RPF Task Group on Bituminous Materials

PG Binder Working Group

PG Specification: Incorporation of Spray Grades

Road Pavement Forum

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Objective

- To revisit Performance Grade (PG) Binder Specification; and
- Consider how to apply PG for surfacings
  - Emulsions
  - Spray grades

Contents

- Summary: Performance Grade Binder Specification (PG for HMA)
- What about Performance Binders for Surfacings?
  - Surface Performance Grade Binders (SPG)
  - Emulsions Performance Grade (EPG)
- Compare PG with SPG/EPG
- How to use PG for SPG, practical approach
- Conclusion

Surface Seal: Demands on Specification

Johannes, Bahia & Mturi (CAPSA 2015)

TABLE II. COMMON FAILURES OCCURING IN CHIP SEALS CONSTRUCTED WITH EMULSIONS LINKED TO RELEVANT EMULSION PROPERTIES

Treatment Type	Distress Type	Emulsion/Residue Property	Temp
During Construction	Storage stability	Viscosity	Storage
	Streaking	Viscosity	Spraying
	Drain-out	Viscosity	Pavement
Short-term Perfomance	Aggregate loss	Cohesive & adhesive bond strength	Intermediate/ High temp
Long-term Performance	Raveling & moisture damage	Bond strength & strain tolerance	Intermediate
	Bleeding	Stiffness/creep compliance	High
	Reflective cracking	Stiffness & elasticity	Intermediate
	Low temp cracking	Creep stiffness & stress relaxation rate	Low

PG Specification in a nutshell

Test Property	Traffic class				Test Method
	S	H	V	E	
Max pavement design temperature (°C)	T_{max}				
Minimum grading temperature (°C)	T_{min}				
G* and δ at $[(T_{max} + T_{min})/2+4]$°C	Compulsory report only				ASTM D7175
G*/sinδ @10rad/s (kPa) @ $T = T_{max}$ Report G* and δ separately	Compulsory report				ASTM D7175
Viscosity at 165°C (Pa.s) ≥ 30 sec^{-1}	≤ 0.9				ASTM D4402
Storage Stability at 180°C (% diff in G* at T_{max})	≤ 15				ASTM D7175
Flash Point (°C)	≥ 230				ASTM D92b
	After RTFO Ageing				ASTM D2872 / TG1 MB3
G* and δ at $[(T_{max} + T_{min})/2+4]$°C,	Compulsory report only				ASTM D7175
Mass Change (% m/m)	≤ 1.0				ASTM D2872 / TG1 MB3
J_{nr} at T_{max} (kPa^{-1})	≤ 4.5	≤ 2.0	≤ 1.0	≤ 0.5	ASTM D7405
Ageing ratio $[G^*_{RTFO} / G^*_{Original}]$	≤ 3.0				ASTM D7175
	After RTFO plus PAV Ageing				ASTM D6521
G* and δ at $[(T_{max} + T_{min})/2+4]$°C,	Compulsory report only				ASTM D7175
Maximum creep stiffness tested at temperature [S (60s) ≤ 300 MPa]	T_{min} + 10°C				ASTM D6648
Minimum m-value tested at temperature [m (60s) ≥ 0.300]	T_{min} + 10°C				
ΔT_c (°C) = $T_{c,S} - T_{c,m}$	≥ -5				ASTM D7643
Ageing ratio $[G^*_{PAV} / G^*_{Original}]$	≤ 6.0				ASTM D7175

PG Binder-grades:

- PG58-22
- PG64-16
- PG70-10

Traffic classes:

- S = standard
- H = High
- V = Very high
- E = Extreme

Design traffic (million E80)	Traffic Speed (km/h)			Asphalt mix design level
	< 20	20 - 80	>80	
< 0.3	S	S	S	IA
0.3 - 3	H	S	S	IB
3 - 10	V	H	S	II
10 - 30	E	V	H	
30 - 100	E	E	V	III
>100	E	E	E	

What about Spray-grade Binders and Emulsions

- Surface Performance Grade (SPG) from USA
  - Emulsions and hot-applied bitumen/binder
- Emulsion Performance Grade (EPG) from USA
  - Emulsions only

Grading Temperature

- PG grading based on:
  - a depth of 20 mm in asphalt and
  - allowable rut depth of 12.7 mm
  - Grading temperatures are typically based on 98% statistical reliability
- PG 58-22, PG 64-16, PG 70-10

- For EPG/SPG specifications, surface temperature grade - shifted 3°C from the existing HMA PG grade increments
- SPG 61-19, SPG 67-13, SPG 73-7

Temperature difference surface and 20 mm depth = -3.9°C, recommend +3°C shift for surfacings

- Shift of 4°C more accurate - more practical to use 3°C to tie in with intervals

Temperature and Traffic definition: Seals

- Temperatures

Binder for Chip seals and Microsurfacing			
PG gradings	58 -22	64 -16	70 -10
Corresponding SPG/EPG	61 -19	67 -13	73 -7

- Traffic

SPG/EPG	PG
Low	S
Medium	S
High	H

SANS 4001: BT1

Table 1 — Grade requirements

Spray-grade Binder

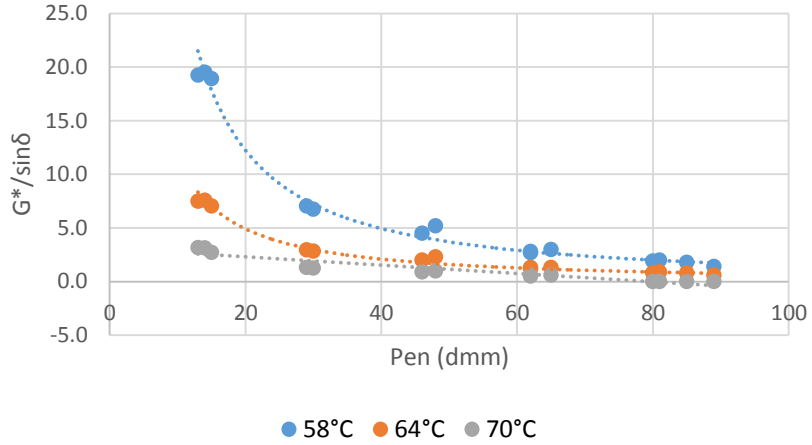
1	2	3	4	5	6	7	8
Property	Penetration grade						Test method
	10/20	15/25	35/50	50/70	70/100	150/200	
	Requirements						
Penetration at 25 °C/100 g/5 s, 1/10 mm	10 – 20	15 – 25	35 – 50	50 – 70	70 – 100	150 – 200	EN 1426
Softening point (ring and ball), °C	58 – 78	55 – 71	49 – 59	46 – 56	42 – 51	36 – 43	ASTM D36M[a]
Minimum viscosity at 60 °C, Pa.s	700	550	220	120	75	30	ASTM D4402M[b]
Viscosity at 135 °C, mPa.s	≥ 750	≥ 650	270 – 700	220 – 500	150 – 400	120 – 300	ASTM D4402M[b]
Flash point, °C	≥ 245	≥ 235	≥ 240	≥ 230	≥ 230	≥ 220	ASTM D92
Performance when subjected to the rolling thin film oven test:							ASTM D2872
a) mass change, % (by mass fraction), max.	–	0,5	0,3	0,3	0,3	0,3	ASTM D2872
b) viscosity at 60 °C, % of original, max.	–	–	300	300	300	300	ASTM D4402M[b]
c) softening point (ring and ball), °C, min.	–	57	52	48	44	37	ASTM D36M[a]
d) increase in softening point, °C, max.	10	8	7	7	7	7	ASTM D36M[a]
e) retained penetration, % of original, min.	–	55	60	55	50	50	EN 1426
Spot test[c], % xylene, max.	–	–	30	30	30	30	AASHTO T102

[a] Using shouldered ring.

[b] Recommended apparatus is the RV viscometer, using SC 4 spindles with thermosel system.

[c] Actual values to be reported in five-unit intervals (see annex A).

Amdt 1; amdt 2; amdt 3



G* and δ is reported

Isotherms at intermediate temperature is reported
Viscosity at 165 °C
Flashpoint ≥ 230

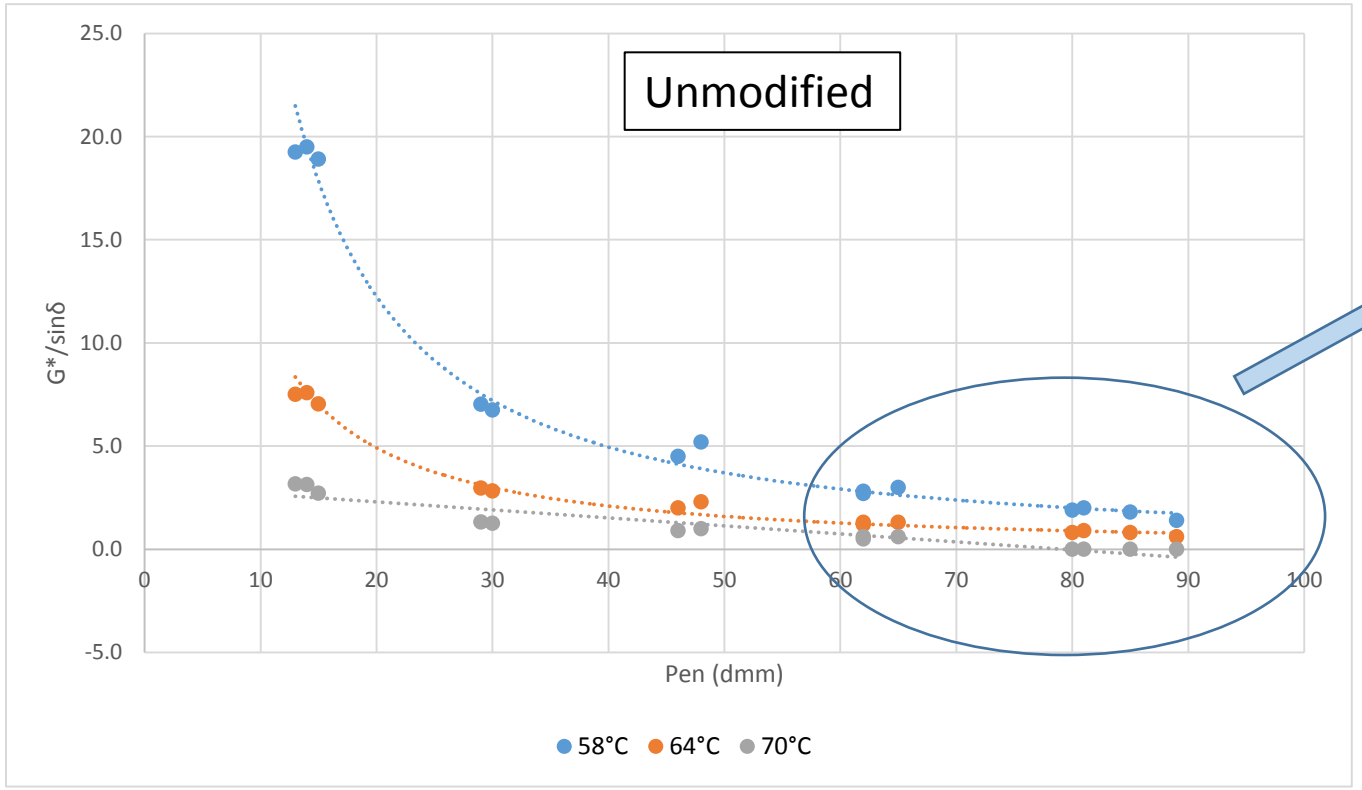
Mass change ≤ 1.0

Isotherms at intermediate temperature is reported

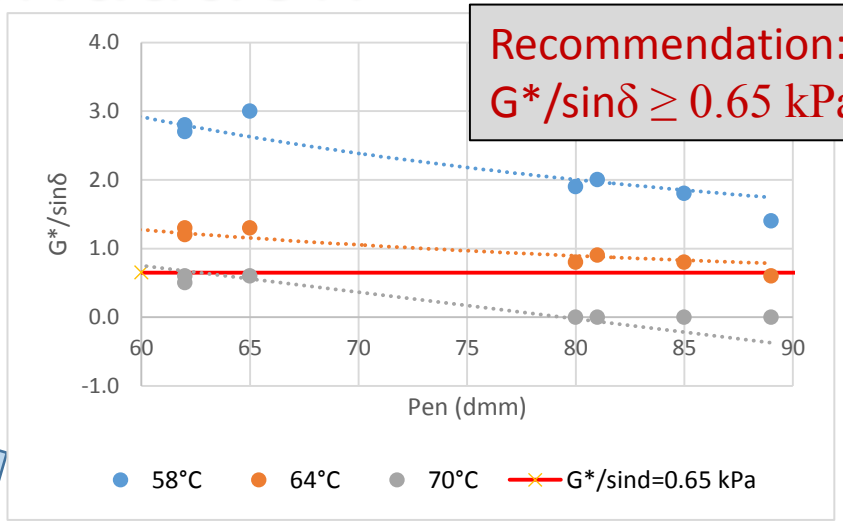
G* and δ is reported

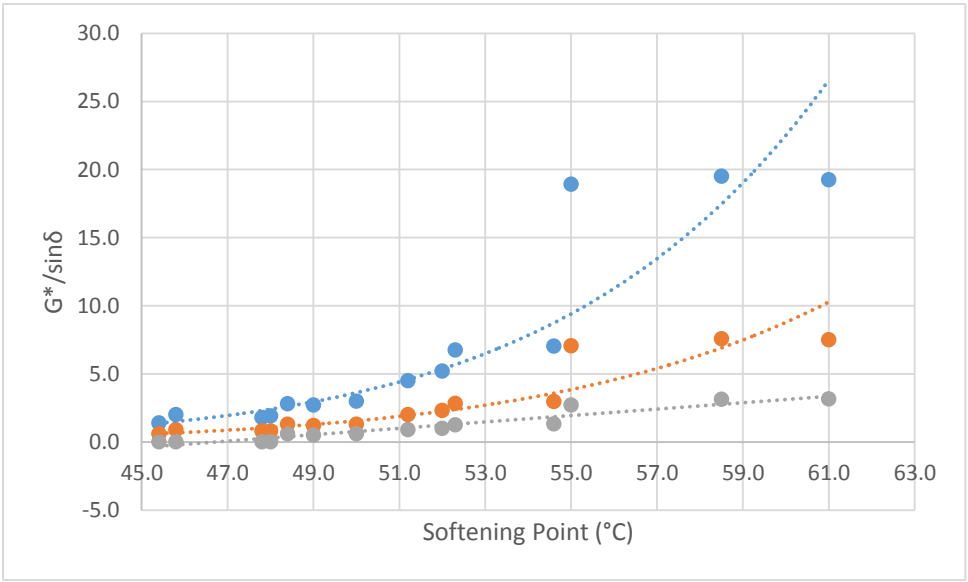
Not reported

High Temperature Recommendation



Recommendation:
$G^*/\sin\delta \geq 0.65$ kPa





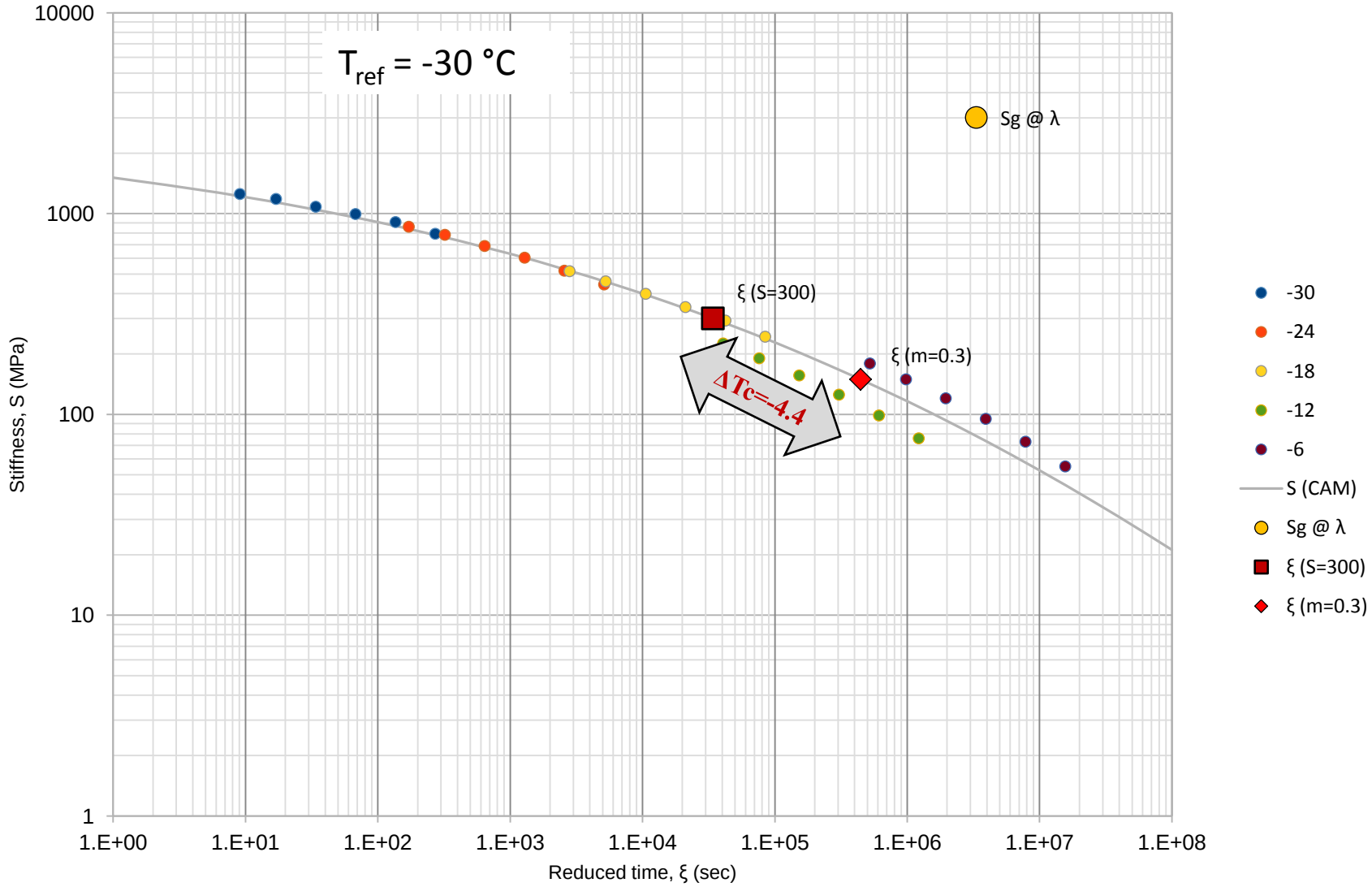
Or: J_{nr} and %R from MSCR test

What about Low Temperature?

- In PG
  - $S(60) \leq 300$ MPa
  - $m(60) \geq 0.3$
  - $\Delta Tc \geq -5$
- In EPG/SPG
  - $S(8) \leq 500$ MPa
  - $m(80) \geq 0.24$
  - $\Delta Tc \geq -3$

New values can be calculated from Mastercurve

Asphalt Binder: ΔTc ≥ -5.0

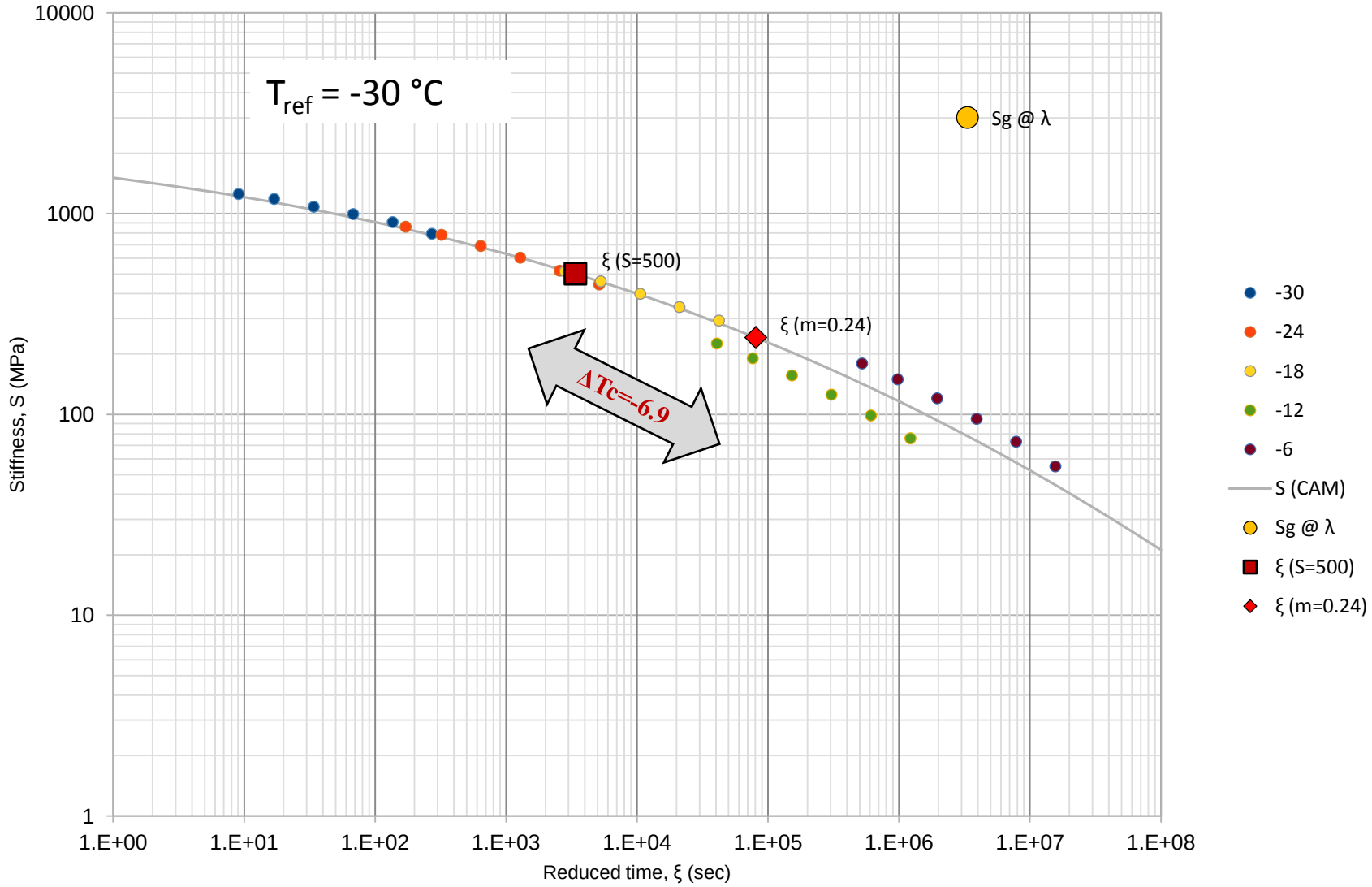


$$S = S_g\left[1+\left(\frac{t}{\lambda}\right)^{\beta}\right]^{-\kappa/\beta}$$ CAM Model

$$\log a_T = a + b\left(\frac{1}{T}-\frac{1}{T_{ref}}\right)$$ Arrhenius

$$\xi = \frac{t}{a_T}$$ Reduced time

Surfacing Binder: ΔTc ≥ -3.0



$$S = S_g\left[1+\left(\frac{t}{\lambda}\right)^{\beta}\right]^{-\kappa/\beta}$$ CAM Model

$$\log a_T = a + b\left(\frac{1}{T}-\frac{1}{T_{ref}}\right)$$ Arrhenius

$$\xi = \frac{t}{a_T}$$ Reduced time

TG1: Modified Binders (homogeneous)

Property	Unit	Test Method	Class	
Before ageing			S-E1	S-E2
Softening Point	°C	MB-17	50-70	60-80[1]
Elastic recovery @ 15°C	%	MB-4	>50	>60
Dynamic Viscosity @ 165°C	Pa.s	MB–18	≤0.55	≤0.60
Storage Stability @ 180°C[2]	°C	MB-6	≤5	≤5
Flash Point	°C	ASTM D92	≥230	≥230
After ageing (RTFOT)				
Mass change[3]	%	MB-3	≤1.0	≤1.0

Property		Unit	Test Method	Class			
				SC-E1		SC-E2	
Binder content (m/m)[1]		%	MB–22	65-68	70-73	65-68	70-73
Saybolt Furol viscosity @ 50°C		sec	MB–21	51-200	51-400	51-200	51-400
Residue on sieving[2] (/100 ml)	710µm sieve	g	MB-23	≤0.1		≤0.1	
	150µm sieve			≤0.5		≤0.5	
Particle charge			MB–24	positive		positive	
Sedimentation after 60 rotations			SANS 4001 BT3	nil		nil	
Recovered binder residue			MB-20[3]				
Softening point		°C	MB–17	≥48		≥55	
Elastic recovery @ 15°C		%	MB-4	≥50		≥55	

Comparative results BT1 to SATS 3208 (CSIR)

Binder for PG64	70/100 Binder 1	70/100 Binder 2	70/100 Binder 3	50/70 Binder 1	50/70 Binder 2	50/70 Binder 3	35/50 Binder 1	35/50 Binder 2	35/50 Binder 3
Penetration (10^{-1}mm)	89	85	81	65	62	62	48	46	38
Softening Point (˚C)	45.4	47.8	45.8	50.0	48.4	49.0	52.0	51.2	52.6
DSR |G*|/sinδ @ 64 ˚C	0.6	0.8	0.9	1.3	1.3	1.2	2.3	2.0	4.4
After Rolling Thin Oven Test									
Mass Change (m/m%)	+ 0.1	+ 0.1	+ 0.1	+ 0.1	+ 0.1	0.0	+ 0.1	+ 0.1	0.0
J_{nr} (at σ = 3.2 kPa) at 64 ˚C	9.8	6.2	6.9	4.1	5.0	4.9	2.0	2.1	2.2
Binder Class	AE1 Binder 1	AE1 Binder 2	AE2 Binder 1	AE2 Binder2	AE2 Binder 3	AP1 Binder 1	AP1 Binder 2	AH1 Binder 1	AH2 Binder 1
Softening Point (˚C)	57.7	58.8	67.6	66.2	73.0	65.8	65.6	54.6	90.0
Elastic Recovery (%)	78	82	90	86	89	80	76	UTT	90
DSR |G*|/sinδ	2.5	1.6	4.8	3.3	2.7	3.9	4.7	3.1	4.4
Mass Change (m/m%)	0.0	0.0	- 0.1	0.0	+ 0.2	0.0	0.0	+ 0.1	+ 0.1
J_{nr} (at σ = 3.2 kPa) at 64 ˚C	1.2	2.3	0.8	0.9	0.9	0.2	0.3	1.7	1.7

A Possible Testing Framework for EMULSIONS

Johannes, Bahia & Mturi (CAPSA 2015)

Engineering Property	Test Method	Parameter(s) Measured
Tests on Fresh Emulsion Properties (Constructability)		
Storage Stability	Modified ASTM D6930 – Settlement and Sedimentation	▪ Rotational Viscosity, η, ▪ B-24-hour Separation Ratio (R_s) ▪ C-24-hour Stability Ratio (R_d)
Sprayability	Modified AASHTO TP48 - Rotational Viscometer	▪ Rotational Viscosity, η, ▪ @ high shear at (XX 1/sec)
Drain-Out	Modified AASHTO TP48-Rotational Viscometer	▪ Rotational Viscosity, η, ▪ @ low shear rate (XX 1/sec)
Resistance to Early Raveling /Curing	AASHTO TP 91-11 Bitumen Bond Strength (BBS)	▪ A-Minimum Pull-Out Tensile Strength (POS) @ XX hrs. of Curing Time
Residue Recovery Method: ASTM D7497 Method B		
Resistance to Bleeding and Flushing	Multiple Stress Creep and Recovery Test (AASHTO TP 70)	▪ J_{nr} ▪ Stress Sensitivity
Resistance Raveling	Bitumen Bond Strength Test (AASHTO TP-91)	▪ Wet and Dry Pull-off Bond Strength ▪ Moisture Damage ratio
	DSR-Linear Amplitude Test	▪ Strain at maximum Stress
Early Fatigue	Linear Amplitude Sweep Test (LAS)	▪ Number of Cycles to failure (N_f) at specified % Strain
Polymer Identifier	Elastic Recovery DSR	▪ % recovery
Tests on PAV Aged (AASHTO R28) Materials		
Late Fatigue	Linear Amplitude Sweep Test (LAS)	▪ Cycles to failure (N_f) at specified % Strain ▪ Aging Susceptibility
Resistance to Thermal Cracking	DSR Frequency Sweep to estimate BBR properties.	▪ Estimated S(60), m(60)

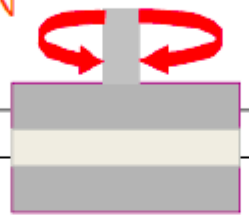
A Possible Testing Framework for SPG (USA)

(Hanz (Emulsions Task Force (ETF), 2017)

SPG

Specification Tests & Limits

Example: SPG 73 - XX

*MAX δ FOR EMULSION RESIDUE = 84 	Performance Grade SPG 73			
	-13	-19	-25	-31
	<73			
	>-13	>-19	>-25	>-31
Original Binder				
G*/Sinδ ≥ 0.65 kPa by T 315 Test Temperature @ 10rad/s, °C	73			
Phase angle (δ), Max, @ temp. where G*/sin δ = 0.65 kPa	80*	80*	80*	80*

PAV Residue				
S ≤ 500 MPa by T 313 Test Temperature @ *8s*, °C	-13	-19	-25	-31

A Proposed Testing Framework for EPG (USA)

(Hanz (Emulsions Task Force (ETF), 2017)

High Temperature Specification

Surface Treatment Type	PG Test	Performance Parameter	Traffic Level	Test Temp. Range	EPG Limit
Chip Seal	DSR MSCR	Maximum *Jnr* @ 3.2 kPa	Low	High	< 8 kPa^{-1}
			Med		< 5.5 kPa^{-1}
			High		< 3.5 kPa^{-1}
Microsurfacing	DSR MSCR	Maximum *Jnr* @ 3.2 kPa	Low		< 5 kPa^{-1}
			Med & High		< 1.5 kPa^{-1}

Low (0-500 AADT), Medium (500 – 2500 AADT), High (>2500 AADT)

Low Temperature Specification

Surface Treatment Type	PG Test	Performance Parameter	Traffic Level	Test Temp. Range	EPG Limit
Chip Seal	DSR Frequency Sweep	Maximum |G*| @δc	Low	5°C and 15°C	< 30 MPa
			Med		< 20 MPa
			High		< 10 MPa
Microsurfacing	DSR Frequency Sweep	Maximum |G*| @δc	All Traffic Levels		< 16 MPa

- Parameters evaluated on as-recovered residue. No PAV aging.

Similarities EPG (USA) and SPG (USA)

- Six degree grade increments and shift of +3°C to both high and low temperature grade for surface grading.
- AASHTO PP-72 Residue Recovery Procedure
- High temperature grading on as-recovered residue.

Difference EPG (USA) and SPG (USA)

Issue	SPG	EPG
Application	Hot-Applied and Emulsion Chip Seals	Emulsion for spray and mixing application.
High Temperature Parameter	G*/sinδ (T315)	Jnr @ 3.2 kPa (T350)
Traffic Considerations	Grade Bumping for high temp.	Grade remains the same, spec. thresholds (HT and LT) change.
Polymer Identifier	Phase Angle	None
Low Temperature Parameter (Standardized?)	BBR (Yes)	G* at critical phase angle (No)
Long Term Aging	PAV	None
Basis for setting thresholds.	Field Performance (Validation over a ~15 yrs)	Lab Testing - Long term validation needed.

Conclusion

- Keep it simple, use PG specification and don't deviate too much
- Impossible to develop specification that address all seal behaviours and failures
- **Update TRH3** – practical approach can be described in TRH3
  - And/or **SAPEM**?
- RPF BITMAT Task Group in mean time re-look EPG/SPG approach
- **Funding required!!**

Thanks