Federal Lands Highway Polymer-Modified Emulsion Program

NEPPPP Meeting
October 21, 2008

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Summary

- Sponsored by FHWA (~2006)
  - Administered by NCPP
  - G. King – Program manager

- Extensive PME literature review completed
  - J. Johnston – NCPP – White paper

- Deliverable – Proposed spec for PME’s
  - Field projects – Central Bureau Fed Lands
  - Report-only data – BASF, PRI, Paragon
PME Specification Targets

- Low temperature recovery method
  - Preserves polymer morphology/structure
  - Requires Supplier Certification Program

- All residue testing completed on DSR

- Includes performance testing
  - Chip seal
  - Polymer-modified slurry
  - Micro surfacing
### Testing Protocol for 2008 Evaluations

<table>
<thead>
<tr>
<th>PROPERTY</th>
<th>TEST METHOD</th>
<th>SPEC</th>
<th>RESULT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asphalt Emulsion as Received</td>
<td>Standard AASHTO or ASTM tests:</td>
<td>AASHTO M-140 Emulsified Asphalt or AASHTO M-208 Cationic Emulsified Asphalt</td>
<td></td>
</tr>
<tr>
<td>Field Viscosity Test</td>
<td>WYDOT 538.0</td>
<td></td>
<td>Report</td>
</tr>
</tbody>
</table>

### Residue Recovery (24 hours @ 25°C, 24 hours @ 60°C, For ced Draft Oven)

<table>
<thead>
<tr>
<th>Frequency Sweep (25 mm, 0.1 – 100 rad/sec, 10% Strain)</th>
<th>HTG*</th>
<th>AASHTO T 315</th>
<th>TP 70-08</th>
<th>% Recovery &amp; Jnr at each stress level</th>
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<td>Multiple Stress Creep Recovery (100, 1000, 3200 &amp; 10,000Pa)</td>
<td>HTG - 6°C</td>
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- Resistance to Deformation: $G^*/sind @ 12\%$ Strain
- Strain Tolerance: Strain Level at which $G^* < 90\%$ $G^*$ initial
- Failure Properties: Strain Level at which $G^* <50\%$ $G^*$ initial
<table>
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<tr>
<th>Test Type</th>
<th>Temperature</th>
<th>Report</th>
<th>Test Method</th>
</tr>
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<tbody>
<tr>
<td>Pressure Aging Residue (100°C, 300 psi, 20 hours)</td>
<td>R 28</td>
<td></td>
<td>Strawman PME Specification Intermediate and Low T Testing</td>
</tr>
<tr>
<td>(PAV run on residue obtained by Forced Draft Oven Method run in PAV pan)</td>
<td></td>
<td></td>
<td></td>
</tr>
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<td>Frequency Sweep (25 mm, 0.1 – 100 rad/sec,1% Strain)</td>
<td>HTG*</td>
<td>AASHTO T 315</td>
<td>Frequency Sweep (G*, δ, etc…)</td>
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<td>Frequency Sweep (8 mm, 0.1-100 rad/sec, % Strain (TBD))</td>
<td>0°C</td>
<td>AASHTO T 315</td>
<td>Frequency Sweep (G*, δ, etc…)</td>
</tr>
<tr>
<td>Frequency Sweep (8 mm, 0.1-100 rad/sec, % Strain (TBD))</td>
<td>10°C</td>
<td>AASHTO T 315</td>
<td>Frequency Sweep (G*, δ, etc…)</td>
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<td>Frequency Sweep (8 mm, 0.1-100 rad/sec, % Strain (TBD))</td>
<td>20°C</td>
<td>AASHTO T 315</td>
<td>Frequency Sweep (G*, δ, etc…)</td>
</tr>
<tr>
<td>Test Strain Sweep, 1 – 50% strain, 10 rad/s</td>
<td>25°C</td>
<td></td>
<td>Resistance to Deformation: G*/sind @ 12% Strain</td>
</tr>
<tr>
<td>Bending Beam Rheometer</td>
<td>-12°C + -18°C</td>
<td>AASHTO T 313</td>
<td>Strain Tolerance: Strain Level at which G* &lt; 90% G* initial</td>
</tr>
<tr>
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<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Stiffness + m-value</td>
</tr>
<tr>
<td>Performance tests for Chip Seals</td>
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<td>---------------------------------</td>
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<tr>
<td>Sweep Test</td>
<td>Modified ASTM D-7000 Report</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
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<tr>
<th>Performance tests for Polymer Modified Slurry Seals and Micro-Surfacing</th>
<th></th>
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<tbody>
<tr>
<td>Recommended Performance Guidelines for Emulsified Asphalt Slurry Seal Surfaces</td>
<td>ISSA A105</td>
</tr>
<tr>
<td>Recommended Performance Guidelines for Polymer Modified Micro-Surfacing</td>
<td>ISSA A143</td>
</tr>
<tr>
<td>Tests recommended by Caltrans Slurry/Micro-Surface Mix Design Procedure Project /Contract 65A0151</td>
<td>TBD</td>
</tr>
</tbody>
</table>

* High Temperature Performance Grade as selected for local climate (LTPPBind version 3.1)
Central Bureau Fed Lands Projects Strawman – Report-Only Data

<table>
<thead>
<tr>
<th>Project</th>
<th>Date</th>
<th>System(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Utah Parks</td>
<td>September, 2008</td>
<td>Chip Seal - CRS-2P (SBR) Micro Surfacing (NRL, Ralumac)</td>
</tr>
<tr>
<td>Dinosaur Natl. Monument</td>
<td>September, 2008</td>
<td>Chip Seal - PASS - CRS-2P (Latex)</td>
</tr>
<tr>
<td>Death Valley</td>
<td>November, 2008</td>
<td>Chip Seal (SBR, SBS?)</td>
</tr>
<tr>
<td>Crater Lake</td>
<td>Spring 2009</td>
<td>Chip Seal (TBD)</td>
</tr>
</tbody>
</table>

Testing Labs (Third Party + Industry):
- PRI Asphalt Technologies, Inc (Tampa, FL)
- Paragon Technical Services, Inc. (Richland, MS)
- BASF Corporation (Charlotte, NC)
Emulsions 101
Polymer-Modified Emulsions for Surface Treatments

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Outline

- Asphalt emulsion primer
- What are polymers?
- Why polymers for asphalt emulsions?
- Modification of asphalt emulsions
- Polymer networks in asphalt emulsions
- Impact on performance + properties
Asphalt Emulsions - Formulation

Components

- Asphalt
- Surfactant (surface active agents, emulsifiers)
- Water
- Mechanical energy (colloid mill)

Other Ingredients

- Additives (calcium chloride, cutback agents, …)
- Modifiers – Polymers
Dispersion of asphalt in water
- Water – continuous phase
- Asphalt – non-continuous or dispersed phase
  - Stabilized by surfactant

Surfactant → emulsion class.
- Cationic
- Anionic
- Nonionic
Asphalt Droplets

Asphalt Droplets

Particle Size, µm

Volume %

0.1 1 10 100
What are Polymers?

- Comprised of many small molecules
  - Poly = many
  - Monomers = small molecules or repeat units

- Monomers chemically react → larger molecules
  - Water-based polymers – latex form (SBR)
  - Solvent-based polymers – pellets, bale (SB-,SBS)

- Properties are determined by:
  - Types and sequence of monomers
  - Molecular weight
Polymer Types for Asphalt Mod.

- **SBR Latex** – Chip Seals, Slurry and Micro Surfacing
- **SB/SBS** – Chip Seals
- **Natural Rubber Latex** – Ralumac (Micro Surfacing)
- **Other** – Neoprene, EVA, GTR (REAS), Fibers
Typical Monomers

- **Styrene**
- **Butadiene**
- **Isoprene (NR)**
Viscoelastic Behavior
Cured Latex Modified Asphalt Emulsion

- $G^* = f(T) = $ deform. resist.

- **Asphalt**
  - High $G^*$ at low $T$ – brittle
  - Low $G^*$ at high $T$ – viscous
  - $\Delta G^*(80^\circ C - 20^\circ C) = 1000x$

- **SBR Polymer**
  - Lower $G^*$ at low $T$ – flexible
  - Higher $G^*$ at high $T$ – elastic
  - $\Delta G^*(80^\circ C - 20^\circ C) = 10x$

Complex Modulus [$G^*$], Pa

- $G^*$ at 80°C – 20°C for different materials:
  - AAA-1 Asphalt
  - SBR Polymer
Polymer Modification of Asphalt Emulsions

- Emulsify polymer modified asphalt
  - “Pre-modified” emulsion
  - Polymers – SBS, SB-
  - Higher mod. asphalt viscosity
    - higher asphalt + mill temp.
  - Exit temp. > 100°C
  - Heat exchanger, back press.

- Polymer inside asphalt droplet
Polymer Modification of Asphalt Emulsions

- Add latex external to asphalt
  - Methods
    - soap batching
    - co-milling – asphalt line
    - co-milling – soap line
  - Polymers – SBR, NR latex
  - Lower asphalt process T
  - No special mill, handling
- Polymer in water phase
- Continuous polymer film formation on curing
Latex Polymer-Modified Asphalt Emulsion

Latex Modified Emulsion

Cured Bitumen Emulsion

• Optimum for Fine Polymer Network Formation
Chip Seal – Field Application
Chip Seal Surface Treatment

Near Taos, NM
**CRS-2 vs. CRS-2P(LM) – Physical Props.**

<table>
<thead>
<tr>
<th>Test Method</th>
<th>CRS-2</th>
<th>CRS-2P</th>
</tr>
</thead>
<tbody>
<tr>
<td>R&amp;B Softening Point (°F)</td>
<td>ASTM D 36</td>
<td>115</td>
</tr>
<tr>
<td>Ductility (4°C, cm)</td>
<td>ASTM D 113</td>
<td>21</td>
</tr>
<tr>
<td>Elastic Recovery (10°C, %)</td>
<td>AASHTO T 301</td>
<td>5</td>
</tr>
</tbody>
</table>

3 wt.% SBR latex polymer (on asphalt)

- **Residue**
  - ASTM D 6934 - Oven evaporation at 163°C

- **Polymer**
  - Raises SP, drastically increases ductility and ER
Sweep Testing – CRS-2P vs CRS-2
ASTM D7000 - 04
Chip Seal with Latex Modified CRS

- Latex polymers accumulate at optimum location
  - Act to glue aggregate together!!!
Curing of CRS-2LM Emulsion

- Water in asphalt emulsion wicks the aggregate surface.
  - Order of migration = Water, latex particles, asphalt droplets
Latex Polymer Distribution – Unstable CRS-2L Emulsion

- Latex particles migrate together with water???
  - Polymer rich regions around aggregate = NO
Latex Polymer Distribution – Stable CRS-2L Emulsion

Latex particles migrate together with water!
- Polymer rich regions around aggregate = YES
Micro Surfacing Operation

1 min < Mix Time < 3 min

Cohesion Development < 1 hr
Micro Surfacing – High ADT + ESAL’s

Paved in Oct. 2001
Photo from Sept. 2003
Micro Surfacing Mix Formulation

- Blade Coating Operation
  - 2 m wide + <1 cm thick
  - 4-5 km/hour
  - Traffic within 1 hour

- Latex Polymer Binds
  - Asphalt
  - Fines to Aggregates

Latex Polymer = 3% of Asphalt
Micro Surfacing – Polymer Morphology Field Application

Texas State Highway 84
- Near Waco, TX
- Paved in 1998
- Samples taken in 2001
Cured Latex Polymer Network

Micro Surfacing

Latex Foam
SBR latex polymer

- 50% reduction in loss
  - one hour soak
- 67% reduction in loss
  - six day soak

- Surface of mix
  - tougher
  - more abrasion res.

- Adhesion + water resistance
  - improved
Micro Surfacing Residue – SHRP Grade

Rutting resistance temperature, °C

Curing Time, day

Emulsion Only

Emulsion+Cement

Emulsion+Cement+SBR

Latex

30 days Cured

Phase Angle at $G' \sin(\delta) = 1$ kPa, degree

Emulsion only

+ Cement

+3% Latex

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Summary – Polymer Modified Emulsions

- **Chip seals**
  - Early and long term chip retention
  - High temperature strength
  - Low temperature flexibility

- **Slurry seal and micro surfacing**
  - Improved mix cohesion
  - Reduction in abrasion loss of aggregate
  - Resistance to deformation