Performance Guidelines for Selection of Hot-Poured Bituminous Crack Sealant

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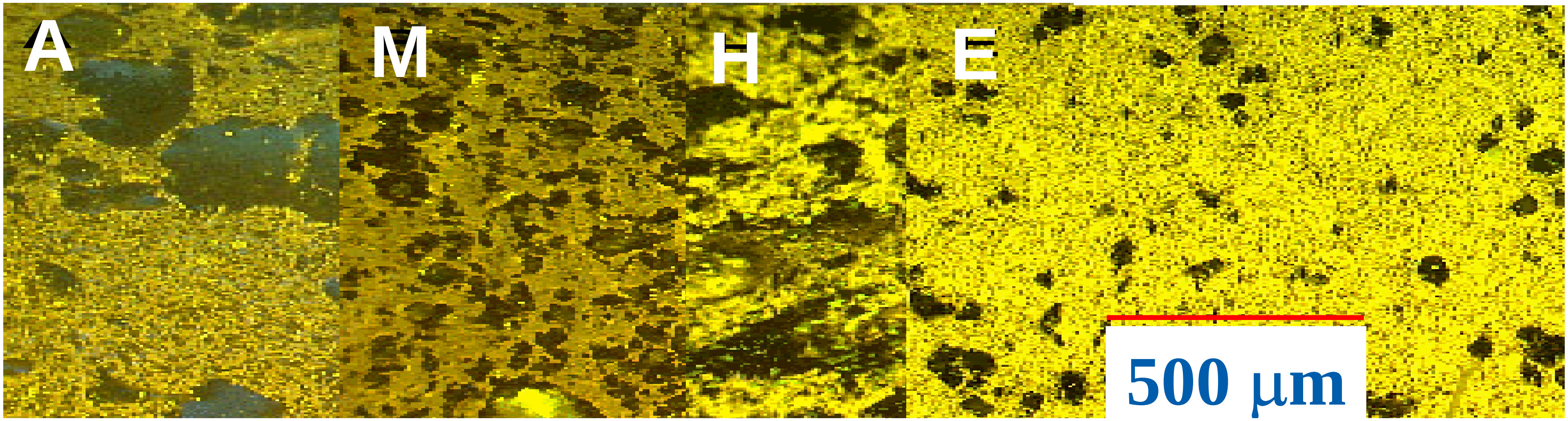
What is Crack Sealant?

- Blends of bitumen and
  - styrene-butadiene copolymer (SB, SBS)
  - recycled rubber
  - additives
    - inorganic filler
    - bonding agent



Crack Sealing

- Crack sealing/ filling is the most widely used maintenance activity of in-service pavements
- Inexpensive, quick, and a well-proven technique to delay pavement deterioration
  - Reduce water penetration
  - Maintain pavement structural capacity
  - Improves road rideability
  - Extend pavement service life (3 to 5 years)

Field Performance of Crack Sealant

- Installation related parameters (QC/QA, crack cleaning and preparation, etc.)
- Sealant related parameters (viscosity, softness, bond strength, compatibility, etc.)

Sealant Failure Modes

- Tracking: sealant is smeared on the pavement due to passing traffic
- Adhesive failure: loss of bonding between sealant material and its substrate
- Cohesive failure: failure within sealant material
- Intrusive failure: foreign objectives intrude into sealants

Available Specifications

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

Objective

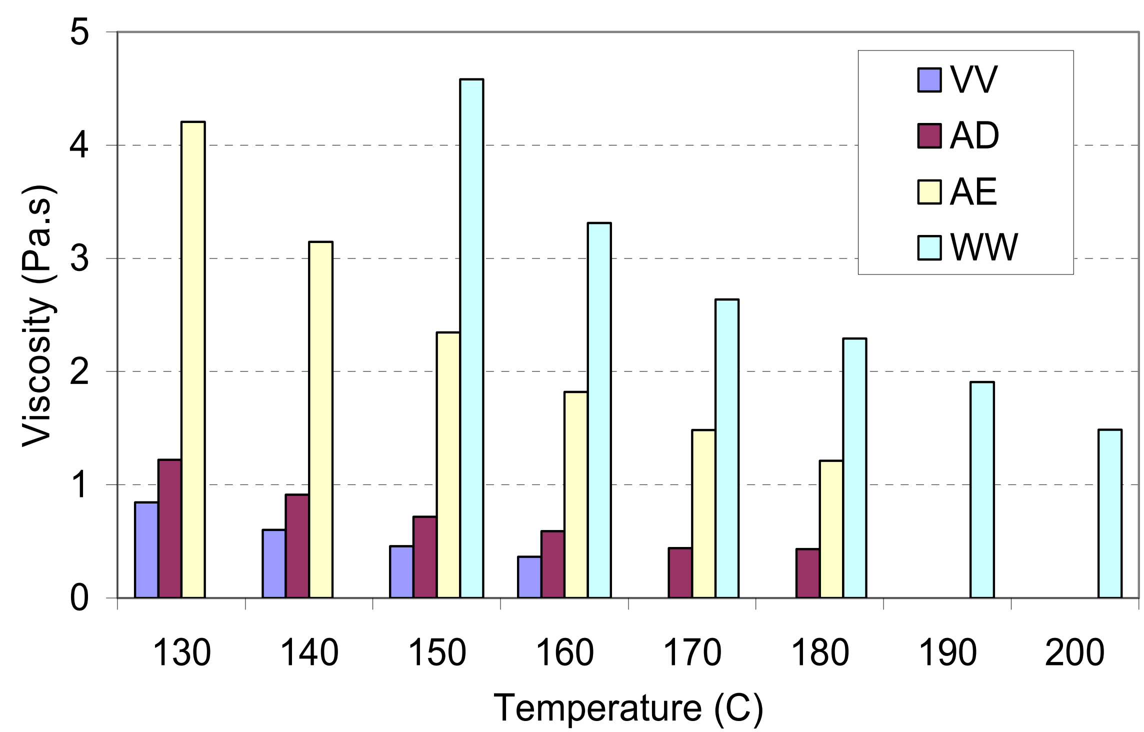
- Development of performance-based guidelines for the selection hot-poured crack sealant
  - Make use of SuperPave™ binder-testing equipment
  - Adapting spirit of the binder Performance Grade (PG) specifications

Viscosity Test (SC-2)

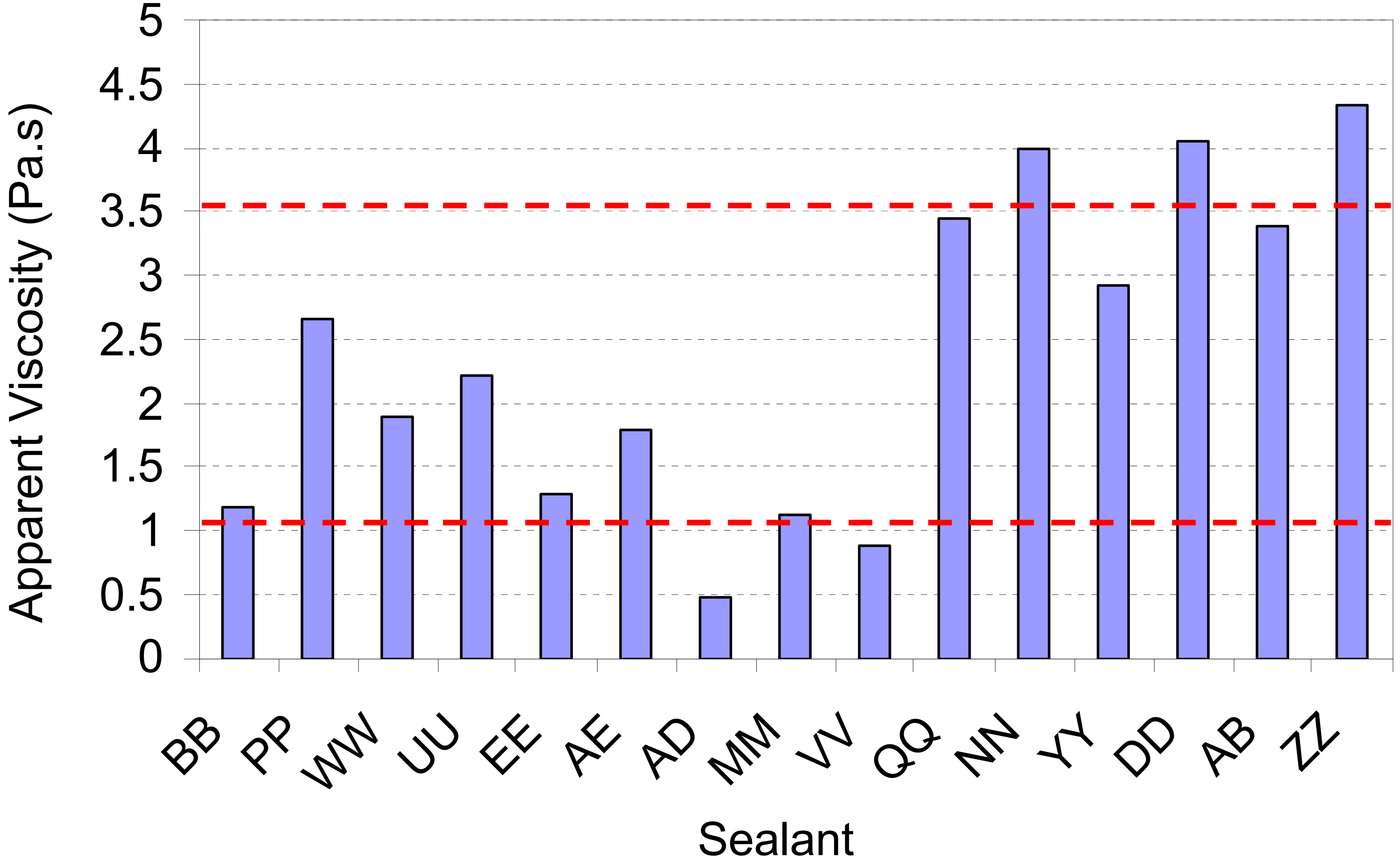
- At Installation Temperature

Test Development

- Instrument and Testing Optimization
  - Rigid rod
  - Melting time
    - 20min
  - Spindle size
    - SC-27
  - Speed
    - 60rpm
  - Waiting time
    - 30s
- Test variable
  - Temperature



Apparent Viscosity Threshold



Vacuum Oven Aging (SC-3)

- Simulate Crack Sealant Weathering in Kettle & Field

Test Development

- Microwave aging
- Small-kettle aging and pressure aging
- Small-kettle aging, pressure aging and vacuum oven aging
- Pressure aging
- Vacuum oven aging

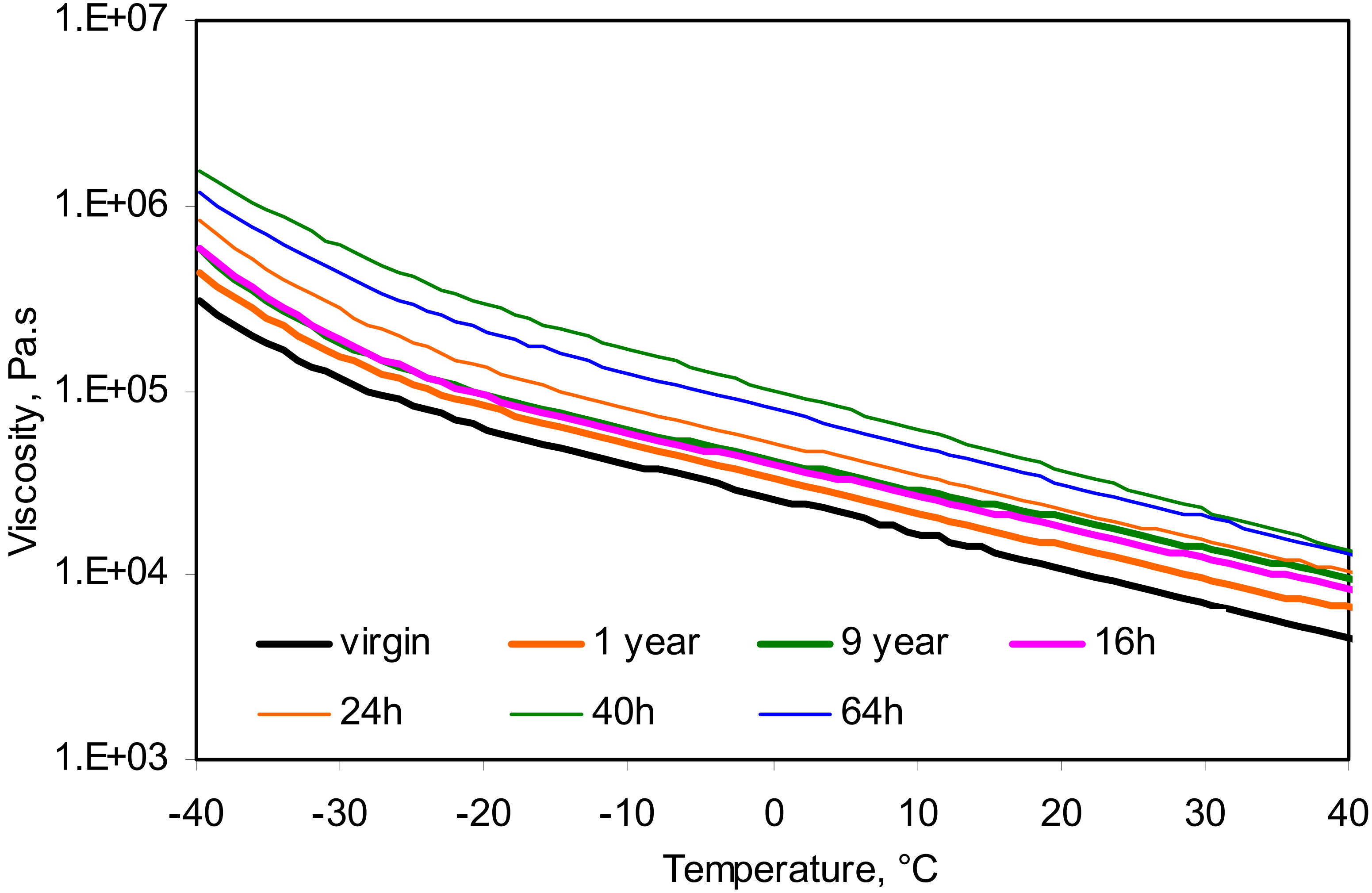
Test Development

Method	Output
GPC	Separation of bitumen and polymer
FTIR	Fingerprint of composition
TGA	Weight loss upon heating
DSR	Stiffness, relaxation

Test Procedure

- 35g in each pan
- Vacuum oven at 30″ Hg and 115°C for 16hr
- Shelves spacing designed to allow uniform temperature profile

Test Verification

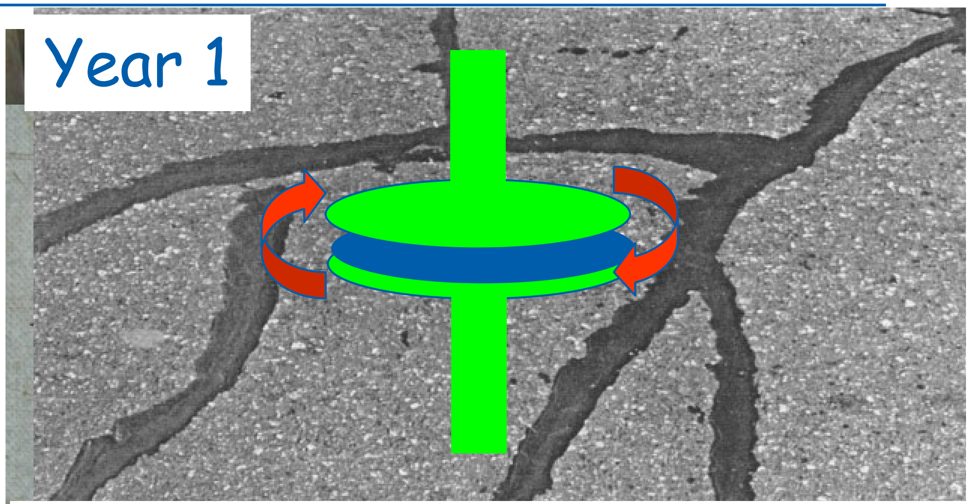


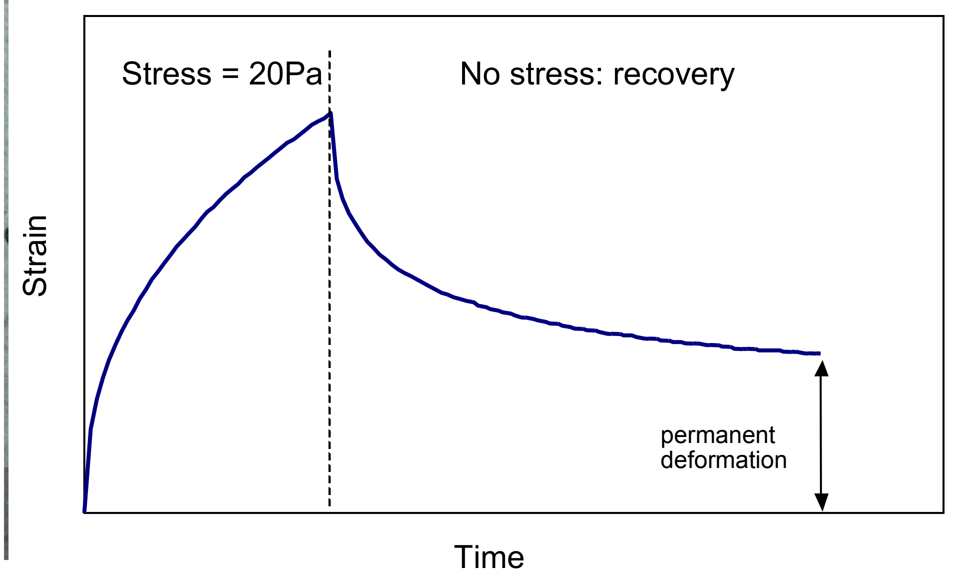
Dynamic Shear Rheometer Test (SC-4)

- Intermediate Temperature for Tracking Resistance

Test Development

- Taber Abraser to simulate field failure
- Correlate tracking flow as measured with DSR
- Shear stress is applied for 2s then removed to allow recovery for 18s
- 8 levels of stresses were applied



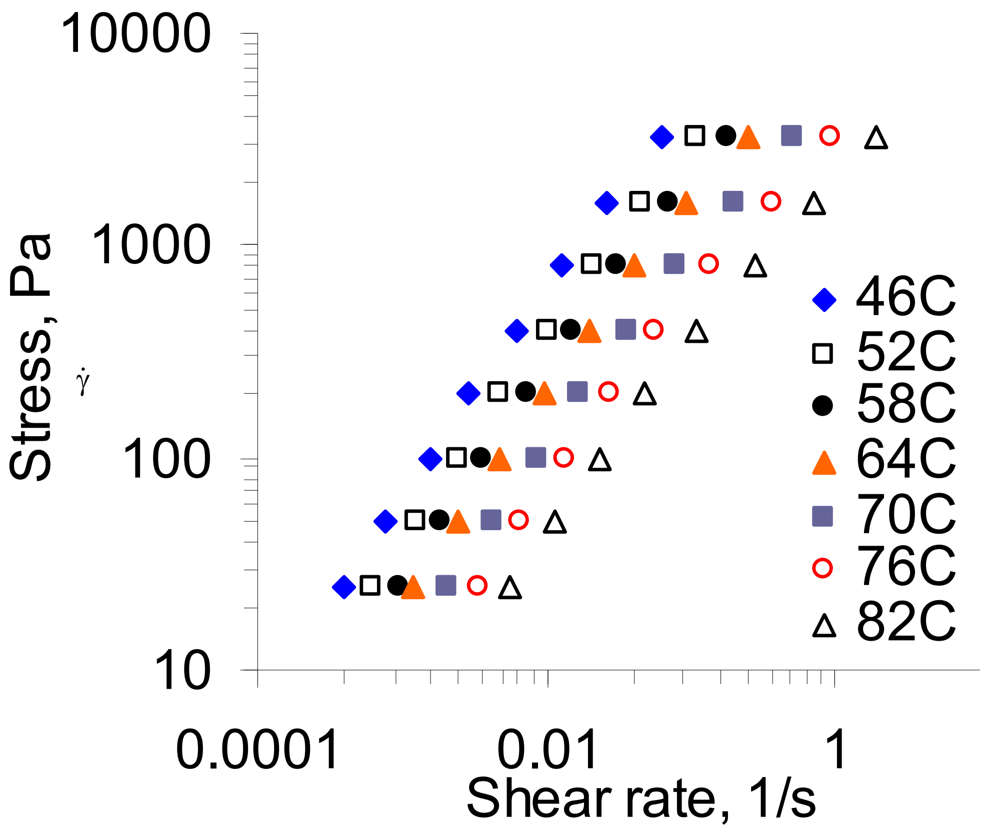


Test Parameter

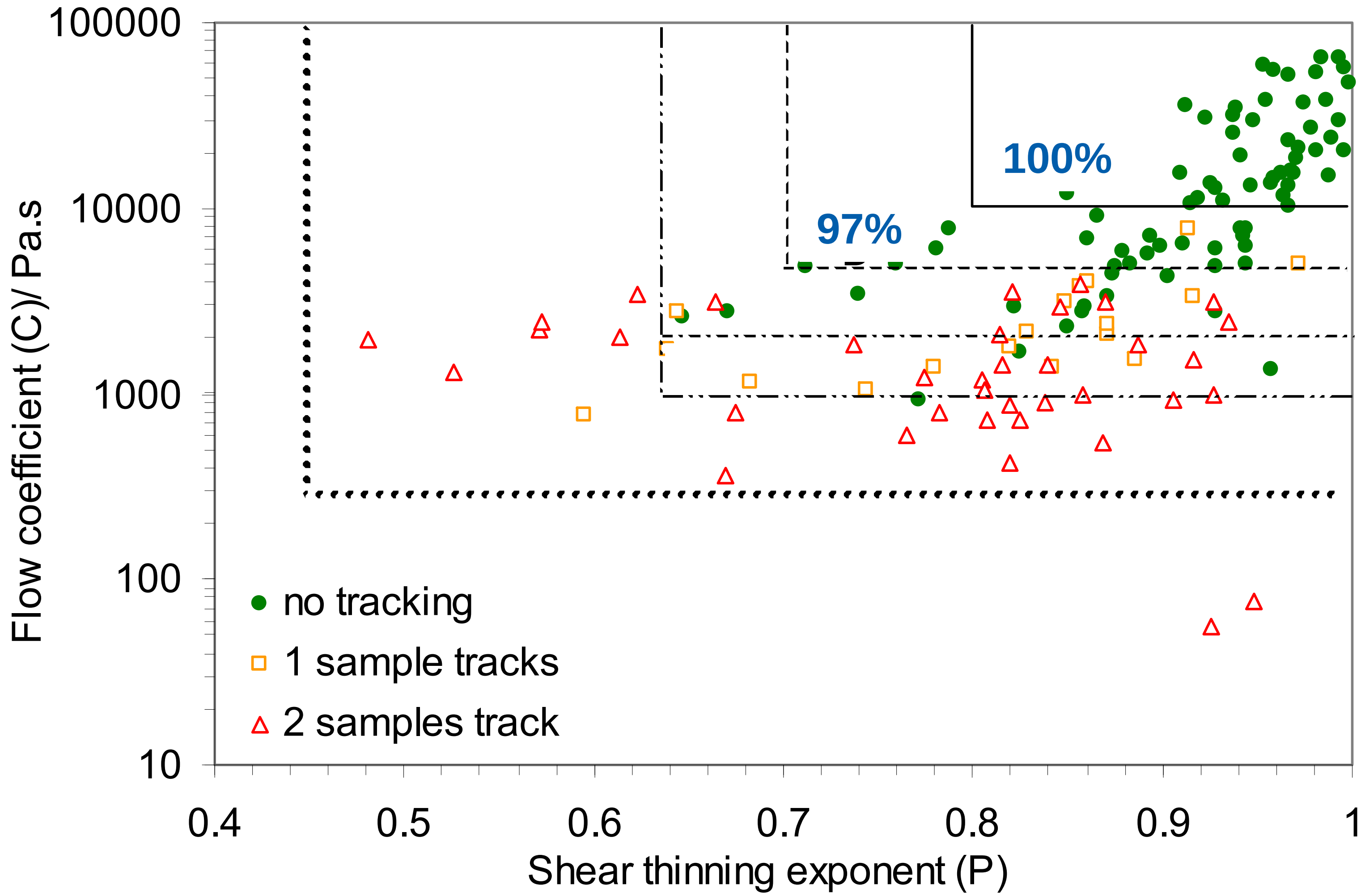
- Ostwald-DeWaele power-law

$$\sigma = C(\dot{\gamma})^{P}$$

  - C: flow coefficient
  - P: shear thinning exponent



Selection Criteria

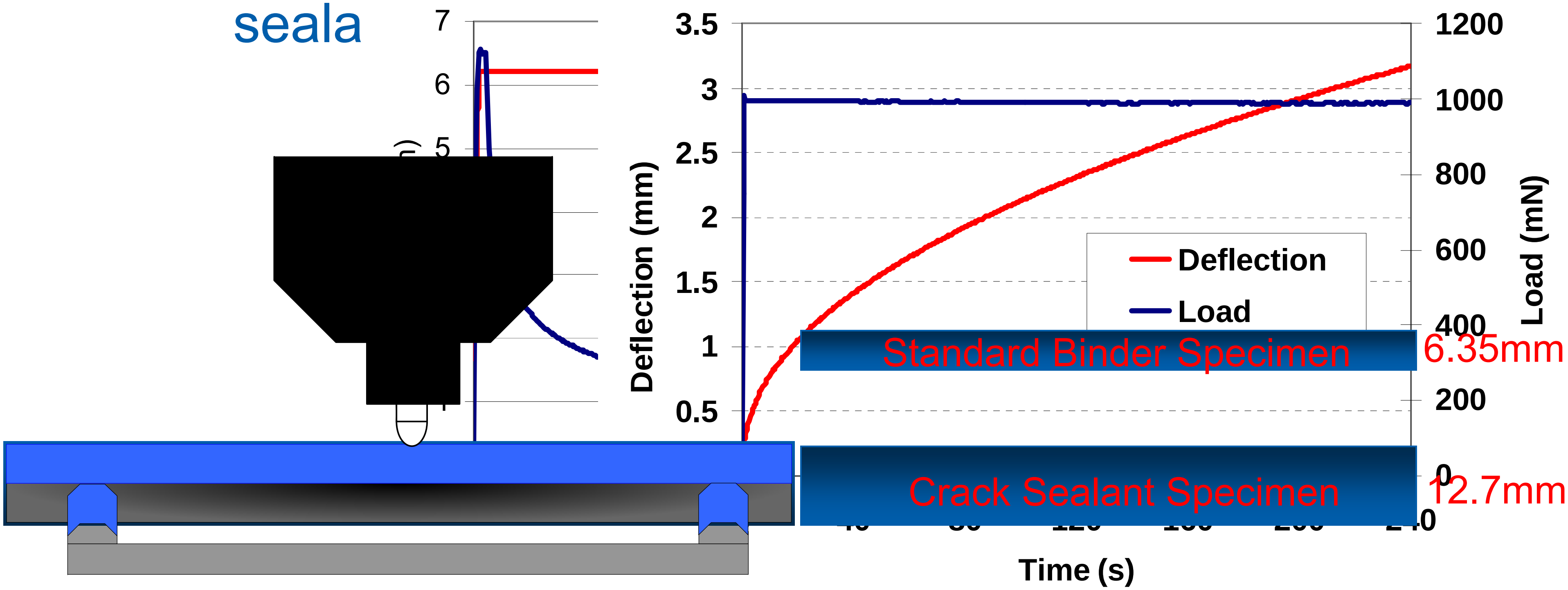


Bending Beam Rheometer (SC-5)

- Low Temperature Flexural Properties

Test Development

- Deflection of the sealant bean is above the limit of the current BBR device
  - Doubling the beam thickness
  - Modifying BBR device to support both binder and seala



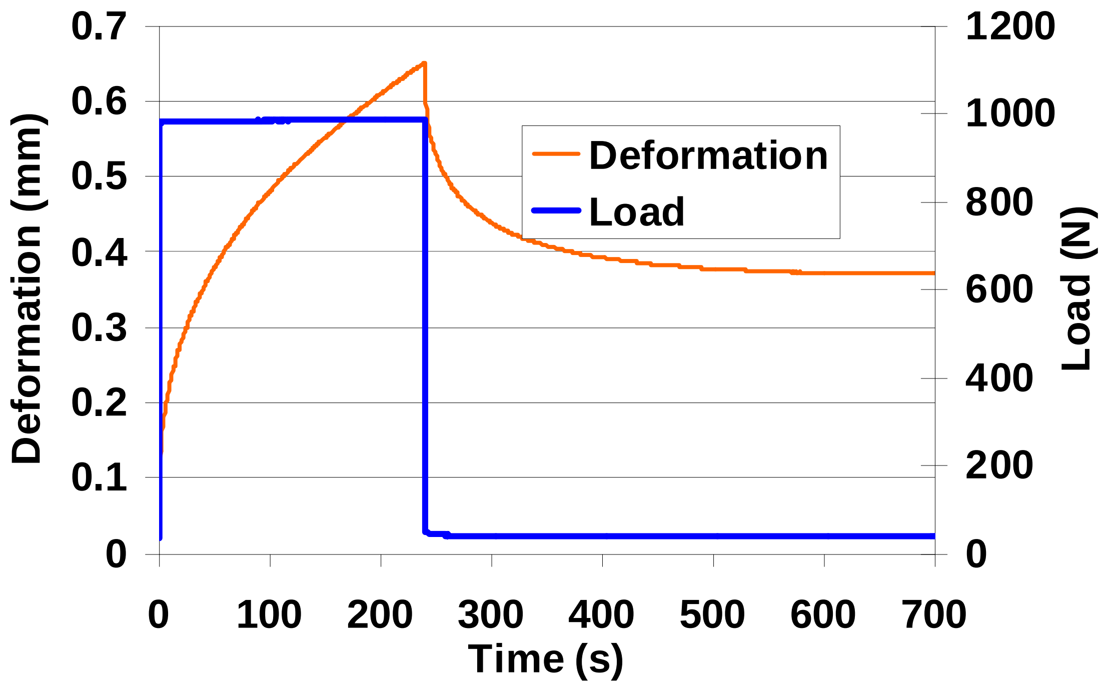
Test Parameter

- Stiffness @ 240s

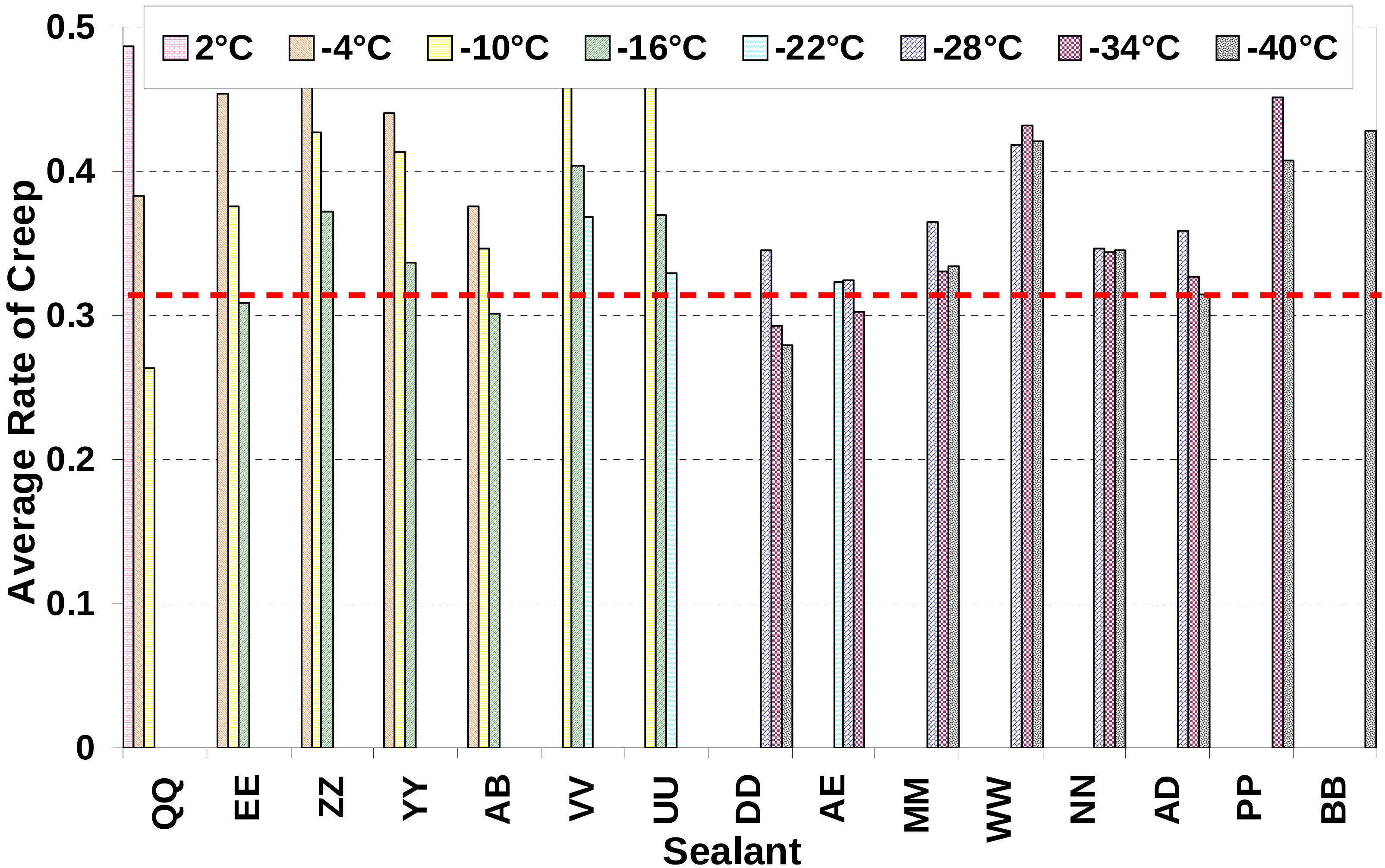
$$S(t) = \frac{PL}{4bh^3\delta(t)}$$

- Average creep rate

$$\varepsilon(t) = At^{\overline{C}}$$



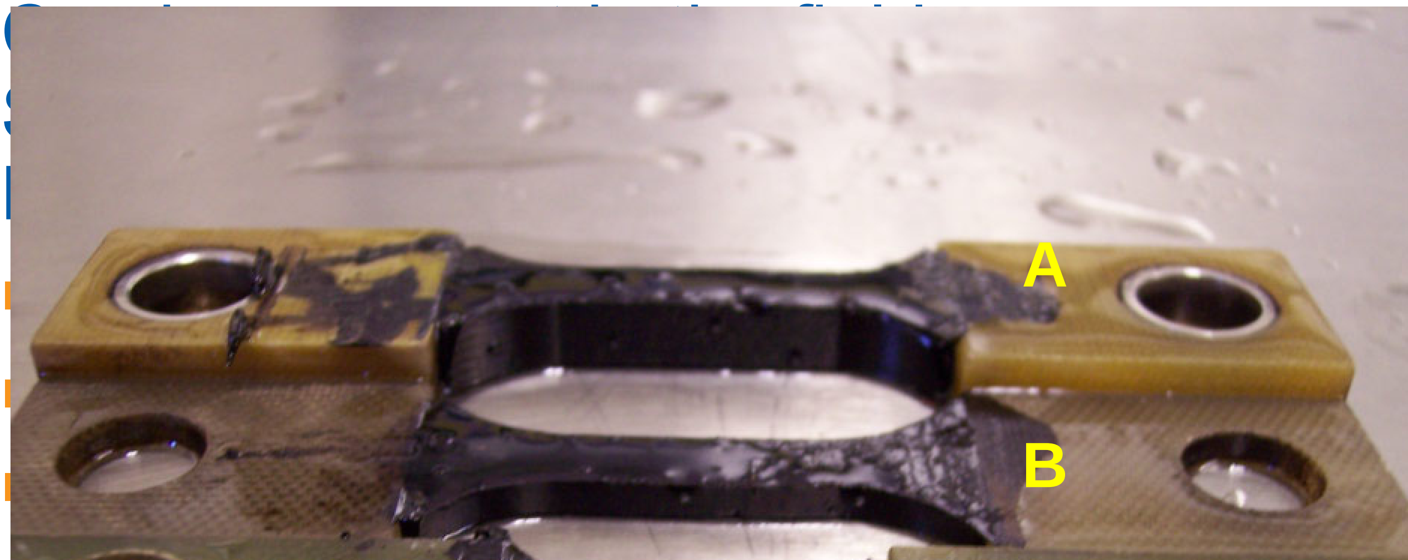
CSBBR Threshold



CSDTT Test (SC-5)

- Low Temperature Extendibility

Test Development



Studies	Max Crack (%)	Min Crack (%)	Fast Move. (mm/min)	Slow Move. (mm/min)
Smith & Romine, 1993	18	2.5	$5x10^{-3}$	$2.77x10^{-4}$
Linde, 1988	63	N/A	$8x10^{-3}$	$5x10^{-5}$
Cook et al., 1991	+90	6	N/A	N/A
Masson & Lacasse, 1999	16	7	N/A	N/A

Test Parameters

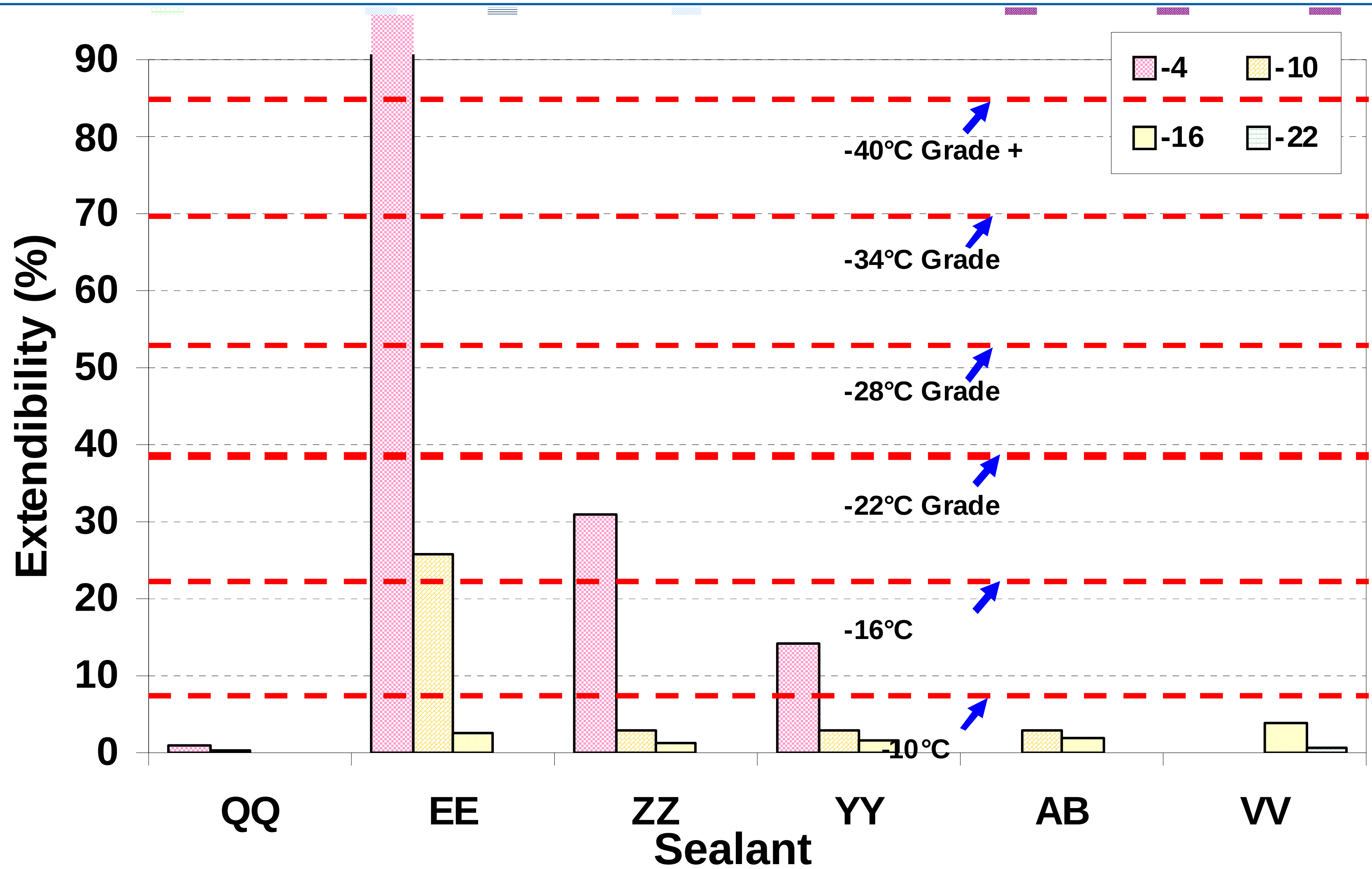
- Extendibility (l)
  - Effective gauge length (L_{eff}=20mm)

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

- The extendibility criterion is suggested based on various climatic conditions

T (°C)	-4	-10	-16	-22	-28	-34	-40
λ (%)	10%	25%	40%	55%	70%	85%	85+

CSDT Threshold

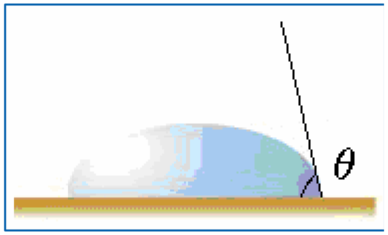


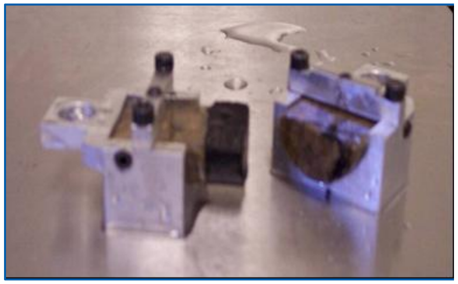
Adhesion Test (SC-7)

- For Low Temperature Bonding

Test Development

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

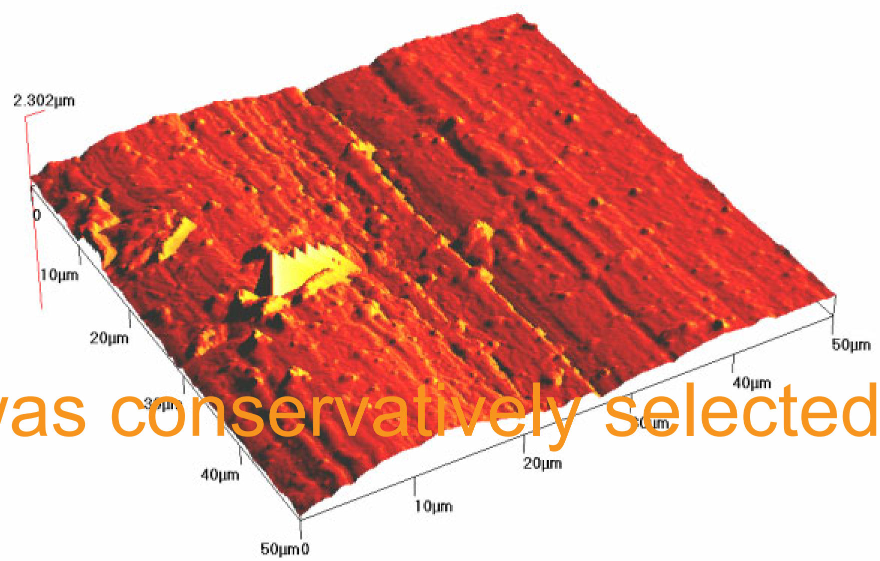




Substrate Selection

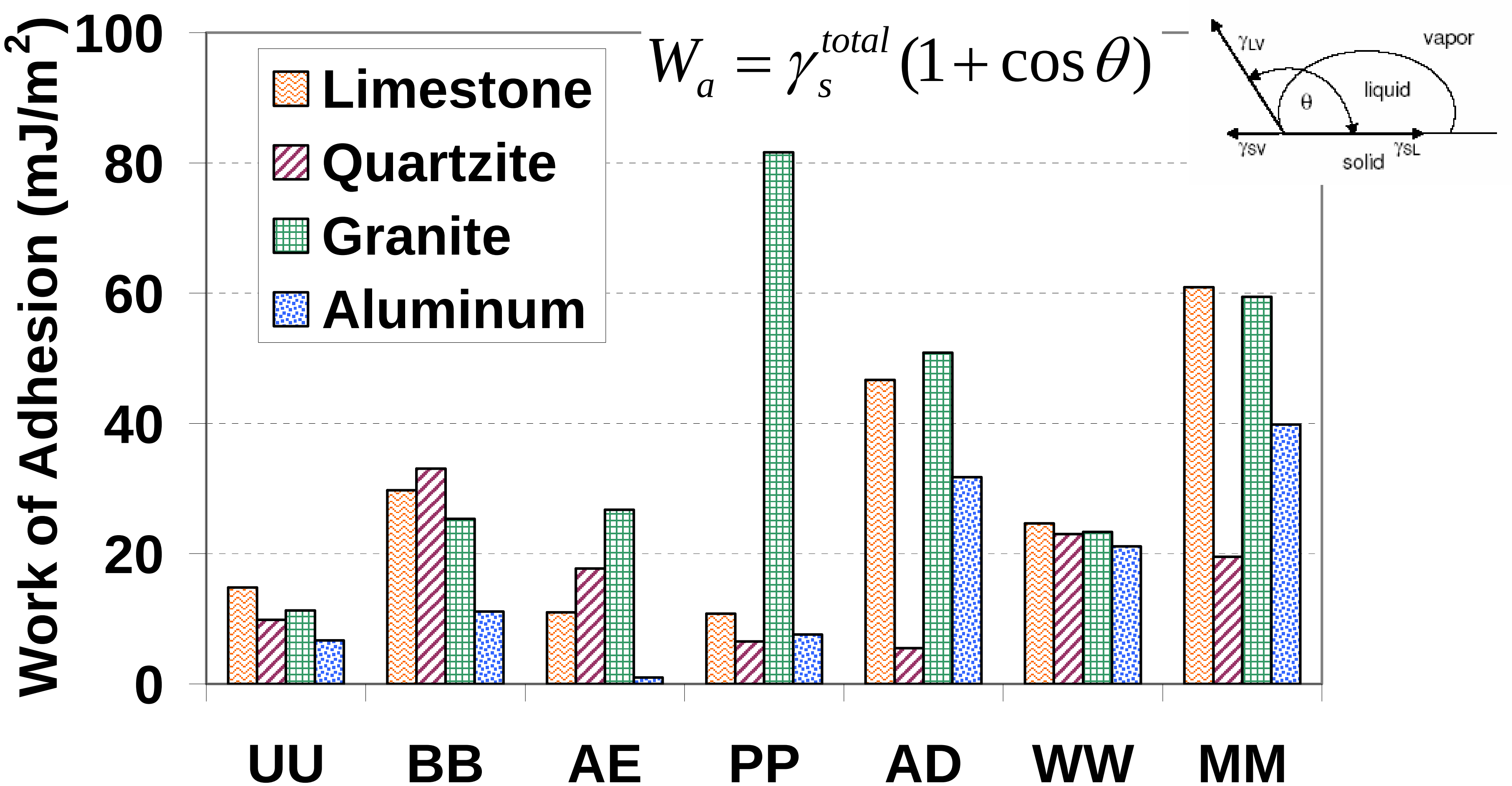
- Coefficient of Thermal Expansion
- Surface Energy

Material	Coeff. of Thermal Exp., cm/cm/°C x 10^{-6}	Surface Energy, mJ/m^2
Aluminum o		70
Soda Lime G		72
Polycarbona		46
Stainless Ste		57
Granite		425
Limestone		111
Quartzite		200
Sandstone		105
Basalt		74



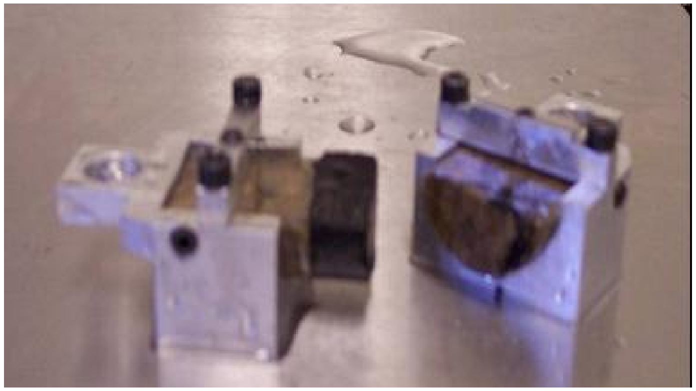
Aluminum was conservatively selected as substrate

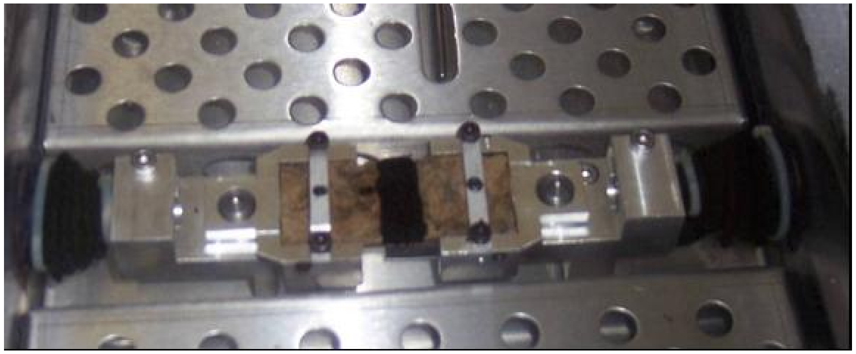
1st Level Adhesion Test: Work of Adhesion



2nd Level Adhesion Test: Direct Bond Test (CS-7)

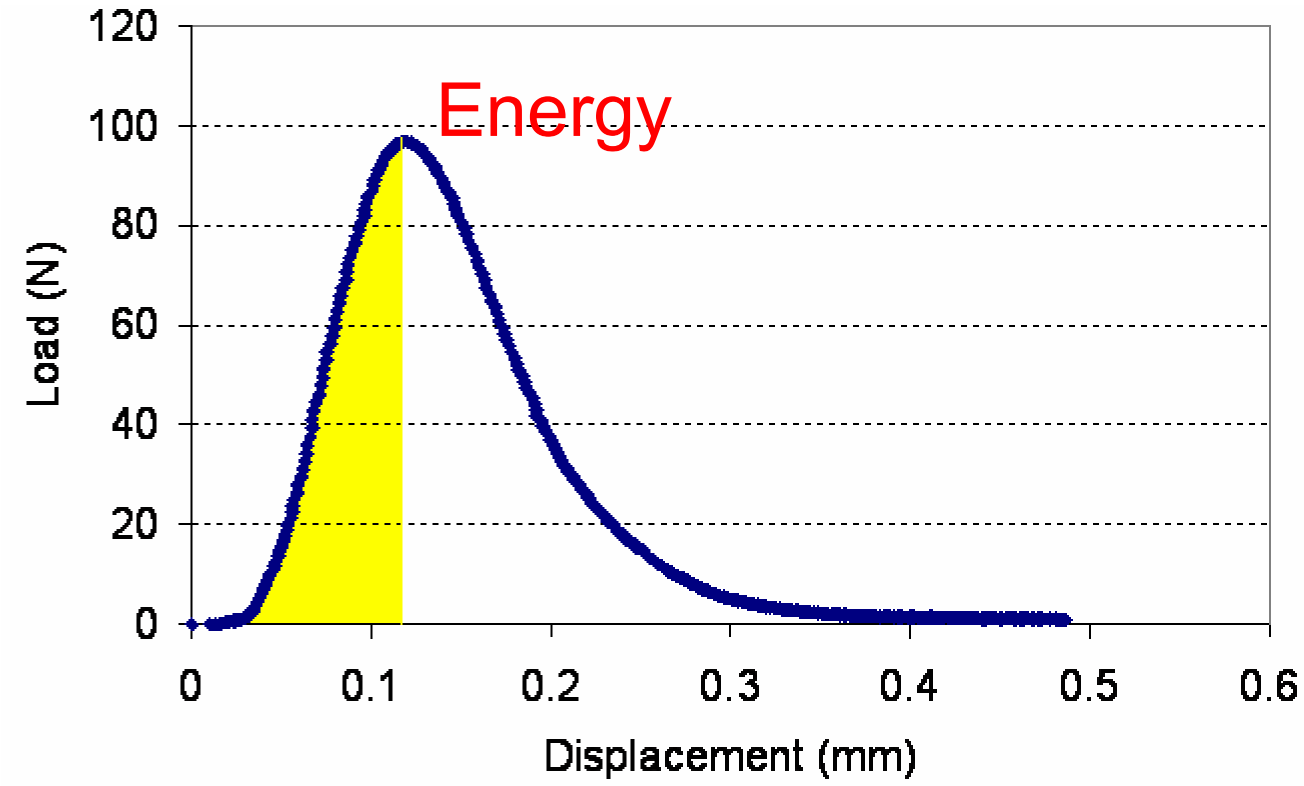
- Fixture designed to be used in the DT device
  - Two aluminum half-cylinders
  - Diameter: 25mm
  - Sealant thickness: 10mm
- Simulates sealant installation
- Simulates crack expansion
  - Displacement rate: 0.05mm/s
- Specific failure location



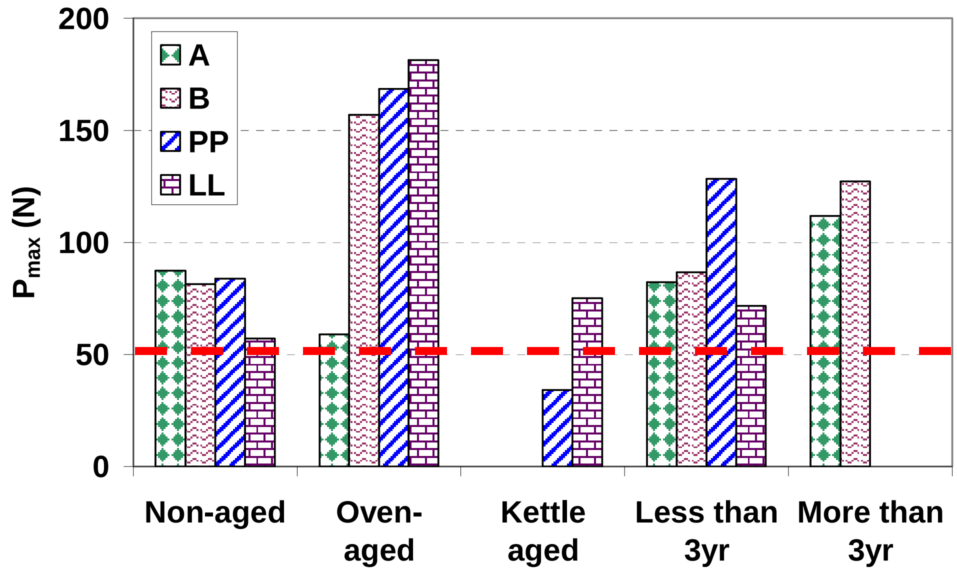


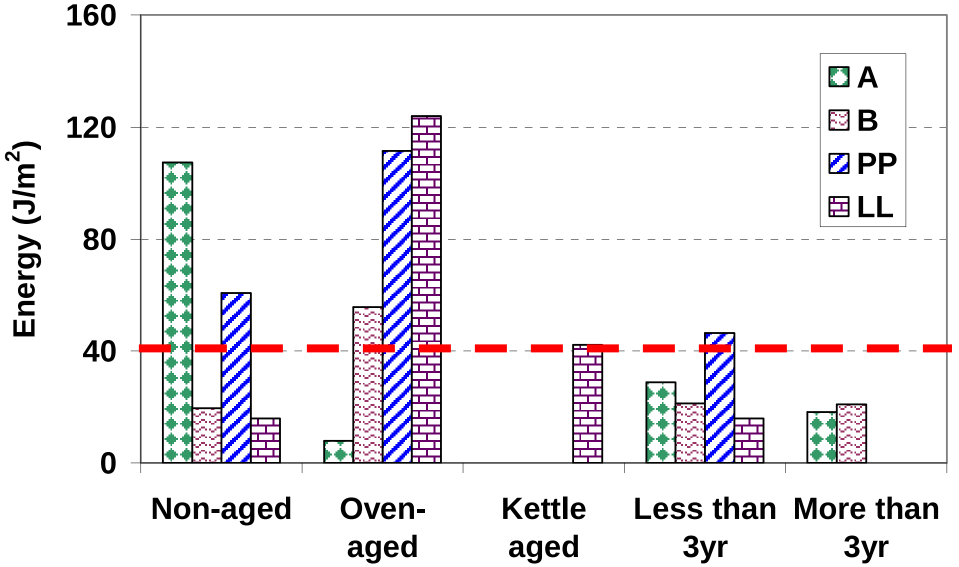
Test Parameter

- P_{max}
- De-bond Energy



Bonding Threshold



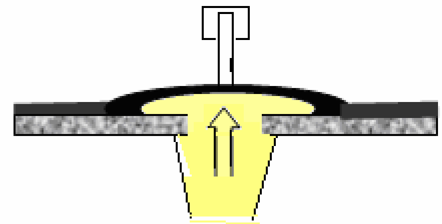


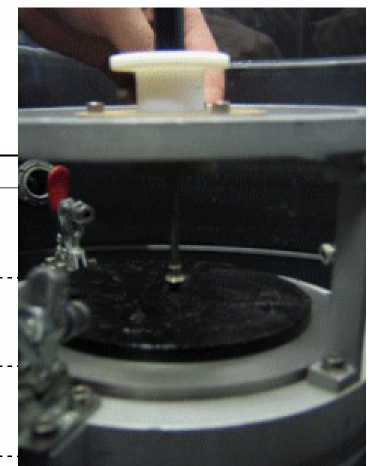
3rd Level Adhesion Test: Blister Test

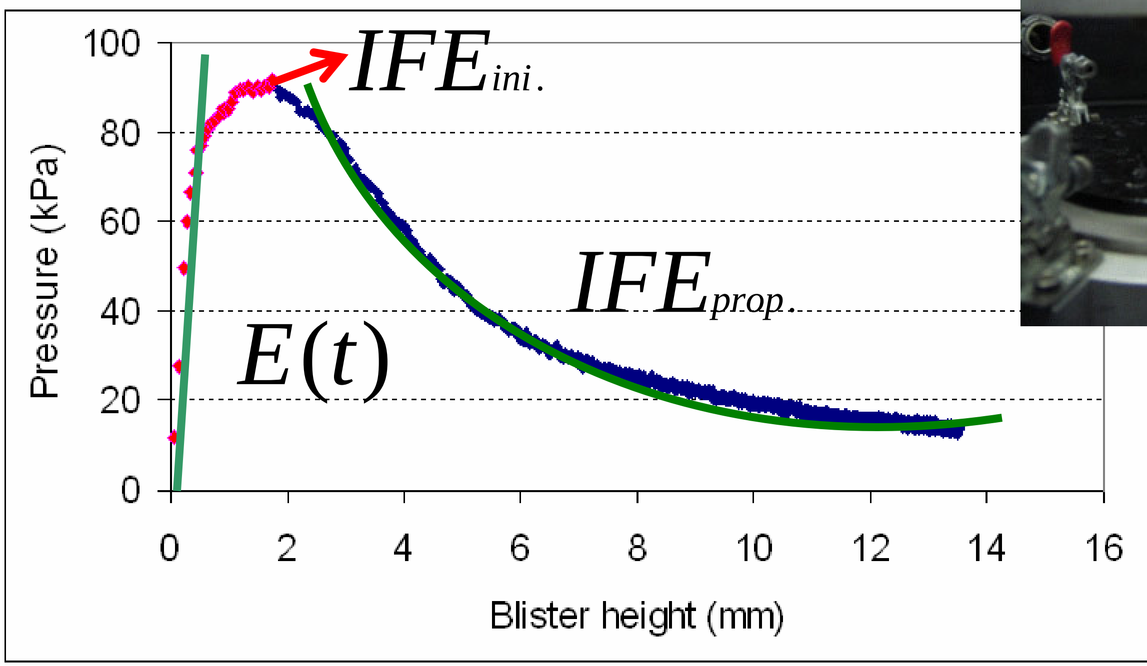
P(t)

IFEprop. = AVG[IFE(t)]

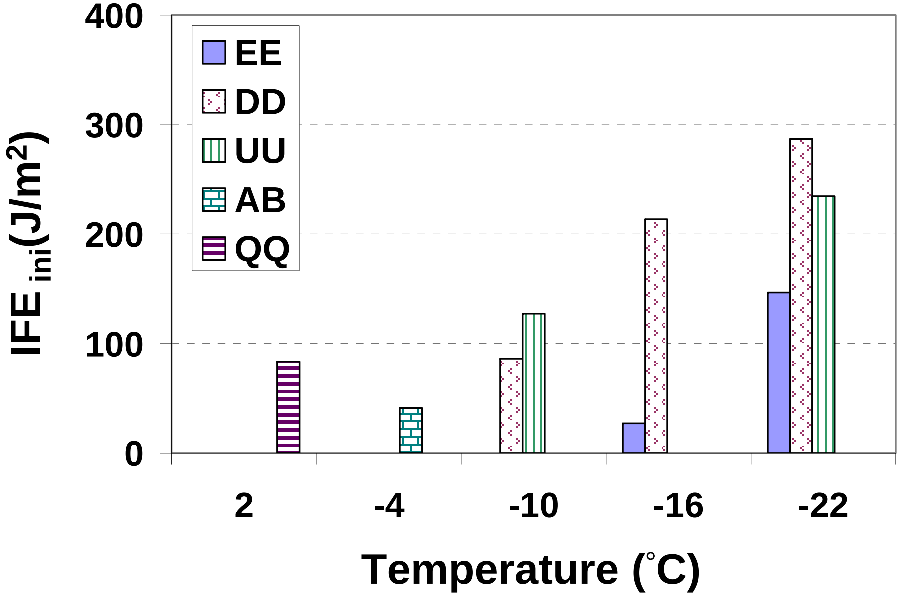
d(t)

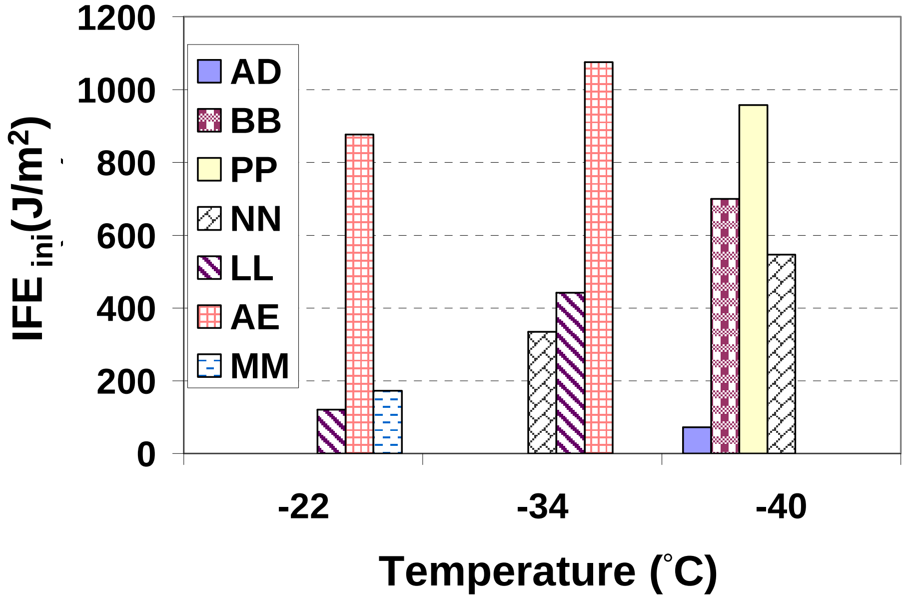






Test Parameter





Crack Sealant Performance Grade	SG-46							SG-52							SG-58							SG-64							SG-70							SG-76							SG-82						
	-46	-40	-34	-28	-22	-16	-10	-46	-40	-34	-28	-22	-16	-10	-46	-40	-34	-28	-22	-16	-10	-46	-40	-34	-28	-22	-16	-10	-46	-40	-34	-28	-22	-16	-10	-46	-40	-34	-28	-22	-16	-10	-46	-40	-34	-28	-22	-16	-10
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/m²)	**40**																																																

Outcome of the Study

- Comprehensive tests based on sealant rheological properties was developed
- Selection criteria is proposed
- A significant economic impact on the sealant industry and the pavement preservation program is expected

Future Plan

- Laboratory validation
- Field validation
  - Monitoring test section for four years
- Fine tuning thresholds
- Quantify cost effectiveness of crack sealant

Acknowledgements

- Federal Highway Administration Pool-fund TPF5 (045)
- The US-Canadian Crack Sealant Consortium
- Participating US states, Canadian provinces, airport and city agencies, and industry

- A continuation of this pool-fund study has been decided in the last consortium meeting
- Virginia will be the lead state
- Please contact:
  - Kevin McGhee of VTRC (Email:Kevin.McGhee@VirginiaDOT.org)
  - Imad Al-Qadi (Email:alqadi@ad.uiuc.edu)
  - Eli Fini and S-H Sam Yang

Thanks