FLH Study on Polymer Modified Emulsions
Evaluating performance-based emulsion tests

Midwestern PPP Meeting
October 28, 2009, Schaumburg, IL
Outline

✓ Background / Objectives of Study
✓ Tasks & Findings
  ▪ Literature Review
  ▪ Industry Survey & Outreach
  ▪ Strawman specifications & Field Trials
  ▪ Recommendations & Final Report
✓ Conclusions / What’s Next
Objectives/Need for Study

✓ No national standards exist within a single document to guide practitioners on the use of polymer modified asphalt emulsions.

✓ The currently measured physical & chemical properties of emulsions do not always correlate with performance.

✓ Encourage level “playing field” for producers.

- CQS-1HLM
- CRS-2L
- RoadArmor®
- PMCRS
- CHFRS-2P
- CRS-2P
- HFRS-2sP
- LMCRS-2P
- Ralumac®
- CRS-LTP
- CRS-2HLM
- PASS®
- CRS-2R
- MSE®
Objectives/Need for Study

✓ Address cost/benefit of polymer modification
✓ Address parking lots & biking trails
✓ Address climate extremes for FLH

In brief, FLH desired guidance on when, where, how, and why to use polymer modified asphalt emulsions.
Death Valley N.P.

Bryce Canyon N.P.

Climate Extremes
Information Gap – No climatic grading system or guidance for emulsions

- Recently completed or soon to be completed FLH surface treatments
Objectives/Need for Study

Research Needs

✓ Pavement Preservation Research Roadmap needs: Materials 05: “Performance Grading System for Asphalt Emulsions”

✓ TRB Research Needs Statement
  • Pavement Preservation Committee - AHD18
  • Support from General Issues in Asphalt Committee (AFK10)

✓ Research Needs Total in the Millions of Dollars
Scope

- Use of polymer modified asphalt emulsions in surface treatment applications:
  - Chip Seals
  - Slurry Seals (micro-surfacing)
  - Cape Seals

- Strawman specification and field trials primarily focused on rheology (testing on residue)
Background of Study

✓ Principle Investigators:
  - National Center for Pavement Preservation (NCPP), Larry Galehouse
  - GHK, Inc. is a sub-consultant (Gayle and Helen King)

✓ Lab Testing Services: PRI
Background of Study

✓ Technical Panel Includes: AEMA, FHWA, & Suppliers representatives
✓ Contributors include: Academia, ETGs, Industry, Suppliers

[Logos of Asphalt Research Consortium, BASF, NCHRP, Ultrapave, Kraton, SemMaterials, FHWA]
Common polymer dosage rates: 3 – 5 %

Unequivocally, PMEs have significant performance benefits over unmodified emulsions

- Improved elasticity / ductility
- Improved chip/stone retention
- Improved high temperature performance
Literature Review

✓ Non-roadway applications (biking trails, parking lots): No pertinent literature
✓ Polymer concentration: Formation of continuous polymer network within an PME is critical to optimizing performance benefits
✓ Most common polymer modification: SBR and SBS
✓ Benefits of PME likely far outweigh its additional cost.
Industry Survey & Outreach

- Knowledge gathering sessions: Industry, academic, federal & local government agencies
- On-line user/producer survey
- Presentations & input: AEMA/ARRA/ISSA, TRB, ETGs, AASHTO, PPPs
Goals of the On-Line Survey

✓ Solicit industry and agency input
  - To create a framework for performance-based asphalt emulsion specifications
  - Validate and/or influence direction of specifications/testing

Joshua Tree N.P.
Survey Questionnaire Areas

- Approved Supplier Certification Program
- Residue Recovery Methods
- Emulsion Specification Tests
- Emulsion Residue Specifications
- Application-Specific Performance-Related Specifications
- Construction/Acceptance
Survey Primary Recommendations

✓ Approved Supplier Certification program
  ▪ Reduce shipping & construction delays

✓ Update AASHTO T-59 & ASTM D-244
  ▪ Adopt a low temperature residue recovery method
  ▪ Revise emulsion viscosity method
    • Lab test: Brookfield or paddle method
    • Field acceptance test
Survey Primary Recommendations

✓ Residue performance-graded specifications
  • Superpave binder tests preferred
  • Aging: Use PAV, do not use RTFO

✓ Need performance-related tests for applications
  • Must include aggregate
  • Evaluate cure time to traffic

✓ Aggregate testing important
## Strawman Specification

### Emulsion Residue Recovery & Testing

<table>
<thead>
<tr>
<th>Purpose</th>
<th>Test</th>
<th>Conditions</th>
<th>Report</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residue Recovery</td>
<td>Forced Draft Oven</td>
<td>24 hrs @ambient + 24 hrs @60°C</td>
<td>✓ % Residue</td>
</tr>
</tbody>
</table>

### Tests on Residue from Forced Draft Oven

<table>
<thead>
<tr>
<th>High Temperature (Rutting/Bleeding)</th>
<th>Test</th>
<th>Conditions</th>
<th>Report</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DSR-MSGR</td>
<td>$T_h$</td>
<td>✓ $J_{nr}$, ✓ $G^*$ &amp; phase angle</td>
</tr>
<tr>
<td></td>
<td>DSR freq sweep</td>
<td>$T_h$</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Polymer Identifier (Elasticity/Durability)</th>
<th>Test</th>
<th>Conditions</th>
<th>Report</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DSR-MSGR</td>
<td>$T_h$ @3200 Pa</td>
<td>✓ % Recoverable Strain</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>High Float Identifier (Bleeding)</th>
<th>Test</th>
<th>Conditions</th>
<th>Report</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DSR - non-linearity</td>
<td>$T_h$</td>
<td>✓ Test to be developed</td>
</tr>
</tbody>
</table>

### Tests on PAV after Forced Draft Oven Residue

<table>
<thead>
<tr>
<th>Low Temperature (Aged Brittness)</th>
<th>Test</th>
<th>Conditions</th>
<th>Report</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DSR freq sweep</td>
<td>10 &amp; 20° C Model low T</td>
<td>✓ $G^*$, ✓ Phase Angle</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Polymer Degradation (Before/After PAV)</th>
<th>Test</th>
<th>Conditions</th>
<th>Report</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DSR-MSGR</td>
<td>$T_h$ @3200 Pa</td>
<td>✓ Recoverable Strain Ratio</td>
</tr>
</tbody>
</table>

$T_h$ = high pavement temp; DSR = dynamic shear rheometer; MSCR = multiple stress creep recovery
Emulsion Residue Recovery

✓ Forced Draft Oven (FDO) Method:
  - ASTM D7497 - 09
  - Standard Practice for Recovering Residue from Emulsified Asphalt Using Low Temperature Evaporative Technique
  - 24 hour ambient; 24 hour in 60°C oven

TTI evaluating other methods
Residue Performance Test: AASHTO M 316

- Penetration 25°C, 100-175 dmm
- Ductility, 30 cm at 4°C and 125 cm at 25°C
- Elastic Recovery, 50%
- Polymer solids content (2.5% minimum)

“One size fits all” specification.
No traffic or climate criteria
Dynamic Shear Rheometer
Residue Performance Test: High Temperature Grade

- DSR Frequency Sweep
  - \( G^* \) and phase angle
- Multi-Stress Creep Recovery Test (MSCR)
  - \( J_{nr} \) (compliance)
- Spec limit determined for each emulsion grade based upon application & traffic
  - Test temperature set by climate
    - 6°C increments from LTPPBind
Chip Seal Emulsion Residue Temperature Grading (SHRP Parameters)

- Temp at $G^*/\sin d = 1.0 \, (^\circ C)$
- Temp at BBR Stiffness = 300 Mpa ($^\circ C$)
- Temp at BBR m-value = 0.300 ($^\circ C$)

CRS-2L-UT Utah Parks
CRS-2L-DV Death Valley NP
Pass Dinosaur NM
MSCR

Effect of Temperature on $J_{nr}$ @ 3200 Pa

MSC

$J_{nr}$

3200 Pa

(kPa-1)

Temperature, degrees C

58

64

70

Ralumac

CRS-2L-DV

CRS-2L-UT

Pass
Residue Performance Test: Aging on the Pavement

✓ PAV - Pressure Aging Vessel
- Emulsion cured in PAV pan per FDO procedure
- Use standard PAV time & temp for climate

No Hot Mix Plant - No RTFO
Pressure Aging Vessel (PAV)
Effect of Aging on 64°C $J_{nr}$ for Ralumac & CRS-2L(DV)

**Stress (Pascals)**

**MSCR 64°C $J_{nr}$ (kPa-1)**

- **Ralumac**
- **Ralumac after PAV**

7.7 PAV aging ratio

**MSCR 64°C $J_{nr}$ (kPa-1)**

- **CRS-2L-DV**
- **CRS-2L-DV after PAV**

8.3 PAV aging ratio
Residue Performance Test: Low Temperature Grade

- DSR Frequency Sweep
  - Determine $G^*$ and $\delta$ after PAV
- Spec limit set by application & traffic
- Alternative methods:
  - Intermediate temperature test with CAM model extrapolation
  - $T_{L+10}^\circ C$ using 4-mm plates
- Climate temperature from LTPPBind

Note: replaces BBR
Residue Performance Test: Polymer Elasticity

✓ Multi-Stress Creep Recovery Test (MSCR)
  ▪ Determine % recovered strain
MSCR
Effect of Temp on Recovery @ 3200 Pa

MSCR Recovery @ 3200 Pa (%)

Temperature (°C)

- Ralumac
- CRS-2L-DV
- CRS-2L-UT
- Pass
MSCR

Effect of Temp on Recovery @ 3200 Pa

<table>
<thead>
<tr>
<th>Temperature, °C</th>
<th>MSCR @ 3200 kPa, Recovery, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td></td>
</tr>
<tr>
<td>60</td>
<td></td>
</tr>
<tr>
<td>70</td>
<td>50</td>
</tr>
</tbody>
</table>

Symbols:
- ▲ Ralumac
- ▲ CRS-2L-UT
- ▲ CRS-2P-CL
- ▲ CRS-2L-CL
- ▲ CRS-2
- ● Pass
- ● CRS-2L-DV

Federal Lands Highway
Commitment to Excellence

FHWA
Residue Performance-Related Test: Chip Loss

- Cohesive failure
  - Ambient temperature - shelling
    - DSR Strain Sweep
      - Determine strain for given % modulus loss
      - Test before & after PAV aging
  - Low temperature - snow plow damage
    - Vialit Pendulum ???

- Adhesive failure - dry & wet
  - Needs R&D
Strain Sweeps on PME Residues

![Graph showing strain sweeps on PME residues with various markers and lines representing different materials and conditions.]
Performance-Related Test: Chip Seal - Cure Time for Traffic

✓ Sweep Test - ASTM D7000

- Standard Test Method for Sweep Test of Bituminous Emulsion Surface Treatment Samples
Performance-Related Test: Chip Seal - Cure Time for Traffic

**Sweep Test - Modified ASTM D7000 Results**

<table>
<thead>
<tr>
<th>Project / Emulsion</th>
<th>Test Lab</th>
<th>Mass Loss (%)</th>
<th>Average</th>
<th>STD</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arches /CRS-2L-UT</td>
<td>BASF</td>
<td>11.1 %</td>
<td>2.0</td>
<td>5.3</td>
<td></td>
</tr>
<tr>
<td>Arches /CRS-2L-UT</td>
<td>Paragon</td>
<td>16.5 %</td>
<td>0.4</td>
<td>0.9</td>
<td></td>
</tr>
<tr>
<td>Arches /CRS-2L-UT</td>
<td>PRI</td>
<td>13.1 %</td>
<td>1.0</td>
<td>2.4</td>
<td></td>
</tr>
<tr>
<td>Arches /CRS-2L-UT</td>
<td>Ave.</td>
<td>13.5 %</td>
<td>2.7</td>
<td>5.4</td>
<td></td>
</tr>
<tr>
<td>Death Valley /CRS-2L-DV</td>
<td>BASF</td>
<td>9.7 %</td>
<td>1.5</td>
<td>3.2</td>
<td></td>
</tr>
<tr>
<td>Death Valley /CRS-2L-DV</td>
<td>PRI</td>
<td>11.9 %</td>
<td>1.1</td>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td>Death Valley/CRS-2L-DV</td>
<td>Ave.</td>
<td>10.8 %</td>
<td>0.2</td>
<td>1.1</td>
<td></td>
</tr>
<tr>
<td>Dinosaur/ Pass</td>
<td>PRI</td>
<td></td>
<td>Insufficient curing @ 2hrs, all chips lost</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Surface Treatment Project Locations – For Evaluating Strawman Specifications

- Crater Lake N.P.
- Death Valley N.P.
- Dinosaur N.M.
- 4 Parks in Utah
Utah Parks - Construction

- 90 miles total 9/6/08 – 10/17/08
  - Arches & Canyonlands Nat’l Parks,
  - Natural Bridges & Hovenweep Nat’l Monuments
- Chip Seal – 1,140,000 sy (fogged)
  - CRS-2L (SBR latex modified)
- Microsurfacing – 60,000 sy
  - Natural latex modified Ralumac®
Utah Parks - Performance

Arches National Park chip seal test section:
✓ 1800-2000 ADT in the spring & summer
✓ Pre-existing condition: transverse cracking

<table>
<thead>
<tr>
<th>Milepost (location)</th>
<th>Cracking (unsealed)</th>
<th>Raveling (loss of chips)</th>
<th>Flushing/Bleeding</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.76 (Rt 10)</td>
<td>27 feet (3%)</td>
<td>None</td>
<td>390 sq ft (3.5%)</td>
</tr>
</tbody>
</table>
Utah Parks - Performance
Arches National Park
Utah Parks - Performance

Canyonlands National Park chip seal test section:

✓ Pre-existing condition - good

<table>
<thead>
<tr>
<th>Milepost (location)</th>
<th>Cracking (unsealed)</th>
<th>Raveling (loss of chips)</th>
<th>Flushing/Bleeding</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.84 (Rt 11)</td>
<td>None</td>
<td>None*</td>
<td>Very minor</td>
</tr>
</tbody>
</table>

*Some snow plow scrapes at centerline.
Utah Parks - Performance Micro-surfacing
Other Observations:

- Fog seal has worn off surface of aggregates
- Bleeding at most intersections within Park
- Some raveling of the micro-surfacing
- Snow plow damage and scrapes were noted
11.4 miles – 9/23/08 – 9/30/08

Chip seal – 135,000 sy
- Neoprene modified emulsion, PASS®

Test plan:
- PRI: emulsion & aggregates
- CFLHD Lab: acceptance testing only
Dinosaur National Monument - Performance

Dinosaur National Monument chip seal test section:

- Pre-existing condition: very good; 2-year old pavement

<table>
<thead>
<tr>
<th>Milepost</th>
<th>Cracking</th>
<th>Raveling</th>
<th>Flushing/Bleeding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Park Entrance</td>
<td>None</td>
<td>Very minor (not in wheel paths)</td>
<td>None</td>
</tr>
<tr>
<td>(Rt 10)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Dinosaur National Monument - Performance
Dinosaur National Monument - Performance
Dinosaur National Monument - Performance

Other Observations:
✓ Fog seal has worn off surface of aggregates
✓ Some minor bleeding at intersections within Park
✓ Chips were easily dislodged by fingers
✓ Residue asphalt not as “stretchy” as ARCH and CANY
Death Valley National Park

✓ 13 miles - 11/11/08 - 11/14/08
✓ Chip seal - 161,400 sy
  ▪ SBR latex modified CRS-LM

✓ Test plan:
  ▪ PRI: emulsion & aggregates
  ▪ Paragon: emulsion & aggregates
  ▪ BASF: emulsion & aggregates
  ▪ CFLHD Lab: acceptance testing only
23 miles chip seal
- Summer 2009
- 367,000 sy

SB/S modified CRS-2P (1 or 2 tankers)
SBR modified CRS-2L on remainder

Test Plan
- PRI, Paragon, BASF, Kraton Polymers, Ultrapave: emulsion & aggregates
- WFLHD Lab: acceptance testing only
Polymer modified asphalt emulsions should be used for surface treatments (chip, slurry, micro) for all traffic and climate conditions.

Pursue performance based specifications as opposed to specifying polymer percentages.

Adopt low temperature residue recovery method.
Recommendations

✓ Continue validating strawman specifications
  ▪ Test methods & field performance

✓ Further Investigation Needs
  ▪ Critical limit for $J_{nr}$
  ▪ Optimum test temperatures & operating conditions for MSCR recovery
  ▪ Use of DSR for determining low temperature properties
  ▪ Improve inter-lab agreement with Sweep Test
To further the numerous research projects underway and to support the Emulsion Task Force with specification development, it is suggested that a Transportation Pooled Fund Study (TPF) be developed.
The Need...

- Validation of lab testing protocol with field performance
- Refinement of testing methodology
- Better establish failure mechanisms and validate tests that will predict premature failure
- If a TPF study is not set up to validate and support spec development...who will??
Development of Transportation Pooled Fund Study

The Current Support...
- PP ETG’s Emulsion Task Force (customer)
- Pavement Preservation Research Roadmap, TRB
- Industry (technical input)
- FHWA Office of Asset Management ($20k)
- FHWA Federal Lands Division ($20k)

- Need Support of at least 8 to 10 State DOT’s with commitment of $20k or more
- Is a State willing to lead or co-lead effort?
Thank You.
michael.voth@dot.gov