National Center for Asphalt Technology
NCAT
at AUBURN UNIVERSITY

NCHRP 10-114

Developing Performance and Safety Specifications for Rejuvenating Seals

AASHTO TSP•2 - Emulsion Task Force (ETF) Meeting

November 26, 2024

Research Team

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Background
Rejuvenating seals

- Designed to penetrate into the asphalt material near the pavement surface to renew the hardened/oxidized asphalt binder.
  - Rejuvenators can be combined with emulsified asphalt binders and/or other materials (e.g., polymers) to seal low-severity surface cracks and inhibit raveling.

- Can be applied to preserve asphalt pavement surfaces functional and structural integrity from age hardening and deterioration.
  - Not recommended for pavements with low surface permeability, poor surface texture, large cracks, rutting, shoving, or other structural deficiencies.

Objectives

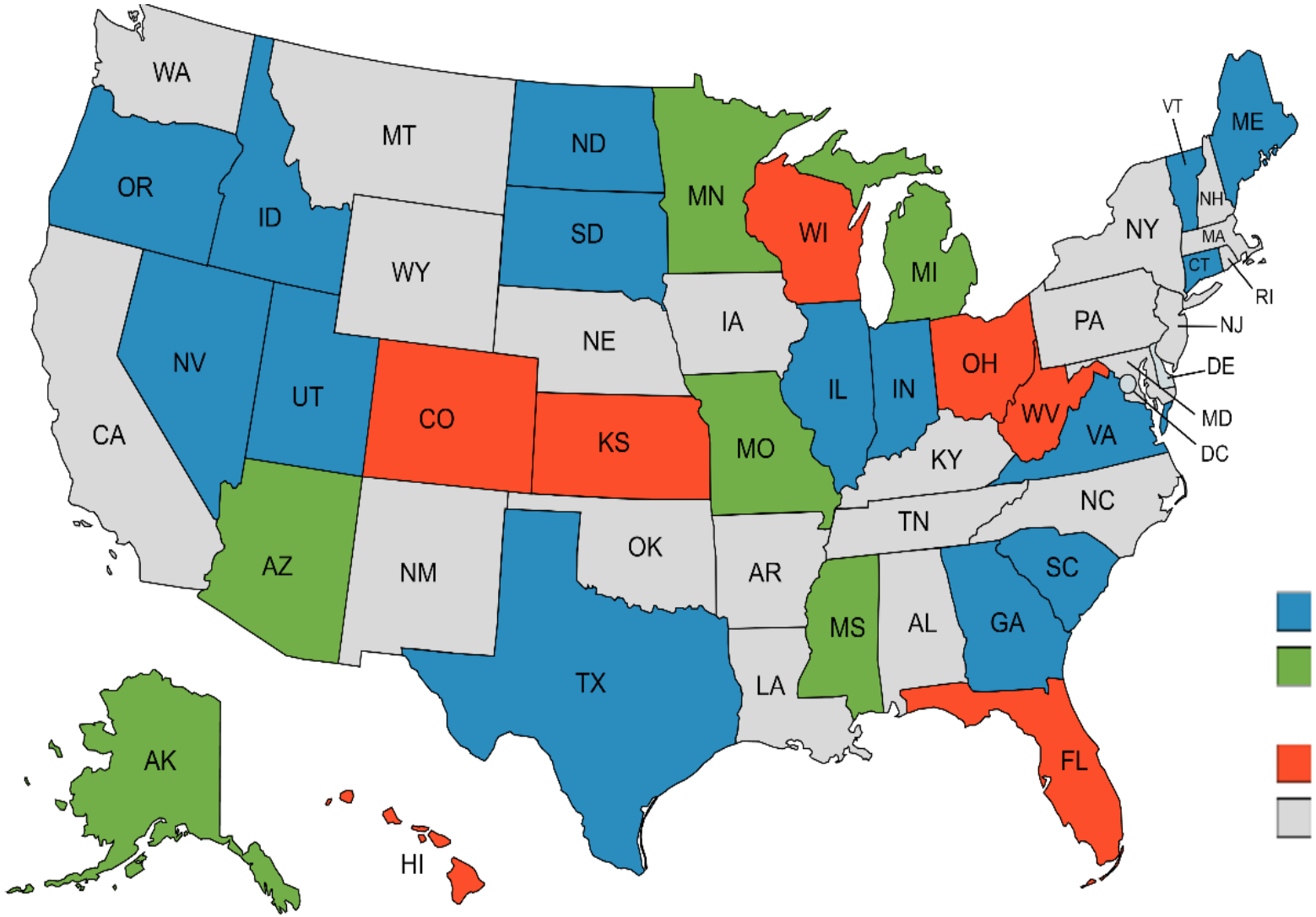
- Characterize rejuvenating seals based on chemistry and rheology,
- Determine how different rejuvenating compounds are penetrating and rejuvenating the underlying pavement,
- Determine how the desired performance for a rejuvenating seal is measured and quantified (laboratory and field),
- Determine the life-extending benefit (LEB) and impact on friction properties of a rejuvenating seal (laboratory and field), and
- Guide on selecting a rejuvenating seal's optimum dose and application rate.

- **36 months: 08/04/2022 to 08/04/2025**

Research Approach

- **Phase I** ✓
  - Task 1. Literature review
  - Task 2. Review previous work related to similar preservation treatments and survey
  - Task 3. Materials Selection
  - Task 4. Interim report
- **Phase II**
  - Task 5. Determine the efficacy of rejuvenating additives in rejuvenating seals ✓
  - Task 6. Determine the LEB of a rejuvenating seal
  - Task 7. Determine the effect of rejuvenating seals on pavement friction, and macro texture and micro texture properties
  - Task 8. Guide dosage selection
  - Task 9. AASHTO specification
  - Task 10. Final deliverables

Survey Responses



- **32 responses**
  - 28 U.S. State DOTs
  - 2 Canadian provinces
  - 2 local U.S. agencies

Asphalt Emulsion Fog Seals	47%
Alsphalt Emulsion Fog Seals and Rejuveneting Seals	22%
Do not use either treatment	22%
No response	

Tasks 1 and 2 Summary
Major knowledge gaps

- Guidance on the selection of rejuvenating seals
- Property characterization of rejuvenating seals
- Impact of rejuvenating seals on binder characteristics
- Impact on pavement surface characteristics
- Dosage selection
- Safety concerns
- Test methods employed (lab and field evaluation)
- Long-term pavement performance

Task 3. Materials Selection

- Collect 12 products, including both petroleum- and bio-based rejuvenators.

Product Name	Producer	Description
BioRestor®	BioBased Spray Systems LLC	Bio-based
BioRestor® Low VOC		
BioMAG™	Iowa State University	
Invigorate™		
Delta Mist®	Collaborative Aggregates LLC	
RPE-R	H. G. Meigs, LLC	
RePlay™	BioSpan Technologies	
GSB-88®	Asphalt Systems, Inc.	Hybrid product containing bio- and petroleum-based components
ARA1 Ti	Tricor Refining, LLC	Petroleum-based
CRF®		
Reclamite®	Pavement Technology, Inc.	
Replenify™	Flint Hills Resources	

NCAT and MnROAD Field Sections

NCAT Test Track

MnROAD

Task 4. Interim Report

- **Submitted with findings of Tasks 1 and 2**
  - Over 140 literature documents

- **Description of Phase II work plan to**
  - Determine the efficacy of rejuvenating additives in rejuvenating seals
  - Determine the LEB of a rejuvenating seal
  - Determine the effect of rejuvenating seals on pavement friction, and macro texture and micro texture properties
  - Guide dosage selection

Phase II Work Plan (5 Tasks)

1. Determine the Efficacy of Rejuvenating Additives in Rejuvenating Seals
2. Determine the Life Extending Benefit (LEB) of a Rejuvenating Seal (laboratory and field)
3. Determine the Effect of Rejuvenating Seals on Pavement Friction, and Macrotexture and Microtexture Properties
4. Guide Dosage Selection
5. AASHTO Specification

Task 5. Determine the Efficacy of Rejuvenating Additives in Rejuvenating Seals

- Three approaches

  - ***Experiment 1*.** Stand-alone characterization of rejuvenating seals.
  - ***Experiment 2.*** Characterization of rejuvenating seals after application on the pavement surface.
  - ***Experiment 3.*** Evaluation of the potential interrelationship between pavements' permeability and rejuvenating seals' chemical characteristics.

Experiment 1. Stand-alone Characterization of Rejuvenating Seals

- 12 rejuvenating seal products. ✓

Experiment	Property	Test	Research Parameter
Experiment 1	Chemical Composition	Gas Chromatograph/Mass Spectrometry (GC/MS)	Fatty acids; presence of water and solvents in formulation
		SAR-AD™ Fractionation	Content of saturates and asphaltenes fractions (colloidal instability)
	Molecular Weight	Gel Permeation and Size Exclusion Chromatography (GPC/SEC)	Changes in molecular weight of binders; presence of polymer in formulation
	Surface Tension	Tensiometer	Surface tension (ability of rejuvenating seals to penetrate an asphalt binder surface)
	Viscosity	Brookfield Rotational Viscometer	Viscosity (durability of rejuvenating seals)

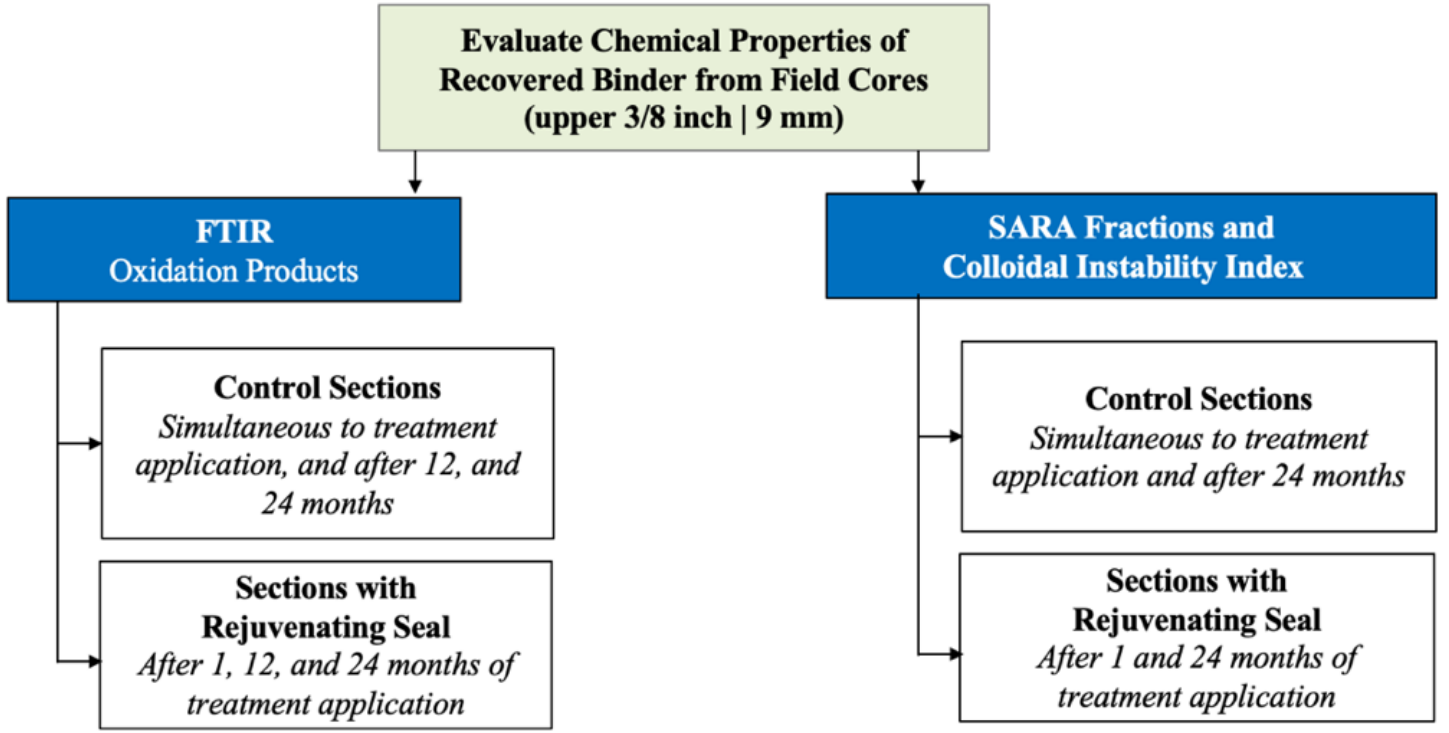
Experiment 1. Stand-alone Characterization of Rejuvenating Seals

Product	Petroleum Asphalt	Triglyceride Fatty Acid	Fatty Acid Ester	Carrier	Surfactant	Glycol Ether	Phthalate	Polymer
Product 1			X	X				X
Product 2			X		X			X
Product 3			X	X				X
Product 4			X					X
Product 5 Part A		X				X		
Product 5 Part B		X		X				
Product 6		X						
Product 7		X			X			
Product 8 Part A							X	X
Product 8 Part B	X	X						
Product 9	X							
Product 10	X							
Product 11	X							
Product 12	X							

Experiment 2. Characterization of Rejuvenating Seals after Application on Pavement Surface

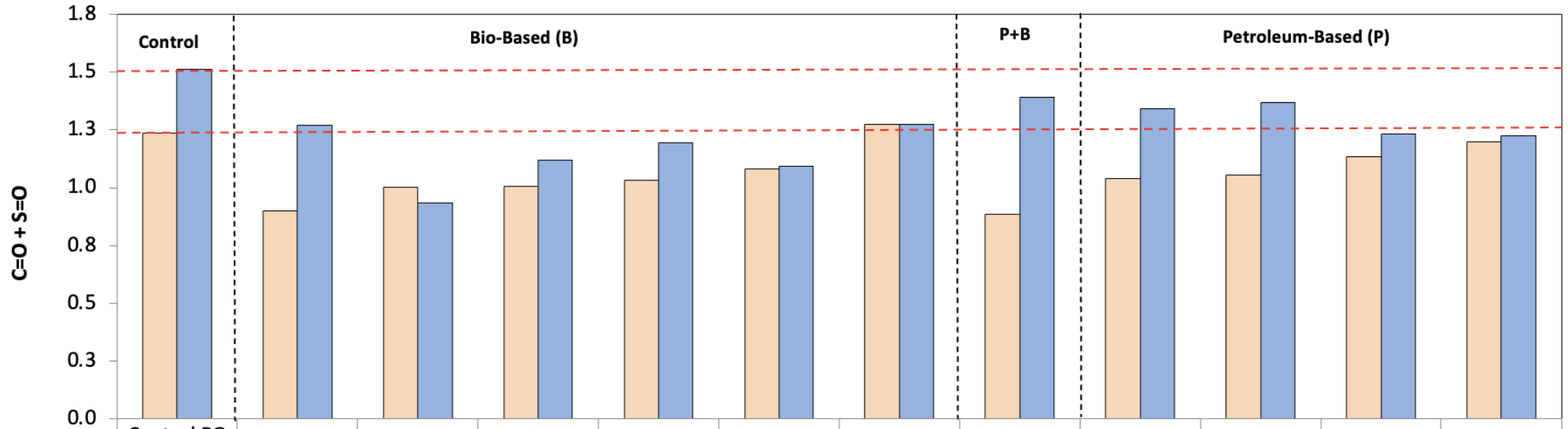
- **Available field sections constructed at MnROAD, a low-volume road**
  - Short- and long-term effectiveness of 12 rejuvenating seal products

- **Three dense-graded surface mixtures**
  - Two were constructed in 2021 with 20% RAP (neat PG58S-28 binder and polymer-modified PG58H-34 binder)
  - One constructed in 2020 with 20% RAP and a polymer-modified PG58H-34 binder.



FTIR C=O+S=O Area
PG 58S-28

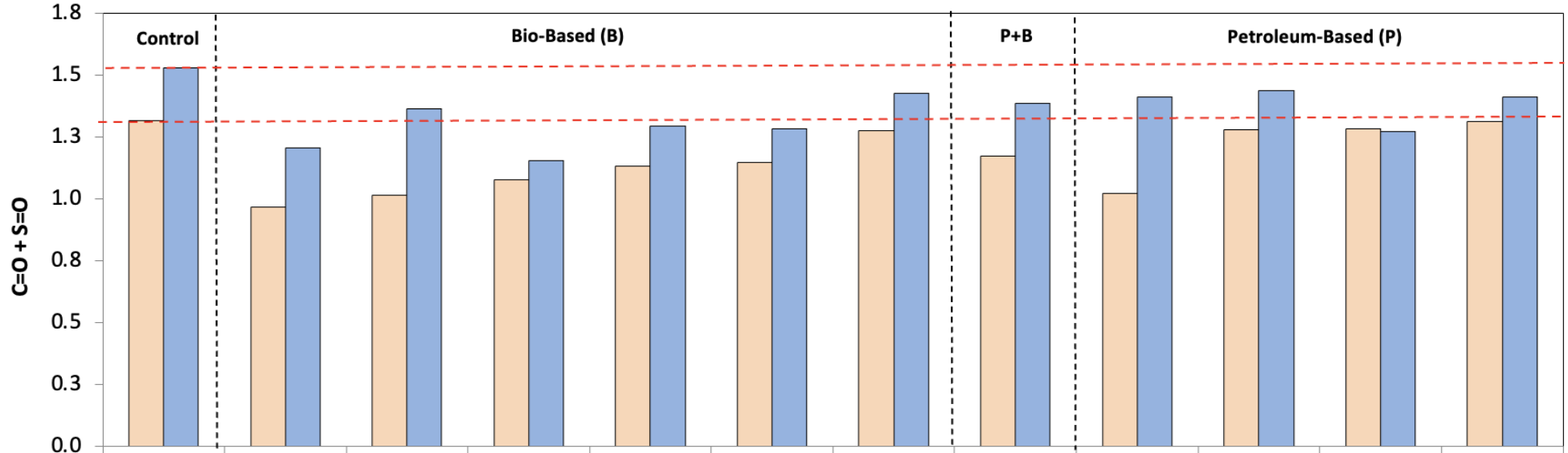
Binders with higher C=O+S=O areas have experienced greater oxidative aging than those with lower C=O+S=O areas.



	Control PG 58S-28	Product 7 B	Product 4 B	Product 6 B	Product 2 B	Product 5 B	Product 3 B	Product 8 P+B	Product 10 P	Product 12 P	Product 9 P	Product 11 P
1-month	1.24	0.90	1.00	1.01	1.03	1.08	1.27	0.89	1.04	1.05	1.13	1.20
12-month	1.51	1.27	0.93	1.12	1.19	1.09	1.27	1.39	1.34	1.37	1.23	1.23

FTIR C=O+S=O Area
PG 58H-34

Binders with higher C=O+S=O areas have experienced greater oxidative aging than those with lower C=O+S=O areas.



	Control PG 58H-34	Product 5 B	Product 2 B	Product 6 B	Product 4 B	Product 7 B	Product 3 B	Product 8 P+B	Product 12 P	Product 11 P	Product 9 P	Product 10 P
1-month	1.32	0.97	1.02	1.08	1.13	1.15	1.28	1.17	1.02	1.28	1.28	1.31
12-month	1.53	1.21	1.36	1.16	1.29	1.29	1.43	1.39	1.41	1.44	1.27	1.41

SARA Fractions Bio-Based Products

Product Code	Parameter	1 Month Value (%)	24 Months Value (%)	Difference due to Aging, Rate of Aging (%)		Difference in Rate of Aging versus Control (%)	
Control PG 58S-28	Asphaltenes	25.4	27.7	9.1	Increase in fraction		
	Saturates	6.5	7.2	10.8	Increase in fraction		
	Aromatics	36.1	33.6	-6.9	Decrease in fraction		
	Resins	32.0	31.4	-1.9	Decrease in fraction		
Product 2	Asphaltenes	23.9	26.8	12.1	Increase in fraction	3.1	Faster buildup of fraction versus control
	Saturates	5.5	7.0	27.3	Increase in fraction	16.5	Faster buildup of fraction versus control
	Aromatics	37.2	32.9	-11.6	Decrease in fraction	-4.6	Slower buildup of fraction versus control
	Resins	33.3	33.3	0.0	Decrease in fraction	1.9	Faster buildup of fraction versus control
Product 3	Asphaltenes	26.1	28.2	8.0	Increase in fraction	-1.0	Slower buildup of fraction versus control
	Saturates	7.2	8.3	15.3	Increase in fraction	4.5	Faster buildup of fraction versus control
	Aromatics	34.7	33.6	-3.2	Decrease in fraction	3.8	Faster buildup of fraction versus control
	Resins	32.1	29.9	-6.9	Decrease in fraction	-5.0	Slower buildup of fraction versus control
Product 4	Asphaltenes	26.4	28.5	8.0	Increase in fraction	-1.1	Slower buildup of fraction versus control
	Saturates	6.4	7.9	23.4	Increase in fraction	12.7	Faster buildup of fraction versus control
	Aromatics	35.2	30.5	-13.4	Decrease in fraction	-6.4	Slower buildup of fraction versus control
	Resins	31.9	33.0	3.4	Increase in fraction	5.3	Faster buildup of fraction versus control
Product 5	Asphaltenes	25.6	28.8	12.5	Increase in fraction	3.4	Faster buildup of fraction versus control
	Saturates	7.2	5.6	-22.2	Decrease in fraction	-33.0	Slower buildup of fraction versus control
	Aromatics	36.6	29.7	-18.9	Decrease in fraction	-11.9	Slower buildup of fraction versus control
	Resins	30.7	35.8	16.6	Increase in fraction	18.5	Faster buildup of fraction versus control
Product 6	Asphaltenes	24.8	28	12.9	Increase in fraction	3.8	Faster buildup of fraction versus control
	Saturates	6.2	6.8	9.7	Increase in fraction	-1.1	Slower buildup of fraction versus control
	Aromatics	37.2	32.2	-13.4	Decrease in fraction	-6.5	Slower buildup of fraction versus control
	Resins	31.8	33.0	3.8	Increase in fraction	5.6	Faster buildup of fraction versus control
Product 7	Asphaltenes	23.7	27.1	14.3	Increase in fraction	5.3	Faster buildup of fraction versus control
	Saturates	6.1	7.4	21.3	Increase in fraction	10.5	Faster buildup of fraction versus control
	Aromatics	37.1	32.4	-12.7	Decrease in fraction	-5.7	Slower buildup of fraction versus control
	Resins	33	33.1	0.3	Increase in fraction	2.2	Faster buildup of fraction versus control

SARA Fractions Hybrid- and Petroleum-Based Products

Product Code	Parameter	1 Month Value (%)	24 Months Value (%)	Difference due to Aging, Rate of Aging (%)		Difference in Rate of Aging versus Control (%)	
Control PG 58S-28	Asphaltenes	25.4	27.7	9.1	Increase in fraction		
	Saturates	6.5	7.2	10.8	Increase in fraction		
	Aromatics	36.1	33.6	-6.9	Decrease in fraction		
	Resins	32.0	31.4	-1.9	Decrease in fraction		
Product 8	Asphaltenes	26.5	27.9	5.3	Increase in fraction	-3.8	Slower buildup of fraction versus control
	Saturates	5.5	7.9	43.6	Increase in fraction	32.9	Faster buildup of fraction versus control
	Aromatics	36.0	30.5	-15.3	Decrease in fraction	-8.4	Slower buildup of fraction versus control
	Resins	32.0	33.6	5.0	Increase in fraction	6.9	Faster buildup of fraction versus control
Product 9	Asphaltenes	24.8	25.3	2.0	Increase in fraction	-7.0	Slower buildup of fraction versus control
	Saturates	8.4	8.0	-4.8	Decrease in fraction	-15.5	Slower buildup of fraction versus control
	Aromatics	36.6	35.7	-2.5	Decrease in fraction	4.5	Faster buildup of fraction versus control
	Resins	30.2	31.0	2.6	Increase in fraction	4.5	Faster buildup of fraction versus control
Product 10	Asphaltenes	23.7	26.7	12.7	Increase in fraction	3.6	Faster buildup of fraction versus control
	Saturates	7.9	6.8	-13.9	Decrease in fraction	-24.7	Slower buildup of fraction versus control
	Aromatics	35.1	31.9	-9.1	Decrease in fraction	-2.2	Slower buildup of fraction versus control
	Resins	33.2	34.6	4.2	Increase in fraction	6.1	Faster buildup of fraction versus control
Product 11	Asphaltenes	23.9	25.9	8.4	Increase in fraction	-0.7	Slower buildup of fraction versus control
	Saturates	6.1	8.2	34.4	Increase in fraction	23.7	Faster buildup of fraction versus control
	Aromatics	37.7	33.5	-11.1	Decrease in fraction	-4.2	Slower buildup of fraction versus control
	Resins	32.3	32.3	0.0	Decrease in fraction	1.9	Faster buildup of fraction versus control
Product 12	Asphaltenes	25.3	26.3	4.0	Increase in fraction	-5.1	Slower buildup of fraction versus control
	Saturates	6.0	7.9	31.7	Increase in fraction	20.9	Faster buildup of fraction versus control
	Aromatics	37.7	34.0	-9.8	Decrease in fraction	-2.9	Slower buildup of fraction versus control
	Resins	31.1	31.8	2.3	Increase in fraction	4.1	Faster buildup of fraction versus control

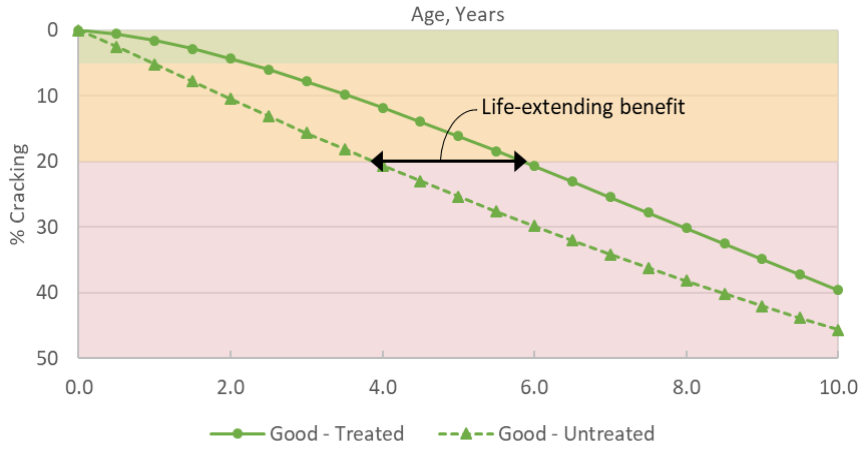
Experiment 3. Potential Interrelationship Between Permeability of Pavements and Characteristics of Rejuvenating Seals

- By utilizing the available field sections constructed at MnROAD, the in-situ permeability of up to 12 treated field sections will be collected using the NCAT field permeameter (AP-1B).

- <u>Contact angle, surface tension and viscosity</u> will play a role when predicting the penetration capability of rejuvenating seal.

Task 6. Determine the Life Extending Benefit (LEB) of a Rejuvenating Seal (laboratory and field)

- The methodology developed compares performance over time of <u>treated *versus* untreated</u> pavements.
  - *LEB*: difference in the time required to reach a threshold cracking value for treated and untreated sections.



- **10-114**:
  - Existing field and laboratory data (AL, MN)
  - Rheological properties (stiffness and relaxation)
  - Time for rejuvenated sections to return to values similar to untreated
  - Binder test results will correlate directly with field performance data

Task 6. Determine the Life Extending Benefit (LEB) of a Rejuvenating Seal (laboratory and field)

Rheological Evaluation

Control Sections

Extract Asphalt Binder from Field Cores (upper 3/8 inch | 9 mm)

MnROAD sections: Simultaneous to treatment application and after 12, and 24 months
NCAT section S3: Simultaneous to treatment application and after 24, 36, and 48 months
NCAT section S4: Simultaneous to treatment application and after 24 months

Sections with Rejuvenating Seal

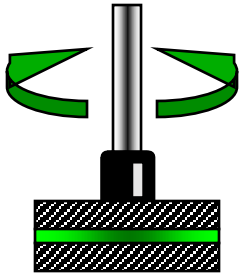
Extract Asphalt Binder from Field Cores (upper 3/8 inch | 9 mm)

MnROAD sections: After 1, 12, and 24 months of treatment application
NCAT section S3: After 1, 6, 12, 18, 24, 36, and 48 months of treatment application
NCAT section S4: After 1, 6, 12, 18, and 24 months of treatment application

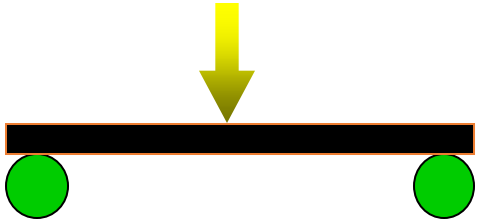
Evaluate Properties of Recovered Binder

- DSR, Performance Grade (high and intermediate temperature) - AASHTO M320
- DSR, Performance Grade (high temperature) - AASHTO M332
- BBR, Performance Grade (low temperature) and ΔTc - AASHTO T313
- DSR, Frequency Sweep from 10 to 70°C and 0.1 to 10 rad/s, Master Curve and Glover-Rowe Parameter
- DSR, Complex Modulus (|G*|) @ 60°C, 10 rad/sec - AASHTO T315
- DSR, Phase Angle (δ) @ 60°C - AASHTO T315
- Rotational Viscosity @ 135°C - AASHTO T316

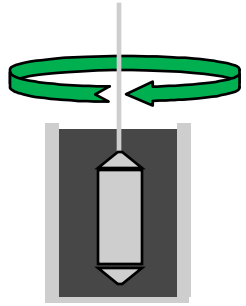
Per FAA P-632 Bituminous Pavement Rejuvenation Specification



Dynamic Shear Rheometer



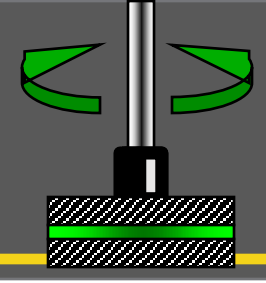
Bending Beam Rheometer



Rotational Viscosity

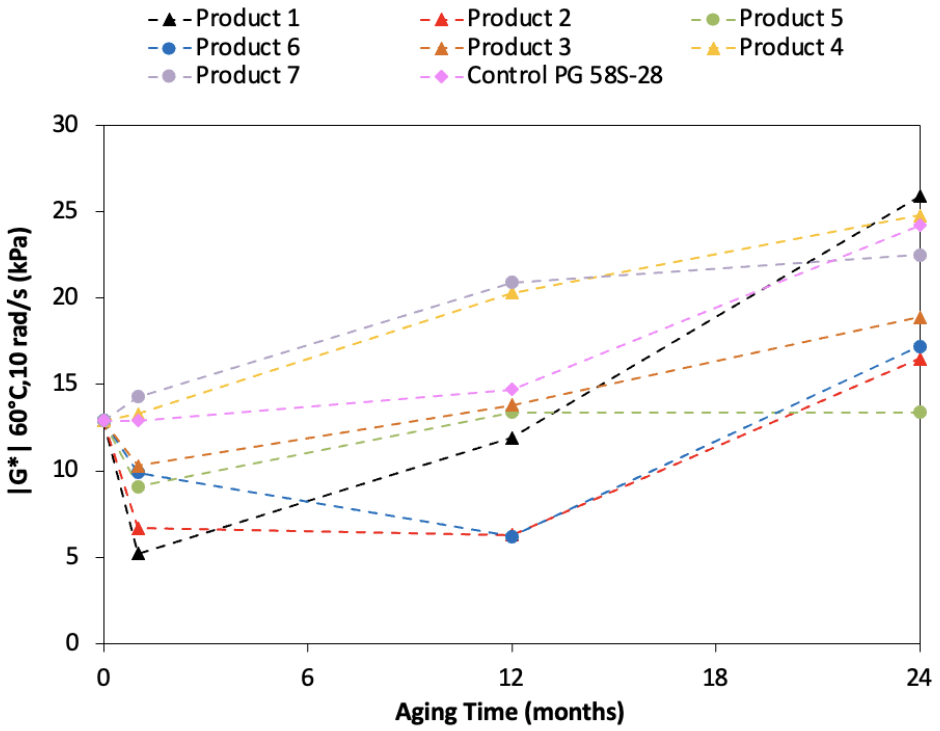
|G*| @ 60°C and 10 rad/s (FAA P-632)

PG 58S-28

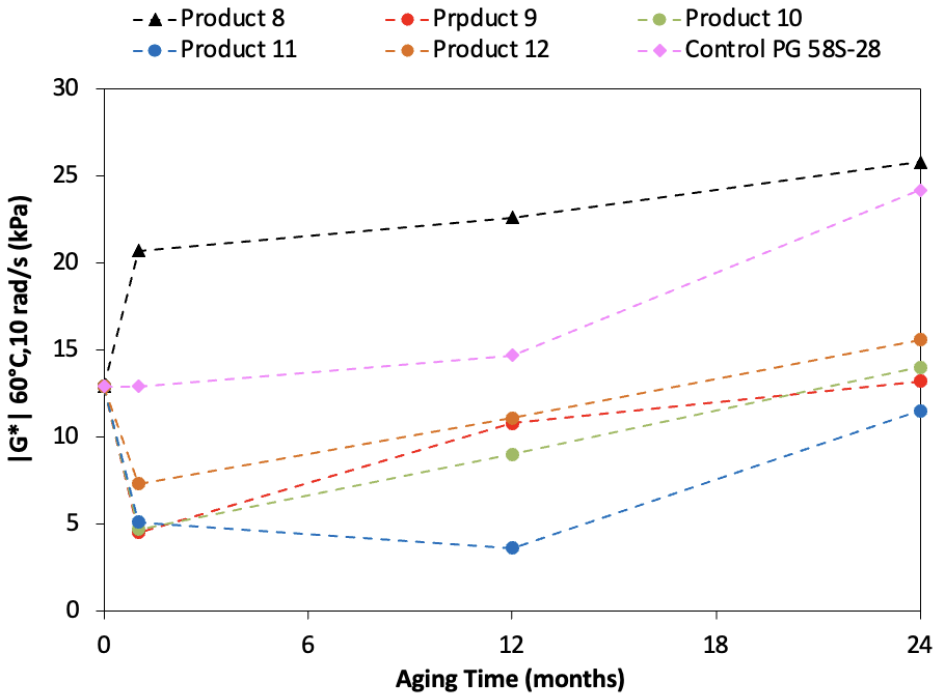


Dynamic Shear Rheometer

Bio-Based

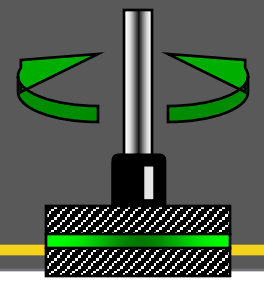


Petroleum-Based



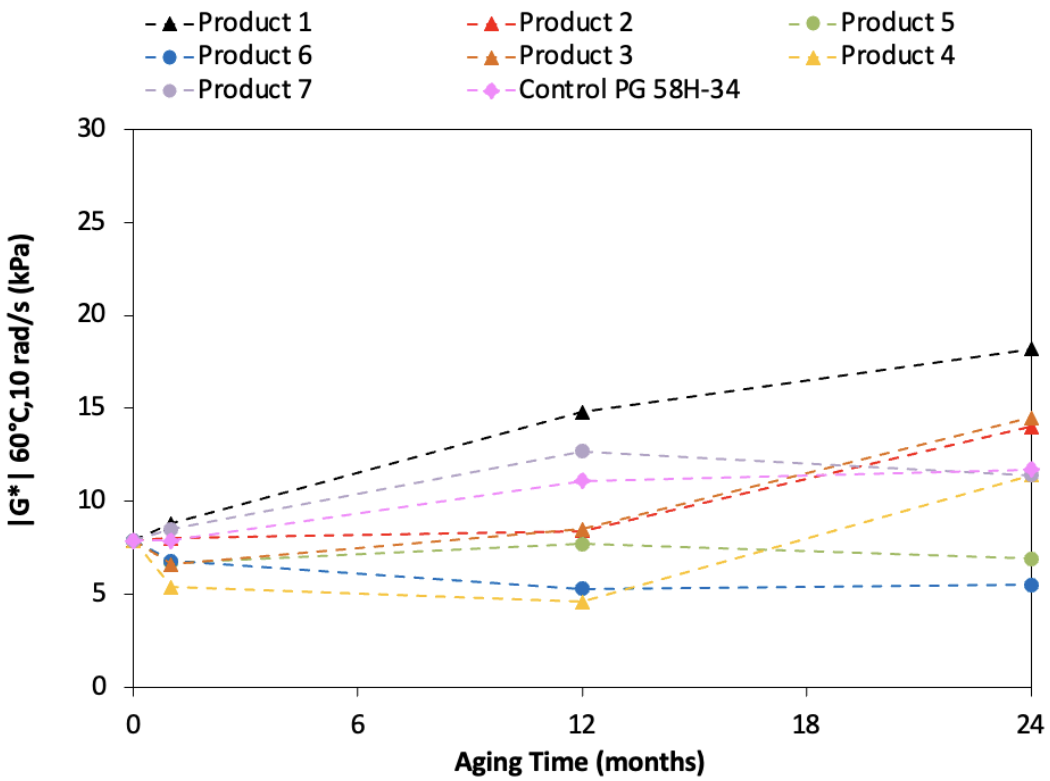
|G*| @ 60°C and 10 rad/s (FAA P-632)

PG 58H-34

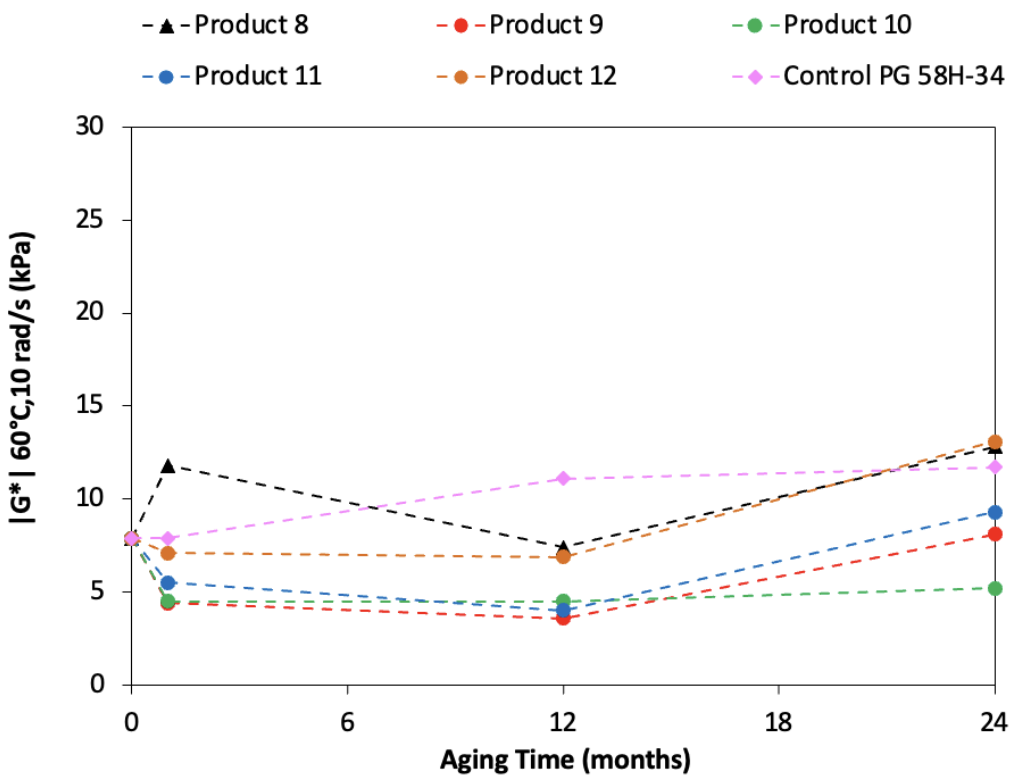


Dynamic Shear Rheometer

Bio-Based



Petroleum-Based



Task 7. Determine the Effect of Rejuvenating Seals on Pavement Friction, and Macro Texture and Micro Texture Properties

Field and laboratory experiments

Pavement micro texture

Locked Wheel Skid Trailer (LWST)

Dynamic Friction Tester (DFT)

Pavement macro texture

Circular Track Meter (CTM)

Traffic simulation

Three-Wheel Polishing Device (TWPD)

Task 7. Determine the Effect of Rejuvenating Seals on Pavement Friction, and Macrotexture and Microtexture Properties

Field Testing: NCAT Test Track E7 and E8 (dense-graded mixtures placed 2015) (Duration: 3-6 months)

Rejuvenating Seal Treatment	Application Rate	Test Length	Friction Measure	Macro Texture Measure
A	High	100 ft	Ribbed Tire LWST (pre-treatment and monthly) Supplement with DFT	Point Laser (pre-treatment and weekly) Supplement with CTM
	Low	100 ft		
B	High	100 ft		
	Low	100 ft		

Laboratory Testing: NCAT Lab TWPD (Duration: 70,000 cycles)

Rejuvenating Seal Treatment	Application Rate	No. of Replicates	Friction Measure	Macro Texture Measure
A	High	2	DFT* (pre-treatment and every 500 TWPD cycles or adjusted as needed)	CTM (before and after treatment)
	Low	2		
B	High	2		
	Low	2		

*pavement microtexture

Task 7. Determine the Effect of Rejuvenating Seals on Pavement Friction, and Macrotexture and Microtexture Properties

Field Experiment

- One bio-based and one petroleum-based treatment was applied in October. 31

Task 8. Guide Dosage Selection

- Results of Tasks 1 through 7 will be used to formulate a practical approach for agencies to determine a correct rejuvenating seal dosage.

- The approach will consider:
  - (1) existing pavement surface type and age,
  - (2) climatic conditions,
  - (3) rejuvenating seal type, and
  - (4) minimum allowable post-application friction (traffic level crash risk).

Task 9. AASHTO Specification

- The Research Team will prepare a two-part AASHTO deliverable.
- **Part 1** will focus on the material specifications for petroleum- and bio-based rejuvenating seals.
  - Selection, property characterization, and dosage optimization for pavement sealing applications.
- **Part 2** will focus on the best practices for determining the impacts of rejuvenating seals on the performance and surface characteristics (friction and texture) and the life span of underlying asphalt pavements.

Task 10. Final Deliverables

- **A draft final report**
  - Documenting the results from the project, summarizing findings, drawing conclusions, and presenting the proposed AASHTO Standard Practice to implement performance-based evaluation of rejuvenating seals.

- **A virtual workshop and associated materials**
  - Describing the research results and the proposed comprehensive AASHTO Standard Practice to be given to the AASHTO Transportation System Preservation-Technical Services Program (TSP2) Emulsion Task Force (ETF).

Thank You

Questions?

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