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Correlating Laboratory Conditioning with Field Aging for Asphalt Using Rheological Parameters

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Introduction

- Study the aging effects on asphalt material is of great importance for design of more reliable and durable asphalt pavement.
- This study directly addresses four of the six FHWA high-priority highway challenges: enhancing performance; promoting sustainability; maintaining infrastructure integrity; preparing for future.

Objective

- Evaluate how the rheological parameters of asphalt binders change over time, as well as evaluating changes in the aging kinetics with pavement depth; and,
- Provide a way to optimize the laboratory conditioning durations with respect to pavement life (time) and depth (location) within the pavement structure.

Materials

- Nine mixtures and four field cores (4 years in service) are included.
- Binder samples are extracted and recovered from the mixtures and field cores.

Mixture ID	Virgin Binder PG	Total Binder Content (%)	Recycled Binder Content (%)
5234LM	52-34	5.3	18.9
5234LL	52-34	5.3	28.3
5834LM	58-34	5.4	18.5
5828LM	58-28	5.3	18.9
5828LL	58-28	5.3	28.3
6428SV	64-28	6.4	0
6428SM	64-28	6.3	18.5
7034LV	70-34	5.8	0
7628SM	76-28	6.1	14.8

Methodology

Laboratory Conditioning Methods

- STA: Plant produced materials
- LTOA: Long term aging condition

5 days and 12 days, 95ºC, loose mix (NCHRP 09-54 project)

24-hour, 135ºC, loose mix (Asphalt Institute)

Test Method

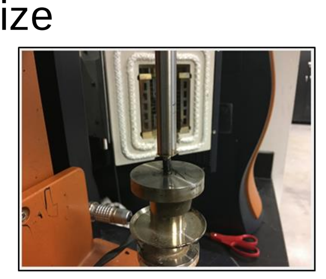
- 4mm Dynamic Shear Rheometer (DSR) Characterize stiffness and relaxation capability of binder.
- Test Output:

Complex Modulus mastercurve

Phase angle mastercurve

Rheological Indices:

Glover-Rowe Parameter; R-value; ΔTc; PGLT



NCHRP 09-54 Binder Oxidation Aging Model

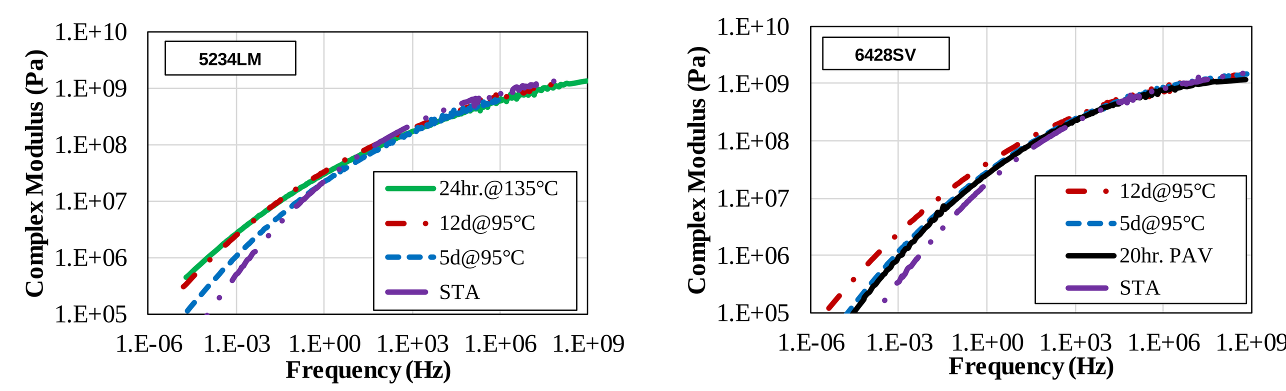
- Using log G* at 64°C and 10 rad/s frequency as the AIP:

$$\log G^* = \log G_0^* + M\left(1-\frac{k_c}{k_f}\right)\left(1-\exp(-k_f t)\right) + k_c M t$$

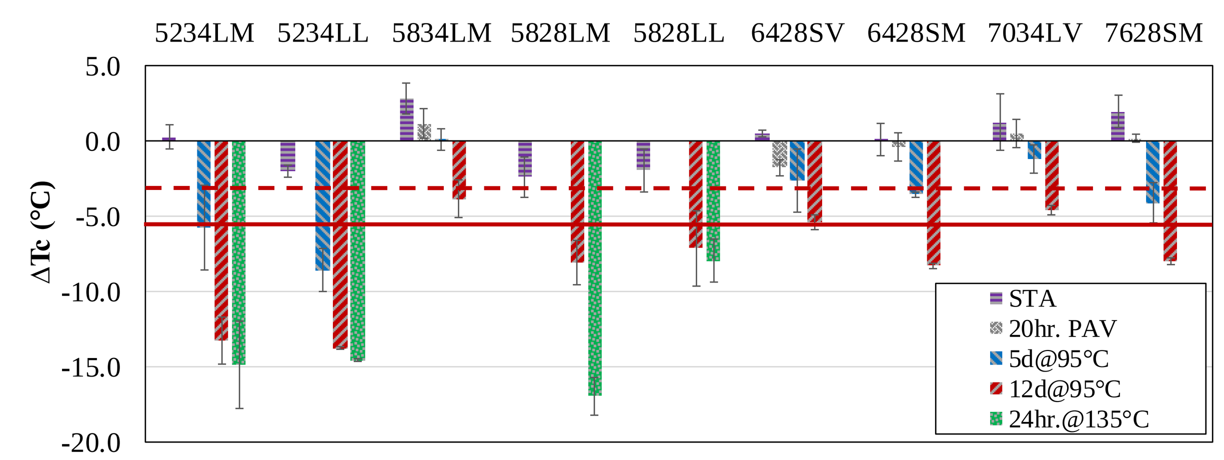
$$k_f = A_f\left(\exp\frac{-E_{af}}{RT}\right);\ k_c = A_c\left(\exp\frac{-E_{ac}}{RT}\right)$$

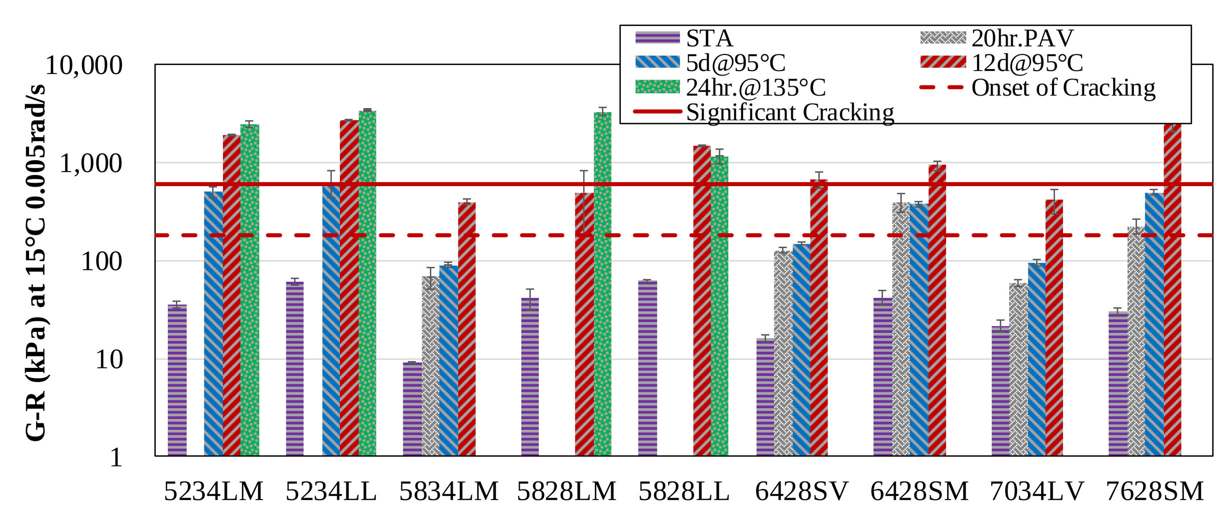
- This oxidation aging model is employed in this study to correlate the different laboratory conditioning methods with field aging .

Change of Rheological Properties with Aging

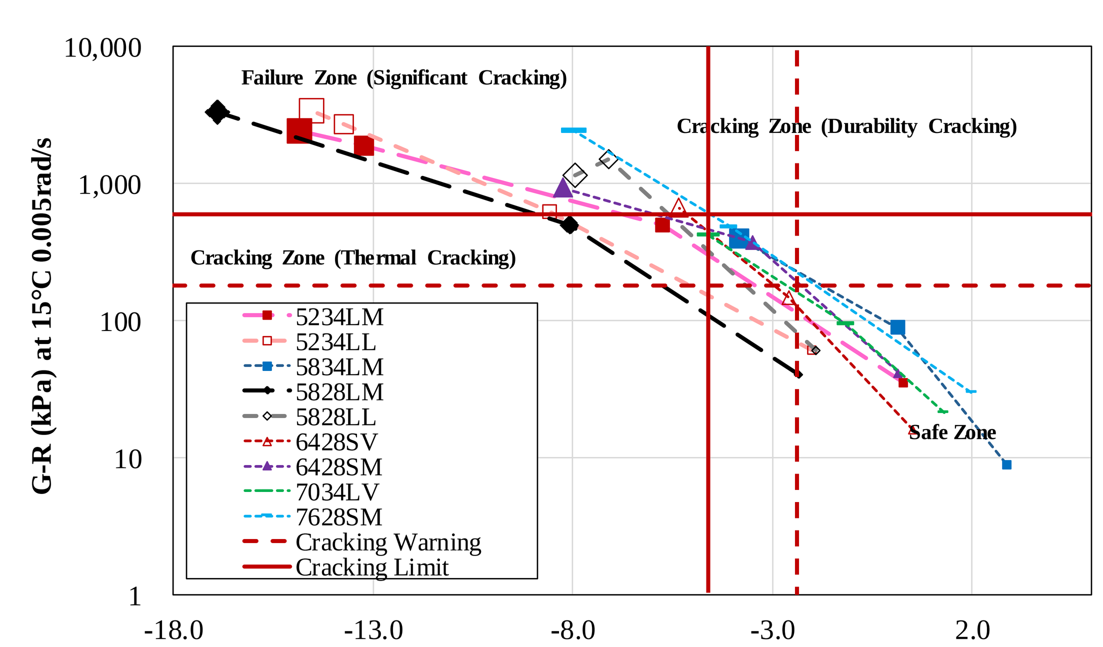


- 24 hr. at 135°C and 12 days at 95°C show similar complex modulus and phase angle values.
- 20 hr. PAV samples typically fall in between STA and 5 days at 95°C aging level.



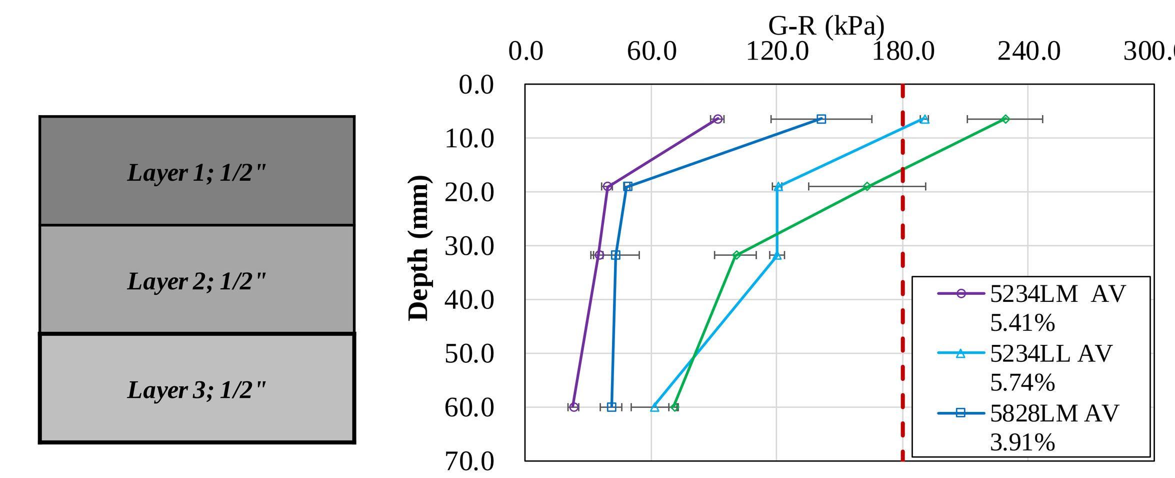


- 5834LM, 6428SV, and 7034LV show better cracking performance after each aging condition compared with other materials.
- 5234LM, 5234LL and 7628SM generally show good cracking performance for STA. However, these binders have a greater change in the rheological indices with aging.
- **Other performance indices** (PGLT and R-value) show the similar trend.



- Providing a way to combine G-R and ΔTc to evaluate the thermal and durability cracking susceptibility of the binders after different aging conditions together.
- 5834LM and 7034LV, after 5 days aging, are located in the safe zone, and even after 12 days aging condition the ΔTc value and G-R parameter are still within the cracking limits.

Aging Gradient (Field Cores)



- The mid-depth location of each layer is selected as the representative depth to reflect the performance of each layer.
- The rate of field aging within the first inch of the pavement is much faster than the layers below it for all four mixtures.
- 5828LM shows the largest difference in G-R between layer 1 and layer 2, however, it does not change significantly below layer 2. 5828LM has the lowest air void, this restricts the rate of oxidation due to lower oxygen availability.

Correlate Laboratory Conditions with Field Aging

Binder ID	5234LM	5234LL	5828LM	5828LL
M	0.89	0.83	0.74	0.7

- Table above presents the values of the calibrated oxidation aging model parameters.
- The universal values of the kf and kc parameters are obtained from a least mean square error optimization of the data obtained from the calibration binders (the binders with STA, 5 and 12 days at 95°C aging conditions).
- 5234LM and 5234LL generally show a higher aging rate (M-value) as compared with other two binders, consistent with the results from the DSR data.
- Higher RAP content results in a lower M value (slower aging rate).

Layers (Top to Bottom)	Laboratory Aging Duration (hour)				
	5234LM	5234LL	5828LM	5828LL	Average
Layer 1	62	54	48	46	52
Layer 2	45	30	22	37	33
Layer 3	15	25	12	19	18

- The aging rate of asphalt material within the first layer is approximately 1.5 times faster than the second layer and 3 times faster than the third layer.
- 5 days of mixture aging in the lab appears to simulate around 8 years field aging for the top 12.5 mm layer based on New Hampshire climate condition, while 12 days can simulate approximately 20 years.
- The 20 hr. PAV appears to simulate less than 8 years field aging in New Hampshire.

Summary and Conclusions

- Virgin binders generally show the good cracking performance;
- 5234LM, 5234LL and 7628SM show higher aging susceptibility.
- 5 days of mixture aging in the lab appears to simulate around
- 8 years field aging for the top 12.5 mm layer based on New Hampshire climate condition, while 12 days can simulate approximately 20 years.
- The general methodology described in this study provides agencies a way to optimize the laboratory conditioning durations with respect to pavement life (time), and depth (location) within the pavement structure.

Future Work

- Future work and analysis are planned to continue testing the binder sampled during production and extracted from field cores to further evaluate and correlate the different laboratory aging protocols with field aging durations.
- Additional tests that evaluate the binders beyond the linear viscoelastic, as well as the chemical analytical test are being investigated for inclusion in comprehensive evaluation of the change of asphalt binders' properties with aging.

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