Estimating the Life Expectancy of Thin Asphalt Overlays in New Jersey

Ayman Ali, Ph.D.
Manager, Center for Research and Education in Advanced Transportation Engineering Systems (CREATEs)
Rowan University
109 Gilbreth Parkway
Mullica Hill, NJ 08062
Tel: (908) 283-0467
Email: alia@rowan.edu
Acknowledgement

- Dr. Hashim Rizvi
- Ms. Caitlin Purdy
- Mr. Ian Sennstrom
- Mr. Andrae Francoise
- Ms. Eileen Sheehy
- Ms. Susan Gresavage
- Mr. Paul Hanczaryk
- Mr. Robert Blight
- Dr. Giri Venkiteela
- Ms. Kimbrali Davis
In this presentation...

- Why Thin Overlays?
- Study Goals & Objectives
- Research Approach
- Construction of Sections & Instrumentation
- HVS Testing Plan
- Preliminary Testing Results
- Final Remarks
- Questions
Why Thin Asphalt Overlays?
Why Thin Asphalt Overlays?

- Around 50% of NJDOT’s roads are PCC pavements.
- These roads are generally in poor condition.
- Thin overlays are typically used to extend the life of these pavements.
- However, these overlays have been performing poorly in the field.
Goals and Objectives
Goals

- Conduct **accelerated full-scale pavement testing to evaluate the performance** of thin asphalt overlay treatments used on Portland Cement Concrete (PCC) pavements.

- Analyze testing results to **estimate the expected life of thin asphalt overlays** applied over PCC pavements.
Research Approach
Research Approach

1. Conduct A Comprehensive Literature Review
2. Evaluate Current Condition of PCC Pavements in NJ
3. Identify Major Factors Affecting Life Expectancy of Thin Asphalt Overlays
4. Construct Full-Scale PCC Sections Overlaid with Thin Asphalt Overlays.
Research Approach

5. Apply Accelerated Loading Using a Heavy Vehicle Simulator (HVS)

6. Monitor Performance of Thin Asphalt Overlays as Loading Progresses

7. Analyze Testing Results

8. Provide NJDOT with Findings and Recommendations
## Overlays Considered

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>9.5 mm. NMAS Superpave Mix (<em>Control</em>)</td>
</tr>
<tr>
<td>B</td>
<td>12.5 mm. NMAS Stone Matrix Asphalt (SMA)</td>
</tr>
<tr>
<td>C</td>
<td>High Performance Thin Overlay (HPTO)</td>
</tr>
<tr>
<td>D</td>
<td>Binder Rich Intermediate Course (BRIC)</td>
</tr>
</tbody>
</table>
Full-Scale Pavement Sections

- A total of six sections were constructed at CREATEs accelerated pavement testing facility.
- Combinations of the four overlays with varying thicknesses.
- The supporting PCC pavement structure was similar for all sections.
Full-Scale Pavement Sections

- The sections were instrumented using a set of sensors including:
  - Thermocouples
  - Soil Compression Gauges
  - Pressure cells
  - Asphalt Strain Gauges
  - LVDTs

- The goal was to compare field performance (rutting and reflective cracking).
Full-Scale Sections

Section No. 1:
- 9.5 mm. NMAS Superpave
- Control Section
Section No. 2:
- 12.5 mm. NMAS SMA
- A Specialty NJDOT Overlay mix
Full-Scale Sections

Section No. 3:
- High Performance Thin Overlay
- A Specialty NJDOT Overlay mix
**Full-Scale Sections**

**Section No. 4:**
- A combination of 9.5 mm. Superpave and Binder Rich Intermediate Course (BRIC) Mixes.
- BRIC is a Specialty NJDOT Overlay mix
Full-Scale Sections

Section No. 5:
- A combination of 12.5 mm. SMA and BRIC Mixes.

<table>
<thead>
<tr>
<th>Layer</th>
<th>Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.5 mm. NMAS SMA (2 inches)</td>
<td></td>
</tr>
<tr>
<td>Binder Rich Intermediate Course (1 inch)</td>
<td></td>
</tr>
<tr>
<td>PCC Layer (8 inches)</td>
<td></td>
</tr>
<tr>
<td>Subbase Layer (16 inches)</td>
<td></td>
</tr>
<tr>
<td>Compacted Natural Soil (12 inches)</td>
<td></td>
</tr>
<tr>
<td>Natural Soil</td>
<td></td>
</tr>
</tbody>
</table>
Full-Scale Sections

Section No. 6:
- A combination of HPTO and BRIC Mixes.

<table>
<thead>
<tr>
<th>Layer</th>
<th>Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Performance Thin Overlay (1 inch)</td>
<td></td>
</tr>
<tr>
<td>Binder Rich Intermediate Course (1 inch)</td>
<td></td>
</tr>
<tr>
<td>PCC Layer (8 inches)</td>
<td></td>
</tr>
<tr>
<td>Subbase Layer (16 inches)</td>
<td></td>
</tr>
<tr>
<td>Compacted Natural Soil (12 inches)</td>
<td></td>
</tr>
<tr>
<td>Natural Soil</td>
<td></td>
</tr>
</tbody>
</table>
Construction of Full-Scale Sections
Construction Phase-I (Facility)

Construction Site: Work Begins
Construction Phase-I (Facility)

Construction Site: Foundations
Construction Phase-I (Facility)

Construction Site: Steel Structure
Construction Phase-I (Facility)

Construction Site: Fabric Cover
Construction Phase-I (Facility)

Construction Site: Fabric Cover
Construction Phase-I (Facility)

Construction Site: Fabric Structure (Inside)
Construction Phase-I (Facility)
Construction Phase-I (Facility)

Construction Site: Completed Facility
Construction Phase-II (NJDOT Sections)

NJDOT Sections: Marking Sections Locations
Construction Phase-II (NJDOT Sections)

NJDOT Sections: Milling Existing Pavement
Construction Phase-II (NJDOT Sections)

NJDOT Sections: Milling Existing Pavement
Construction Phase-II (NJDOT Sections)

NJDOT Sections: Concrete Forms
Construction Phase-II (NJDOT Sections)

NJDOT Sections: Concrete Placement (Slabs)
Construction Phase-II (NJDOT Sections)

NJDOT Sections: Final PCC Slabs
Construction Phase-II (NJDOT Sections)
Construction Phase-II (NJDOT Sections)

NJDOT Sections: HMA Overlays Paving
Construction Phase-II (NJDOT Sections)

NJDOT Sections: HMA Overlays Paving
Construction Phase-II (NJDOT Sections)
Instrumentation of Sections
Goals of Instrumentation

- Assess the impact of reflective cracking on performance of thin asphalt overlays.
- Assess the impact of joint vertical movements on performance of thin asphalt overlays.
- Characterize rutting potential in thin asphalt overlays.
Instrumentation Plan

Longitudinal Asphalt Strain Gauge (Total: 2)
Pressure Cell (Total: 1)
LVDT (Total: 2)
Soil Compression Gauge (Total: 2)
HMA Temperature Sensor (Total: 3
T-type Thermocouples)
Type T thermocouples will be used for temperature measurements.
Instrumentation

- **Pressure Cells (Geokon Inc.)**
  - To measure pressure in sub-base (I-3) layer at both sides of transverse joints of PCC slabs
  - 6 pressure cells have been installed in NJDOT sections
Instrumentation

Instrumentation of NJDOT Sections: Pressure Cells
Instrumentation of NJDOT Sections: Leveling
Instrumentation of NJDOT Sections: Covering
Instrumentation of NJDOT Sections: Locating
Instrumentation (Thermocouples)

- **Thermocouples (Omega)**
  - To measure temperature in subbase and overlays at various depths (2” interval for subbase and 0.5” interval in overlays)
  - 48 thermocouples were installed in six Test sections
Instrumentation of NJDOT Sections: Preparation and Testing
Instrumentation

Instrumentation of NJDOT Sections: Installation
Instrumentation of NJDOT Sections: Installation
Instrumentation of NJDOT Sections: Installation
Instrumentation

Pressure Cell Location

Center Line Reference

Manhole

Instrumentation of NJDOT Sections: Thermocouples
Thermocouple Installation (Surface Layer)

Thermocouple bed preparation, installation, and manual compaction
Instrumentation

- Soil Compression Gauges (CTL Group)
  - To measure vertical deformation in sub-base (I-3) layer at both sides of transverse joints
  - 12 soil compression gauges have been installed in NJDOT sections
Instrumentation

Instrumentation of NJDOT Sections: Soil Compression Gauges
Instrumentation

Instrumentation of NJDOT Sections: Soil Compression Gauges
Instrumentation of NJDOT Sections: Soil Compression Gauges
Instrumentation

- Two LVDTs have been installed in PCC slabs
- LVDTs used to measure lateral movement of the PCC slabs under accelerated loading.

Linear Variable Differential Transducers (LVDTs)
Instrumentation of NJDOT Sections: LVDTs
Instrumentation of NJDOT Sections: LVDTs
Instrumentation

Instrumentation of NJDOT Sections: LVDTs
Instrumentation

- 12 strain gauges have been installed in NJDOT sections
- Strain gauges utilized to simultaneously measure longitudinal and transverse strains in asphalt layer.

Asphalt Strain Gauges
(Tokyo Sokki KM-100HAS H-gauge)
Instrumentation

Instrumentation of NJDOT Sections: Wire trenches
Instrumentation of NJDOT Sections: ASGs
Instrumentation of NJDOT Sections: ASGs
All Sections
Testing Plan
HVS Testing Protocol

- One section, out of the six, will be subjected to loading using the HVS until failure (i.e., failing one section at a time).

- Air Temp. around section is controlled using CREATEs Cooling/Heating System (25°C).

- Therefore, HVS loading will be conducted in the following sequence: Section 1 loaded until failure, followed by Section 2, followed by Section 3, and so on.

<table>
<thead>
<tr>
<th>9.5ME</th>
<th>SMA</th>
<th>HPTO</th>
<th>95/BRIC</th>
<th>SMA/BRIC</th>
<th>HPTO/BRIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 to 2 Months</td>
<td>1 to 2 Months</td>
<td>1 to 2 Months</td>
<td>1 to 2 Months</td>
<td>1 to 2 Months</td>
<td>1 to 2 Months</td>
</tr>
</tbody>
</table>
Testing Plan

30’ Total Test section length

23’ Test Zone of HVS

1.5 feet breaking and accelerating zones

20’ Effective Test Zone of HVS

12’ Width of PCC slab

Manhole
Field Testing Steps

- Perform HWD Testing
- Verify Sensor Condition
- Mark Loading Zone
- Cover Test Section
Field Testing Steps

Perform Profile Testing

Apply Sealing in HVS
Station Cooling Trailer
Field Testing Steps

Station HVS on Section

Install Thermostat for Heaters

Ensure Testing Strip is Aligned

Heat Control Thermostat
Field Testing Steps

- Apply Side Insulation
- Set-up Data Acquisition
- Apply Rain Covers
- Attach Cooling Hoses
Heating System

- Contains infrared heating elements.
- Heating angle can be adjusted depending on desired heating coverage within the section.
- Used for controlling the air temperature around section (within sealed enclosure).

- Temperature Range:
  - Depends on ambient temperature.
  - On average, it can maintain the air temperature around the pavement to up to 120°F.
Heating System
Cooling System

- Based on a vapor compression refrigeration cycle (i.e., uses a refrigerant to cool).

- Works by cycling air through the enclosure covering the HVS. As a result, it is also used for controlling the air temperature around section (within sealed enclosure).

- Temperature Range:
  - Depends on ambient temperature.
  - On average, it can maintain the air temperature around the pavement to (comfortably) 32°F.
Cooling System
Cooling System
Data Collection Protocol

- The CREATEs cDAQ system will be utilized to collect data from all sensors after the application of the following load passes:

<table>
<thead>
<tr>
<th>Data Sampling Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>1, 5, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 125, 150, 175, 200, 250, 300, 350, 400, 450, 500, 600, 700, 800, 900, 1000, 1200, 1400, 1600, 1800, 2000, 2500, 3000, 3500, 4000, 4500, 5000, 6000, 7000, 8000, 9000, 10000, …</td>
</tr>
</tbody>
</table>

- Incremented by 5,000 after 10k
- Incremented by 10,000 after 40k
- Incremented by 20,000 after 100k
- Incremented by 40,000 after 200k
HWD Testing

- A field test that is typically conducted evaluate the structural integrity of pavements.
- The HWD “drops” (freefall) a weight on a particular location.
- Geophones (seven) are used to measure deflections at various locations: Forming a Deflection Basin.

![Diagram of HWD Testing](image)
HWD Testing

- Heavy Weight Deflectometer (HWD) testing will be conducted before HVS loading and after failure.
- Six locations will be tested on each section.
### HWD Test Configurations

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Types</th>
<th>No. of Drops</th>
<th>Stress (psi)</th>
<th>Load (lbf)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Load</strong></td>
<td>Seating</td>
<td>3</td>
<td>60, 85, 110, 140</td>
<td>7k, 9.5k, 12.5k, 16k</td>
</tr>
<tr>
<td></td>
<td>Drop height 1</td>
<td>4</td>
<td>60</td>
<td>7k</td>
</tr>
<tr>
<td></td>
<td>Drop height 2</td>
<td>4</td>
<td>85</td>
<td>9.5k</td>
</tr>
<tr>
<td></td>
<td>Drop height 3</td>
<td>4</td>
<td>110</td>
<td>12.5k</td>
</tr>
<tr>
<td></td>
<td>Drop height 4</td>
<td>4</td>
<td>140</td>
<td>16k</td>
</tr>
<tr>
<td><strong>Loading Plate</strong></td>
<td>Diameter</td>
<td>12 in.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Transverse Laser Profilometer

- Characterizes the transverse profiles of pavements.
- Uses a laser distance measuring device and collect data every 2 mm.
- Useful in measuring permanent deformation (rutting) within the pavement structure.
Transverse Laser Profilometer

- Transverse profiles will be measured using a laser profilometer on daily basis.
- Seven locations will be tested as shown in the schematic below:
Visual Inspection and Mapping

- In addition, visual inspection will be conducted to collect information about the section.
- That is, crack maps and pictures of cracks as loading progresses.
# Visual Inspection and Mapping

| Technician Name: | | | | | |
|------------------|------------------|------------------|------------------|------------------|
| Date of Survey:  | | | | | |
| Time of Survey:  | | | | | |
| Air Temperature: | | | | | |
| Pavement Temperature: | | | | |
| Test Section ID: | | | | | |

<table>
<thead>
<tr>
<th>Crack ID</th>
<th>Type of Crack</th>
<th>No. of Pass</th>
<th>C. Length</th>
<th>C. Width</th>
<th>C. Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>40k-1</td>
<td>Fatigue/Reflective</td>
<td>40,000</td>
<td>1.5 cm</td>
<td>2 mm</td>
<td>2 mm</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Visual Inspection and Mapping

[Diagram with fields for technician name, date of survey, time of survey, hours, air temperature, pavement temperature, and test section ID]
Preliminary Testing Results
Section Temperature (Before Testing)

Approximately 12 Hours

Pavement Temperature (°F)

- 0.5 in from Surface
- 1 in from Surface
- 1.5 in from Surface
- 1 Foot
- 2 Foot
- 4 Foot
- 7 Foot
- Inside Air Temperature

Pass

9:36 14:24 19:12 0:00 4:48 9:36 14:24

12 ft.

4 ft. 1 ft.

7 ft.

2 ft.
Temperature (Surface Thermocouples)

Day 1
Outside Temp: 65°F
Heating

Day 2 (Thursday April 27)
Outside Temp: 81°F
Cooling

Day 3 (Friday April 28)
Outside Temp: 84°F
Cooling

Pavement Surface Temperature (°F)

Pass Number

1 ft. 2 ft. 4 ft. 7 ft.

12 ft.
Temperature (HMA Embedded Thermocouples)

Day 1
Outside Temp: 68°F
Heating

Day 2
Outside Temp: 81°F
Cooling

Day 3
Outside Temp: 84°F
Cooling

Pavement Temperature (°F) vs Pass Number

- 0.5 in from Surface
- 1 in from Surface
- 1.5 in from Surface

Loading
Soil Compression Gauge (Gauge 1)
Soil Compression Gauge (Gauge 2)

![Graph showing Soil Compression Gauge results](graph.png)

- SGC2 Signal (volts)
- Loading Time (seconds)
- Pass 1
- Pass 1000
- Pass 2000
- Pass 6000
- Pass 9000

Gauge is Compressed at 4 seconds.
Soil Compression Gauge (Gauge 2)
LVDT 1 (Horizontal Joint Opening)

Wheel on top of joint.

Loading Time (seconds)

Loading
LVDT 2 (Horizontal Joint Opening)

Wheel on top of joint.

Joint is Opening

Loading Time (seconds)

Loading
Pressure Cell

![Pressure Cell Graph]

- **Pass 1**
- **Pass 1000**
- **Pass 2000**
- **Pass 6000**
- **Pass 9000**

**Axes:**
- **Y-axis:** Pressure Cell Signal (volts)
- **X-axis:** Loading Time (seconds)

**Legend:**
- Blue dots: Pass 1
- Orange dots: Pass 1000
- Black dots: Pass 2000
- Blue circles: Pass 6000
- Yellow stars: Pass 9000

**Additional Elements:**
- Diagram of Pressure Cell and Loading mechanism

---

**Rowan University**

**Center for Research & Education in Advanced Transportation Engineering Systems**

---

98
HWD Testing (Deflection Basins)
Final Remarks
Final Remarks

- The Heavy Vehicle Simulator is capable of simulating damage applied by truck and aircraft wheels in an accelerated fashion.

- Full-Scale accelerated testing of pavements provides valuable information about field performance.

- Data extracted from sensors can be used to develop performance measures for evaluating pavement performance.
Questions?
Thank You!

Ayman Ali, Ph.D.
Tel: (908) 283-0467
Email: alia@rowan.edu
www.rowan.edu/creates