Performance Guidelines for the Selection of Hot-Poured Bituminous Crack Sealants

Imad L. Al-Qadi
S-H Yang
Eli Fini
J-F Masson
Kevin McGhee

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<table>
<tr><th rowspan="2">Crack Sealant Performance Grade</th><th colspan="7">SG-46</th><th colspan="7">SG-52</th><th colspan="7">SG-58</th><th colspan="7">SG-64</th><th colspan="7">SG-70</th><th colspan="7">SG-76</th><th colspan="7">SG-82</th></tr>
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<tr><th>Apparent Viscosity, SC-2</th><td colspan="49">Installation Temperature</td></tr>
<tr><th>Max. Viscosity (Pa.s)</th><td colspan="49">3.5</td></tr>
<tr><th>Min. Viscosity (Pa.s)</th><td colspan="49">1</td></tr>
<tr><th colspan="50">Vacuum Oven Residue (SC-3)</th></tr>
<tr><th>Dynamic Shear, SC-4</th><td colspan="7">46</td><td colspan="7">52</td><td colspan="7">58</td><td colspan="7">64</td><td colspan="7">70</td><td colspan="7">76</td><td colspan="7">82</td></tr>
<tr><th>Min. Flow Coefficient (kPa.s)</th><td colspan="49">4</td></tr>
<tr><th>Min. Shear Thinning</th><td colspan="49">0.7</td></tr>
<tr><th>Crack Sealant BBR, SC-5</th><td>-40</td><td>-34</td><td>-28</td><td>-22</td><td>-16</td><td>-10</td><td>-4</td><td>-40</td><td>-34</td><td>-28</td><td>-22</td><td>-16</td><td>-10</td><td>-4</td><td>-40</td><td>-34</td><td>-28</td><td>-22</td><td>-16</td><td>-10</td><td>-4</td><td>-40</td><td>-34</td><td>-28</td><td>-22</td><td>-16</td><td>-10</td><td>-4</td><td>-40</td><td>-34</td><td>-28</td><td>-22</td><td>-16</td><td>-10</td><td>-4</td><td>-40</td><td>-34</td><td>-28</td><td>-22</td><td>-16</td><td>-10</td><td>-4</td><td>-40</td><td>-34</td><td>-28</td><td>-22</td><td>-16</td><td>-10</td><td>-4</td></tr>
<tr><th>Max. Stiffness (MPa)</th><td colspan="49">25</td></tr>
<tr><th>Min. Avg. Creep Rate</th><td colspan="49">0.31</td></tr>
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<tr><th>Min. Extendibility (%)</th><td>>85</td><td>>85</td><td>>70</td><td>>55</td><td>>40</td><td>>25</td><td>>10</td><td>>85</td><td>>85</td><td>>70</td><td>>55</td><td>>40</td><td>>25</td><td>>10</td><td>>85</td><td>>85</td><td>>70</td><td>>55</td><td>>40</td><td>>25</td><td>>10</td><td>>85</td><td>>85</td><td>>70</td><td>>55</td><td>>40</td><td>>25</td><td>>10</td><td>>85</td><td>>85</td><td>>70</td><td>>55</td><td>>40</td><td>>25</td><td>>10</td><td>>85</td><td>>85</td><td>>70</td><td>>55</td><td>>40</td><td>>25</td><td>>10</td><td>>85</td><td>>85</td><td>>70</td><td>>55</td><td>>40</td><td>>25</td><td>>10</td></tr>
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<tr><th>Min. Load (N)</th><td colspan="49">50</td></tr>
<tr><th>Min. Energy (J/m^2)</th><td colspan="49">40</td></tr>
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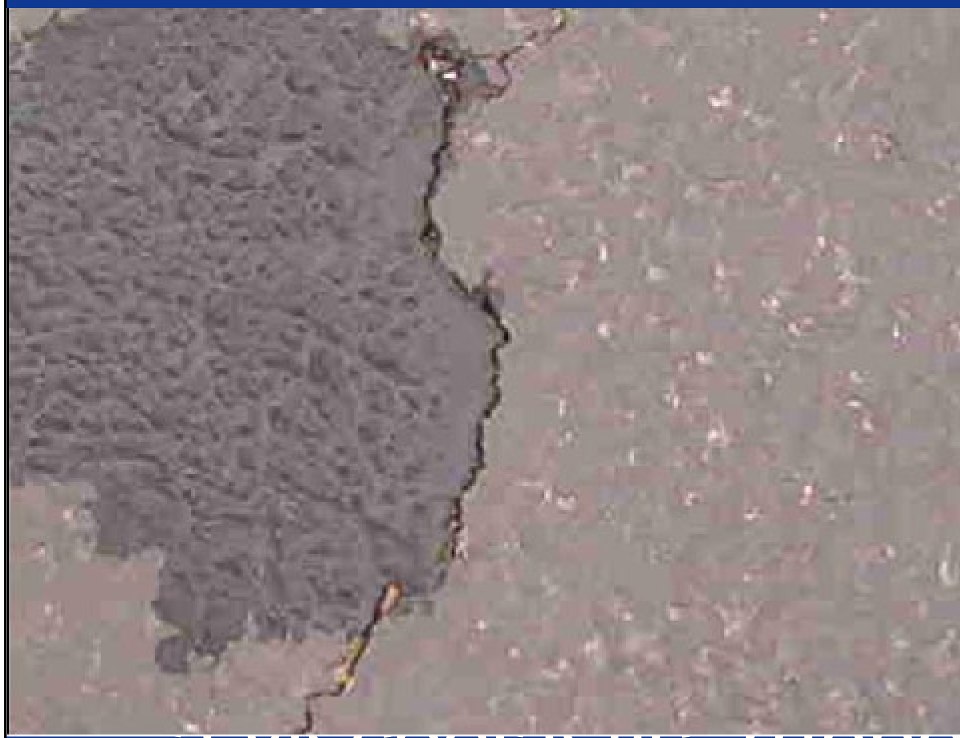
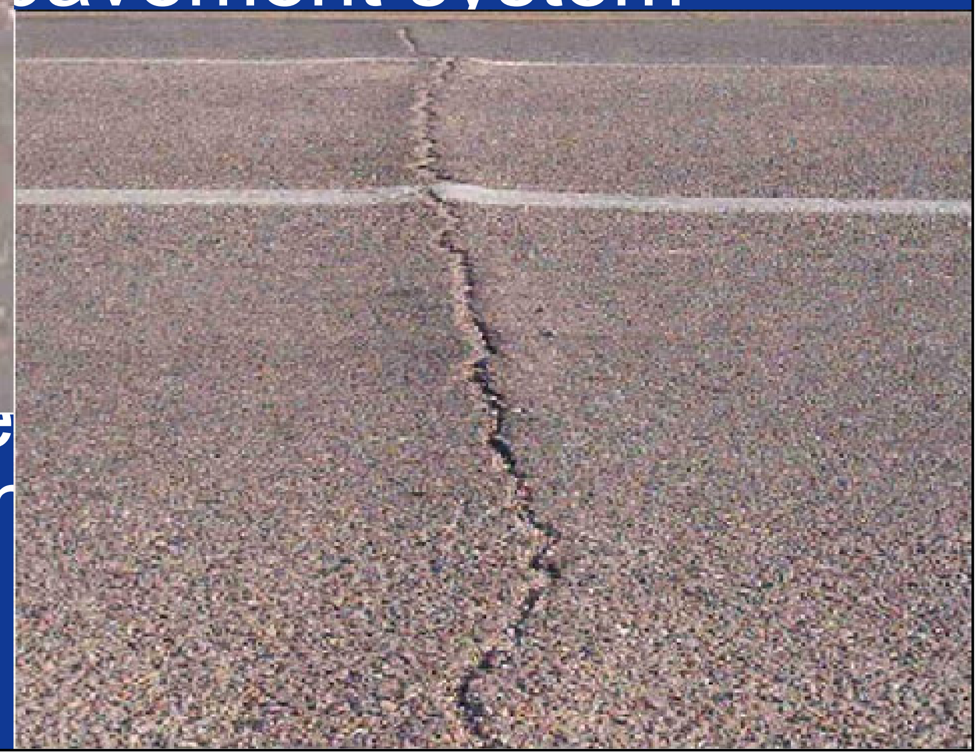
Outline

- Introduction on Crack Sealants
- Study Objectives
- Study products/specifications
  - Constructability
  - Accelerated aging
  - High temperature
  - Low temperature
- Preliminary field validation
- Summary & Future Research

Crack Sealant

esses both adhesive
ties to form a seal
ds and solids from
pavement system --

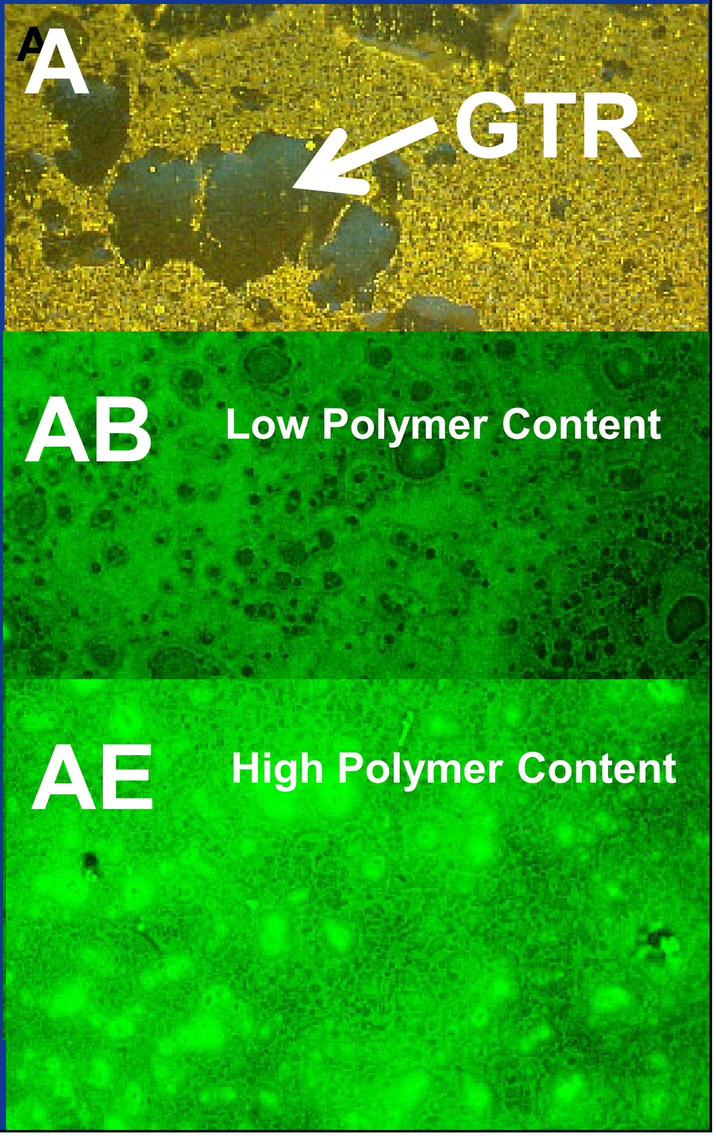




a viscoelastic, rubbe
withstands extension
weathering

Crack Sealant

- Polymer-modified bitumen with a filler
  - Polymer
    - Styrene-Butadiene copolymer (SBS)
    - Reduces thermal susceptibility
  - Filler
    - Ground tire rubber (GTR)
    - Mineral filler
    - Provides body and improves wearing resist

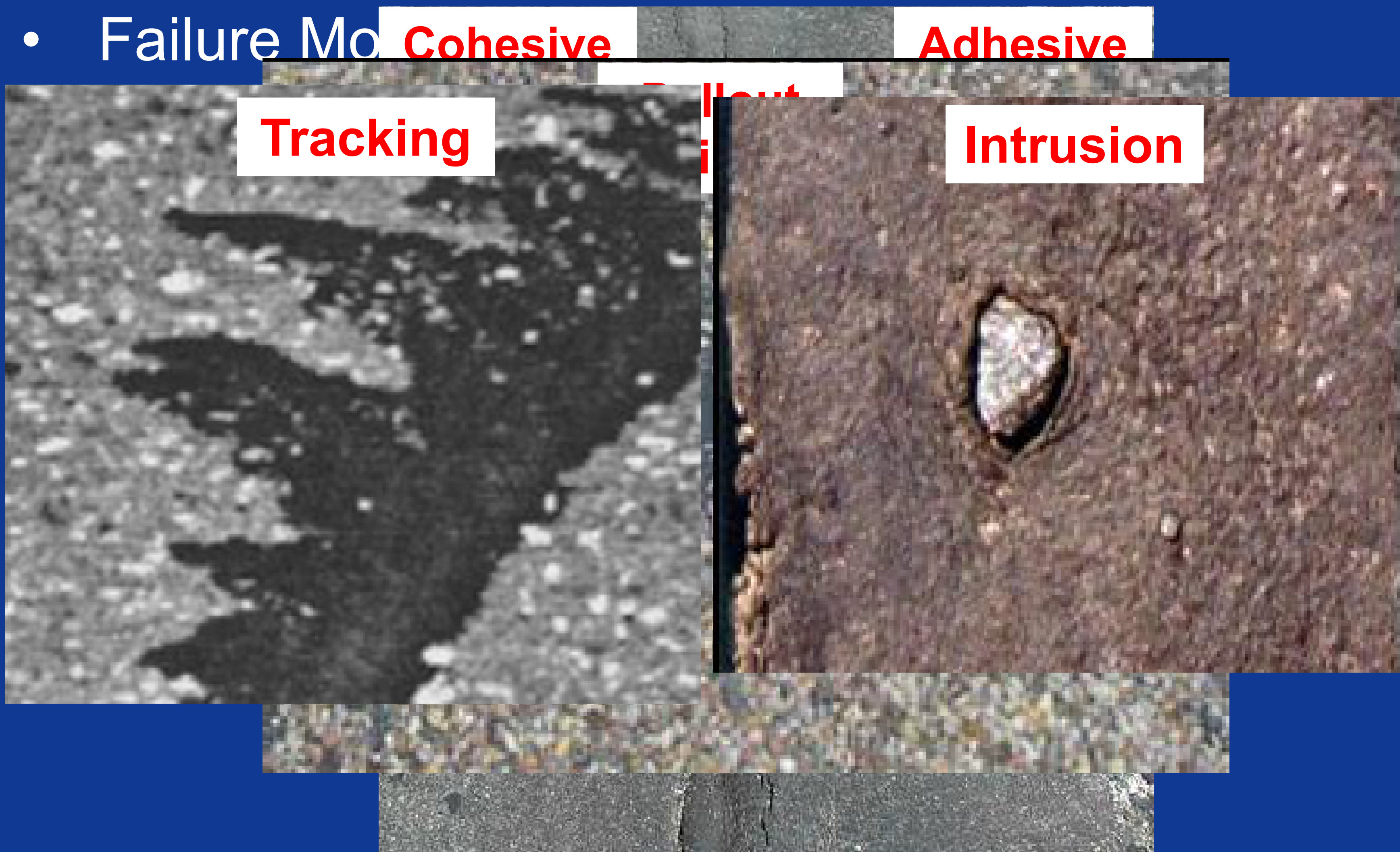


Crack Treatment Action

- Crack sealing/ filling is the most widely used maintenance activity of in-service pavements
  - Sealing – use for working crack
  - Filling – use for non-working crack
- Inexpensive, quick, and a well-proven technique to delay pavement deterioration
  - Reduces water penetration
  - Maintains pavement structural capacity
  - Improves road rideability
  - Extends pavement service life (2years↑)

Crack Sealant Failure

- Failure Mo



Current ASTM Specifications

Sealant Property	Test Method	ASTM Spec.
Application Characteristics	Viscosity (binder)	D4402
Adhesion	Bond Test Asphalt Compatibility	D5329 D5329
Extensibility	Elongation (rubber) Ductility (binder)	D412 D113
Durability	Track Abrasion (slurry)	D3910
Flexibility	Flexibility Cone Penetration	D5329 D5329
Tracking	Flow Softening Point	D5329 D36
Intrusion Resistance	Resilience Aged Resilience	D5329 D5329

Objective – Phase 1 Study

- Development of performance-based guidelines for the selection of hot-poured crack sealant
  - Make use of SuperPave™ binder-testing equipment
  - Adapt the spirit of the binder Performance Grade (PG) specifications
  - Place emphasis on fundamental properties that relate in a rational way to performance

Crack Sealant Used in the Study

ID	Notes	Cone Pen. 25° C (dmm)	Flow 60° C (mm)	Aged Resilience 25° C (%)	Bond (P/F)	Asphalt Comp. (P/F)	Softening Point (° C)
QQ	**Stiffest sealant**	**22**	**0**	**36**	**N/A**	**P**	**220**
ZZ	**San Antonio, TX**	**42**	**N/A**	**N/A**	**P**	**N/A**	**212**
AB	**San Antonio, TX**	**40**	**N/A**	**23**	**N/A**	**N/A**	**N/A**
UU	**SHRP H106**	**62**	**1.5**	**N/A**	**P**	**N/A**	**N/A**
LL	**Virginia**	**68**	**2**	**50**	**P**	**N/A**	**N/A**
NN	**Minnesota**	**75**	**0**	**70**	**P**	**P**	**N/A**
AE	**NY, VA, and NH**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**
PP	**Minnesota**	**130**	**1**	**44**	**P**	**P**	**N/A**
A	**Montreal**	**86**	**0.5**	**57**	**F**	**N/A**	**N/A**
B	**Montreal**	**68**	**0.5**	**64**	**P**	**N/A**	**N/A**
E	**Montreal**	**124**	**1**	**73**	**P**	**N/A**	**N/A**
G	**Montreal**	**50**	**0.5**	**51**	**F**	**N/A**	**N/A**
J	**Montreal**	**66**	**6**	**48**	**P**	**N/A**	**N/A**

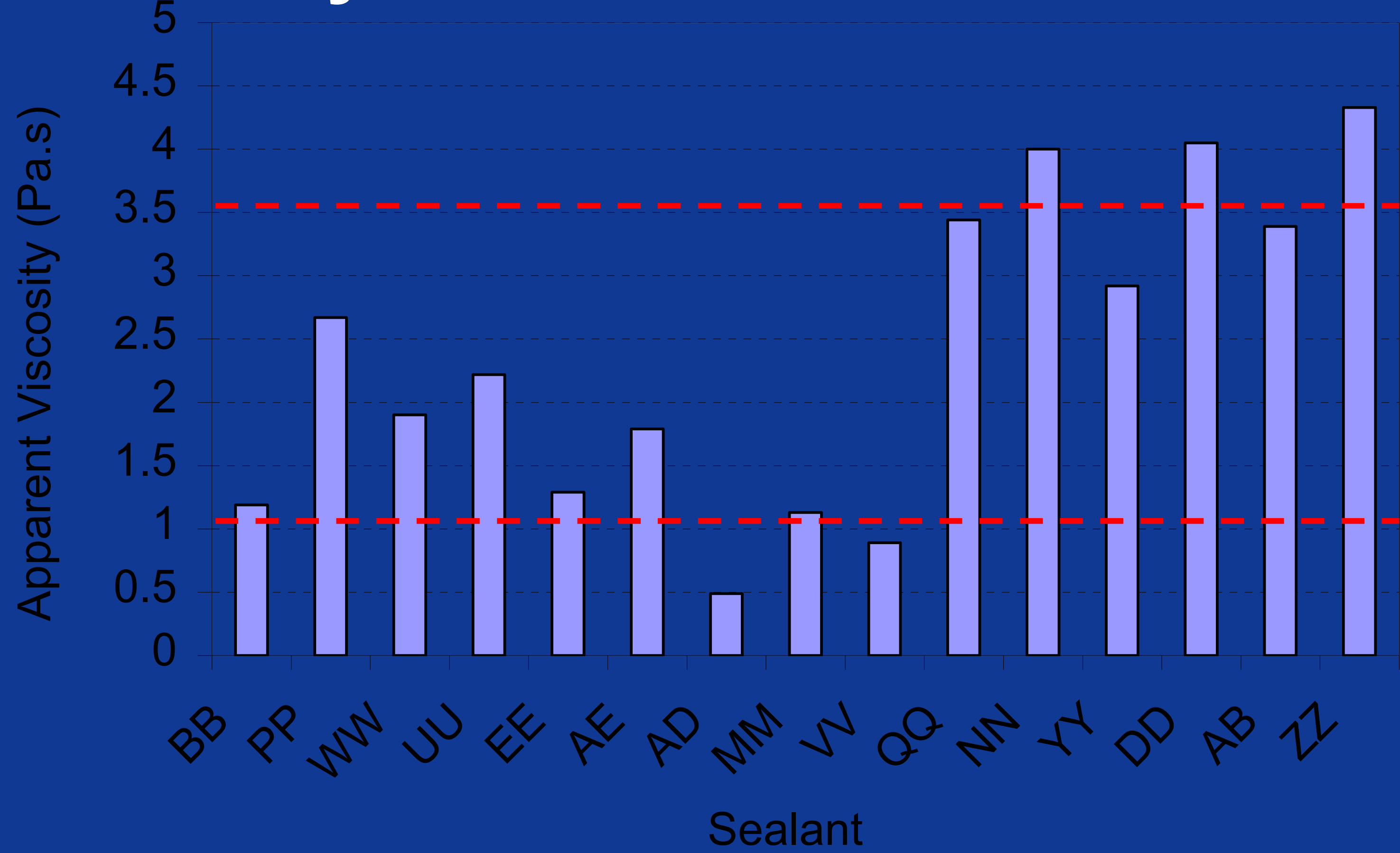
Crack Sealant Performance Tests

Apparent Viscosity (SC-2)

- Evaluate sealant constructability
- Test modifications and protocol
  - Rotational Viscometer (Brookfield)
  - Rigid rod
  - Melting time
    - 20min
  - Spindle size
    - SC-27
  - Speed
    - 60rpm

Apparent Viscosity (SC-2)

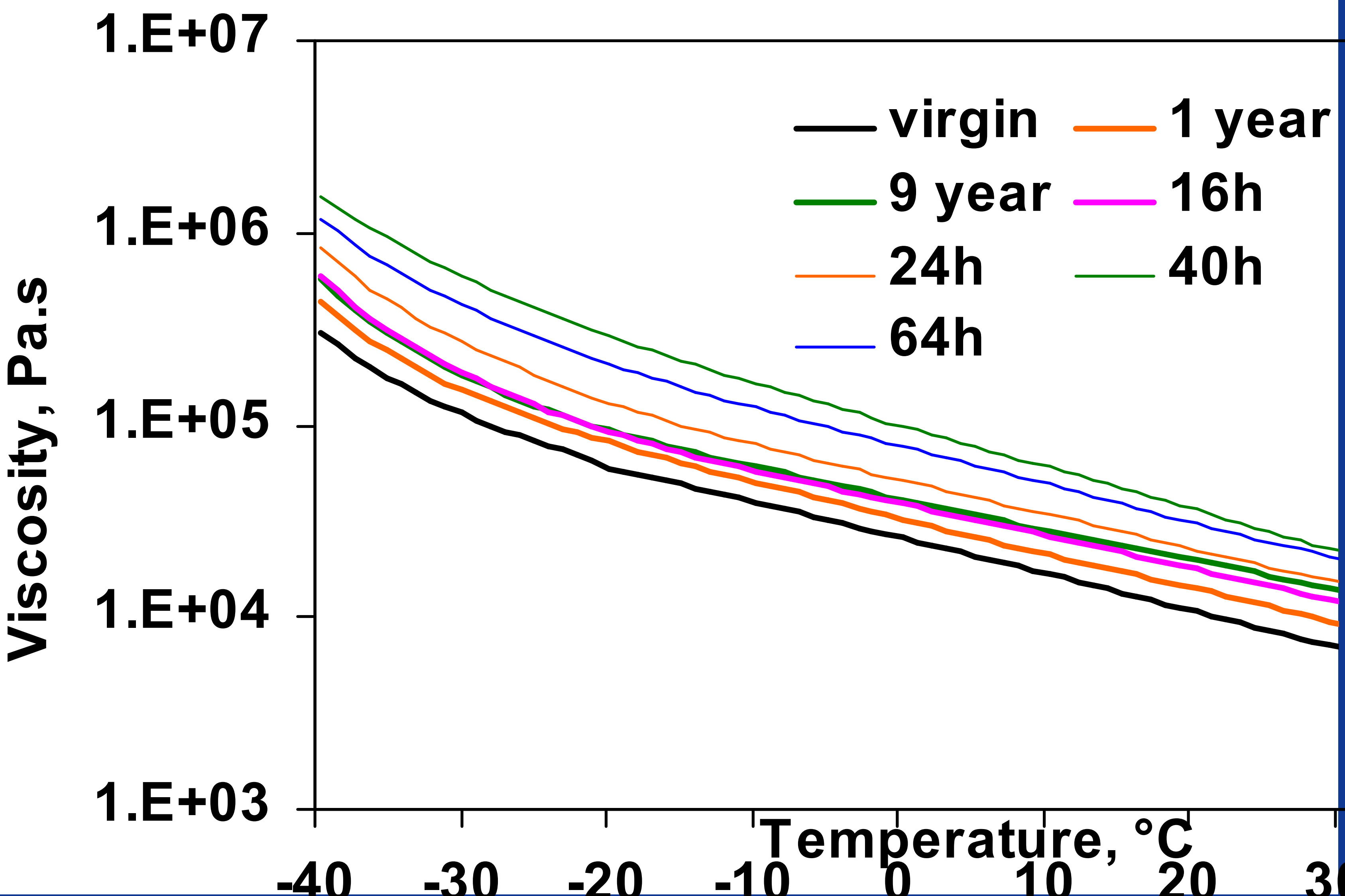
- A minimum and maximum apparent viscosity of 1 and 3.5 Pa.s



Vacuum Oven Aging (SC-3)

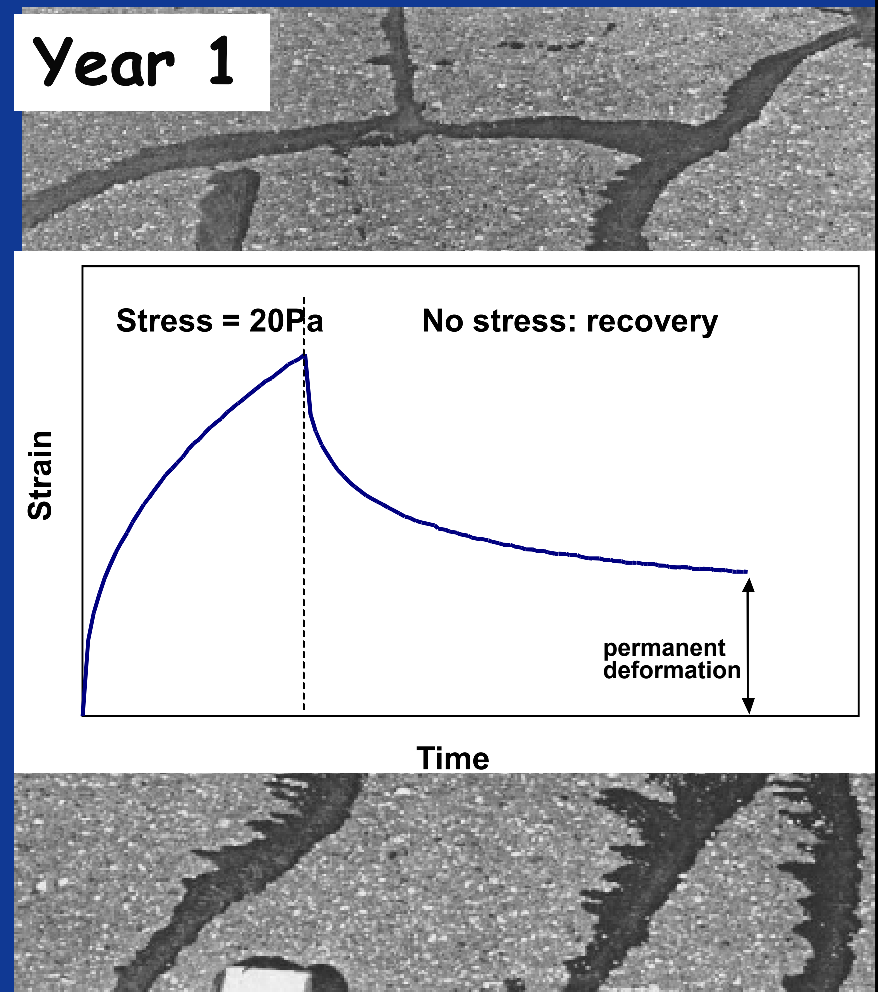
- **Simulates Crack Sealant Weathering in Kettle & Field**
- Test method
  - Vacuum oven aging
- Test protocol
  - Place 30 ± 0.5g of sealant on a PAV pan
  - Thickness of the sealant film ~ 2mm
  - Apply 115°C in vacuum oven for 16hrs

VOA (SC-3) - Verification



Dyn. Shear Rheom. (SC-4)

- High temperature tracking resistance
- Correlate tracking flow with DSR
- Test protocol
  - Creep-recovery test
  - Apply 2s of shear stress followed by 18s of recovery
  - Apply 8 levels of stresses (25, 50, 100, 200, 400, 800, 1600, and 3200 Pa)



Dyn. Shear Rheom. (SC-4)

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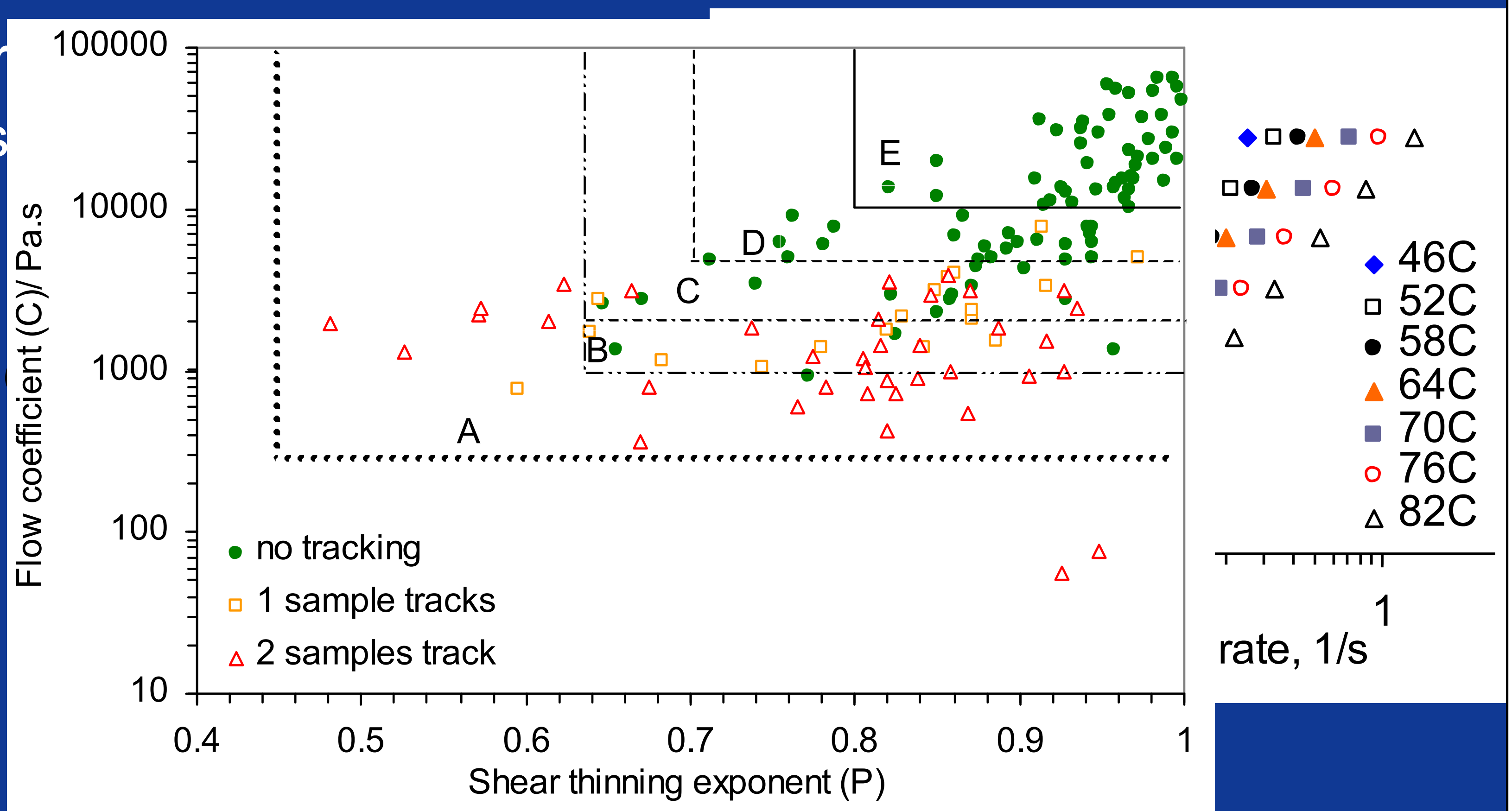
  - Os



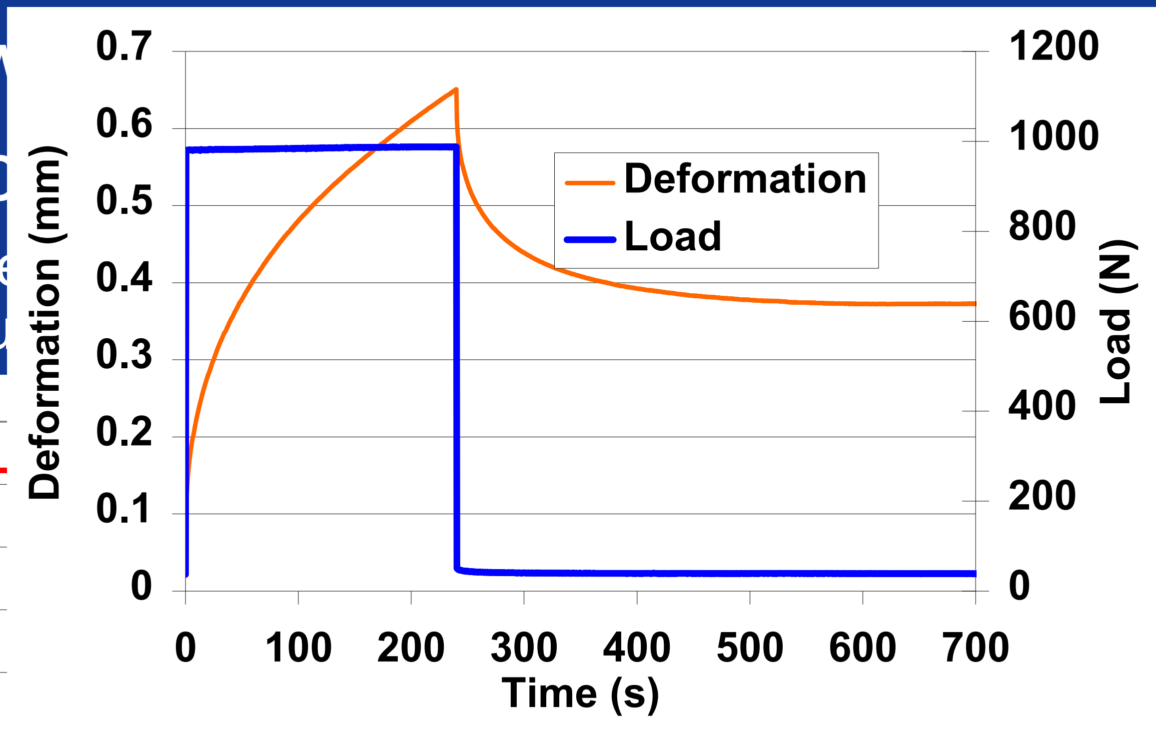
- A minimum flow coefficient of 4k Pa.s and a shear thinning exponent of 0.7

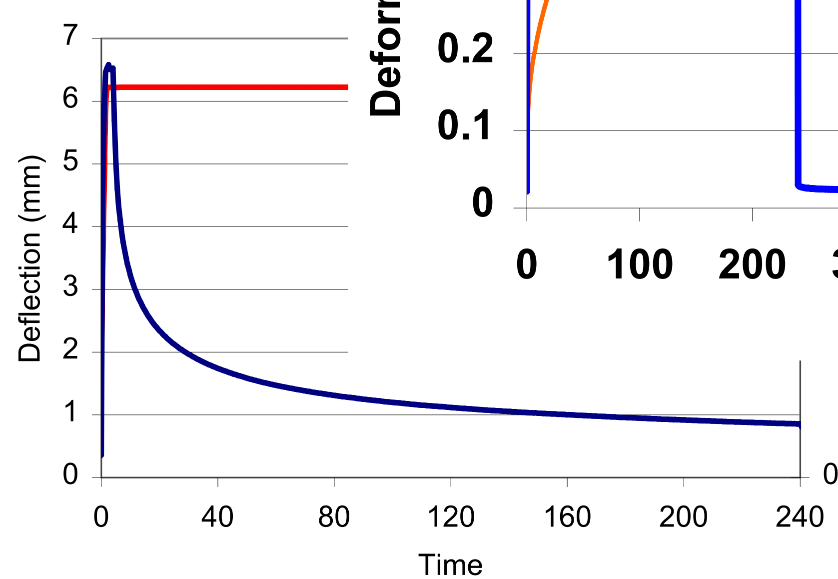
Low Temperature Performance

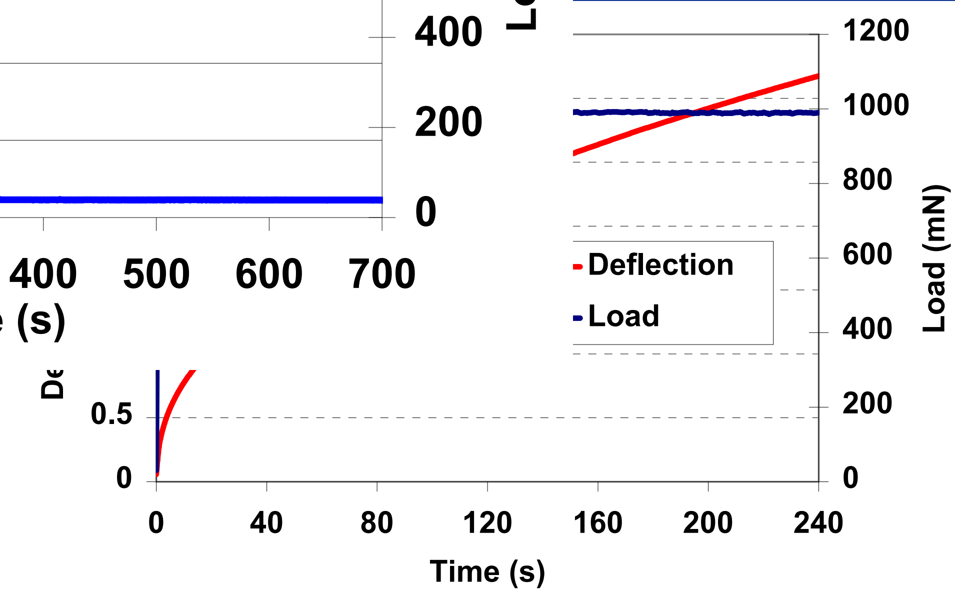
- Bulk Properties
  - Flexural Properties
    - Modified Bending Beam Rheometer (SC-5)
  - Extendibility
    - Direct Tension Test (SC-6)
- Adhesion Properties
  - Work of Adhesion
  - Direct Adhesion Test (SC-7)
  - Blister Test (SC-8?)

Bending Beam Rheom. (SC-5)

- Low ... ties
- Exc ... nt
  - De ... it of the cu ...

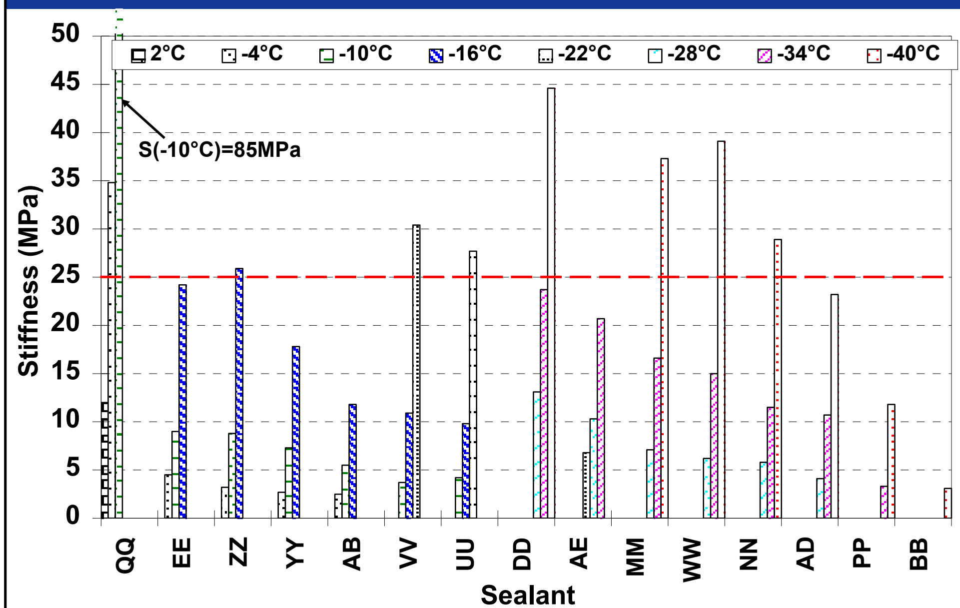


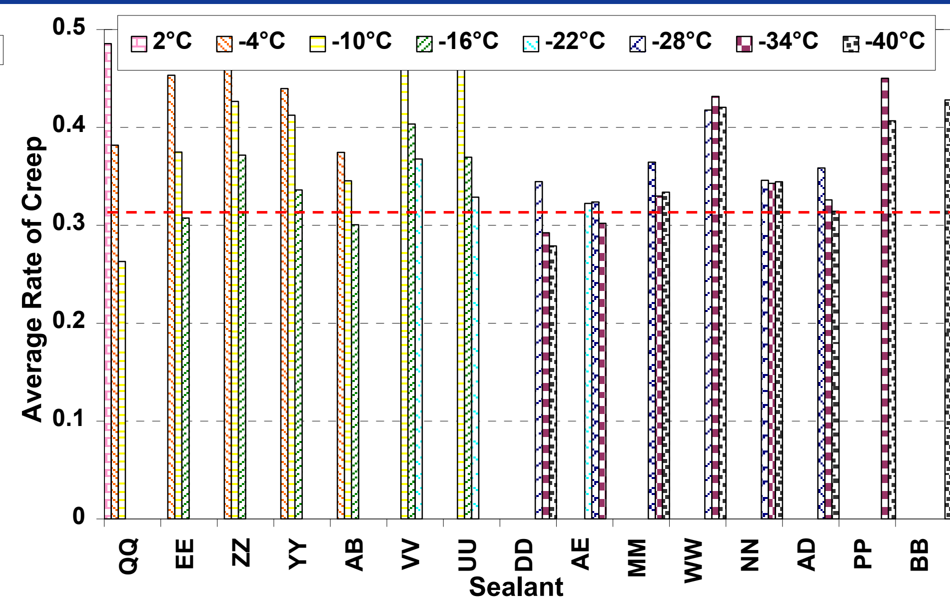




Bending Beam Rheom. (SC-5)

- Performance parameter





- **A maximum stiffness of 25MPa and a minimum average creep rate of 0.31**

Direct Tension Test (SC-6)

- Low Temperature Extendibility
- Simulates loading condition in the field
- Test modifications and protocol
  - Increase extension capacity
    - SuperPave™ (33%) → Crack Sealant (90^{+}%)
  - Specimen Dimension
    - 3mm (depth) x 24mm (length)

Studies	Max Crack (%)	Min Crack (%)	Fast Move. (mm/min)	Slow Move. (mm/min)
Smith & Romine, 1993	18	2.5	5×10^{-3}	2.77×10^{-4}
Linde, 1988	63	N/A	8×10^{-3}	5×10^{-5}
Cook et al., 1991	+90	6	N/A	N/A
Masson & Lacasse, 1999	16	7	N/A	N/A

Direct Tension Test(SC-6)

- Performance parameter
  - Extendibility (λ)

$$\lambda = \frac{\Delta L}{L_{eff}}$$

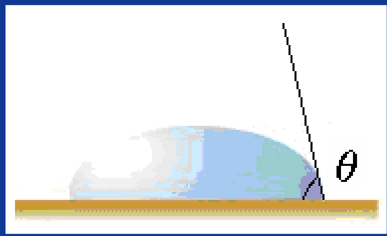
- ΔL = at breaking point
  = at max. deformation
  = at point ($P_2/P_1<90\%$)

- **The extendibility criterion based on various climatic conditions**

λ

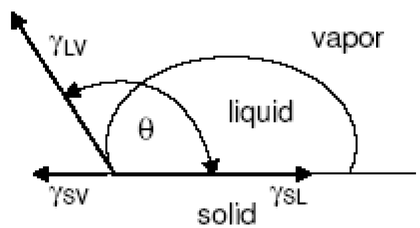
Adhesion Test (SC-7)

- Low temperature adhesion property
- Surface Energy Method (Work of Adhesion)
  - A compatibility test for sealant producers
- Direct Bond Method
  - A quality control test for practitioners
- Blister Test Method
  - Fundamental test for advanced research

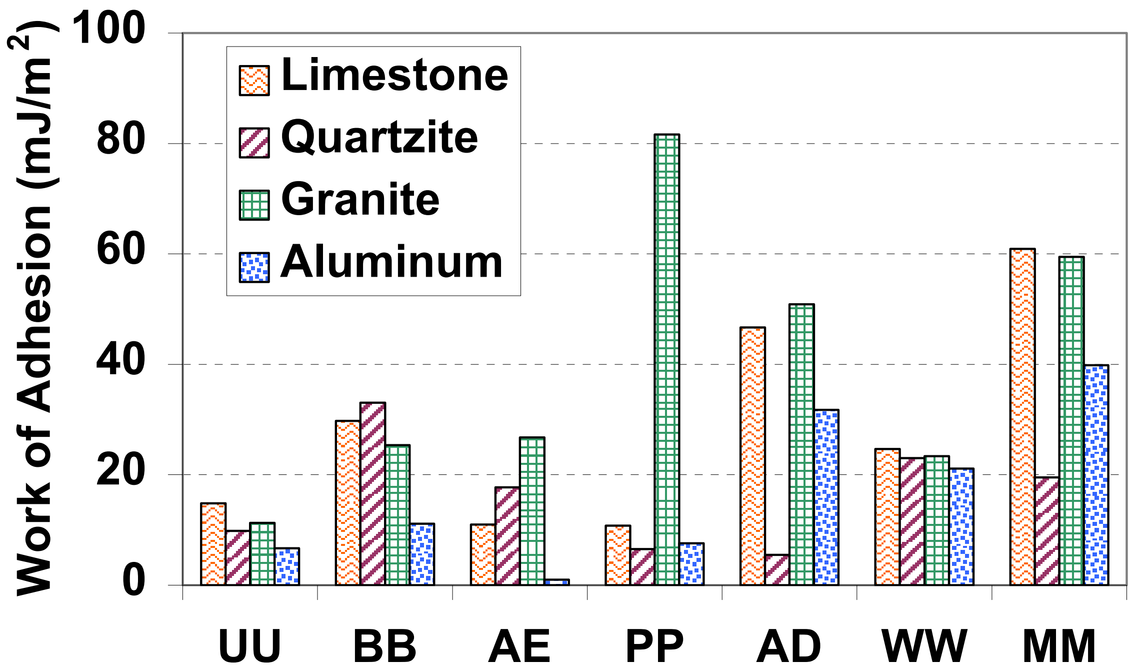


Work of Adhesion

- A fundamental property but not conclusive characterization of interface
- Test method
  - Sessile Drop

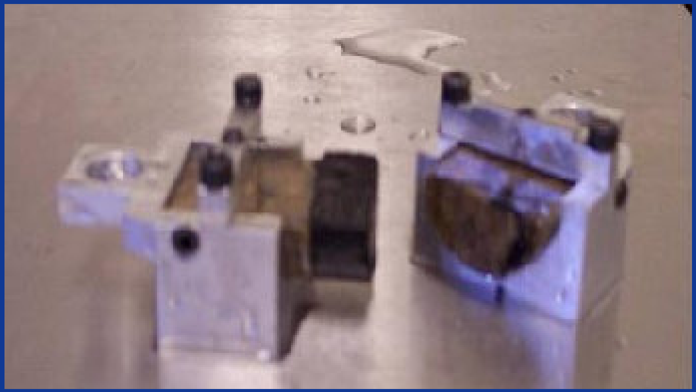


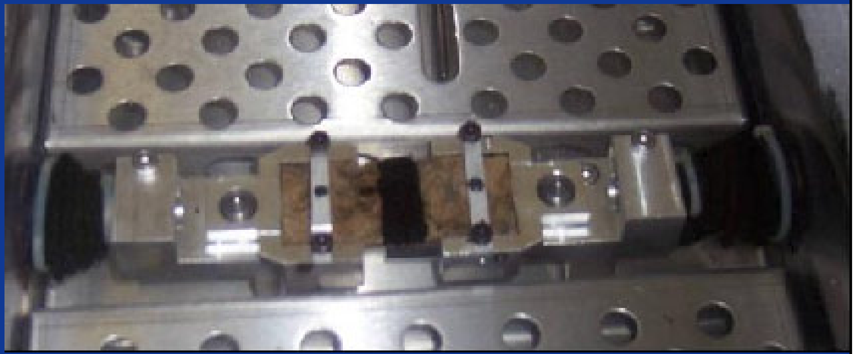
$$W_a = \gamma_s^{total}(1+\cos\theta)$$



Direct Bond Test (CS-7)

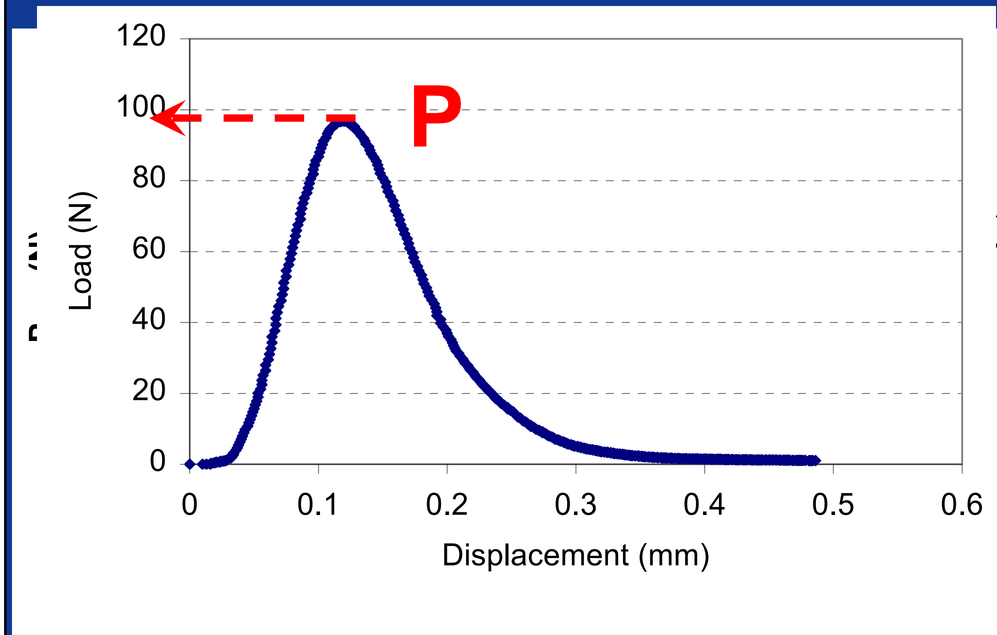
- Deformation rate controlled test
- Test protocol
  - Two aluminum half-cylinders
  - Diameter
    - 25mm
  - Sealant thickness
    - 10mm
  - Displacement rate
    - 0.05mm/s
- Specific failure location

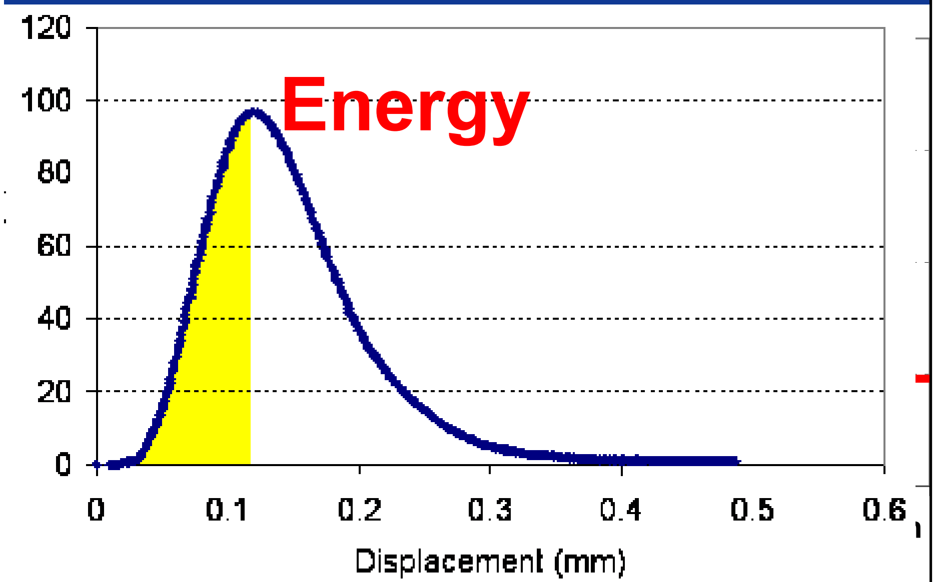




Direct Bond Test Threshold

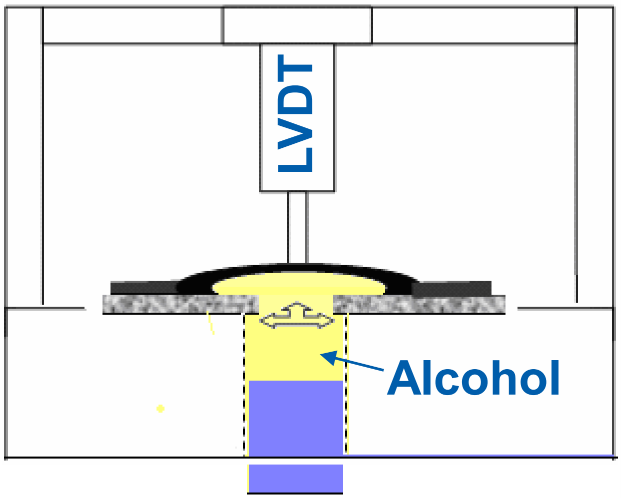
- Performance Parameter
  - P_{min}
  - De-bond Energy
- A minimum load of 50N and a minimum de-bonding energy of 40J/m^2

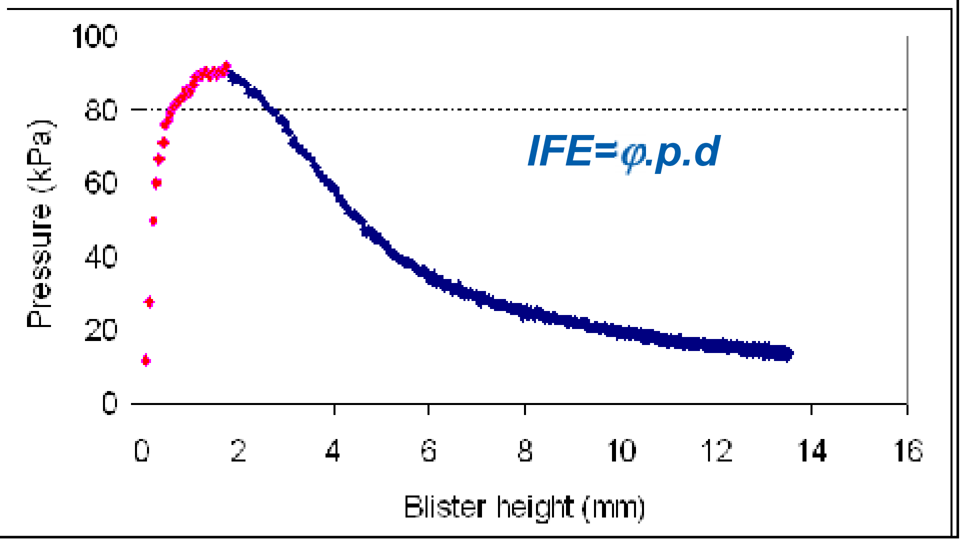




Blister Test

- Displacement rate controlled test
- Test protocol
  - Orifice size
    - 25 mm
  - Sealant film thickness
    - 4.7mm
  - Displacement rate
    - 0.12mm/s



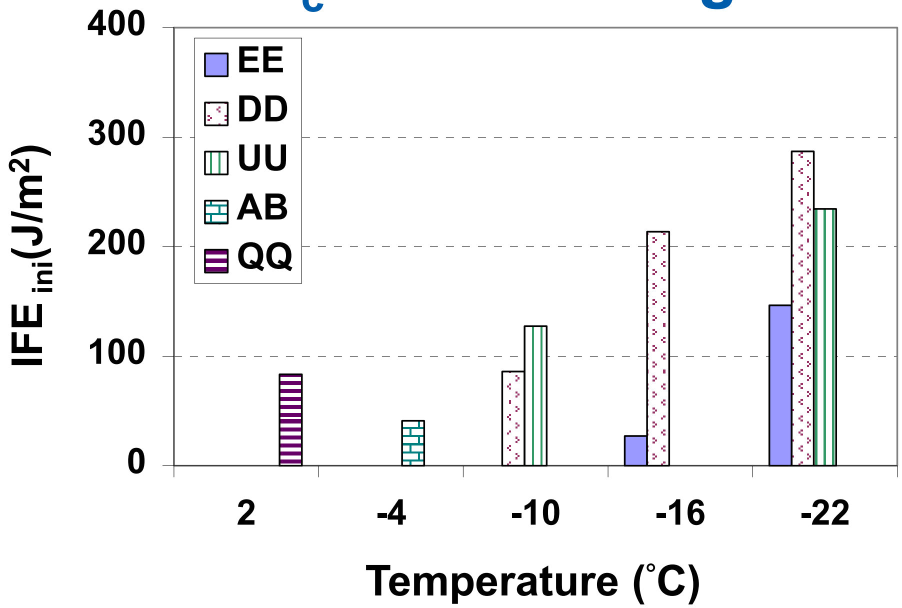


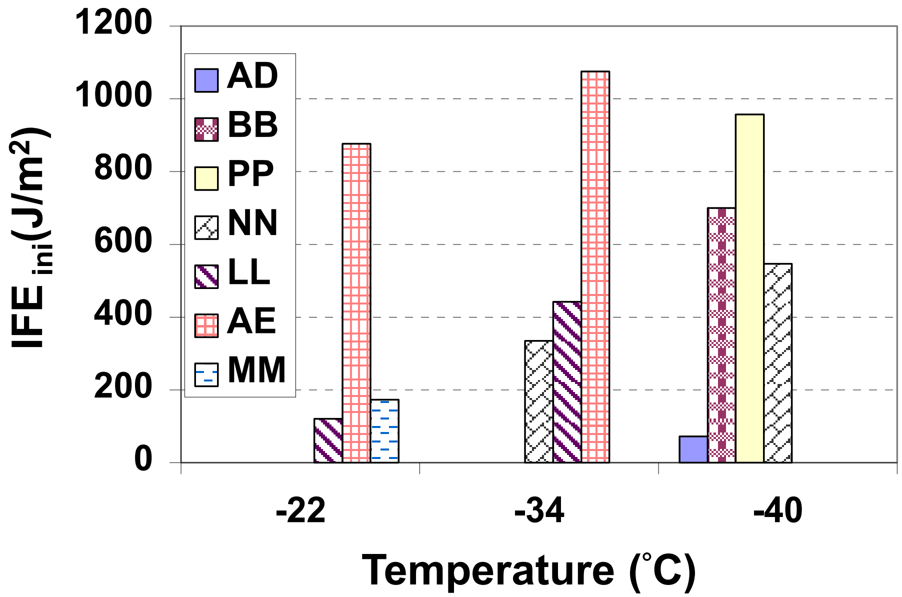
Blister Test Parameter

- Interfacial fracture energy

$$IFE = 0.5 p_c d_c$$

  - p_c = peak pressure
  - d_c = blister height

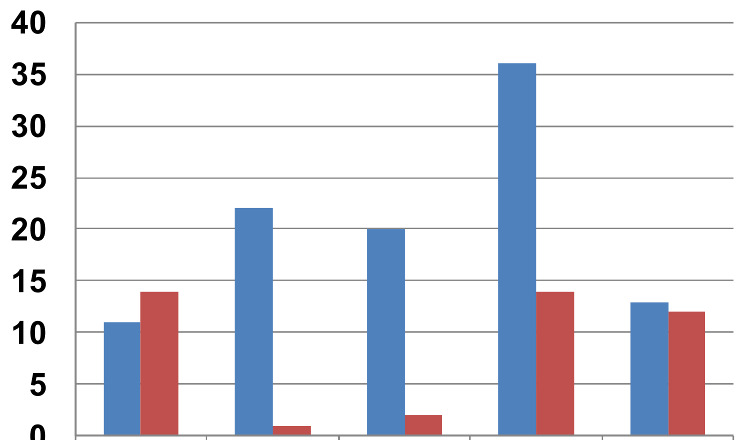




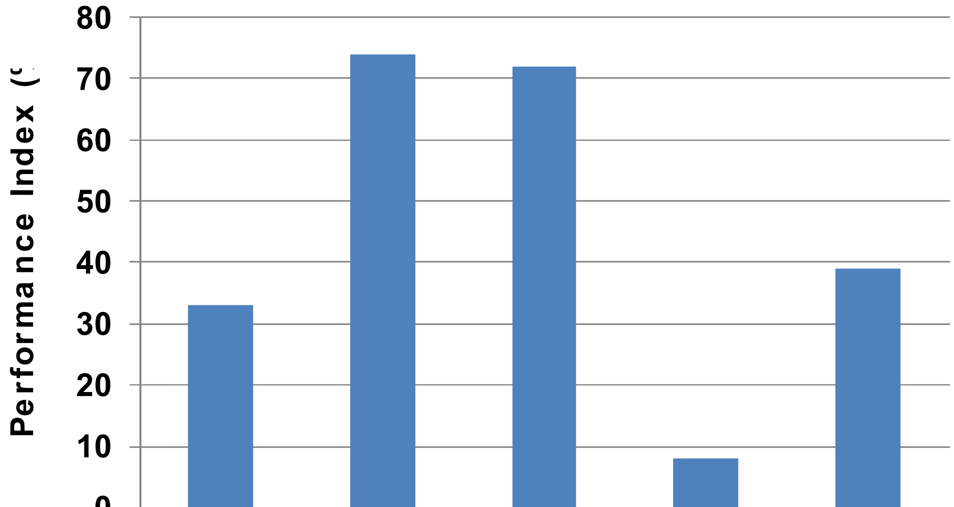
Field Validation (Limited)

- Year of installation
  - 1990
- Test site location
  - Montreal, Quebec, Canada
- Performance survey and field sample collection
  - At years 1, 3, 5, and 9
- Sealant Performance Index (PI)
  - PI = 100- (D+nP)
    - PI = sealant performance index;
    - D = percent de-bonded length of the sealant;
    - P = percent pull-out length; and
    - n = an integral that accounts for the effect of pull- out over de-bonding on performance.

Sealant Performance Index



	A	B	E	G	J
De-bonding (%)	11	22	20	36	13
Pull-out (%)	14	1	2	14	12



	A	B	E	G	J
PI (%)	33	74	72	8	39

Specification Comparison

ASTM D 6690 Type II Test Specification

Test	Cone Penetration	Flow	Resilience	Bond	Result
Temp (C)	(25°C)	60°C	(25°C)	(-29°C)	
Criteria	(<90 dmm)*, †	(<3 mm)*	(>60%)*	(3 cycles)*	
A	**86**	**0.5**	57	F	**Fail**
B	**68**	**0.5**	**64**	**P**	**Pass**
E‡	104	**1**	**73**	**P**	**Fail**
G	**50**	**0.5**	51	F	**Fail**
J	**66**	6	**48**	**P**	**Fail**

Sealant Performance Based Specification

Test	DSR		CSBBR		CSDTT	CSAT	Result
Performance Parameter	**C (kPa)**	**P**	**S (MPa)**	**A. C. R. Rate**	**λ (%)**	**Max. P (N)**	
Criteria	**>4.0**	**>0.70**	**<25**	**>0.31**	**>85**	**>50**	
Temp (C)	**58**	**58**	**-34**	**-34**	**-34**	**-34**	
A	3.0	**0.67**	**21**	0.30	11	**59**	**Fail**
B	**38.3**	**0.98**	**22**	0.31	**92**	**157**	**Pass**
E	**19.3**	**0.94**	**3**	**0.44**	**93**	**No de-bond**	**Pass**
G	**7.0**	**0.94**	126	0.24	0.4	**50**	**Fail**
J	**7.6**	**0.94**	602	0.16	0.7	**N/A**	**Fail**

Crack Sealant Performance Grade	SG-46							SG-52							SG-58							SG-64							SG-70							SG-76							SG-82						
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Apparent Viscosity, SC-2	Installation Temperature																																																
Max. Viscosity (Pa.s)	3.5																																																
Min. Viscosity (Pa.s)	1																																																
Vacuum Oven Residue (SC-3)																																																	
Dynamic Shear, SC-4	46							52							58							64							70							76							82						
Min. Flow Coefficient (kPa.s)	4																																																
Min. Shear Thinning	0.7																																																
Crack Sealant BBR, SC-5	-40	-34	-28	-22	-16	-10	-4	-40	-34	-28	-22	-16	-10	-4	-40	-34	-28	-22	-16	-10	-4	-40	-34	-28	-22	-16	-10	-4	-40	-34	-28	-22	-16	-10	-4	-40	-34	-28	-22	-16	-10	-4	-40	-34	-28	-22	-16	-10	-4
Max. Stiffness (MPa)	25																																																
Min. Avg. Creep Rate	0.31																																																
Crack Sealant DTT, SC-6	-40	-34	-28	-22	-16	-10	-4	-40	-34	-28	-22	-16	-10	-4	-40	-34	-28	-22	-16	-10	-4	-40	-34	-28	-22	-16	-10	-4	-40	-34	-28	-22	-16	-10	-4	-40	-34	-28	-22	-16	-10	-4	-40	-34	-28	-22	-16	-10	-4
Min. Extendibility (%)	>85	>85	>70	>55	>40	>25	>10	>85	>85	>70	>55	>40	>25	>10	>85	>85	>70	>55	>40	>25	>10	>85	>85	>70	>55	>40	>25	>10	>85	>85	>70	>55	>40	>25	>10	>85	>85	>70	>55	>40	>25	>10	>85	>85	>70	>55	>40	>25	>10
Crack Sealant DBT, SC-7	-40	-34	-28	-22	-16	-10	-4	-40	-34	-28	-22	-16	-10	-4	-40	-34	-28	-22	-16	-10	-4	-40	-34	-28	-22	-16	-10	-4	-40	-34	-28	-22	-16	-10	-4	-40	-34	-28	-22	-16	-10	-4	-40	-34	-28	-22	-16	-10	-4
Min. Load (N)	50																																																
Min. Energy (J/m^2)	40																																																

Summary (1)

- Comprehensive tests based on sealant rheological properties was developed
- For pumping and sealing, apparent viscosity at installation temperature is recommended between 1 and 3.5Pa.s
  - Brookfield Rotational Viscometer (*un-aged material)*
- For resistance to tracking at high service temperatures, a minimum flow coefficient of 4k Pa.s and a shear thinning exponent of 0.7 are recommended
  - Dynamic Shear Rheometer (DSR)

Summary (2)

- To withstand low-temperature conditions, a maximum S_{240s} of 25MPa and a minimum average creep rate of 0.31 are recommended
  - Modified BBR test (CSBBR)
- For crack extension, a measurement of extendibility over in-service temperature range is recommended
  - Direct Tension Tester (CSDTT)
- For appropriate sealant-crack wall bonding, a minimum load of 50N and debonding energy of 40J/m^2 at tested temperature are recommended
  - Direct Adhesion Test

AASHTO Protocols - Status

- Completed Tech Section (TS-4e) Ballot:
  - SC-2, Apparent Viscosity
  - SC-3, Sealant Aging
  - SC-5, Crack Sealant BBR
  - SC-6, Crack Sealant DTT
  - SC-7, Adhesion (DAT)
- Proceeding to concurrent Ballot (SOM):
  - SC-2, 3, 5, 6, 7
  - SC-8, Blister Test

Recommended Future Work

- Laboratory validation
- Field validation
  - Monitoring test sections for four years
  - Fine-tune thresholds
- Quantify crack sealant cost effectiveness

Acknowledgements

- Federal Highway Administration Pool-Fund TPF - 5(045)
- The US-Canadian Crack Sealant Consortium:
  - New Hampshire, Virginia, Connecticut, New York, Minnesota, Texas, Washington D.C., Michigan, Georgia, Rhode Island, Maine, FHWA, City of Edmonton, Greater Toronto Airport Authority, City of Toronto, Department of National Defense-Canada, Regional Municipality of Niagara, City of Calgary, Regional Municipality of Peel, Lafarge, Ministry of Transportation of Ontario, City of Winnipeg, City of Ottawa, McAsphalt Industries Ltd.

The rest of the story? Go to:

www.vtrc.net

Look for:
VTRC 09-CR7

FINAL
CONTRACT REPORT
VTRC 09-CR7

DEVELOPMENT OF PERFORMANCE-BASED GUIDELINES FOR SELECTION OF BITUMINOUS-BASED HOT-POURED PAVEMENT CRACK SEALANT: AN EXECUTIVE SUMMARY REPORT

IMAD L. AL-QADI
Founder Professor of Engineering
Director, Illinois Center for Transportation
Department of Civil and Environmental Engineering
University of Illinois at Urbana-Champaign

JEAN-FRANCOIS MASSON
Senior Research Officer
Institute for Research in Construction
National Research Council of Canada

SHIH-HSIEN YANG and ELI FINI
Graduate Research Assistants
Department of Civil and Environmental Engineering
University of Illinois at Urbana-Champaign

KEVIN K. McGHEE
Senior Research Scientist
Virginia Transportation Research Council

http://www.virginiadot.org/vtrc/main/online_reports/pdf/09-cr7.pdf

Phase 2 – Validate & Implement

www.pooledfund.org

- solicitation number 1233

- **Validation and Implementation of Hot-Poured Crack Sealant Performance-Based Guidelines**

Phase 2 – Anticipated Tasks

- Task 1 – Lab Validation
  - Conduct round-robin tests to develop precision and bias
  - Develop training program
- Task 2 – Field Validation
  - 8 test sections in four environmental regions
  - Two sealant types in each section

Phase 2 – Anticipated Tasks

- Task 3 – Monitoring
  - Conduct regular field inspections
  - Collect sealant samples annually:
    - Measure rheological properties to identify any changes
  - Monitor crack movement and temperature variation to provide insight into the selection of the current temperature shift used in the proposed guidelines.

Phase 2 – Anticipated Tasks

- **Task 4: Fine-Tuning Threshold Values**
  – Use field performance to fine-tune the testing parameter thresholds in the proposed guidelines.
- **Task 5: Quantify the Cost Effectiveness of Using Crack Sealants**
  – Measure pavement condition annually, in accordance with SHRP Distress Manual, to examine the cost effectiveness of crack sealant.

TPF Solicitation 1233

- Lead State and Contact:
  - Virginia, Kevin McGhee
    (Kevin.McGhee@VDOT.Virginia.gov)
- Partners (confirmed):
  - NH, NY, VA, WI, (MN?)
- Commitments:
  - Suggested - $25k/yr for four years
  - Required - $1,000,000 Total
  - Received - $325,000
- Solicitation Expires – 2/27/2010!!

Questions
&
Comments