

NCHRP 9-54 Update

Selection of the Laboratory Aging Method and Aging Temperature

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Presented to the Asphalt Mixture ETG
Fall River, MA

September 14, 2016

Overview

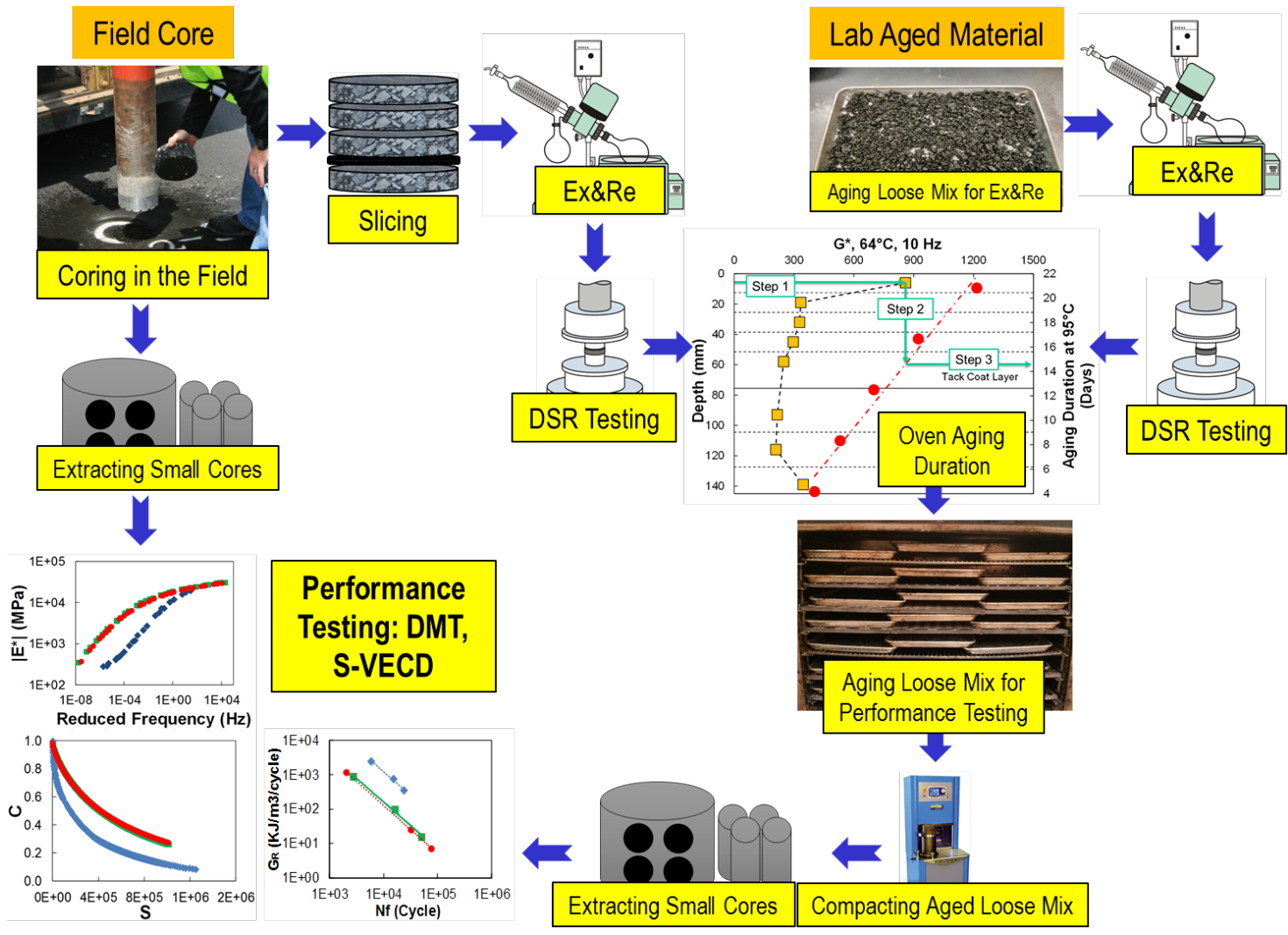
□ NCHRP 9-54 objective

- Develop a calibrated and validated procedure to simulate long-term aging of asphalt mixtures for performance testing and prediction

□ Progress to date

- Selection of the loose mixture aging method
- Selection of 95°C as the laboratory aging temperature
- Matching field aging levels

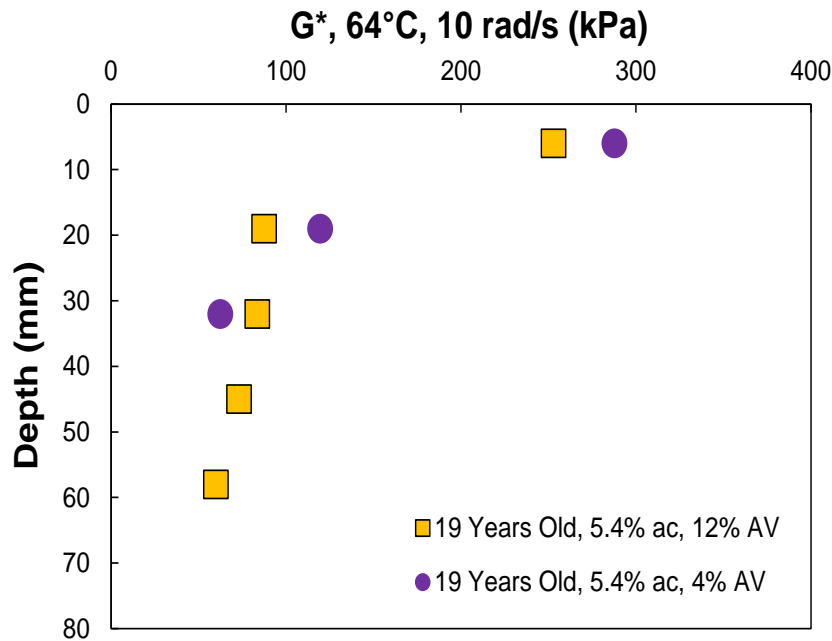
Experimental Steps



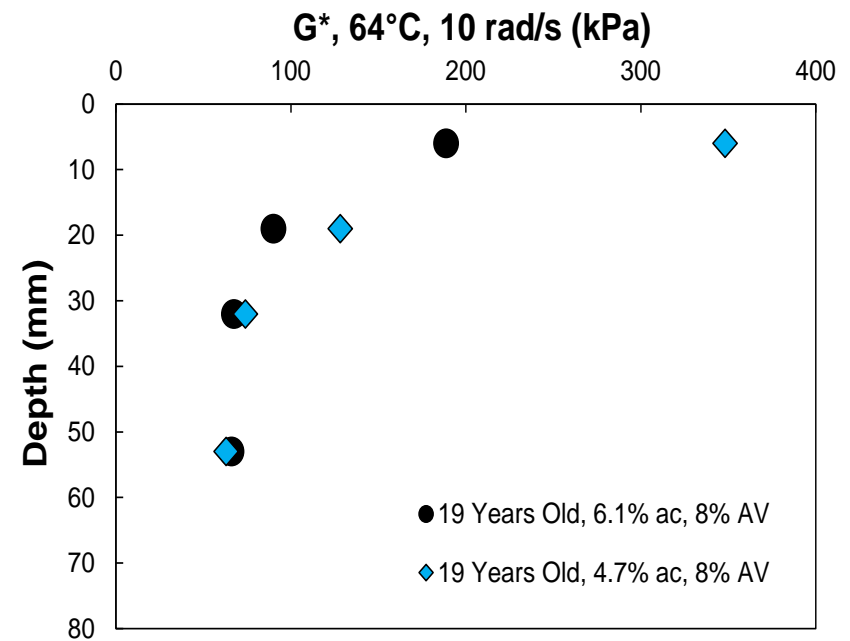
WesTrack Project

Factors that May Affect Aging Gradient

Effect of Air Void Content

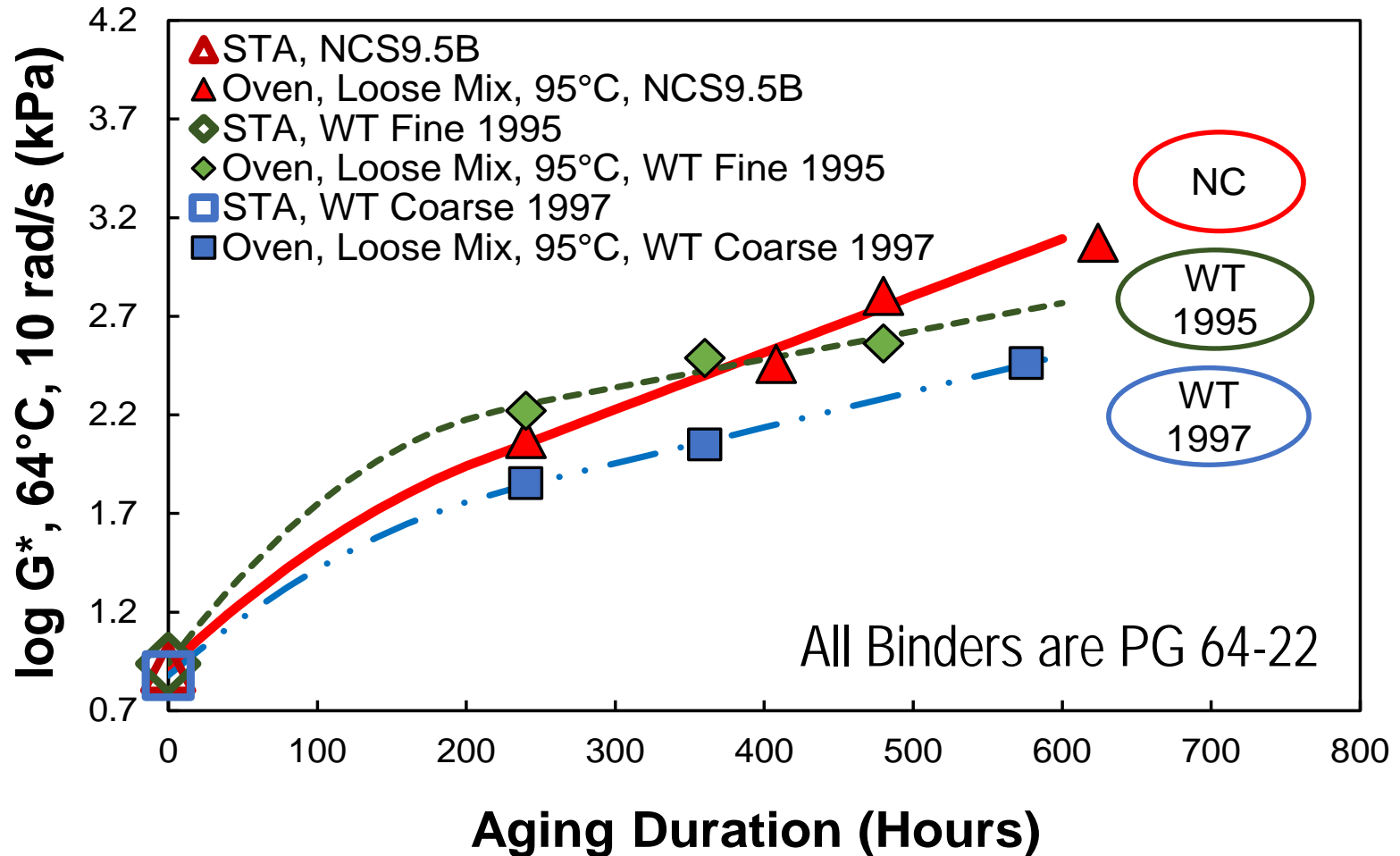


Effect of Asphalt Content



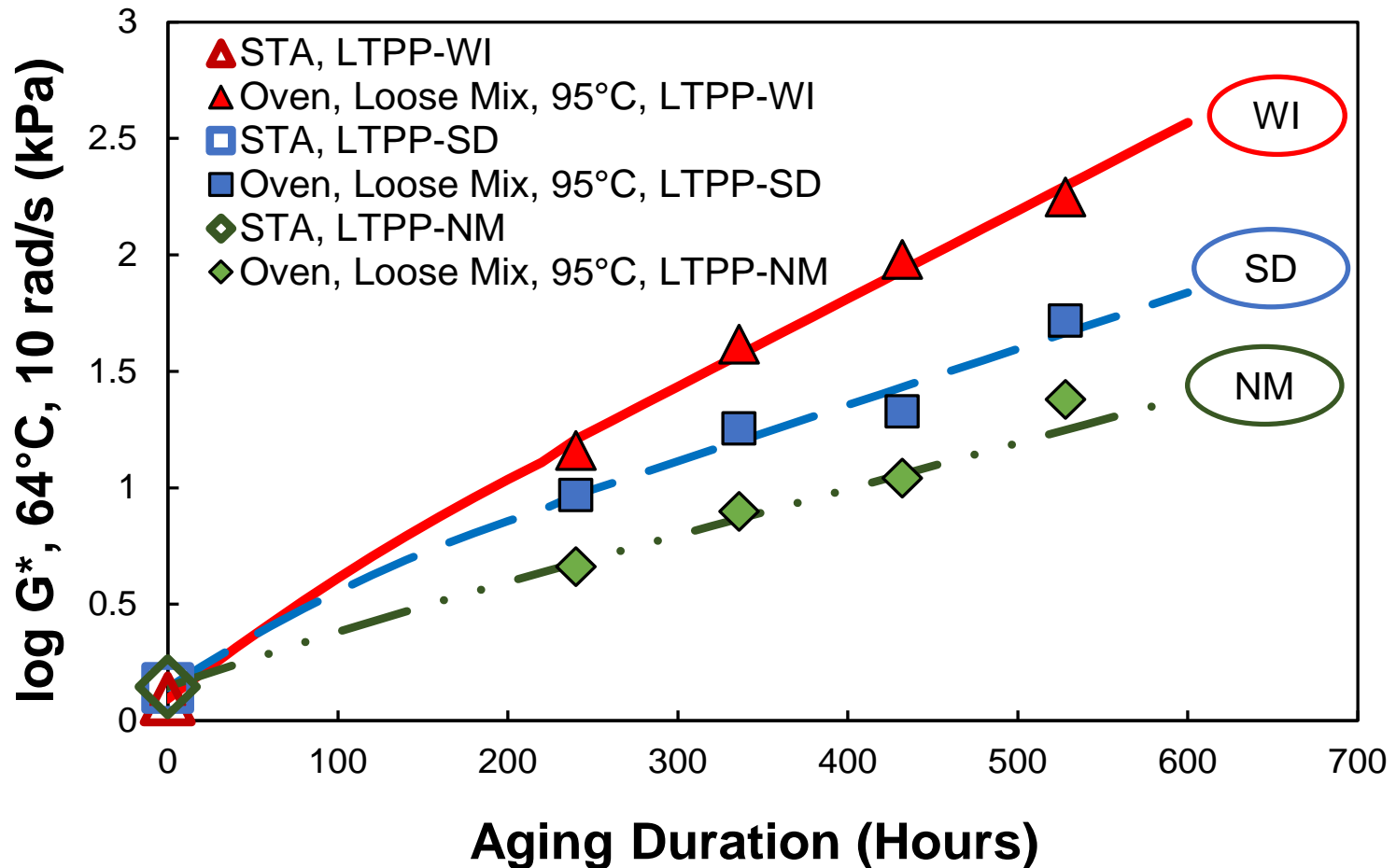
WesTrack Project

Different Oxidation Rates of Binders with Similar PG-Grades



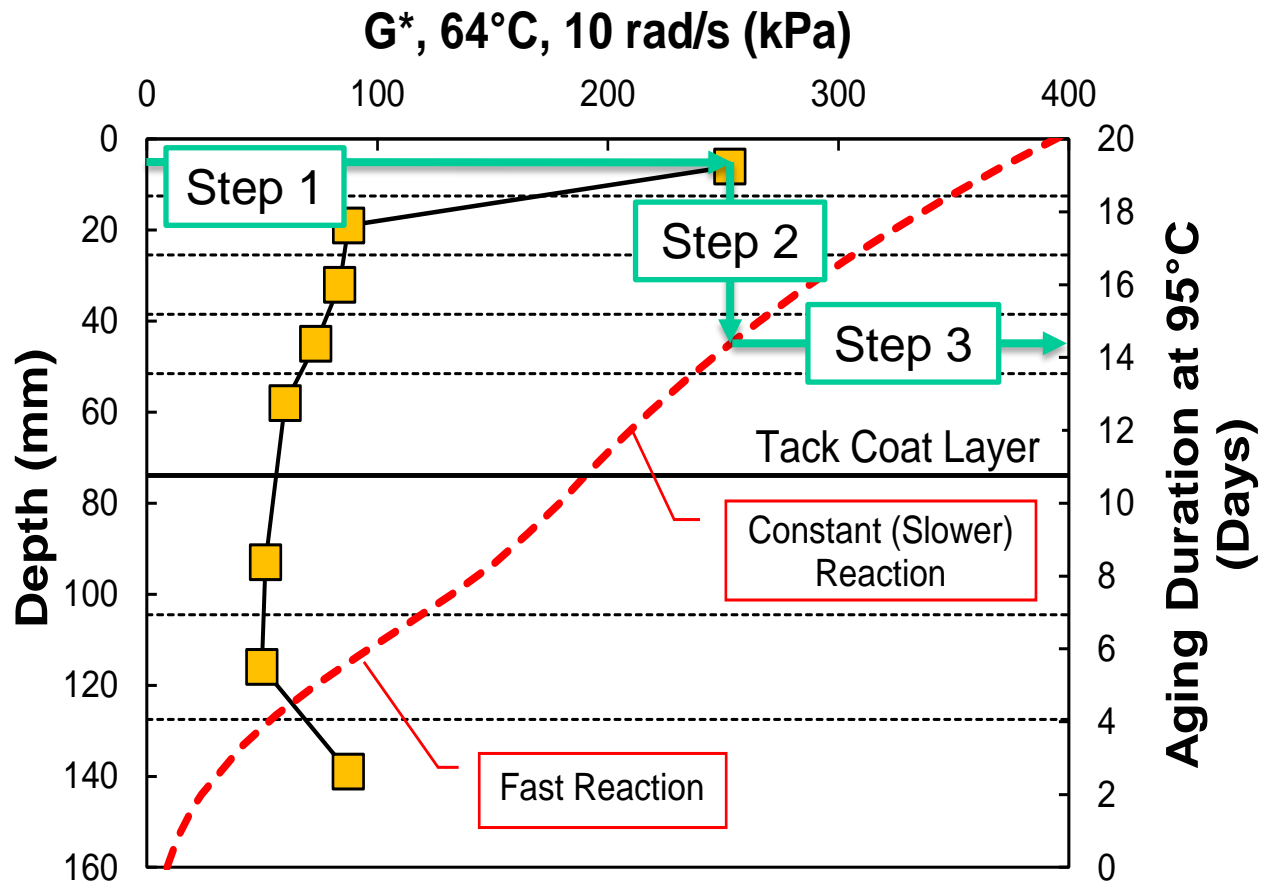
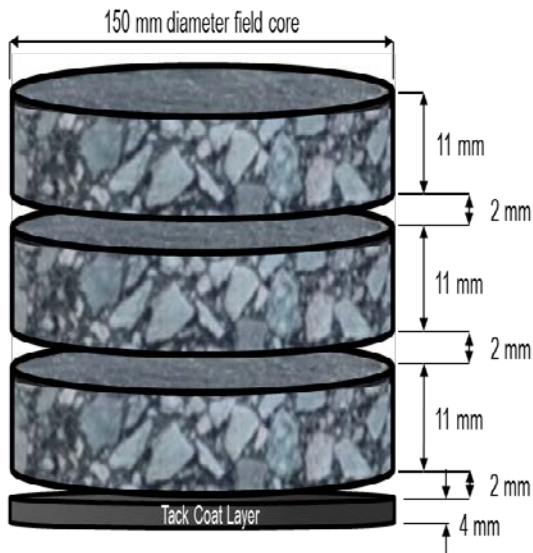
LTPP Sections

Laboratory Aging Rates at 95°C



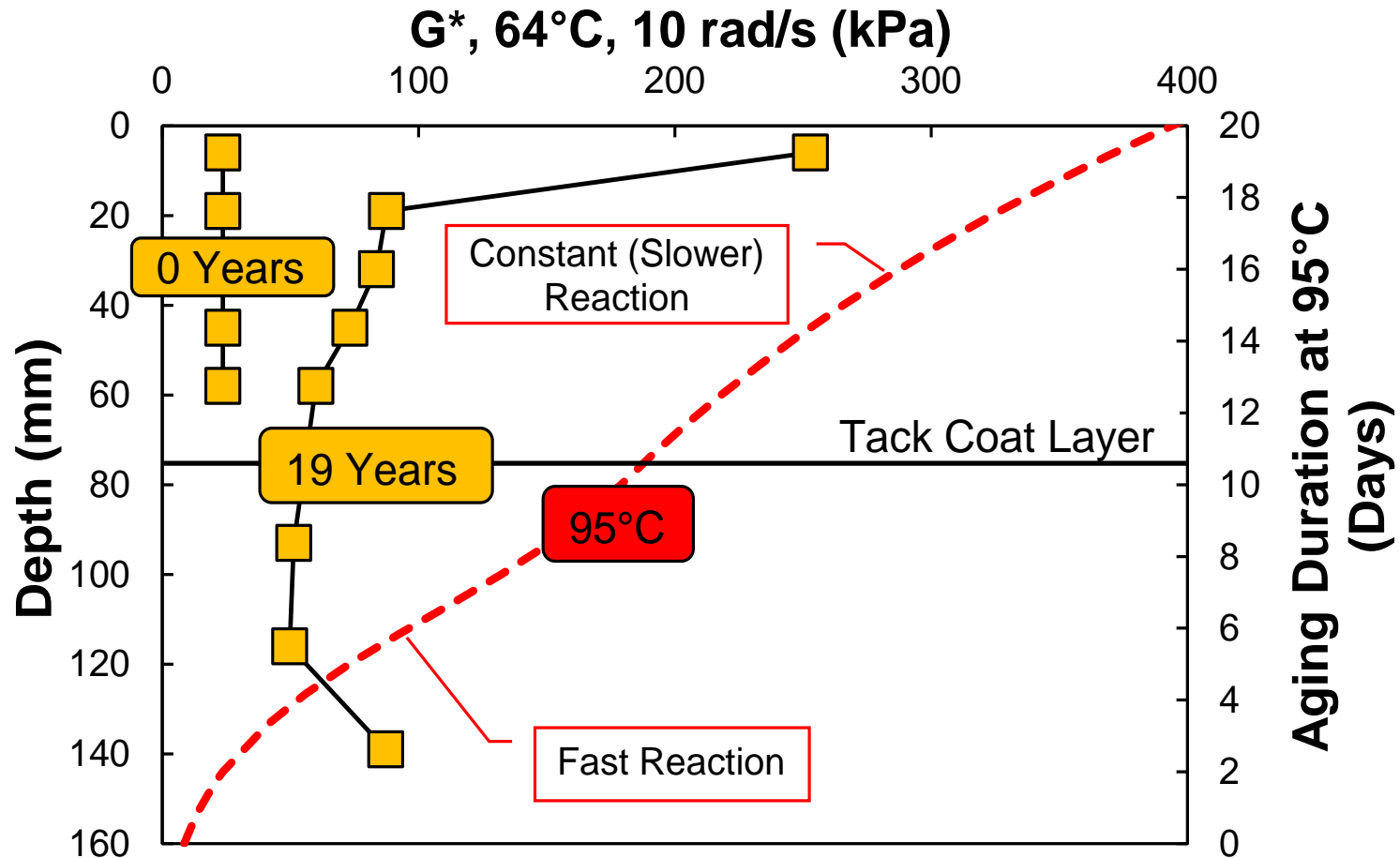
Steps to Match Field Aging Levels in the Laboratory

Field



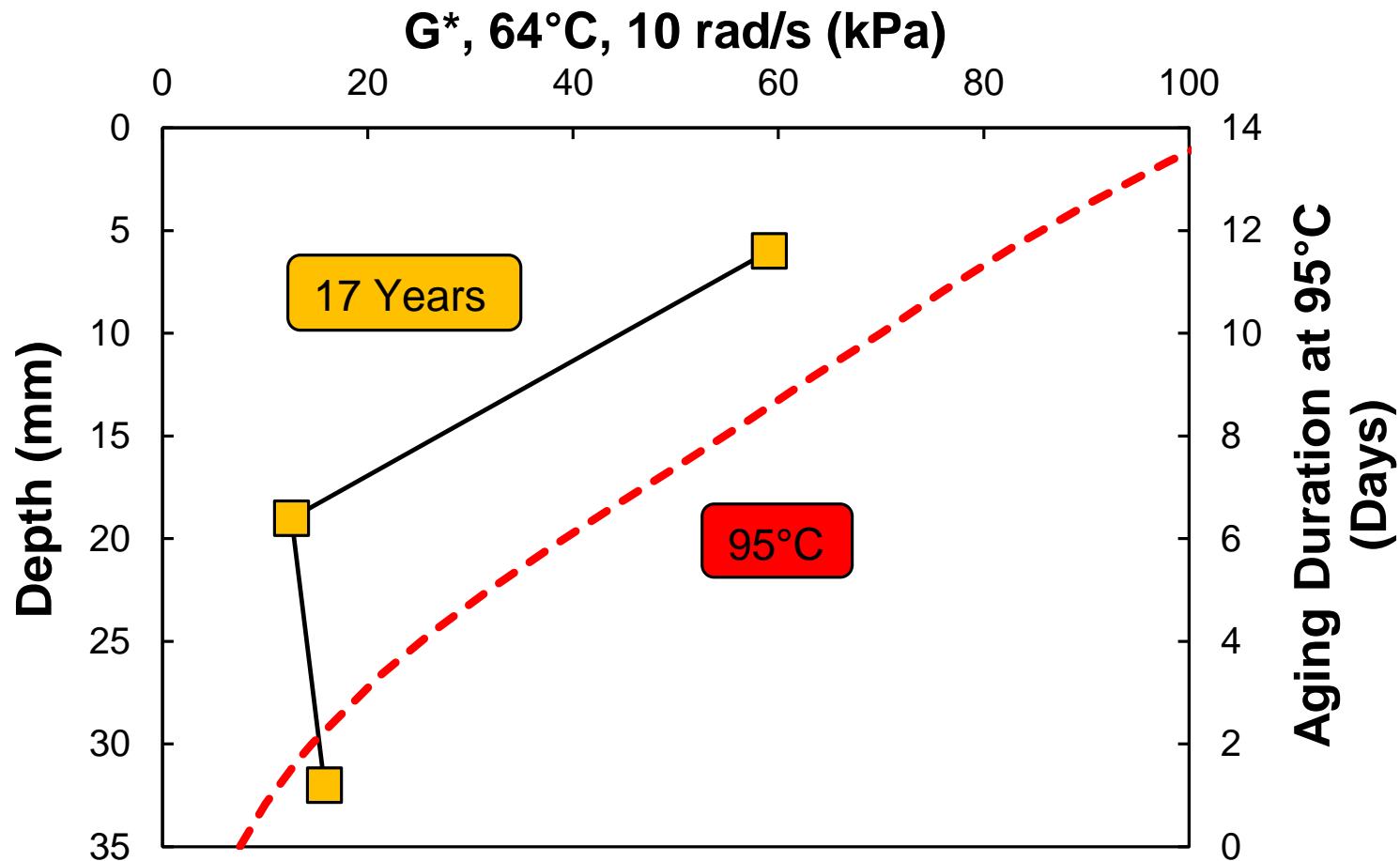
WesTrack Fine Section 1995

Field Aging Gradient and Laboratory Aging Rates



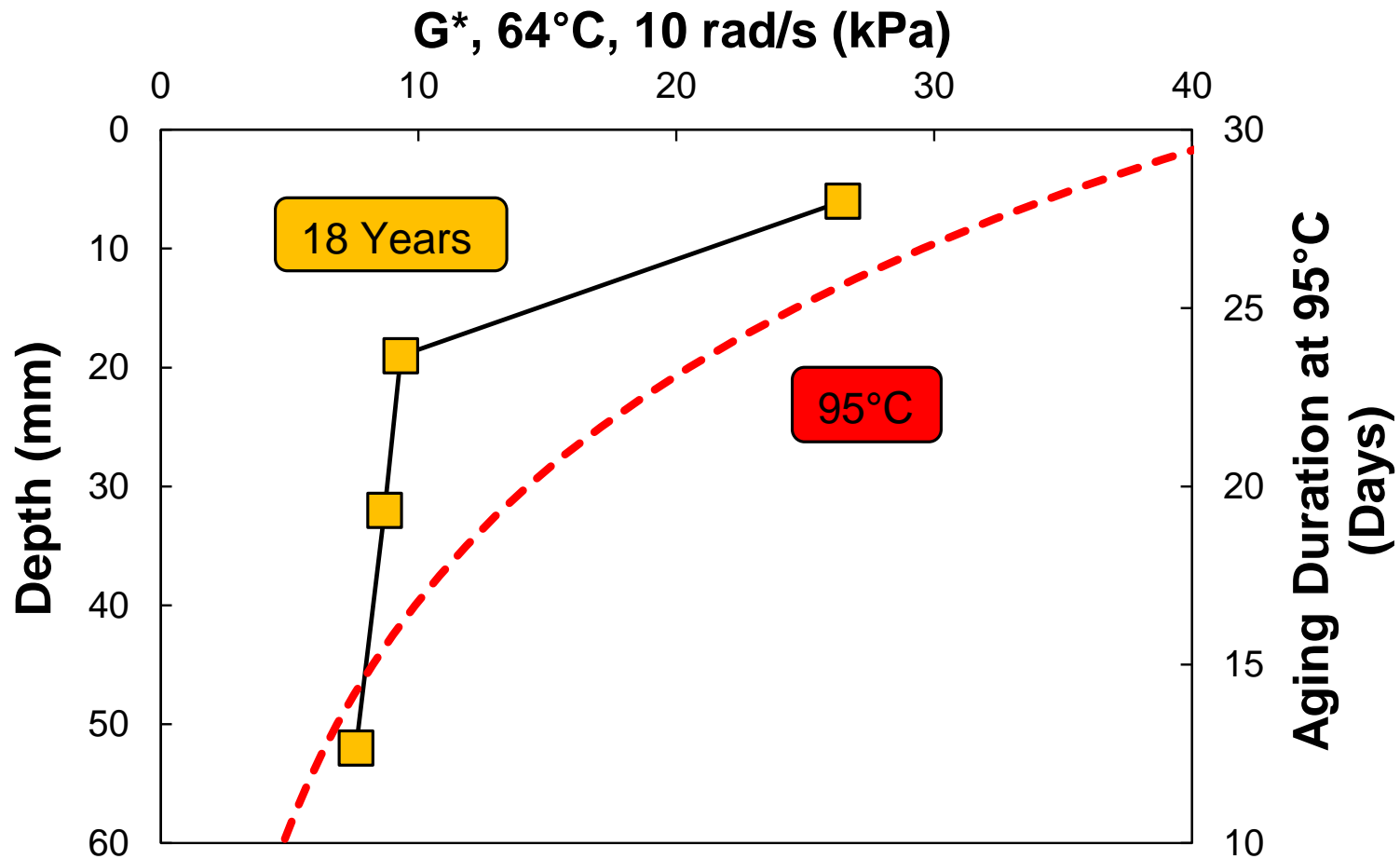
WesTrack Coarse Section 1997

Field Aging Gradient and Laboratory Aging Rates



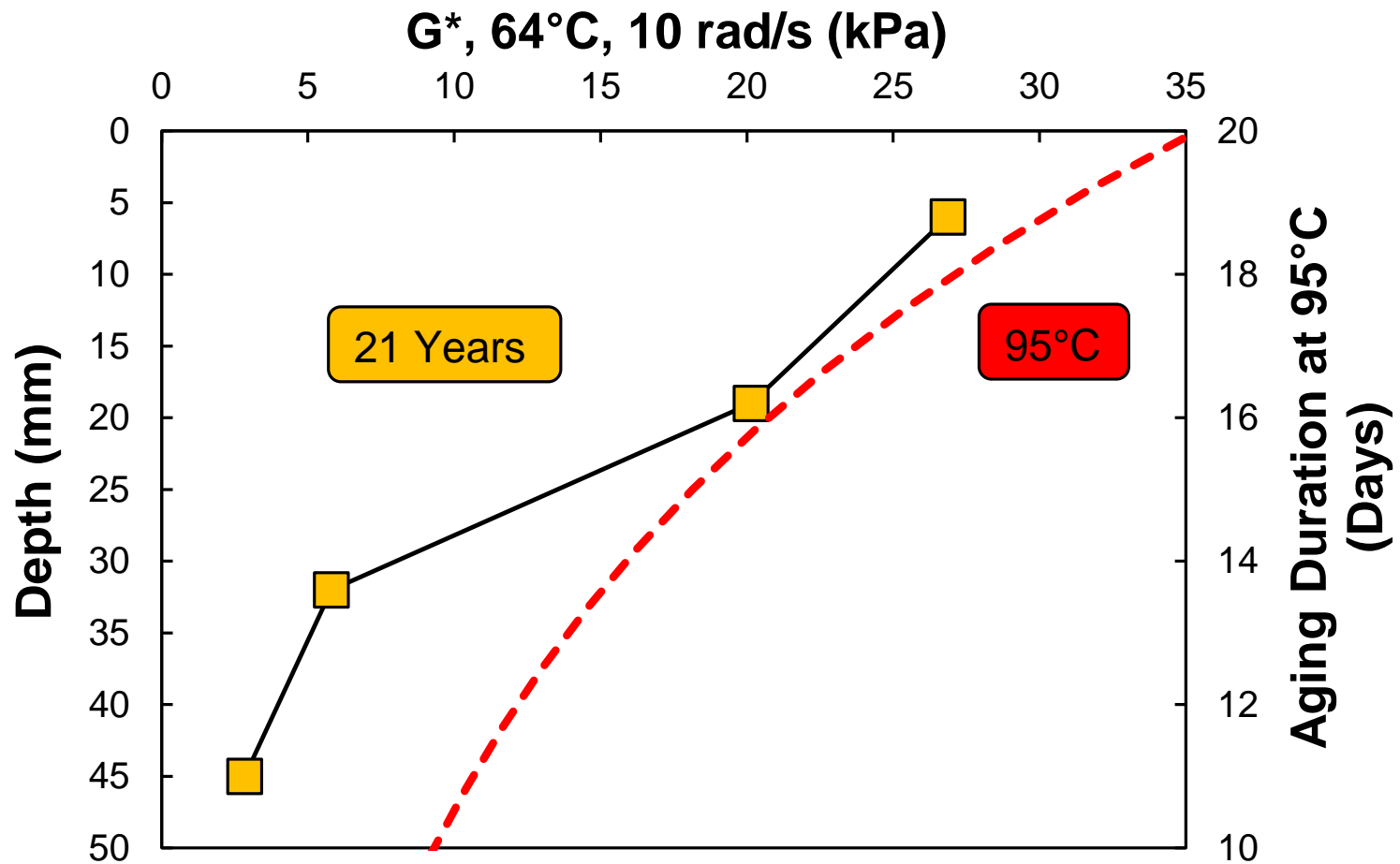
LTPP New Mexico

Field Aging Gradient and Laboratory Aging Rates



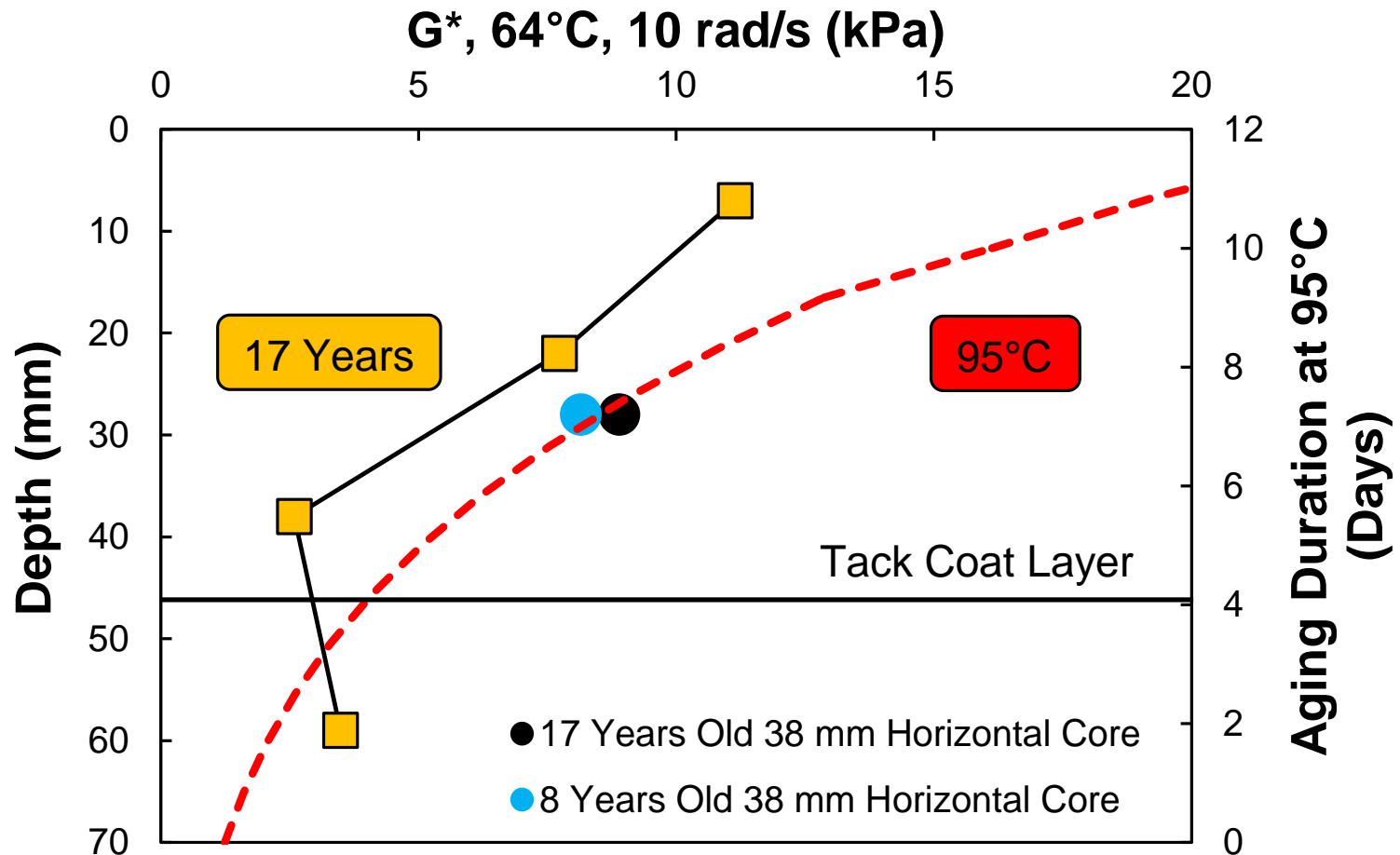
LTPP South Dakota

Field Aging Gradient and Laboratory Aging Rates



LTPP Wisconsin

Field Aging Gradient and Laboratory Aging Rates



WesTrack Project

Required Durations to Match Field Aging Levels

Field Section	Climate Zone	Location	Age	Depth	Required Durations at 95°C
WesTrack Fine 1995 5.4% AC, 8% AV	Dry, Non-Freeze	Western Nevada	19 Years	6 mm	14.4 days
				19 mm	5.6 days
			0 Year	6 mm	2 days
				19 mm	2 days
WesTrack Coarse 1997 5.7% AC, 8% AV	Dry, Non-Freeze	Western Nevada	17 Years	6 mm	8.4 days
				19 mm	2.1 days
			2 Years	6 mm	4.5 days

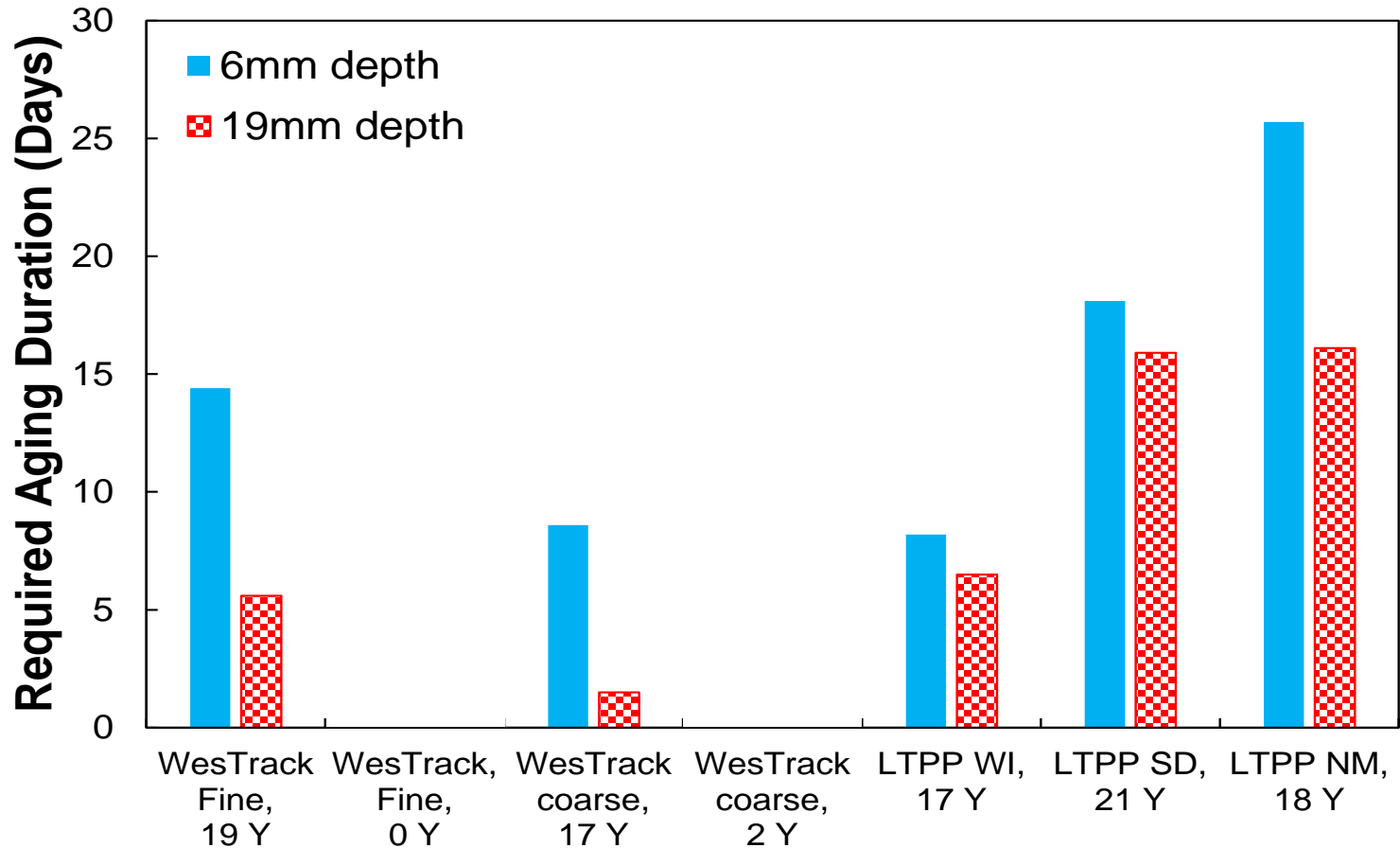
LTPP Sections

Required Durations to Match Field Aging Levels

Field Section	Climate Zone	Location	Age	Depth	Required Durations at 95°C
LTPP Wisconsin	Wet, Freeze	Marathon County, WI	17 Years	6 mm	8.2 days
				19 mm	6.5 days
LTPP South Dakota	Dry, Freeze	Campbell County, SD	21 Years	6 mm	18.1 days
				19 mm	15.9 days
LTPP New Mexico	Dry, Non-Freeze	Grant County, NM	18 Years	6 mm	25.7 days
				19 mm	16.1 days

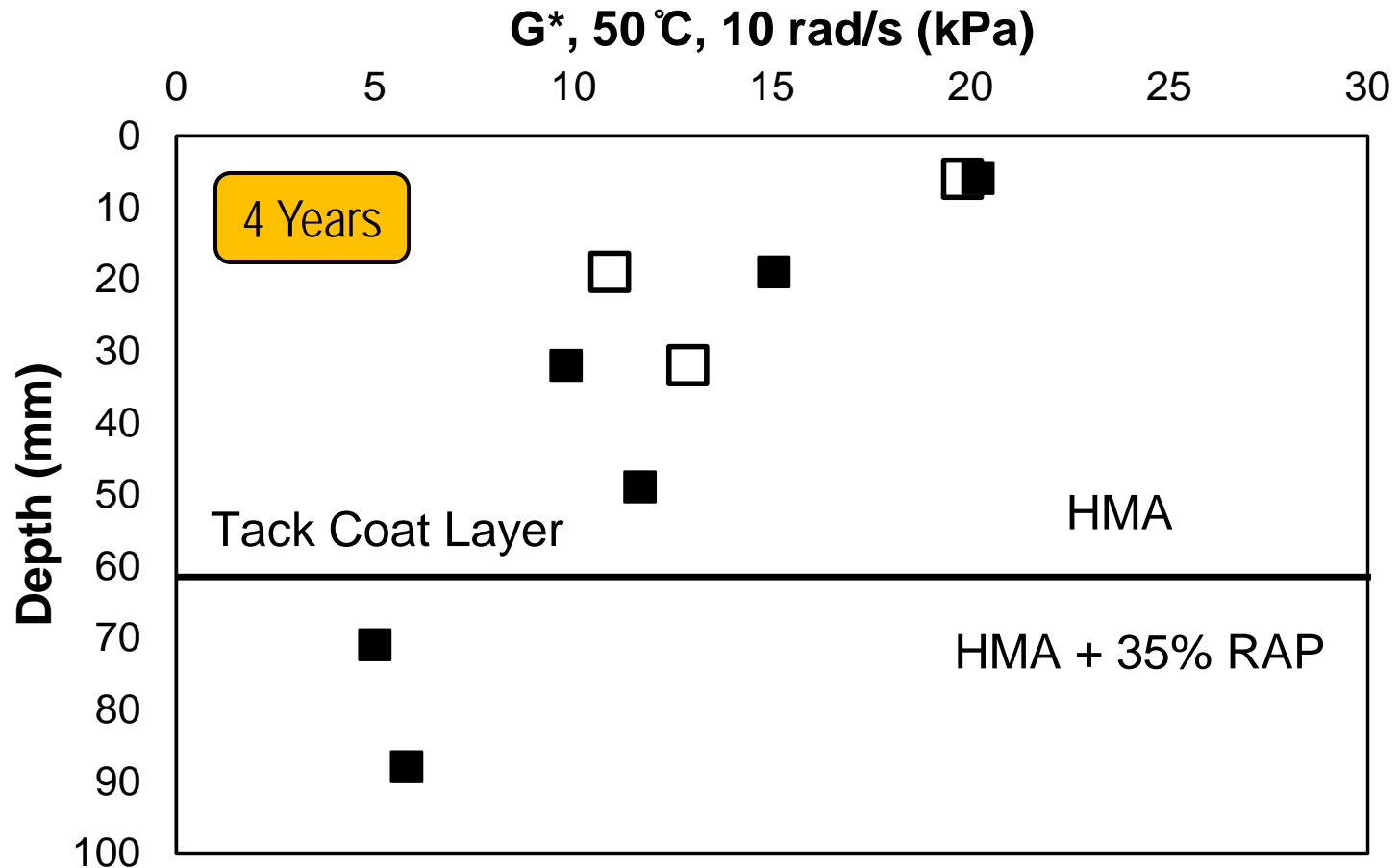
General Summary

Required Durations to Match Field Aging Levels



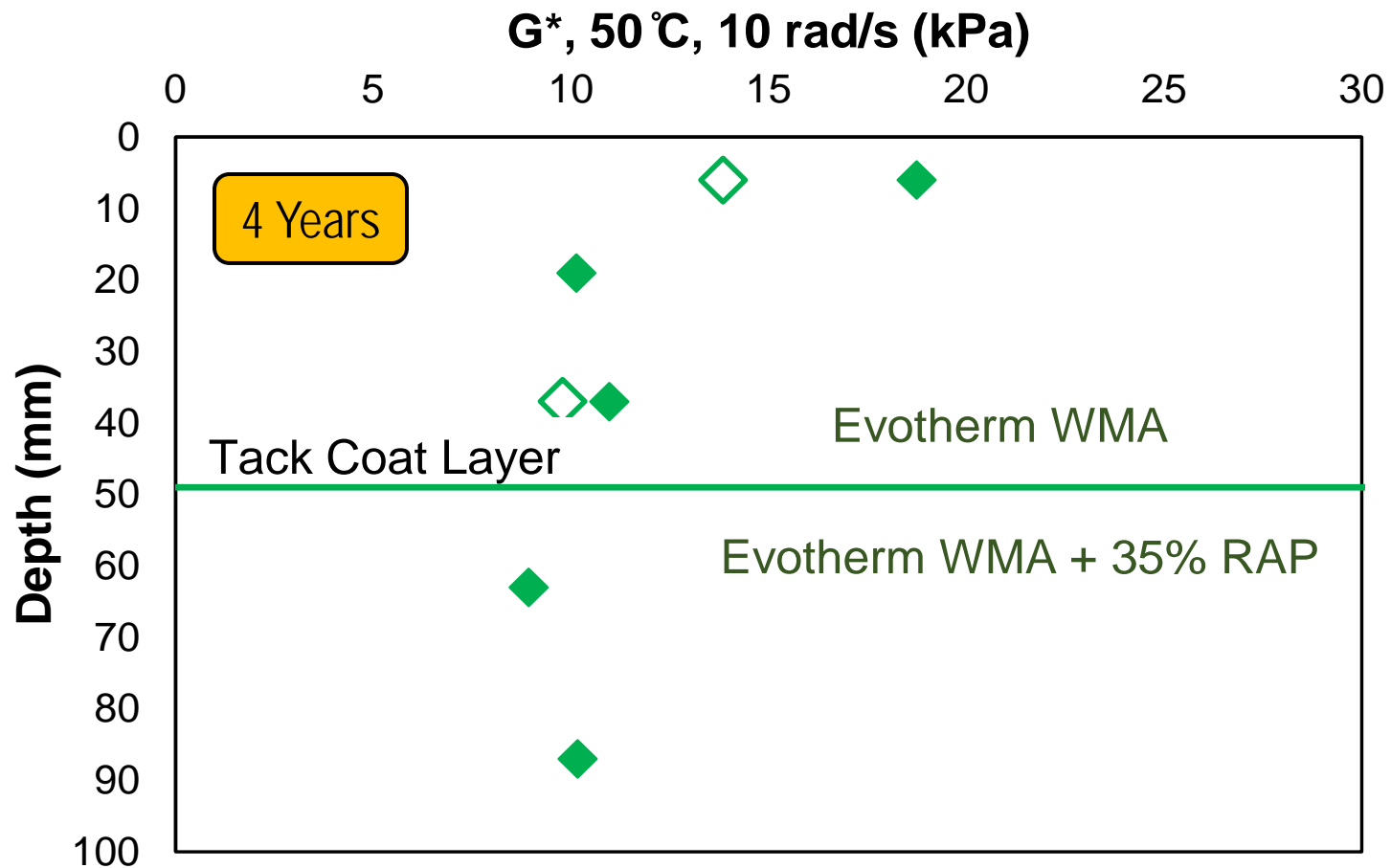
Manitoba – HMA

Field Aging Gradient and Variability



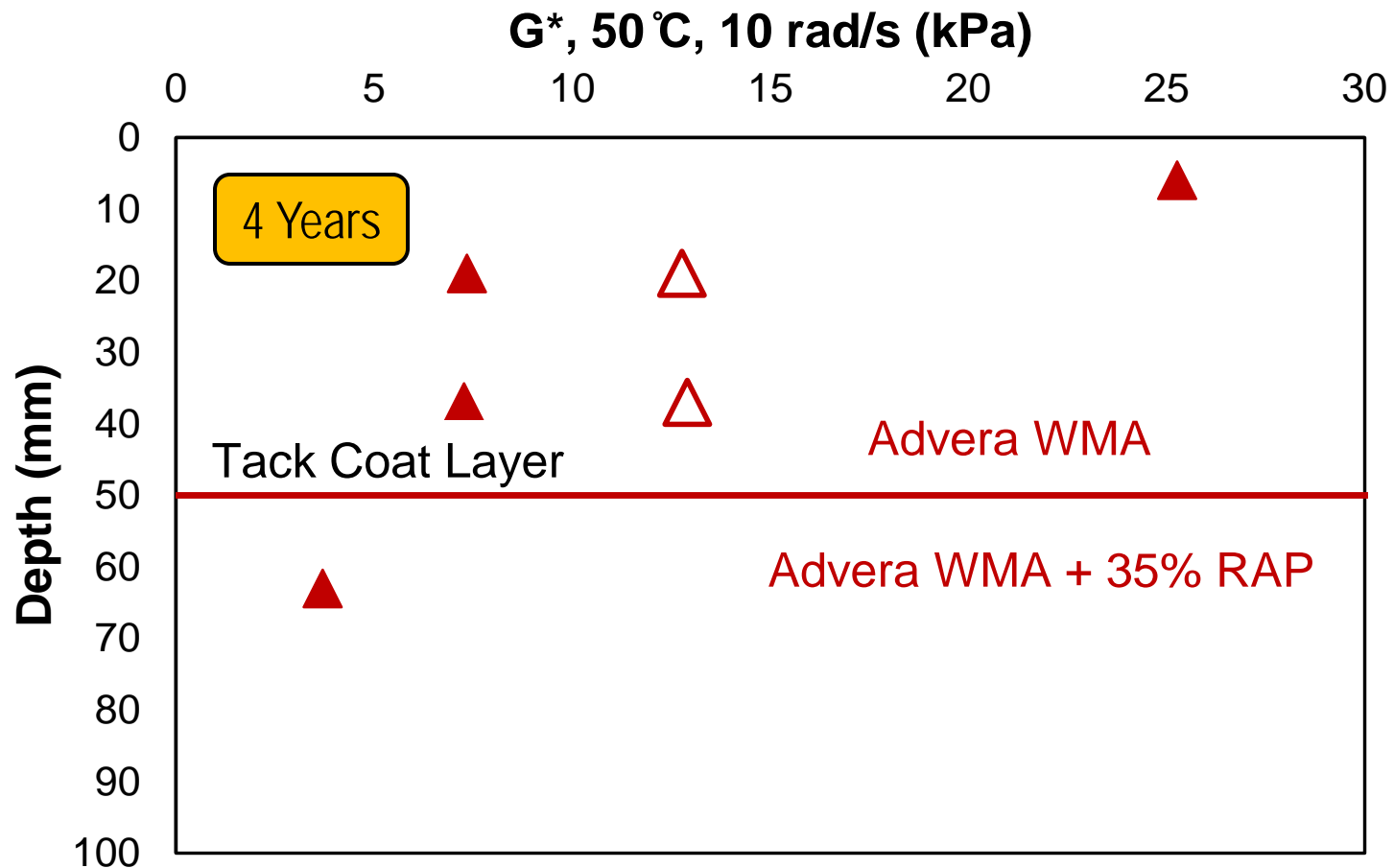
Manitoba – Evotherm WMA

Field Aging Gradient and Variability



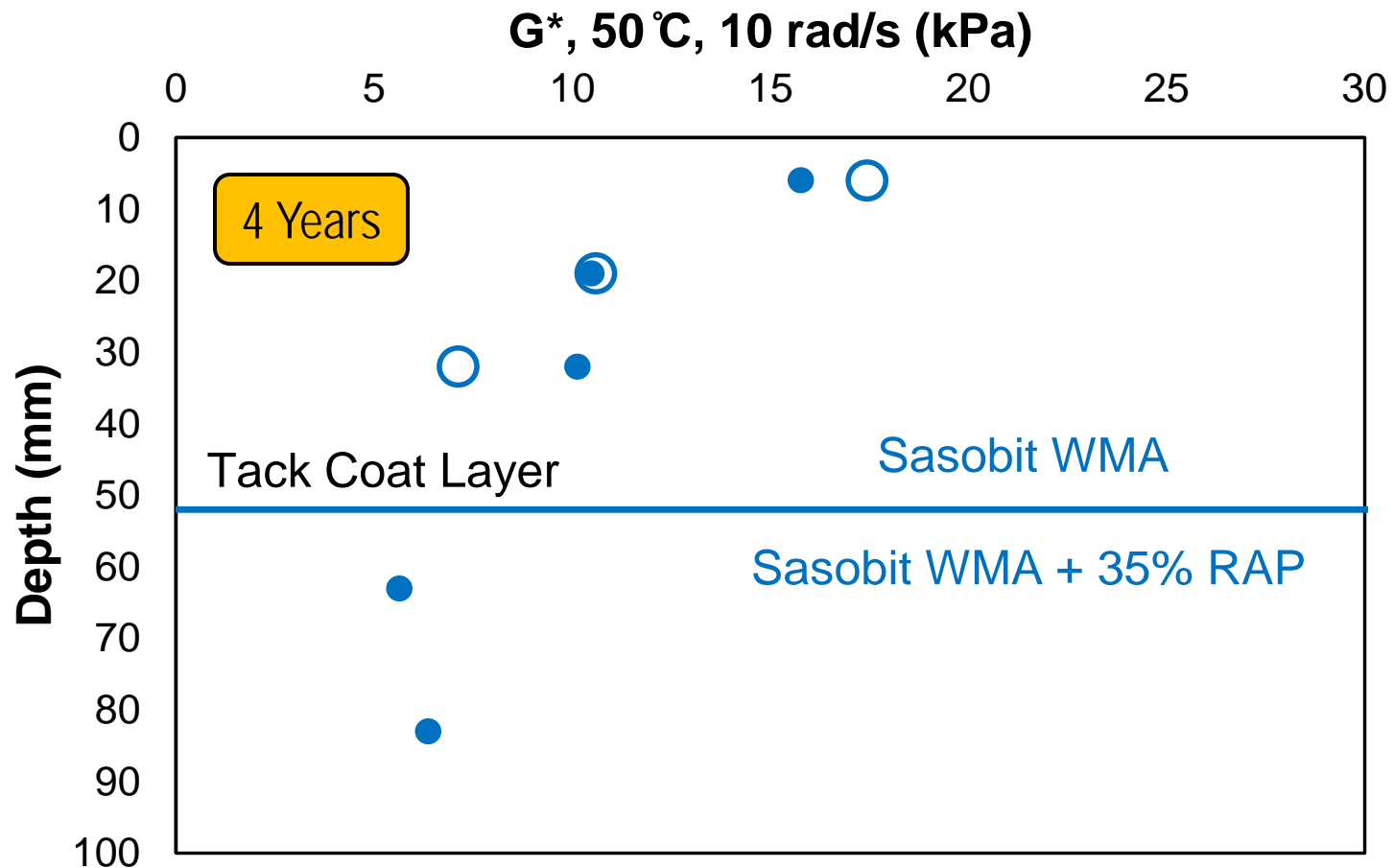
Manitoba – Advera WMA

Field Aging Gradient and Variability

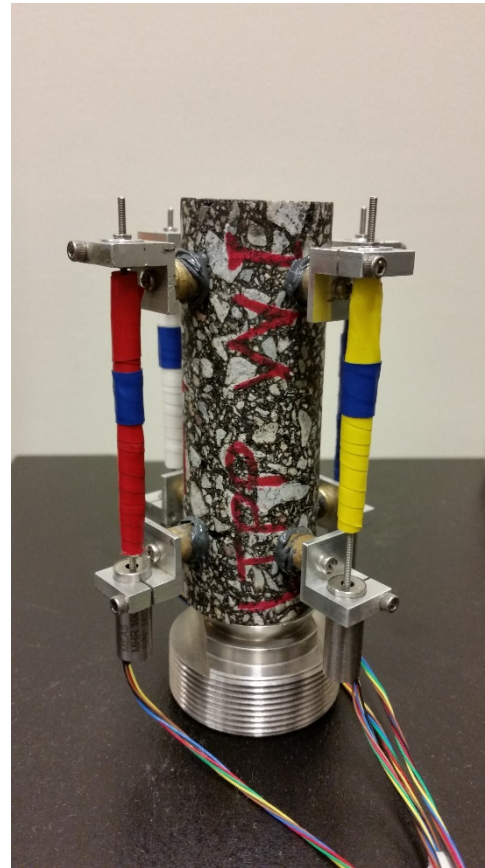
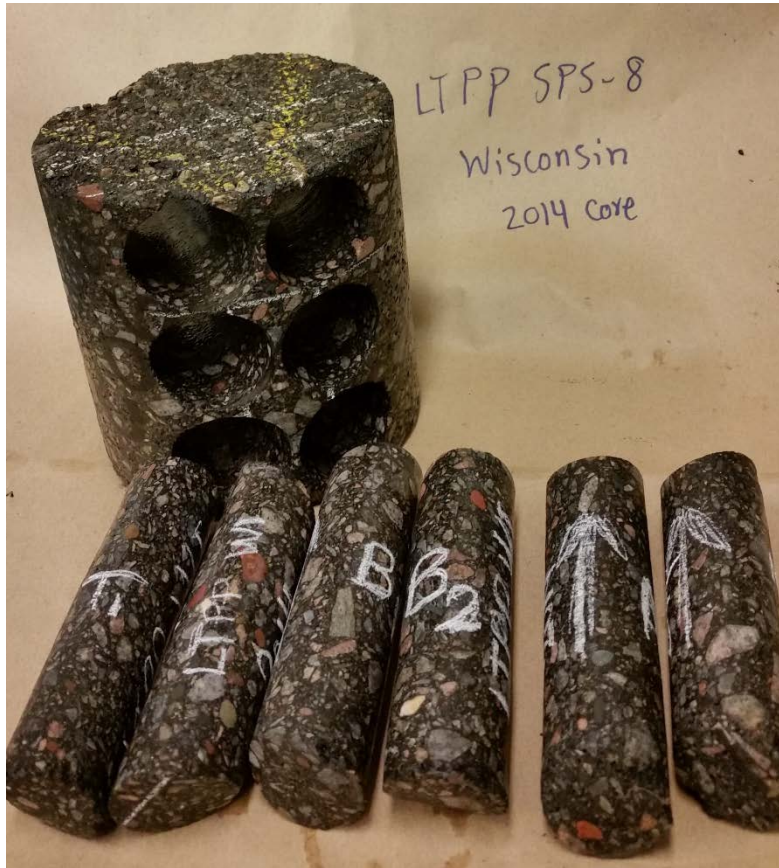


Manitoba – Sasobit WMA

Field Aging Gradient and Variability



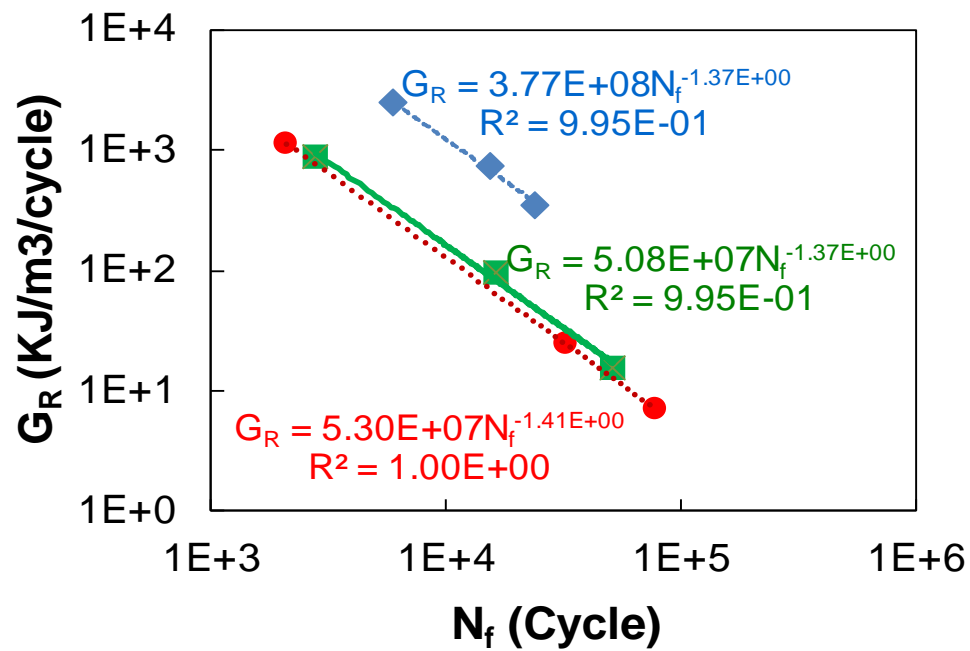
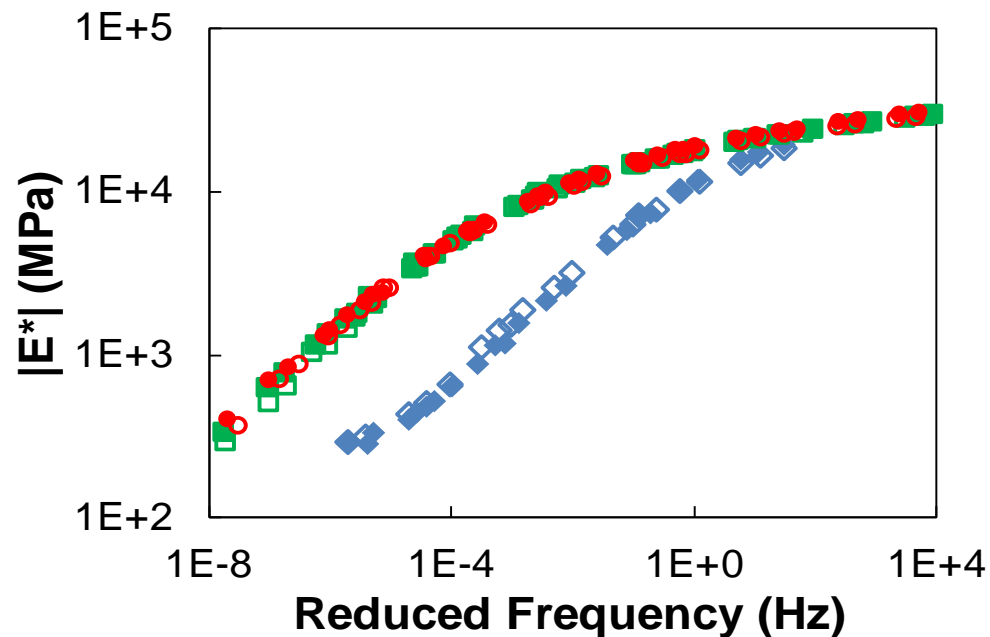
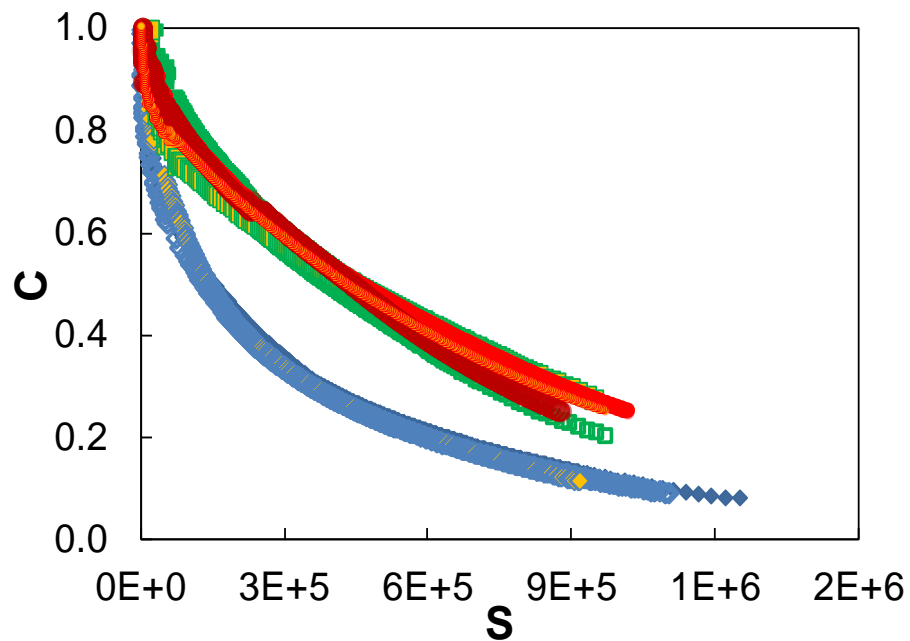
Fatigue Testing on Field Cores



Performance Test Results

FHWA ALF-SBS Mix

- ◆ Short-term Aged
- Oven, Loose Mix, 135°C, 52 hours
- Oven, Loose Mix, 95°C, 21 days



Pavement Performance Prediction

LVECD Program

3-dimensional viscoelastic analysis under moving loads and temperature gradients estimated by EICM

The screenshot displays the LVE Program software interface. On the left is a project tree with categories like General Information, Design Structure, and Results. The main window is divided into several panels:

- Structure General Information:** Structure Name: Flexible 3-Layer Pavement, Pavement/Lane Width (ft): 12. Buttons: Add Layer, Remove Layer, Move Layer.
- Layer Properties:** Layer: AC1, Thickness (inch): 6, Material Type: Asphalt Concrete. Includes fields for Specific Gravity (180) and Expansion Co. (1/F) (0.00002778).
- Strength/Modulus:** A table of material properties for AC1, AC2, Base, and Subgrade.
- Material Data Tables:** Tables for Poisson's Ratio, Emodulus, Ref. Temp., Shift Factors, and Fatigue/Rutting parameters.
- Mathematical Models:** Formulas for Shift Factor, Prony Series, and Fatigue Model.

Layer	Poisson's Ratio	Einf (psi)	Ref. Temp. (F)	Shift Factor a1	Shift Factor a2	Shift Factor a3
AC1	0.3000	1.4112e+04	41	2.1487e-04	-0.1038	3.8936
AC2						
Base						
Subgrade						

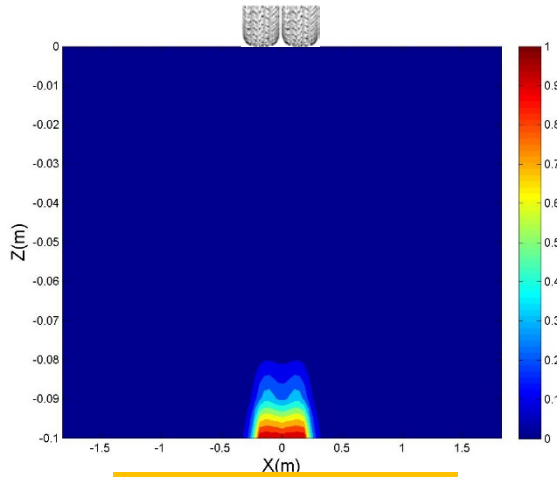
Parameter	Value	Parameter	Value
Alpha	2.6192	Alpha	0.6400
a	0.0017	A	0
b	0.5449	B	0.0031
ER	1	C	0.3342
Initial C	0.8000	TR(F)	129.2000
a1	14.6832	a2	0.0246
a3	-14.8515	b1	0.0034
b2	1.2866	b3	-1.2804

Mathematical Models:

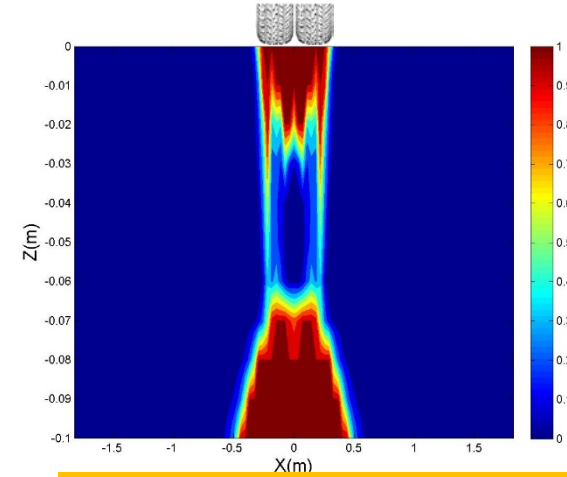
- Shift Factor: $\log(a_T) = a_1 T^2 + a_2 T + a_3$, Rutting Model: $\epsilon_{rp} = \frac{A + BN}{(C + N)^a}$
- Prony Series: $E = E_{inf} + \sum E_i e^{-t/\tau_i}$, $\Delta N_{ref} = \Delta N_{phy} \times 10^{a_{ref}}$
- Fatigue Model: $\frac{\partial S}{\partial t} = \left(-\frac{\partial W^R}{\partial S} \right)^a$, $a_{total} = a_{t_1} + a_{t_2}$, $a_{t_1} = a_1 \frac{1}{C_p} \sigma_1^{a_2} + a_3$, $a_{t_2} = b_1 \sigma_d^{b_2} + b_3$
- C(S) = e^{-aS^b}

LVECD Simulation

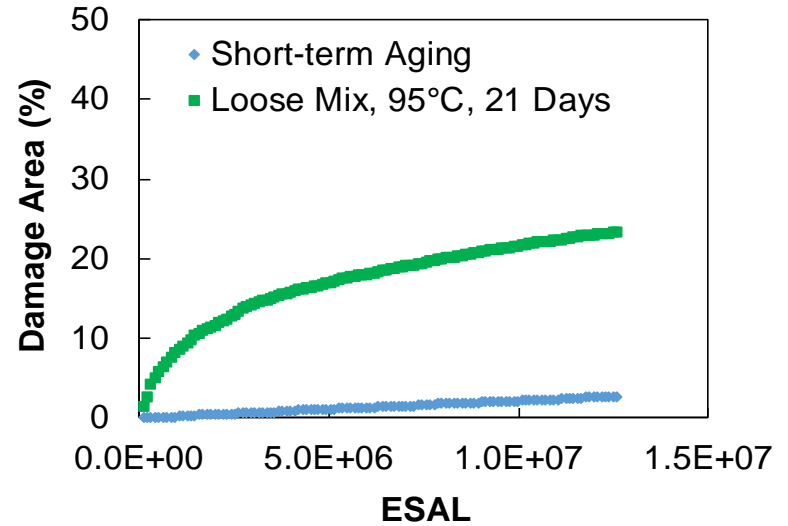
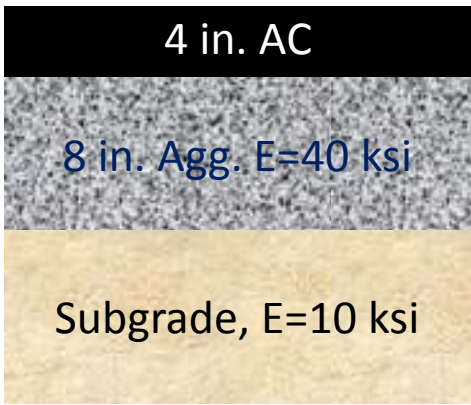
FHWA ALF-SBS Mix



Short-term Aging



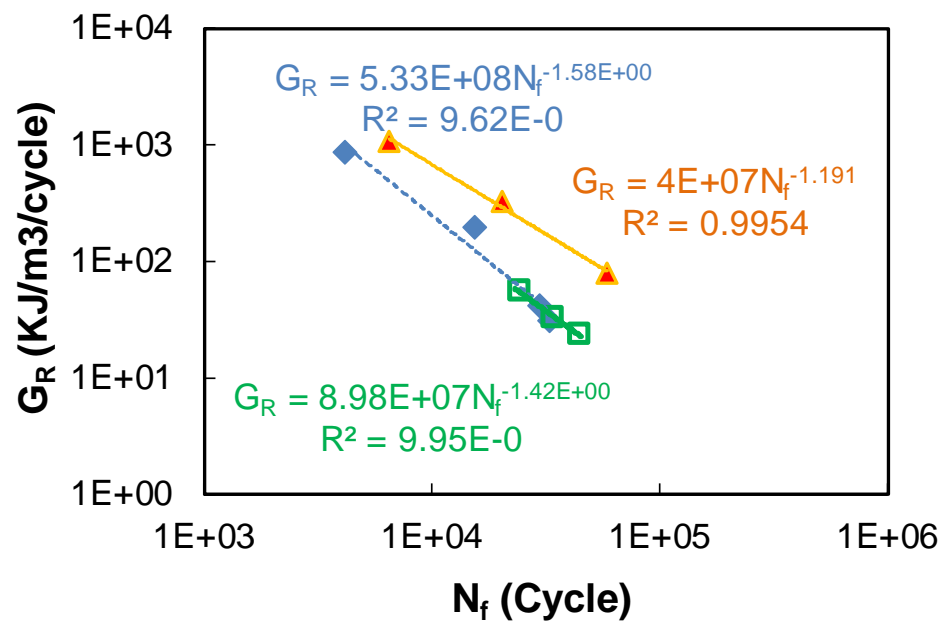
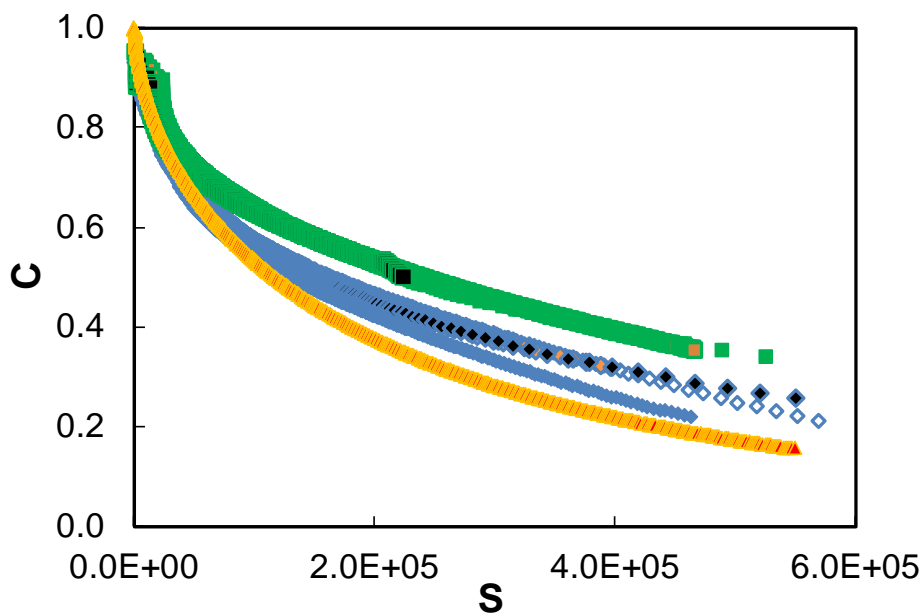
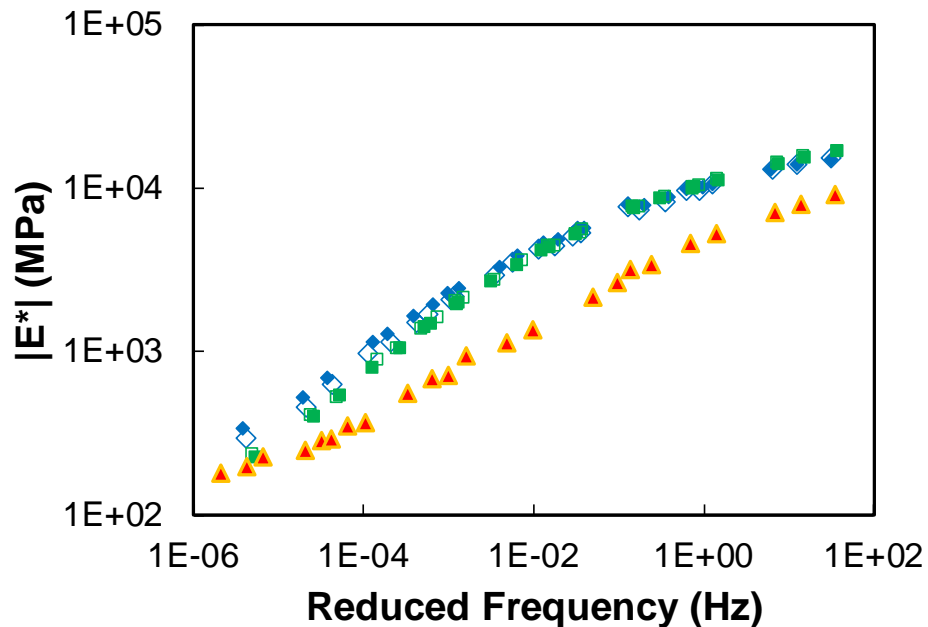
Loose Mix, 95°C, 21 Days



Performance Test Results

LTPP-Wisconsin

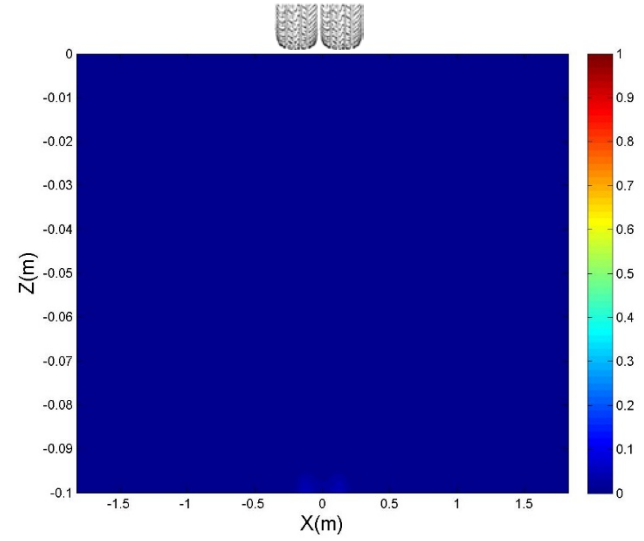
- ▲ Short-term Aged
- ◆ Field, 8 yrs Old, Bottom Lift, 5.4% AV
- Field, 8 yrs Old, Top Lift, 8% AV



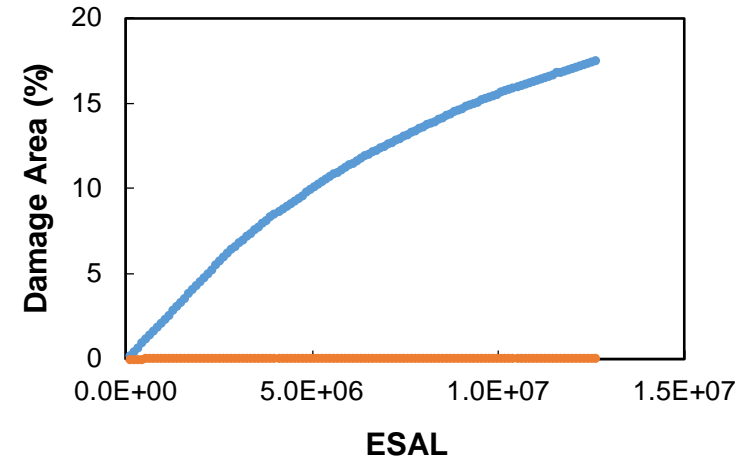
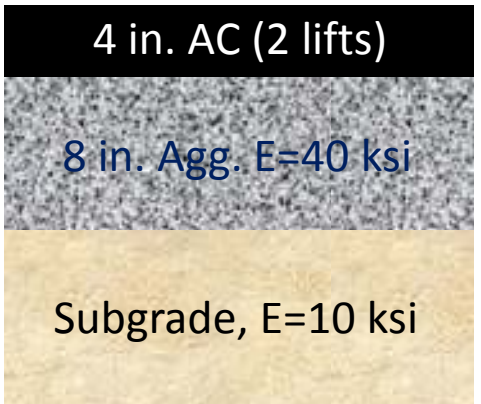
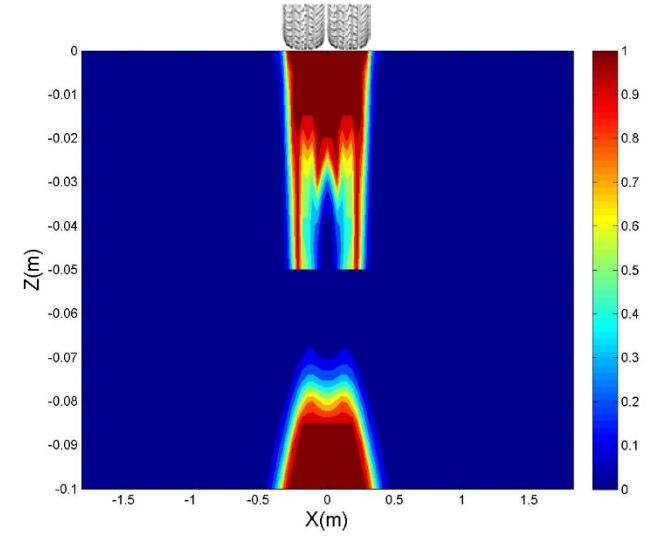
LVECD Simulation

LTPP Wisconsin

Short-term Aged, Two-lift Pavement



8-Years Old, Two-lift Pavement



Questions?