Performance Based Specifications for Hot-Poured Crack Sealant
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.
<table>
<thead>
<tr>
<th>Sealant Property</th>
<th>Test Method</th>
<th>ASTM Spec.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application Characteristics</td>
<td>Brookfield Viscosity</td>
<td>D2994</td>
</tr>
<tr>
<td>Adhesion</td>
<td>Bond Test</td>
<td>D5329</td>
</tr>
<tr>
<td></td>
<td>Asphalt Compatibility</td>
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<td>Extensibility</td>
<td>Elongation</td>
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<td>Ductility</td>
<td>D113</td>
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<td>Durability</td>
<td>Track Abrasion</td>
<td>D3910</td>
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<tr>
<td>Flexibility</td>
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<td>C711</td>
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<td></td>
<td>Cone Penetration</td>
<td>D3407</td>
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<tr>
<td>Tracking</td>
<td>Flow</td>
<td>D3407</td>
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<td>Softening Point</td>
<td>D36</td>
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<td>Sealant Grade</td>
<td>SG-52</td>
<td>SG-46</td>
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<td><strong>Viscosity @ Installation Temperature</strong></td>
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<tr>
<td><strong>Maximum:</strong></td>
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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%

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<thead>
<tr>
<th></th>
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<th>Reproducibility</th>
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<tr>
<td>ASTM D4402-02</td>
<td>3.5%</td>
<td>14.5%</td>
</tr>
<tr>
<td>AASHTO 2006 T316</td>
<td>3.5%</td>
<td>12.1%</td>
</tr>
<tr>
<td>Crack Sealant</td>
<td>4.6%</td>
<td>16.9%</td>
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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 at 240s

<table>
<thead>
<tr>
<th>Sealant</th>
<th>-4°C</th>
<th>-10°C</th>
<th>-16°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>QQ</td>
<td>30</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>ZZ</td>
<td>0</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>YY</td>
<td>0</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>AB</td>
<td>0</td>
<td>0</td>
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### Stiffness at Other Temperatures

<table>
<thead>
<tr>
<th>Sealant</th>
<th>-22°C</th>
<th>-28°C</th>
<th>-34°C</th>
<th>-40°C</th>
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<tbody>
<tr>
<td>AE</td>
<td>10</td>
<td>8</td>
<td>15</td>
<td>20</td>
</tr>
<tr>
<td>MM</td>
<td>12</td>
<td>10</td>
<td>18</td>
<td>22</td>
</tr>
<tr>
<td>NN</td>
<td>18</td>
<td>15</td>
<td>24</td>
<td>28</td>
</tr>
<tr>
<td>PP</td>
<td>10</td>
<td>8</td>
<td>15</td>
<td>20</td>
</tr>
<tr>
<td>BB</td>
<td>0</td>
<td>0</td>
<td>0</td>
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</table>
Average Creep Rate

AVG Creep Rate (mm/s)

-4°C
-10°C
-16°C

QQ  ZZ  YY  AB

AVG Creep Rate (mm/s)

-22°C
-28°C
-34°C
-40°C

AE  MM  NN  PP  BB

Sealant
Dissipated Energy Ratio

Sealant

- DER
-22°C
-28°C
-34°C
-40°C

AE
MM
NN
PP
BB

QQ
ZZ
YY
AB
DTT Test

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

Two conventional ovens
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 ($\lambda$)
  – Stress at rupture/ highest extensibility
  – Percent modulus reduction at 10s $M_r(10)$
Extensibility ($\lambda$)

- **Extensibility ($\lambda$)**
  \[ \lambda = \frac{\Delta L}{L_{\text{eff}}} \]

- **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 $\Rightarrow$ less stress is cumulated inside the sealant $\Rightarrow$ less possible to cause damage or rapture

- Modulus reduction percentage after 10sec of loading is

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

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

\[ \text{IFE} = 0.5p \cdot d \]
## Sealant Grade

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## Viscosity @ Installation Temperature

**Maximum:**

**Minimum:**

## Adhesion (Aged)

**CSAT (also Blister):**

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## Cohesion (Aged)

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