Asphalt Aging and its Impact on the Timing of Preventive Maintenance

Mike Anderson
Asphalt Institute

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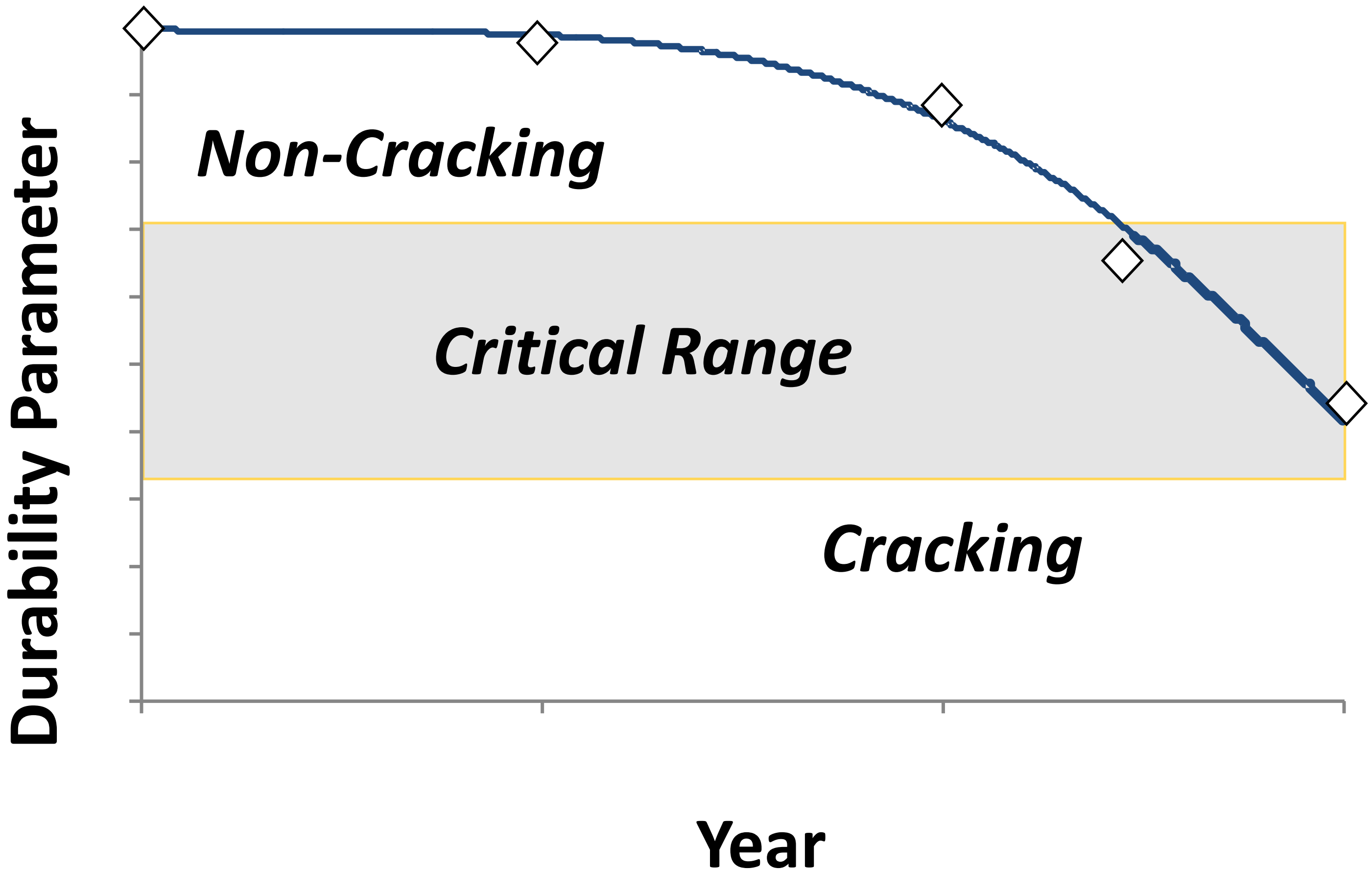
Acknowledgments

- 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



Non-Cracking
Critical Range
Cracking
Durability Parameter
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

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- 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 Oxidation

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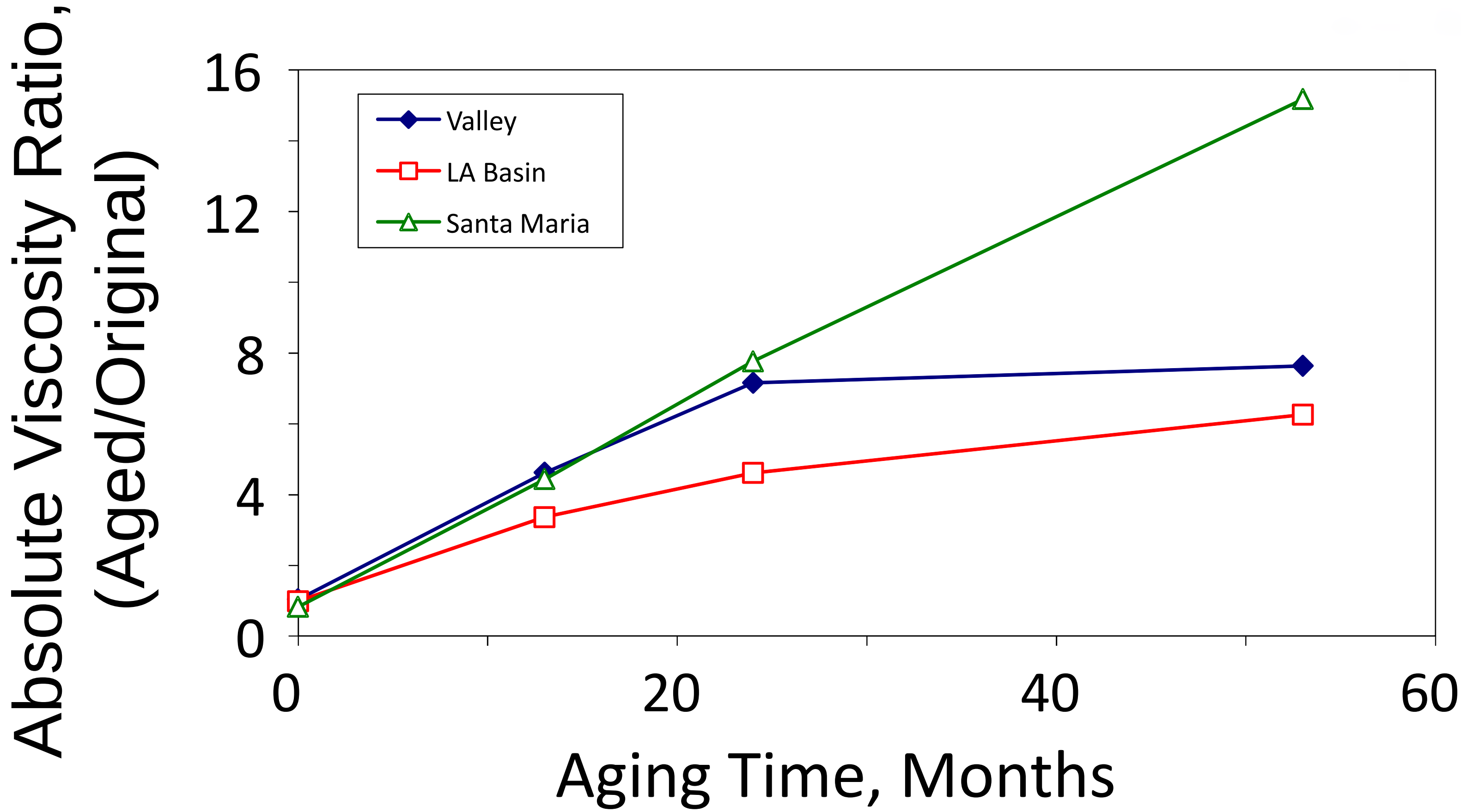
- Physical Changes – Ductility
  - Block cracking severity related to ductility at 60°F (15°C) – Kandhal (1977)
    - "Low-Temperature Ductility in Relation to Pavement Performance", ASTM STP 628, 1977
  - Loss of surface fines as ductility = 10 cm
  - Surface cracking when ductility = 5 cm
  - Serious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

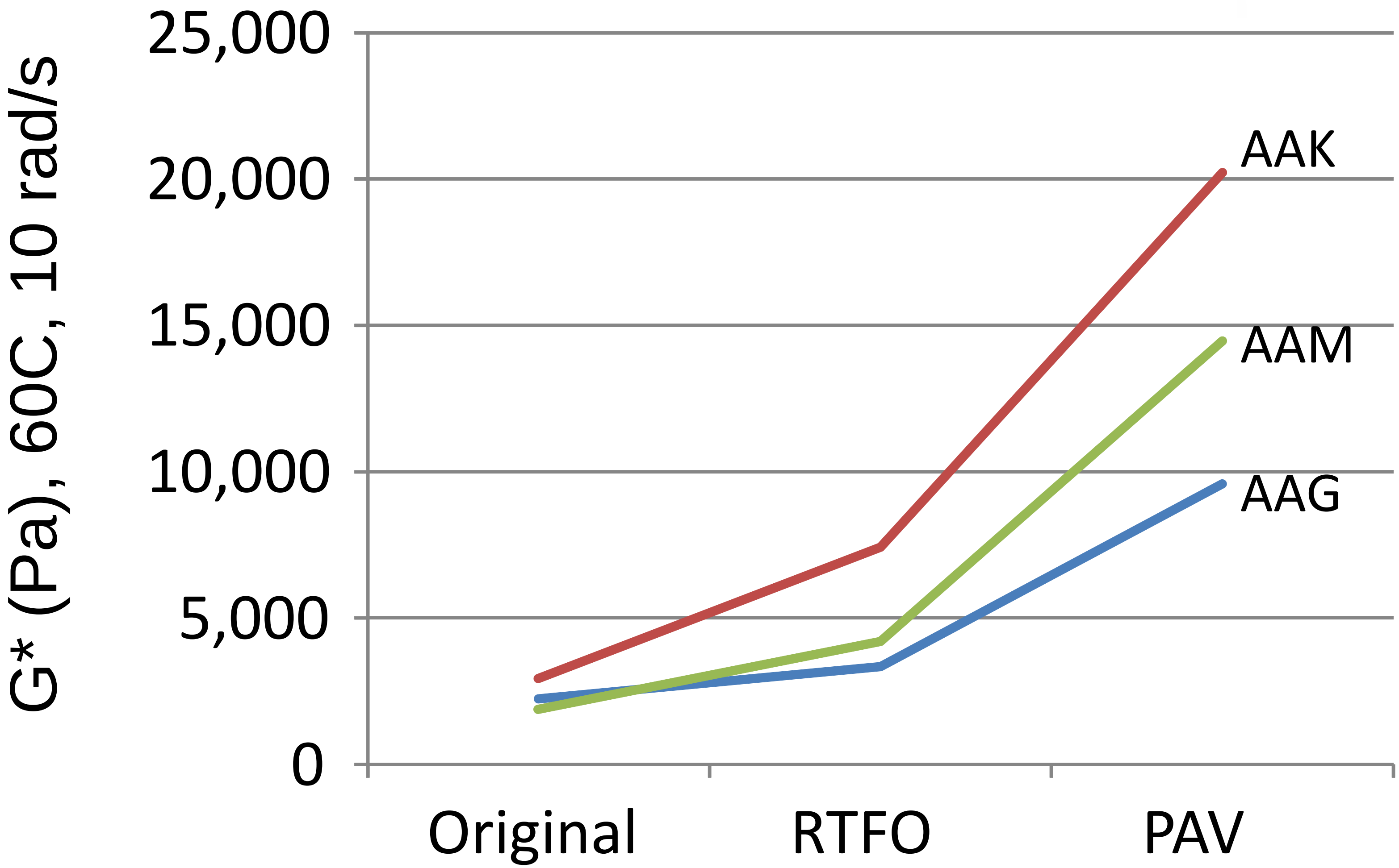
1981 CA Durability Study



Kemp, et.al.

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

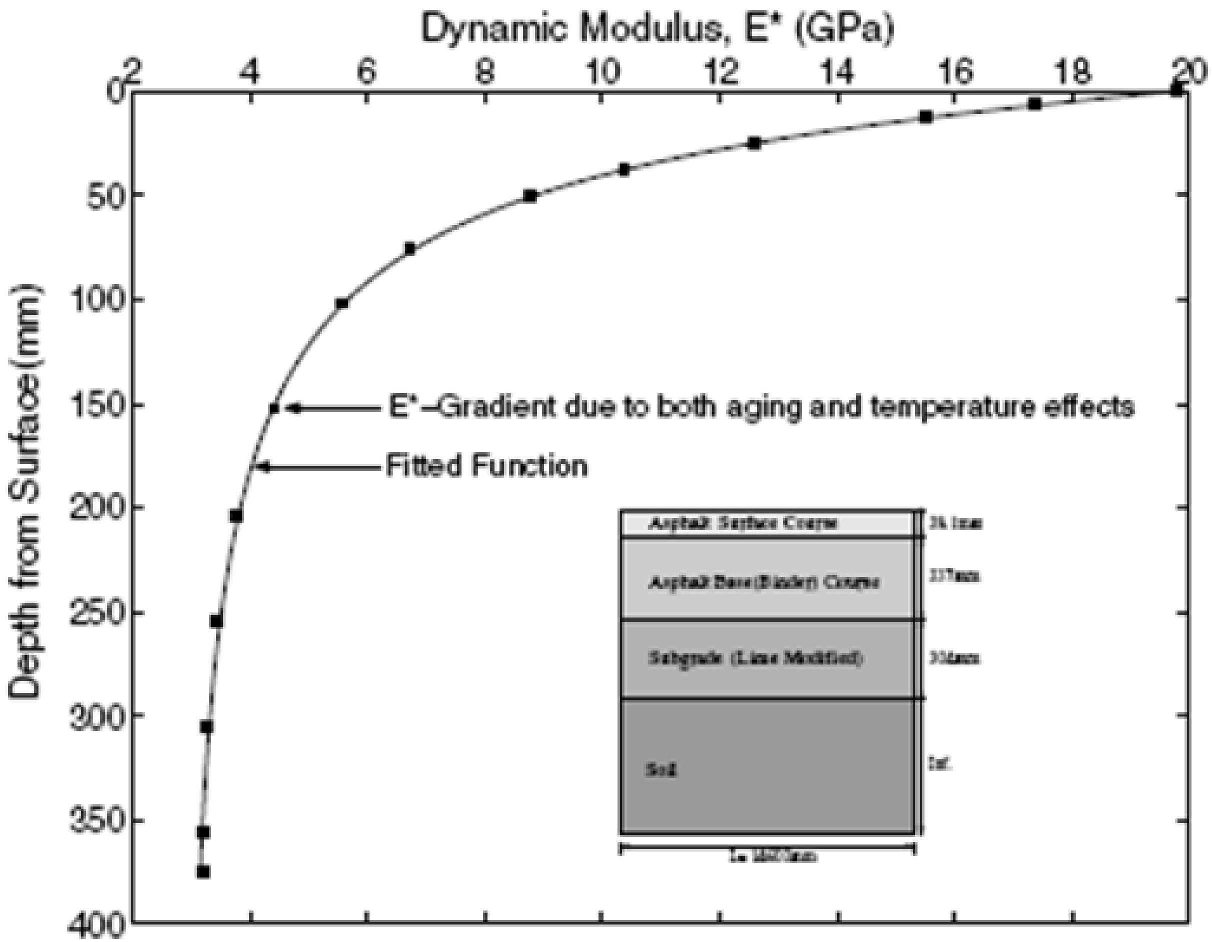
Rate of Aging



Witczak and Mirza: Global Aging Model (1995)

Stiffness

Depth

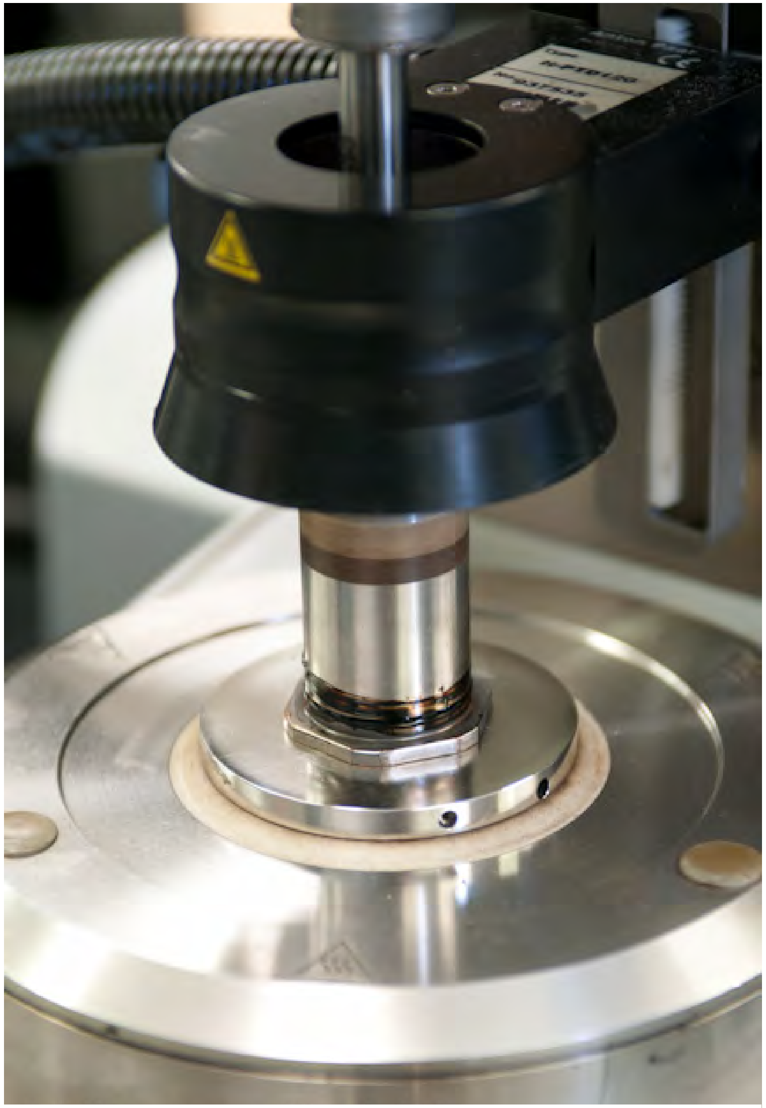


More Recent Aging Research

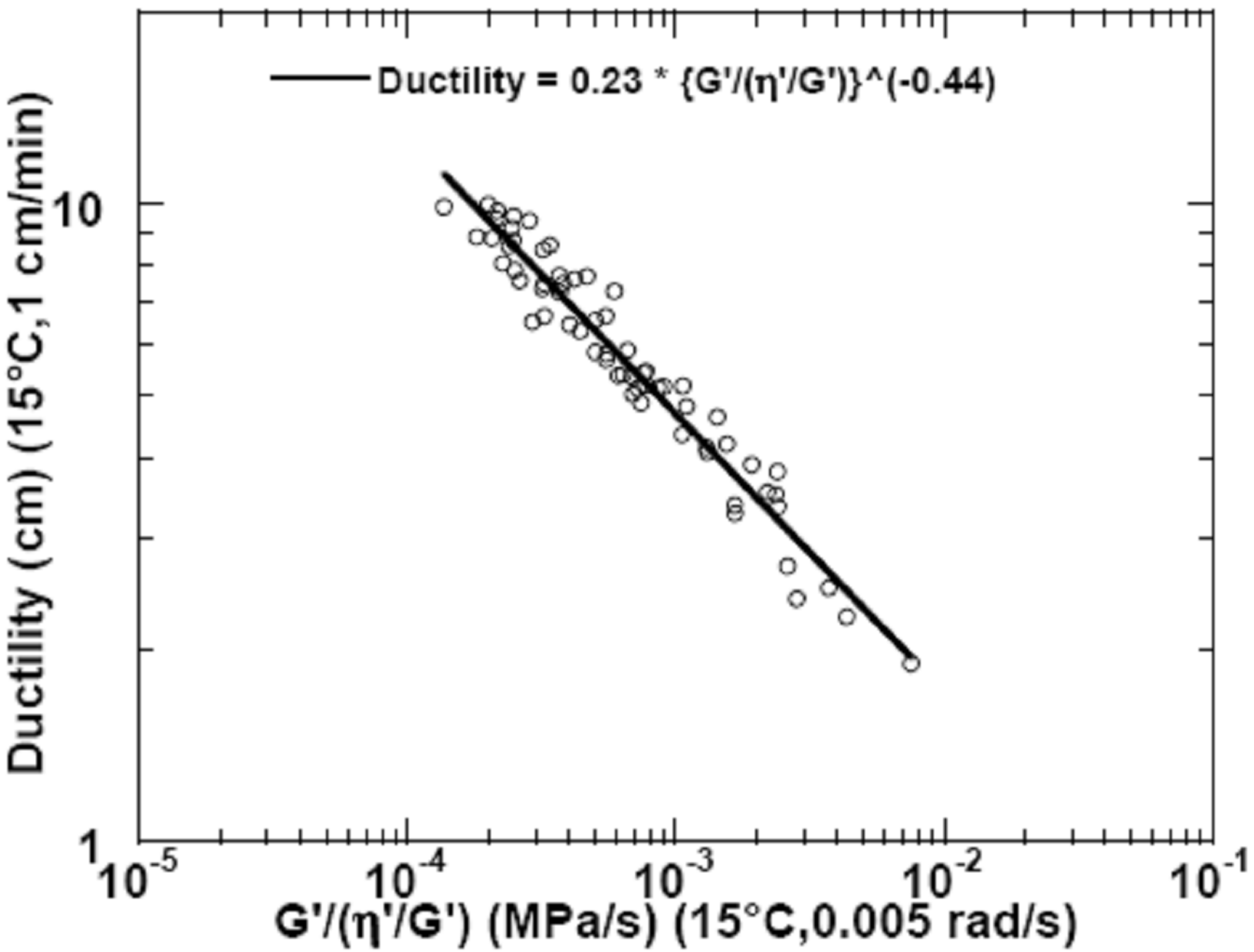
- Texas A&M Research (Glover, et.al.)
  - 2005
  - "Development of a New Method for Assessing Asphalt Binder Durability with Field Evaluation"
  - Build on work by Kandhal suggesting block cracking and raveling is related to low binder ductility after aging
  - Identified rheological parameter related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

Dynamic Shear Rheometer

- 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

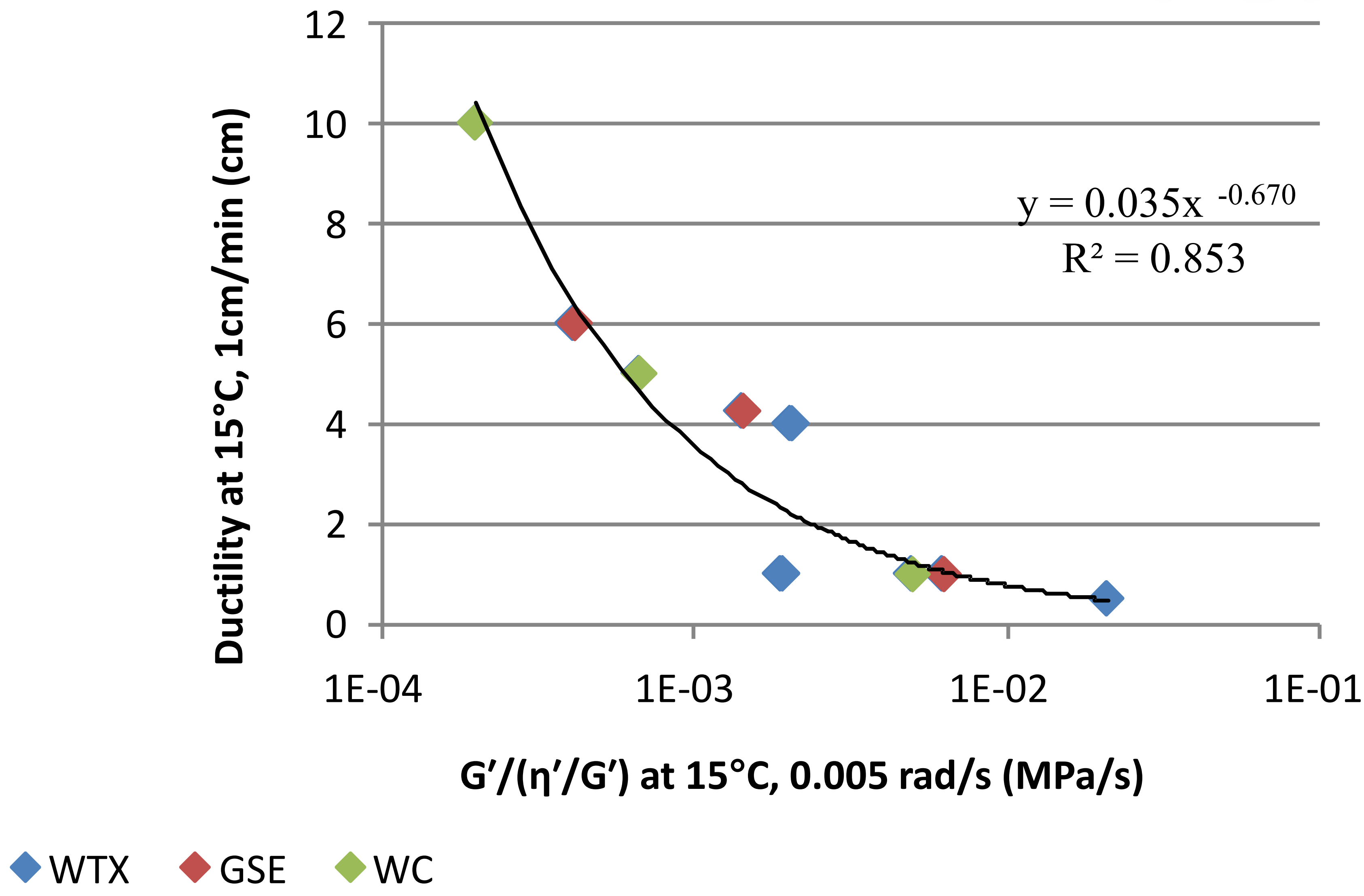


(Glover et.al., 2005)

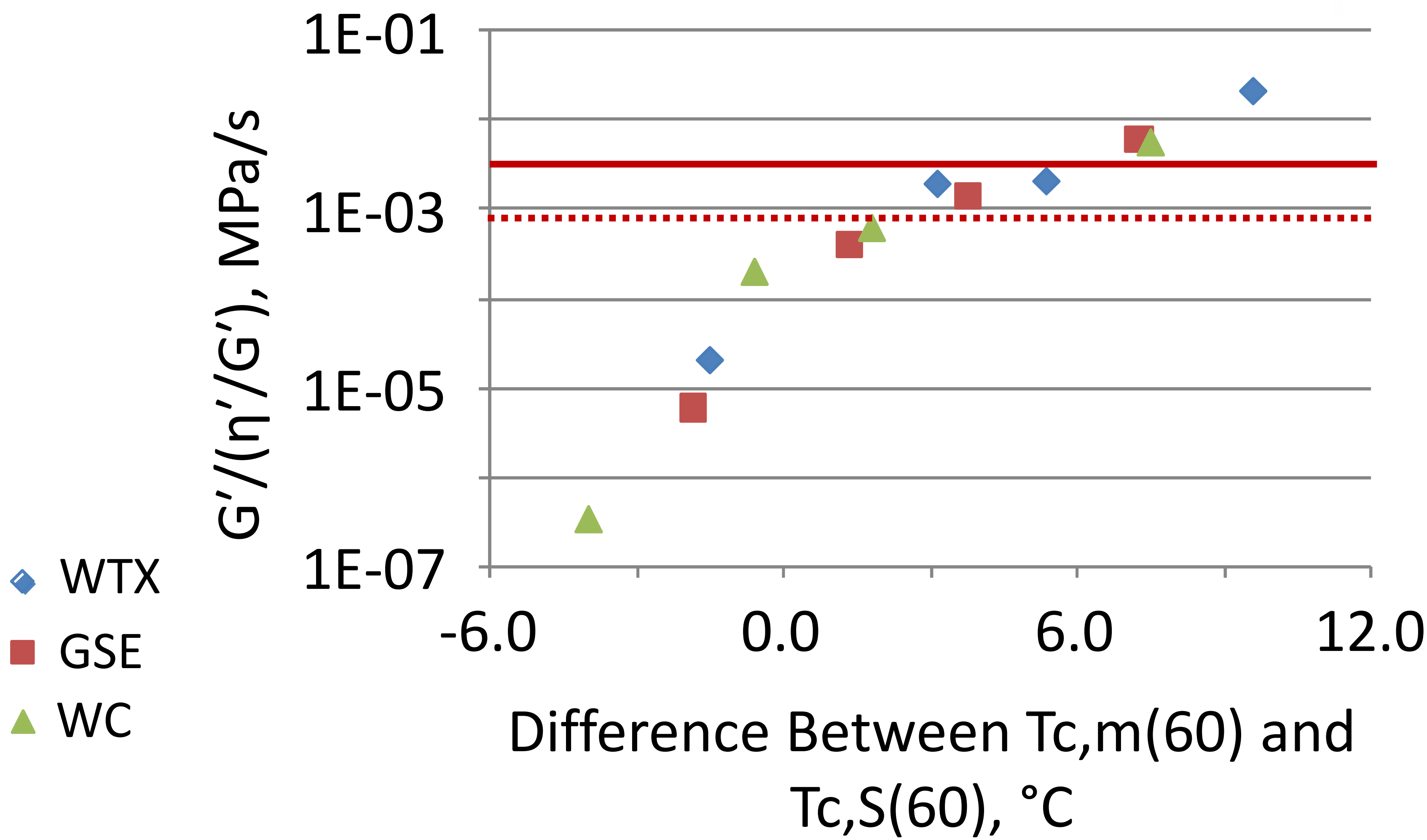
Asphalt Binders

- 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

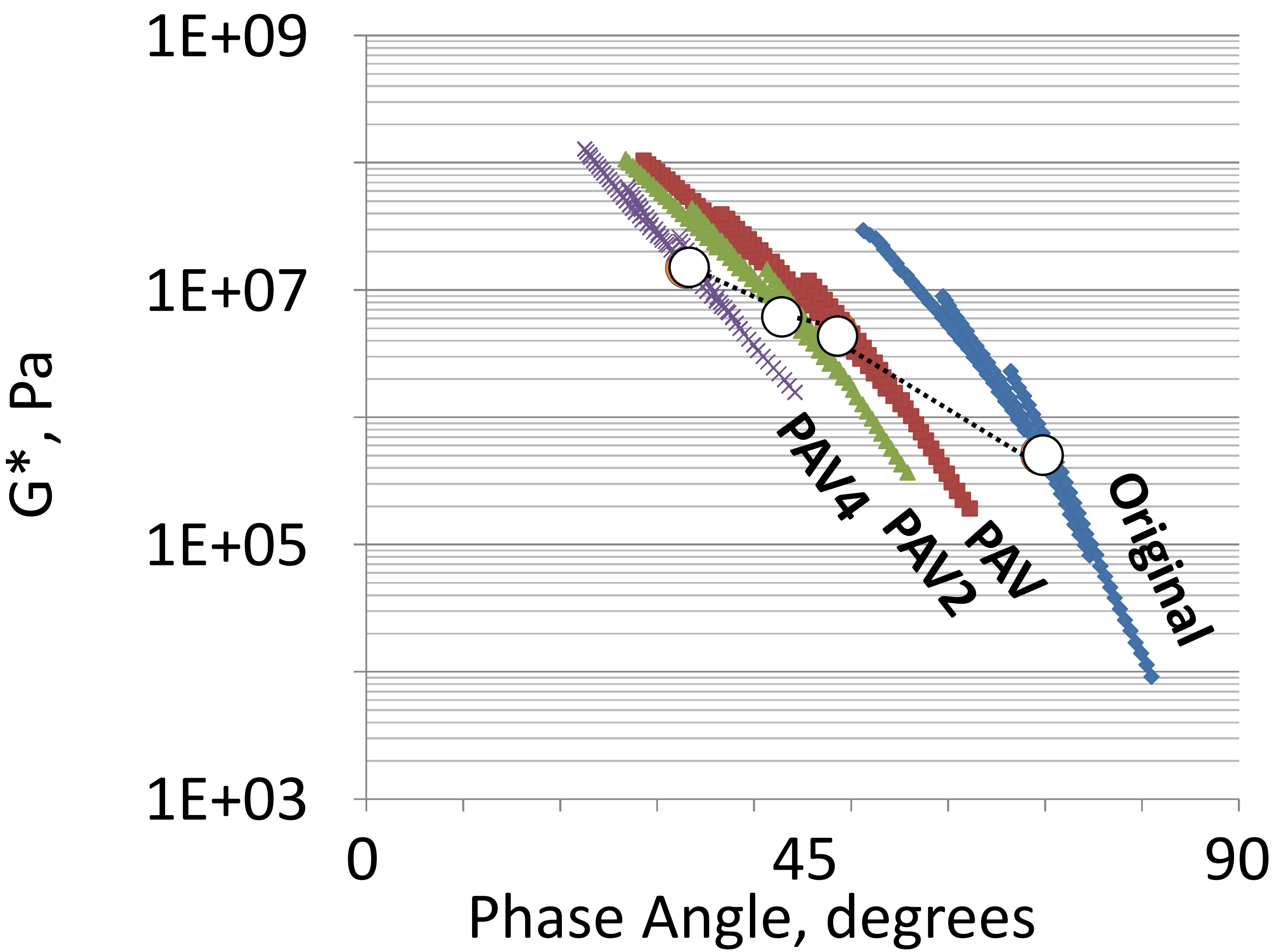
Mastercurve Procedure



Relationship between $G'/(\eta'/G')$ and ΔT_c



Effect of Aging



Glover-Rowe Parameter

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

	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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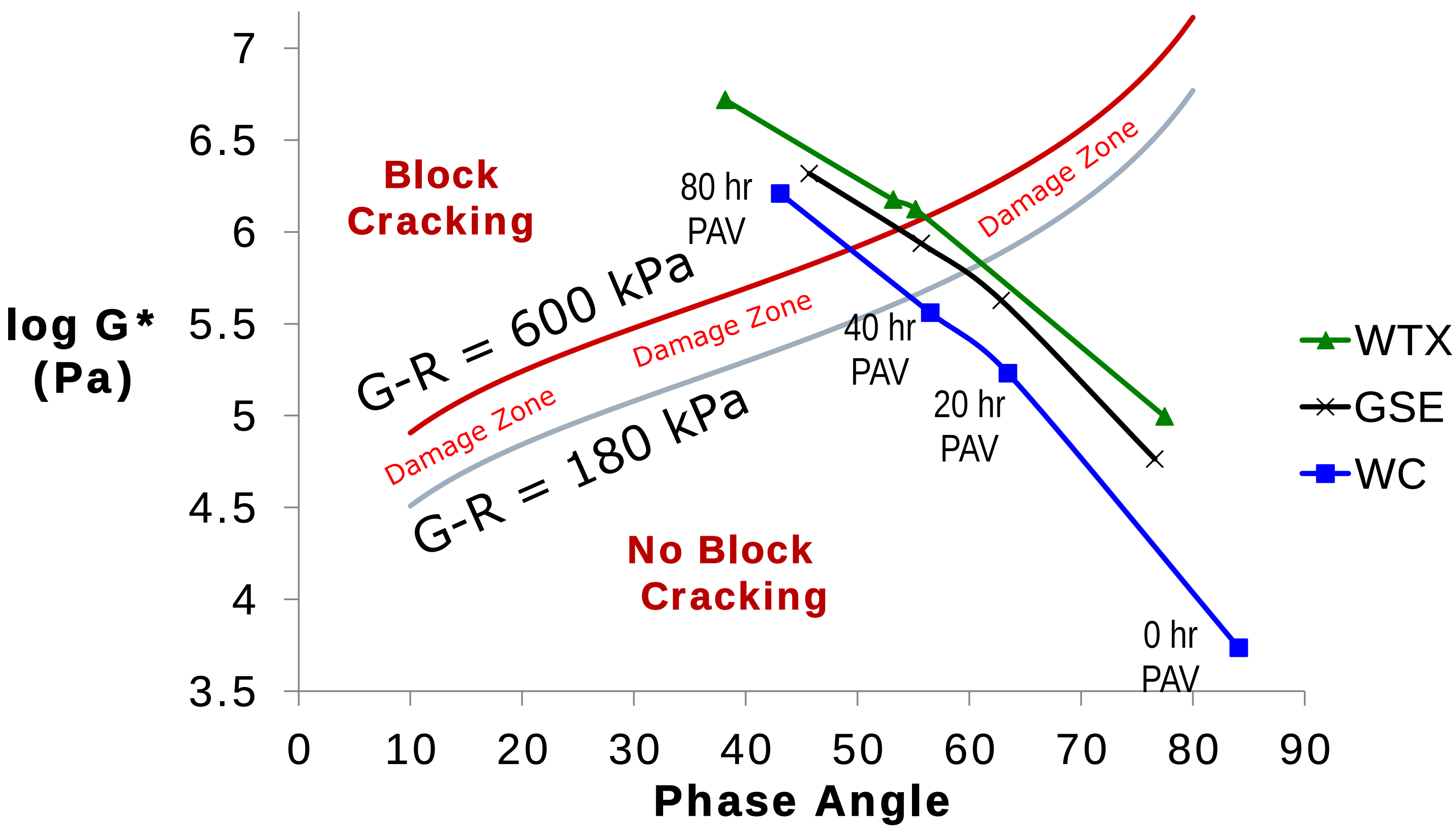


Rowe: Prepared Discussion to M. Anderson paper - AAPT 2011

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

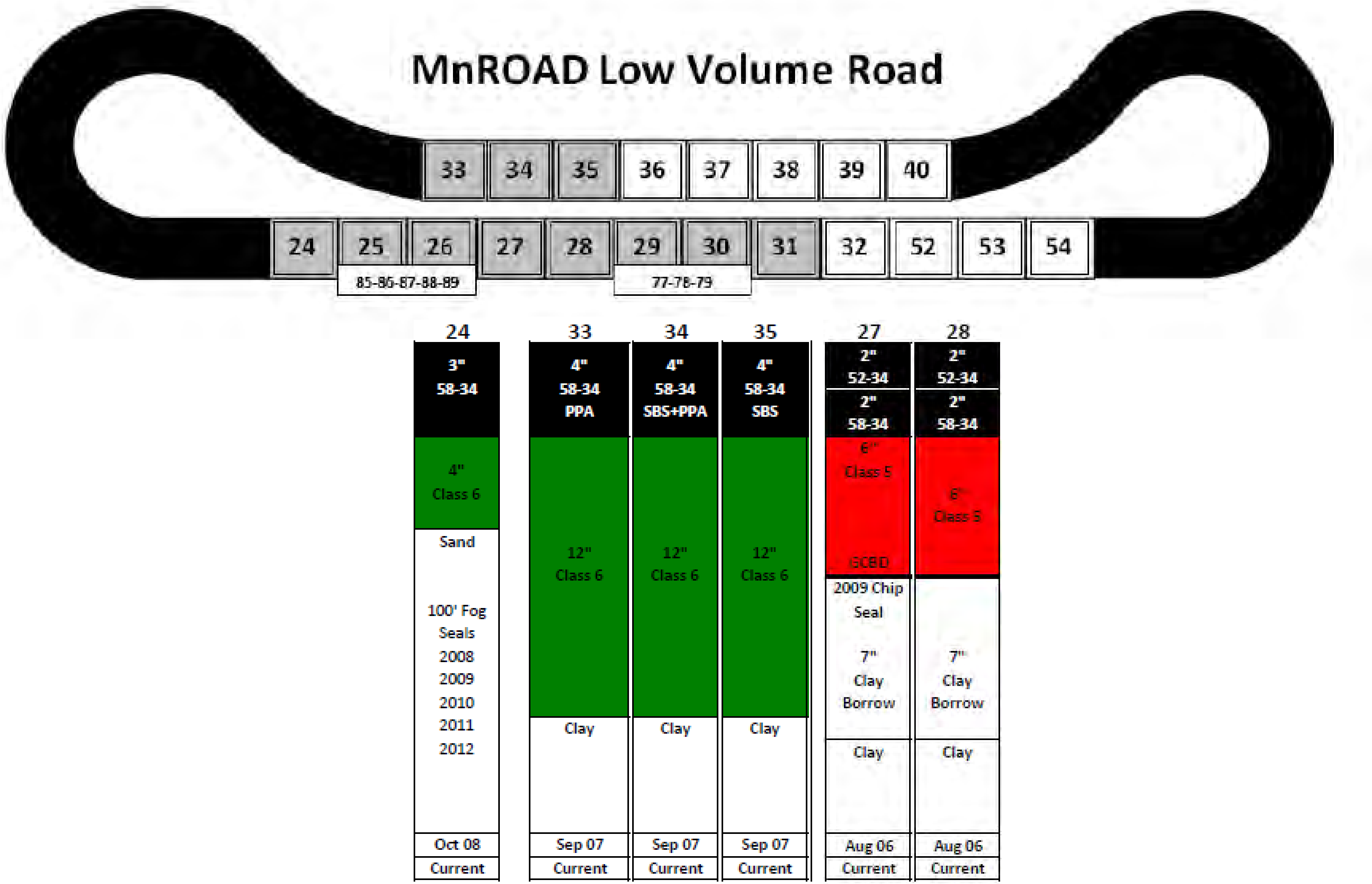
Summary – AAPTP 06-01 Research

- 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, ΔTc, 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

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.

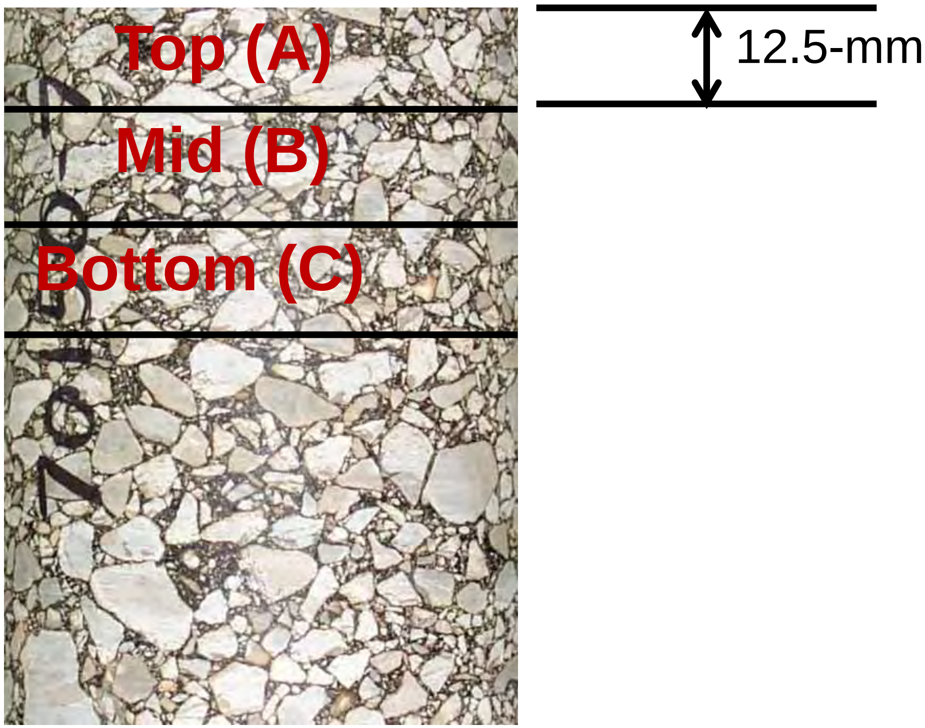
MnROAD Low Volume Road



MnROAD Cell 24

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

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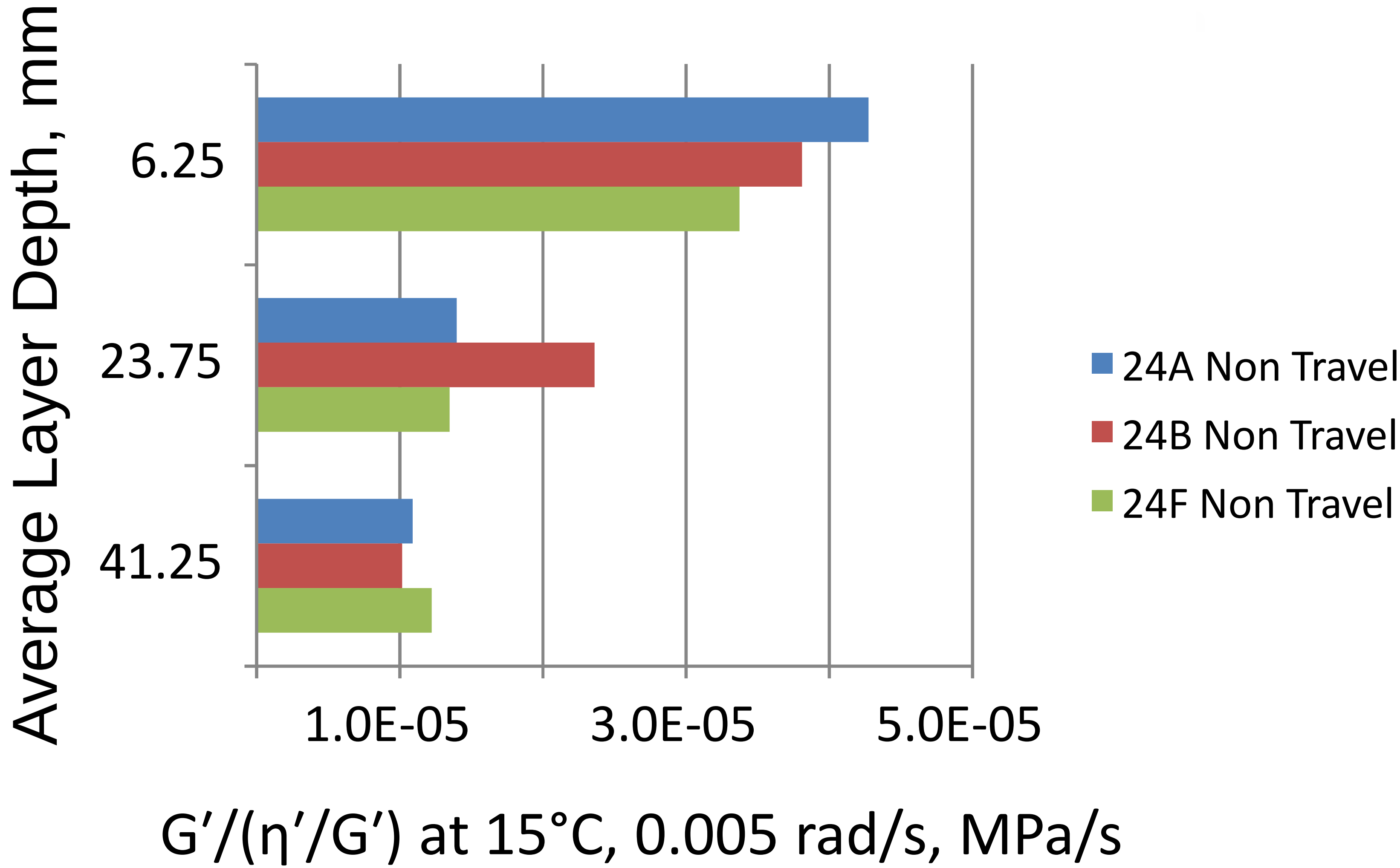

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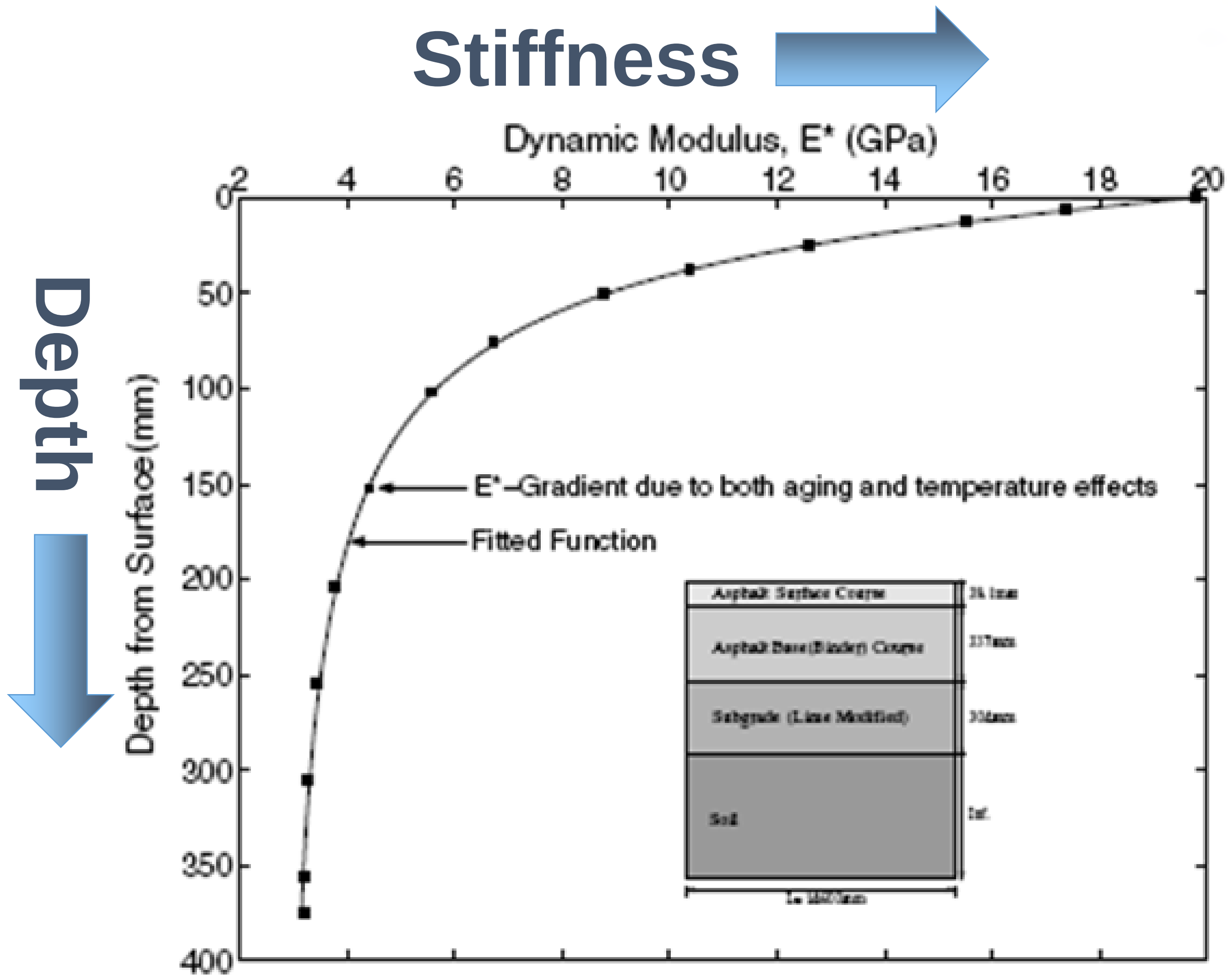
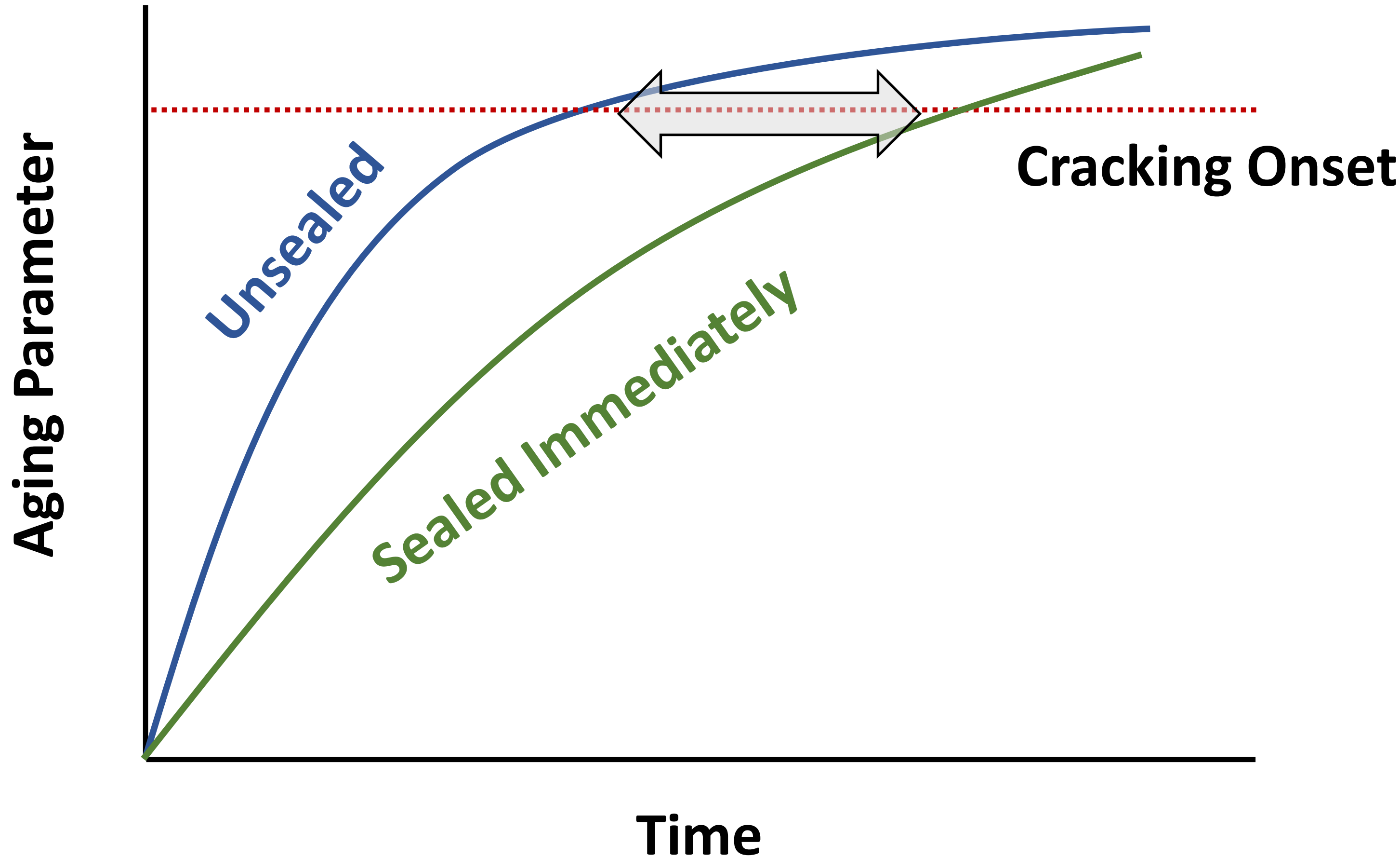
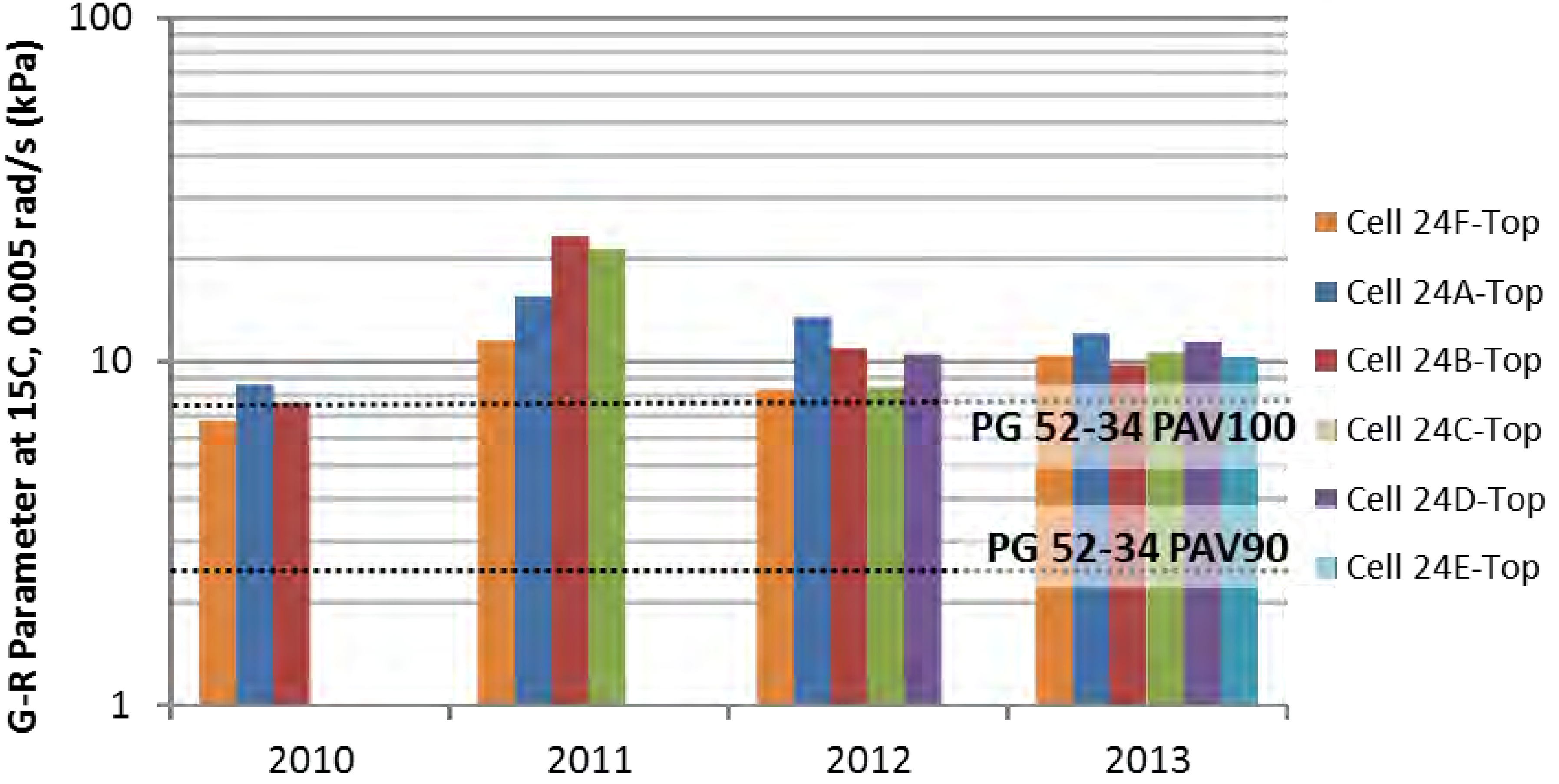


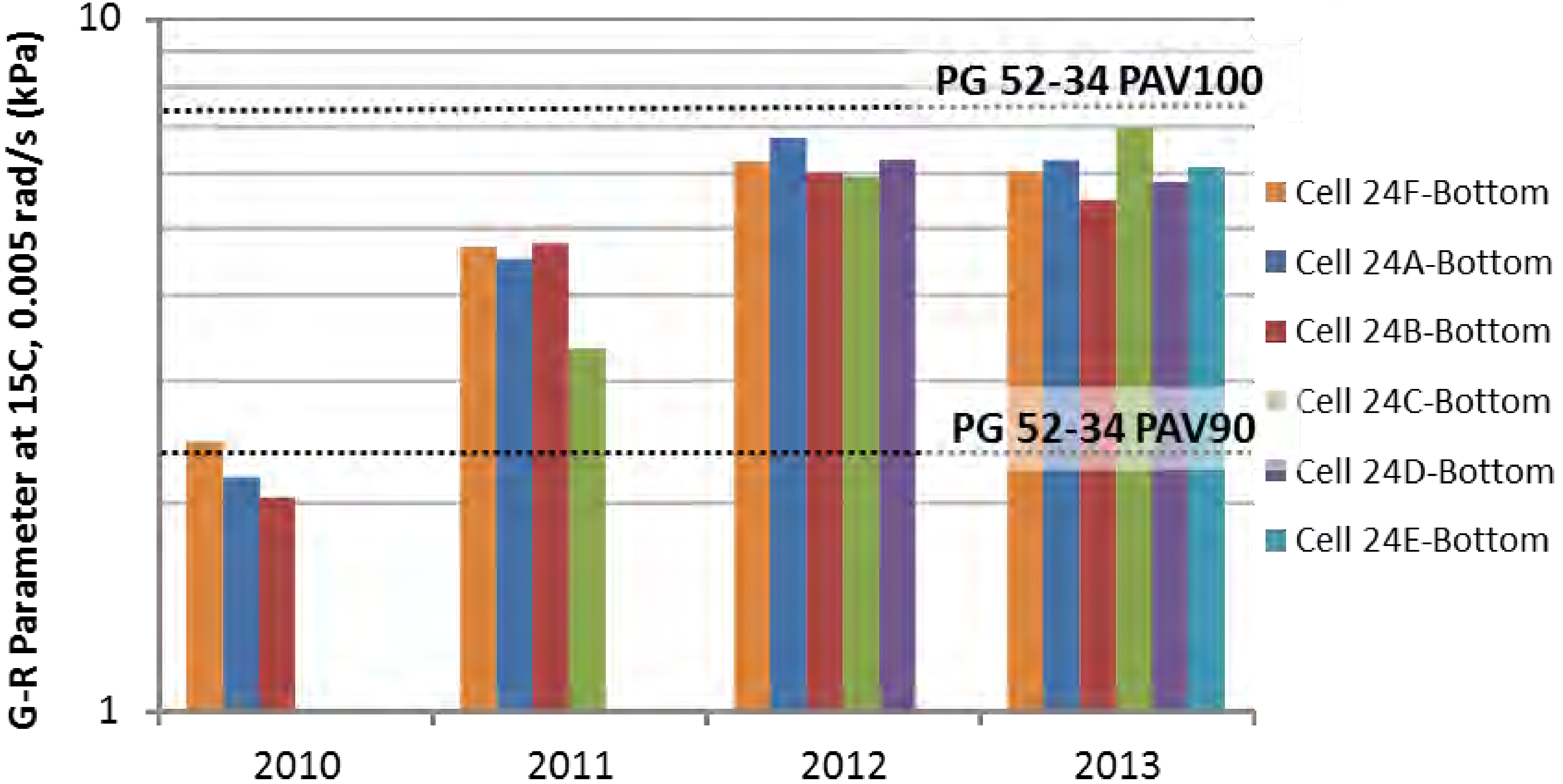
Expected Results



G-R Parameter: MnROAD Cell 24 Top Layers



G-R Parameter: MnROAD Cell 24 Bottom Layers



Black Space Diagram: Progression of Aging

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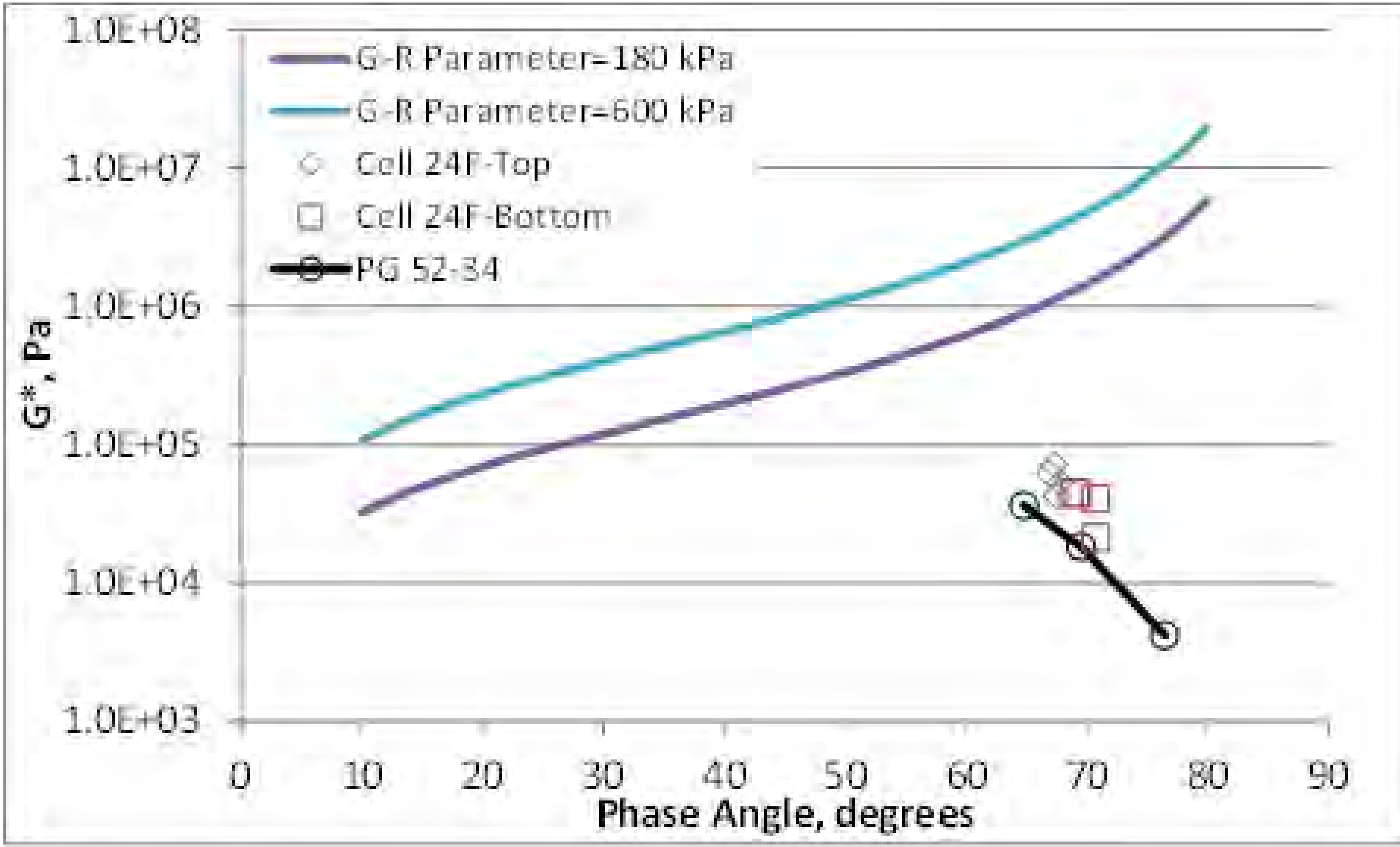
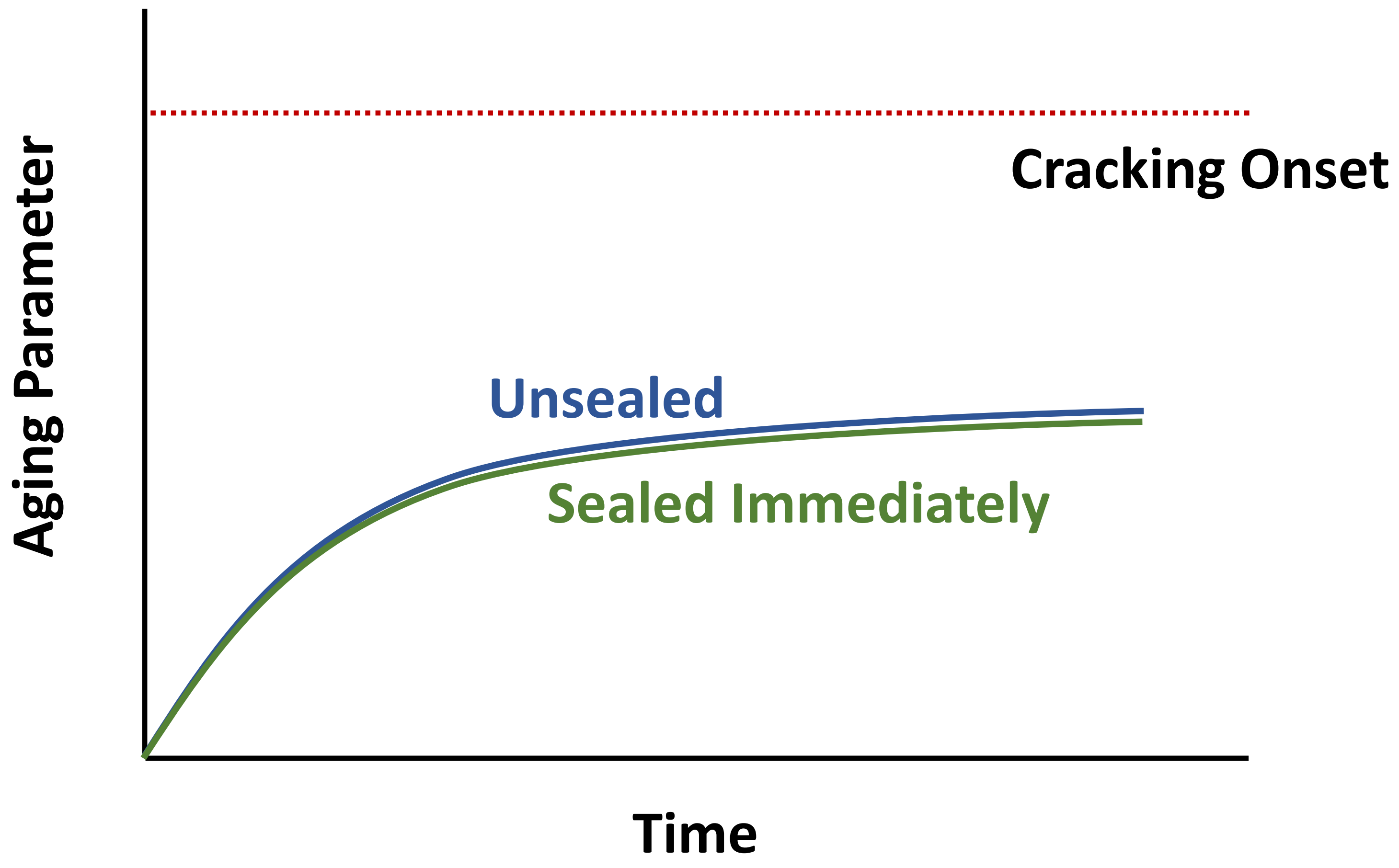
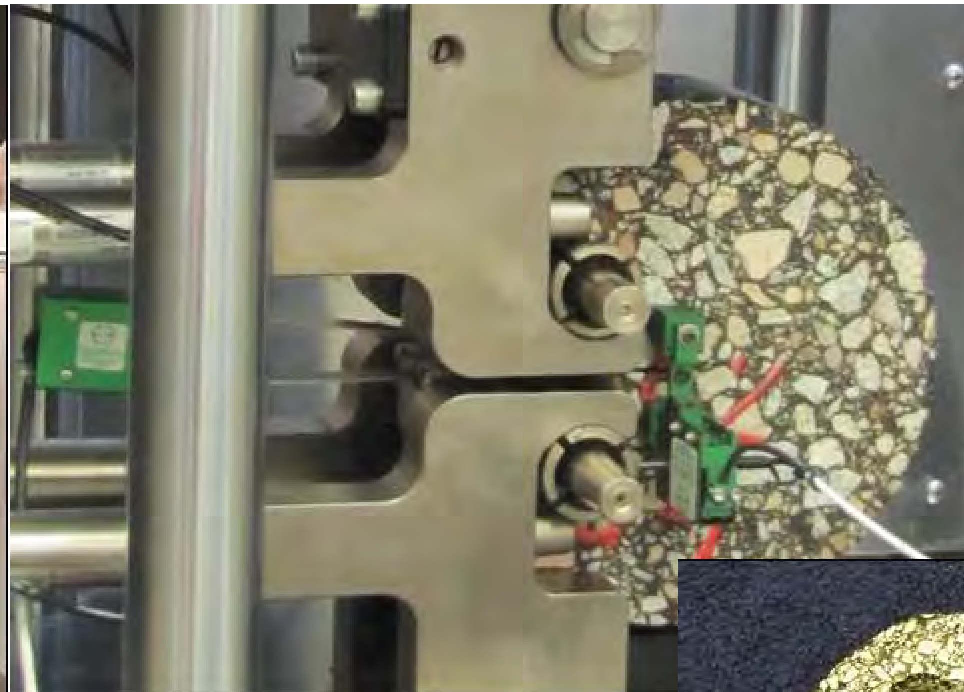
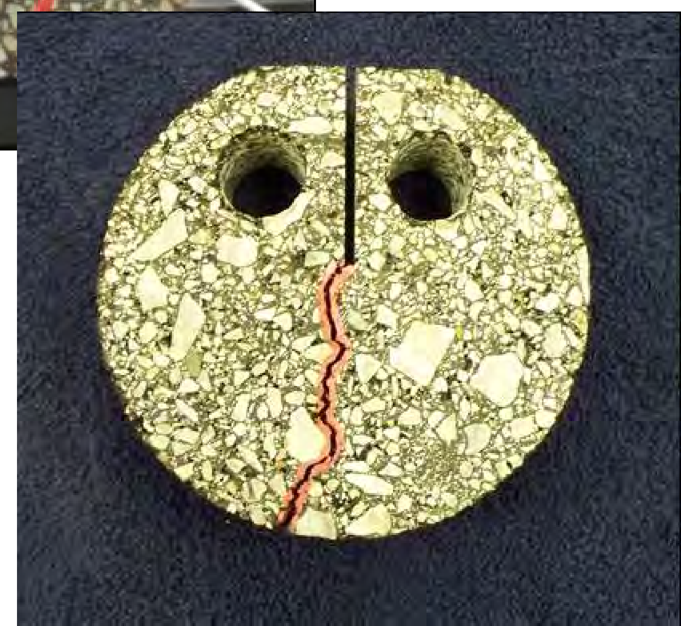


Experiment Results

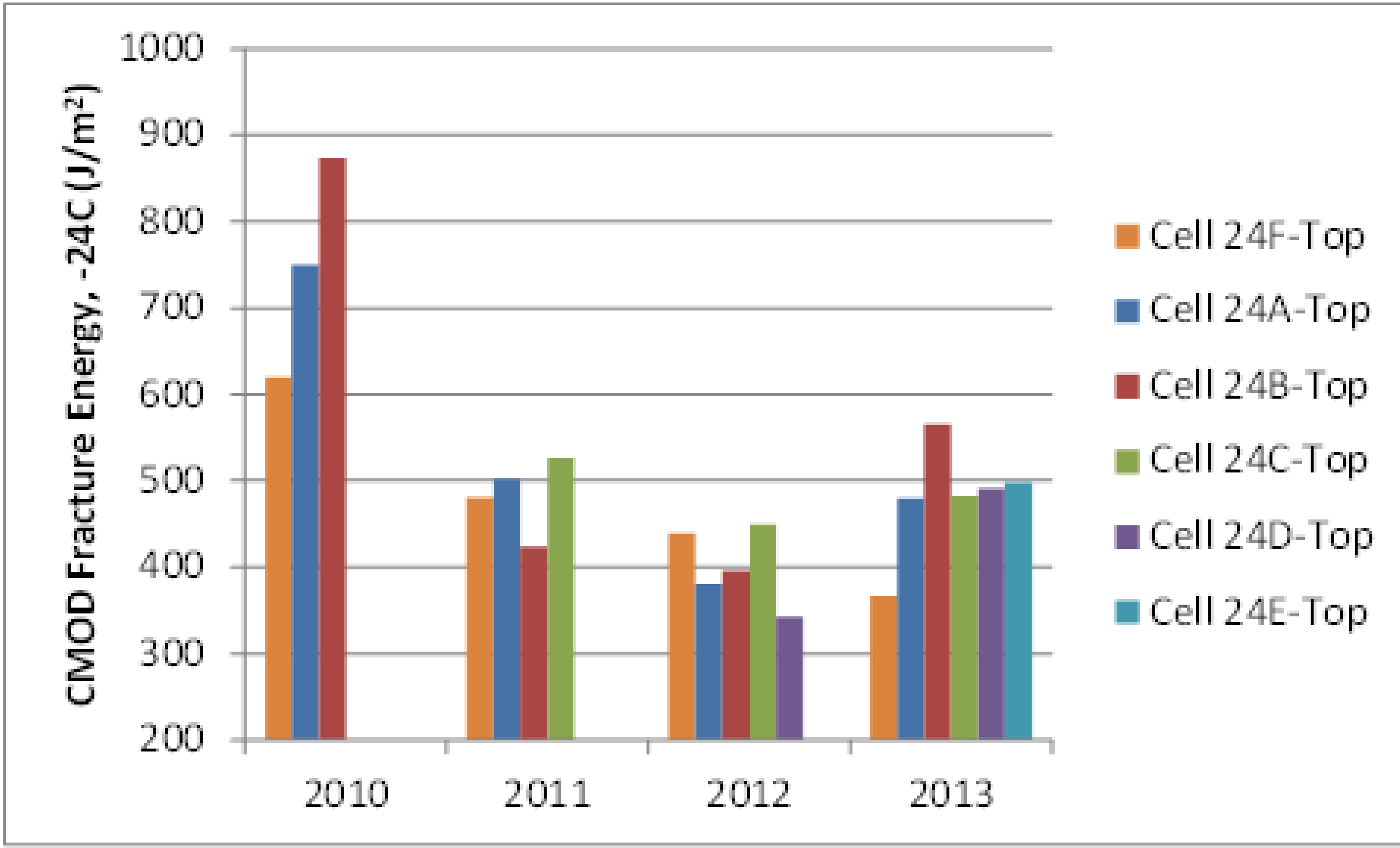


Disk-Shaped Compact Tension Test: DC(T)

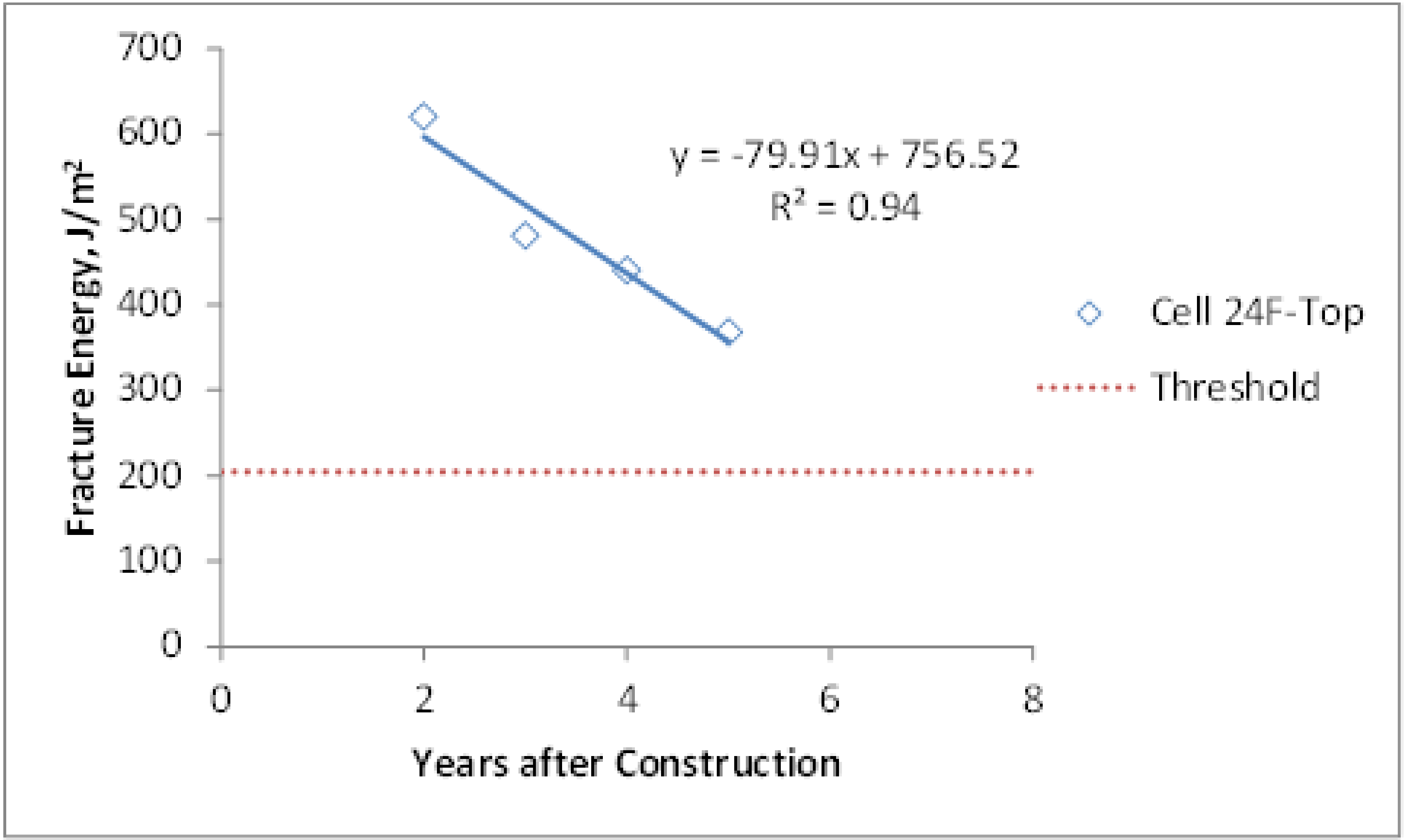




Fracture Energy: MnROAD Cell 24 Top Layers



Fracture Energy: MnROAD Cell 24F Top



Key Findings from MnROAD Cell 24

- MnROAD Cell 24 Test Section
  - Binder Test Results
    - Aging of the asphalt pavement, as measured using several asphalt binder properties, was shown to be significantly higher near the surface (within the top 12.5 millimeters) than further down in the pavement structure. Near the surface, the asphalt binder shows an increase in stiffness and a decrease in phase angle, indicating a loss of relaxation properties as the binder ages.

Key Findings from MnROAD Cell 24

- MnROAD Cell 24 Test Section
  - Binder Test Results
    - The aging expected to occur as the time is extended from construction to sealing was not readily seen in the asphalt binder properties.
      - Contrary to expectations and initial data analysis all of the subsections, including the Control, exhibited no discernible trend indicating that time from construction to sealing had a significant effect on asphalt binder properties.
        - Only five years of service from construction to the last coring
        - More aging may be needed to see any significant effects.

Key Findings from MnROAD Cell 24

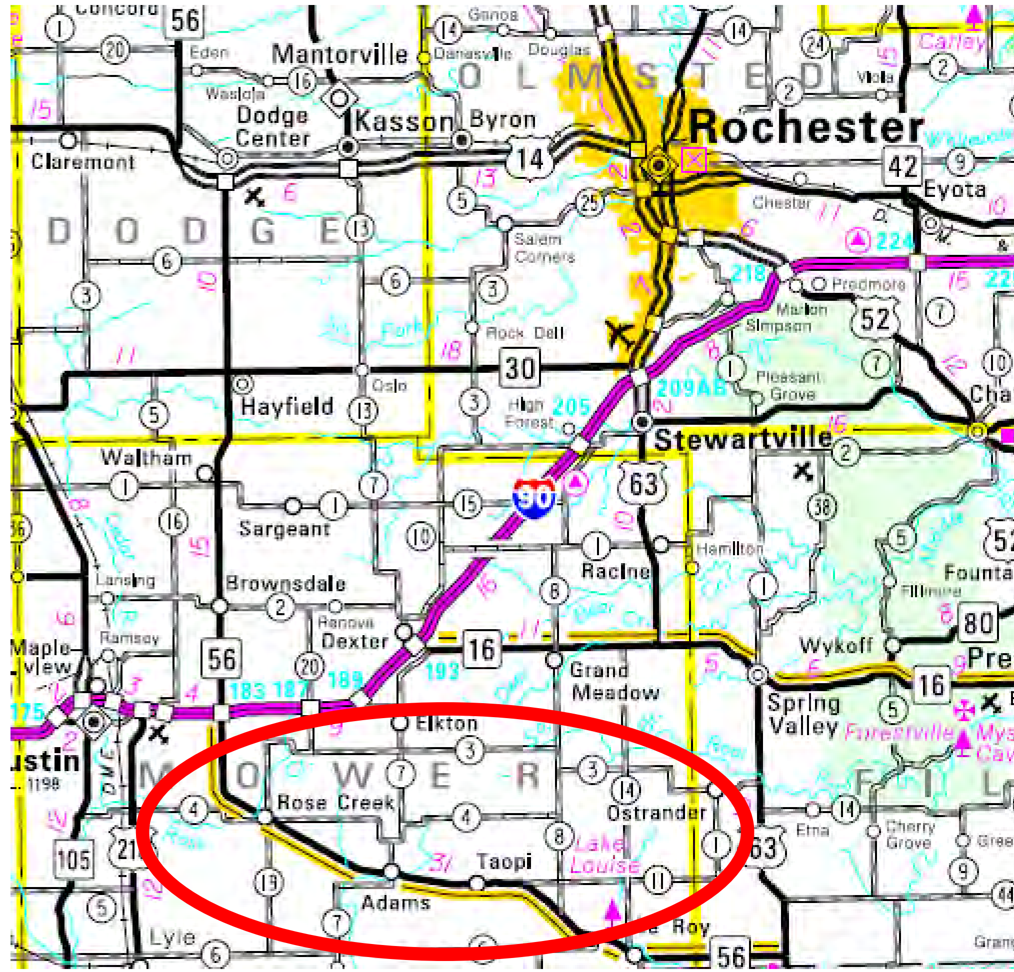
- MnROAD Cell 24 Test Section
  - Binder Test Results
    - Bottom layers illustrated aging with time was observed by a change in the asphalt binder properties.
    - None of the subsections had values for the $G'/(\eta'/G')$ and G-R parameters that were close to the limiting values suggested by other research as thresholds for cracking.
      - Not surprising given the relatively young age of the pavement (five years at the time of the last coring) and lack of cracking noted on any of the test sections from distress surveys.

Key Findings from MnROAD Cell 24

- MnROAD Cell 24 Test Section
  - Mixture Test Results
    - Mixture testing generally did not show any significant trends of aging as the time from construction to sealing increased with the exception of the indirect tensile strength of the Top layers.
      - Cores from subsections sealed in 2009 and later had higher indirect tensile strength values than the Control subsection and the subsection sealed in 2008 (using a CSS-1 emulsion instead of a CRS-2P emulsion).
      - The indirect tensile strength values of all subsections decreased as time increased.

TH56 Test Sections

- TH56
  - two-lane rural highway with ADT of 2000 (reported at time of construction)
  - test sections located between I-90 and Leroy, MN



TH56 Test Sections

MINNESOTA TH 56 SITE LAYOUT

10 to 11	11 to 12	12 to 13	13 to 14	14 to 15
Control	2003	2002	2001	2000
Age when treated	4 YEAR	3 YEAR	2 YEAR	1 YEAR
ORIGINAL CONSTRUCTION - 1999				
	CRS-2P 0.40 gal/yd^2	CRS-2P 0.38-0.42 gal/yd^2	CRS-2P 0.34 gal/yd^2	CRS-2P 0.32 gal/yd^2

TH56 Test Sections

Specimen Group ID	Control	T1	T2	T3	T4
Original Construction	1999	1999	1999	1999	1999
Chip Sealing Year	N/A	2000	2001	2002	2003
Age at Treatment Time, yr.	N/A	1	2	3	4
Emulsion Type	N/A	CRS-2P	CRS-2P	CRS-2P	CRS-2P
Aggregate Type	N/A	New Ulm Quartzite	Dresser Trap Rock	Dresser Trap Rock	Dresser Trap Rock
Binder Application Rate, gal/yd^2	N/A	0.32	0.34	0.38-0.42	0.40
Chip Application Rate, lb./yd^2	N/A	16	17-18	18-22	19

N/A= not applicable

TH56 Cores

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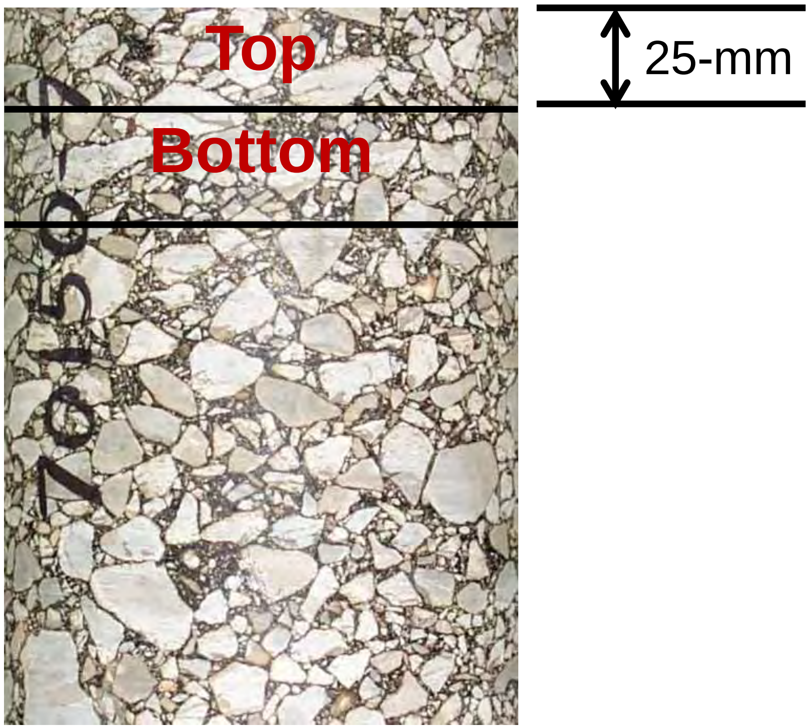
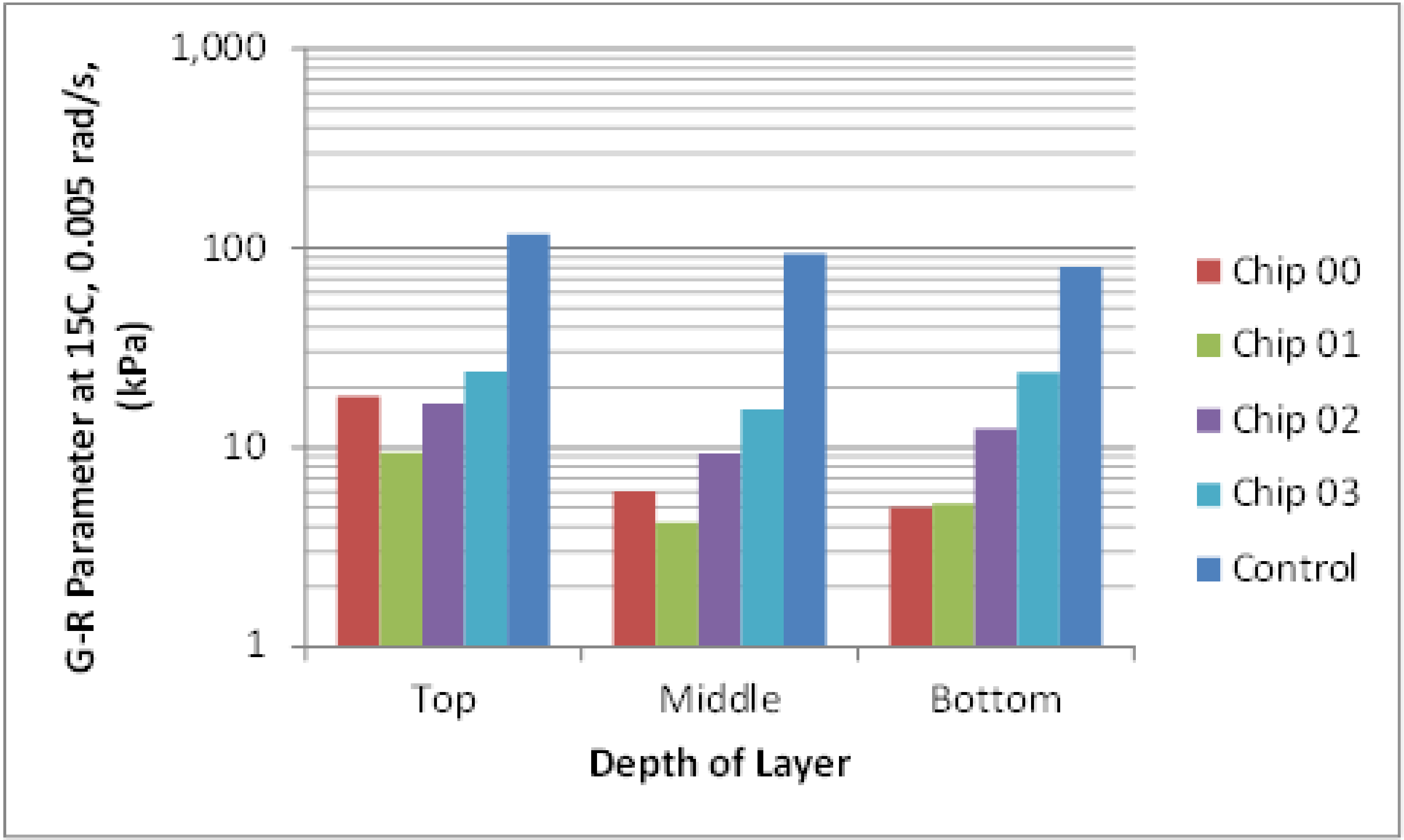
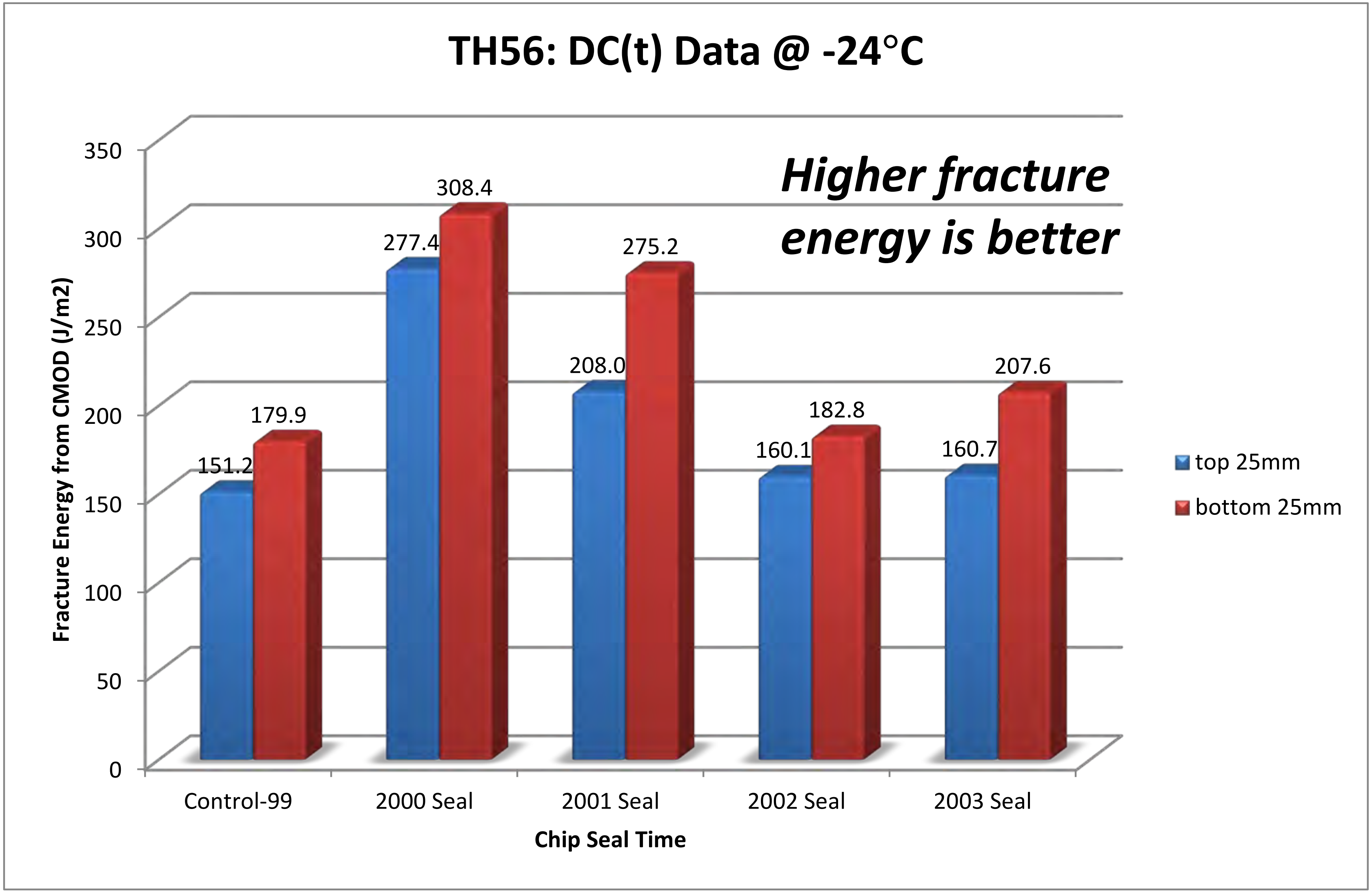


- Cores
  - Remove chip seal (if any)
  - Cut into two 25-mm layers
  - Test for fracture energy (cracking potential)
  - Recover component asphalt to check aging

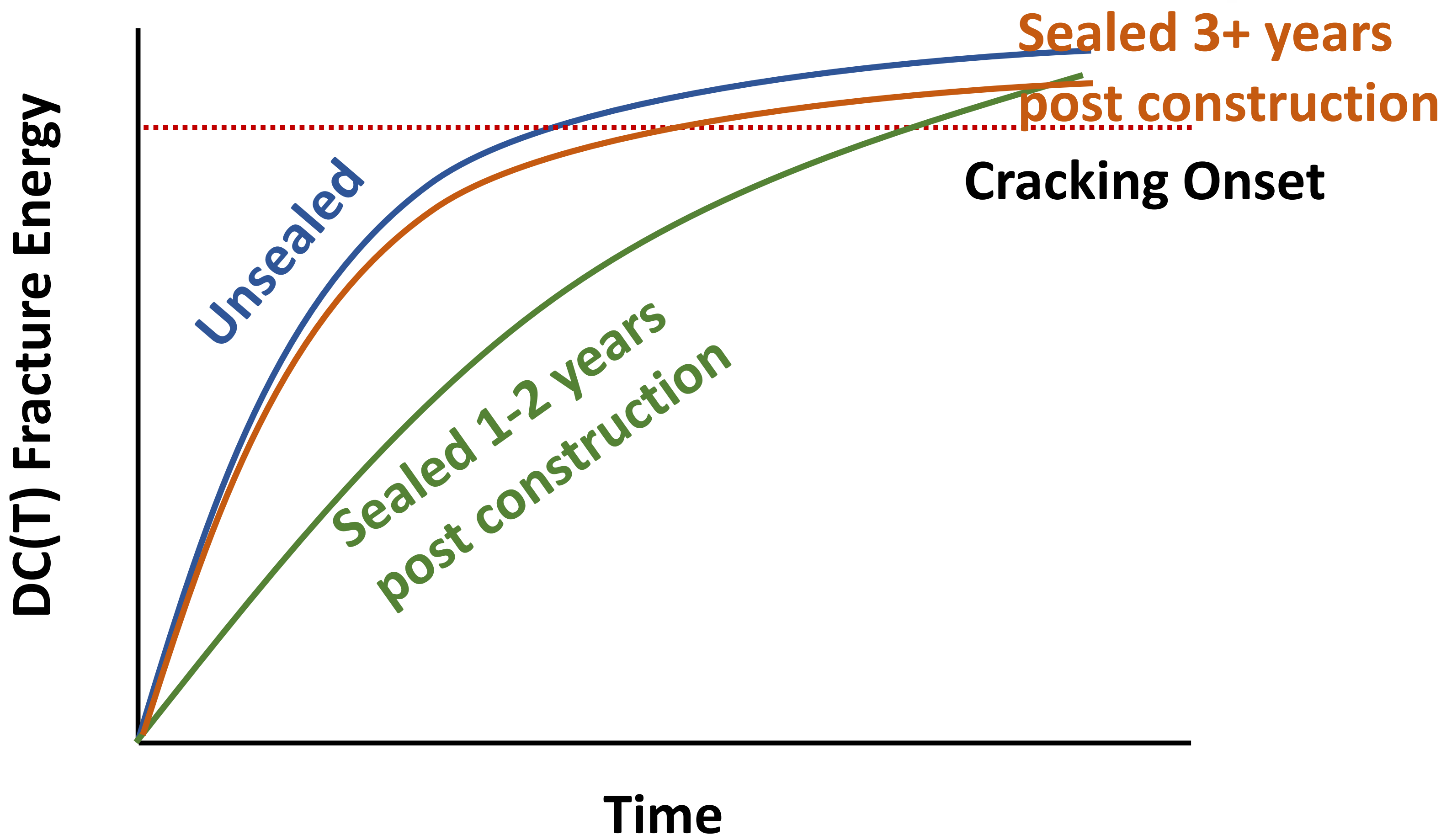
G-R Parameter: TH56



DC(T) Results: TH-56



Experiment Results



Key Findings from Minnesota TH56

- Minnesota TH 56 Test Section
  - Binder Test Results
    - Top layers of all the test sections had higher values of asphalt binder aging parameters than their corresponding layers further from the surface.
    - The time between construction and sealing also had an effect on the asphalt binder aging parameters with the earliest chip seal section exhibiting the lowest values (indicating the least aging) and the Control (unsealed) section exhibiting the highest values (indicating the most aging).

Key Findings from Minnesota TH56

- Minnesota TH 56 Test Section
  - Mixture IDT Test Results
    - Generally confirmed the results of the binder testing
    - Decreased indirect tensile strength and increased Critical Cracking Temperature as time from construction to sealing increases.

Key Findings from Minnesota TH56

- Minnesota TH 56 Test Section
  - Mixture DC(T) Results
    - Fracture energy decreased for the first two years after construction and then reached a plateau
      - below the threshold value suggested for cracking
    - Fracture energy of the cores from the 2002 and 2003 Chip Seal sections was the same as the Control (unsealed) section after 12 years of service.

Key Findings from Minnesota TH56

- Minnesota TH 56 Test Section
  - Mixture DC(T) Results
    - The analysis indicates that waiting more than two years after construction to place a chip seal could result in fracture properties that would ultimately be the same as if the pavement were not sealed at all.
    - Not to suggest that other benefits could not be realized by a later chip seal, but rather that the aging that impacts the fracture properties can be mitigated by sealing earlier.

TH56 Findings

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- Sealing improves resistance to aging (cracking)
- Sooner is better when sealing
    - Waiting for 3 or more years to seal after construction produced same results as unsealed pavement
    - Sealing after 1 or 2 years showed improvement in resistance to aging (cracking)

Thanks!

R. Michael (Mike) Anderson, P.E.
Director of Research and Laboratory Services
Asphalt Institute
2696 Research Park Dr.
Lexington, KY 40511-8480
859.288.4984 office
859.422.1301 FAX
manderson@asphaltinstitute.org
www.asphaltinstitute.org