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
<table>
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<tr>
<th>Crack Sealant Performance Grade</th>
<th>SG-46</th>
<th>SG-52</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
Crack Sealant

Compresses both adhesive properties to form a seal between voids and solids from the pavement system — a viscoelastic, rubbery material that withstands extension and 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 (2 years ↑)
Crack Sealant Failure

- Failure Modes:
  - Cohesive
  - Adhesive
  - Tracking
  - Intrusion
# Current ASTM Specifications

<table>
<thead>
<tr>
<th>Sealant Property</th>
<th>Test Method</th>
<th>ASTM Spec.</th>
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<tr>
<td>Application Characteristics</td>
<td>Viscosity (binder)</td>
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<td>Adhesion</td>
<td>Bond Test</td>
<td>D5329</td>
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<td>Asphalt Compatibility</td>
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<td>Track Abrasion (slurry)</td>
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<td>Cone Penetration</td>
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<td>Softening Point</td>
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<tr>
<td></td>
<td>Aged Resilience</td>
<td>D5329</td>
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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

<table>
<thead>
<tr>
<th>ID</th>
<th>Notes</th>
<th>Cone Pen. 25° C (dmm)</th>
<th>Flow 60° C (mm)</th>
<th>Aged Resilience 25° C (%)</th>
<th>Bond (P/F)</th>
<th>Asphalt Comp. (P/F)</th>
<th>Softening Point (° C)</th>
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Crack Sealant Performance Tests
Evaluate sealant constructability

Test modifications and protocol
- Rotational Viscometer (Brookfield)
- Rigid rod
- Melting time
  - 20min
- Spindle size
  - SC-27
- Speed
  - 60rpm
A minimum and maximum apparent viscosity of 1 and 3.5 Pa.s
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
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)
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 load
- Excess deformation
  - Deformation
  - Load
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)

<table>
<thead>
<tr>
<th>Studies</th>
<th>Max Crack (%)</th>
<th>Min Crack (%)</th>
<th>Fast Move. (mm/min)</th>
<th>Slow Move. (mm/min)</th>
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<tr>
<td>Smith &amp; Romine, 1993</td>
<td>18</td>
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<td>$5 \times 10^{-3}$</td>
<td>$2.77 \times 10^{-4}$</td>
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<td>Linde, 1988</td>
<td>63</td>
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<td>Cook et al., 1991</td>
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<td>Masson &amp; Lacasse, 1999</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
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\(^2\)
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

<table>
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<tr>
<th>Test</th>
<th>Cone Penetration</th>
<th>Flow</th>
<th>Resilience</th>
<th>Bond</th>
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<td>(Temp (C))</td>
<td>60°C</td>
<td>(Temp (C))</td>
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<td>(&lt;3 mm)</td>
<td>(&gt;60%)</td>
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#### Sealant Performance Based Specification

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<th>CSDTT</th>
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- 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
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.
DEVELOPMENT OF PERFORMANCE-BASED GUIDELINES FOR SELECTION OF BITUMINOUS-BASED HOT-POURED PAVEMENT CRACK SEALANT: AN EXECUTIVE SUMMARY REPORT

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University of Illinois at Urbana-Champaign

KEVIN K. McGHEE
Senior Research Scientist
Virginia Transportation Research Council

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