National Performance-Related Specification for Emulsified Asphalt Binder

Mike Anderson, Asphalt Institute

NATIONAL PAVEMENT PRESERVATION CONFERENCE
NPPC23
IMPACTS AND BENEFITS FROM PAVEMENT PRESERVATION
ncpp National Center for Pavement Preservation
MICHIGAN STATE UNIVERSITY
AASHTO TSP2 PAVEMENT PRESERVATION
ROCKY MOUNTAIN WEST PAVEMENT PRESERVATION PARTNERSHIP
SOUTHEAST PAVEMENT PRESERVATION PARTNERSHIP
MIDWESTERN PAVEMENT PRESERVATION PARTNERSHIP
NORTHEAST PAVEMENT PRESERVATION PARTNERSHIP

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  - NCHRP 09-63 Panel Members
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  - NCHRP 09-50 Research Team
    - Dr. Y. Richard Kim
  - Texas A&M Research Team
    - Dr. Amy Epps Martin
- AASHTO TSP·2 Emulsion Task Force
- Member Companies of the Asphalt Institute

Disclaimer

This investigation is sponsored by TRB under the NCHRP Program. Data reported are work in progress. Contents of this research may have not been reviewed by the project panel of NCHRP, nor do they constitute a standard, specification, or regulation.

Project Objectives

- Develop a national performance-related material specification for emulsified asphalt binder for use with chip seals and microsurfacing/slurry seals that:
  a) is similar in concept and format to AASHTO M 320 and M 332
  b) is calibrated and validated with performance data from field test sections
  c) uses readily available testing equipment (i.e., Superpave test equipment)
  d) reflects varying climatic and traffic conditions

NCHRP 09-63 Project Team

asphalt institute

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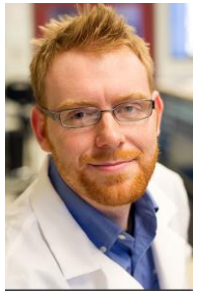
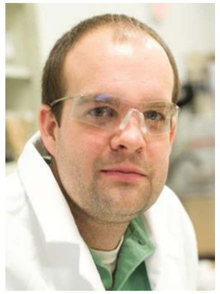


Wes Cooper



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Project Status

- May 2023
  - Completion of Phase II
  - Final Report in progress
- Phase III (Continuation)
  - NCHRP Administration in progress

Preliminary EAPG Specification

- Starting point was draft Performance Graded Emulsified Asphalt Specification (EPG) developed by the AASHTO TSP·2 Emulsion Task Force (ETF)
  - A blend of specification systems proposed by the North Carolina State research (from NCHRP Report 837) and the Texas A&M research (from the Texas DOT report)
  - Supported by analysis of round-robin testing conducted by a working group of the ETF
- **EAPG**
  - **E**mulsified **A**sphalt **P**erformance **G**rading
  - Blend of Texas A&M (SPG) and NCSU (EPG) concepts

NCHRP 09-63 Draft EAPG Specification (V1): Chip Seals

Emulsion Performance Grade	EPG 55					EPG 61					EPG 67			
	-19	-25	-31	-37	-43	-13	-19	-25	-31	-37	-13	-19	-25	-31
Surface design high temperature[1], °C	< 55					< 61					< 67			
Surface design low temperature[1], °C	> -19	> -25	> -31	> -37	> -43	> -13	> -19	> -25	> -31	> -37	> -13	> -19	> -25	> -31
Tests on Recovered Residue (AASHTO R78, Procedure B)														
High Temperature Parameter														
$G^*/\sin\delta \geq 0.65$ kPa, 10 rad/s @ Test Temperature, °C[2]	55					61					67			
Low Temperature Parameter														
G^* at δ_c, MPa[3]														
Low Traffic[4] $G^* \leq 30$ MPa @ δ_c, degrees / High Traffic[5] $G^* \leq 15$ MPa @ δ_c, degrees	48	45	42	39	36	51	48	45	42	39	51	48	45	42
OPTIONAL Polymer Presence Indicator														
Max. δ at $T_{c,high}$, degrees[6]	n/a	n/a	n/a	84	80	n/a	n/a	n/a	84	80	n/a	n/a	84	80

NOTES:

1 Determined at the pavement surface to represent the high and low design temperature for the EPG. Temperatures may be determined from experience or may be estimated using equations LTPPBind Online, modified to represent the expected surface temperature. High surface temperatures are generally 3°C to 4°C greater than those determined for PG asphalt binders used for paving.

2 AASHTO T315 is used to determine the $G^*/\sin\delta$ value of the EPG asphalt binder.

3 G^* at δ_c is determined using temperature-frequency sweep testing at 5 and 15°C following the research test procedure described in NCHRP Report 837.

4 Low traffic is defined as having an AADT of 1,000 vehicles or less.

5 High traffic is defined as having an AADT greater than 1,000 but less than 20,000 vehicles.

6 Phase angle (δ) is determined at the continuous high temperature grade – $T_{c,high}$ – where $G^*/\sin\delta = 0.65$ kPa. Two temperatures are needed – one where $G^*/\sin\delta < 0.65$ kPa and one where $G^*/\sin\delta > 0.65$ kPa – so that the phase angle can be interpolated at the temperature where $G^*/\sin\delta = 0.65$ kPa.

NCHRP 09-63 Draft EAPG Specification (V1): Chip Seals

- Some Features
  - Emulsion residue recovered by AASHTO R 78 Procedure B
    - Recovering Residue from Emulsified Asphalt Using Low-Temperature Evaporative Techniques
      - Silicone mat
      - Wet-film applicator to produce a film thickness of 0.381 mm (0.015 in)
      - Condition in forced draft oven at 60°C for 6 hours ± 15 minutes
    - Recommended by both Texas A&M and NCSU research

NCHRP 09-63 Draft EAPG Specification (V1): Chip Seals

- Some Features
  - Alternatives for Residue Recovery
    - Distillation
      - 260°C
      - Still
      - Unrealistic temperatures never seen by emulsions
      - Damage to modification systems
    - AASHTO T 59 Section 7, Evaporation Procedure
      - Condition in forced draft oven at 163°C for 3 hours
      - Beaker
      - Still too high for application and use temperatures
      - Probably no damage to modification systems

NCHRP 09-63 Draft EAPG Specification (V1): Chip Seals

- Some Features
  - Alternatives for Residue Recovery
    - AASHTO R 78 Procedure A, Low Temperature Evaporation
      - Similar low temperature evaporation as Procedure B
      - Silicone mat, no wet-film applicator
      - Adjusted mass to produce a spread rate of 1.5-2.0 kg/m^2
        - Approximately 5x thickness as Procedure B
      - 24 hours at room temperature followed by 24 hours in a forced draft oven at 60°C
      - Low temperature, longer recovery time, more residue recovered
    - ASTM D7944, Vacuum Procedure
      - Silicone mat, wet film applicator (0.38 mm thickness)
      - 60°C vacuum oven for 3 hours under vacuum (1.3 kPa)
      - Lower temperature, shorter time

NCHRP 09-63 Draft EAPG Specification (V1): Chip Seals

- Some Features
  - Upper and lower design temperatures shifted higher by 3 degrees from standard PG temperatures
    - Paving grade binders are specified using high pavement temperatures that are based on the temperature at a depth of 20 mm
      - Considered to be a combination of the maximum temperature (occurring at the surface) and the maximum location of shear stress (at a depth in the mixture)
      - Result is lower temperature than what is seen at the surface (by ~ 3°C)
    - Same shift for low pavement temperature to keep temperature spread the same
      - Low temperature occurs at the surface – same for paving grade asphalt binders used in mixtures as asphalt emulsion used in surface treatments

NCHRP 09-63 Draft EAPG Specification (V1): Chip Seals

- Some Features
  - High temperature parameter ($G^*/\sin \delta$) is the same as paving grade asphalt binders
    - Same equipment (DSR) and testing script
    - Different criterion
      - $G^*/\sin \delta \geq 0.65$ kPa
    - Different rationale
      - minimize the contribution of the emulsion residue stiffness to bleeding distress
    - Recommended by Texas A&M research

NCHRP 09-63 Draft EAPG Specification (V1): Chip Seals

- Some Features
  - Intermediate temperature parameter also uses DSR with 8-mm parallel-plate geometry
    - Temperature-frequency sweep at 5 and 15°C
    - Determination of G* at a critical phase angle related to LT grade
      - Criterion is maximum allowable G* at critical phase angle
      - Colder LT grade = lower critical phase angle
      - Maximum allowable G* increases for low traffic and decreases for high traffic.
    - Rationale
      - minimize the contribution of the emulsion residue stiffness to chip seal aggregate loss (not too stiff)
    - Recommended by NCSU research through NCHRP 09-50 project

NCHRP 09-63 Draft EAPG Specification (V1): Chip Seals

- Some Features
  - Optional polymer identification parameter at high temperature
    - Based on phase angle at $T_{c,high}$ (temperature where $G^*/\sin\delta = 0.65$ kPa)
    - Greater temperature spread between HT grade and LT grade indicates greater need for modification
      - Maximum phase angle decreases

NCHRP 09-63 Draft EAPG Specification (V1): Chip Seals

- Some Features
  - No aging before determining intermediate temperature properties
    - Stiffer residue related to chip seal aggregate loss (per NCSU)
    - Some disagreement…
      - NCSU: "The critical low-temperature distresses in both chip seals and microsurfacing typically occur during the first winter following the PST construction. Because the low winter temperatures occur only a few months after the initial construction, it was assumed that the low-temperature distresses were the most critical distresses before the residue aged significantly."
      - Texas A&M: "…the critical aging time for binders used in surface treatments is approximately one year, with failure of the majority of surface treatments either in the first summer (high temperature) or winter (low temperature)."

NCHRP 09-63 Draft EAPG Specification (V1): Chip Seals

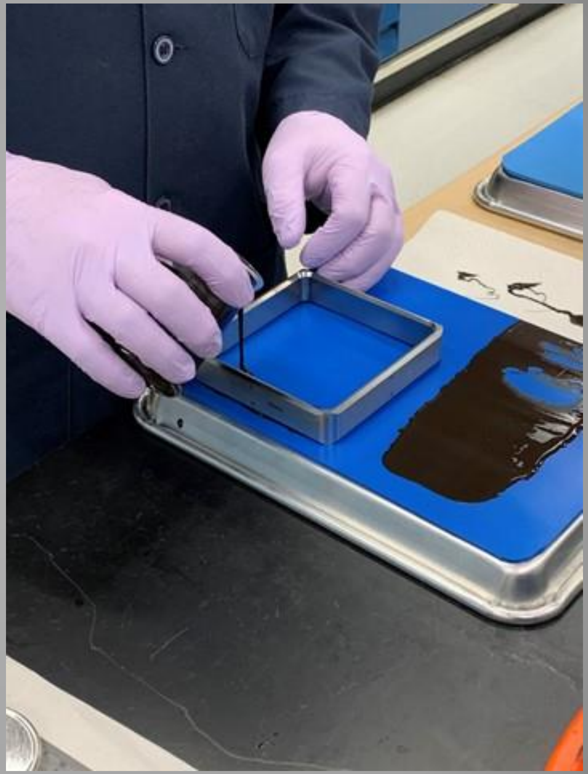
- Some Features (Recap)
  - Recovery of residue using AASHTO R 78 Procedure B (thin film, 60°C, 6 hours)
  - High temperature parameter, G*/sin δ, same as paving grade binders using same DSR script but different criterion
  - Optional determination of polymer presence based on high temperature DSR properties (phase angle)
  - No aging before determining intermediate temperature properties
  - Intermediate temperature properties based on DSR temperature-frequency sweep tests and determination of G* at a critical phase angle

EAPG Specification

- Features of a Good EAPG Specification
  - Uses reproducible, quick, technician-friendly **recovery procedure**
    - Key first point before testing
    - Minimize opportunity for variability due to technician procedures
    - Reasonable speed of recovery
  - Uses reproducible, quick, technician-friendly **testing procedures**
  - **Provides reasonable assurance that the asphalt emulsion residue properties will not disproportionately contribute to surface treatment distress**
    - Don’t expect it to correlate perfectly as many other factors influence distress

AASHTO R 78 Procedure B and ASTM D7944





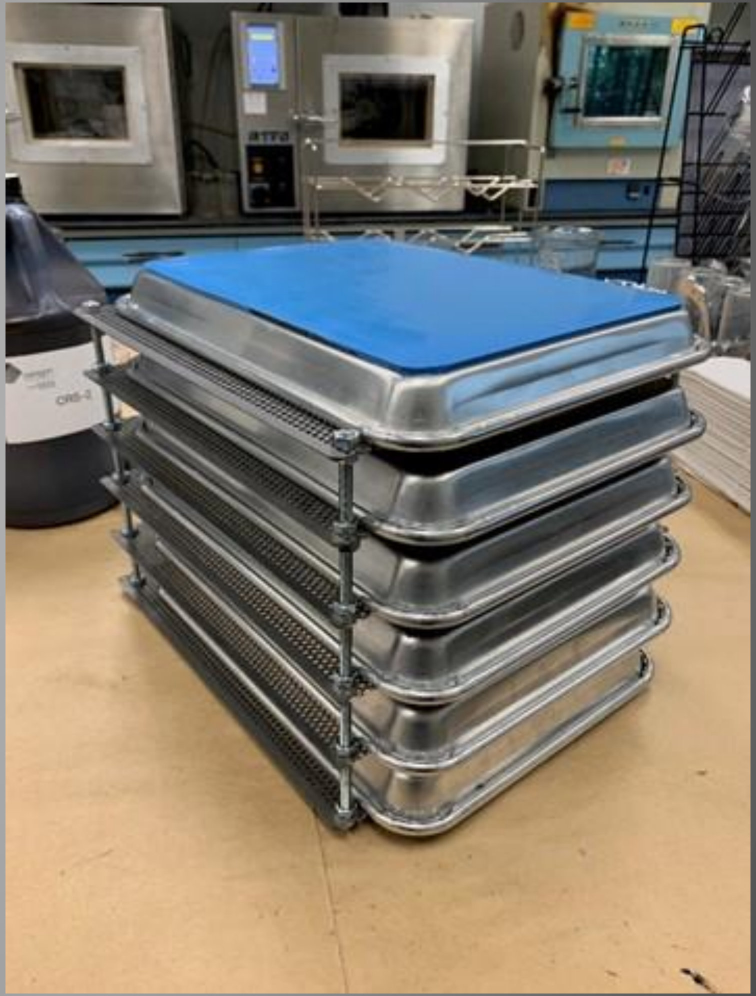

AASHTO R 78 Procedure B: SBR-Modified Emulsion

Old Mat

New Mat

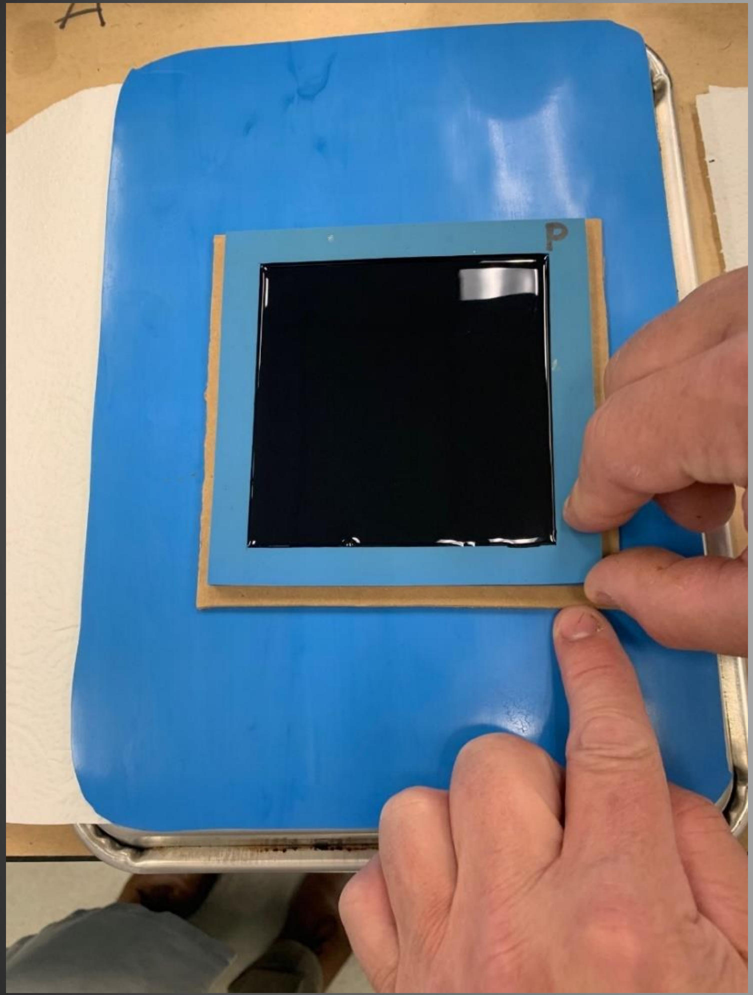
New Mat After Wiping and Reapplication

ASTM D7944

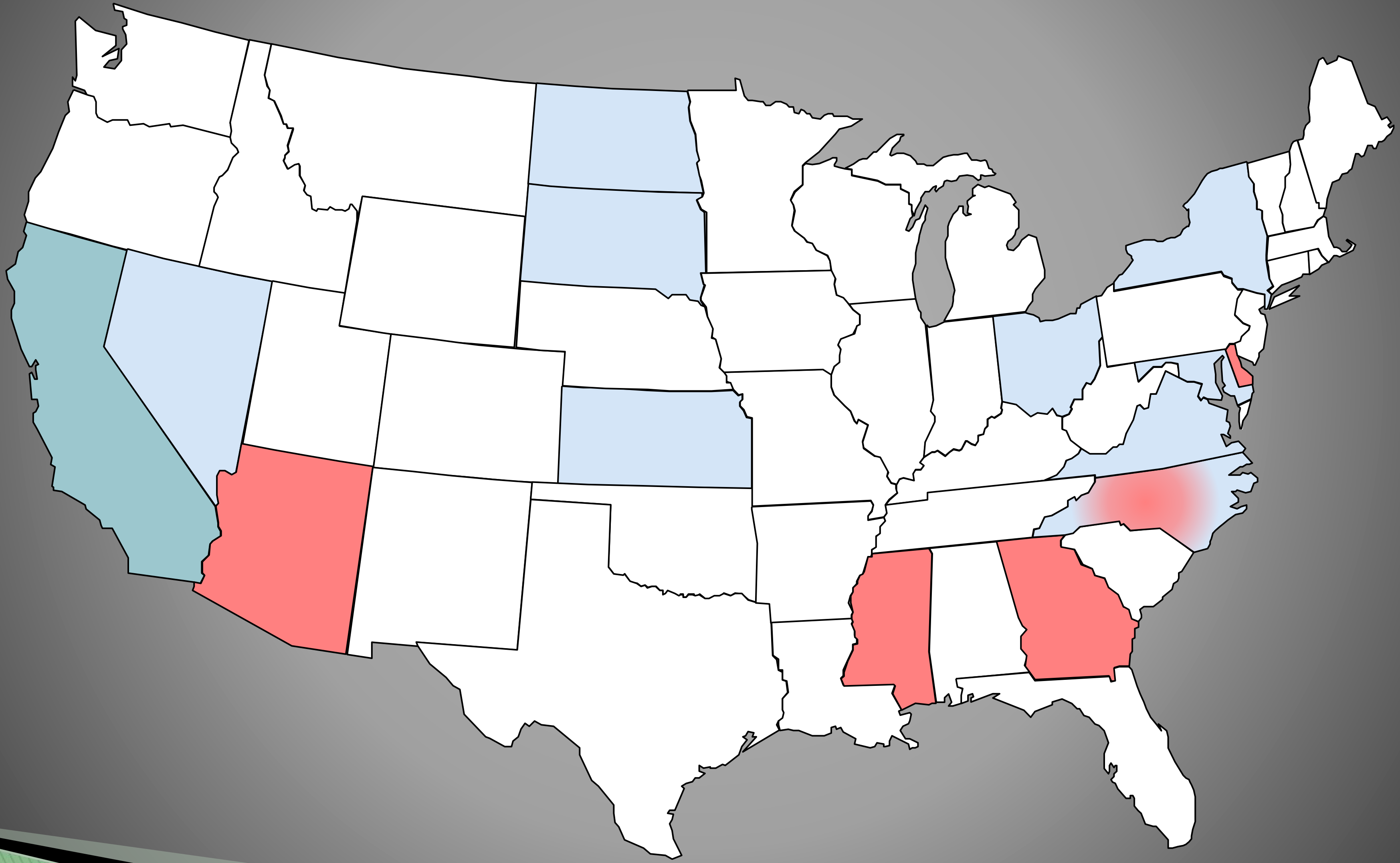


ASTM D7944 Challenges

AASHTO R 78 Procedure A and EN 13074



Field Projects 2020–22



Field Project: Microsurfacing (OH)

Field Project: Microsurfacing (OH)

Field Project: Microsurfacing (OH)

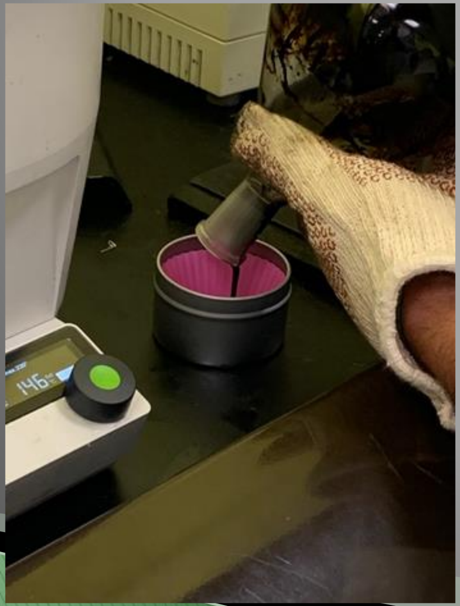
Evaluation of 2020 Field Projects

TABLE 4. Field Sampling of Surface Treatment After ~12 Months in Service

ID	State	Placement Date	Sample Date	Sample Obtained, g
20-01	NY	7/17/20	7/26/21	935
20-02	NC	7/22/20	7/28/21	620
20-03	NY	8/10/20	8/12/21	815
20-04	OH	8/20/20	8/29/21	620
20-05	ND	8/27/20	9/16/21	670
20-06	ND	8/28/20	9/16/21	600
20-07	SD	9/1/20	9/15/21	625
20-08	NV	9/10/20	9/24/21	550
20-09	KS	9/17/20	9/14/21	775
20-10	VA	9/21/20	10/8/21	570
20-11	VA	9/22/20	10/7/21	650
20-12	MD	9/25/20	10/10/21	650

At each site, the research team sampled the treatment by using a rotary hammer with a chisel bit so that just the treatment could be removed.

Recovery of Asphalt Emulsion Residue from Surface Treatment



Recovery of Asphalt Emulsion Residue from Surface Treatment: 2020 Field Projects

TABLE 13. Project 20-01: HFRS-2P, NY, Chip Seal w/ Fog and Sand

	Asphalt Emulsion Residue (Construction)				Asphalt Emulsion Residue (In-Service)			
Temp, °C	**G*, kPa**	**δ, deg.**	**G*/sin δ, kPa**	**$T_{c,high}$, °C**	**G*, kPa**	**δ, deg.**	**G*/sin δ, kPa**	**$T_{c,high}$, °C**
55	3.94	74.0	4.10	72.7	46.51	68.0	50.16	89.0
61	2.04	75.8	2.10		20.74	70.2	22.04	
67	1.09	77.2	1.12		9.47	72.5	9.93	
73	0.62	77.6	0.63		4.45	75.1	4.60	
79					2.16	77.8	2.21	

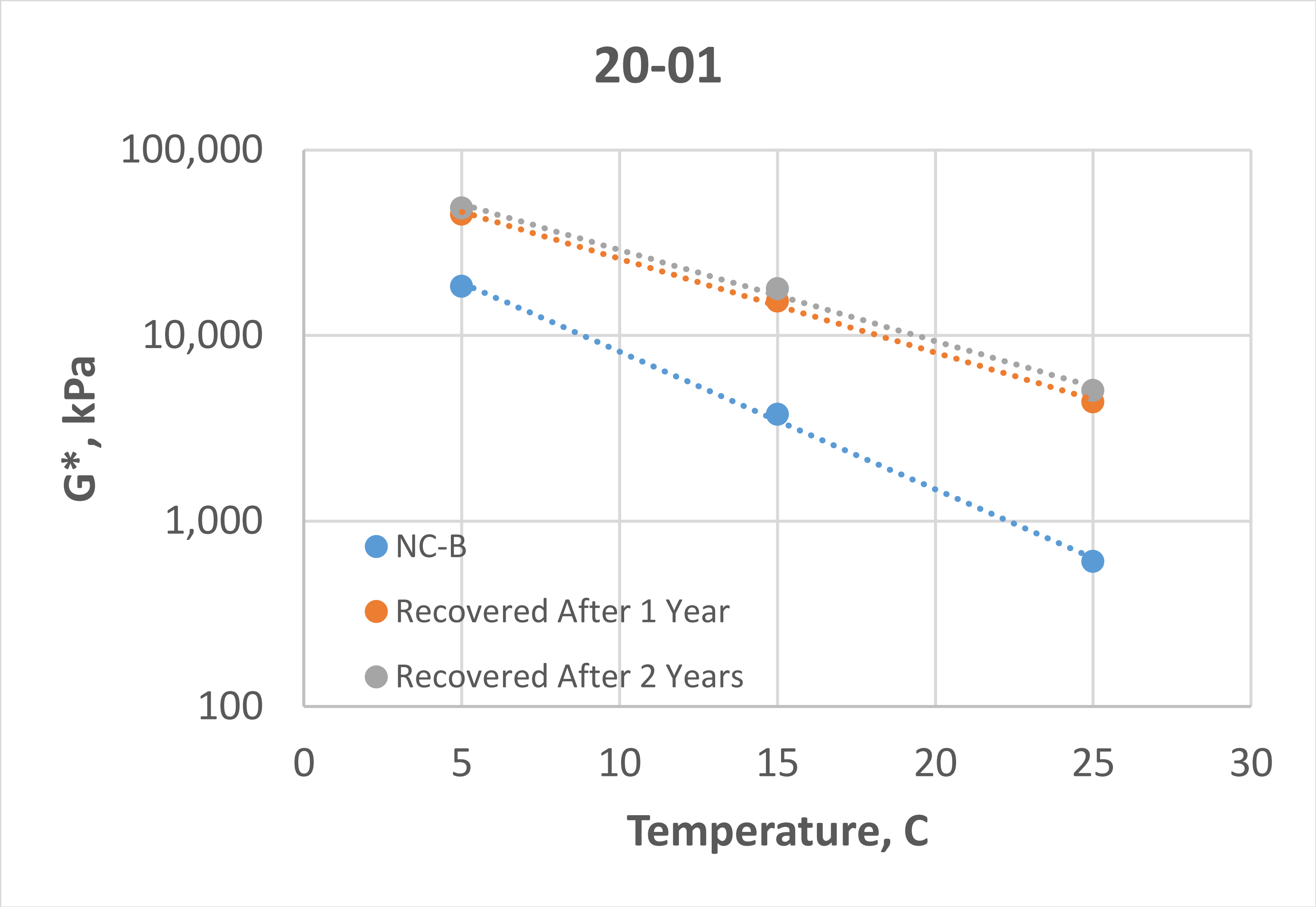
	τ = 0.1 kPa		τ = 3.2 kPa		τ = 0.1 kPa		τ = 3.2 kPa	
	J_{nr}, kPa^{-1}	**R, %**	**J_{nr}, kPa^{-1}**	**R, %**	**J_{nr}, kPa^{-1}**	**R, %**	**J_{nr}, kPa^{-1}**	**R, %**
55	0.866	52.5	2.271	11.6	0.068	53.2	0.076	48.0

	G*, kPa	**δ, deg.**	**G-R, kPa**	**G*, kPa**	**δ, deg.**	**G-R, kPa**
5	18,500	43.2	14,361	45,121	30.45	66,029
15	3,760	54.9	1,519	15,357	37.1	16,162
25	607	63.9	131	4,394	45.2	3,078

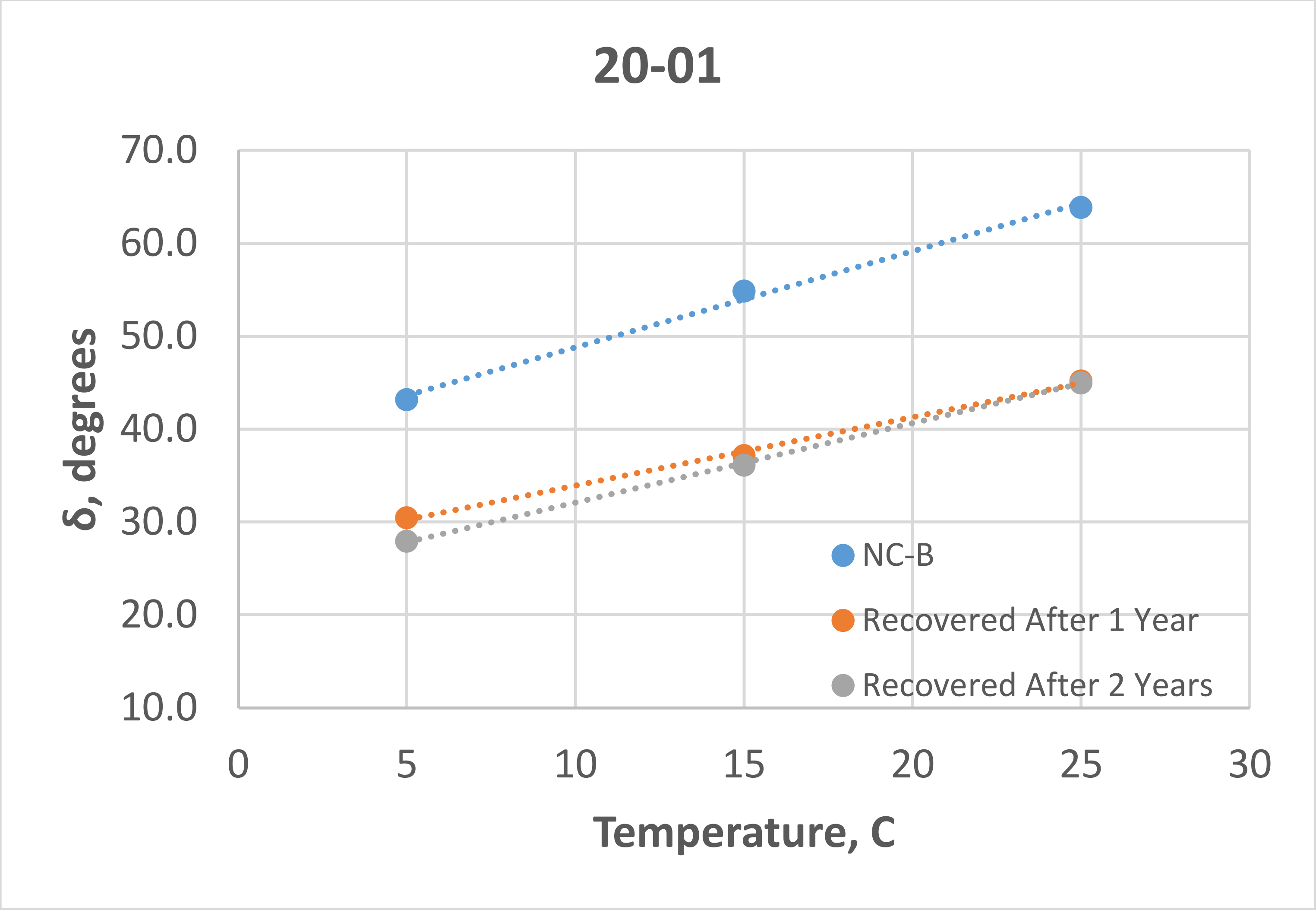
Recovery of Asphalt Emulsion Residue from Surface Treatment: 2020 Field Projects

ID	20-01-02		
Emulsion	HFRS-2P		
State	NY		
Expected Grade	EAPG 61-25		
Intermediate Temperature, °C	25		
Condition	Laboratory	Field: 1 Year in-Service	Field: 2 Years in-Service
Recovery Procedure	AASHTO R 78B	ASTM D2172 and D7906	ASTM D2172 and D7906
Recovery Lab	NCAT	AI	AI
Testing Lab	NCAT	AI	AI
Intermediate Temperature			
G* at 10 rad/s, kPa	628	4,573	5,330
δ at 10 rad/s, degrees	64.4	44.9	44.9
GRP at 10 rad/s, kPa	135	3,233	3,777
R	1.77	2.34	2.28

Recovery of Asphalt Emulsion Residue from Surface Treatment



Recovery of Asphalt Emulsion Residue from Surface Treatment



NCHRP 09-63 Draft EAPG Specification (V1): Chip Seals

Emulsion Performance Grade	EPG 55					EPG 61					EPG 67			
	-19	-25	-31	-37	-43	-13	-19	-25	-31	-37	-13	-19	-25	-31
Surface design high temperature[1], °C	< 55					< 61					< 67			
Surface design low temperature[1], °C	> -19	> -25	> -31	> -37	> -43	> -13	> -19	> -25	> -31	> -37	> -13	> -19	> -25	> -31
Tests on Recovered Residue (AASHTO R78, Procedure B)														
High Temperature Parameter														
$G^*/\sin\delta \geq 0.65$ kPa, 10 rad/s @ Test Temperature, °C[2]	55					61					67			
Low Temperature Parameter														
G^* at δ_c, MPa[3]														
Low Traffic[4] $G^* \leq 30$ MPa @ δ_c, degrees / High Traffic[5] $G^* \leq 15$ MPa @ δ_c, degrees	48	45	42	39	36	51	48	45	42	39	51	48	45	42
OPTIONAL Polymer Presence Indicator														
Max. δ at $T_{c,high}$, degrees[6]	n/a	n/a	n/a	84	80	n/a	n/a	n/a	84	80	n/a	n/a	84	80

NOTES:

1 Determined at the pavement surface to represent the high and low design temperature for the EPG. Temperatures may be determined from experience or may be estimated using equations LTPPBind Online, modified to represent the expected surface temperature. High surface temperatures are generally 3°C to 4°C greater than those determined for PG asphalt binders used for paving.

2 AASHTO T315 is used to determine the $G^*/\sin\delta$ value of the EPG asphalt binder.

3 G^* at δ_c is determined using temperature-frequency sweep testing at 5 and 15°C following the research test procedure described in NCHRP Report 837.

4 Low traffic is defined as having an AADT of 1,000 vehicles or less.

5 High traffic is defined as having an AADT greater than 1,000 but less than 20,000 vehicles.

6 Phase angle (δ) is determined at the continuous high temperature grade – $T_{c,high}$ – where $G^*/\sin\delta = 0.65$ kPa. Two temperatures are needed – one where $G^*/\sin\delta < 0.65$ kPa and one where $G^*/\sin\delta > 0.65$ kPa – so that the phase angle can be interpolated at the temperature where $G^*/\sin\delta = 0.65$ kPa.

NCHRP 09-63 Draft EAPG Specification: Chip Seals

Emulsion Performance Grade	EAPG 55				EAPG 61				EAPG 67				EAPG 73		
	-19	-25	-31	-37	-13	-19	-25	-31	-7	-13	-19	-25	-7	-13	-19
Surface design high temperature[1], °C	< 55				< 61				< 67				< 73		
Surface design low temperature[1], °C	> -19	> -25	> -31	> -37	> -13	> -19	> -25	> -31	> -7	> -13	> -19	> -25	> -7	> -13	> -19
Residue Recovered using AASHTO R 78 Procedure B[2]															
High Temperature Parameter															
G*/sin δ ≥ 0.65 kPa, 10 rad/s @ Test Temperature, °C[3]	55				61				67				73		
Lab Extended Aging on Recovered Residue[4]															
Intermediate Temperature Parameter															
GRP ≤ 5000 kPa, 10 rad/s @ Test Temperature, °C[5]	28	25	22	20	30	28	25	22	32	30	28	25	32	30	28
R ≤ 2.50 @ Test Temperature[6]	28	25	22	20	30	28	25	22	32	30	28	25	32	30	28

NOTES:

1 Determined at the pavement surface to represent the high and low design temperature for the EPG. Temperatures may be determined from experience or may be estimated using equations LTPPBind Online, modified to represent the expected surface temperature. High surface temperatures are generally 3°C to 4°C greater than those determined for PG asphalt binders used for paving.

2 AASHTO R 78 Procedure B is used as the residue recovery procedure. In the event of pooling of the asphalt emulsion or if a proper drawdown cannot be accomplished, then AASHTO R 78 Procedure A shall be used.

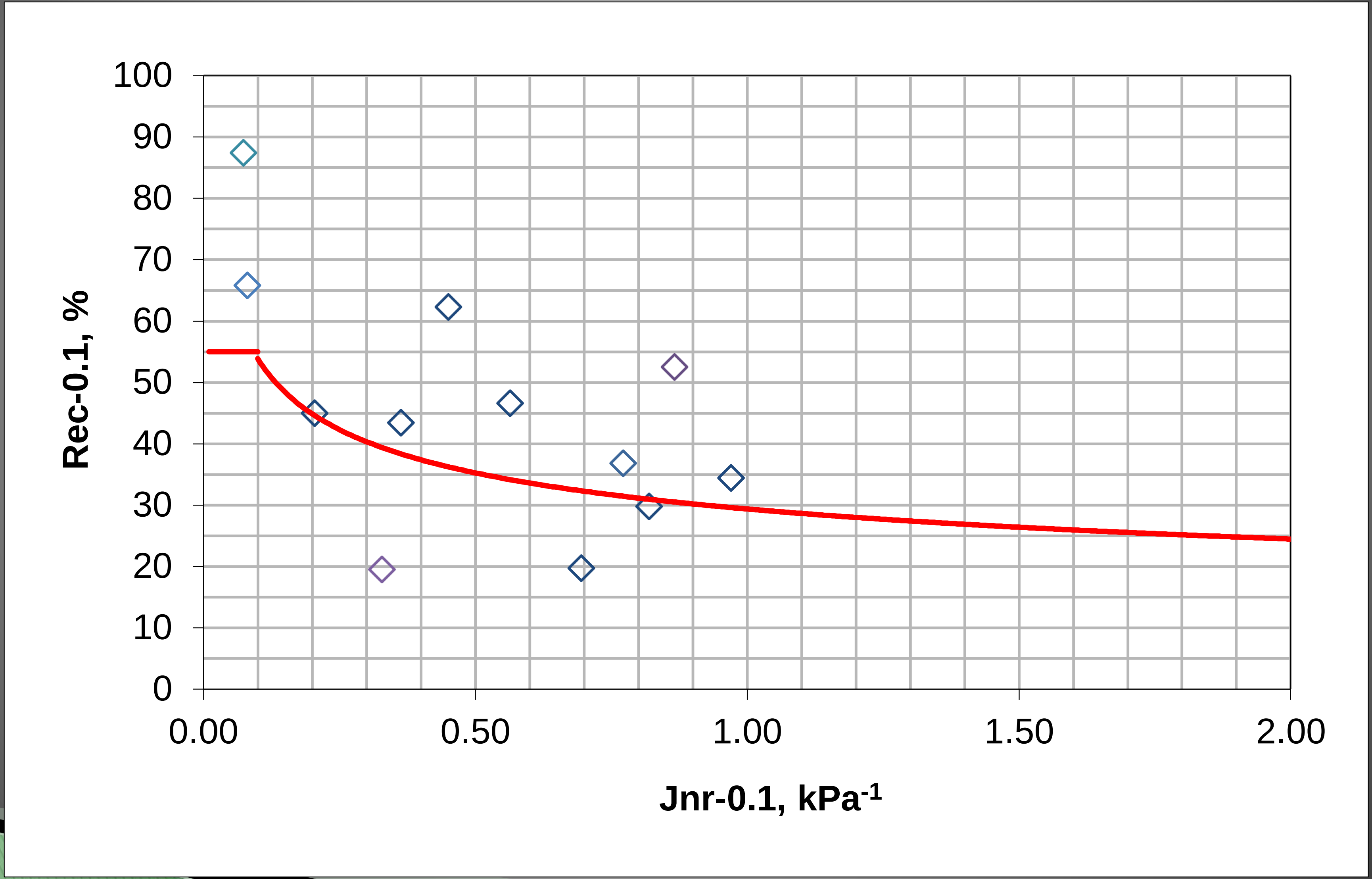
3 AASHTO T 315 is used to determine the G*/sin δ value of the EAPG asphalt binder.

4 Lab extended aging shall be performed on the recovered residue following AASHTO R xx before determining intermediate temperature properties.

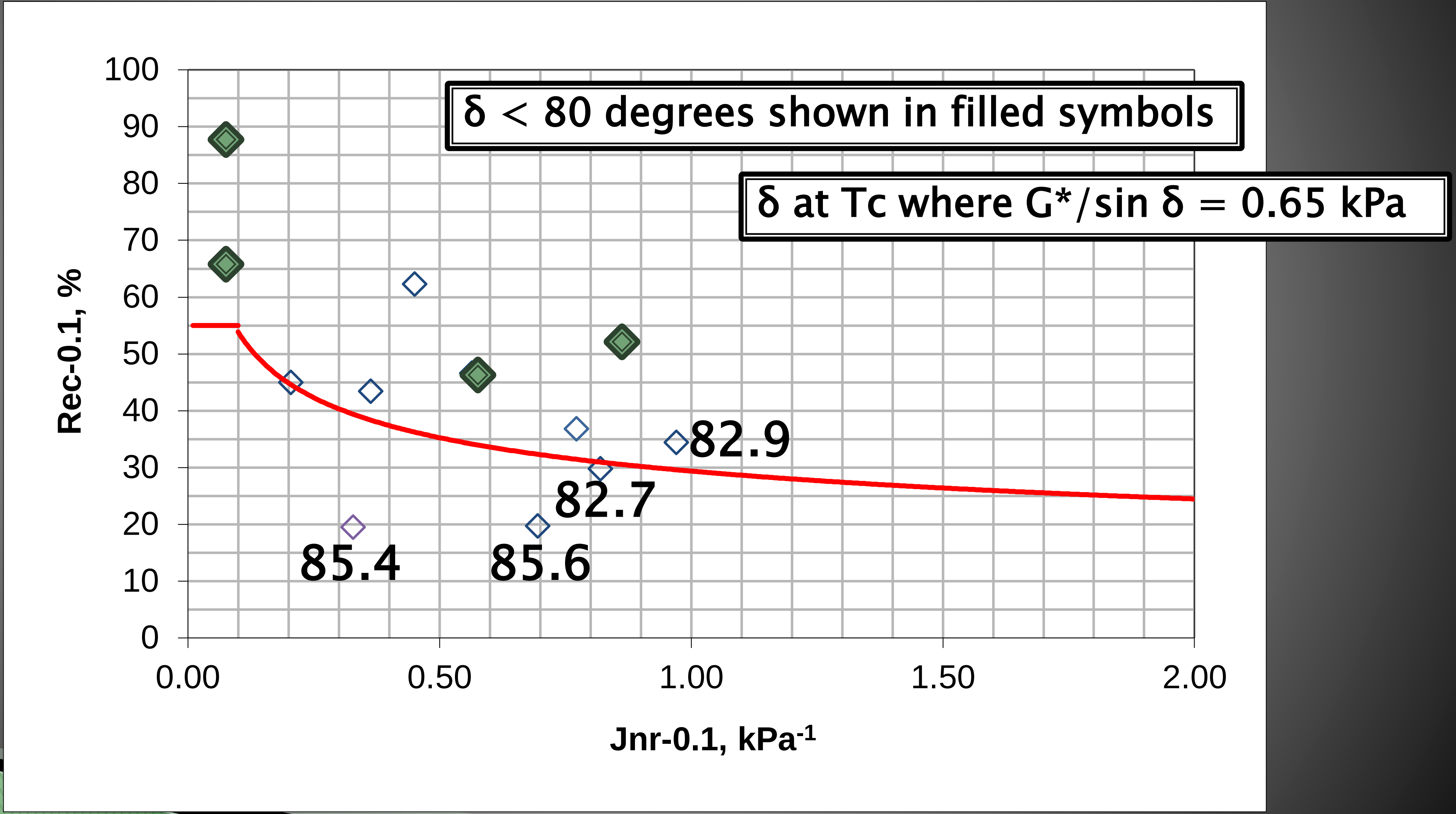
5 "GRP" is the Glover-Rowe Parameter, defined as $G^*(\cos\delta)^2/\sin\delta$. Testing is conducted using AASHTO T 315

6 "R" is a parameter related to the shape of the asphalt mastercurve and an indirect indicator of relaxation properties. It is determined using G* and d from the same test used to determine GRP and is calculated as $R = \log(2) * \frac{\log(G^*/1{,}000{,}000)}{\log(1-(\delta/90))}$ where G* is in kPa and δ is in degrees.

NCHRP 09-63 Draft EAPG Specification: Polymer Identification

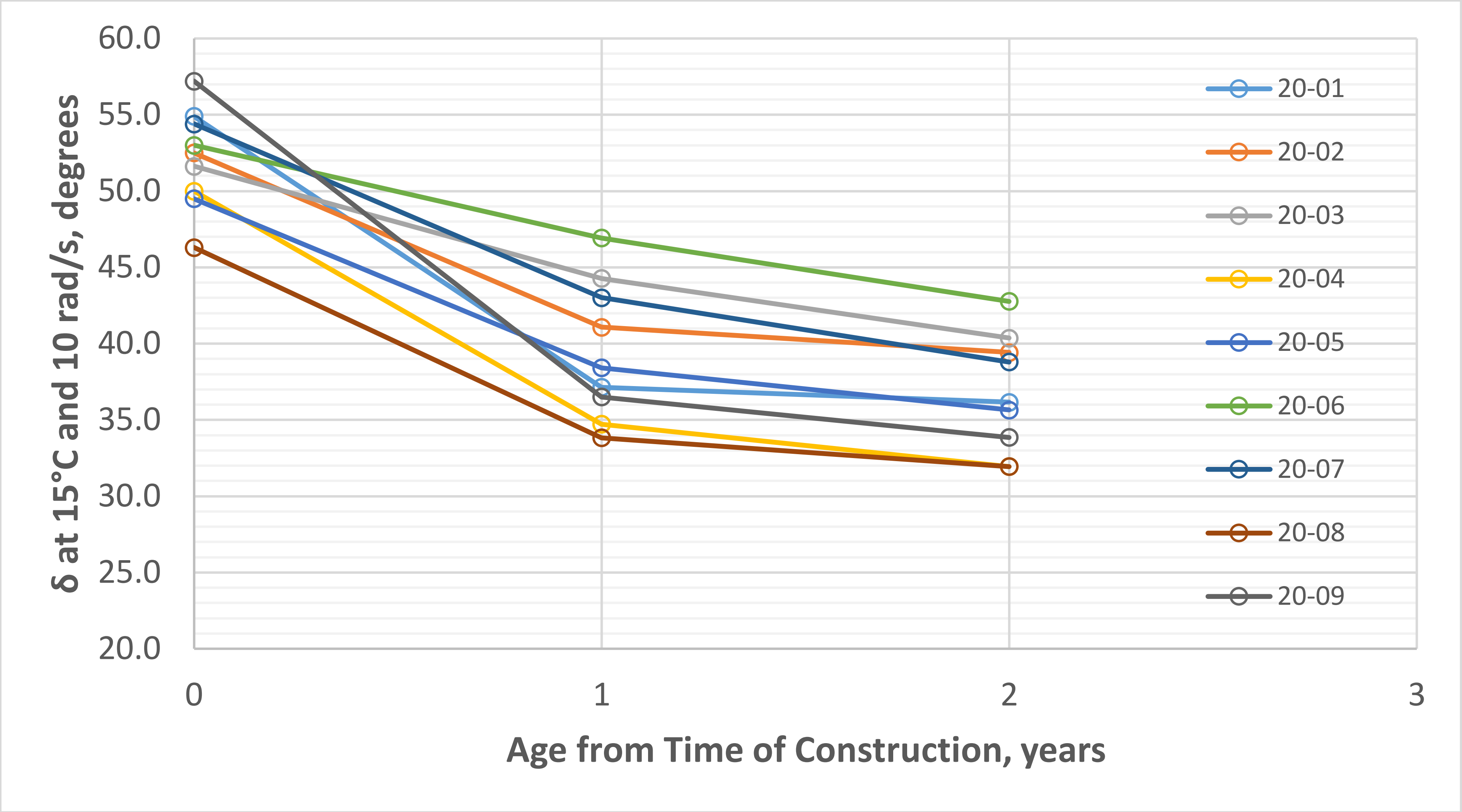


NCHRP 09-63 Draft EAPG Specification: Polymer Identification



2020 Field Projects: Aging Profiles for G*

2020 Field Projects: Aging Profiles for δ



Oxidation (Age Hardening) of Asphalt Materials

- Transportation Research Circular E-C140, *A Review of the Fundamentals of Asphalt Oxidation: Chemical, Physicochemical, Physical Property, and Durability Relationships*
  - Authored by J. Claine Petersen
  - Published in October 2009.
  - "there appears to be an initial fast reaction in which the asphalt ages significantly in a relatively short time, followed by a slower, steady state increase."
- Relevance
  - Assume the oxidation kinetics generally hold true for asphalt emulsion residue used in surface treatments as they do for paving grade asphalt binders
  - May be sufficient to simulate in the lab the aging of the asphalt emulsion residue in-service for only one year, with the expectation that steady state aging will occur after that initial reaction.
    - Generalization that may or may not be accurate

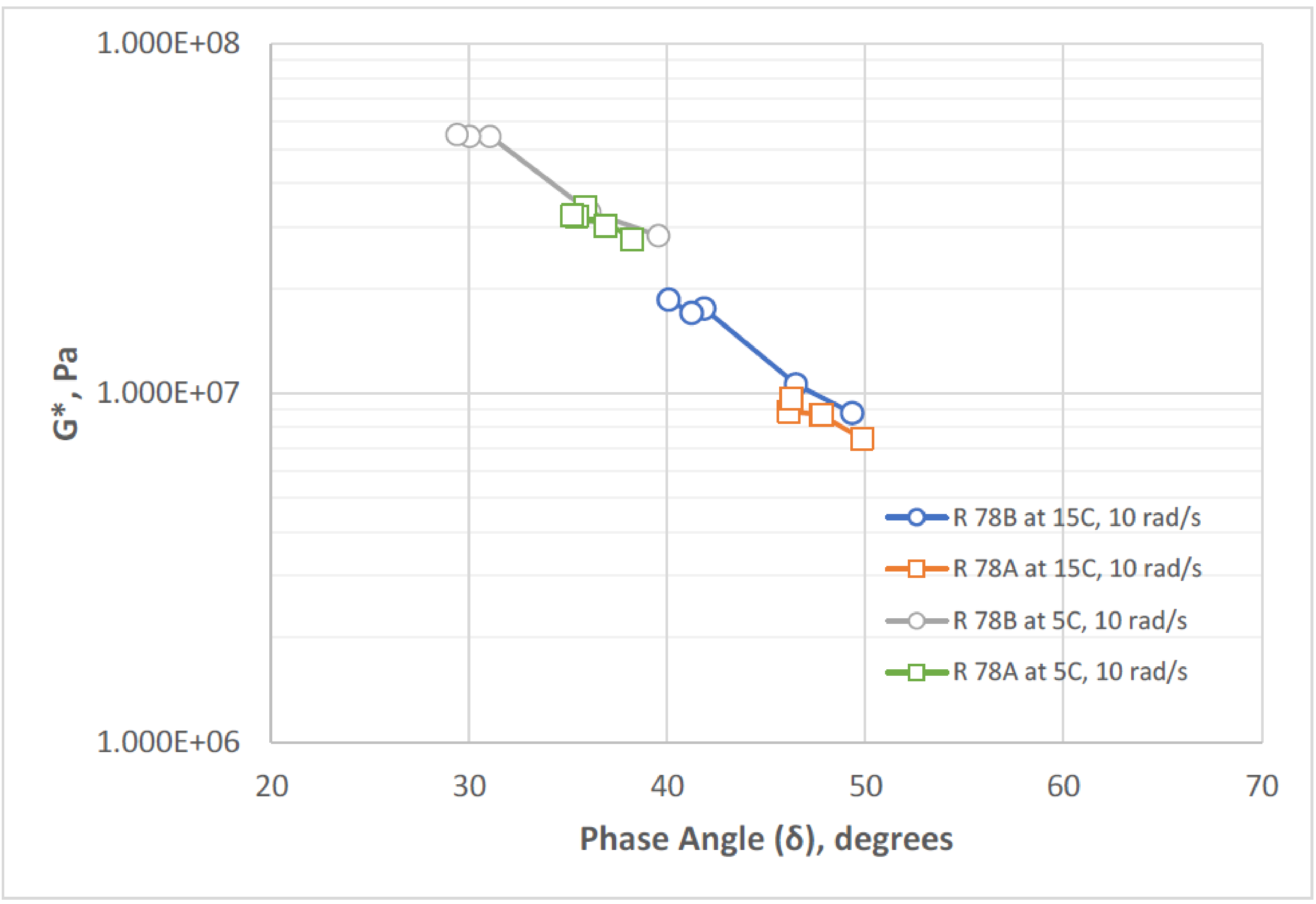
Oxidation (Age Hardening) of Asphalt Materials

- Simulating Aging in the Lab?
  - PAV
  - Environmental chamber
  - Other
- Lab Experiment on Field Sample in 2022
  - Conduct extended aging on the same test sample prepared in the laboratory for recovery of the asphalt emulsion residue following AASHTO R 78.
    - Prepare two samples for recovery following AASHTO R 78.
    - Conduct the laboratory recovery procedure as described on one of the samples.
    - Subject second sample to further conditioning in the forced draft oven at the same temperature for an extended time.

California PMCRS-2h: Impact of Extended Aging

5°C, 10 rad/s					
Procedure	**G*, Pa**	**δ, deg.**	**Procedure**	**G*, Pa**	**δ, deg.**
R 78 A	2.755E+07	38.2	R 78 B	2.827E+07	39.6
R 78 A + 16	3.421E+07	35.8	R 78 B + 16	3.302E+07	36.1
R 78 A + 20	3.024E+07	36.9	R 78 B + 20	5.443E+07	31.0
R 78 A + 24	3.216E+07	35.4	R 78 B + 24	5.439E+07	30.0
R 78 A + 48	3.225E+07	35.2	R 78 B + 48	5.509E+07	29.4
15°C, 10 rad/s					
Procedure	**G*, Pa**	**δ, deg.**	**Procedure**	**G*, Pa**	**δ, deg.**
R 78 A	7.408E+06	49.8	R 78 B	8.779E+06	49.3
R 78 A + 16	8.672E+06	47.8	R 78 B + 16	1.062E+07	46.5
R 78 A + 20	8.680E+06	47.8	R 78 B + 20	1.748E+07	41.9
R 78 A + 24	8.876E+06	46.1	R 78 B + 24	1.697E+07	41.2
R 78 A + 48	9.633E+06	46.2	R 78 B + 48	1.851E+07	40.1

California PMCRS-2h: Impact of Extended Aging on Black Space



Extended Aging – A Possible Path Forward

- Results of Extended Aging Experiment with California PMCRS-2h Field Sample
  - R 78 Procedure A and B produced comparable results with Procedure B being slightly stiffer
  - Procedure A data was clustered indicating less impact of extended aging time
  - Procedure B data showed most significant changes of aging up to 20 hours with lessening effect after 20 hours
  - Differences in Procedure A and Procedure B extended aging caused by film thickness (1.5 mm vs. 0.38 mm)

Extended Aging – A Possible Path Forward

- (Far Too Early) Interpretation of Results of Extended Aging Experiment
  - For seven of nine analyzed projects from 2020
    - average increase in G* at 15°C was 2.4 times the lab recovered value
    - average decrease in phase angle (δ) was 10.7 degrees.
  - AASHTO R 78 Procedure B + extended aging period of 20 hours
    - lab recovered 22-01 asphalt emulsion residue
    - increase in G* at 15°C was 2.0 times the lab recovered value
    - decrease in phase angle (δ) was 7.5 degrees
  - No aging data from 22-01 yet, but…
    - the change in G* and δ using extended lab aging (AASHTO R 78 Procedure B for 20 hours) appears to be comparable to what has been seen from the recovered residue on a majority of field projects from 2020 after one year in service.

EAPG Specification

- Features of a Good EAPG Specification
  - Uses reproducible, quick, technician-friendly **recovery procedure**
    - Key first point before testing
    - Minimize opportunity for variability due to technician procedures
    - Reasonable speed of recovery
  - Uses reproducible, quick, technician-friendly **testing procedures**
  - **Provides reasonable assurance that the asphalt emulsion residue properties will not disproportionately contribute to surface treatment distress**
    - Don’t expect it to correlate perfectly as many other factors influence distress

Thanks!

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