Incorporating Impact of Aging on Cracking Performance of Mixtures during Design

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Introduction

- Hot mix asphalt pavements undergo aging during mixing and compaction, and over the service life. Aging results in more cracking susceptibility and shortening the service lives and lowered serviceability of pavement.

- It is important to have an understanding of how the cracking resistance of the binders and mixtures will change over time at the time materials are selected and pavements are constructed.
- The results of this study will help NHDOT to improve the selection of asphalt mixtures to resist cracking, resulting in long term cost savings and better ride quality. The experimental study will provide the NHDOT and industry with information on cracking characteristics of mixtures including different mix variables.

Objectives

- Develop a screening tool (including aging protocol) to identify crack susceptible binders/mixtures during material selection and mix design.
- Quantitatively evaluate how the cracking potential of typical NHDOT mixtures change with different aging levels for future maintenance and rehabilitation planning.

Materials

- 11 plant produced mixtures; Field cores are available for four of the mixtures.
- Binder samples are extracted and recovered from the mixtures and field cores.

Mixture ID	Virgin Binder Grade	Design Gyration Levels	NMAS (mm)	Total Binder Content (%)	Recycled Binder Content (%)
5234LM	PG 52-34	50	12.5	5.3	18.9
5234LL					28.3
5834LM	PG 58-34			5.4	18.5
5828SM	PG 58-28		9.5	5.9	16.9
5828LM			12.5	5.3	18.9
5828LL		75			28.3
6428SV	PG 64-28		9.5	6.4	0
6428SM				6.3	18.5
6428LM			12.5	5.8	
7034LV	PG 70-34				0
7628SM	PG 76-28		9.5	6.1	14.8

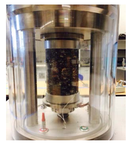
Aging Methods

- **STA:** Short term aging during production.
- **LTOA:** Long term aging condition
  - 95ºC, loose mix (NCHRP project) for 1-12 days
    - (5 and 12 days are the primary conditions)
  - 24-hour, 135ºC, loose mix (Asphalt Institute)

Performance Tests

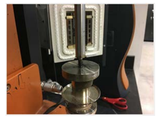
Dynamic Modulus (AASHTO T342)

- Characterize stiffness and relaxation capability of mixture.
- Test Output:
  - Dynamic Modulus mastercurve
  - Phase angle mastercurve
  - Mixture Glover-Rowe Parameter



4mm Dynamic Shear Rheometer (DSR) (MTE)

- Characterize stiffness and relaxation capability of binder.
- Test Output:
  - Complex Modulus mastercurve
  - Phase angle mastercurve
  - Rheological Indices:
  - *Glover-Rowe Parameter; R-value; ΔTc; PGLT*



Disk-shaped Compact Tension (DCT) (ASTM D7313)

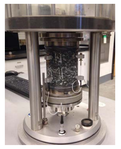
- Evaluate low temperature/thermal cracking performance of mixture
- Test Output Parameters:
  - Fracture Energy (G_f)
  - Fracture Strain Tolerance (FST)

Semi-circular Bend (SCB) (AASHTO TP124)

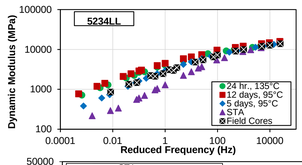
- Evaluate intermediate temperature cracking performance of mixture
- Test Output Parameters:
  - Fracture Energy (G_f)
  - Flexibility Index (FI)

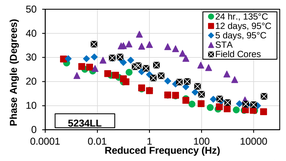
S-VECD Fatigue (AASHTO TP107)

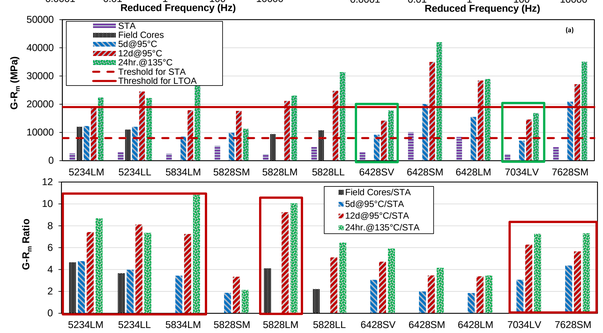
- Characterize fatigue behavior of asphalt mixture
- Test Output Parameters:
  - D^R
  - N_f @ G^R =100



Selected Mixture Results

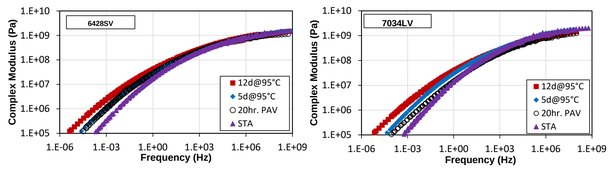




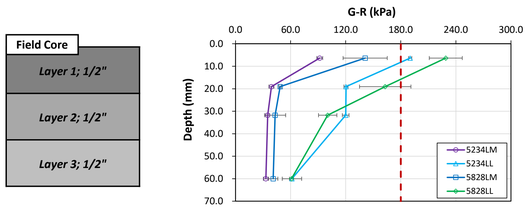


- Field cores overlap with 5 days at 95ºC laboratory aging condition.
- Considering the lower air void content of the field cores, the 5 days aging condition likely simulates more than four years of field aging.
- 12 days at 95ºC laboratory aging condition simulates more than 10 years of field aging in NH based on Climatic Aging Index (CAI) proposed by NCHRP 09-54 project.
- Two virgin mixtures show good cracking performance after each aging condition.
- Mixtures with softer binder (5234LM, 5234LL, 5834LM, 5828LM), and those with large difference between PGHT and PGLT (7034LV and 7628SM) show higher aging susceptibility.
- **Other performance indices (FI; FST; D^R)** show the similar trend.

Selected Binder Results

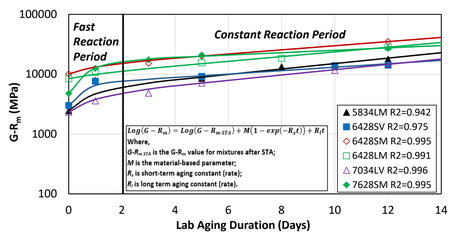


- 3 mixture aging levels are compared with RTFO/PAV binder aging method.
- 20 hr. PAV binder aging condition simulates less than 4 years' field aging, thus cannot represent the long-term performance of the asphalt material.



- Binder samples are extracted and recovered from the three layers of field cores;
- Binder G-R parameter is calculated, showing the aging gradient within the pavement structure.
- The middle point of each layer is selected as the representative depth to reflect the performance of each layer (60mm represents the pavement below the surface layer that doesn't age significantly).
- The rate of field aging within the first inch of the pavement is much faster than the layers below it.

Mixture Aging Model



- The mixture Glover-Rowe ($G\text{-}R_m$) parameter is selected and used to model the change of mixture properties with aging.
- The advantage of using the $G\text{-}R_m$ parameter for modelling is that it incorporates both stiffness and relaxation capacity (phase angle) to evaluate the cracking performance of asphalt mixtures.
- The mixture aging model can be used to quantitatively evaluate and predict the change of mixture cracking performance, as well as aging susceptibility over pavement service life.

Guidance for Material Selection and Design

Guidance for Binder Selection

- **Aging Protocol:** An extended protocol (e.g. 40hr.PAV) is suggested to capture the aging and long-term cracking susceptibility of asphalt binder.
- **Testing Method:** 4mm DSR test is suggested to measure the multiple rheological indices to evaluate the different properties of asphalt binder; However, mixture fatigue testing should be included to specifically evaluate the fatigue performance of the designed mixtures since 4mm DSR cannot capture the fatigue behavior of asphalt binder.

Rheological Indices	Cracking Warning	Cracking Limit
Glover-Rowe (G-R)	180kPa	600kPa
ΔTc	-2.5ºC	-5.0ºC

Guidance for Mixture Selection and Design

- **Aging Protocol:** 135ºC can be used for the fabrication of complex modulus test specimens; 95ºC conditioning temperature is recommended for the evaluation of fatigue and fracture properties of mixtures; Appropriate conditioning time is determined based on the desired equivalent field aging duration.

Field Aging Duration (year)	4	6	8	10	12	14	16	18	20
Lab Aging Duration (hr.@95ºC)	120	180	235	295	360	420	475	535	600

- **Testing Method:** Mixture aging model is suggested as the screening tool; Only complex modulus test is needed; Only three aging conditions (selected from table above) are required to calibrate the aging model.

Cracking Limit	STA	LTOA
Mixture $G\text{-}R_m$ Parameter	8,000MPa	19,000MPa

Future Work

- **Asphalt Binder Evaluation:** Appropriate binder aging/conditioning protocols to simulate long term field performance need to be further explored; Additional tests that evaluate the binders beyond the linear viscoelastic response should be investigated for inclusion in material selection, design, and quality assurance.
- **Asphalt Mixture Evaluation:** Continued collection of field performance data and periodic sampling of field cores for study mixtures and additional projects to calibrate the threshold values for different performance indices, refine the aging model and better define the aging gradient with depth.

Acknowledgement

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