Aging of Asphalt

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29 August 2012

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

Acknowledgments

- 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

AAPTP 06-01 Research Objectives

- Develop a practical guide identifying means to prevent and mitigate cracking caused by environmental effects.
- Develop one or more test procedures that could be used by a pavement manager to determine when preventative maintenance is needed to prevent the development of cracking (specifically block cracking).

TPF-5(153) Research Objectives

- Primary Objective
  - to develop and validate technology that can be used by highway agencies to determine the proper timing of preventive maintenance in order to mitigate damage caused by asphalt aging

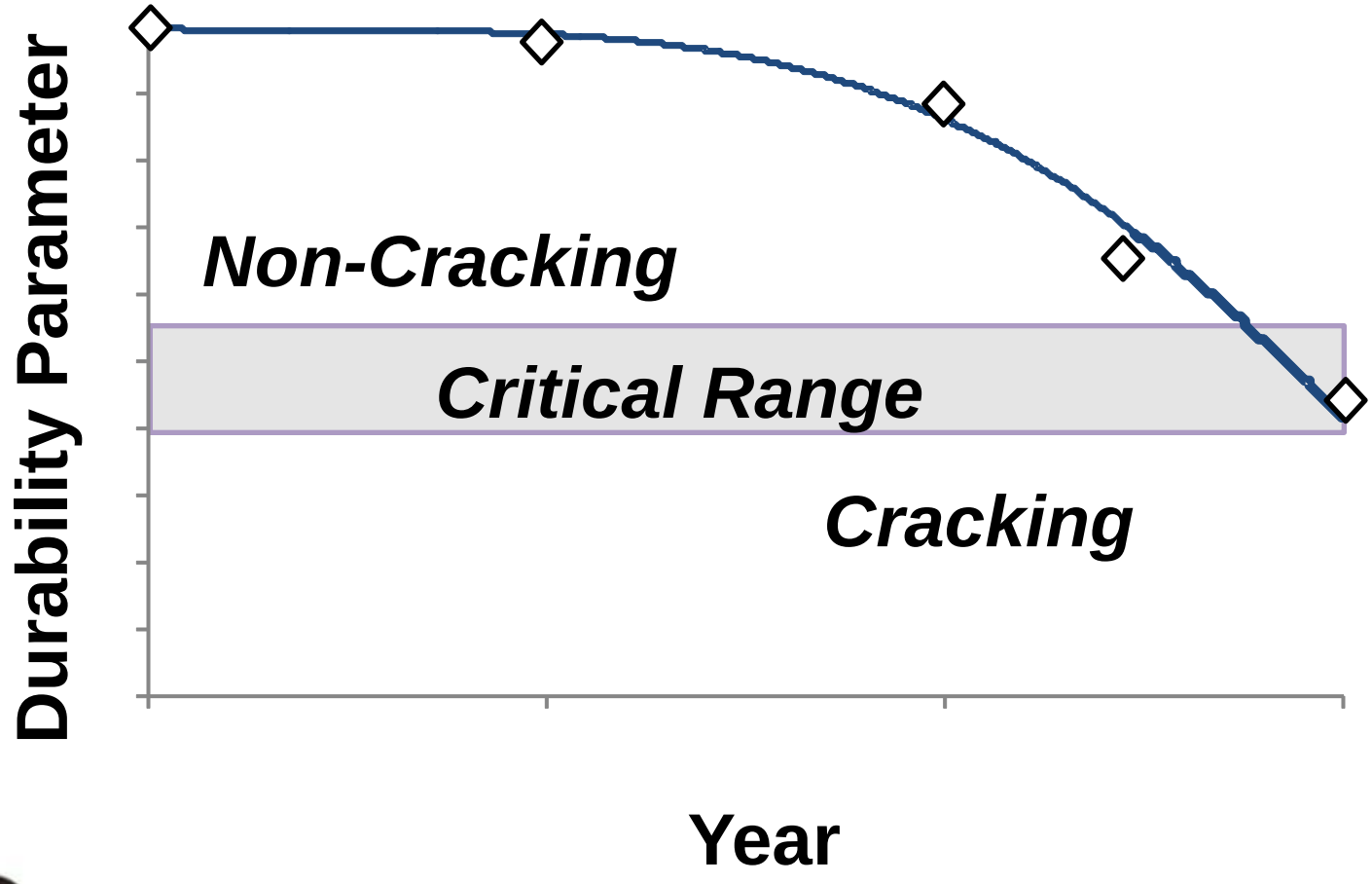
TPF-5(153) Research Objectives

- Primary Objective
  - Help highway agencies define a pavement preservation strategy which optimizes life-cycle cost with primary emphasis on countering the deleterious effects of asphalt aging

AAPTP 06-01 Research Question

- As the Airport Manager…
  - What test do I run or what calculation can I do that will tell me when the pavement is expected to begin showing significant non-load related distress?

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

- 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

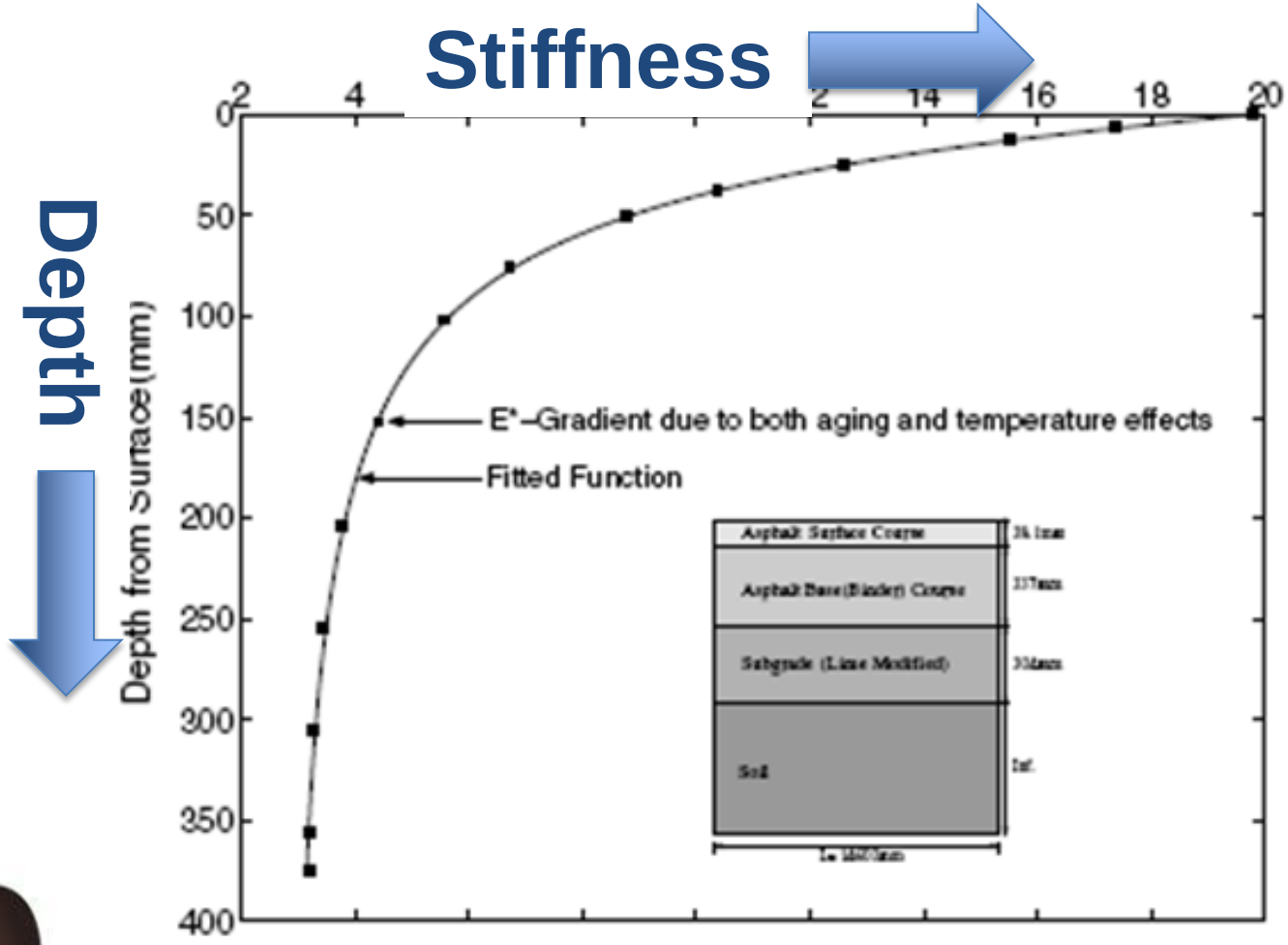
Asphalt Oxidation

Vallerga: Age-Embrittlement

Raveling

Block Cracking

Witczak and Mirza: Global Aging Model (1995)



Asphalt Oxidation

- 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

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

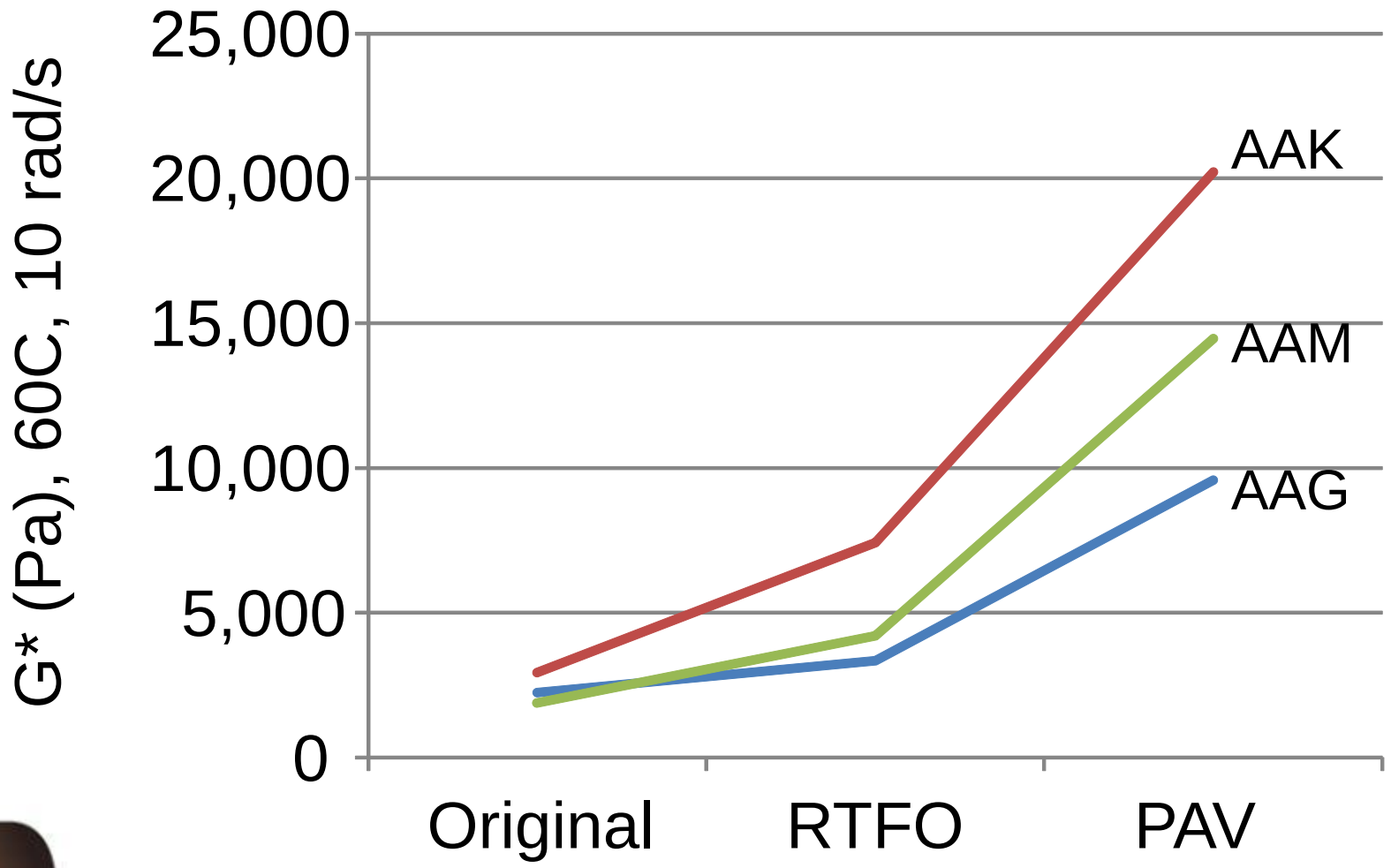
AAPTP 06-01

- 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

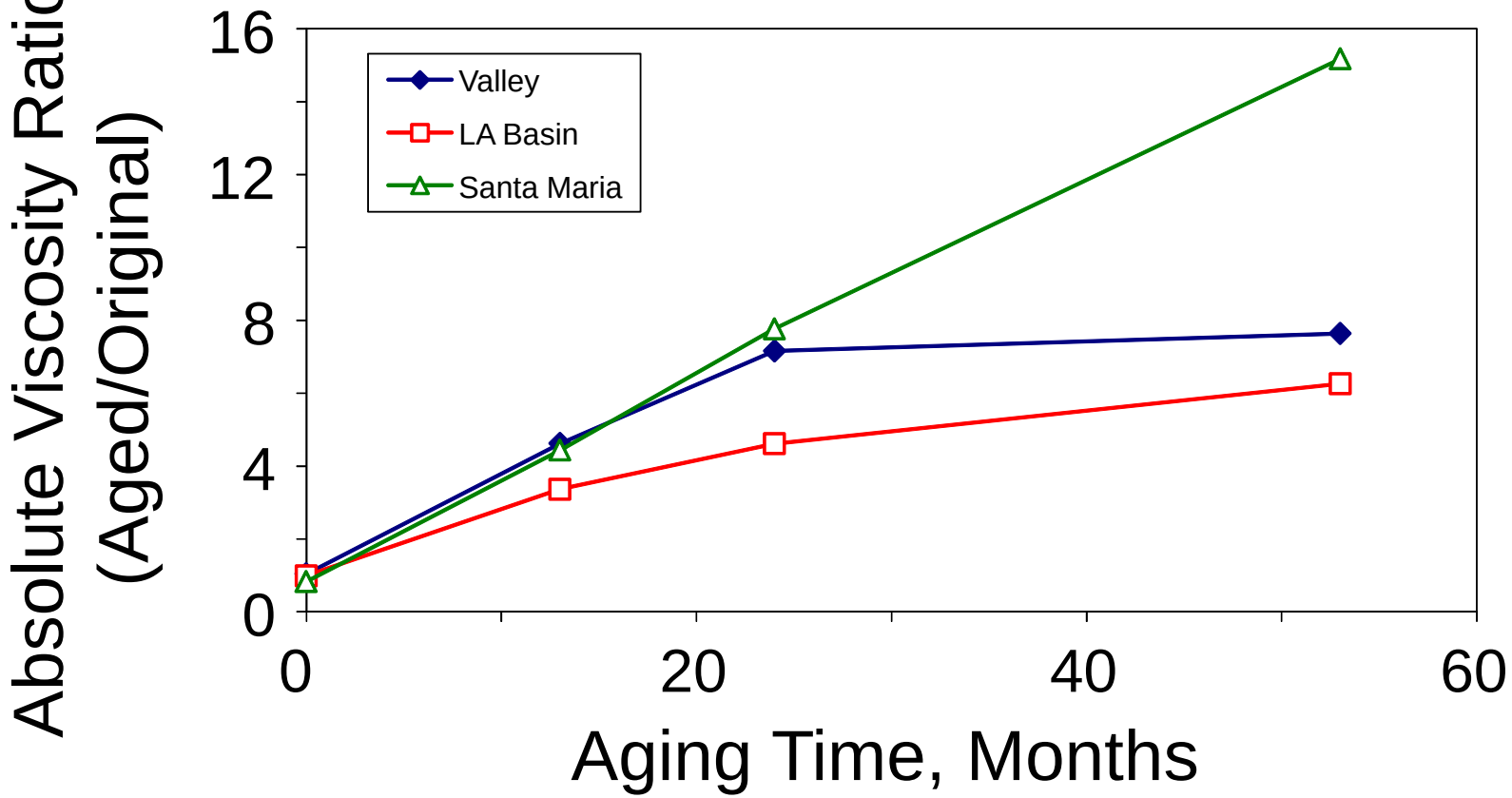
Asphalt Binders

- 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)
  - Gulf Southeast (PG 64-22)
  - Western Canadian (PG 64-28)

Rate of Aging



1981 CA Durability Study

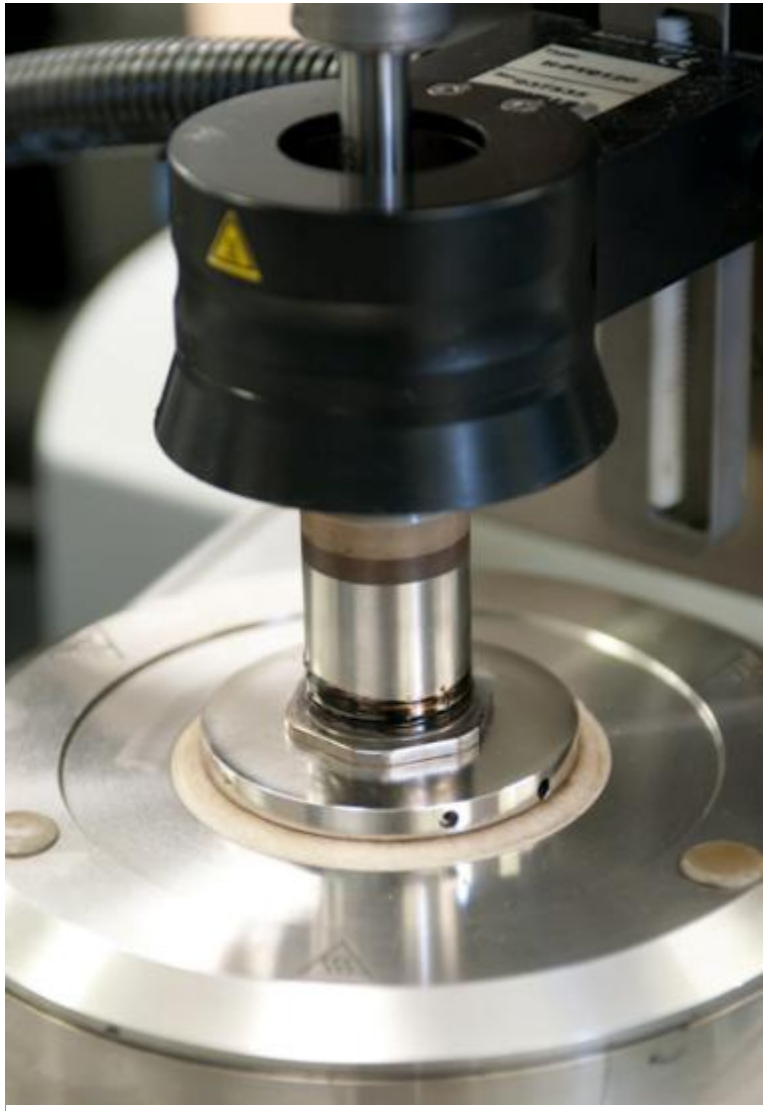


Kemp, et.al.

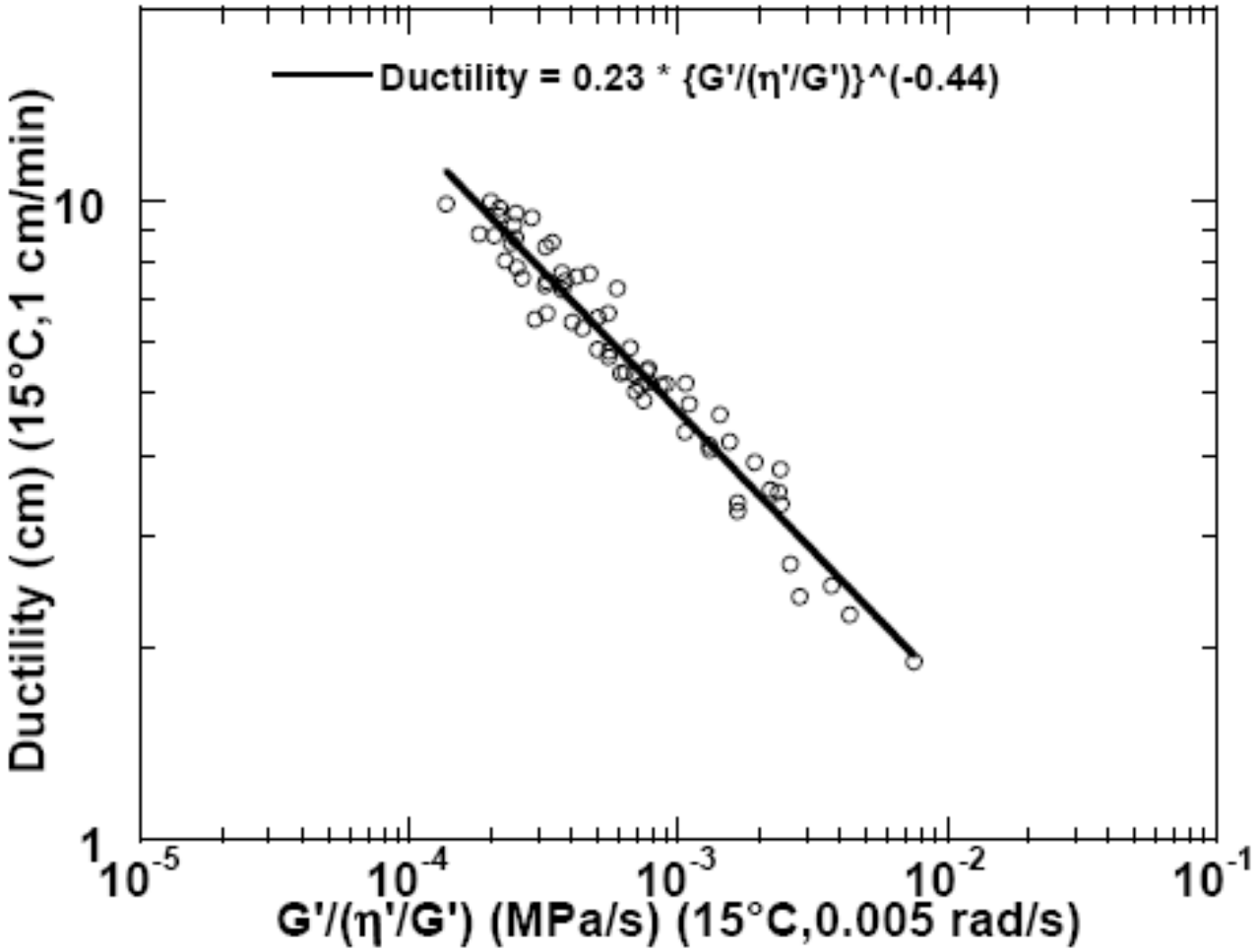
Sacramento (62.9C), 7-9% Air Voids, Non-Absorptive Aggregate

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′/(η′/G′)
    - Related to ductility at 15°C and 1 cm/min.



Ductility and DSR Parameter



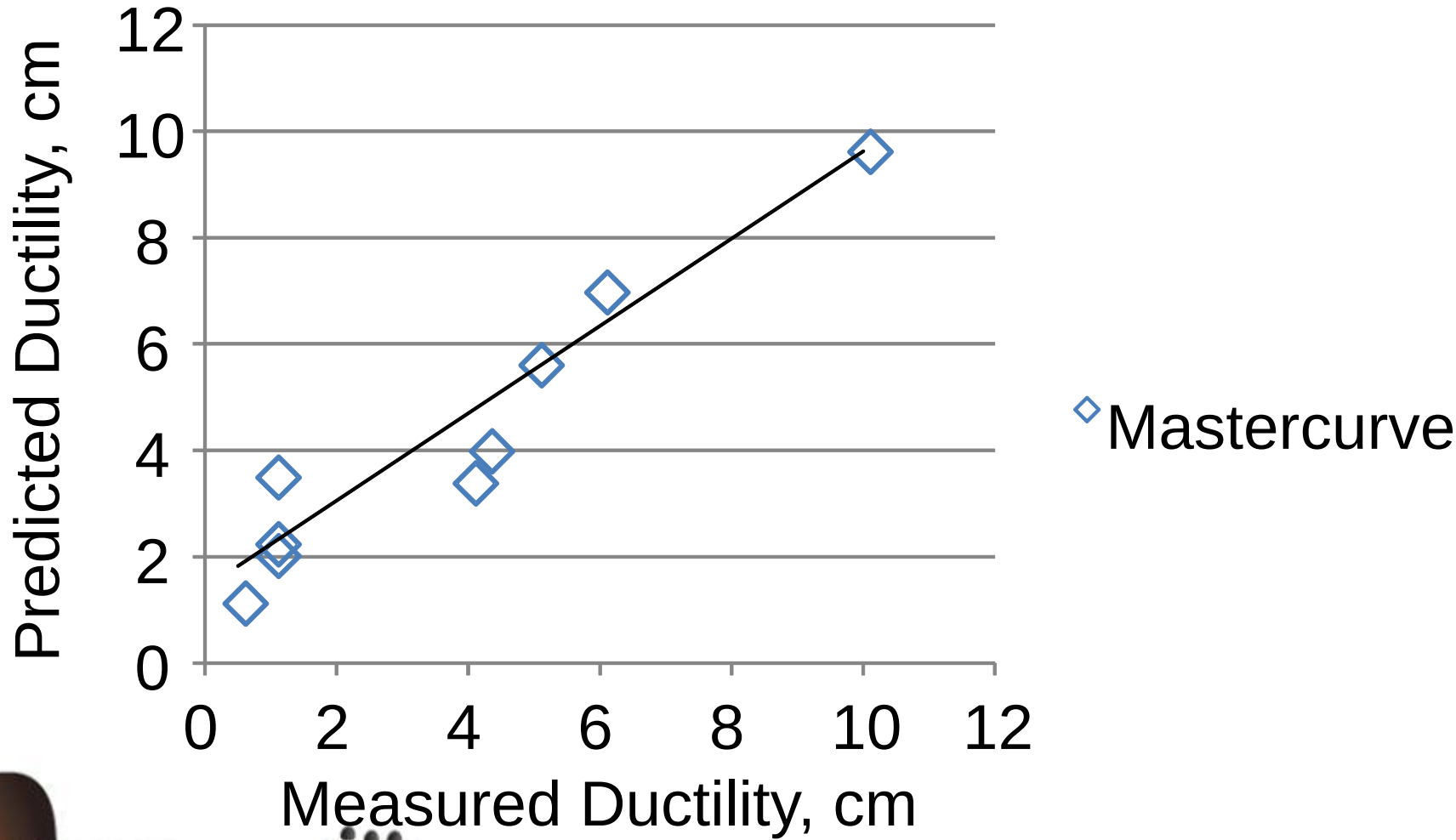
(Glover et.al., 2005)

DSR Parameter (Mastercurve)

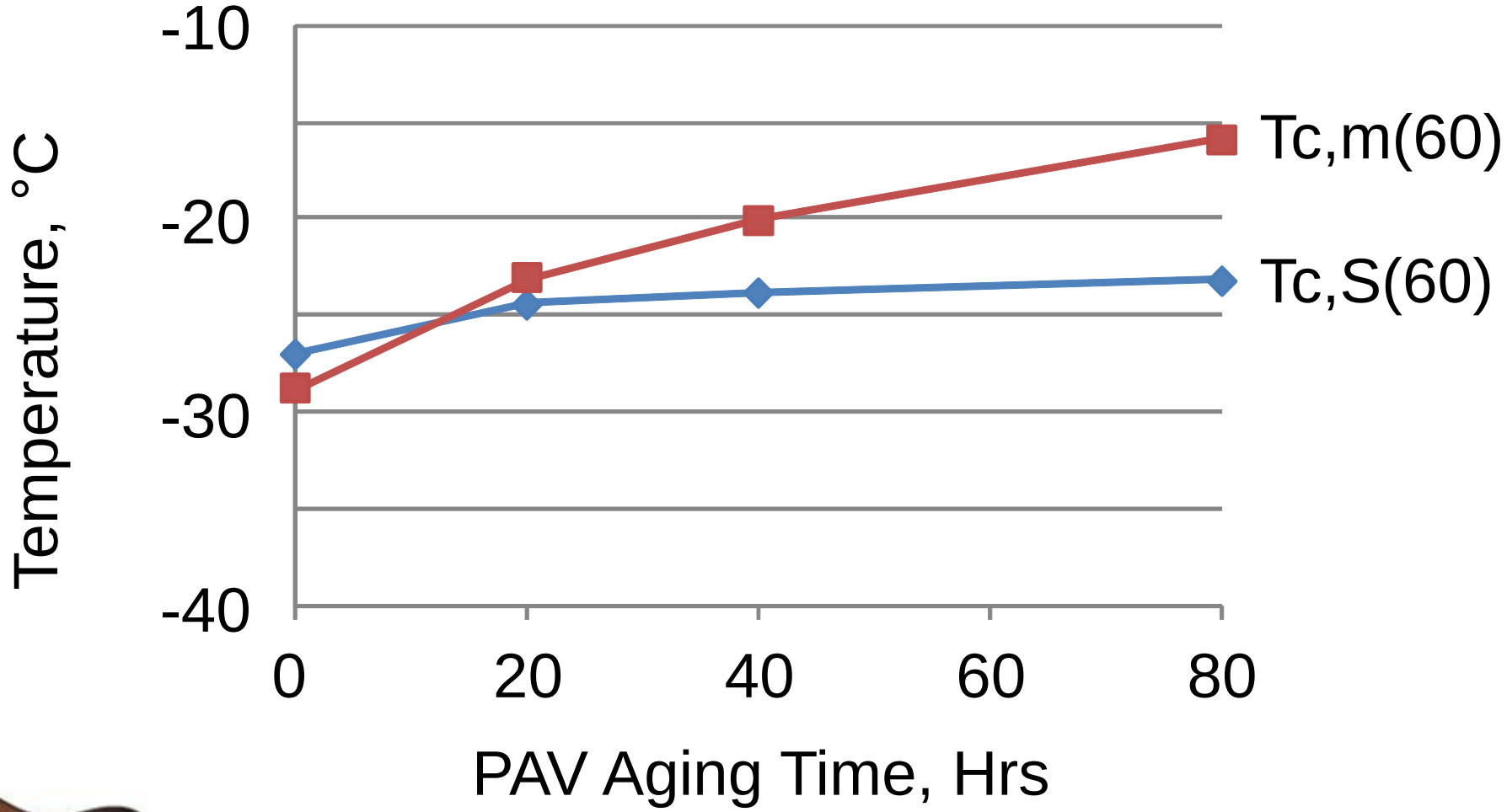
Table 5: G′/(η′/G′) at 15°C, 0.005 rad/s (MPa/s) – WC Asphalt Binder

	PAV0	PAV20	PAV40	PAV80
Replicate 1	3.53E-07	1.98E-04	6.36E-04	5.72E-03
Replicate 2	2.66E-07	2.04E-04	6.13E-04	6.25E-03
Replicate 3	3.77E-07	1.98E-04	7.56E-04	2.92E-03
Average	**3.32E-07**	**2.00E-04**	**6.68E-04**	**4.96E-03**
Std. Deviation (1s)	5.48E-08	3.46E-06	7.67E-05	1.79E-03
Coefficient of Variation (1s%)	17.6%	1.7%	11.6%	36.1%

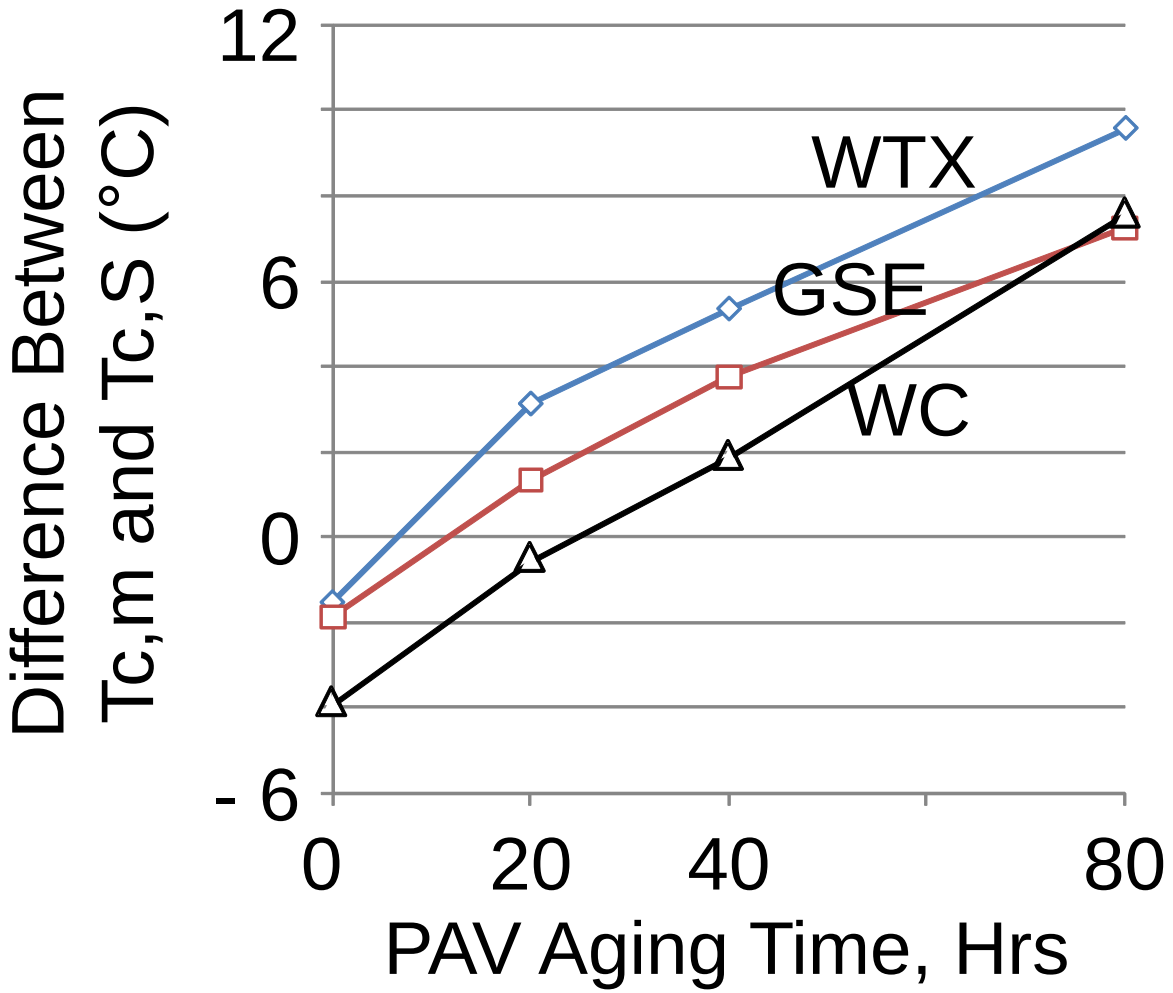
Relationship between DSR Parameter and Ductility



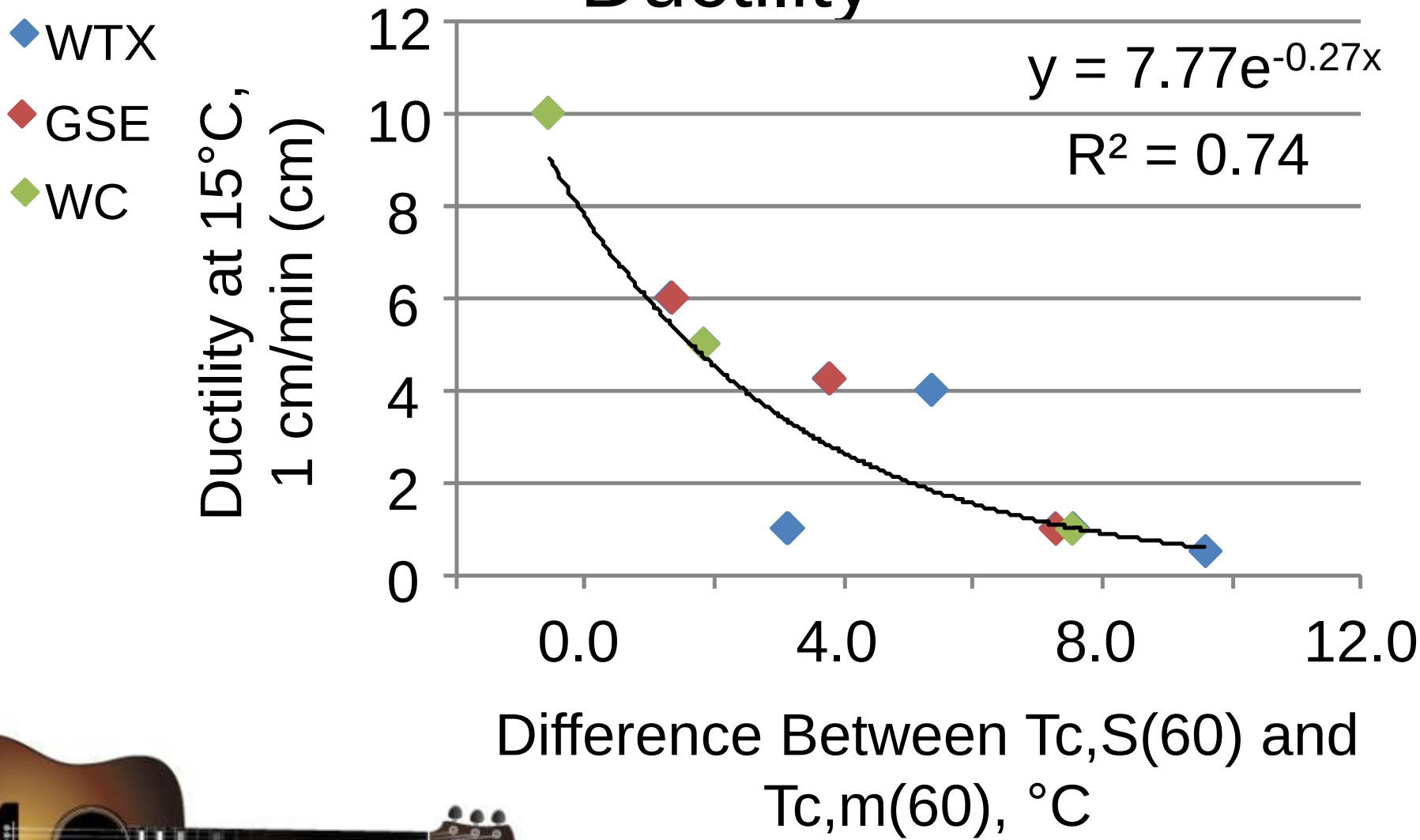
BBR: Gulf-Southeast (GSE)



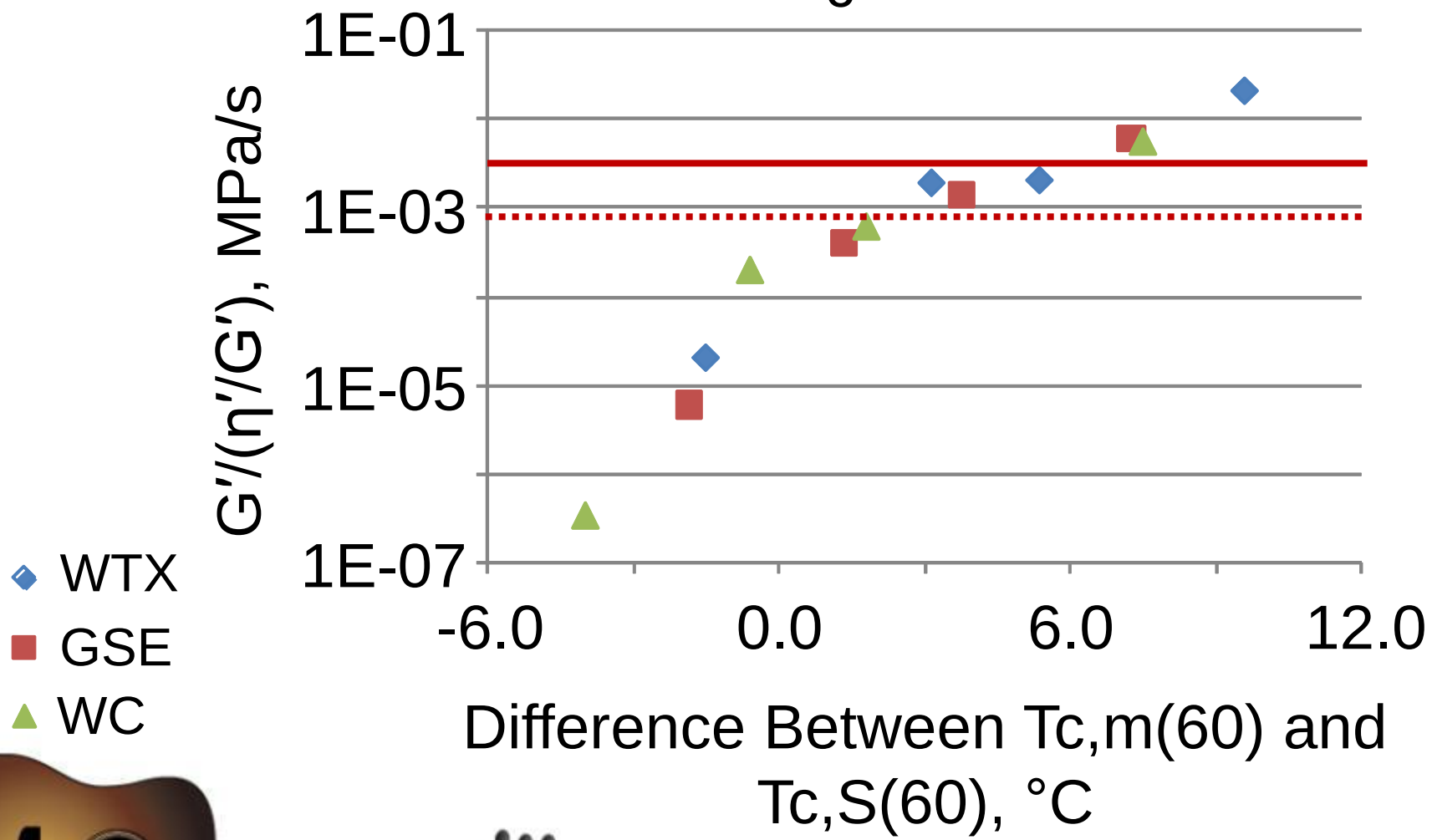
Effect of PAV Aging Time on ΔT_c



Relationship between ΔT_c and Ductility



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



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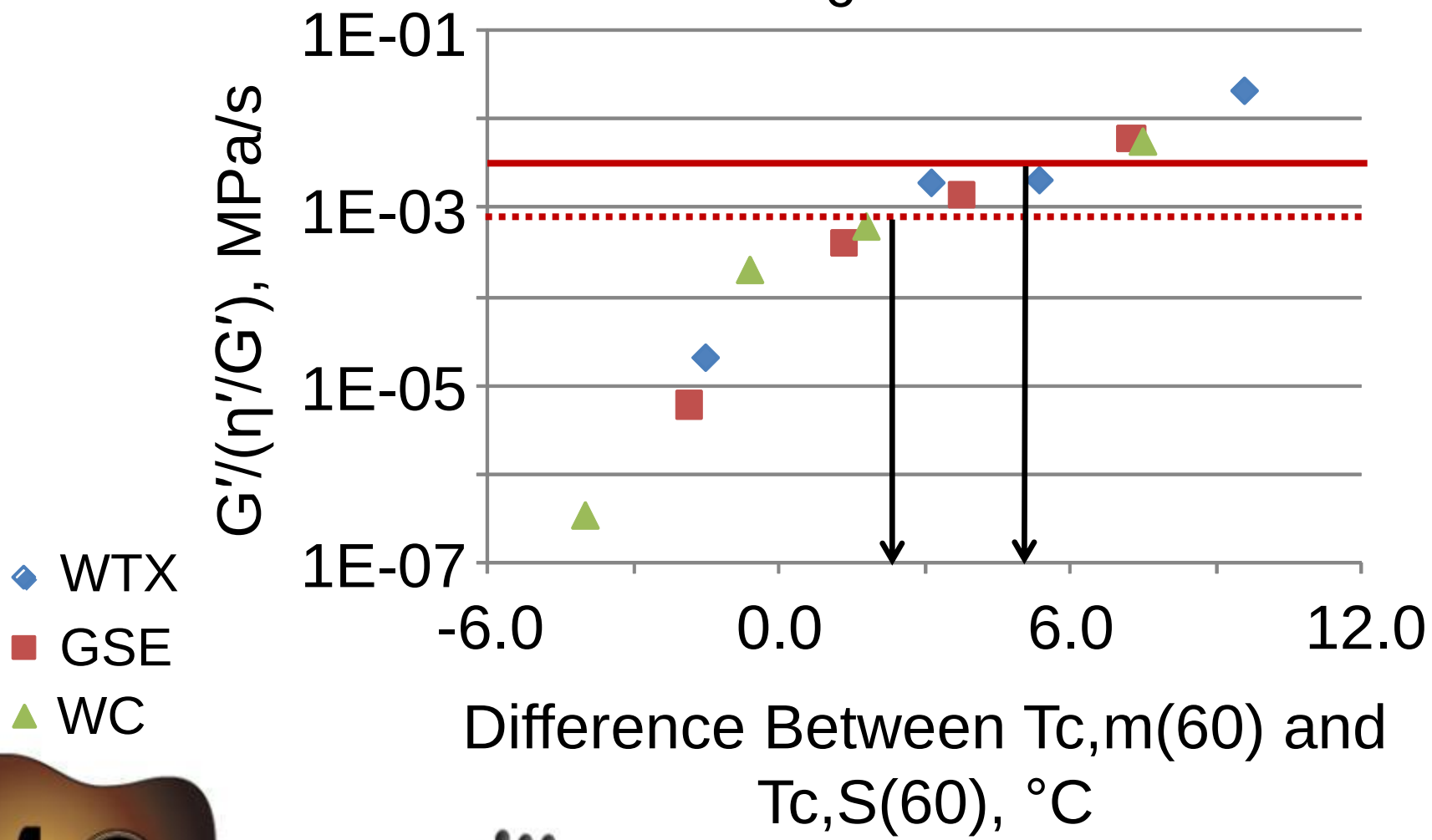
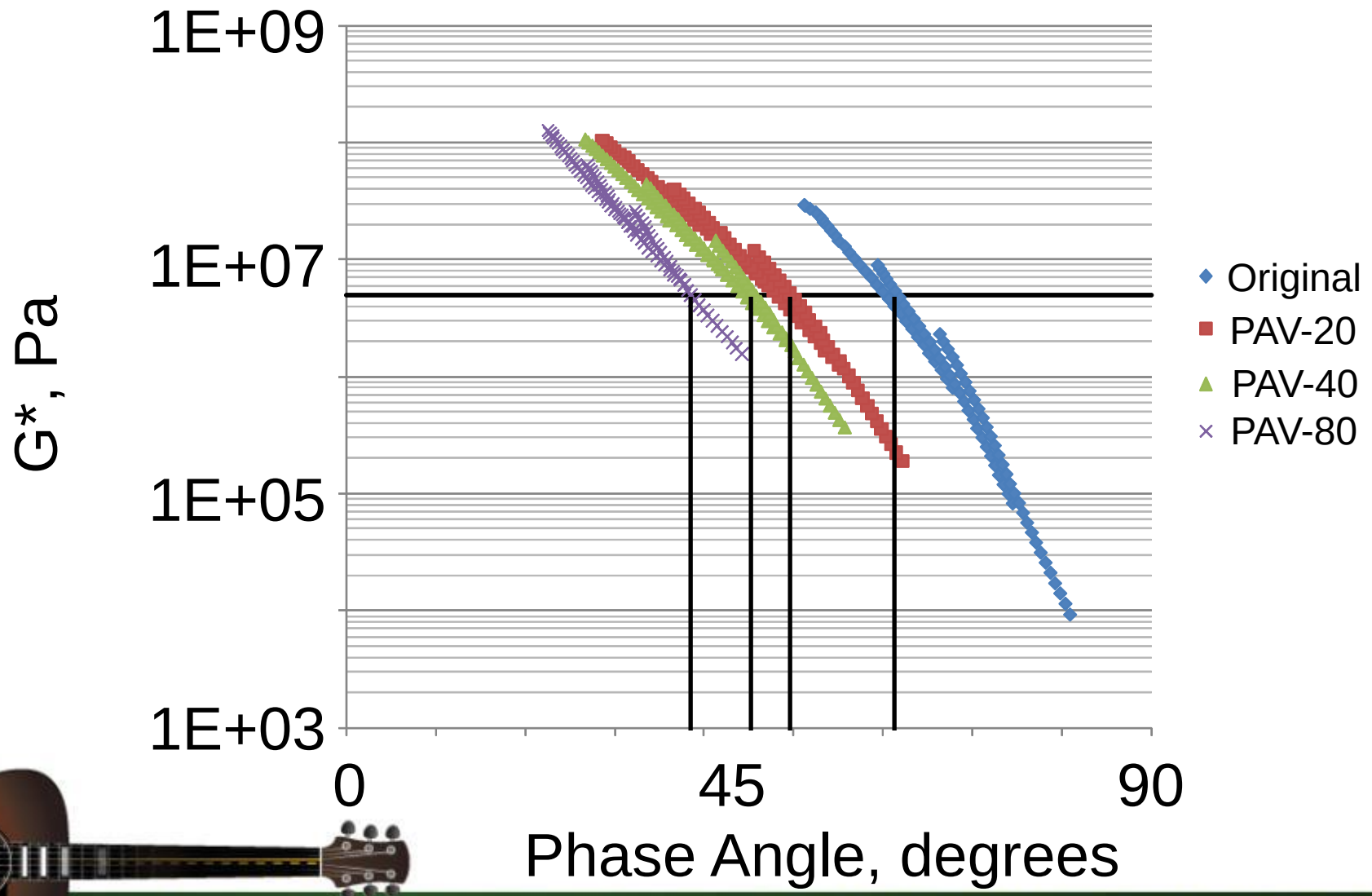
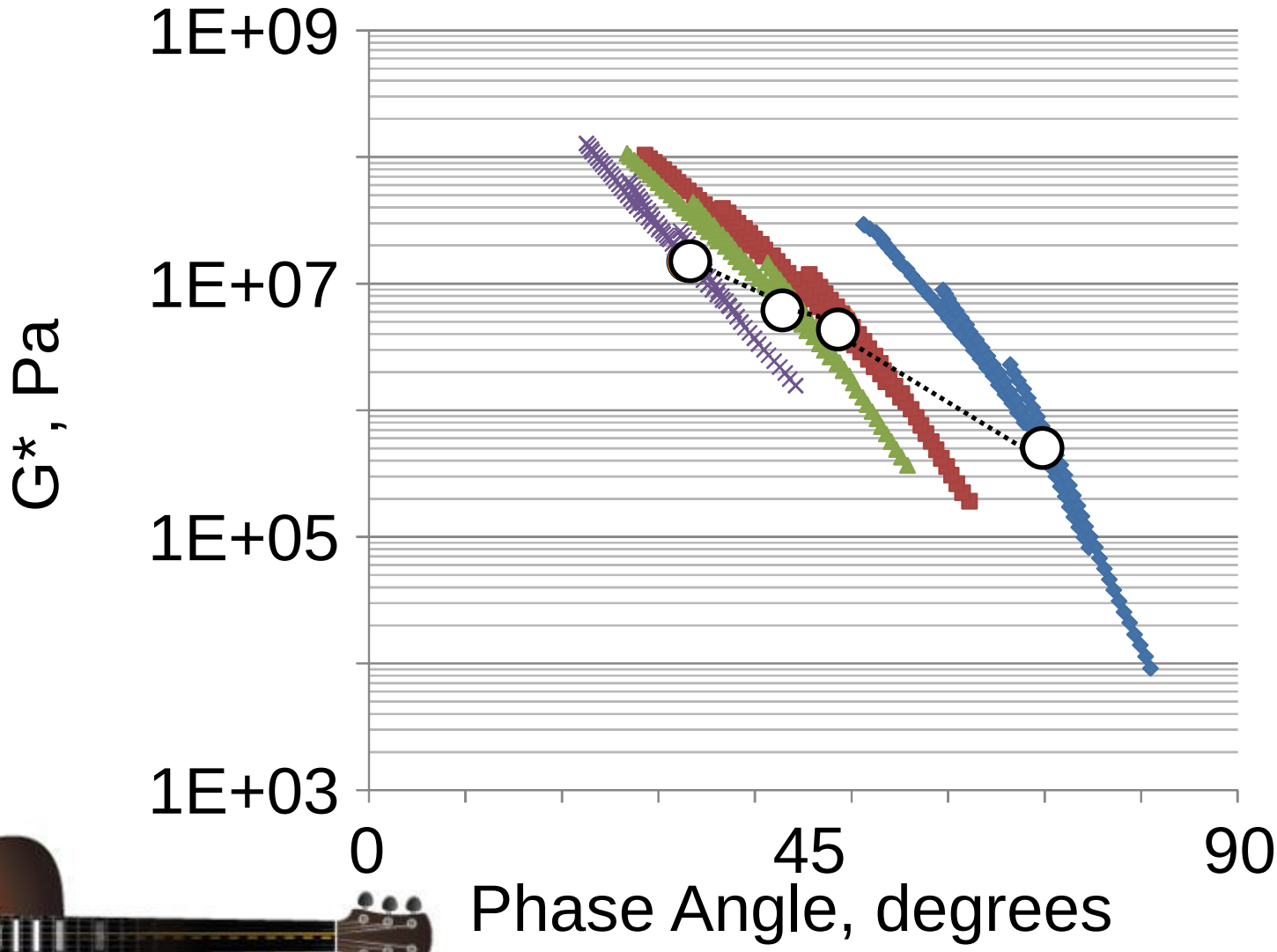


Black Space Diagram: WC Binder



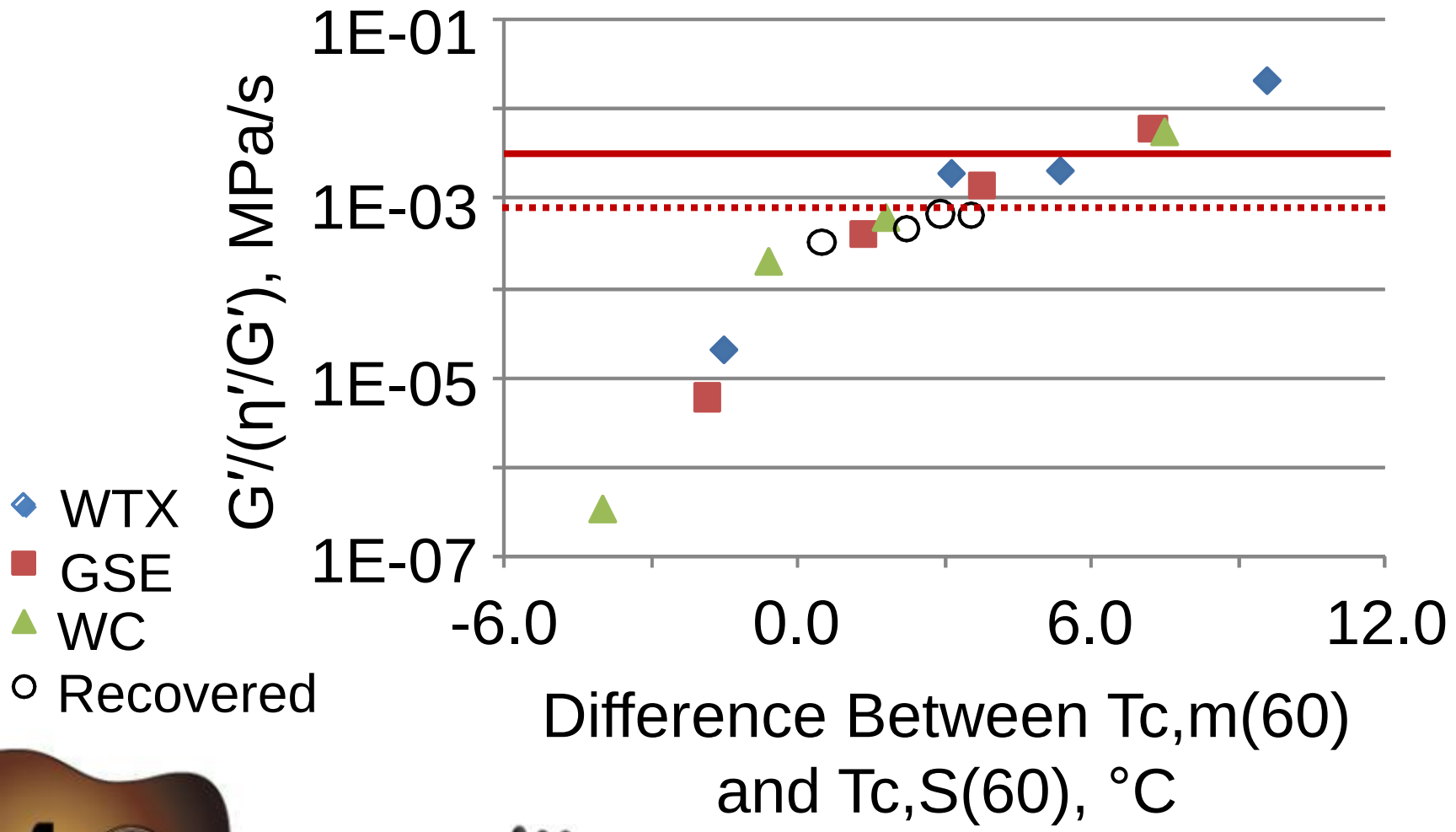
Effect of Aging



Field Validation

- Three general aviation (GA) airport projects representing four in-service pavements
  - Roundup (Montana)
  - Clayton (New Mexico)
  - Conchas Lake (New Mexico)

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



TPF-5(153)

- Laboratory and Field Evaluation of MnROAD and Other Test Sections
  - identify test methods that correctly rank distress
  - determine critical binder or mixture failure limits that might be used as objective triggers for the various preservation strategies

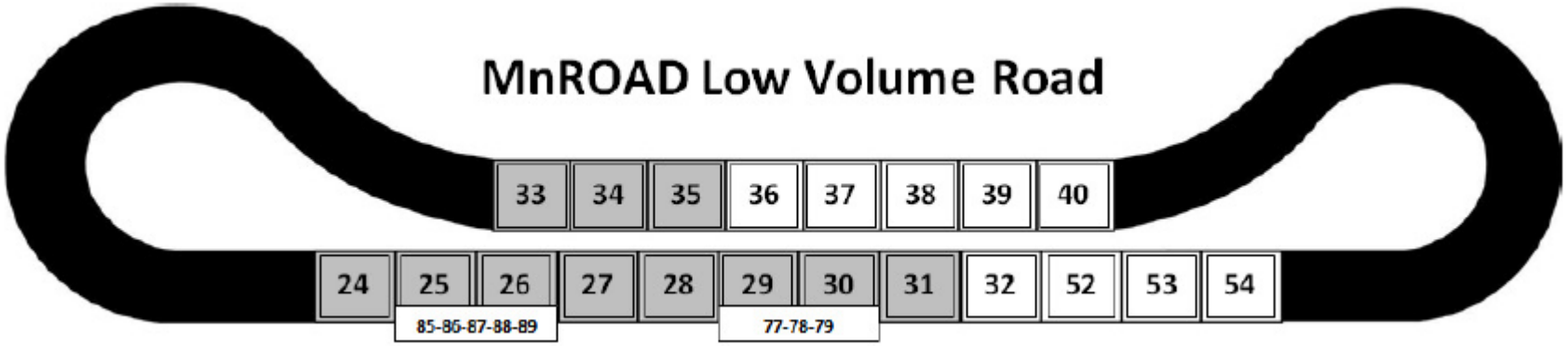
TPF-5(153)

- 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.

TPF-5(153)

- Selected Test Sections
  - Inspected on a yearly basis for age-related damage
  - Cores (6) taken in travel, non-travel lanes; closely spaced longitudinally

MnROAD Low Volume Road



24	33	34	35	27	28
3" 58-34	4" 58-34 PPA	4" 58-34 SBS+PPA	4" 58-34 SBS	2" 52-34	2" 52-34
				2" 58-34	2" 58-34
4" Class 6	12" Class 6	12" Class 6	12" Class 6	6" Class 5 GCBD	6" Class 5
Sand 100' Fog Seals 2008 2009 2010 2011 2012	Clay	Clay	Clay	2009 Chip Seal 7" Clay Borrow Clay	7" Clay Borrow Clay
Oct 08	Sep 07	Sep 07	Sep 07	Aug 06	Aug 06
Current	Current	Current	Current	Current	Current

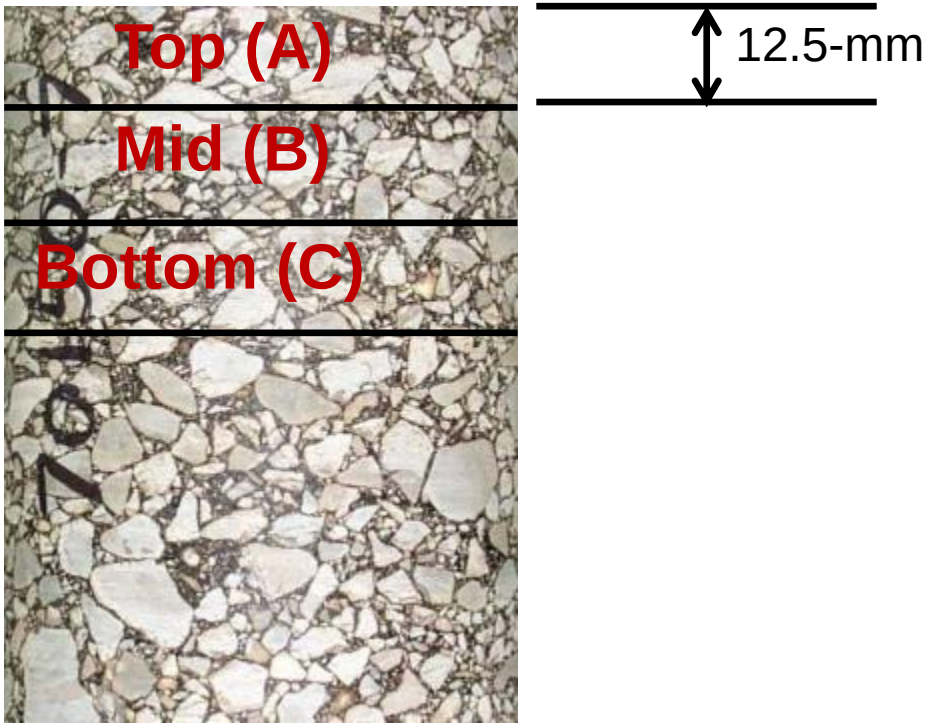
MnROAD Cell 24

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

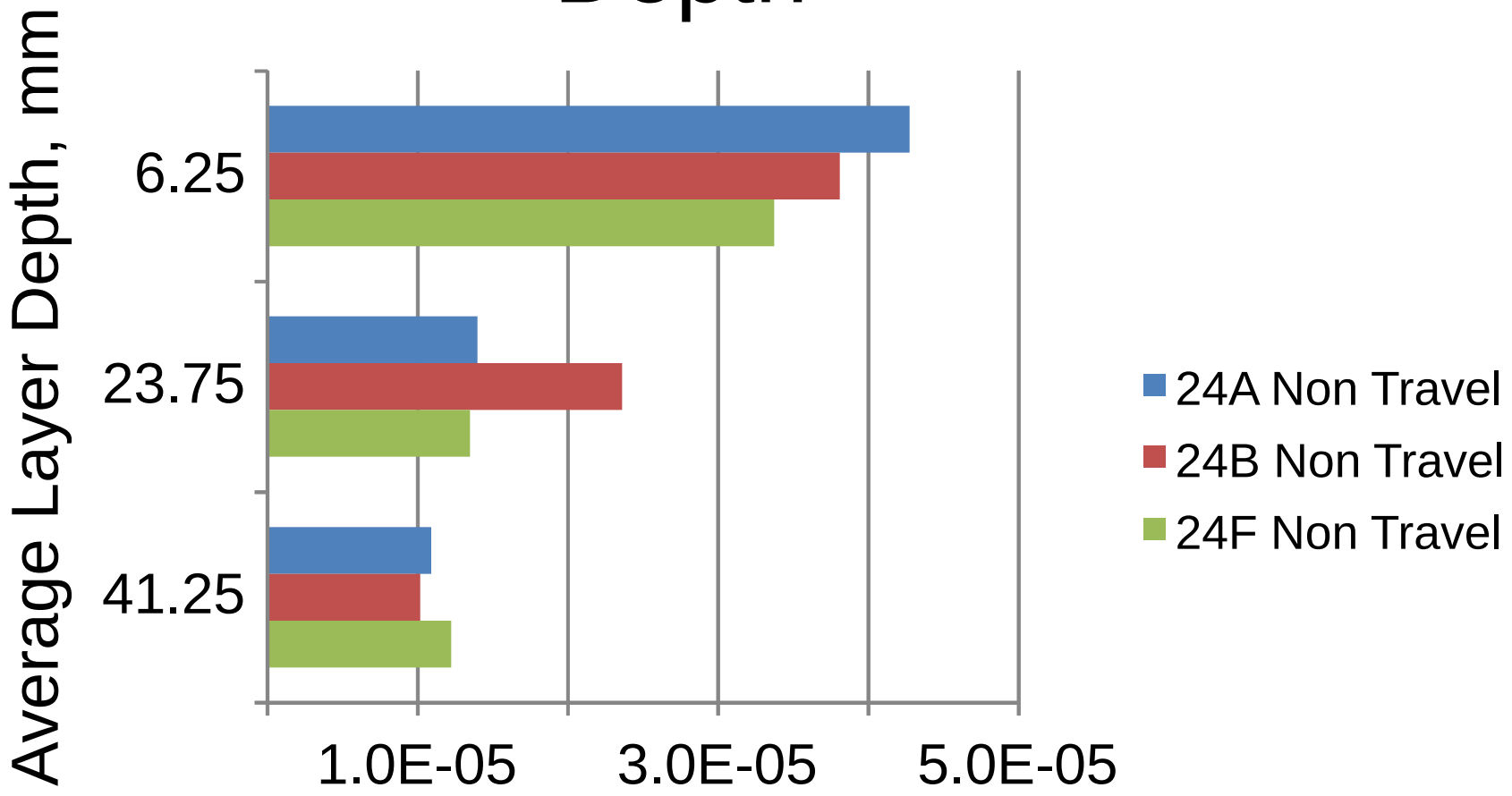
MnROAD Cores: Binder Testing

- 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)

MnROAD Cores: Binder Testing

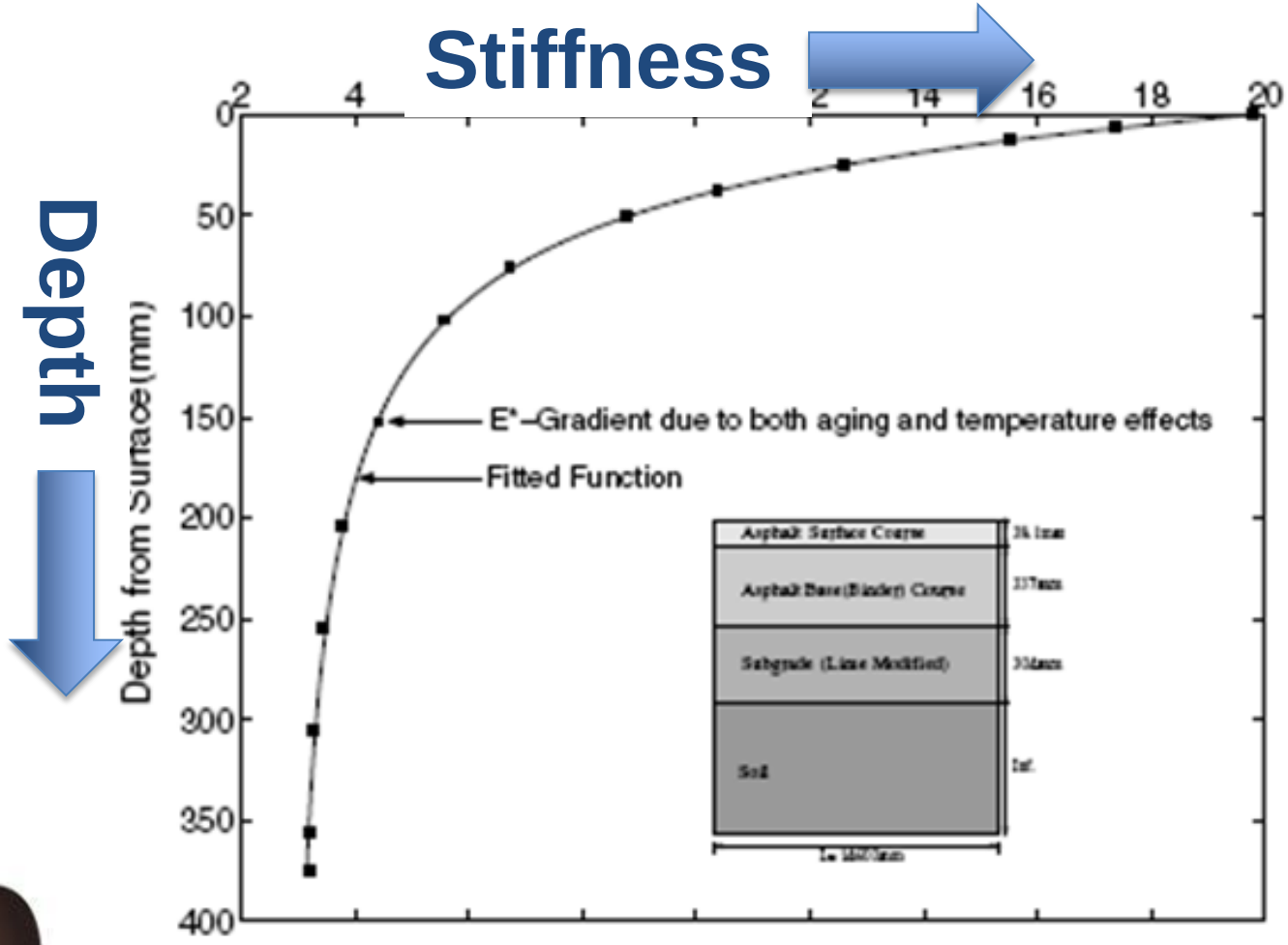
- Each Layer
  - BBR
    - 2-3 temperatures
    - T_c determined to the nearest 0.1°C for S(60) and m(60)
    - Difference in T_c (ΔT_c)

MnROAD Cell 24: Effect of Layer Depth



G′/(η′/G′) at 15°C, 0.005 rad/s, MPa/s

Witczak and Mirza: Global Aging Model (1995)



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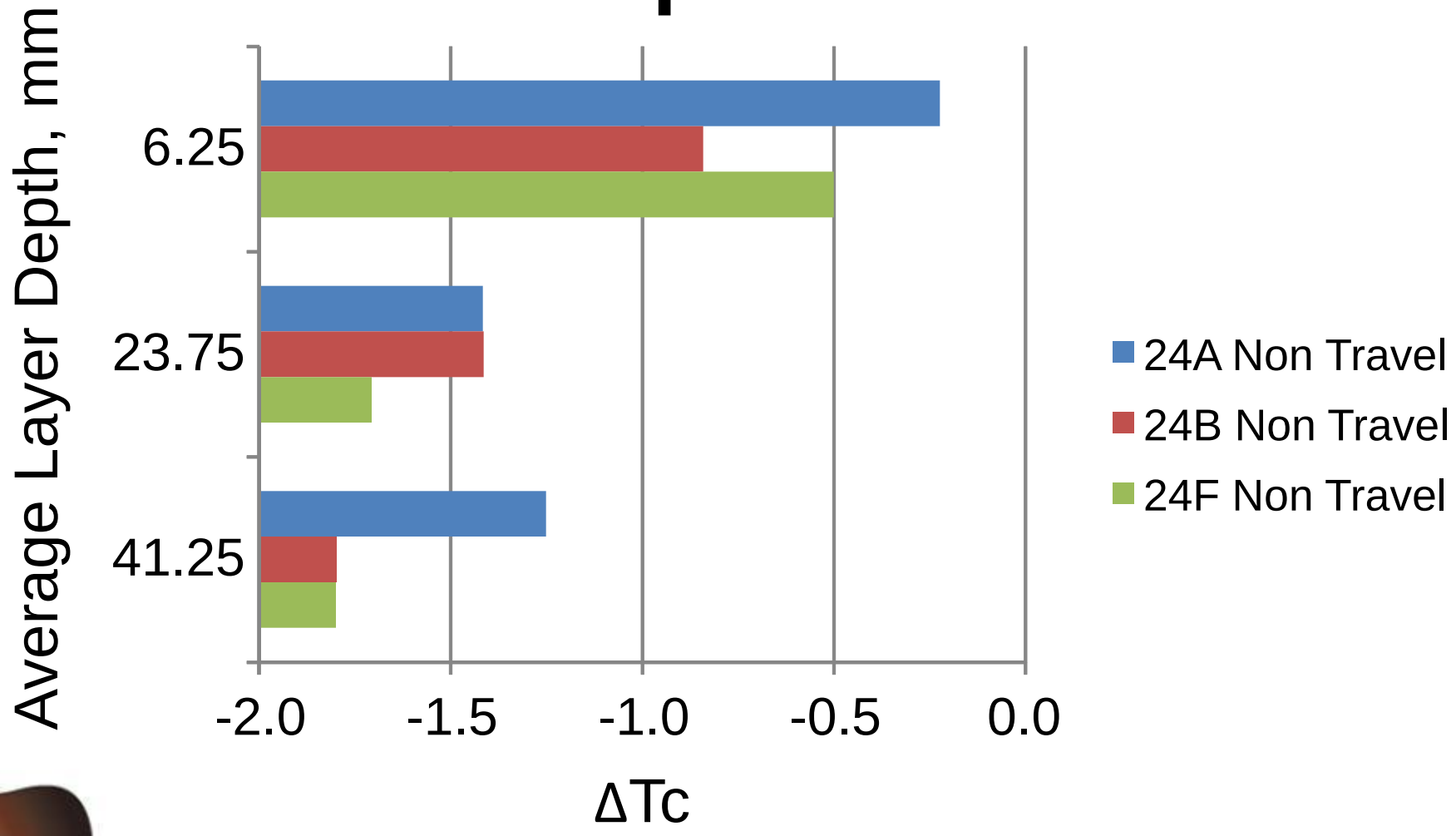


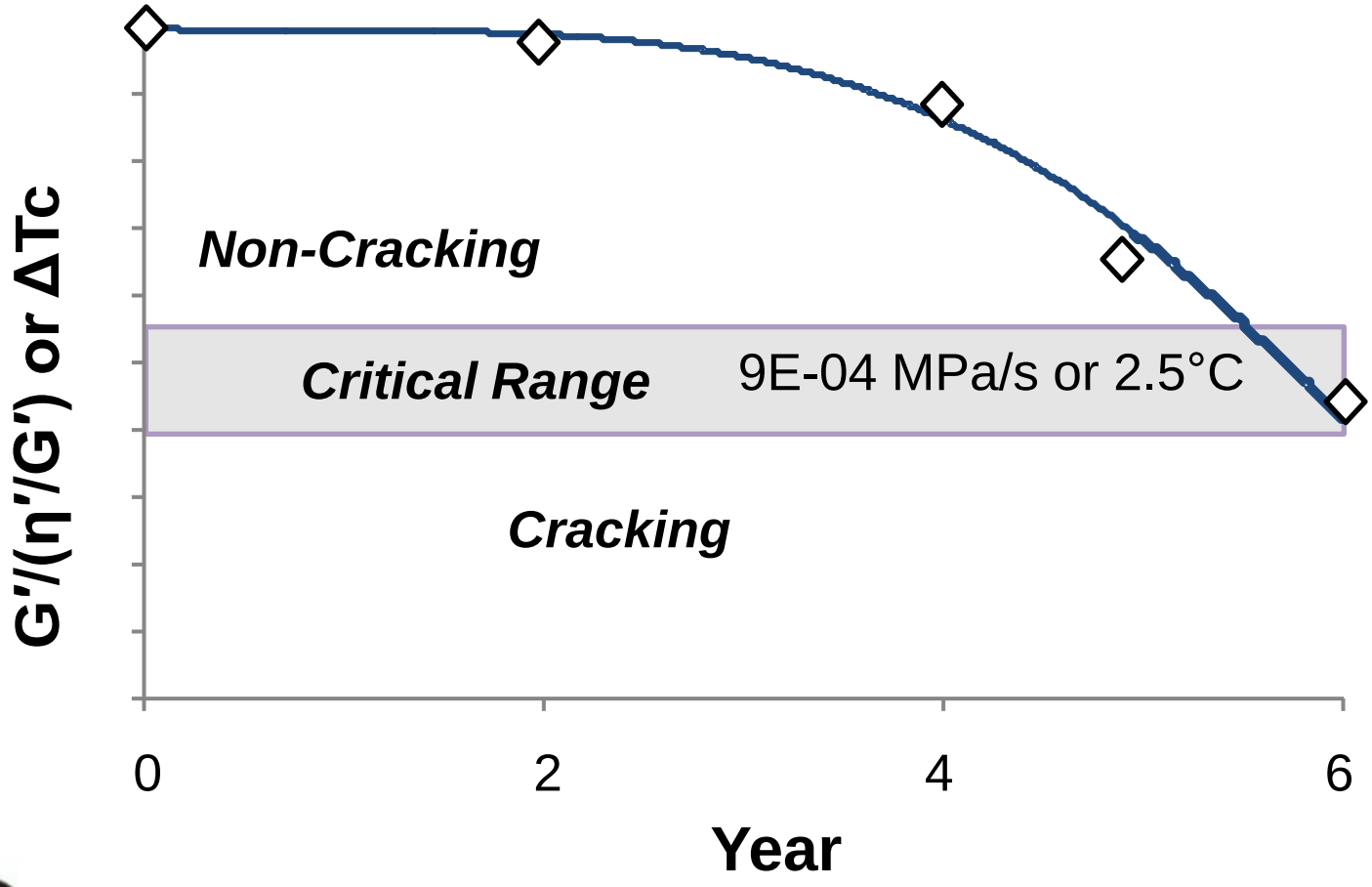
Implementation?

- Pavement Manager
  - Coordinate the extraction and recovery of asphalt binder from the mixture and determine the value of G'/(η'/G') and/or ΔT_c at the time of pavement construction to establish baseline values

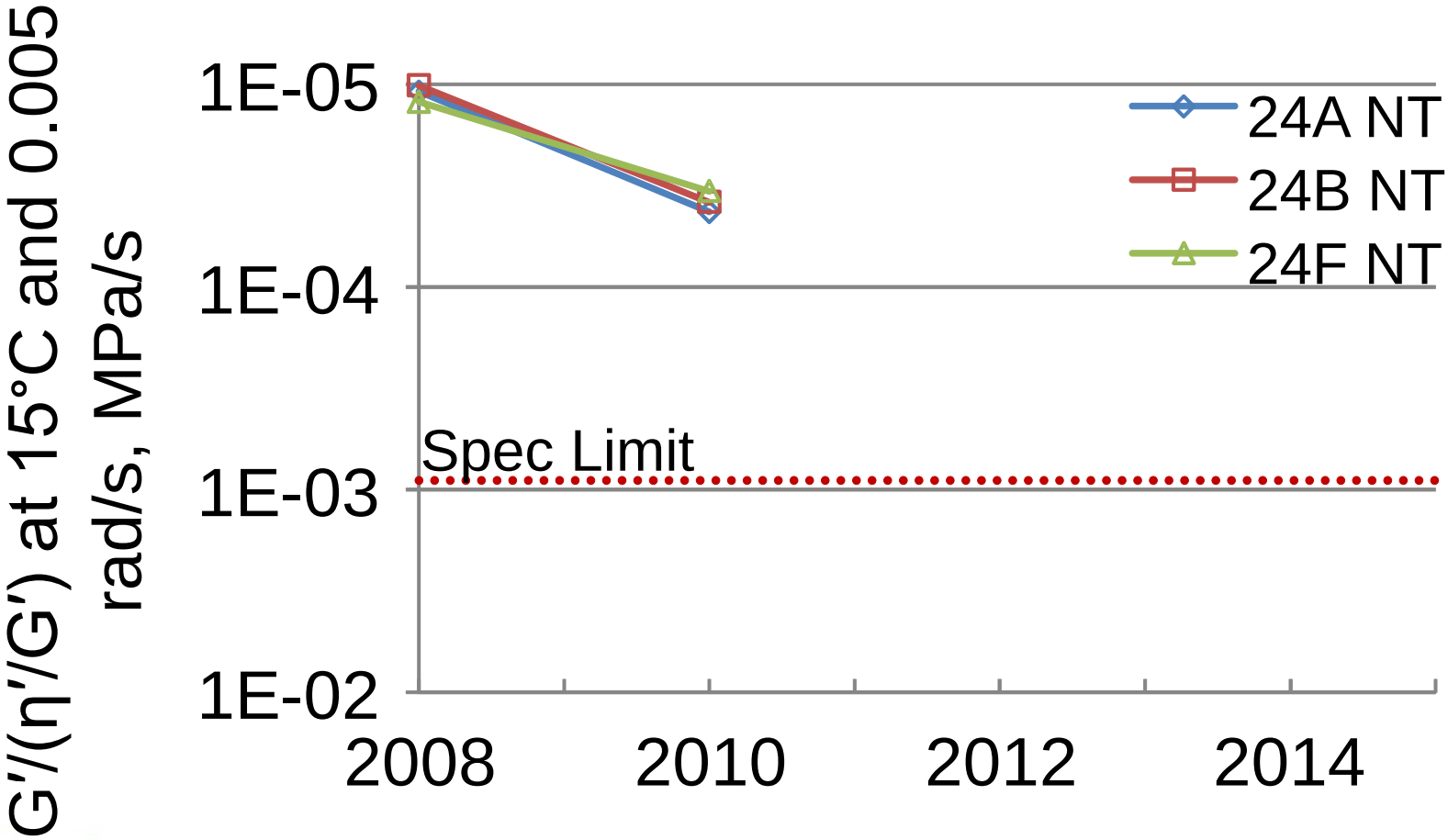
Implementation?

- Pavement Manager
  - Periodically coordinate the removal of one or more cores and have a testing lab perform a solvent extraction and recovery to obtain aged asphalt binder
    - Test to determine values of $G'/(\eta'/G')$ and/or ΔT_c at an aged state
    - As the values approach a critical state, consider that the risk of cracking is increased and preventative action should be taken

Concept


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

MnROAD Cell 24: Aging Profile



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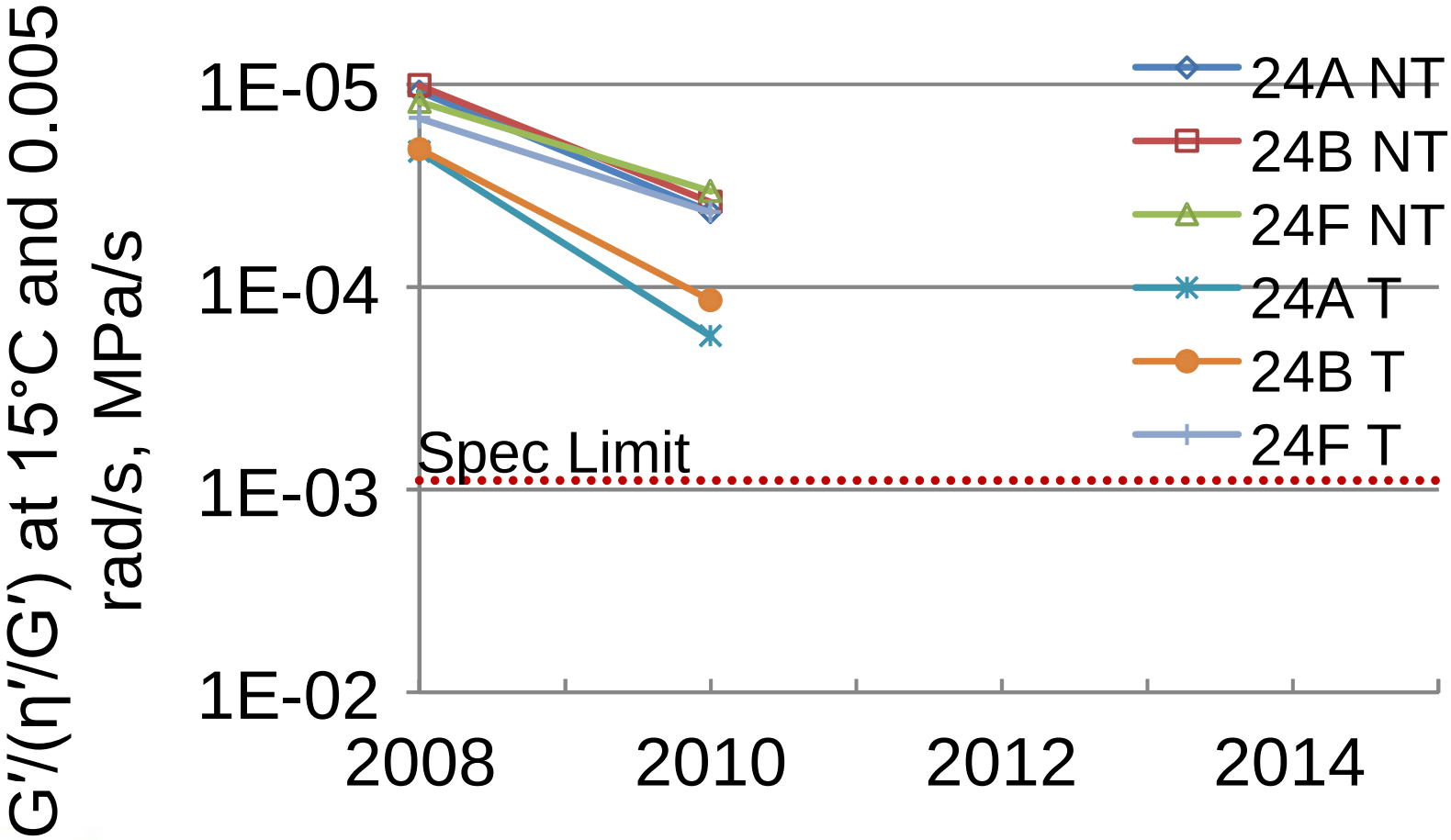

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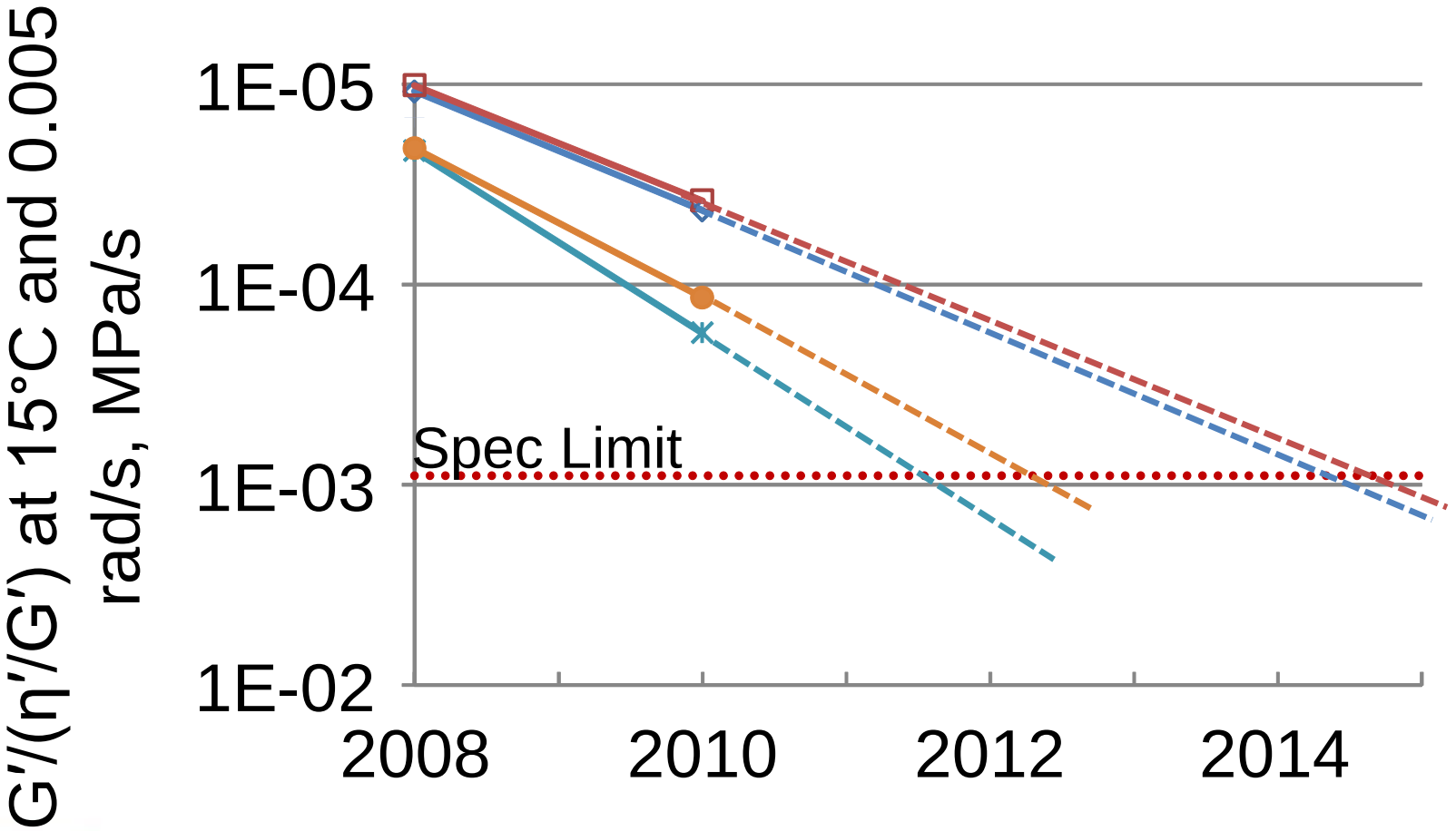


Summary

- Aging is influenced by multiple factors
  - Environment
  - Traffic
  - Air voids (Density)
  - Asphalt Binder
  - Aggregate

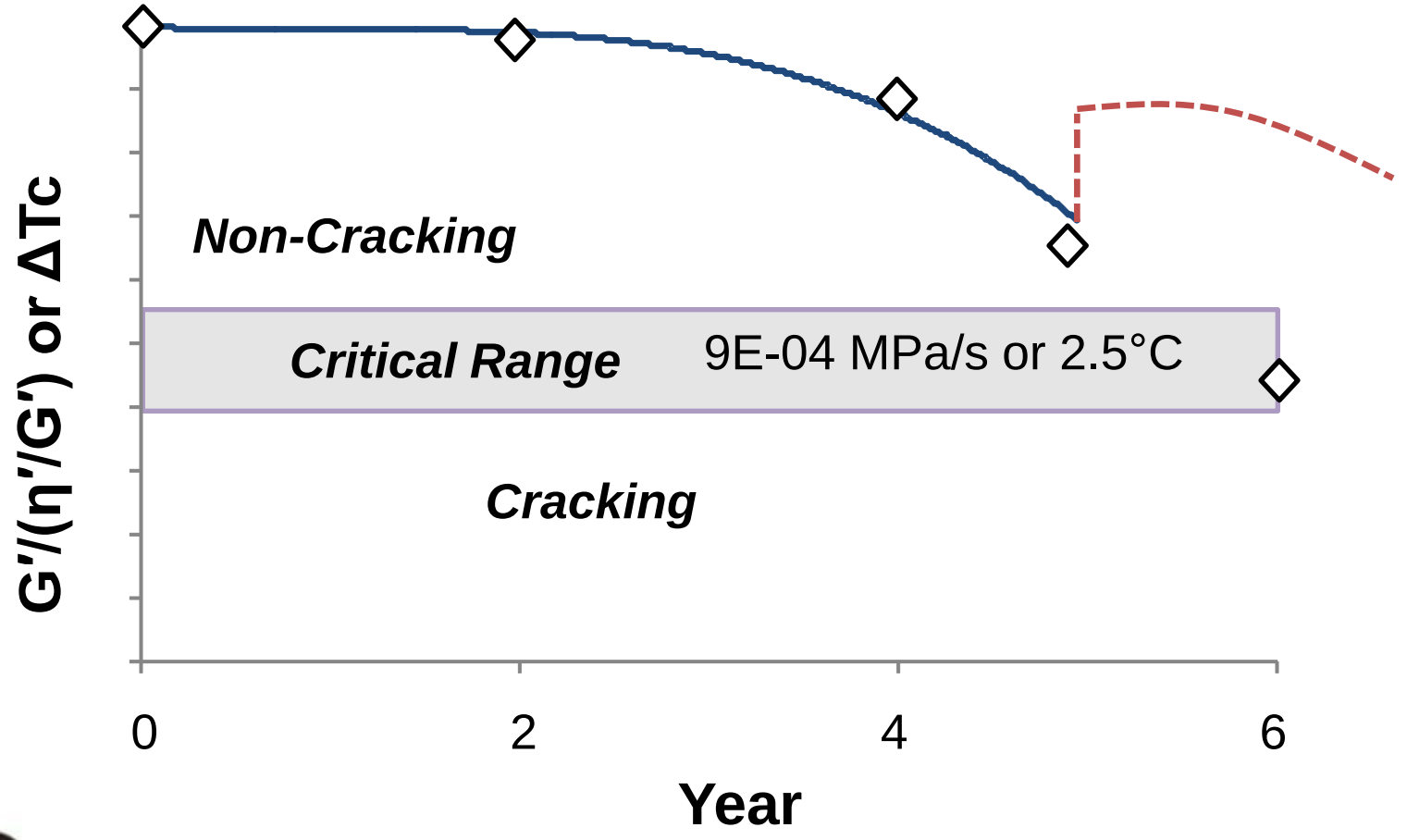
Summary

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

Summary

- Goal
  - Identify proper durability parameter
  - Monitor parameter with time
  - Model expected life to loss of durability and onset of cracking
  - Apply preservation treatment to maintain durability

Concept


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

Thanks!

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