WELCOME TO THE

AASHTOWare™

PAVEMENT

ME DESIGN

WEBINAR SERIES

- The webinar will start at 11:00 AM Central/12:00 AM Eastern

FY 2024 Webinar #3
Semi-Rigid Pavement Design

February 20, 2024

FY 2024 Webinar #3,
Semi-Rigid Pavement Design

Moderator:

- Hari Nair, PE, Virginia Department of Transportation; Chairperson

Presenters:

- John Donahue, PE, ARA

Presentation will be available for viewing on the ME-Design Resource website:
http://www.me-design.com

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Pavement ME Task Force Members

1. Ryan Fragapane, AASHTO, Product Director
2. Ben Sade, AASHTO, Associate Product Manager
3. Hari Nair, PE, Virginia DOT, Chair
4. Ian Rish, PE, Georgia DOT, Vice-Chair
5. Patrick Bierl, PE, Ohio DOT
6. Nusrat Morshed, PE, New Jersey DOT
7. Kumar Dave, PE, Indiana DOT
8. Dulce Feldman, PE, California DOT
9. Jason Simmons, PE, Utah DOT
10. Susanne Chan, Ontario MOT, TAC Liaison
11. Tom Yu, PE, FHWA Liaison

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FY 2024 Webinar #3, Semi-Rigid Pavement Design

- Phones are being muted.
- Please post your questions in the Q&A box. This can be accessed by clicking on the WebEx Q&A button.
- The presenters will answer all questions at the end of the webinar/demonstration as time permits.
- Questions not answered, because of time, will be responded to separately.

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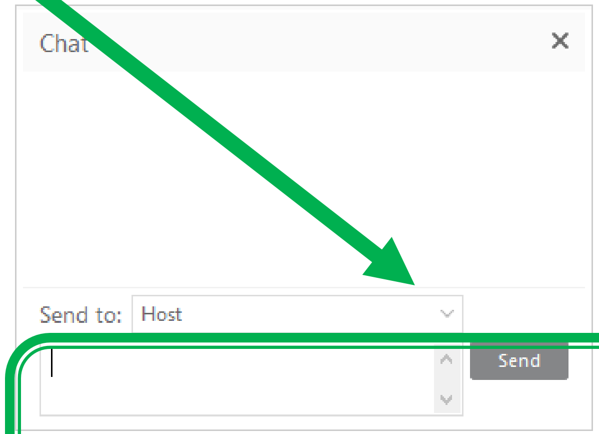
Housekeeping Items

If you have an issue during the webinar



If you have an issue with the sound and are using your computer audio, please dial in using a phone.

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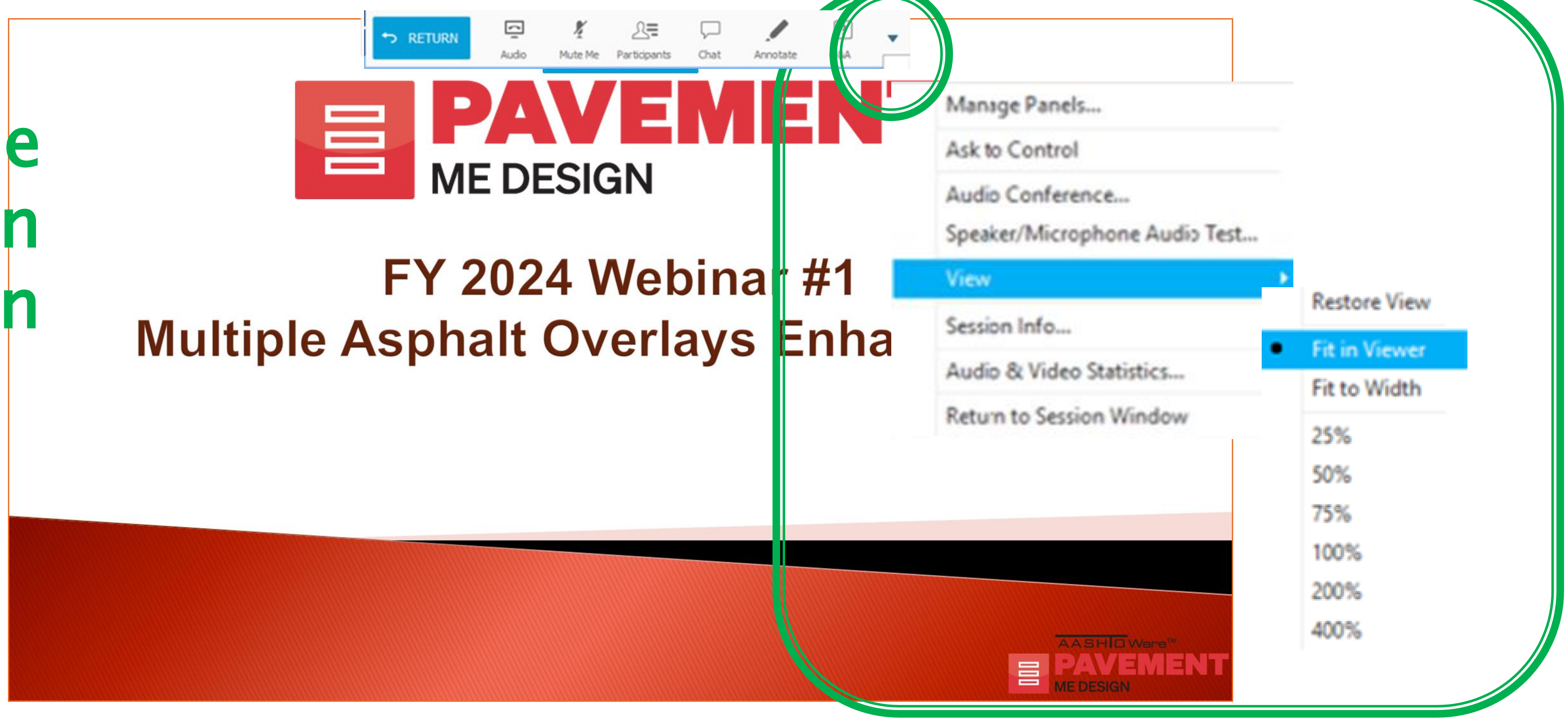
Housekeeping Items

To see presentation in full screen



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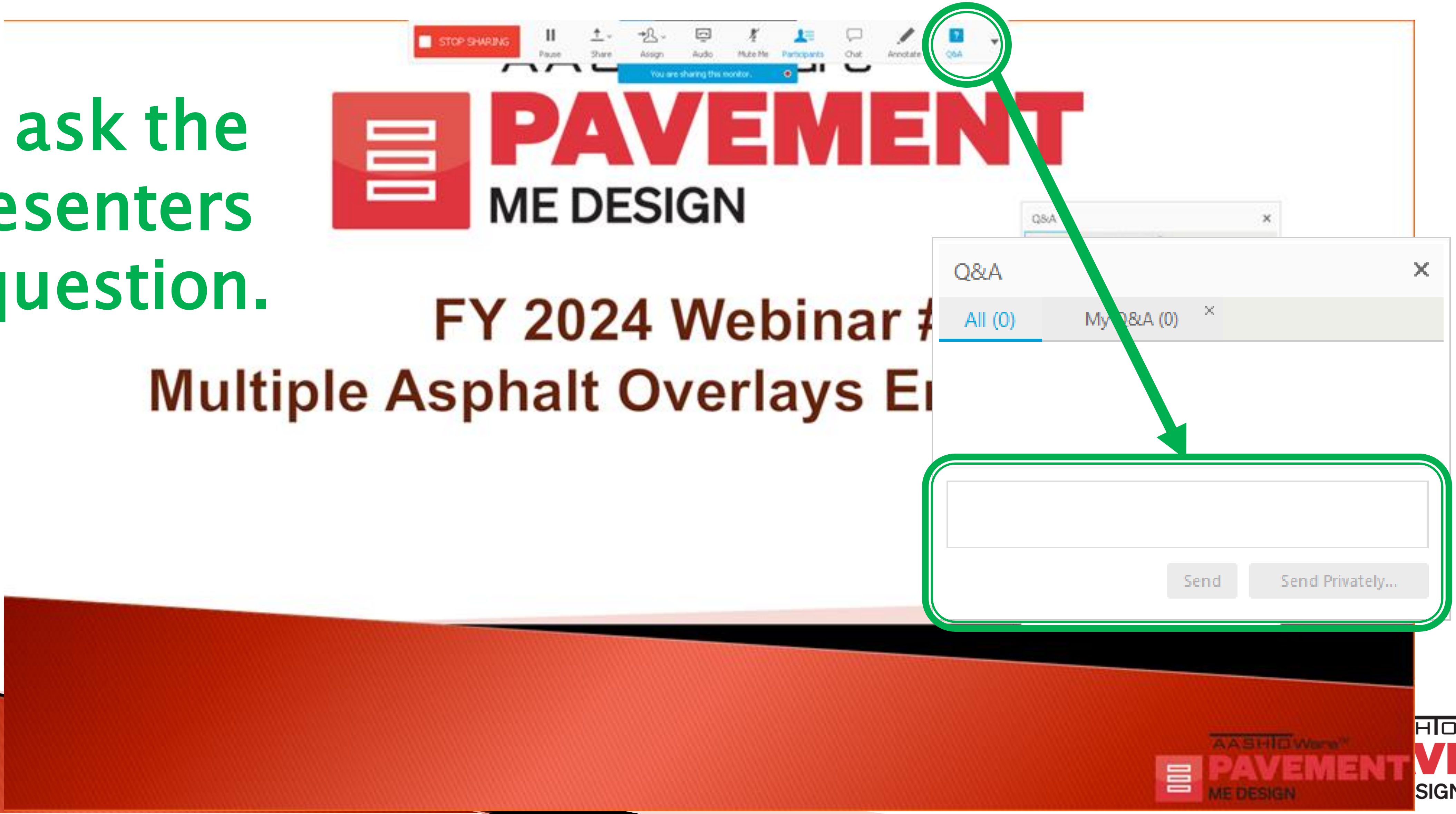
Housekeeping Items

To ask the presenters a question.



FY 2024 Webinar #3 Semi-Rigid Pavement Design

Poll 1: Questions 1, 2, and 3

1. How many individuals are viewing this webinar at your location?
   - ❑ 1
   - ❑ 2
   - ❑ 3 to 5
   - ❑ More than 5

2. What is your affiliation?
   - ❑ State Government
   - ❑ Federal Government
   - ❑ Contractor/Association
   - ❑ Consultant
   - ❑ Academia

3. What version of the PMED software are you or your organization using?

- ❑ None, do not have a license
- ❑ Earlier Desktop before version 2.5
- ❑ Desktop version 2.5 or 2.6
- ❑ Web App Version 3
- ❑ Multiple versions – dependent on client.

FY 2024, Webinar #3: Semi-Rigid Pavement Design

Webinar Outline:

1. Introduction
2. Defining Semi-Rigid
3. PMED Analysis
4. Sensitivity
5. Calibration Coefficients
6. Summary and Takeaways
7. Question and Answer Session

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Introduction

- AASHTOWare Pavement M-E Design (PMED) users have the option to create and analyze semi-rigid pavement designs.

- The semi-rigid design model was last globally calibrated for the PMED 2.5 version, thus the model in the 2.6 desktop and 3.0 web applications are also *globally* current.

- Global calibration of semi-rigid models in PMED used performance data from LTPP test sections.

Introduction

- Semi-rigid pavements can be designed with a second overlay in PMED.

- PMED semi-rigid designs can be locally calibrated in the Calibration Assistance Tool (CAT).

Introduction

- This presentation will only cover cement and/or fly ash stabilized bases, that behave as bound layers with flexural strength, *directly* under an asphalt pavement.

- It will *not* cover
  - Stabilized bases under JPCP and CRCP
  - AC pavements with an unbound layer between the AC and stabilized base.

Webinar Assumptions

Attendee has prior experience with:

- PMED desktop or web application versions
- AASHTO MEPDG Manual of Practice (MOP)
- Characterizing layers in a pavement structure
- Agency performance thresholds for distress/IRI.

Learning Outcomes

1. Define the meaning of a semi-rigid pavement within the context of the PMED software.
2. Select inputs for semi-rigid design in PMED.
3. Understand key input sensitivity for PMED semi-rigid design predictions.
4. Comprehend the influence of transfer function calibration coefficients on predicted performance.

FY 2024, Webinar #3: Semi-Rigid Pavement Design

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Defining Semi-Rigid Design

A semi-rigid pavement design consists of an asphalt layer(s) directly on a cementitious treated base layer having flexural strength.

Defining Semi-Rigid Design

Types of semi-rigid layers include –

- Cement treated base (CTB)
- Roller compacted concrete (RCC)
- Lean concrete base (LCB)

Cementitious materials in the semi-rigid layer may also include lime, lime-fly ash, and other SCMs.

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Defining Semi-Rigid Design

A CTB layer is chemically stabilized, but not all chemical stabilization yields a semi-rigid or bound layer.

- Higher amounts of Portland cement and/or other cementitious materials produce a bound layer capable of resisting tensile stress and fatigue cracks; responds as a bound layer.

- Lower amounts of Portland cement and/or other cementitious materials produce a layer that does not resist tensile stresses; responds as an unbound layer.

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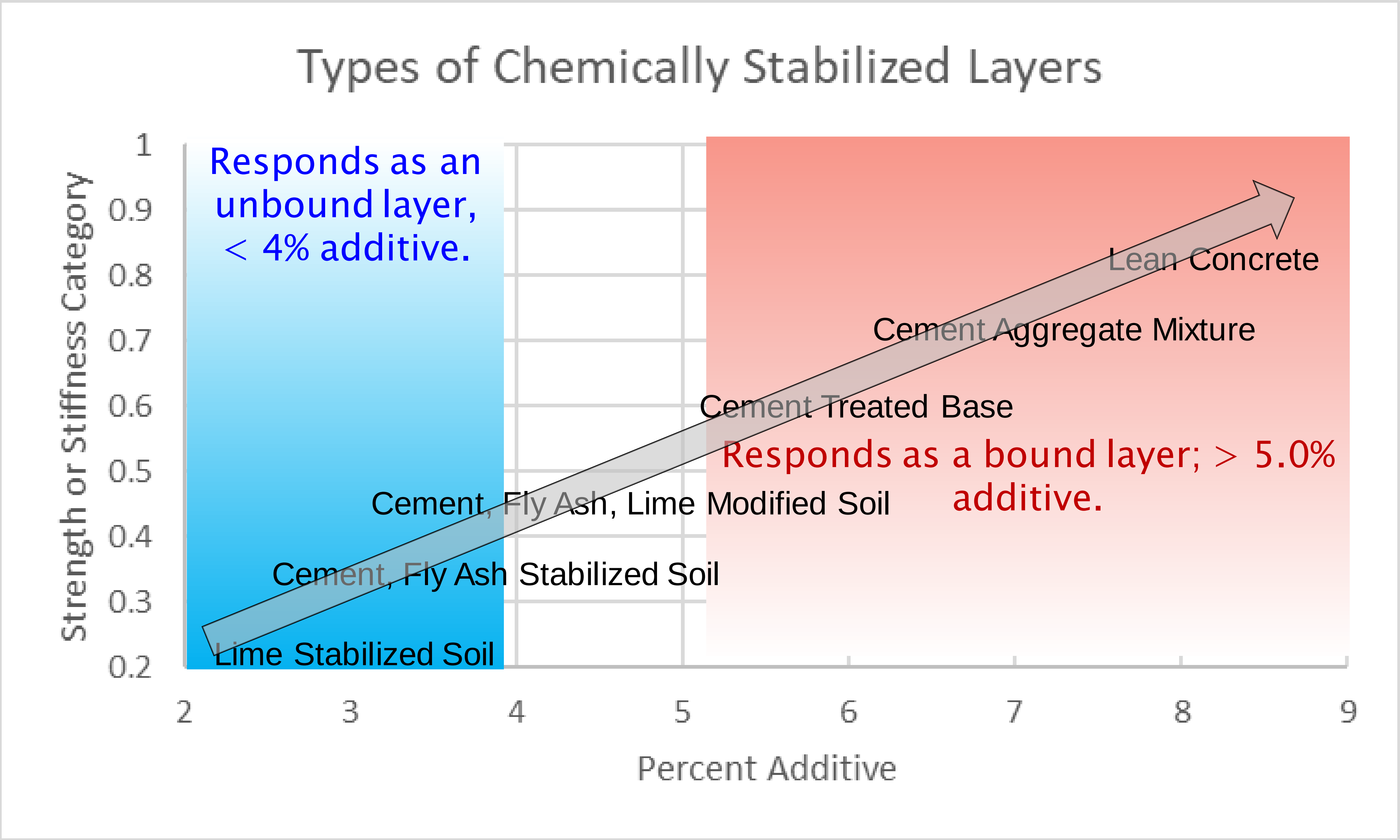

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A composite pavement consisting of AC placed over PCC is technically a semi-rigid pavement, however, it is less likely to be constructed as a practical application of the semi-rigid design concept, because of cost.

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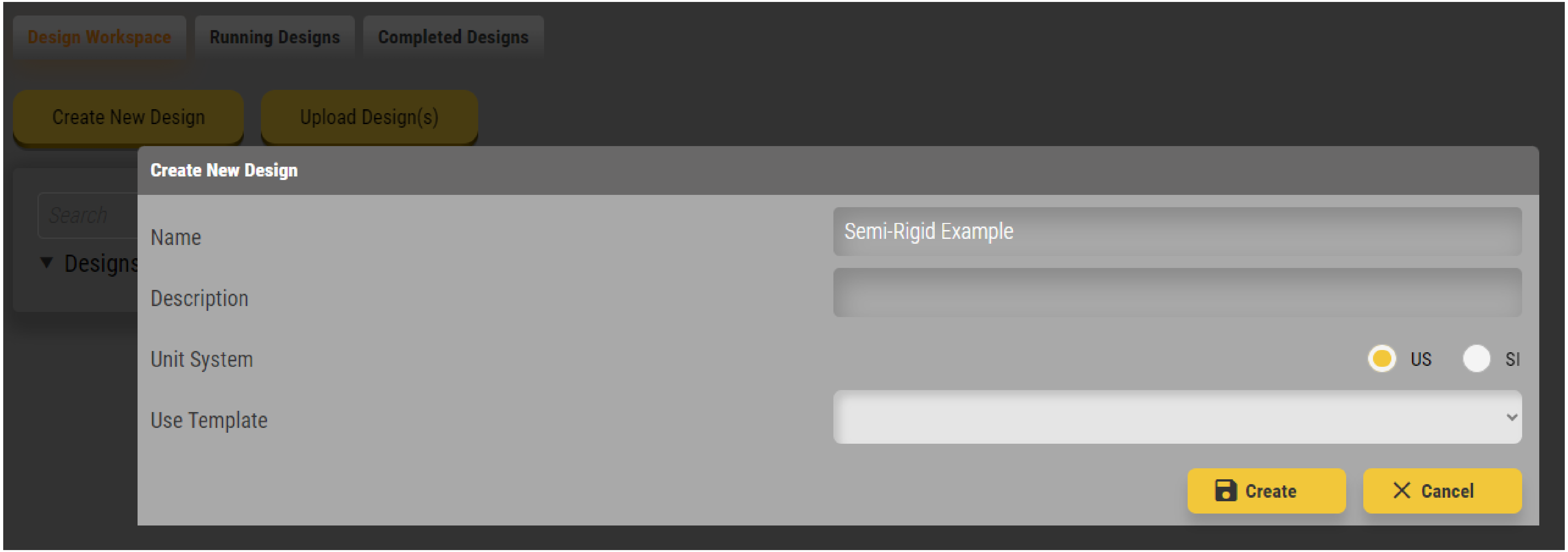
PMED Semi-Rigid Analysis



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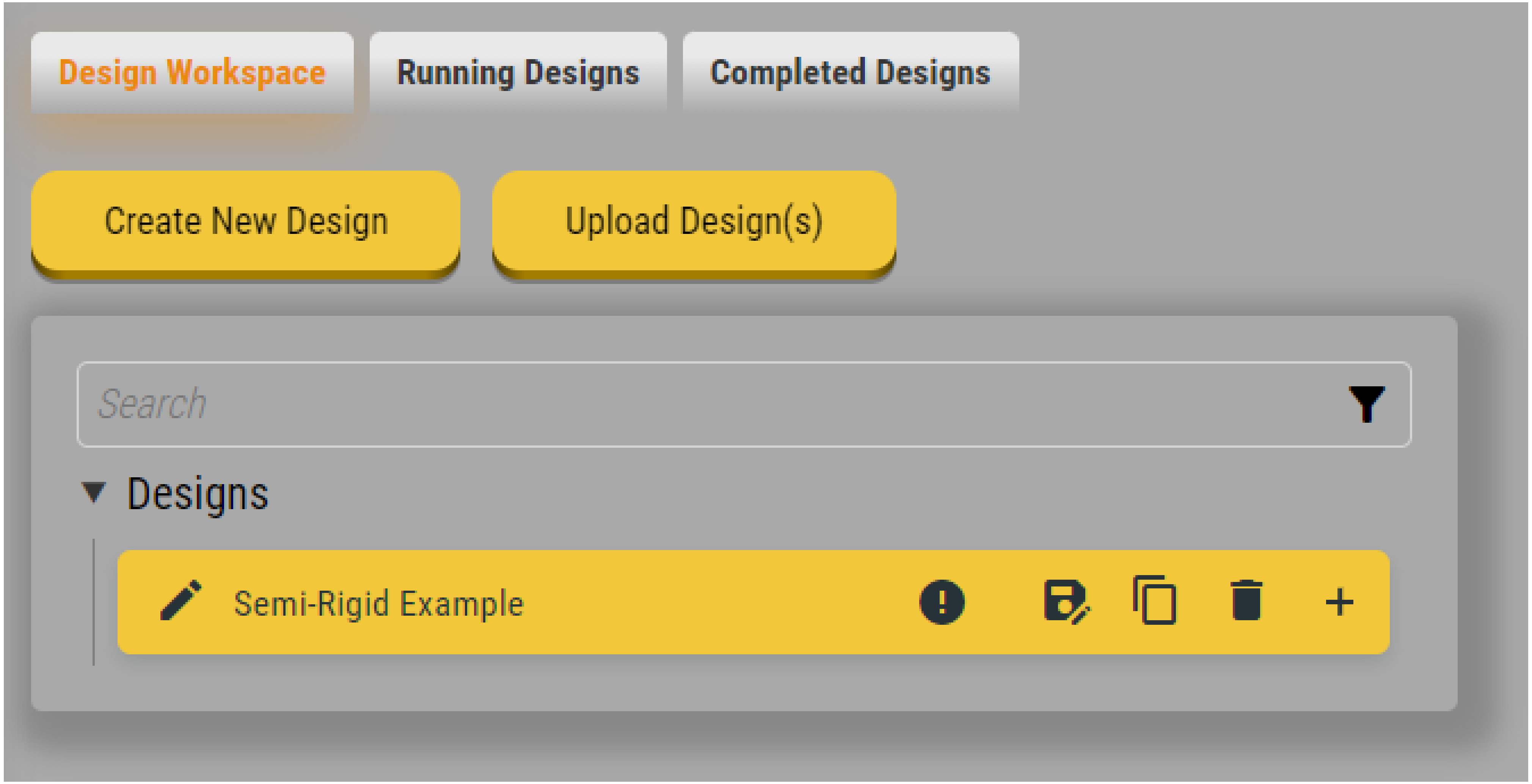
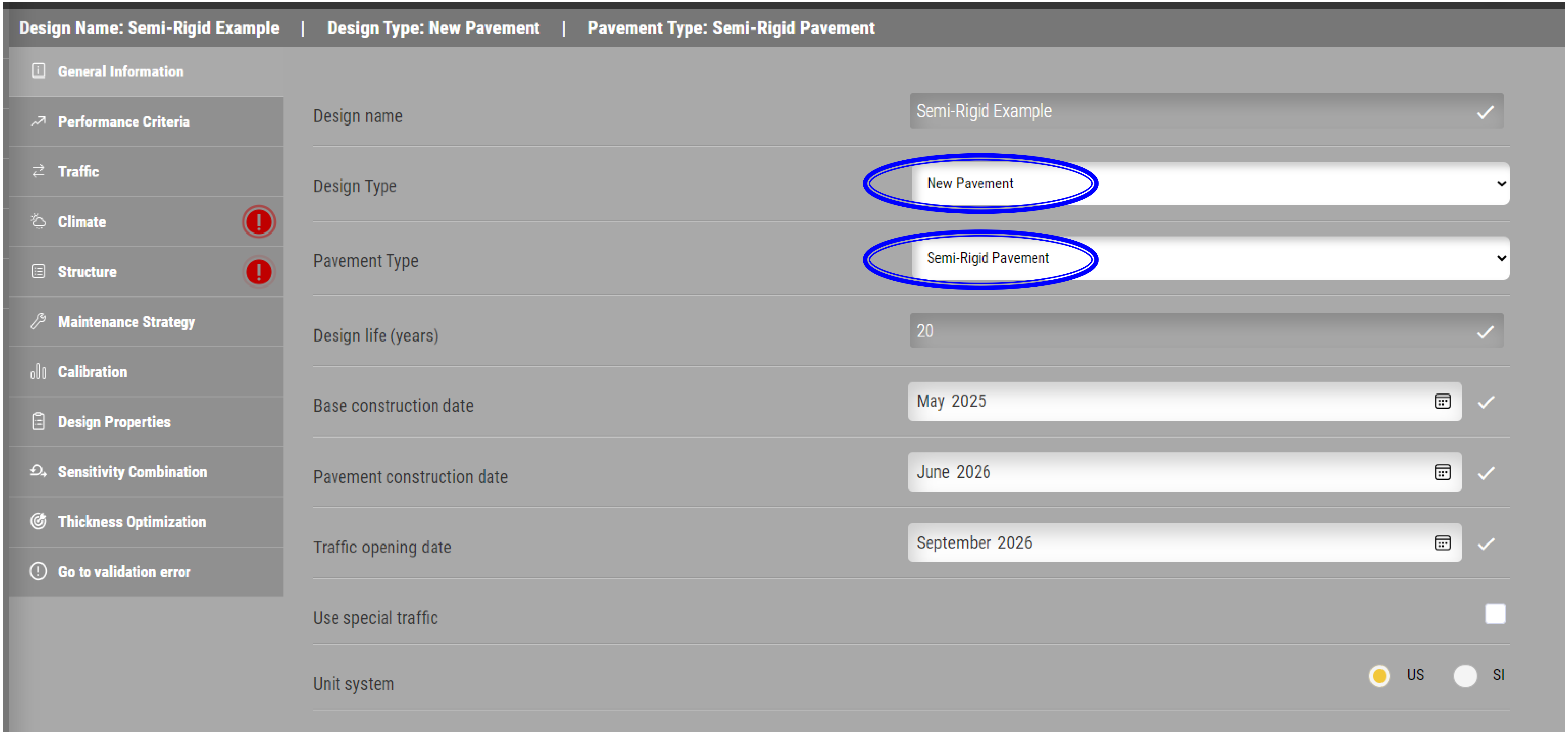

Design Workspace
Running Designs
Completed Designs
Create New Design
Upload Design(s)
Search
Designs
Semi-Rigid Example



Design Name: Semi-Rigid Example | Design Type: New Pavement | Pavement Type: Semi-Rigid Pavement
General Information
Performance Criteria
Traffic
Climate
Structure
Maintenance Strategy
Calibration
Design Properties
Sensitivity Combination
Thickness Optimization
Go to validation error
Design name
Semi-Rigid Example
Design Type
New Pavement
Pavement Type
Semi-Rigid Pavement
Design life (years)
20
Base construction date
May 2025
Pavement construction date
June 2026
Traffic opening date
September 2026
Use special traffic
Unit system
US
SI

Semi-Rigid Performance Criteria

Design Name: Semi-Rigid Example | Design Type: New Pavement | Pavement Type: Semi-Rigid Pavement

- General Information
- Performance Criteria
- Traffic
- Climate
- Structure
- Maintenance Strategy
- Calibration
- Design Properties
- Sensitivity Combination
- Thickness Optimization
- Run analysis

Performance Criteria	Limit	Reliability	Report Visibility
Initial IRI (in/mi)	63		☑
AC thermal cracking (ft/mi)	1000	50	☑
AC bottom up fatigue cracking (% of lane area)	25	50	☑
AC top down fatigue cracking (% of lane area)	25	90	☑
Permanent deformation (AC only) (in)	0.25	90	☑
Permanent deformation (total pavement) (in)	0.75	90	☑
Terminal IRI (in/mi)	172	90	☑
Chemically stabilized layer - fatigue fracture (% lane area)	25	50	☑
AC total fatigue cracking: bottom-up + reflective (% lane area)	25	90	☑
AC total transverse cracking: thermal + reflective (ft/mi)	2500	90	☑

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Semi-Rigid Prediction Models

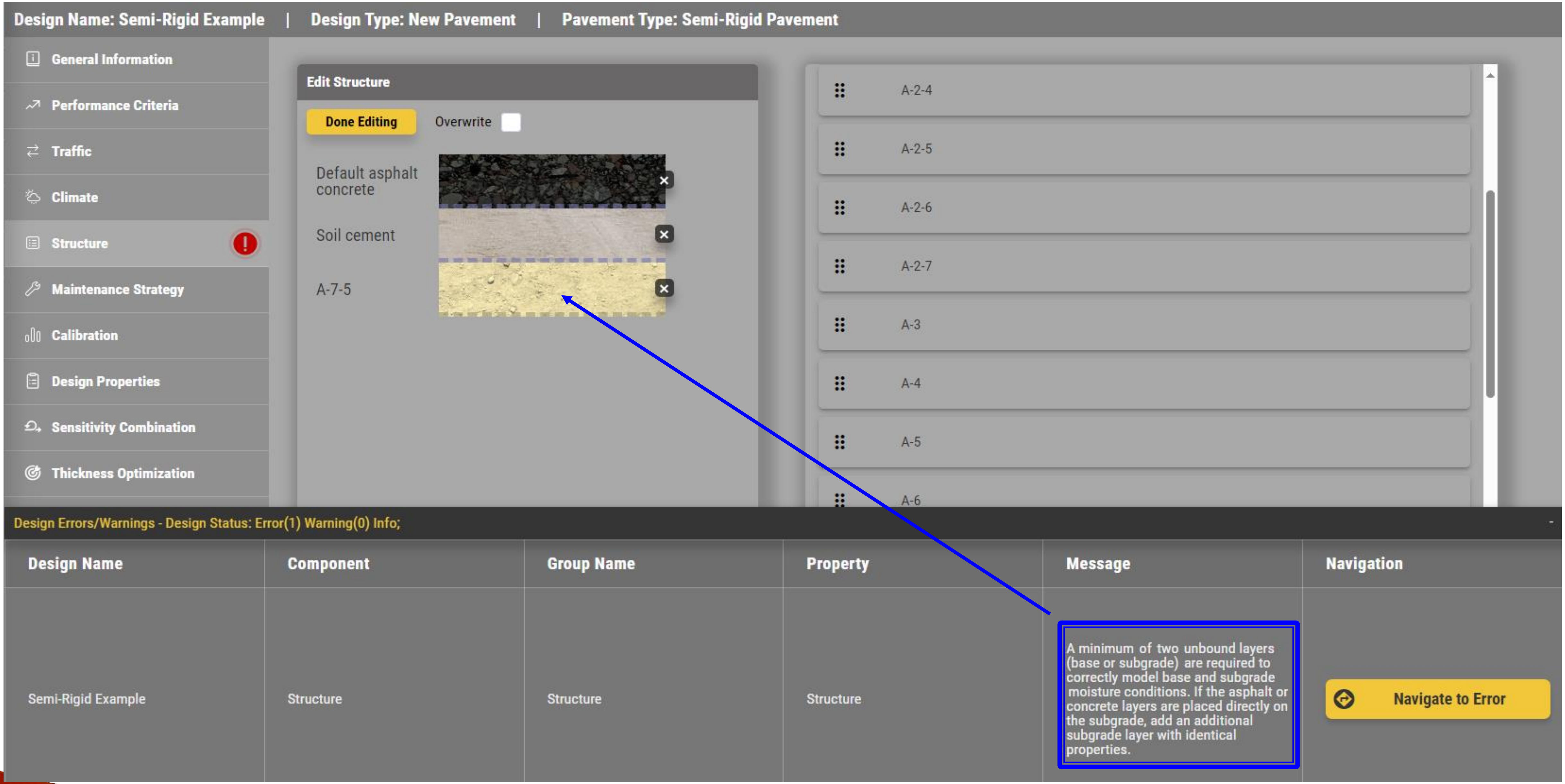
- Total rut depth and individual AC, unbound aggregate base, and subgrade layer rutting (only recommend total rut depth model for implementation unless individual layer rutting measured)
- Bottom-up fatigue cracking – AC
- Top-down fatigue cracking – AC
- Fatigue cracking – CTB (not recommended for design)
- Transverse cracking – AC
- Reflection cracking of CTB fatigue cracks – AC
- Reflection cracking of CTB transverse cracks – AC
- IRI

Recommend using total fatigue cracking for design

Semi-Rigid Prediction Models

- Total rut depth and individual AC, unbound aggregate base, and subgrade layer rutting (only recommend total rut depth model for implementation unless individual layer rutting measured)
- Bottom-up fatigue cracking – AC
- Top-down fatigue cracking – AC
- Fatigue cracking – CTB
- Transverse cracking – AC
- Reflection cracking of CTB fatigue cracks – AC
- Reflection cracking of CTB transverse cracks – AC
- IRI

Recommend using total transverse cracking for design



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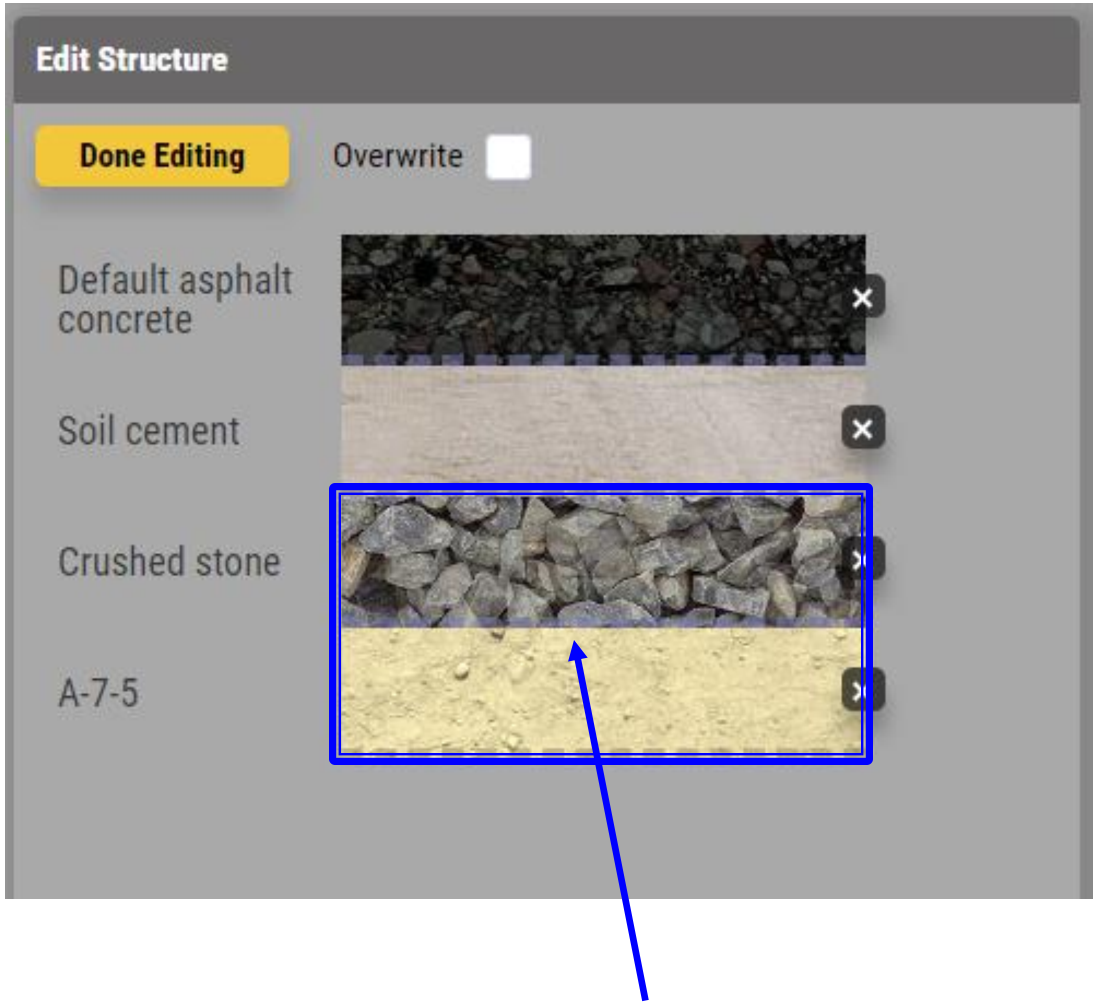
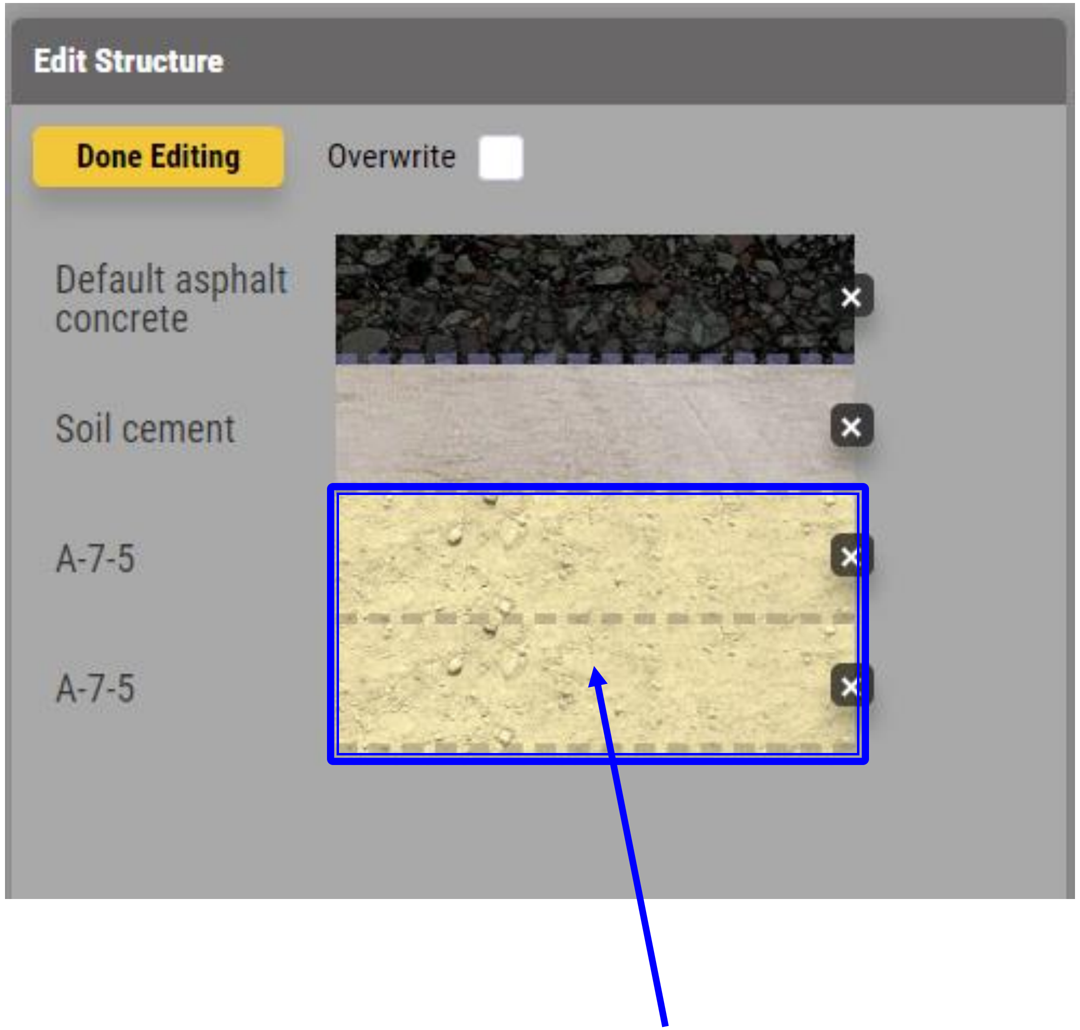


Unbound base layer / subgrade



Unbound base layer / subgrade

Two Layer Options

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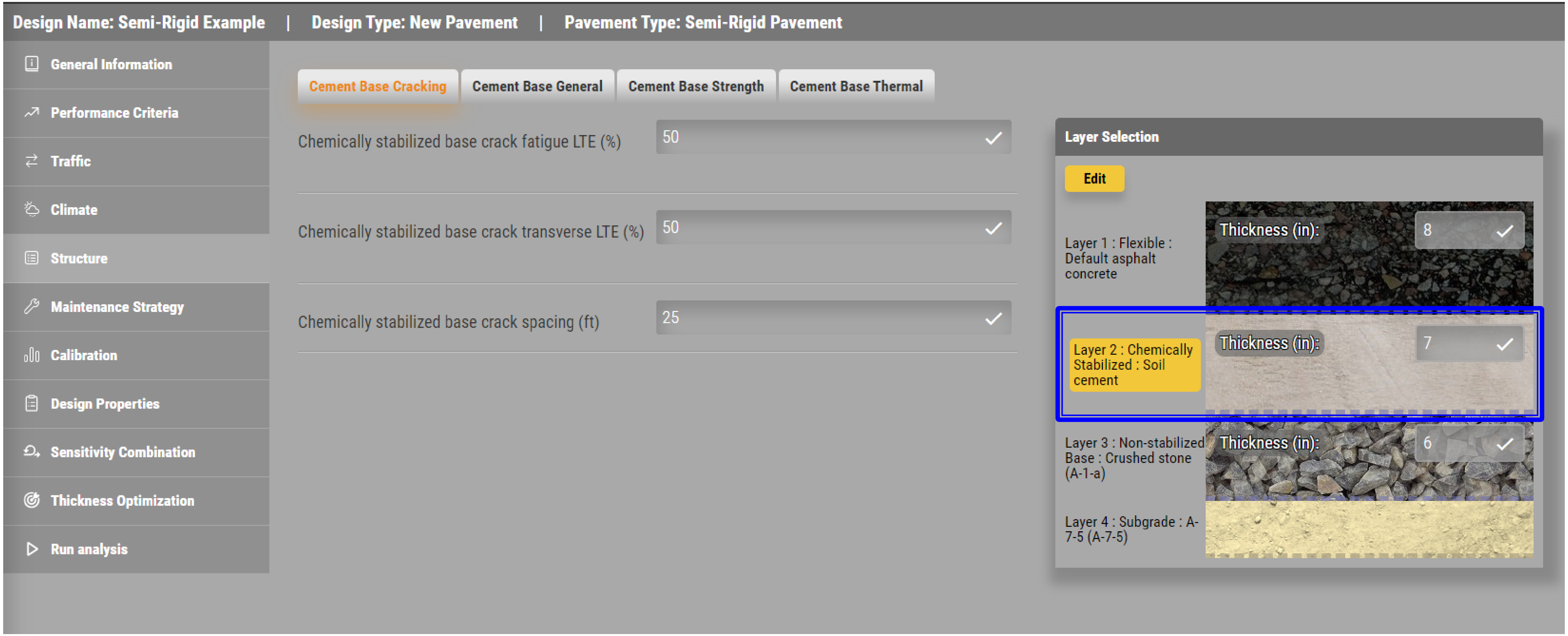

Semi-Rigid Layer Structural Inputs

(Material inputs listed in MOP Table 10-6)

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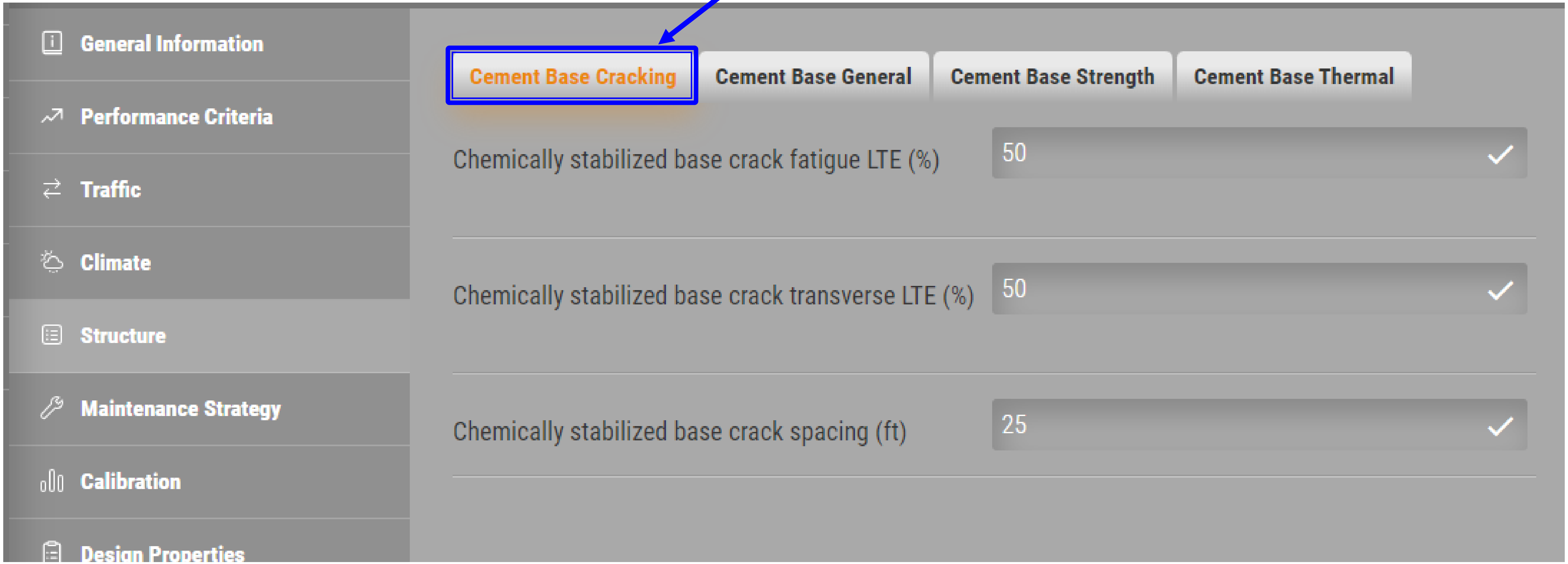
Physical Layer Characteristics



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CTB Layer Crack Spacing

- User must input CTB crack spacing from shrinkage cracking (10' – 40' typical range)
- Crack spacing is fixed will *not* decrease for duration of analysis period
- Crack spacing can be defined by cement content
- Crack spacing determines maximum transverse reflective cracking (ft/mile)

  Ex. For 25' spacing – (5280/25)*12' width ≃ 2500'

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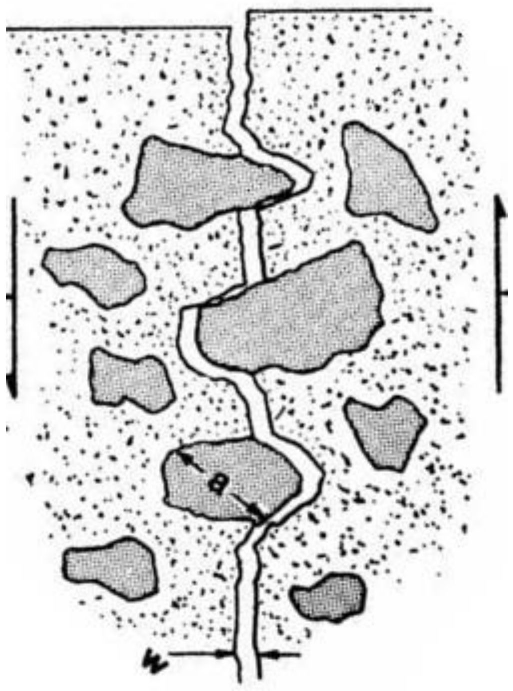
CTB Crack Load Transfer Efficiency (LTE)

- User must input CTB LTE for both fatigue and transverse cracks
- LTE is fixed and will *not* change for duration of PMED analysis
- LTE influences stress intensity factor (SIF) in fracture mechanic model simulation and, therefore, determines rate of reflective crack formation.



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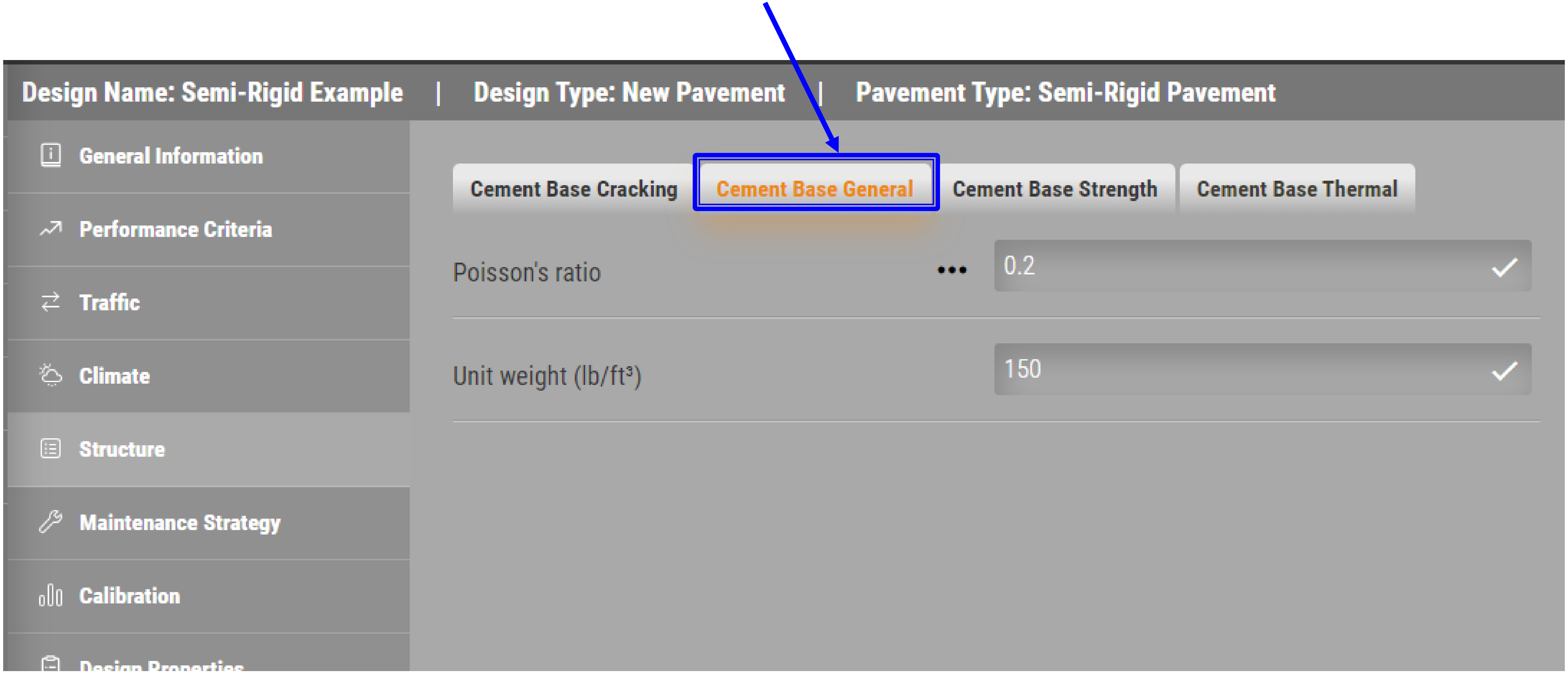
CTB LTE

- Fatigue crack LTE is a calibration parameter that <u>cannot</u> be measured directly.

- Transverse crack LTE is a calibration parameter that <u>can</u> be measured directly.

Engineering Properties and Volumetric Characteristics



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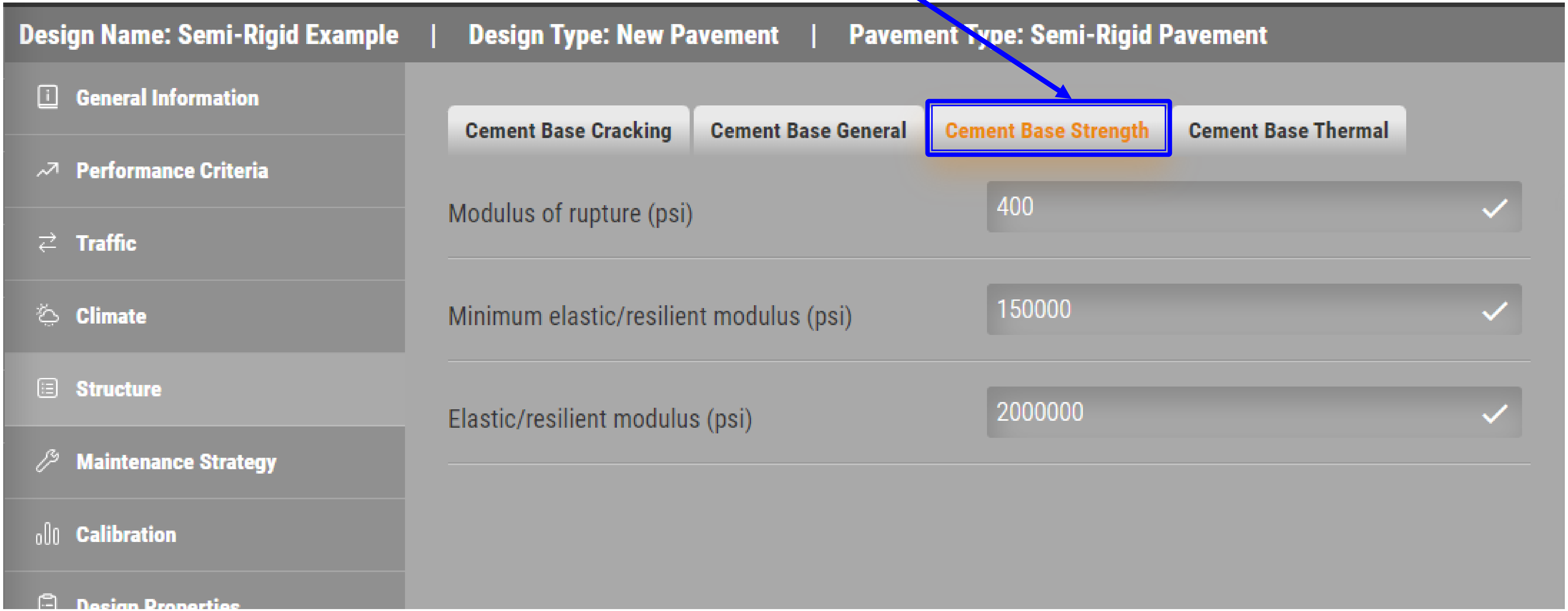
Engineering Properties and Volumetric Characteristics



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Engineering Properties and Volumetric Characteristics

Semi-Rigid Material Inputs	Test Standard
Unit Weight	AASHTO T 121
Flexural Strength; 28-day	AASHTO T 97
Poisson's Ratio	ASTM C469
Elastic Modulus; 28-day	ASTM C469
Minimum Elastic/Resilient Modulus	*********

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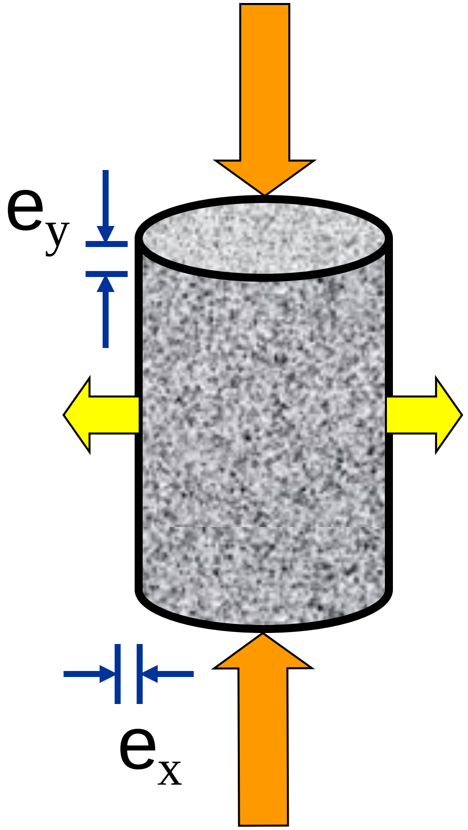
Poisson's Ratio

Default – 0.20

$$\mu = \frac{\varepsilon_x}{\varepsilon_y}$$



Modulus of Rupture

- 28-day strength flexural strength (modulus of rupture) for CTB ~ 300 – 500 psi
  - Default value: 400 psi

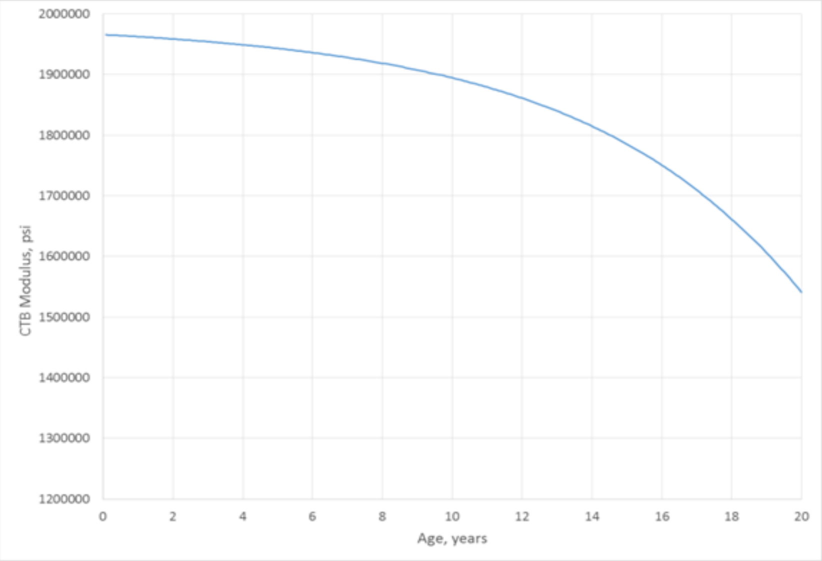
- Can correlate compressive strength (AASHTO T 22) to flexural strength

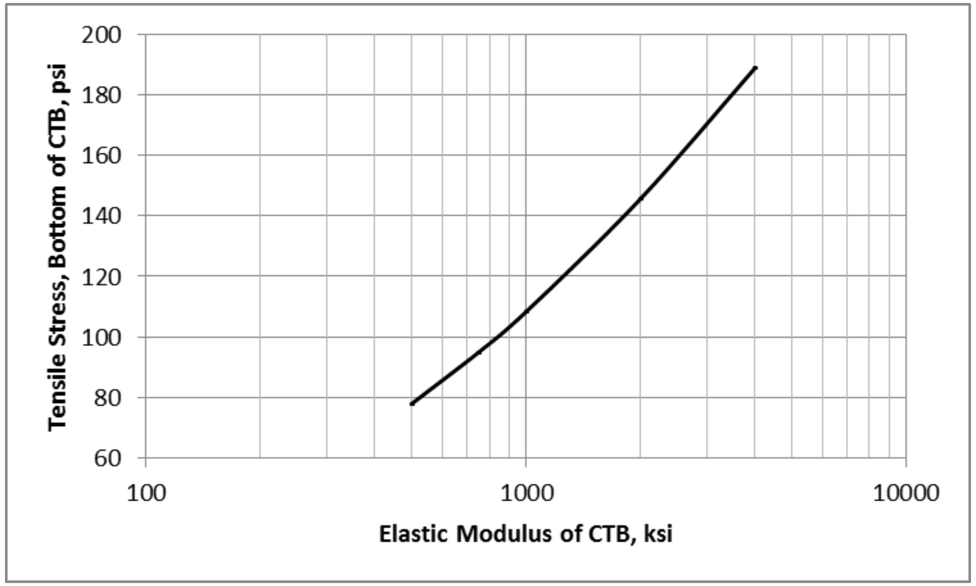
- The flexural strength does not change over time in the PMED software.

Elastic Modulus (28-Day)

- 28-day elastic modulus of rupture) for CTB ~ 1,000,000 – 4,000,000 psi
  - Default value: 2,000,000 psi

Elastic Modulus (Minimum)





Age increase → Modulus decrease because of fatigue damage

Modulus decrease → Tensile stress decrease, so damage per wheel load decreases

Fixed flexural strength and decreasing tensile stress means fatigue damage would decrease to zero unless a minimum elastic modulus value was set in PMED.

PMED default value is 150,000 psi, however, suggested value for the minimum elastic modulus is the 28-day elastic modulus to ensure fatigue damage accumulation continues.

Strength and Modulus Design Considerations

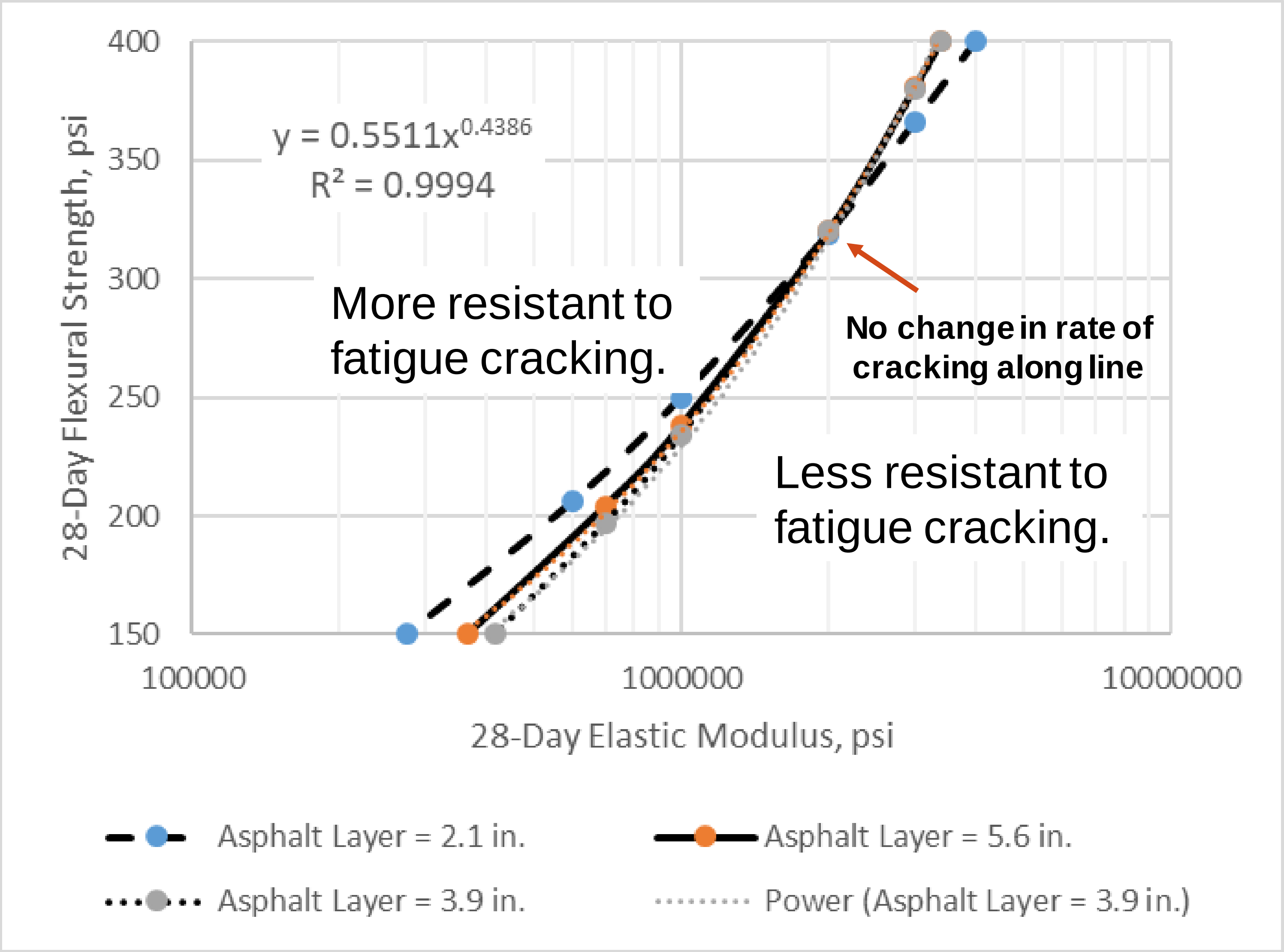
1. Relationship between the elastic modulus and flexural strength will vary depending on degree of semi-rigid layer stabilization.

2. Minimum layer thicknesses for the asphalt and cement stabilized layers are input for consistent strength-modulus relationship in fatigue crack modeling.

3. Full bond should be retained between the asphalt and cement stabilized layers over the design period.

Relationship between Strength and Modulus

CTB



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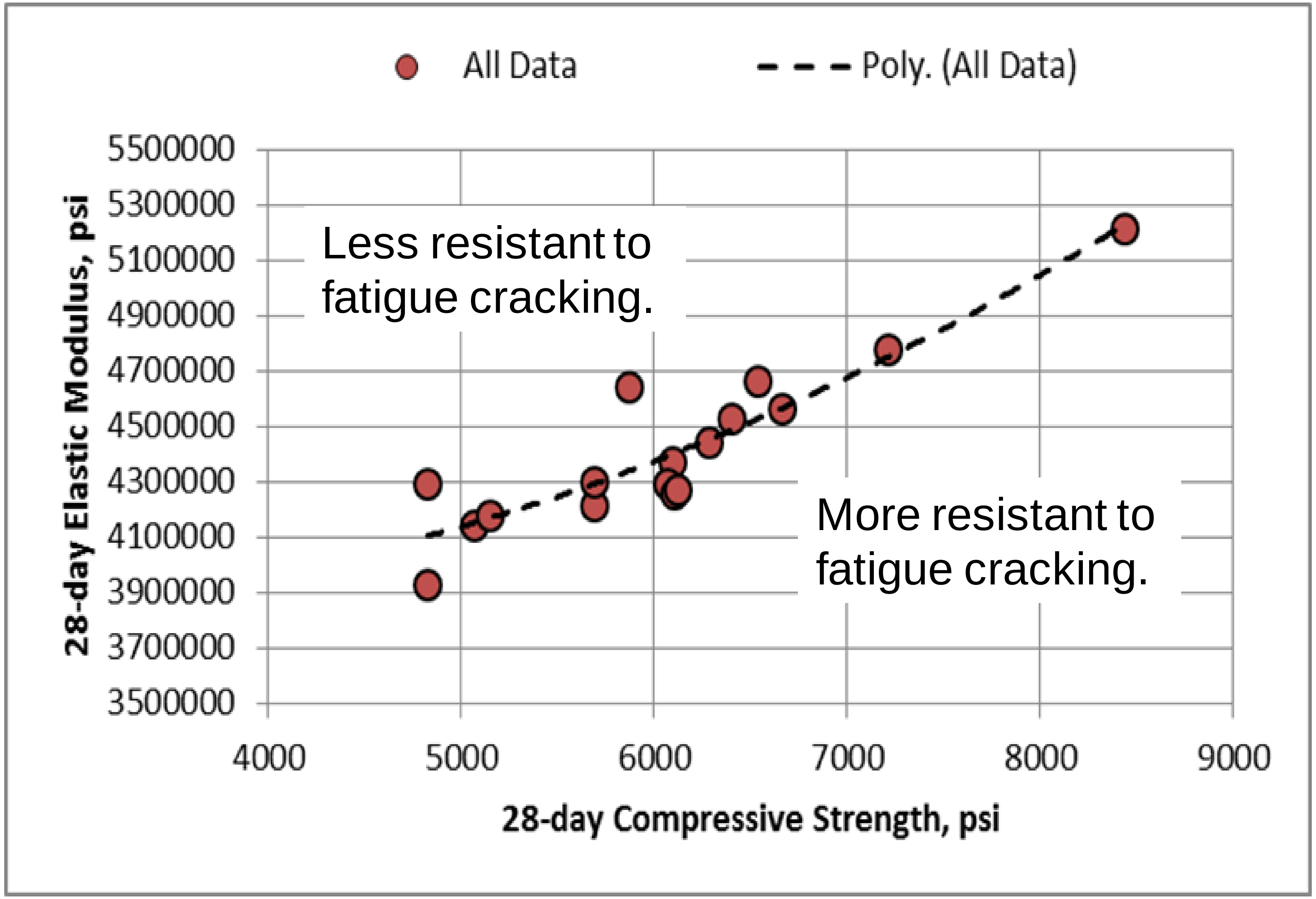
Relationship between Strength and Modulus

LCB



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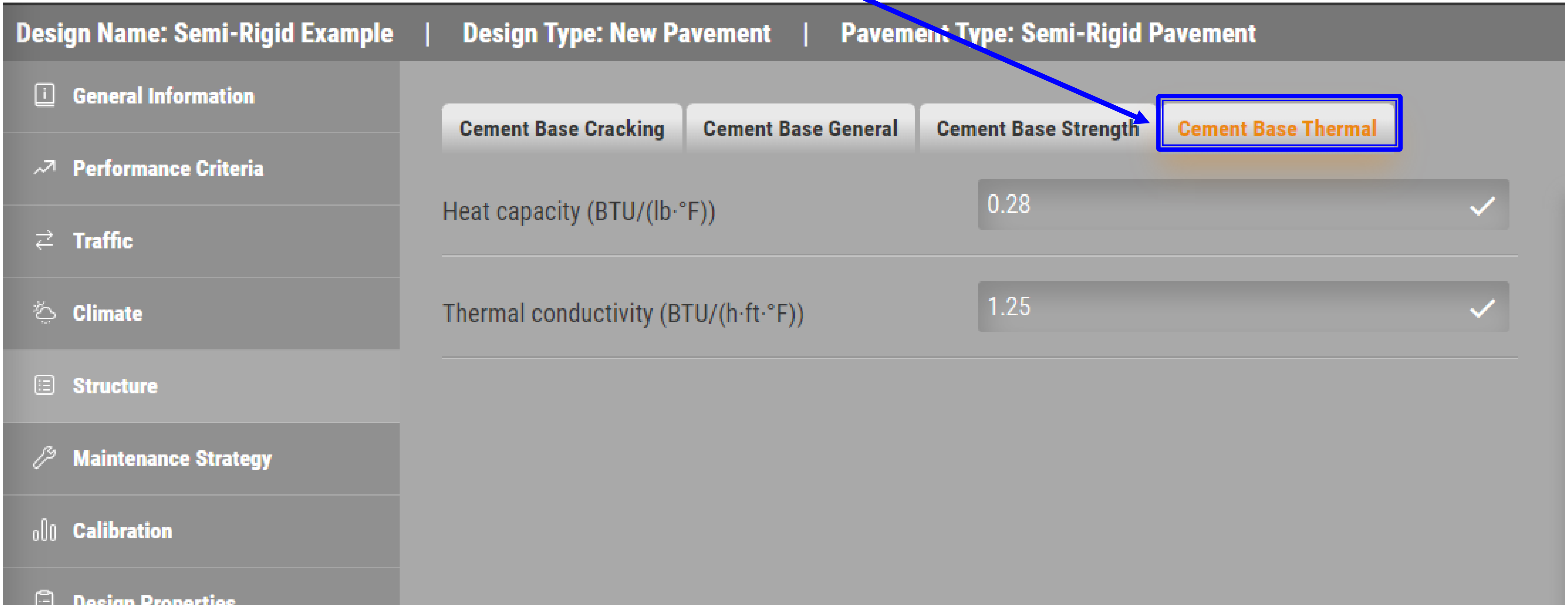
Thermal Property Characteristics



Thermal Property Tests

Semi-Rigid Material Inputs	Test Standard
Heat Capacity	ASTM D2766
Thermal Conductivity	ASTM E1952

Heat capacity range ~ 0.10 – 0.50 Btu/(lb)(°F)

Default – 0.28

Thermal conductivity range ~ 0.2 – 2.0 Btu/(ft)(hr)(°F)

Default – 1.25

Semi-Rigid Thickness Optimization

Design Name: Semi-Rigid Example | **Design Type: New Pavement** | **Pavement Type: Semi-Rigid Pavement**

- General Information
- Performance Criteria
- Traffic
- Climate
- Structure
- Maintenance Strategy
- Calibration
- Design Properties
- Sensitivity Combination
- Thickness Optimization
- Run analysis

Design Layers

	Layer	Current Thickness (in)	Minimum	Maximum
☐	Layer 1 : Flexible : Default asphalt concrete	12	0	0
☑	Layer 2 : Chemically Stabilized : Soil cement	10	8	12
☐	Layer 3 : Subgrade : A-7-5 (A-7-5)	8	0	0
☐	Layer 4 : Subgrade : A-7-5 (A-7-5)	-1	0	0

Run Thickness Optimization

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Semi-Rigid Sensitivity Combination

Design Name: Semi-Rigid Example | Design Type: New Pavement | Pavement Type: Semi-Rigid Pavement

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- Performance Criteria
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Sensitivity Combination Is Factorial ☐

Enabled	Layer	Property	Current Value	Minimum Value	Maximum Value	Number of Increments
☐		Two-way AADTT	4000	0	0	0
☐	Layer 1 : Flexible : Default asphalt concrete	Air voids (%)	7	0	0	0
☐	Layer 1 : Flexible : Default asphalt concrete	Effective binder content (%)	11.6	0	0	0
☐	Layer 1 : Flexible : Default asphalt concrete	Thickness (in)	10	0	0	0
☐	Layer 2 : Chemically Stabilized : Soil cement	Elastic/resilient modulus (psi)	200000(	0	0	0
☑	Layer 2 : Chemically Stabilized : Soil cement	Thickness (in)	10	8	12	4
☐	Layer 3 : Subgrade : A-7-5 (A-7-5)	Thickness (in)	8	0	0	0
☐	Layer 3 : Subgrade : A-7-5 (A-7-5)	Unbound modulus input (variant)	10000	0	0	0
☐	Layer 4 : Subgrade : A-7-5 (A-7-5)	Thickness (in)	-1	0	0	0
☐	Layer 4 : Subgrade : A-7-5 (A-7-5)	Unbound modulus input (variant)	10000	0	0	0

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FY 2024, Webinar #3: Semi-Rigid Pavement Design

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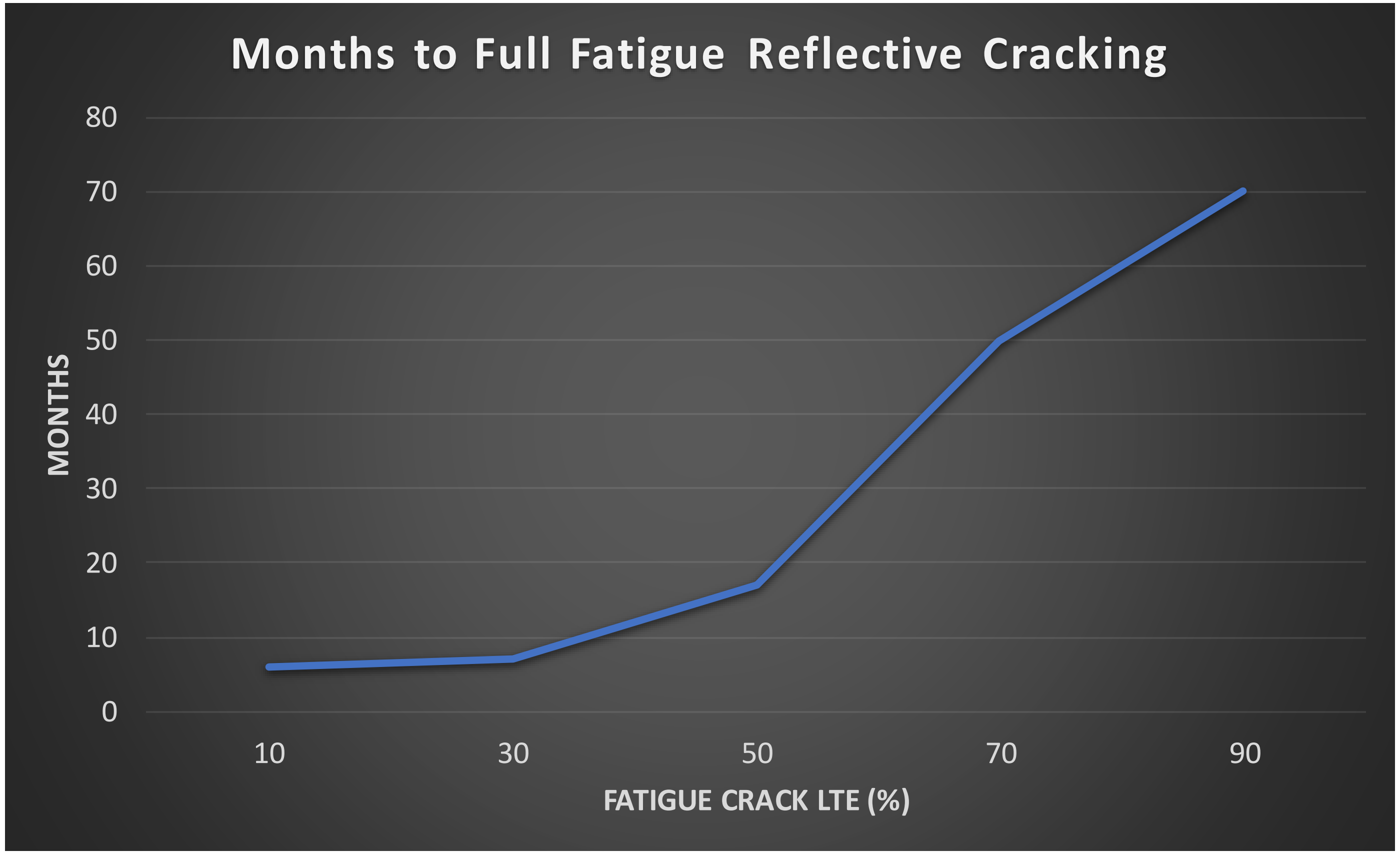
Sensitivity Factors

- CTB
  - Fatigue LTE
  - Transverse LTE
  - Elastic Modulus
  - Flexural Strength
  - Thickness

- AADTT

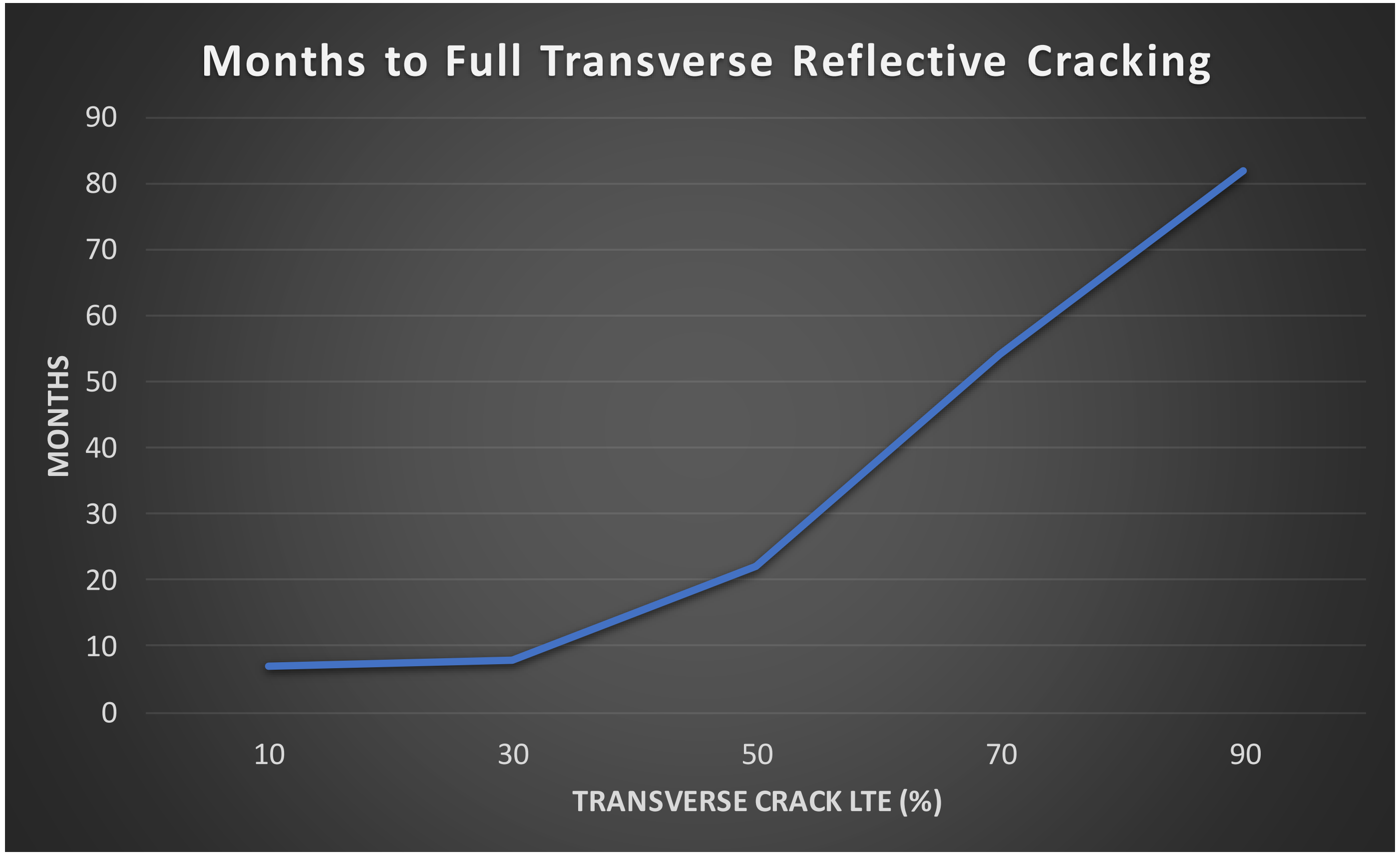
CTB Fatigue LTE

- Fixed inputs
  - 10” AC
  - 7” CTB
  - 25’ CTB crack spacing
  - Flex – 400 psi
  - 10,000 AADTT



CTB Transverse LTE

- Fixed inputs
  - 10” AC
  - 7” CTB
  - 25’ CTB crack spacing
  - Flex – 400 psi
  - 10,000 AADTT



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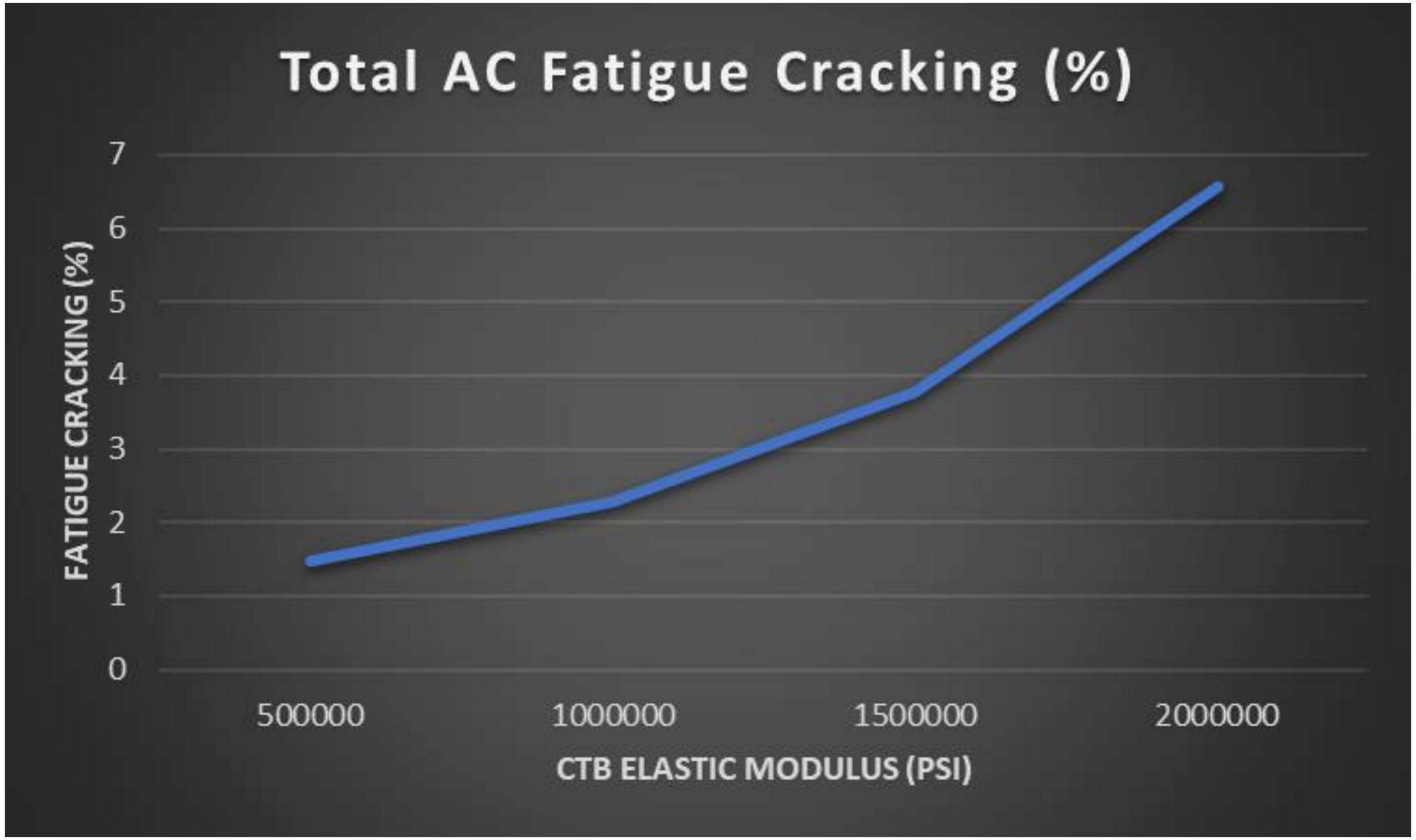
CTB Elastic Modulus

- Fixed inputs
  - 8" AC
  - 7" CTB
  - 50% transverse LTE
  - 50% fatigue LTE
  - Flex – 400 psi
  - 10,000 AADTT



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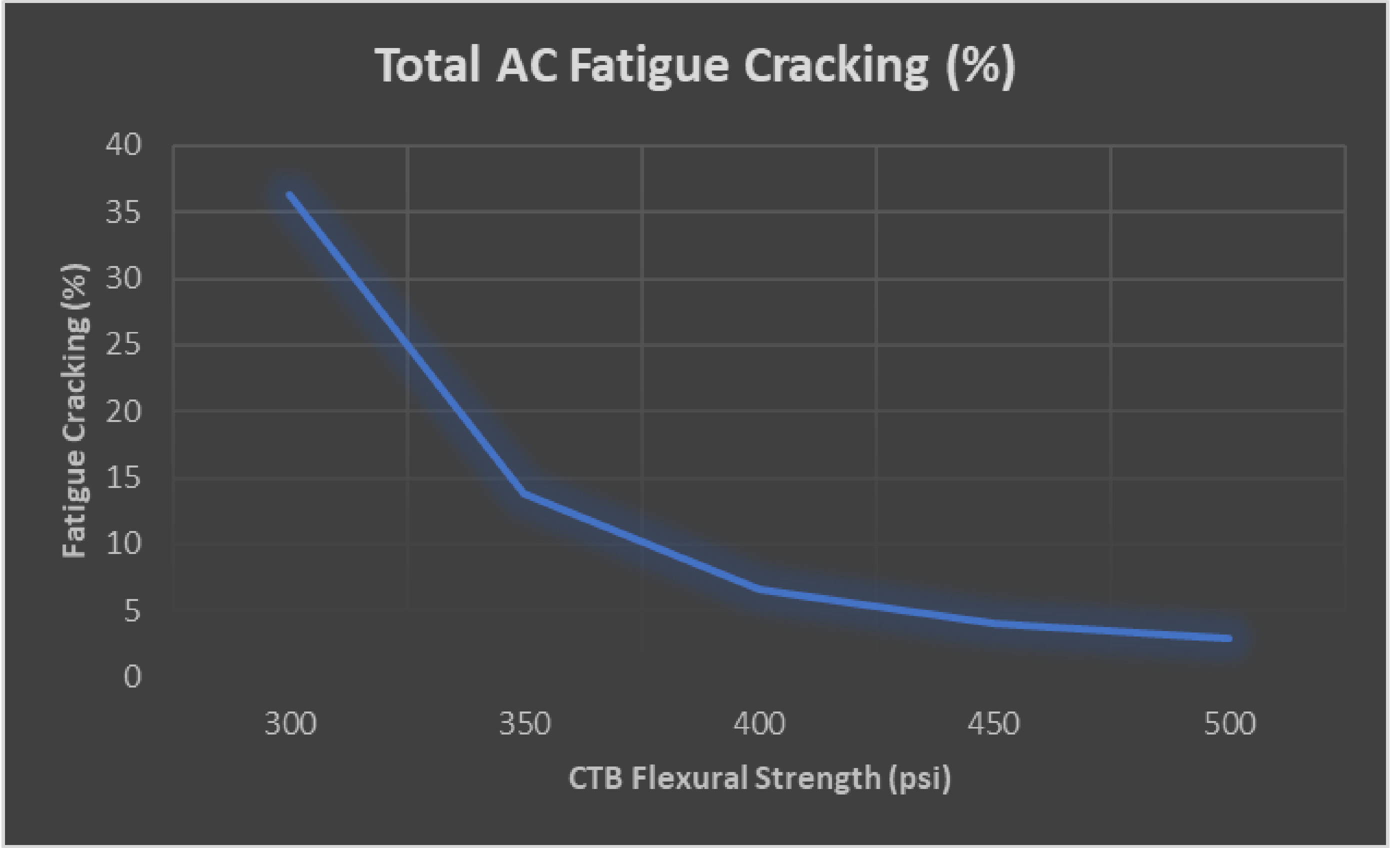
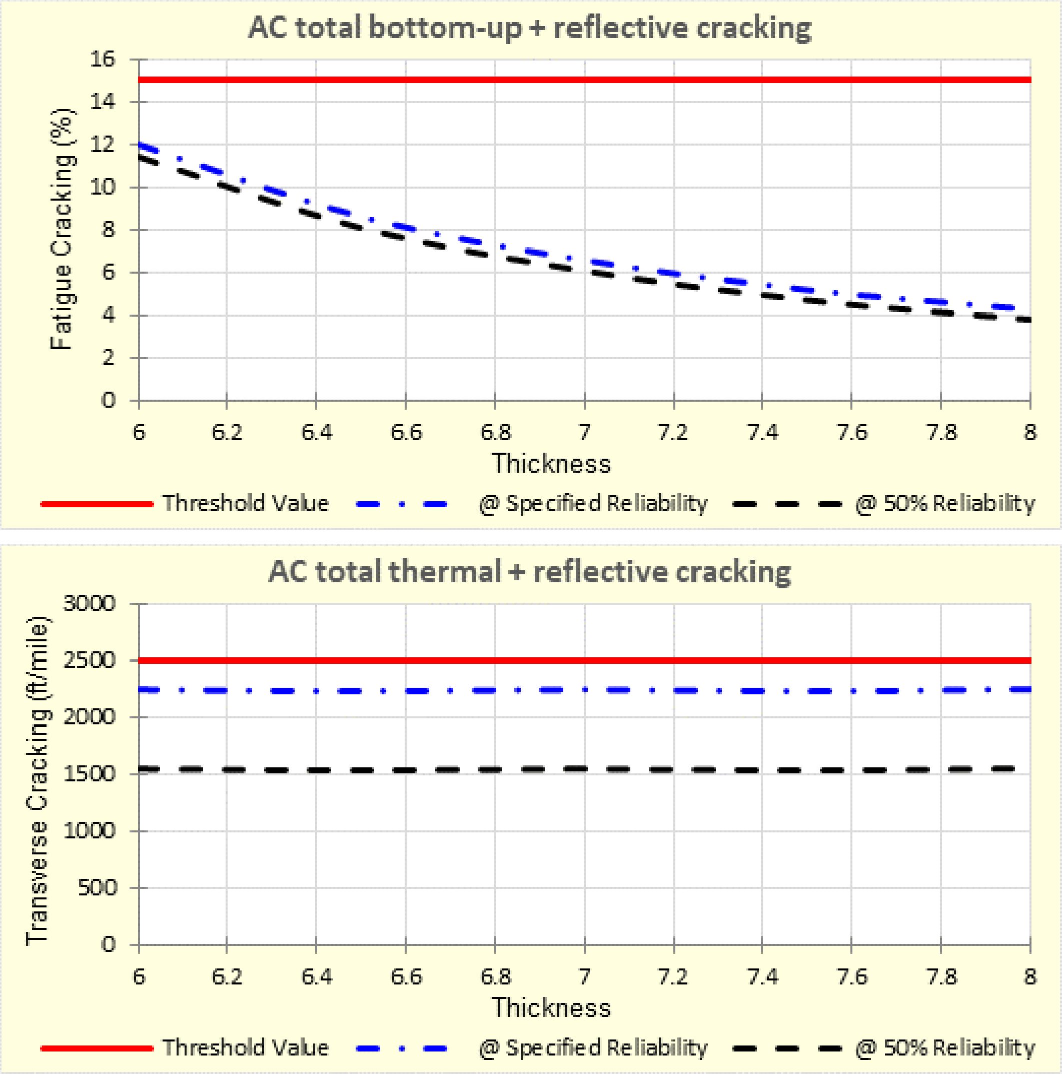
CTB Flexural Strength

- Fixed inputs
  - 8” AC
  - 7” CTB
  - 50% transverse LTE
  - 50% fatigue LTE
  - Modulus – 2,000,000 psi
  - 10,000 AADTT



CTB Thickness

- Fixed inputs
  - 8” AC
  - 50% transverse LTE
  - 50% fatigue LTE
  - Flex – 400 psi
  - Modulus – 2,000,000 psi
  - 10,000 AADTT



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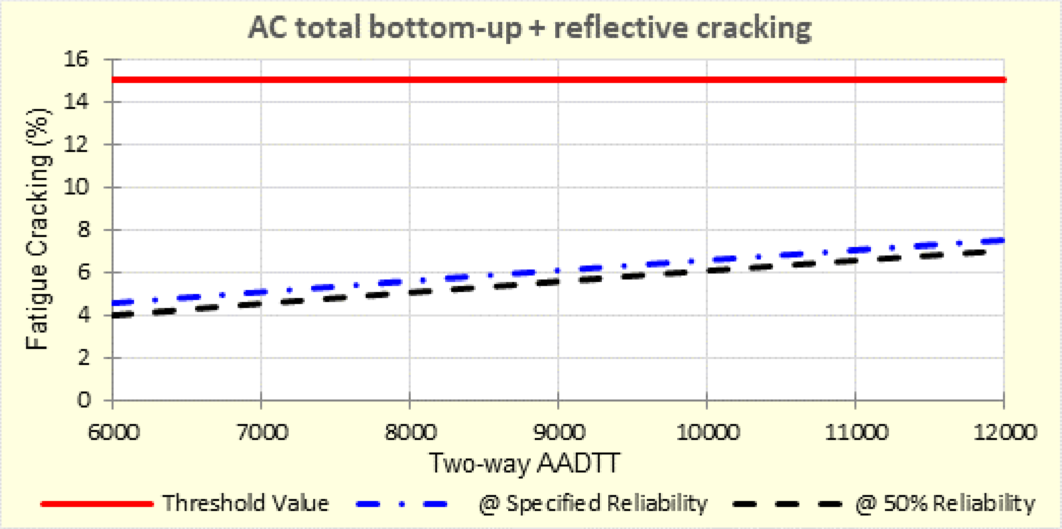
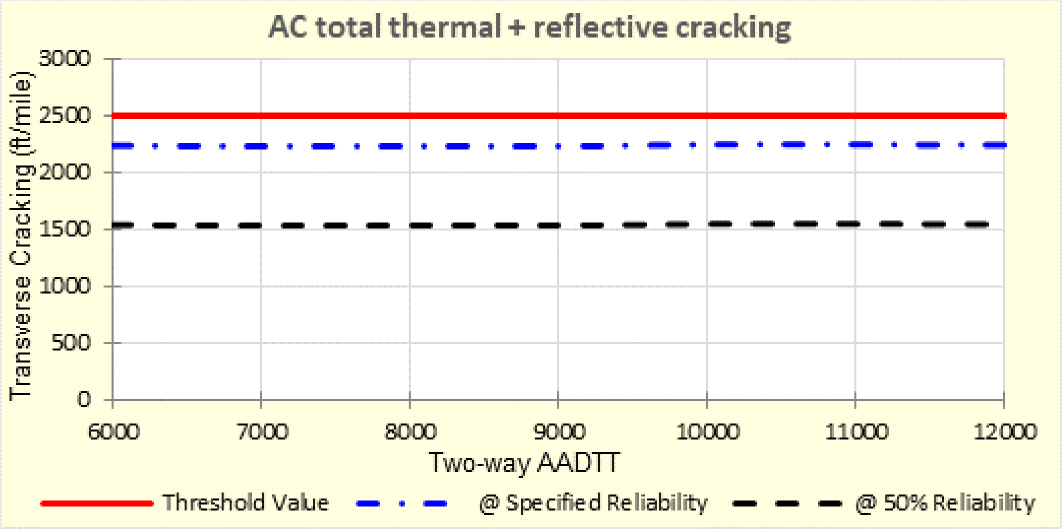
Truck Traffic

- Fixed inputs
  - 8" AC
  - 7" CTB
  - 50% transverse LTE
  - 50% fatigue LTE
  - Flex – 400 psi
  - Modulus – 2,000,000 psi





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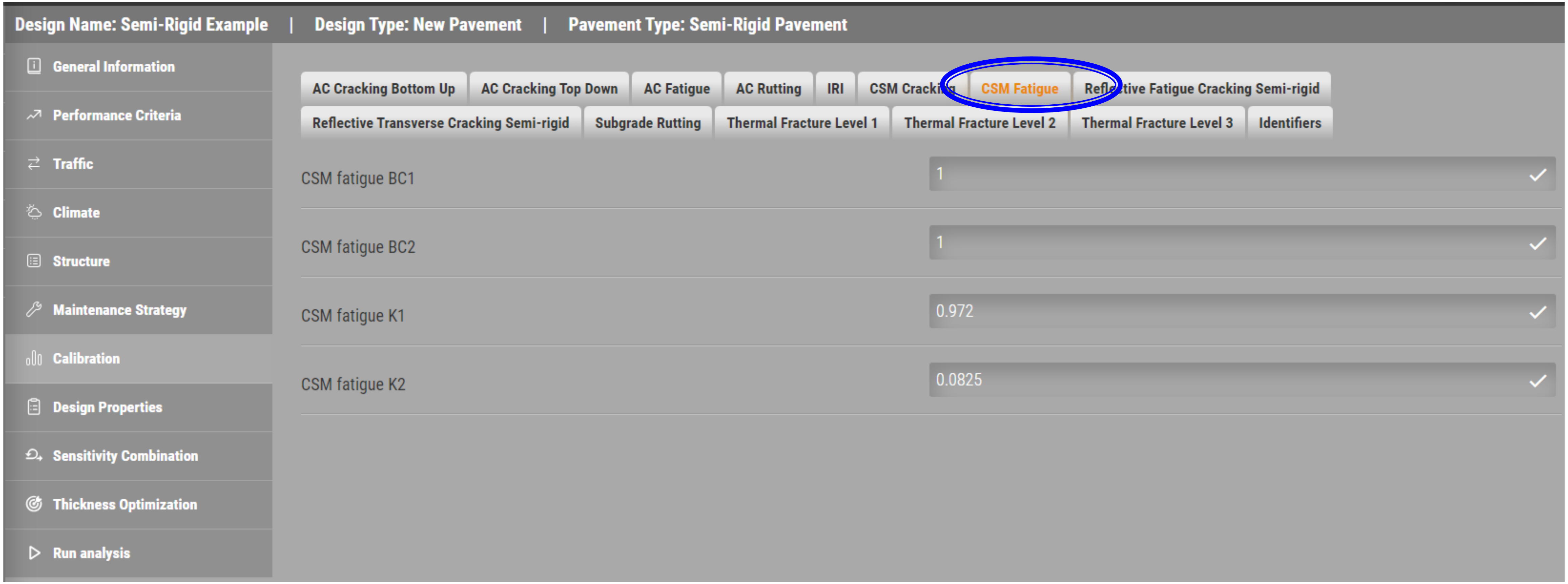
Semi-Rigid Calibration Coefficients

- Cement stabilized material (CSM) fatigue
- CSM cracking
- Reflective fatigue cracking semi-rigid
- Reflective transverse cracking semi-rigid

CSM fatigue model predicts cumulative damage in CTB layer.



Local calibration not practical/possible

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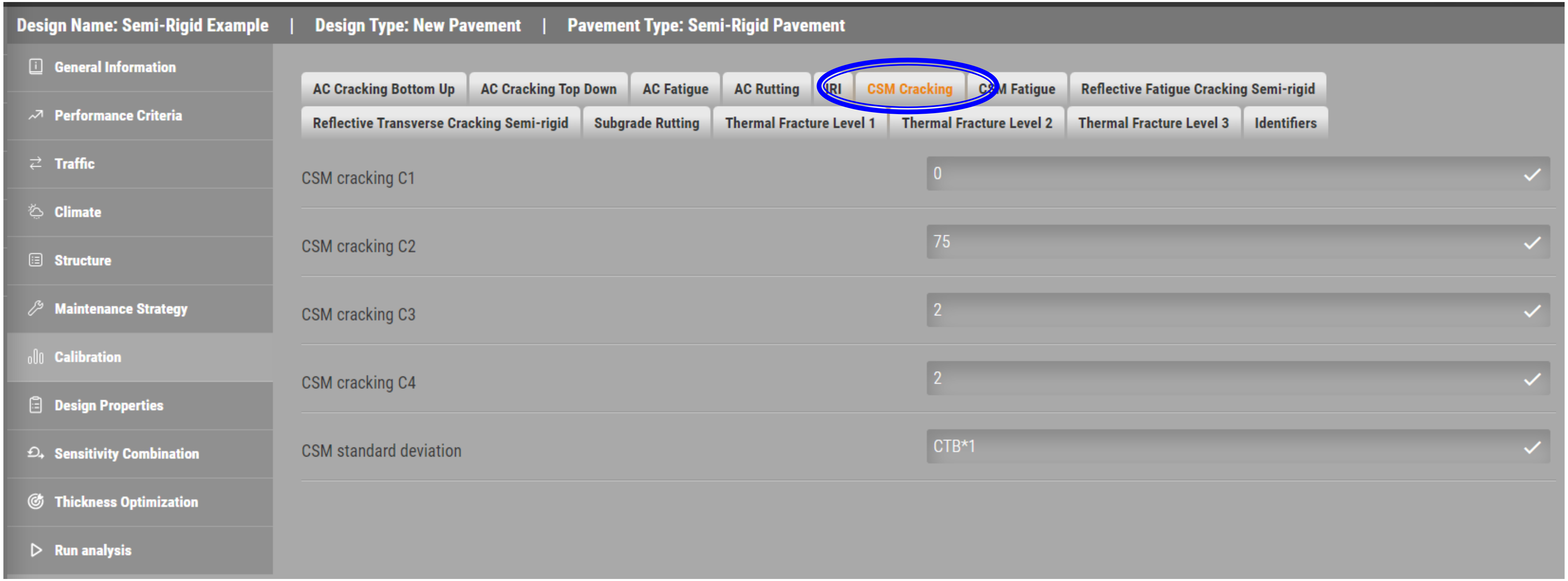
CSM cracking model converts damage to cracking in CTB layer.



Local calibration not practical/possible

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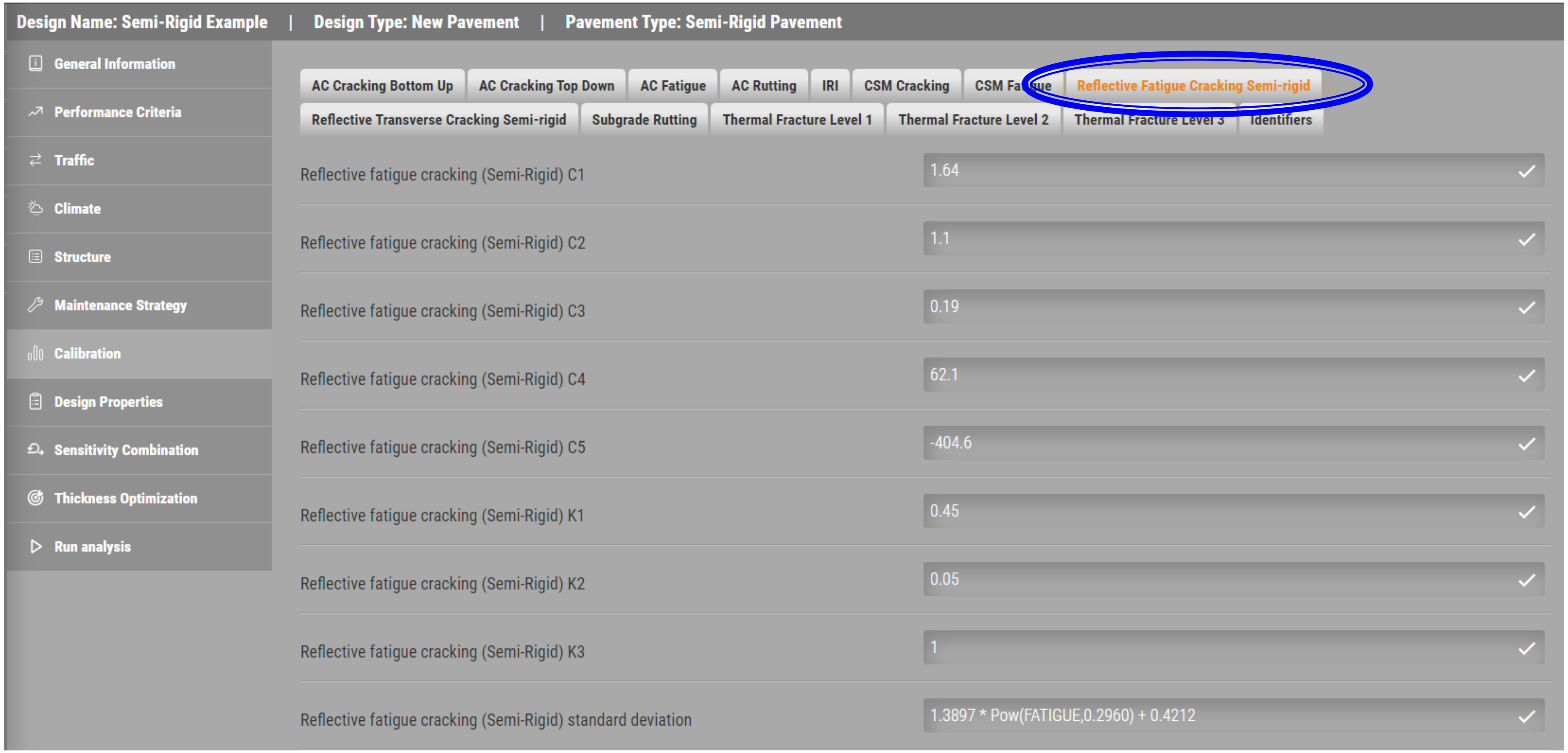
Reflective fatigue cracking semi-rigid model predicts longitudinal cracking area percent.



Local calibration possible

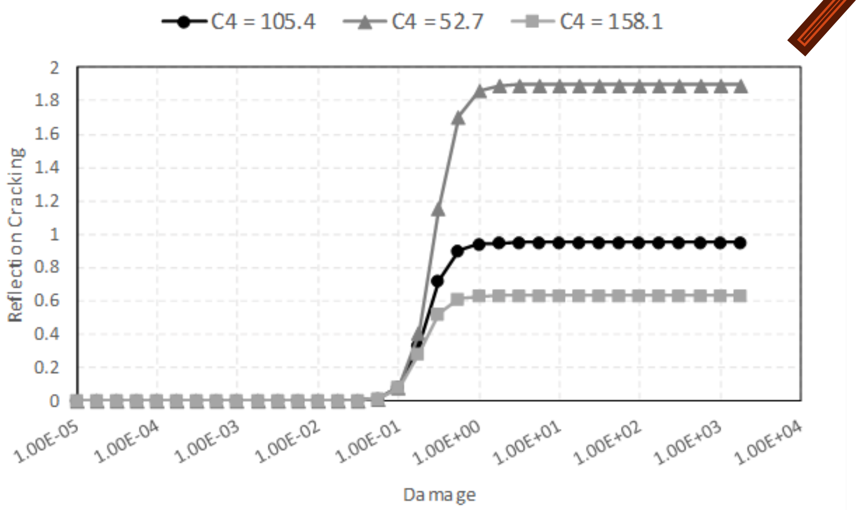
Reflective Fatigue Cracking Semi-Rigid Model Calibration

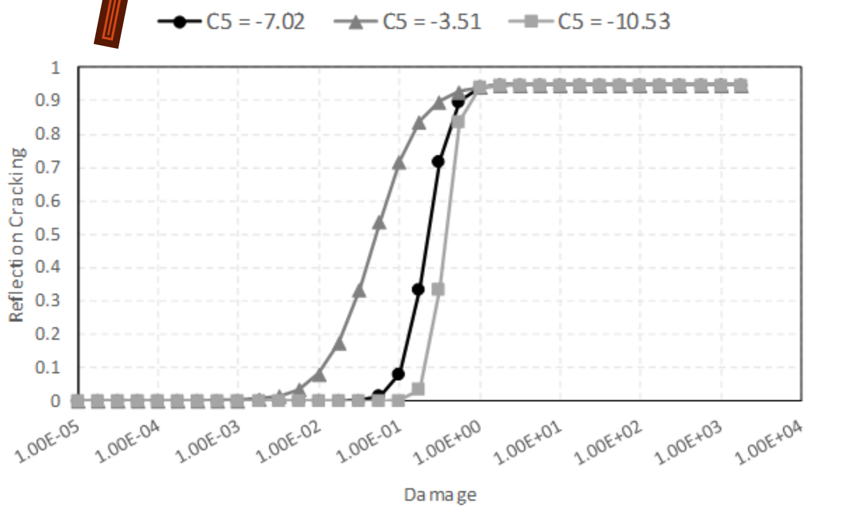
$$\Delta DI_i = \sum_{i=1}^{m} A\left[\left(C_1 k_1 \left(\Delta K_B\right)^n + C_2 k_2 \left(\Delta K_S\right)^n + C_3 k_3 \left(\Delta K_T\right)^n\right)\right]$$

$$RCR_i = C_k g\left(\frac{100}{C_4 + e^{C_5 LogDI_i}}\right)$$

⇧ C4 = ⇩ Cracking

⇧ C5 = ⇧ Cracking





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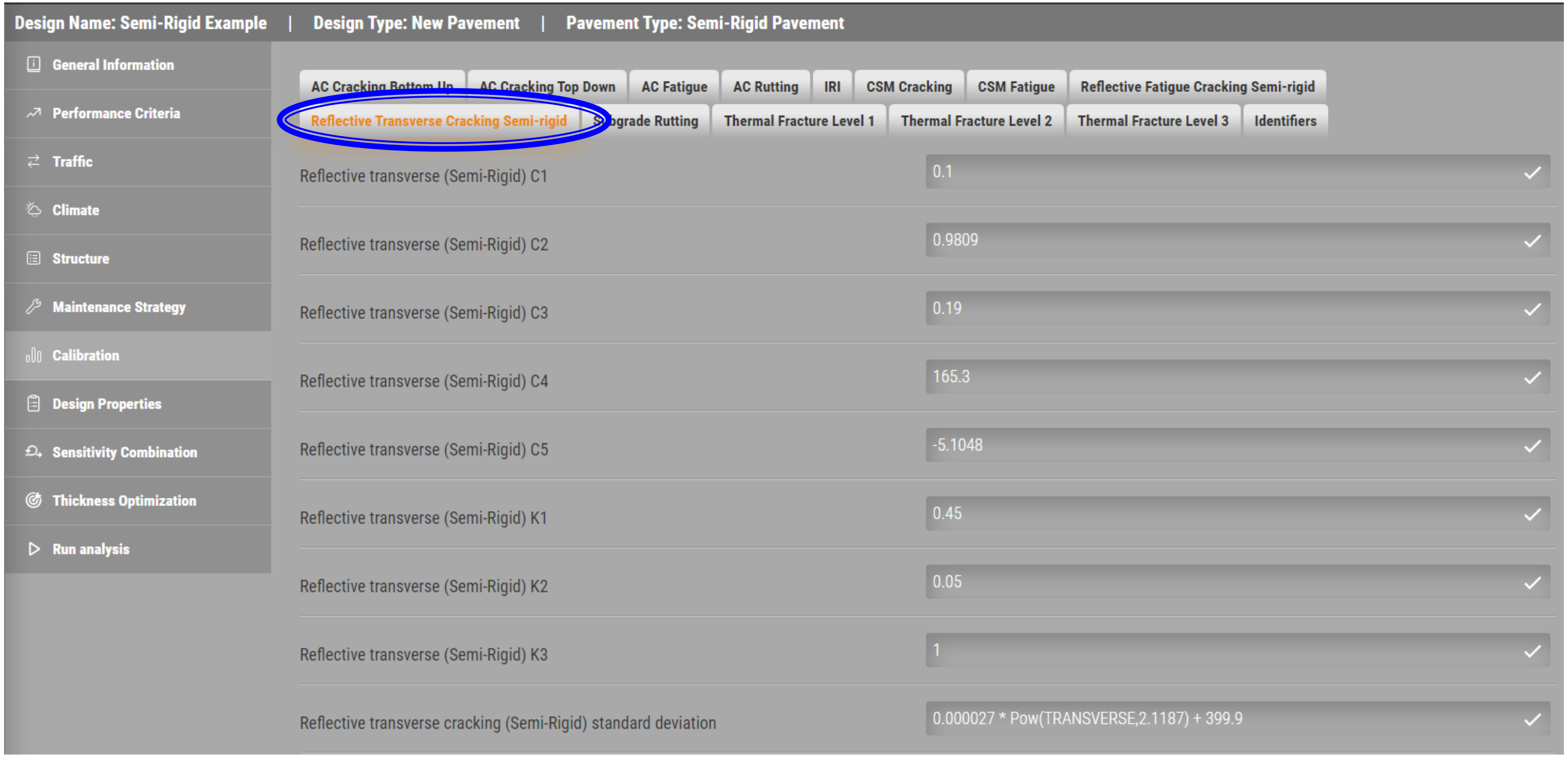
Reflective transverse cracking semi-rigid model predicts longitudinal cracking area percent.



Local calibration possible

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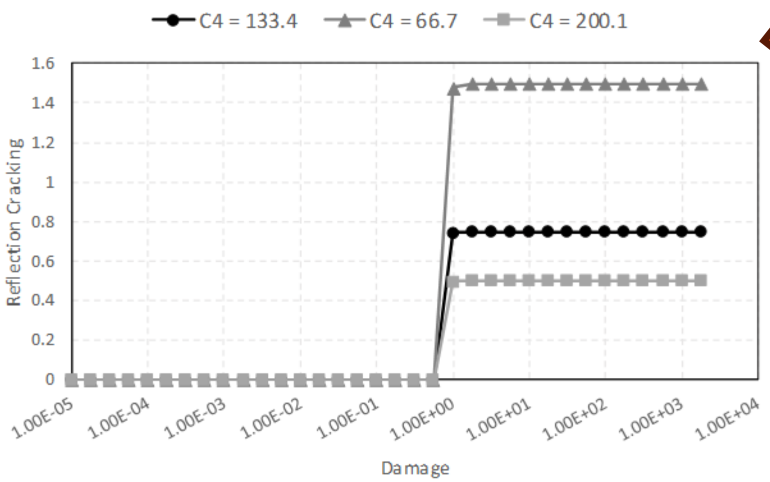
Reflective Transverse Cracking Semi-Rigid Model Calibration

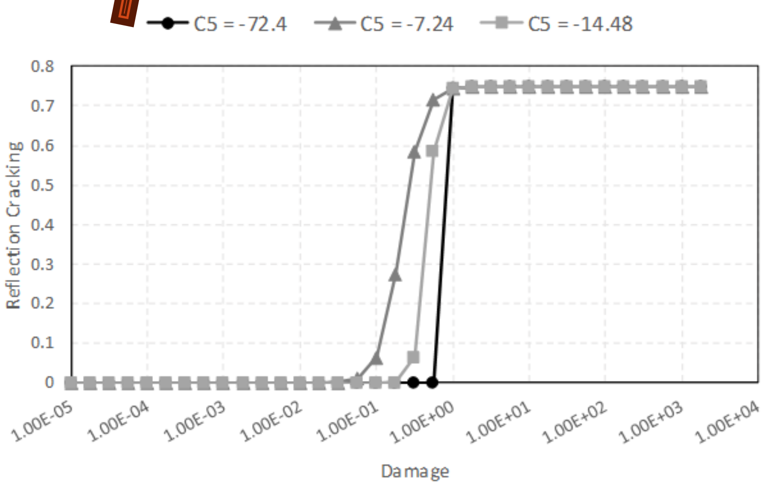
$$\Delta DI_i = \sum_{i=1}^{m} A\left[\left(C_1 k_1 (\Delta K_B)^n + C_2 k_2 (\Delta K_S)^n + C_3 k_3 (\Delta K_T)^n\right)\right]$$

$$RCR_i = Ckg\left(\frac{100}{C_4 + e^{C_5 LogDI_i}}\right)$$

⇧ C4 = ⇩ Cracking

⇧ C5 = ⇧ Cracking





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FY 2024, Webinar #3: Semi-Rigid Pavement Design

Webinar Outline:

1. Introduction
2. Defining Semi-Rigid
3. PMED Analysis
4. Sensitivity
5. Calibration Coefficients
6. Summary and Takeaways
7. Question and Answer Session

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Summary and Takeaways

- A semi-rigid layer must have flexural strength.
- PMED requires semi-rigid (CTB) layer directly below AC layer.
- Crack spacing, input by user, remains constant in analysis.
- *Total* transverse and fatigue cracking predictions should be primary crack distress indicators for design analysis.

Summary and Takeaways

- Flexural strength (MR) and elastic modulus (E) have opposite influence on CTB damage accumulation. MR assumed to remain constant, therefore, minimum CTB E input required to prevent full cessation of fatigue damage increase.

- CTB layer fatigue and transverse LTE determine respective rates of reflective cracking in AC layer.

- C4 and C5 transfer function coefficients are primary means of calibrating fatigue and transverse reflection cracking models.

FY 2024 Webinar #1 Multiple Asphalt overlays

Poll 2: Questions 4 to 6

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QUESTION AND ANSWER SESSION

We welcome comments & suggestions for future webinars; Send an email to pavementmedesign@ara.com.

Upcoming Webinars for FY 2024

- Webinars 3 and 4: Will be announced later this year (defined by the task force in October).

- Reminder:
  - Slides, Q&A, and recording can be found at:
    - AASHTOWare Pavement ME Design – Webinar Series (me-design.com)

Looking for webinar topics for FY 2025 – Please submit any webinar topic suggestions.


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PAVEMENT
ME DESIGN
Save the Date!
2024 AASHTOWare PMED User Group Meeting
September 4-5, 2024 | Atlanta, GA

Thank you for Attending the Webinar!

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Webinar is closed.

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