Performance Based Specifications for Hot-Poured Crack Sealant

ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Field performance of crack sealants

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

Sealant fails either cohesively or adhesively

Current Specifications

Sealant Property	Test Method	ASTM Spec.
Application Characteristics	Brookfield Viscosity	D2994
Adhesion	Bond Test	D5329
	Asphalt Compatibility	D5329
Extensibility	Elongation	D412
	Ductutility	D113
Durability	Track Abrasion	D3910
Flexibility	Flexibility	C711
	Cone Penetration	D3407
Tracking	Flow	D3407
	Softening Point	D36

Upcoming Specifications

Sealant Grade	SG-52	SG-46	SG-40	SG-34	SG-28	SG-22	SG-16
Viscosity @ Installation Temperature							
Maximum:							
Minimum:							
Adhesion (Aged)							
CSAT (also *Blister*):	-40	-34	-28	-22	-16	-10	-4
Peak Load (N), Bond Energy (J/m^2),							
Cohesion (Aged)							
CSDTT:	-40	-34	-28	-22	-16	-10	-4
Modulus Red. Rate (MPa/s),							
Max. Strain, ε_{max} =							
CSBBR:	-40	-34	-28	-22	-16	-10	-4
Max. Stiffness @ 240s (MPa),							
Avg. Creep Rate @ 240s(mm/s),							
Dissip. Energy Ratio,							

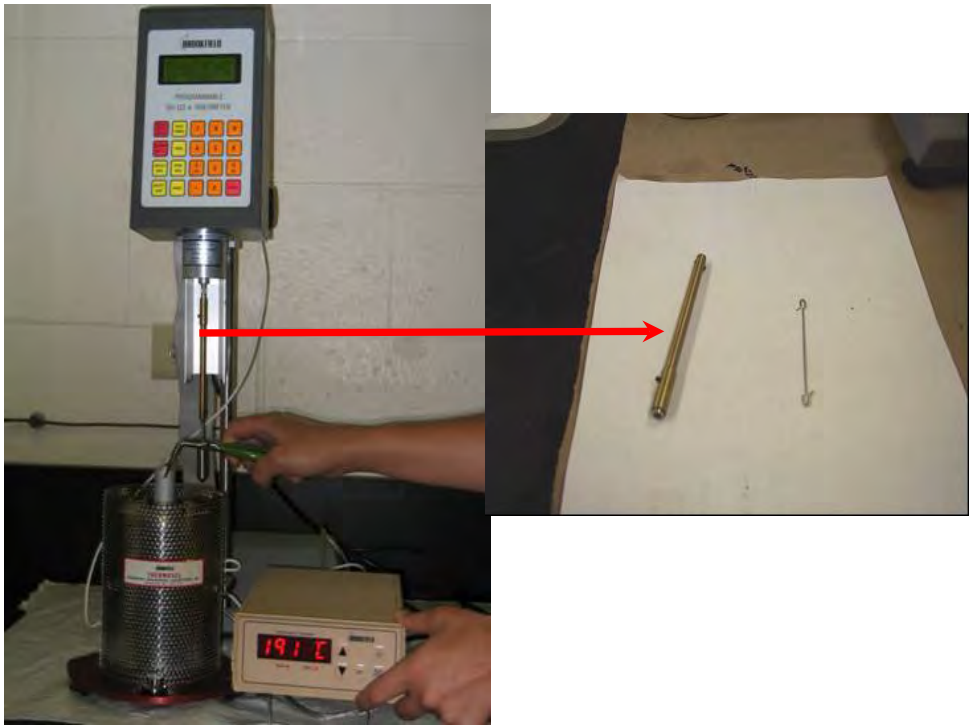
Aging procedure

- vacuum oven aging (VOA) was used to simulate the aging and weathering of crack sealants during installation and service.

Viscosity Test

Sealant Viscosity Affects both Installation and Bond Strength.

Lower/upper limit need to be defined



Test Procedure

- Rigid rod
- Sample preparation protocol
- Spindle #27
- Testing procedure:
  - Specimen conditioning = 20 min
  - Waiting period = 30 sec
  - Spindle speed 60 rpm

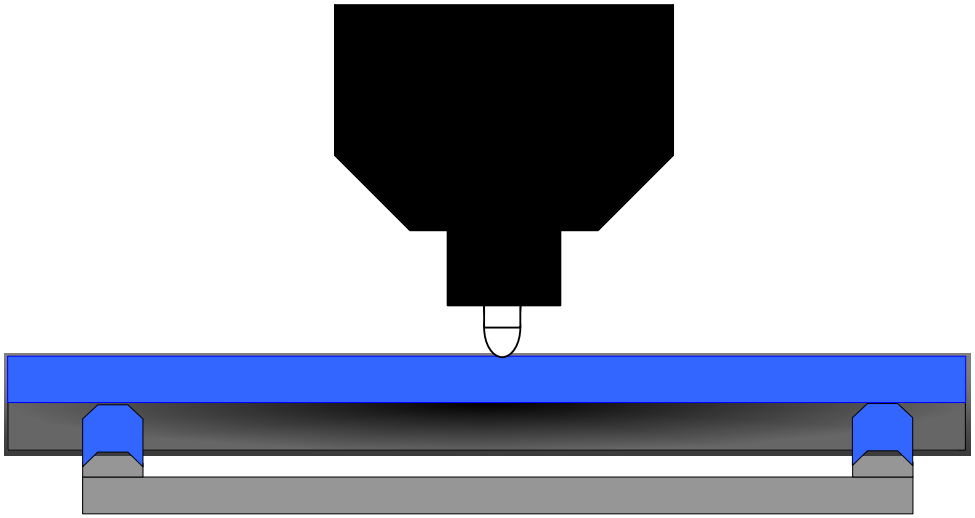
Viscosity Test Precision

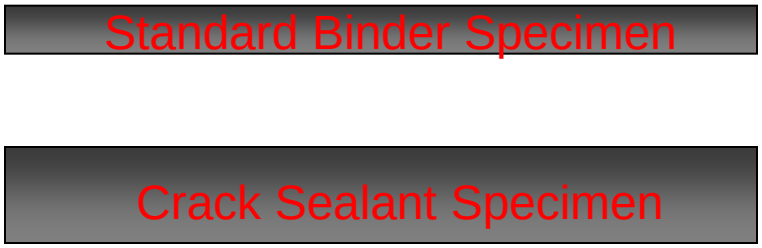
- **Repeatability → 4.6%**
- **Reproducibility → 16.9%**

	Repeatability	Reproducibility
ASTM D4402-02	3.5%	14.5%
AASHTO 2006 T316	3.5%	12.1%
Crack Sealant	4.6%	16.9%

Modified BBR Test (CSBBR)

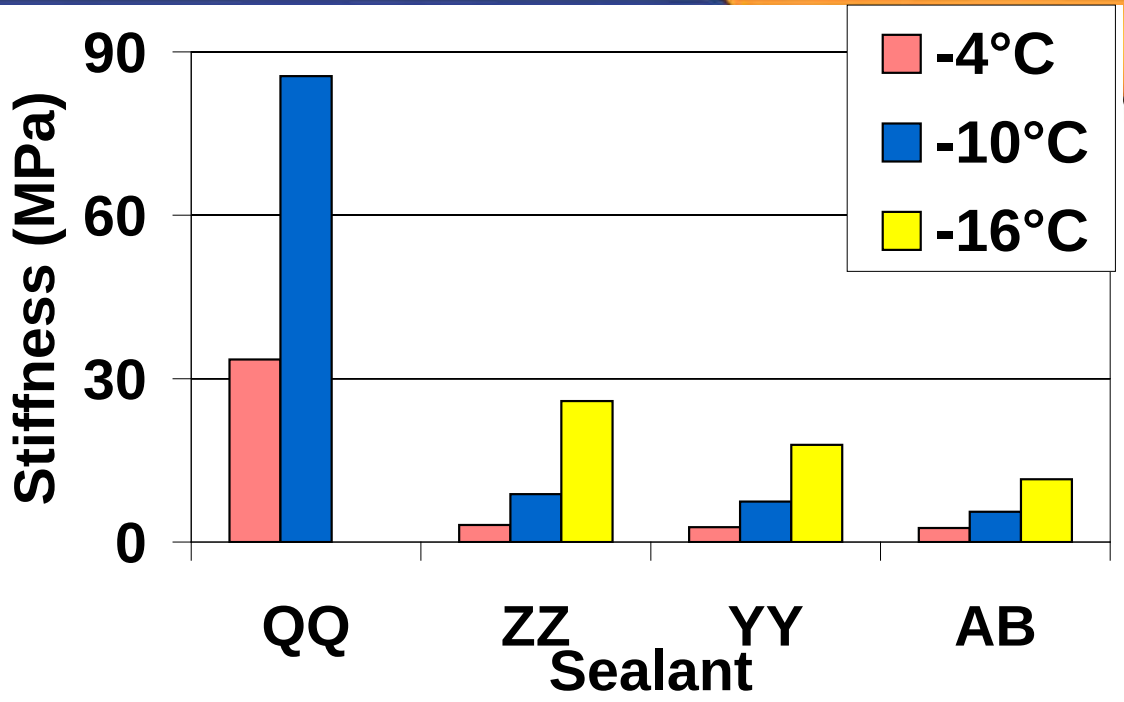
- **Machine**
  - Changing sample support
  - New software version allows measuring various loading and unloading modes
- **Specimen**
  - Doubled specimen thickness to decrease resulting soft sealant deformation.
  - Deflection due to shear increased from 1% to 4%



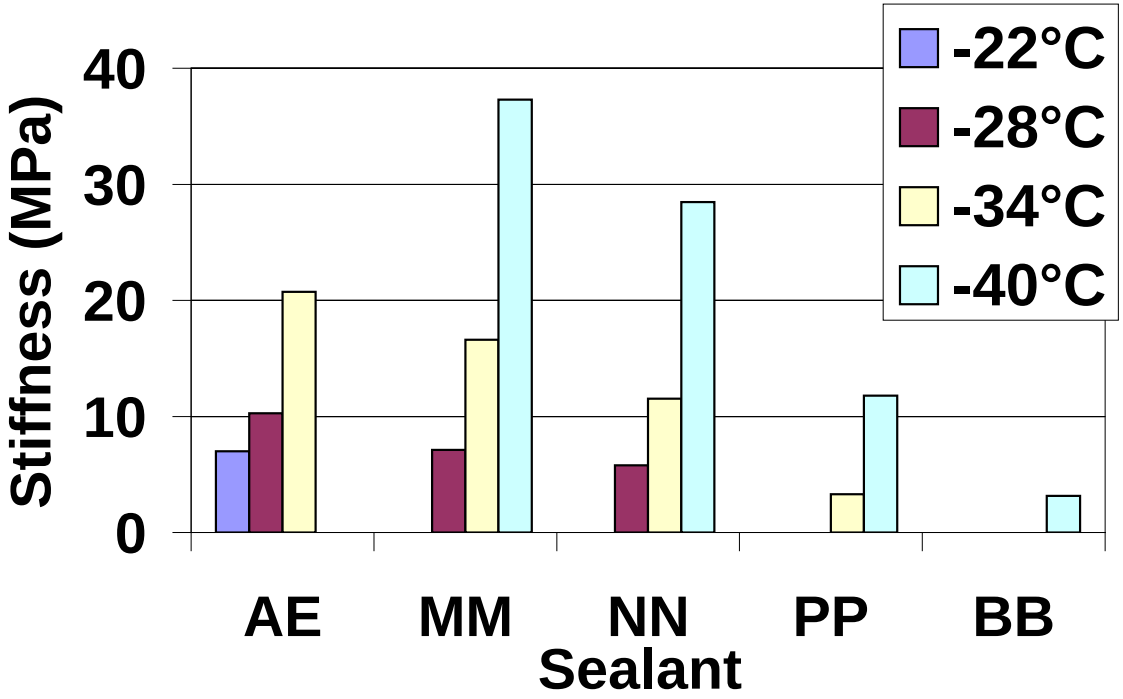


Parameter Selection

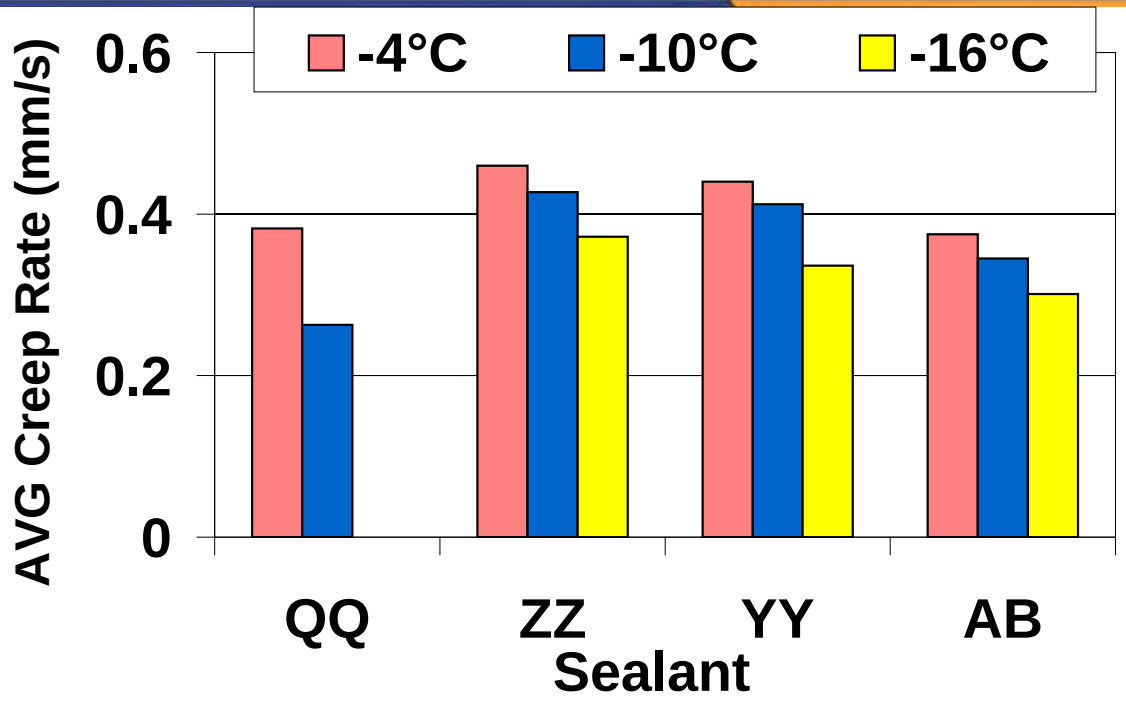
- Parameter selection criteria
  - Ability to describe the rheological behavior
  - Ease of measurement and calculation
  - repeatability
- Evaluated Parameter
  - Stiffness @ 240s
  - Average creep rate
  - Dissipated energy ratio



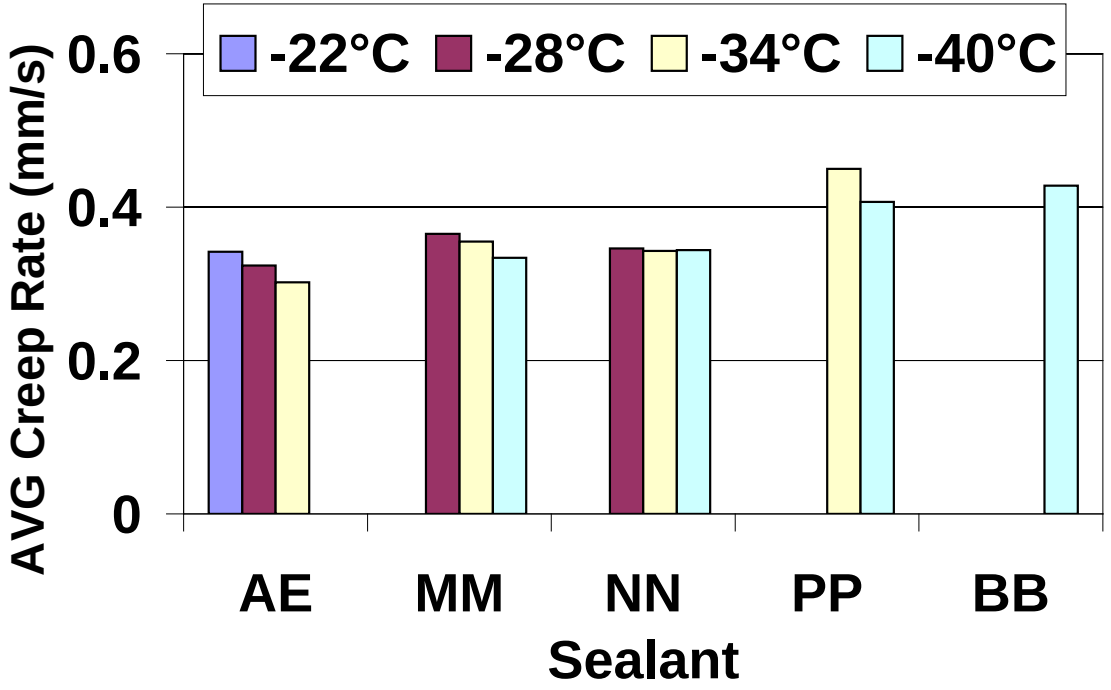
Stiffness @ 240s



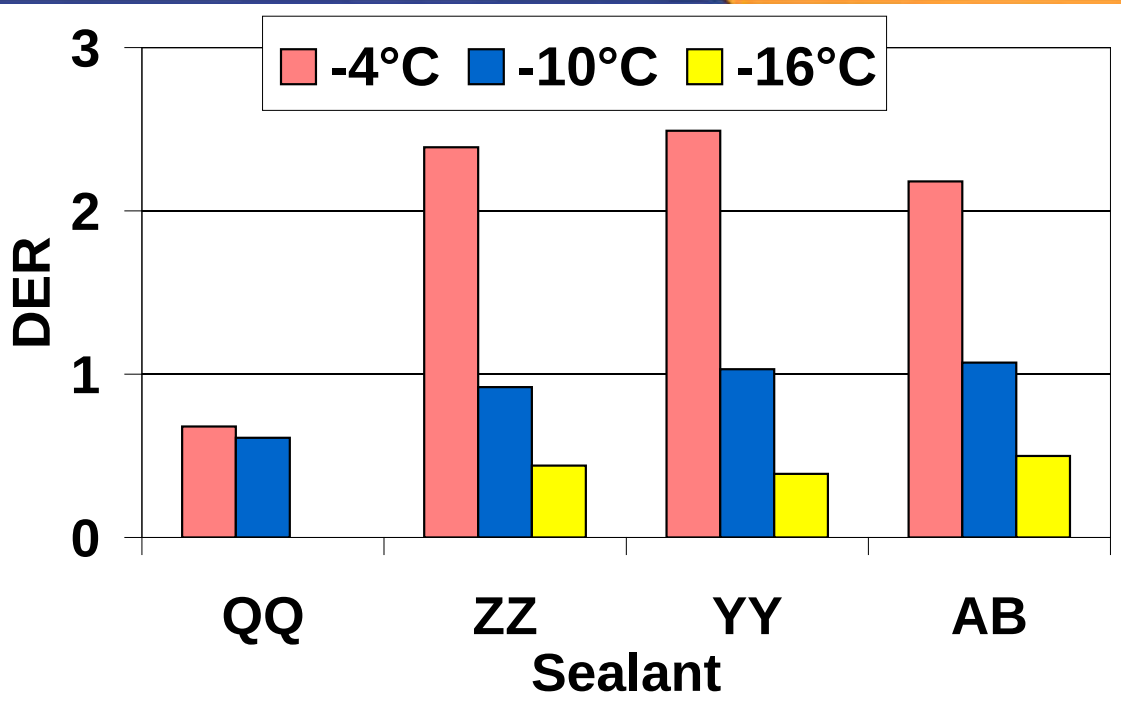
ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN



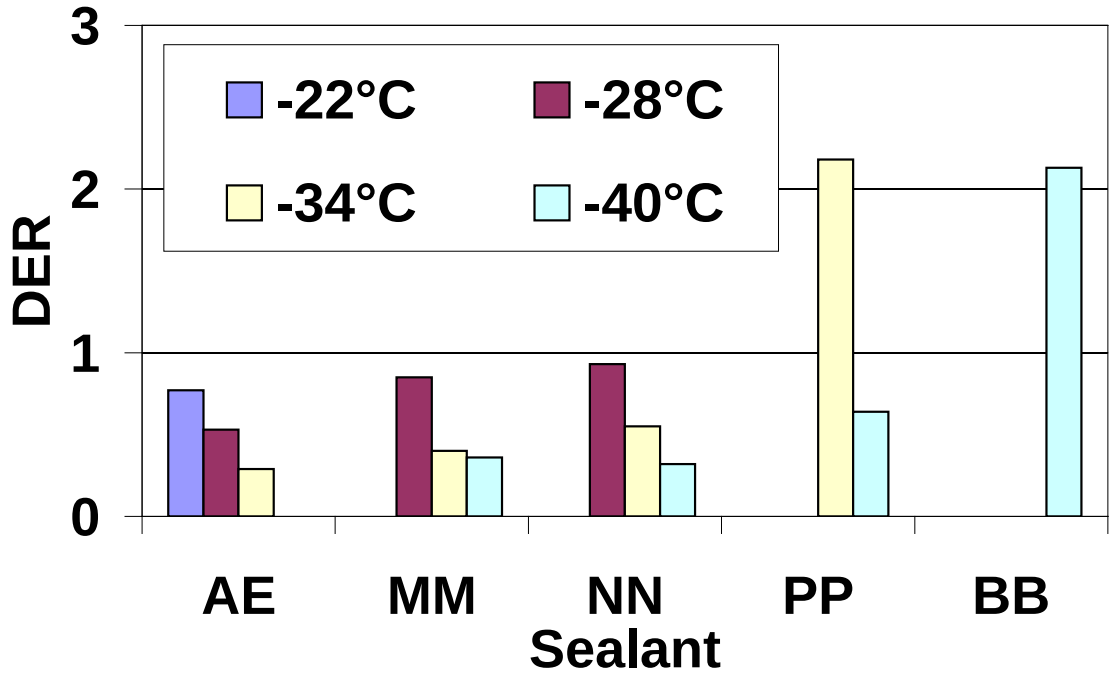
Average Creep Rate



ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN



Dissipated Energy Ratio

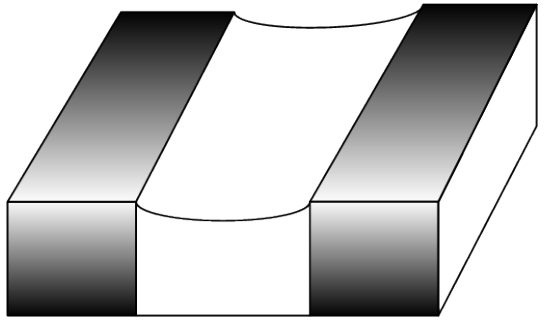


ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

DTT Test

- Interlaken Direct Tension Tester
- Jullabo Temperature control Chiller
- Shel Lab vacuum oven

Two conventional ovens



ILLINOIS CENTER FOR TRANSPORTATION

Test Protocol

- Specimen geometry
  - LxWxT (24mmx6mmx3mm)
- Strain rate:
  - 6%/min
- Testing temperature
  - Based on LTTbind

Failure Mechanism

- Sealant's Failure is stress controlled or strain controlled? → Both
- Brittle stage
  - More sensitive to high stress (stress controlled)
- Ductile stage
  - More sensitive to high strain (strain controlled)
- Selection criteria should consider both
- Report Parameter
  - Extensibility (λ)
  - Stress at rupture/ highest extensibility
  - Percent modulus reduction at 10s $M_r(10)$

Extensibility (λ)

- **Extensibility (λ)**

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

- **Criteria**
  - **Pass** $(\lambda > 100\%)$
    - No rapture or descending load due to internal damage
  - **Fail** $(\lambda < 20\%)$
    - Rapture of descending load is observed
  - **Check M_R (Modulus Reduction) if $20\% < \lambda < 100\%$**

Percent Modulus Reduction $M_r(10)$

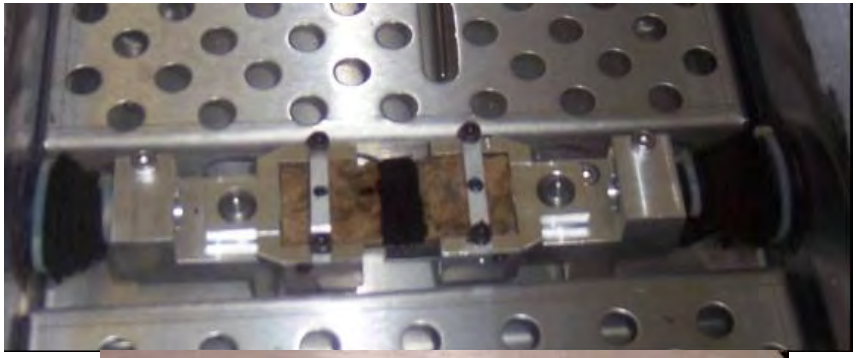
- When load is applied to sealant,
  - greater modulus reduction → less stress is cumulated inside the sealant → less possible to cause damage or rapture
- Modulus reduction percentage after 10sec of loading is

$$Mr(10) = \frac{E_0 - E(10)}{E_0}$$

Adhesion Tester

Sealant is sandwiched between two end pieces of substrate; one of the end pieces is pulled apart at constant rate causing sealant to debond from substrate.

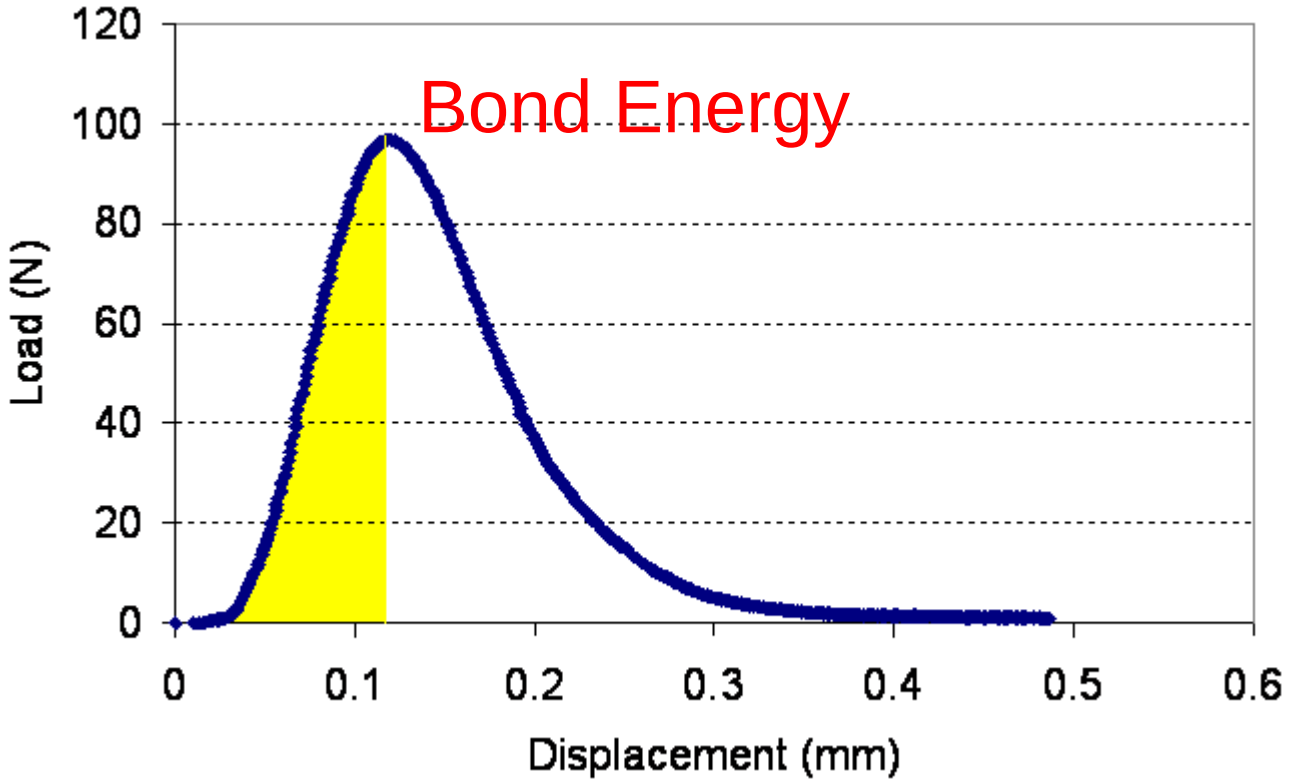
- Simple preparation
- Simulates crack filling & trimming
- Specific failure location (Predebond area at one edge)



Test Procedure

- Two aluminum half-cylinders
- Diameter: 25 mm
- Sealant thickness: 10 mm
- Displacement rate: 0.05 mm/s
- Sample preparation protocol
- Testing procedure:
  - Curing time = 60 min (room temp.)
  - Cooling time before demolding = 15 min
  - Cooling time after demolding = 45 min

Adhesion Test Parameters

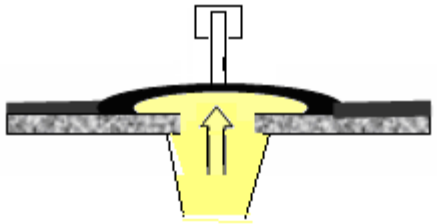


Blister Test

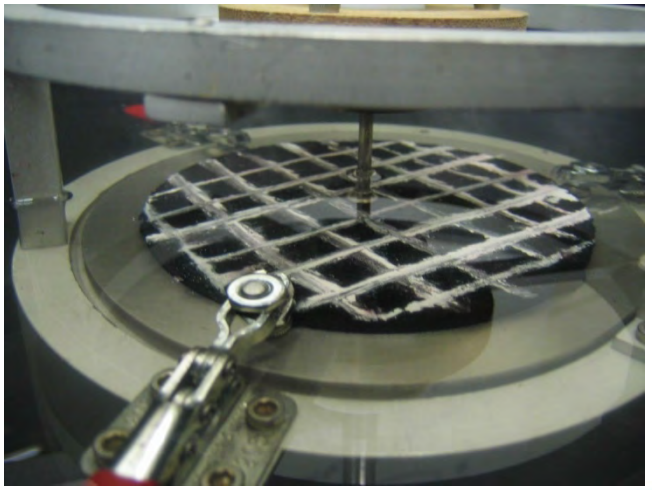
Blister test may be able to measure a fundamental property of the interface.

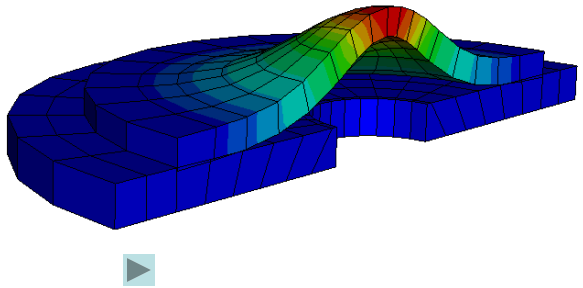
- **Principle of the test:**
  - **A liquid is injected between aggregate and sealant. The result is a detachment in the form of a blister:**
  - **Calculate the work needed to detach the sealant from aggregate**

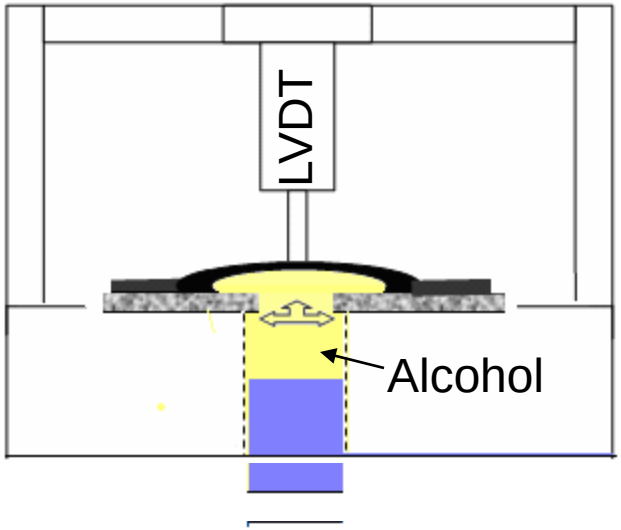
Three values are recorded through the test:

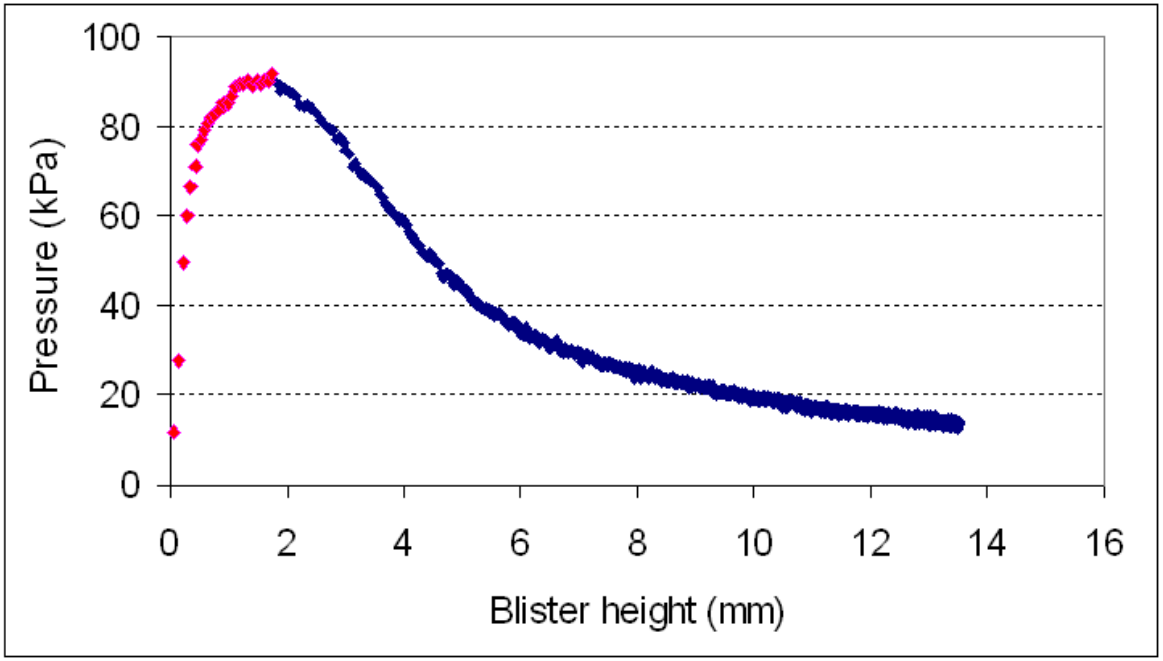


Pressure of the alcohol vs. time
Injected volume of alcohol vs. time
Height of the blister vs. time





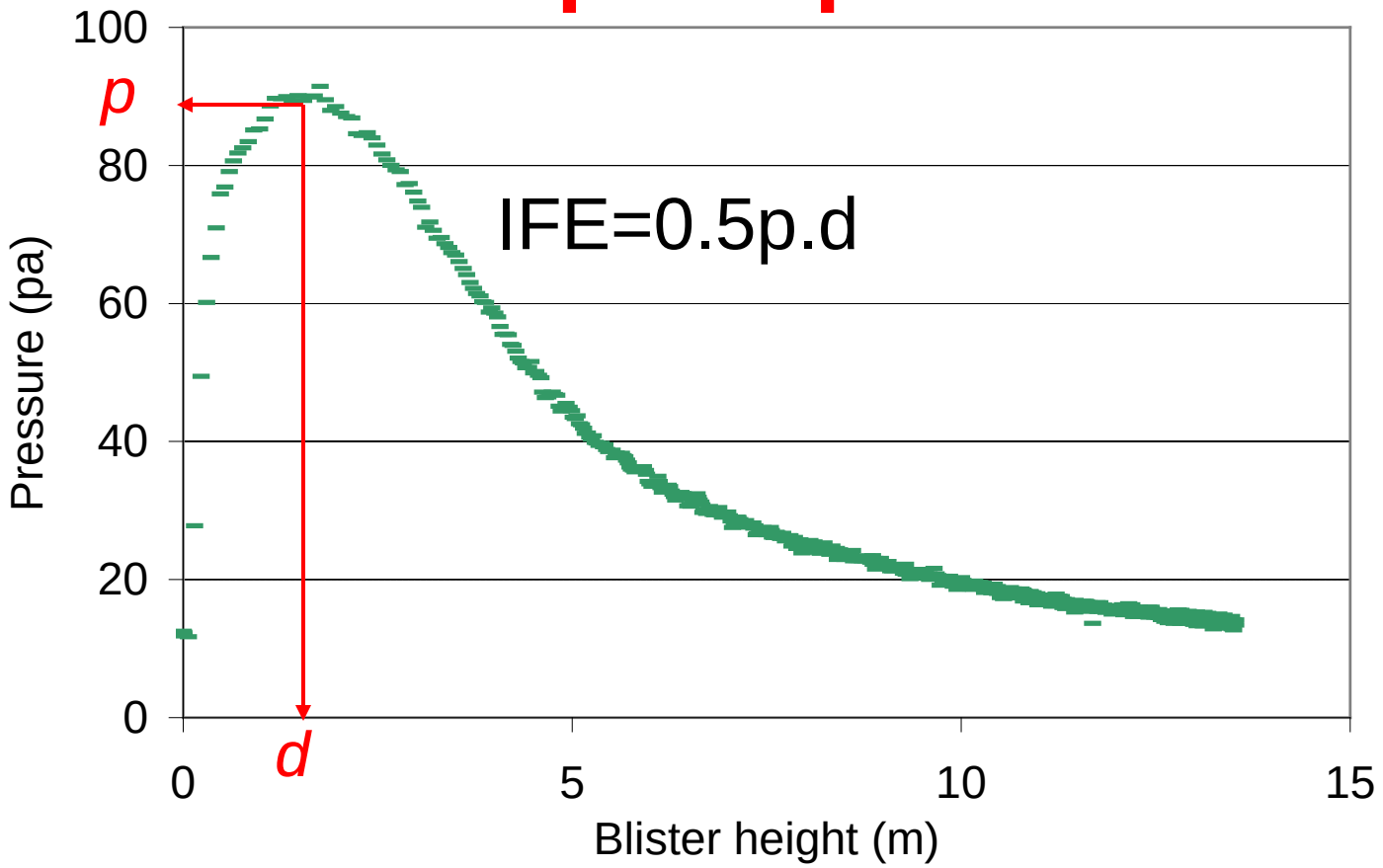




ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

ILLINOIS CENTER FOR TRANSPORTATION

Interfacial Fracture Energy (IFE) is calculated using fracture mechanics principle



Sealant Grade	SG-52	SG-46	SG-40	SG-34	SG-28	SG-22	SG-16
Viscosity @ Installation Temperature							
Maximum:							
Minimum:							
Adhesion (Aged)							
CSAT (also *Blister*):	-40	-34	-28	-22	-16	-10	-4
Peak Load (N), Bond Energy (J/m^2),							
Cohesion (Aged)							
CSDTT:	-40	-34	-28	-22	-16	-10	-4
Modulus Red. Rate (MPa/s),							
Max. Strain, ε_{max} =							
CSBBR:	-40	-34	-28	-22	-16	-10	-4
Max. Stiffness @ 240s (MPa),							
Avg. Creep Rate @ 240s(mm/s),							
Dissip. Energy Ratio,							