Rutting Evaluation of Hot and Warm Mix Asphalt Concrete Under High Aircraft Tire Pressure and Temperature at National Airport Pavement and Materials Research Center (NAPMRC)

N. Garg, H. Kazmee, L. Ricalde, T. Parsons

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By: Navneet Garg, Ph.D.

Date: January 10, 2018
ACKNOWLEDGEMENTS

Hasan Kazmee
Lia Ricalde
Tim Parsons
Outline

• **Introduction**
• Objectives
• Full-Scale Tests at NAPMRC – TC1
• Results
• Summary
• Future Research
FAA Airport Technology R&D Program

• Research conducted at the FAA William J. Hughes Technical Center, Atlantic City, NJ, USA.

• Sponsor: FAA Office of Airport Safety and Standards (AAS100), Washington, DC.

• Provide support for development of FAA pavement standards (Advisory Circulars).
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Aircraft Tire Pressure Trends

New X Category Limit

Old X Category Limit

<table>
<thead>
<tr>
<th>Aircraft (SWL-kg)</th>
<th>Old X Category Limit</th>
<th>New X Category Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>737-200 (19,300)</td>
<td>11.7</td>
<td>14.1</td>
</tr>
<tr>
<td>737-300 (13,700)</td>
<td>11.7</td>
<td>14.1</td>
</tr>
<tr>
<td>757-300ER (21,900)</td>
<td>11.9</td>
<td>14.4</td>
</tr>
<tr>
<td>A300-C4 (19,300)</td>
<td>12.4</td>
<td>15.2</td>
</tr>
<tr>
<td>737-700 (16,100)</td>
<td>12.5</td>
<td>15.7</td>
</tr>
<tr>
<td>A320-200 (18,000)</td>
<td>14.1</td>
<td>16.1</td>
</tr>
<tr>
<td>A340-600 (27,400)</td>
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<td>15.7</td>
</tr>
<tr>
<td>747-400ER (24,200)</td>
<td>15.0</td>
<td>16.1</td>
</tr>
<tr>
<td>A380-800 (25,700)</td>
<td>15.0</td>
<td>15.2</td>
</tr>
<tr>
<td>A380-800F (28,100)</td>
<td>15.0</td>
<td>15.2</td>
</tr>
<tr>
<td>787-8 (25,200)</td>
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<td>15.2</td>
</tr>
<tr>
<td>A350-900 Prelim (31,300)</td>
<td>16.6</td>
<td>16.6</td>
</tr>
</tbody>
</table>
Aircraft Gross Weight Trends

[Published by the International Industry Working Group (IIWG), 2010]
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Heavy Vehicle Simulator – Airport (HVS-A)

- Wheel loads - 10,000 (44.48 kN) to 100,000 lbs (444.8 kN).
- Pavement temperatures up to 150°F (67°C)
- Test speeds - 0.17 to 5 mph (0.27 to 8 kmph)
- Single and Dual-Wheel configuration.
- Single wheel - radial aircraft tire size 52x21.0R22
- Dual wheel assembly (B-737-800)
- Wander Width – 6 feet (1.83 m)
Aircraft Gross Weight Trends
Research at NAPMRC

EVALUATION OF NEW ASPHALT TECHNOLOGIES FOR AIRFIELD PAVEMENTS
- Warm Mix Asphalt, Stone Matrix Asphalt, Polymer Modified Binders,
  RAP Mixes, Full-Depth Rehabilitation

PROBLEM: Lack of Guidance/Standards/Specifications
- Lack of Performance Data

Laboratory Performance Evaluation
- Evaluate:
  - Rutting
  - Fatigue
  - Moisture Susceptibility
  - Durability
  - Low Temperature Cracking

Full-Scale APT NAPMRC
- Full-Scale APT:
  - Rutting
  - Fatigue
  - Tire Pressure Effects
  - WMA
  - RAP/RAS
  - Full Depth Reclamation

Compare to P-401 HMA

Field Performance Evaluation

Field Projects:
- Lab Evaluation of Field Mixes
- Construction Evaluation
- Evaluate:
  - Mix Design
  - Production, Construction
  - Support from AAS-100, ADO
Outline

• Introduction
• Objectives
• Full-Scale Tests at NAPMRC – TC1
• Results
• Summary
• Future Research
Test Cycle 1 (TC1) Objectives

- Compare WMA performance with P401 HMA performance (rutting);
- Effect of tire pressure on pavement rutting;
- Effect of polymer modified binder (PMA) on pavement rutting;
- Effect of temperature on pavement rutting.
Outline

• Introduction
• Objectives
• **Full-Scale Tests at NAPMRC – TC1**
• Results
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Test Parameters – Traffic Tests

- Pavement Temperature: 120°F (49°C) measured at a depth of 2-inch (50 mm) below pavement surface.
- Test Speed: 3-mph (4.8 kmph)
- Failure criteria: 1-inch (25 mm) surface rut

<table>
<thead>
<tr>
<th>Test Area</th>
<th>Load Module</th>
<th>Wheel Load, lbs</th>
<th>Tire Pressure, psi</th>
</tr>
</thead>
<tbody>
<tr>
<td>South</td>
<td>Single Wheel</td>
<td>61,300</td>
<td>210</td>
</tr>
<tr>
<td>North</td>
<td>Single Wheel</td>
<td>61,300</td>
<td>254</td>
</tr>
</tbody>
</table>

(27.8 metric ton) (1.45 MPa) (1.75 MPa)
HVS-A TC1: Wander Pattern

Wander Width with Tire Imprint: 56 in.
Wander Sequence: 62 passes
Pavement Width: 12 ft
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NAPMRC TC1: MATERIAL & BINDER EFFECTS AT LOW TIRE PRESSURE

Rut Depth, inch

PG 64-22

PG 76-22

0.0 0.5 1.0 1.5 2.0 2.5 3.0

0 500 1000 1500 2000 2500 3000 3500 4000 4500

Passes

L1S: WMA PG76-22; 210 psi
L2S: WMA PG64-22; 210 psi
L3S: HMA PG76-22; 210 psi
L4S: HMA PG64-22; 210 psi

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NAPMRC TC1: INDOORS vs OUTDOORS - HMA

- L6N: HMA PG76-22; 254 psi; Indoors
- L6S: HMA PG76-22; 210 psi; Indoors
- L6C: HMA PG76-22; 254 psi; 90 deg.F; Indoors
- L3N: HMA PG76-22; 254 psi; Outdoors
- L3S: HMA PG76-22; 210 psi; Outdoors
- L3C: HMA PG76-22; 254 psi; 90 deg.F; Outdoors

Rut Depth, inch

0.0  0.5  1.0  1.5  2.0  2.5  3.0  3.5  4.0

0  1000  2000  3000  4000  5000  6000

Passes

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NAPMRC-TC1 SOUTH TEST AREA (210-psi; 120°F)

No. of Passes to Failure: 870
Traffic Tests Terminated: 3906

No. of Passes to Failure: 250
Traffic Tests Terminated: 930

No. of Passes to Failure: 780
Traffic Tests Terminated: 3534

No. of Passes to Failure: 280
Traffic Tests Terminated: 992
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No. of Passes to Failure: 610
Traffic Tests Terminated: 2914

No. of Passes to Failure: 170
Traffic Tests Terminated: 496

No. of Passes to Failure: 870
Traffic Tests Terminated: 3968

No. of Passes to Failure: 150
Traffic Tests Terminated: 620
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### TC1 Posttraffic Tests

#### Loose Mix with Two Replicates

<table>
<thead>
<tr>
<th>Test Priority</th>
<th>Schedul e Priority</th>
<th>Test Objective</th>
<th>Test Type</th>
<th>Number of Reported Tests</th>
<th>Standard Specification</th>
<th>Performing Organization</th>
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<tbody>
<tr>
<td>Primary</td>
<td>1</td>
<td>Quality Assurance</td>
<td>Bulk Specific Gravity, $G_{mb}$</td>
<td>All of prepared specimens</td>
<td>AASHTO T166</td>
<td>FAA Materials Lab</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Theoretical Maximum Specific Gravity, $G_{mm}$</td>
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<td>2</td>
<td>8</td>
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<tr>
<td></td>
<td>2</td>
<td>Rutting Potential</td>
<td>Asphalt Pavement Analyzer</td>
<td>4</td>
<td>2</td>
<td>8</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Indirect Tension (IDT- High Temp.)</td>
<td>4</td>
<td>2</td>
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<td>3</td>
<td>Stiffness Characterization</td>
<td>Conventional Dynamic Modulus</td>
<td>Flow Number</td>
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<td>5</td>
<td>Fracture Energy</td>
<td>Disk-Shape Compact Tension</td>
<td>4</td>
<td>2</td>
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<td>6</td>
<td>Rutting Potential</td>
<td>Hamburg Wheel</td>
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<td>7</td>
<td>Stiffness</td>
<td>IDT Dynamic Modulus</td>
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<tr>
<td></td>
<td>8</td>
<td>Fatigue Performance</td>
<td>Semi-Circular Bend (Intermediate Temp)</td>
<td>4</td>
<td>2</td>
<td>8</td>
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</table>

#### Field Cores with Two Replicates

<table>
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<th>Test Priority</th>
<th>Schedul e Priority</th>
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<th>Test Type</th>
<th>Number of</th>
<th>Standard</th>
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<tbody>
<tr>
<td>Primary</td>
<td>1</td>
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<td>All of prepared specimens</td>
<td>AASHTO T166</td>
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<td></td>
<td>2</td>
<td>Rutting Potential</td>
<td>Asphalt Pavement Analyzer</td>
<td>6</td>
<td>2</td>
<td>12</td>
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<td>Indirect Tension (IDT- High Temp.)</td>
<td>6</td>
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<tr>
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<td>4</td>
<td>Fatigue Energy</td>
<td>Disk-Shape Compact Tension</td>
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<td>12</td>
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<tr>
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<td>Fatigue Performance</td>
<td>Beam Fatigue</td>
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<tr>
<td>Secondary</td>
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<td>Rutting Potential</td>
<td>Hamburg Wheel</td>
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<td>Stiffness</td>
<td>IDT Dynamic Modulus</td>
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<td></td>
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Summary

• Compare WMA performance with P401 HMA performance (rutting);
  Comparable Performance in rutting.
  Cracking performance need to be evaluated (TC2)

• Effect of tire pressure on pavement rutting;
  Significant effects on mixes with unmodified binders.
  Insignificant effects on mixes with PMA.

• Effect of polymer modified binder (PMA) on pavement rutting;
  Improves rutting performance significantly.

• Effect of temperature on pavement rutting.
  Rutting performance of HMA/WMA is more sensitive to temperature than tire pressure.
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Pavement Cross Section: TC-2

NAPMRC TC-2 PAVEMENT CROSS SECTION

SANDY SUBGRADE CBR 15

P-154 SUBBASE 12 inches (305 mm)

P-209 CRUSHED STONE BASE 8 inches (203 mm)

P-401 HMA/WMA SURFACE 9 inches (229 mm)
MATERIAL

RUTTING (test at high temperature)

CRACKING (test during winter)

Tire Pressure 254 psi

NAPMRC Test Cycle-2 (TC-2)

Rutting Evaluation of Hot and Warm Mix Asphalt Concrete Under High Aircraft Tire Pressure and Temperature at NAPMRC
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Future Research

- PANDA-AP (Pavement Analysis using Non-linear Damage Approach for Airports) is currently being developed.

- Implements mechanistic-based models that account for damage and rutting not only in the asphalt concrete layer but also unbound pavement layers (including base, sub-base, and subgrade).

- Drucker-Prager CAP model for unbound materials, and stress-dependent material behavior.

- Compare performance of different asphalt mixes, and pavement structures. Results from NAPMRC and NAPTF are being used to calibrate PANDA-AP.
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ACKNOWLEDGEMENTS

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