NCHRP 9-60 Update

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Binder ETG, Fall River, MA
May 10, 2018

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Acknowledgements

- **NCHRP 09-60 – Project**
  - Edward T. Harrigan
  - The Panel and the Team
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  - Fundamental Properties of Asphalts (FPIII)
  - Asphalt Research Consortium (ARC)
  - Jack Youtcheff
- **Asphalt Industry Research Consortium (AIRC) – Binders Matrix**
  - Commercial Clients

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Introduction

Objectives

- Address the Impacts of Changes in Asphalt Binder Formulation and Manufacture on Pavement Performance (Thermal Cracking, Block Cracking, and Raveling).
- Propose Changes to the Current PG Asphalt Binder Specifications, Tests, and Practices.

Updated Completion Date

- Effective Date: 7/6/2016
- Completion Date: 6/30/2019

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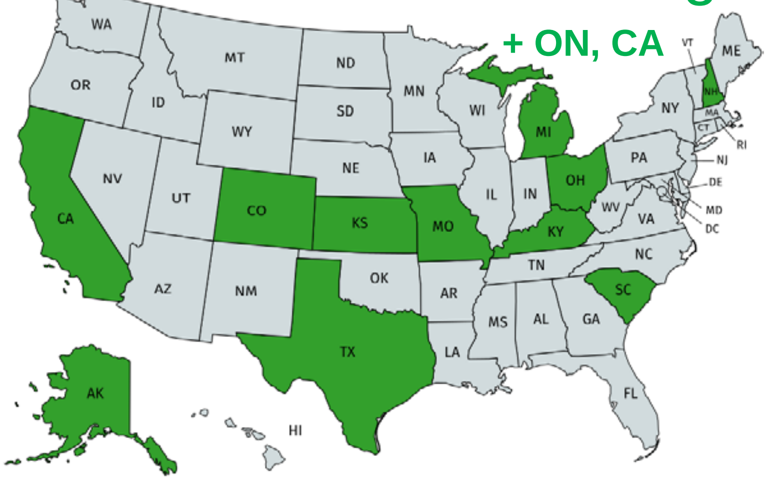
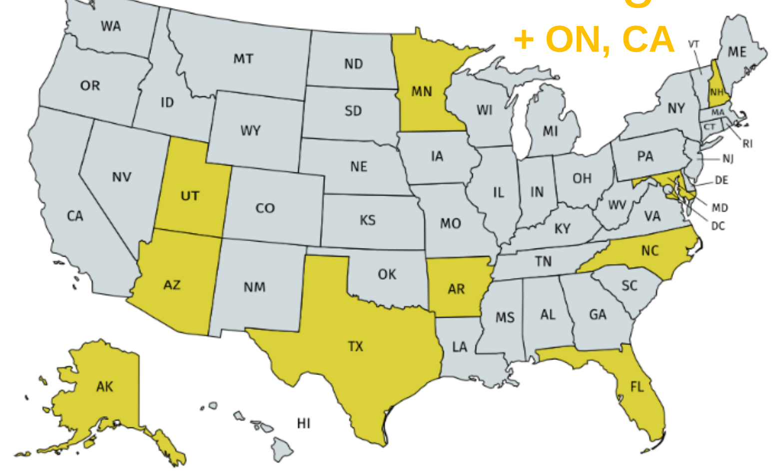
Agency Survey

❑ Identified Issues

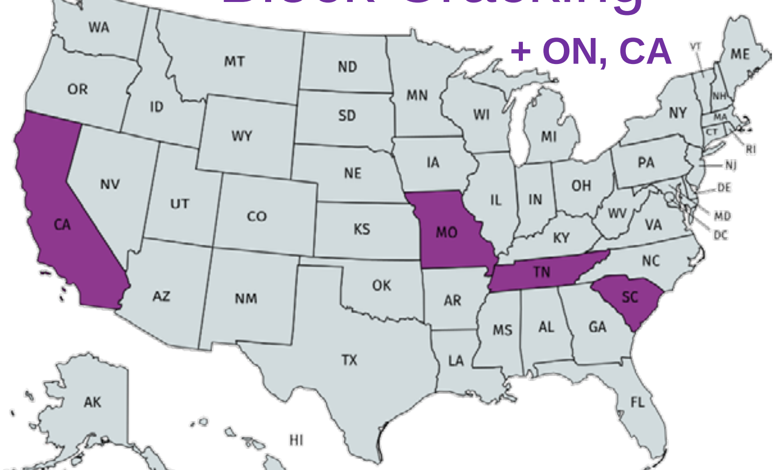
Transverse Cracking



Miscellaneous Surface Cracking



Block Cracking



Raveling

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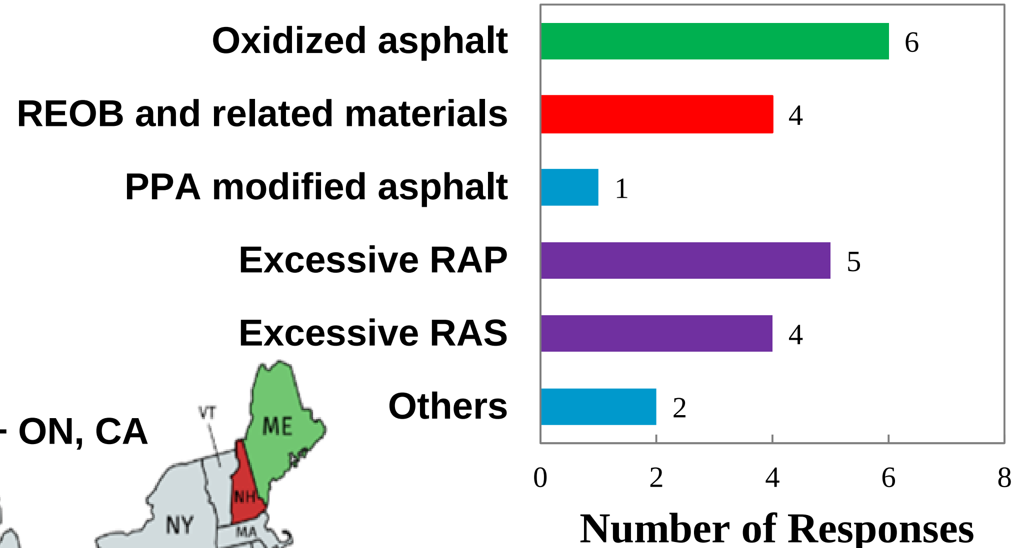
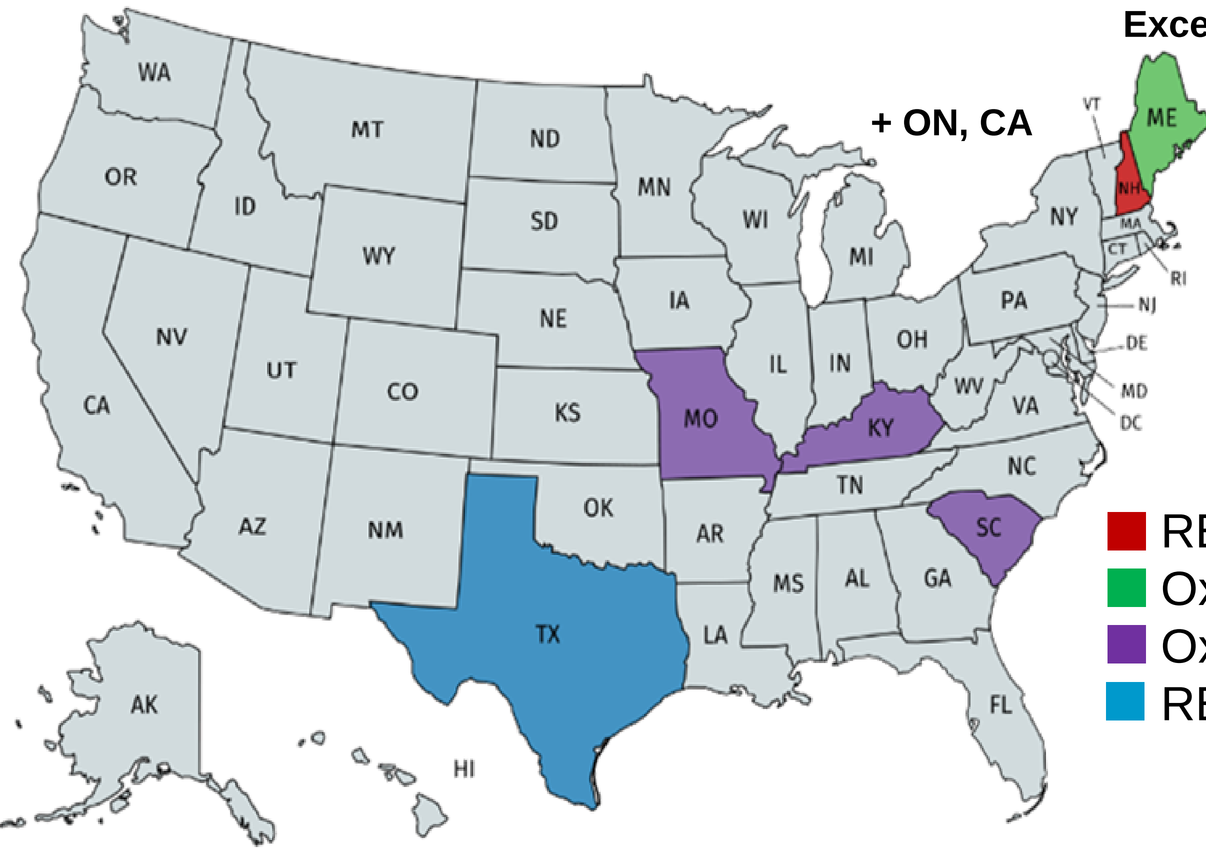
Agency Survey

❑ Potential Binder Issues



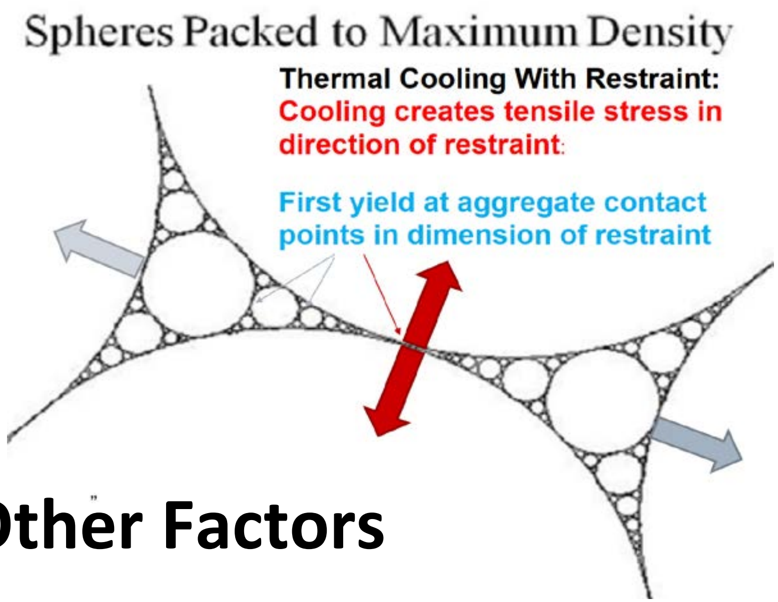


REOB
Oxidized Asphalt, Others
Oxidized Asphalt, RAP, RAS
REOB, PPA, RAP, RAS

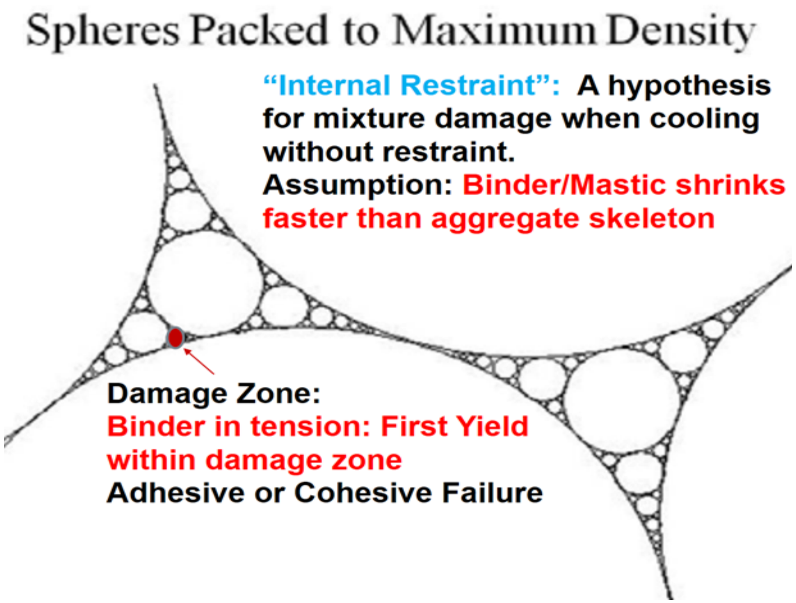
Factors Considered

❑ Internal Restraint Mechanism (Hypothesis)

- Restraint Mix in red or gray directions



- Mastic Restraint Within the Aggregate Structure



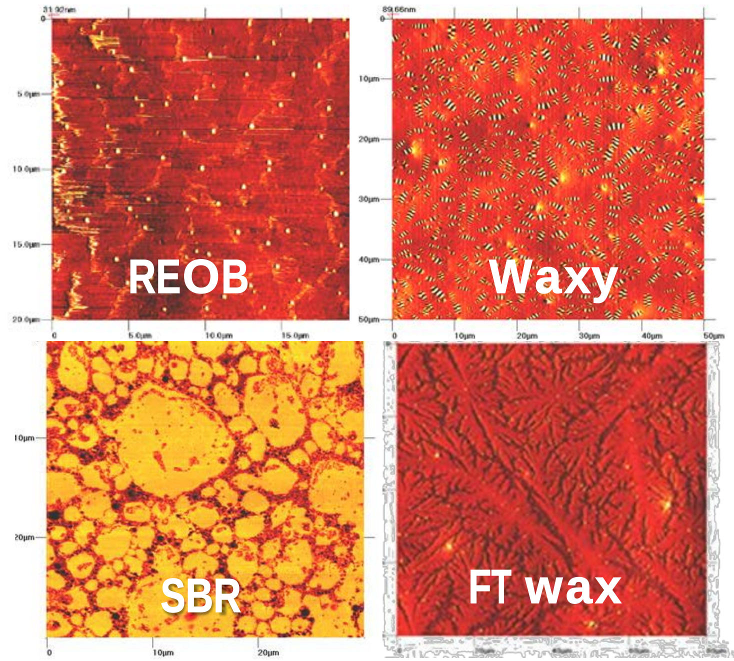
❑ Other Factors

- Long-Term Aging Potential
- Physical Hardening
- Healing Potential

Binder Matrix

Problematic Binders

- High ΔT_c and generally "out of balance", incompatible blends and modifications.
  - REOB blends
  - Airblown, oxidized blends
  - Hard SDA / Soft blends
  - Visbroken Residue (IMO 2020)
  - Waxy binders
  - Incompatible blends
    - Fracking crudes / Heavy Crudes
  - Inhomogeneous modified binders
    - Polymers – EVA, SBS, SBR, Terpolymers
    - Additives – PPA, Wax, Biomass
  - High RAP / RAS



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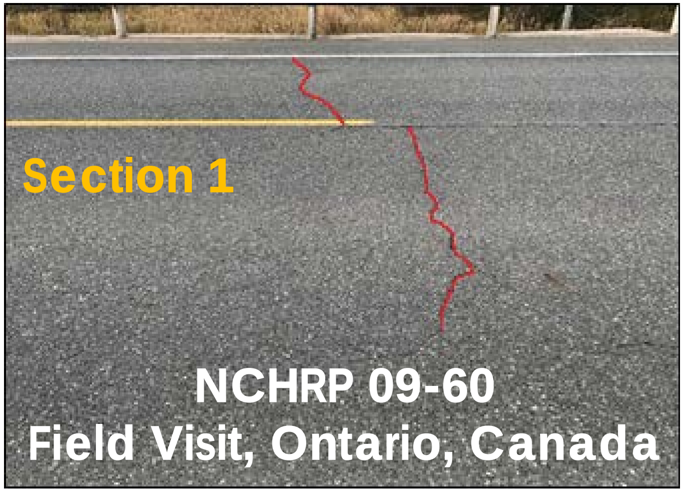
Binder Matrix

Binder with Corresponding Field Sections

- Highway 655, Ontario, Canada MTO (7 sections)
- Rochester, MN (4 sections)
- US 93, AZ (4 sections)
- I 295 SB, Portland, ME
- Route 1, Presque Isle, ME
- Route 11, Wallagrass, ME
- Route 12, Westmorland, NH
- SH 195, Florence, TX
- FAA/AI Study (3 Sections)



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Experimental Plan

Binders From Suppliers

In progress ✓

	Binder Testing Plan	Mixture Testing Plan
Laboratory Conditioning	Short-Term Aging (RTFO) ✓; Long-Term Aging (PAV/2PAV/4PAV) ✓; Physical Hardening (BBR/DSR/ABCD)	Loose Mix Aging 5 and 10 days @ 95°C ✓; Physical Hardening & Thermal Cycling
Chemical Microstructural Characterization	SAR-AD™ ✓; FT-IR ✓; GPC; AFM	
Thermal Characterization	DSC ✓	
Rheological Characterization	PG-Grading (DSR&BBR) ✓; Mastercurve (DSR 60°C to -30°C) ✓; Adhesion/Healing Parameters (DSR) ✓	
Ductility & Cracking Performance	DTT; SDENT ✓; ABCD ✓	Sliver Test ✓

Experimental Plan

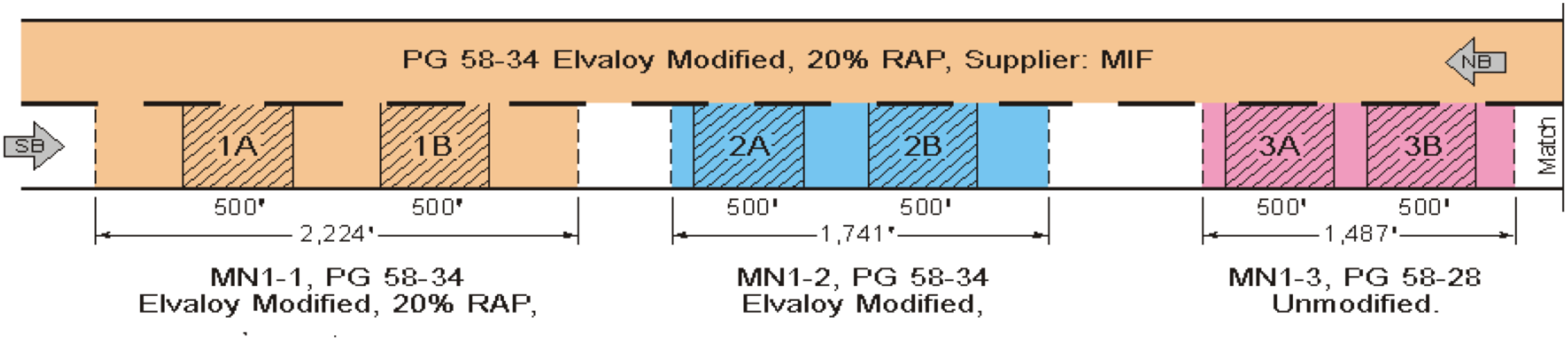
❑ Field Cores

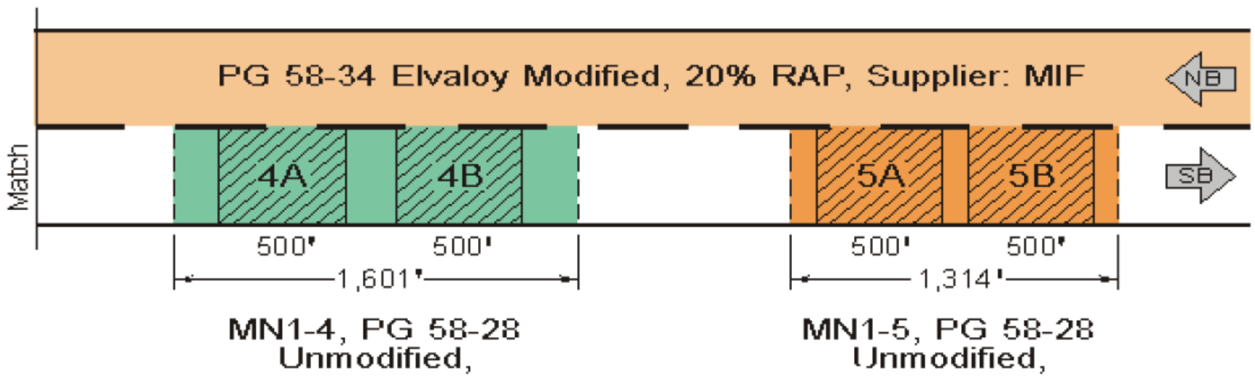
In progress ✓

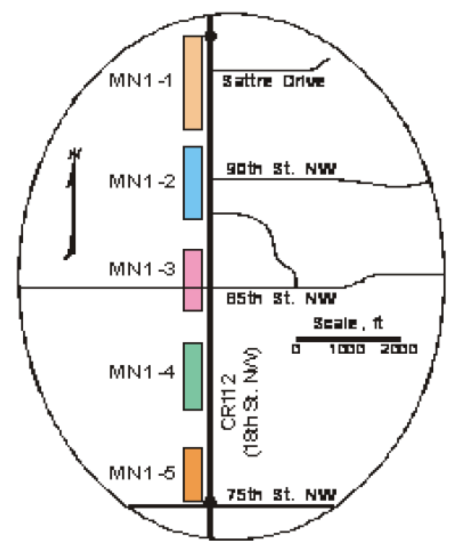
	Binder Testing Plan	Mixture Testing Plan
Field Cores	Field Cores (Extraction and Recovery) ✓	Field Cores
Chemical Microstructural Characterization	SAR-AD™ ✓; FT-IR ✓; GPC; AFM	
Thermal Characterization	DSC ✓	
Rheological Characterization	PG-Grading (No BBR) ✓; Mastercurve (DSR 60°C to -30°C) ✓; Adhesion/Healing Parameters (DSR) ✓	
Ductility & Cracking Performance		Sliver Test

Minnesota Sections

Rochester, MN







Minnesota Sections

Rochester, MN

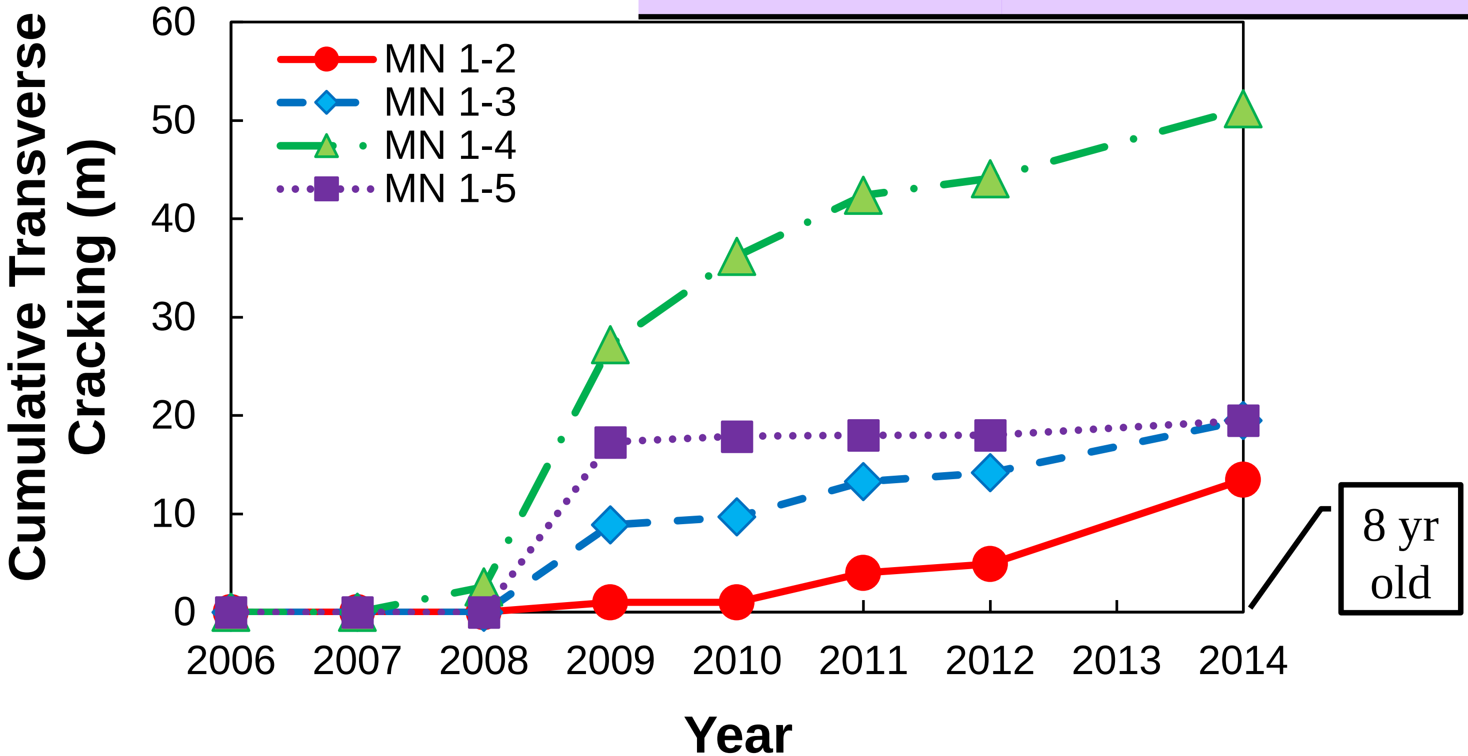
Binder ID	PG-grade	Binder Source	Modification
MN 1-2	PG 58-34	Canadian Blend	Terpolymer
MN 1-3	PG 58-28	Canadian Blend	N/A
MN 1-4	PG 58-28	Middle East Blend	REOB
MN 1-5	PG 58-28	Venezuelan Blend	N/A

- 8% REOB in MN 1-4, by XRF (FHWA-TF)
- MN 1-2 *PG 58-34* was produced by (Elvaloy + PPA) modification of a *PG 52-34* base binder came from a blend of Canadian crudes similar to the MN 1-3 *PG 58-28*

Minnesota Sections

- **Rochester, MN**
  - Field Performance

Binder ID	Binder Source	Modification
MN 1-2	Canadian Blend	Terpolymer
MN 1-3	Canadian Blend	N/A
MN 1-4	Middle East Blend	REOB
MN 1-5	Venezuelan Blend	N/A



2006-2012 Data was collected by WRI, 2014 Data was obtained from (M. Corrigan, 2016)

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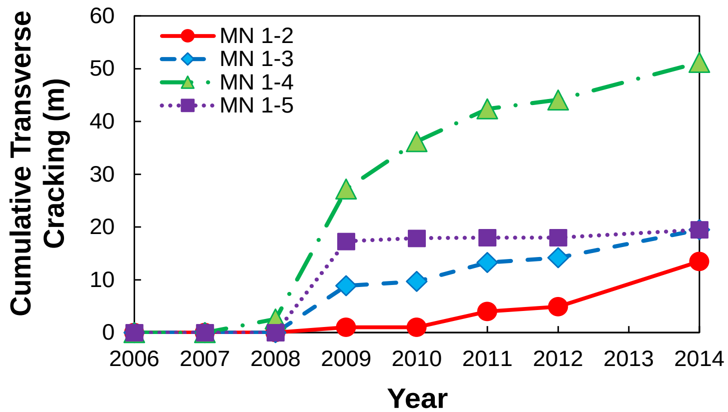
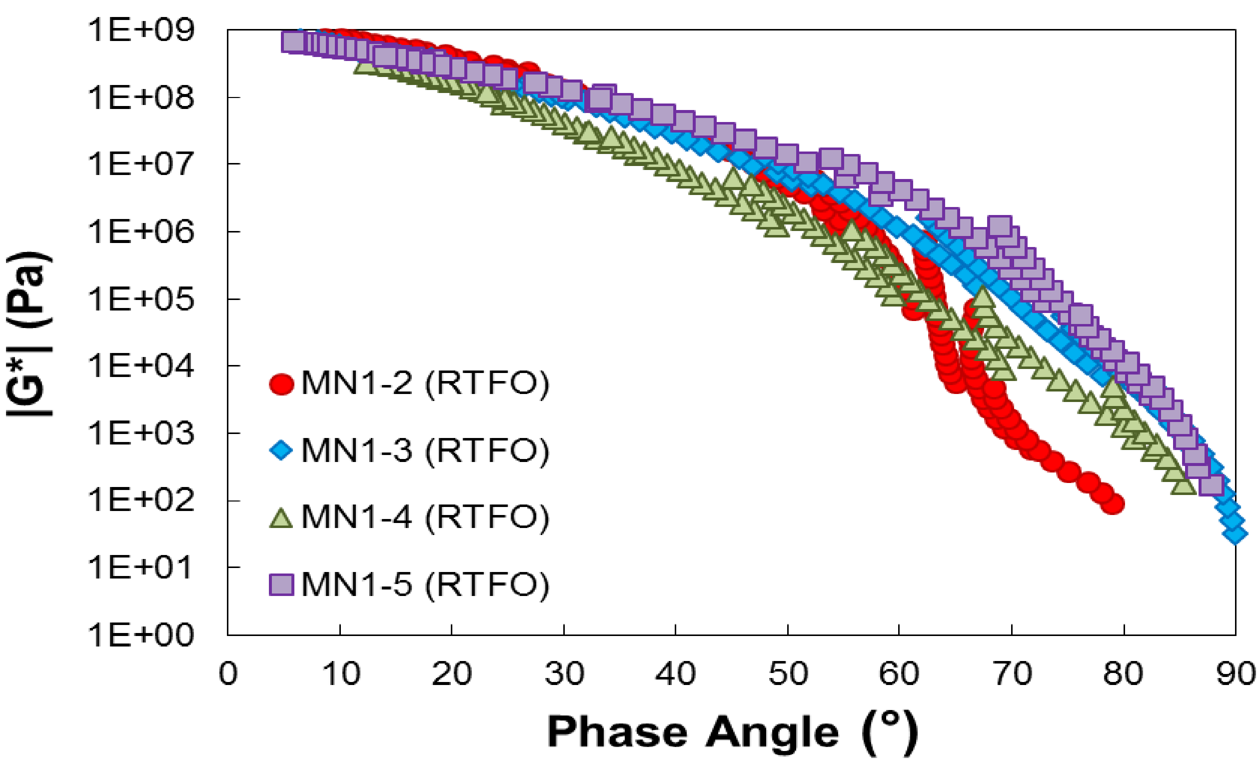
Minnesota Sections

- **Rochester, MN**
  - Black Space (RTFO)

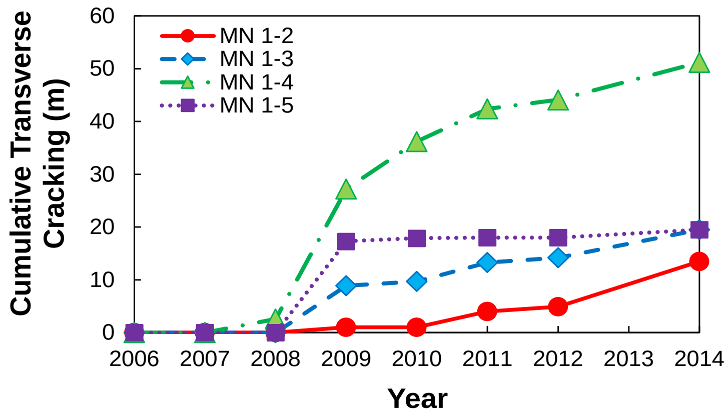


Binder ID
MN 1-2 (CA Blend / Terp.)
MN 1-3 (CA Blend)
MN 1-4 (M.E. Blend / REOB)
MN 1-5 (Ven. Blend)



Minnesota Sections

- Rochester, MN
  - Black Space (PAV 40H)



Binder ID
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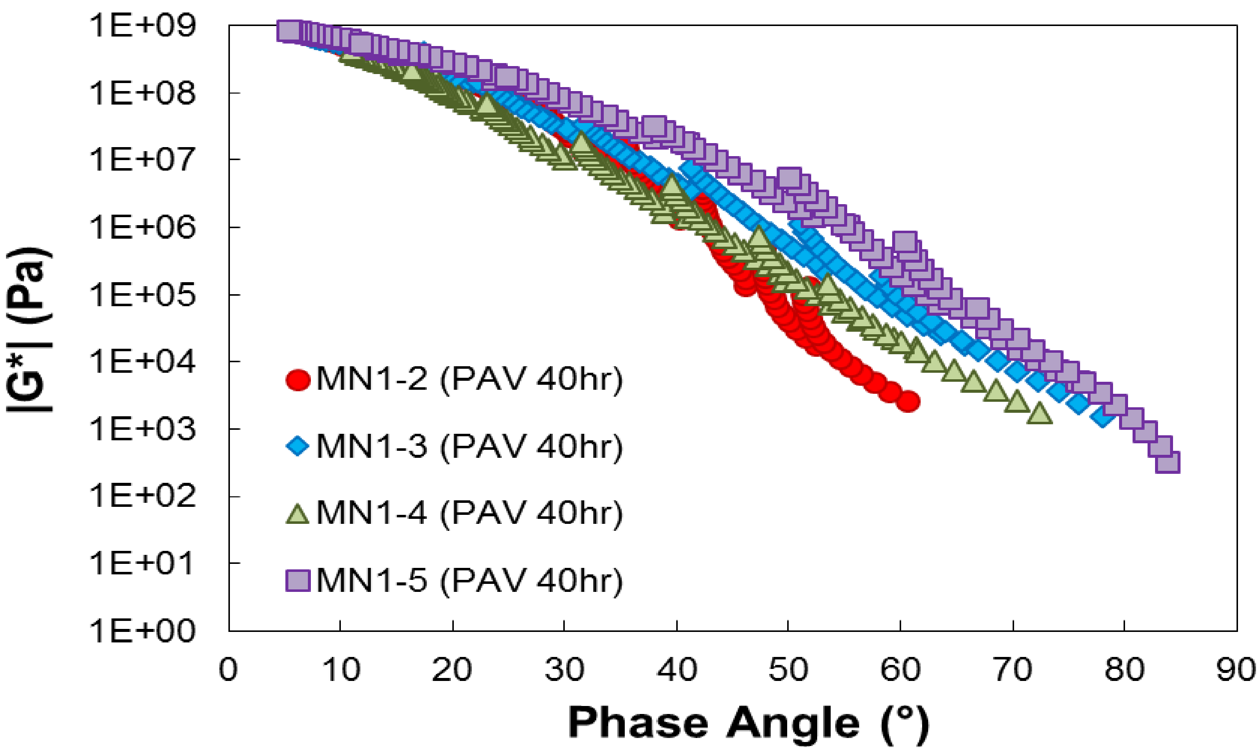
MN 1-3 (CA Blend)
MN 1-4 (M.E. Blend / REOB)
MN 1-5 (Ven. Blend)



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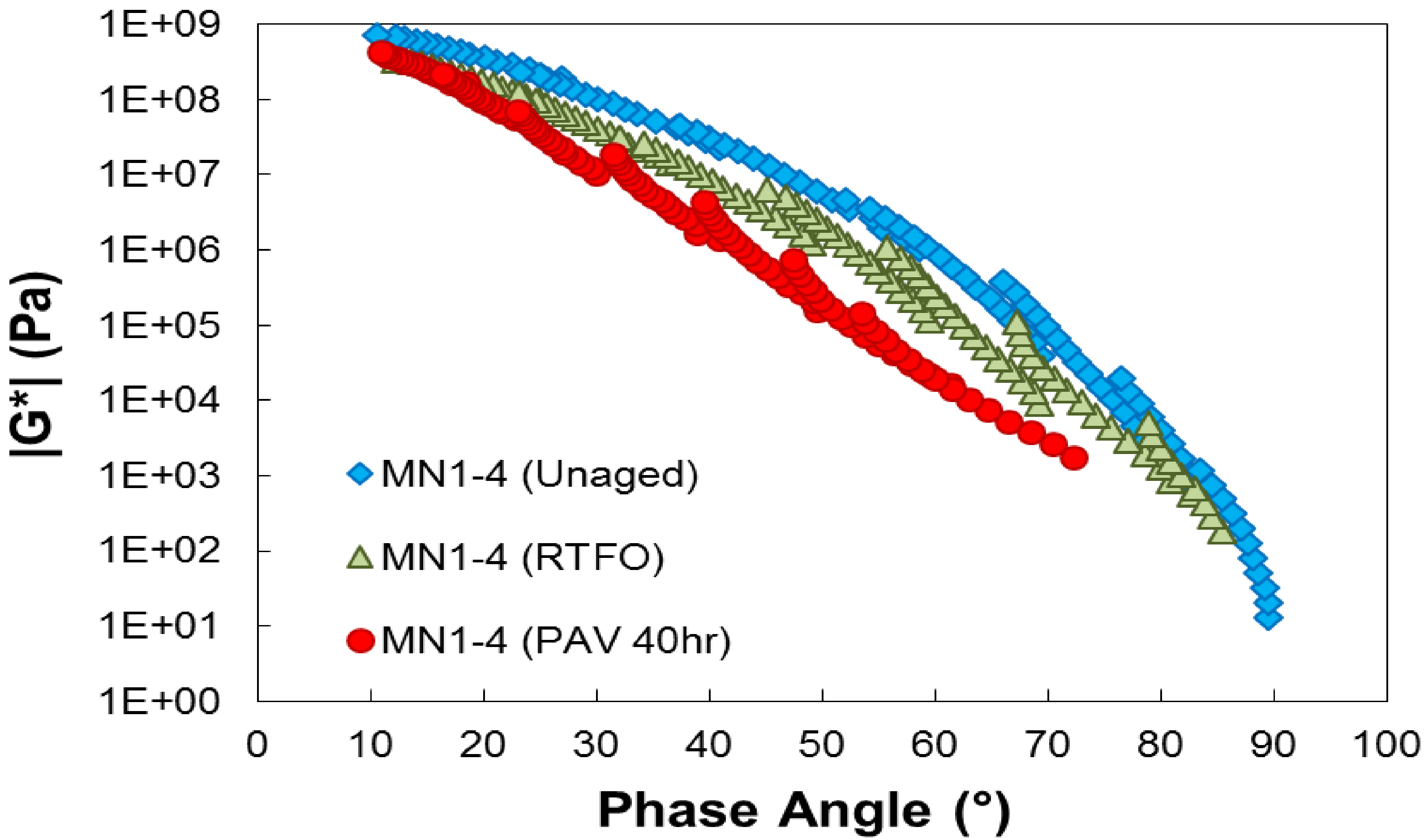
Minnesota Sections

Oxidative Aging Effect

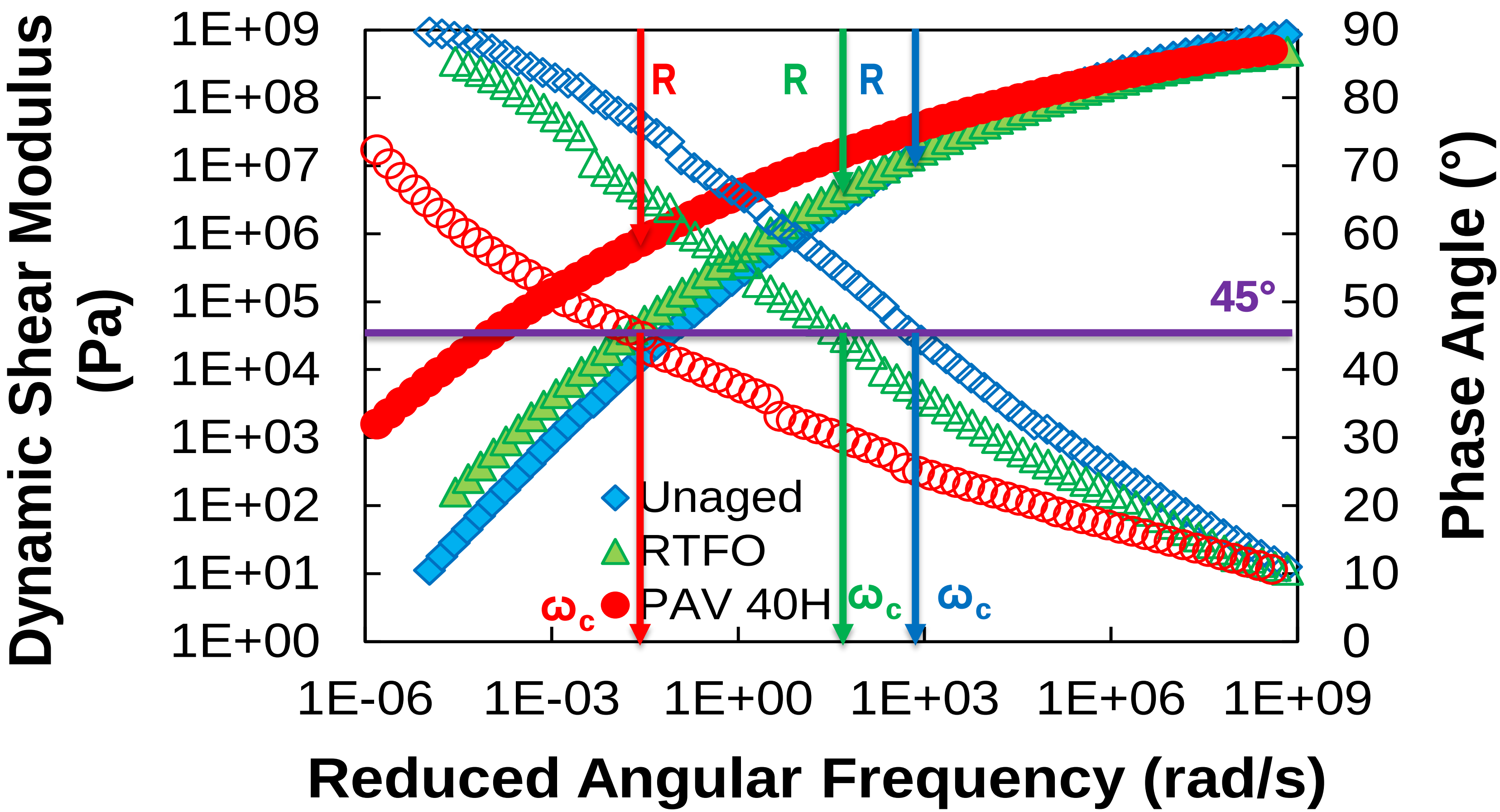
- Black Space – MN (1-4)



Minnesota Sections

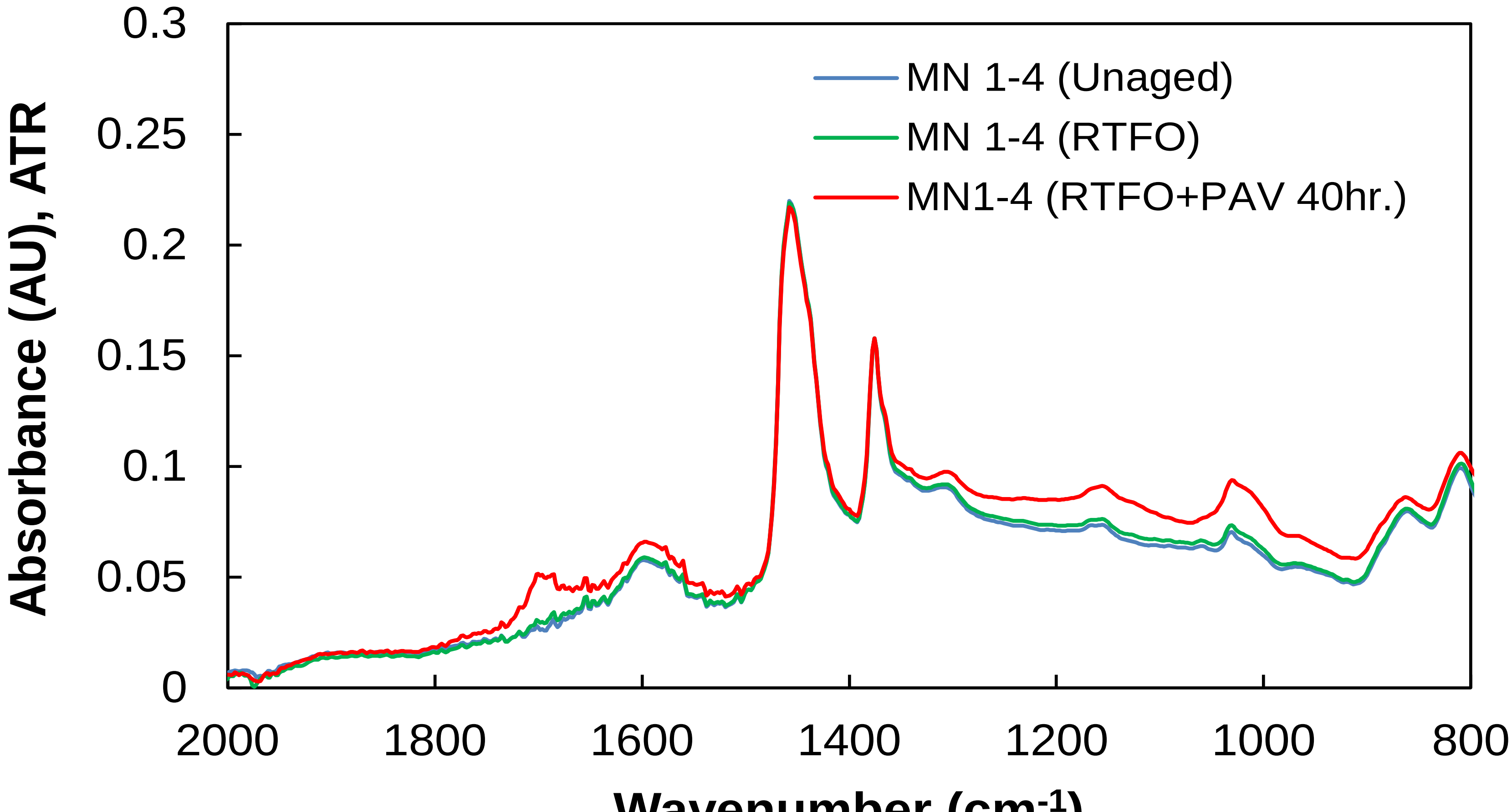
❑ Oxidative Aging Effect

- Mastercurve– MN (1-4)



Oxidative Aging Effect

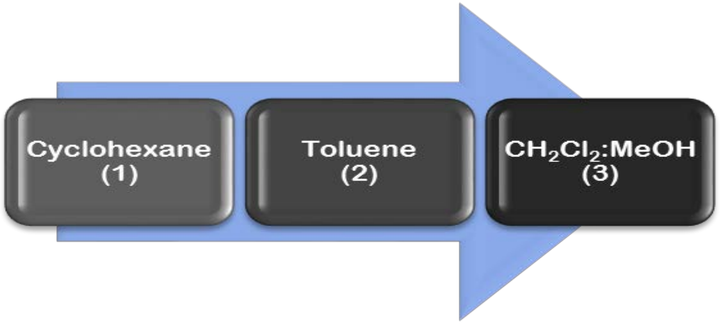
- FT-IR (ATR) – MN (1-4)

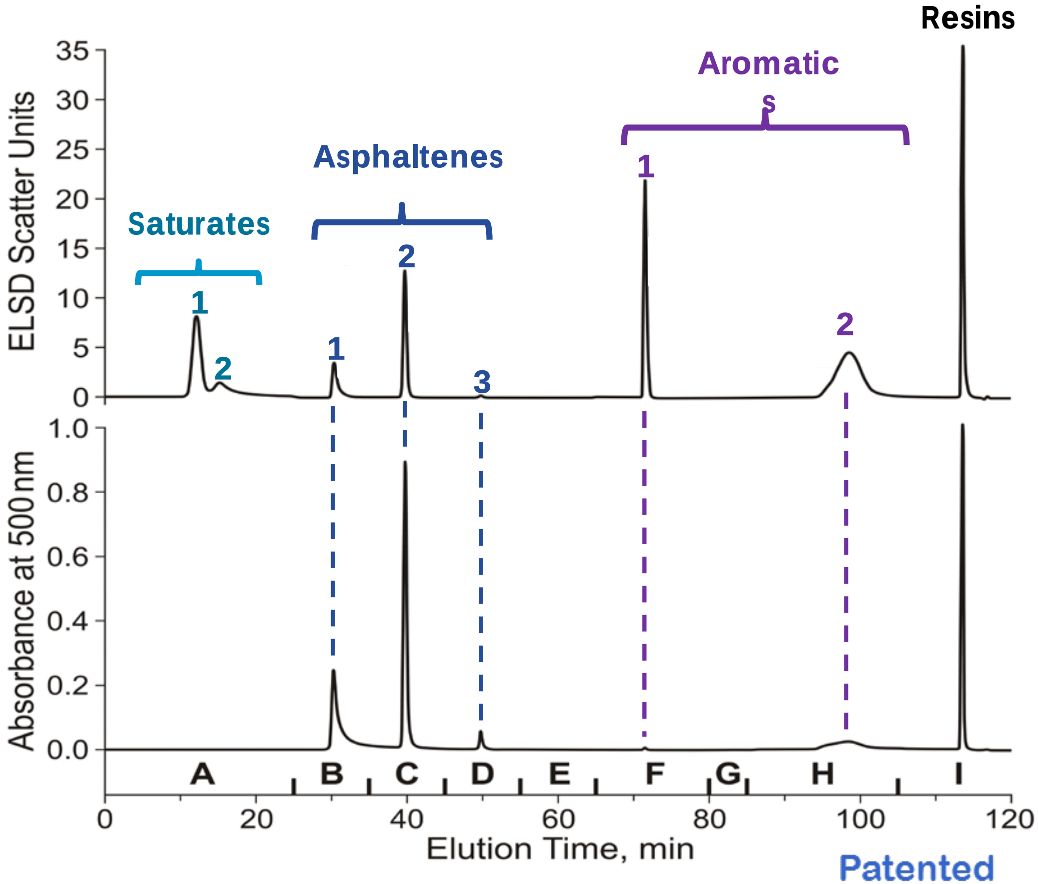


SAR-AD™

❑ Saturates, Aromatics, Resins – Asphaltene Determinator

- Fully automated SAR separation (Chromatography) coupled to AD asphaltene fractionation (Solubility)

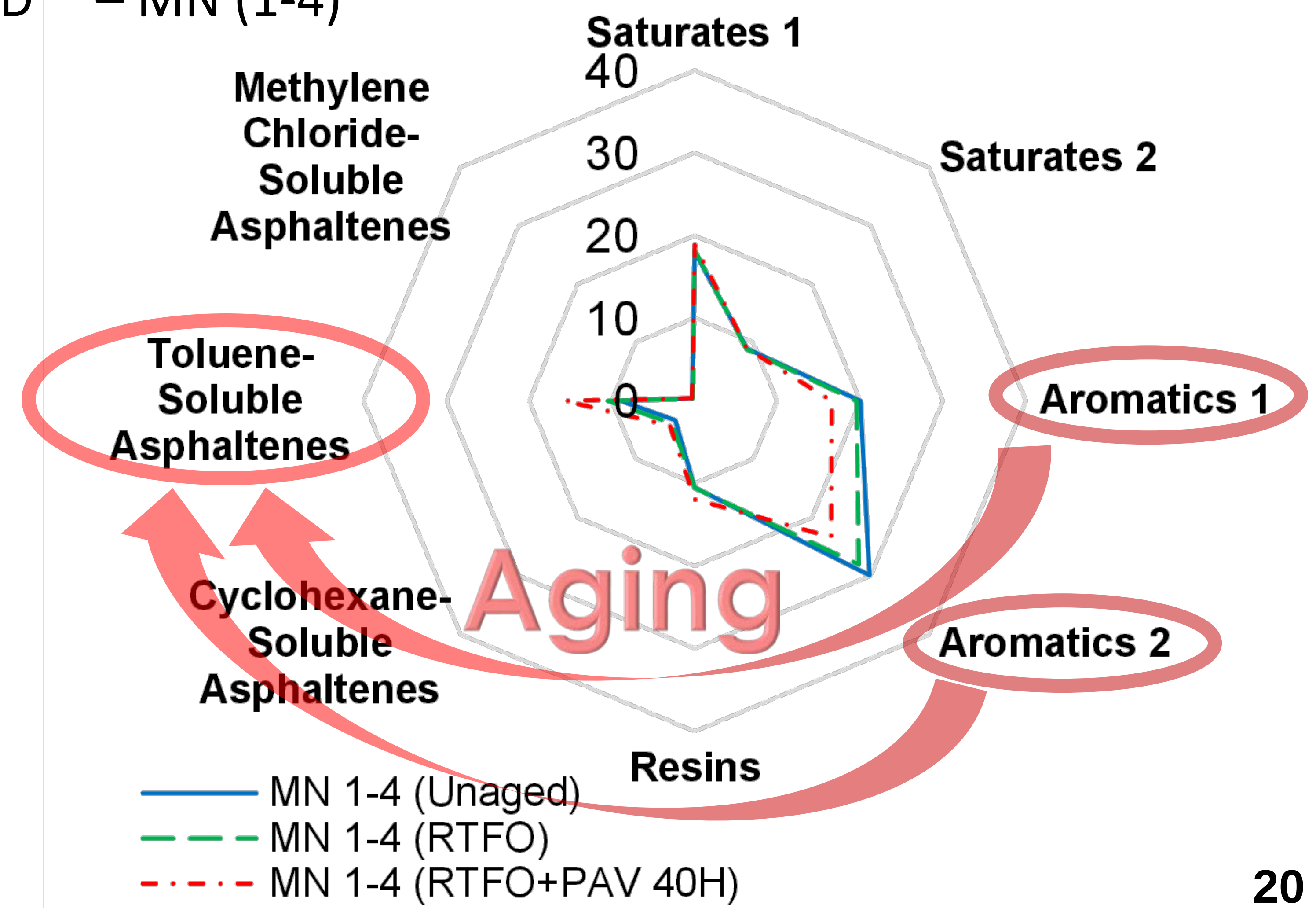




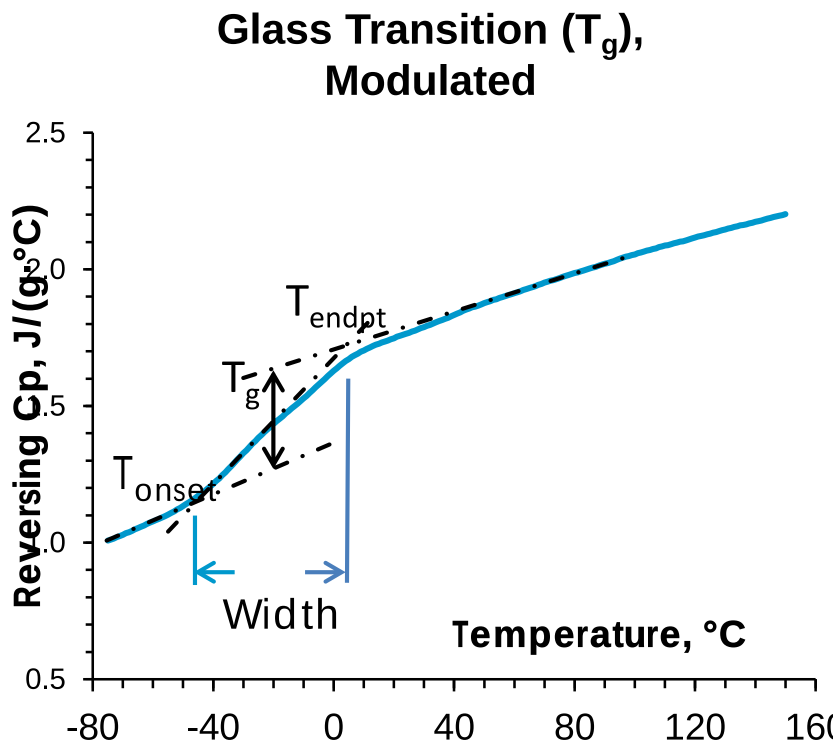
Patented

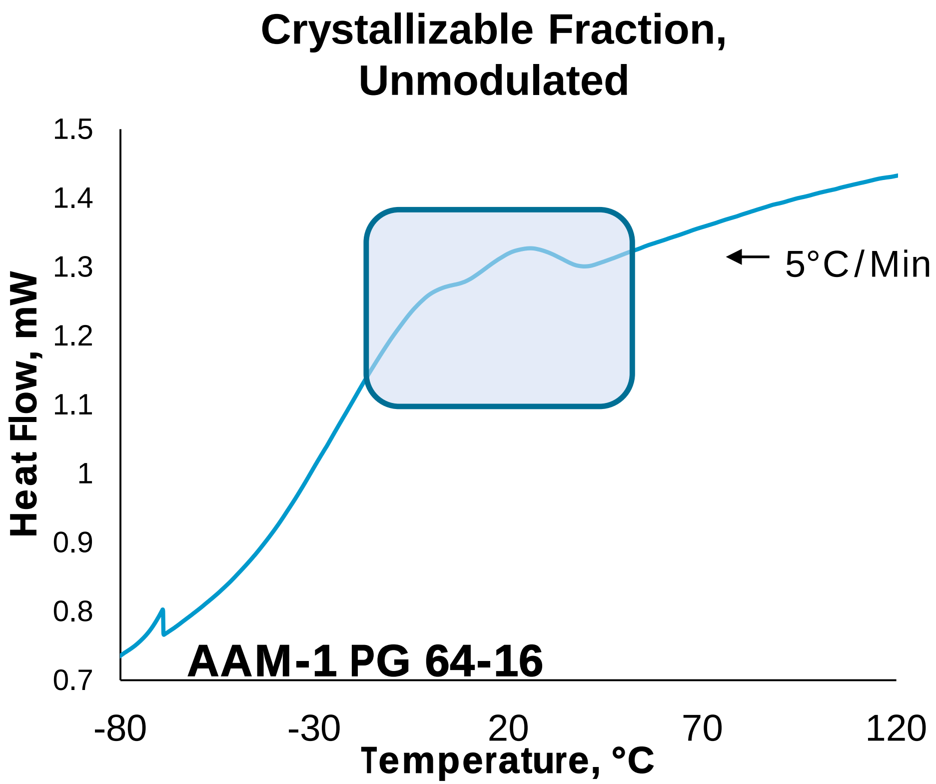
Oxidative Aging Effect

- SAR-AD™ – MN (1-4)



❑ Differential Scanning Calorimetry (DSC)

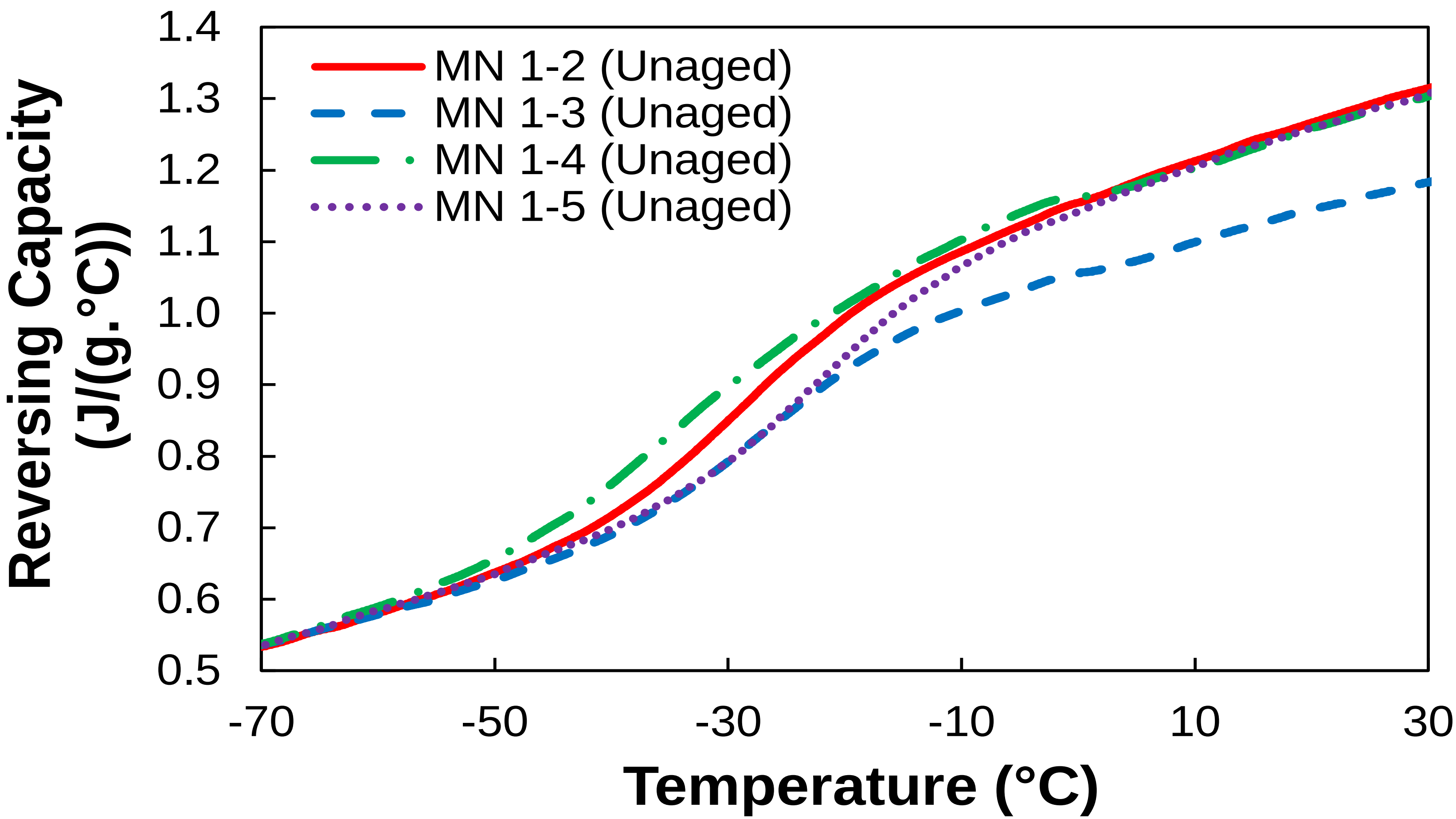




Minnesota Sections

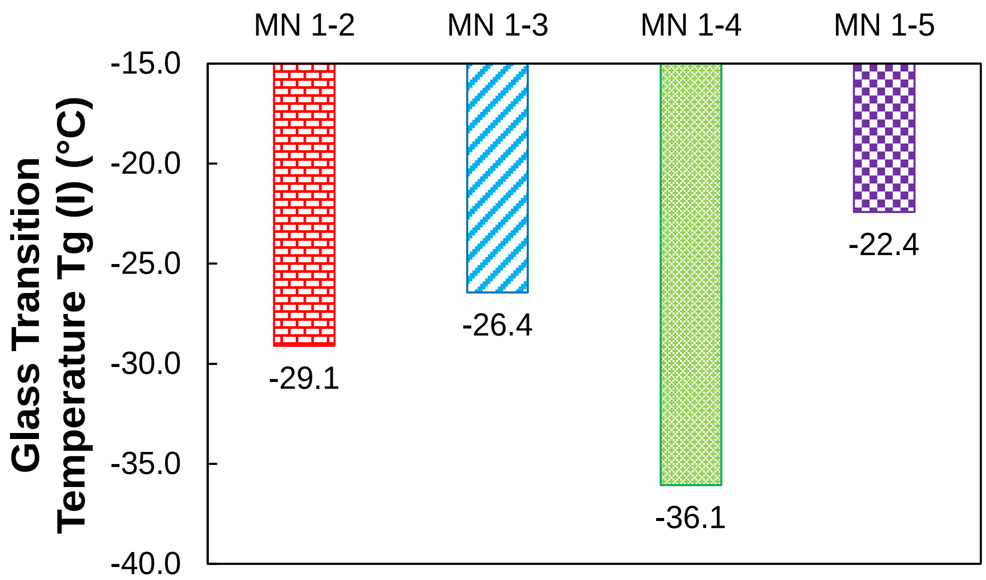
Rochester, MN

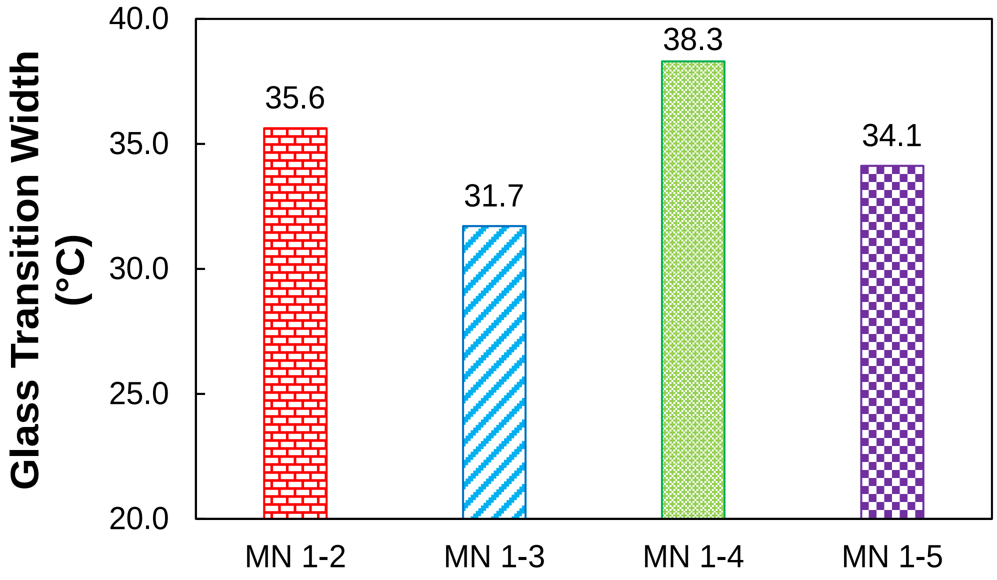
- Glass Transition (DSC) – Modulated Heating (2°C/min)



Minnesota Sections

- **Rochester, MN**
  - Glass Transition (DSC) (Unaged)

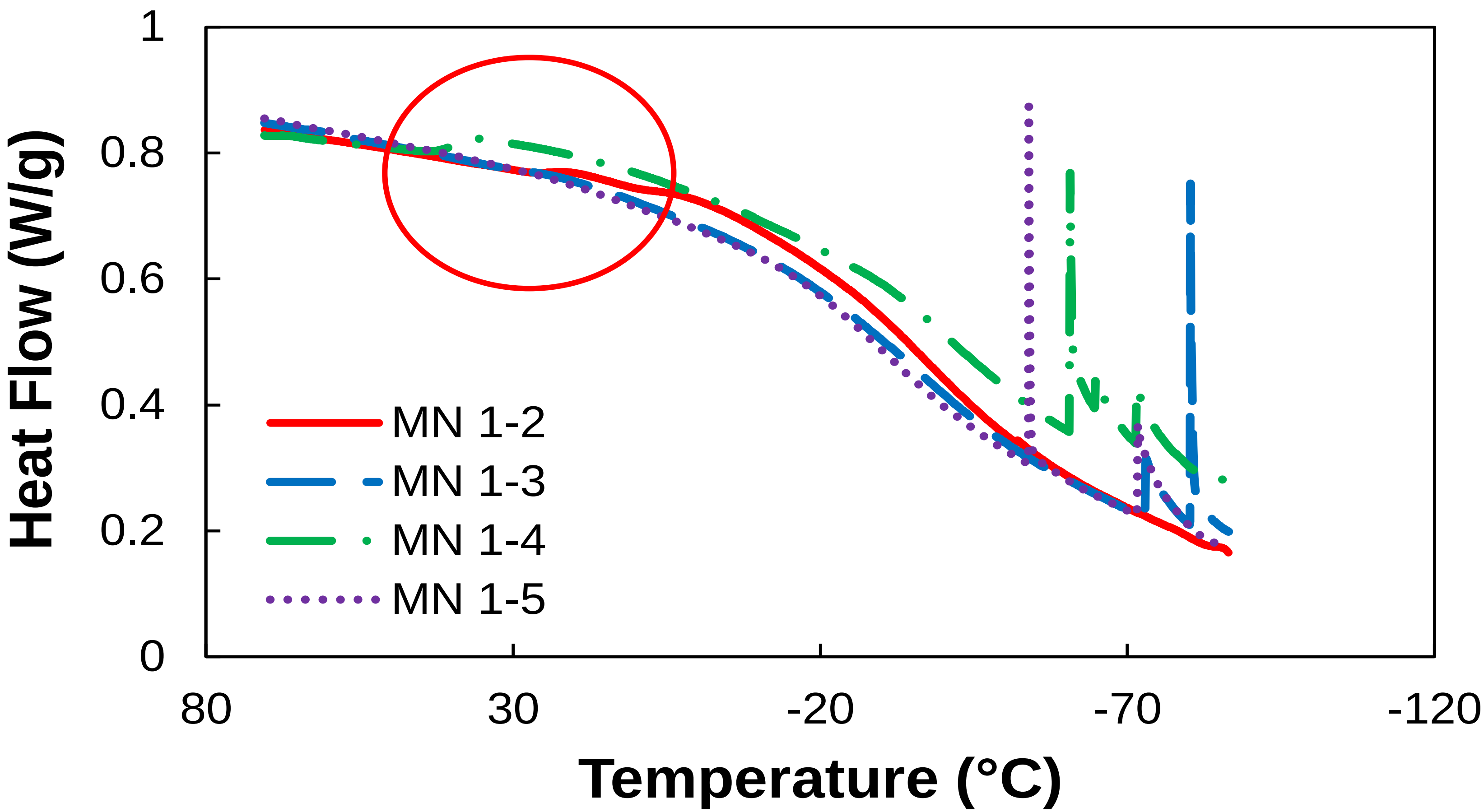




Minnesota Sections

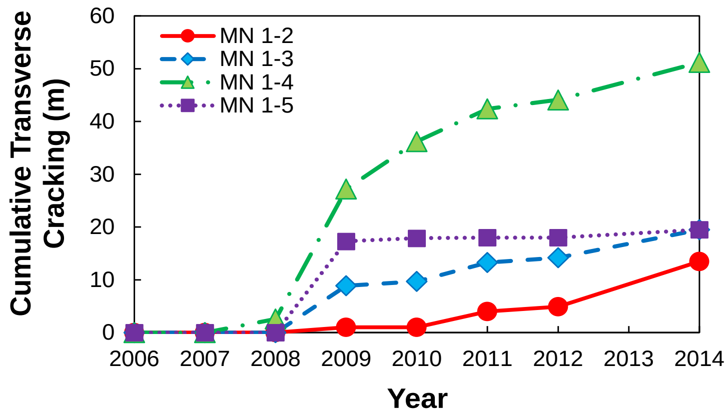
❑ Rochester, MN

- Glass Transition (DSC) – Unmodulated Cooling (-5°C/min)

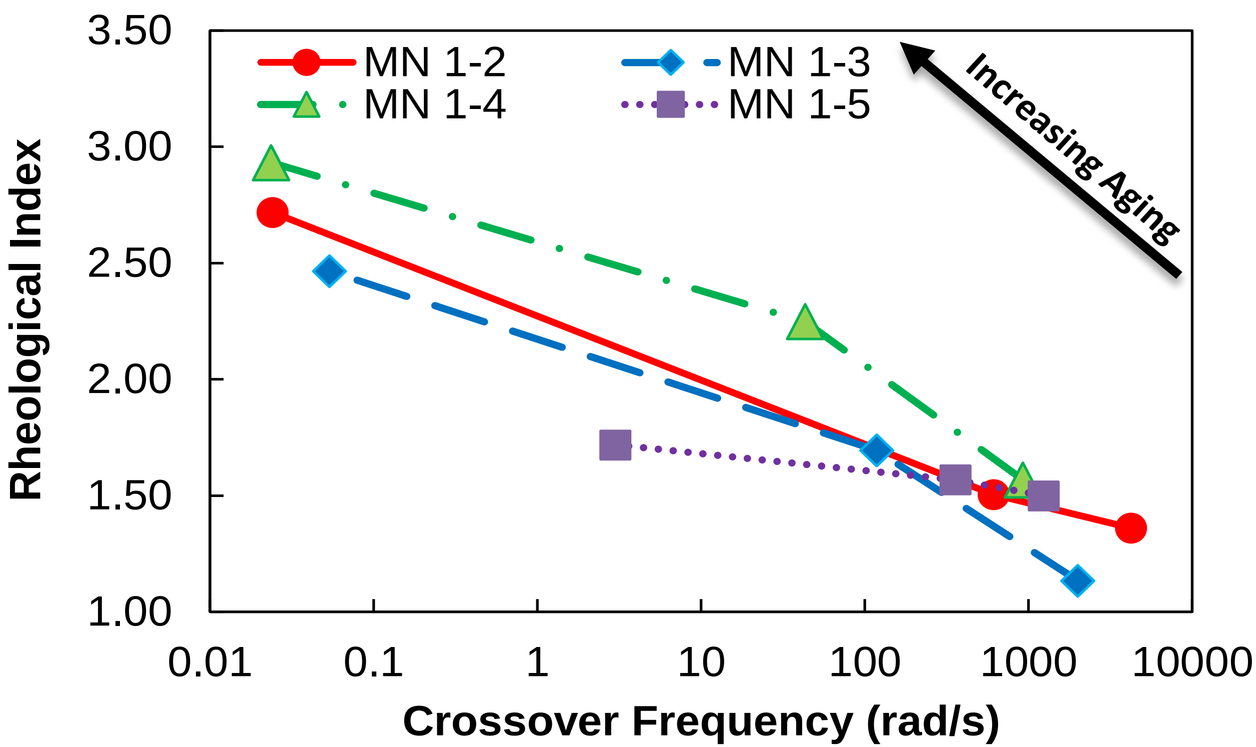


Minnesota Sections

- **Rochester, MN**
  - R vs. ω_c (Fresh, RTFO, PAV 40H)

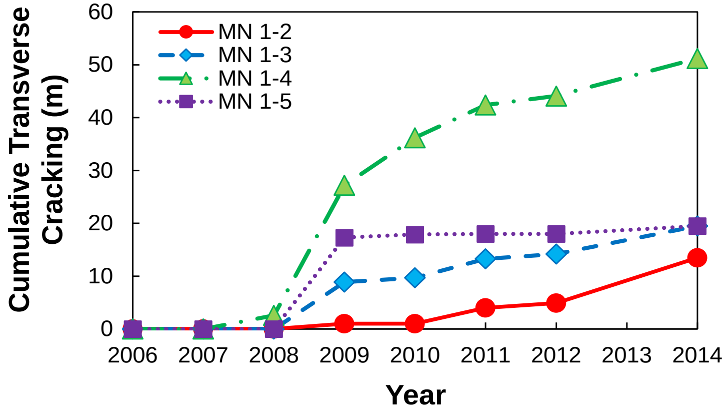


Binder ID
MN 1-2 (CA Blend / Terp.)
MN 1-3 (CA Blend)
MN 1-4 (M.E. Blend / REOB)
MN 1-5 (Ven. Blend)



Minnesota Sections

- **Rochester, MN**
  - G-R Parameter (Fresh, RTFO, PAV 40H)



Binder ID
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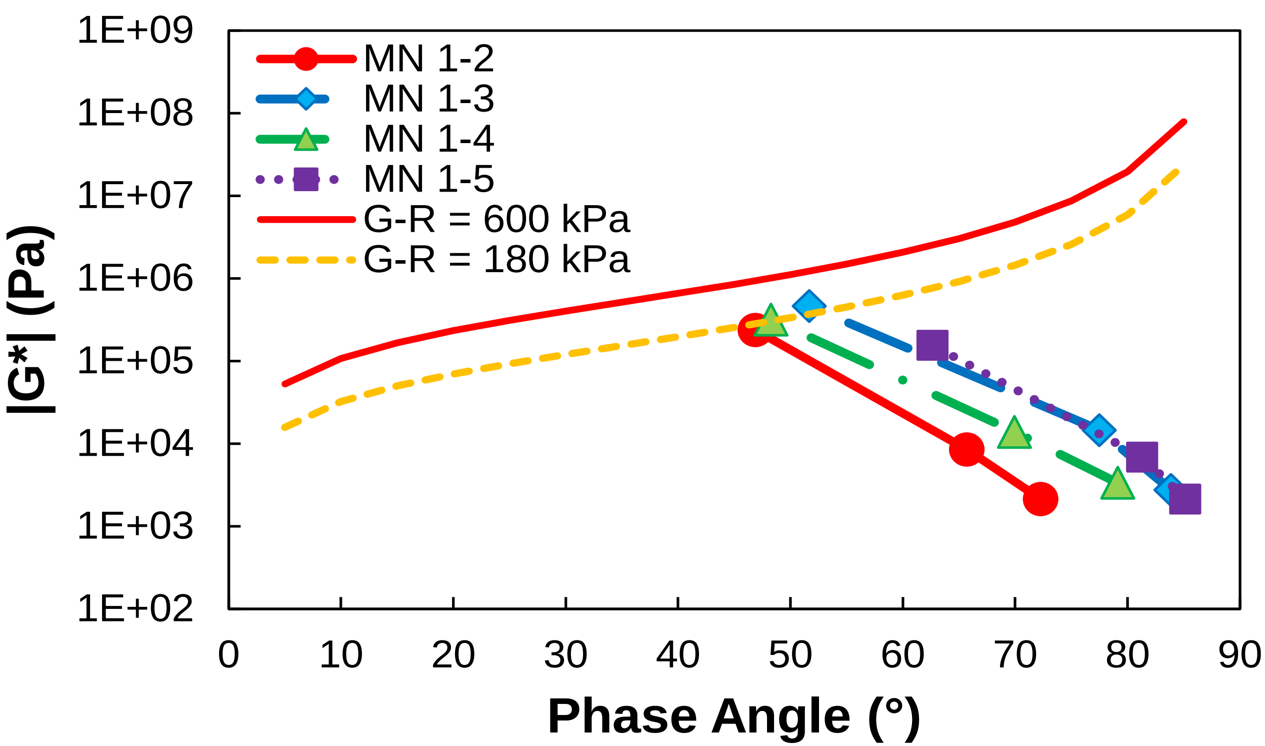
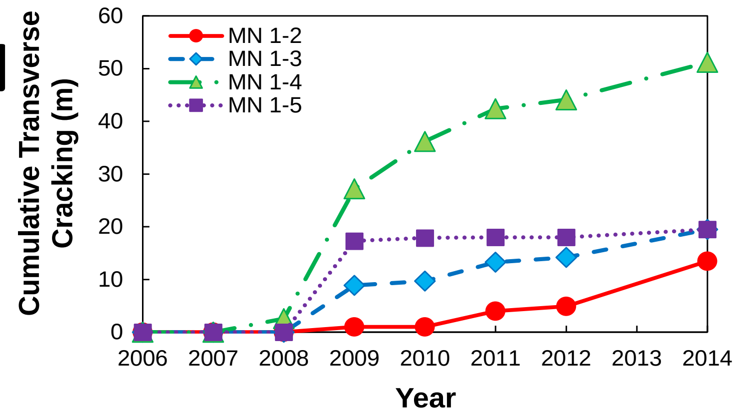
MN 1-3 (CA Blend)
MN 1-4 (M.E. Blend / REOB)
MN 1-5 (Ven. Blend)



Minnesota Sections

- **Rochester, MN**
  - ΔT$_c$, 4mm-DSR (PAV 40H)



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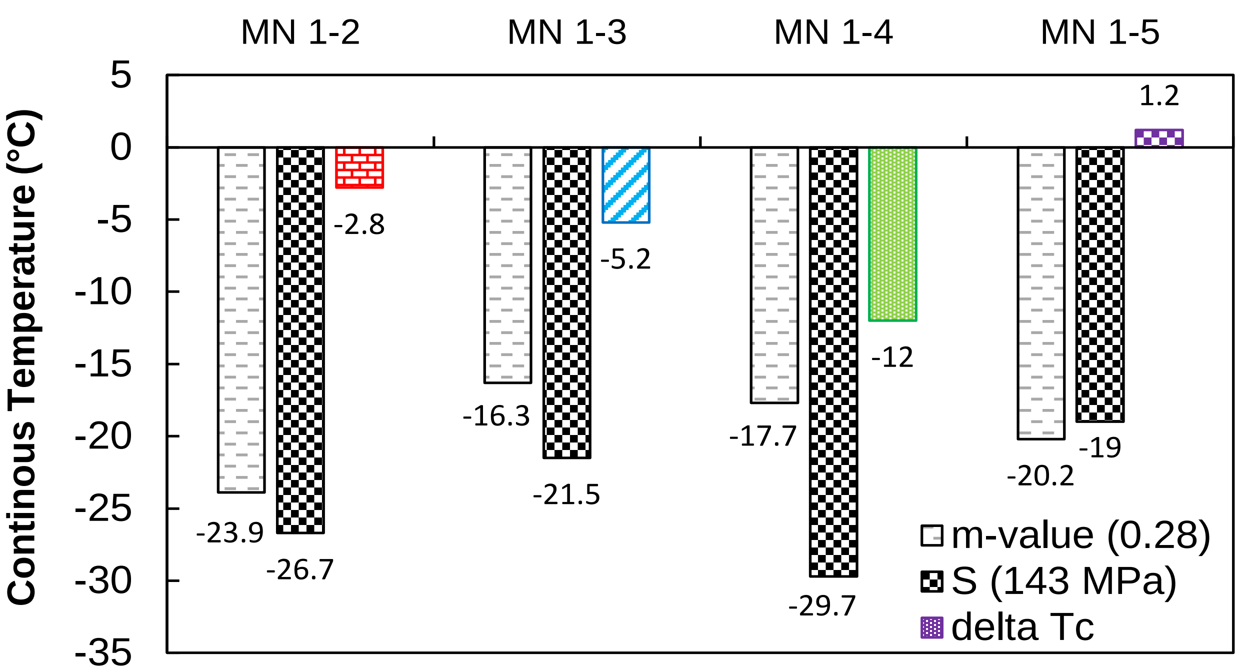
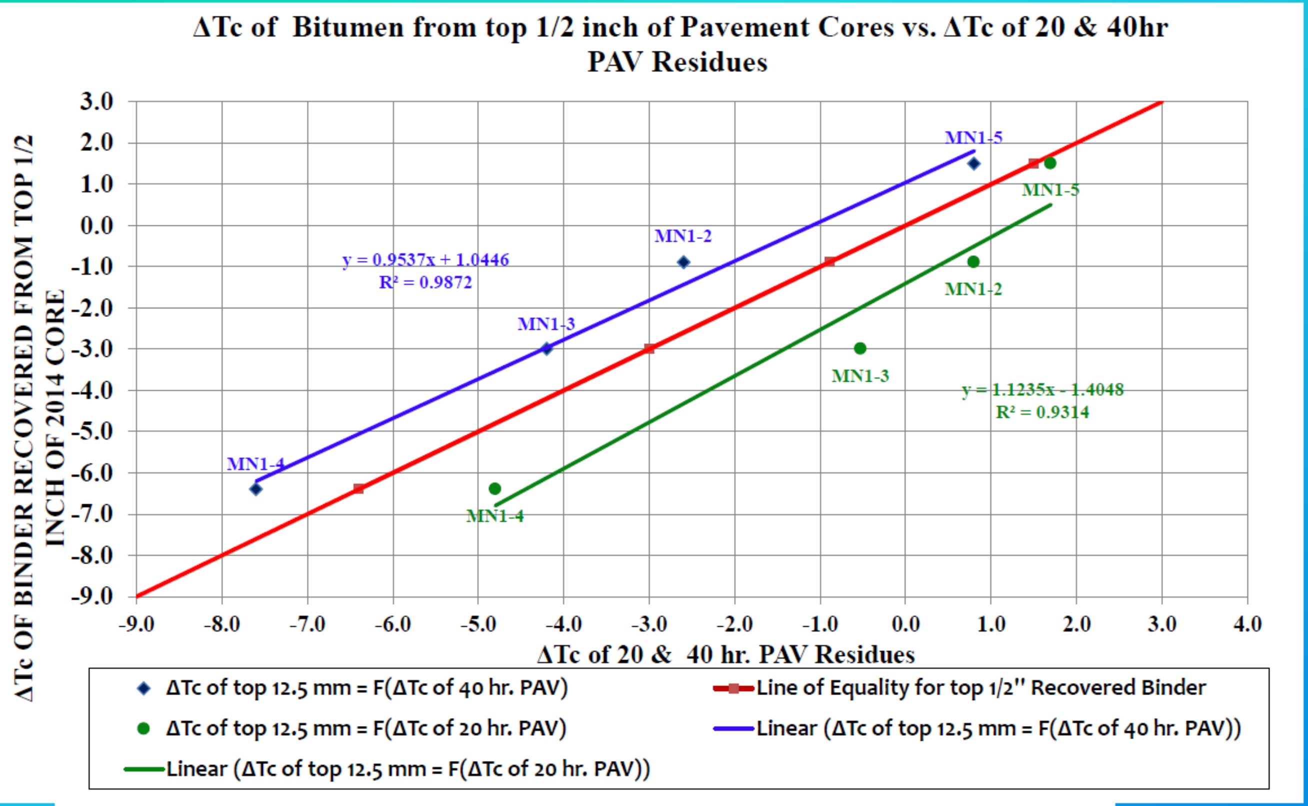
MN 1-3 (CA Blend)
MN 1-4 (M.E. Blend / REOB)
MN 1-5 (Ven. Blend)



Existing Data

Lab aged binder ΔT_c vs. extracted binder ΔT_c



ΔTc OF 20 HR. PAV UNDER PREDICTS THE ΔTc VALUE OF 8 YEAR FIELD CORE BINDER (TOP ½”) TO A SLIGHTLY GREATER EXTENT THAN THE 40 HR. PAV OVERPREDICTS THE ΔTc VALUE

(G. Reinke, 2017)

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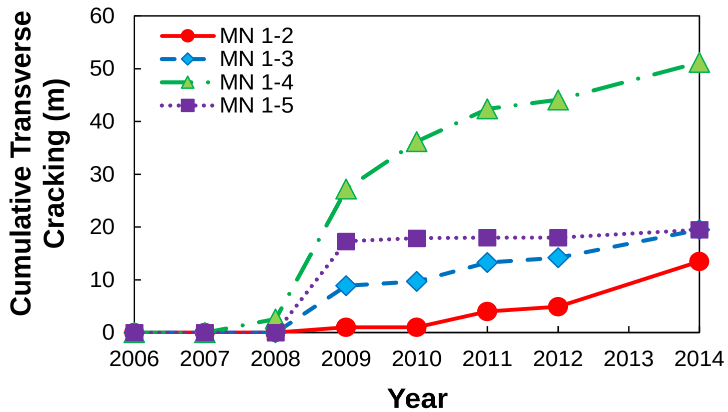
Minnesota Sections

❑ Rochester, MN

- ➢ ABCD Test (PAV 40H) -10°C/min



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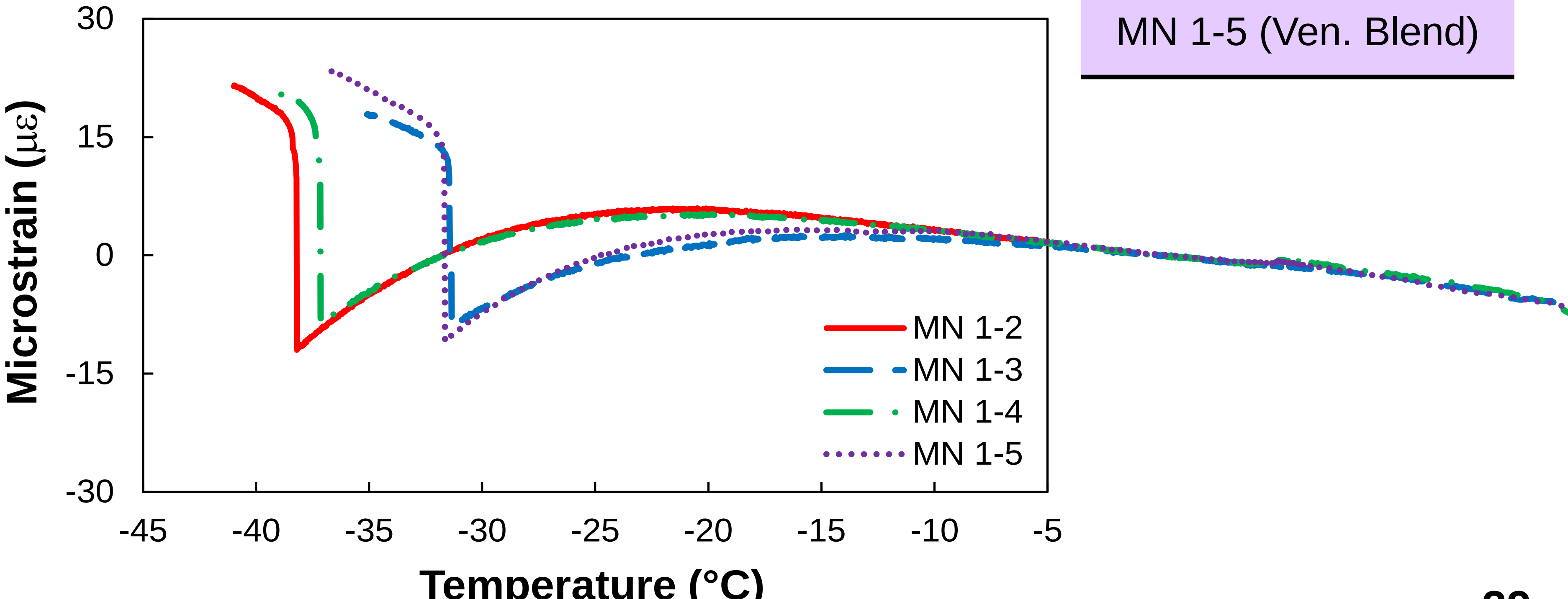

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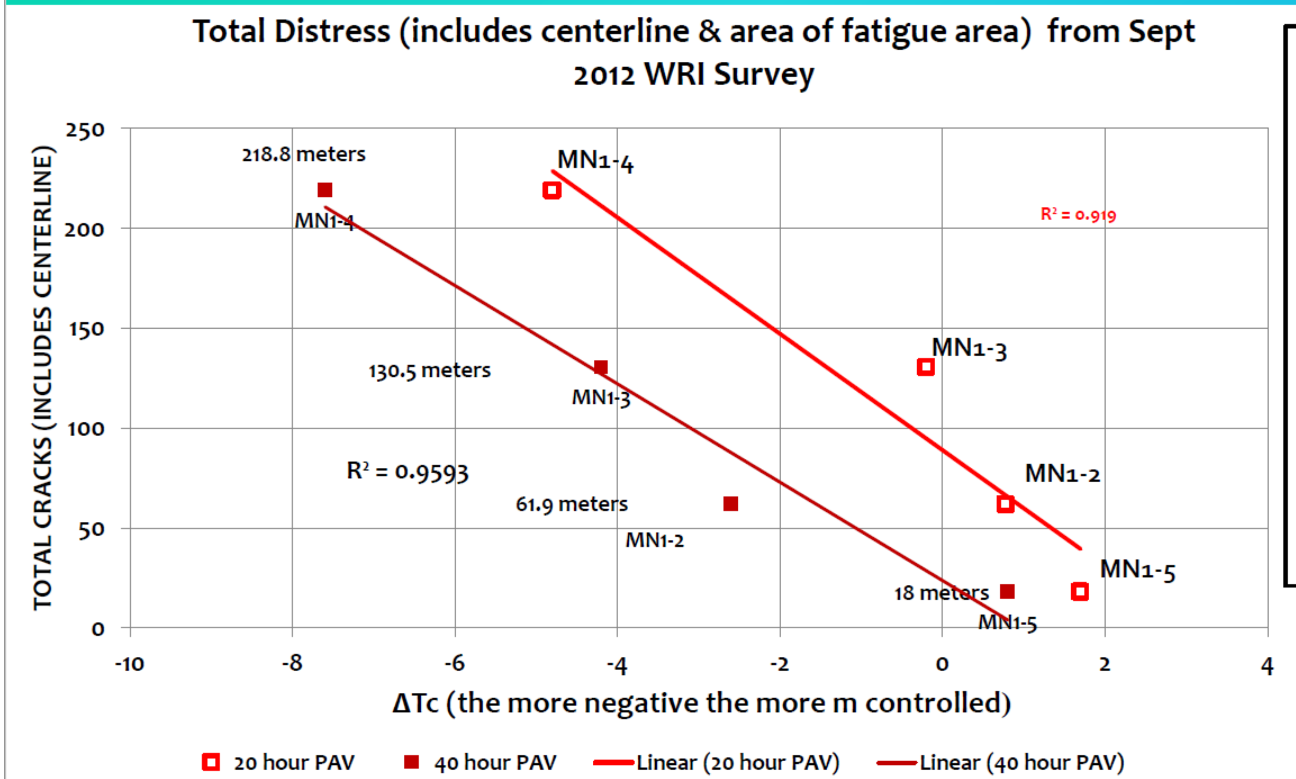
Existing Data

❑ Total Cracks (6 yr) vs. ΔT_c – Rochester, MN Sections

CORRELATION BETWEEN ΔTc OF 20 & 40 HOUR PAV AND CRACKS IN 2012 FOR OLMSTED CTH 112



COMMENTS

1. Plot of ΔTc for 20 and 40 hour PAV residues versus the amount of cracking after 6 years of service
2. The correlation is slightly better for the 40 hour PAV data than the 20 hour data
3. Regardless of the ΔTc values there is a strong correlation between worsening pavement performance and worsening ΔTc

MN1-4	PG 58-28 Arab heavy/Arab medium/Kirkuk blend
MN1-3	PG 58-28 Canadian blend
MN1-5	PG 58-28 Venezuelan blend
MN1-2	PG 58-34 PMA based on Canadian blend

(G. Reinke, 2017)

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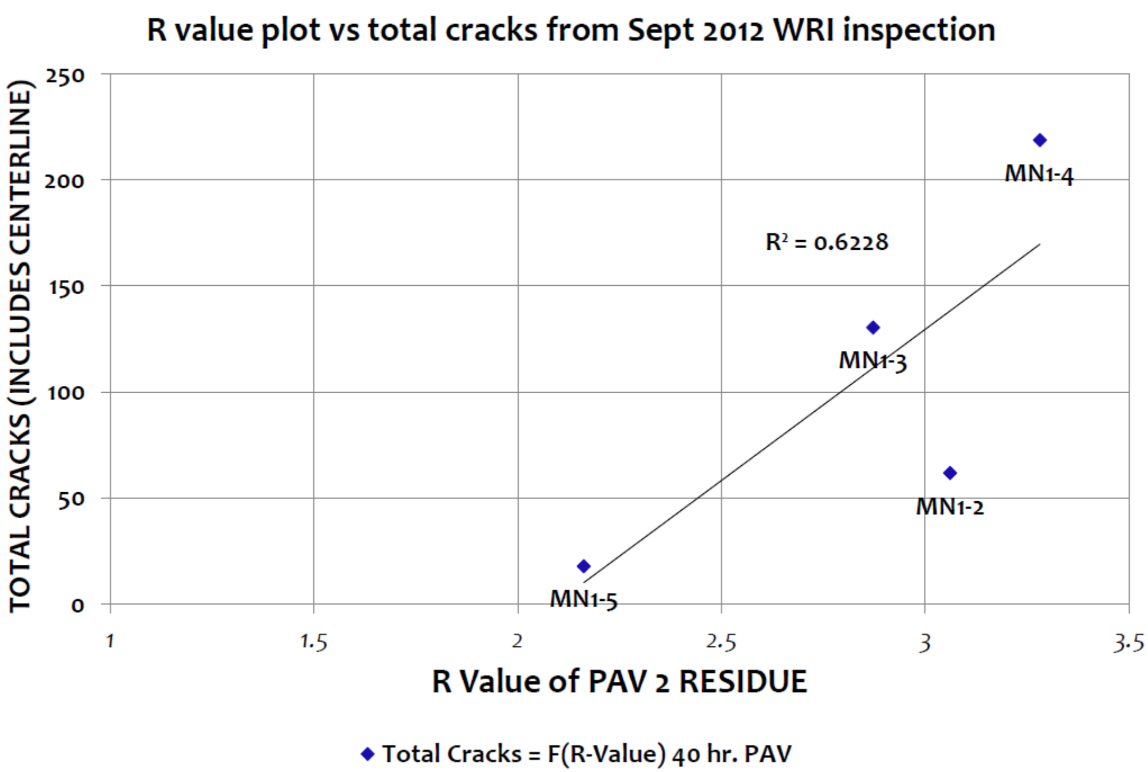
Existing Data

❑ Total Cracks (6 yr) vs. R Value – Rochester, MN Sections

CORRELATION BETWEEN R-VALUE OF 40 HOUR PAV AND CRACKS IN 2012 FOR OLMSTED CTH 112



MN1-4	PG 58-28 Arab heavy/Arab medium/Kirkuk blend
MN1-3	PG 58-28 Canadian blend
MN1-5	PG 58-28 Venezuelan blend
MN1-2	PG 58-34 PMA based on Canadian blend

COMMENTS

1. The correlation between R-Value and total cracking for the 4 virgin test sections is not good
2. This is because the R-Value for the PMA section (MN1-2) does not follow the same trend line as the unmodified PG 58-28 binders
3. Visually one can see that the R-Value versus cracking for the 3 PG 58-28 binders is quite good
4. One of the strengths of comparing binders based on ΔTc is that it is little affected by differences in binder grade of formulation, whereas R-Value is

(G. Reinke, 2017)

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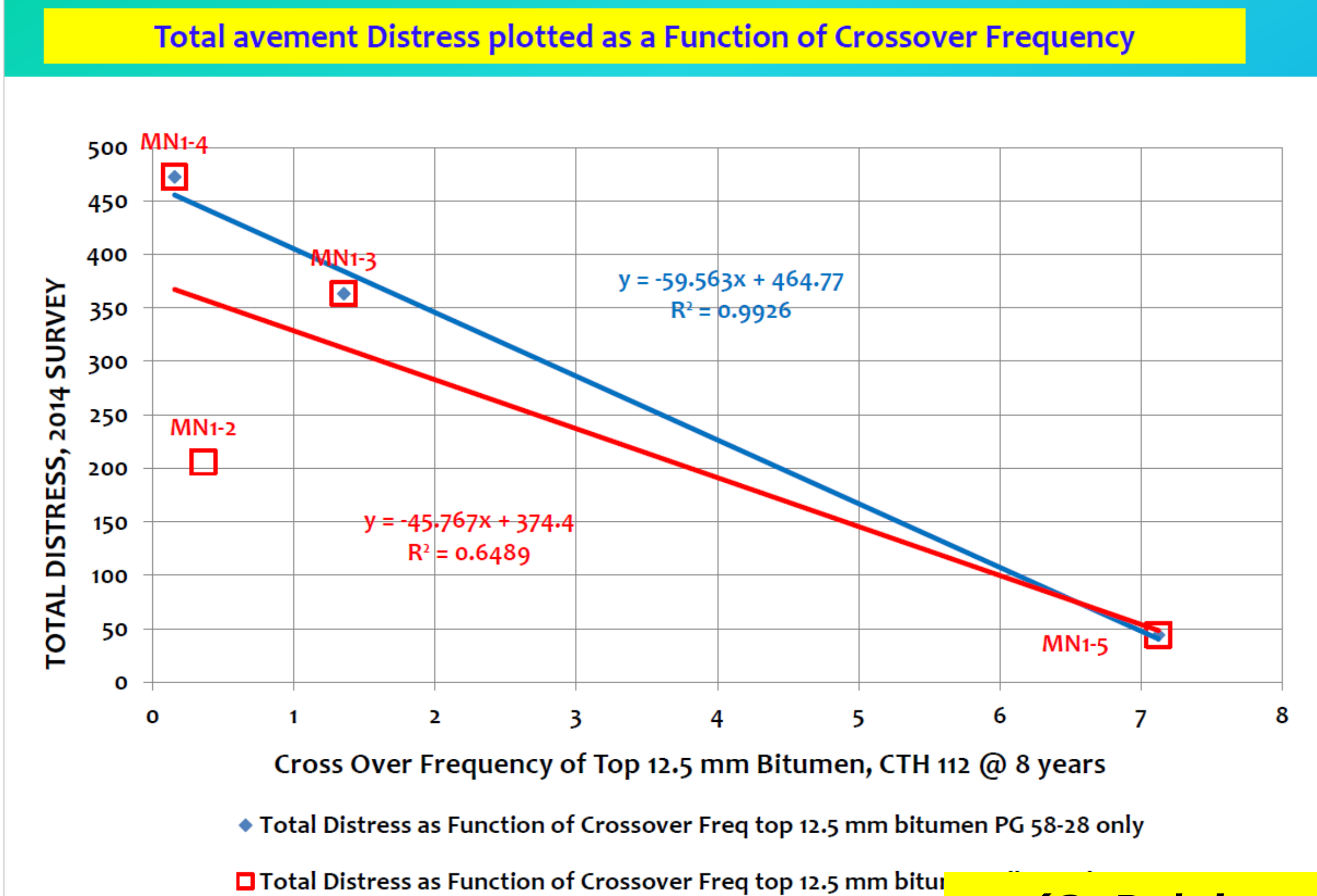
Existing Data

❑ Total Cracks (8 yr) vs. ω_c – Rochester, MN Sections



COMMENTS

1. It stands to reason that if R-Value is does not correlate well to pavement performance that crossover frequency would not given that one of the inputs for R-Value is crossover frequency.
2. MN1-2 has a crossover frequency slightly better than MN1-4, the worst performer.
3. Crossover frequency correlates strongly for the non-modified binders even though they are from 3 distinct crude sources.
4. Crossover frequency does not correlate across different binder formulations

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(G. Reinke, 2017)

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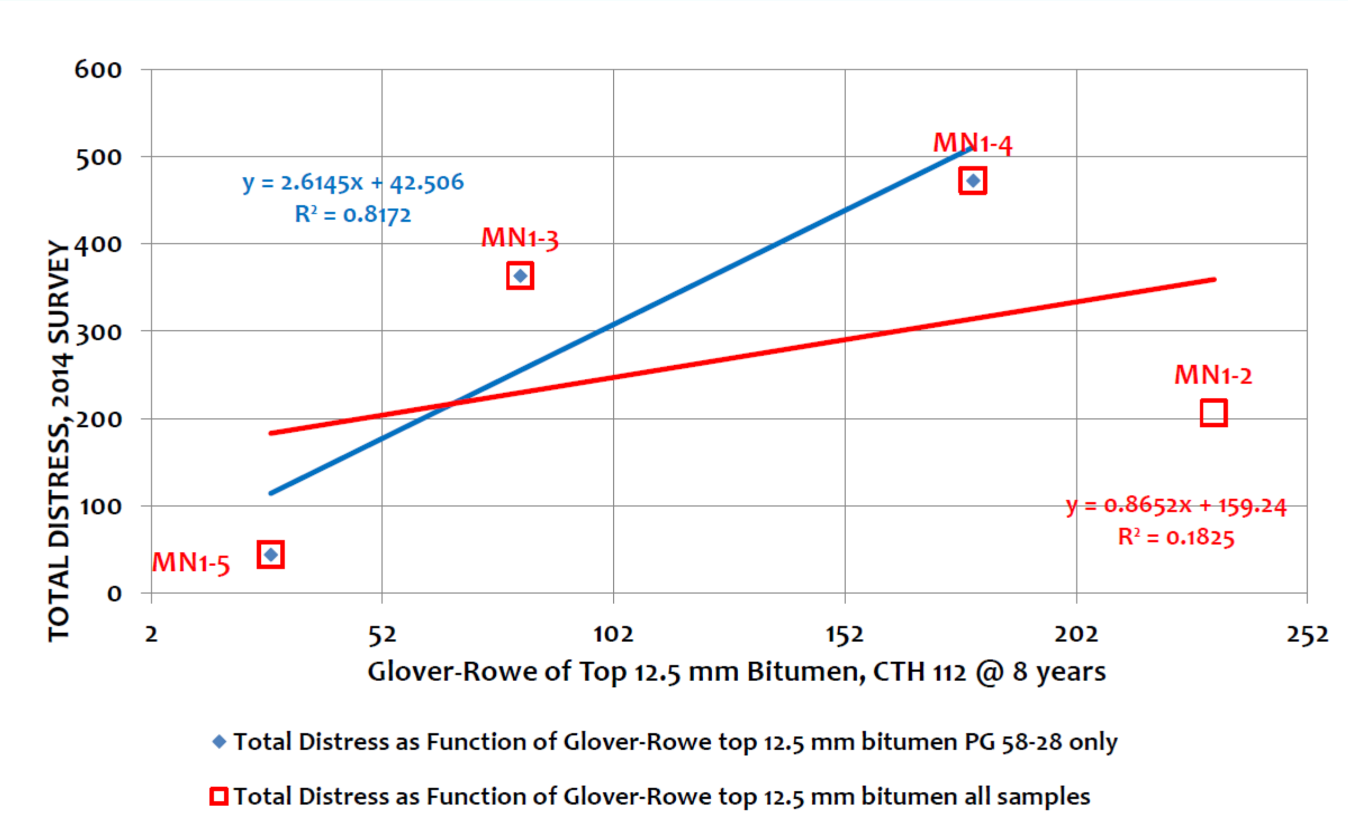
Existing Data

❑ Total Cracks (8 yr) vs. G-R – Rochester, MN Sections



COMMENTS

1. This is a plot of the slope of the Glover-Rowe parameter vs total pavement distress on CTH 112.
2. Due to modification MN1-2 has the highest G* value at 15°C and a crossover frequency only slightly higher than MN1-4 and ultimately has the worst Glover-Rowe value even though its pavement distress is 2nd best of all binders
3. The correlation of Glover-Rowe for the non modified PG 58-28 mixtures is reasonable at R^2=0.82

(G. Reinke, 2017)

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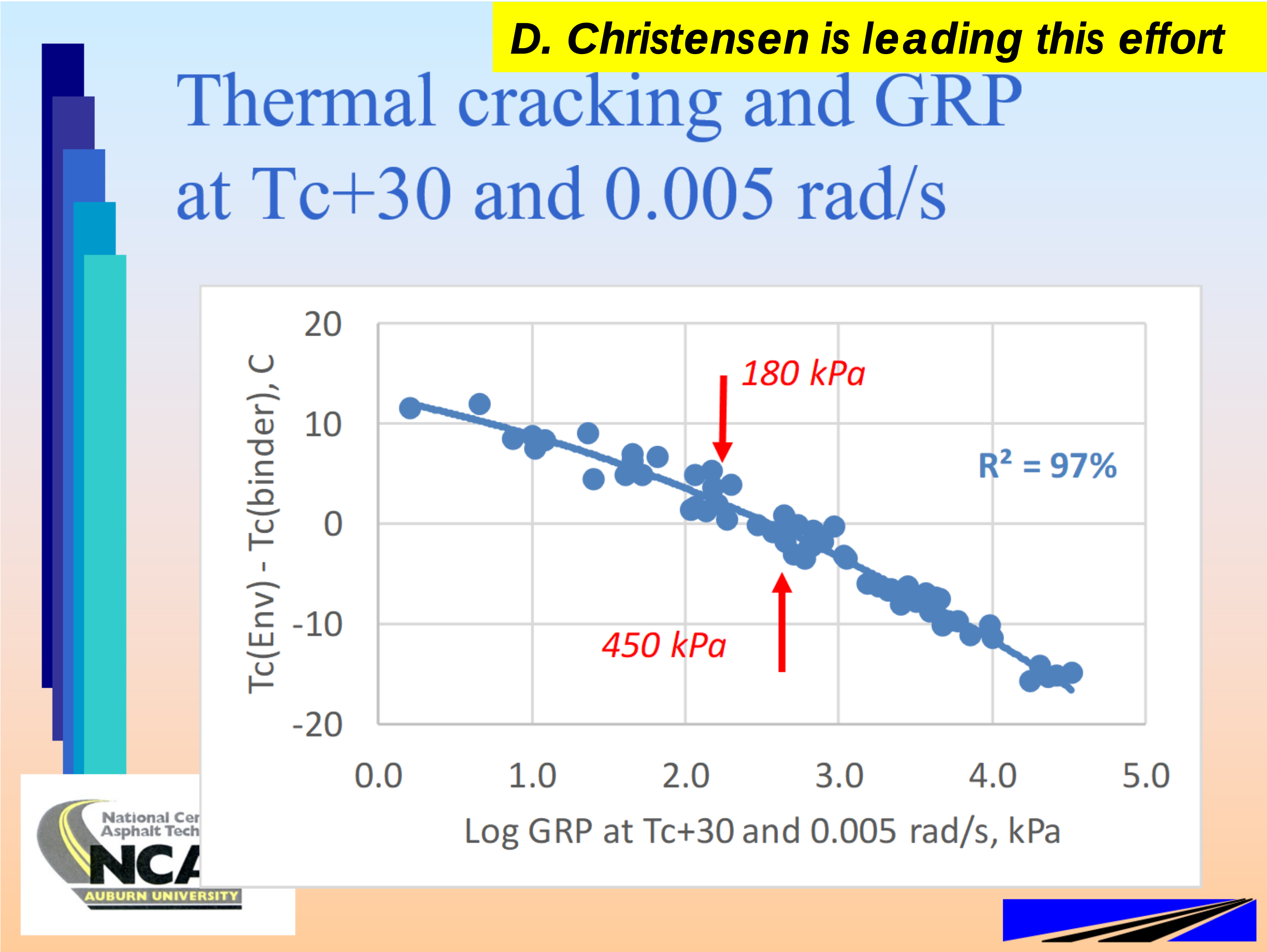
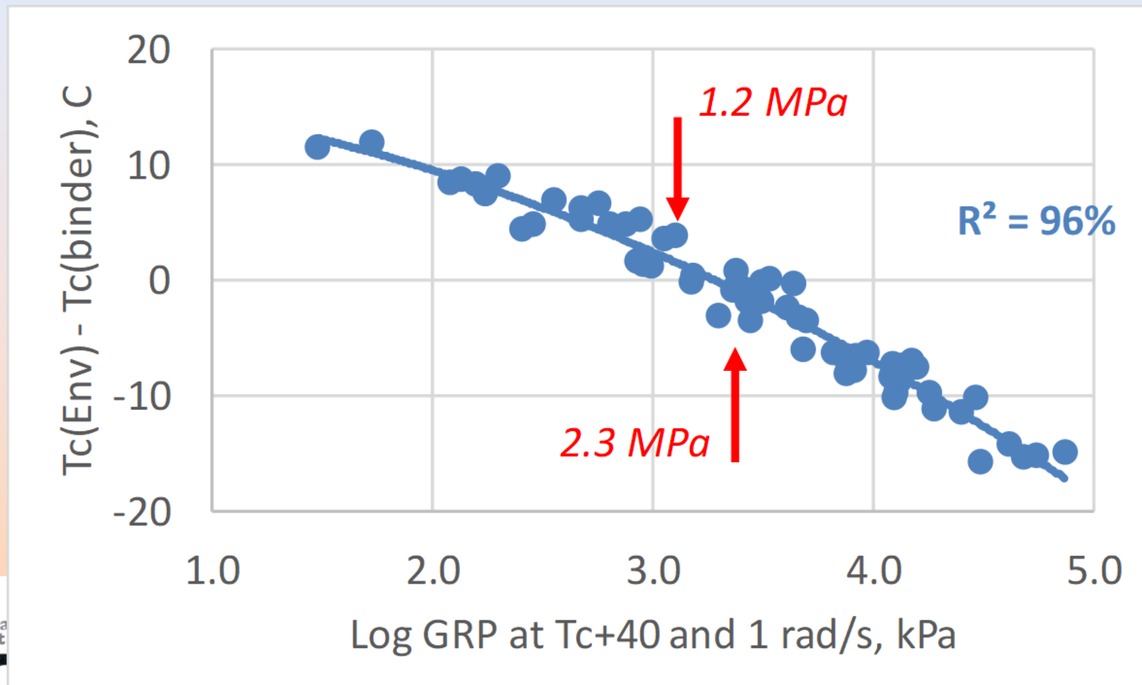
Evaluation / Modification of G-R Parameter



❑ Evaluation / Modification of G-R Parameter

D. Christensen is leading this effort

Thermal cracking and GRP at Tc+40 and 1 rad/s



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Summary of The Interim Findings

- Black Space is an important tool to evaluate binder performance. The shape of black space curve is meaningful – polymer plateau, structural “feathers”, … etc.
- ΔT_c is a reliable rheological index that can capture the effect of various modification (e.g., REOB). Other indices are still under investigation.
- Low glass transition temperature (before aging) (e.g., T_g < -35 for MN 1-4) does not directly indicate good performance at low temperature.
- (T_{cr}) from ABCD test may not directly correlate with field performance. Further analysis is required to evaluate different strain tolerance at low temperature.

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Summary of The Interim Findings

- **Binder performance will be further studied using SDENT, DTT, and Mix Sliver Tests, among others.**
- **These results “confirm or deny” previous ones and are intermediary only – current findings are based on MN sections and may change based on future results – stay tuned!**

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References

- Corrigan, M. (2016) "REOB: ETG Status and Emerging Knowledge", NCAUPG meeting, Indianapolis, IN.
- Planche, J.P.; Turner, F.; Farrar, M.; Glaser, R.; Grimes, W.; Boysen, R.; Pauli, T. (2015) "Blended REOB Binder Advanced Chemical & Physical Characterization:, Binder ETG, Fall River, MA.
- Reinke, G. (2017) "The Relationship of Binder Delta Tc (ΔTc) to Mixture Fatigue", SEAUPG meeting, Jacksonville, FL.
- Rowe, G. (2011) "Prepared Discussion Presented in Response to M. Anderson, et al., AAPT, V. 80, 2011".
- Anderson, R.M.; King, G.N.; Hanson, D.I.; Blankenship, P.B. (2011) "Evaluation of the Relationship between Asphalt Binder Properties and Non-Load Related Cracking. AAPT, V. 80, pp. 615-649.
- King, G.; Anderson, M.; Hanson, D.; and Blankenship, P. (2012) "Using Black-Space Diagrams to Predict Age-Induced Cracking. RILEM Fatigue Cracking Conference. Delft, June.

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