Intermediate Temperature Parameter for PG Asphalt Binders

Asphalt Binder Expert Task Group Meeting

16 September 2014

Baton Rouge, LA

Asphalt Binder ETG: Intermediate Temperature Parameter Task Force

- Task Force
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  - Gaylon Baumgardner
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  - Bob McGennis
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  - Gerald Reinke
  - Geoff Rowe
  - Hassan Tabatabaee

Intermediate Temperature Parameter Task Force

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- Purpose
  - To evaluate the existing intermediate temperature parameter and criterion in AASHTO M320 and MP332 and, if necessary, revise and/or develop one or more parameters that:
    - do not require significantly more testing than the current intermediate temperature parameter ($G^* \sin \delta$) determined using AASHTO T315;
    - have reproducibility at least comparable to, but preferably better than the d2s% values for the current intermediate temperature parameter; and
    - are related to the rheological and failure properties of the asphalt binder at intermediate temperature.

Intermediate Temperature Parameter Evaluation

- Materials
  - It has been suggested that the asphalt binders being produced today may be different enough from the SHRP binders that the G*sin δ parameter and/or the criterion may not be applicable.

Intermediate Temperature Parameter Evaluation

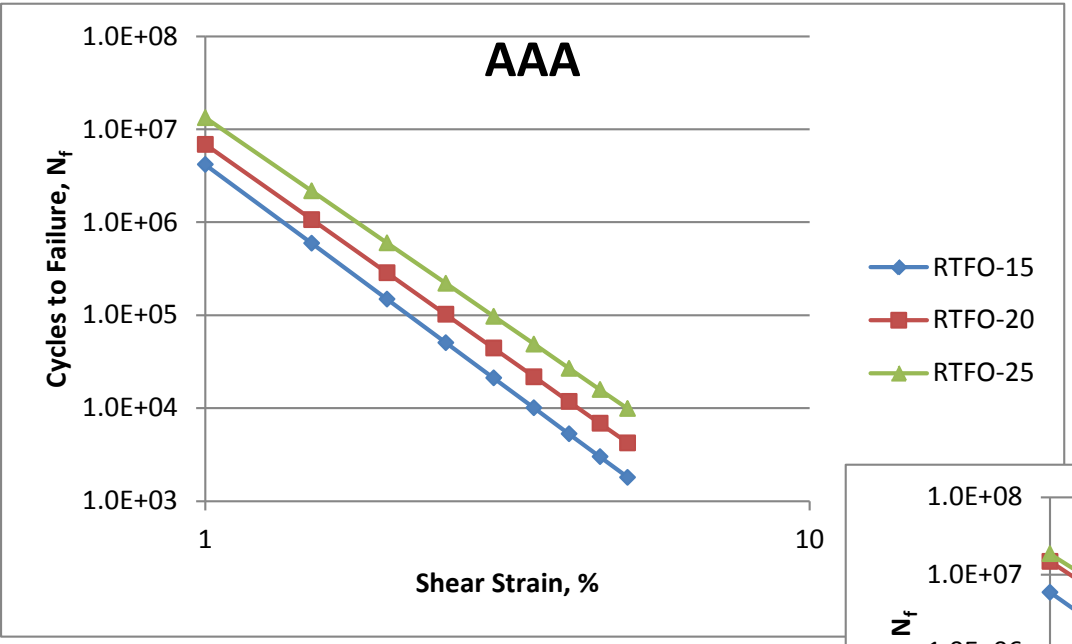
- "Old Conventional"
  - SHRP MRL asphalt binders
  - Used in developing the current PAV DSR parameter
- "New Conventional"
  - Current production
  - Represent cross-section of asphalt binders in US
  - AI to acquire approximately 50 gallons of each for current and future testing. AI to distribute samples as needed to the testing labs
- "New Unconventional"
  - Asphalt binders formulated by Bob McGennis (HollyFrontier) to represent binders that are expected to have some unusual intermediate temperature responses compared to "New Conventional" asphalt binders

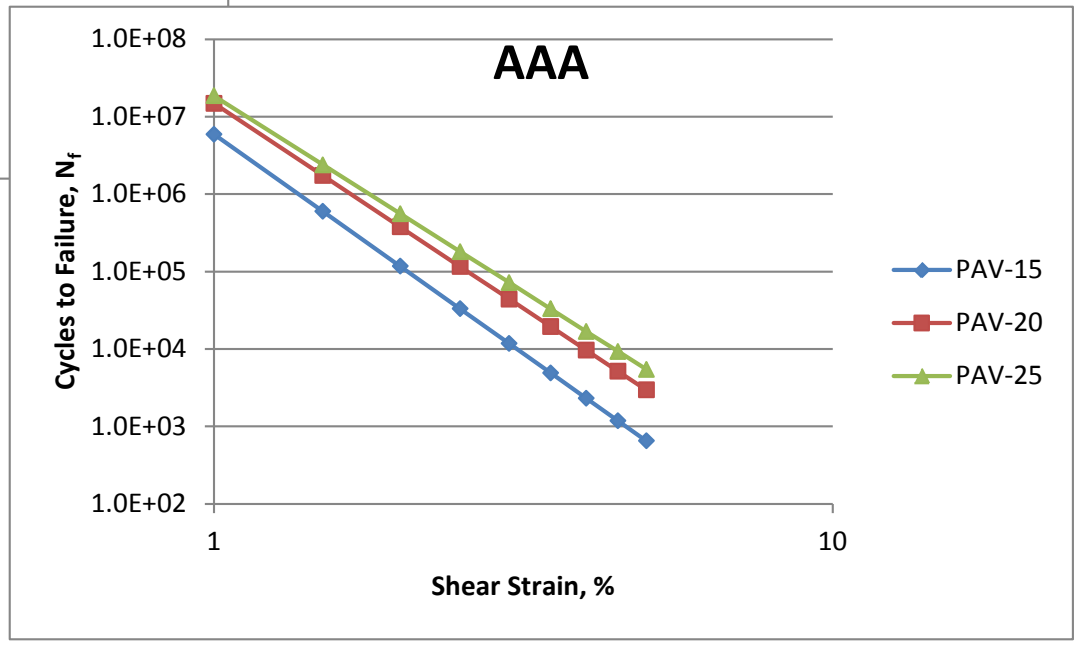
“Old Conventional” Asphalt Binders

- SHRP MRL Binders
  - Used in developing the current PAV DSR parameter
  - Evaluate existing data
  - New testing conducted
    - Linear Amplitude Sweep
      - Conducted on RTFO- and PAV-aged binder at 15, 20, and 25°C
      - Additional temperatures for PAV-aged binders corresponding to T_{int} (according to M320 grade)

LAS Data for AAA:

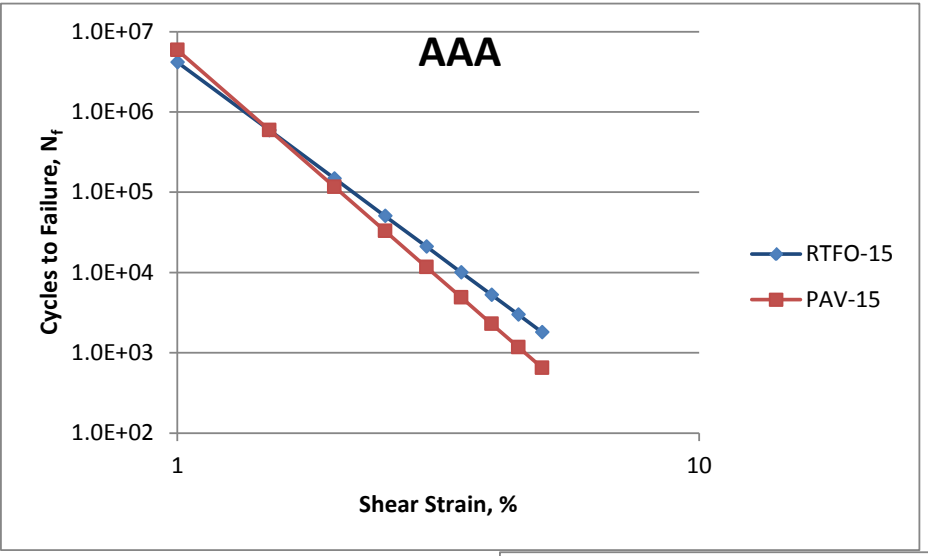
Comparison of Temperature Effect at Varying Aging

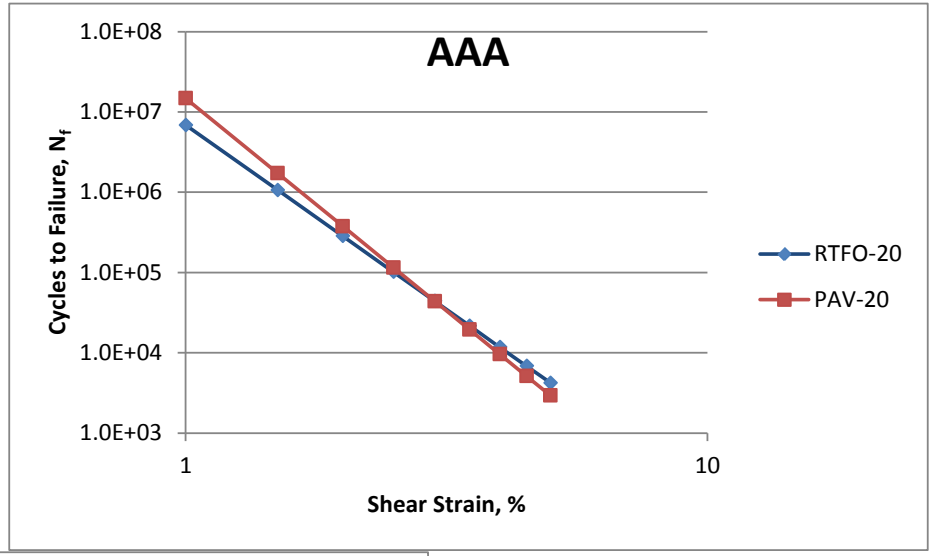


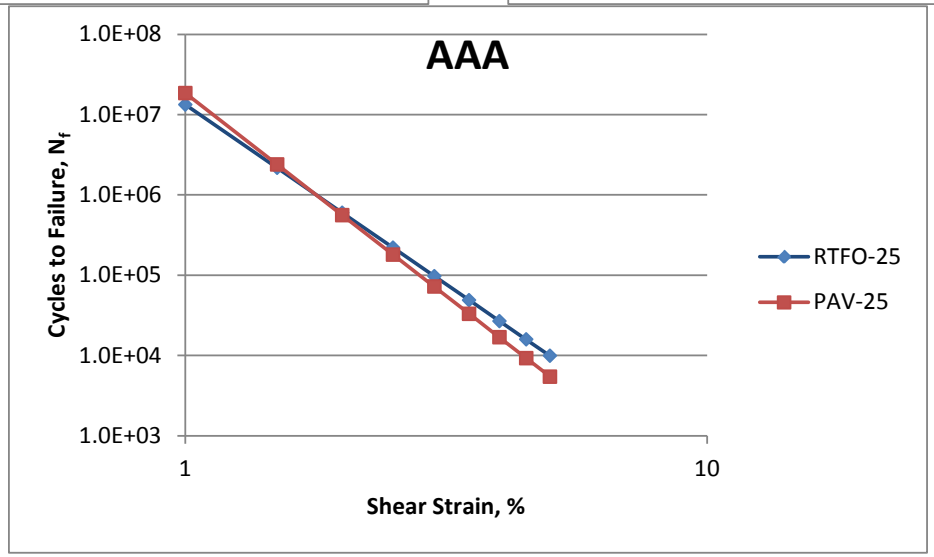


LAS Data for AAA:

Comparison of Aging Effect at Varying Temperature

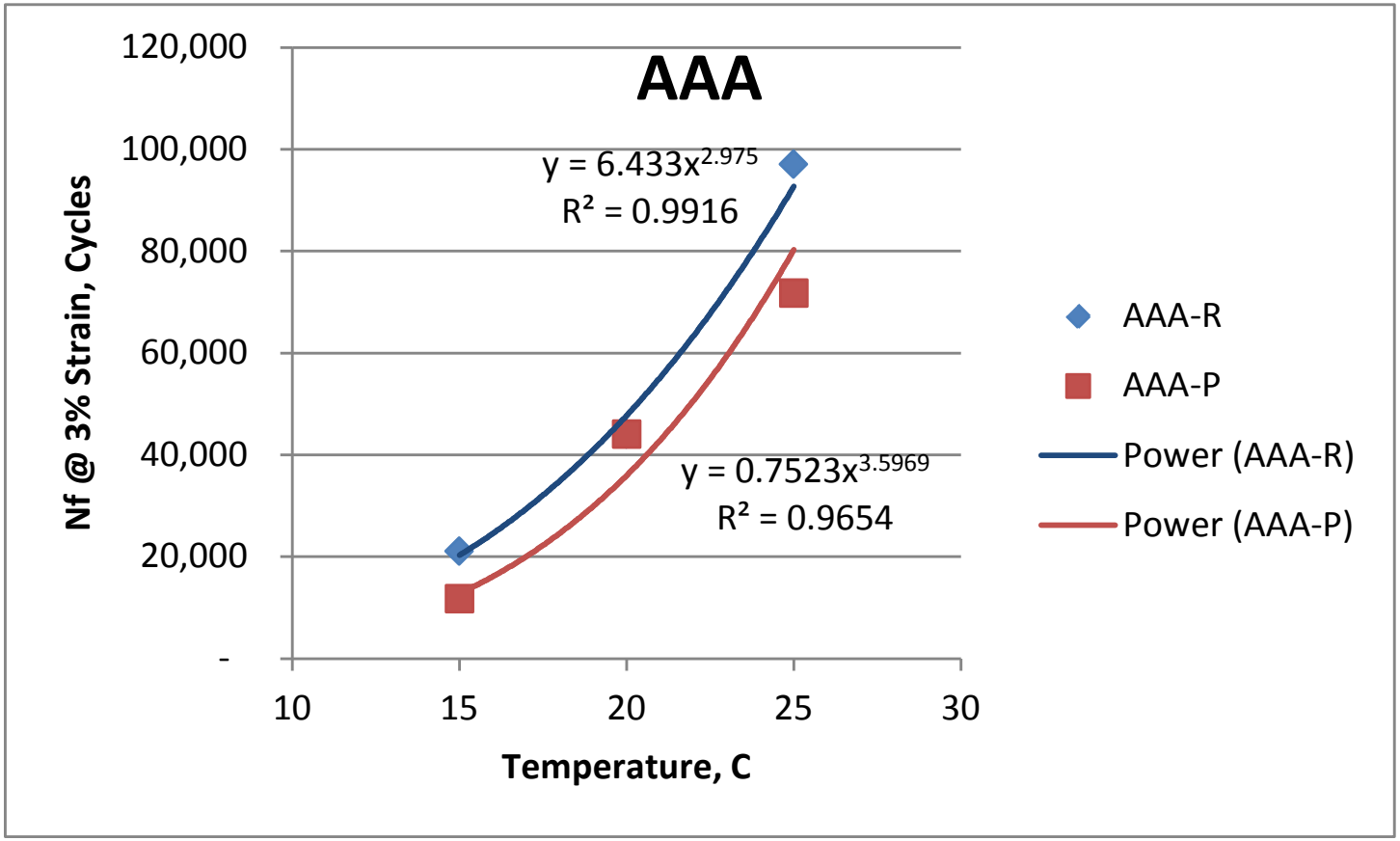






LAS Data for AAA:

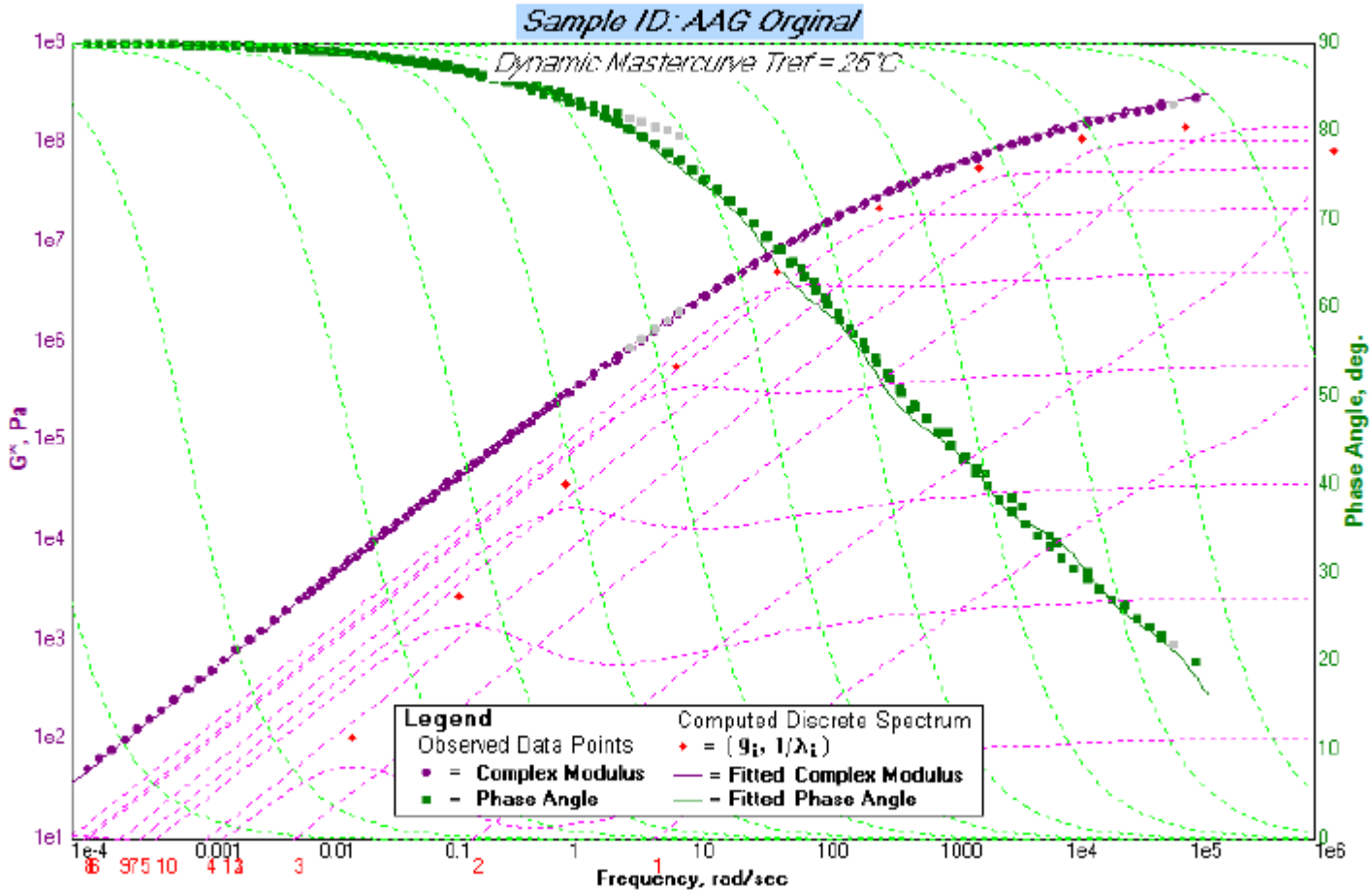
Comparison of Temperature and Aging Effects at Constant Strain



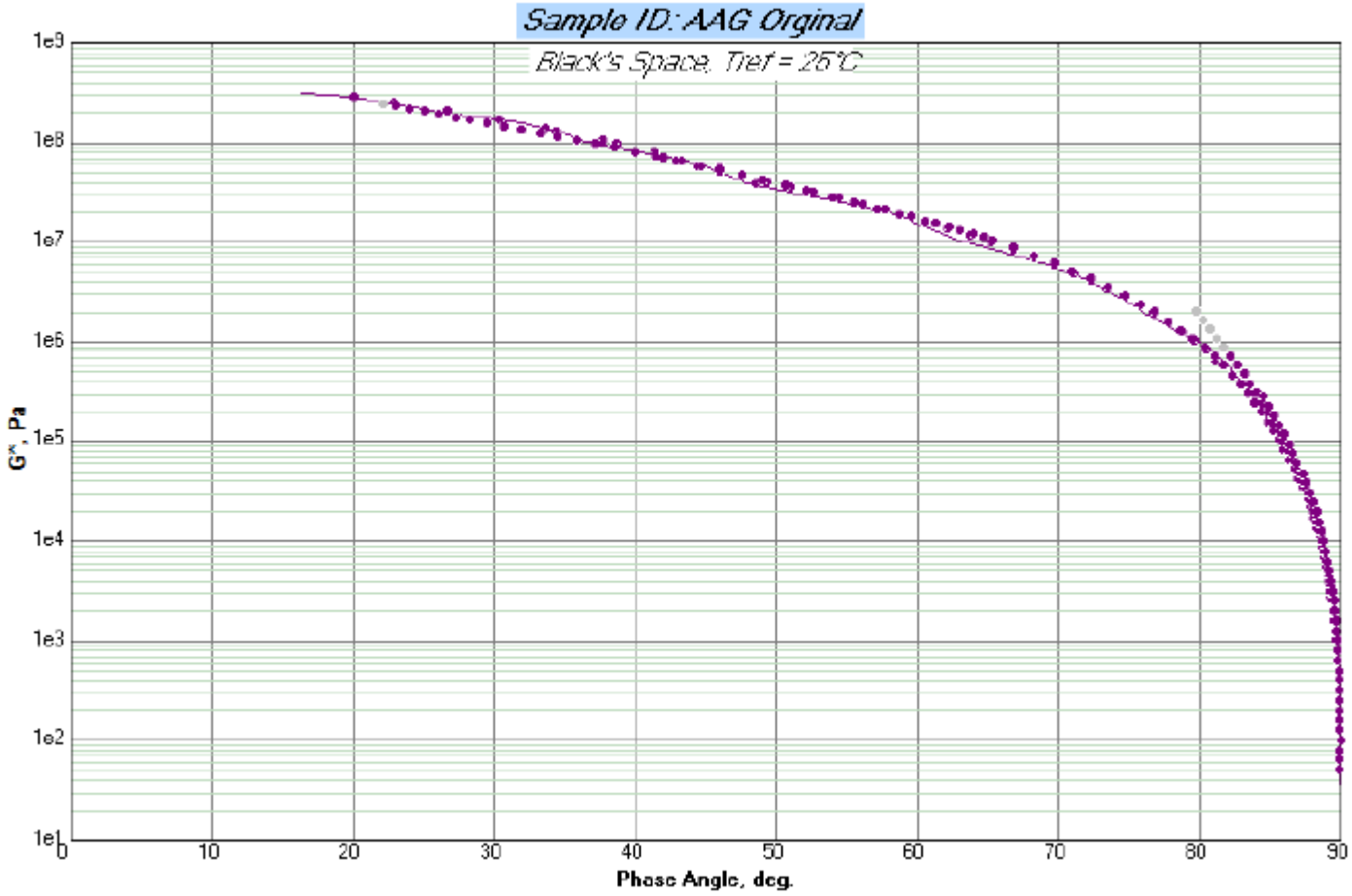
“Old Conventional” Asphalt Binders

- SHRP MRL Binders
  - New testing conducted
    - Temperature-Frequency Sweep
      - Conducted on Original, RTFO-aged, and PAV-aged binders
      - Temperature sweep from 5-55°C
      - Frequency sweep from 0.1 to 100 rad/s (10 pts/decade)
    - BBR Testing
      - Conducted on Original, RTFO-aged, and PAV-aged binders
      - Used with temperature-frequency sweep data to complete mastercurve
    - Mastercurve analysis
      - Geoff Rowe

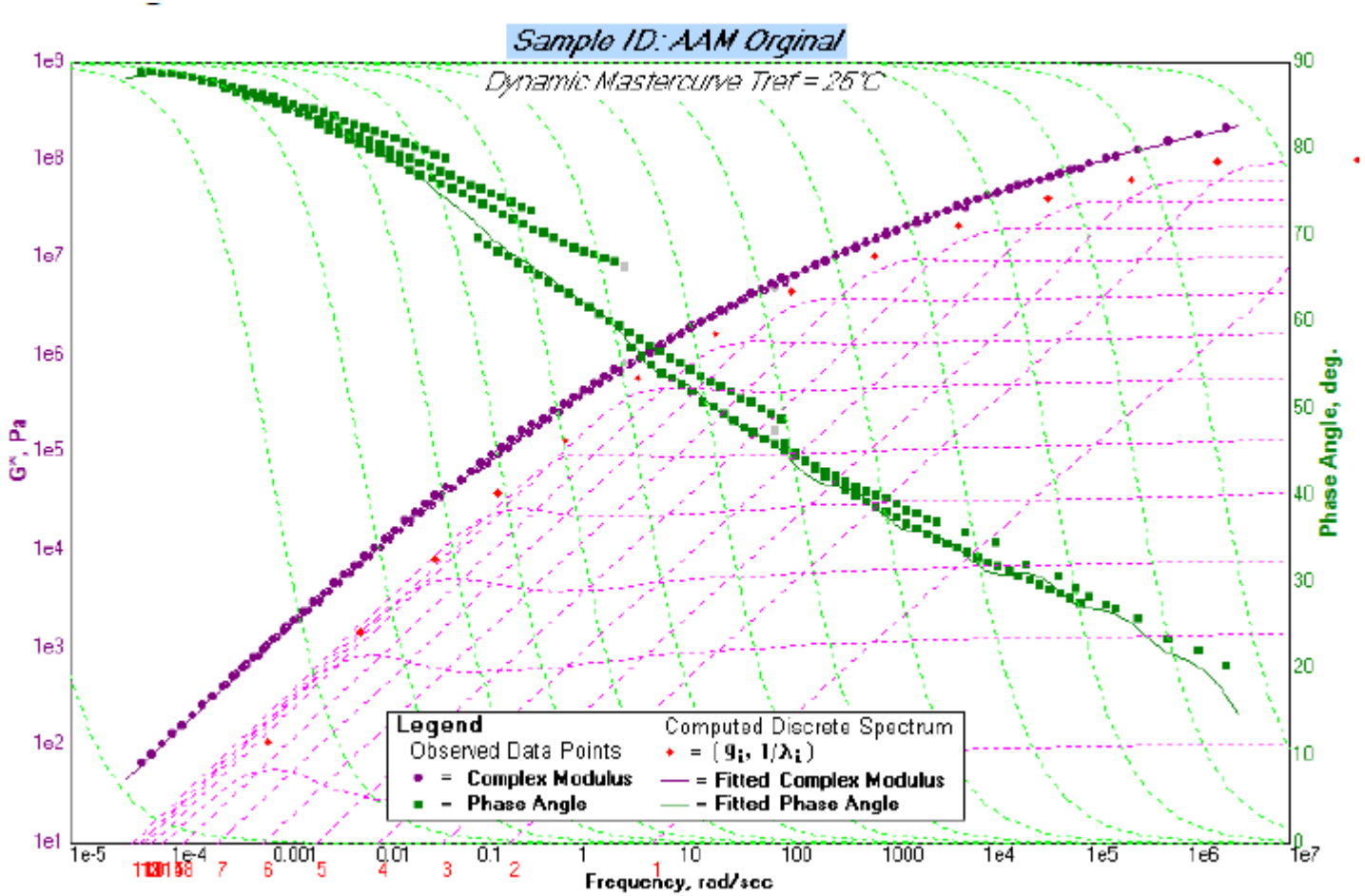
Mastercurve: AAG-Original



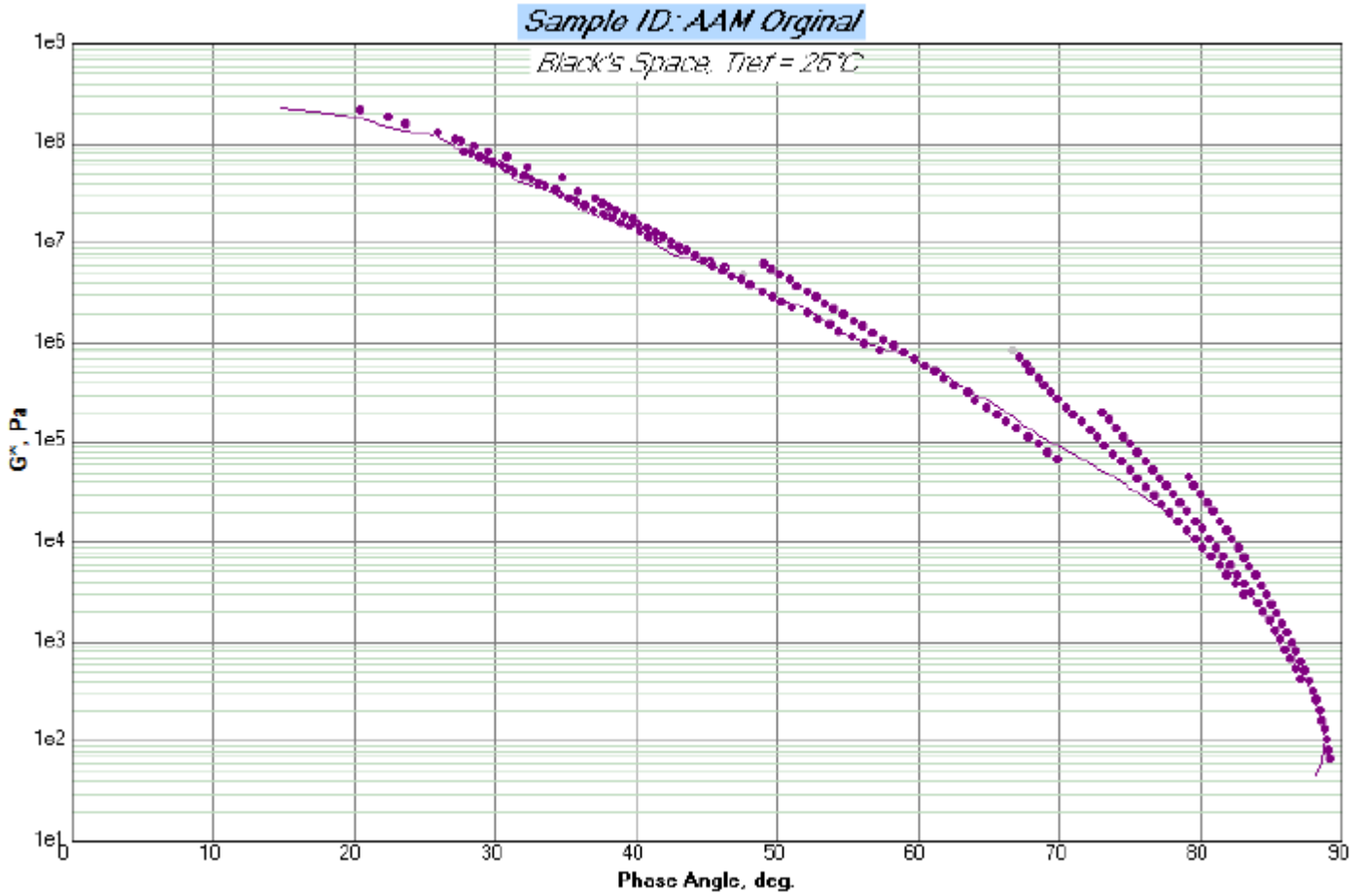
Black Space: AAG-Original



Mastercurve: AAM-Original



Black Space: AAM-Original



“Old Conventional” Asphalt Binders

- SHRP MRL Binders
  - New testing conducted
    - DSC
      - Differential Scanning Calorimeter
      - Used to determine glass transition and crystallization properties
      - Conducted by Western Research Institute
      - Testing complete on AAD, AAG, AAK, and AAM for all three aged conditions (Original, RTFO, and PAV)
    - SAR-AD
      - Automated saturates, aromatics, resins, and Asphaltene Determinator™(AD)
      - Conducted by Western Research Institute
      - Testing complete on AAD, AAG, AAK, and AAM for all three aged conditions (Original, RTFO, and PAV)

DSC Results

Table 2. Summary of DSC Results

Sample	First Heating Scan revHF (u1)					Second Heating Scan revHF (u2)					First Heating Scan HF (u1)		Second Heating Scan HF (u2)		Second Cooling Scan (d2)
	T_{gi} °C	Onset °C	End °C	Width °C	Height J/g	T_{gi} °C	Onset °C	End °C	Width °C	Height J/g	Melting Enthalpy J/g	Crystalline Content mass %	Melting Enthalpy J/g	Crystalline Content, mass %	Crystallization Onset Temperature °C
AAD-O	-25.2	-42.8	4.1	46.9	0.48	-26.0	-43.2	3.7	46.8	0.45	1.49	0.8	1.70	0.9	29.6
AAD-R	-27.8	-42.3	-1.5	40.8	0.42	-27.1	-42.4	-0.7	41.7	0.41	1.78	1.0	1.02	0.6	30.8
AAD-P	-26.7	-43.4	0.7	44.1	0.40	-26.8	-42.5	0.6	43.1	0.39	2.06	1.1	2.04	1.1	34.7
AAG-O	-6.5	-24.3	17.4	41.7	0.38	-5.3	-24.5	17.5	42.0	0.39	0.00	0.0	0.00	0.0	-
AAG-R	-7.9	-25.6	16.3	41.9	0.42	-6.9	-26.8	17.1	43.9	0.42	0.00	0.0	0.00	0.0	-
AAG-P	-6.2	-27.1	18.0	45.1	0.40	-6.0	-28.5	20.0	48.5	0.39	0.00	0.0	0.00	0.0	-
AAK-O	-22.5	-38.6	5.8	44.4	0.36	-24.9	-38.6	3.4	42.1	0.36	2.19	1.2	1.74	1.0	41.0
AAK-R	-22.0	-37.4	3.1	40.5	0.36	-22.0	-38.7	1.3	39.9	0.33	1.73	1.0	1.62	0.9	38.9
AAK-P	-22.6	-39.2	10.5	49.7	0.37	-21.8	-37.9	7.2	45.1	0.36	1.42	0.8	1.30	0.7	41.1
AAM-O	-24.7	-40.8	3.7	44.6	0.44	-24.4	-39.2	6.7	45.9	0.42	6.73	3.7	6.75	3.7	49.7
	39.5	*38.2*	*42.9*	*4.7*	*0.05*	-	-	-	-	-					
AAM-R	-24.0	-40.1	4.1	44.2	0.44	-22.0	-37.6	2.8	40.3	0.36	6.07	3.4	6.68	3.7	49.3
	40.6	*38.7*	*42.1*	*3.4*	*0.05*	-	-	-	-	-					
AAM-P	-23.1	-40.4	4.9	45.3	0.45	-23.7	-37.9	3.2	41.0	0.36	6.75	3.8	6.58	3.7	50.8
	41.0	*38.7*	*42.7*	*4.0*	*0.06*	-	-	-	-	-					

“Old Conventional” Asphalt Binders

- SHRP MRL Binders
  - New testing conducted
    - Torsion Bar
      - Conducted by MTE Services
      - Testing on AAD, AAG, AAK, and AAM for all three aged conditions (Original, RTFO, and PAV)
    - 4-mm Parallel Plate DSR
      - Conducted by MTE Services
      - Testing complete on AAD, AAG, AAK, and AAM for all three aged conditions (Original, RTFO, and PAV)
    - Vialit
      - Coordinated by Geoff Rowe
      - Analysis forthcoming

“New Conventional” Asphalt Binders

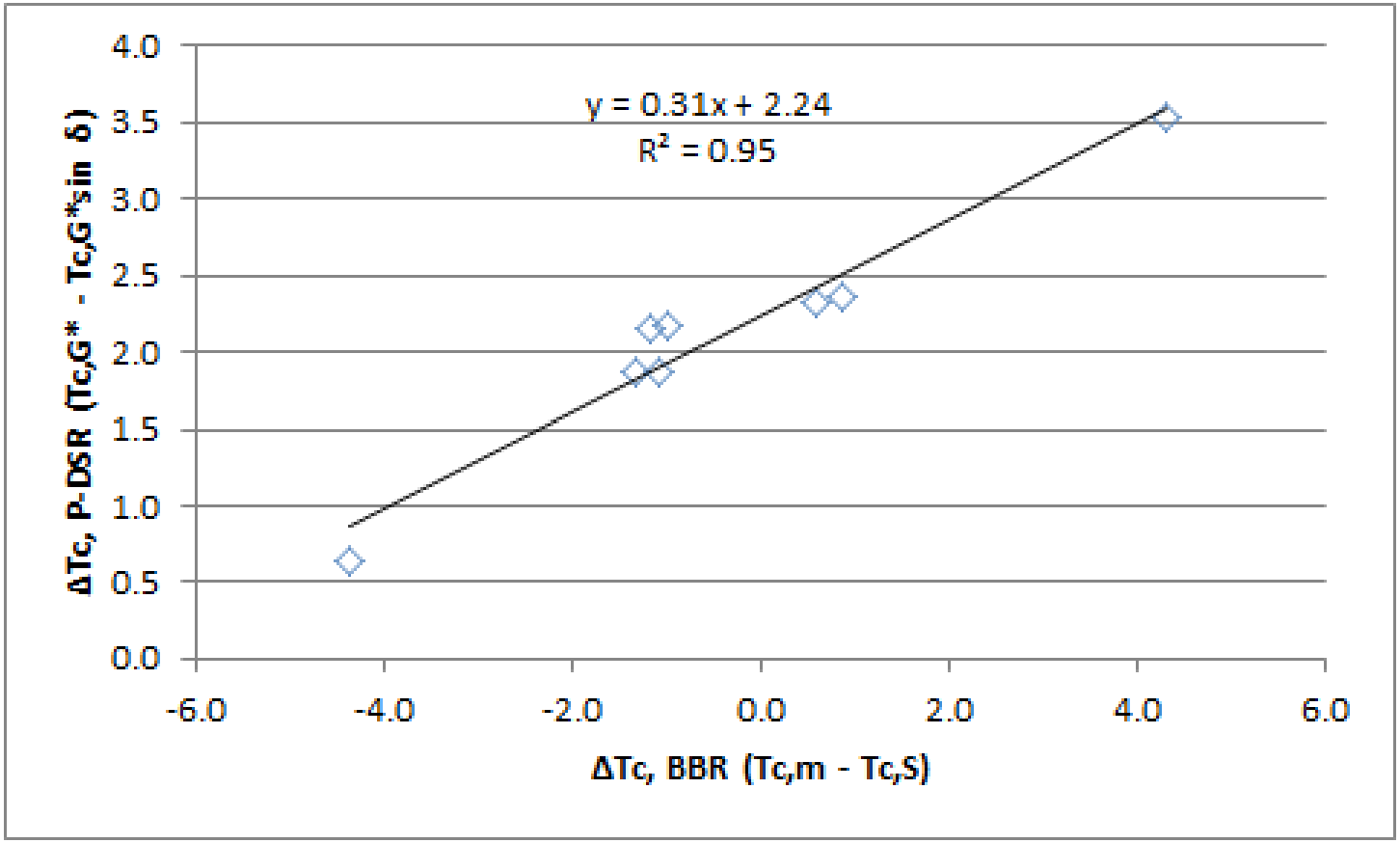
- “New Conventional”
  - Current production
  - Represent cross-section of asphalt binders in US
    - Approximately 8-10 binders
    - Eight sources (50 gallons each) now at AI
  - M320 testing followed by additional testing TBD

Binder ID	Grade
NC-A	PG 58-28
NC-B	PG 58-31
NC-C	PG 58-28
NC-D	PG 64-22
NC-E	PG 64-16
NC-F	PG 64-22
NC-G	PG 67-22
NC-H	PG 70-10

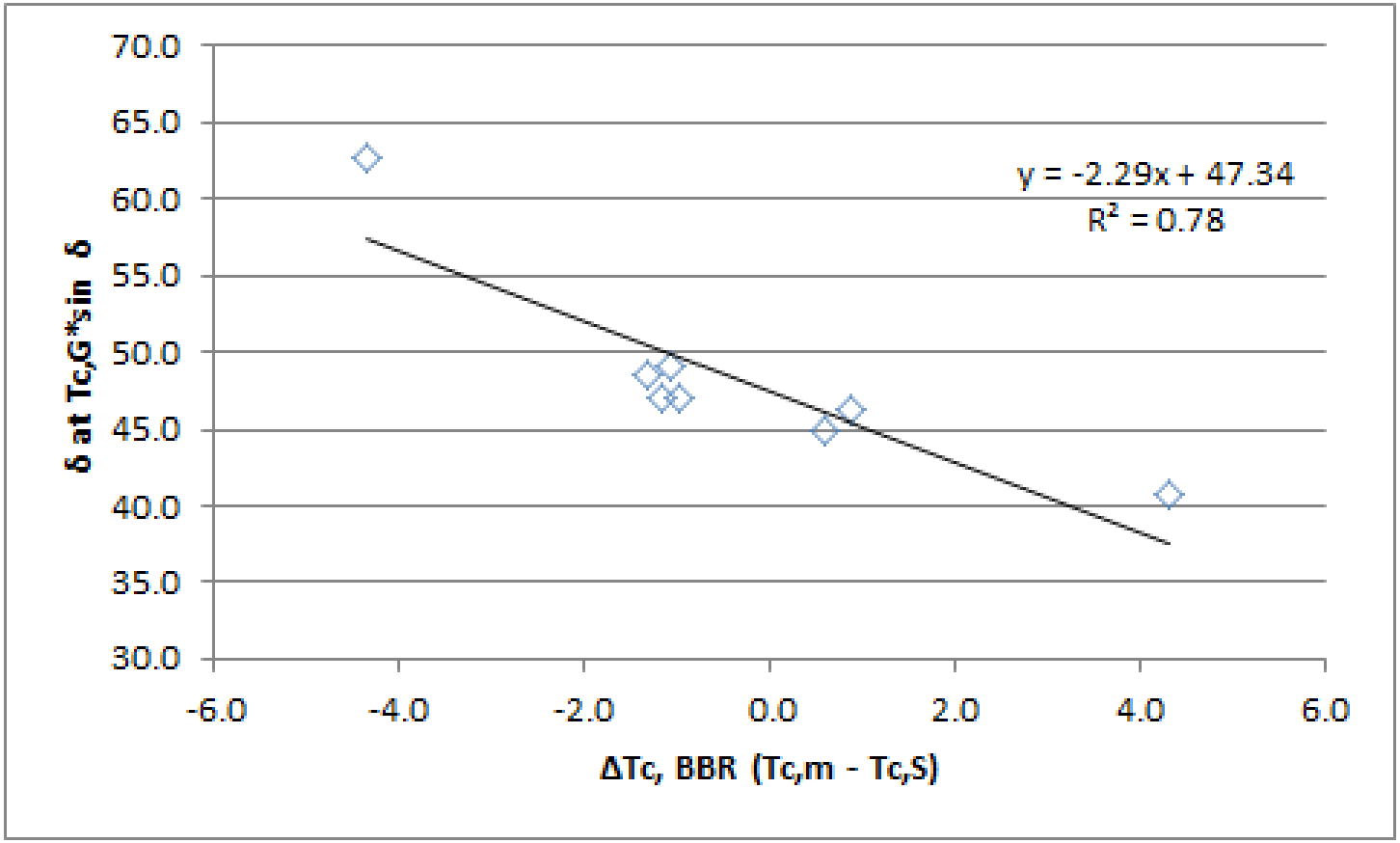
New Conventional Binders: M320

	NC-A	NC-B	NC-C	NC-D	NC-E	NC-F	NC-G	NC-H
Tc,O-DSR	60.4	59.5	58.1	66.4	67.5	66.0	69.7	72.0
Tc,R-DSR	60.6	60.6	58.9	68.4	67.8	66.8	70.8	71.0
Tc,P-DSR	18.7	15.6	17.1	22.5	26.4	23.5	22.0	34.7
Tc,P-G*	20.6	17.7	19.4	26.0	28.3	25.9	24.2	35.4
ΔTc,Int	1.9	2.2	2.3	3.5	1.9	2.4	2.2	0.6
δ at Tc,P-DSR	48.5	46.9	44.9	40.8	49.0	46.2	47.0	62.7
Tc,S	-30.1	-32.1	-31.0	-28.6	-22.9	-26.1	-27.7	-10.8
Tc,m	-31.4	-33.3	-30.4	-24.3	-23.9	-25.3	-28.7	-15.2
ΔTc,Low	-1.3	-1.2	0.6	4.3	-1.1	0.9	-1.0	-4.4
Grade	60.4-30.1	59.5-32.1	58.1-30.4	66.4-24.3	67.5-22.9	66.0-25.3	69.7-27.7	71.0-10.8

New Conventional Binders



New Conventional Binders

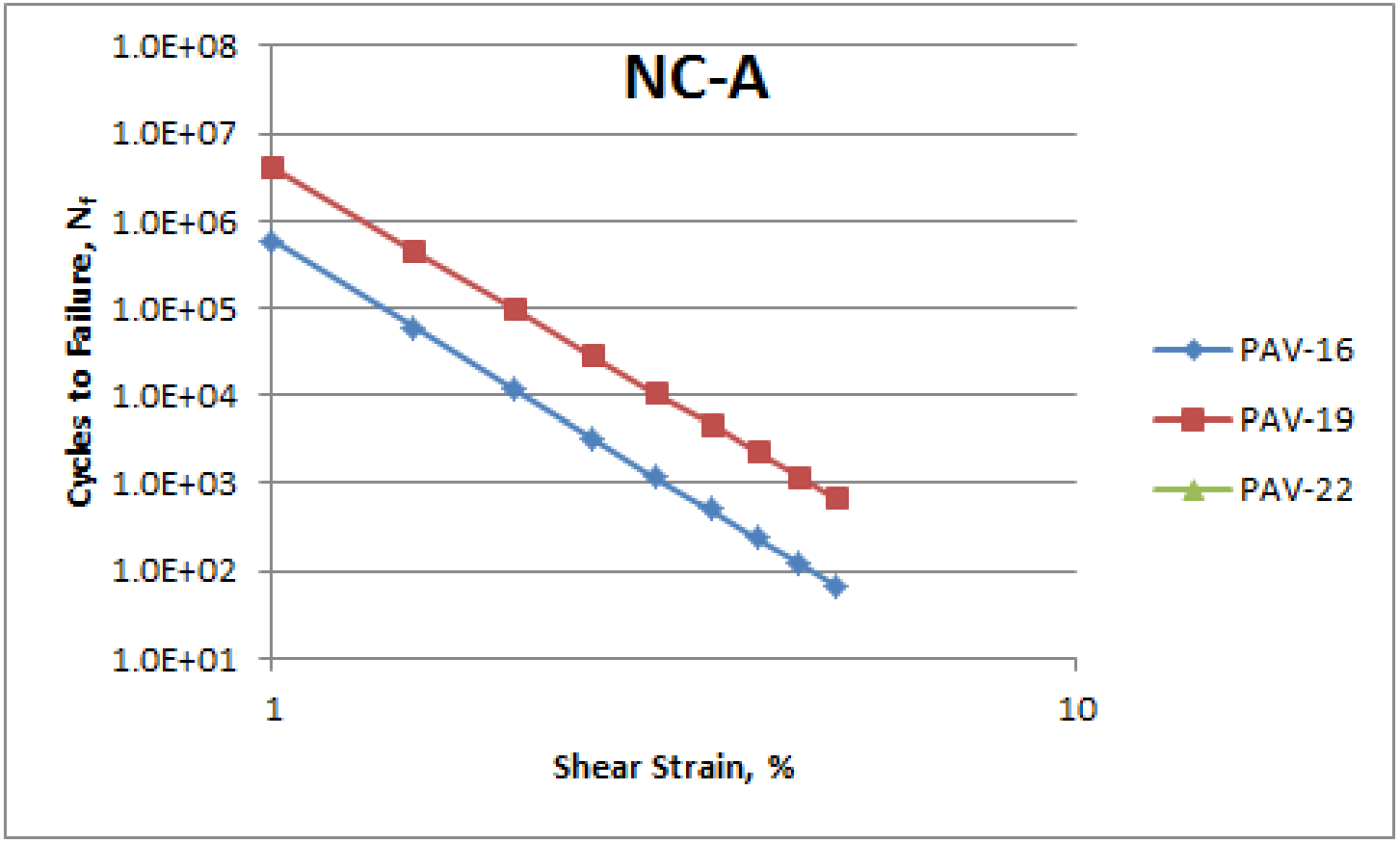


New Conventional Binders

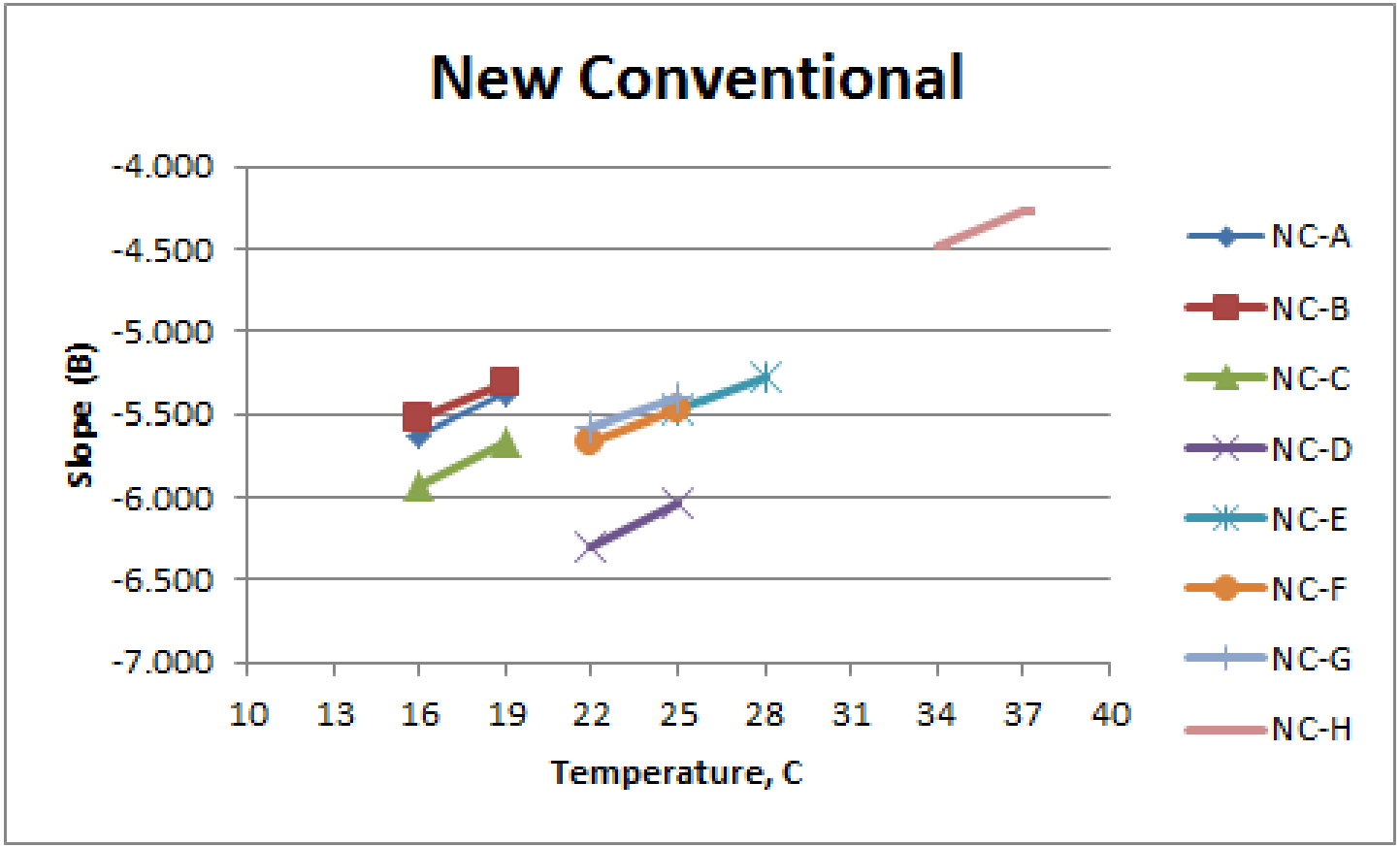
- LAS Testing
  - Two temperatures
    - Intermediate grade temperature (T_{int}), T_{int} -3°C

		LAS Temperature, °C		Tc,P-DSR, °C
NC-A	PG 58-28	16	19	18.7
NC-B	PG 58-31	16	19	15.6
NC-C	PG 58-28	16	19	17.1
NC-D	PG 64-22	22	25	22.5
NC-E	PG 64-16	25	28	26.4
NC-F	PG 64-22	22	25	23.5
NC-G	PG 67-22	22	25	22.0
NC-H	PG 70-10	34	37*	34.7

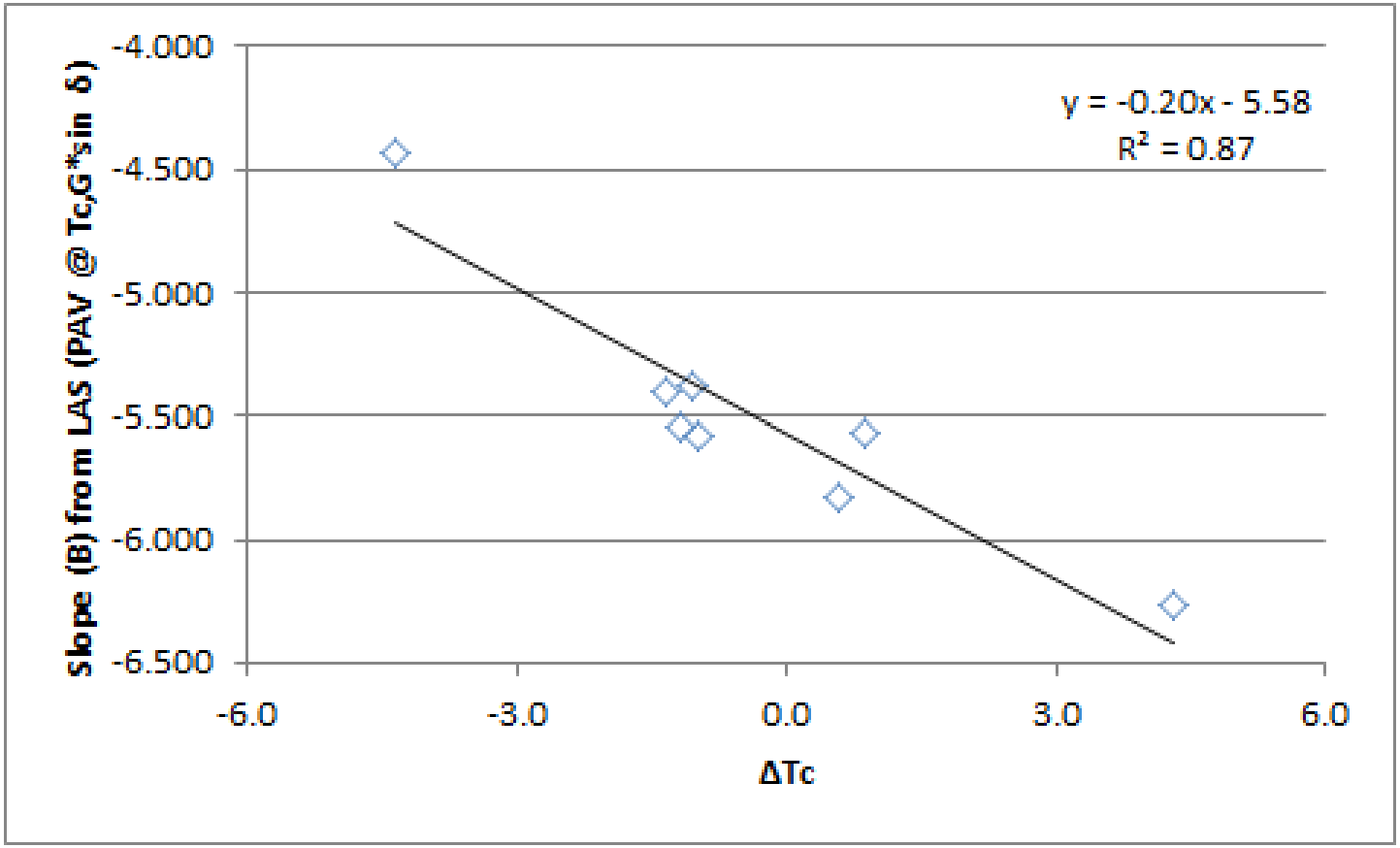
New Conventional Binders: LAS



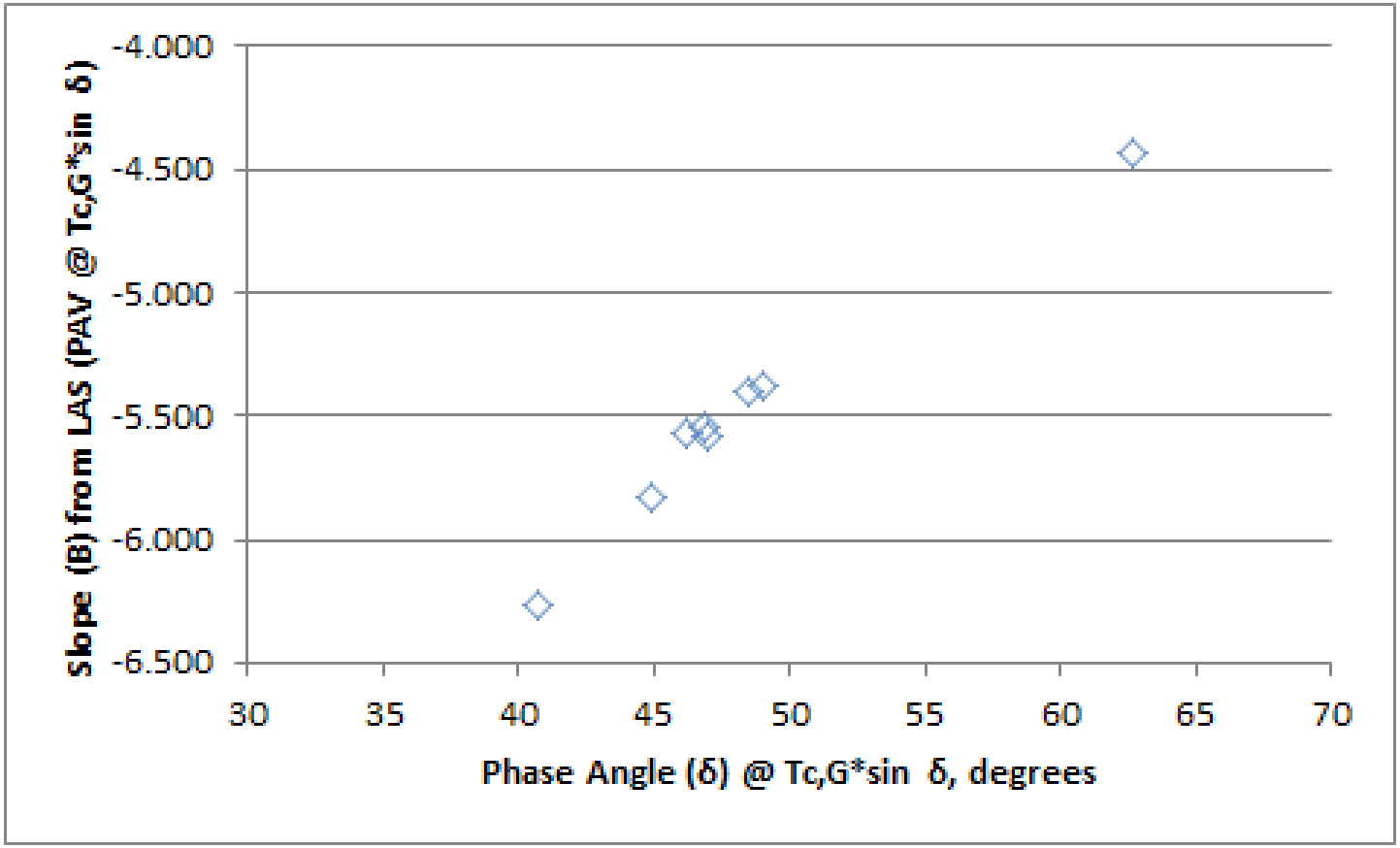
New Conventional Binders: LAS Slope (B) as *f*(T)



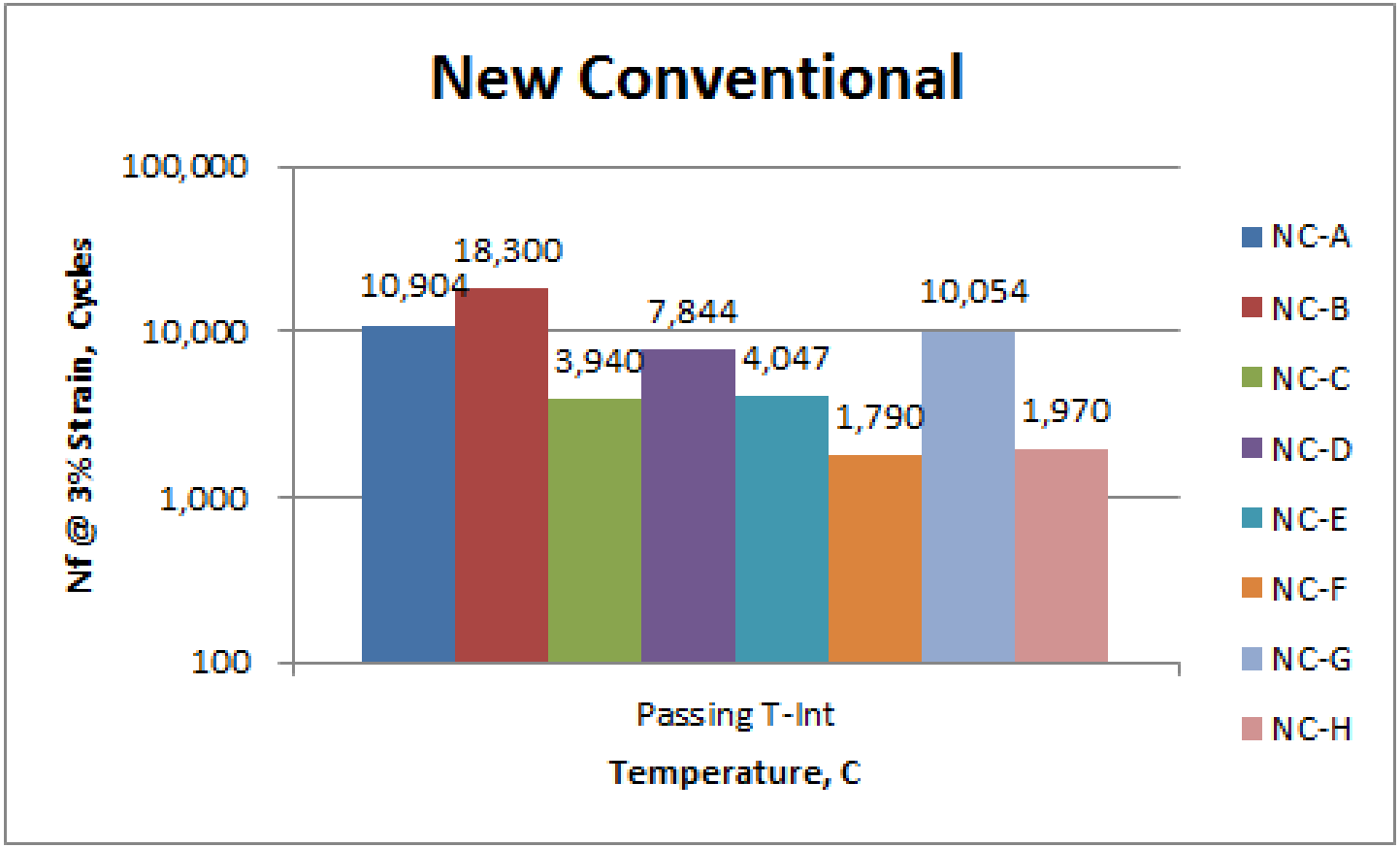
New Conventional Binders: LAS Slope (B) as $f(\Delta T_{c,Low})$



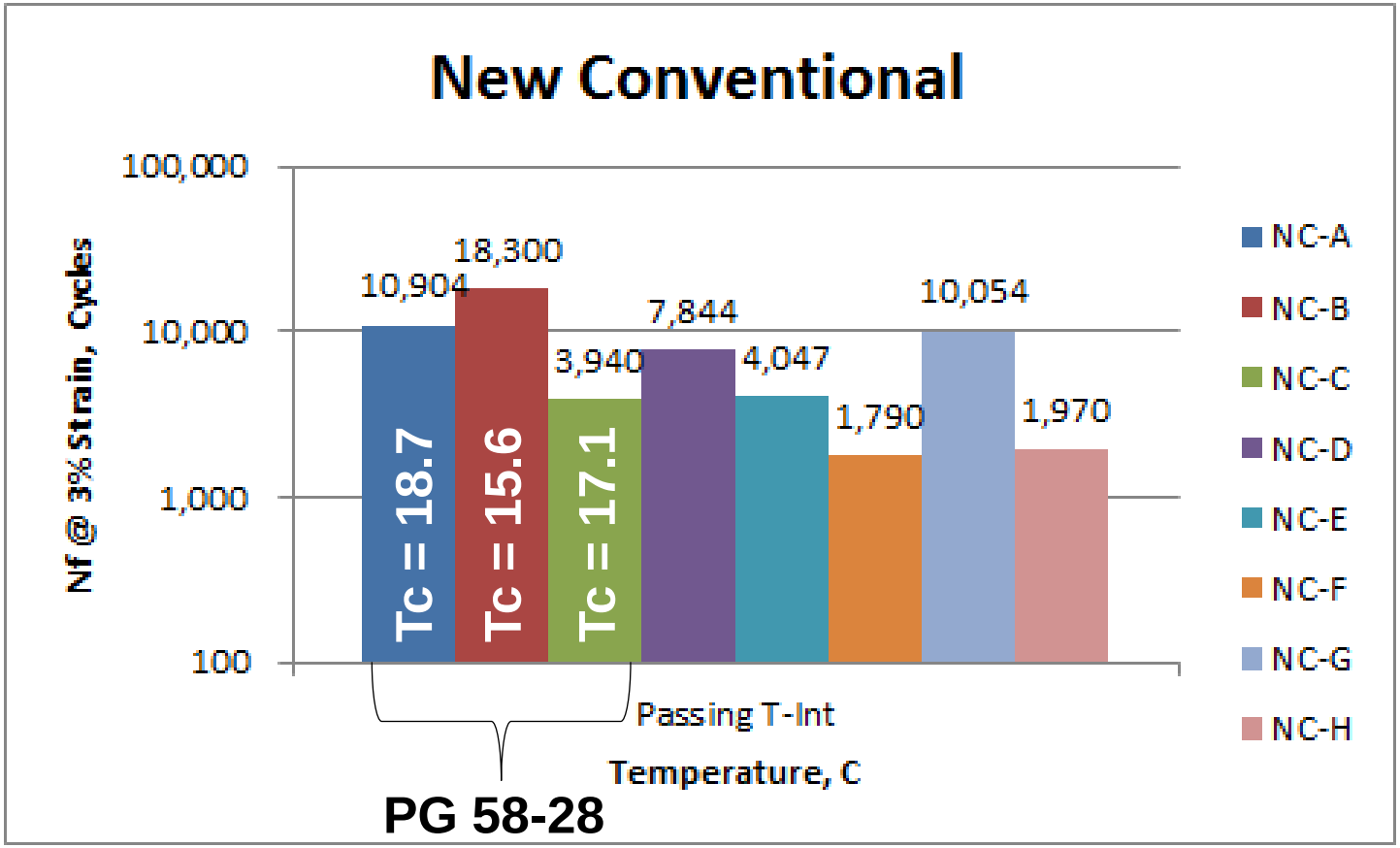
New Conventional Binders: LAS Slope (B) as $f(\delta@T_{c,P\text{-}DSR})$



New Conventional Binders: LAS N_f at 3% Strain and Grade T_{int}



New Conventional Binders: LAS N_f at 3% Strain and Grade T_{int}



“New Unconventional” Binder Testing Matrix

	Hard Blend Component			
Soft Blend Component	PDA Asphalt	SDA Asphalt	ROSE Pitch from WTS	ROSE Pitch from WCS
Low Vis Aromatic Oil	x	x	x	x
High Vis Aromatic Oil	x	x	x	x
Soft PDA Asphalt	x	x	x	x
REOB #1	x			
REOB #2	x	x		
Waste Motor Oil	x	x		
Low Vis VTB (low temp spread)	x	x	x	x

Other materials:
Non-blended material – PG 64-16 (oxidized binder)
PG binder containing Fisher-Tropsch wax
PG binder containing oxidized polyethylene wax

“New Unconventional” Asphalt Binders

- “New Unconventional” Binder Testing
  - Targeting 1.2 kPa @ 64°C and testing as PG 64-22.
  - MSCR
  - Thanks to Bob McGennis and Thomas Ludlum, both HollyFrontier
- Purpose
  - Evaluate “New Unconventional” binders and determine which to include in complete testing program

“New Unconventional” Asphalt Binders

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		Original	RTFO	PAV			
		DSR			BBR		
		64°C	64°C	25°C	-12°C		
Soft Blend Component	Hard Blend Component	G*/sin δ, kPa	G*/sin δ, kPa	G*/sin δ, kPa	S(60), MPa	m(60)	Est. ΔT_c
Low Vis Aromatic Oil	PDA Asphalt	1.24	2.94	4071	362	0.297	-1.2
	SDA Asphalt	1.25	6.31	4043	187	0.274	+1.1
	ROSE Pitch WCS	1.19	3.19	5227	306	0.324	-3.1
	ROSE Pitch WTS	1.19	3.25	4756	275	0.334	-3.3
High Vis Aromatic Oil	PDA Asphalt	1.24	2.54	6124	301	0.308	-1.0
	SDA Asphalt	1.22	4.72	3202	172	0.286	+6.4
	ROSE Pitch WCS	1.28	2.92	5161	236	0.325	-0.9
	ROSE Pitch WTS	1.17	2.74	4917	214	0.333	-1.1
Soft PDA Asphalt	PDA Asphalt	1.35	2.75	4426	246	0.299	+1.8
	SDA Asphalt	1.14	2.67	1897	184	0.313	+2.6
	ROSE Pitch WCS	1.37	2.93	4155	209	0.314	+1.4
	ROSE Pitch WTS	1.24	2.70	3917	202	0.313	+1.8
REOB #1	PDA Asphalt	1.22	3.70	3552	146	0.255	+11.6
REOB #2	PDA Asphalt	1.20	3.63	3685	179	0.244	+11.2
	SDA Asphalt	1.35	22.55	2521	66	0.188	+26.5
Waste Motor Oil	PDA Asphalt	1.34	4.53	4183	220	0.267	+6.7
	SDA Asphalt	1.19	18.52	3017	90	0.190	+23.6
Low Vis VTB	PDA Asphalt	1.21	2.89	6538	359	0.268	+2.2
	SDA Asphalt	1.25	4.14	4065	244	0.245	+8.4
	ROSE Pitch WCS	1.20	3.27	5991	285	0.263	+4.8
	ROSE Pitch WTS	1.11	2.75	5337	263	0.277	+4.9
FT Wax 1	PG 58-28	1.21	3.12	2347	119	0.340	+3.1
	PG 64-22	(a)	(a)	(b)	185	0.300	+4.2
FT Wax 2	PG 58-28	1.21	3.12	2347	119	0.340	+3.1
	PG 64-22	(a)	(a)	(b)	202	0.270	+7.0
Oxidized PE	PG 58-28	1.19	2.91	2415	118	0.345	+2.7
Oxidized	PG 64-16	1.14	2.65	(b)	(c)	(c)	+11.5

“New Unconventional” Asphalt Binders

		Original	RTFO	PAV			
		DSR			BBR		
		64°C	64°C	25°C	-12°C		
Soft Blend Component	Hard Blend Component	G*/sin δ, kPa	G*/sin δ, kPa	G*/sin δ, kPa	S(60), MPa	m(60)	Est. ΔT_c
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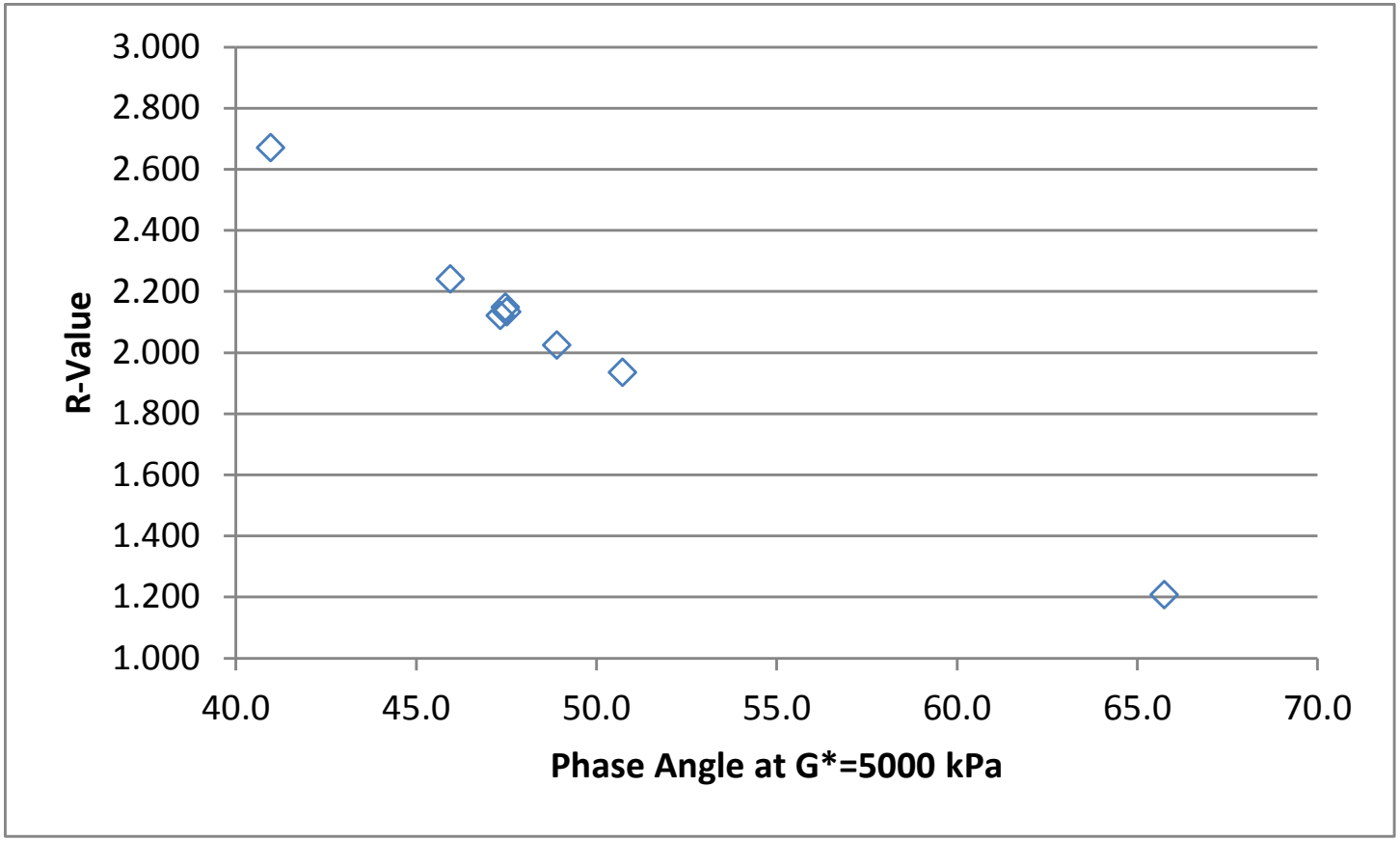
	SDA Asphalt	1.22	4.72	3202	172	0.286	+6.4
	ROSE Pitch WCS	1.28	2.92	5161	236	0.325	-0.9
	ROSE Pitch WTS	1.17	2.74	4917	214	0.333	-1.1

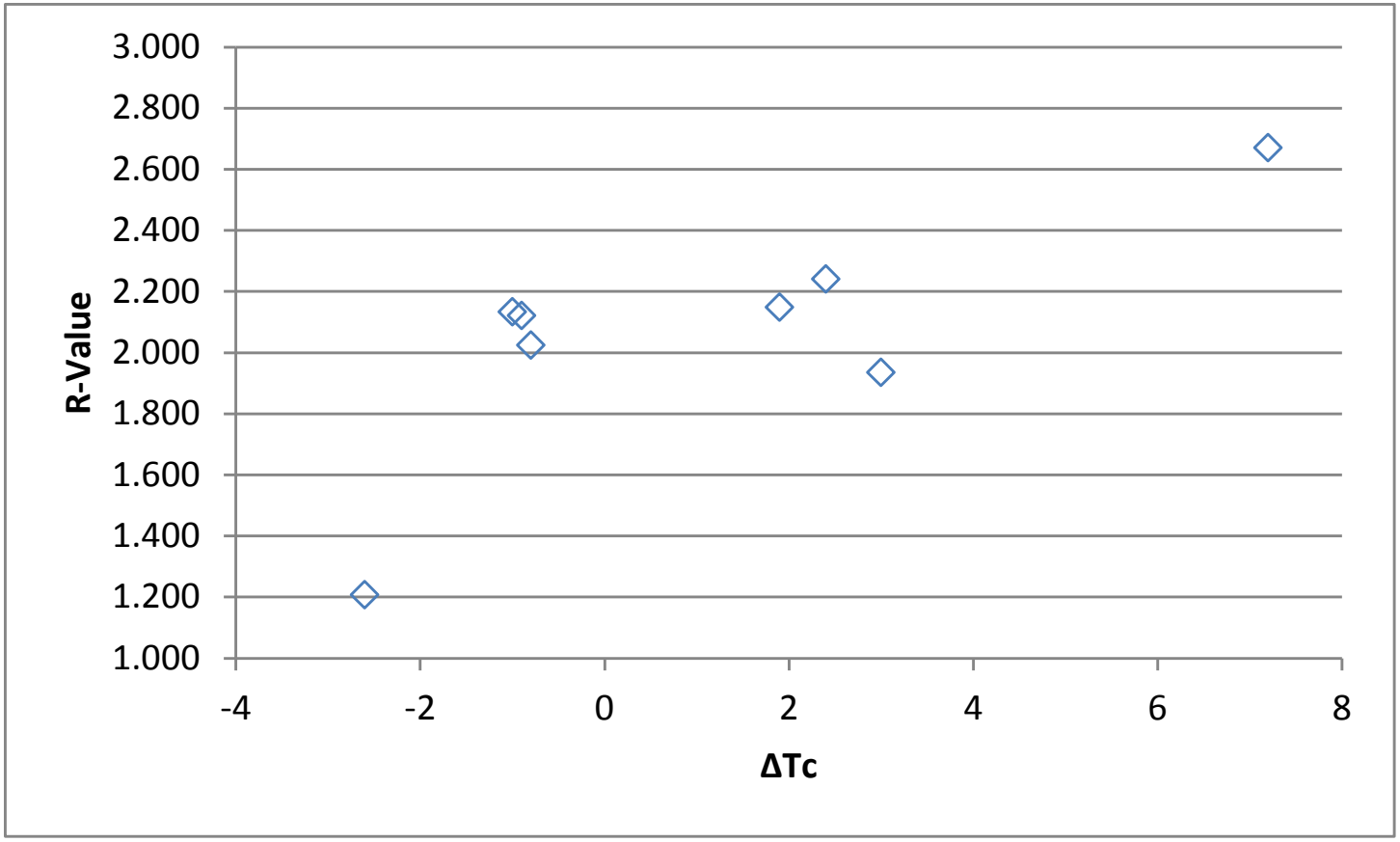
Next Steps

- Conference Call – September 2014
  - General agreement that we still have some effort to go before we solve the issue
  - Aging still a consideration
    - May need to get more aging than is currently provided by PAV practice
    - WRI USAT one possible option
  - So…what can we do within the existing specification?
    - Capturing effects of excessive age-related cracking?
      - R-value
      - Minimum phase angle at intermediate temperature grade (or more appropriately at G*=5000 kPa)
      - ΔTc

“Old Conventional” Asphalt Binders: R-Value as a Function of Phase Angle



“Old Conventional” Asphalt Binders: R-Value as a Function of ΔTc



Next Steps

- Continue Evaluation of “Old Conventional” Asphalt Binders
  - 4-mm PP DSR, DSC, SAR-AD, Vialit, LAS
  - Other
- Continue Evaluation of “New Conventional” Asphalt Binders
  - Selected tests
- Select “New Unconventional” Asphalt Binders for Evaluation

Thanks!