LTPP SPS-2 Experiment

October 16, 2018
Bismark, ND

Kevin Senn, P.E.—NCE
Presentation Overview

- Review of SPS-2 Experiment
  - Purpose
  - National SPS-2 Experimental Design
  - Lay of the Land Today
SPS-2 Purpose

- Determine the influence of concrete strength and pavement drainage on PCC pavement performance
  - Neither had quality experimental field data
- Find impact of widened lanes
- Determine impact of other design factors (slab thickness, base type)
SPS-2 Purpose (cont.)

- Planned products
  - Evaluation of existing design methods
  - Development of improved design equations
    - New and reconstructed pavements
  - Effects of specific design features on pavement performance
  - Development of a comprehensive database for pavement community
National SPS-2 Experimental Design

<table>
<thead>
<tr>
<th>Slab thickness, inches</th>
<th>Flexural strength, psi</th>
<th>Lane width, ft</th>
<th>Drainage</th>
<th>Base type</th>
<th>Drainage</th>
<th>Base type</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>8</td>
<td>550</td>
<td>12</td>
<td>AGG</td>
<td>No</td>
<td>PATB</td>
</tr>
<tr>
<td></td>
<td></td>
<td>14</td>
<td>0201</td>
<td>LCB</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>550</td>
<td>14</td>
<td>0213</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>900</td>
<td>12</td>
<td>0214</td>
<td></td>
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<td>14</td>
<td>12</td>
<td>0202</td>
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<tr>
<td></td>
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<td>900</td>
<td>14</td>
<td>0215</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>11</td>
<td>12</td>
<td>0203</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>14</td>
<td>14</td>
<td>0216</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

LONG TERM Pavement PERFORMANCE
SPS-2: Experimental Layout

- Primary Factors
  - Subgrade: fine and coarse
  - Temperature: freeze and non-freeze
  - Moisture: wet and dry

- Secondary Factors
  - PCCP drainage: yes and no
  - PCCP strength and thickness
  - Lane width
  - Base type
# National SPS-2 Experimental Design

<table>
<thead>
<tr>
<th>Subgrade</th>
<th>Climatic Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Wet</td>
</tr>
<tr>
<td>Freeze</td>
<td>No-Freeze</td>
</tr>
<tr>
<td>Ohio, Kansas (J)</td>
<td>North Carolina (N)</td>
</tr>
<tr>
<td>Michigan, Iowa (K)</td>
<td>Arkansas (O)</td>
</tr>
<tr>
<td>Delaware (L)</td>
<td>*(P)</td>
</tr>
<tr>
<td>Wisconsin (M)</td>
<td>* (Q)</td>
</tr>
</tbody>
</table>

* = Cell not filled
Lay of the Land Today

- 10 of 14 Projects are Active
  - 66% (136/207) Sections are Active
- SPS-2 Pavement Preservation Pooled Fund:
Questions?
Performance of SPS-2 Concrete Pavements

October 16, 2018
Bismark, ND

Kevin Senn, P.E.—NCE
Overview

- National SPS-2 Performance
- National SPS-2 PavementME Predictions
- North Dakota SPS-2 PavementME Predictions
SPS-2
Traffic and Climate

- Non-freeze: 420 KEASL/YR
- Freeze: 480 KEASL/YR
- Dry: 390 KEASL/YR
- Wet: 570 KEASL/YR
- Non-freeze: 720 KEASL/YR
- Freeze: 760 KEASL/YR

Map of the United States with data points indicating traffic and climate conditions.
National SPS-2 Performance Roughness

- The initial IRI of SPS-2 sections after placement ranged from 48 to 139 in/mi with a mean of 82 in/mi.
- JPCP constructed on PATB were smoother than sections constructed on LCB or untreated aggregate base.
National SPS-2 Performance Roughness

![Bar chart showing average change in IRI per year (in/mi/yr) for different intervals of test sections.](image)

- Number of Test Sections
- Average Change in IRI per Year (in/mi/yr)

Intervals:
- < 0
- 0-2
- 2-4
- 4-8
- 8-16
- > 16

Bars indicate the number of test sections for each interval.
National SPS-2 Performance Faulting

- Widened slab sections show less faulting than conventional width slabs.
- Sections with aggregate base show the highest joint faulting level. Sections with LCB and PATB have the lowest joint faulting.
National SPS-2 Performance Transverse Cracking

- Thinner (203 mm) slabs show more transverse cracks than thicker slabs. Sections with a thinner slab and a widened slab show the highest level of transverse cracking.

- Sections with PATB show the lowest percentage of slabs cracked transversely, while the sections with an LCB show the highest transverse cracking.
National SPS-2 Performance Longitudinal Cracking

- Sections with PATB show the lowest total longitudinal cracking levels, while the sections with LCB show the highest longitudinal cracking.
National SPS-2 Performance Lessons Learned (so far)

- In general, LCB provided the worst performance and PATB over DGAB provided the best performance.
- Longitudinal cracking was influenced by base type and slab thickness.
- Widened lanes contributed to lower transverse joint faulting.
National SPS-2 PavementME Predictions

Slabs Cracked Transversely

<table>
<thead>
<tr>
<th>PREDICTED SLABS CRACKED</th>
<th>MEASURED SLABS CRACKED</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOW</td>
<td>HIGH</td>
</tr>
<tr>
<td>LOW</td>
<td>I</td>
</tr>
<tr>
<td>HIGH</td>
<td>III</td>
</tr>
</tbody>
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### National SPS-2 PavementME Predictions

<table>
<thead>
<tr>
<th>Type I sections</th>
<th>Type III sections</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower traffic loads</td>
<td>Heavier traffic loads</td>
</tr>
<tr>
<td>Thicker PCC</td>
<td>PCC with lower strength and/or more elastic</td>
</tr>
<tr>
<td>34% with PATB and 24% with LCB</td>
<td>No LCB sections</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type 2 sections</th>
<th>Type IV sections</th>
</tr>
</thead>
<tbody>
<tr>
<td>28% with PATB and 47% with LCB</td>
<td>Most design factors are near the average</td>
</tr>
<tr>
<td>PCC with higher strength and/or less elastic</td>
<td></td>
</tr>
</tbody>
</table>
# National SPS-2 PavementME Predictions

<table>
<thead>
<tr>
<th>State</th>
<th>Type I</th>
<th>Type II</th>
<th>Type III</th>
<th>Type IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arizona</td>
<td>10</td>
<td>5</td>
<td>4</td>
<td>-</td>
</tr>
<tr>
<td>Arkansas</td>
<td>5</td>
<td>2</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>California</td>
<td>3</td>
<td>5</td>
<td>1</td>
<td>3</td>
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<tr>
<td>Colorado</td>
<td>9</td>
<td>4</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Delaware</td>
<td>13</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Iowa</td>
<td>12</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Kansas</td>
<td>9</td>
<td>2</td>
<td>1</td>
<td>1</td>
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<tr>
<td>Michigan</td>
<td>7</td>
<td>6</td>
<td>-</td>
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<tr>
<td>Nevada</td>
<td>2</td>
<td>10</td>
<td>-</td>
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<tr>
<td>North Carolina</td>
<td>12</td>
<td>2</td>
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<tr>
<td>North Dakota</td>
<td>16</td>
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<tr>
<td>Ohio</td>
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<td>1</td>
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<tr>
<td>Washington</td>
<td>9</td>
<td>4</td>
<td>-</td>
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<tr>
<td>Wisconsin</td>
<td>20</td>
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</table>
### National SPS-2 – Slabs Cracked Transverse vs. Total

<table>
<thead>
<tr>
<th>Slabs Cracked Transverse</th>
<th>Slabs Cracked - Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
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<tr>
<td>0</td>
<td>112</td>
</tr>
<tr>
<td>0-20</td>
<td>0</td>
</tr>
<tr>
<td>20-40</td>
<td>0</td>
</tr>
<tr>
<td>40-60</td>
<td>0</td>
</tr>
<tr>
<td>60-80</td>
<td>0</td>
</tr>
<tr>
<td>80-100</td>
<td>0</td>
</tr>
</tbody>
</table>
Predictions using agency calibration coefficients did not significantly improve upon predictions using default calibration values.

However, the Root Mean Square Error (RMSE) of Type III predictions reduced by 13.6 (% of slab cracked) on average.

\[
RMSE = \left[ \frac{1}{N} \sum_{i=1}^{N} (x_m - x_p)^2 \right]^{1/2}
\]

Where:

- \( x_m \) = measured performance
- \( x_p \) = predicted performance
- \( N \) = sample size
National SPS-2
RMSE Distribution – Faulting

Number of Test Sections

RMSE Bins (inch)

0-0.015 (GOOD)
0.015-0.03 (FAIR)
0.03-0.06 (POOR)
0.06-0.19 (VERY POOR)

Default Calibration
Agency Calibration
North Dakota SPS-2 Measured Roughness

Survey Date

IRI (in/mi)

Surface Grinding

Patching and AC Shoulder Restoration
North Dakota SPS-2
Predicted Roughness
North Dakota SPS-2 Measured Faulting

Survey Date

Faulting (in)
North Dakota SPS-2
Predicted Faulting

Faulting (in)

Date
0213, 0214, 0217, 0221, 0222, 0259, 0261

Other Sites

0213, 0214, 0217, 0221, 0222, 0259, 0261

Other Sites

LONG TERM PERFORMANCE
North Dakota SPS-2 Measured Cracked Slabs

Slabs with Transverse Cracking (%)

Date

Other Sites

0217

0220

Patching and Slab Replacement on 0217

Patching
North Dakota SPS-2
Predicted Cracked Slabs

Slabs with Transverse Cracking (%)

Date

All Sites

Jan-93 Jan-95 Jan-97 Jan-99 Jan-01 Jan-03 Jan-05 Jan-07 Jan-09 Jan-11 Jan-13 Jan-15 Jan-17 Jan-19

LONG TERM PAVEMENT PERFORMANCE
North Dakota SPS-2 Over-Prediction

- All PavementME predictions showed very little to no distress (less than 1%).
- Therefore, none of the North Dakota SPS-2 test sections performed significantly better than the PavementME prediction.
Example (Arizona) Over-Prediction
North Dakota SPS-2
No Significant Distress

Similar Sites:
0213, 0214, 0215, 0216, 0218, 0219, 0221, 0222, 0223, 0224, 0259, 0260, 0261, 0262, 0263, and 0264
North Dakota SPS-2 Under-Prediction

Year
01/01/85 01/01/90 01/01/95 01/01/00 01/01/05 01/01/10 01/01/15 01/01/20

Cracked Slabs - Transverse (%)

Measured

Predicted with Default Calibrations

Similar Site:
0220
North Dakota SPS-2 PavementME Findings

- 0217 performed worse than predicted; having 21% of slabs cracked by 2003.
- The cracked slabs were repaired by 2009, but new cracks continued to appear.
- 0219 and 0220 also had about 3% of slabs cracked.
North Dakota SPS-2 PavementME Findings

- 0217, 0218, 0219, 0220 and 0262 have a LCB base type.

<table>
<thead>
<tr>
<th>Pavement Thickness</th>
<th>Low Strength</th>
<th>High Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>8” PCC</td>
<td>0217 (many cracks)</td>
<td>0218 (no cracks)</td>
</tr>
<tr>
<td>11” PCC</td>
<td>0219 (few cracks) 0262 (no cracks)</td>
<td>0220 (few cracks)</td>
</tr>
</tbody>
</table>

- All other sections performed well.
SPS-2 Future

- LTPP monitoring
- SPS-2 Pavement Preservation Pooled Fund Study
For more information:
https://www.fhwa.dot.gov/research/tfhrc/programs/infrastructure/pavements/ltpp/getdata.cfm
ksenn@ncenet.com

More products and information at:
https://infopave.com

Thank You