National Center for Asphalt Technology
NCAT
at AUBURN UNIVERSITY

Spray-on Rejuvenators Evaluation Sections S3 & S4

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SEVENTH
RESEARCH CYCLE

NCAT TEST TRACK CONFERENCE

Objective

- Evaluate over time the field performance of four spray-on rejuvenator products commercially available in the United States

Spray-on Rejuvenators

- Petroleum- or bio-based oils with chemical and physical characteristics selected to restore properties of hardened/oxidized asphalt binder in the surface layer
- Can be combined with emulsified asphalt binders (to produce rejuvenating fog seals) and/or other materials (e.g., polymers) to seal low-severity surface cracks and inhibit raveling

Materials – Section S3, Mississippi DOT

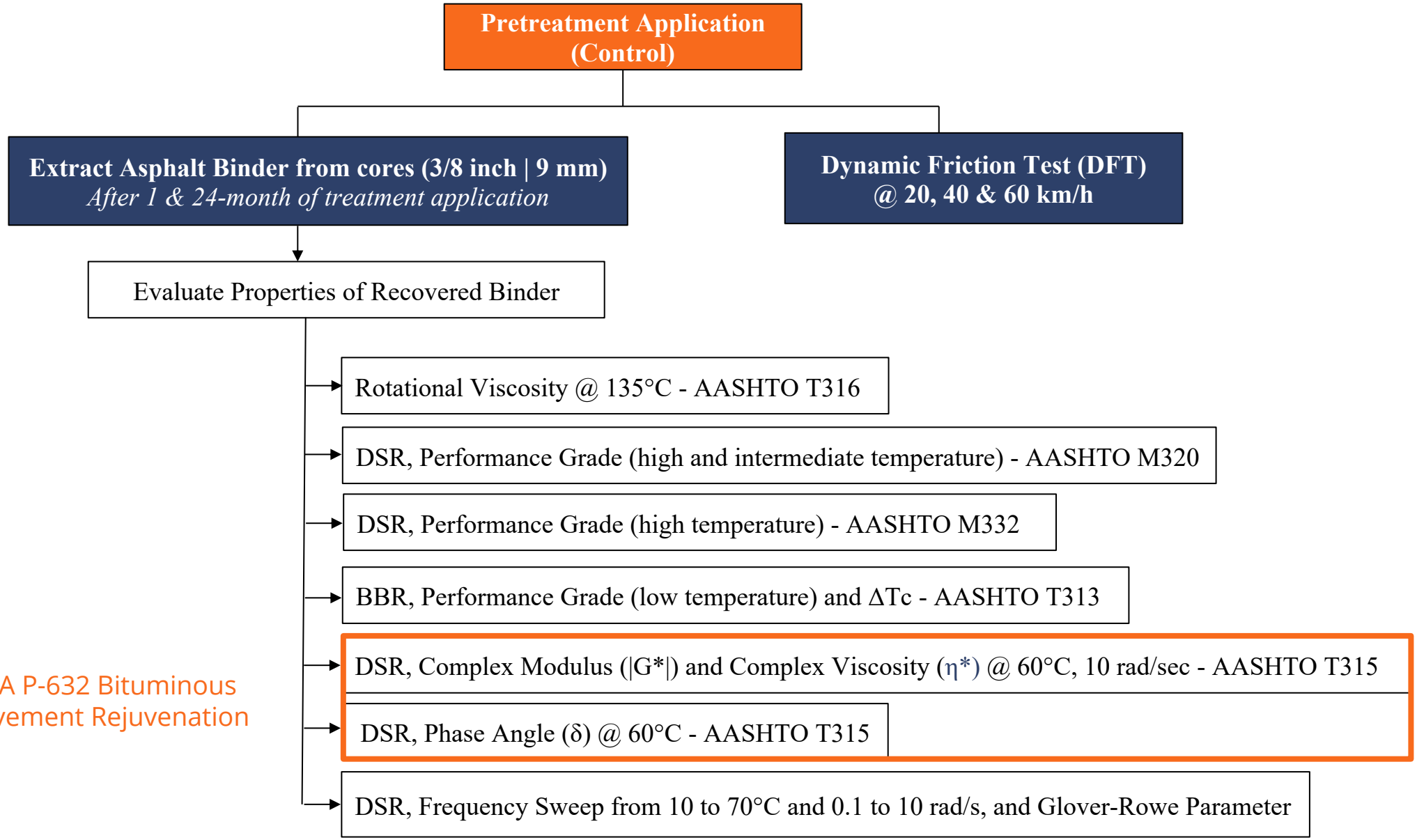
- Dense-graded mix with sand and gravel containing 25% RAP, constructed in 2012
- Asphalt content = 6.8% (PG 67-22 neat)
- Spray-on rejuvenator products were applied after Section S3 was subjected to a total of ≈20.0 million ESALs of traffic since construction

Surface Treatment	*Composition*	*Product Use by Manufacturer Recommendation*	*Dilution Rate*	*Residual Application Rate*
S3-A	Proprietary	Age-regenerating surface treatment	2:1	0.014 gal/yd^2
S3-B	Plant-based rejuvenator	Topical rejuvenating seal	Undiluted	0.020 gal/yd^2

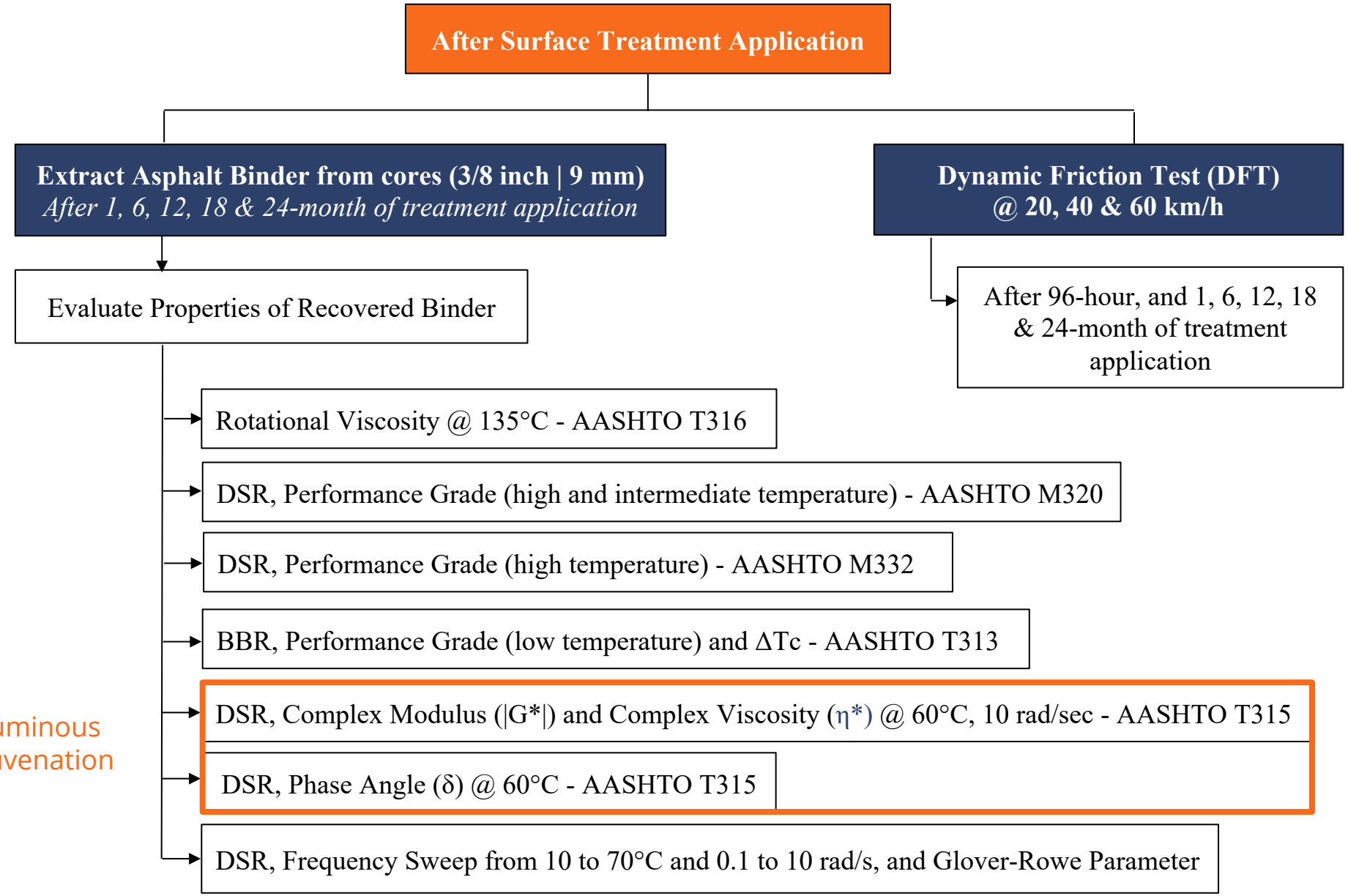
Materials – Section S4, Tennessee DOT

- Dense-graded mix with sand and limestone containing 15% F-RAP, constructed in 2015
- Asphalt content = 6.2% (PG 67-22 neat)
- Spray-on rejuvenator products were applied after Section S4 was subjected to a total of ≈10.0 million ESALs of traffic since construction

Surface Treatment	*Composition*	*Product Use by Manufacturer Recommendation*	*Dilution Rate*	*Residual Application Rate*
S4-A	Polymer-modified asphalt base	Rejuvenating fog seal	Undiluted	0.024 gal/yd^2
S4-B	Maltene-based from napthenic crude base	Asphalt pavement rejuvenator	1:1	0.040 gal/yd^2

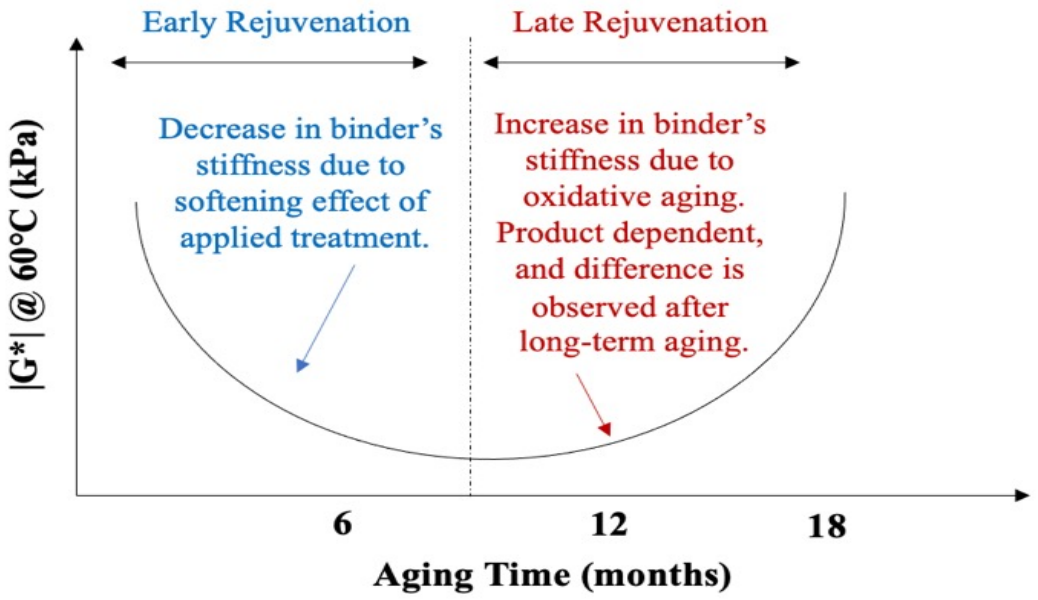


FAA P-632 Bituminous Pavement Rejuvenation



FAA P-632 Bituminous Pavement Rejuvenation

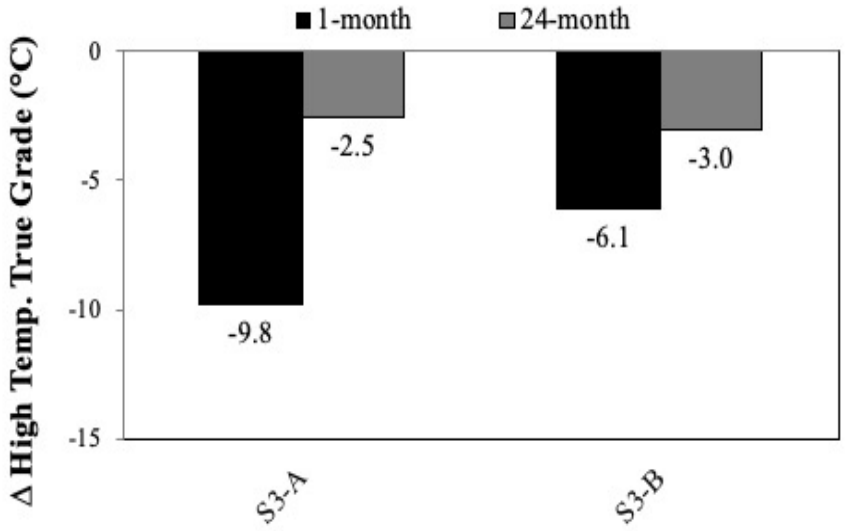
When to evaluate effectiveness of spray-on rejuvenators?



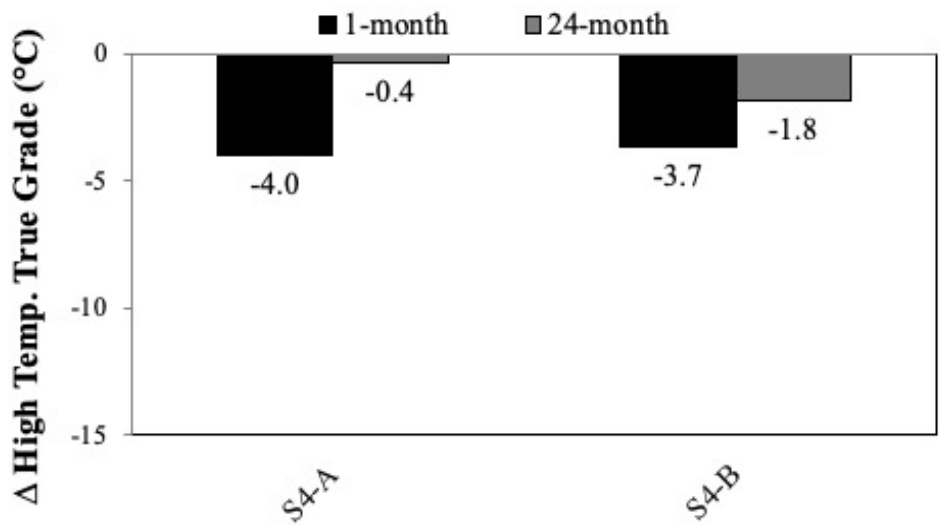
- The restoration capacity of a spray-on rejuvenating product can be separated into **early rejuvenation** and **late rejuvenation**.
- During **early rejuvenation**, the restoration capacity increases rapidly as a result of the decrease in asphalt binder stiffness but then begins to slowly decrease with oxidative aging as a result of the embrittlement of the binder (**late rejuvenation**).
- During late rejuvenation, the restoration capacity is product-dependent and can only be fully captured after long-term aging.

Superpave Performance Grade Classification – *High Temperature observed change 1 month and 24 months after treatment application*

Section S3



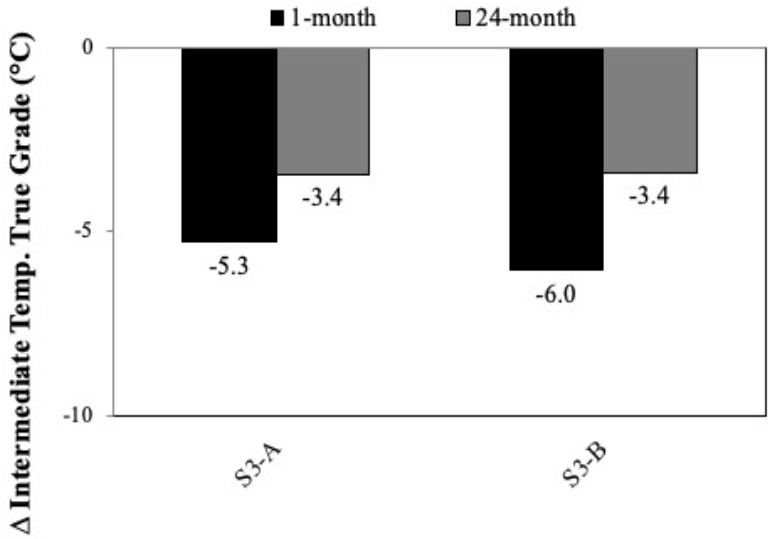
Section S4



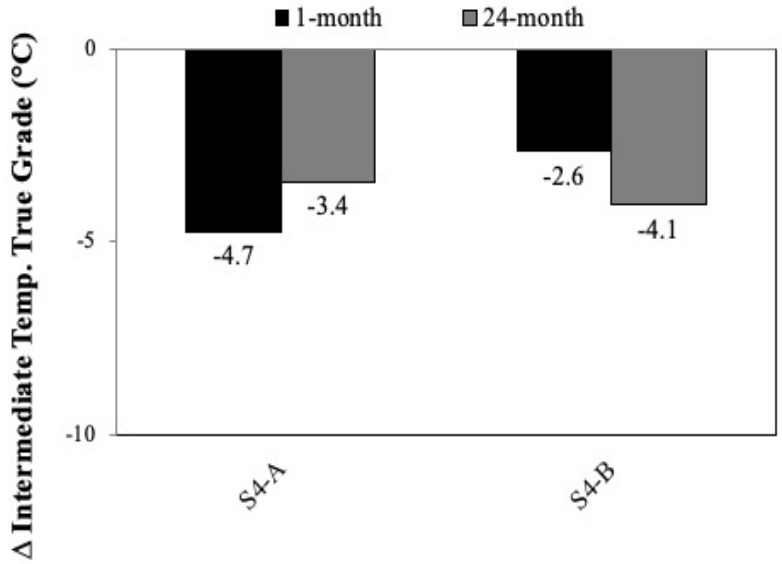
- A decrease in the high pass/fail temperature of control binders was observed after treatment application.
  - Change was calculated in comparison to control binders after 1- and 24-months of field aging.

Superpave Performance Grade Classification – *Int. Temperature observed change 1 month and 24 months after treatment application*

Section S3



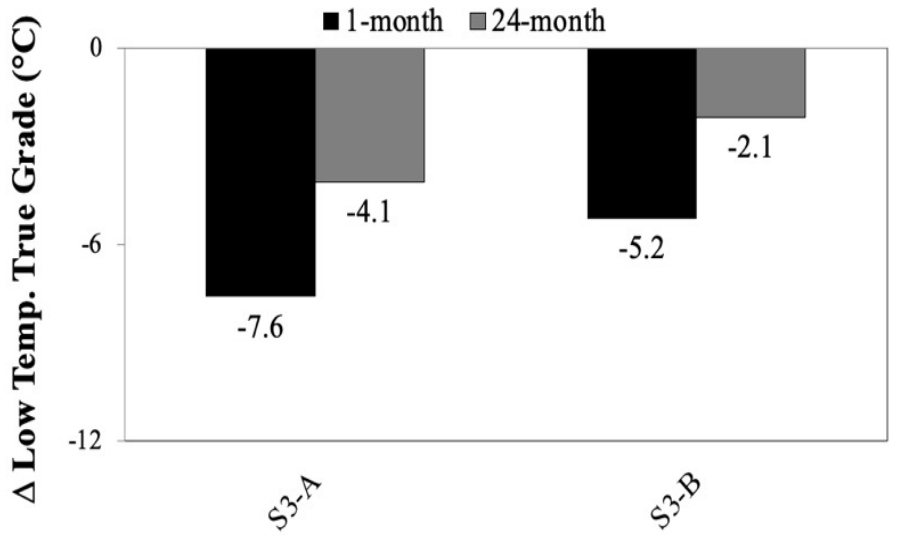
Section S4



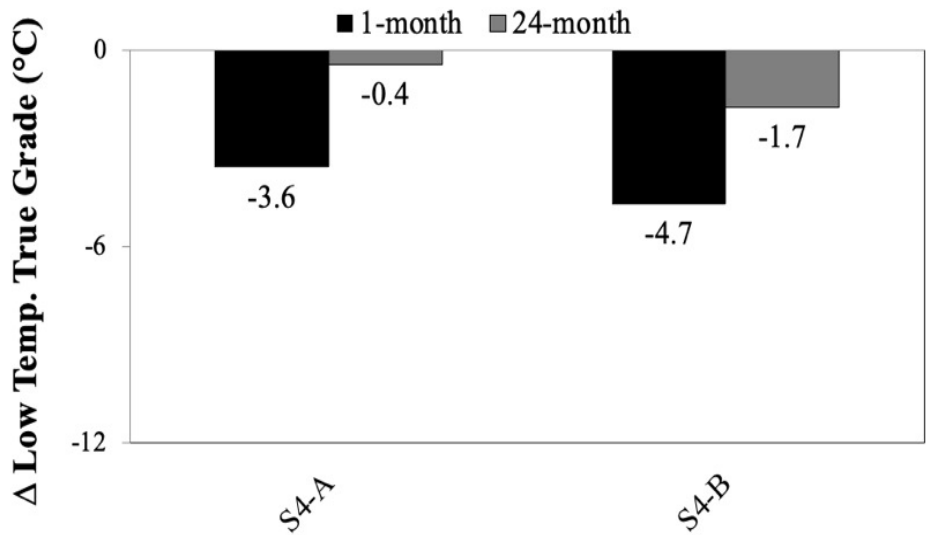
- A decrease in the intermediate pass/fail temperature of control binders was observed after treatment application, increasing the fatigue resistance of control binders.
  - Change was calculated in comparison to control binders after 1- and 24-months of field aging.

Superpave Performance Grade Classification – *Low Temperature observed change 1 month and 24 months after treatment application*

Section S3



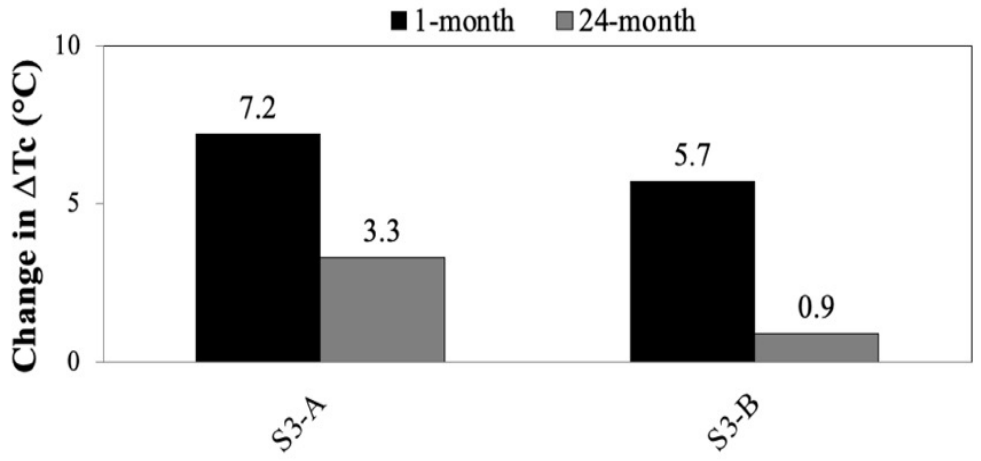
Section S4



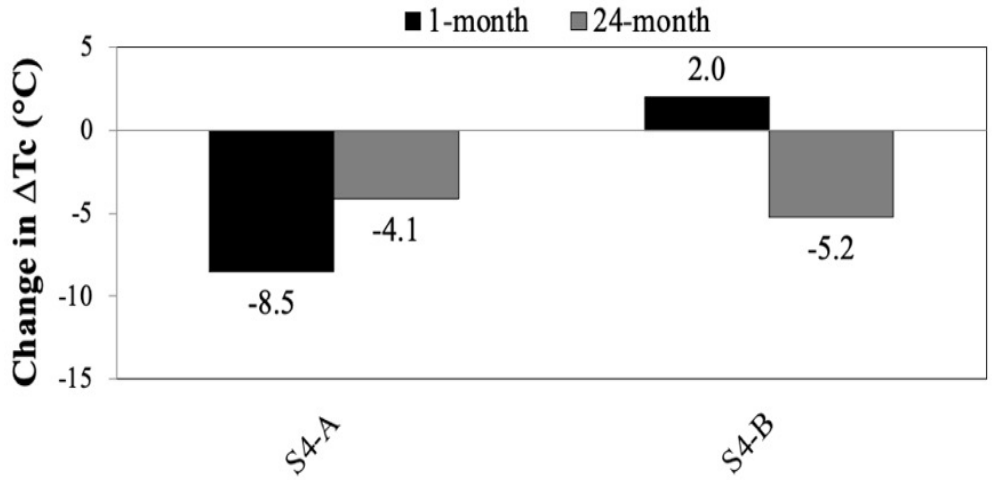
- A decrease in the low pass/fail temperature of control binders was observed after treatment application.
  - Change was calculated in comparison to control binders after 1- and 24-months of field aging.

ΔT_c parameter – *Low Temperature*
observed change 1 month and 24 months after treatment application

Section S3



Section S4

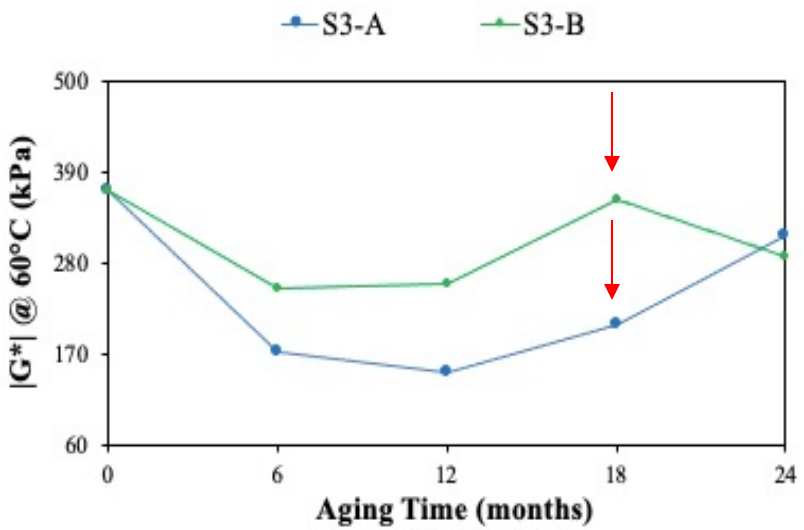


- Products S3-A and S3-B improved ΔT_c (less negative) 1- and 24-months after treatment.
- S4-A did not improve the ΔT_c parameter.
- S4-B improved the ΔT_c of the control S4 binder 1 month after treatment.

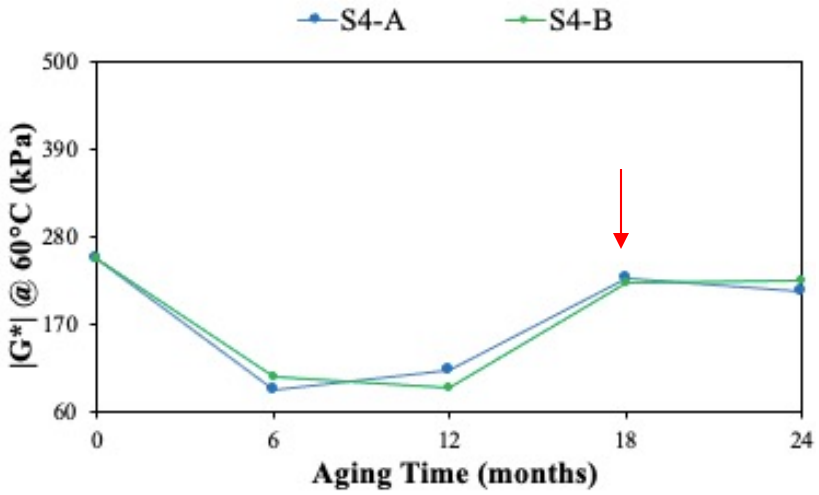
Complex Modulus ($|G^*|$)$_{\text{at 10 rad/s}}$ at 60°C

FAA P-632 evaluation parameter

Section S3



Section S4

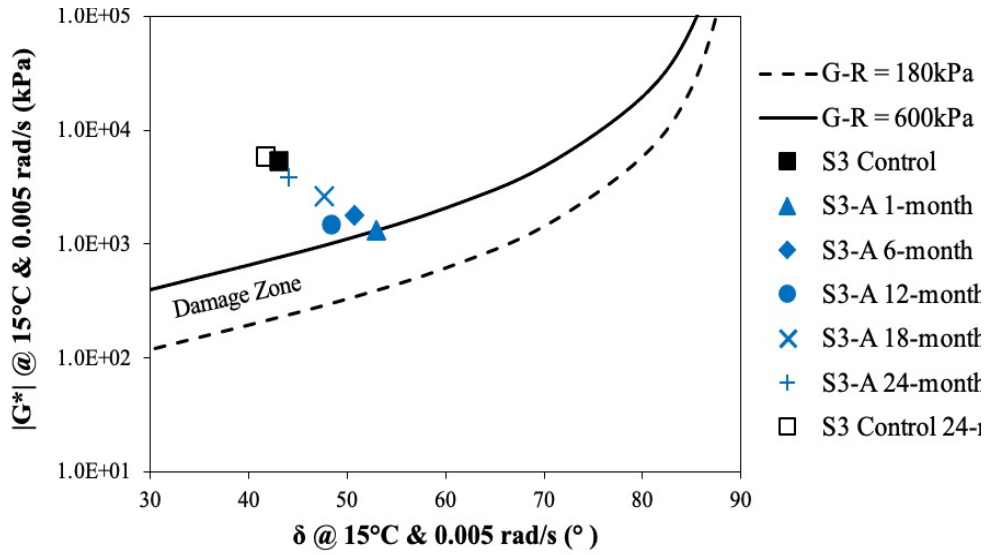


- Maximum rejuvenating capability of the applied spray-on rejuvenator products was achieved between 6 and 12 months of treatment application.
- A minimum 18 months of field aging was required to differentiate among products and to observe a finer indication of a product's effectiveness.

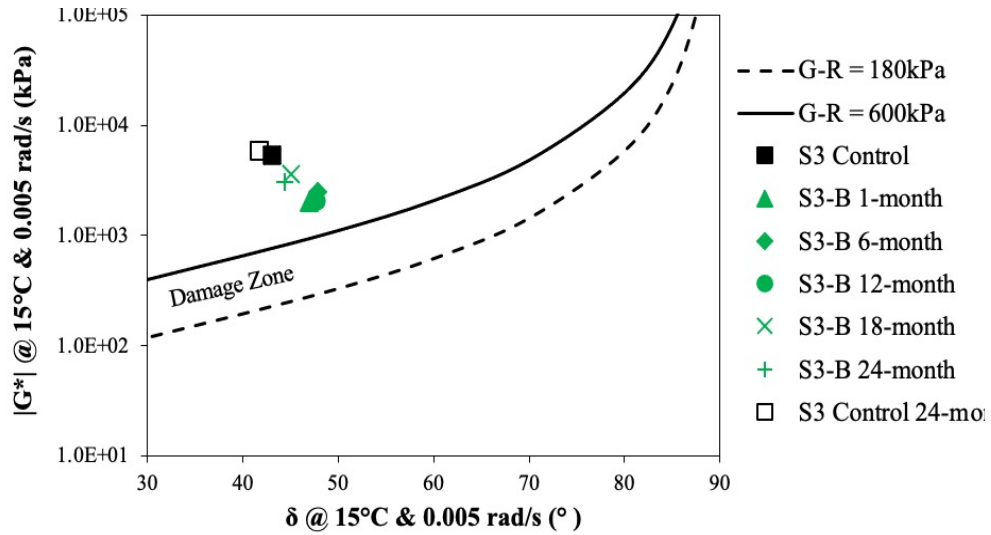
Glover-Rowe (G-R) Parameter and Black Space Diagram

considers binder stiffness and embrittlement, indication of cracking potential at 15°C

Section S3 - Product A



Section S3 - Product B

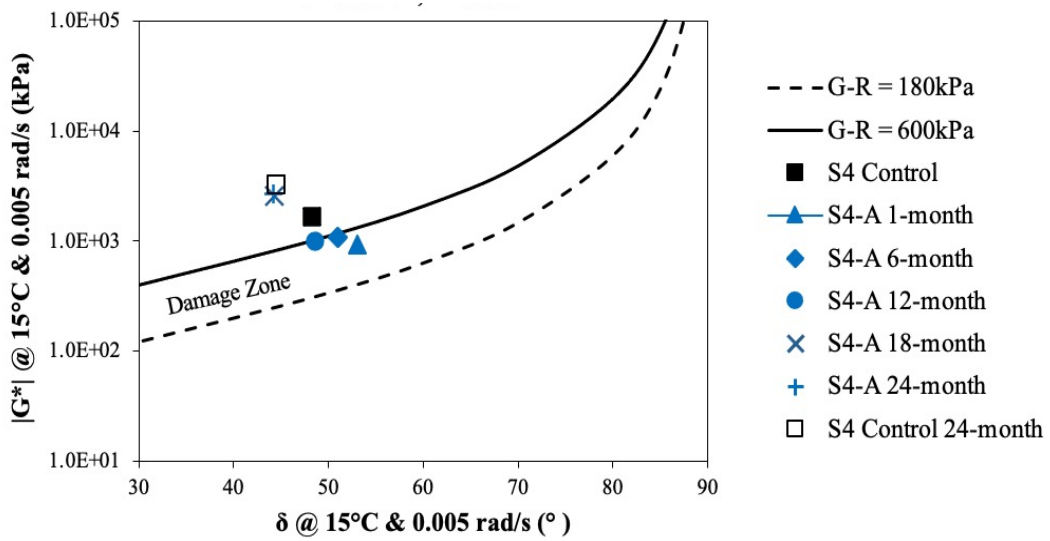


- S3 control binders (1- and 24-month field aging) located above the *G-R* 600 kPa limit.
- For product S3-B, regardless the time interval after application, all binders were located above the *G-R* 600 kPa limit that relates to visible cracking issues.

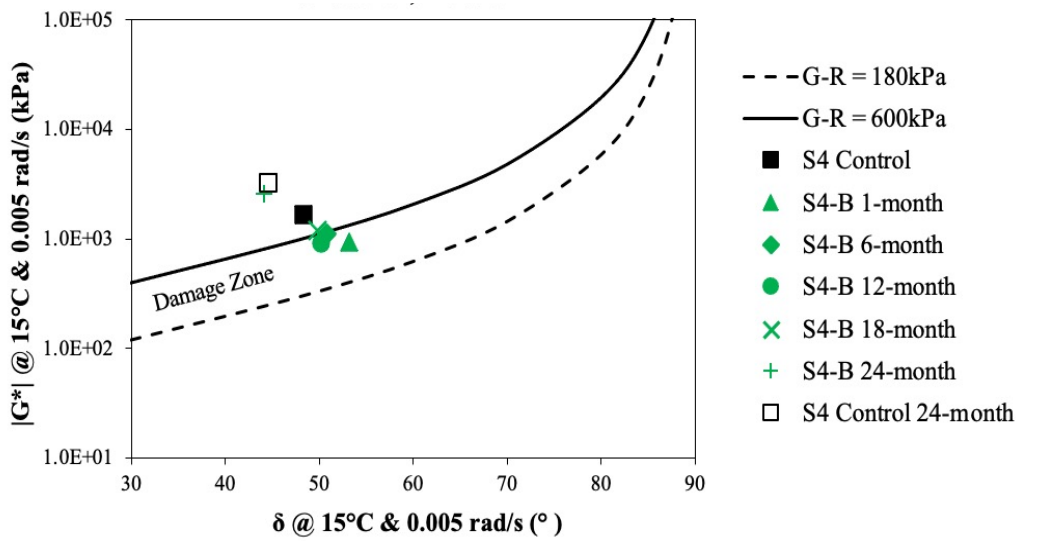
Glover-Rowe (G-R) Parameter and Black Space Diagram

considers binder stiffness and embrittlement, indication of cracking potential at 15°C

Section S4 - Product A



Section S4 - Product B

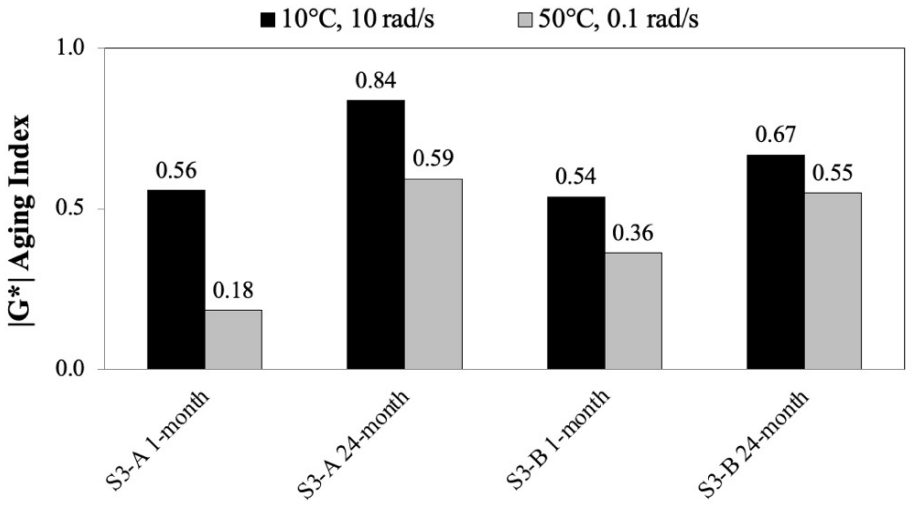


- S4 control binders (1- and 24-month field aging) located above the *G-R* 600 kPa limit.
- After 24-month field aging, none of the treated sections were located within the "cracking damage zone" on the Black Space diagram.

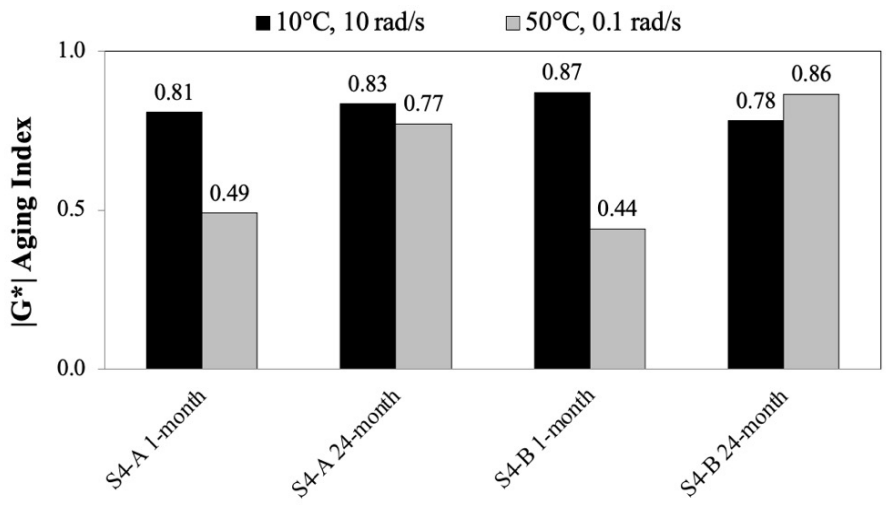
Complex Modulus |G*| Aging Indexes at 10°C and 50°C

$$\text{Aging Index } (|G^*|) = \frac{Treated\ Section\ (|\mathbf{G}^*|)_{1-\text{month, 24}-\text{month}}}{Control\ Section\ (|\mathbf{G}^*|)_{1-\text{month, 24}-\text{month}}}$$

Section S3



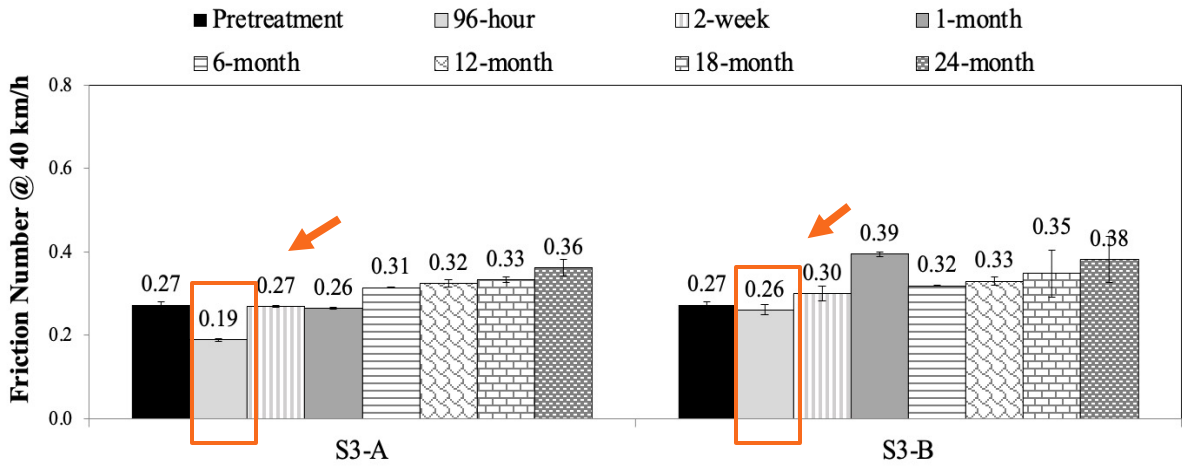
Section S4



- All spray-on rejuvenator products showed |G*| aging index below 1.0 after 1 month and 24 month of application, indicating that the stiffness of the binders extracted from the treated sections remained below the stiffness of the control binders measured after 1 month and 24 month of field aging.

Dynamic Friction Tester (DFT)

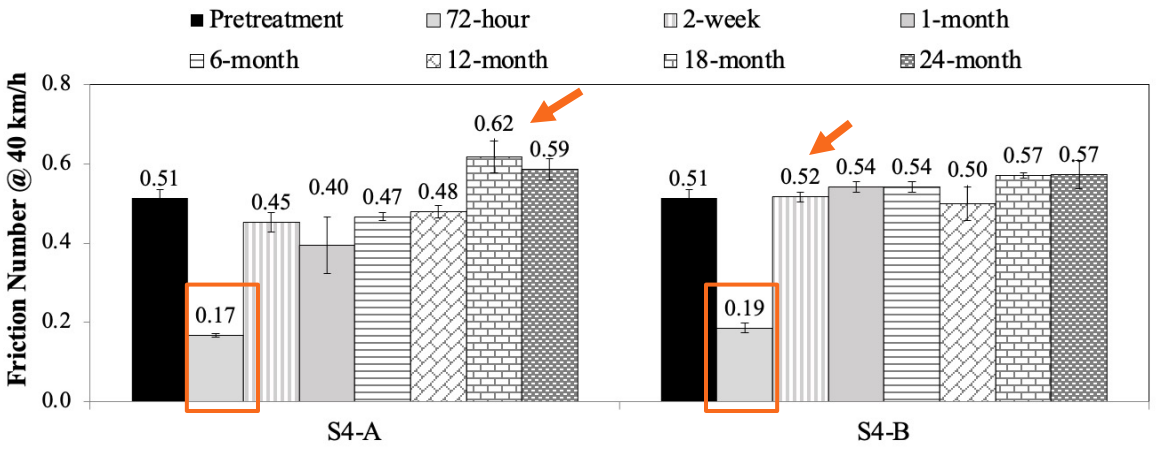
Section S3



- Friction of the pavement surface decreased after application of treatments, but the friction results improved with time.
- Between pretreatment and 96 hours of treatment application, product S3-A showed the highest decrease in friction (29.6%), while product S3-B showed the smallest decrease in friction (3.7%).
- Two weeks after application, products S3-A and S3-B showed friction values equal (0.27) and higher (0.30) than the S3 control section.

Dynamic Friction Tester (DFT)

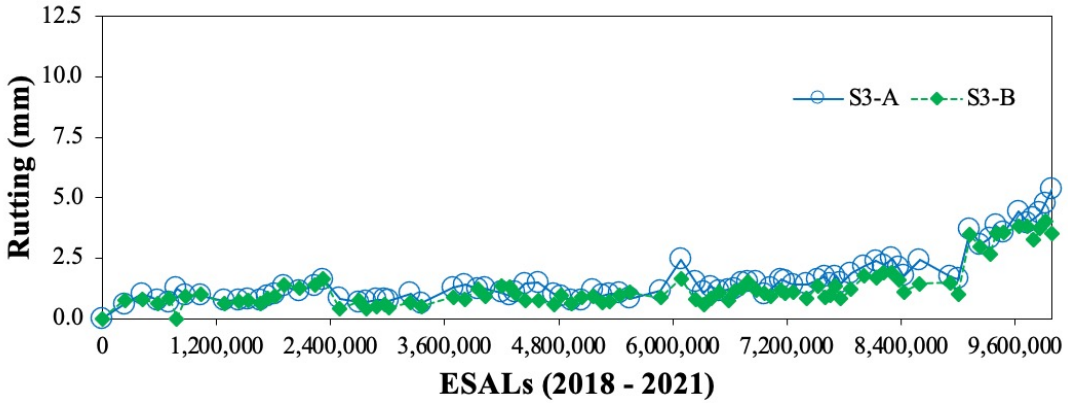
Section S4



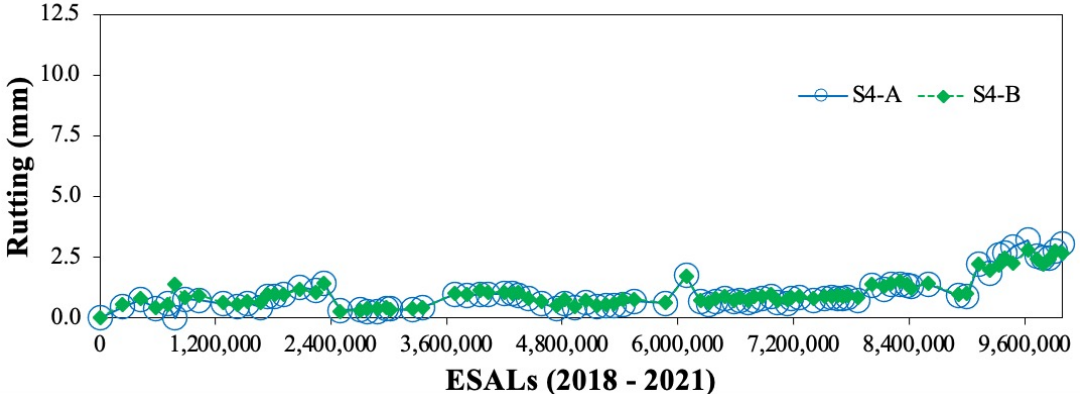
- For Section S4, the decrease in friction was sharp after application of the surface treatments.
- Between pretreatment and 72 hours of treatment application, product S4-A showed the highest decrease in friction (66.6%), while product S4-B showed the smallest decrease in friction (62.7%).
- Product S4-B showed friction value higher (0.52) than the S4 control section 2 weeks after application, while product S4-A showed friction value higher (0.62) than the control section only after 18 months of application.

Field Performance - Rut Depth *versus* ESALs

Section S3



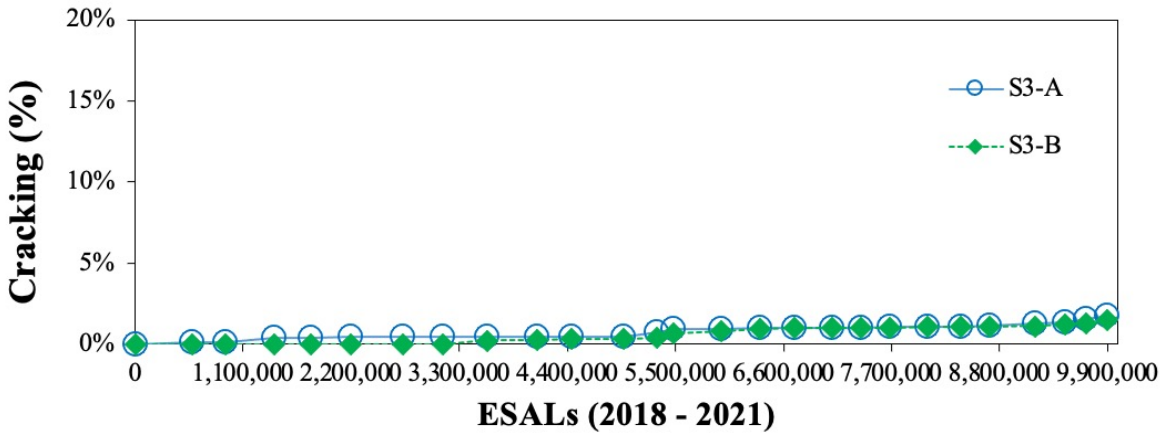
Section S4



- Average rut depth for ≈10 million ESALs of traffic
  - **S3-A = 5.36 mm, and S3-B = 3.52 mm**
  - **S4-A = 3.03 mm, and S4-B = 2.66 mm**
  - Obtained field rut values were smaller than the rut depth limit of 12.5 mm

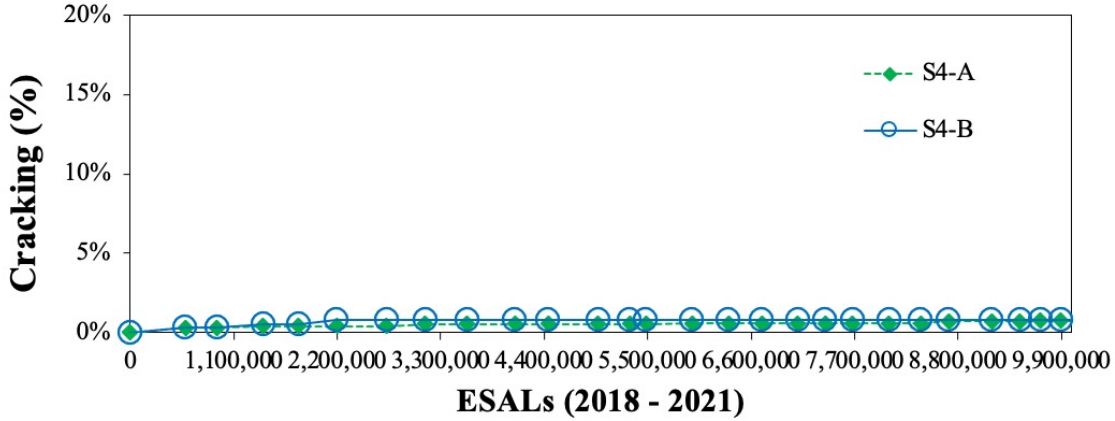
Field Performance - Cracking *versus* ESALs

Section S3



- After around 10.0 million ESALs of traffic (total of ≈30.0 million ESALs since 2012)
  - Section treated with **product S3-A** exhibited 2.0% of lane area cracked
  - Section treated with **product S3-B** exhibited 1.7% of lane area cracked

Section S4

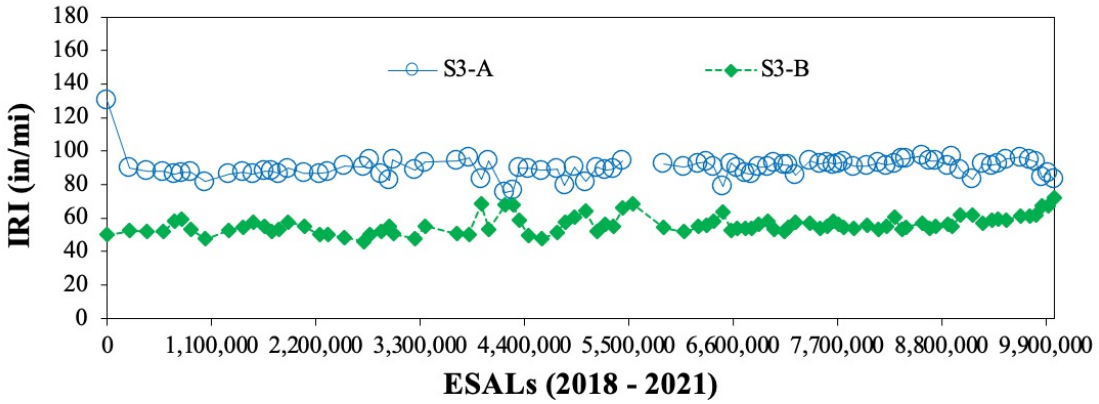


- After around 10.0 million ESALs of traffic (total of ≈30.0 million ESALs since 2012)
  - Section treated with **product S4-A** exhibited 0.7% of lane area cracked
  - Section treated with **product S4-B** exhibited 0.8% of lane area cracked

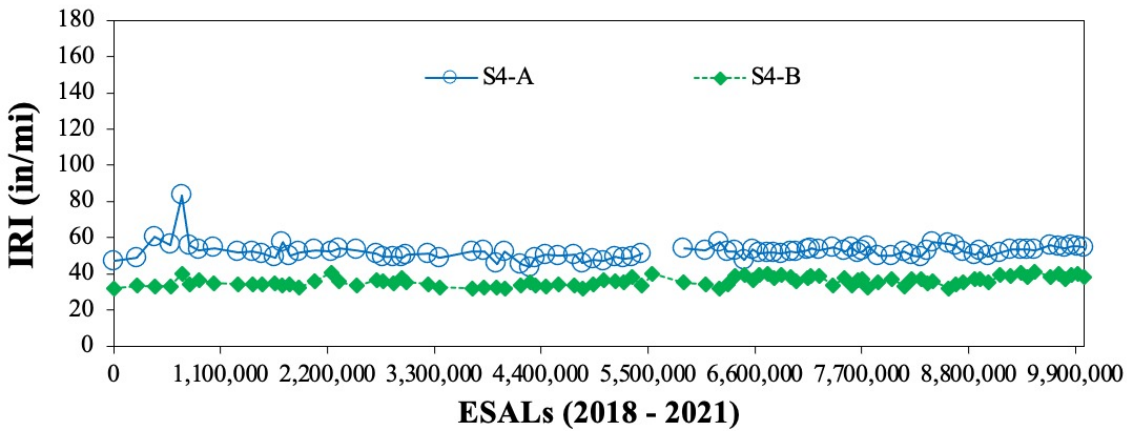
Field Performance - Roughness *versus* ESALs

quantified using the International Roughness Index (IRI)

Section S3



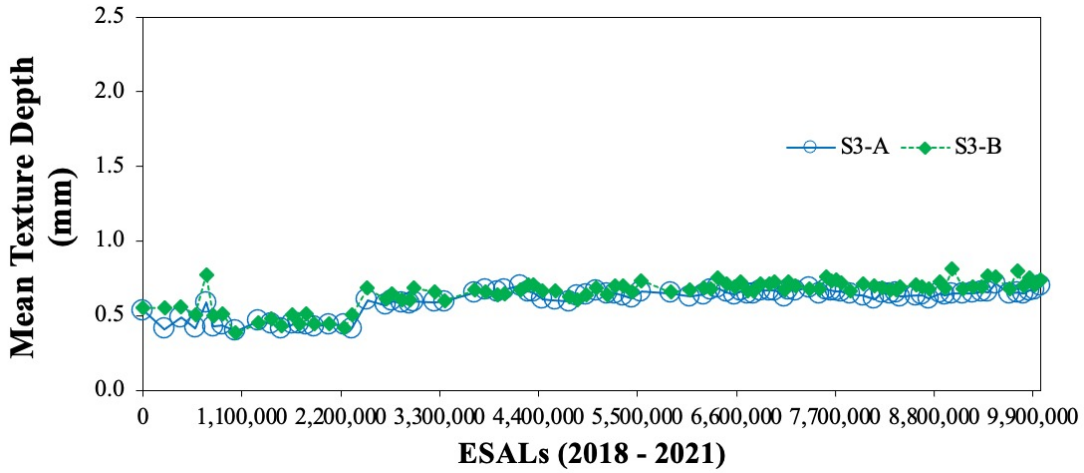
Section S4



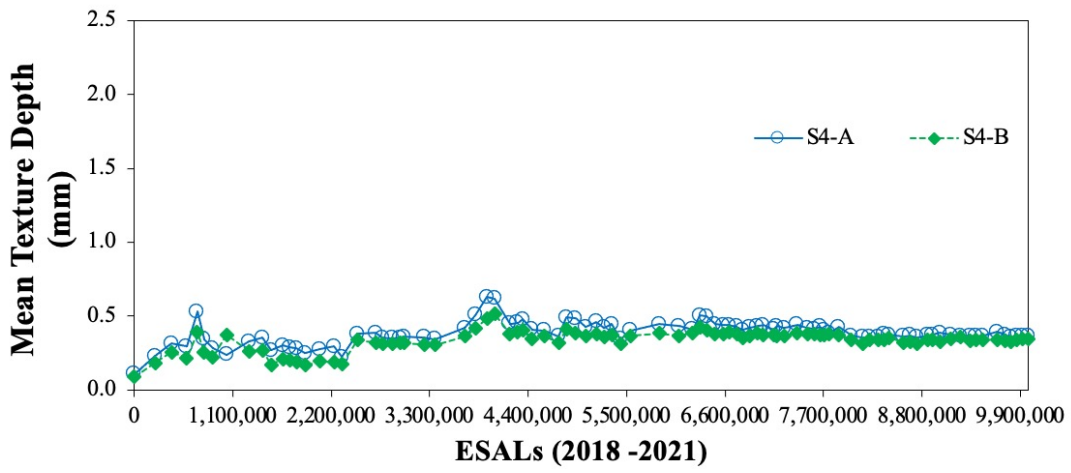
- Overall IRI for ≈10 million ESALs of traffic
  - **S3-A = 90.1 in/mile, and S3-B = 56.1 in/mile**
  - **S4-A = 52.2 in/mile, and S4-B = 35.8 in/mile**

Field Performance - Mean Texture Depth *versus* ESALs

Section S3



Section S4



- Overall MTD for ≈10 million ESALs of traffic
  - **S3-A = 0.61 mm, and S3-B = 0.65 mm**
  - **S4-A = 0.38 mm, and S4-B = 0.33 mm**

Conclusions

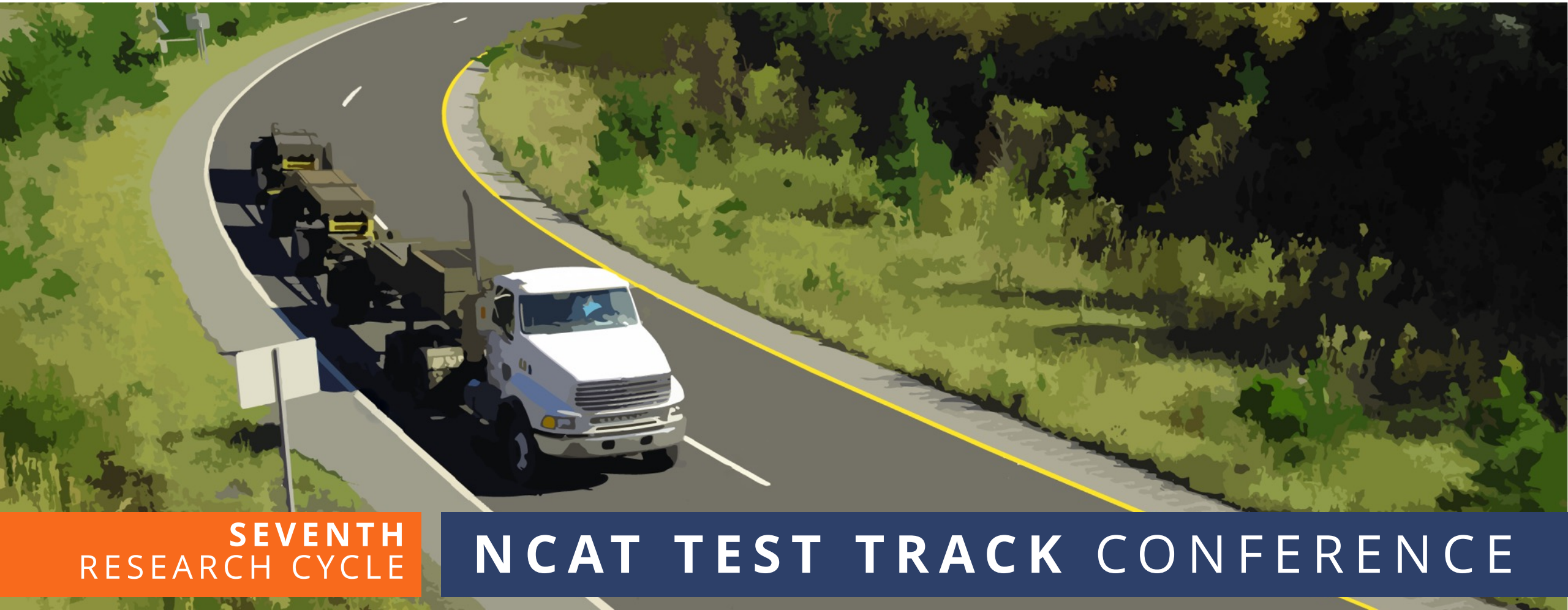
- Spray-on rejuvenators can slow the rate of pavement aging caused by oxidation.
  - Could be applied every three years to prolong pavement life

- After 24 months of the application of the spray-on rejuvenator products, the asphalt binder properties of the treated sections are still “improved” in comparison to the control sections.
  - This improvement was found as dependent of the spray-on product type, and was influenced by the characteristics of the asphalt material present in the surface of each section as well as the construction time of each section.

Conclusions

- The 1-month (four-week) aging time proposed in the FAA P-632 procedure can be misleading for assessment of a spray-on rejuvenator product's long-term effectiveness.
  - In most cases, 18 months of field aging is required to differentiate among products and to observe a finer indication of a product's effectiveness.
- To ensure safety, the coefficient of friction of the existing pavement surface should be measured before and after the application of the spray-on rejuvenators.
- Both sections are recommended for traffic continuation in the next research cycle to further monitor and evaluate the long-term performance of the applied products, indicating the time interval where these products will lose effectiveness.

Questions and Answers (moraes@auburn.edu)



SEVENTH
RESEARCH CYCLE

NCAT TEST TRACK CONFERENCE