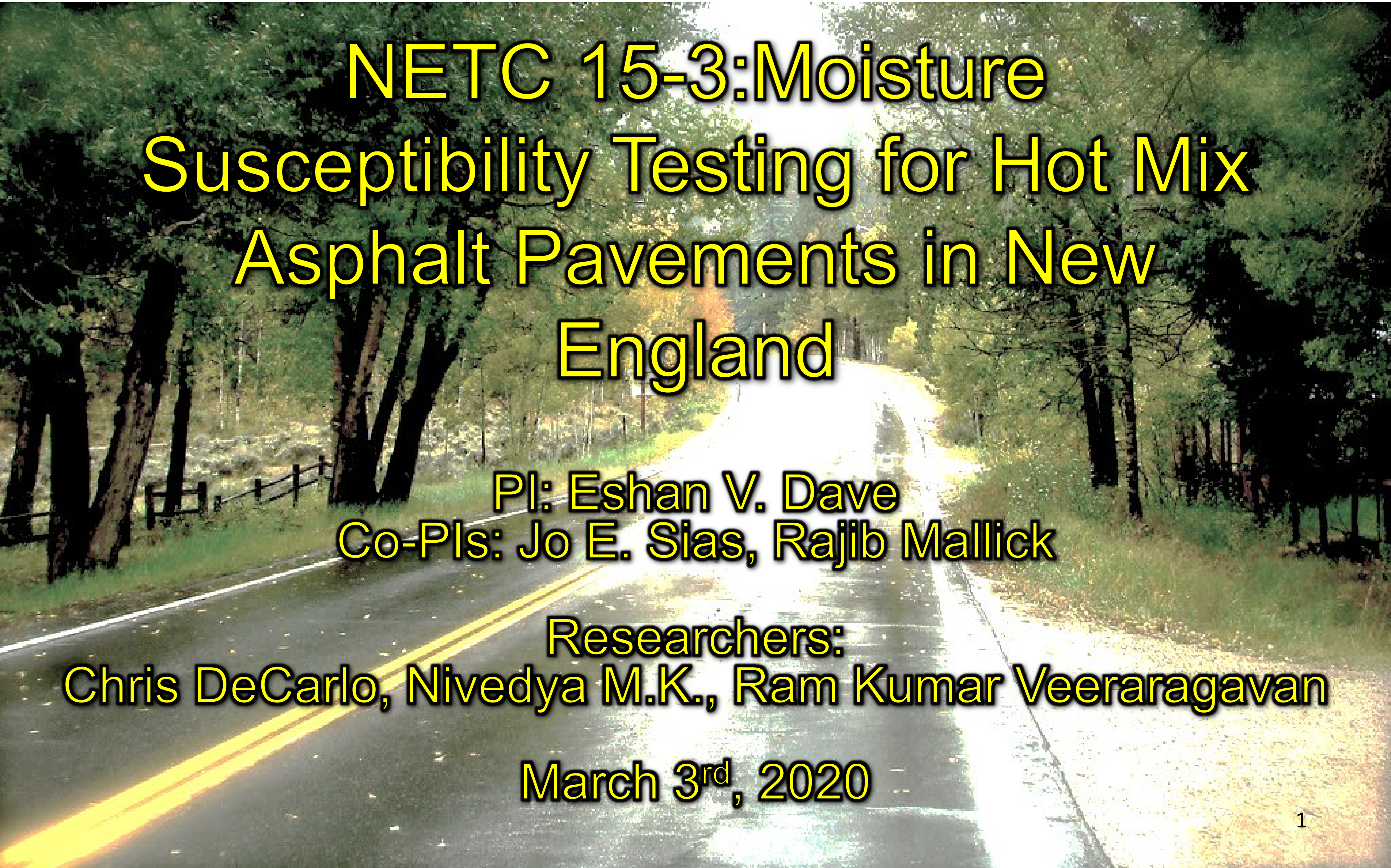

NETC 15-3:Moisture Susceptibility Testing for Hot Mix Asphalt Pavements in New England

PI: Eshan V. Dave
Co-PIs: Jo E. Sias, Rajib Mallick

Researchers:
Chris DeCarlo, Nivedya M.K., Ram Kumar Veeraragavan

March 3rd, 2020

Background

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

- 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

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Moisture Damage in Asphalt

- Moisture induced damage mechanisms:
  - Loss of adhesion (asphalt binder-aggregate)
  - Loss of cohesion (within asphalt binder)
- Dependent upon many factors
  - Aggregate Mineralogy
  - Mix Design
  - Binder Properties
  - Duration and Temperature of Moisture Exposure
  - Forced Saturation versus Inundation
- Excessive asphalt moisture damage can lead to other subsequent pavement distresses (base failure)

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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
- Determine impacts of remedial measures in reducing moisture susceptibility
- Recommend a framework of test procedures, specification, and analysis procedures that is reliable and suitable for moisture susceptibility testing in New England

Project Flow

1. State of the practice and literature review
2. Identify and inspect moisture susceptible mixes, testing plan
3. Laboratory testing
4. Final report and recommendations

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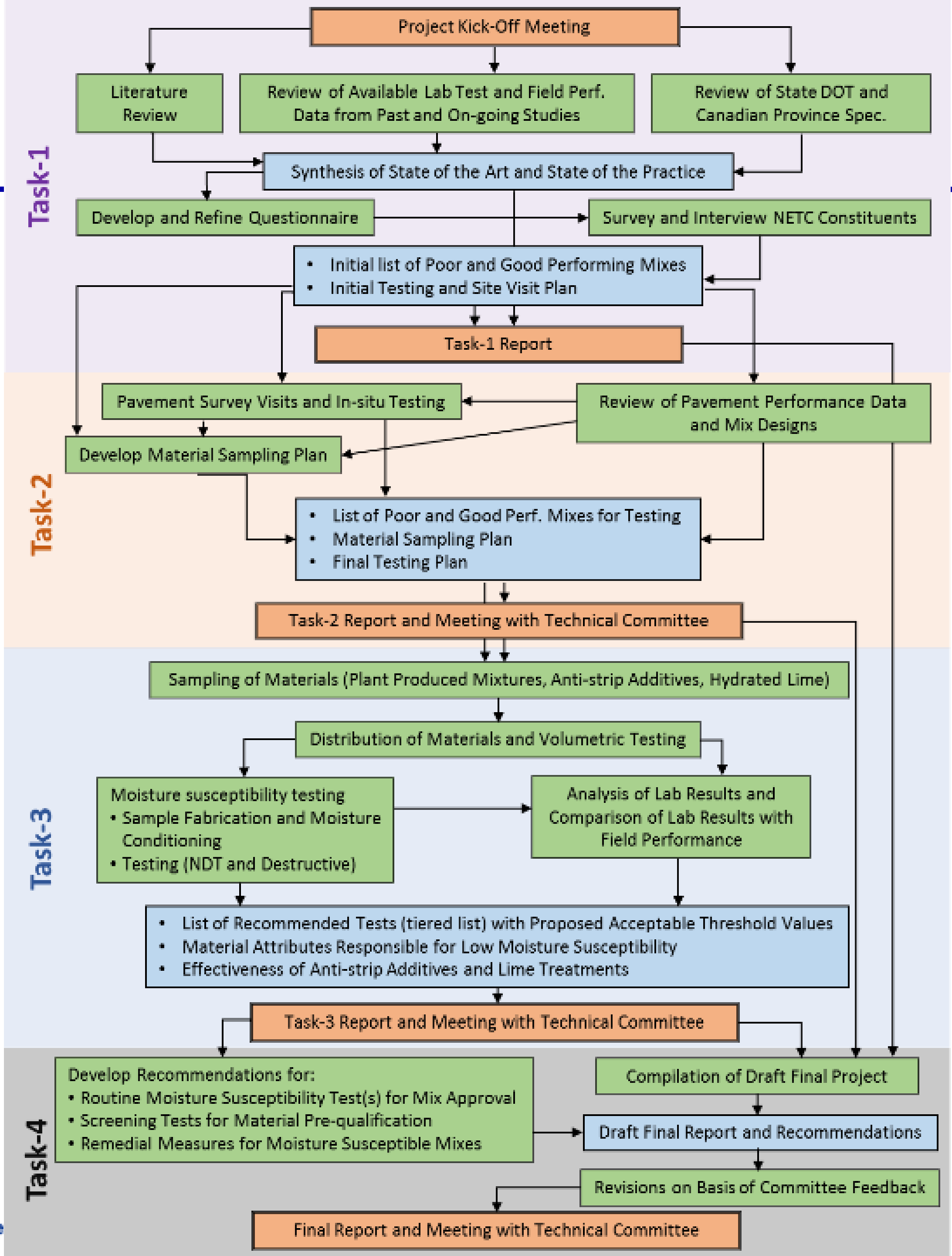


Task-1

Project Kick-Off Meeting

Literature Review

Review of Available Lab Test and Field Perf. Data from Past and On-going Studies

Review of State DOT and Canadian Province Spec.

Synthesis of State of the Art and State of the Practice

Develop and Refine Questionnaire

Survey and Interview NETC Constituents

- Initial list of Poor and Good Performing Mixes
- Initial Testing and Site Visit Plan

Task-1 Report

Task-2

Pavement Survey Visits and In-situ Testing

Review of Pavement Performance Data and Mix Designs

Develop Material Sampling Plan

- List of Poor and Good Perf. Mixes for Testing
- Material Sampling Plan
- Final Testing Plan

Task-2 Report and Meeting with Technical Committee

Task-3

Sampling of Materials (Plant Produced Mixtures, Anti-strip Additives, Hydrated Lime)

Distribution of Materials and Volumetric Testing

Moisture susceptibility testing
- Sample Fabrication and Moisture Conditioning
- Testing (NDT and Destructive)

Analysis of Lab Results and Comparison of Lab Results with Field Performance

- List of Recommended Tests (tiered list) with Proposed Acceptable Threshold Values
- Material Attributes Responsible for Low Moisture Susceptibility
- Effectiveness of Anti-strip Additives and Lime Treatments

Task-3 Report and Meeting with Technical Committee

Task-4

Develop Recommendations for:
- Routine Moisture Susceptibility Test(s) for Mix Approval
- Screening Tests for Material Pre-qualification
- Remedial Measures for Moisture Susceptible Mixes

Compilation of Draft Final Project

Draft Final Report and Recommendations

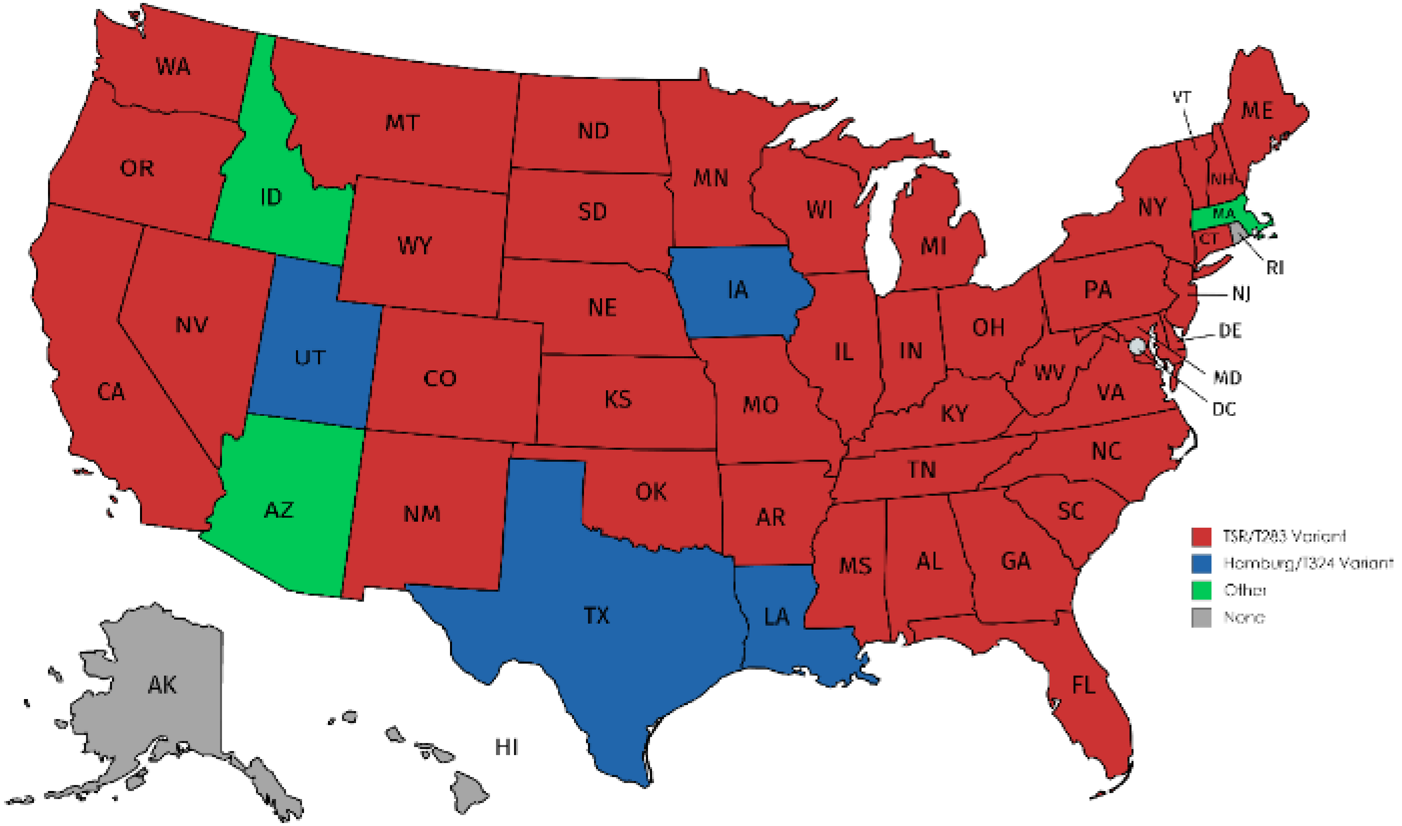
Revisions on Basis of Committee Feedback

Final Report and Meeting with Technical Committee

Moisture Susceptibility Testing in the US

In 2017, 47 US state transportation agencies required some form of moisture susceptibility testing

- 40 used some variant of the Lottman-Indirect Tensile Strength approach (AASHTO T283)

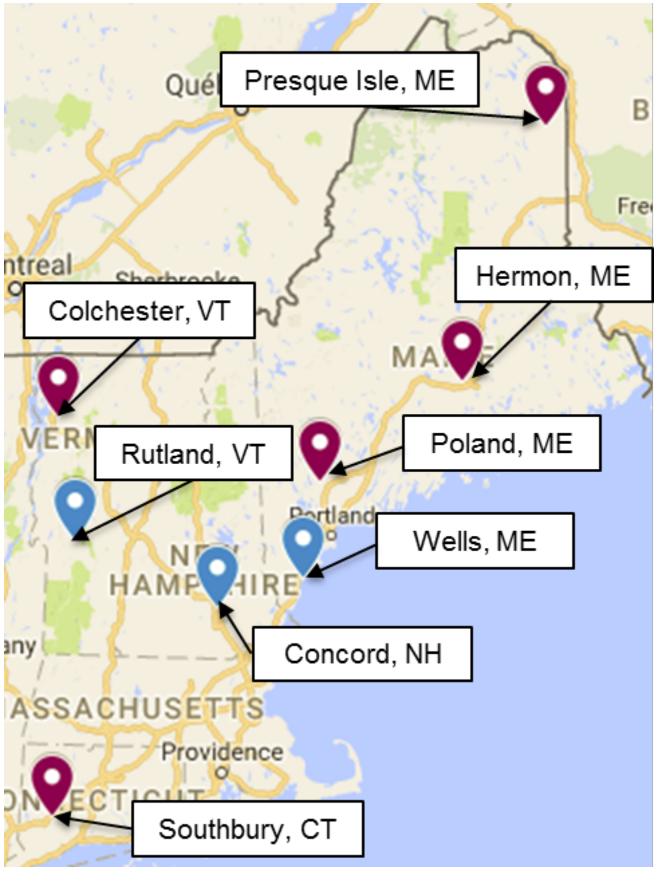


Mixture Selection

- Mixtures chosen by surveying New England transportation agencies
- 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**

Mixture Selection

- 10 mixtures sampled
  - 3 good performers, 7 poor performers
  - 5 from Maine
    - 2 – Presque Isle - Poor
    - 1 – Hermon - Poor
    - 1 – Poland - Poor
    - 1 – Wells - Good
  - 3 from Vermont
    - 2 – Colchester - Poor
    - 1 – Rutland - Good
  - 1 from Connecticut and New Hampshire
    - 1 – Concord NH - Good
    - 1 – Southbury CT - Poor

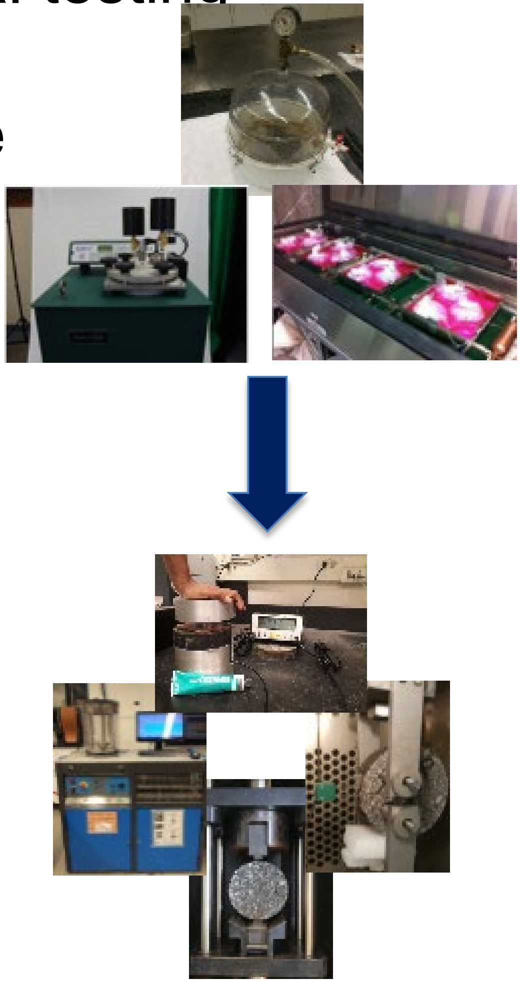


Study Mixtures

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 Poor/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

Moisture Susceptibility Testing

- Typically a form conditioning and mechanical testing are combined
- Conditioning methods – Simulative in nature
  - Lottman procedure (Vacuum saturation)
  - Moisture Induced Stress Tester (MIST)
  - Multi-cycle freeze-thaw
  - Saturated Ageing Tensile Stiffness (SATS) Test
- Mechanical testing methods – Widely varied
  - Indirect Tensile Strength
  - Ultrasonic Pulse Velocity (UPV)
  - Dynamic Modulus
  - Fracture energy-based approaches (DCT, SCB)
- Combined: Hamburg Wheel Tracker



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Moisture Susceptibility Testing

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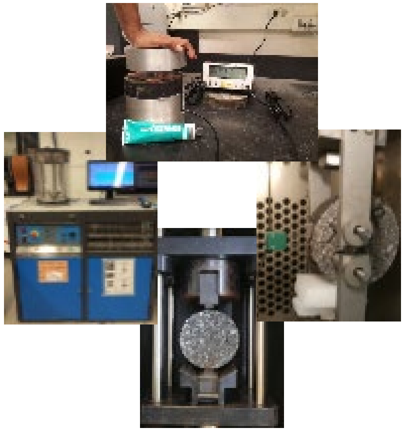

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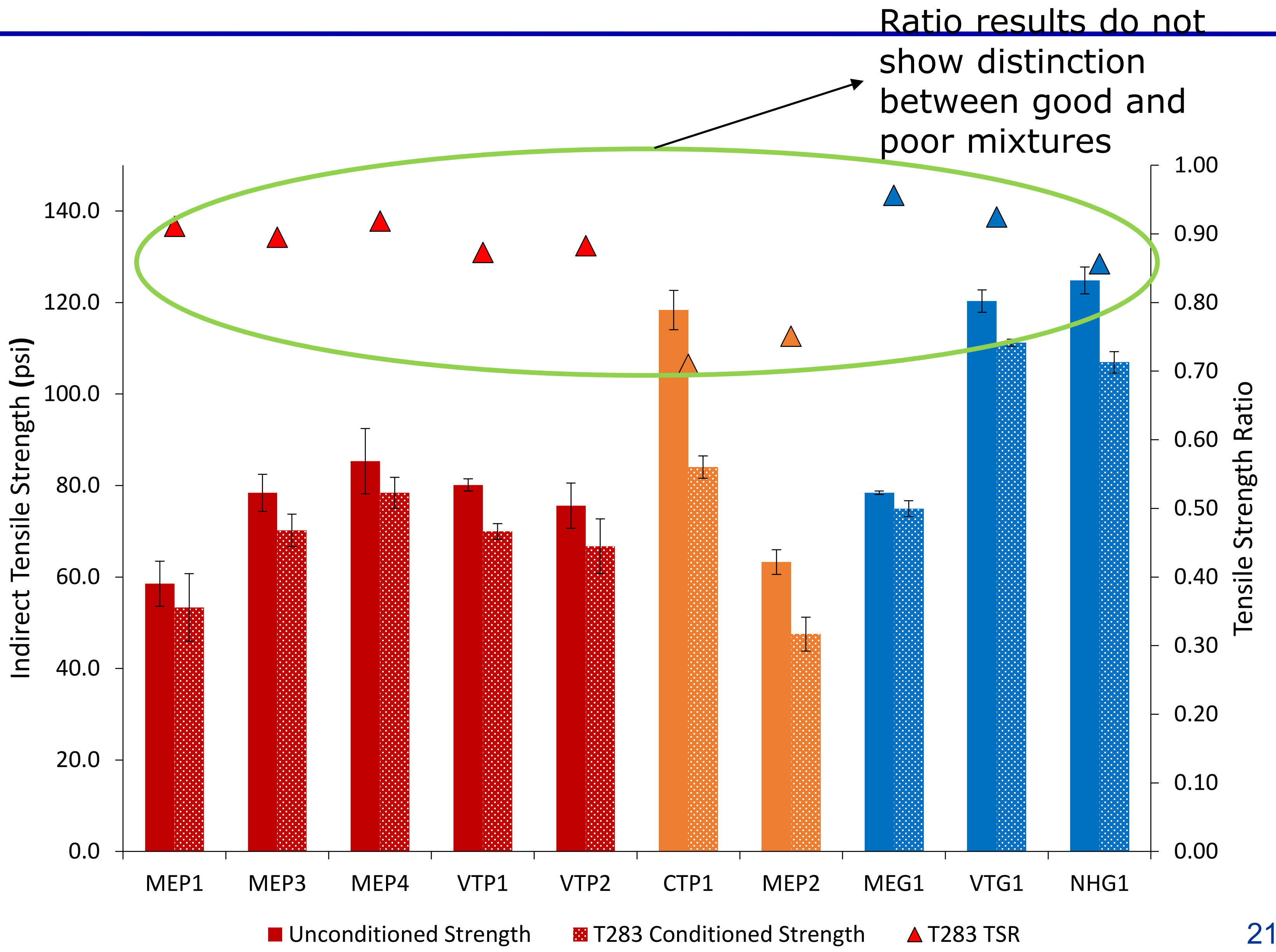
AASHTO T283 and ITS

- Most popular moisture susceptibility test
- Main outcome is the Tensile Strength Ratio (TSR)
  - $TSR = \frac{Average\ Strength\ of\ Conditioned\ Specimens}{Average\ Strength\ of\ Unconditioned\ Specimens}$
  - Typically used as a pass/fail parameter (between 0.75 and 0.85)
  - Some agencies incorporate minimum strength requirements as well
- Widely used
- Gives indication of cohesion and adhesion of mixes
- Relatively simple
- Can obtain total dissipated energy

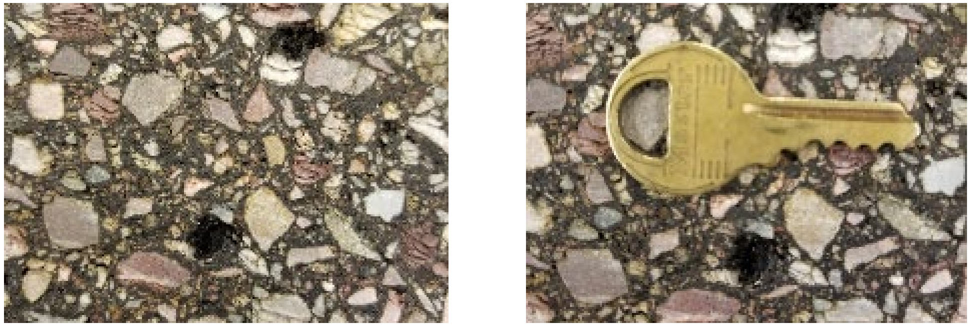
AASHTO T283 Results



Ratio results do not show distinction between good and poor mixtures

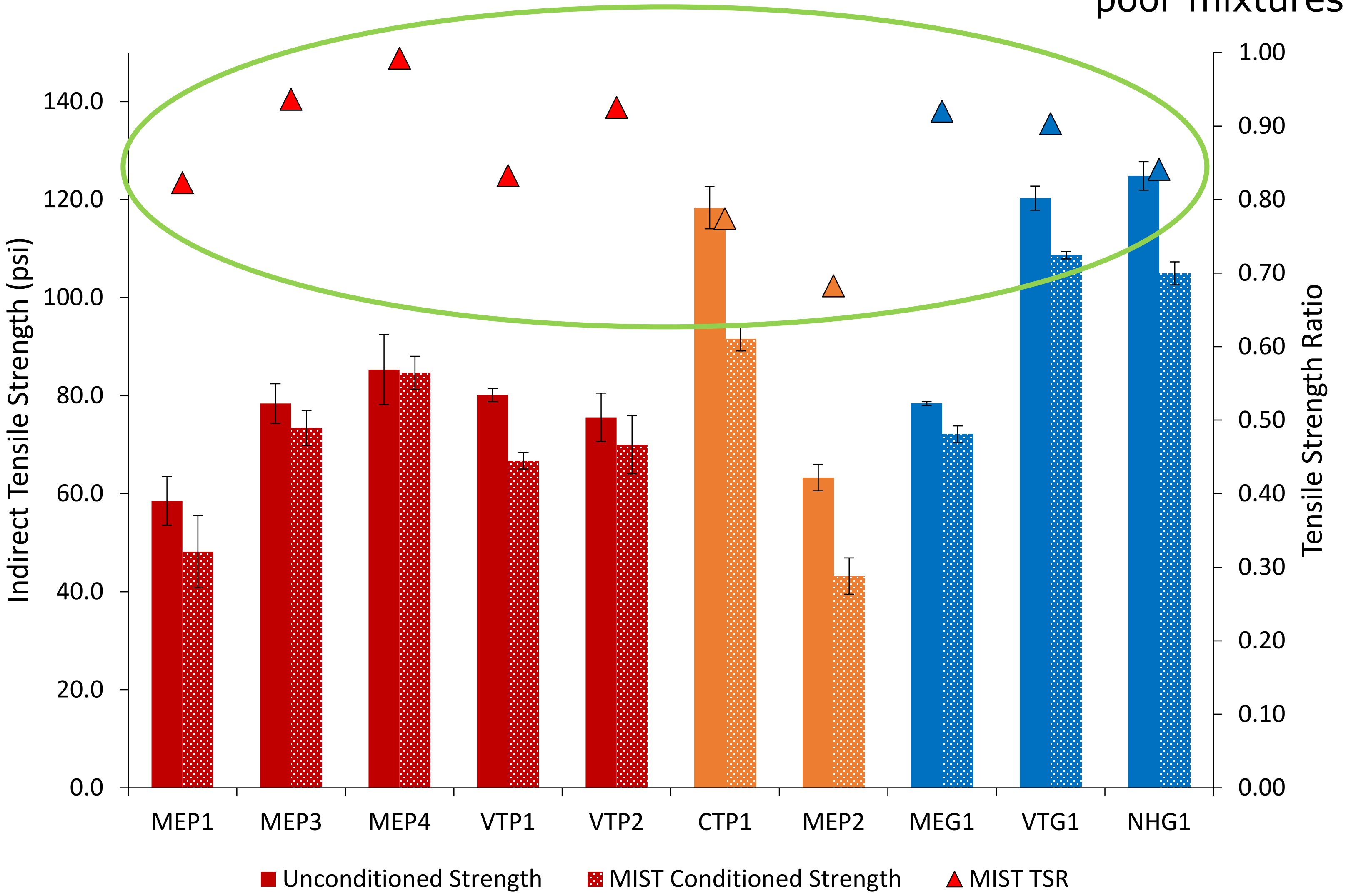
MIST Conditioning

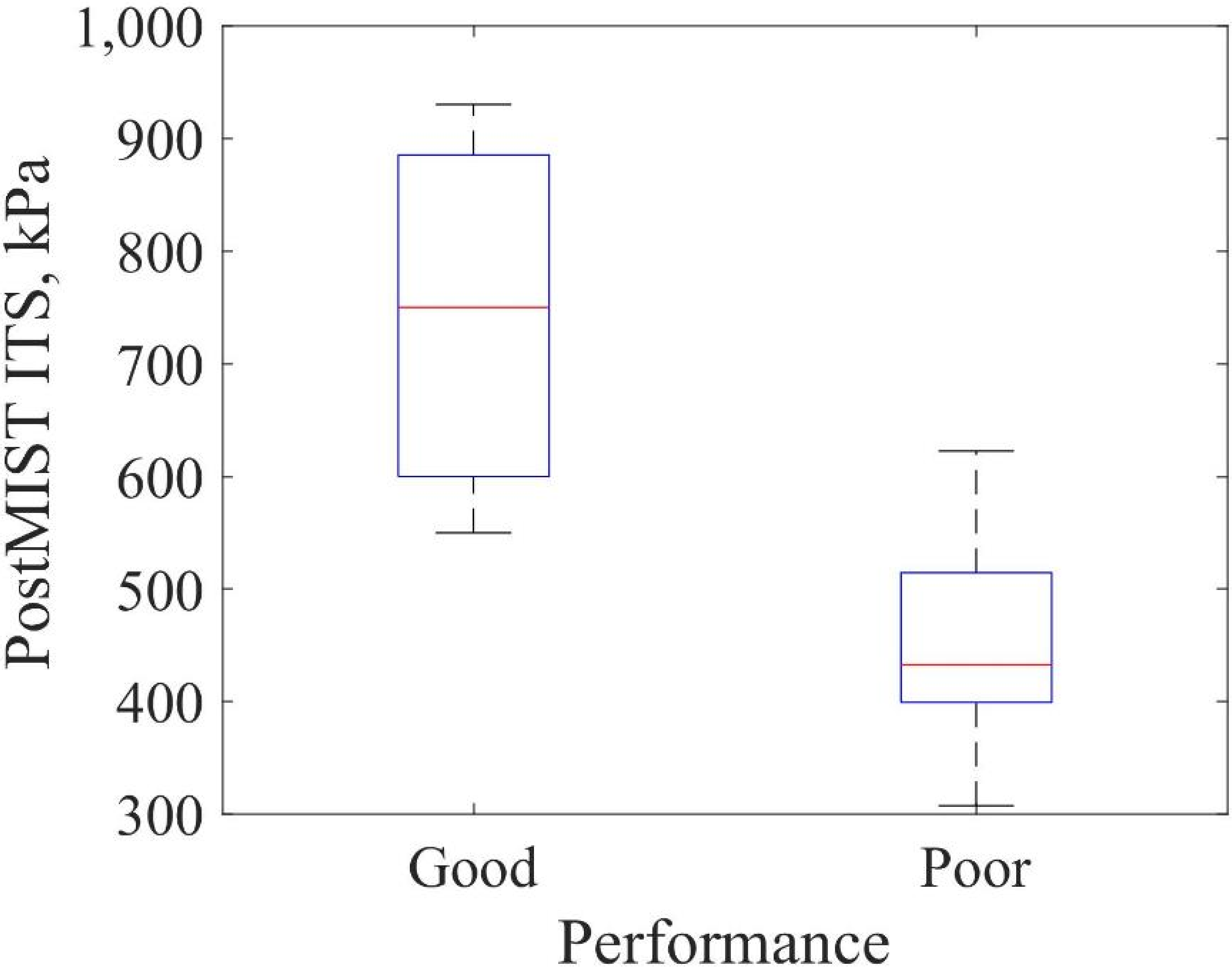
- Moisture induced Stress Tester (ASTM D7870)
- Simulates effect of water under repeated traffic loading at different pressures and temperatures
  - Test temperature
    - 60^{o}C for PG 64-28
    - 50^{o}C for PG 58-28
  - Cycles – 3,500
  - Pressure – 40 psi
  - Adhesion phase – 20 hours (moisture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



AASHTO T283 with MiST

Ratio results do not show distinction between good and poor mixtures,




1,000
900
800
700
600
500
400
300
PostMIST ITS, kPa
Good
Poor
Performance

Ultra-sonic Pulse Velocity

- UPV: Measures P wave velocity to determine bulk modulus (can be converted to seismic modulus)
  - ASTM C597/E494
  - Transducer type – P waves (compression waves)
  - Frequency - 150 kHz
  - Test Temperature – 25C
- Nondestructive
- Gives indication of stiffness
- Can utilize modulus values for design

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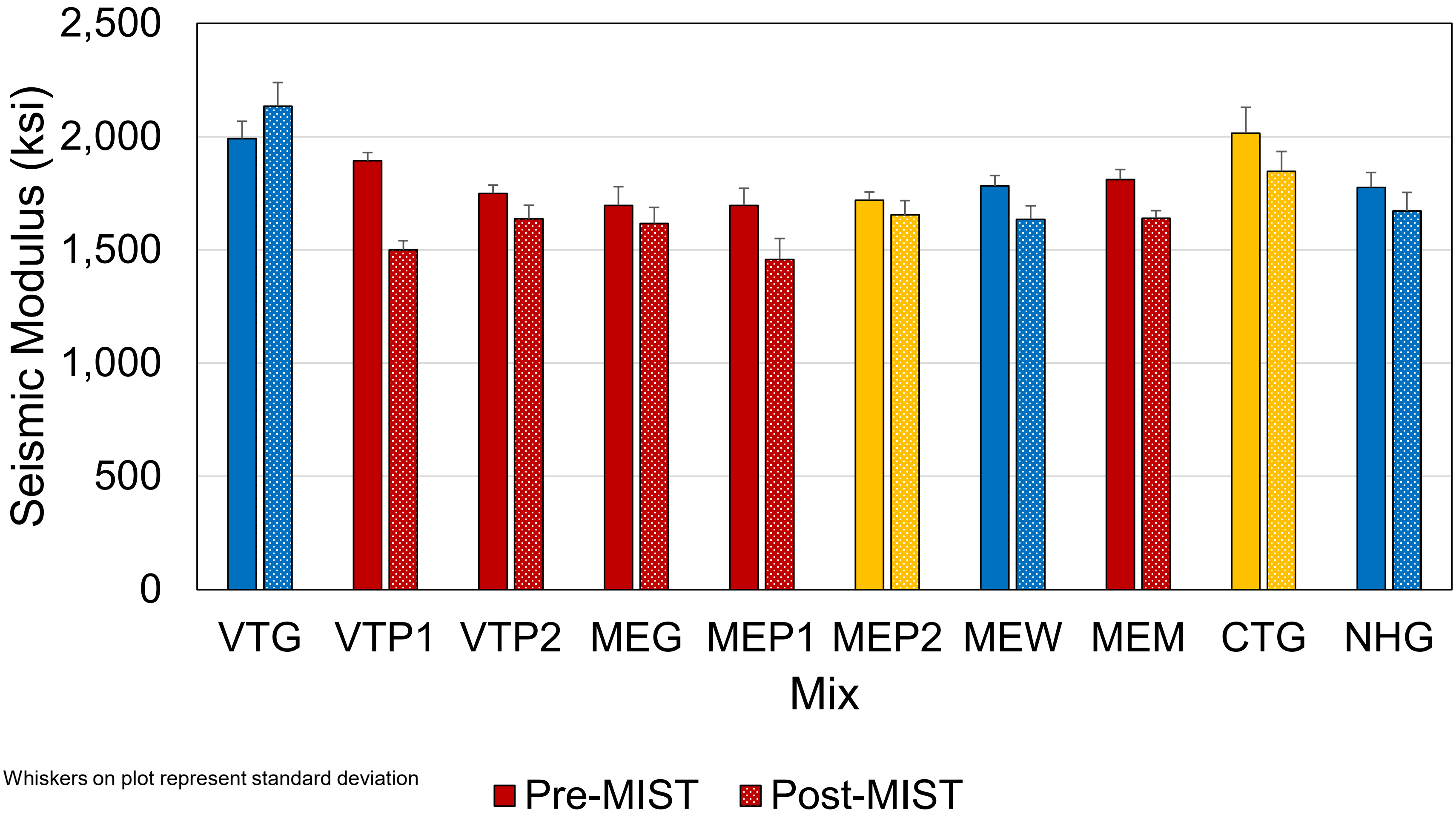
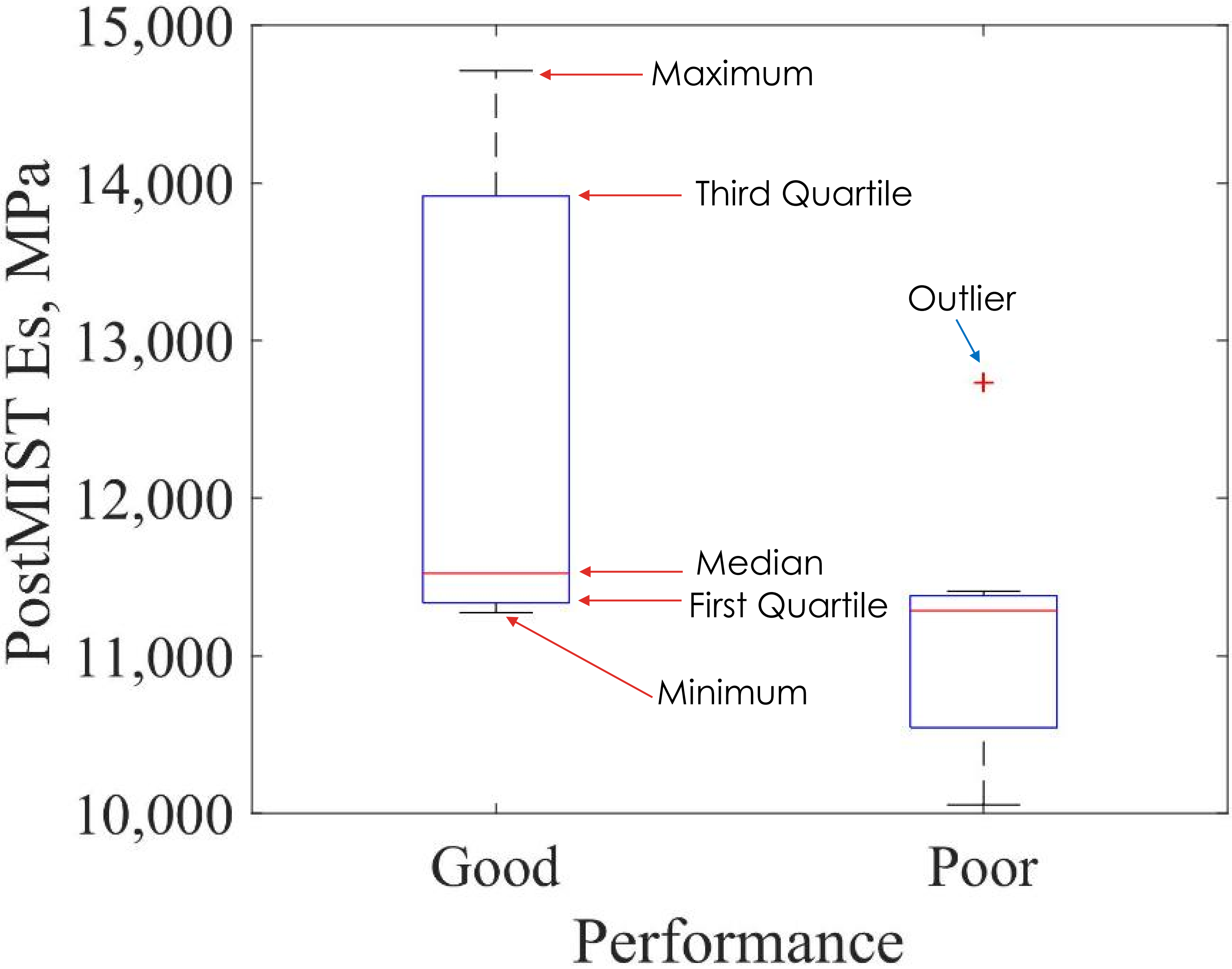
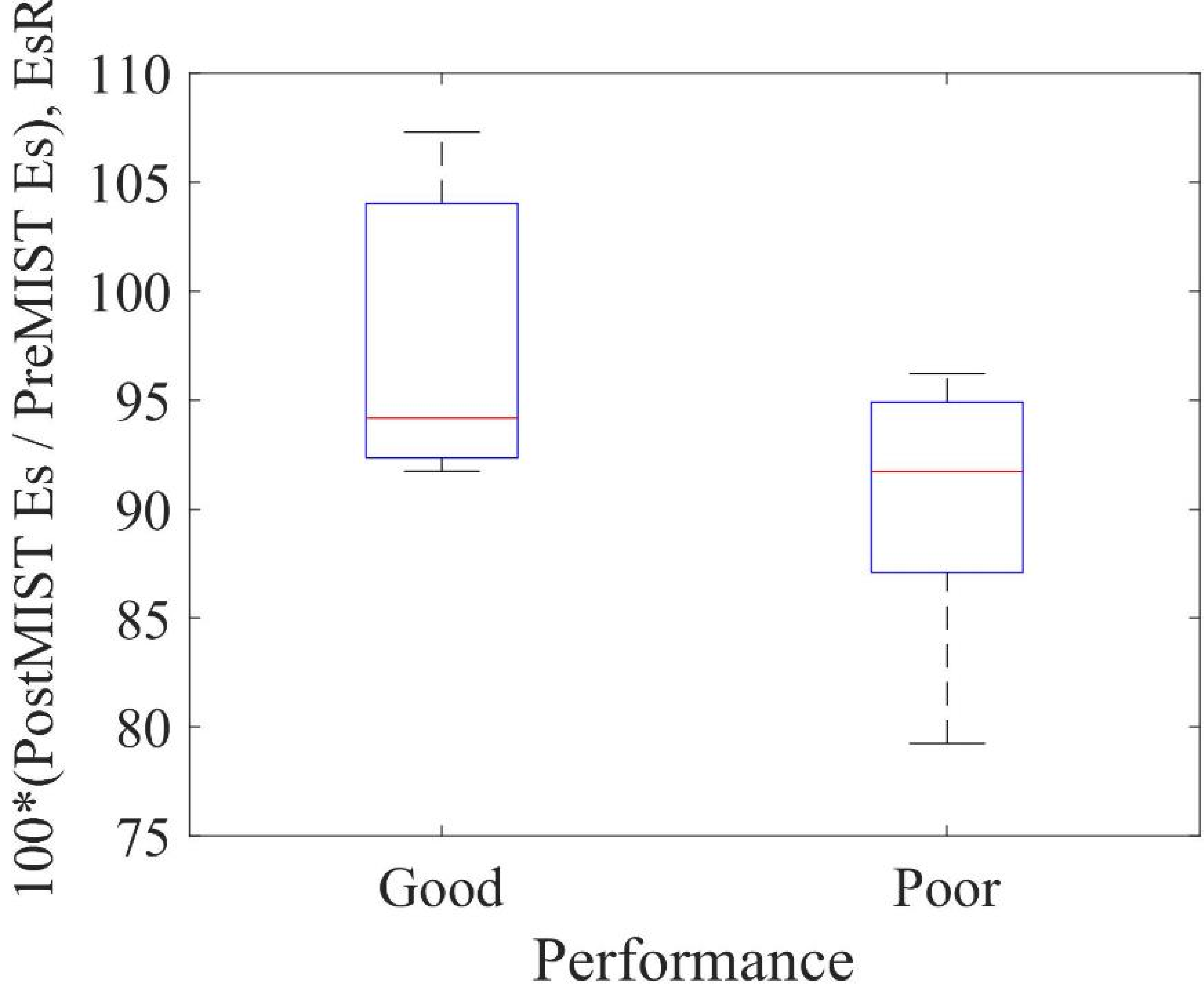
Ultra-sonic Pulse Velocity



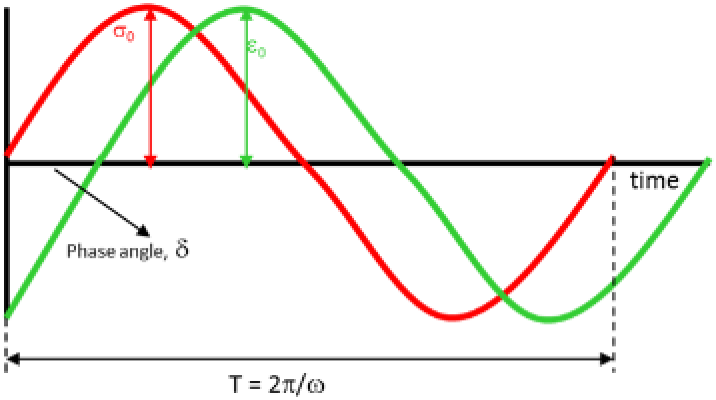
Whiskers on plot represent standard deviation


15,000
14,000
13,000
12,000
11,000
10,000
PostMIST Es, MPa
Good
Poor
Performance
Maximum
Third Quartile
Outlier
Median
First Quartile
Minimum


100*(PostMIST Es / PreMIST Es), EsR
110
105
100
95
90
85
80
75
Good
Poor
Performance

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 be related to changes in structural capacity of pavement)



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1865

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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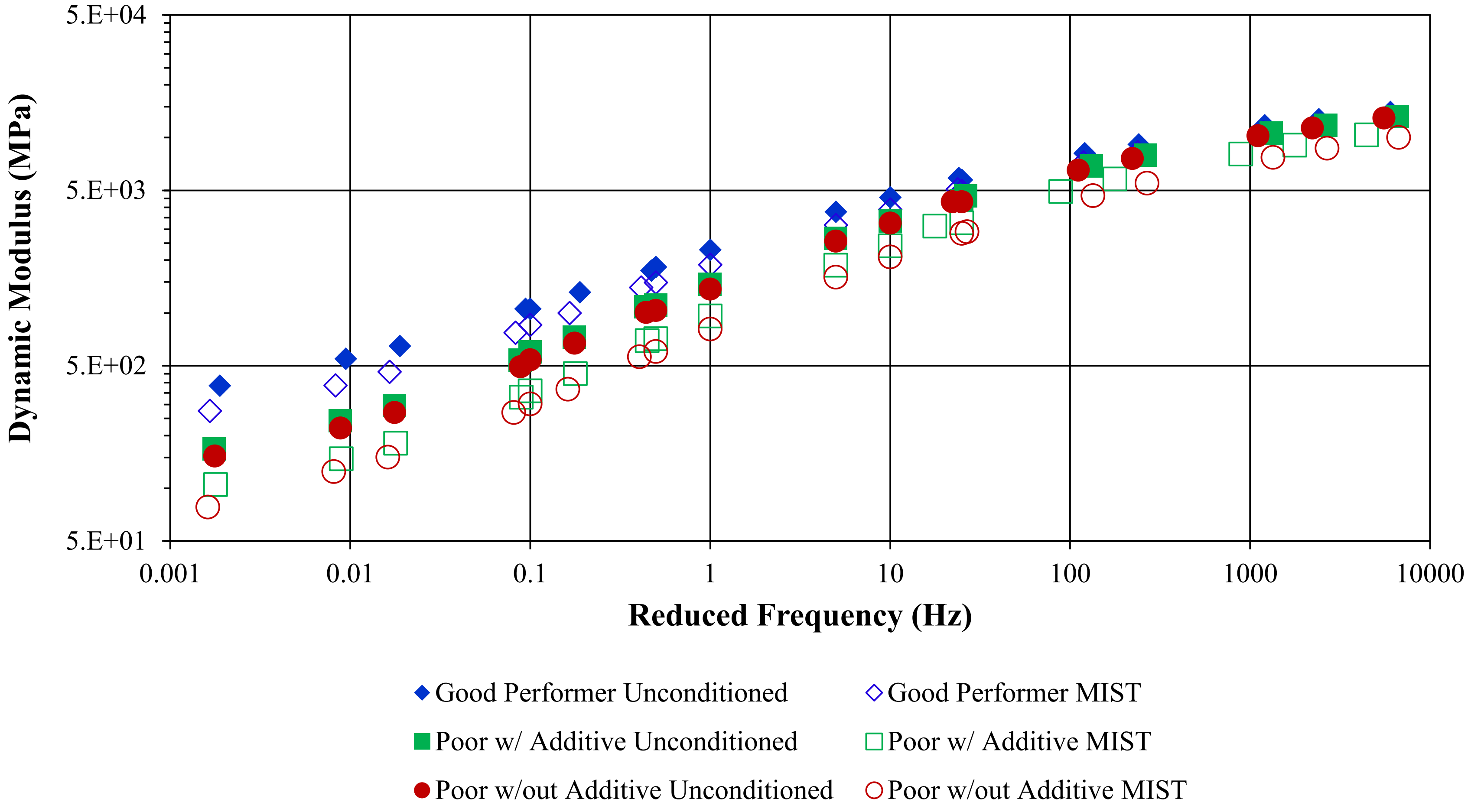
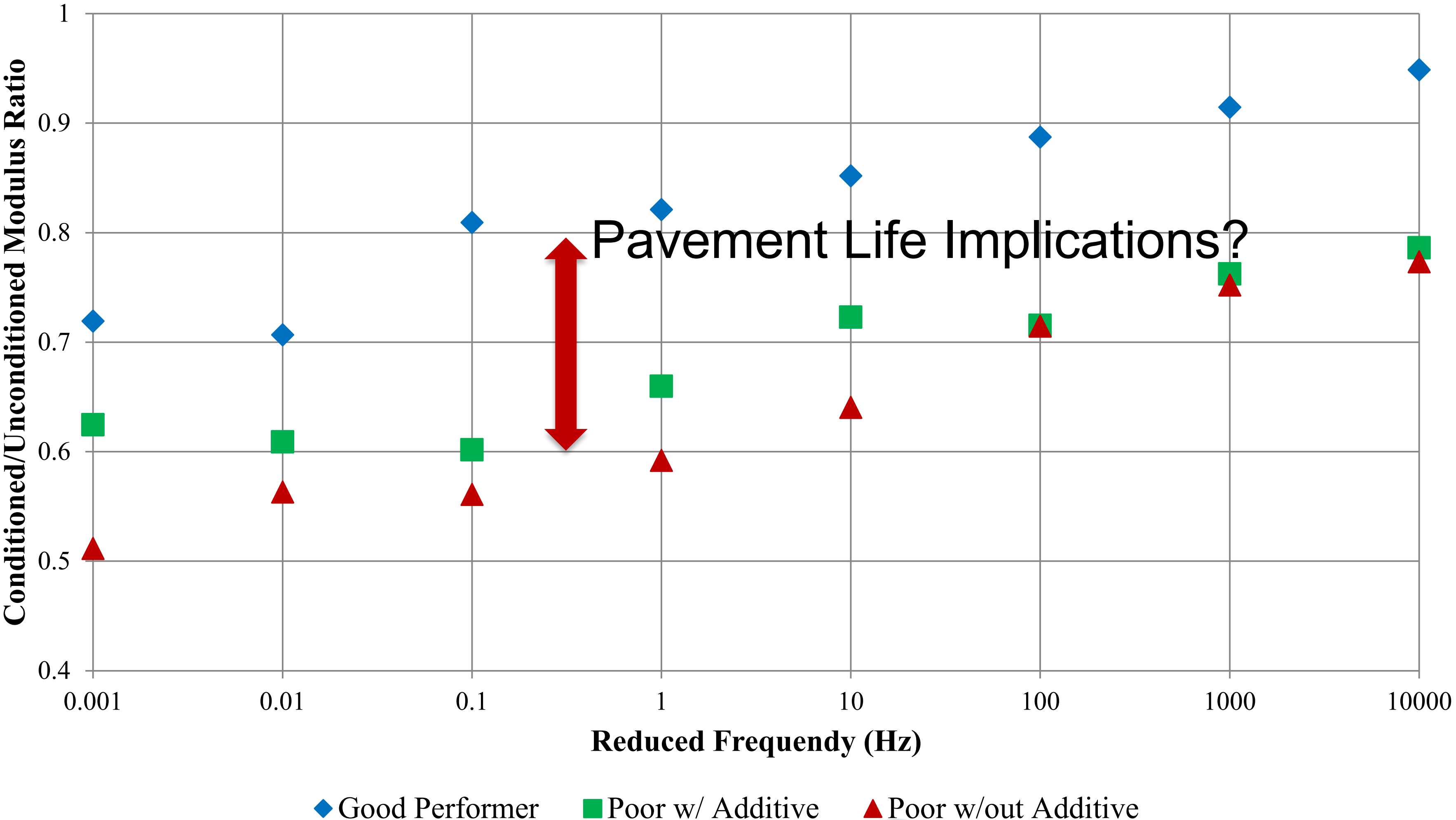
AASHTO T342 – Dynamic Modulus

- Vermont mixtures



AASHTO T342 – Dynamic Modulus



Pavement Life Implications?

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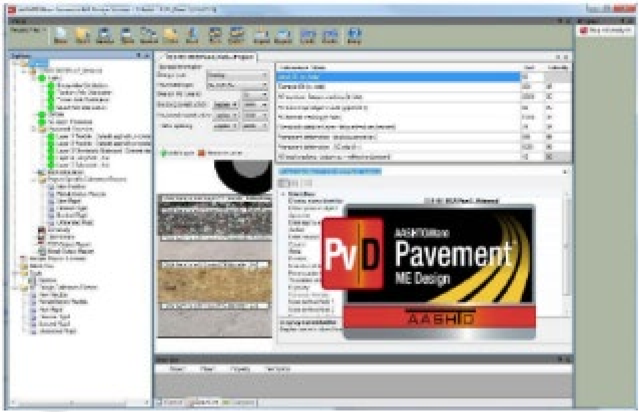
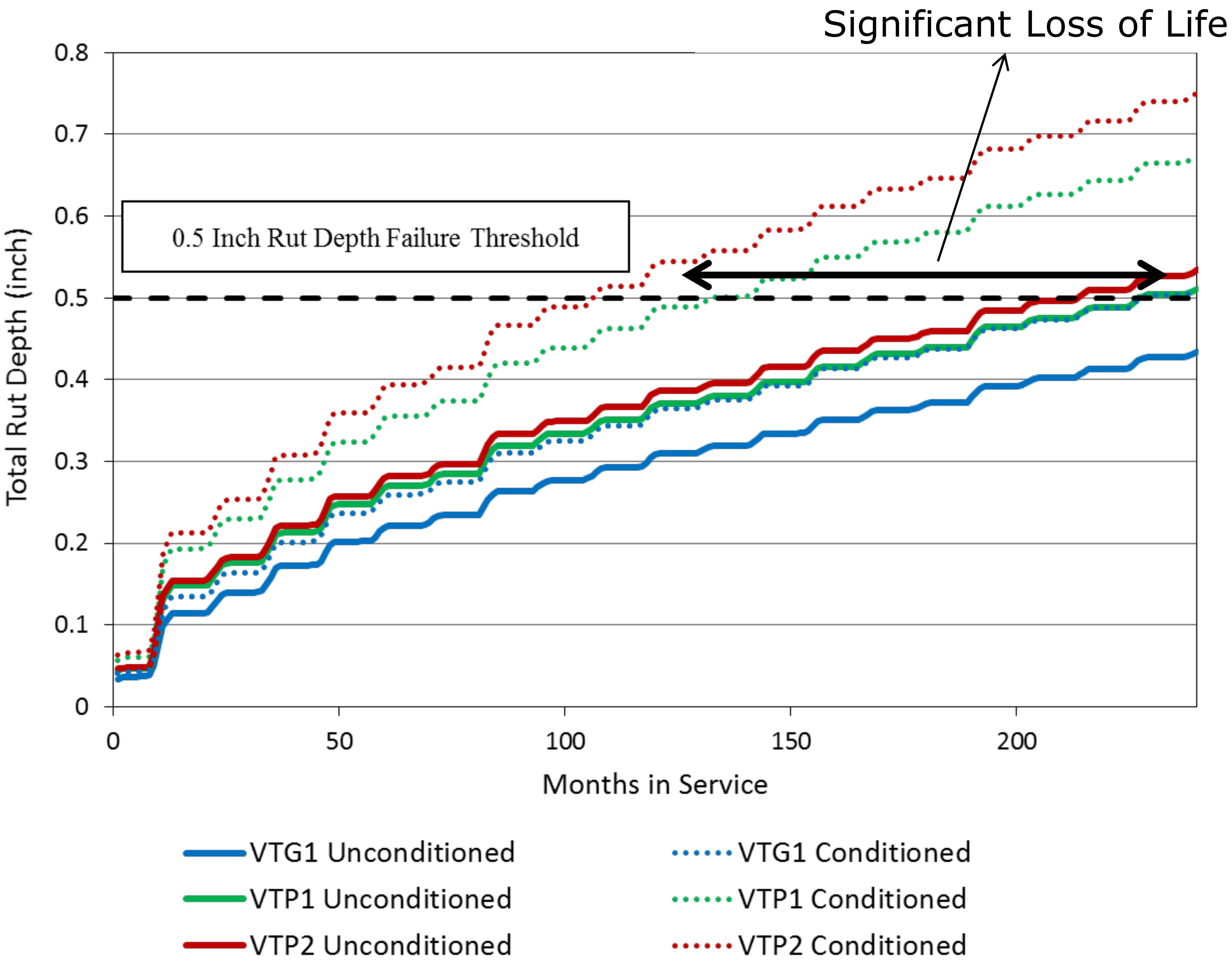
AASHTOWare Pavement ME

- 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

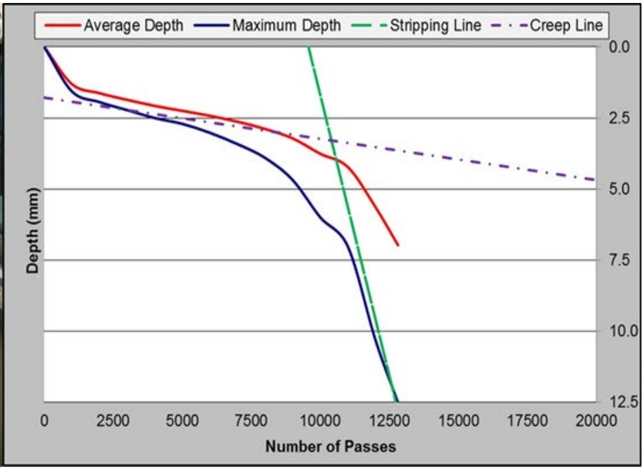


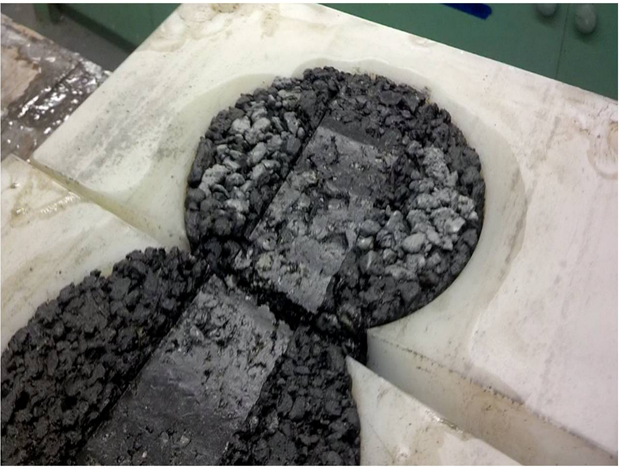
PavementME Results-Rutting



AASHTO T324 - Hamburg

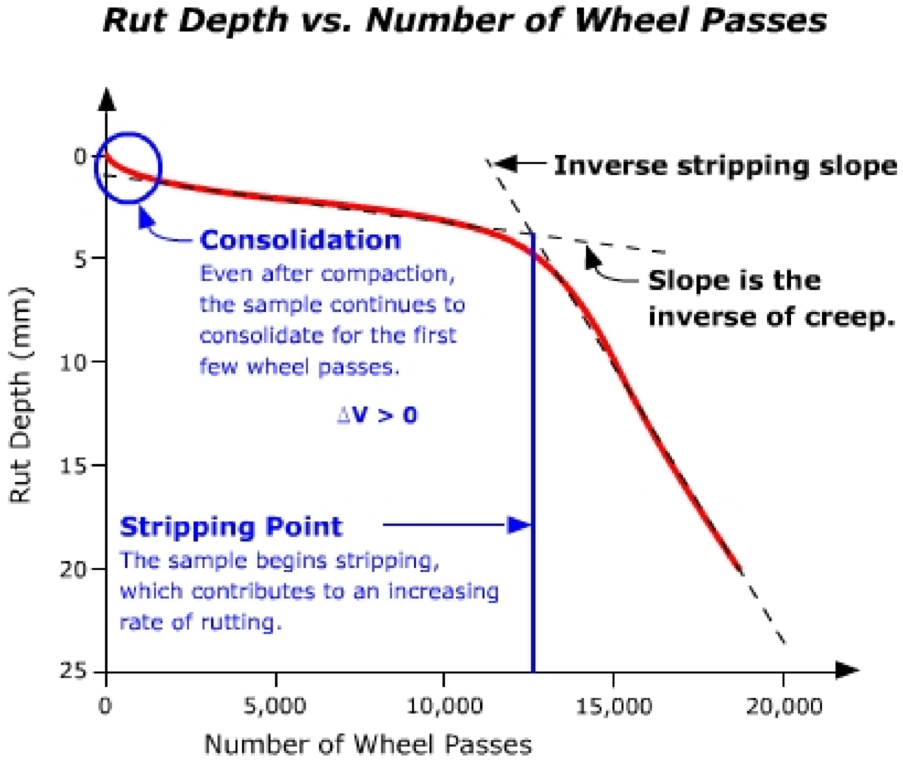
- Simulative test that applies repeated traffic loads through steel wheels (tests conducted on dry and submerged specimens)
- Measure rut depth and number of wheel passes (typically go to 20,000 passes)
- Some agencies already use this for moisture testing, several agencies are already equipped to conduct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





AASHTO T324 - Hamburg

- All Hamburg testing was conducted by Maine DOT
- All mixtures tested at 45C
- Conventional Analysis → Stripping Inflection Point (SIP)
- TAMU Analysis Method



Rut Depth vs. Number of Wheel Passes

Inverse stripping slope

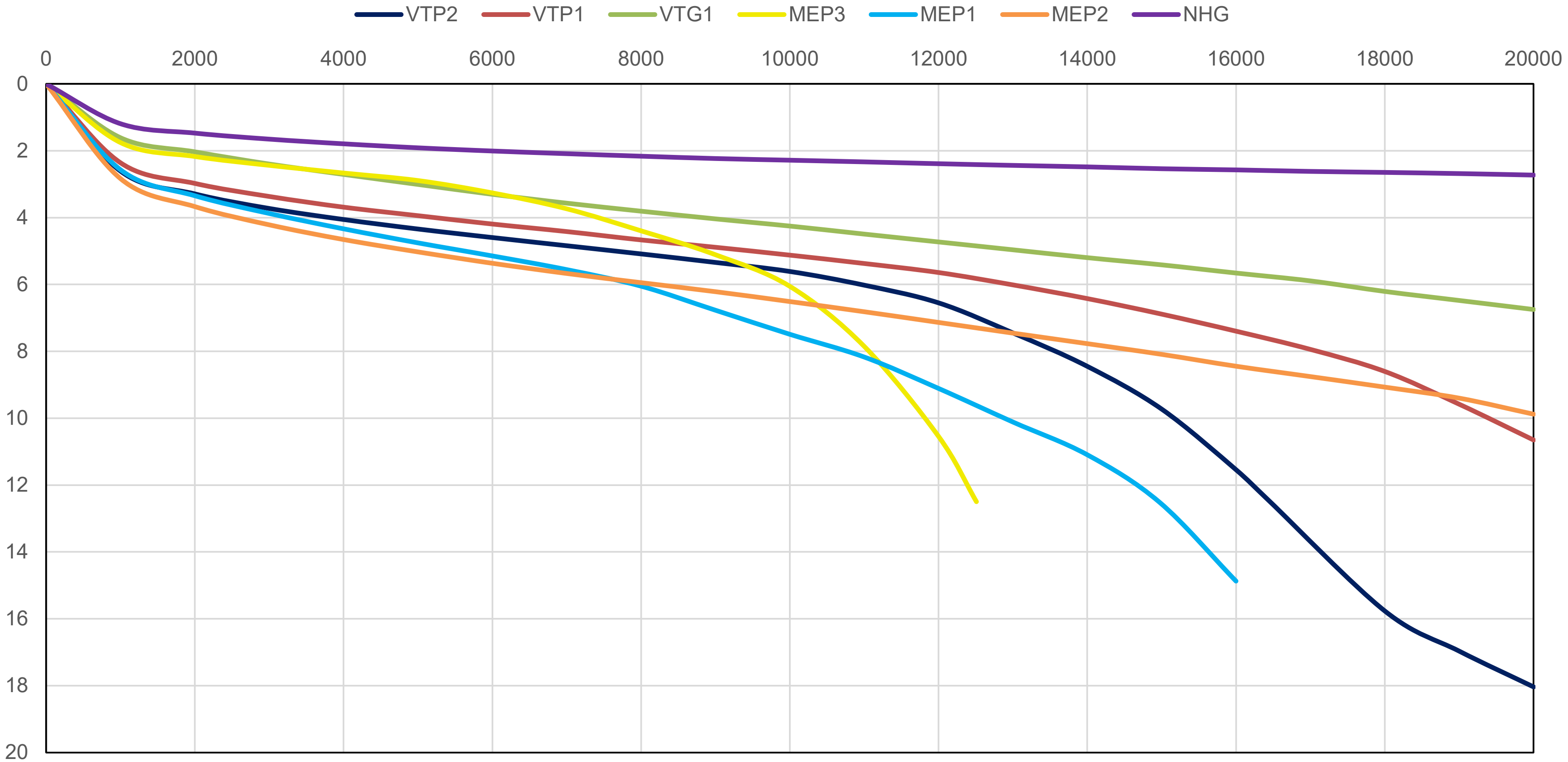
Slope is the inverse of creep.

Consolidation
Even after compaction, the sample continues to consolidate for the first few wheel passes.

$\Delta V > 0$

Stripping Point
The sample begins stripping, which contributes to an increasing rate of rutting.

AASHTO T324 - Hamburg



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

Yellow < Light Blue < Dark Blue < Red < Orange < Green < Purple

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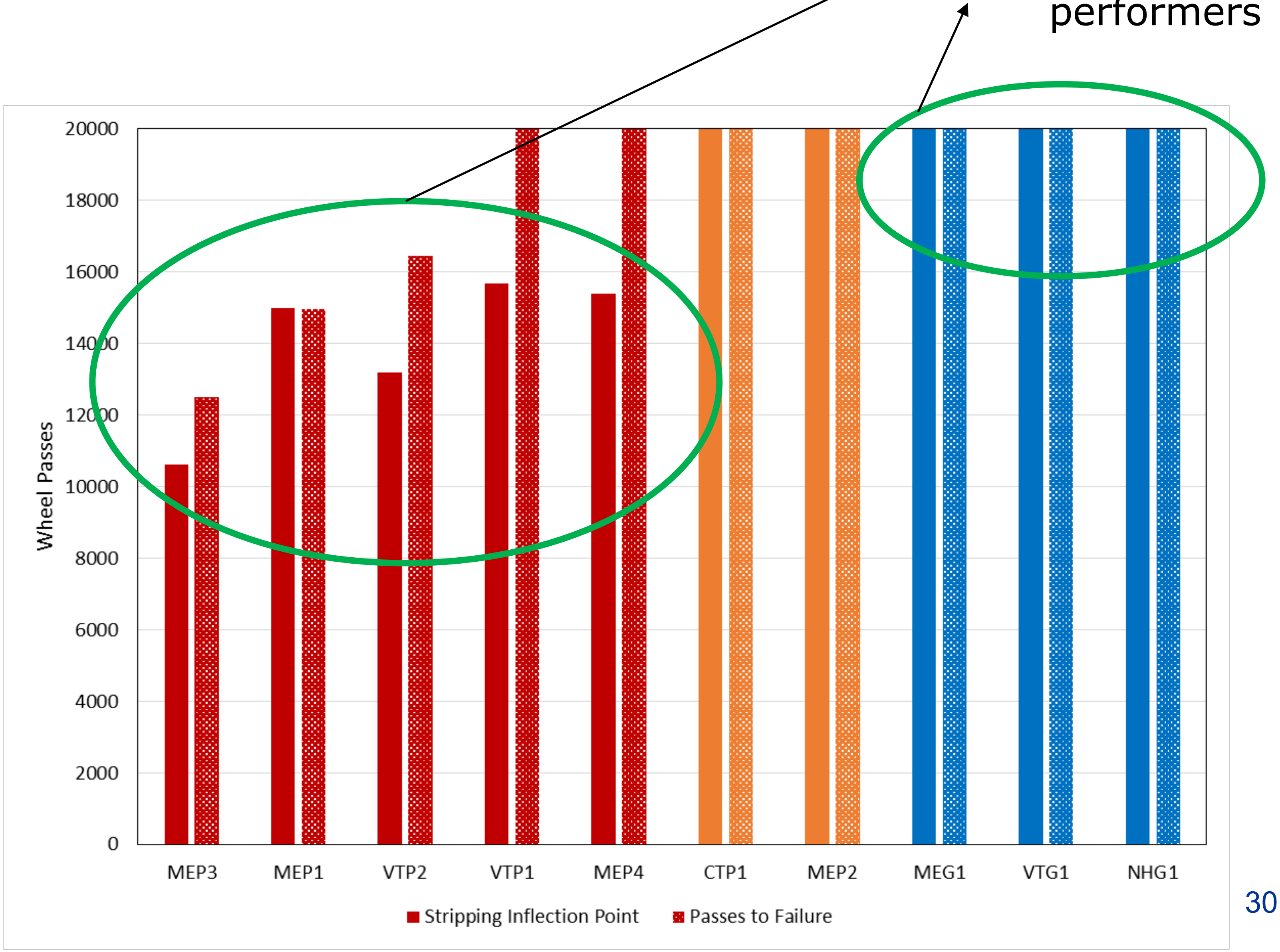
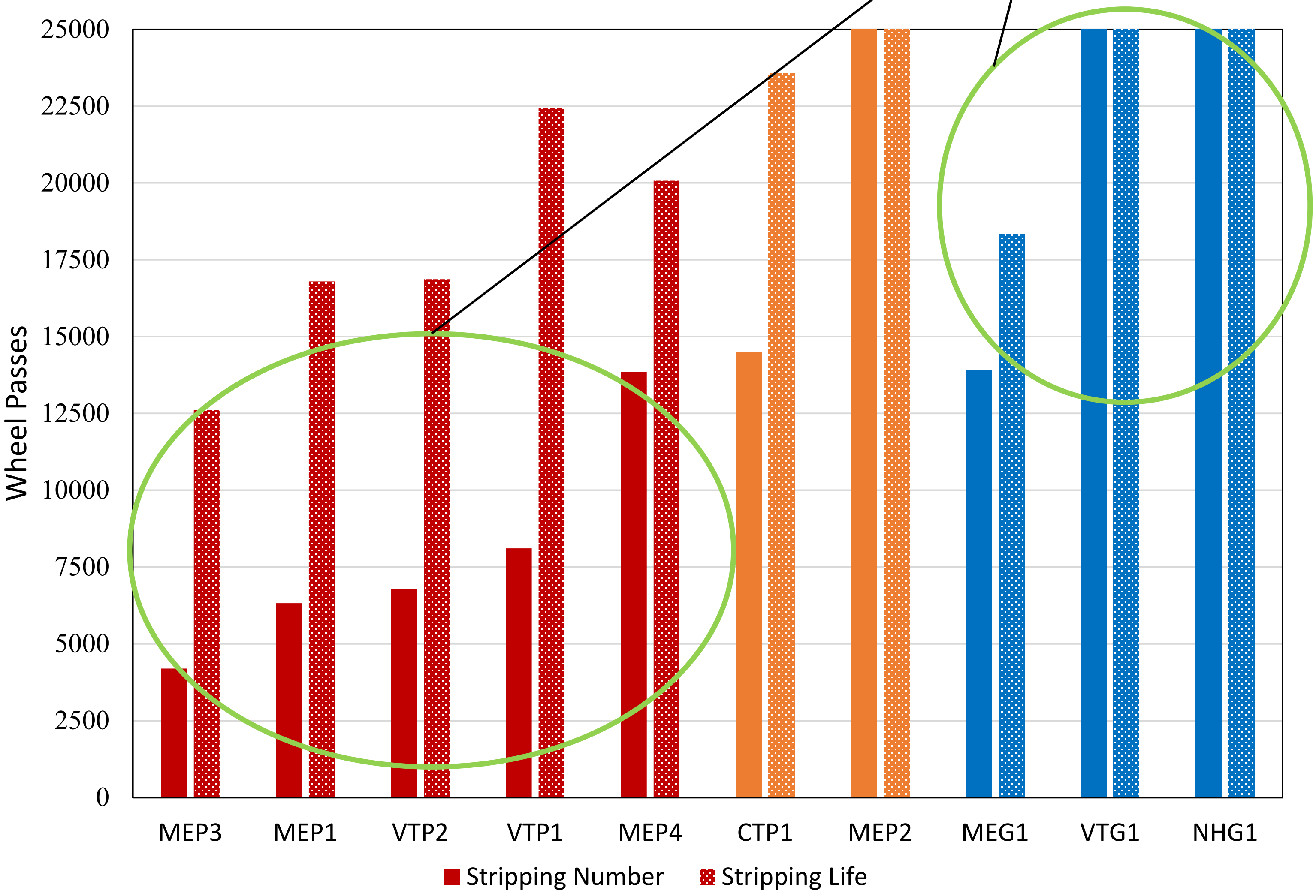
Hamburg: Traditional

Much clearer distinction between good and poor performers



Hamburg: TAMU Method



Clear distinction between good and poor performers

Conclusions

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

Recommendations

- As a mix design/screening test to ensure adequate field performance, the Hamburg wheel tracker is recommended
  - Both traditional and TAMU method work well
- Ultra-sonic pulse velocity (UPV) as a non-destructive test showed very promising result
- For performance-based design/specifications and life cycle cost-based design, dynamic modulus (with MiST conditioning) paired with pavement analysis is recommended.

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Potential Future Extensions

- Binder-aggregate compatibility testing
  - Binder Bond Strength (BBS)
- Impacts/Sensitivity of mix design parameters
- Wider variety of treatment types and dosages
- Verification of results between Hamburg/Dynamic Modulus and field

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Final Report:

https://www.newenglandtransportationconsortium.org/research/netc-research-projects/15-3/

Acknowledgements: Project Technical Committee
Derek Nener-Plante: Maine Department of Transportation
Andy Willette: Vermont Agency of Transportation
Beran Black: New Hampshire Department of Transportation
Eliana Carlson: Connecticut Department of Transportation
Mark Brum: Massachusetts Department of Transportation
Michael Byrne: Rhode Island Department of Transportation

Results – Volumetrics

Mix Name	Performance	Asphalt Binder Content (%)	Voids in Mineral Aggregates (VMA, %)	Voids Filled with Asphalt (VFA, %)	P200 (%)	P200/P_{be}	Hamburg SN, Rank	Hamburg ST, Rank
MEP1	Poor	5.9	15.3	75	5.1	0.9	9	9
MEP2	Poor-Moderate	5.9	15.3	75	5.1	0.9	1	1
MEP3	Poor	5.7	15.0	75	4.4	0.9	10	10
MEP4	Poor	5.6	15.1	74	5	1.0	5	5
MEG1	Good	5.8	15.2	74	4.5	0.8	6	6
VTP1	Poor	6.0	16.5	76	4.5	-	7	7
VTP2	Poor	6.0	16.5	76	4.5	-	8	8
VTG1	Good	4.9	15.5	74	4	-	1	1
CTP1	Poor-Moderate	5.0	15.5	72	3	0.5	4	1
NHG1	Good	5.7	15.6*	75*	4.1	0.8	1	1

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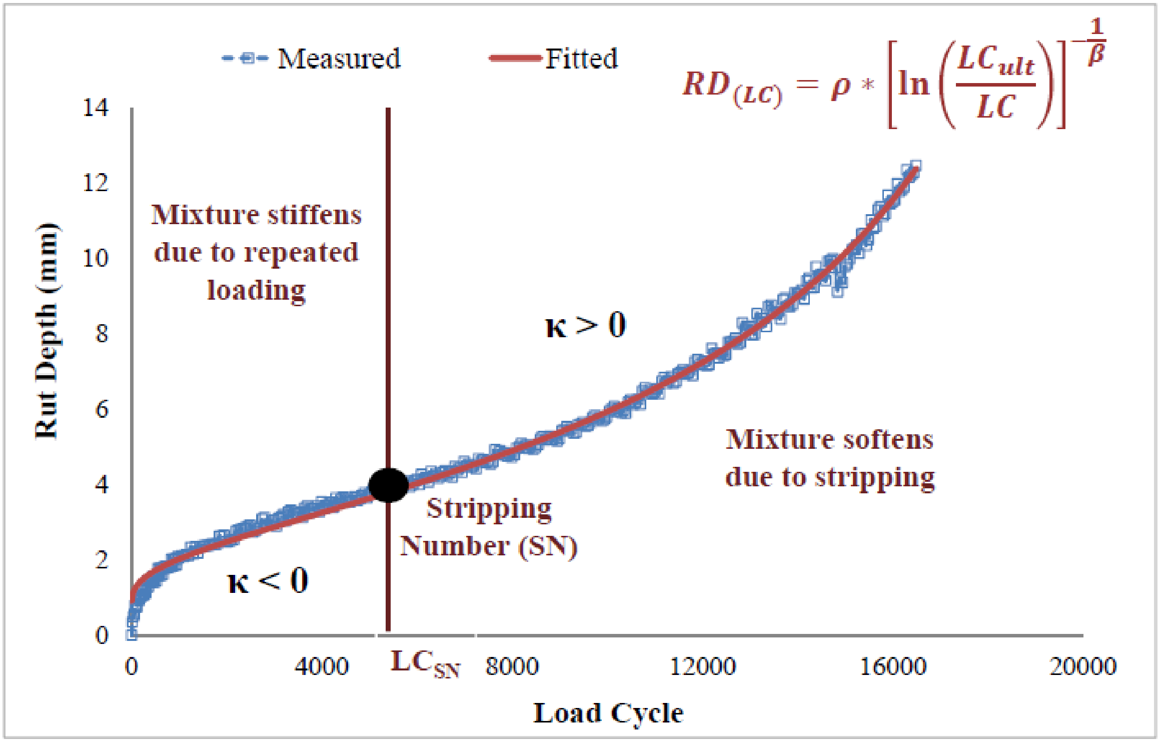
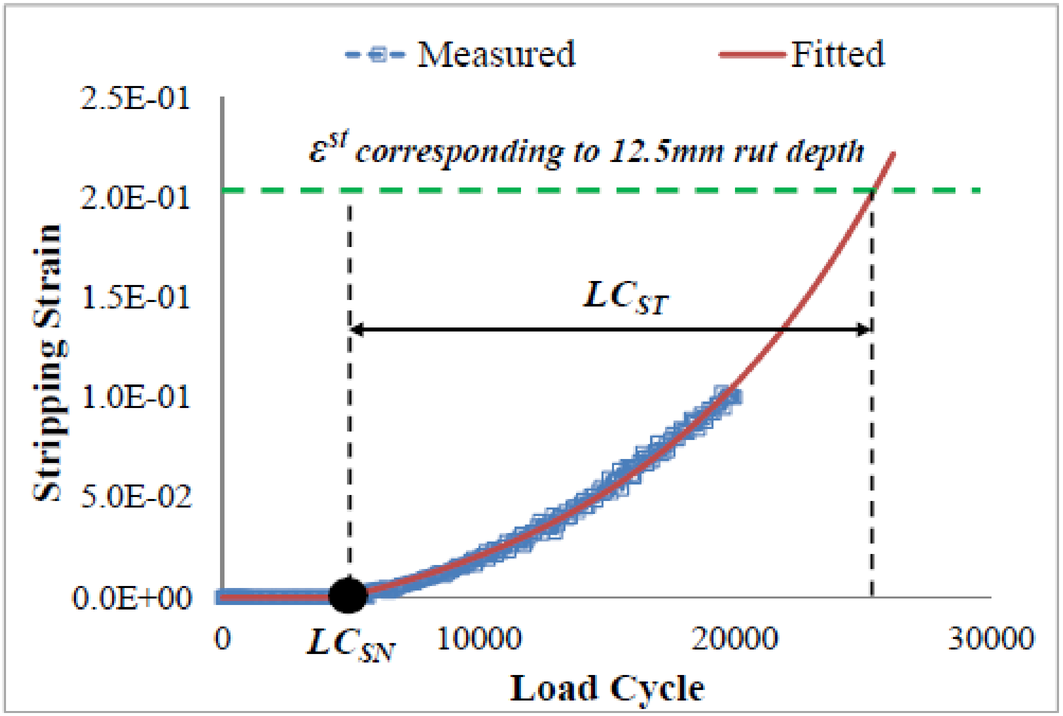
Hamburg– TAMU Method

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



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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Results – Geology

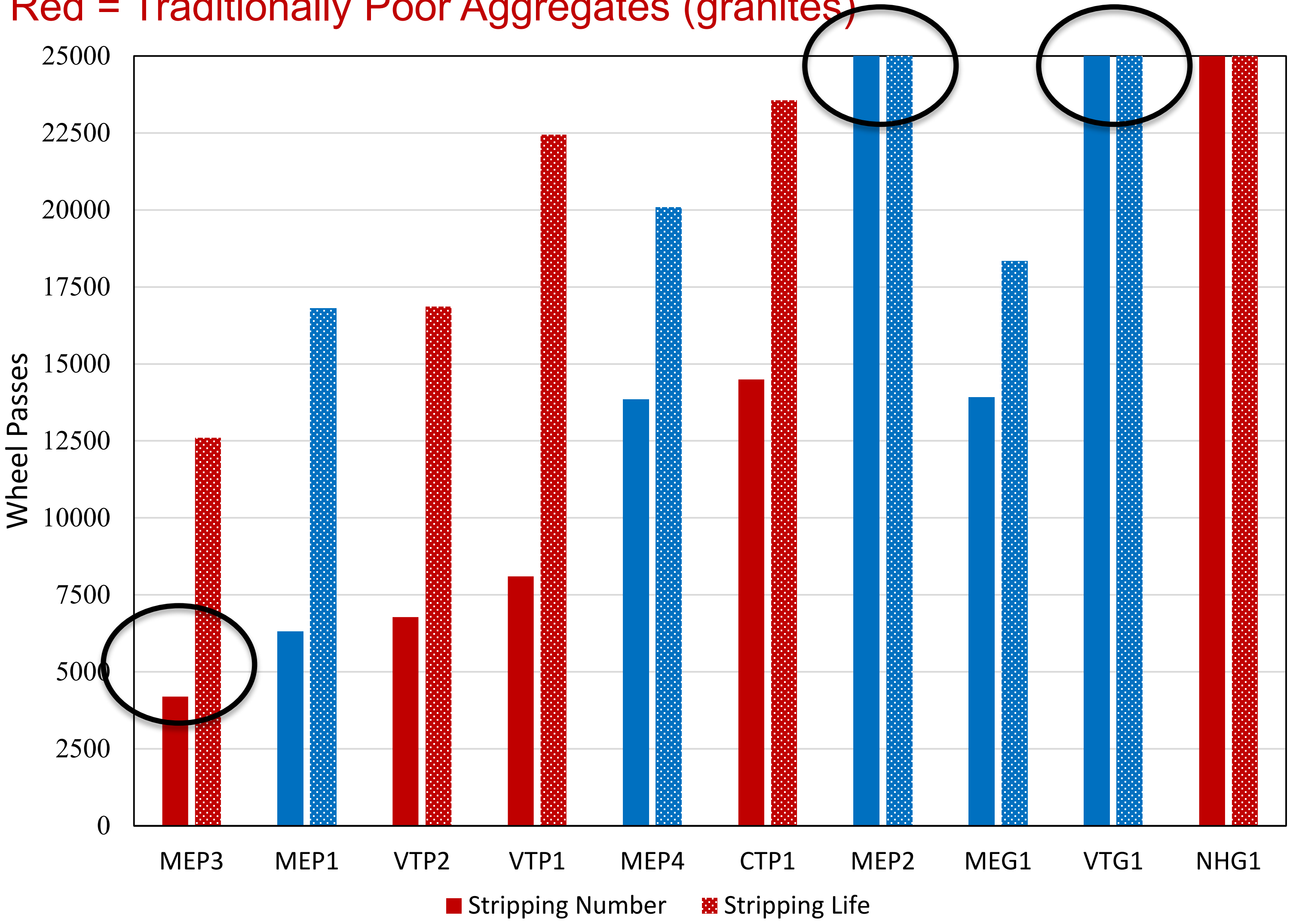
Mix Name	Location	Performance	Aggregate Type	Hamburg SN, Rank	Hamburg ST, Rank
MEP1[1]	Presque Isle, ME	Poor	Limestone	9	9
MEP2[1]	Presque Isle, ME	Poor-Moderate	Limestone	1	1
MEP3	Poland, ME	Poor	Granite	10	10
MEP4	Hermon, ME	Poor	Limestone	5	5
MEG1	Wells, ME	Good	Diorite	6	6
VTP1[2]	Colchester, VT	Poor	Granite	7	7
VTP2[2]	Colchester, VT	Poor	Granite	8	8
VTG1	Rutland, VT	Good	Dolomite	1	1
CTP1	Southbury, CT	Poor-Moderate	Granite	4	4
NHG1	Concord, NH	Good	Granite	1	1

Results – Geology

Some make sense…

Blue = Traditionally Good aggregates (limestone, diorite)

Red = Traditionally Poor Aggregates (granites)



Results – Geology

But others don’t.

Blue = Traditionally Good aggregates (limestone, diorite)

Red = Traditionally Poor Aggregates (granites)