Performance Evaluation of Jet Fuel Resistant Polymer-Modified Asphalt for HMA Pavements

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Background

- Airports experience jet fuel spills on aprons and taxiways
  - Fueling operations
  - Aircraft sitting in queues
  - Softens (weakens) asphalt
  - Causes permanent deformations and failures
- Truck stops, vehicle fueling areas and parking lots also suffer fuel spills
Fuel Resistant Pavement Sealers

- Coal tar sealers are most commonly used to protect Hot Mix Asphalt pavements from fuel damage.
- Different coefficient of expansion for coal tar causes substantial alligator cracking within 2-3 years.
- Cracking allows fuel penetration - short service life.
Fuel Resistant Pavement
Sealers

- Coal tar sealers are carcinogenic
  - MSDS – “Unusual Chronic Toxicity: May cause cancer of the skin, lungs, kidney and bladder.”
  - Adding carcinogenic material to pavement that may be recycled – future exposure
- Austin, TX and United States Geological Survey Report
  - 90% of PAHs in waterways may come from runoff from coal tar sealed pavements
  - Austin may outlaw use
- Coal Tar sealers are outlawed in California
Development of Fuel-Resistant PMA

- Kuala Lumpur Airport specified jet fuel resistant asphalt pavements for new construction in 1995
- Ooms Avenhorn Holding, Netherlands, developed Fuel-Resistant PMA for airport usage
- Objective – add fuel resistance to SBS technology without sacrificing performance
- Contains no Coal Tar
Specifications required compacted mix samples to be immersed in jet fuel for 24 hours.

Average weight loss of 4 Marshall or Superpave specimens must be less than 1.0%
Development of Fuel-Resistant PMA

- Standard Hot Mix Asphalt mixture loses 10% weight from 24 hour soak in jet fuel
- Standard Polymer Modified Asphalt (PG 76-22) loses 4.5% weight after 24 soak in jet fuel
- Fuel Resistant PMA – less than 0.5% weight loss
Asphalt Binder Testing

- Compared original asphalt with asphalt submersed in jet fuel
  - Recovered asphalt soaked in jet fuel for 3 hours and dried for 5 days
- Compared unmodified 40/60 pen asphalt (PG 70-22) with PMA PG 76-22 and fuel resistant PMA
Asphalt Binder Testing

- Complex Shear Modulus ($G^*$)
Master curves for shear modulus of recovered bitumen
(T_{ref}: 20°C)

40/60 bitumen (untreated)
40/60 bitumen (immersed in jet fuel)
Master curves for shear modulus of recovered bitumen
(T_{ref}: 20°C)

- PMB S (untreated)
- PMB S (immersed in jet fuel)
Master curves for shear modulus of recovered bitumen

(T_{ref}: 20°C)

- PMB JR (untreated)
- PMB JR (immersed in jet fuel)
Master curves for shear modulus of recovered bitumen

\((T_{\text{ref}}: 20^\circ\text{C})\)

- PMB JR (untreated)
- PMB JR (immersed in jet fuel)
- 40/60 bitumen (untreated)
- 40/60 bitumen (immersed in jet fuel)
Asphalt Binder Testing

- Repeated Creep-Recovery Test
  - Apply 10 kPa load for 11 seconds, followed by 11 second recovery period
  - 17 Creep-Recovery cycles were applied at 40°C
  - Deformation was continuously recorded
Results of repeated creep-recovery tests at 40°C

- 40/60 bitumen (untreated)
- PMB S (untreated)
- PMB JR (untreated)
Results of repeated creep-recovery tests at 40°C

- 40/60 bitumen (immersed in jet fuel)
- PMB S (immersed in jet fuel)
- PMB JR (immersed in jet fuel)
Laboratory Testing - Mixture

- Compared original hot mix asphalt (HMA) with mix submersed in jet fuel
- Compared unmodified PG 70-22 with PMA PG 76-22 and fuel resistant PMA
- Tested resistance to rutting and cracking
Tested resistance of mixture to cracking with indirect tensile strength test

- Test temperature 0°C
- Deformation rate of 0.85 mm/sec
- Measured fracture energy
Indirect Tensile Strength Test

Fracture Energy [Nmm/mm²]

- 40/60 asphalt
- PMA S
- PMA JR

Original
Immersed in Jet Fuel
Tested resistance of mixture to permanent deformation with uniaxial cyclic compression test

- Test temperature 40°C (60°C for St Maarten)
- 0.4 MPa load applied for 0.3 seconds
- Rest period 0.7 seconds
- Test stopped at 10,000 cycles or 7% permanent deformation
Uniaxial Cyclic Compression Test

Results of uniaxial cyclic compression tests at 40°C (untreated)

- PMB JR
- PMB S
- 40/60 bitumen

Load repetitions

Deformation [%]

0 1000 2000 3000 4000 5000 6000 7000 8000 9000 10000

0 1 2 3 4 5 6 7 8
Results of uniaxial cyclic compression tests at 40°C (after immersion in jet fuel)

<table>
<thead>
<tr>
<th>Load repetitions</th>
<th>Deformation [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PMB JR</td>
</tr>
<tr>
<td></td>
<td>PMB S</td>
</tr>
<tr>
<td></td>
<td>40/60 bitumen</td>
</tr>
</tbody>
</table>

- PMB JR
- PMB S
- 40/60 bitumen
Results of uniaxial cyclic compression tests at 60°C

Uniaxial Cyclic Compression Test – St Maarten Airport

- Trinidad Lake Asphalt
- PMB S
- PMB JR
Asphalt Pavement Analyzer (APA) Testing

64°C Test Temp.; 100 psi Hose Pressure; 100 lb Wheel Load

APA Rutting @ 8,000 Loading Cycles

- CITGO FR (3.0% Air Voids) = 1.3 mm
- PG82-22 Mix (3.3% Air Voids) = 2.1 mm
Flexural Beam Testing

1,000 Micro-strains, 15°C, 10 Hz

Flexural Stiffness (MPa)

<table>
<thead>
<tr>
<th>Sample Type</th>
<th>Initial Stiffness, S₀ (MPa)</th>
<th>Slope, b</th>
<th>Air Voids (%)</th>
<th>Fatigue Life, Nf, 50% (cycles)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PMA 82-22 #1</td>
<td>6,453.9</td>
<td>-3.654 E-5</td>
<td>2.8</td>
<td>18,970</td>
</tr>
<tr>
<td>PMA 82-22 #2</td>
<td>7,787.1</td>
<td>-3.612 E-5</td>
<td>2.9</td>
<td>19,190</td>
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<tr>
<td>PMA 82-22 #3</td>
<td>6,949.5</td>
<td>-5.736 E-5</td>
<td>3.4</td>
<td>11,980</td>
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<tr>
<td><strong>PMA 82-22 Mix Average</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>CITGO FR #1</td>
<td>7,898.0</td>
<td>-1.4 E-5</td>
<td>2.5</td>
<td>49,511</td>
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<tr>
<td>CITGO FR #2</td>
<td>7,086.7</td>
<td>-1.664 E-5</td>
<td>2.6</td>
<td>41,656</td>
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</tbody>
</table>
| **CITGO FR Mix Average** | | | | | 45,584
First Fuel-Resistant PMA Usage - Kuala Lumpur International Airport
Kuala Lumpur International Airport

- Constructed between 1996 and 1998
- 450mm cement treated base
- 100mm HMA base – conventional asphalt
- 150mm HMA base and surface containing jet fuel resistant PMA
- 260,000 tons HMA
Fuel-Resistant PMA Usage

Fuel Resistant PMA Airport Projects Around the World

- Cairo, Egypt Airport – Reconstruction of main runway – 1997 (220,000 tons)
- Aden, Yemen Airport – Reconstruction of main runway – 1999-2000 (40,000 tons)
- St Maarten Airport – Reconstruction of apron – 2001 (12,000 tons)

- All projects report excellent performance to date
Fuel-Resistant PMA Usage

- First Construction Project in US – La Guardia Airport
- Test section on taxiway – 450 tons
Fuel-Resistant PMA Usage – La Guardia

- Placed Fuel Resistant PMA at La Guardia Airport August 2002
- Graded as PG 94-22
- Pumped into plant at 330°F
- Produced mix at 340°F
- Placed in silo for 4 hours
Fuel-Resistant PMA Usage – La Guardia

- Paved at 330°F
- No problems with placement
- Handwork and longitudinal joints look good
- Density achieved
- Paving crew could not see a difference in fuel resistant PMA material from standard PMA
Fuel-Resistant PMA Usage – La Guardia

- Inspected fuel resistant pavement in October 2003
- Excellent condition
  - No rutting
  - No cracking
  - No surface deterioration
Fuel-Resistant PMA Usage

- At major airports, coarse mixes used to prevent rutting
  - Low AC %
  - Prone to segregate
  - Durability
- Recommend 1 ½” surface containing fuel resistant PMA to provide fuel resistance to entire pavement structure
  - Use ½” P-401 mix
  - Design at 2.5% air voids
Fuel-Resistant PMA Usage

- Developed generic specification for fuel resistant HMA
  - Minimum PG 82-22 polymer modified asphalt
    - Pass fuel resistance test
    - Minimum 85% Elastic Recovery
  - Standard test method for fuel resistance
  - ½” P-401 mix
    - 50 blow Marshall design
    - Design at 2.5% air voids
Fuel-Resistant Usage – Logan Airport

- Placed 1300 tons of fuel resistant mix on Taxiway N and Runway 4L-22R at Logan Airport in June 2004
Fuel-Resistant Usage – Logan Airport

- Fuel Resistant Asphalt graded as PG 94-22
- 1/2” P-401 mix designed at 2.5% air voids
- 7% asphalt content design target
Fuel-Resistant Usage – Logan Airport

- Mix produced in drum plant at 340°F
- Placed at 325°F without difficulty
- Met density specification
- Excellent surface appearance
Fuel-Resistant Usage – Logan Airport

- Revisited Logan in October 2004 & October 2005
- Previous HMA materials on this taxiway exhibited plastic flow (rutting and shoving) after one summer
Fuel-Resistant Usage – Logan Airport

- October 2005 – after 2 summers
  - No rutting
  - No raveling
  - No cracking
  - “Grooving looks like the day we cut them”
Fuel-Resistant Usage – Logan Airport

- October 2005 – Alleyway Project
  - Mill 8” of existing HMA
  - Base - 6.0” of ¾” P-401 with PG 82-22 PMA
  - Surface – 2” of ½” P-401 with PG 94-22 FR
Fuel-Resistant Usage – Logan Airport
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Fuel-Resistant Usage – Logan Airport

- October 2005 – Alleyway Project
  - Project in 8 phases to maintain air traffic
  - Planes pushed back one day after paving on new HMA
Fuel-Resistant Usage – Future Projects

- **Boston, MA - Logan Airport**
  - Alleyway Project – Summer 2006
- **Charlotte, NC - Douglas International Airport**
  - Taxiway Project – Summer 2006
- **Florida DOT**
  - I-95 Truck Inspection Station – Summer 2006
Cost Comparison

- PG 64-22
- PG 76-22
- Fuel-Resistant PMA

Costs:
- $0.00
- $1.00
- $2.00
- $3.00
- $4.00
- $5.00
- $6.00
- $7.00
- $8.00
- $9.00
- $10.00

Legend:
- HMA Surface
- HMA Surface + Coal Tar Sealer
- HMA Surface + Resin Sealer
Fuel Resistant PMA Summary

- Polymer-Modified Asphalt developed specifically to resist fuel damage
- Eliminate need for coal-tar sealers
- Environmentally sensitive solution for fuel spills on HMA pavements
  - Airports
  - Truck stops
  - Truck inspection facilities
  - Parking lots
Questions?