FAA’s Asphalt Pavements Research for Airport Pavements

Presented to: 2021 Annual Meeting of the NJ Asphalt Pavement Association

By: Navneet Garg, Ph.D.
NAPMRC Program Manager
Federal Aviation Administration (FAA)

Date: March 16, 2021
Outline

• Introduction
• Research Facilities
• Research at
  – NAPTF
  – NAPMRC
  – Field Instrumentation & Testing
• New Research Initiatives
• Summary
The Office of Airports

- Sets airport standards, certifies air carrier airports and provides financial assistance to optimize safety, capacity and efficiency
Figure 3. FY2018 AIP Grants Awarded by Project Type

- Airside, 67.4%
- Roads, 1.0%
- Noise, 4.5%
- Landside (mostly terminals), 12.8%
- State Block Grants & Misc., 14.2%

Distribution of PFC Funds: Airside Funding

- Runways, 50%
- Zoning, 15%
- Terminal, 15%
- Equipment, 10%
- Land, 9%
- Planning, 2%
- Lighting, 2%
- Other, 8%

SOURCE: FAA, PFC Branch
December 31, 2018
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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).
Airport Pavement R&D Program

Dr. Michel Hovan
Branch Manager Pavements & Safety

Jeff Gagnon – Pavements Branch Manager
– Dr. David Brill
– Dr. Navneet Garg
– Robert “Murphy” Flynn
– Qingge Jia
– Ryan Rutter
– Wilfredo Villafane
– Dr. Richard Ji
– Matthew Brynick
– Dr. Gabriel Bazi

Support Contractor – GDIT
Consultants
Universities – Grants, BAA’s, OTA’s
ERDC – Interagency Agreements
Aircraft Gross Weight Trends

[Published by the International Industry Working Group (IIWG), 2010]
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>16.1</td>
</tr>
<tr>
<td>737-300 (17,200)</td>
<td>11.7</td>
<td>16.1</td>
</tr>
<tr>
<td>737-300ER P1 (16,000)</td>
<td>11.9</td>
<td>16.1</td>
</tr>
<tr>
<td>A320-C4 (19,300)</td>
<td>12.4</td>
<td>16.1</td>
</tr>
<tr>
<td>A320-200 (15,100)</td>
<td>12.5</td>
<td>16.1</td>
</tr>
<tr>
<td>A320-200 (15,100)</td>
<td>14.1</td>
<td>15.7</td>
</tr>
<tr>
<td>A320-200 (15,100)</td>
<td>14.4</td>
<td>15.0</td>
</tr>
<tr>
<td>A340-600 (27,400)</td>
<td>15.2</td>
<td>15.0</td>
</tr>
<tr>
<td>A340-600ER (24,200)</td>
<td>15.7</td>
<td>15.0</td>
</tr>
<tr>
<td>A350-900 (28,100)</td>
<td>15.0</td>
<td>15.0</td>
</tr>
<tr>
<td>A350-900F (28,100)</td>
<td>15.2</td>
<td>15.0</td>
</tr>
<tr>
<td>747-8 (25,200)</td>
<td>15.0</td>
<td>15.0</td>
</tr>
<tr>
<td>747-8 (25,200)</td>
<td>15.2</td>
<td>15.0</td>
</tr>
<tr>
<td>757-900 Prelim (31,300)</td>
<td>16.6</td>
<td>16.6</td>
</tr>
</tbody>
</table>
Airport Pavement R&D Program
Four Major Pavement Focal Areas

Pavement Thickness Design
- FAARFIELD 1.4
- Concrete or Asphalt
- Support Anticipated Aircraft Loads for Design Life (20 Year)
- Avoid Premature Failure
- Minimize Construction Cost

Aircraft / Airport Compatibility
- Support ICAO Compatibility Criteria (ACN-PCN Method)
- Improvements
  - New Alpha Factors
  - ICAO Tire Pressure Categories
  - Computer Program - COMFAA
- Changes Adopted by US and Worldwide

Airport Pavement Management
- FAA PAVEAIR Program
  - Free Web Based Management Software
  - Airports Manage Pavement Inventory
  - FAA to Monitor AIP Grants
- Nondestructive Testing and Evaluation
  - Roughness
  - Smoothness

Advanced Pavement Materials
- New Technologies
  - Reduce Construction Cost
  - Improve Durability
  - Environmental Benefit
- Active R&D
  - Warm Mix Asphalt
  - Establish standards for Gyratory Mix Design
  - Characterizing Subgrade Soil
  - Deicing Agents
Airport Pavement R&D Program - Facility Layout

[Image of facility layout with labeled sections: NAPMRC, Soil Processing, Materials Laboratory, Office Space, Safety Technology, Future Expansion, NAPTF]
National Airport Pavement Test Facility (NAPTF)

Facility Facts:
- FAA / Boeing (CRDA) Partnership at $21M
- Opened April 1999
- Fully Enclosed Facility
- Accelerated Traffic Testing
- 900 ft. x 65 ft. of Test Pavement Surface
- Full-scale Pavement Structures and Landing Gear Loads

Test Vehicle Facts:
- Fully Automated & Programmed Wander Patterns
- Up to 5-dual wheel configuration
- Roughly 1.3 Million lbs.
- Up to 75,000 lbs. per wheel
National Airport Pavement Materials Research Center (NAPMRC)

Facility Facts:
- Dedication Ceremony August 2015
- Indoor and Outdoor Testing Capability
- Accelerated Traffic Testing
- Outdoor: 150ft. x 300ft. & Indoor: 72ft. x 300ft.
- Accelerated resurfacing

HVS-A Facts:
- 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)
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Testing at NAPTF

- CC-1: Flexible & Rigid Pavements
- CC-2, CC2-OL, CC-4, CC-6, CC-8: Rigid Pavements
- CC-3, CC-5, CC-7, CC-9: Flexible Pavements
CC7 - HMA Fatigue in FAARFIELD

- FAARFIELD is a computer program for airport pavement thickness design. FAA AC 150/5320-6F.

- Old HMA Fatigue Model: Heukelom & Klomp [1962]
  \[ \log_{10}(C) = 2.68 - 5 \times \log_{10}(\varepsilon_h) - 2.665 \times \log_{10}(E_A) \]

\[ N_f = 0.4801 \times PV^{-0.9007} \]

\[ PV = 44.422 \times \varepsilon_h^{5.14} \times S^{2.993} \times VP^{1.85} \times GP^{-0.4063} \]

where PV is the estimated value of RDEC plateau value (dimensionless),
S is HMA flexural stiffness (psi),
\( \varepsilon_h \) is horizontal strain at the bottom of the asphalt layer,
VP is the volumetric parameter, and
GP is gradation parameter.
CC7 - HMA Fatigue in FAARFIELD

\[ VP = \frac{V_a}{V_a + V_b} \]
\[ GP = \frac{(P_{NMS} - P_{PCS})}{P_{200}} \]

where
- \( V_a \) is air voids,
- \( V_b \) is asphalt content by volume,
- \( P_{NMS} \) is the % of aggregate passing the nominal maximum size sieve,
- \( P_{PCS} \) is the % of aggregate passing the primary control sieve, and
- \( P_{200} \) is the % of aggregate passing the #200 (0.075 mm) sieve.
CC-7 Pavement Cross Sections

15 inch
34 inch
12 inch
37 inch
10 inch
39 inch
10 inch
34 inch
29 inch
39 inch
LFP-1N
LFP-2N
LFP-3N

8 inch
5 inch
8 inch
5 inch
29 inch
8 inch
41 inch
5 inch
29 inch
LFP-4N
LFP-5N
LFP-6N

P401 HMA
SURFACE
DRAINABLE
BASE
P154 SUBBASE
P209 CRUSHED
STONE BASE
SUBGRADE
(CBR 5-6)
CC7 - Pavement Instrumentation
CC7 - Traffic Tests

- Standard NAPTF wander pattern.

- 55 kips (245 kN) wheel load

- 6-wheel gear.
CC7 - Traffic Tests

- Pavement Monitoring
  - Straight Edge Rut Depth Measurements
  - Surface profiles
  - Crack maps
CC7 – Pavement Performance

Straight Edge Rut Depth Measurements

Crack Monitoring

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CC7 – Pavement Performance
## PREDICTED & OBSERVED FATIGUE LIFE

<table>
<thead>
<tr>
<th>Test Section</th>
<th>HMA Strain (from FAARFIELD)</th>
<th>PV</th>
<th>Pass to Coverage (P/C Ratio)</th>
<th>$N_f$ from FAARFIELD</th>
<th>$N_f$ from Full-Scale APT</th>
<th>Ratio ($N_{APT}/N_{FAARFIELD}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PP-1</td>
<td>0.000524</td>
<td>2.14E-06</td>
<td>0.650</td>
<td>40000</td>
<td>61538</td>
<td>NO CRACKS OBSERVED</td>
</tr>
<tr>
<td>PP-2</td>
<td>0.000657</td>
<td>6.86E-06</td>
<td>0.730</td>
<td>15385</td>
<td>21075</td>
<td></td>
</tr>
<tr>
<td>PP-3</td>
<td>0.000781</td>
<td>1.67E-05</td>
<td>0.790</td>
<td>7407</td>
<td>9376</td>
<td>21450</td>
</tr>
<tr>
<td>PP-4</td>
<td>0.000932</td>
<td>4.14E-05</td>
<td>0.860</td>
<td>3636</td>
<td>4228</td>
<td>11814</td>
</tr>
</tbody>
</table>
CC9 Objectives

- Verify/Refine/Modify fatigue model based on the ratio of dissipated energy change (RDEC)
- Effect of P-209 Layer Thickness on Pavement Life
- Effect of Geosynthetics use on Flexible Pavement Performance
- Cement Treated Permeable Base Performance
- Strain Criterion for Allowable Overload

Bender Element Sensor developed by UIUC Team led by Dr. Erol Tutumluer
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Test Cycle-1 (TC1)

- 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 (1.45 MPa)</td>
</tr>
<tr>
<td>North</td>
<td>Single Wheel</td>
<td>61,300</td>
<td>254 (1.75 MPa)</td>
</tr>
</tbody>
</table>

(27.8 metric ton)
**Test Cycle-1 (TC1)**

**Test Cycle-1 Completed**

- Compare WMA performance with P401 HMA performance (rutting);
  - Comparable Performance in rutting.
- Cracking performance need to be evaluated (TC2)
- 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.
Test Cycle-2 (TC2) Objectives

- Compare WMA performance with P401 HMA performance (rutting);
- Compare WMA performance with P401 HMA performance (fatigue);
- Compare performance (rutting & fatigue) of different WMA additives;
- Evaluate performance of RAP+WMA
Test Cycle-2 (TC2)

- Construction May 2019
- Material
  - P-401 HMA
  - WMA (3)
  - RAP (2)
- Tire pressure 254 psi (1.75 MPa)
- Failure criterion:
  - fatigue cracking & rutting
- Testing in progress
Test Cycle-2 (TC2) – Test Section Layout

- High Temperature (120 deg F) Rutting Tests
- Variable Temperature & High Temperature Rutting Tests
- Low Temperature (68 deg F) Fatigue Tests

START AFTER COOLING SYSTEM INSTALLATION

COMPLETE

IN PROGRESS

Indoor Lanés
- Lane-5: 3 in WMA Organic + RAP
- Lane-6: 6 in WMA Organic + RAP

Outdoor Lanés
- Lane-1: HMA
- Lane-2: WMA Chemical
- Lane-3: WMA Organic
- Lane-4: WMA Hybrid

NAPMRC TEST CYCLE-2
Test Condition
Temperature: 120°F (49°C)
Tire Pressure: 254 psi (1.75 MPa)
Wheel Load: 61.3 kip (272.7 kN)
Fatigue Tests

AGING OF TEST AREA:

- Pavement Temperature: 120 deg. F measured at a depth of 2-inch below pavement surface.
- Test Lane will be subjected to these conditions for a period of 336 hours (14 days).
- After 336 hours of aging, heaters will be turned off and insulation panels removed.
- Wait till the pavement temperature stabilizes to ambient conditions.
- Place insulation panels back and prepare for Response Tests & Traffic Tests.
- Fatigue Test Pavement Temperature – 68 deg. F.
Testing at NAPTF

• Full-scale test data used to improve failure models in FAARFIELD, and FAA AC 150/5320-6.
Developing advanced pavement analysis tool PANDA-AP to use material characterization properties – **improved pavement life prediction, compare predicted life of two materials before being placed on airport.**

Standalone PANDA-AP:
- Considers failure mechanisms
- Can be used as a supplement to FAARFIELD for refined analysis
- Allows for the definition of different gear configurations, loading type, and pavement structure
- User-friendly and customized for airfield pavements
- Will be free to public and independent of commercial FE software, such as Abaqus and Ansys
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No Delamination
Early Indications
Delamination
Runway 27L Extension and Associated Taxiways

New Construction on Taxiway P2:
- 18" P-501
- 17" P-401
FAA NextGen Pavement Materials Lab

- **2010:** Laboratory Opened
- **2013:** AASHTO Material Reference Laboratory (AMRL)
- **2013:** Cement and Concrete Reference Laboratory (CCRL)
- **Full Test Capabilities:** Asphalt, Concrete, Soils
- **Advanced Test Capabilities:**
  - Asphalt Pavement Analyzer (APA)
  - Asphalt and Concrete beam fatigue
  - Semi-Circular Bending (SCB)
  - Disk-Shaped Compact Tension (DCT)
- **Benefits to the NAPTF & NAPMRC:**
  - Quality Control of Testing
  - Expedient Testing of Materials During Construction
  - Perform Advanced Materials Characterization On-site
  - Development of Performance Based Specification
HMA Characterization

- **Performance Testing**
  - Mixture Stiffness (Dynamic Modulus)
  - Fatigue Cracking (Flexural Beam Fatigue, Overlay Tester, SCB Flexibility Index)
  - Rutting Resistance (AMPT Flow Number)
  - Asphalt Pavement Analyzer (APA)
Relationship between HVS-A & APA Results

**Relationship between HVS-A and APA Test Results (Field Cores)**

- Equation: $y = 1731x^{-0.10}$
- $R^2 = 0.7245$

**Relationship between HVS-A and IDT Test Results**

- Equation: $y = 0.0196e^{0.001}$
- $R^2 = 0.8201$
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New Research Initiatives

- **Asphalt Pavements**
  - new Airport Asphalt Pavement Technology Program (AAPTP)
  - Administered by NAPA.

- **Concrete Pavements**
  - Administered by the National Concrete Pavement Technology Center at Iowa State University
Other Research Projects

- In-Service Performance of Airport Pavements Constructed Following State Specifications for Highway Materials
- Stabilized Bases
- Surface Treatments
- Seasonal Frost and Permafrost
- Pavement Roughness
- Minimum material, construction, and acceptance recommendations for P401, P403, and P-404.
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