



TriDurLE

National Center for Transportation
Infrastructure Durability & Life Extension
2024 Annual Symposium

Developments in Rheological Test Implementation to Improve the Performance of Advanced Crack and Joint Sealant Materials

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February 26-27, 2024

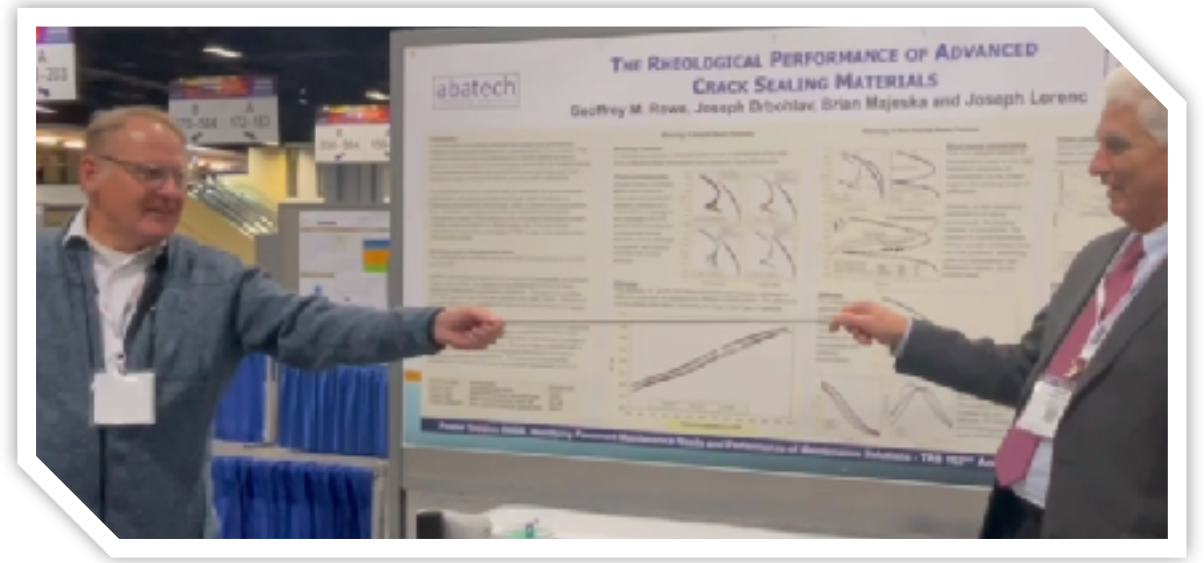
College Station, TX

Introduction – Developing a new Paradigm

- Last year we introduced information on new materials being developed for joint sealants
 - Material developed for high relaxation properties while maintaining visco-elastic solid behavior
 - Objective - longer lasting seals 👍

- Overview

1. What rheology, why is this different?
2. Specification approach
3. Implementation
4. Summary



What do we need from a sealant product?



It Needs to be Sustainable (Did we Get Here...)

1. The Customer Need Meets...



2. The Polymer Chemist & Rheologist Meet the Need



3. The Polymer Chemist & Rheologist Learn About the Playground

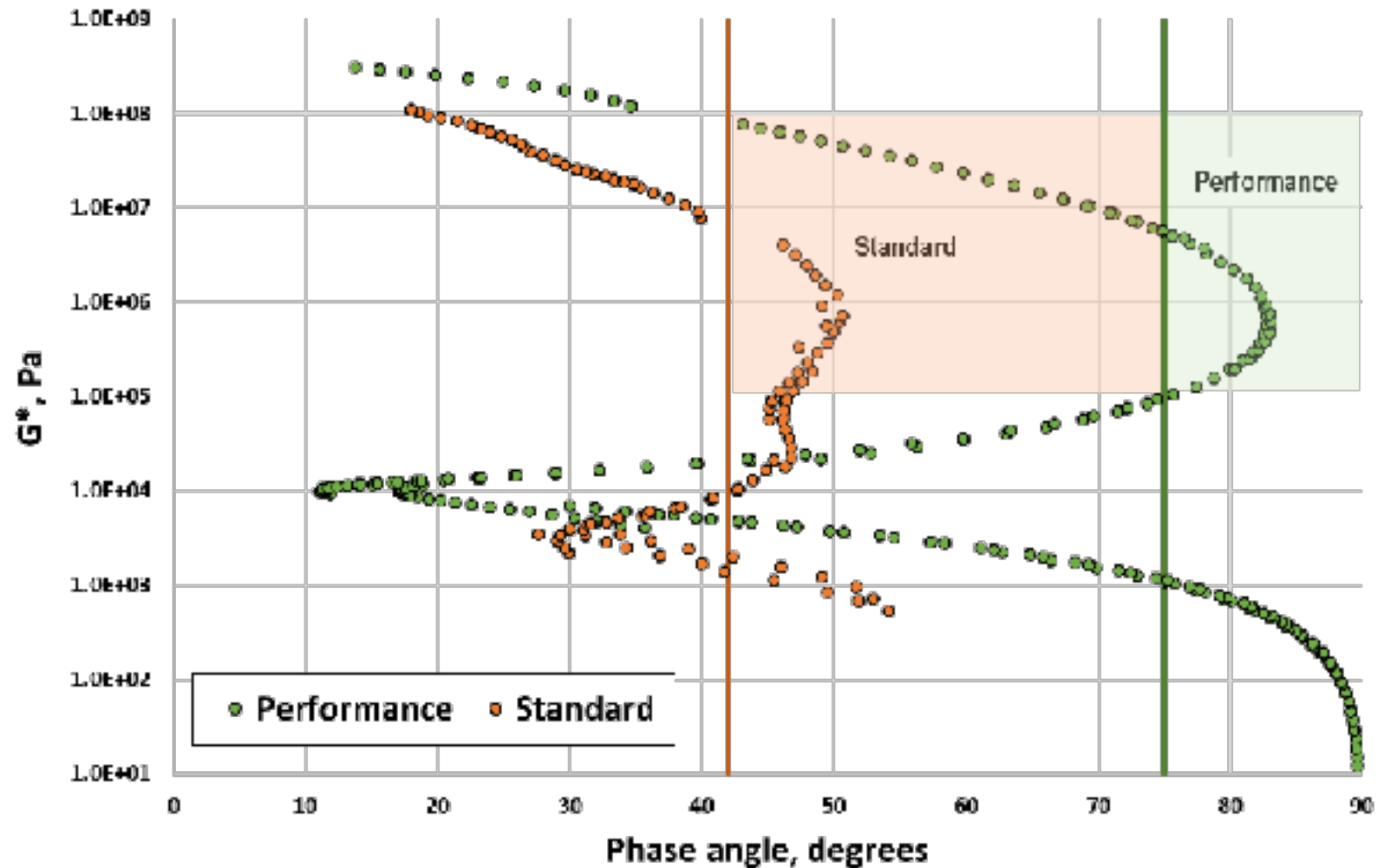


The World Gets the First Sustainable Performance Joint Sealant



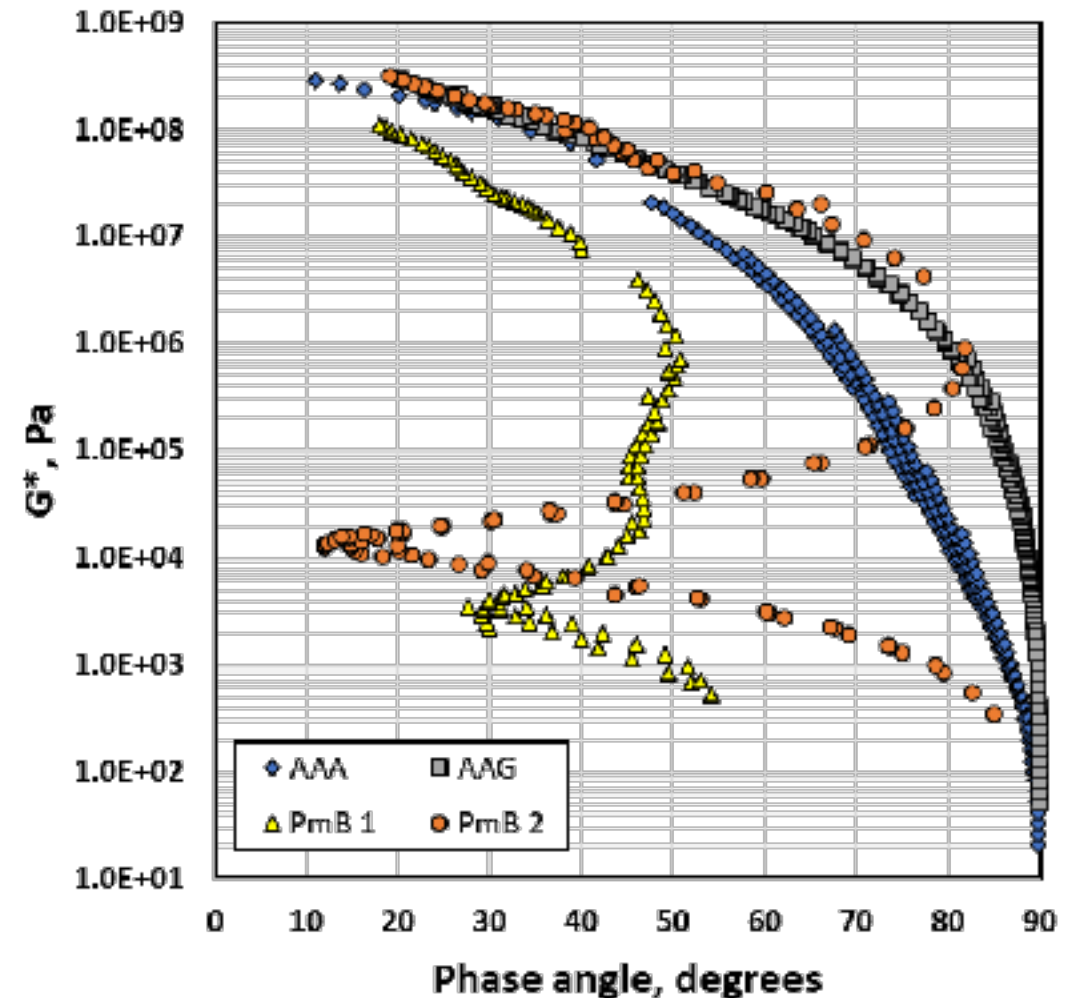
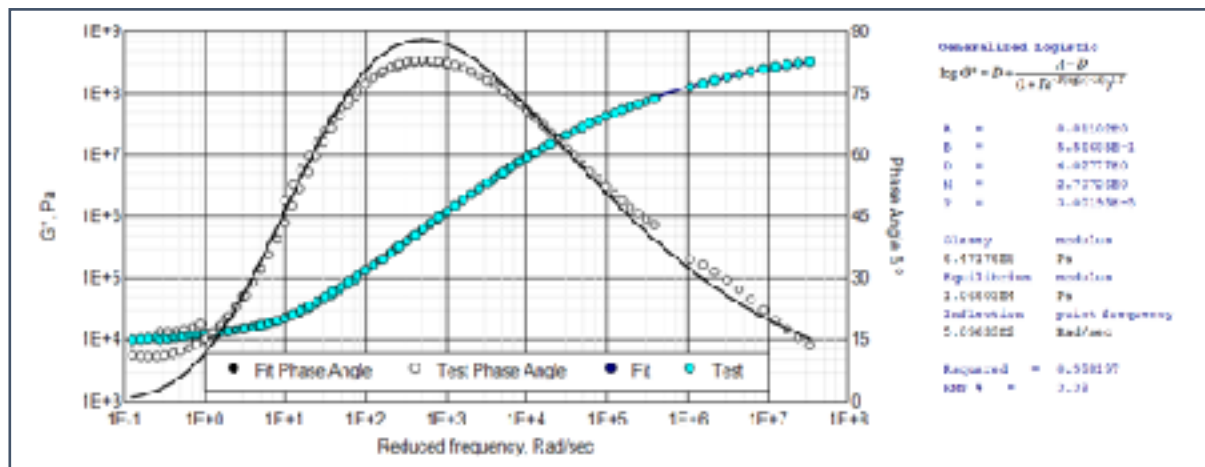
#1 - Rheology – Enhanced Relaxation Properties Standard and Performance

- As thermo-plastic materials will transition from VE solid to VE liquid in a given temperature range, generally when stiffness drops to be below 10^4 Pa
 - Allows flow behavior and wand application at higher temperatures
- VE solid behavior prevents creep and flow
 - At service temperatures



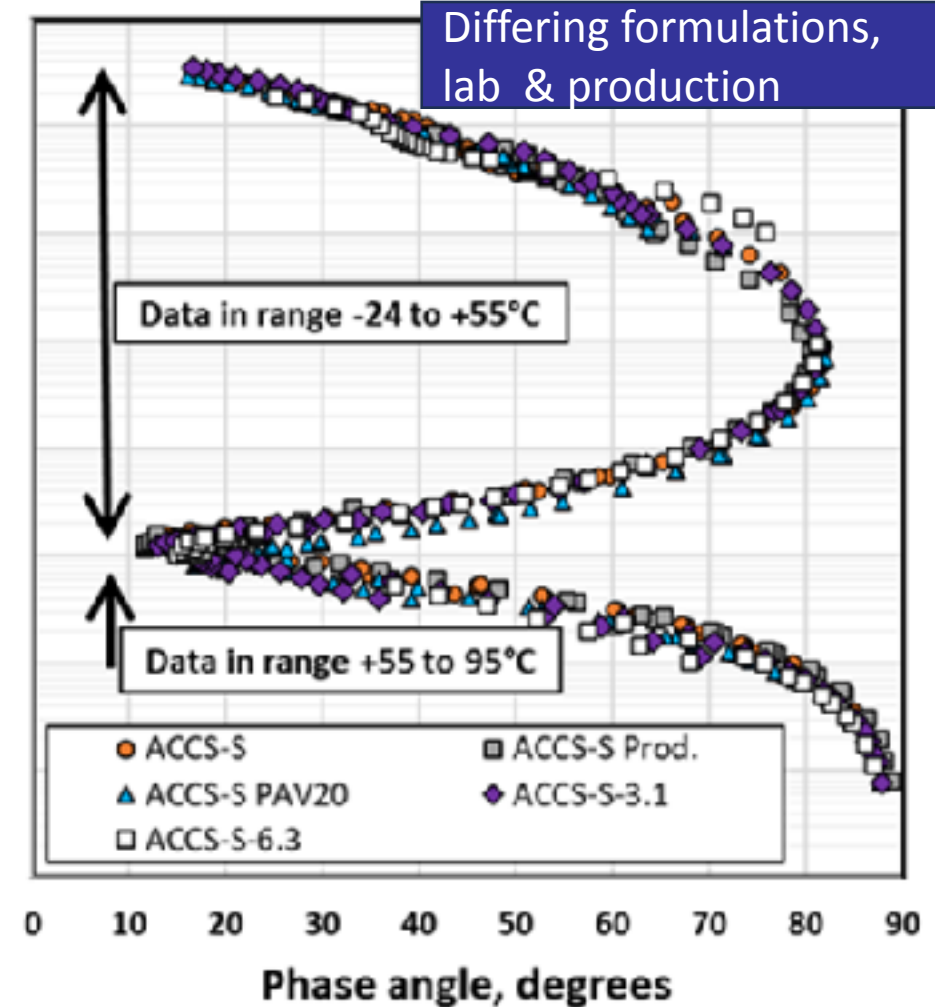
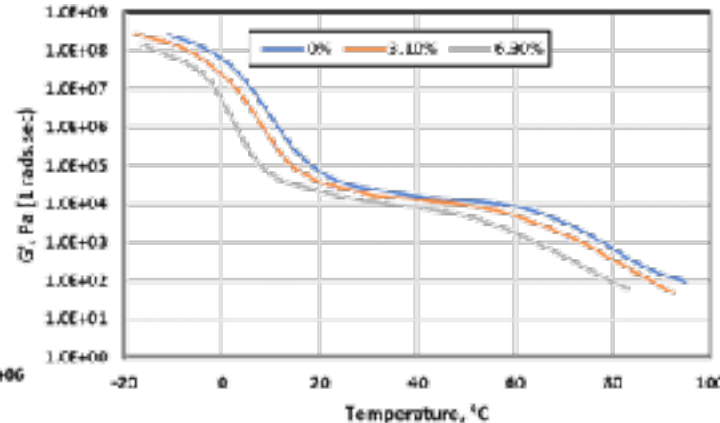
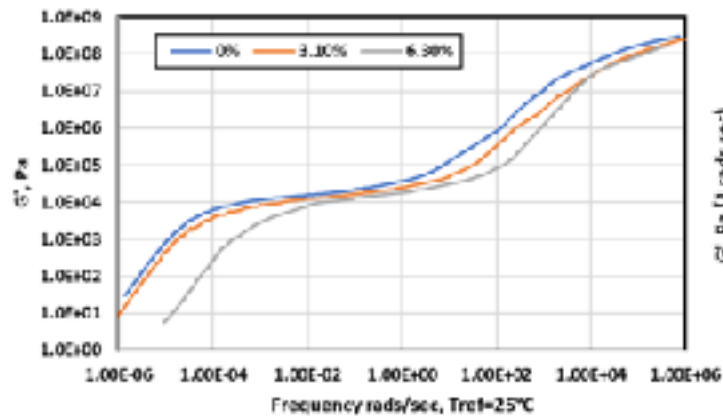
#1 – Rheology – Assessment of VE Solid Behavior

- The comparison shown is with conventional asphalts
 - Conventional materials show VE liquid behavior in stiffness range 1e4Pa and higher
 - If G^* data is plotted on frequency scale – then sigmoidal plot, consistent with VE solid model – format shown is against Richards sigmoid



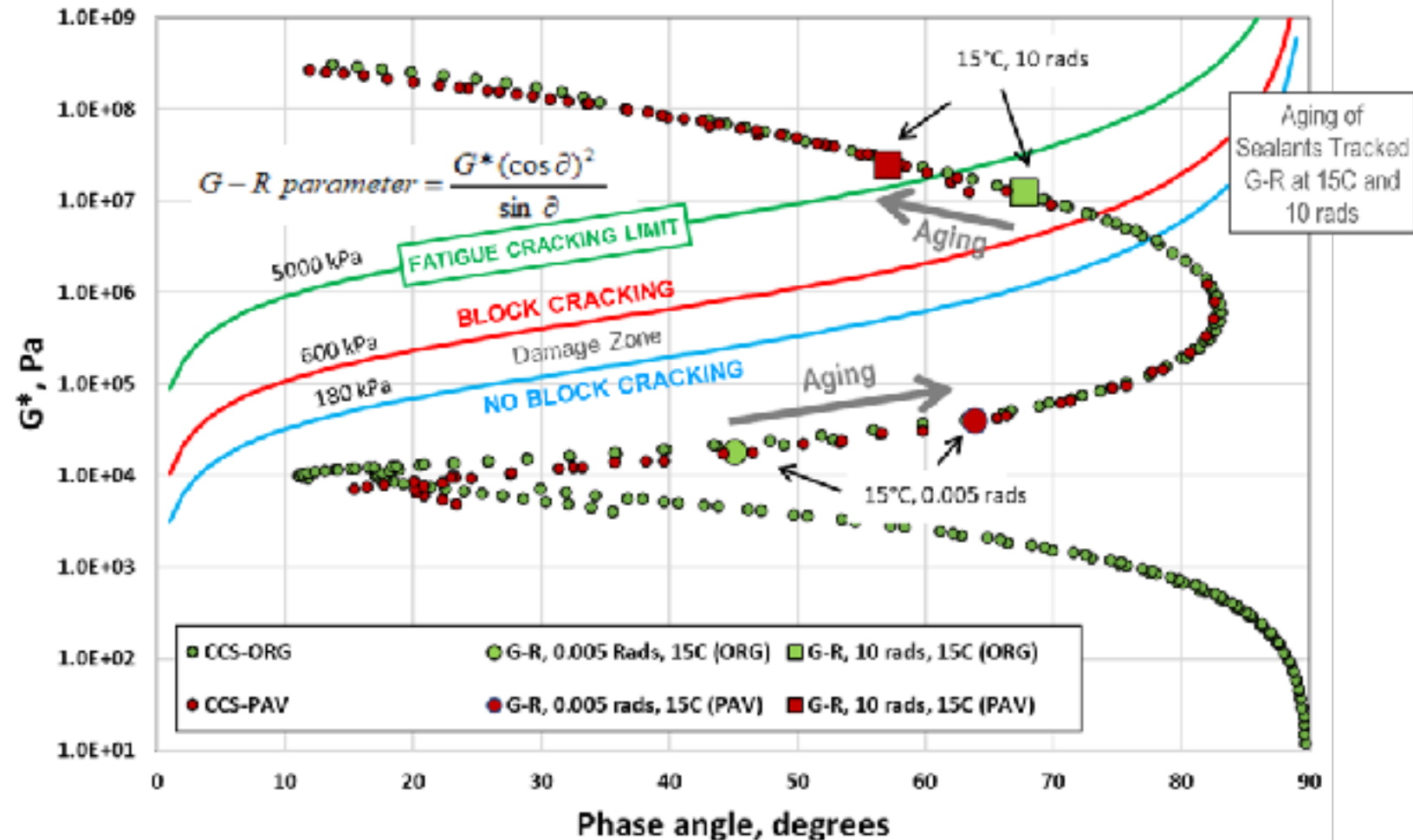
#1 – Rheology - Transforming rheology to critical time and temperature

- Can explore properties on frequency (loading time) and temperature scales to assess suitability for climates.
 - Adjustments to formulations enables sealants to be customized to different climate needs while still maintaining VE Solid, relaxation and aging performance



#1 Rheology – Glover Rowe – Aligning Binder Methods to Crack Sealant Aging Behavior

- G-R used as aging criteria – but at 15°C and 10 rads to capture critical zone relating to cracking performance
 - Ratios reviewed before and after PAV aging
 - Standard ≤ 5.0
 - Performance ≤ 2.5
- Standard based on analysis of SHRP Core asphalts



#2 - Specification Table

- Table looks at follows:

Material Grade	High Temperature	Intermediate Temperature		Low Temperature		Original 4°C	PAV Aged 4°C	Aging
	J_{nr} , 80°C, 1/KPa (maximum)	G^* , MPa (minimum)	δ , degrees (minimum)	G^* , MPa (maximum)	δ , degrees (minimum)	Ductility cm (minimum)	Ductility cm (minimum)	G-R ratio (maximum)
Standard	2.0, $T_{HT} < 58$	0.10	42.0	100.0	30.0	30		5
Performance	1.0, $T_{HT} > 64$		70.0	75.0	35.0	35	25	2.5

- All testing follows standard published well adopted methods
 - ASTM D7175 - DSR at 10 rads/sec
 - ASTM D7405 - MSCR test (3,200 Pa stress level)

#2 - Rheology based specification

- **High temperature stiffness**

- Assessed by Jnr at 3200Pa – this is a high stress test and we consider two requirements based on climatic area to ensure that material will not deform excessively at the higher temperatures.

- **Intermediate temperature**

- Calculation of the MAPT + 4C → rounded to closest of 15, 17, 19, 22, 25, 27 or 29°C.
- Ensures good relaxation and full recovery. If stiffness is too low, the stresses due to thermal movements will relax and recovery will not occur as desired. The stiffness range as specified ensures that the material will behave close to VE solid in normal working temperatures.

- **Low temperature**

- Calculated from the LTTP bind software (round to closest of -10, -4, 2, 8, 14, 20°C) or equivalent plus 30° → test at 10 radians/second.

- **Aging**

- Expressed on the G-R ratio using 15°C and 10 radians / second. This is calculated from tests on ORIGINAL and PAV conditioned samples. Note – the RTFO step as with paving grade binders is not performed for these sealant binders.

3 – Implementation – A New Paradigm

- Climate based performance
 - LTTP Bind – Low Temperature
 - Additional analysis at intermediate temperatures
 - High temperature – simplified into two zones
- Materials evaluated at production and at implementation
- QC manual and procedures for work flow
- Customization of appearance



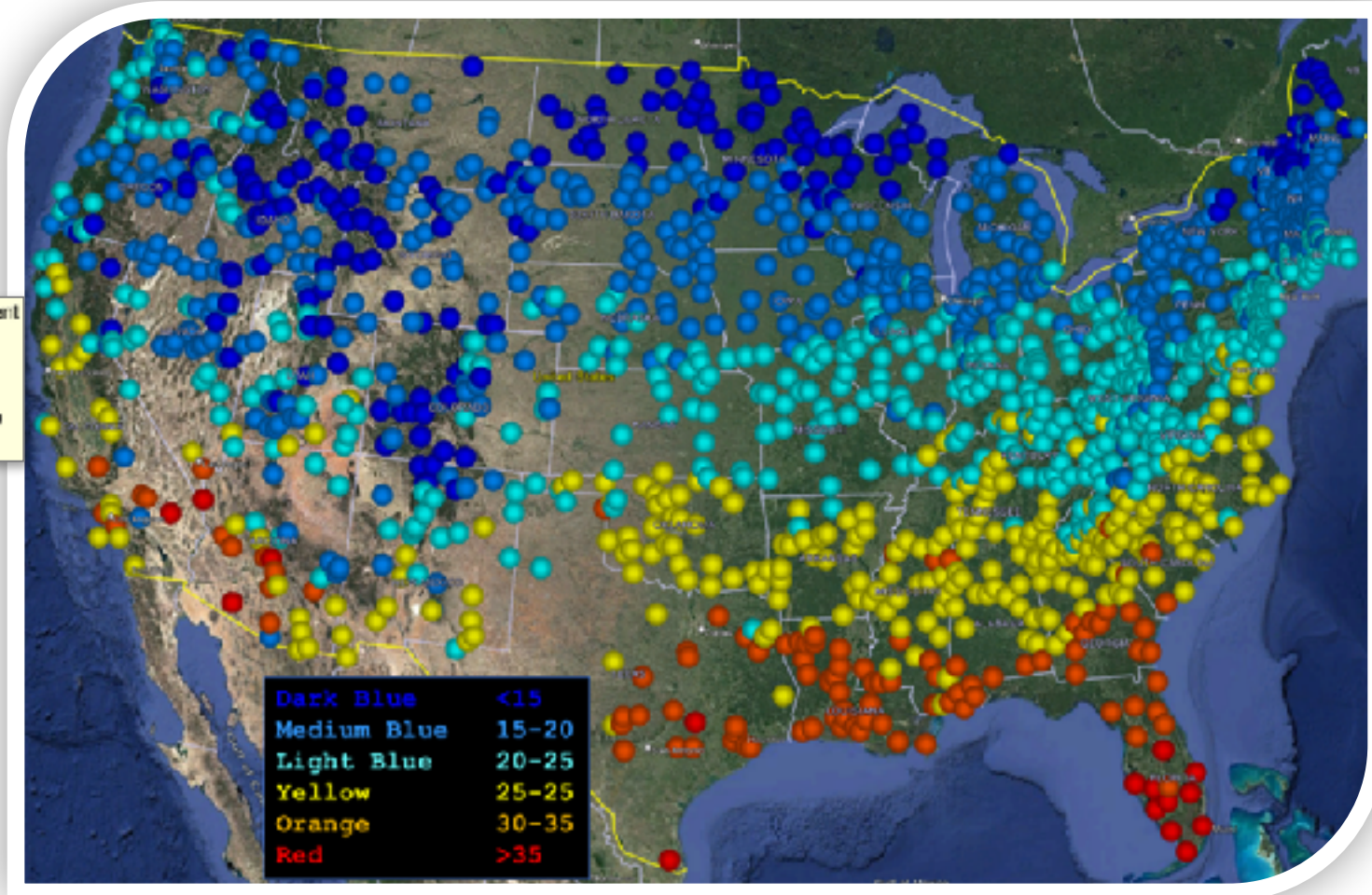
#3 – Implementation - Climate Analysis for Intermediate Temperature

- NOAA data used to assess pavement temperature
- Witczak developed equation for estimate of pavement temperature

$$M_p = M_a \left[1 + \frac{1}{M_a + 4} \right] - \frac{34}{M_a + 4} + 6$$

M_p = mean average pavement temperature (°F),
 M_a = mean annual air temperature (°F), and
 z = depth of desired location within pavement (in.)

- Used ideas developed in NCHRP in 9-59 work to estimate an intermediate temperature
- MAPT determined by averaging data developed for a 20 year data set



#3 – Implementation - Specification Examples for Locations with Composite Joint & Crack Sealants

Adhesion Performance Requirements	
Adhesion in Peel to Mortar (ASTM C794)	Max Adhesion Force (lbs-force), min.
Standard	20
Performance	40

Location Based Performance Specification						
Location	Low	Low + 30 rounded	Int. + 4	Int. (Rounded)	High	Sealant Grade ¹
Minneapolis	-27	2	14	15	53	58(15)-28
Kansas City	-21	8	22	22	61	64(22)-22
Dallas	-8	20	29-33	30	73	76(30)-10
Los Angeles ²	-4 to -5	20	29-33	30	73	76(30)-10

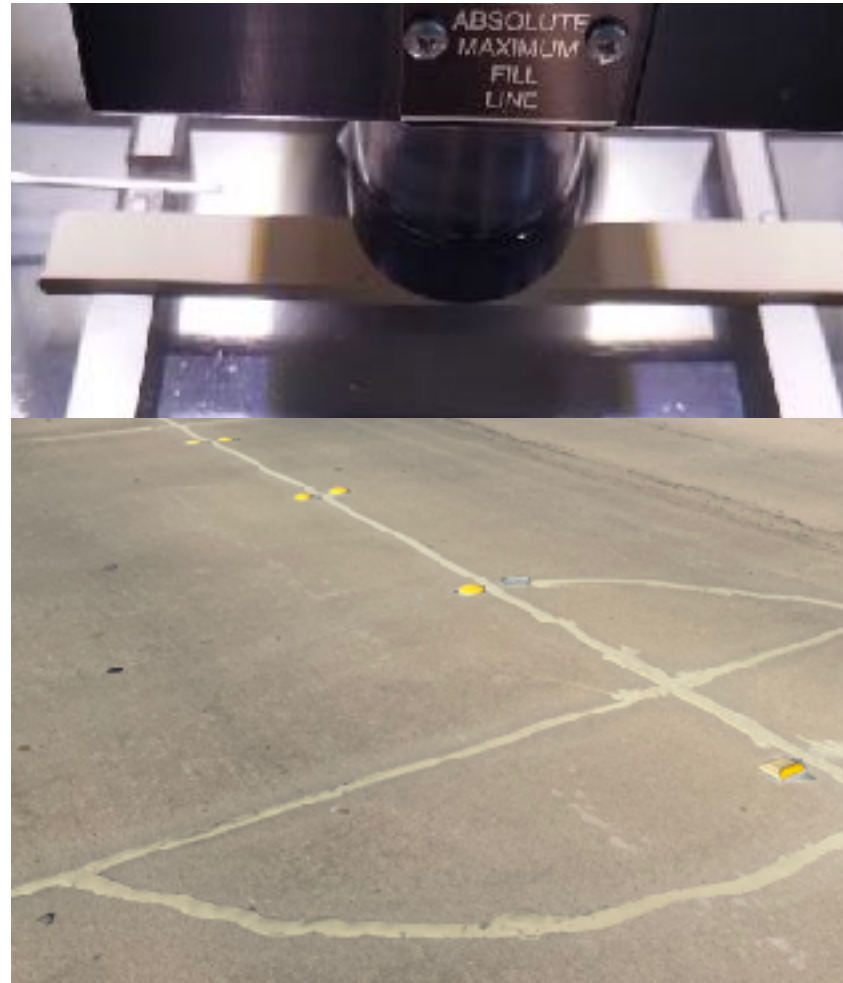
1. Sealant grade is using the basis as the PG grade system for binders. Use SG to reflect standard grade and PG to reflect Performance grade.

2. Locations close to LA in mountains have a considerably colder low temperature.

3 - Implementation - Assessment of Materials is Conducted for Climate Zone

Product Code	Temperature	High Temperature S ≤2.0, T _{HT} <58 P ≤1.0, T _{HT} ≥58	Intermediate Temperature (S ≥0.10, ≥42.0) (P ≥0.10, ≥70.0)		Low Temperature (S ≤100.0, ≥30.0) (P ≤75.0, ≥35.0)		Aging	Notes		
		Jnr, 80C	G*, MPa	δ, degrees	G*, MPa	δ, degrees	G-R ratio			
		<table border="1"> <tr><td>Performance</td></tr> <tr><td>Standard</td></tr> <tr><td>Fail requirements</td></tr> </table>								Performance
Performance										
Standard										
Fail requirements										
EF	2, 15	0.7105	2.61	47.7	16.4	34.2	11.13/2.622 = 4.2	Standard in all areas. Stiffness reduces for warmer climates. The PAV aging results in a failure for all locations. PAV – for information only.		
	8, 22		0.59	48.6	7.2	41.7				
	20, 30		0.22	46.55	2.23	47.7				
CCS	2, 15	0.559 Prod. 0.5029 QC	1.84	62.3	143.6	32.0	7.222 /4.506 = 1.60	Fails Minneapolis due to high stiffness and phase at low temperature. KC and LA area meets premium product.		
	8, 22		1.45	78.9	49.8	47.9				
	20, 30		2.10	74.8	2.47	77.6				
CCS+3.1	2, 15	0.7443	3.41	75.5	61.0	44.9	502.7/364.4 = 1.38	Premium product. Product that meets all three zones.		
	8, 22		0.76	77.9	20.1	61.5				
	20, 30		0.13	71.2	1.21	78.0				
CCS+6.3	2, 15	1.449	1.11	83.6	44.9	48.2	37.26/13.29 = 2.80	Pass as premium for MN. Lacks stiffness/ recovery for KC, LA. For KC – the Jnr is too low!		
	8, 22		0.13	73.8	7.8	78.5				
	20, 30		0.03	51.4	2.1	78				
Asphalt Based Traditional	2, 15	0.294	8.9	41.9	46.2	30.9	20.48 /7.412 = 2.763	Marginal pass for MN area.		
	8, 22		2.52	47.1	20.4	36.2				
	20, 30		0.80	49.6	3.40	46.5				
GF	2, 15	0.53	22.0	57.0	192.5	28.96	12.38/7.797 = 1.59	Too stiff and poor relaxation at cold temperature for MN climate. Premium product in KC and LA.		
	8, 22		2.53	74.2	69.6	42.9				
	20, 30		0.35	74.5	4.3	71.3				
GF+2.5	2, 15	0.83	7.0	71.1	75.7	40.6	1.516/0.7748 = 1.96	Premium product. Product that meets all three zones.		
	8, 22		0.94	70.7	26.2	56.5				
	20, 30		0.16	71.3	1.52	78.18				

3 – Implementation is in Progress



#4 - Summary

- New materials for crack sealing have been implemented with DOTs and Municipalities in various states around the USA.
 - Materials have exceptional properties
 - VE solid in working range with very high relaxation properties
 - Specification approach developed based on rheology
 - Specification approach recognizes existing products in market – enables customer to evaluate sealant performance for different applications
 - Implementation
 - Makes use of t-T analysis to assess properties at different conditions
 - Once climate analysis performed – pass/fail determined by DSR standard tests
 - QC includes site samples from application location



Thank you for listening
Questions or Comments?

