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

NEPPP Meeting - November 4, 2009
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<th>Crack Sealant Performance Grade</th>
<th>SG-46</th>
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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
A material that possesses both adhesive and cohesive properties to form a seal which prevents liquids and solids from penetrating into the pavement system -- ASTM D5535.

Crack sealant is formulated to keep its shape as applied and hardens through chemical and/or physical processes to form a viscoelastic, rubber-like material that withstands extension or compression and weathering.
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 Sealant

Low Polymer Content

High Polymer Content

GTR
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 (2 years↑)
Crack Sealant Failure

- **Failure Modes**
  - Cohesion failure: fracture is evident within the treatment.
  - Adhesion failure: loss of bonding between the treatment material and crack reservoir wall.
  - Pullout: complete removal of a sealant section from the pavement.

Superficial Distress:
- Bubbling, extrusion, tracking, stone intrusion, weathering and wear.

Cohesive Failure
Adhesive Failure
Pullout Failure
Intrusion Tracking
## Current ASTM Specifications

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<th>Sealant Property</th>
<th>Test Method</th>
<th>ASTM Spec.</th>
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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

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Crack Sealant Performance Tests
Apparent Viscosity (SC-2)

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

Viscosity, Pa.s

Temperature, °C

-40 -30 -20 -10  0  10  20  30

1.E+07
1.E+06
1.E+05
1.E+04
1.E+03

virgin  1 year
9 year  16h
24h     40h
64h
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)
- Performance parameters
  - Ostwald-DeWaele power-law

- 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?)
- Low temperature flexural properties
- Excessive softness of crack sealant
  - Deflection of the sealant beam is above the limit of the current BBR device

Test modifications and protocol
- Doubling the beam thickness
- Modifying BBR device to be able to perform both binder and sealant tests
- Sealant beam dimension: 12.7x12.7x102mm
- Apply 240s creep load follow by 480s of recovery
**Performance parameter**

- A maximum stiffness of 25MPa and a minimum average average creep rate of 0.31
Direct Tension Test (SC-6)

- Low Temperature Extensibility
- 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)
- Effective gauge length

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<tr>
<th>Studies</th>
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<td>Linde, 1988</td>
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<td>Cook et al., 1991</td>
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Direct Tension Test (SC-6)

- **Performance parameter**
  - Extendibility ($\lambda$)
    \[ \lambda = \frac{\Delta L}{L_{\text{eff}}} \]
    - $\Delta L$ = at breaking point
    - = at max. deformation
    - = at point ($P_2/P_1 < 90\%$)

- The extendibility criterion based on various climatic conditions
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

\[ W_a = \gamma_s^{\text{total}} (1 + \cos \theta) \]
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
  - $P_{\text{min}}$
  - 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
    - 4.7 mm
  - Displacement rate
    - 0.12 mm/s

\[
IFE = \varphi \cdot p \cdot d
\]
Blister Test Parameter

- **Interfacial fracture energy**
  
  \[ IFE = 0.5p_c d_c \]

  - \( p_c \) = 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

De-bonding (%)

- A: 11%
- B: 22%
- E: 20%
- G: 36%
- J: 13%

Pull-out (%)

- A: 14%
- B: 1%
- E: 2%
- G: 14%
- J: 12%

Performance Index (%)

- A: 33%
- B: 74%
- E: 72%
- G: 8%
- J: 39%
### Specification Comparison

#### ASTM D 6690 Type II Test Specification

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#### Sealant Performance Based Specification

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<td>Min. Load (N)</td>
<td>50</td>
<td></td>
<td></td>
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<tr>
<td>Min. Energy (J/m²)</td>
<td>40</td>
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</tr>
</tbody>
</table>
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 3.5 Pa.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)
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
• 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
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
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.
• 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