Moisture Susceptibility Testing of New England Mixtures

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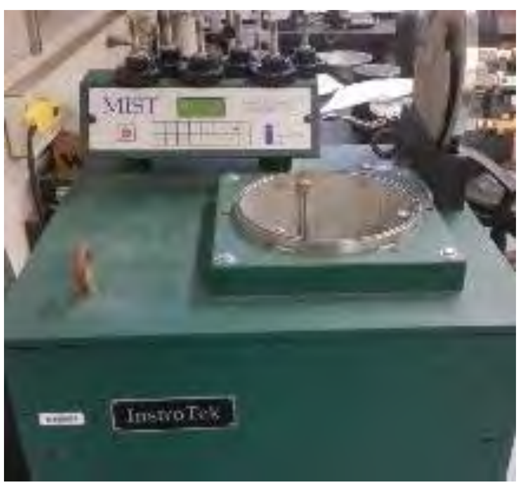

Acknowledgements

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- Andy Willete – VTrans
- Eliana Carlson – ConnDOT
- Mark Brum – MassDOT
- Beran Black - NHDOT

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Project Background

- Moisture susceptibility: Extent to which an asphalt mixture is prone to experiencing moisture induced damage

- Moisture Damage results in significant reduction of pavement performance and service life

- Testing methods need to be able to effectively and reliably capture the extent of moisture damage susceptibility
  - Some New England DOTs have struggled with this recently

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Project Objectives

- Evaluate good and poor performing asphalt mixtures in New England
    - Assess mechanisms responsible for poor performing mixtures
- Measure impacts of moisture induced-damage on pavement performance and service life
- Recommend a framework of testing and analysis procedures that is reliable and suitable for moisture susceptibility testing in New England

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Test Plan Development

Mixture Selection

- Mixtures chosen on the basis of feedback from agency survey
- Goal was to incorporate a wide variety of properties
  - Mix designs
  - Volumetric properties
  - Aggregate Minerology
  - Binder Properties
  - Liquid Anti-Strip Additives (type and dosage)
  - Location/Climate
  - **Historical Performance**

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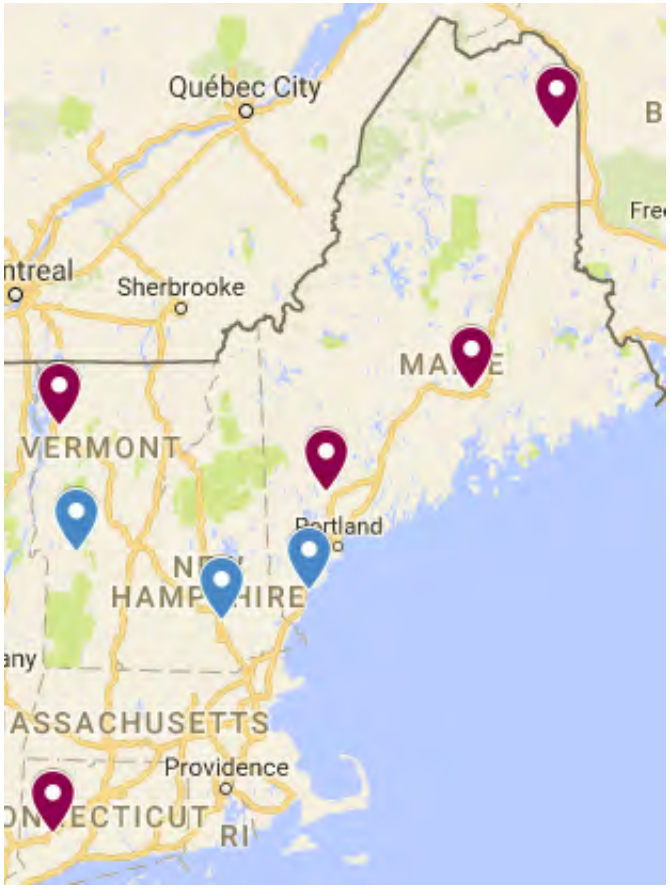
Mixture Selection

- 10 mixtures sampled
  - 3 good performers, 7 poor performers
  - 5 from Maine
  - 3 from Vermont
  - 1 from Connecticut and New Hampshire



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Mixture Selection Table

Mix	Description
MEP1	***12.5mm Poor, No additive, 64-28***
MEP2	***12.5mm Poor/Moderate, Amine-based anti-strip additive, 64-28***
MEP3	12.5mm Poor, No additive, 64-28
MEP4	12.5mm Poor, No Additive, 64-28
VTP1	**9.5mm Poor, WMA/Anti-strip additive, 58-28**
VTP2	**9.5mm Poor, No additive, 58-28**
CTP1	12.5mm Moderate, Amine-based anti-strip additive, 64-22
MEG1	12.5mm Good, No Additive, 64-28
VTG1	12.5mm Good, WMA Additive, 70-28
NHG1	12.5mm Good, No additive, 64-28

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Testing Plan Approach

Preparation

- Sample materials
- Specimen fabrication and volumetric testing
- Divide specimens into testing sub sets



Conditioning

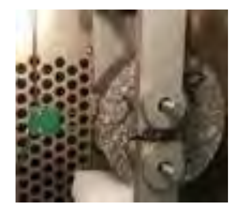
- Modified Lottman procedure (AASHTO T283)
- MIST (ASTM D7870)
- Multi-cycle freeze-thaw



Laboratory Testing

- AASHTO T283: Indirect Tensile Strength
- AASHTO T324: Hamburg Wheel Track
- AASHTO T342: Dynamic Modulus
- Fracture Test: DCT and SCB



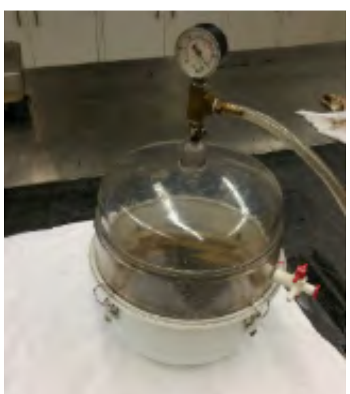
Laboratory Testing and Results

Testing Protocols

- All specimens produced by reheating loose mixture
  - Buckets only used once (no re-heating to minimize aging and variability)
- All specimens produced at 7 +/- 0.5% air voids

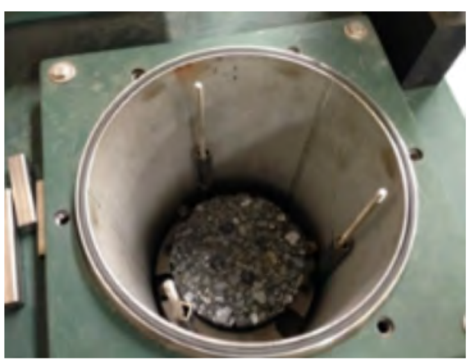
AASHTO T283 and ITS

- Most popular moisture susceptibility test
- Main outcome is the Tensile Strength Ratio (TSR)
  - $TSR = \dfrac{Average\ Strength\ of\ Conditioned\ Specimens}{Average\ Strength\ of\ Unconditioned\ Specimens}$
- Widely used
- Gives indication of cohesion and adhesion of mixes
- Relatively simple



MIST Conditioning

- Moisture induced Stress Tester (ASTM D7870)
- Simulates effect of water under repeated traffic loading at different pressures and temperatures
  - Test temperature
    - 60^{o}C for PG 64-28
    - 50^{o}C for PG 58-28
  - Cycles – 3,500
  - Pressure – 40 psi
  - Adhesion phase – 20 hours (moisture conditioning)
  - Cohesion phase – 3.5 hours (pressure cycles)



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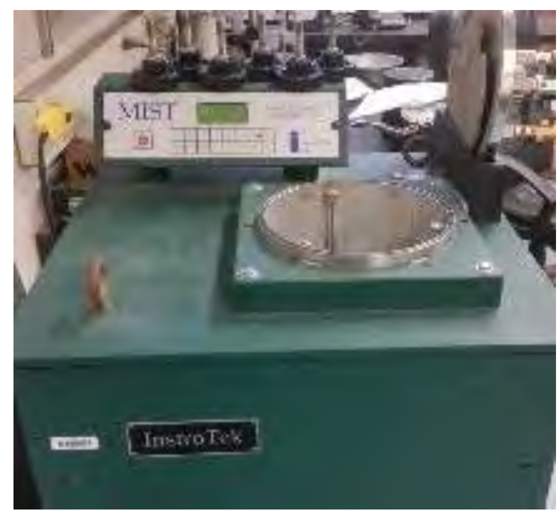
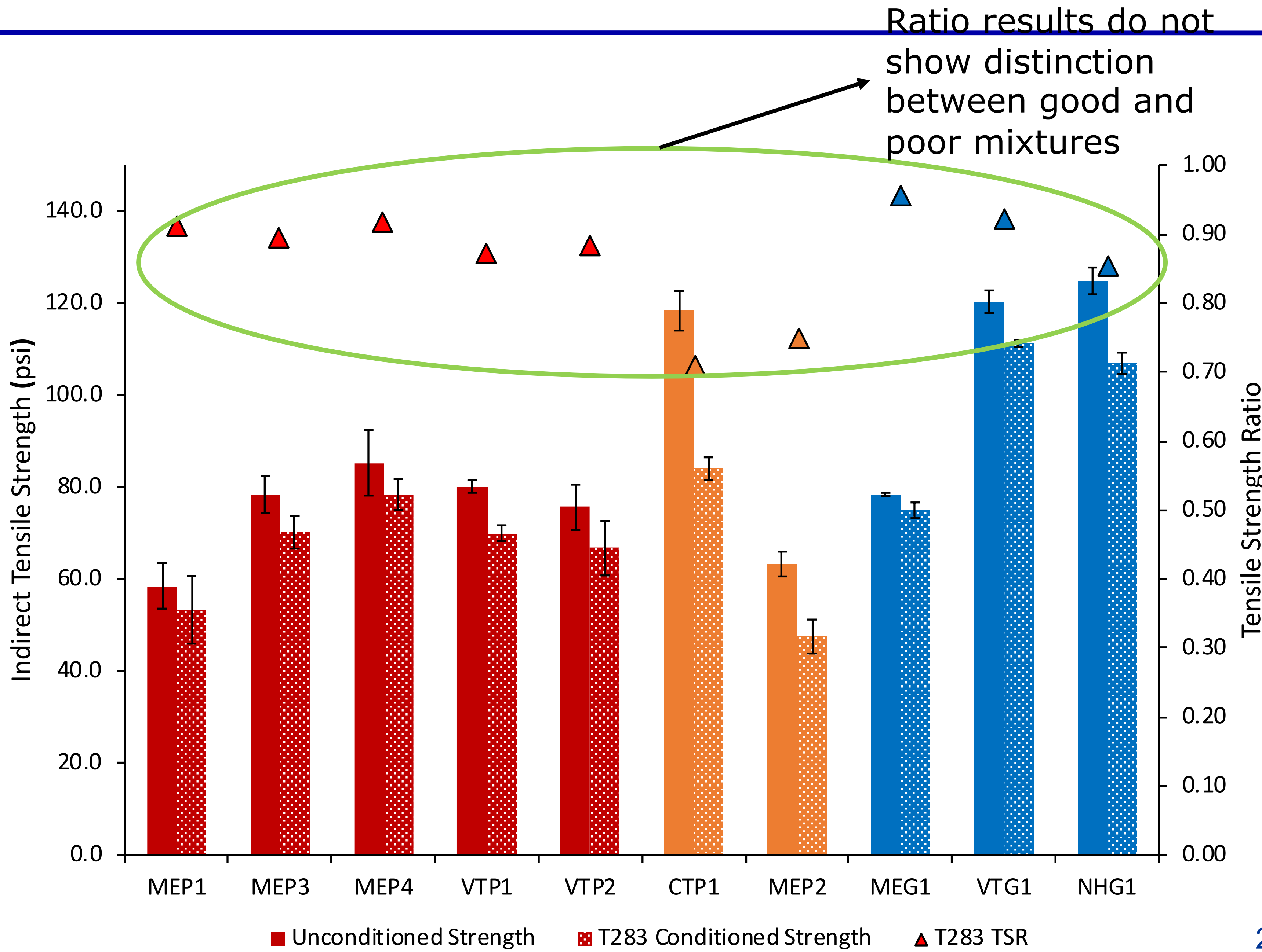
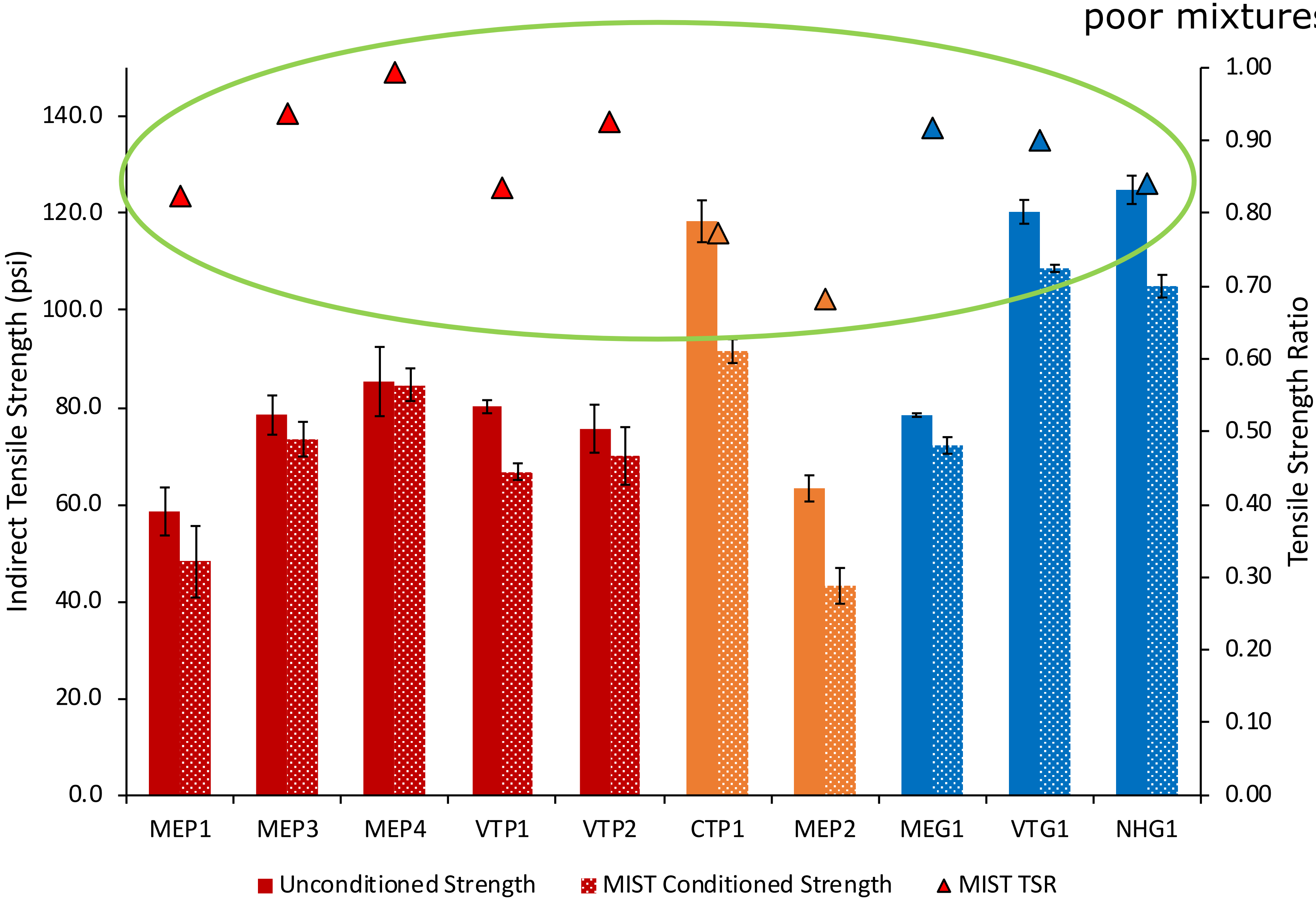


AASHTO T283 Results



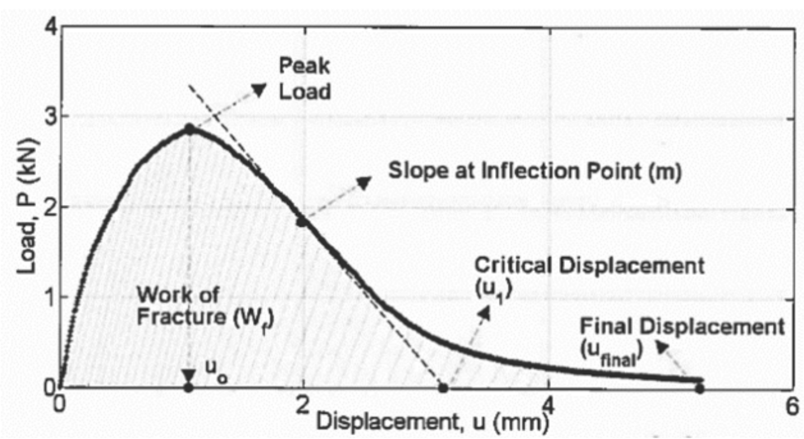
AASHTO T283 with MiST

Ratio results do not show distinction between good and poor mixtures



AASHTO TP105 - SCB

- Semi Circular Bend Test (AASHTO TP105)
  - Focused on fatigue cracking evaluation
  - Several alternative analysis methods
  - Typically tested at intermediate temperatures (25C)
  - Illinois method (IFIT) used with MiST conditioning
    - Fracture Energy and Flexibility Index



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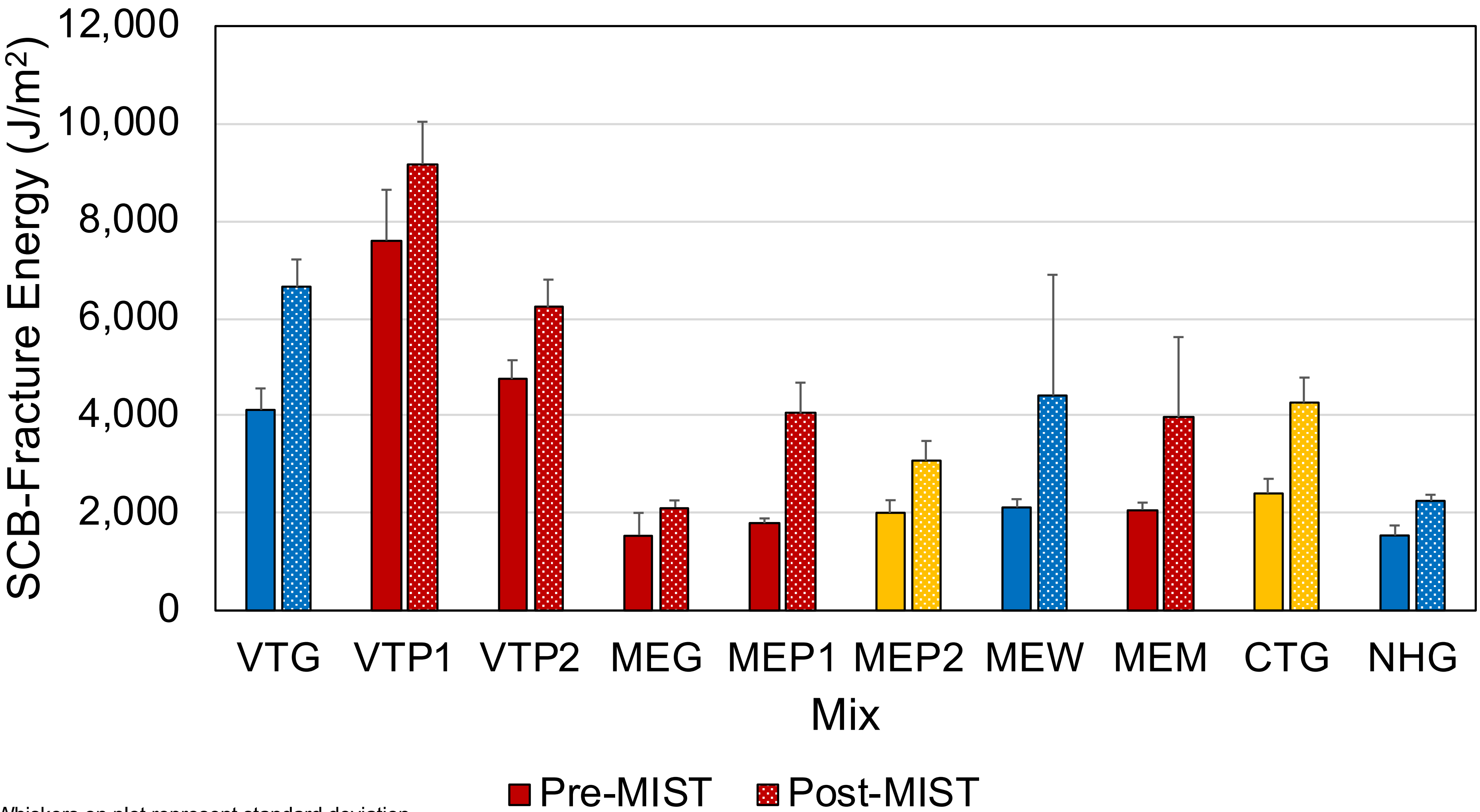
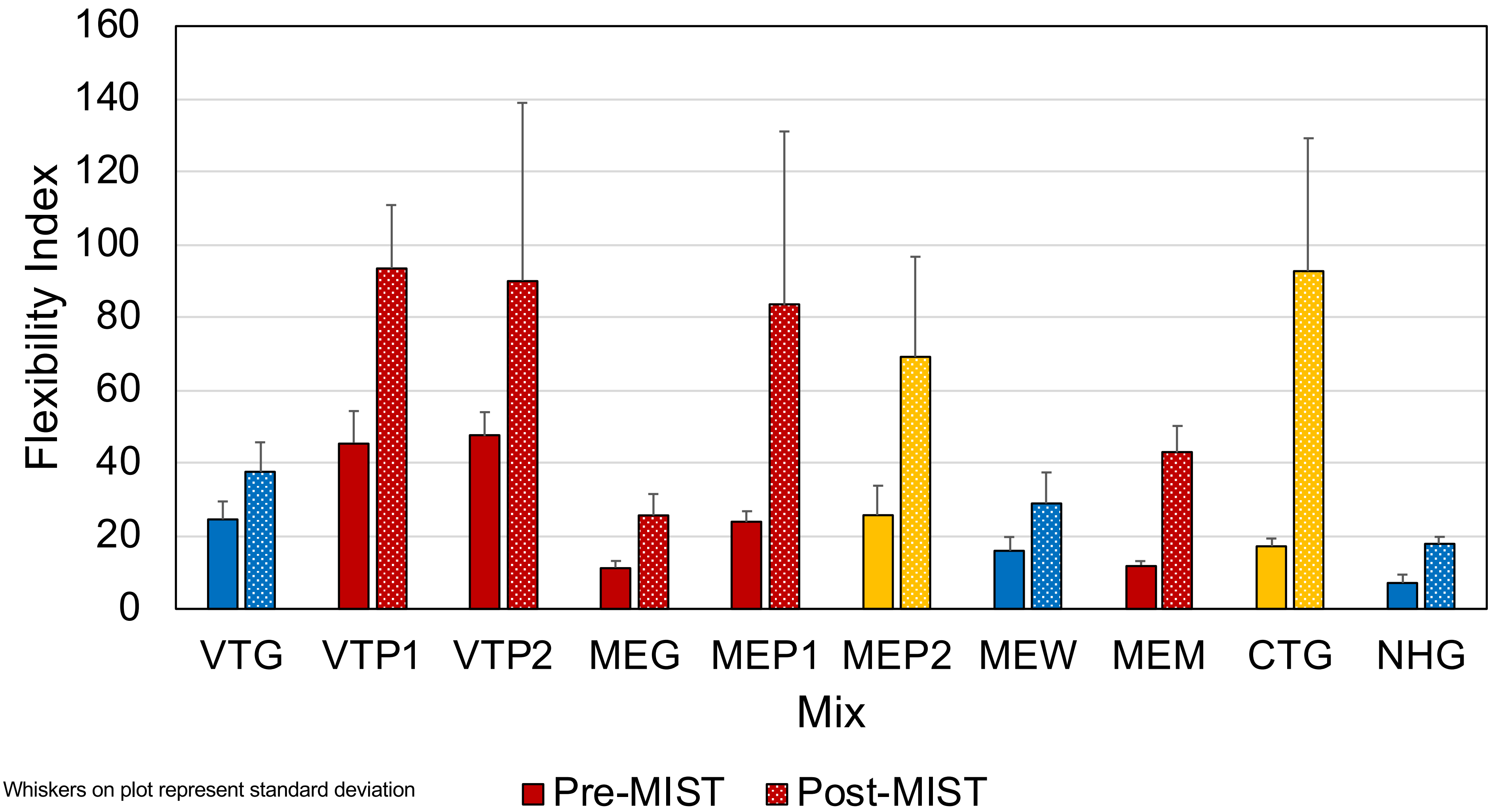
AASHTO TP105 - SCB



Whiskers on plot represent standard deviation

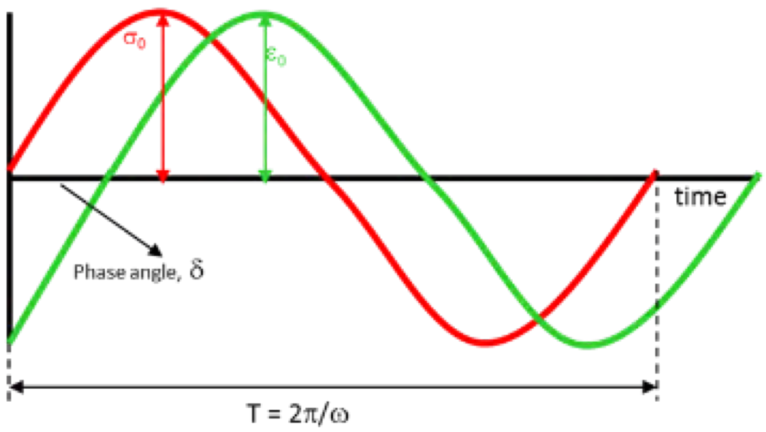
AASHTO TP105 - SCB



Whiskers on plot represent standard deviation

AASHTO T342 – Dynamic Modulus

- Measures the stiffness of mixtures at various temperatures and loading frequencies
- Specimen loaded in compression sinusoidally
- Carried out on the Asphalt Mixture Performance Tester (AMPT)
- Dynamic modulus is a fundamental material property (can related to changes in structural capacity of pavement)



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Materials

Mix	Description
VTP1	**9.5mm Poor Performer, WMA/Anti-strip additive, 58-28**
VTP2	**9.5mm Poor Performer, No additive, 58-28**
VTG1	**12.5mm Good Performer, WMA Additive, 70-28**

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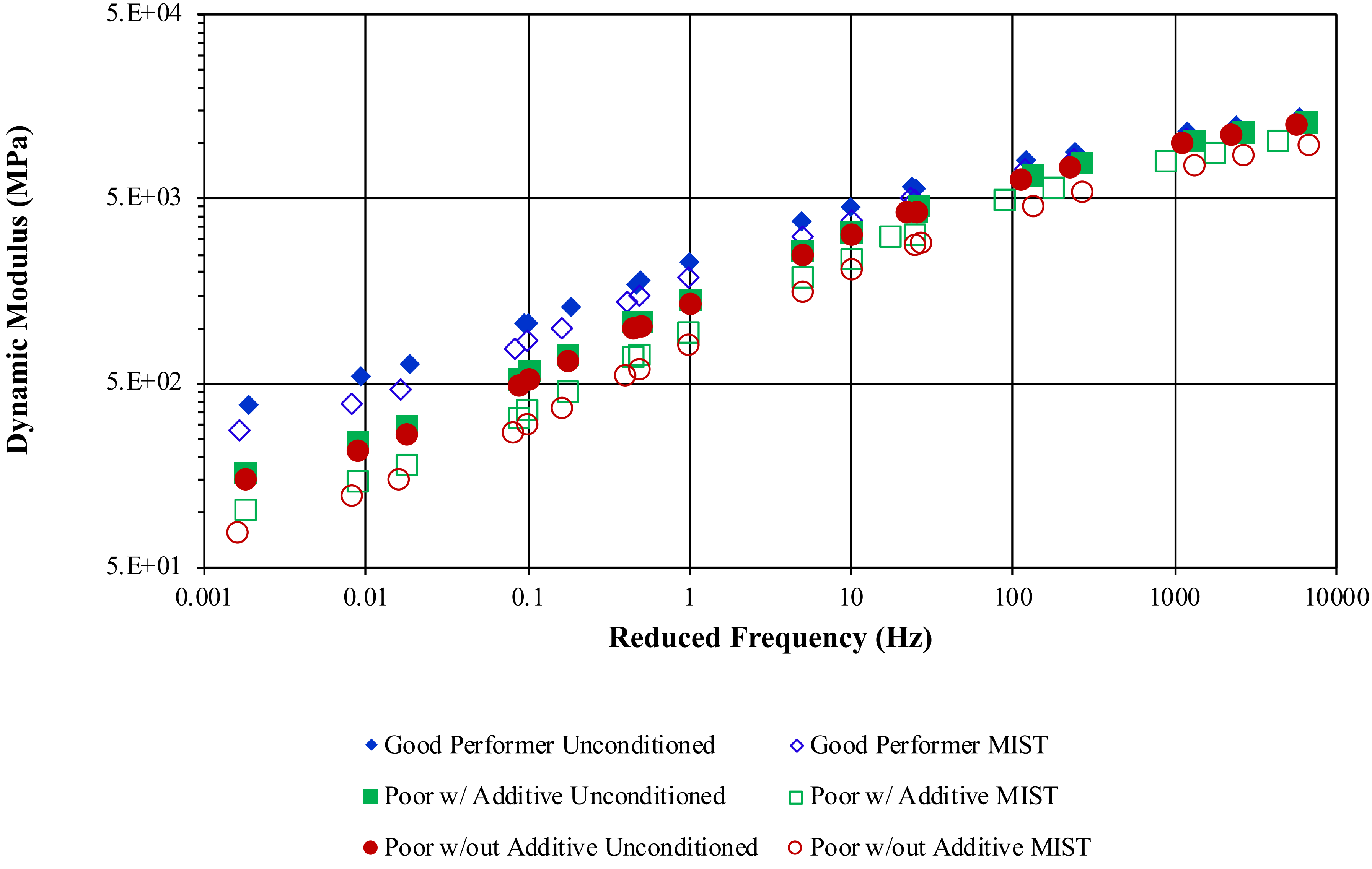
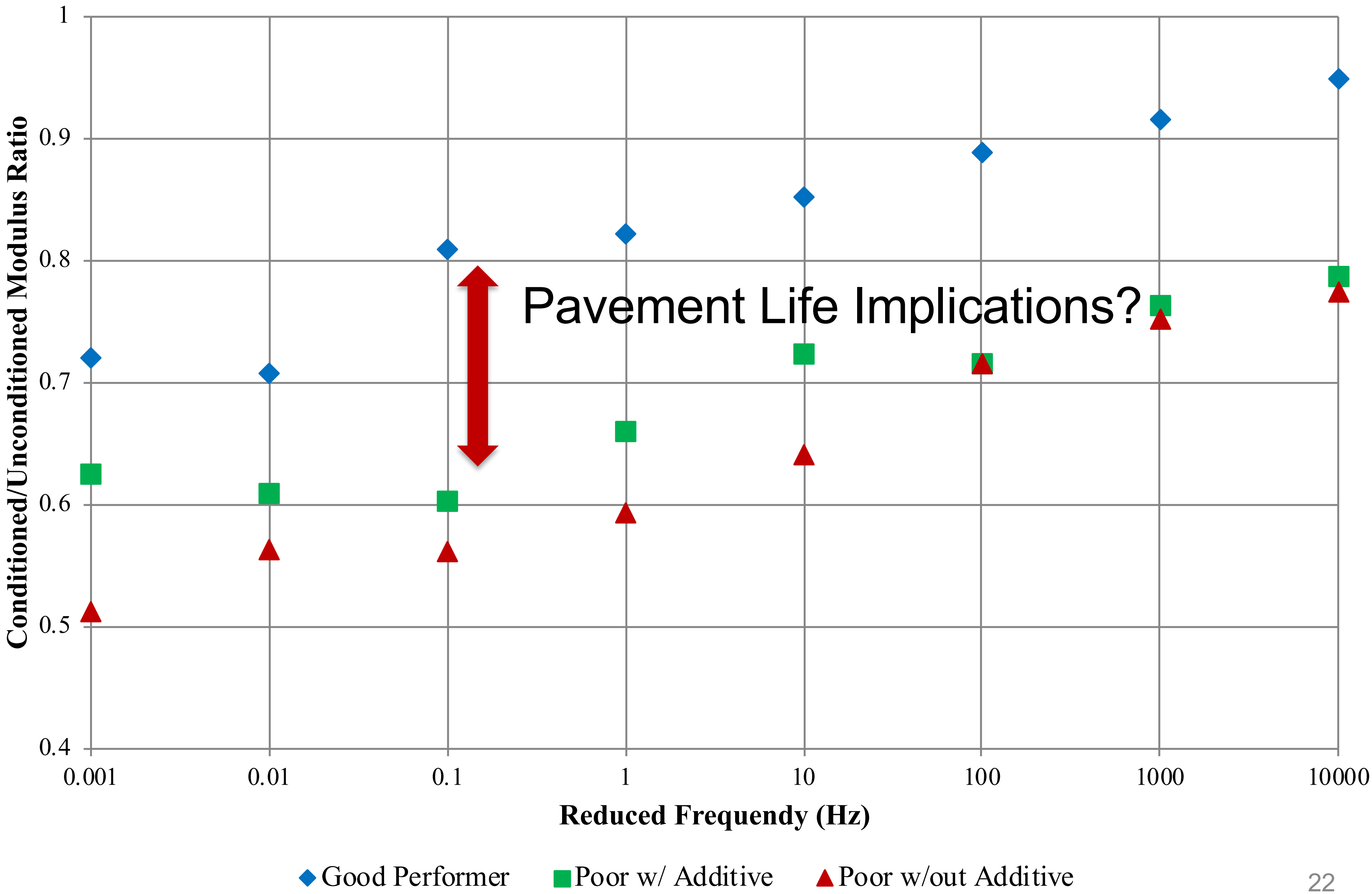
AASHTO T342 – Dynamic Modulus



AASHTO T342 – Dynamic Modulus



AASHTO PavementME

- Mechanistic-Empirical analysis procedure
  - Mechanistic structural response (stress, strains)
  - Empirical distress prediction (transfer functions)
- Dynamic modulus – primary asphalt material input
  - Simulated as worst case scenario
  - Only dynamic modulus change-everything else remained constant

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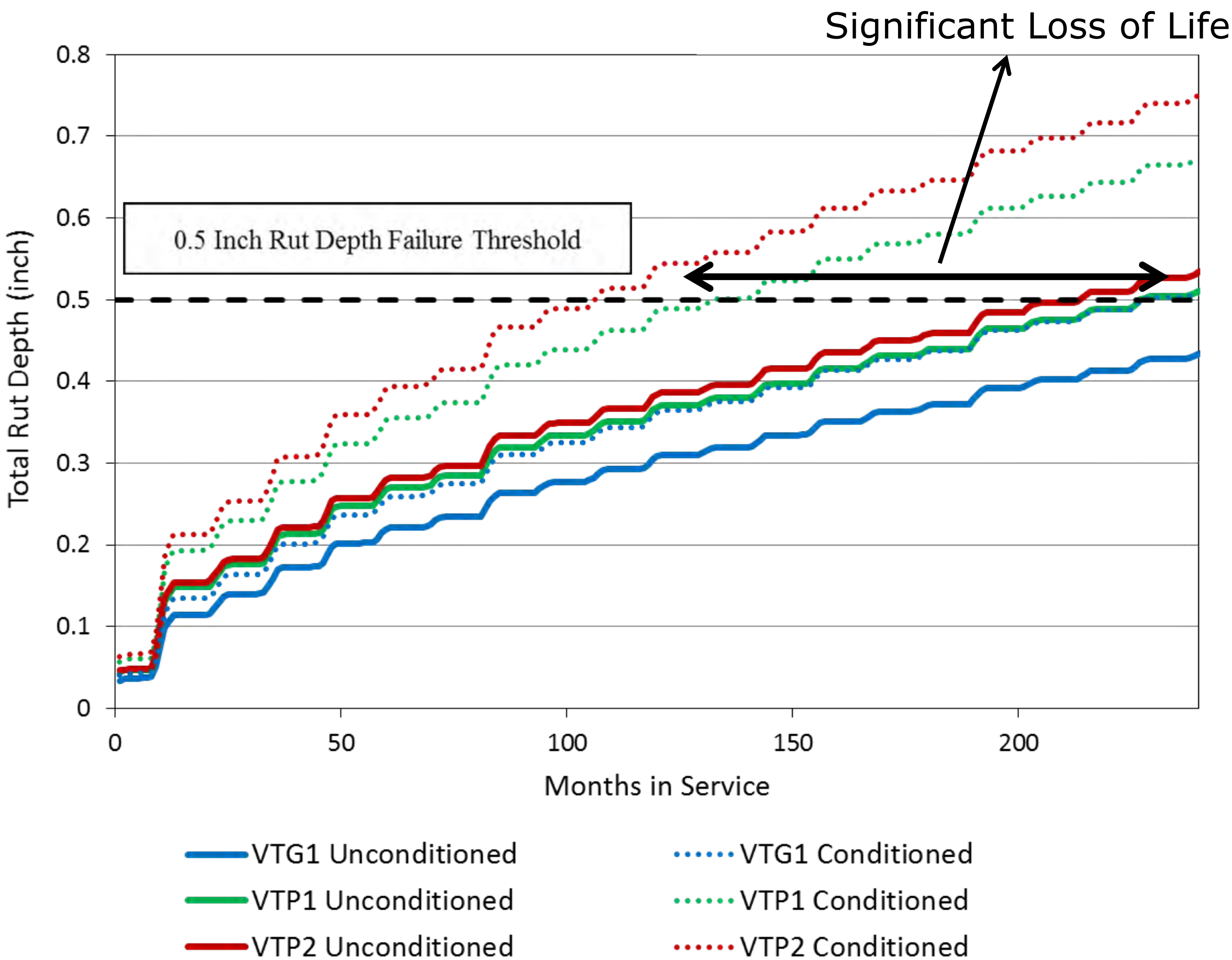
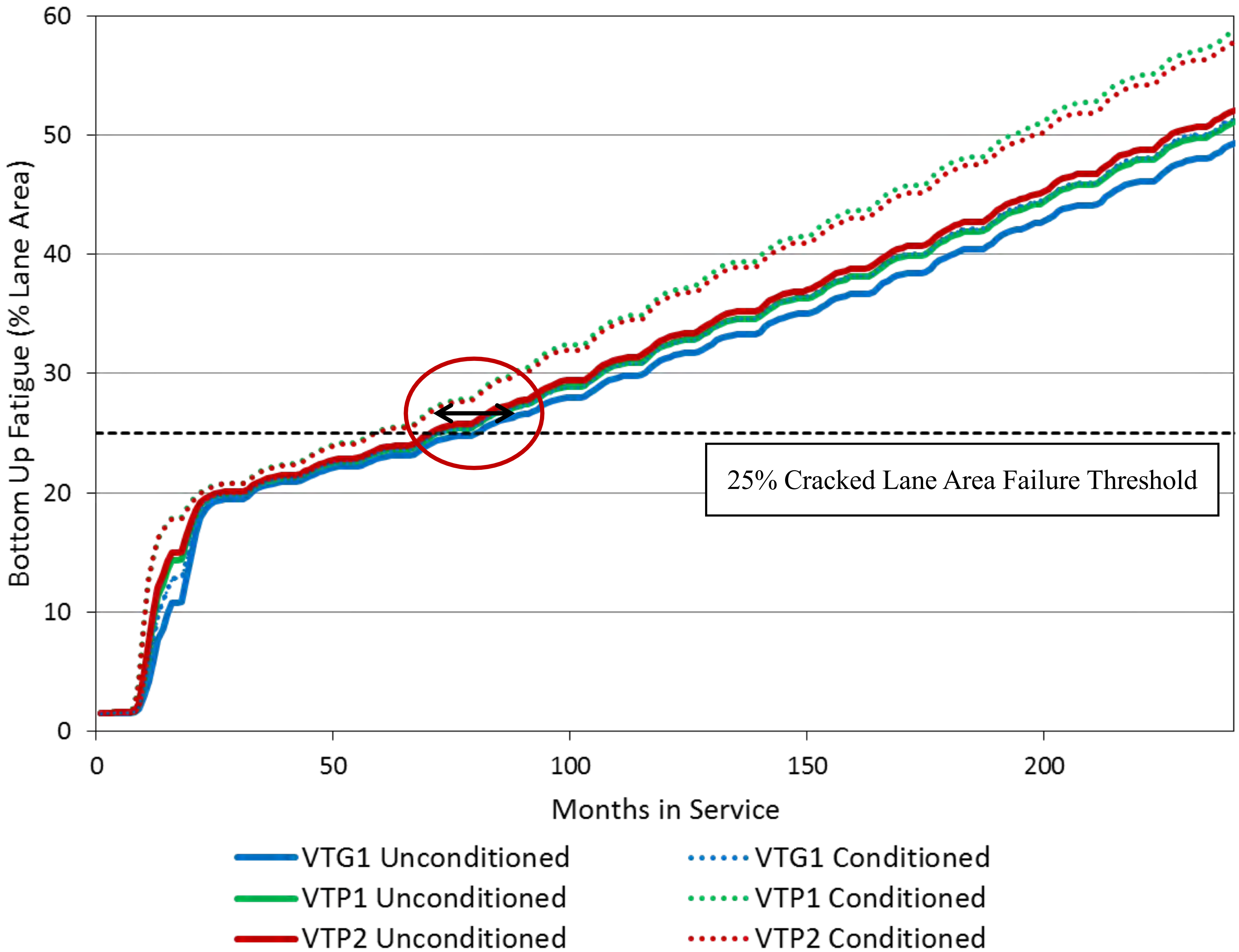
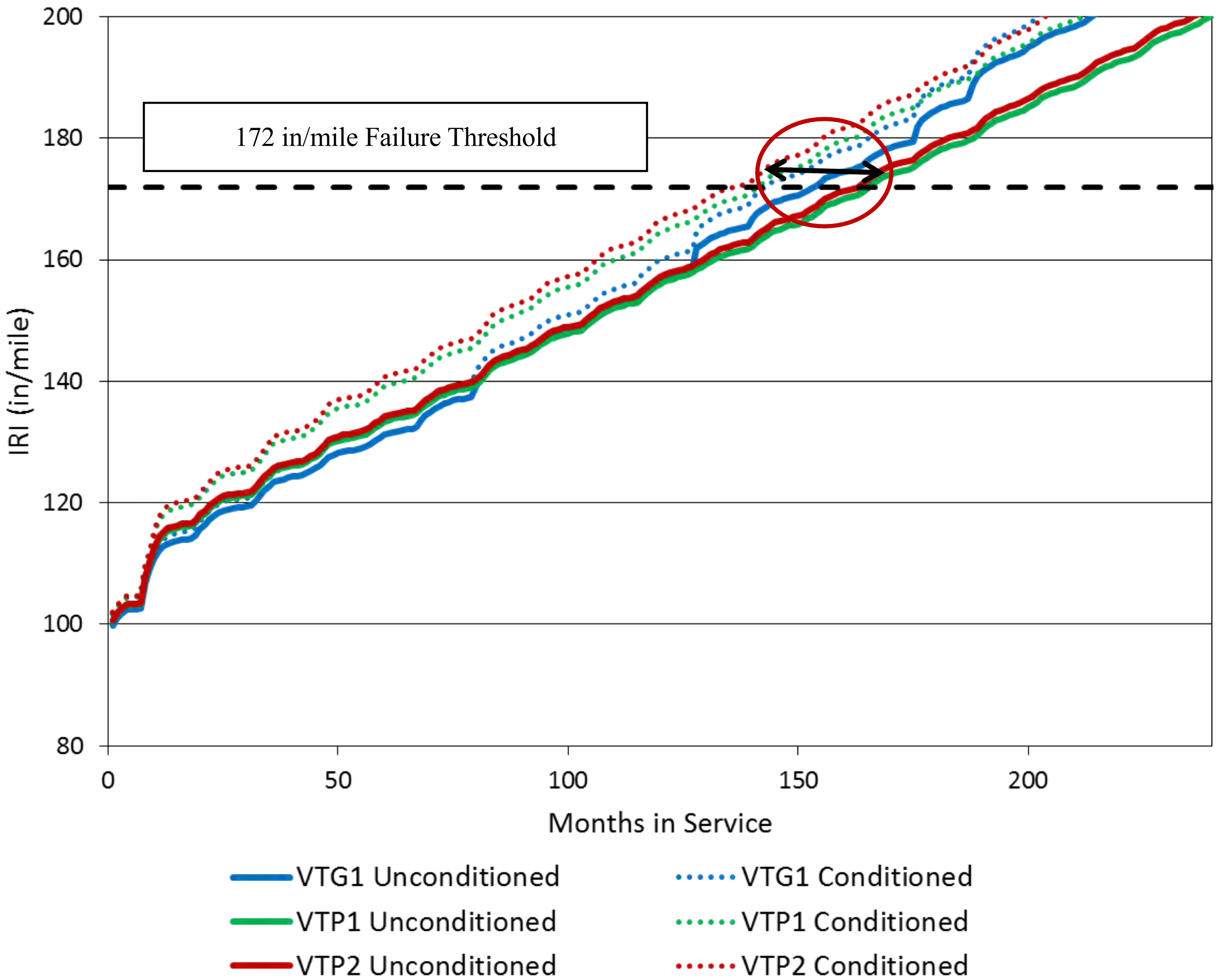
PavementME Results-Rutting



PavementME Results-Fatigue



PavementME Results-Roughness



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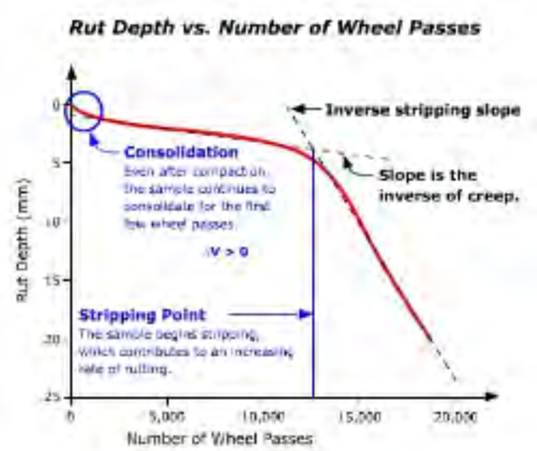
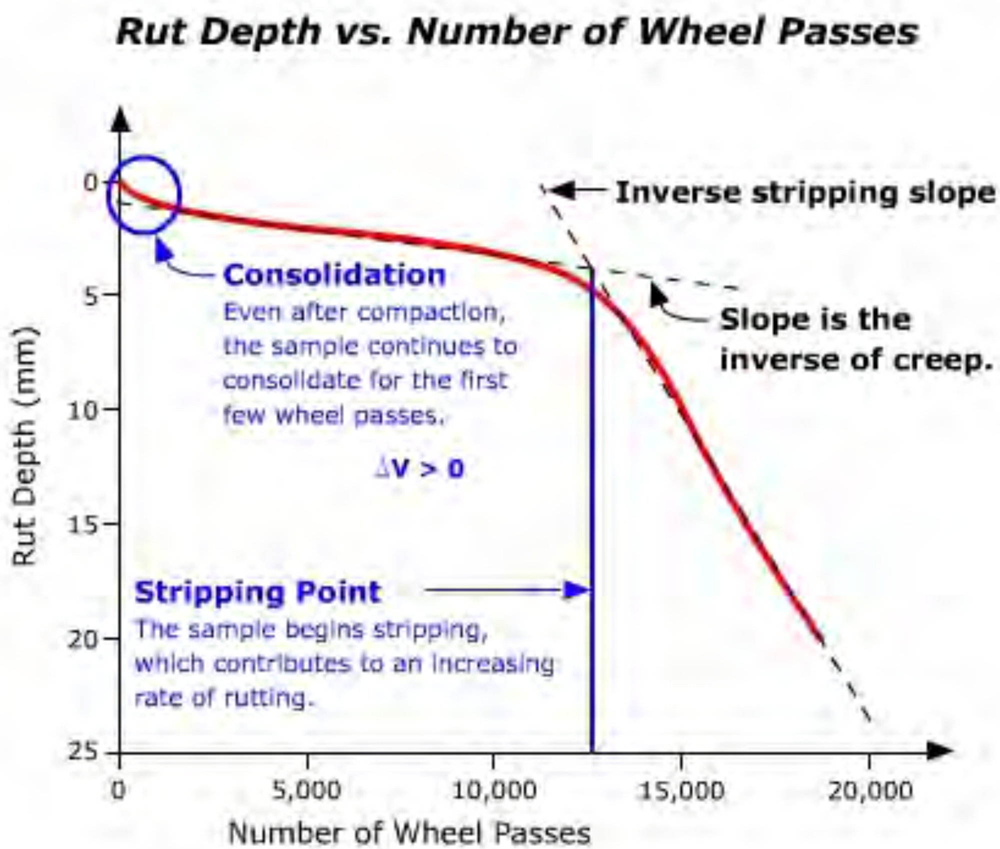
AASHTO T324 - Hamburg

- Simulative test that applies repeated traffic loads through steel wheels (tests conducted on dry and submerged specimens)
- Measure rut depth and number of wheel passes (typically go to 20,000 passes)
- Some agencies already use this for moisture testing, several agencies are already equipped to conduct this test



AASHTO T324 - Hamburg

- Hamburg testing done by Maine DOT
- All mixtures tested at 45C
- Conventional Results-Taken from sheets provided by Maine DOT

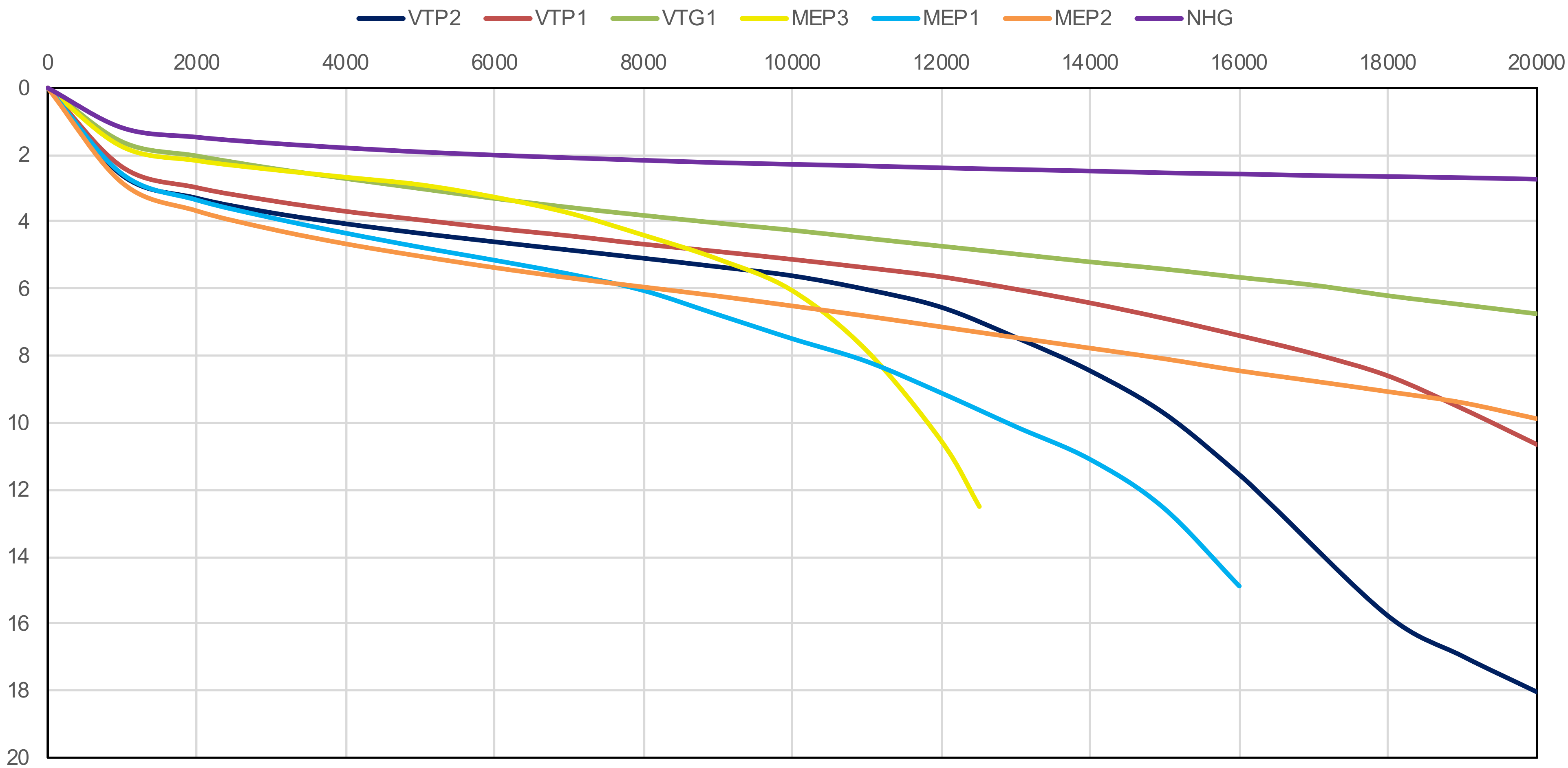


AASHTO T324 - Hamburg

- 7 Mixtures shown here

Mix	Description
MEG1	12.5mm Poor, No additive
MEP1	12.5mm Poor, No additive
MEP2	12.5mm Poor/Moderate, Amine-based anti-strip additive
VTP1	9.5mm Poor, WMA/Anti-strip additive
VTP2	9.5mm Poor, No additive
VTG1	12.5mm Good, WMA Additive
NHG1	12.5mm Good, No additive

AASHTO T324 - Hamburg



MEP3 < MEP1 < VTP2 < VTP1 < MEP2 < VTG1 < NHG
Yellow < Light Blue < Dark Blue < Red < Orange < Green < Purple

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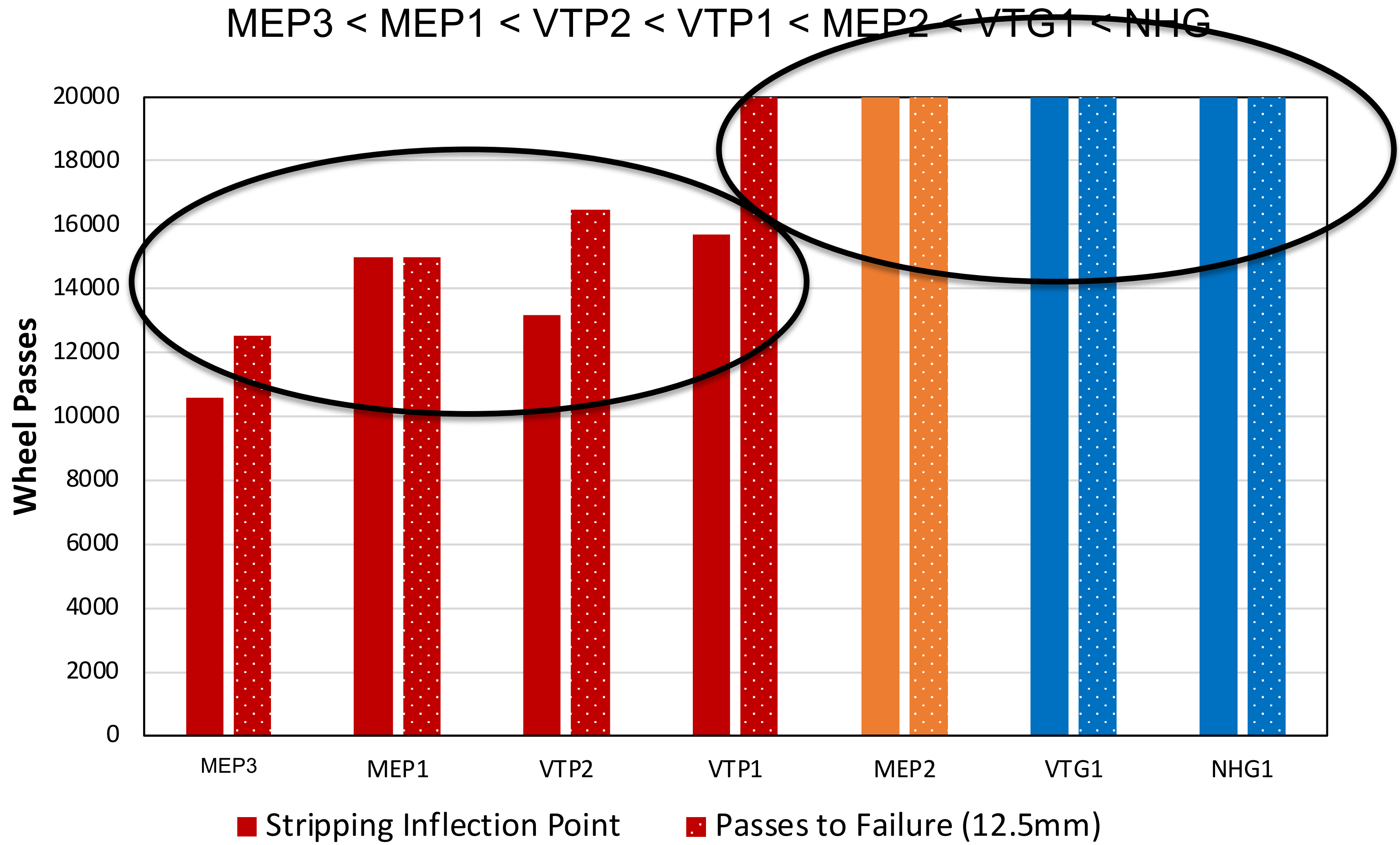
AASHTO T324 - Hamburg

MEP3 < MEP1 < VTP2 < VTP1 < MEP2 < VTG1 < NHG



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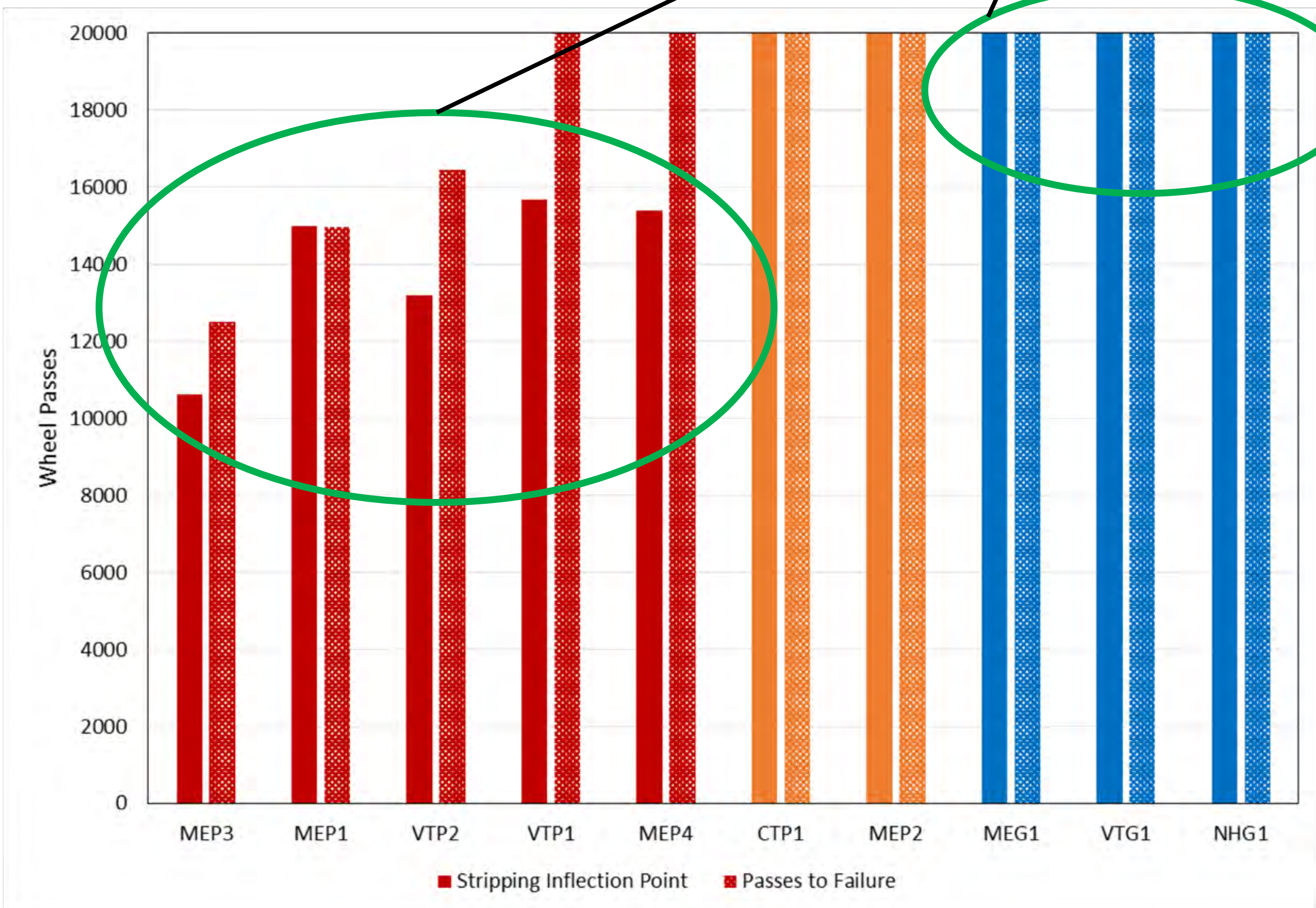
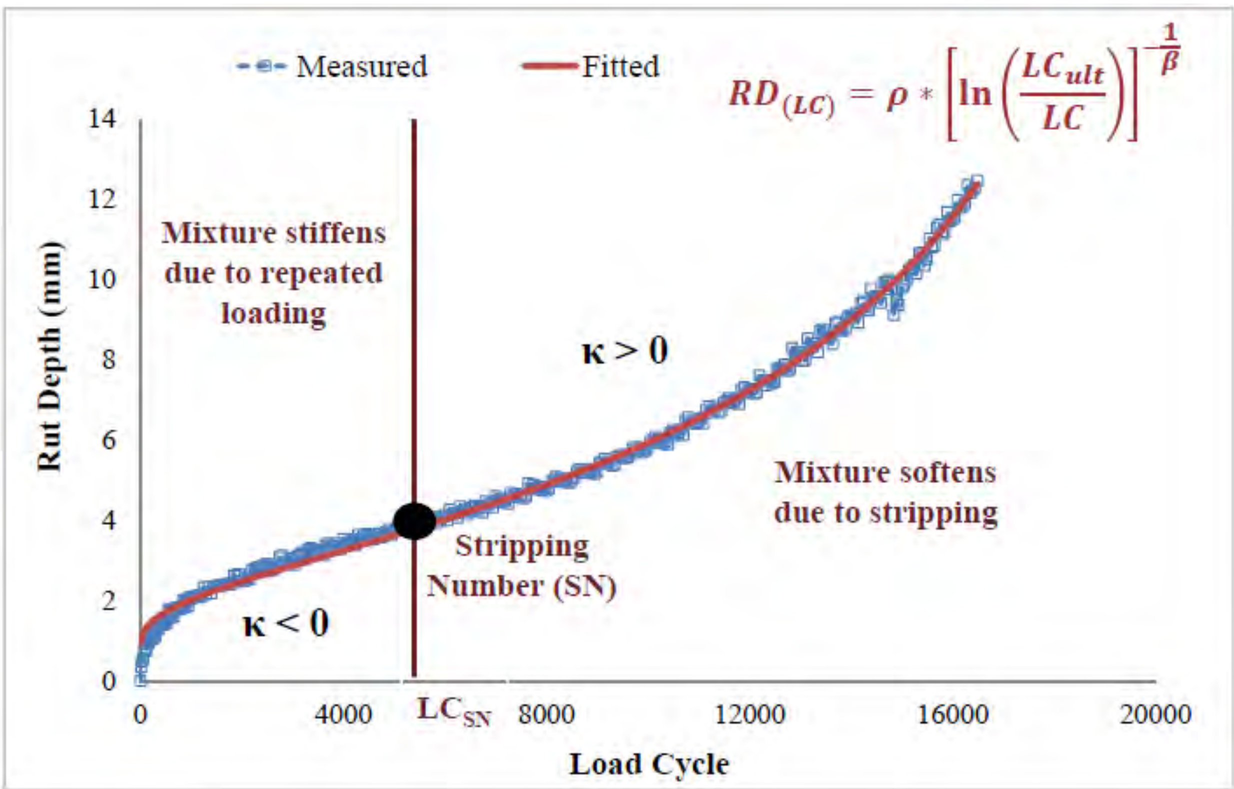
Hamburg Results-Traditi

Much clearer distinction between good and poor performers



Hamburg– TAMU Method

- Proposed by Yin et al. (2015)
- Uses Stripping Number (SN) and Stripping Life Threshold (ST)
- Higher SN and ST → Better Moisture Resistance



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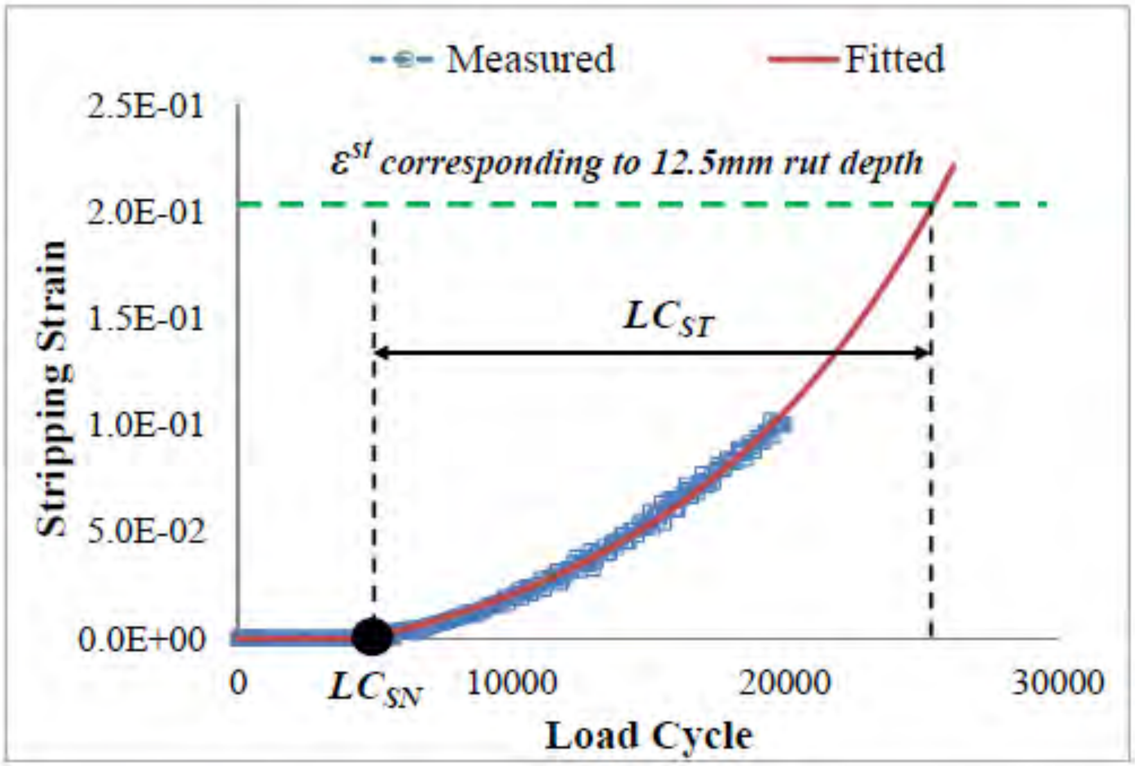
Hamburg– TAMU Method

- Stripping Life Threshold (ST)



$LC > LC_{SN}$:

$$\varepsilon^{st} = \varepsilon_0^{st}[e^{\theta(LC - LC_{SN})} - 1]$$

Remaining Life (LC_{ST})

- Additional load cycles to create 12.5mm rut depth after LC_{SN}

Higher LC_{ST} = better resistance to stripping

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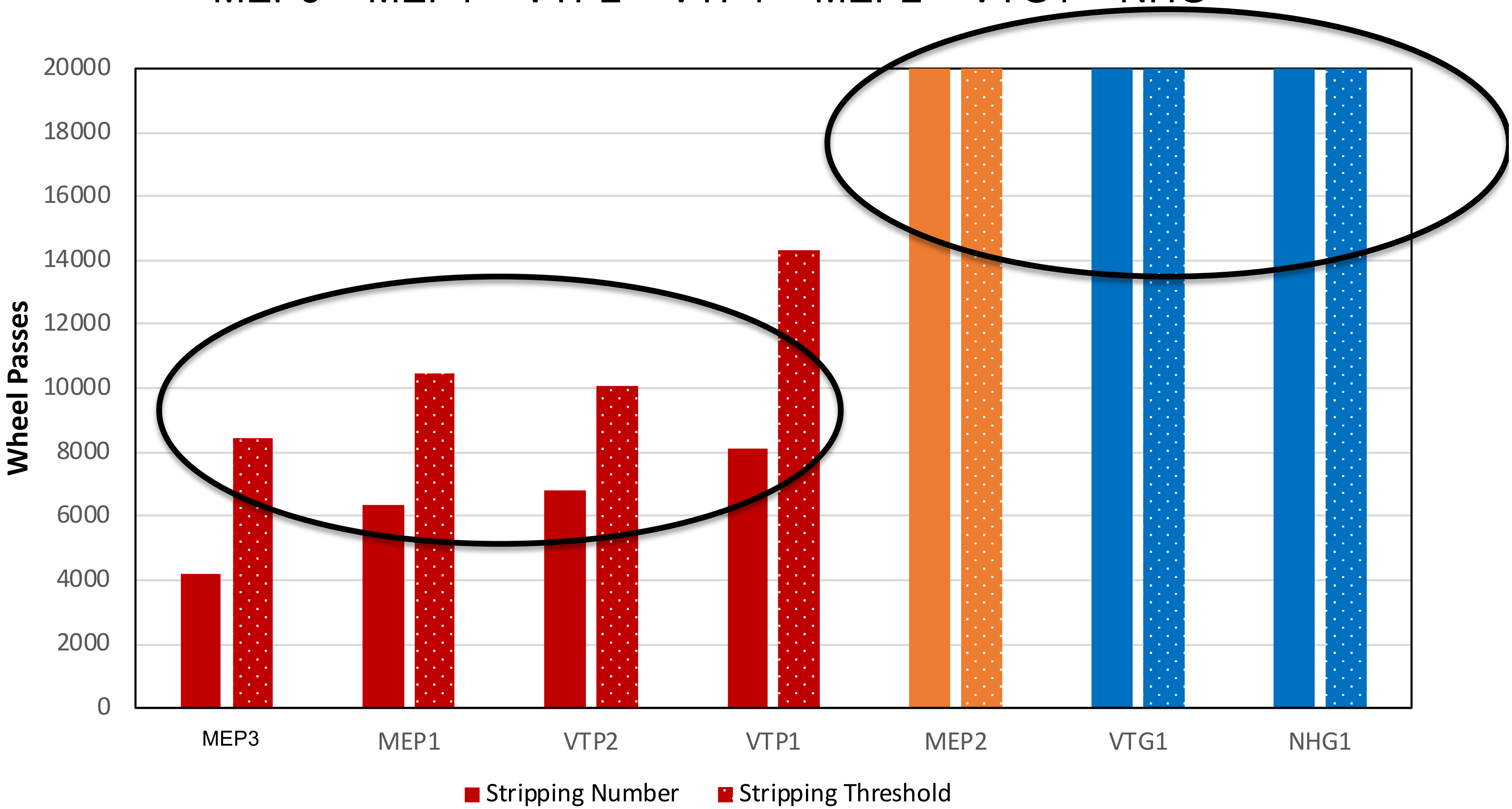
Hamburg– TAMU Method

MEP3 < MEP1 < VTP2 < VTP1 < MEP2 < VTG1 < NHG



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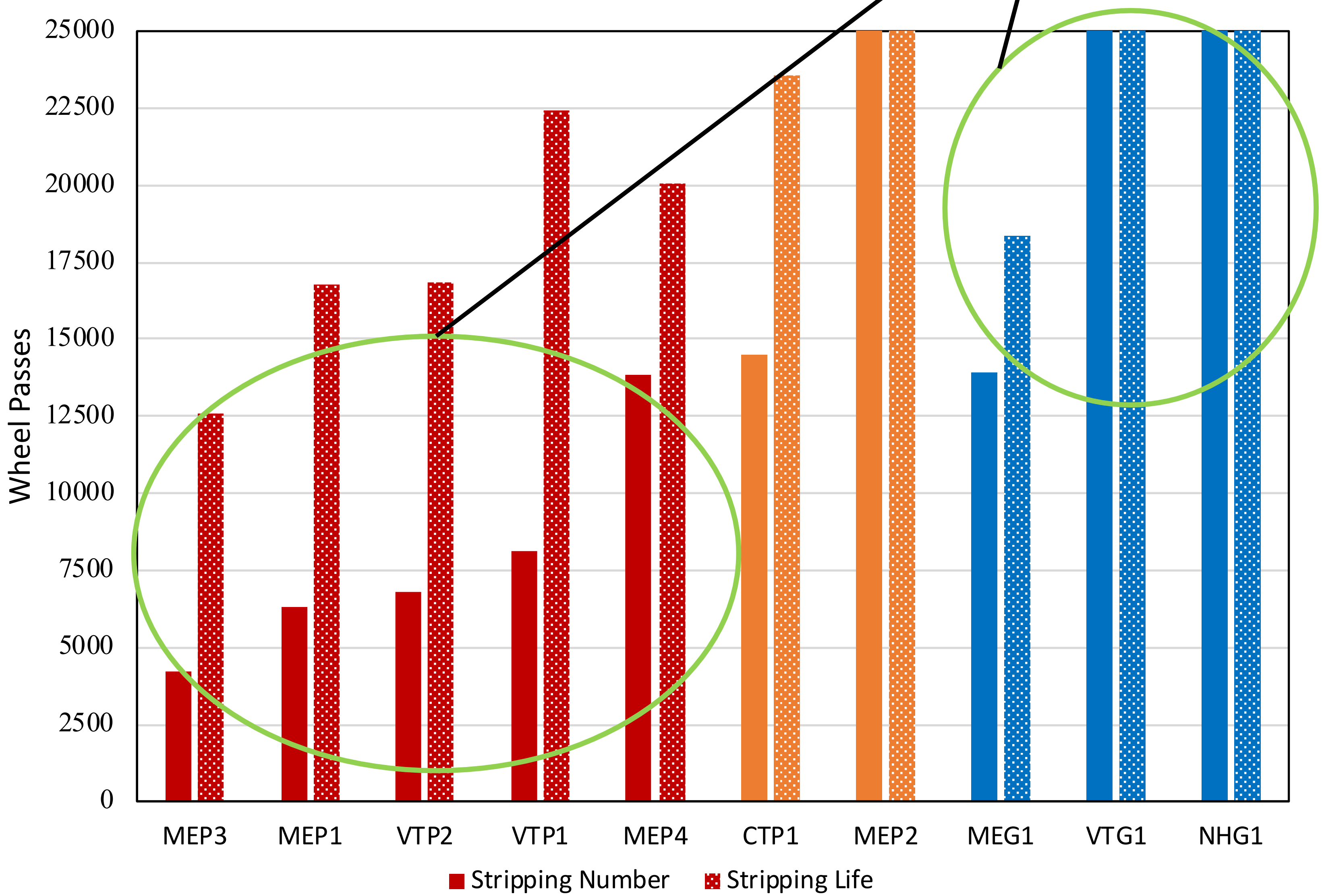
Hamburg Results-TTI Me

Clear distinction between good and poor performers



Results – Overall Conclusions

- All mixes (good and poor) pass TSR requirements showing lack of distinction in current AASHTO T-283 approach
- Substantial drop in asphalt mix dynamic modulus after MiST conditioning
  - Loss of serviceability and reduced pavement life
- SCB fracture tests did not show promising results with moisture conditioning
- Hamburg wheel tracking test shows most promise at differentiating moisture susceptible mixes
  - Analysis conducted using standard method and new approach

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Results – Recommendations

- As a mix design/screening test to ensure adequate field performance, the Hamburg wheel tracker is recommended
    - Both traditional and Texas method work well

- For performance-based design/specifications and life cycle cost-based design, dynamic modulus paired with pavement analysis is recommended.

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Questions and Comments?

Thank you for your attention!

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