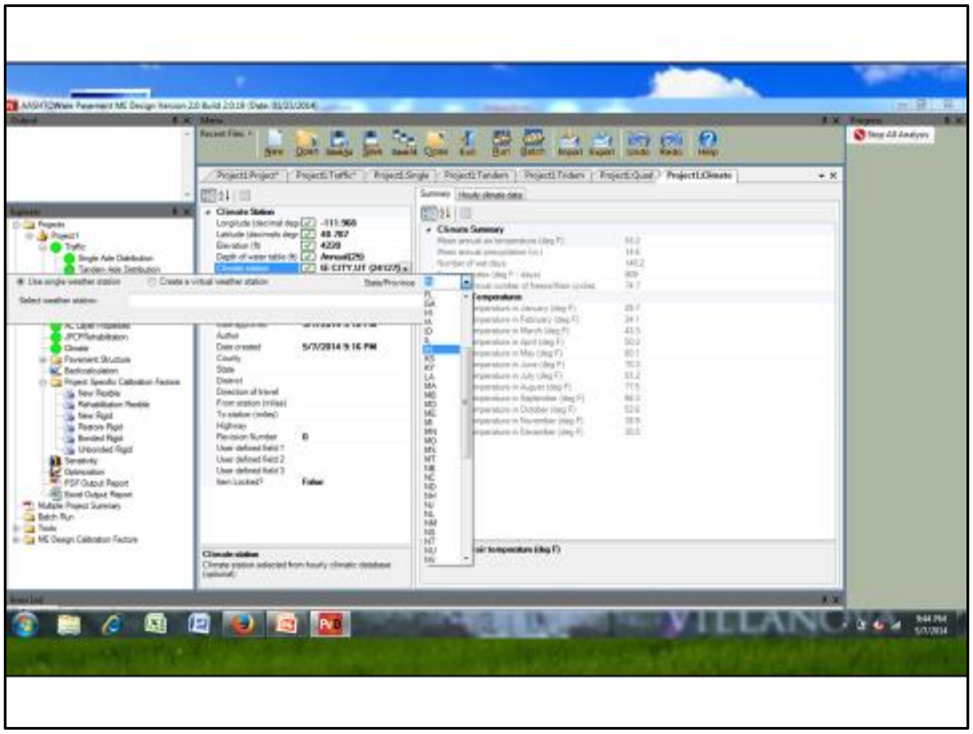
Slide 140



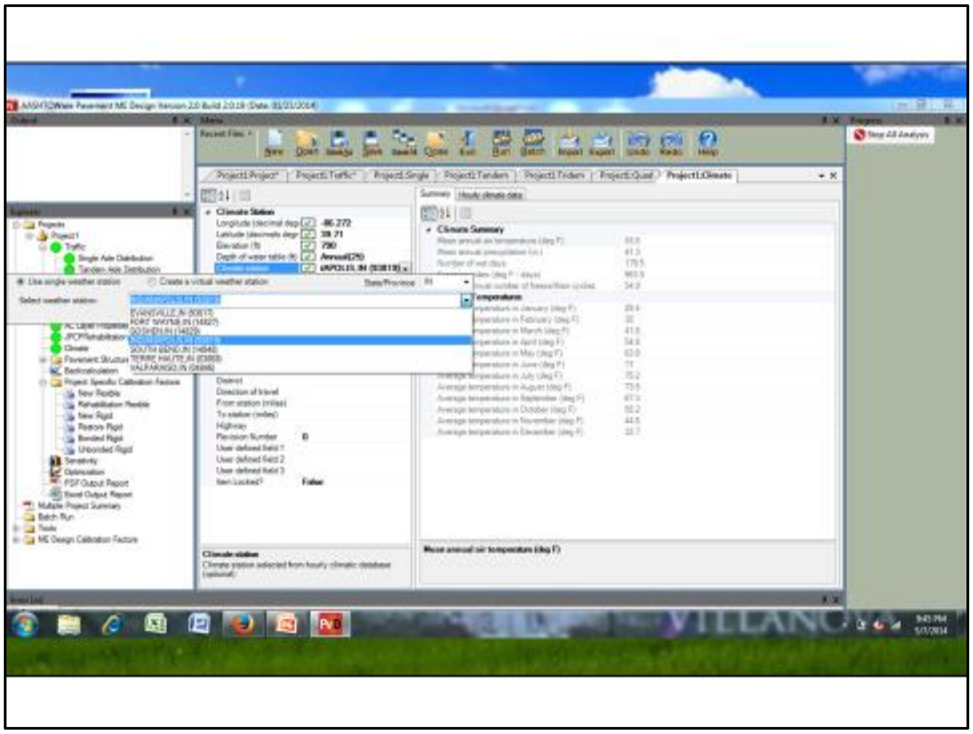
Climate Station
Longitude (decimal deg) -111.968
Latitude (decimals deg) 40.787
Elevation (ft) 4229
Depth of water table (ft) Annual(25)
Climate station SL CITY,UT (24127)

Author
Date created 5/7/2014 9:16 PM
County
State
District
Direction of travel
From station (miles)
To station (miles)
Highway
Revision Number 0
User defined field 1
User defined field 2
User defined field 3
Item Locked? False

Climate station
Climate station selected from hourly climatic database (optional)

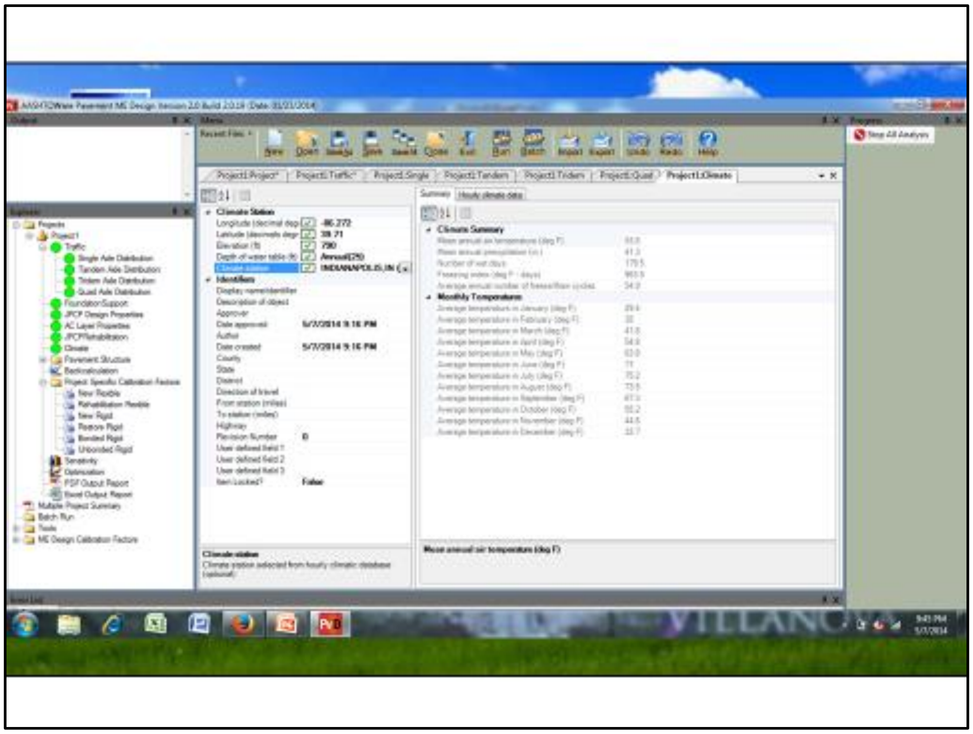
Select IN. Then select Weather Station (shown on the next screen).

Slide 141



Select Indianapolis.

Slide 142



Select Depth of Water Table (shown on the next screen).

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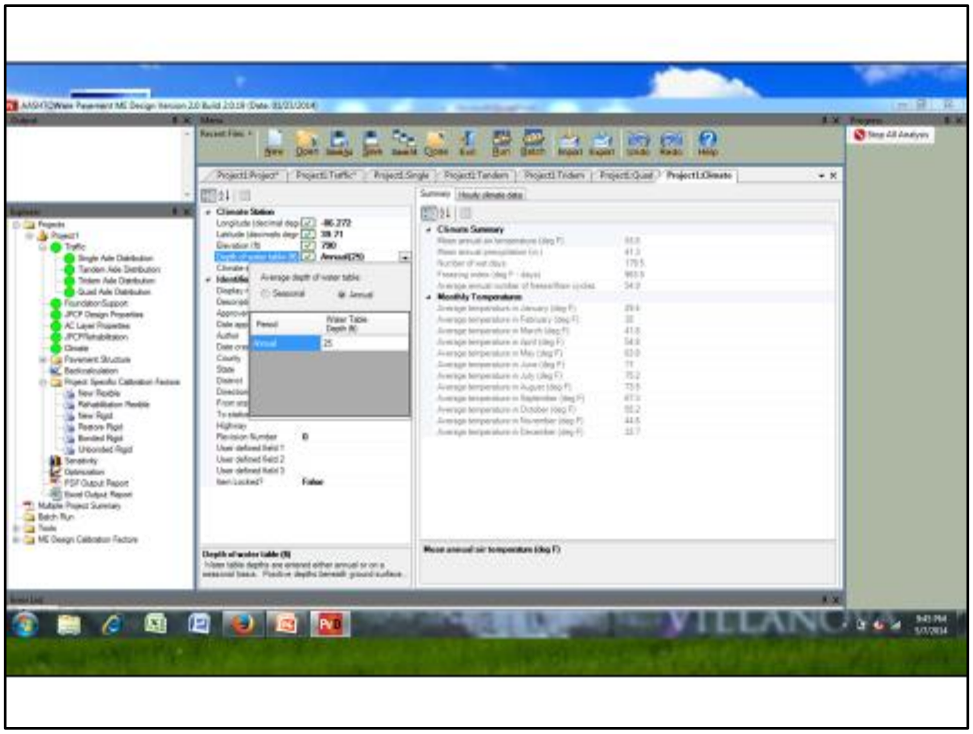
Slide 143



Climate Station
Longitude (decimal deg) -86.272
Latitude (decimals degr 39.71
Elevation (ft) 790
Depth of water table (ft) Annual(25)

Average depth of water table:
○ Seasonal ● Annual

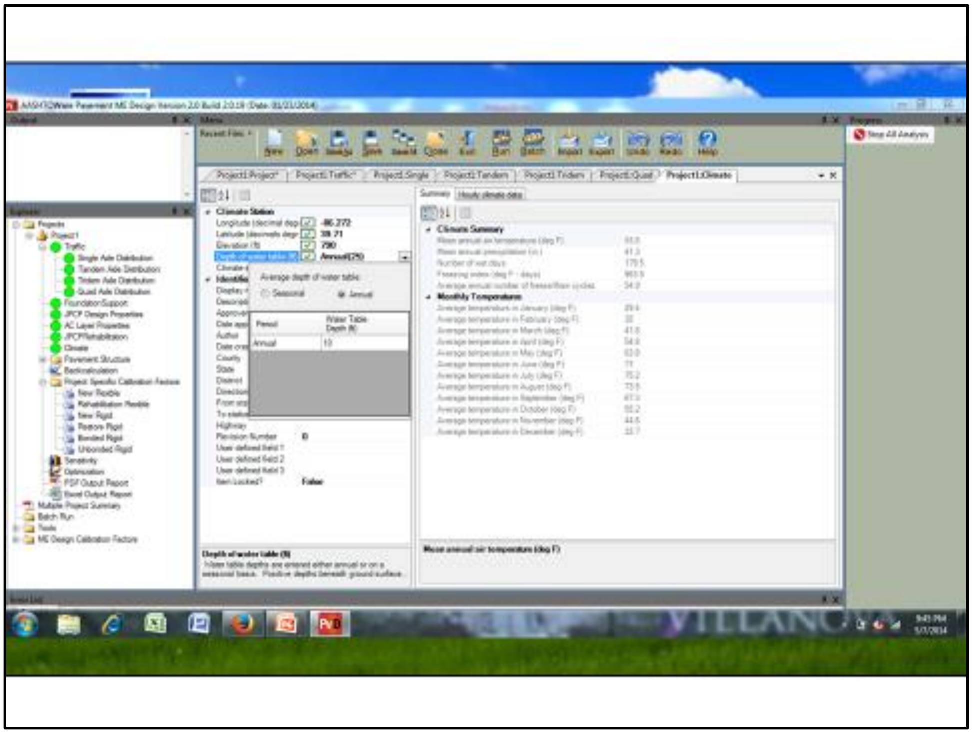
Period	Water Table Depth (ft)
Annual	25

Revision Number 0
Item Locked? False

Depth of water table (ft)
Water table depths are entered either annual or on a seasonal basis. Positive depths beneath ground surface.

Change value to 10 (shown on the next screen).

Slide 144



Climate Station

Longitude (decimal degrees): -86.272

Latitude (decimal degrees): 39.71

Elevation (ft): 790

Average depth of water table

○ Seasonal ● Annual

Period	Water Table Depth (ft)
Annual	10

Revision Number: 0

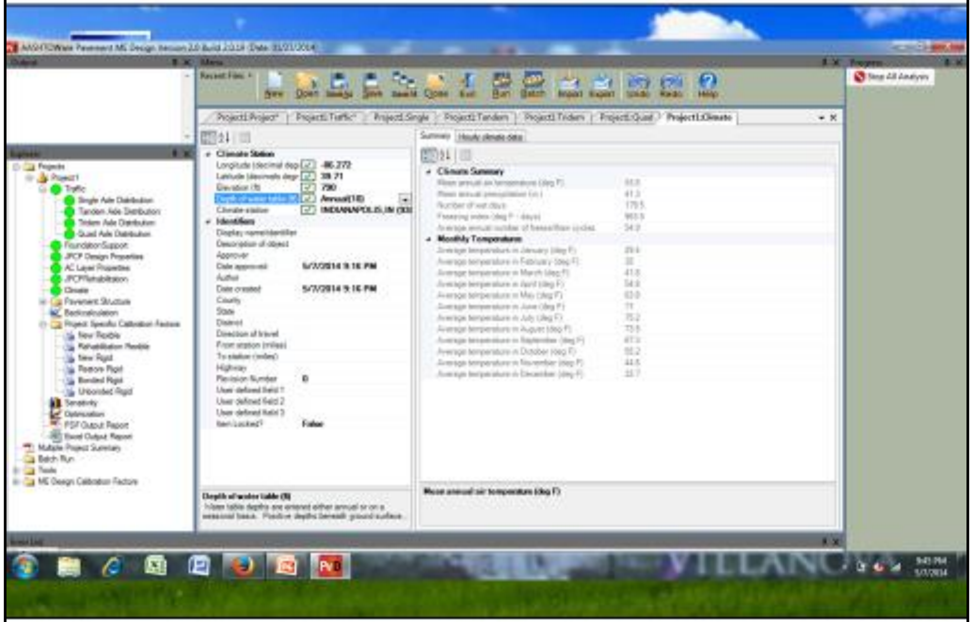
Item Locked?: False

Depth of water table (ft)

Water table depths are entered either annual or on a seasonal basis. Positive depths beneath ground surface.

This screen shows the value as 10.

Slide 145

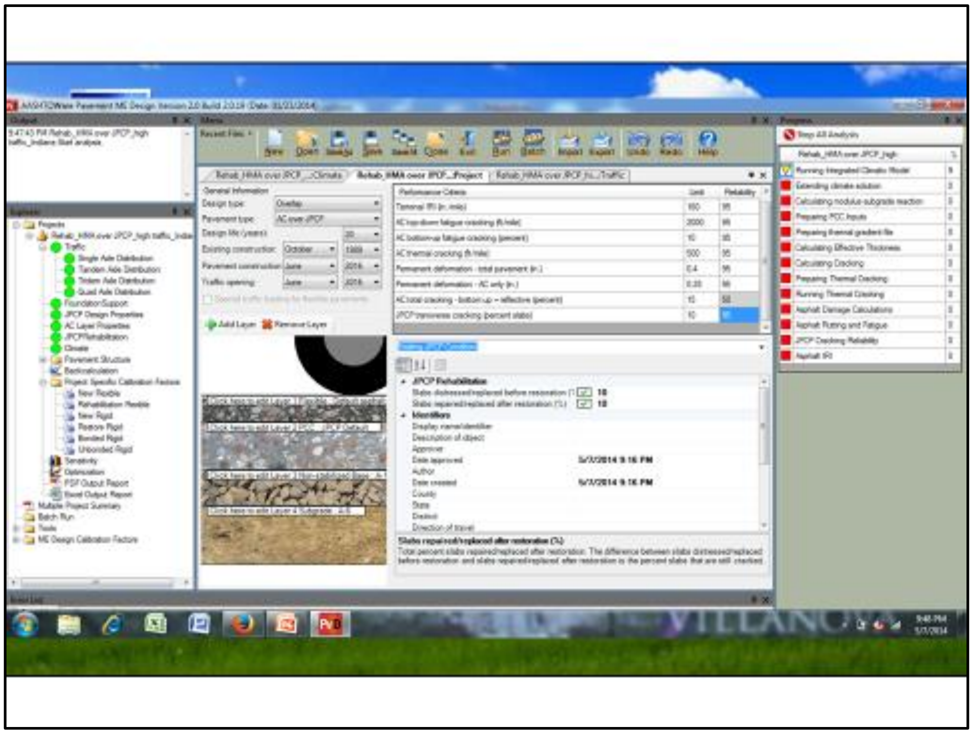


Climate Station
Longitude (decimal deg) ☑ -86.272
Latitude (decimals deg) ☑ 39.71
Elevation (ft) ☑ 790
Depth of water table (ft) ☑ Annual(10)
Climate station ☑ INDIANAPOLIS, IN

Identifiers
Date approved 5/7/2014 9:16 PM
Date created 5/7/2014 9:16 PM
Revision Number 0
Item Locked? False

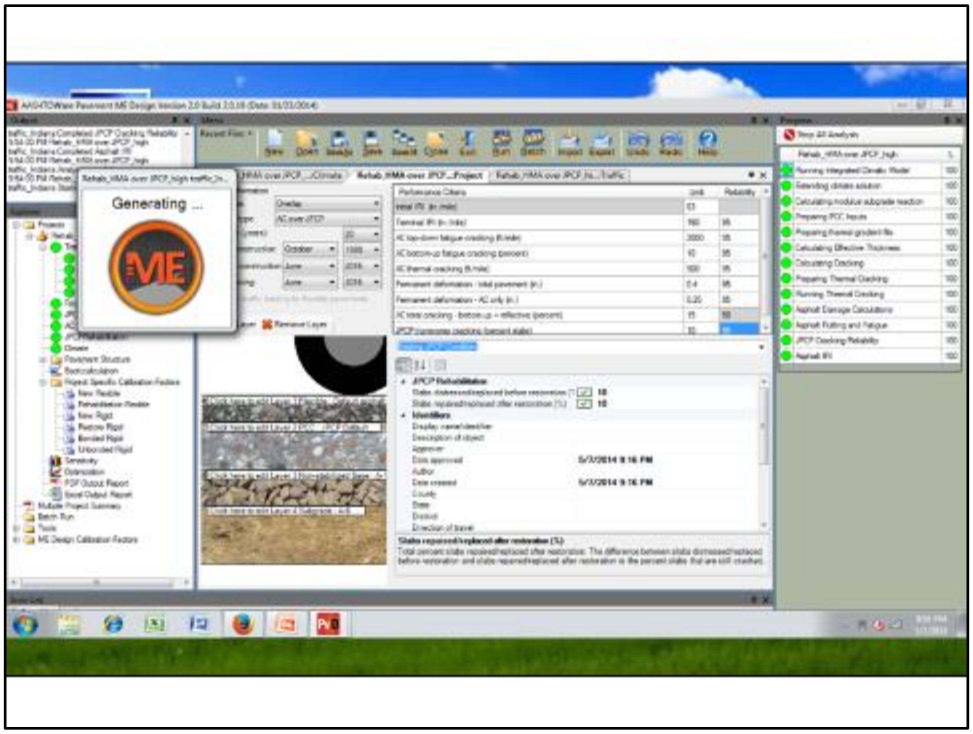
Save the project by selecting Save. Select Run to run the analysis.

Slide 146



The demonstration shows that the analysis is underway on the right-hand side of the screen, and as the software runs, each portion first turns from a red square to a yellow triangle to a green circle sequentially as it progresses fully through the analytical engine.

Slide 147



Analysis progress is shown on the right-hand side of the screen.

When the analysis is complete, the software will generate the output (PDF and Excel).

Slide 148

PvD
AASHTOWare
Pavement
ME Design
AASHTO

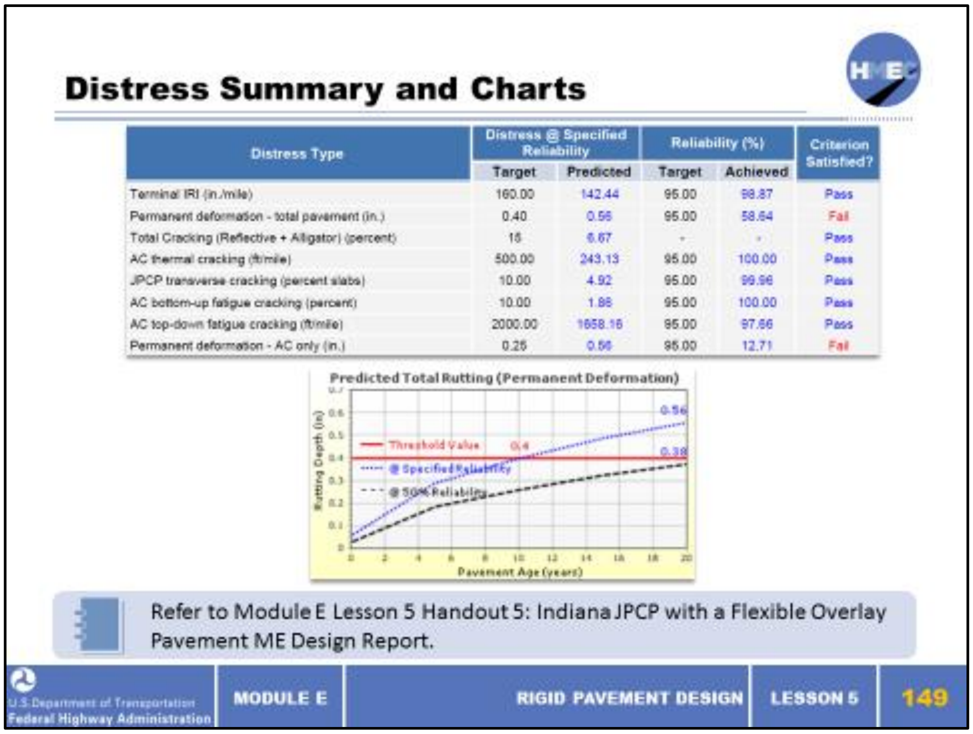
Software Demonstration for Rigid Pavement

End Demonstration

Flexible Overlay over a Jointed Rigid Pavement Example

U.S. Department of Transportation Federal Highway Administration | MODULE E | RIGID PAVEMENT DESIGN | LESSON 5 | 148

Slide 149



Distress Summary and Charts

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	142.44	95.00	98.87	Pass
Permanent deformation - total pavement (in.)	0.40	0.56	95.00	58.64	Fail
Total Cracking (Reflective + Alligator) (percent)	15	6.67	-	-	Pass
AC thermal cracking (ft/mile)	500.00	243.13	95.00	100.00	Pass
JPCP transverse cracking (percent slabs)	10.00	4.92	95.00	99.96	Pass
AC bottom-up fatigue cracking (percent)	10.00	1.86	95.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	2000.00	1658.16	95.00	97.66	Pass
Permanent deformation - AC only (in.)	0.25	0.56	95.00	12.71	Fail

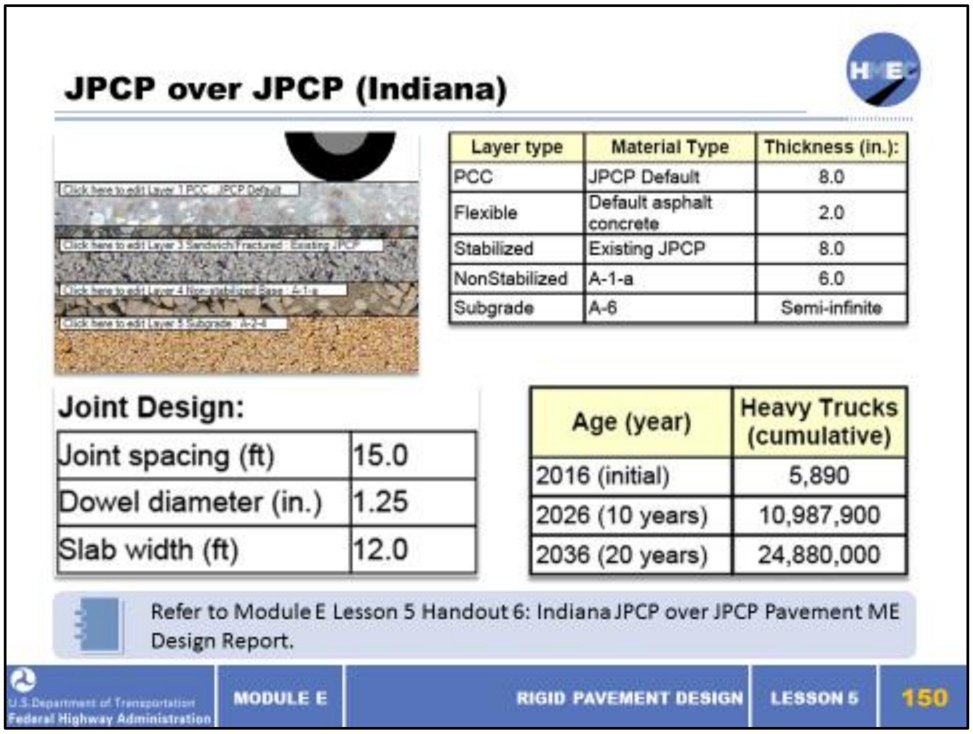
Refer to Module E Lesson 5 Handout 5: Indiana JPCP with a Flexible Overlay Pavement ME Design Report.

MODULE E | RIGID PAVEMENT DESIGN | LESSON 5 | 149

The purpose of the screen is to help participants interpret output from the rehabilitated rigid pavement (JPCP) with a flexible overlay.

The AASHTO Joint Task Force on Pavements has made the reflective cracking model as a top priority for implementation and improvement in the future versions of the Pavement ME Design software in the next coming years.

Slide 150


Click here to edit Layer 1 PCC : JPCP Default
Click here to edit Layer 3 Sandwich Fractured : Existing JPCP

JPCP over JPCP (Indiana)

Layer type	Material Type	Thickness (in.):
PCC	JPCP Default	8.0
Flexible	Default asphalt concrete	2.0
Stabilized	Existing JPCP	8.0
NonStabilized	A-1-a	6.0
Subgrade	A-6	Semi-infinite

Joint Design:

Joint spacing (ft)	15.0
Dowel diameter (in.)	1.25
Slab width (ft)	12.0

Age (year)	Heavy Trucks (cumulative)
2016 (initial)	5,890
2026 (10 years)	10,987,900
2036 (20 years)	24,880,000

Refer to Module E Lesson 5 Handout 6: Indiana JPCP over JPCP Pavement ME Design Report.

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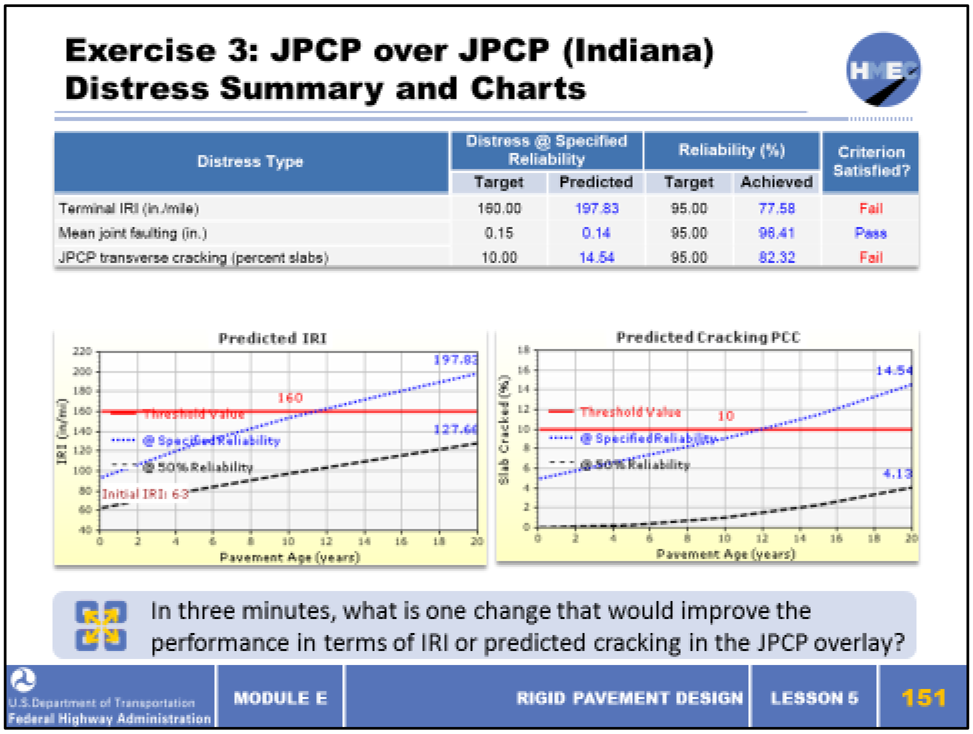
MODULE E | RIGID PAVEMENT DESIGN | LESSON 5 | 150

The purpose of the screen is to introduce the analysis of a rigid (JPCP) overlay of an existing jointed rigid pavement.

The schematic shows the structure, and the tables show the design features and traffic summary for the sample pavement project from Indiana.

Slide 151



Exercise 3: JPCP over JPCP (Indiana) Distress Summary and Charts

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	197.83	95.00	77.58	Fail
Mean joint faulting (in.)	0.15	0.14	95.00	98.41	Pass
JPCP transverse cracking (percent slabs)	10.00	14.54	95.00	82.32	Fail

In three minutes, what is one change that would improve the performance in terms of IRI or predicted cracking in the JPCP overlay?

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MODULE E | RIGID PAVEMENT DESIGN | LESSON 5 | 151

The purpose of the screen is to help participants interpret output from the rehabilitated rigid pavement (JPCP) with a rigid (JPCP) overlay.

The analysis predicted shows that although the faulting does not appear to be a problem, the percent slabs cracked and smoothness are both exceeding the performance criteria at the 95% reliability level.

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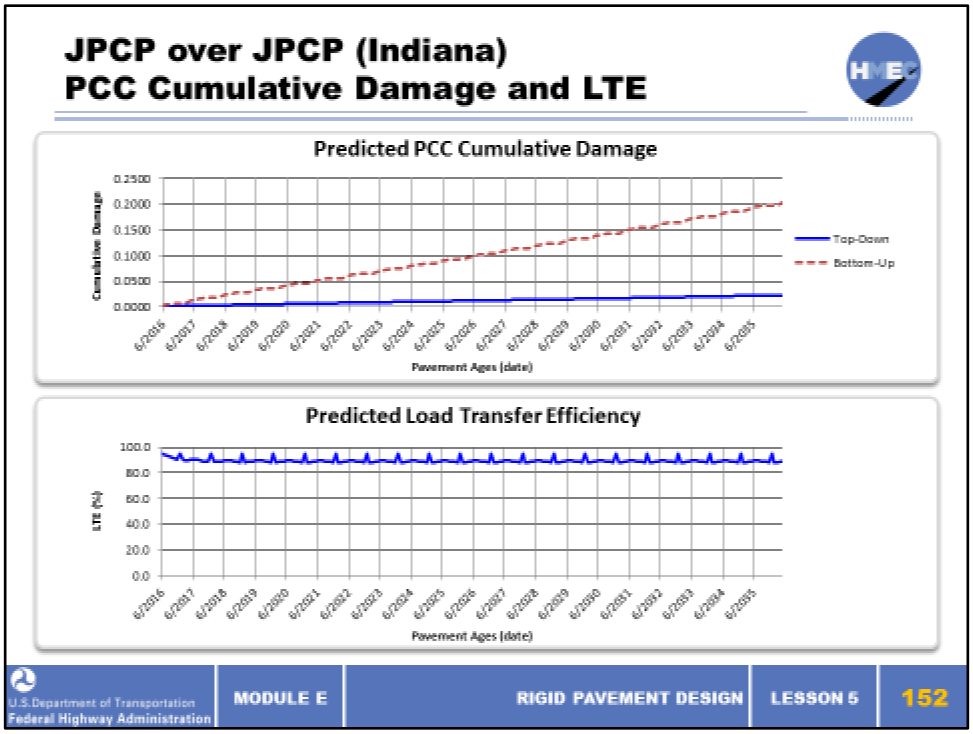
Slide 152



JPCP over JPCP (Indiana)
PCC Cumulative Damage and LTE

Predicted PCC Cumulative Damage

Predicted Load Transfer Efficiency

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MODULE E | RIGID PAVEMENT DESIGN | LESSON 5 | 152

The purpose of the screen is to help participants interpret output from the rehabilitated rigid pavement analysis (JPCP) beyond just the plots, to introduce again the LTE and cumulative damage output.

The cumulative damage (both bottom-up and top-down) can be observed in the output of the Pavement ME Design software, along with the load transfer efficiency of the dowels. There is relatively minor damage occurring from the top-down; however, there is a steady increase in damage over time from the bottom-up. The load transfer efficiency remains very good over the life of the pavement (doesn't dip below 90%), which is a positive performance factor for the trial design and may further explain the minimal impact of faulting.

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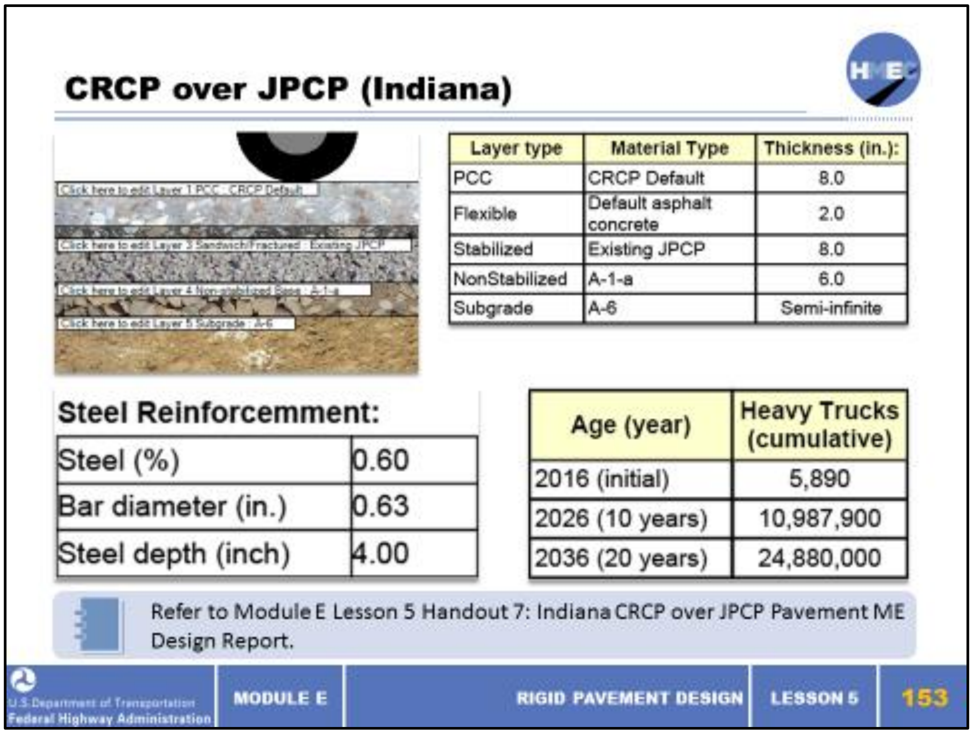
Slide 153


Click here to edit Layer 1 PCC : CRCP Default
Click here to edit Layer 3 Sandwich/Fractured : Existing JPCP
Click here to edit Layer 4 Non-stabilized Base : A-1-a
Click here to edit Layer 5 Subgrade : A-6

CRCP over JPCP (Indiana)

Layer type	Material Type	Thickness (in.):
PCC	CRCP Default	8.0
Flexible	Default asphalt concrete	2.0
Stabilized	Existing JPCP	8.0
NonStabilized	A-1-a	6.0
Subgrade	A-6	Semi-infinite

Steel Reinforcemment:

Steel (%)	0.60
Bar diameter (in.)	0.63
Steel depth (inch)	4.00

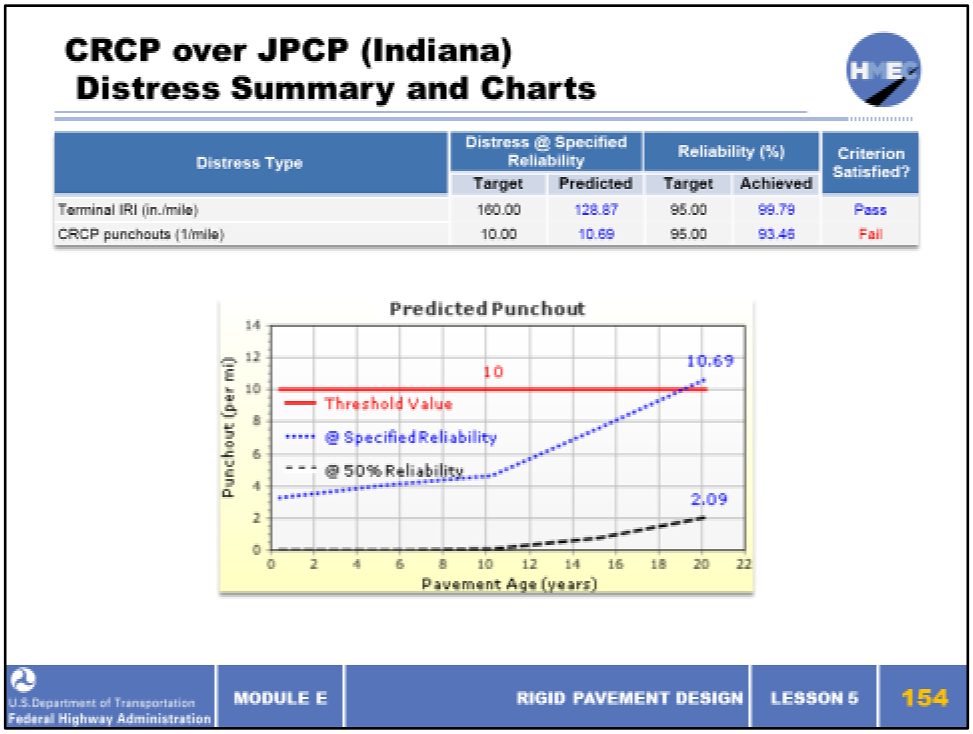
Age (year)	Heavy Trucks (cumulative)
2016 (initial)	5,890
2026 (10 years)	10,987,900
2036 (20 years)	24,880,000

Refer to Module E Lesson 5 Handout 7: Indiana CRCP over JPCP Pavement ME Design Report.

The purpose of the screen is to introduce the analysis of a rigid (CRCP) overlay of an existing jointed rigid pavement.

The schematic shows the structure (including the thin asphalt lift used as a bond breaker between the existing JPCP and the CRCP OL), and the tables show the design features and traffic summary for the sample pavement project from Indiana.

Slide 154



CRCP over JPCP (Indiana) Distress Summary and Charts

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	128.87	95.00	99.79	Pass
CRCP punchouts (1/mile)	10.00	10.69	95.00	93.46	Fail

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MODULE E

RIGID PAVEMENT DESIGN

LESSON 5

154

The purpose of the screen is to help participants interpret output from the rehabilitated rigid pavement (CRCP) with a rigid (JPCP) overlay.

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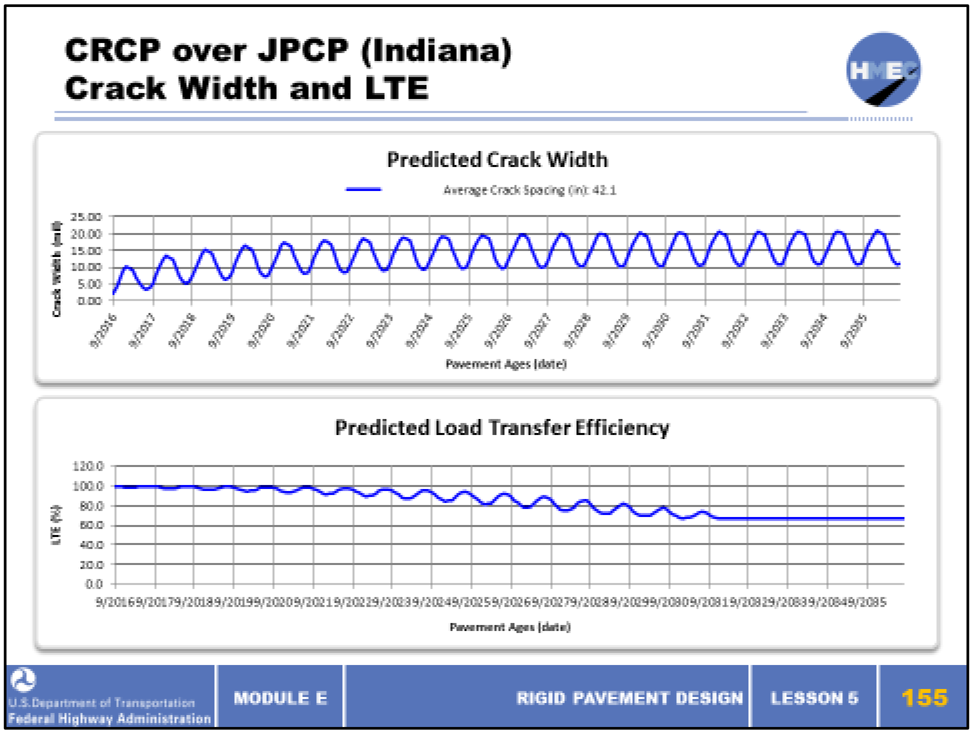
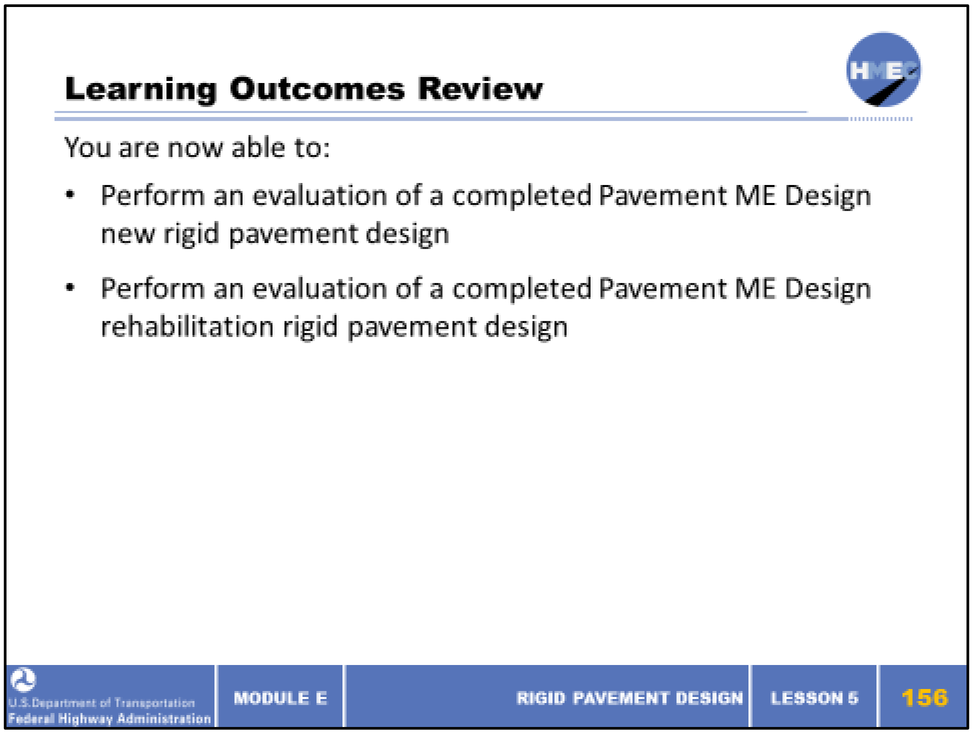
Slide 155



CRCP over JPCP (Indiana) Crack Width and LTE

The purpose of the screen is to help participants interpret output from the rehabilitated rigid pavement analysis (CRCP), beyond just the plots, to introduce again the LTE and crack width.

Slide 156



Learning Outcomes Review

You are now able to:

- Perform an evaluation of a completed Pavement ME Design new rigid pavement design
- Perform an evaluation of a completed Pavement ME Design rehabilitation rigid pavement design

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MODULE E RIGID PAVEMENT DESIGN LESSON 5 156

Slide 1

HMEC

Highway Materials Engineering Course

Lesson 6: Hot Topics

MODULE

E

Mechanistic Empirical Pavement Design Guide (MEPDG)

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Federal Highway Administration

Appendix A: Acronyms

The following are acronyms referenced throughout the course that are important agencies or organizations:

Acronym	Proper Name
AASHTO	American Association of State Highway and Transportation Officials
ACAA	American Coal Ash Association
ACI	American Concrete Institute
ACPA	American Concrete Paving Association
AI	Asphalt Institute
ASTM	American Society for Testing and Materials
AWS	American Welding Society
CFR	Code of Federal Regulations
DOT	U.S. Department of Transportation
EPA	Environmental Protection Agency
FHWA	Federal Highway Administration
NACE	National Association of Corrosion Engineers
NAPA	National Asphalt Pavement Association
NCAT	National Center for Asphalt Technology
NCHRP	National Cooperative Highway Research Program
NEPCOAT	North East Protective Coating
NHI	National Highway Institute
NRC	National Recycling Coalition

Acronym	Proper Name
NRMCA	National Ready Mixed Concrete Association
NSA	National Slag Association
NSBA	National Steel Bridge Alliance
NTPEP	National Transportation Product Evaluation Program
OSHA	Occupational Safety and Health Administration
RCSC	Research Council on Structural Connections
SSPC	Society for Protective Coatings
TRB	Transportation Research Board
USGS	U.S. Geological Survey

Appendix B: Resources

Additional information regarding Module E can be found in the following sources.

ME Design: http://me-design.com

FHWA Design Guide Implementation Team:
http://www.fhwa.dot.gov/pavement/dgit/dgitwork.cfm

American Association of State Highway and Transportation Officials (AASHTO) Guide for Design of Pavement Structures, 4th Edition with 1998 Supplement, Washington, D.C., 1993.

American Association of State Highway and Transportation Officials (AASHTO) AASHTOWare™ Pavement ME Design, Version 2.0, January 2014.

American Association of State Highway and Transportation Officials (AASHTO) Mechanistic-Empirical Pavement Design Guide, Interim Edition: A Manual of Practice, Washington, D.C., 2008.

American Association of State Highway and Transportation Officials (AASHTO) "Standard Specifications for Transportation Materials and Methods of Sampling and Testing" and AASHTO Provisional Standards, 33rd Edition, 2013.

Applied Research Associates, Inc., Guide for Mechanistic-Empirical Design of New and Rehabilitated Pavement Structures, National Cooperative Highway Research Program Project 1-37A, Transportation Research Board, National Research Council, Washington, D.C., 2004, http://onlinepubs.trb.org/onlinepubs/archive/mepdg/guide.htm.

Schwartz, C., Li, R., Kim, S., Ceylan, H., and Gopalakrishnan, K., Sensitivity Evaluation of MEPDG Performance Prediction, National Cooperative Highway Research Program Research Results Digest, RRD 372, National Research Council, Washington, D.C., 2013.

Zapata, C., Lopez, N., Cary, C., and Torres, G., Arizona State University Soil Unit Map Application®, Arizona State University, 2011, http://nchrp923b.lab.asu.edu/

American Society for Testing and Materials (ASTM) *Annual Book of ASTM* Standards, available from ASTM, West Conshohocken, PA, 2013.

Federal Highway Administration, Design Guide Implementation Survey, U.S. Department of Transportation, Washington D.C., 2003, https://www.fhwa.dot.gov/Pavement/dgit/dgitsurvey.pdf.
Florida Department of Transportation, Flexible and Rigid Pavement Design Manuals, 2008 and 2009, Gainesville, Florida, http://www.dot.state.fl.us/rddesign/PM/publicationS.shtm.

Florida Department of Transportation, Standard Specifications for Road and Bridge Construction, 2010, http://www.dot.state.fl.us/specificationsoffice/Implemented/SpecBooks/2010BK.shtm.

Indiana Department of Transportation, Section 400 Asphalt Pavements, Standard Specifications, 2012, http://www.in.gov/dot/div/contracts/standards/book/sep11/4-2012.pdf.

Indiana Department of Transportation, Section 500 Concrete Pavement, Standard Specifications, 2012, http://www.in.gov/dot/div/contracts/standards/book/sep11/5-2012.pdf.

Indiana Department of Transportation, Section 900 Materials Details, Standard Specifications, 2012, http://www.in.gov/dot/div/contracts/standards/book/sep11/9-2012.pdf.

Indiana Department of Transportation, MEPDG Pavement & Underdrain - Design Elements, Chapter 304, Section 52, October 2013, http://www.in.gov/indot/design_manual/files/Ch52_2013.pdf.

Hall, K.T., Darter, M.I., Khazanovich, L, and Hoerner, T.E. *Validation for Guidelines for k-Value Selection and Concrete Pavement Performance Prediction.* Report No. FHWA-RD-96-198. Federal Highway Administration: Washington, D.C., 1997.

Larson, G. and Dempsey, B.J. *Enhanced Integrated Climatic Model (version 2.0).* University of Illinois at Urbana-Champaign. Urbana, IL, 1997.

McCarthy, L., Gudimettla, J., Crawford, G., Guercio, M., and D. Allen, “Impacts of Variability in Coefficient of Thermal Expansion on Predicted Concrete Pavement Performance”, Journal of Construction and Building Materials, Volume 93, 15 September 2015, Pages 711–719.

McCarthy, L. and Bennert, T., Comparing HMA Dynamic Modulus Measured by Axial Compression and IDT Methods, NCHRP Project 9-22B Final Report, National Research Council, 2012, http://onlinepubs.trb.org/onlinepubs/nchrp/docs/NCHRP0922B_FR.pdf.

Moulthrop, J., and Witczak, M., A Performance-Related Specification for Hot-Mixed Asphalt. NCHRP Report 704, Transportation Research Board, National Research Council, Washington D.C., 2011.

Moulthrop, J., James, M., Witczak, M., Jeong, M., McCarthy, L., and D. Mensching, Evaluation of the Quality Related Specification Software (QRSS) Version 1.0. NCHRP Project No. 9-22A Final Report, Transportation Research Board, National Research Council, 2012This page was intentionally left blank