Fatigue of Polymer Modified Asphalt Mixes

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Why Polymers in Asphalt Mixes?

Distresses in Hot Mix Asphalt Surfaces:

- Deformation >>> Rutting
- Cracking >>> Fatigue
- Cracking >>> Low Temperature Shrinkage
High Temperature Phenomenon

Rutting

Statewide Research and Technology Transfer
Intermediate Temperature Phenomenon

FATIGUE CRACKING
Low Temperature Phenomenon

Low Temperature Cracking
Why Polymers in Asphalt Mixes?

S = Temp. Susceptibility = ΔVisc. / ΔTemp.

Binder 1 ⇒ S₁

Binder 2 ⇒ S₂ < S₁
Why Polymers in Asphalt Mixes?

- LTC
- Conventional Binder
- Fatigue
- Rutting

Viscosity vs. Temperature, C

0°  20°  40°
Why Polymers in Asphalt Mixes?

Viscosity

Conventional Binder, $S_1$

Modified Binder, $S_2$

Temperature, $T$ (°C)

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Benefits of PMA

- Rutting Resistance

Florida DOT:
Superpave mixes PG 67-22 & PG 76-22 (~4%SBS)
1- Lab Asphalt Pavement Analyzer:
   Greater rut resistance with the PMA mix
2- Test track HVS: PMA mix showed less rutting
Statewide Research and Technology Transfer

FLDOT mixes tested with HVS
PG 67-22 (unmodified) vs PG 76-22 (modified)

Rut Depth (mm)

HVS Test Wheel Passes
# Benefits of PMA

- Studded Tire Wear: PRALL Test Results

<table>
<thead>
<tr>
<th>Anchorage Mixes</th>
<th>Binder</th>
<th>PRALL Abrasion Value</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>1996 New Seward Hwy SB, Huffman-Dearmoun</td>
<td>AC-5</td>
<td>46</td>
<td></td>
</tr>
<tr>
<td>1982 New Seward Hwy SB, Rabbit Crk</td>
<td>AC-5</td>
<td>45</td>
<td>47</td>
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<tr>
<td>1993 Muldoon Rd SMA</td>
<td>AC-5</td>
<td>50</td>
<td></td>
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<tr>
<td>2003 N. Seward Hwy Superpave Dense Graded</td>
<td>PG 58-28</td>
<td>26</td>
<td></td>
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<tr>
<td>2003 N. Seward Hwy SMA SB , Fireweed-Benson</td>
<td>PG 64-28</td>
<td>23</td>
<td>28</td>
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<tr>
<td>2003 N. Seward Hwy SMA NB , 36th-Benson</td>
<td>PG 64-28</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td>2003 N. Seward Hwy SMA SB , Tudor-Dowling</td>
<td>PG 58-28</td>
<td>30</td>
<td></td>
</tr>
</tbody>
</table>
Benefits of PMA

- Low-Temperature Cracking Resistance

UAF-1997 study (Report No. INE/TRC 97.05)
  - Lab testing of binders and field mix samples
  - Field crack survey

- Main findings:
  - Significant Improvement in LTC resistance with PMA
  - Estimated 30%-40% reduction in crack sealing cost when PMA are used instead of neat asphalt
Benefits of PMA

• Fatigue cracking:
  - Research and field observations show the enhancement imparted by polymers
  - Magnitude of improvement unknown
  - Research project initiated

• Objectives:
  - Fatigue testing of Alaskan Mixes in the Lab
  - Inclusion of fatigue equations into the AK pavement design software (AKFPD)
Materials from the 3 Regions

- Northern Region:
  PG 52-28 & PG 58-28 PMA (EPA)
  Aggregate: Elliott Hwy Material source

- Central Region:
  PG 52-28 & PG58-28 PMA (EPA)
  Aggregate: Central Paving Products source

- South Eastern Region:
  PG58-28 & PG 64-28 PMA (US Oil&Refining)
  Aggregate: DuPont, WA Material source
Materials used in Mixes
Mixing
Roller Compaction
Steel Mold with 2 Ingots Slabs
Mold & Heating Device
Mold Heating Device
Mold Heater
Slab Sawing
Beam Specimens from Slabs
Fatigue Testing

Four-point bending beam test (SHRP M009 protocol) at 3 Temperatures
Four-Point Bending Beam Fatigue
Statewide Research and Technology Transfer

Beam Testing

Tensile Strain, $\varepsilon_t$
Mix Fatigue

\[ E = f \text{(Temperature)} \]

Tensile Strain, \( \epsilon_t \)

Cycles to Failure, \( N_f \)

\[ 10^3 \quad 10^6 \]
Mix Fatigue

TAI Fatigue Eq. for Conventional Dense Graded Mixes

\[ N_f = 0.116 \times \varepsilon_t^{-3.291} \times |E^*|^{-0.854} \]

- **Cycles to Failure**
- **Fatigue Life**
- **Tensile Strain**
- **Mix Stiffness**
PMA Mix Fatigue

Factor = ?

Conventional Mix

Modified Mix

Cycles to Failure, $N_f$

Tensile Strain, $\varepsilon$
PMA Mix Fatigue

Fatigue Equation for PMA Mixes

\[
N_{f}^{PMA} = C \times [0.116 \times \varepsilon_{t} \times |E^{*}|^{-0.854}]
\]

\[
N_{f}^{PMA} = C \times N_{f}^{\text{Conv.HMA}}
\]
PMA Mix Fatigue

• Important Question:
  - Is “C” unique for all mixes or depends on the mix tested?

• Current Project Status:
  Slabs are being fabricated and saw-cut
Summary

• Use of PMA reduces mix Temperature Susceptibility

• Use of PMA in HMA improves mix resistance to:
  - Rutting and studded tire wear
  - Low temperature cracking
  - Fatigue cracking - ADOT&PF research
    - new Transfer Function in AKFPD software

• Economics of PMA:
  - Higher initial cost
  - LCCA >>>>> lower annual cost