PERFORMANCE EVALUATIONS

Of
FOG SEALS
And
REJUVENATORS
Fog Seal Applications

- Dense-Graded HMAC
- OGFC
- Chip Seals
The use of Fog Seal Rejuvenators early in a pavement's life then repeated every 4-6 years can greatly extend the life of a pavement.
Various studies and reports conducted over the past 30+ years have confirmed the effectiveness of fog seal / fog rejuvenators and seal coats in extending pavement life.
The most current and arguably the most comprehensive study was completed within the last two years.

This study compared several types of fog seals with respect to their performance over time.

A large portion of the performance data presented here is attributed to this Sealer/Rejuvenator Study.
How do we develop specifications for fog seal emulsions

1. Define performance criteria
2. Develop tests for performance
   ▪ On-the-road performance criteria
   ▪ Emulsion requirements
     ▪ Determine emulsion performance-related criteria
     ▪ Determine residue performance-related criteria
       ▪ Establish residue recovery method
3. Write specifications with defined limits

Differentiate needs for:
   ▪ HMAC, OGFC, Chip Seal
Fog Seal for Dense HMAC

- Objectives:
  - Penetrate into & renew aged asphalt binder
  - Seal small cracks and surface voids
  - Prevent raveling
  - Skid number maintained

- Emulsion grades:
  - Aromatic/Naphthenic rejuvenator oils: (ETR-1; ARA-1; Reclamite®)
  - AC/rejuvenator oils: (Cyclogen®)
  - PMAC/rejuvenator oils: (Pass®)
Rejuvenator Fog Seals on Dense HMAC Pavements
Asphalt Pavement

- 94% Sand & Stone
- 6% Asphalt Cement (liquid)
Penetrate Into the Pavement

Maltenes must penetrate into the pavement
Asphalt Binder Evaluation

- Viscosity Test
- Penetration Number Test
When viscosity goes up

Asphalt Cement Hardness Increases and Pavement Flexibility goes down
Penetration numbers go down

Asphalt Cement Hardness goes up
Rheology of Extracted Cores - CA 78

Tested by Western Research Institute
Dynamic Shear Rheometry on Liquid Samples Extracted from Field Cores (DSR)
## Test Results on Recovered Binder
City of Nashville, TN – Centennial Blvd.

<table>
<thead>
<tr>
<th>Core Sample</th>
<th>Viscosity@60°C, Poises</th>
<th>Phase Angle, °</th>
<th>MODULUS, Pa</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Complex</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Elastic</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Viscous</td>
</tr>
<tr>
<td>Core # 1: Treated Core A</td>
<td>4824</td>
<td>85.4</td>
<td>4836</td>
</tr>
<tr>
<td>Core # 2: Untreated Core A</td>
<td>9086</td>
<td>83.2</td>
<td>9110</td>
</tr>
</tbody>
</table>
Evaluation of Seal Coat
Runway 16–34
Lajes Field, Azores

by
J. E. Pickett

Geotechnical Laboratory
U.S. Army Engineer Waterways Experiment Station
P.O. Box 631
Vicksburg, Mississippi
March 1983
Runway 16–34 was satisfactory. The penetration test shows an increase of approximately 194 percent and the viscosity test shows a decrease of approximately 94 percent. The specification requires the average penetration to be increased by 20 percent and the average viscosity to be decreased by 40 percent.

4. The contractor for the project was Mr. Colin M. Durante, Pavement Technology, Inc., 11260 Berett Road, Cleveland, Ohio 44102. He elected to use Reclamite, a proprietary material manufactured by the Golden Bear Division of Witco Chemical Corporation, Bakersfield, California, as a rejuvenator. Reclamite is a resin-based emulsion that leaves an oily residue and is applied with a bituminous distributor. The Reclamite material was mixed at the job site in a two to one ratio with water, two parts Reclamite to one part water. The Reclamite mixture at ambient temperature (60–70°F) was sprayed onto the runway pavement by using a 1140 gal bituminous distributor equipped with a 10–ft spray bar. Application rates were varied intentionally to avoid excess rejuvenator in areas, such as recently patched areas, and areas with rubber build-up. Areas outside regular traffic were sprayed heavier, which would not bother air traffic, in case of excess rejuvenator on the surface. Dates of treatment and application rates (gal/yd²) are shown in Table II. The remainder of the material was used to spray various taxiways and parking aprons.

Table I

<table>
<thead>
<tr>
<th>Sample Number</th>
<th>Station From South End R/W &amp; C</th>
<th>Penetration 77°F (25°C) 100 g, 5 sec 0.1 mm</th>
<th>Absolute Viscosity 140°F (60°C) 300.0 mm Hg Vacuum, Poises</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Untreated  11.00  Treated  20.00   Untreated  401, 351  Treated  65, 420</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>2 + 43, 83.7 ft W</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>23 + 55, 134.9 ft W</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>34 + 34, 5.1 ft E</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>52 + 07, 51.3 ft W</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>64 + 36, 32.4 ft E</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>80 + 67, 14.6 ft W</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>86 + 86, 121.4 ft E</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>99 + 17, 17 ft E</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>8.63  194.00</td>
<td>Increase  0.053 gal/sq yd 0.066 gal/sq yd</td>
</tr>
<tr>
<td>Change (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Phase I       | Center 100–ft-wide area          | 0.053 gal/sq yd |
|               | All other areas                   | 0.061 gal/sq yd |
| Phase II      | From center line runway out 50 ft| 0.055 gal/sq yd |
|               | All other areas                   | 0.066 gal/sq yd |
| Phase III     | From center line runway out 50 ft| 0.058 gal/sq yd |
|               | All other areas                   | 0.074 gal/sq yd |

Jack E. Pickett
Materials Engineering Technician
Pavement Systems Division
Geotechnical Laboratory
Permeability

All data < 7 x 10^{-5} = impermeable; test stopped after 30 minutes.

Permeability (cm/sec)

- Control
- CSS-1 '02
- CSS-1 '02 - CRS2Pd '06
- CRS-2P '06
- GSB '02
- GSB '02 - LD-7 '06
- LD-7 '06
- Pass QB '02
- Pass QB '02 & '06
- Pass QB '06
- CRF '02
- CRF '02
- Reclamite '02
- Chip Seal w CRS-2Pd '06
- CR 112 (applied '06)
Comparison of International Friction Index (IFI as measured by DFT/CTM) & Full-Scale Tire Testing (ASTM E-274) on MN 251 - 10/2006 Tests

$r^2 = 0.9019$ for Smooth Tire, $r^2 = 0.9125$ for Ribbed Tire

IFI Testing same day by South Central Superpave Center
E-274 Testing, several days later by Mn/DOT
In 2002 the City of Oak Ridge had Reclamite applied to a 2 year old shoulder on SR62. The results again are very clear.
Two years later the results are clear!
Asphalt Emulsion Fog Seals on Dense HMAC Pavements
Require sufficient voids
Asphalt Emulsion Fog Seal

Before

After
Friction

Comparison of International Friction Index (IFI as measured by DFT/CTM) & Full-Scale Tire Testing (ASTM E-274) on MN 251 - 10/2006 Tests

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Permeability

All data < 7 X 10^-5 = impermeable; test stopped after 30 minutes.
Rheology of Extracted Cores - CA 78

Tested by Western Research Institute
Dynamic Shear Rheometry on Liquid Samples Extracted from Field Cores (DSR)
Impact on skid numbers?

Topical fog seals can leave a thick coating on the aggregate surface.

They also fill in the voids with new material.
Emulsion Type may effect performance
DRIVE THRU
Fog Seals for HMAC

Define

Performance?

- Properties of restored HMAC
  - Resistant to rutting, fatigue, thermal cracking
  - Does not ravel
  - Small surface cracks are filled and heal
  - Permeability reduced
  - Age harden binder improved
  - Quick release to traffic
  - Acceptable skid numbers after application
    - Emulsion penetrates into HMAC

- Provides a Cost/Benefit
Fog Seal for OGFC

- **Objective:**
  Restore aged asphalt binder properties to reduce raveling and cracking

- **Maintain open gradation**

- **Emulsion grades:**
  - Maltene based rejuvenator
  - PMA/rejuvenator oil blends (diluted)
Rejuvenator Fog Seals on OGFC Pavements
Rheology of Extracted Cores - CA 78

Tested by Western Research Institute
Dynamic Shear Rheometry on Liquid Samples Extracted from Field Cores (DSR)
## Table I
### Core Samples
#### Panama City, Bay County, Florida
### Micro viscosity Test Data

<table>
<thead>
<tr>
<th>Malaga Road</th>
<th>Micro viscosity, 25°C, MP</th>
<th>Equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard Asphalt, Close-Graded Mix</td>
<td>0.05 sec(^{-1})</td>
<td>0.001 sec(^{-1})</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Core #6 (Treated @ 1:1, 0.07gsy)</th>
<th>Penetration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top ¼-inch</td>
<td></td>
</tr>
<tr>
<td>Treated</td>
<td>40.2</td>
</tr>
<tr>
<td>Untreated</td>
<td>53.8</td>
</tr>
</tbody>
</table>

<p>| Second ¼-inch                 |             |
| Treated                       | 42.0        | 355         | 16         |
| Untreated                     | 47.0        | 540         | 15         |</p>
<table>
<thead>
<tr>
<th>Location</th>
<th>Core Sample Details</th>
<th>Micro viscosity, 25°C, MP</th>
<th>Equivalent Penetration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beach Street</td>
<td>Open-Graded, Large Aggregate, Cold Placed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Core #8</td>
<td>(Treated @ 1:1, 0.15gsy)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Top ½-inch</td>
<td></td>
<td>0.05 sec(^{-1})</td>
<td>0.001 sec(^{-1})</td>
</tr>
<tr>
<td>Treated</td>
<td>24.5</td>
<td>120</td>
<td>20</td>
</tr>
<tr>
<td>Untreated</td>
<td>Too Hard to Record</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-inch to 1 ½-inch</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treated</td>
<td>27.5</td>
<td>86.0</td>
<td>19</td>
</tr>
<tr>
<td>Untreated</td>
<td>250</td>
<td>790</td>
<td>7</td>
</tr>
</tbody>
</table>
Comparison of International Friction Index (IFI as measured by DFT/CTM) & Full-Scale Tire Testing (ASTM E-274) on MN 251 - 10/2006 Tests

$r^2 = 0.9019$ for Smooth Tire, $r^2 = 0.9125$ for Ribbed Tire

Friction Number (IFI is X100)

Test Section

Control, Control, CRS, 2P(d), LD-7, LD-7 Sanded, Pass QB, Reclamite, Reclamite Sanded, Chip Seal/CRS, 2Pd

IFI Testing same day by South Central Superpave Center
E-274 Testing, several days later by Mn/DOT
PMA / Rejuvenator oil blend
Fog Seals
on
OGFC Pavements
Fog Seals for OGFC

Define Performance?

- Properties of renewed OGFC
  - Resistance to raveling
  - Sensitivity to cracking
  - Binder rheology improved to resist aging/moisture
  - Permeability
Fog Seal over Chip Seal

- **Objective:**
  - Tie down loose aggregate & suppress dust

- **Emulsion Grades:**
  - SS/CSS
  - CRS/RS/HFRS
  - Polymer-modified emulsions
Avoid over application
Fog Seals over Chip Seal
Define Performance?

- Chip retention
  - Broken Windshields
  - Long-term aggregate loss
  - Minor crack sealing

- Dust/particulate emissions
Outcome of Research - Knowledge & Specifications

- Define fog seal applications
  - What materials add life-cycle value
  - What tests define performance
  - How important is product consistency
  - Impact on traffic & safety (skids, cure)

- Specifications (HMAC, OGFC, Chip Seal)
  - Performance tests & failure criteria
  - Emulsion/residue specs
New uses for the fog seal concept

- Stabilizing the area around the longitudinal joint in new construction
- Working in tandem with surface retexturing on high volume pavements
Polymer Maltene Emulsion Being Applied To The Longitudinal Joints
Performance
After 3 years
Applied to rumble strips
On centerline
Maltene Rejuvenator APPLIED BEHIND THE SKI DABRADER
Any agency can implement the use of rejuvenators and/or fog seals by simply deferring a small amount of resurfacing.
QUESTIONS ?