SBR and Natural Rubber Latex-Modified Emulsions for Micro Surfacing

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Outline

- Asphalt emulsion primer
- What are polymers?
- Polymers for micro surfacing emulsions
  - Modification of asphalt emulsions
  - Latex polymer networks
  - Impact on binder + mix properties
- MN DOT micro surfacing perspective
- SBR latex-modified TH 55 demo details
Asphalt Emulsions - Formulation

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

- **Other Ingredients**
  - Additives (calcium chloride, cutback agents, …)
  - Modifiers – *Polymers*
Asphalt Emulsions – Component Distribution

- 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

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, NRL)

- Properties are determined by:
  - Types and sequence of monomers
  - Molecular weight
Polymer Types for Micro Surfacing

- **SBR Latex** – Micro Surfacing
- **Natural Rubber Latex** – Ralumac (Micro Surfacing)
- **Other** – Ground Tire Rubber - GTR (REAS)
Polymers for Micro Surfacing Emulsions

- **Elastomer – Styrene-Butadiene Rubber - SBR**
  - Latex form – polymer particles dispersed in water
  - Random monomer addition – typ. 75/25 Bd/styrene
  - High molecular weight – 1,000,000 g/mole
    - 13,900 Bd “mers”, 2400 styrene “mers”
  - Broad distribution – chains many different lengths
Elastomer – Polyisoprene – Natural Rubber

- Latex form – polymer particles dispersed in water
- Homopolymer of isoprene – harvested from trees
- High molecular weight – 1,000,000 g/mole
- Broad distribution – chains many different lengths

[Chemical structure of isoprene]

Isoprene
Viscoelastic Behavior
Cured Latex Modified Asphalt Emulsion

- $G^* = f(T) = \text{deform. resist.}$

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

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

1 min < Mix Time < 3 min

Cohesion Development < 1 hr
Microsurfacing – 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 (1/4 of Cement)
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

Graph showing:
- Loss (g/ft²) on the y-axis
- Unmod. and SBR on the x-axis
- Bar graph comparing 1 Hour and 6 Day soak

Legend:
- Green bar: 1 Hour
- Red bar: 6 Day

3 wt% SBR (on asphalt)
Cohesion Development – ISSA TB-139

Cohesion (kg-cm)

Unmod.  SBR

3 wt% SBR (on asphalt)

30 minutes  60 minutes

30 minutes  60 minutes
SBR latex at 3% will decrease lateral disp. by ~ 90%
Microsurfacing Residue – SHRP Grade

Rutting resistance temperature, °C

Curing Time, day

Emulsion+Cement+SBR Latex
Emulsion+Cement
Emulsion Only

Phase Angle at G*sin(δ) = 1kPa, degree

30 days Cured

Emulsion only + Cement +3% Latex
Advantages of Latex Polymer Network

- Latex polymer honeycombs remain flexible
  - Absorb stresses without permanent deformation
Micro Surfacing

• Improved mix cohesion
• Reduction in abrasion loss of aggregate
• Resistance to deformation
Micro Surfacing in Minnesota History

- Intro to micro surfacing from Koch in late 1980s
- Small trial projects until 1999
- 1999 – First large contract for micro surfacing
  - Single statewide contract to demonstrate
    - rut filling
    - friction improvement
    - ride improvements
  - About 125 lane miles
Micro Surfacing in Minnesota Current Practices

- Roadways with over 10,000 AADT
- Project selection in Pavement Management System
- Much of our micro surfacing work done at night
  - Minimizes traffic disruption
  - Requires a 1000-foot night time test strip
    - To demonstrate micro surfacing mix meets our one-hour cure time requirement
Micro Surfacing in Minnesota Current Specification

- Requires natural rubber latex polymer
- Contractor provided mix design
- Ambient temperature above 50°F
- Work complete before September 15th
Micro Surfacing in Minnesota
Current Application Areas

- Pavement preservation
- Rut filling
- Centerline longitudinal joint treatment (18” wide)
- Friction improvements
- Some ride improvements
Micro Surfacing in Minnesota Performance

- Generally adds about five years to the life of our bituminous pavements (ride criteria)

- Failure modes include:
  - Debonding
  - Raveling and abrasion wear

- Is it cost effective?
  - About neutral for LCCA
SBR Latex-Modified Micro Surfacing Demo
2008 MPPP - TH 55

Minnesota DOT

**TABLE I**
AGGREGATE ANALYSIS
VANCE BROTHERS, INC.

<table>
<thead>
<tr>
<th>SIEVE #</th>
<th>ISSA TYPE II SPECIFICATIONS</th>
<th>% PASSING</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>90-100</td>
<td>96.9</td>
</tr>
<tr>
<td>8</td>
<td>65-90</td>
<td>75.6</td>
</tr>
<tr>
<td>16</td>
<td>45-70</td>
<td>53.3</td>
</tr>
<tr>
<td>30</td>
<td>30-50</td>
<td>37.5</td>
</tr>
<tr>
<td>50</td>
<td>18-30</td>
<td>24.6</td>
</tr>
<tr>
<td>100</td>
<td>10-21</td>
<td>15.8</td>
</tr>
<tr>
<td>200</td>
<td>5-15</td>
<td>10.8</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>TEST</th>
<th>ISSA SPECIFICATION</th>
<th>RESULT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand Equivalent</td>
<td>65</td>
<td>83</td>
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</tbody>
</table>

**TABLE II**
MICRO-SURFACING EMULSION FORMULATION
VANCE BROTHERS, INC.

<table>
<thead>
<tr>
<th>COMPONENT</th>
<th>PERCENTAGE, BY WEIGHT EMULSION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emulsifier</td>
<td>1.7</td>
</tr>
<tr>
<td>Latex NX 1138</td>
<td>3.5</td>
</tr>
<tr>
<td>Water</td>
<td>32.8</td>
</tr>
<tr>
<td>Hydrochloric Acid</td>
<td>to pH 2.0</td>
</tr>
<tr>
<td>Asphalt: Amoco Whiting AC-20</td>
<td>62.0</td>
</tr>
</tbody>
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TABLE III
MICRO-SURFACING EMULSION TEST RESULTS
VANCE BROTHERS, INC.

<table>
<thead>
<tr>
<th>TEST PROCEDURE</th>
<th>RESULTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residue, %</td>
<td>65.5</td>
</tr>
<tr>
<td>Sieve, %</td>
<td>0.0105</td>
</tr>
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</table>

TABLE IV
MICRO-SURFACING JOB MIX FORMULATION
VANCE BROTHERS, INC.

<table>
<thead>
<tr>
<th>COMPONENT</th>
<th>PERCENTAGE, ON DRY AGGREGATE BASIS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type I Portland Cement</td>
<td>0.25-0.75</td>
</tr>
<tr>
<td>Total Water</td>
<td>10-12</td>
</tr>
<tr>
<td>Pre-Wet Solution (4% Emulsifier in Water)</td>
<td>As Required</td>
</tr>
<tr>
<td>Emulsion</td>
<td>12-13</td>
</tr>
<tr>
<td>Aggregate:</td>
<td>100</td>
</tr>
</tbody>
</table>
### TABLE V
MICRO-SURFACING MIX EVALUATION
VANCE BROTHERS, INC.

<table>
<thead>
<tr>
<th>TEST PROCEDURE</th>
<th>ISSA SPECIFICATION</th>
<th>RESULTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mixing Time, seconds</td>
<td>120 Minimum</td>
<td>120+</td>
</tr>
<tr>
<td>Wet Cohesion, kg-cm @ 30 minutes</td>
<td>12 Minimum</td>
<td>19</td>
</tr>
<tr>
<td>@ 60 minutes</td>
<td>20 Minimum or Near Spin</td>
<td>22</td>
</tr>
<tr>
<td>Wet Track Abrasion Loss, g/ft²,</td>
<td></td>
<td></td>
</tr>
<tr>
<td>One-hour Soak</td>
<td>50 Maximum</td>
<td>12.8</td>
</tr>
<tr>
<td>Six-hour Soak</td>
<td>75 Maximum</td>
<td>25.5</td>
</tr>
<tr>
<td>Lateral Displacement, %</td>
<td>5% Maximum</td>
<td>5.0</td>
</tr>
<tr>
<td>Vertical Displacement, %</td>
<td>None Specified</td>
<td>16.5</td>
</tr>
<tr>
<td>Excess Asphalt by LWT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sand Adhesion, g/ft²</td>
<td>50 Maximum</td>
<td>36.2</td>
</tr>
<tr>
<td>Wet Stripping, %</td>
<td>90 Minimum</td>
<td>90+</td>
</tr>
<tr>
<td>Classification Compatibility, Grade Point</td>
<td>11 Minimum</td>
<td>11+</td>
</tr>
</tbody>
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Acknowledgements

- Paul Nolan – Minnesota DOT

- Vance Brothers, Inc.
  - Mark Smith
  - Marty Burrow
  - Stan Fronckewicz
  - Tim Harrawood

- Peter Montenegro – BASF Corporation