Slide 1


ILT
HMEC
Highway Materials Engineering Course
Lesson 6: Hot Topics
Mechanistic Empirical Pavement Design Guide (MEPDG)
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Federal Highway Administration
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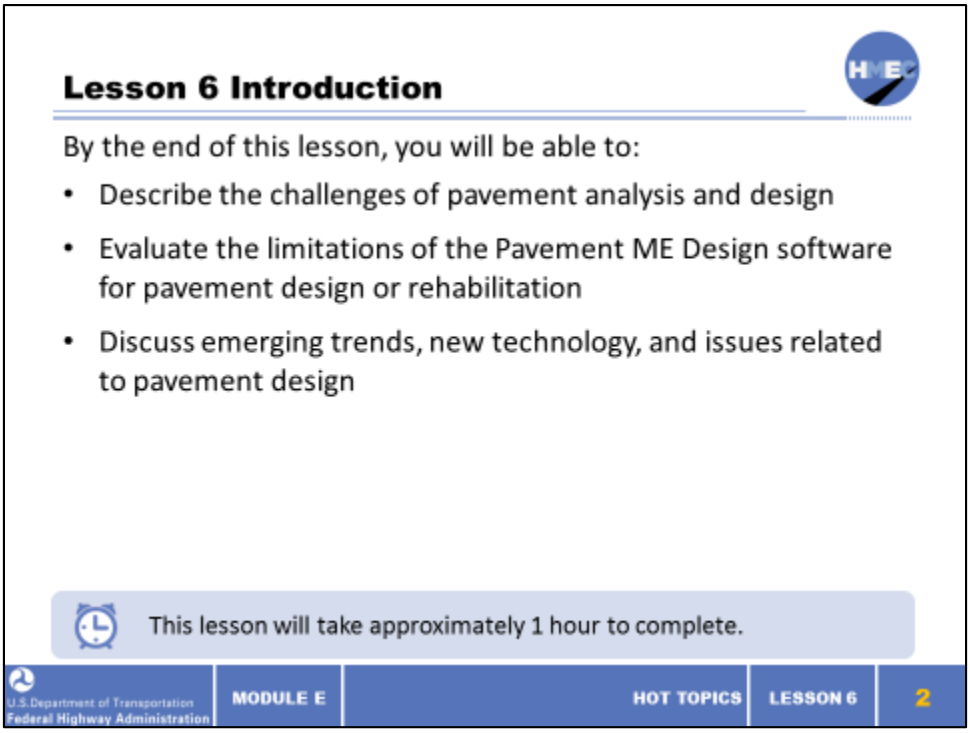
Slide 2


Lesson 6 Introduction
By the end of this lesson, you will be able to:
• Describe the challenges of pavement analysis and design
• Evaluate the limitations of the Pavement ME Design software for pavement design or rehabilitation
• Discuss emerging trends, new technology, and issues related to pavement design
This lesson will take approximately 1 hour to complete.
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Challenges

- Pavement Structural Design
  - Difficulties of design
  - Pavement type selection
  - Political influence
  - Funding levels
  - Materials availability
  - Design periods are evolving (long-life 50 year designs)

- Pavement Construction Quality
  - Attempt to capture variability observed in the field through reliability value in design analysis

Q&A What are a few examples of the difficulties of pavement design?

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MEPDG Pavement Design Process
Ordinary Projects
Shelf time for designs
Contractor not known
Material sources not determined
Primarily Level 3 inputs
Level 2 inputs with catalogs
Can be a forensic tool
Design-Build Projects
Contractor & material sources known
Public private partnerships
Design-build-operate-maintain
DB-finance-operate-maintain
Level 1 inputs possible
Contracts allow innovation
Can be a design tool
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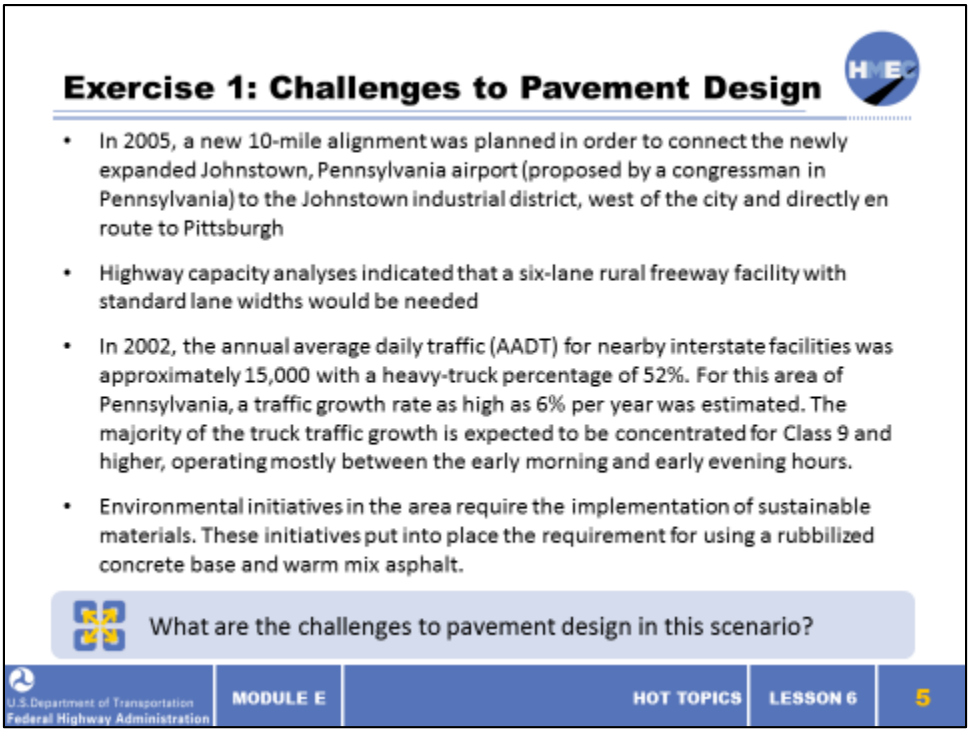
Exercise 1: Challenges to Pavement Design
In 2005, a new 10-mile alignment was planned in order to connect the newly expanded Johnstown, Pennsylvania airport (proposed by a congressman in Pennsylvania) to the Johnstown industrial district, west of the city and directly en route to Pittsburgh
Highway capacity analyses indicated that a six-lane rural freeway facility with standard lane widths would be needed
In 2002, the annual average daily traffic (AADT) for nearby interstate facilities was approximately 15,000 with a heavy-truck percentage of 52%. For this area of Pennsylvania, a traffic growth rate as high as 6% per year was estimated. The majority of the truck traffic growth is expected to be concentrated for Class 9 and higher, operating mostly between the early morning and early evening hours.
Environmental initiatives in the area require the implementation of sustainable materials. These initiatives put into place the requirement for using a rubbilized concrete base and warm mix asphalt.
What are the challenges to pavement design in this scenario?
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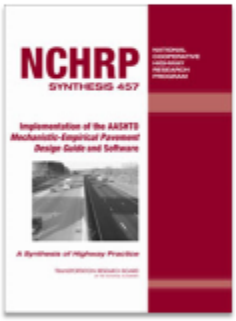
General Limitations

- State DOT Workflow
  - Centralized versus decentralized DOT, assignment of roles, and responsibilities
- Existing Pavements
  - Existing pavement condition? HPMS, DOT PMS, etc.
  - Quality checks on existing PCI data to use for rehabilitation
  - Backcalculation is separate from software
    - Characterization of existing layers
- Data Platforms
  - Data types and formats
  - Existing database properties and missing data



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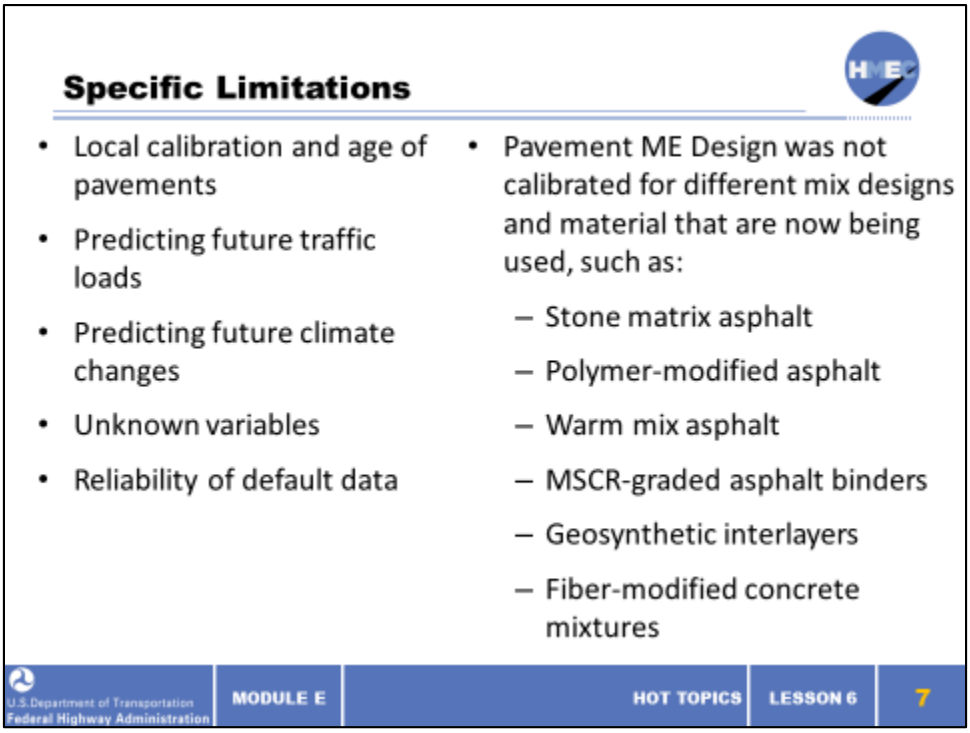
Specific Limitations
• Local calibration and age of pavements
• Predicting future traffic loads
• Predicting future climate changes
• Unknown variables
• Reliability of default data
• Pavement ME Design was not calibrated for different mix designs and material that are now being used, such as:
– Stone matrix asphalt
– Polymer-modified asphalt
– Warm mix asphalt
– MSCR-graded asphalt binders
– Geosynthetic interlayers
– Fiber-modified concrete mixtures
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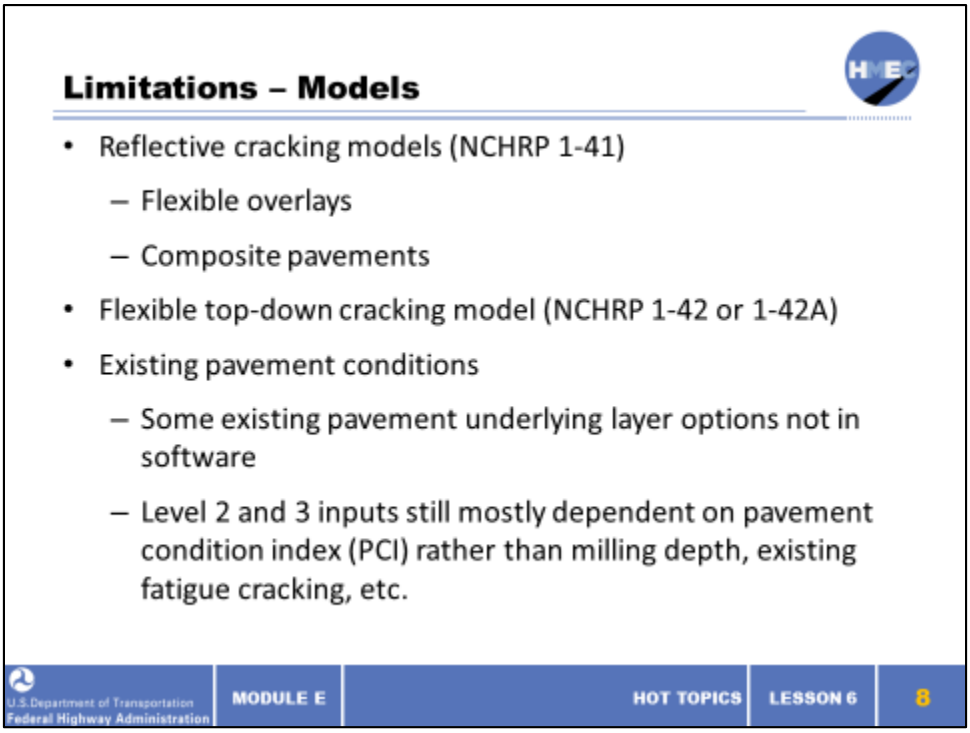
Limitations – Models
• Reflective cracking models (NCHRP 1-41)
– Flexible overlays
– Composite pavements
• Flexible top-down cracking model (NCHRP 1-42 or 1-42A)
• Existing pavement conditions
– Some existing pavement underlying layer options not in software
– Level 2 and 3 inputs still mostly dependent on pavement condition index (PCI) rather than milling depth, existing fatigue cracking, etc.
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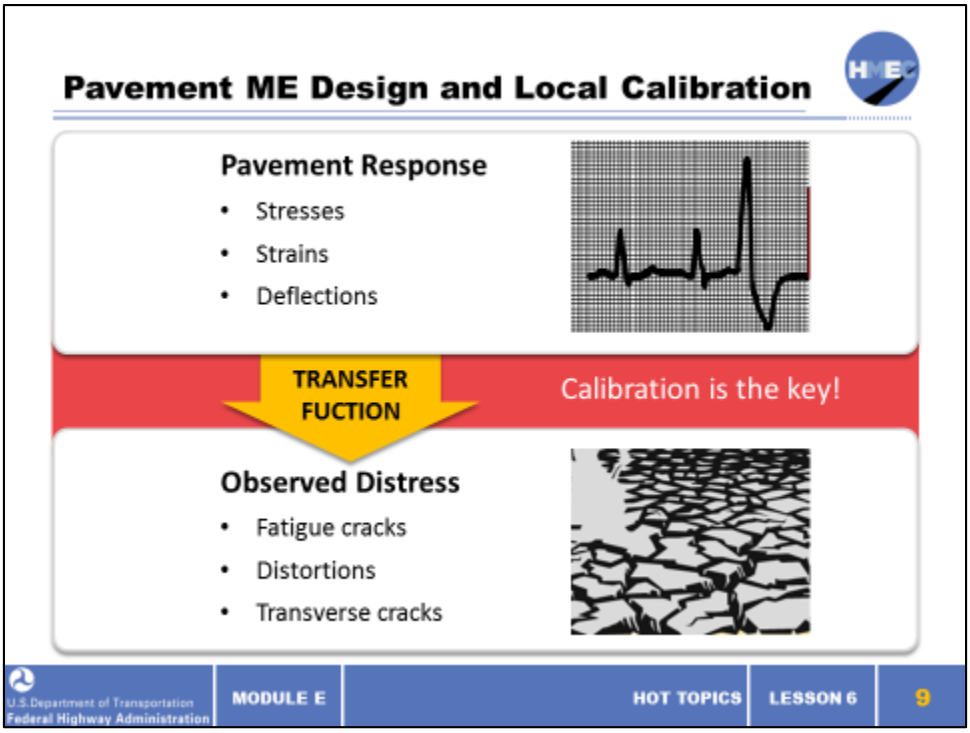
Pavement ME Design and Local Calibration
Pavement Response
• Stresses
• Strains
• Deflections
TRANSFER FUCTION
Calibration is the key!
Observed Distress
• Fatigue cracks
• Distortions
• Transverse cracks
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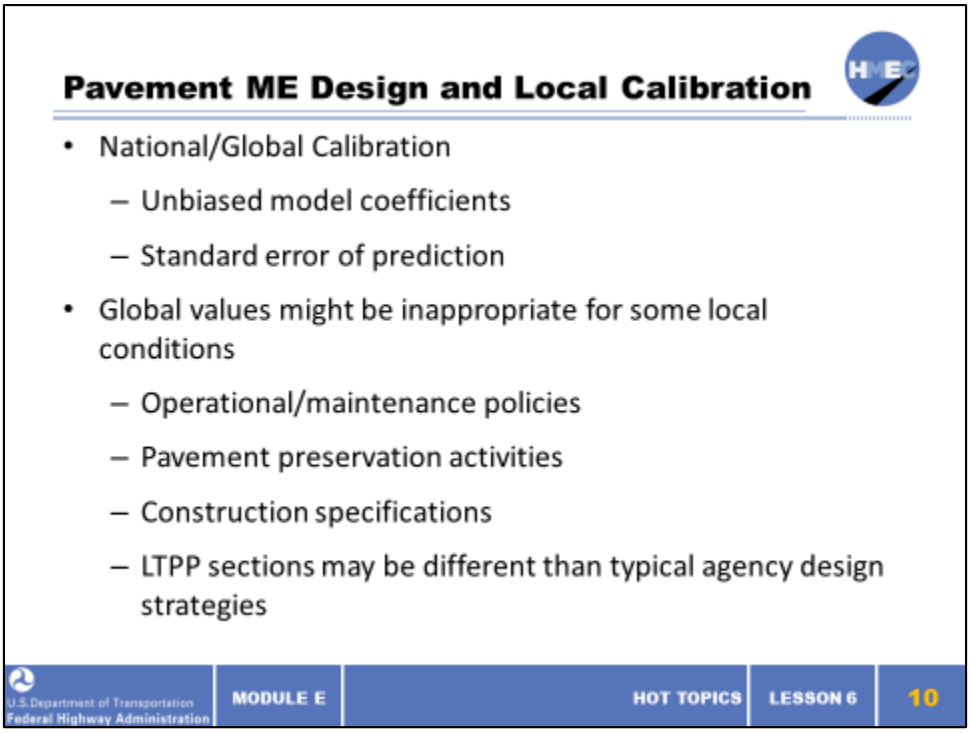
Pavement ME Design and Local Calibration
• National/Global Calibration
– Unbiased model coefficients
– Standard error of prediction
• Global values might be inappropriate for some local conditions
– Operational/maintenance policies
– Pavement preservation activities
– Construction specifications
– LTPP sections may be different than typical agency design strategies
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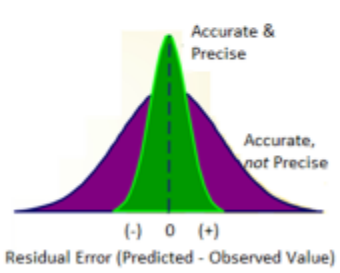
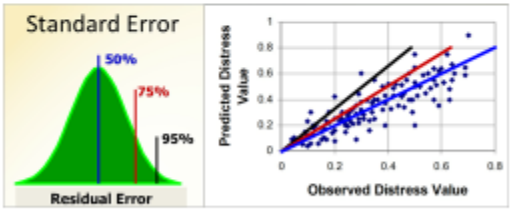
Local Calibration

GOALS:

- As accurate and precise predictions of observed values as possible, while recognizing the variability that results from constructability issues in the field
- Minimize bias and standard error





Increase in precision of transfer function reduces standard error

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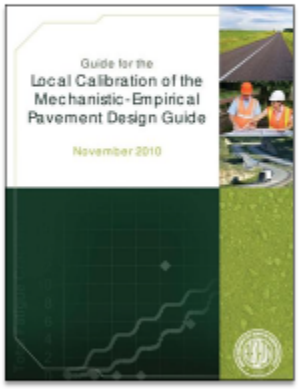
Local Calibration Steps

1. Select hierarchical input level: tradeoffs and implications
2. Develop experimental design and sampling matrix
3. Determine sample size
4. Identify roadway segments
5. Collect and evaluate data
6. Conduct field investigations
7. Assess bias
8. Eliminate bias
9. Assess standard error
10. Improve model precision
11. Interpret results and decide on adequacy of agency calibration factors



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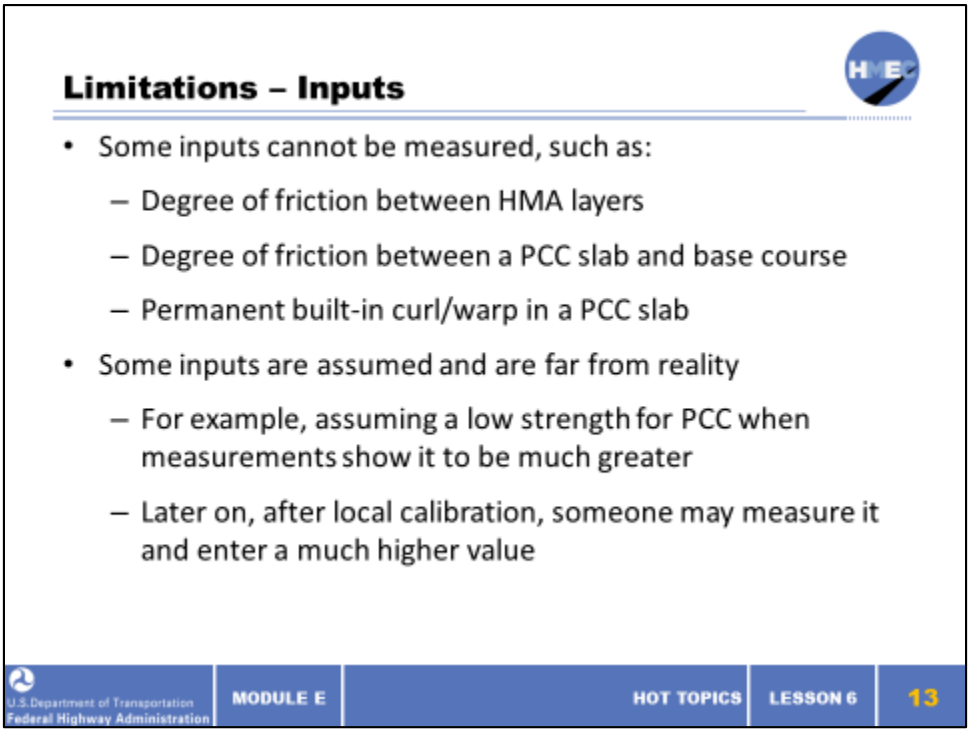
Limitations – Inputs
• Some inputs cannot be measured, such as:
– Degree of friction between HMA layers
– Degree of friction between a PCC slab and base course
– Permanent built-in curl/warp in a PCC slab
• Some inputs are assumed and are far from reality
– For example, assuming a low strength for PCC when measurements show it to be much greater
– Later on, after local calibration, someone may measure it and enter a much higher value
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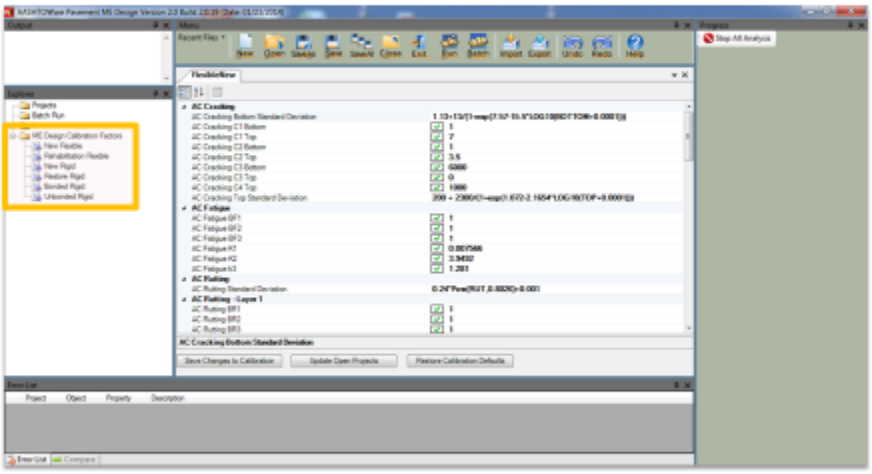
Pavement ME Calibration Coefficients



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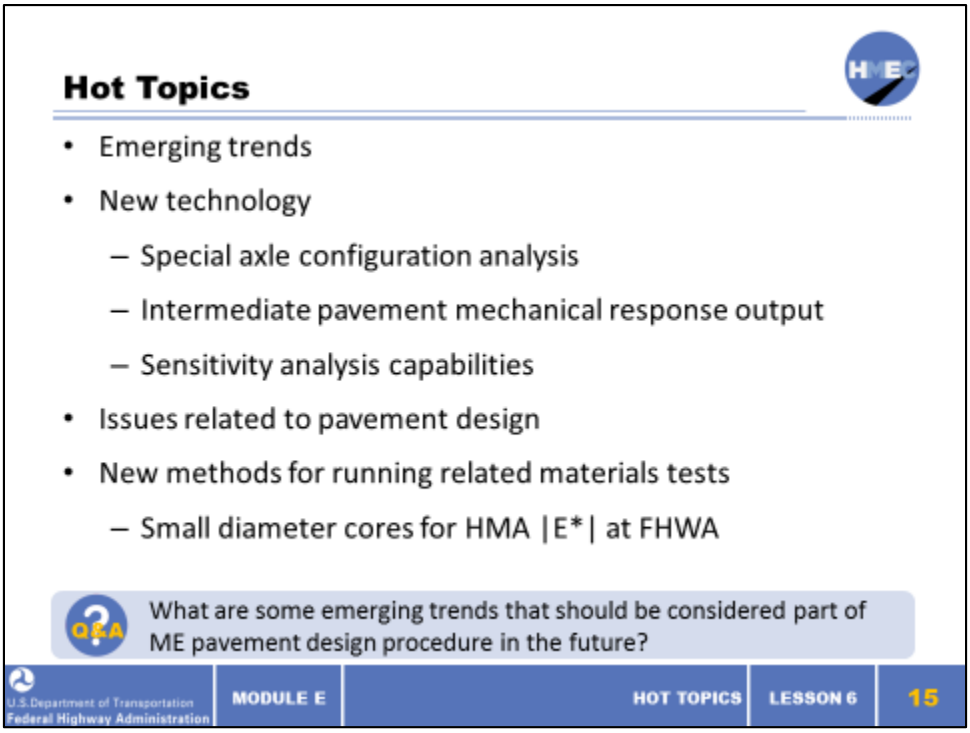
Hot Topics
• Emerging trends
• New technology
– Special axle configuration analysis
– Intermediate pavement mechanical response output
– Sensitivity analysis capabilities
• Issues related to pavement design
• New methods for running related materials tests
– Small diameter cores for HMA |E*| at FHWA
Q&A
What are some emerging trends that should be considered part of ME pavement design procedure in the future?
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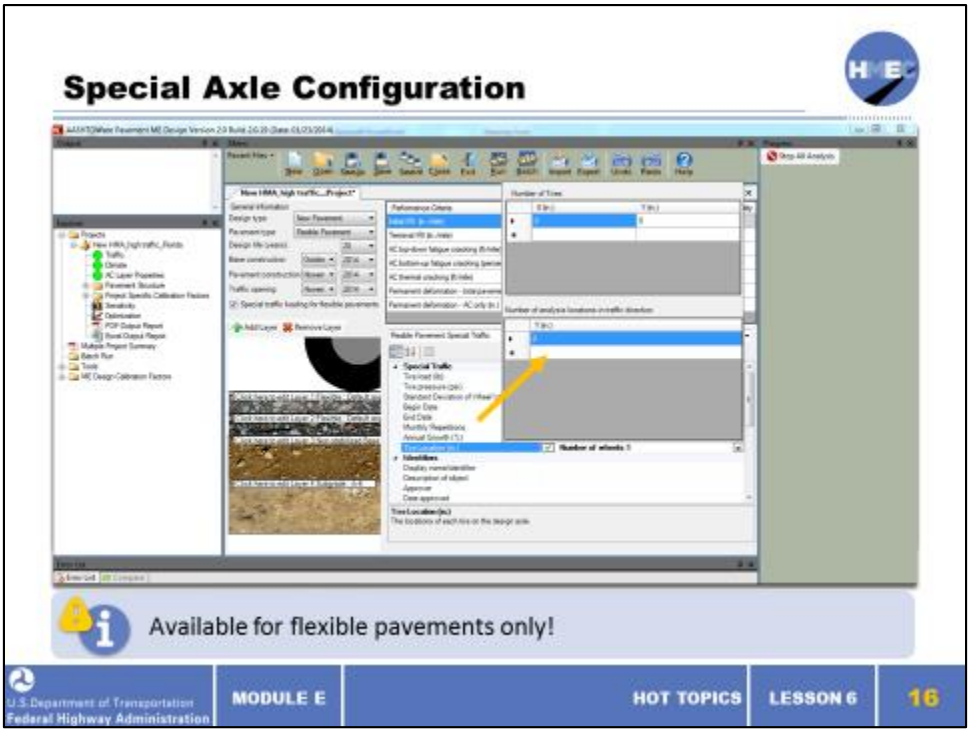
Special Axle Configuration
Available for flexible pavements only!
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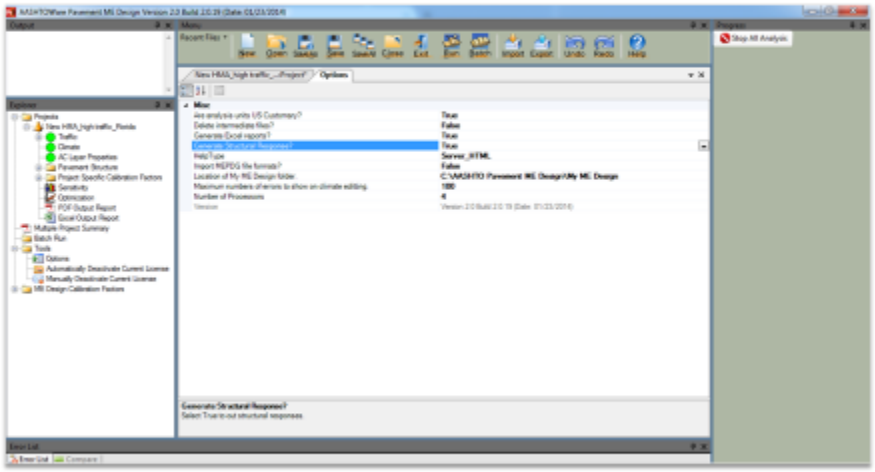
Intermediate Structural Responses



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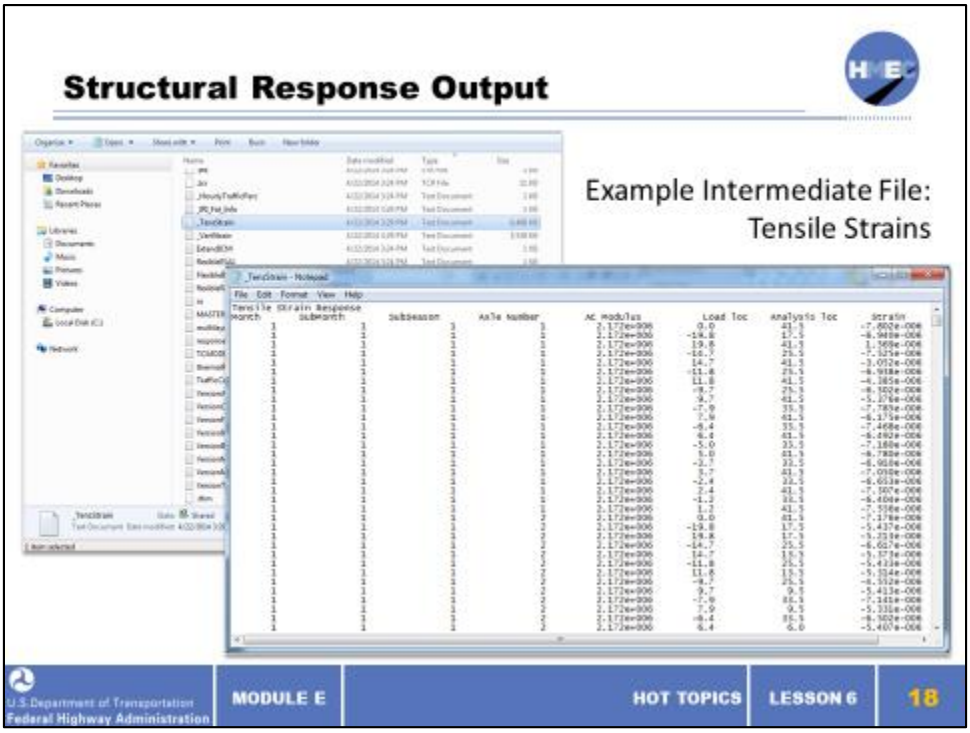
Structural Response Output
Example Intermediate File:
Tensile Strains
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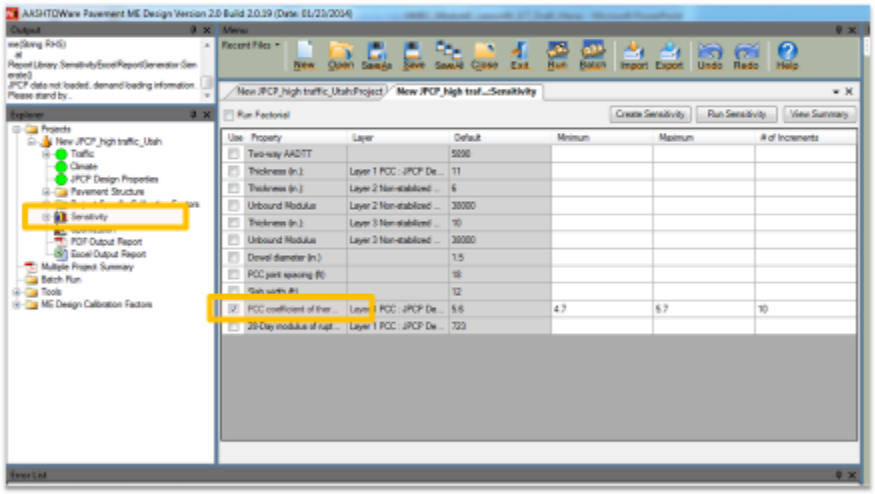
Sensitivity Analysis in Software



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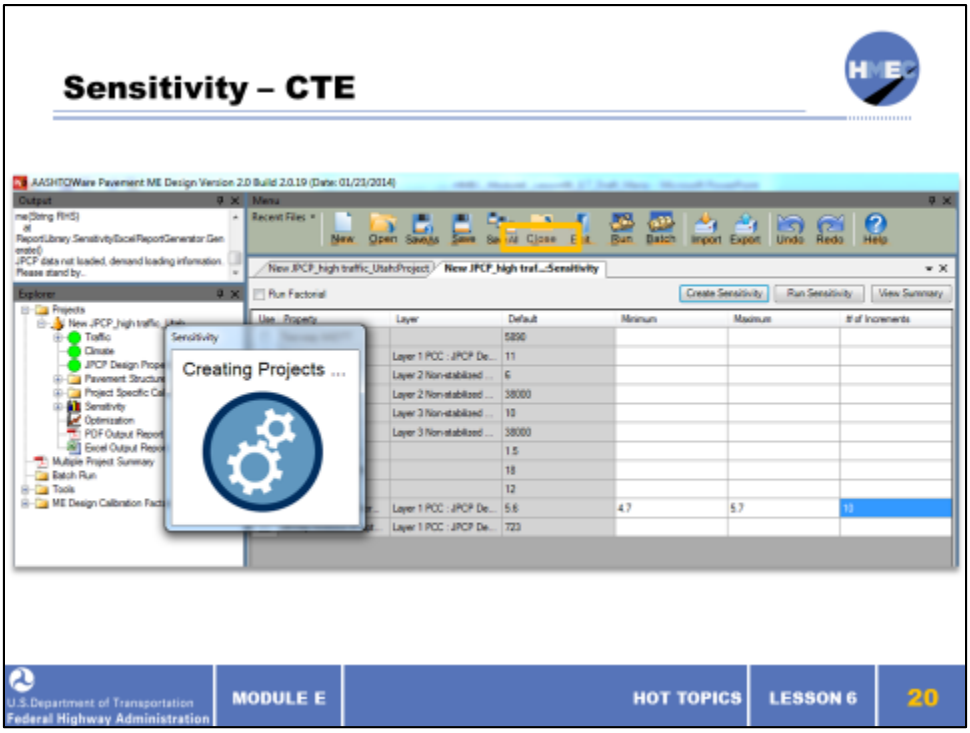
Sensitivity – CTE
Creating Projects ...
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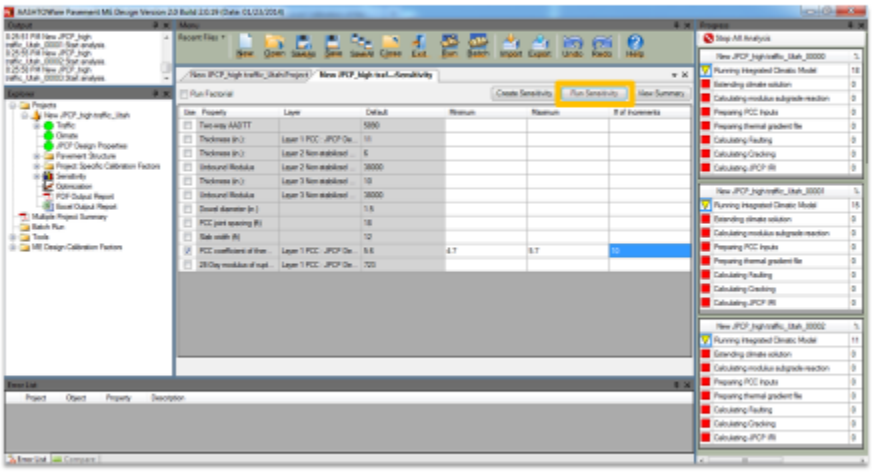
Sensitivity – CTE



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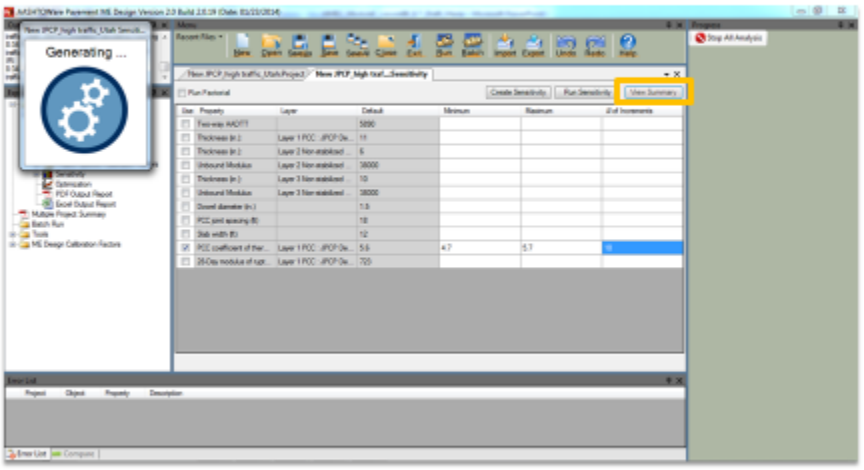
Sensitivity – CTE



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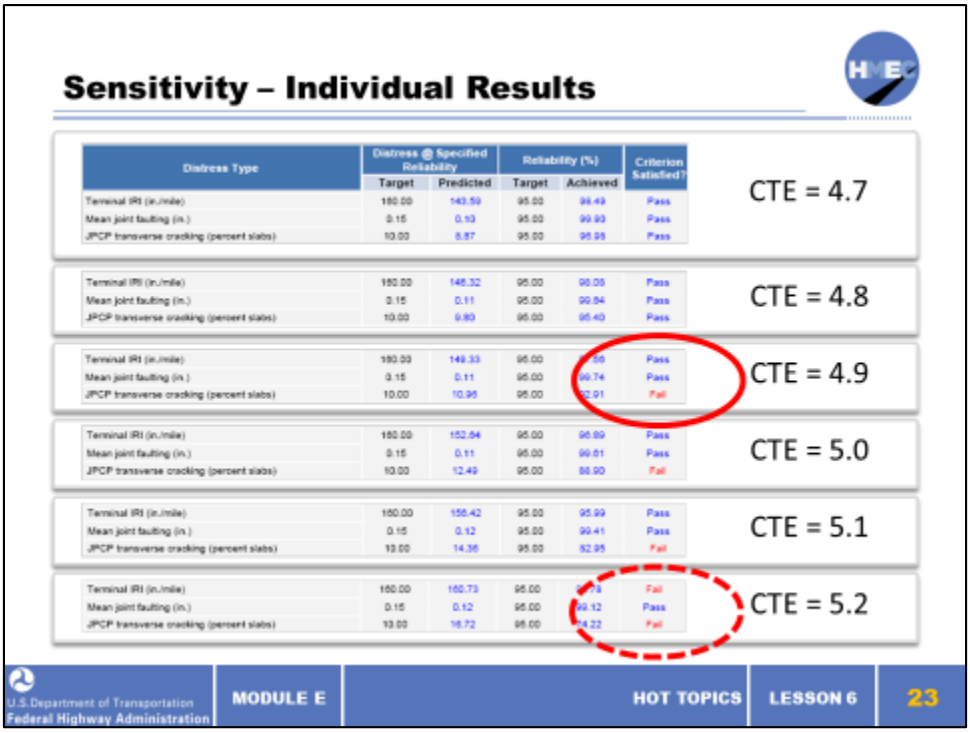
Sensitivity – Individual Results
Distress Type
Distress @ Specified Reliability
Target
Predicted
Reliability (%)
Target
Achieved
Criterion Satisfied?
Terminal IRI (in./mile) 160.00 143.59 95.00 98.49 Pass
Mean joint faulting (in.) 0.15 0.10 95.00 99.93 Pass
JPCP transverse cracking (percent slabs) 10.00 8.87 95.00 95.95 Pass
CTE = 4.7
Terminal IRI (in./mile) 160.00 146.32 95.00 98.09 Pass
Mean joint faulting (in.) 0.15 0.11 95.00 99.84 Pass
JPCP transverse cracking (percent slabs) 10.00 9.80 95.00 95.40 Pass
CTE = 4.8
Terminal IRI (in./mile) 160.00 149.33 95.00 Pass
Mean joint faulting (in.) 0.15 0.11 95.00 99.74 Pass
JPCP transverse cracking (percent slabs) 10.00 10.96 95.00 Fail
CTE = 4.9
Terminal IRI (in./mile) 160.00 152.64 95.00 96.89 Pass
Mean joint faulting (in.) 0.15 0.11 95.00 99.61 Pass
JPCP transverse cracking (percent slabs) 10.00 12.49 95.00 Fail
CTE = 5.0
Terminal IRI (in./mile) 160.00 156.42 95.00 95.99 Pass
Mean joint faulting (in.) 0.15 0.12 95.00 99.41 Pass
JPCP transverse cracking (percent slabs) 10.00 14.36 95.00 Fail
CTE = 5.1
Terminal IRI (in./mile) 160.00 160.73 95.00 Fail
Mean joint faulting (in.) 0.15 0.12 95.00 Pass
JPCP transverse cracking (percent slabs) 10.00 16.72 95.00 Fail
CTE = 5.2
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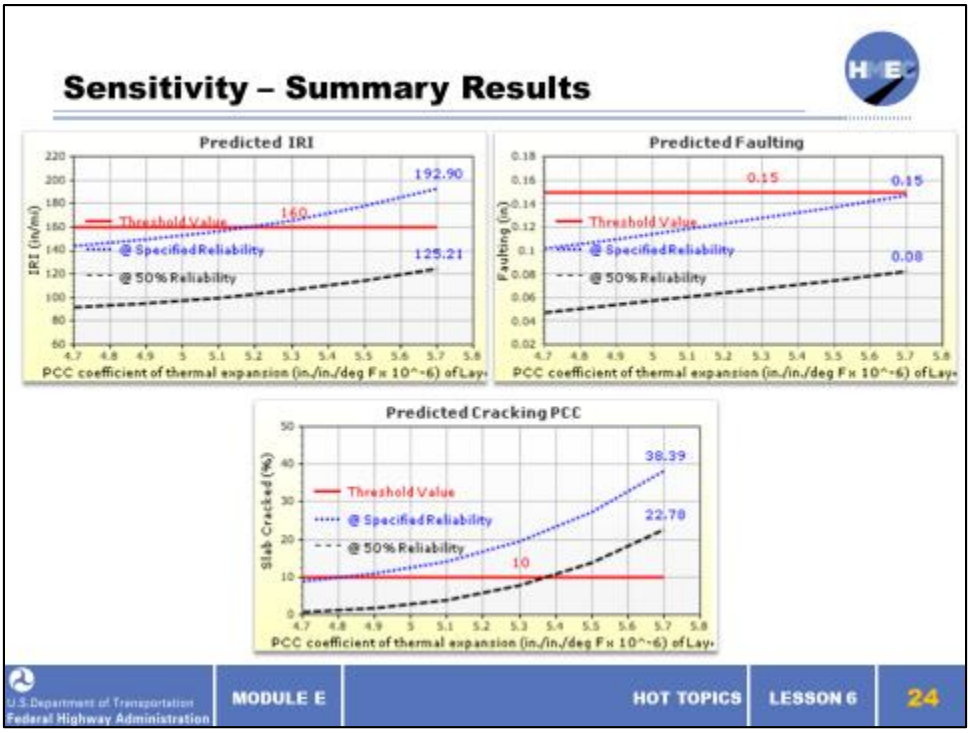
Sensitivity – Summary Results
Predicted IRI
IRI (in/mi)
Threshold Value
@ Specified Reliability
@ 50% Reliability
160
192.90
129.21
PCC coefficient of thermal expansion (in./in./deg F x 10^-6) of Lay
Predicted Faulting
Faulting (in)
Threshold Value
@ Specified Reliability
@ 50% Reliability
0.15
0.15
0.08
PCC coefficient of thermal expansion (in./in./deg F x 10^-6) of Lay
Predicted Cracking PCC
Slab Cracked (%)
Threshold Value
@ Specified Reliability
@ 50% Reliability
10
38.39
22.78
PCC coefficient of thermal expansion (in./in./deg F x 10^-6) of Lay
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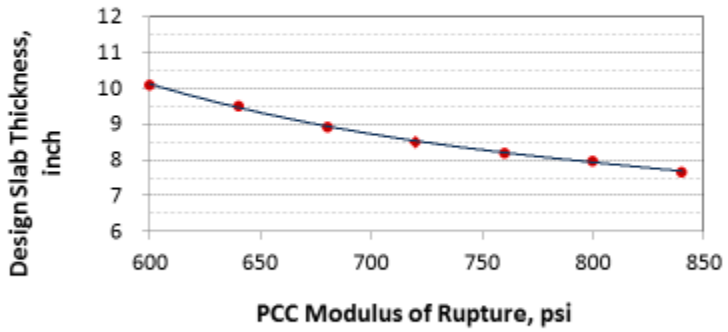
Sensitivity of Design Thickness to MR



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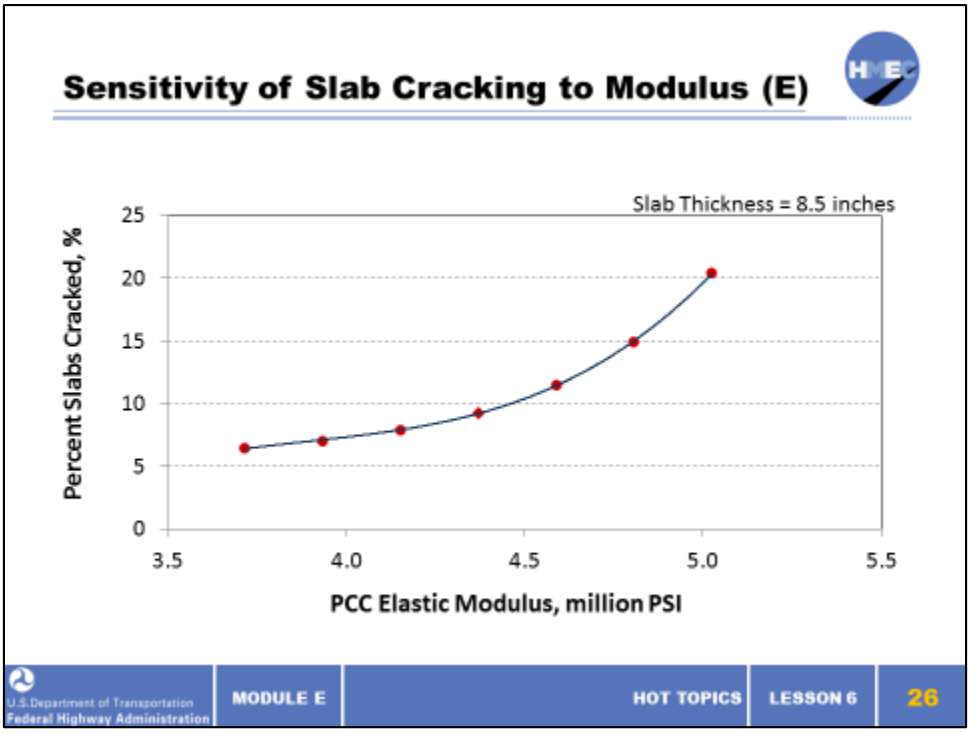
Sensitivity of Slab Cracking to Modulus (E)
Slab Thickness = 8.5 inches
Percent Slabs Cracked, %
25
20
15
10
5
0
3.5
4.0
4.5
5.0
5.5
PCC Elastic Modulus, million PSI
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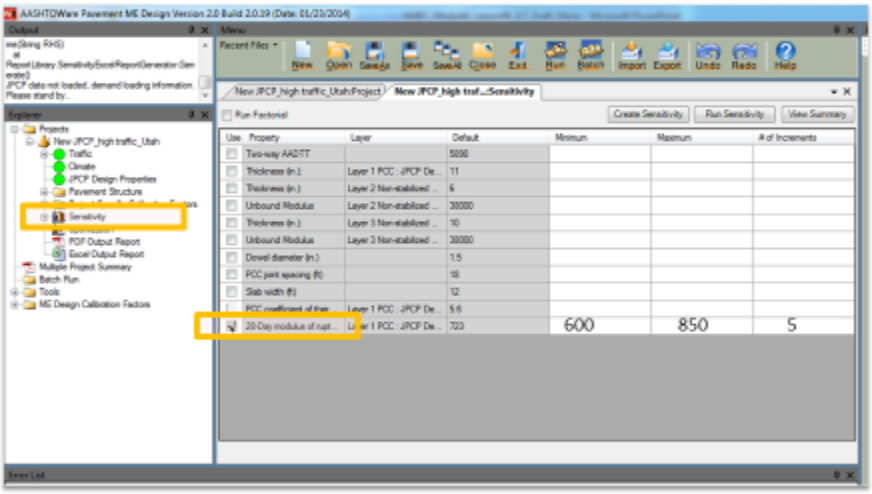
Sensitivity Analysis in Software



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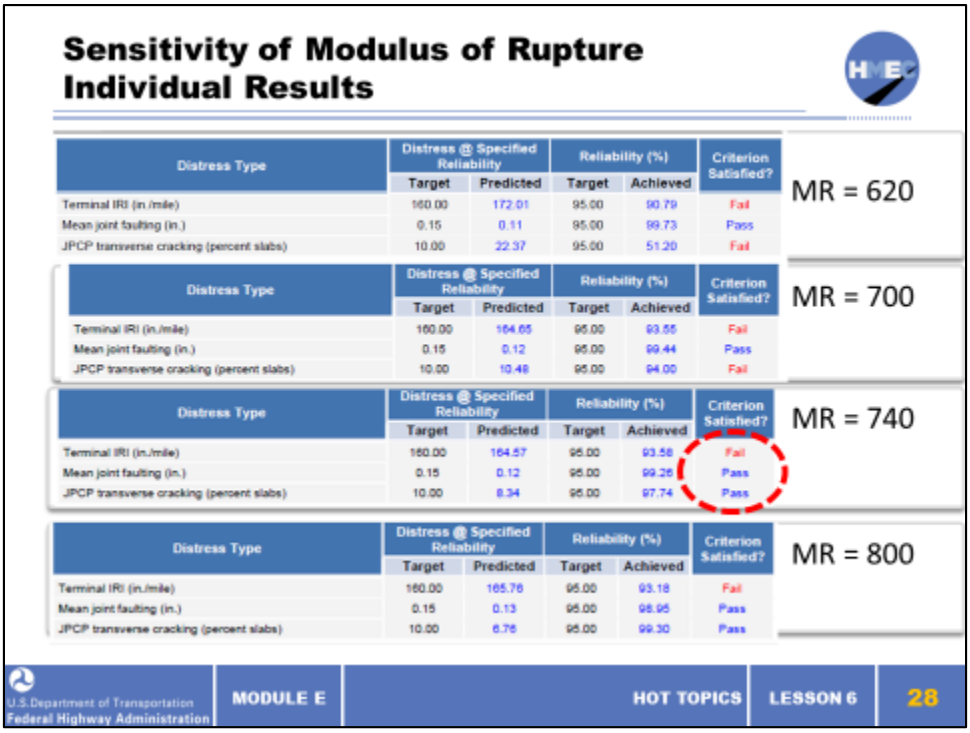
Sensitivity of Modulus of Rupture
Individual Results
Distress Type
Distress @ Specified Reliability
Target
Predicted
Reliability (%)
Target
Achieved
Criterion Satisfied?
Terminal IRI (in./mile) 160.00 172.01 95.00 90.79 Fail
Mean joint faulting (in.) 0.15 0.11 95.00 99.73 Pass
JPCP transverse cracking (percent slabs) 10.00 22.37 95.00 51.20 Fail
MR = 620
Terminal IRI (in./mile) 160.00 164.65 95.00 93.55 Fail
Mean joint faulting (in.) 0.15 0.12 95.00 99.44 Pass
JPCP transverse cracking (percent slabs) 10.00 10.48 95.00 94.00 Fail
MR = 700
Terminal IRI (in./mile) 160.00 164.57 95.00 93.58 Fail
Mean joint faulting (in.) 0.15 0.12 95.00 99.26 Pass
JPCP transverse cracking (percent slabs) 10.00 8.34 95.00 97.74 Pass
MR = 740
Terminal IRI (in./mile) 160.00 165.76 95.00 93.18 Fail
Mean joint faulting (in.) 0.15 0.13 95.00 98.95 Pass
JPCP transverse cracking (percent slabs) 10.00 6.76 95.00 99.30 Pass
MR = 800
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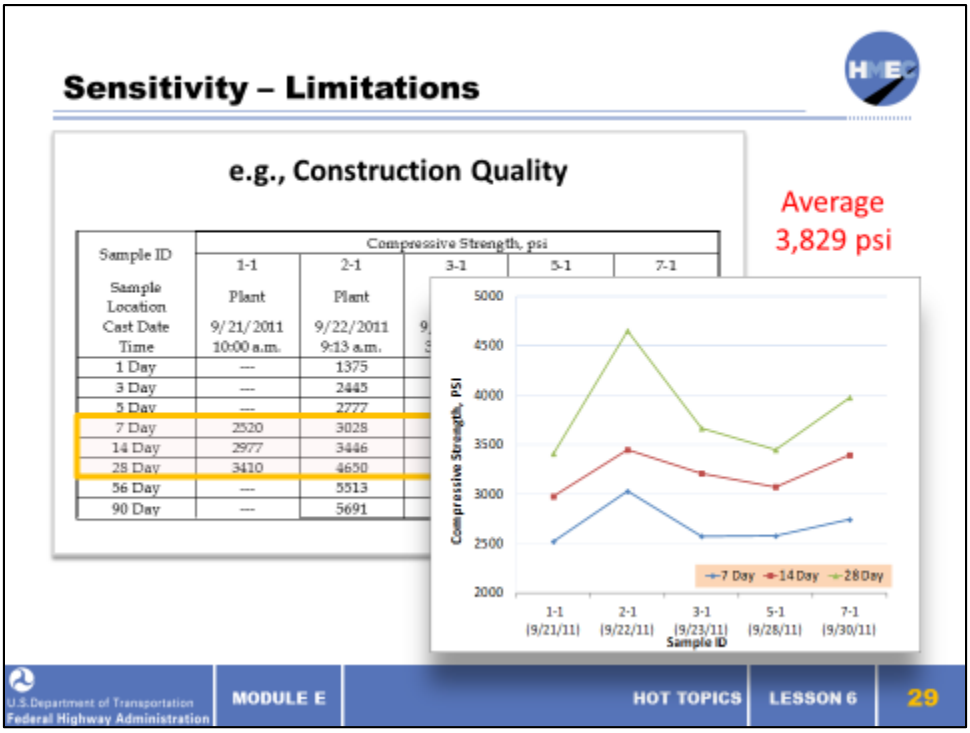
Sensitivity – Limitations
e.g., Construction Quality
Average
3,829 psi
Sample ID
Compressive Strength, psi
1-1
2-1
3-1
5-1
7-1
Sample Location
Plant
Plant
Cast Date
9/21/2011
9/22/2011
Time
10:00 a.m.
9:13 a.m.
1 Day

1375
3 Day

2445
5 Day

2777
7 Day
2520
3028
14 Day
2977
3446
28 Day
3410
4650
56 Day

5513
90 Day

5691
Compressive Strength, PSI
5000
4500
4000
3500
3000
2500
2000
7 Day
14 Day
28 Day
1-1 (9/21/11)
2-1 (9/22/11)
3-1 (9/23/11)
5-1 (9/26/11)
7-1 (9/30/11)
Sample ID
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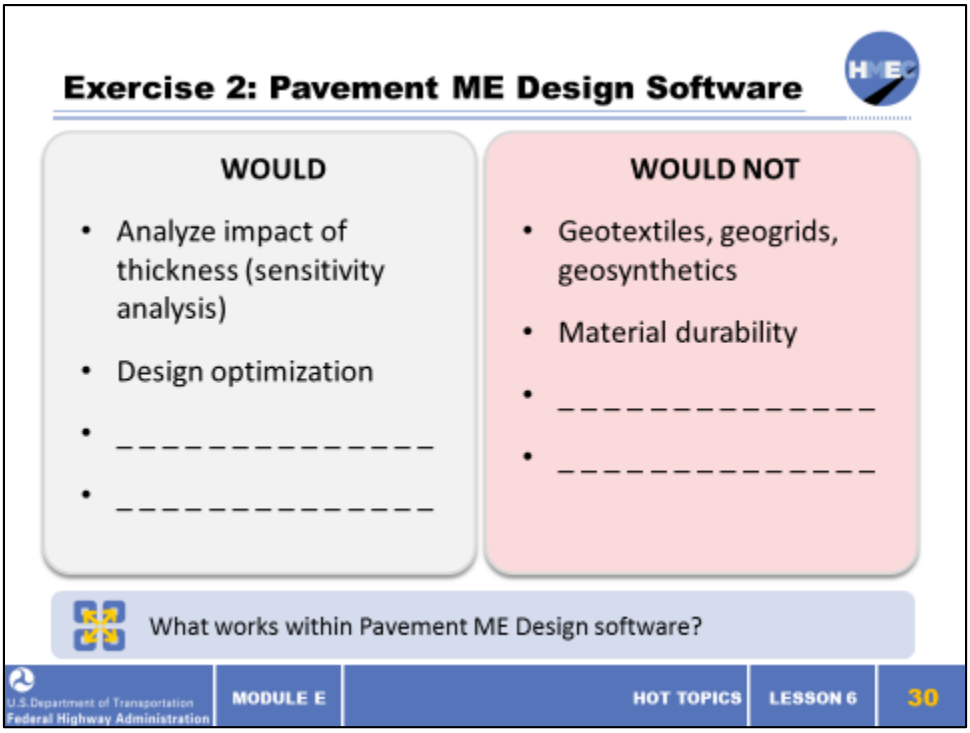
Exercise 2: Pavement ME Design Software
WOULD
Analyze impact of thickness (sensitivity analysis)
Design optimization
_ _ _ _ _ _ _ _ _ _ _ _ _ _
_ _ _ _ _ _ _ _ _ _ _ _ _ _
WOULD NOT
Geotextiles, geogrids, geosynthetics
Material durability
_ _ _ _ _ _ _ _ _ _ _ _ _ _
_ _ _ _ _ _ _ _ _ _ _ _ _ _
What works within Pavement ME Design software?
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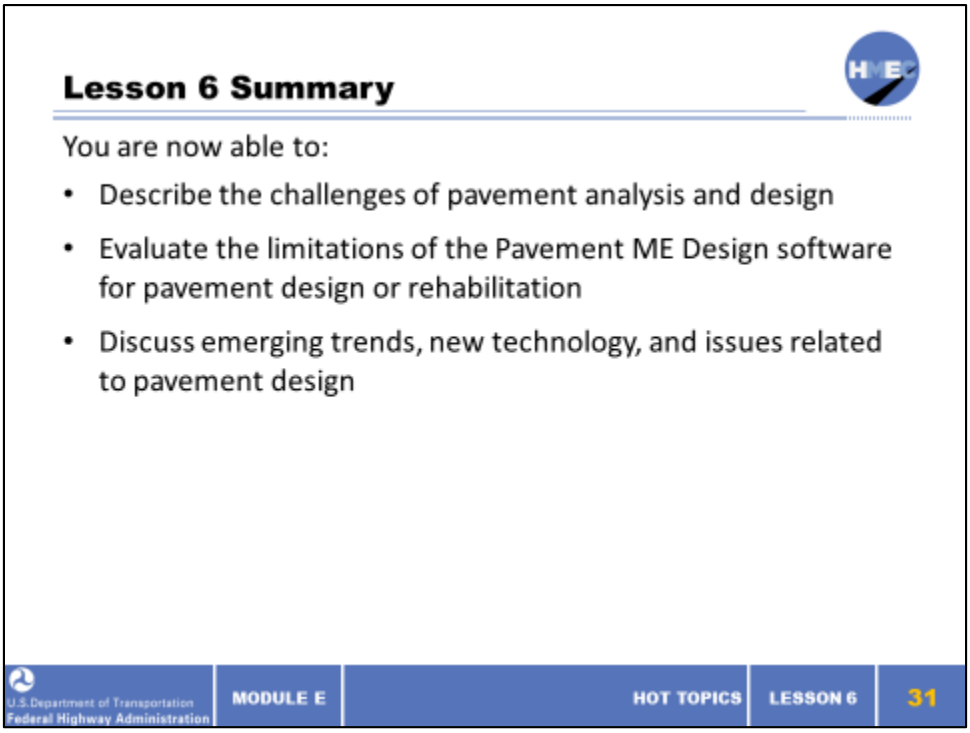
Lesson 6 Summary
You are now able to:
• Describe the challenges of pavement analysis and design
• Evaluate the limitations of the Pavement ME Design software for pavement design or rehabilitation
• Discuss emerging trends, new technology, and issues related to pavement design
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