National Performance-Related Specification for Emulsified Asphalt Binder

Mike Anderson, Asphalt Institute

AASHTO TSP·2 ETF Meeting

June 29, 2023

Acknowledgments

- National Cooperative Highway Research Program (NCHRP)
  - NCHRP 09-63 Panel Members
  - Ed Harrigan, NCHRP Program Officer
  - Roberto Barcena, NCHRP Program Officer
- Foundational Research Teams
  - 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

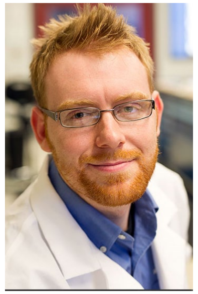
asphalt institute

National Center for Asphalt Technology
NCAT
at AUBURN UNIVERSITY

Mike Anderson
Principal Investigator

Adriana Vargas
Lead Research Engineer

Greg Harder
Research Engineer



Wes Cooper
Lab Manager

Mike Beavin
Research Technician

Raquel Moraes
Research Engineer

Buzz Powell
Research Engineer

Pamela Turner
Research Engineer

Project Status

- May 2023
  - Completion of Phase II
  - Final Report in progress
- Phase III (Continuation)
  - Under consideration and administration by NCHRP

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

Suggested Procedures for Recovery and Testing of Asphalt Emulsion Residue

- Recover the asphalt emulsion residue following the procedure described in AASHTO R 78 Procedure B
  - Make sure the technician understands the proper use of the applicator tool to create the thin film. The numbers on the edges of the standard applicator can be misinterpreted, causing the technician to draw a thinner film than intended.
  - If a uniformly thin film is not created, then the technician must wipe the silicone mat and perform the drawdown again.
  - If a second drawdown does not produce a uniformly thin film, then the technician must recover the asphalt emulsion residue following the procedure described in AASHTO R 78 Procedure A.
    - Alternatively, the technician can choose to skip the second drawdown – particularly if it is obvious that a uniformly thin film cannot be created – and proceed to recover the asphalt emulsion residue following AASHTO R 78 Procedure A.

Suggested Procedures for Recovery and Testing of Asphalt Emulsion Residue

- Recover the asphalt emulsion residue following the procedure described in AASHTO R 78 Procedure B
    - ◦ Ensure that the forced draft recovery oven meets the requirements of ASTM E145 Type IIA – particularly regarding the rate of ventilation.
        - Pay attention to the rack/sample tray spacing and levelness requirements described in AASHTO R 78 Section 4.5.
        - Check the ventilation rate as prescribed in the standard at 80°C above ambient to confirm that it meets the requirements.
            - ◦ In addition, the ventilation rate should be checked at 60°C to determine the number of air changes at the temperature used in the A and B procedures.

Suggested Procedures for Recovery and Testing of Asphalt Emulsion Residue

- Remove the silicone mat from the oven at the end of the recovery period and allow it to cool to room temperature.

Suggested Procedures for Recovery and Testing of Asphalt Emulsion Residue

- Use a putty knife (or hand covered by a latex glove) to peel the residue from the mat. Consolidate the residue and place it in silicone-coated release paper. Place the release paper with residue in an aluminum tin (such as a 3-oz or 6-oz tin) and cover/seal until ready to test.
  - Good practice is that the asphalt emulsion residue should be tested within one week of recovery when held in a sealed tin at ambient conditions in the laboratory.
  - If the sample won’t be tested within one week, it is recommended that the asphalt emulsion residue be covered by the silicone-coated release paper in the tin with the friction lid sealing the tin and placed in a freezer. The sample will need to come to ambient temperature or be reheated before testing.

Suggested Procedures for Recovery and Testing of Asphalt Emulsion Residue

- Use a heated knife and cut a small amount of the cooled residue for DSR testing. Roll the sample between gloved hands to create a ball and place on silicone-coated release paper next to the DSR. Cover the sample with a tin or glassware to minimize contamination before testing.
  - Unlike the practice for paving grade asphalt binders, it is not recommended that the recovered asphalt emulsion sample is reheated until fluid before testing.
  - If reheating is necessary, follow the “Reheated Sample Procedure”. Note that this may affect the physical properties of some asphalt emulsion residues.

Suggested Procedures for Recovery and Testing of Asphalt Emulsion Residue

- Test the recovered asphalt emulsion residue according to the appropriate procedures.

When comparing data between two labs or replicates of the same sample, technicians should understand that variability can come from many sources. When significant differences occur between labs or samples, the technician(s) should review the procedures used to look for sources of potential error. This will help ensure the best possibility repeatability/reproducibility.

Residue Sample Reheating Procedure

- A small metal tin or glass container should be used for reheating.
  - Use a container that will not cause the residue to develop into a thin film.
  - Samples should be covered during reheating to avoid incorporating air or other contaminants.
- Use an oven to reheat any residue.
  - It is recommended that temperatures of 135 ± 5°C be used for reheating unmodified residues
  - It is recommended that temperatures of 165 ± 5°C be used for reheating modified residues.
- Reheating time should be limited to a maximum of 30 minutes, using the lowest possible temperature.

Residue Sample Reheating Procedure

- When the residue becomes fluid, (approximately the consistency of motor oil), the sample should be stirred using a glass or metal rod for 15-20 seconds before pouring any specimens.
  - Stir at a rate such that air bubbles will not be incorporated into the specimen.
- When possible, to prevent further stiffening of the residue, do not reheat the sample a second time.
  - Note if additional reheats are required.

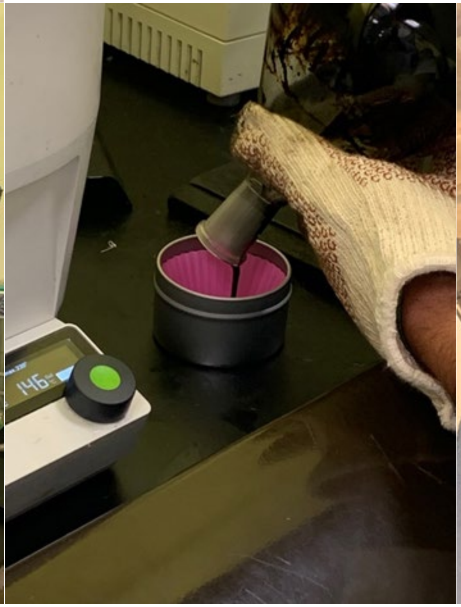
Evaluation of 2020 Field Projects

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

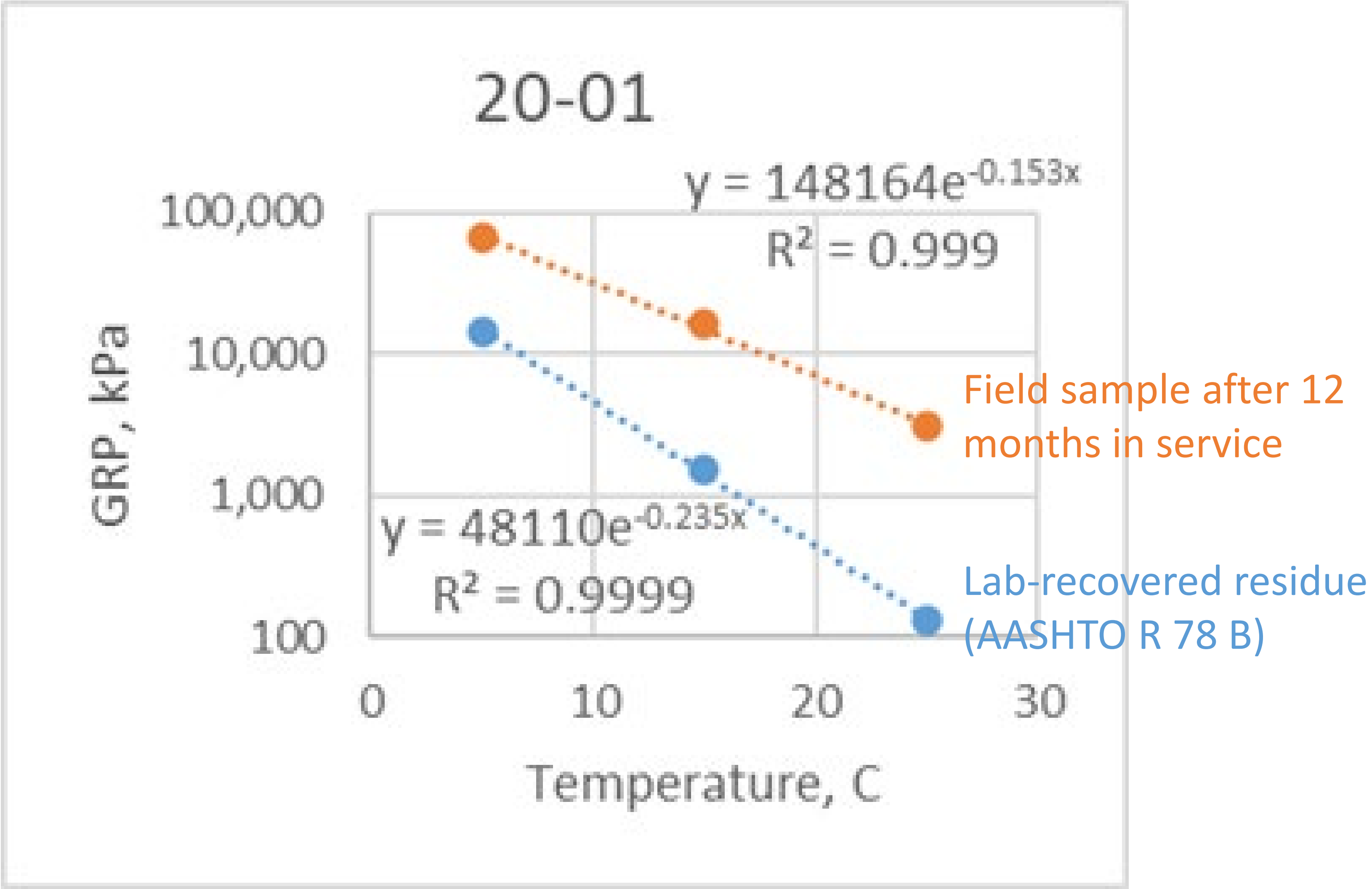
Recovery of Asphalt Emulsion Residue from Surface Treatment: 2020 Field Projects

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
$T_{c,high}$[1], °C	72.7	88.3	88.2
MSCR at 55°C			
$J_{nr,0.1}$, kPa^{-1}	0.866	0.068	0.062
$J_{nr,3.2}$, kPa^{-1}	2.271	0.076	0.068
$R_{0.1}$, %	52.5	53.2	50.9
$R_{3.2}$, %	11.6	48.0	46.9
G* at 10 rad/s, kPa			
5°C	18,500	45,121	48,891
15°C	3,760	15,357	17,919
25°C	607	4,394	5,082
δ at 10 rad/s, degrees			
5°C	43.2	30.5	27.9
15°C	54.9	37.1	36.2
25°C	63.9	45.2	45.0
GRP at 10 rad/s, kPa			
5°C	14,361	66,029	81,438
15°C	1,519	16,162	19,796
25°C	131	3,078	3,592
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

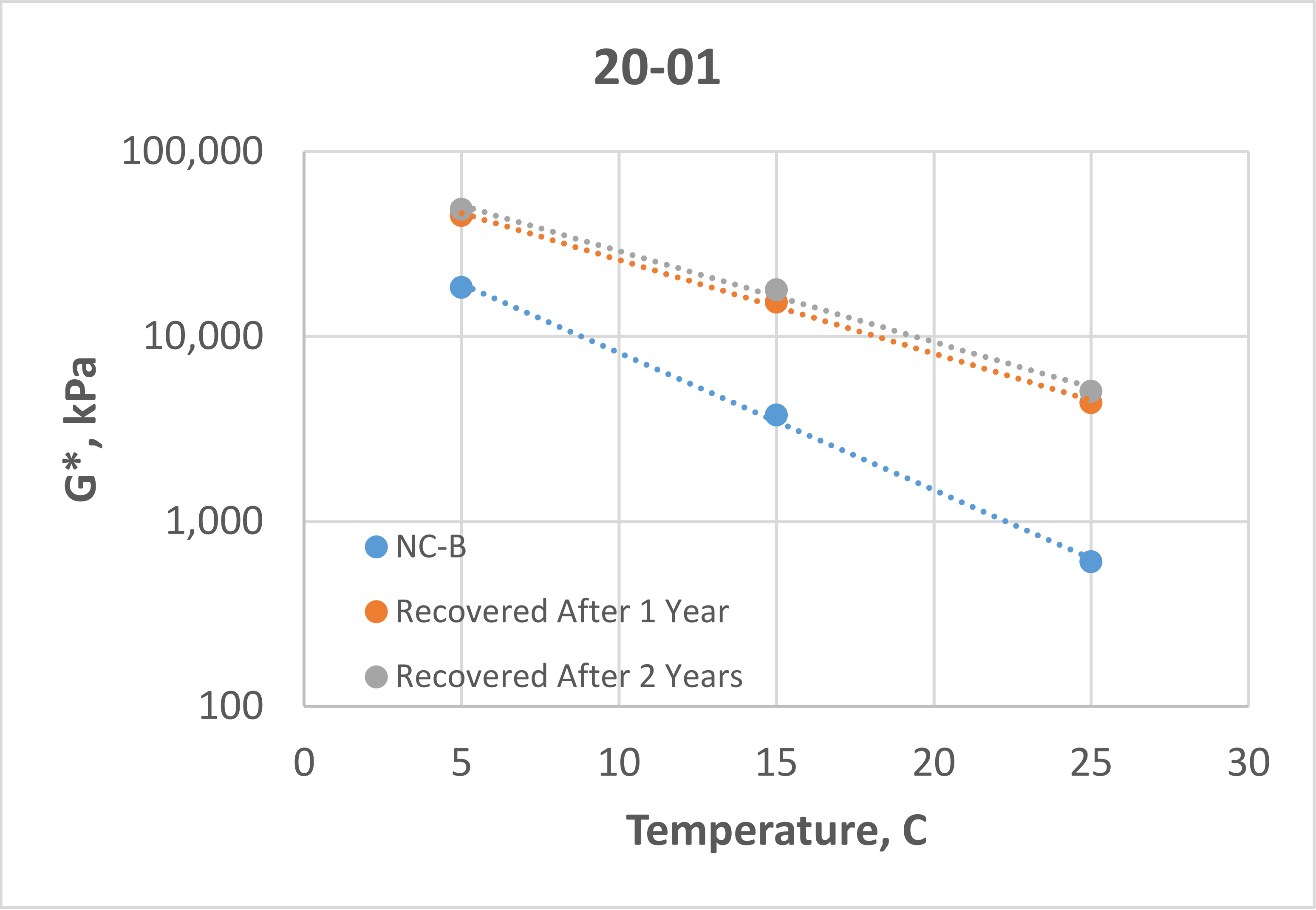
Recovery of Asphalt Emulsion Residue from Surface Treatment: 2020 Field Projects

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

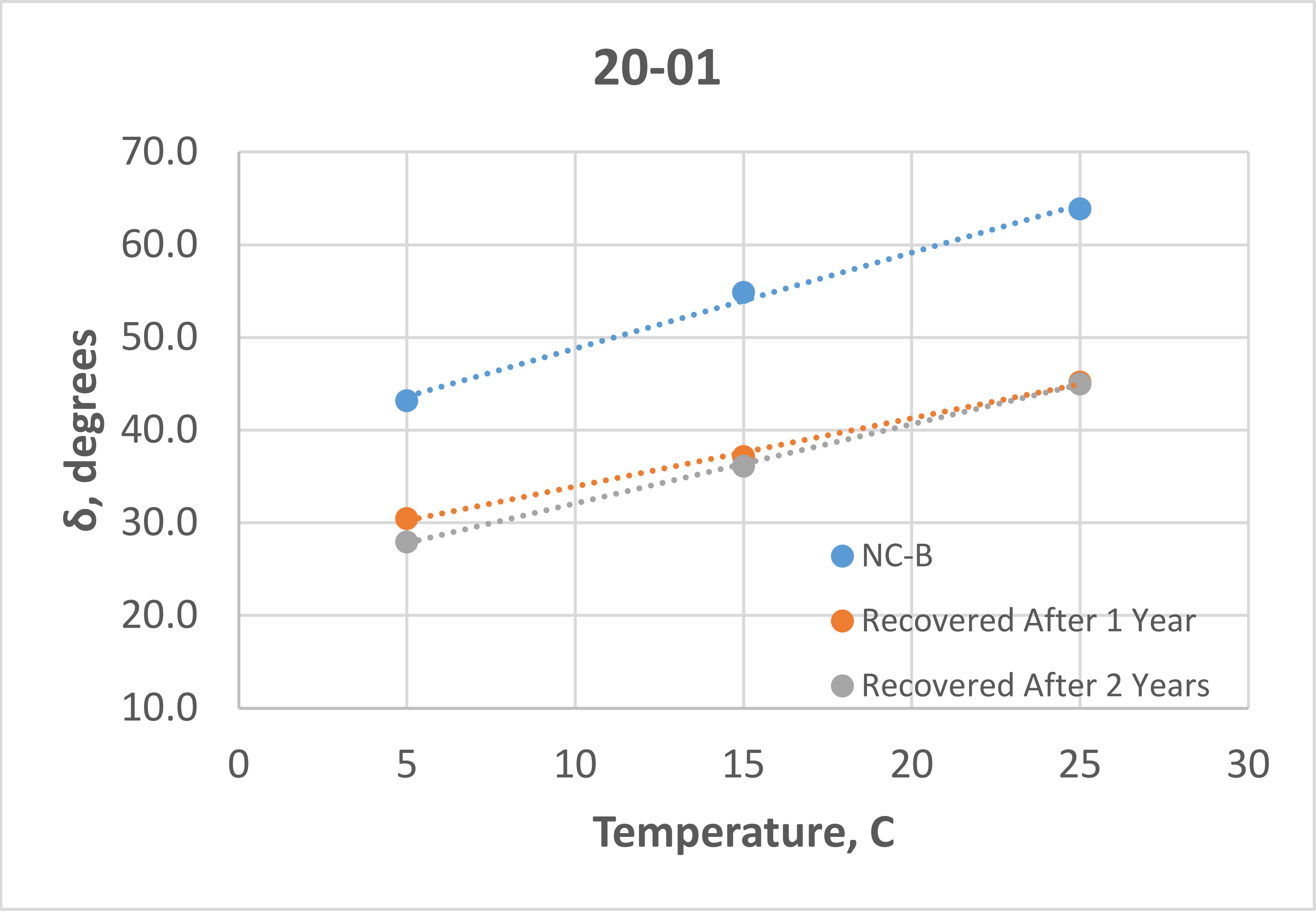
Recovery of Asphalt Emulsion Residue from Surface Treatment



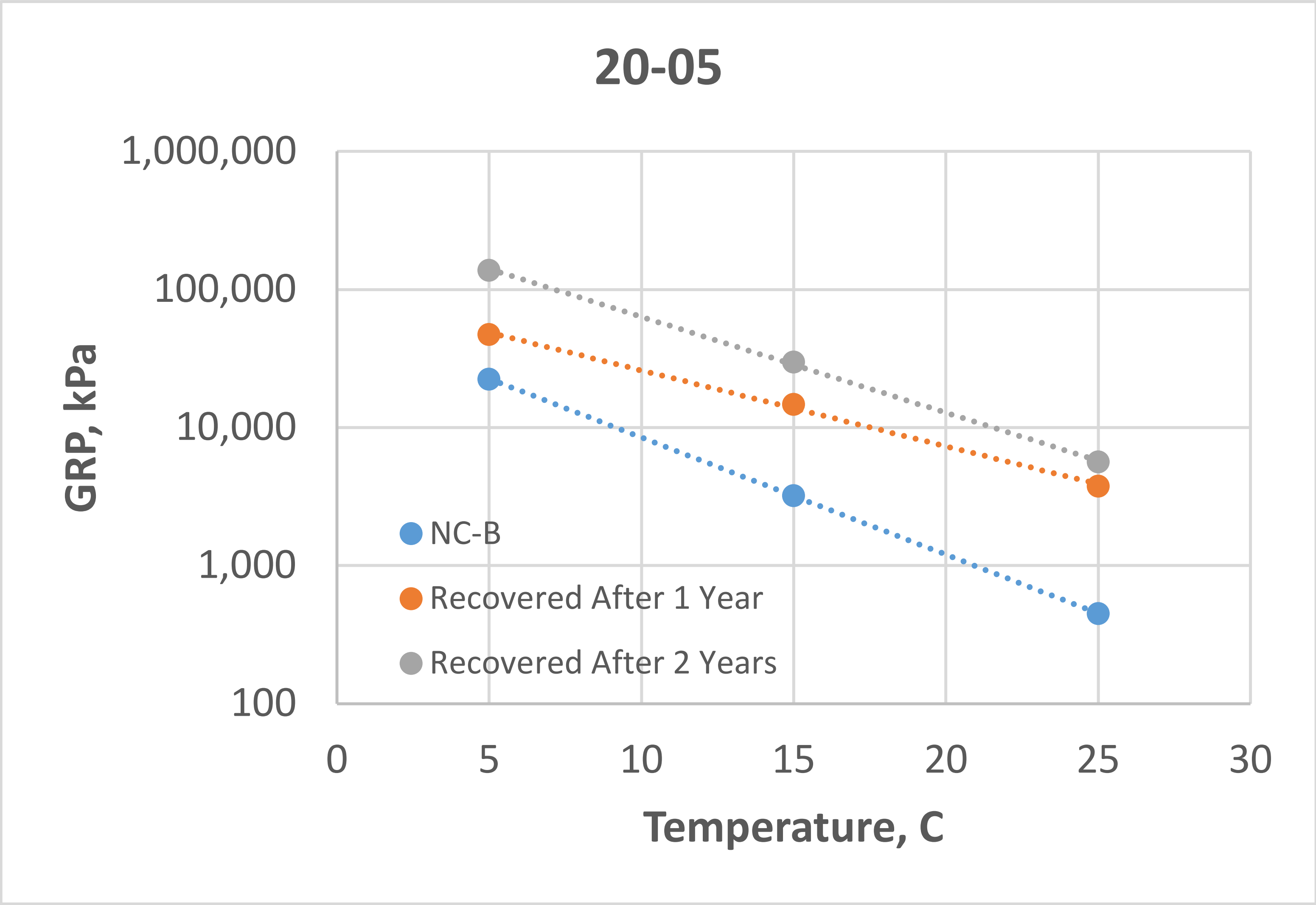
Recovery of Asphalt Emulsion Residue from Surface Treatment



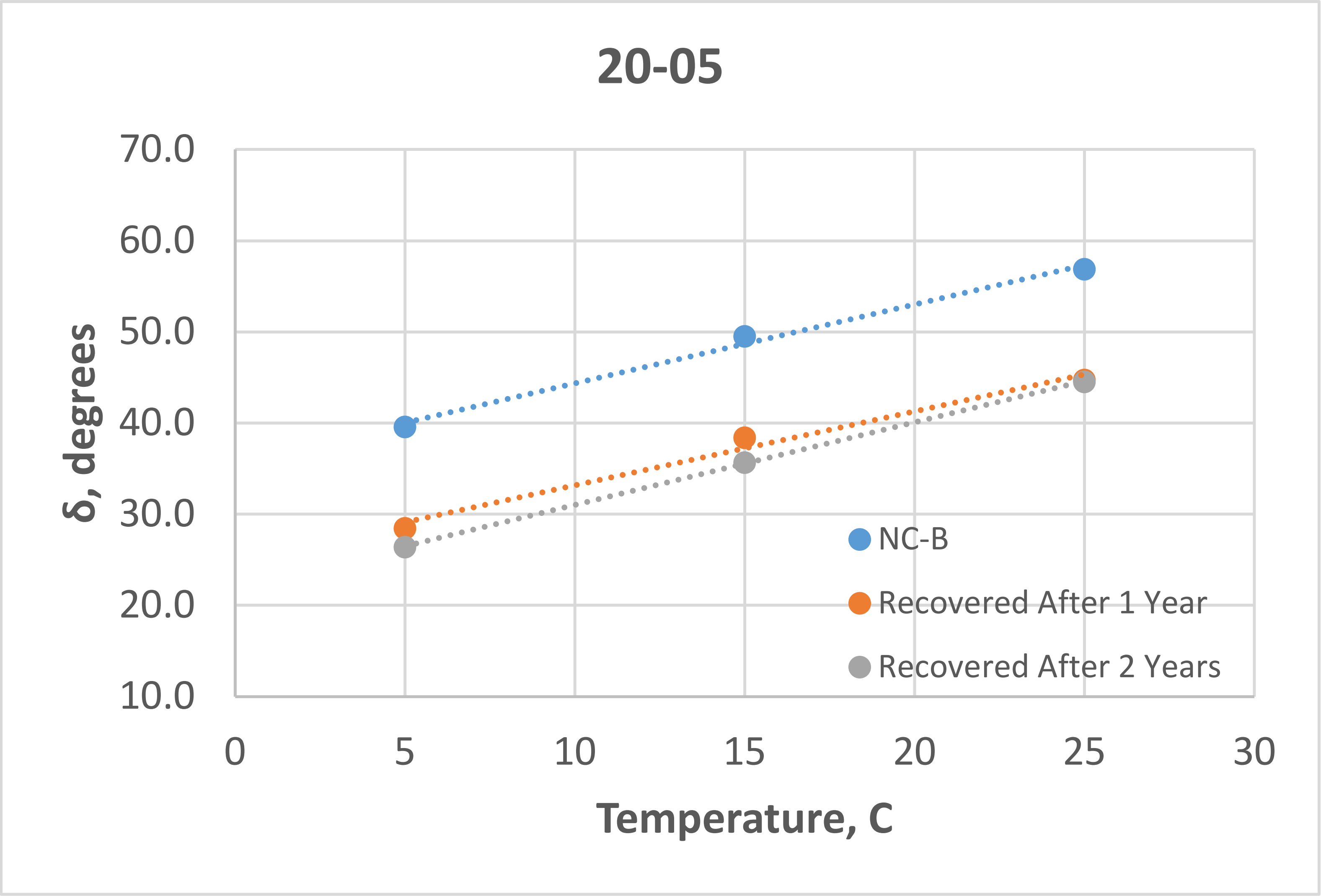
Recovery of Asphalt Emulsion Residue from Surface Treatment



Recovery of Asphalt Emulsion Residue from Surface Treatment



Recovery of Asphalt Emulsion Residue from Surface Treatment



Recovery of Asphalt Emulsion Residue from Surface Treatment

TABLE 11. Residue Properties Determined at Intermediate Test Temperature for 20-01 Project

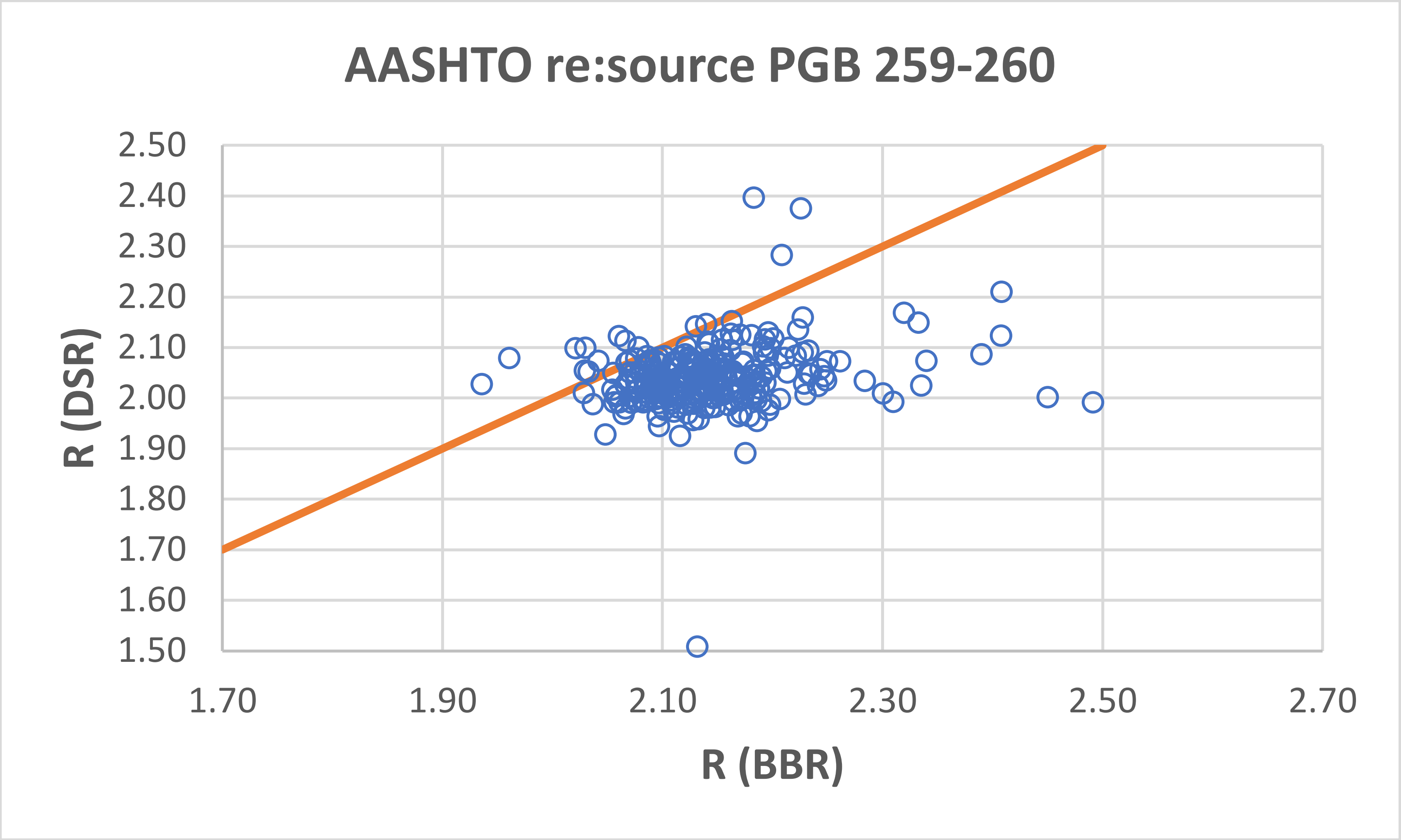
	Intermediate Test Temp, °C	Lab Recovered (NC-B)	Field Recovered (AI)
G*, kPa	22	1050	6477
δ, degrees	22	61.2	42.7
GRP, kPa	22	273	5116
R	22	1.81	2.35

The R value is determined using the following equation:

$$R = \log(2) * \frac{\log\left(G^*/1{,}000{,}000\right)}{\log\left(1-(\delta/90)\right)}$$

where G* is in kPa and δ is in degrees.

Determination of R from DSR and BBR Data



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.

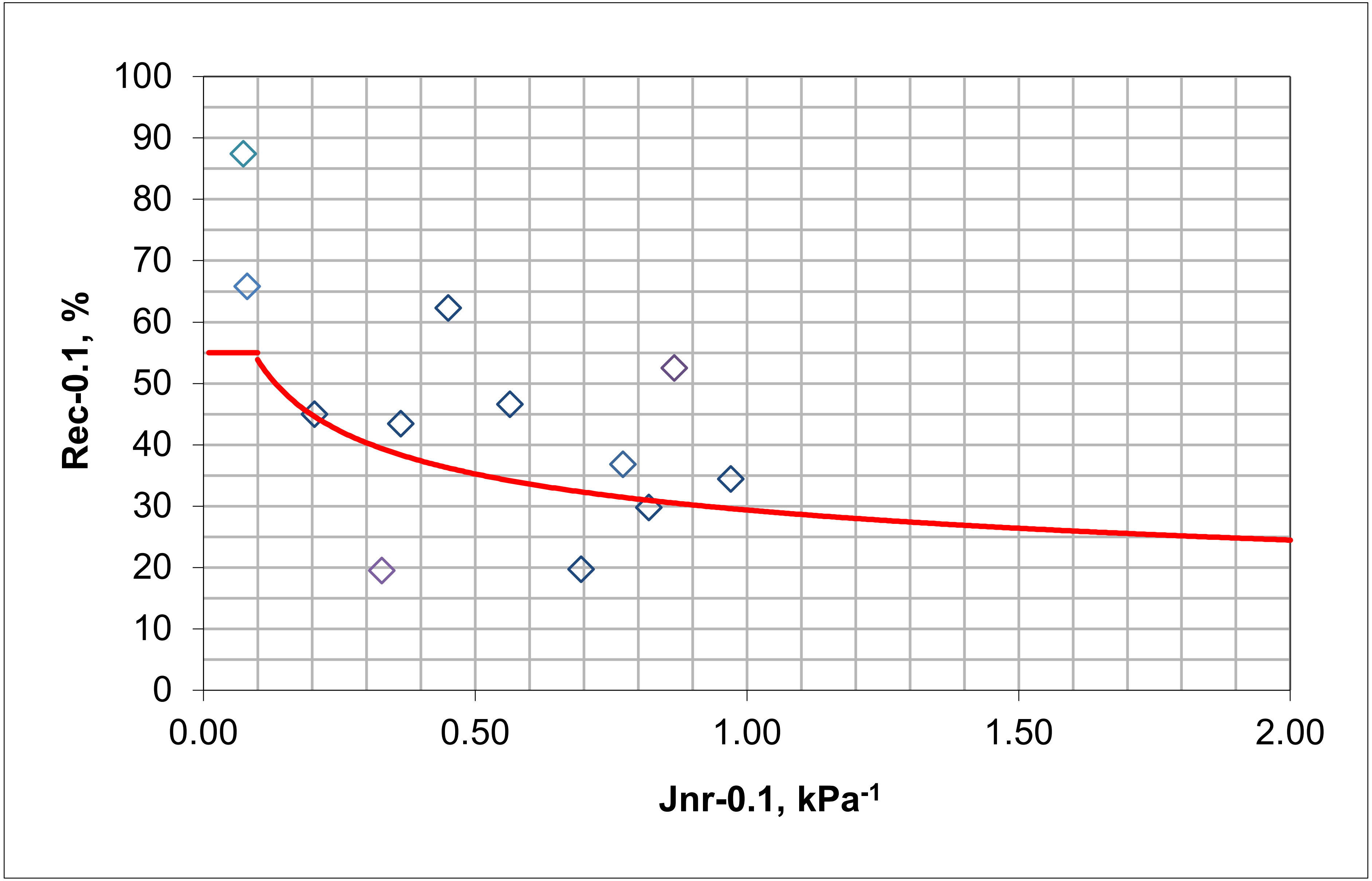
3 AASHTO T 315 is used to determine the G*/sin δ value of the EAPG asphalt binder.

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

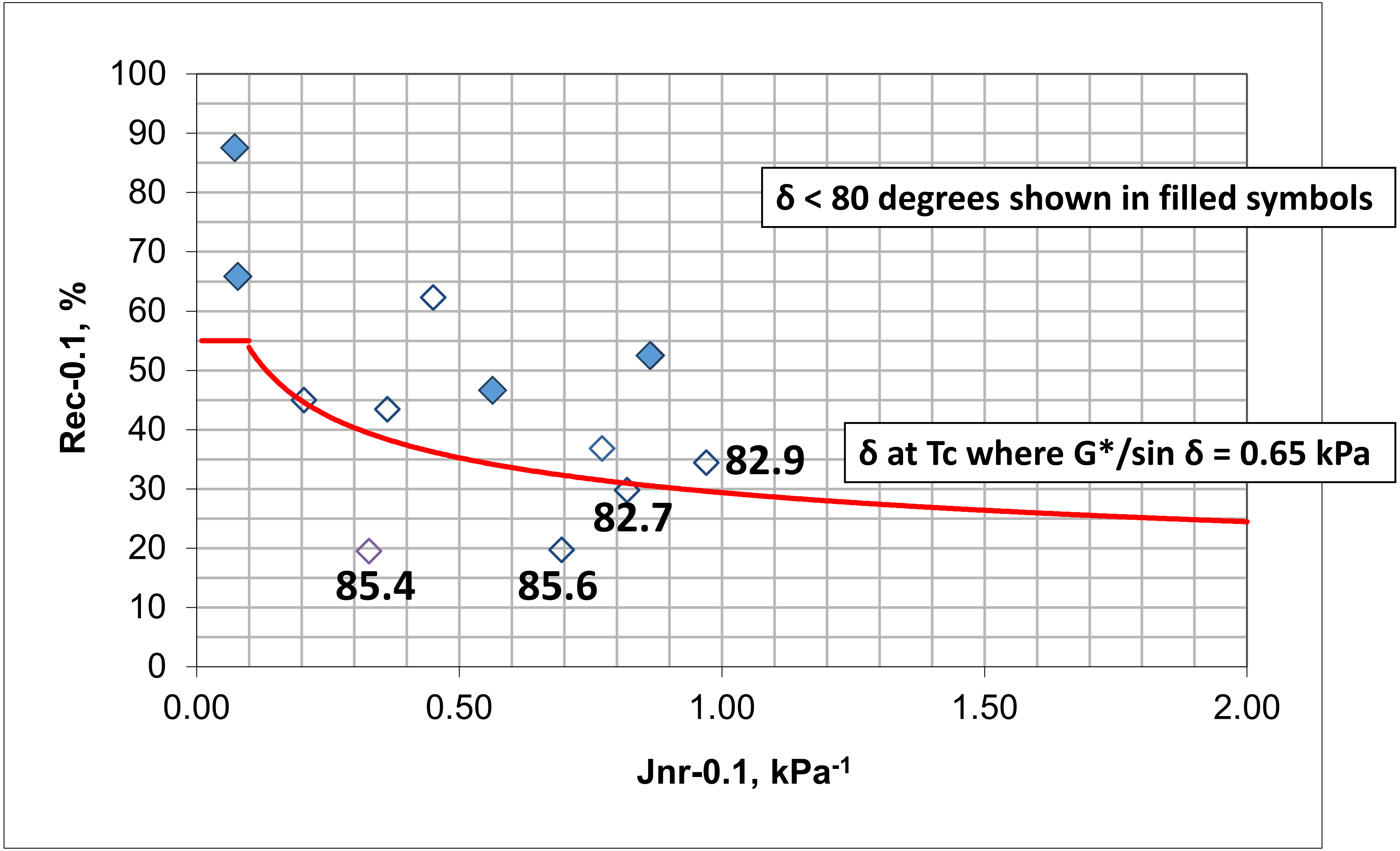
5 "GRP" is the Glover-Rowe Parameter, defined as $G^*(\cos\delta)^2/\sin\delta$. Testing is conducted using AASHTO T 315

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.

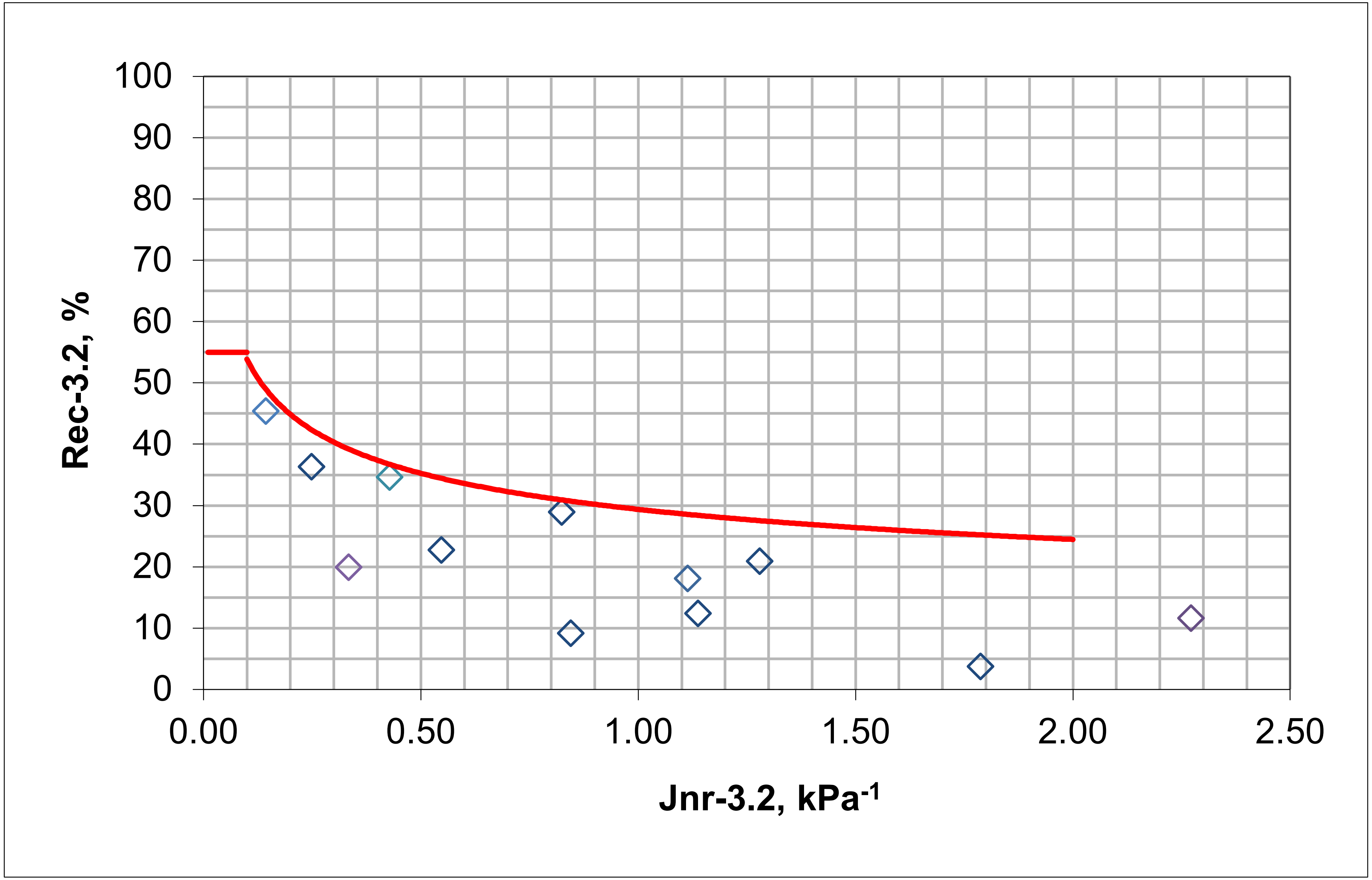
NCHRP 09-63 Draft EAPG Specification: Polymer Identification



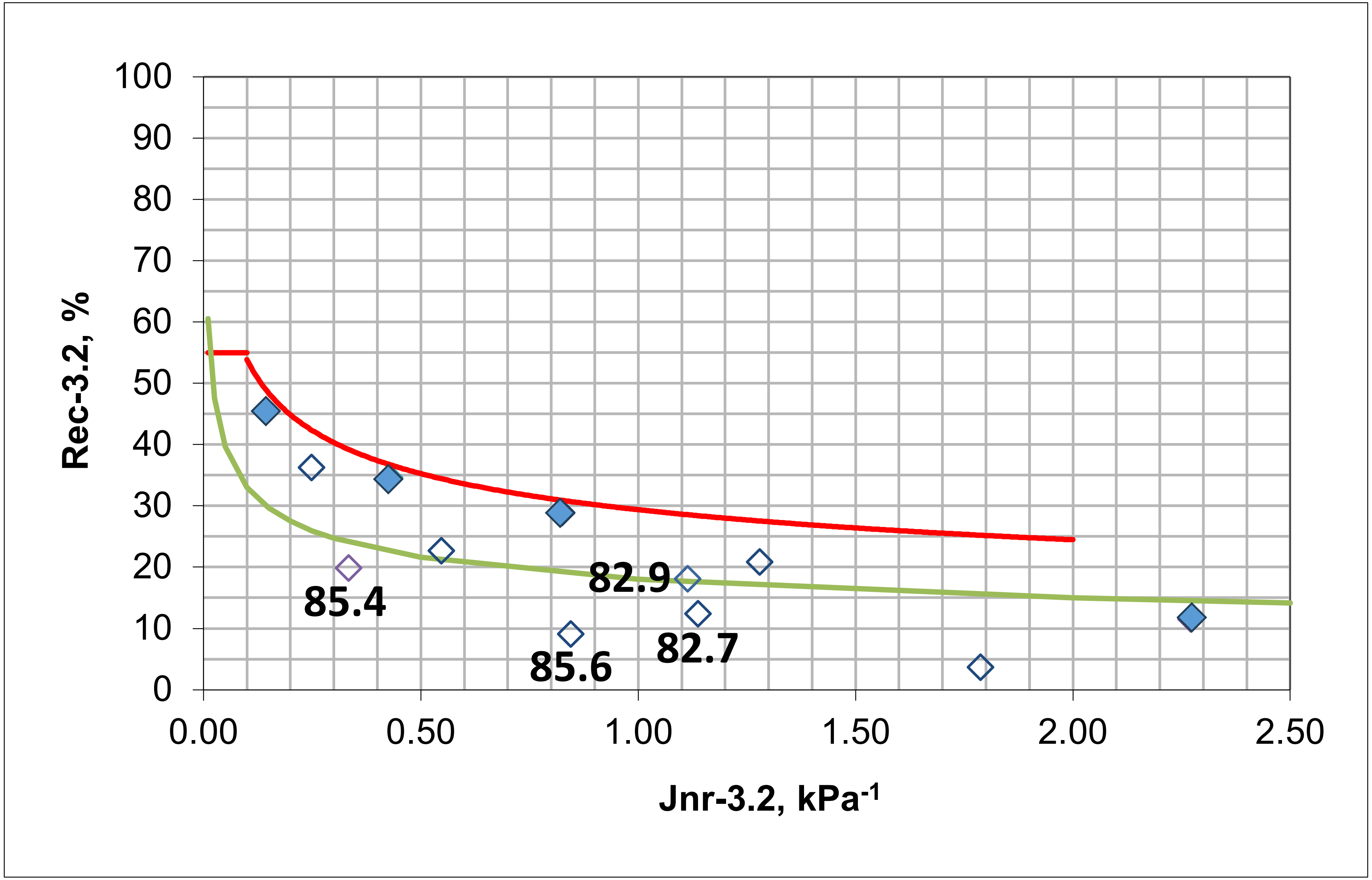
NCHRP 09-63 Draft EAPG Specification: Polymer Identification



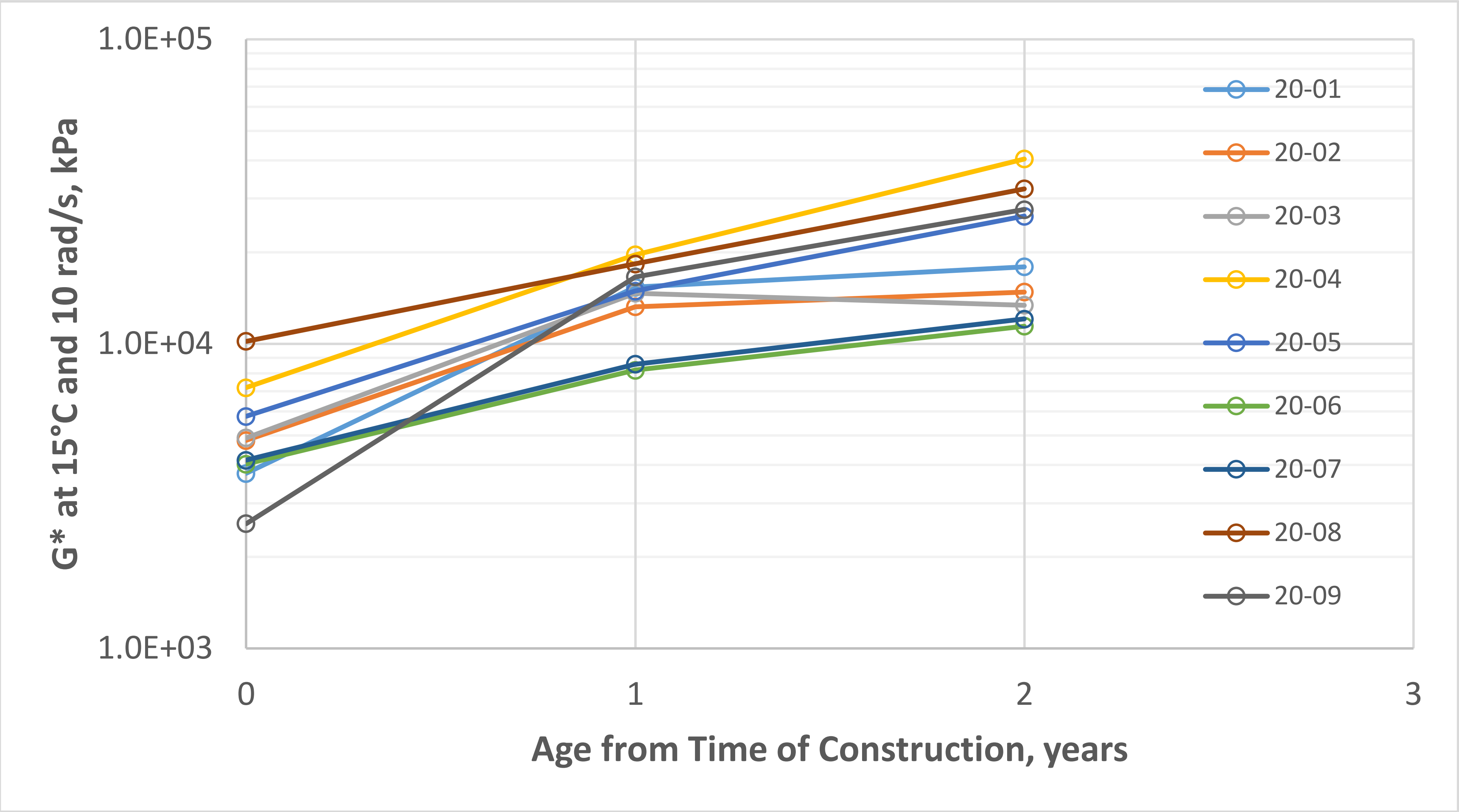
NCHRP 09-63 Draft EAPG Specification: Polymer Identification



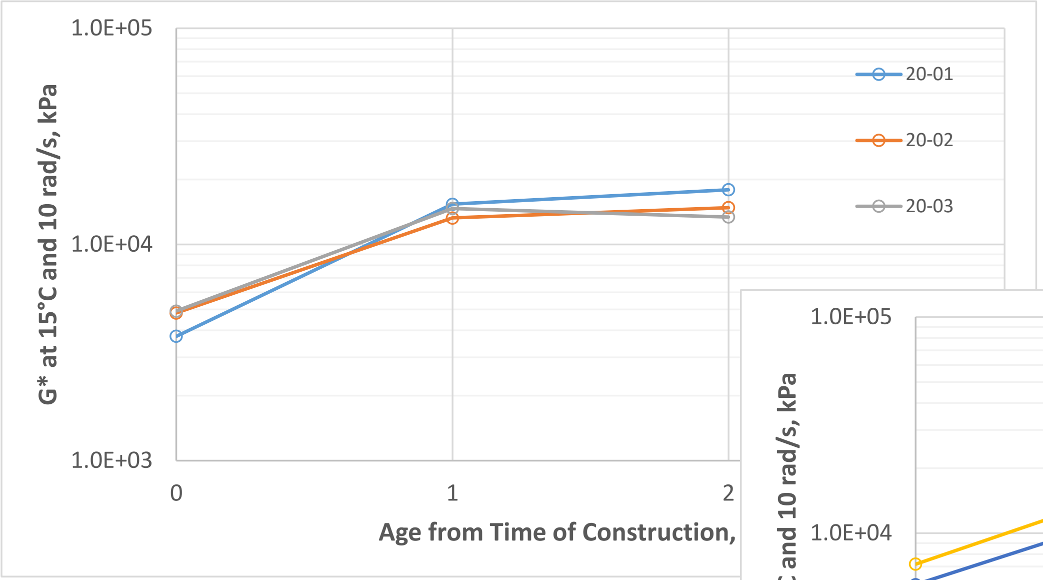
NCHRP 09-63 Draft EAPG Specification: Chip Seals

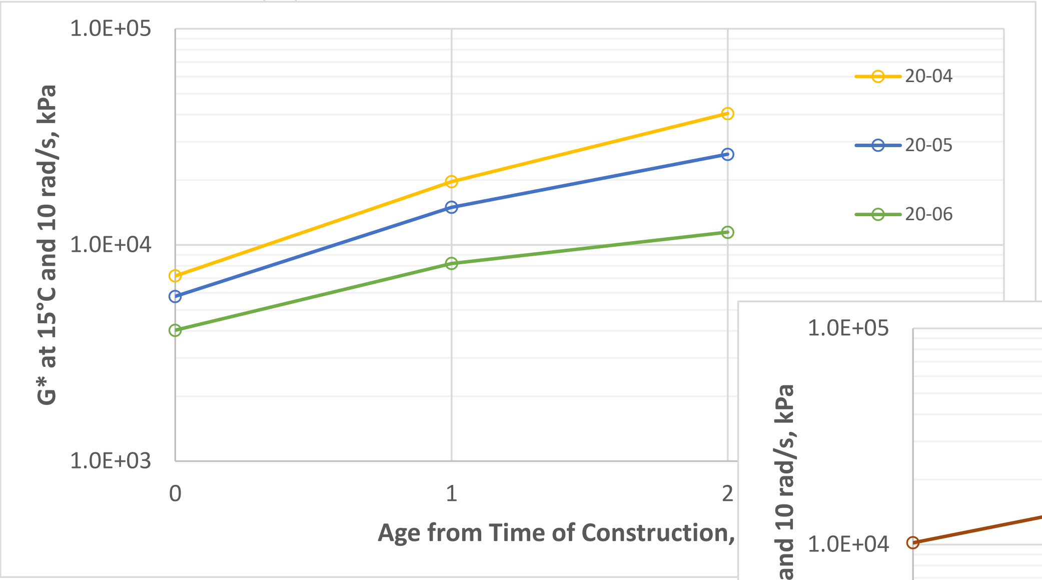


2020 Field Projects: Aging Profiles for G*

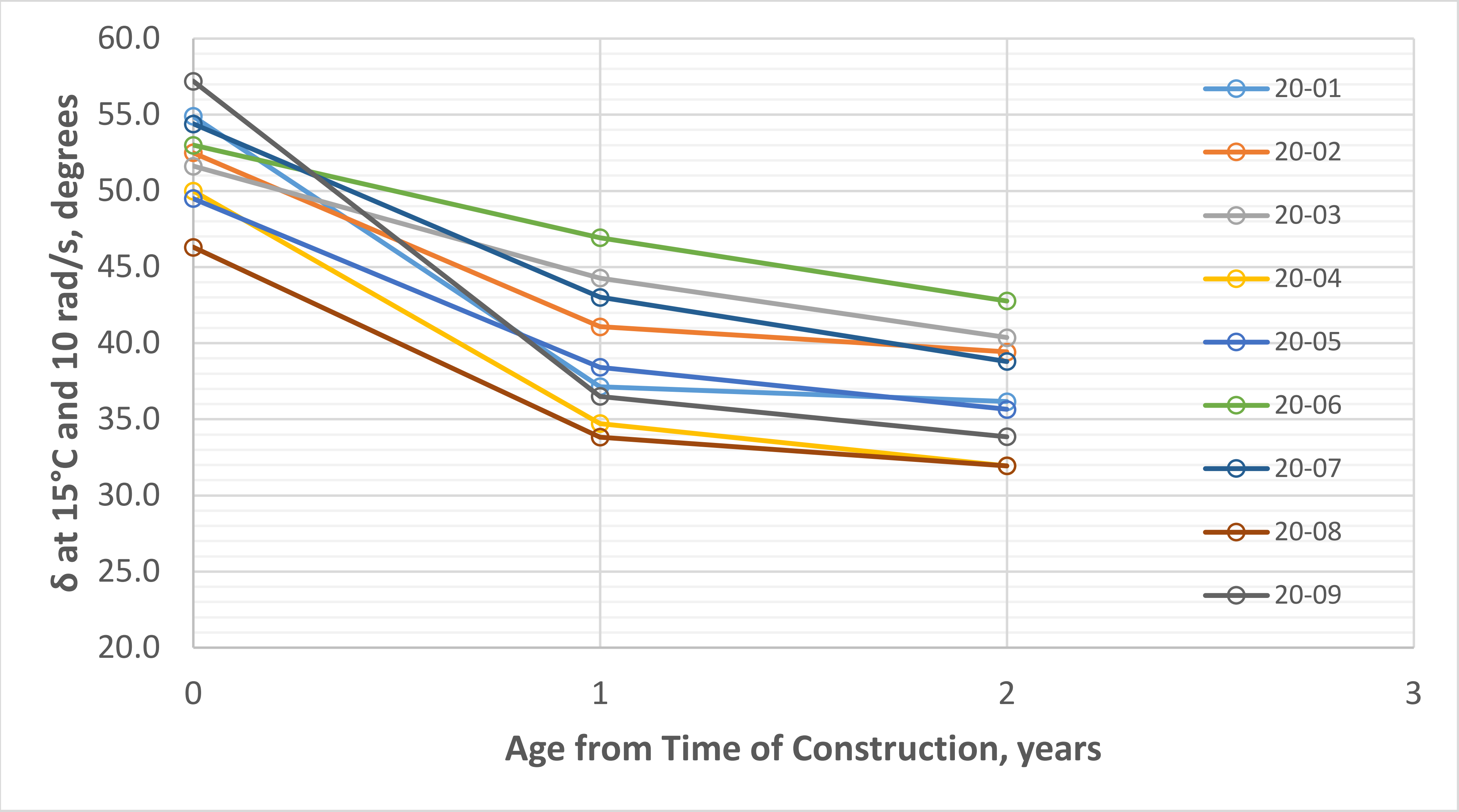


2020 Field Projects: Aging Profiles for G*

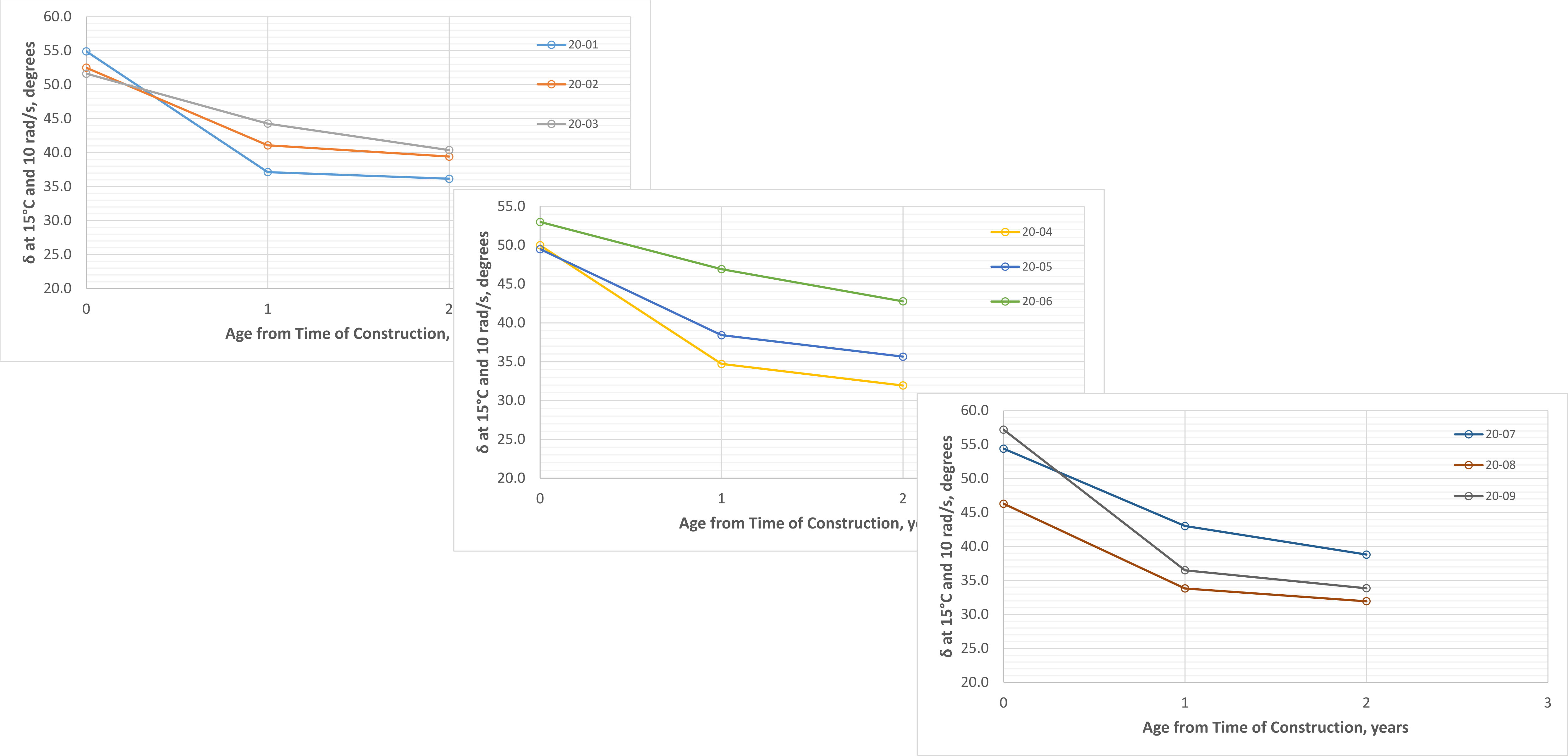




2020 Field Projects: Aging Profiles for δ



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

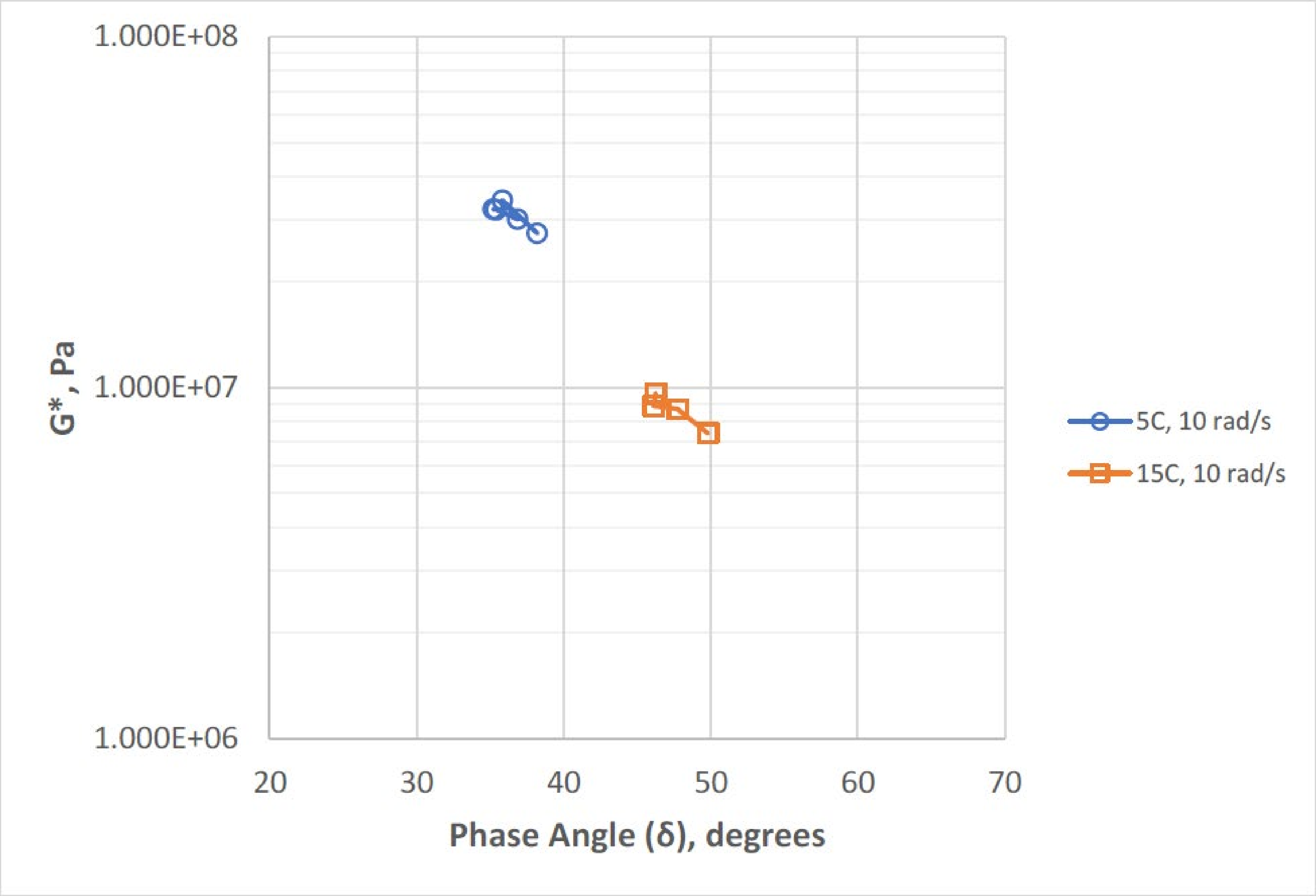
Oxidation (Age Hardening) of Asphalt Materials

- 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.

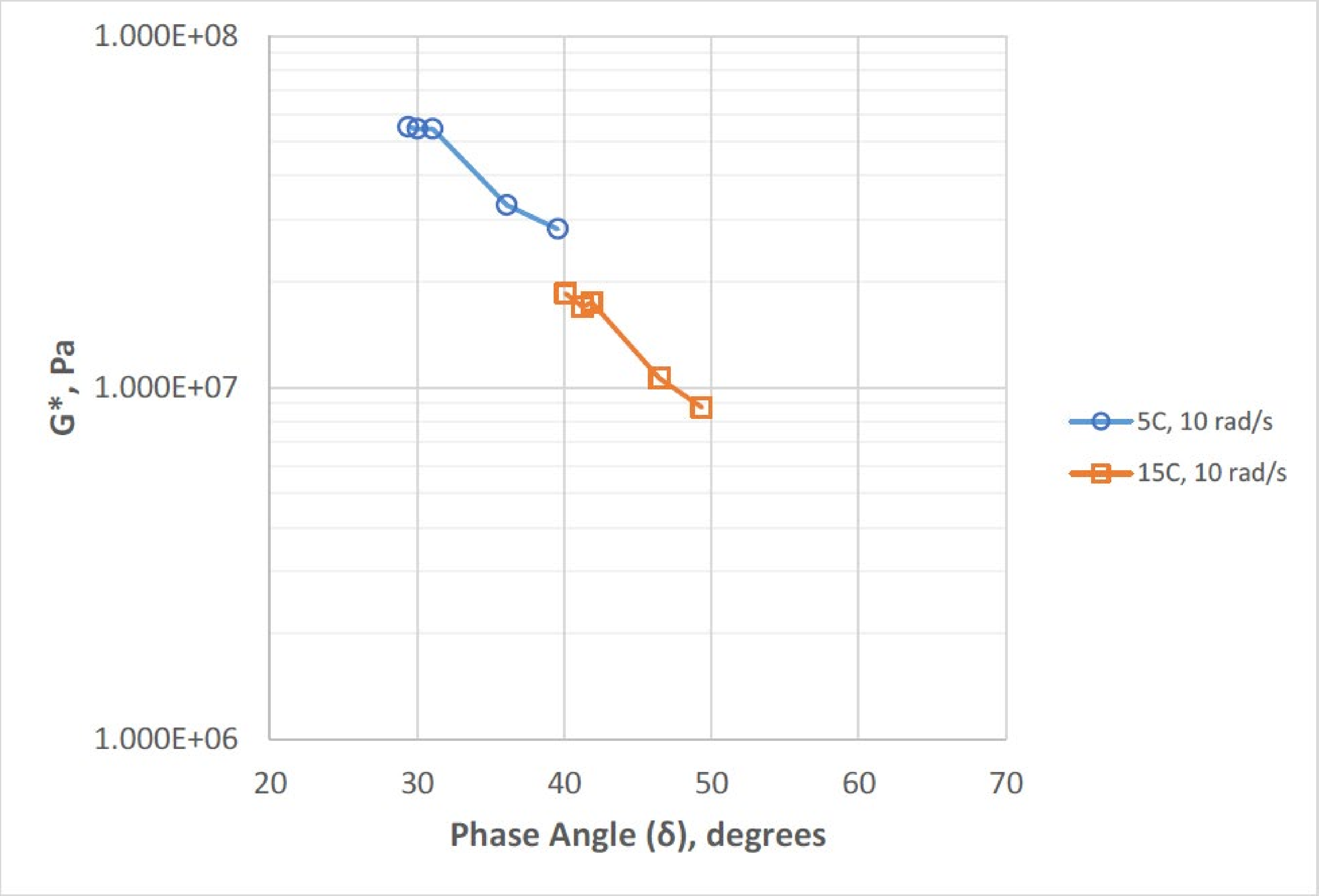
California PMCRS-2h: Impact of Extended Aging

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

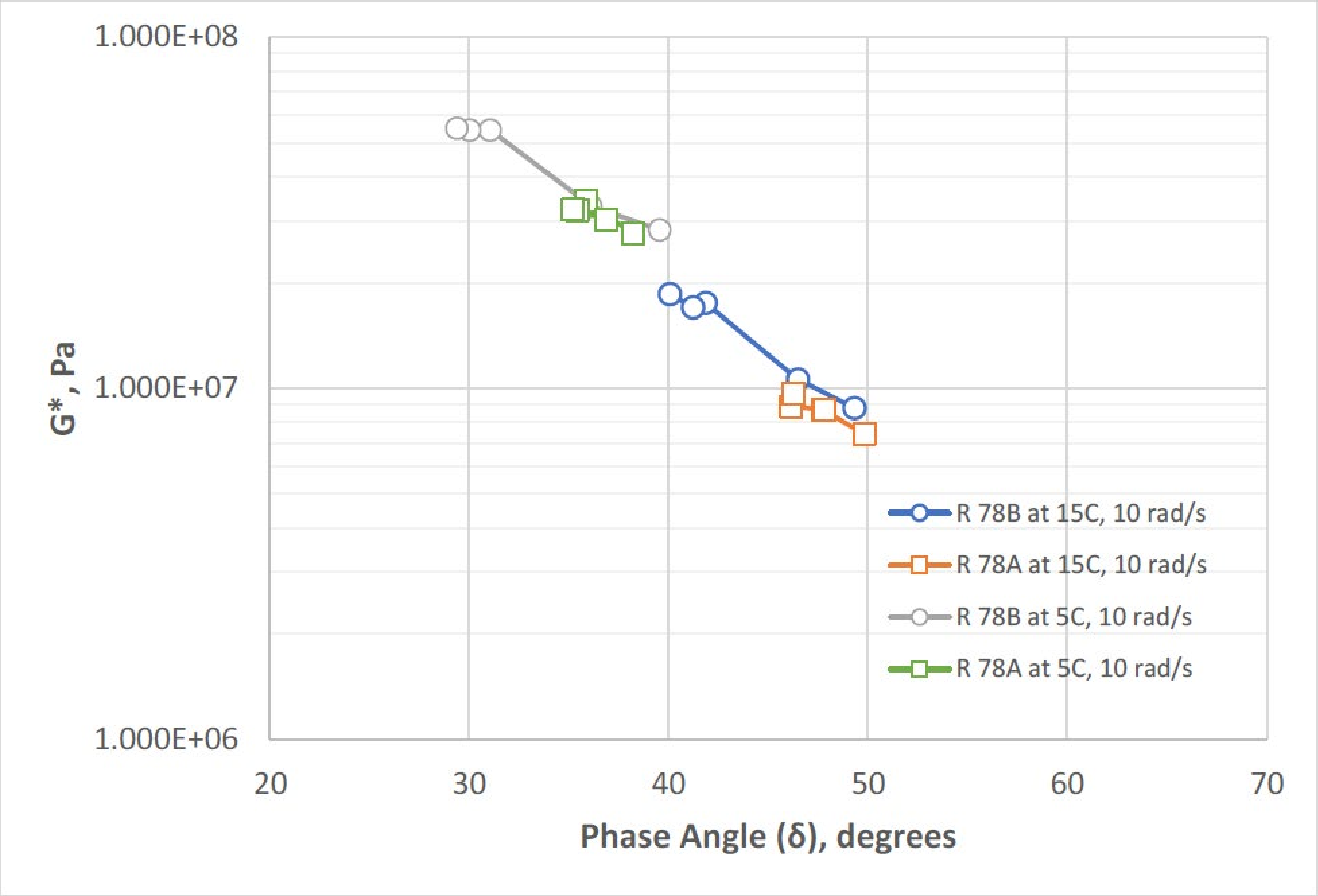
California PMCRS-2h: Impact of Extended Aging on Black Space



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



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!

Mike Anderson

manderson@asphaltinstitute.org

859.288.4984 office

502.641.2262 cell