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Asphalt Binder Characteristics Affecting Durability Cracking

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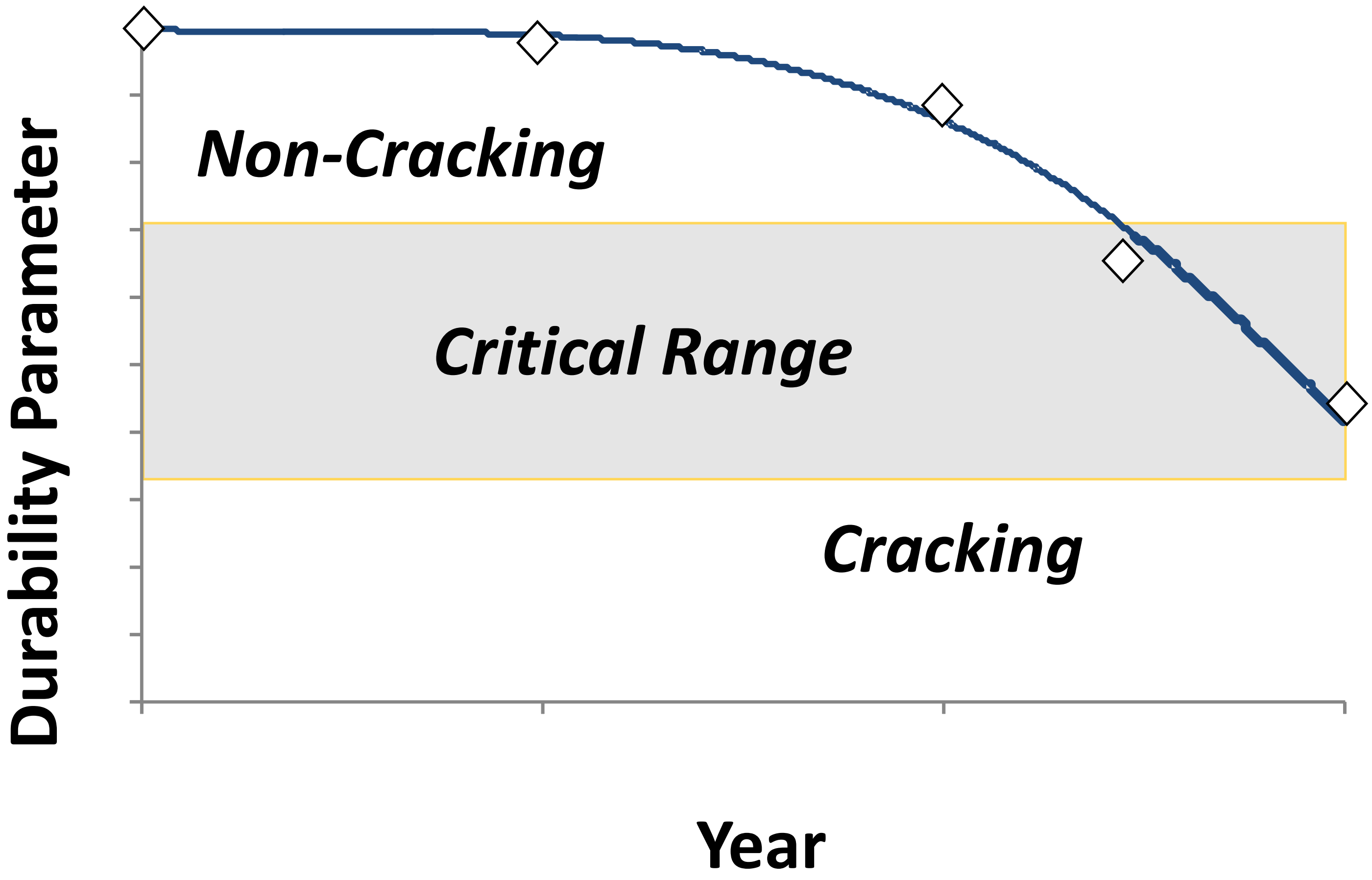
Acknowledgments

- TPF-5(153) Optimal Timing of Preventive Maintenance for Addressing Environmental Aging in Hot-mix Asphalt Pavements
    - MN, MD, OH, TX, WI, LRRB
    - Thomas J. Wood, Lead Agency Contact
- Airfield Asphalt Pavement Technology Program (AAPTP) Project 06-01
    - Techniques for Prevention and Remediation of Non-Load-Related Distresses on HMA Airport Pavements
    - AAPTP sponsors and research panel
- Member Companies of the Asphalt Institute

Team

- Asphalt Institute
- AMEC
  - Doug Hanson, Researcher
- Consultant
  - Gayle King, Researcher

Concept



Durability Parameter
Non-Cracking
Critical Range
Cracking
Year

General Concept

- In-service aging leads to oxidation and loss of flexibility at intermediate and low temperatures
  - Block-cracking
    - when environmental (non-load) conditions create thermal stresses that cause strain in the asphalt mixture that exceeds the failure strain

General Concept

- In-service aging leads to oxidation and loss of flexibility at intermediate and low temperatures
  - Preventing or mitigating distress
    - identify a property of the asphalt binder or mixture that sufficiently correlates with its flexibility
    - provide a procedure to monitor when flexibility reaches a state where corrective action is needed

Asphalt Durability

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- A durable asphalt:
  - has physical properties necessary for desired initial product performance, and
  - is resistant to change in physical properties during long-term, in-use environmental aging

Petersen, J.C., “Chemical Composition of Asphalt as Related to Asphalt Durability-State of-the-Art”, TRR. 999, 1984

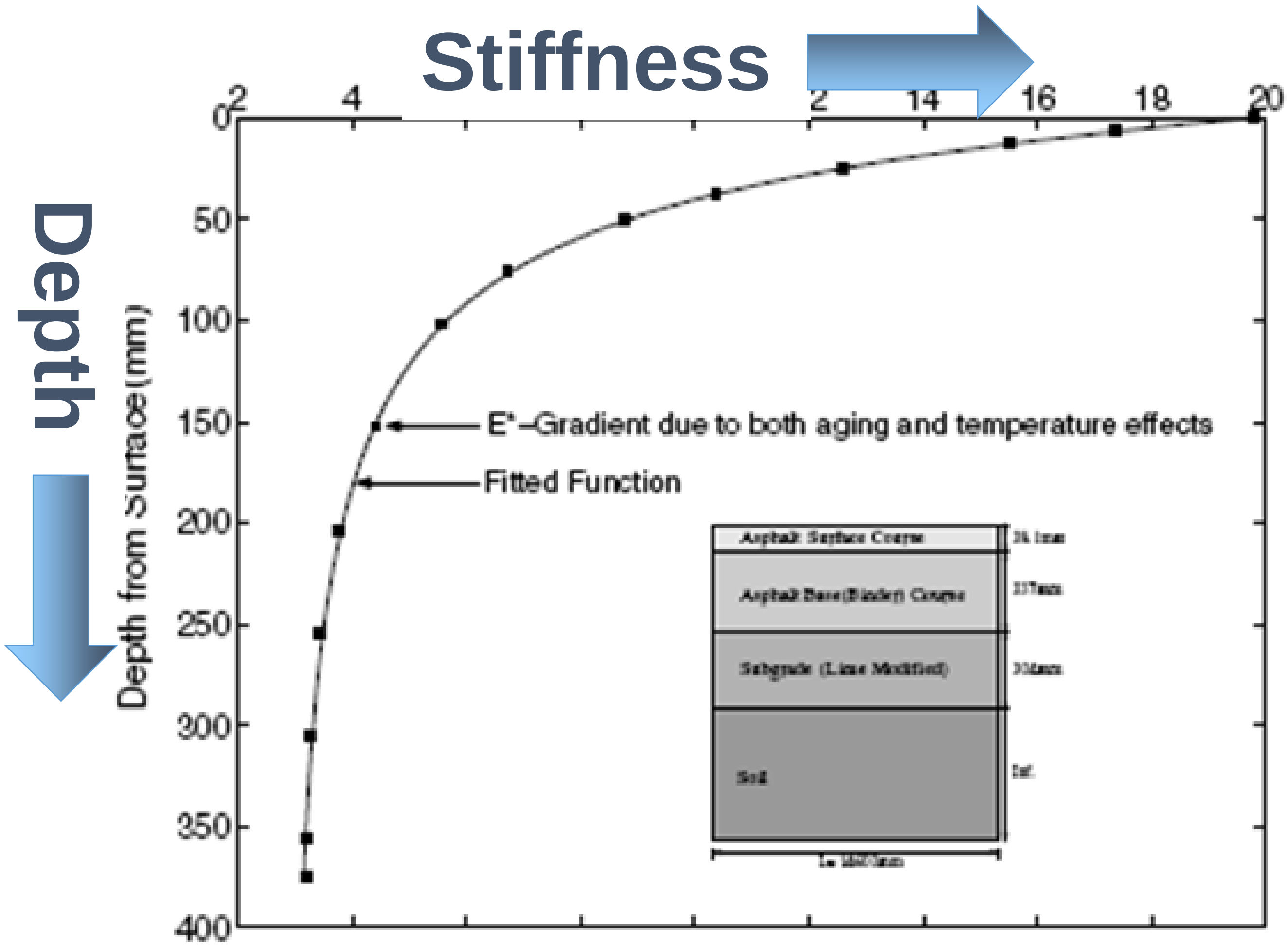
Asphalt Oxidation

Vallerga: Age-Embrittlement

Raveling

Block Cracking

Witczak and Mirza: Global Aging Model (1995)



Asphalt Oxidation

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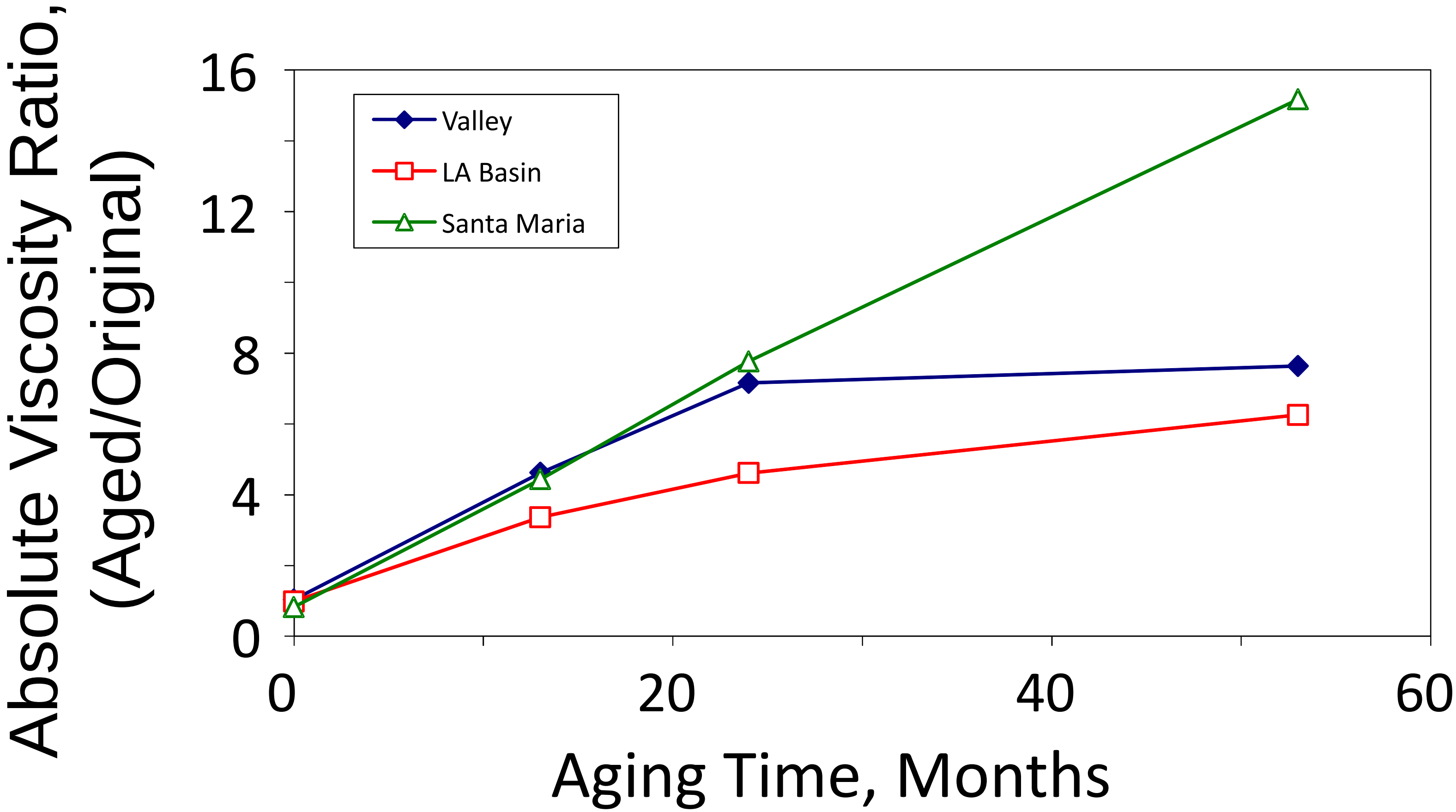
- Physical Changes – Ductility
  - Block cracking severity related to ductility at 60ºF (15ºC) – Kandhal (1977)
    - "Low-Temperature Ductility in Relation to Pavement Performance", ASTM STP 628, 1977
  - Loss of surface fines as ductility = 10 cm
  - Surface cracking when ductility = 5 cm
  - Serious surface cracking when ductility < 3 cm

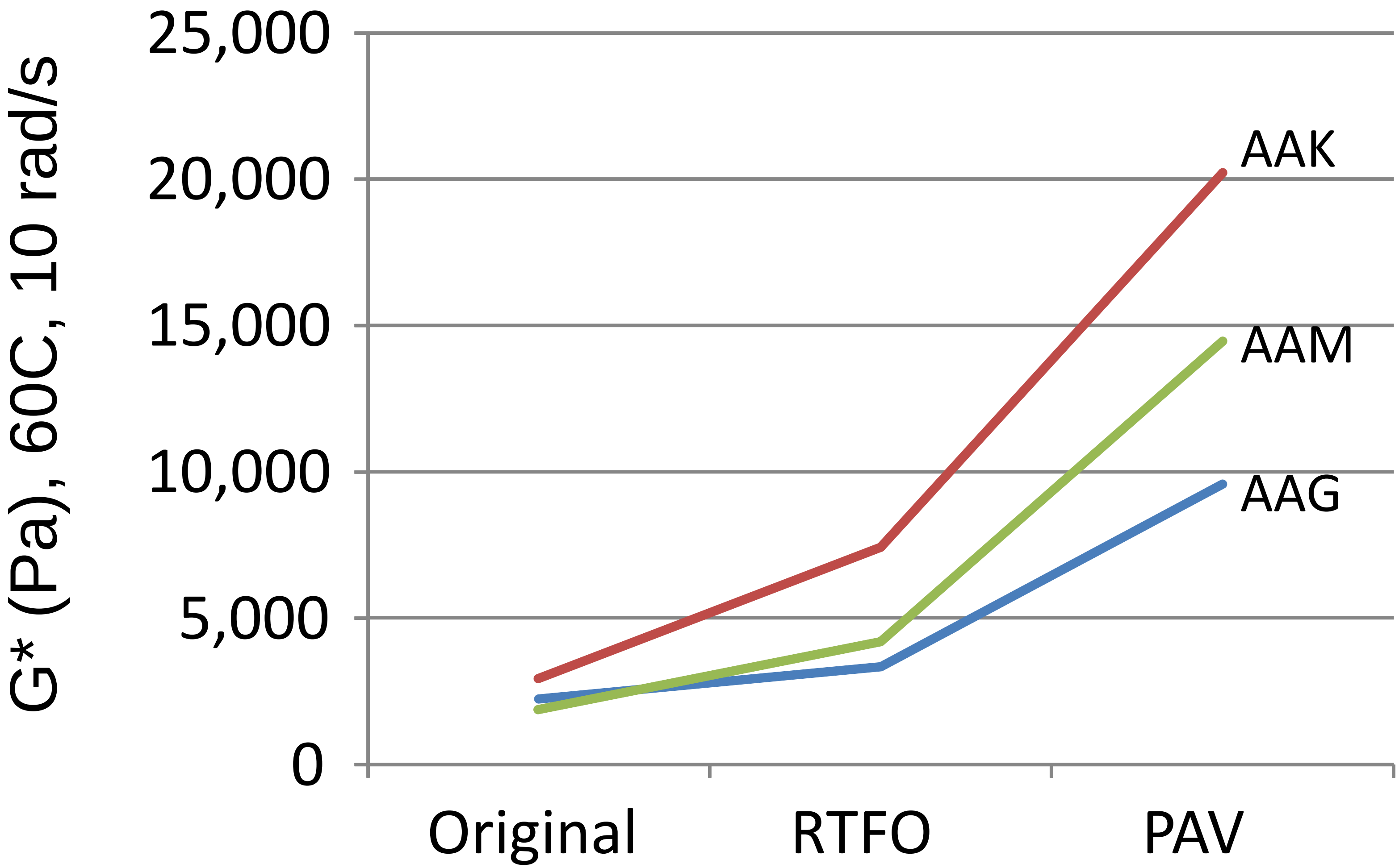
1981 CA Durability Study



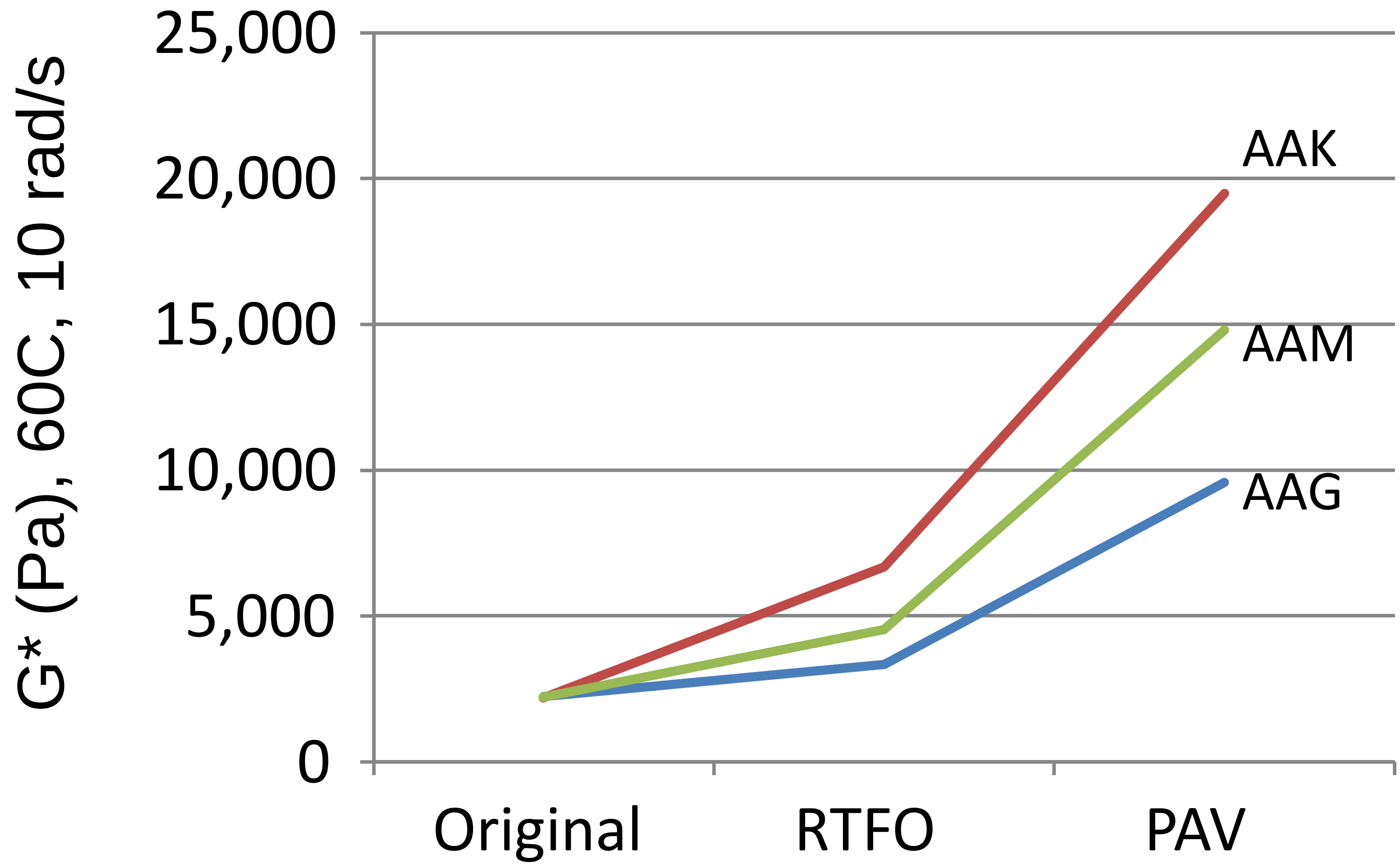
Kemp, et.al.

Sacramento (62.9C), 7-9% Air Voids, Non-Absorptive Aggregate

Rate of Aging



Rate of Aging (Normalized – Original)



More Recent Aging Research

- Texas A&M Research (Glover, et.al.)
  - 2005
  - "Development of a New Method for Assessing Asphalt Binder Durability with Field Evaluation"
  - Build on work by Kandhal suggesting block cracking and raveling is related to low binder ductility after aging
  - Identified rheological parameter related to ductility

Dynamic Shear Rheometer

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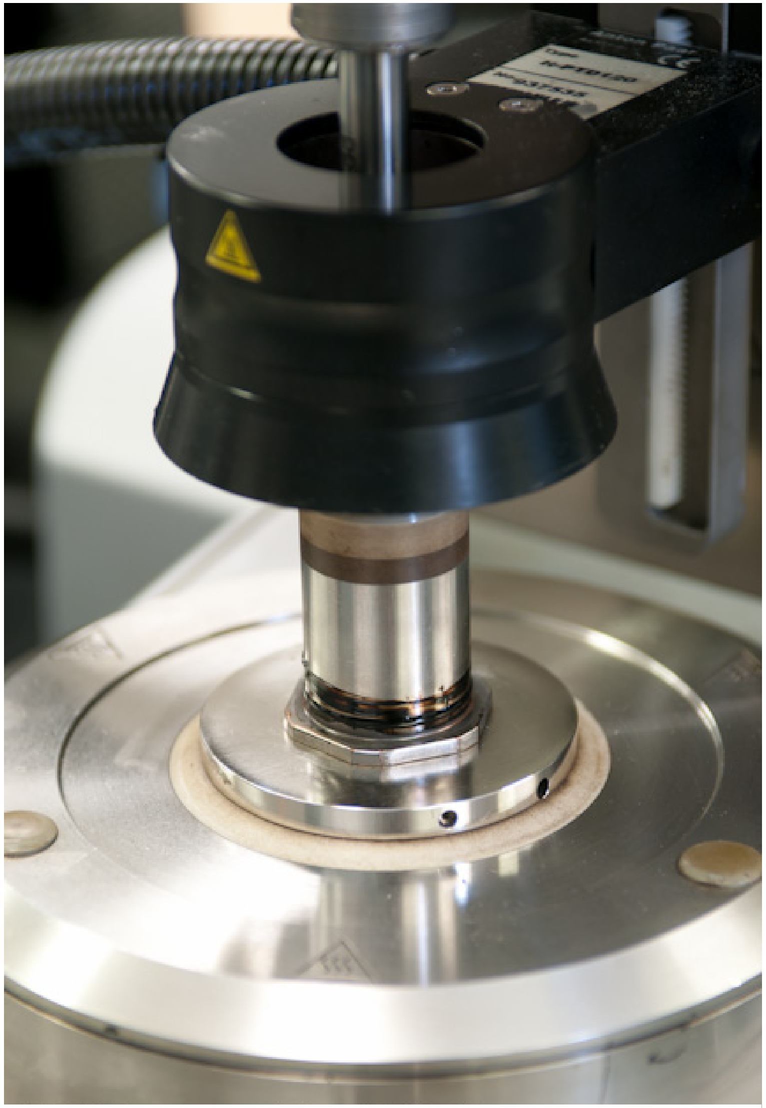
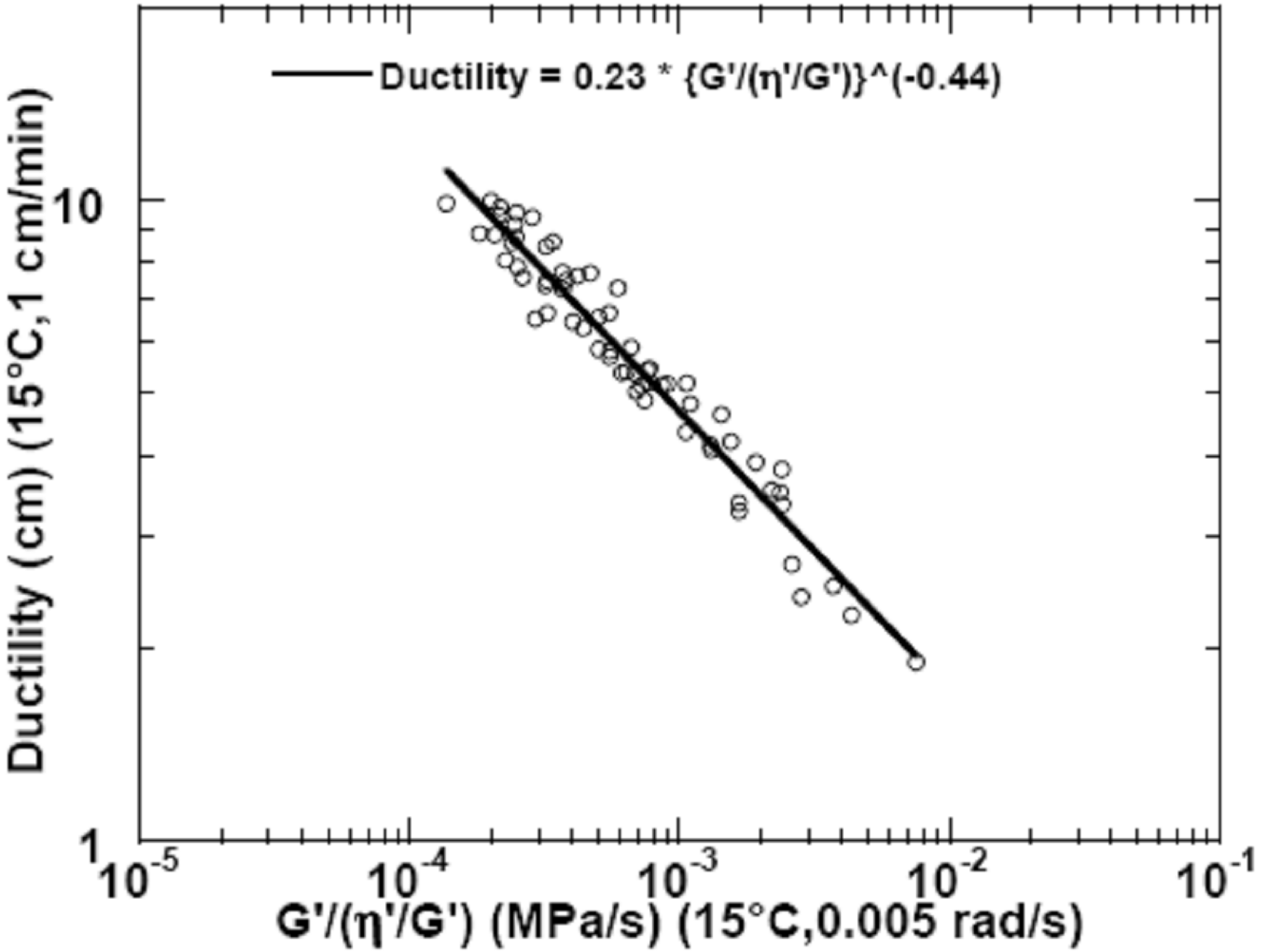
- Mastercurve at 15°C
  - 8-mm parallel plate
  - 5, 15, and 25°C
  - Frequency sweep (0.1 to 100 rad/s)
  - Obtain Texas A&M parameter at 0.005 rad/s
    - $G'/(\eta'/G')$
    - Related to ductility at 15°C and 1 cm/min.



Ductility and DSR Parameter



(Glover et.al., 2005)

AAPTP 06-01

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- Lab Study
  - Asphalt Binder Study
    - Various aged conditions
  - Asphalt Mixture Study
    - Various aged conditions
- Field Study
  - Limited validation of lab findings
  - Asphalt binder and mixture tests

Asphalt Binders

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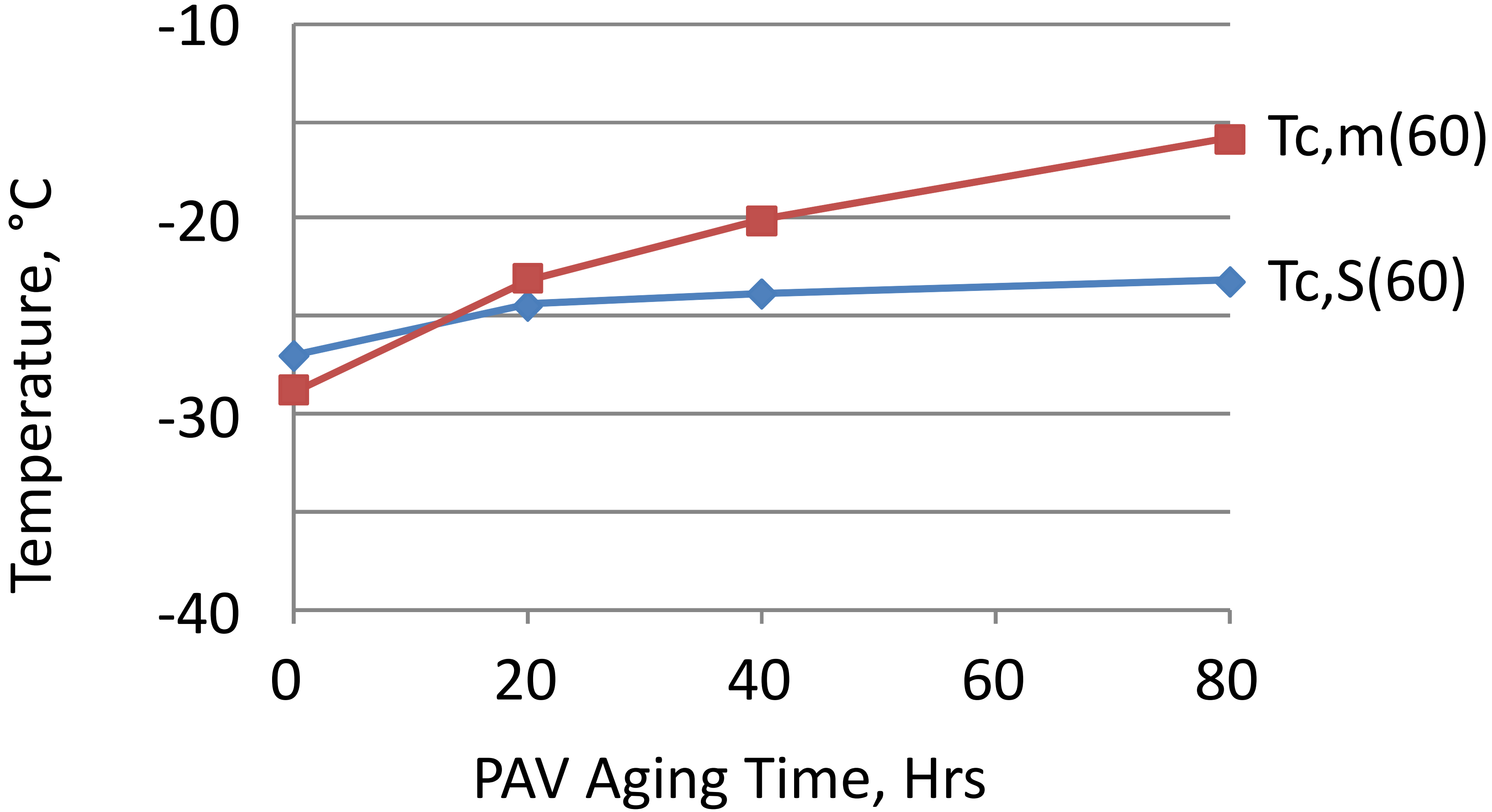
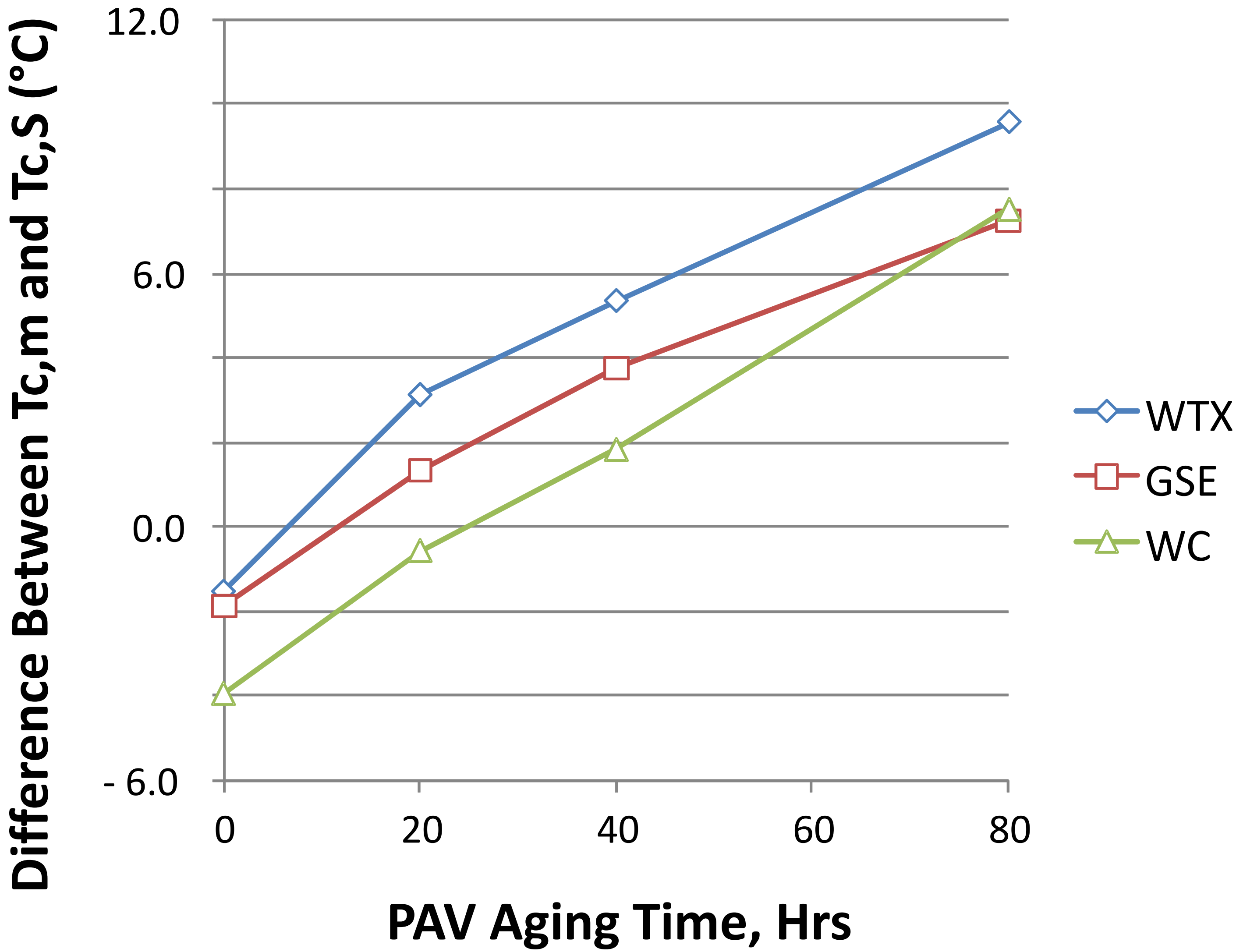
- Three asphalt binders representing different expected aging characteristics
  - Selected based upon the relative relationships between low temperature stiffness (S) and relaxation (m-value)
  - West Texas Sour (PG 64-16)
    - 3.1°C m-controlled
  - Gulf Southeast (PG 64-22)
    - 1.3°C m-controlled
  - Western Canadian (PG 64-28)
    - 0.6°C S-controlled

BBR: Gulf-Southeast (GSE)



Effect of PAV Aging Time on ΔT_c



Mastercurve Procedure

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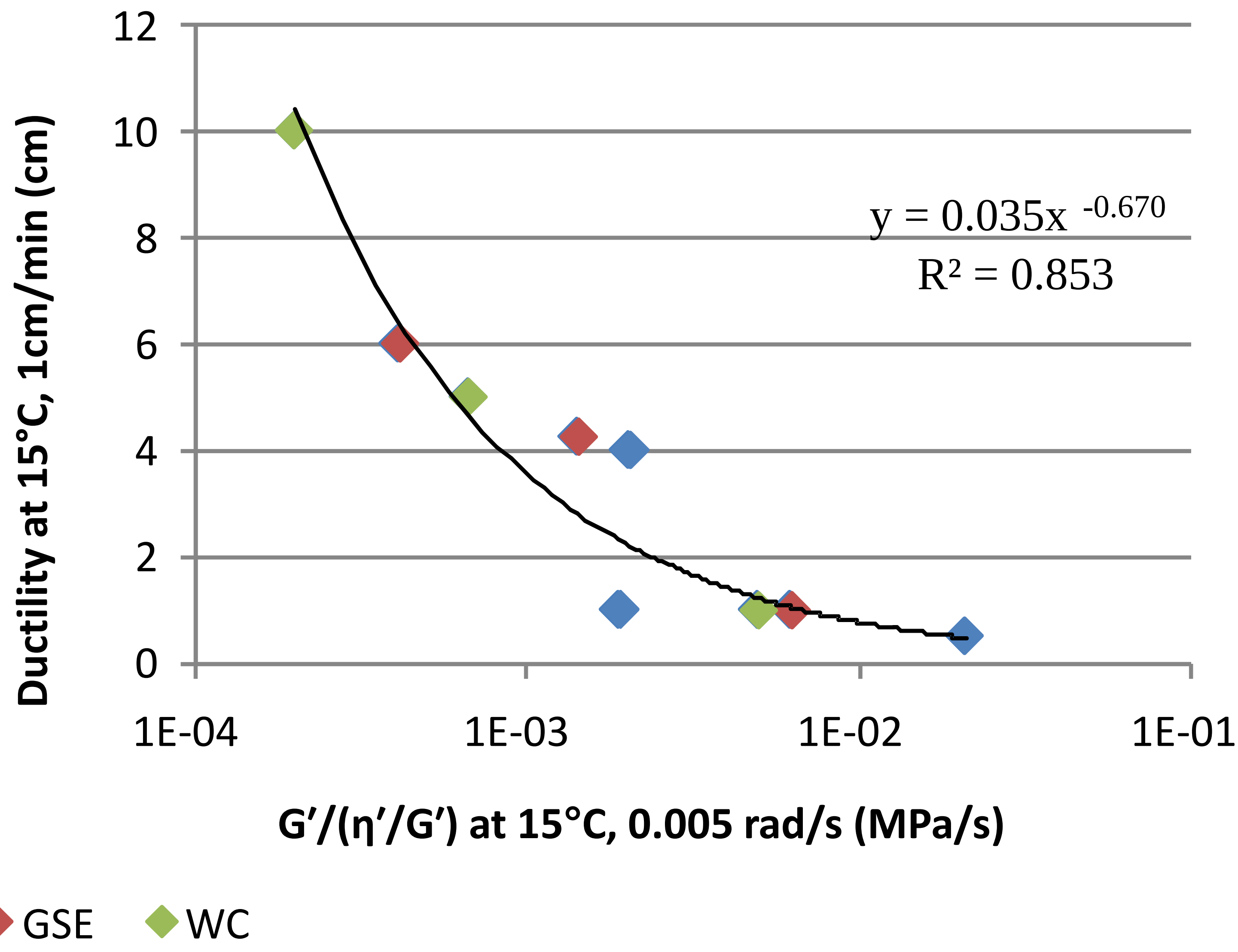
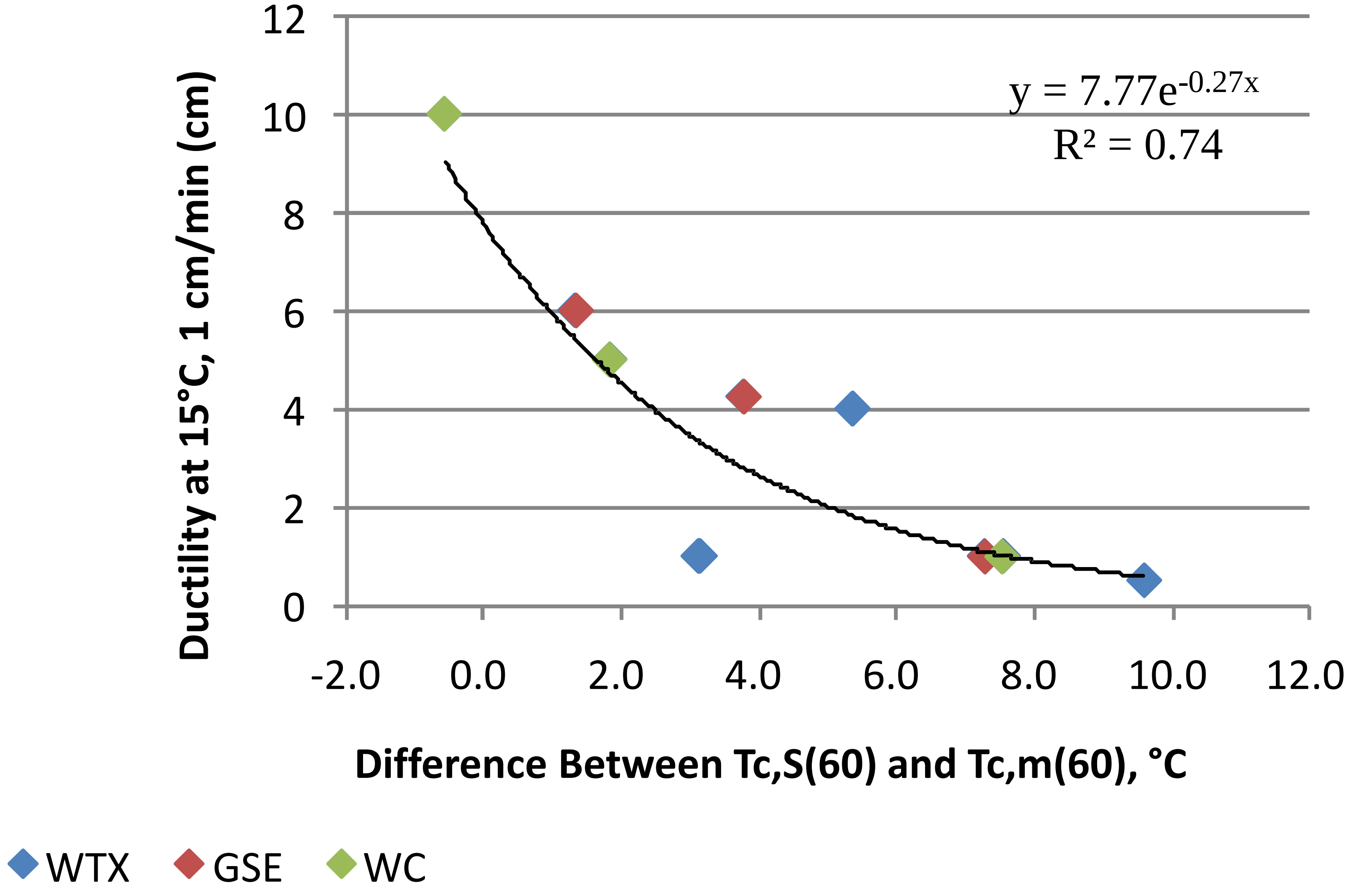
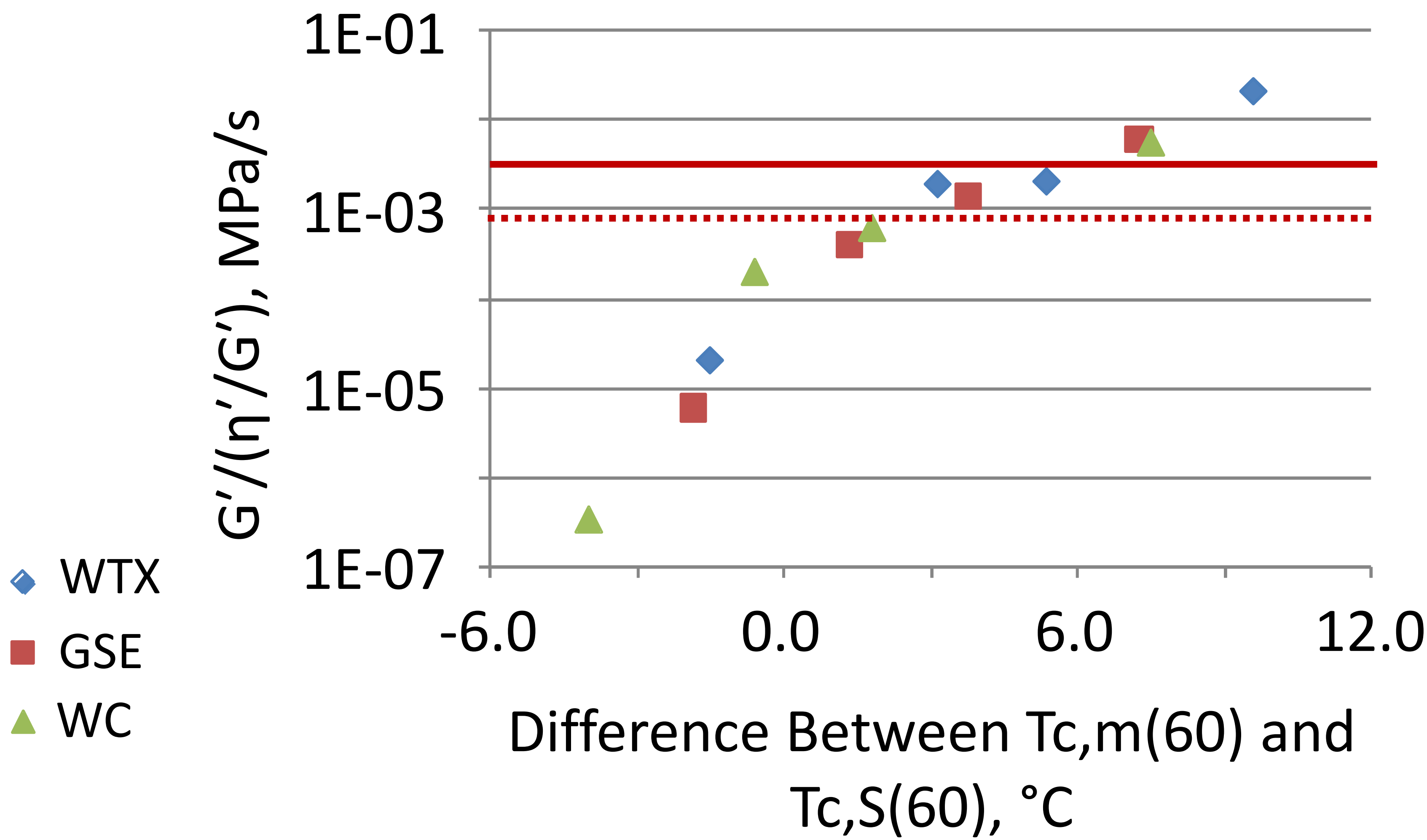


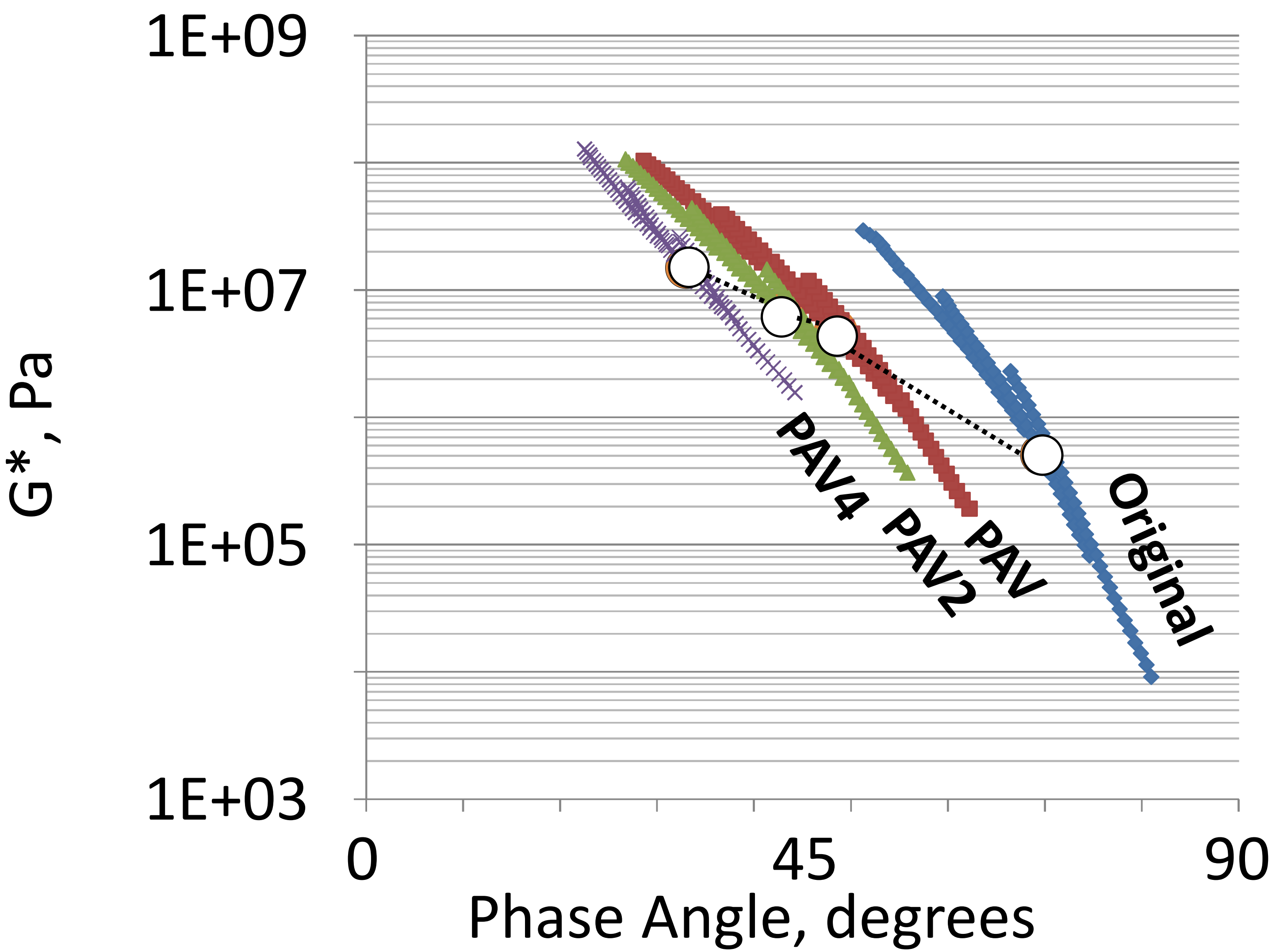
Relationship between ΔT_c and Ductility



Relationship between G'/(η'/G') and ΔT_c



Effect of Aging



Glover-Rowe Parameter

$$G' / \left(\frac{\eta'}{G'}\right) = G^{*}\omega((\cos\delta)^2 / \sin\delta)$$

	Ductility 15C, 1 cm/min	Glover-Rowe 0.005 rad/sec
Damage Onset: Early Raveling	**5**	**180 kPa**
Damage Visible: Surface cracking	**3**	**600 kPa**

Rowe: Prepared Discussion to M. Anderson paper - AAPT 2011

Glover-Rowe Plot in Black Space: DSR on Aged Binders (15°C; 0.005 rad/s)

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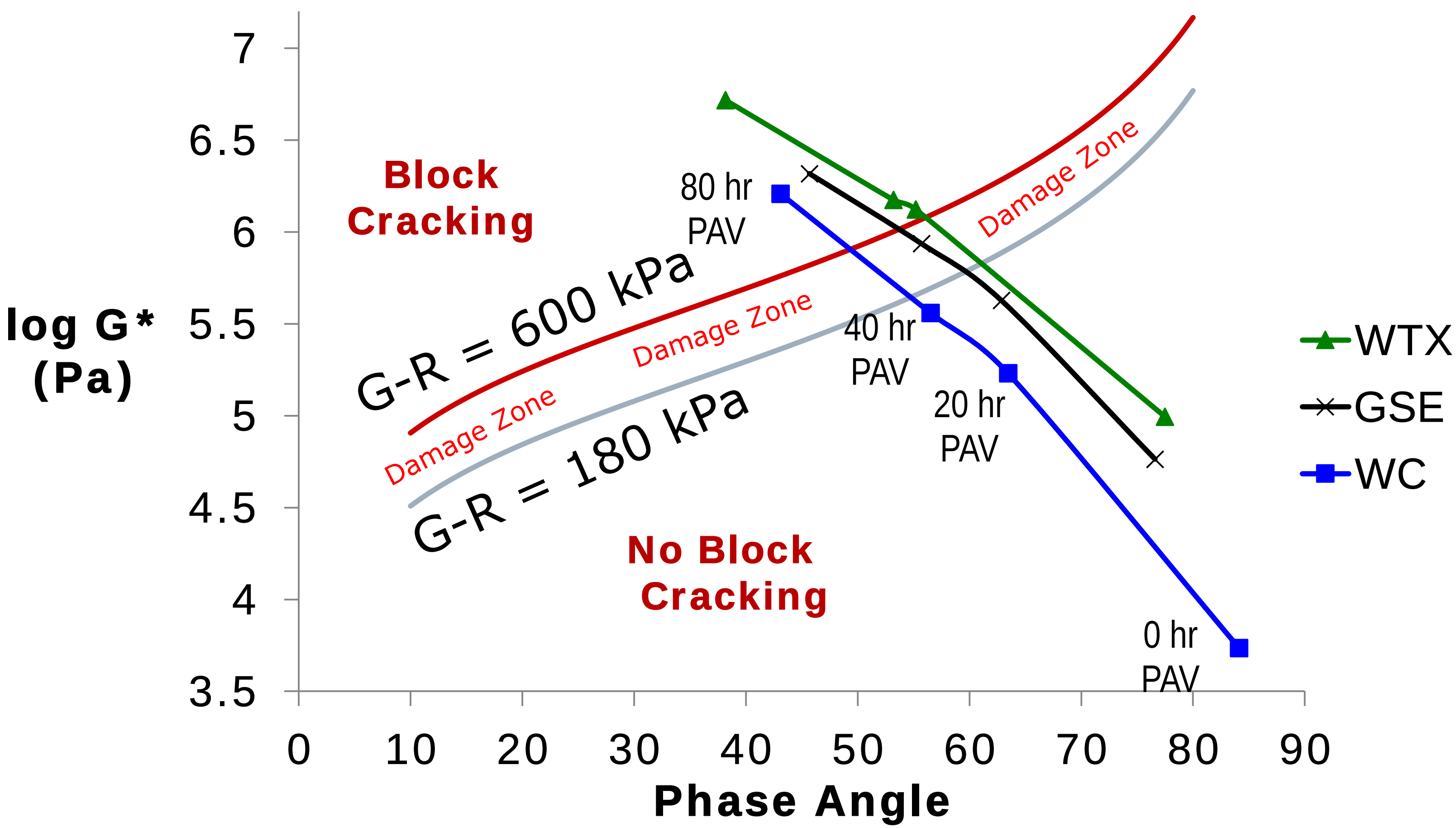

Rowe: Prepared Discussion to M. Anderson paper - AAPT 2011

Field Validation

- Three general aviation (GA) airport projects representing four in-service pavements
  - Roundup (Montana)
    - Upper layer representing the new pavement (Roundup Top)
    - Lower layer representing the older pavement (Roundup Bottom)
  - Clayton (New Mexico)
    - Some low-severity longitudinal cracking and raveling
  - Conchas Lake (New Mexico)
    - Some low-to-moderate severity raveling was identified over most of the paved area
    - Pavement surface appeared slightly oxidized

Relationship between G′/(η′/G′) and ΔT_c (with Field Cores)

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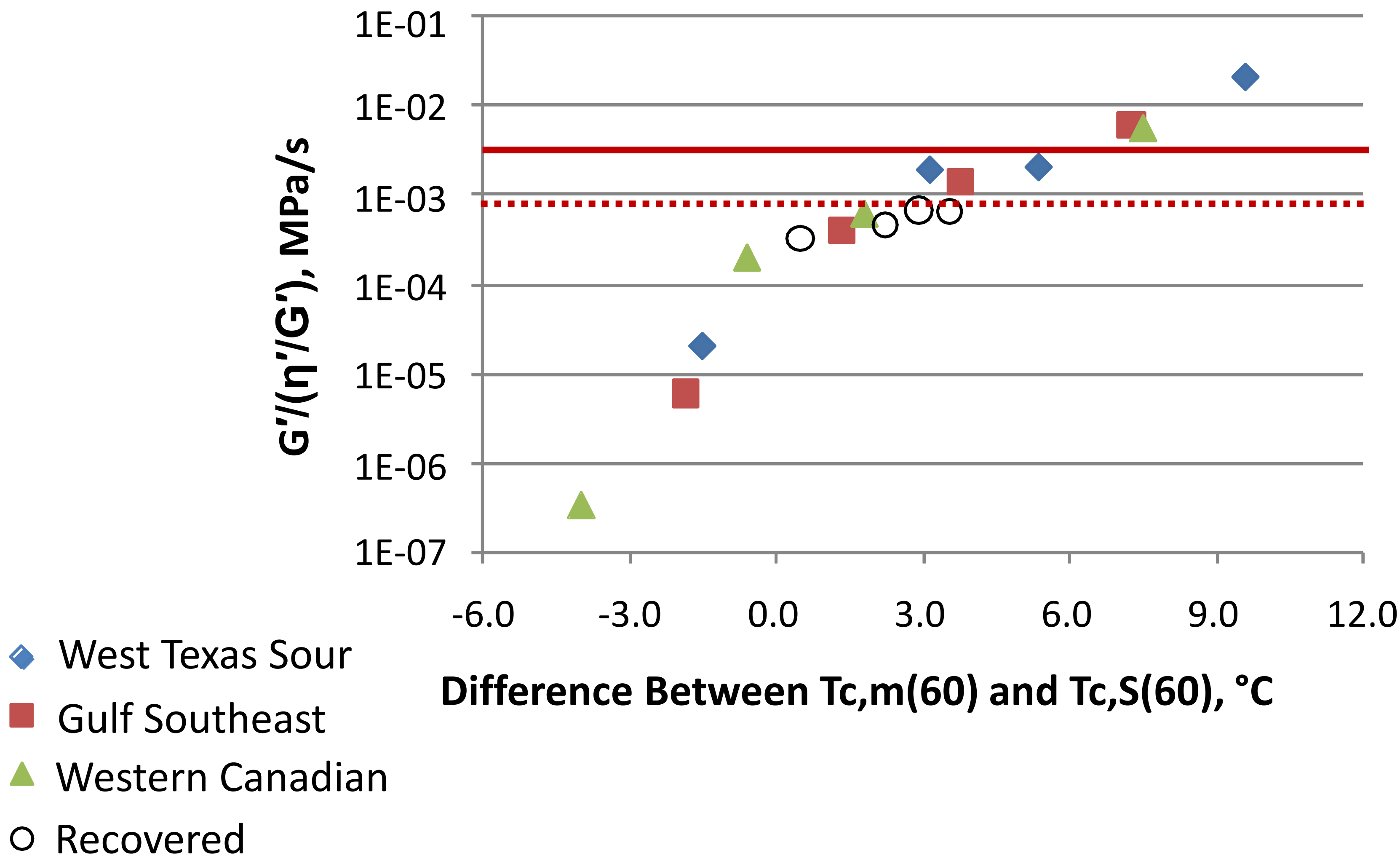


Summary – AAPTP 06-01 Research

- Past research
  - Some relationship between ductility (conducted at an intermediate temperature) and the durability of an asphalt pavement
  - Texas A&M research validated through identification of DSR parameter, $G'/(\eta'/G')$, at 15°C and 0.005 rad/s

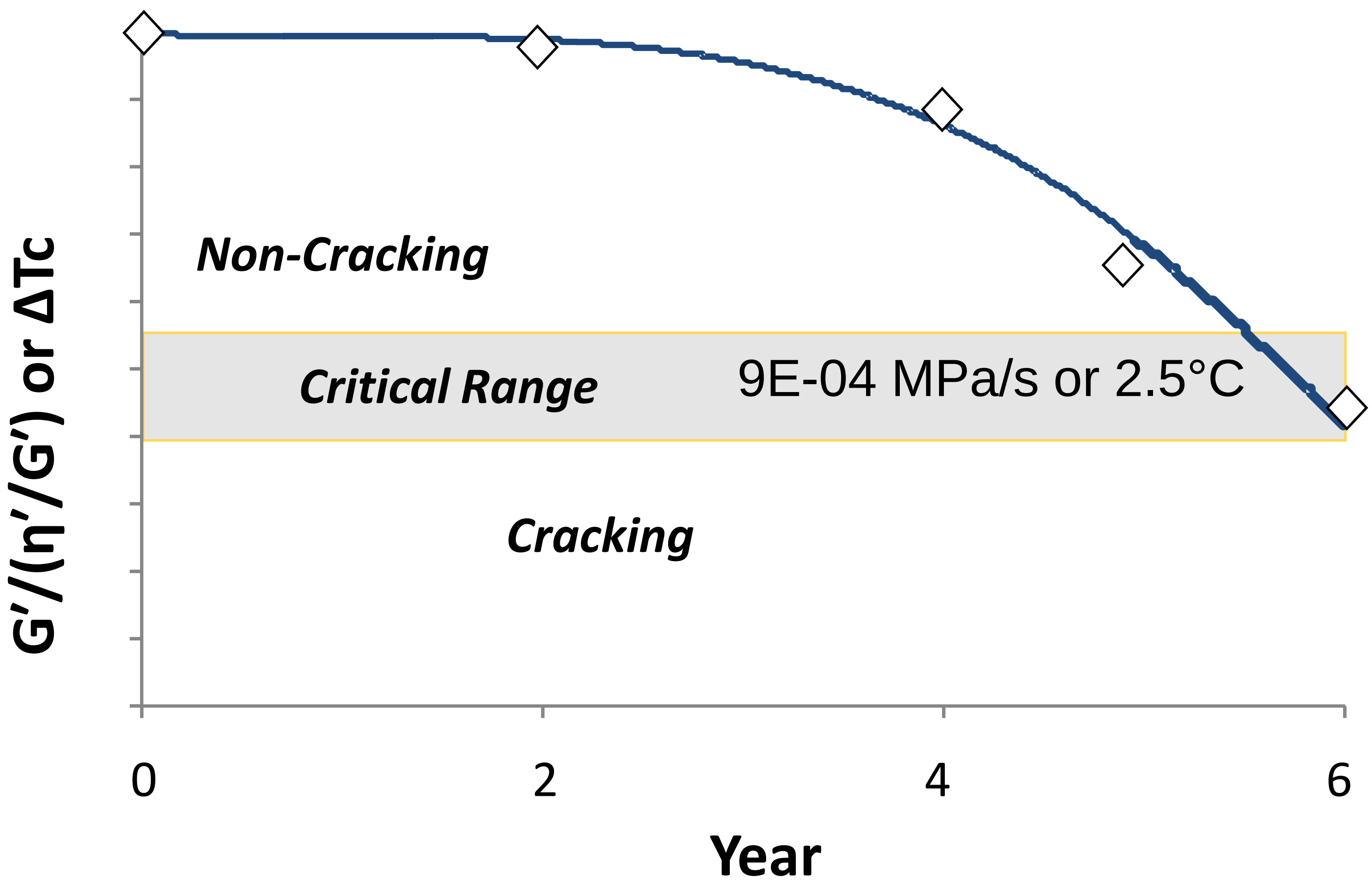
Summary – AAPTP 06-01 Research

- Current research
  - Confirmed relationship of Texas A&M DSR parameter, $G'/(\eta'/G')$, at 15°C and 0.005 rad/s, to ductility
  - Identified similar parameter through BBR testing, ΔT_c, which quantifies the difference in continuous grade temperature for stiffness and relaxation properties
  - Parameters appear to quantify the loss of relaxation properties as an asphalt binder ages

Summary – AAPTP 06-01 Research

- Field Studies
  - Four sections from three GA pavements in Montana and New Mexico
  - Findings generally matched the lab studies, with the newer pavements having values of $G'/(\eta'/G')$ and ΔTc that indicated less aging and more flexibility than the older pavements

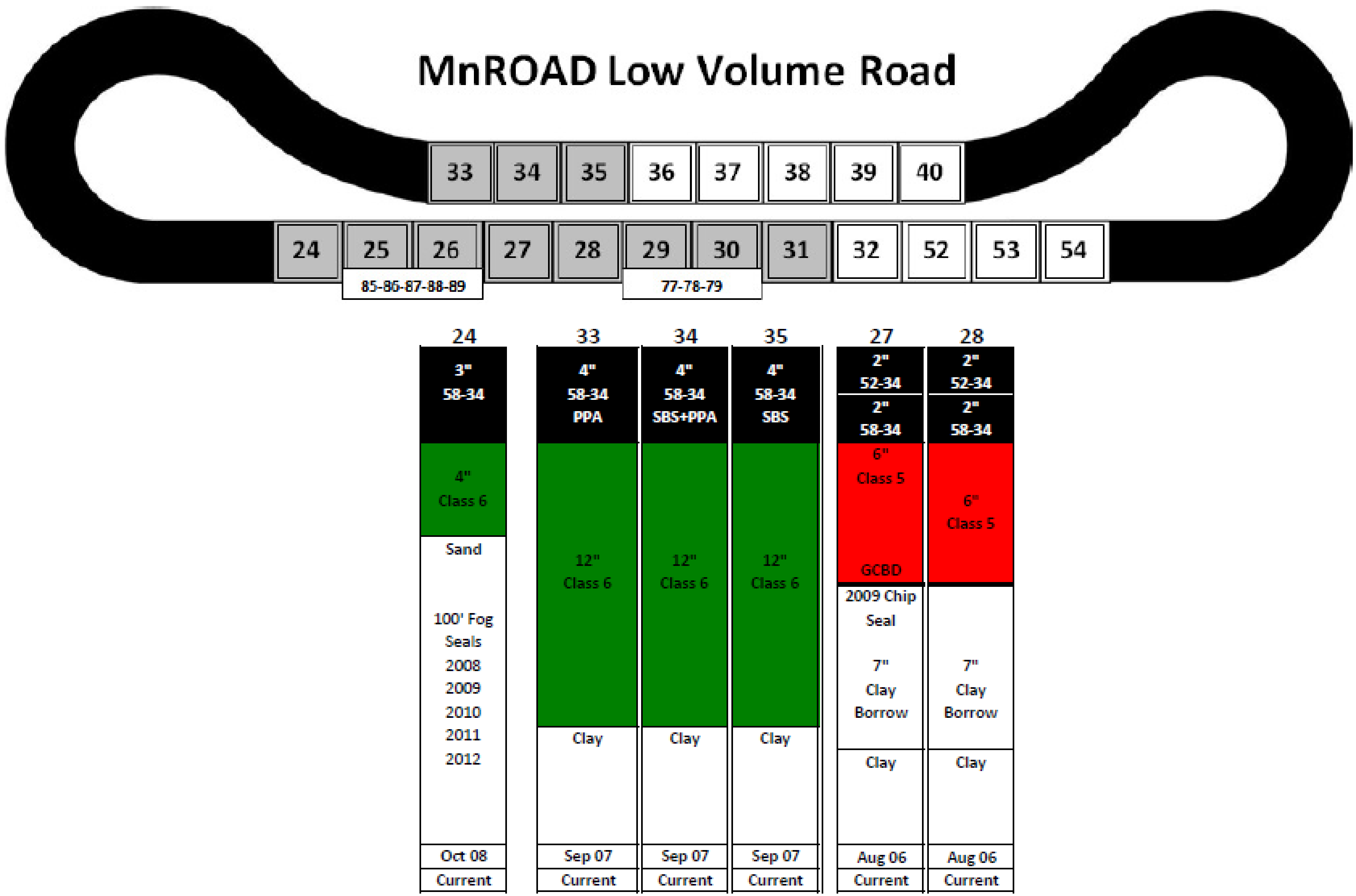
Concept


G'/(η'/G') or ΔTc
Non-Cracking
Critical Range
9E-04 MPa/s or 2.5°C
Cracking
0
2
4
6
Year

TPF-5(153)

- Laboratory and Field Evaluation of MnROAD and Other Test Sections
  - Critical fracture parameters monitored throughout the life of the pavement
    - Appropriate remedial action can be taken as the critical limit is approached
  - Simple tests to be used for field monitoring purposes
    - physical properties from simple tests correlated to crack predictions from DC(t) or other more sophisticated fracture tests.

MnROAD Low Volume Road



MnROAD Cell 24

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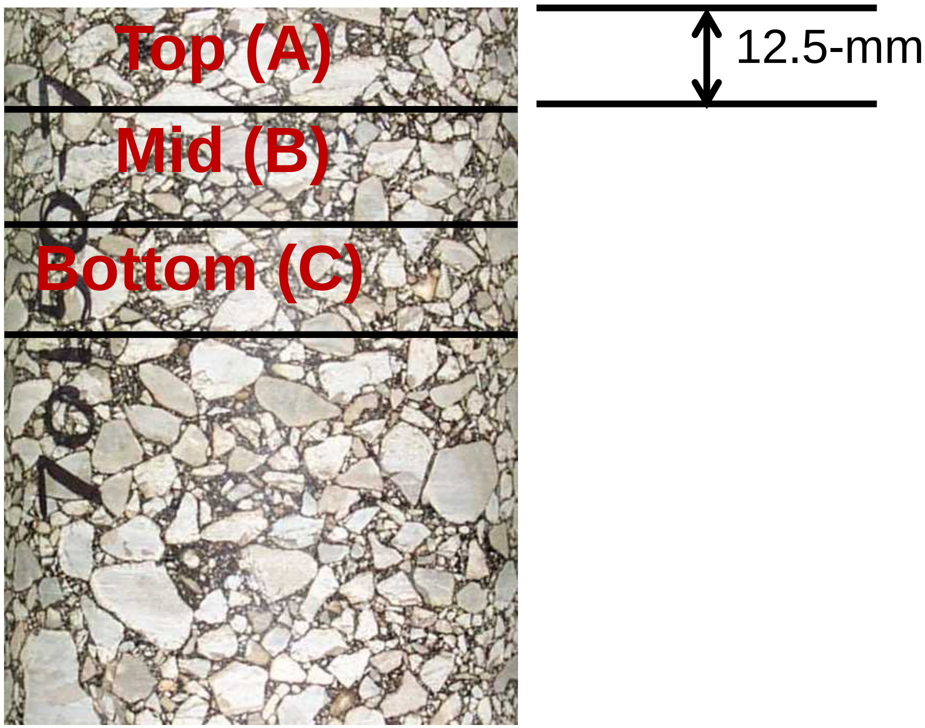
24A (2008)	24B (2009)	24C (2010)	24D (2011)	24E (2012)	24F (2013)
CSS-1	CRS-2P	CRS-2P	CRS-2P		

MnROAD Cores: Recovered Binder Testing

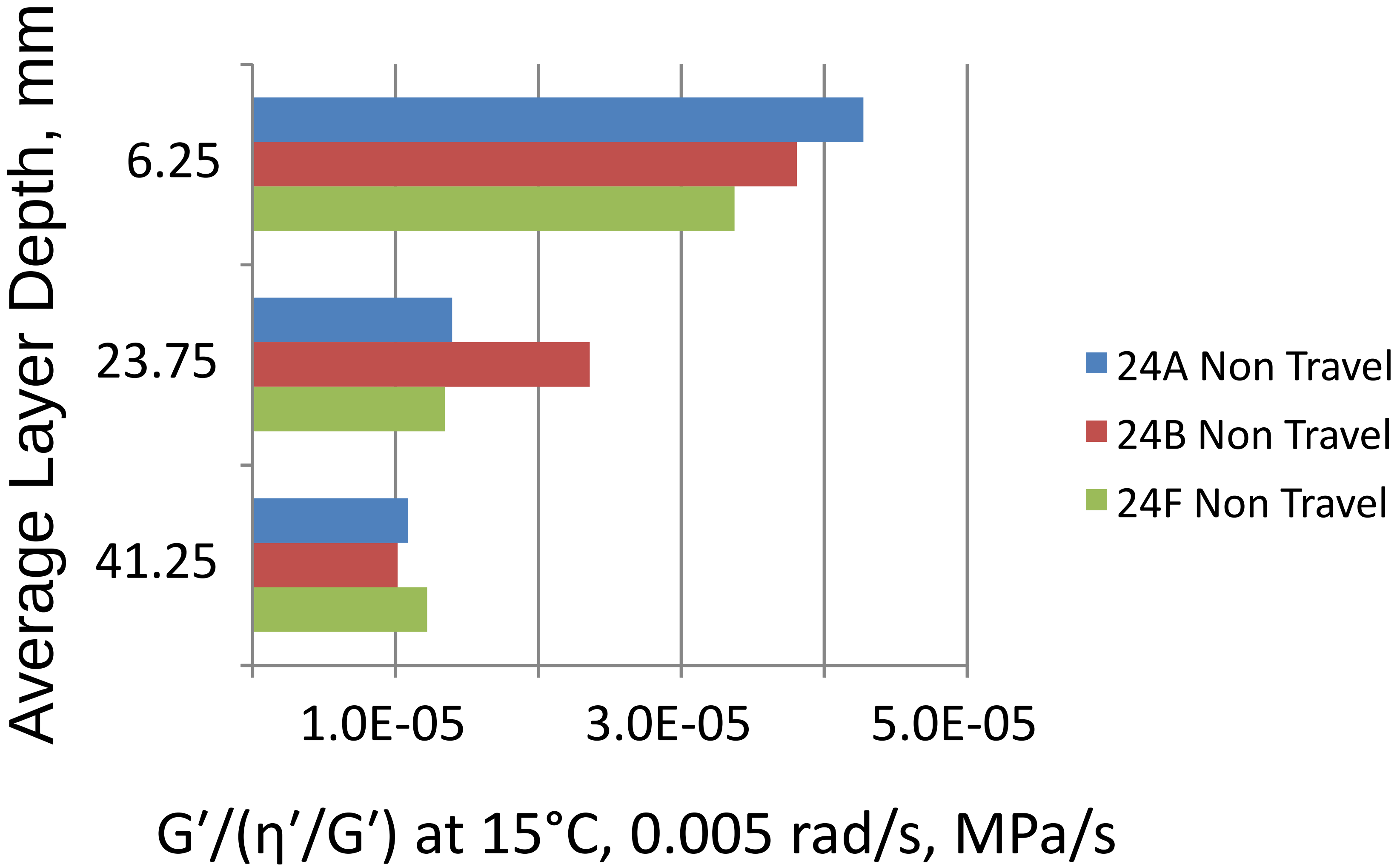


- Extraction/Recovery
  - Centrifuge extraction using toluene/ethanol
  - Recovery using Rotavapor
- 2 Cores (150-mm diameter x 12.5-mm thickness)
  - ~50 grams asphalt

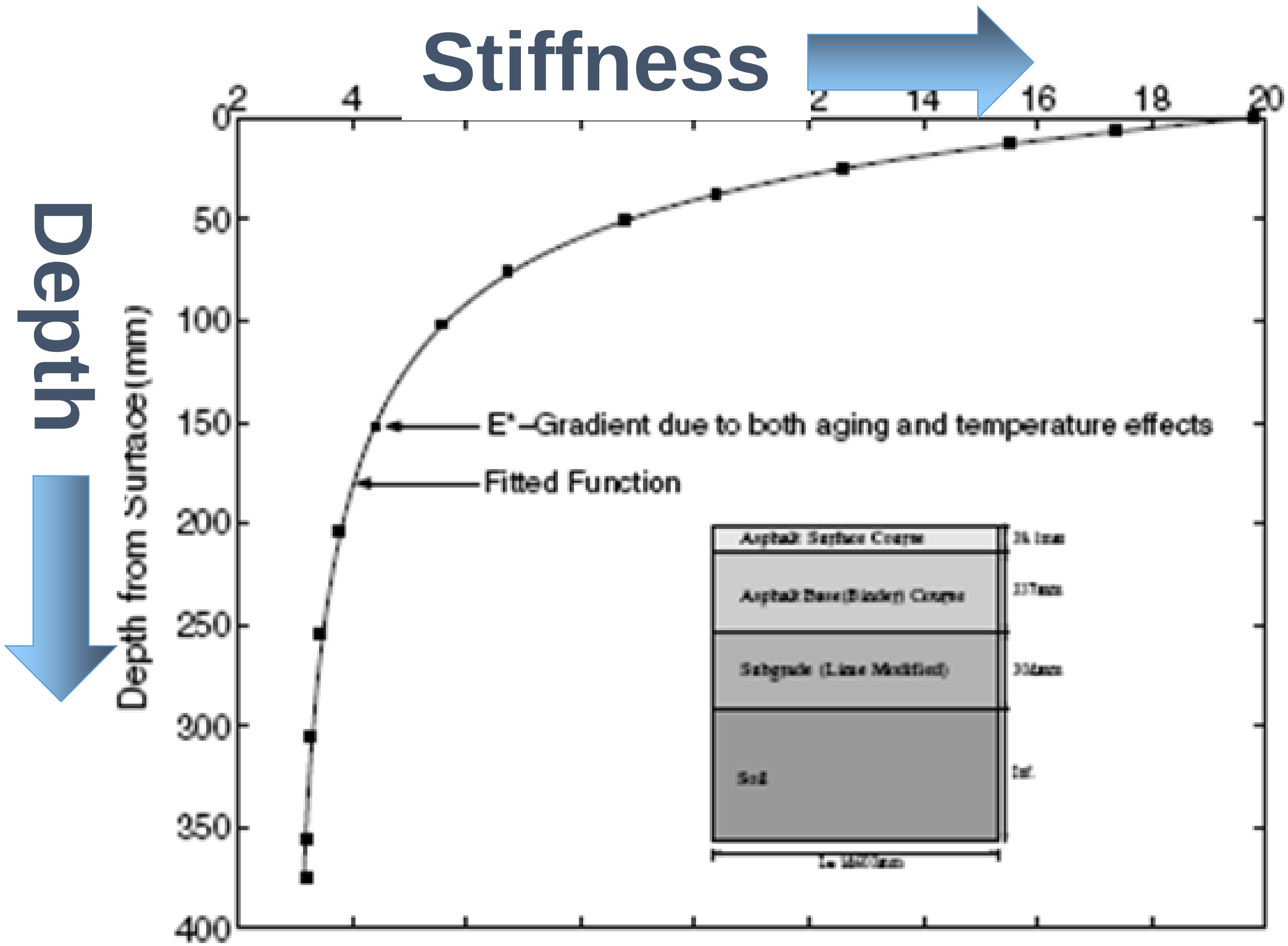
MnROAD Cores: Binder Testing

- Each Layer
  - DSR Temperature-Frequency Sweep
    - Three temperatures (5, 15, 25°C) using 8-mm plates
    - Rheological mastercurves for modulus (G*) and phase angle (δ)
  - BBR
    - Tc determined to the nearest 0.1°C for S(60) and m(60)
    - Difference in Tc (ΔTc)

MnROAD Cell 24: Effect of Layer Depth



Witczak and Mirza: Global Aging Model (1995)

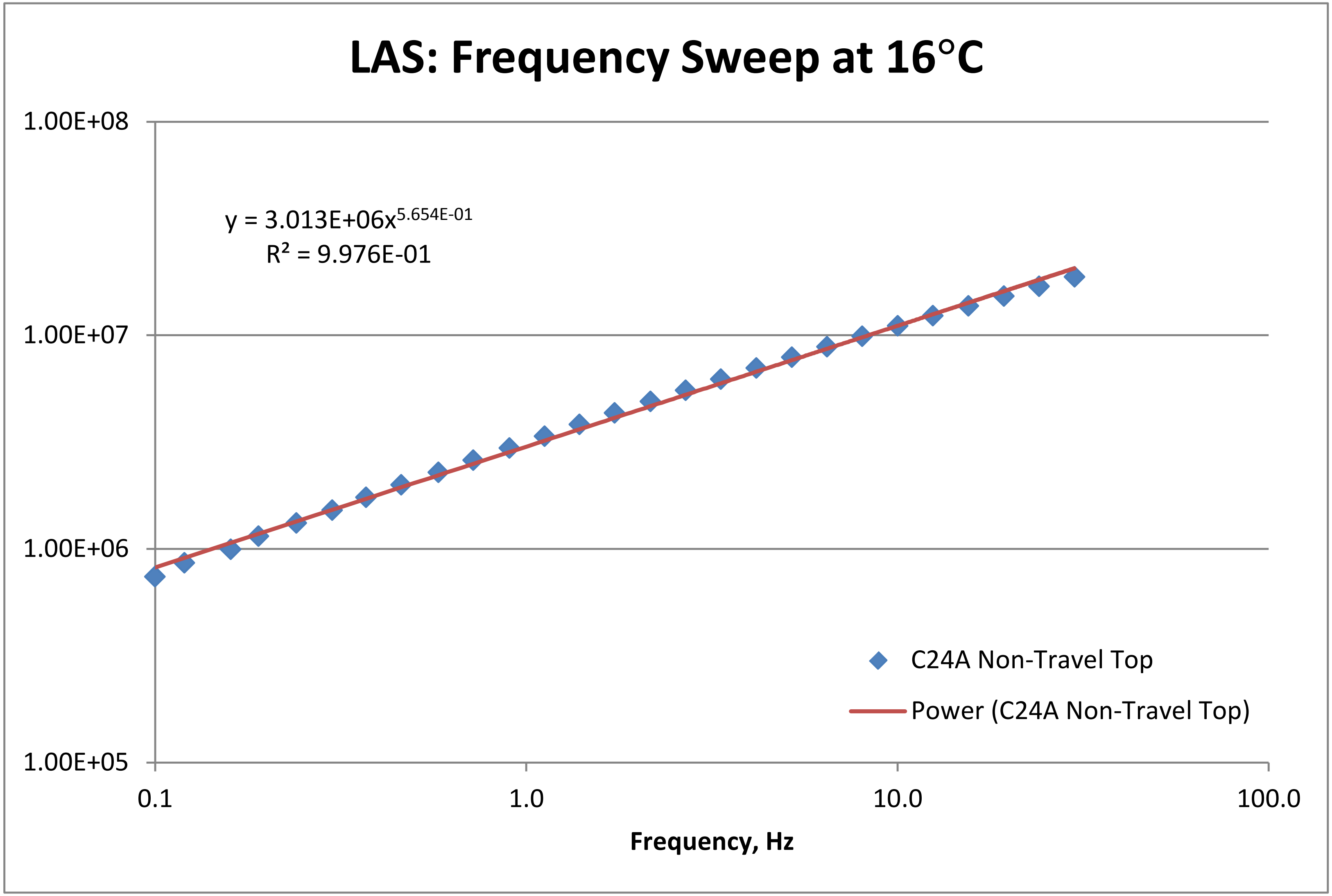


Binder Testing

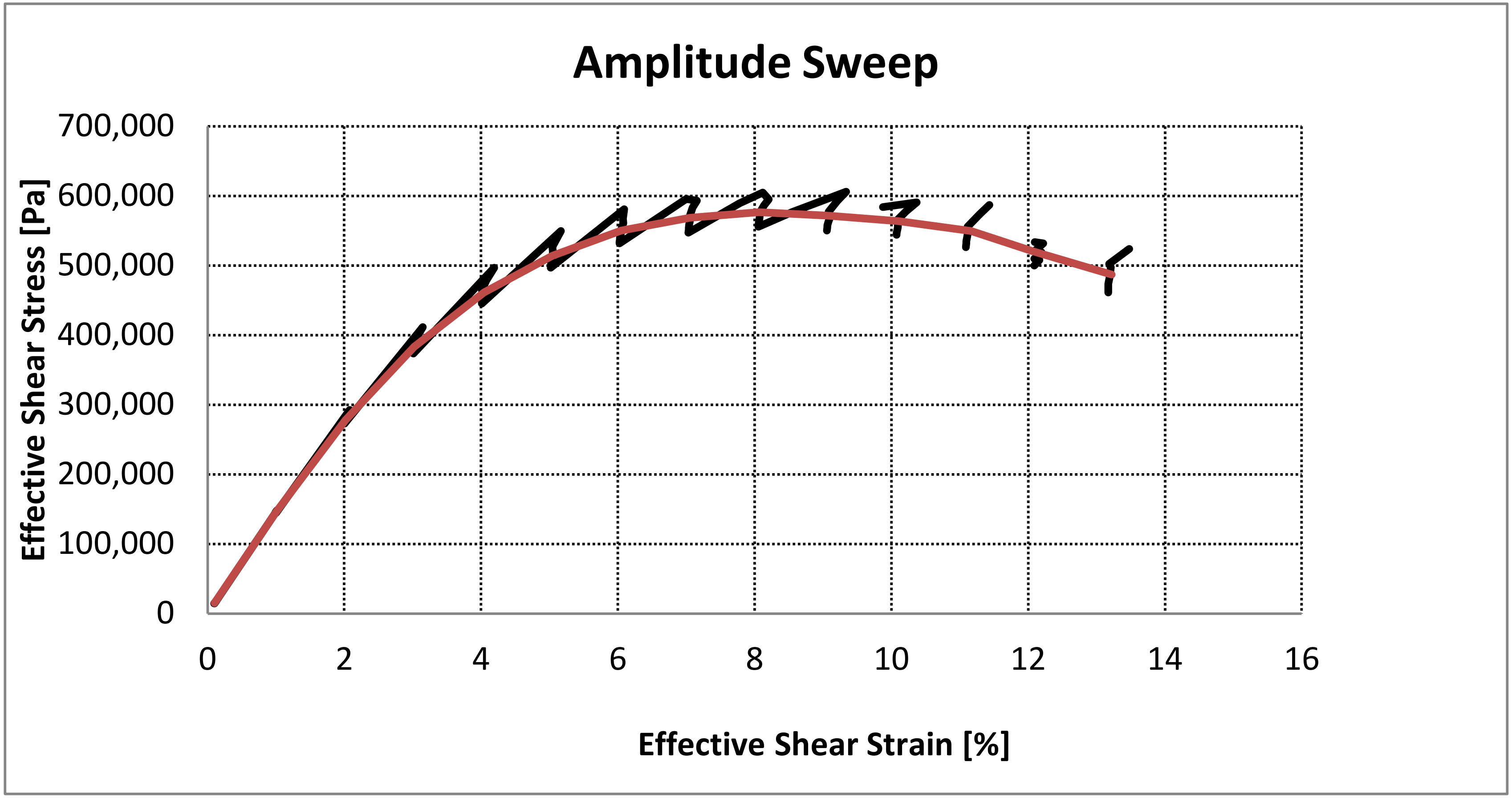
- Linear Amplitude Sweep (LAS) Test
  - DSR Test
    - Frequency Sweep (0.1 – 30 Hz)
    - Continuous Oscillation at 10 Hz with Linearly-Increasing Strain from 0.1 to 30%
    - Viscoelastic Continuum Damage (VECD) analysis to get reduction in G*sin δ
    - Cycles to failure as a function of strain

$$N_f = A\gamma^B$$

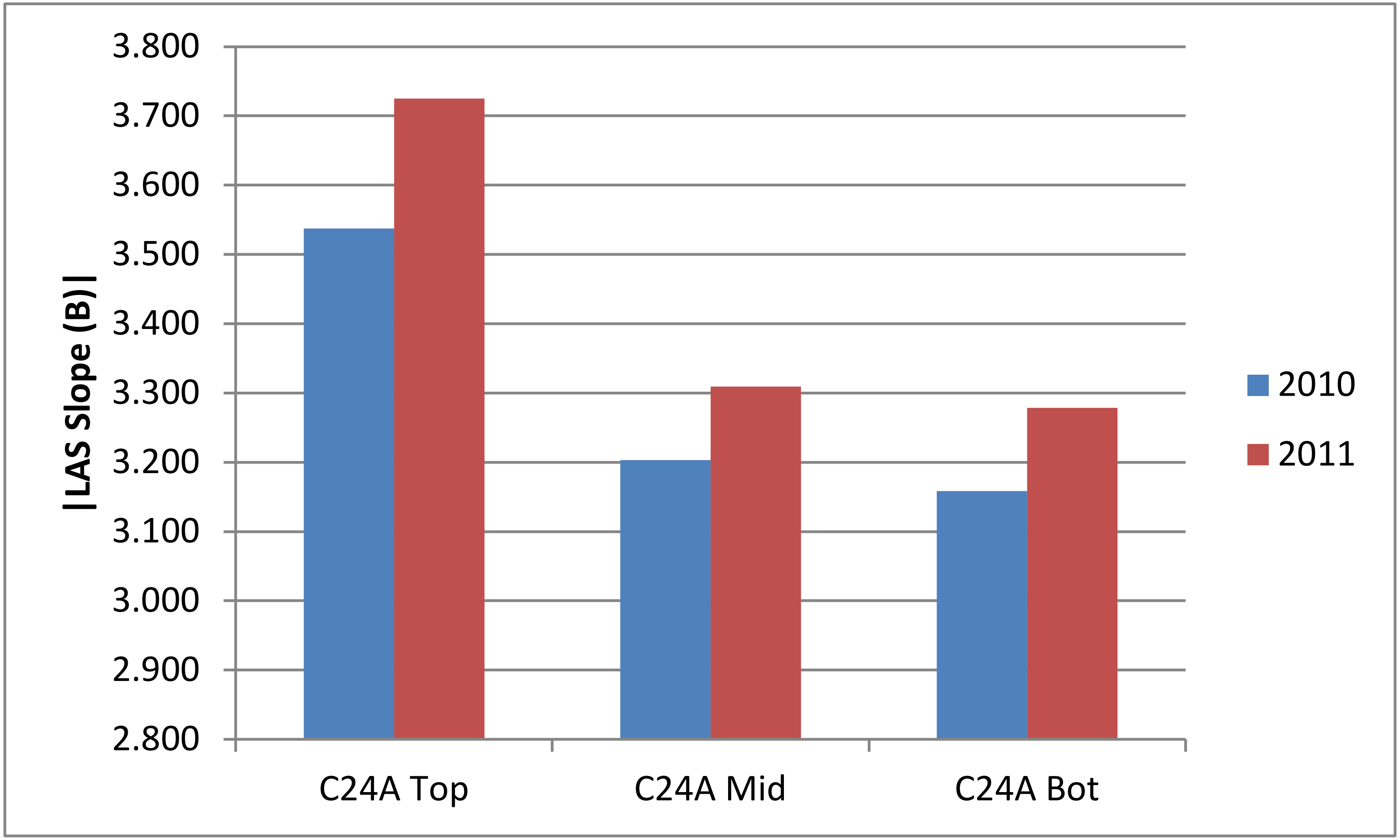
LAS Frequency Sweep



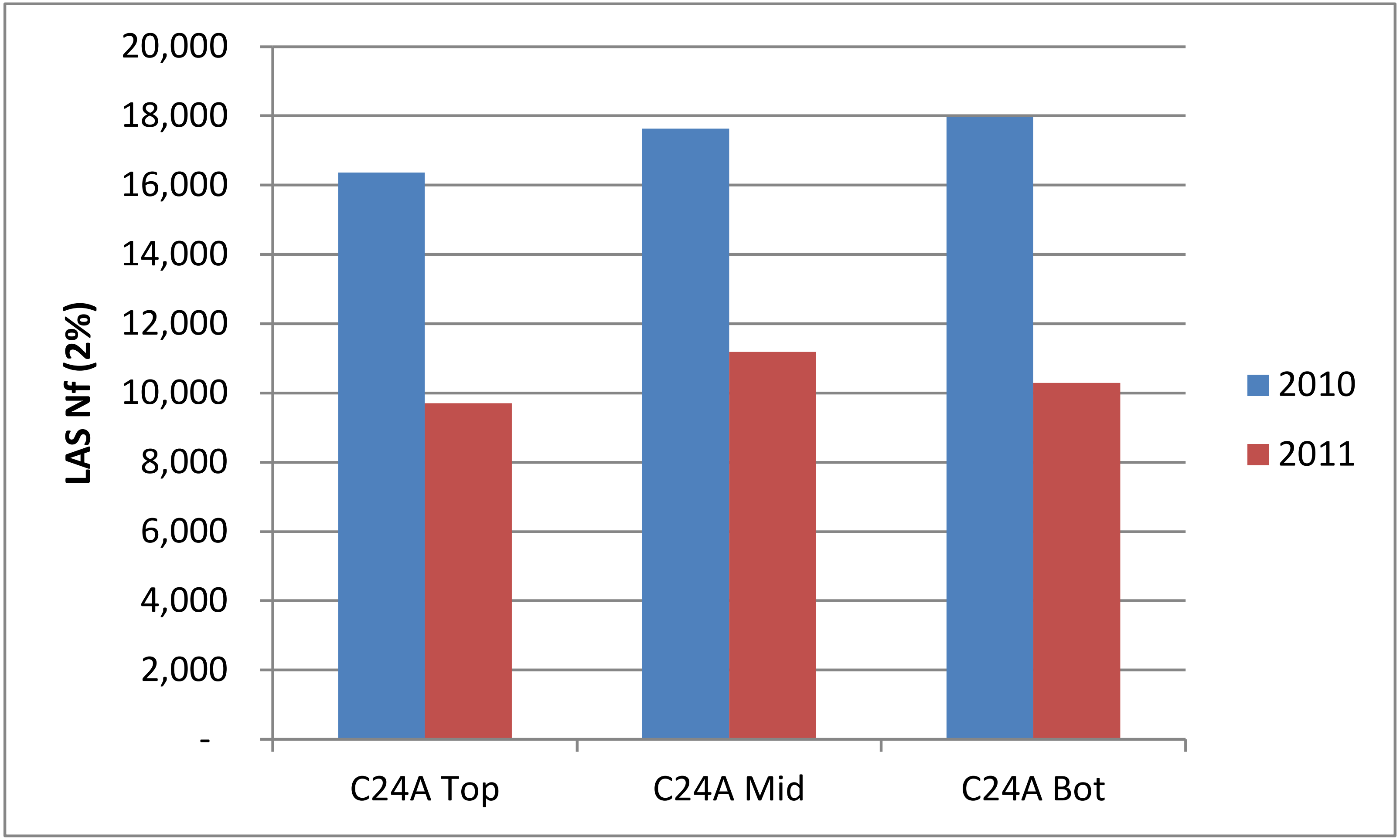
LAS Strain Sweep



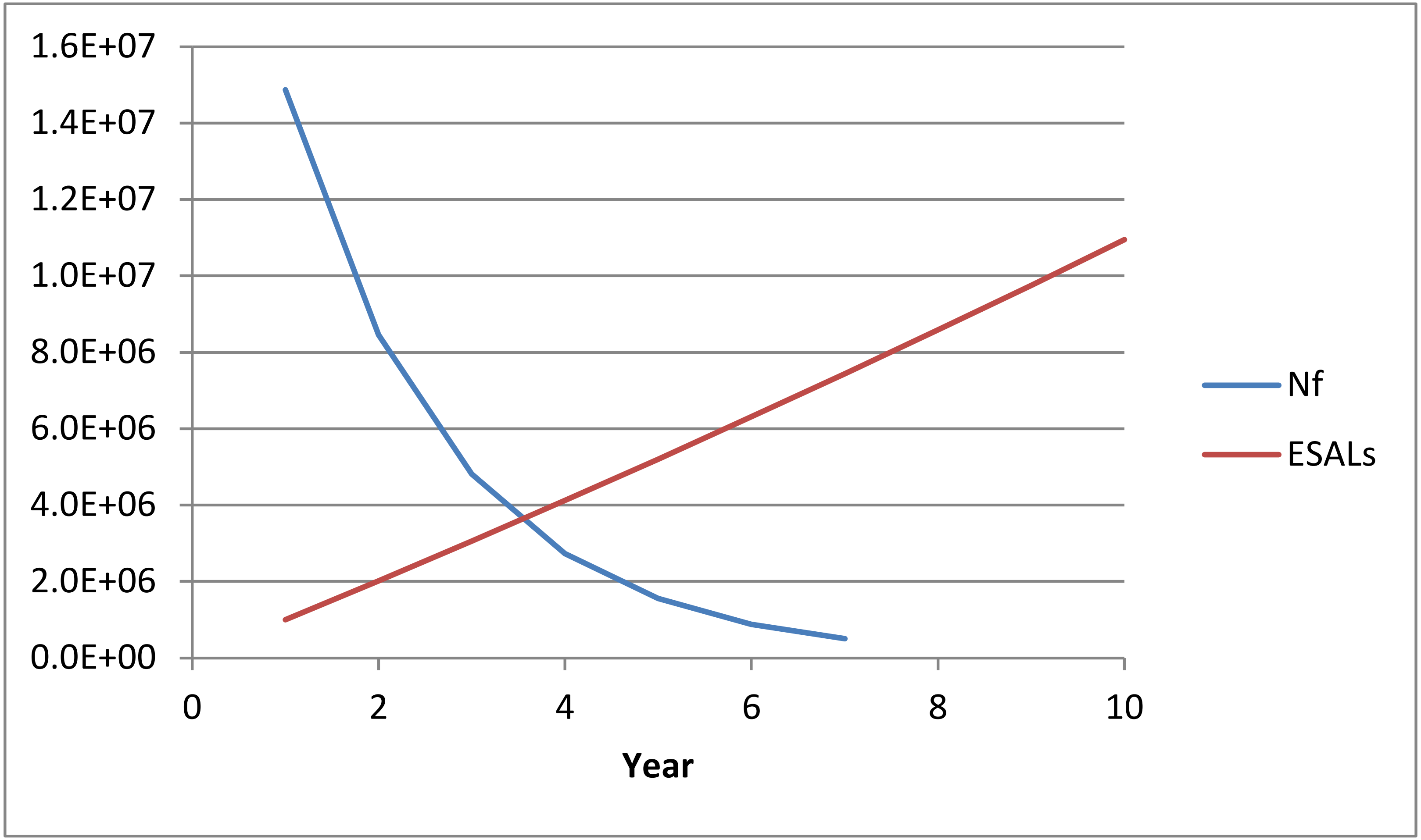
Aging as a Function of Depth and Time: LAS Slope (B)



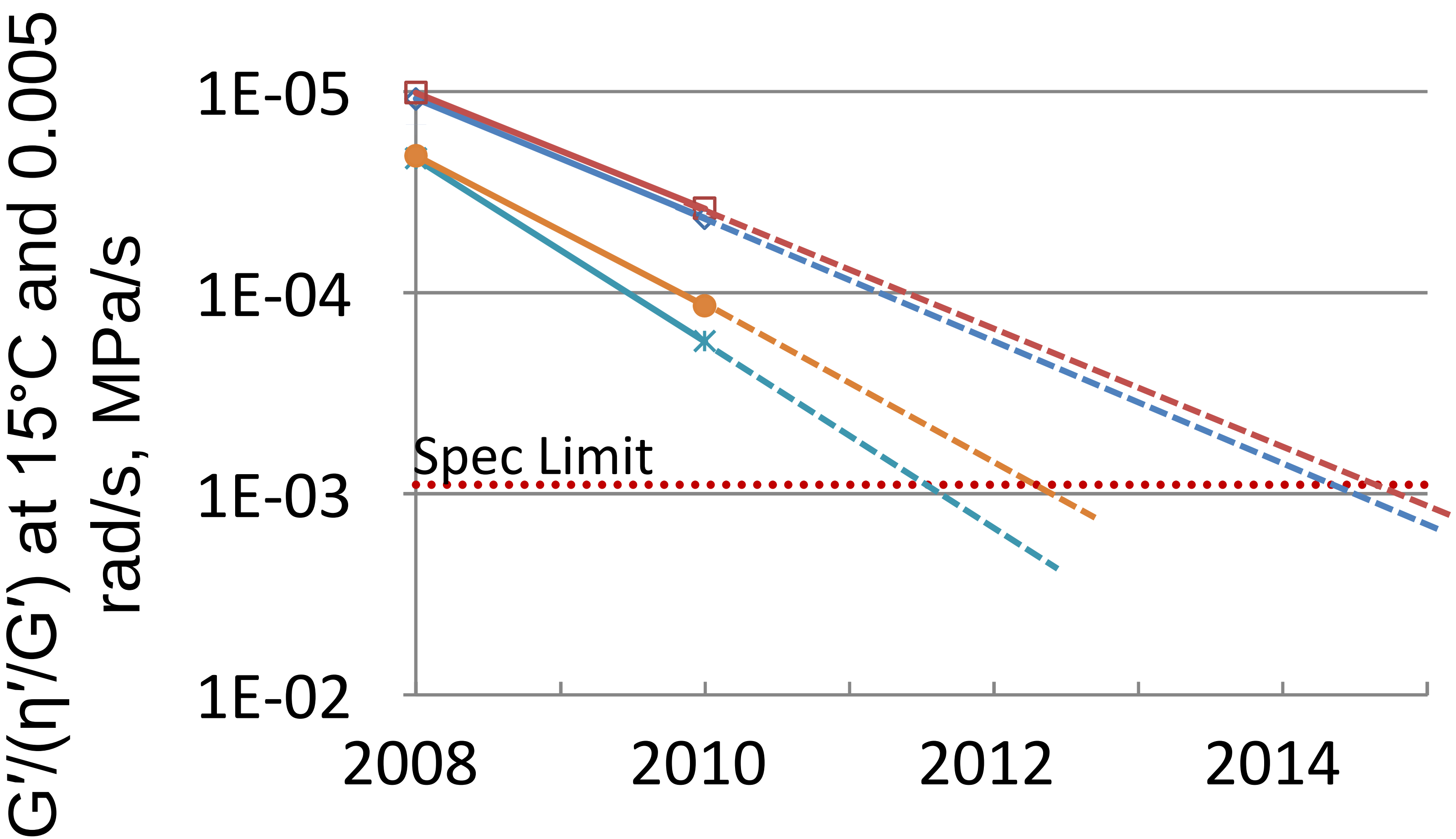
Aging as a Function of Depth and Time: LAS N_f (2%)



Effect of Aging (Conceptual)



MnROAD Cell 24: Aging Profile



Summary

- Effects of Aging
  - Increase stiffness
  - Decrease flexibility
  - Surface Cracking

Thanks!

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