Asphalt Pavement Rejuvenation
Importance of Rejuvenators

• Understanding Rejuvenators

• Using Rejuvenators
• Importance of Rejuvenators
  – Pavement Preservation
  – Economic Benefit
Pavement Preservation Techniques

- Crack Seal
- Rejuvenator
- Slurry Seal
- Micro-Surfacing
- Ultrathin Bonded Wearing Course
- Thin HMA Overlay
Pavement Preservation Timing

- Curve shape determined by quality, traffic, climate, etc.
- Rejuvenator/Fog Seal
- Slurry Seal
- Crack Sealing; Micro-Surface; Ultrathin bonded
- Reflective crack relief system
- In-place recycling
- Base stabilization; Rehab

Timing --- PCI = 70
Asphalt Binder Prices
Cost History: January 2001 thru January 2012

- <$150/Ton: 2002
- >$800/Ton: 2008
- <$700/Ton: 2012
**AC Cost Impact on HMA & Paving**

<table>
<thead>
<tr>
<th>Liq. AC COST ton</th>
<th>AC COST lb.</th>
<th>Lbs. AC in 1 Ton HMA @ 6%</th>
<th>AC Cost in 1 Ton HMA</th>
<th>AC Cost SY 1.5” OL</th>
<th>AC Cost Per Lane Mile (11'w)</th>
<th>HMA COST PER TON IN-PLACE</th>
<th>OL Cost for One Lane Mi.</th>
</tr>
</thead>
<tbody>
<tr>
<td>$150</td>
<td>$0.08</td>
<td>120</td>
<td>$9.00</td>
<td>$0.75</td>
<td>$4,840</td>
<td>$21</td>
<td>$11,012</td>
</tr>
<tr>
<td>$200</td>
<td>$0.10</td>
<td>120</td>
<td>$12.00</td>
<td>$1.00</td>
<td>$6,453</td>
<td>$28</td>
<td>$14,683</td>
</tr>
<tr>
<td>$250</td>
<td>$0.13</td>
<td>120</td>
<td>$15.00</td>
<td>$1.25</td>
<td>$8,066</td>
<td>$35</td>
<td>$18,354</td>
</tr>
<tr>
<td>$300</td>
<td>$0.15</td>
<td>120</td>
<td>$18.00</td>
<td>$1.50</td>
<td>$9,680</td>
<td>$41</td>
<td>$22,025</td>
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<tr>
<td>$350</td>
<td>$0.18</td>
<td>120</td>
<td>$21.00</td>
<td>$1.75</td>
<td>$11,293</td>
<td>$48</td>
<td>$25,696</td>
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<tr>
<td>$400</td>
<td>$0.20</td>
<td>120</td>
<td>$24.00</td>
<td>$2.00</td>
<td>$12,906</td>
<td>$55</td>
<td>$29,366</td>
</tr>
<tr>
<td>$450</td>
<td>$0.23</td>
<td>120</td>
<td>$27.00</td>
<td>$2.25</td>
<td>$14,519</td>
<td>$62</td>
<td>$33,037</td>
</tr>
<tr>
<td>$500</td>
<td>$0.25</td>
<td>120</td>
<td>$30.00</td>
<td>$2.50</td>
<td>$16,133</td>
<td>$69</td>
<td>$36,708</td>
</tr>
<tr>
<td>$550</td>
<td>$0.28</td>
<td>120</td>
<td>$33.00</td>
<td>$2.75</td>
<td>$17,746</td>
<td>$76</td>
<td>$40,379</td>
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<tr>
<td>$600</td>
<td>$0.30</td>
<td>120</td>
<td>$36.00</td>
<td>$3.00</td>
<td>$19,359</td>
<td>$83</td>
<td>$44,050</td>
</tr>
<tr>
<td>$650</td>
<td>$0.33</td>
<td>120</td>
<td>$39.00</td>
<td>$3.25</td>
<td>$20,972</td>
<td>$90</td>
<td>$47,720</td>
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<tr>
<td>$700</td>
<td>$0.35</td>
<td>120</td>
<td>$42.00</td>
<td>$3.50</td>
<td>$22,586</td>
<td>$97</td>
<td>$51,391</td>
</tr>
</tbody>
</table>

Average Cost: HMA In-Place $21/ton to $97 ton past 9 years.

Cost for 1 lane mile - $11K to $51K.
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.
Importance of Rejuvenators

Economic Benefit

10 Miles of Rejuvenator FOR 1 Mile of HMA Overlay
## Importance of Rejuvenators

### Economic Benefit

<table>
<thead>
<tr>
<th>Miles of HMA Overlay</th>
<th>FOR</th>
<th>Miles of Rejuvenator</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 Miles</td>
<td></td>
<td>50 Miles</td>
</tr>
<tr>
<td>2 Miles</td>
<td></td>
<td>20 Miles</td>
</tr>
<tr>
<td>1 Miles</td>
<td></td>
<td>10 Miles</td>
</tr>
<tr>
<td>1/2 Mile</td>
<td></td>
<td>5 Miles</td>
</tr>
</tbody>
</table>

Economic Benefit

### Importance of Rejuvenators
What is a REJUVENATOR?
Asphalt Pavement Rejuvenators

OVERVIEW - 2

- Importance of Rejuvenators
- Understanding Rejuvenators
- Using Rejuvenators
Understanding Rejuvenators

- Chemical Composition of Asphalt
- Asphalt Components/Fractions
- Asphaltenes & Maltenes Fractions
- Maltenes Classes
- Relationship: Asphaltenes & Maltenes
CHEMICAL COMPOSITION OF ASPHALT

- From Organic Matter
- 90-95% C & H - “Hydrocarbon”
- Heteroatoms [N, O, S]
- Trace Metals [Va, Ni, Fe]

- Molecular Structure - Extremely Complex
- State of the Practice – Separate Components by Solubility

Table 1.1 Elemental Analysis of Four Asphalt Cements

<table>
<thead>
<tr>
<th>Asphalt Cement</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon, percent</td>
<td>83.77</td>
<td>85.78</td>
<td>82.90</td>
<td>86.77</td>
</tr>
<tr>
<td>Hydrogen, percent</td>
<td>9.91</td>
<td>10.19</td>
<td>10.45</td>
<td>10.93</td>
</tr>
<tr>
<td>Nitrogen, percent</td>
<td>0.28</td>
<td>0.26</td>
<td>0.78</td>
<td>1.10</td>
</tr>
<tr>
<td>Sulfur, percent</td>
<td>5.25</td>
<td>3.41</td>
<td>5.43</td>
<td>0.99</td>
</tr>
<tr>
<td>Oxygen, percent</td>
<td>0.77</td>
<td>0.36</td>
<td>0.29</td>
<td>0.20</td>
</tr>
<tr>
<td>Vanadium, ppm</td>
<td>180</td>
<td>7</td>
<td>1380</td>
<td>4</td>
</tr>
<tr>
<td>Nickel, ppm</td>
<td>22</td>
<td>0.4</td>
<td>109</td>
<td>6</td>
</tr>
</tbody>
</table>
INFLUENCE OF CHEMICAL COMPOSITION OF ASPHALTS ON PERFORMANCE, PARTICULARLY DURABILITY

By

FRITZ S. ROSTLER
Director of Research

and

RICHARD M. WHITE
Research Chemist

Golden Bear Oil Co.
Bakersfield, Calif.

Reprinted from AMERICAN SOCIETY FOR TESTING MATERIALS
Special Technical Publication No. 277, pp 64-88
1959
Asphalt Binder Fractions

- **Asphaltenes (A)** - fraction of asphalt insoluble in n-pentane.
  - **Bodying agent**

- **Maltenes** – fraction of asphalt material after precipitation of asphaltenes.
  - Four functional classes of Maltenes
## Asphaltenes Fraction/Maltenes Functional Classes

<table>
<thead>
<tr>
<th>Fractional Component</th>
<th>General Description</th>
<th>Definition</th>
<th>Chemical Reactivity</th>
<th>Significant Function</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A</strong> Asphaltenes</td>
<td>High Molecular Wt. Product</td>
<td>Insoluble in n-pentane</td>
<td>Very Low</td>
<td>Bodying Agent</td>
</tr>
<tr>
<td><strong>PC</strong> Polar Compounds</td>
<td>Polar Compounds</td>
<td>Precipitates with 85% H₂SO₄</td>
<td>High</td>
<td>Peptizer for Asphaltenes</td>
</tr>
<tr>
<td><strong>A₁</strong> 1st Acidiffsins</td>
<td>Unsat. Resinous Hydrocarbons</td>
<td>Precipitates with Concentrated H₂SO₄</td>
<td>High</td>
<td>Solvent for Peptized A</td>
</tr>
<tr>
<td><strong>A₂</strong> 2nd Acidiffsins</td>
<td>Slightly Unsat. Hydrocarbons</td>
<td>Precipitates with Fuming H₂SO₄</td>
<td>Low</td>
<td>Solvent for Peptized A</td>
</tr>
<tr>
<td><strong>S</strong> Sat. Hydrocarbons</td>
<td>Wax - Saturated Hydrocarbons</td>
<td>Nonreactive with Fuming H₂SO₄</td>
<td>Low</td>
<td>Gelling Agent</td>
</tr>
</tbody>
</table>
Petroleum Asphalt is comprised of two fractional components: **ASPHALTENES** and **MALTENES**.
ASPHALT FRACTIONAL COMPONENTS
TYPICAL ASPHALT BINDER

- ASPHALTENES
  - Saturated Hydrocarbons
  - 2nd Acidiffins
  - 1st Acidiffins
  - Polar Compounds
  - Asphaltenes

MALTENES
ASPHALT FRACTIONAL COMPONENTS
TYPICAL ASPHALT BINDER

- ASPHALTENES
  - Function as bodying agent when peptized

- POLAR COMPOUNDS
  - Peptizer
  - Highly active resins

- SATURATED HYDROCARBONS
  - Jelling agent function
  - Saturated hydrocarbons

- 2ND ACIDIFFINS
  - Solvent function
  - Unsaturated hydrocarbons

- 1ST ACIDIFFINS
  - Active solvent function
  - Resinous hydrocarbons

UNAGED

AGED

MALTENES
Aging - Reduction of maltenes begins at the HMA plant due to the extreme heating

- Increase in chemical activity
Aging continues over pavement life by:

- Exposure to the UV rays
- Environment
- Oxidation Process
- Stripping Action of Water
- Traffic Wear
AGING OVER PAVEMENT LIFE

MALTENES Chemical Activity
Understanding Rejuvenators

• CRITERIA FOR A REJUVENATOR

  must involve two important phenomena:

  – Must contain Maltenes Fraction, to balance Maltenes to Asphaltene ratio

  – Must penetrate binder to facilitate for chemical activity [fluxing/absorption]
ASPHALT FRACTIONAL COMPONENTS
TYPICAL ASPHALT BINDER

MALTENES

UNAGED

AGED

REJUVENATED

SOLVENT FUNCTION
~UNSATURATED HYDROCARBONS

1ST ACIDIFFINS
ACTIVE SOLVENT FUNCTION
RESINOUS HYDROCARBONS

ASPHALTENES
FUNCTION AS BODYING AGENT
WHEN PEPTIZED

POLAR COMPOUNDS
PEPTIZER
HIGHLY ACTIVE RESINS

2ND ACIDIFFINS
SOLVENT FUNCTION
SATURATED HYDROCARBONS

JELLING AGENT FUNCTION
SATURATED HYDROCARBONS
Rejuvenator Test Sections

8 Years After 1 Treatment

9 Years After 1 Treatment
“Asphalt Pavement Rejuvenators”

- Importance of Rejuvenators
- Understanding Rejuvenators

Using Rejuvenators
Using Rejuvenators

- Pavement Project Candidates
- Specifications [Material/Performance]
- Performance versus Skid Resistance
- Other Requirements [Equipment/Experience/Environmental Conditions]
- Application Rate
Using Rejuvenators – [Excellent Candidates]

- Paved Shoulders
- Residential Streets
- Rural Roads
- Urban Collectors
Using Rejuvenators –
[Unsuitable Candidates]

- High speed Roads & Expressways
- Runways & High Speed Taxi Exits
- Pavement w/Excessive Distress
  - Base and/or Subgrade Failure
  - Structural Distress without Repair: e.g., Alligator Cracking; Shoving
# Using Rejuvenators – [Material Specifications, If Desired]

## Specifications

<table>
<thead>
<tr>
<th>Test</th>
<th>ASTM</th>
<th>AASHTO</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tests on Emulsion:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Viscosity @ 25°C, SFS</td>
<td>D-2444</td>
<td>T-59</td>
<td>15–40</td>
</tr>
<tr>
<td>Residue, % W&lt;sup&gt;1&lt;/sup&gt;</td>
<td>D-244(mod.) T-59(mod.)</td>
<td>60–65</td>
<td>No Coagulation</td>
</tr>
<tr>
<td>Miscibility Test&lt;sup&gt;2&lt;/sup&gt;</td>
<td>D-244(mod.) T-59(mod.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sieve Test, % W&lt;sup&gt;3&lt;/sup&gt;</td>
<td>D-244(mod.) T-59(mod.)</td>
<td>-</td>
<td>0.1</td>
</tr>
<tr>
<td>Particle Charge Test</td>
<td>D-244</td>
<td>T-59</td>
<td>Positive</td>
</tr>
<tr>
<td>Percent Light Transmittance&lt;sup&gt;4&lt;/sup&gt;</td>
<td>GB</td>
<td>GB</td>
<td>30</td>
</tr>
<tr>
<td><strong>Tests on Residue from Distillation:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flash Point, COC, °C</td>
<td>D-92</td>
<td>T-48</td>
<td>196</td>
</tr>
<tr>
<td>Viscosity @ 60°C, cst</td>
<td>D-445</td>
<td>-</td>
<td>100–200</td>
</tr>
<tr>
<td>Asphaltenes, % W&lt;sup&gt;5&lt;/sup&gt;</td>
<td>D-2006-70</td>
<td>-</td>
<td>1.00</td>
</tr>
<tr>
<td>Maltene Dist. Ratio</td>
<td>D-2006-70</td>
<td>-</td>
<td>0.3–0.6</td>
</tr>
</tbody>
</table>

\[
\frac{PC + A_1}{S + A_2}
\]

PC/S Ratio<sup>5</sup>:

<table>
<thead>
<tr>
<th>Test</th>
<th>Method</th>
<th>Min.</th>
<th>Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrocarbons, S&lt;sup&gt;5&lt;/sup&gt;</td>
<td>D-2006-70</td>
<td>21</td>
<td>28</td>
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</table>

**Product Purchase Description**
Using Rejuvenators – [Material Performance, Desired]

<table>
<thead>
<tr>
<th>Table 1. Pavement Three (3) Years or Less in Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Item</td>
</tr>
<tr>
<td>-------</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2a</td>
</tr>
<tr>
<td>2b</td>
</tr>
<tr>
<td>2c</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 2. Pavement More than Three (3) Years in Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Item</td>
</tr>
<tr>
<td>-------</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2a</td>
</tr>
<tr>
<td>2b</td>
</tr>
<tr>
<td>2c</td>
</tr>
</tbody>
</table>
Using Rejuvenators –
[Material Performance, **CONCERN**]

- Trade-Off between ---
  - Performance
    » AND
  - Friction Resistance

- **MOST IMPORTANT PRINCIPAL** for --
  - Using Rejuvenators!!!!!
Using Rejuvenators –
(Material Performance, **CONCERN**)

![Graph showing skid resistance over time](image-url)
Using Rejuvenators –
[Equipment]
Experience/Certification:

- # Years/# Projects Successfully Complete

Environmental Conditions:

- Dry Surface
- Precipitation Forecast: Prohibit, when >0.1-in < 4 hrs.
- Ambient Temperature: > 40 degrees F
Spray Application Rates
Rejuvenators
- 0.03 – 0.08 gal/sy
- "Ring Test"
- Test Patches
- Test Strips
- DO NOT OVER APPLY
“Asphalt Pavement Rejuvenators”
[SUMMARY]

- Importance of Rejuvenators
- Understanding Rejuvenators
- Using Rejuvenators
Project Documentation

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
# Pickett – Lajes Field, Azores [1983]

<table>
<thead>
<tr>
<th>Phase I</th>
<th>Application Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Center 100-ft-wide area</td>
<td>0.053 gal/sq yd</td>
</tr>
<tr>
<td>All other areas</td>
<td>0.061 gal/sq yd</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Phase II</th>
<th>Application Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>From center line runway out 50 ft</td>
<td>0.055 gal/sq yd</td>
</tr>
<tr>
<td>All other areas</td>
<td>0.066 gal/sq yd</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Phase III</th>
<th>Application Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>From center line runway out 50 ft</td>
<td>0.058 gal/sq yd</td>
</tr>
<tr>
<td>All other areas</td>
<td>0.074 gal/sq yd</td>
</tr>
</tbody>
</table>
### Pickett – Lajes Field, Azores [1983]

#### Lajes Rejuvenator, 1983

<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 Hq Vacuum, Poises</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Untreated</td>
<td>Treated</td>
</tr>
<tr>
<td>1</td>
<td>2 + 43, 83.7 ft W</td>
<td>11.00</td>
<td>20.00</td>
</tr>
<tr>
<td>2</td>
<td>23 + 55, 134.9 ft W</td>
<td>11.00</td>
<td>23.00</td>
</tr>
<tr>
<td>3</td>
<td>34 + 34, 5.1 ft E</td>
<td>13.00</td>
<td>31.00</td>
</tr>
<tr>
<td>4</td>
<td>52 + 07, 51.3 ft W</td>
<td>9.00</td>
<td>27.00</td>
</tr>
<tr>
<td>5</td>
<td>64 + 36, 32.4 ft E</td>
<td>4.00</td>
<td>17.00</td>
</tr>
<tr>
<td>6</td>
<td>80 + 67, 14.6 ft W</td>
<td>9.00</td>
<td>22.00</td>
</tr>
<tr>
<td>7</td>
<td>86 + 86, 121.4 ft E</td>
<td>6.00</td>
<td>34.00</td>
</tr>
<tr>
<td>8</td>
<td>99 + 17, 17 ft E</td>
<td>6.00</td>
<td>29.00</td>
</tr>
<tr>
<td>Average Change (%)</td>
<td></td>
<td><strong>8.63</strong></td>
<td><strong>25.38</strong></td>
</tr>
</tbody>
</table>

#### Change (%):

- **Penetration Increase**: 194.00%
- **Viscosity Decrease**: 94.40%
Thank You...

Questions?