Environmental Influence of Early Age Response of PCC Pavement

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Objectives

- Investigate causes for the inconsistence of Load Transfer Efficiencies (LTEs) across transverse joints.
- Evaluate the loss of support for PCC during the curing process and service.
- Investigate the effect of the three different dowel bar diameters and spacing in LTEs and performance.
Objectives (cont.)

- Investigate the effect of dowel bar diameter on consolidation around dowel bars.
- Recommend design for transverse joints and layout of dowel bars.
Instrumentation, Layout and Material Properties

During the week of June 10, 2002, two slabs were instrumented in the driving lanes of West I-490 in Rochester NY. Pavement consisted of jointed 250mm thick concrete, 5 m joint spacing, and 4.26m wide driving lane.
NYDOT Class C mix was used with desired 28 day strength of 31.5 MPa.

The concrete was placed on top of 100mm thick permeable concrete treated base.
Instrumentation

Sensors used for investigation included:
- Four Deep Reference Linear Variable Differential Transducers (LVDTs)
- Two sets of four thermocouple assemblies
- Two sets of Geokon Vibrating Wire Strain Gauges
- Four Shallow Reference LVDTs Holes
- Two baskets of instrumented dowel bars
- Two sets of MM dynamic strain gauges
Instrumentation Layout

- Slab 1
  - Vibrating Wire
  - Strain Gauge

- Slab 2
  - Deep LVDT's
  - Thermocouple Sticks (4 Elements)

Wheel Path

Dimensions:
- 2.13m
- 0.30m
- 1.80m
- 1.85m
- 2.50m
- 4.27m
- 1.85m
- 1.80m
- 0.30m
Mix Design for NYDOT Class C

<table>
<thead>
<tr>
<th>Material</th>
<th>Kilogram per Cubic Meter</th>
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<tbody>
<tr>
<td>Water</td>
<td>158</td>
</tr>
<tr>
<td>Cement</td>
<td>287</td>
</tr>
<tr>
<td>Fly Ash</td>
<td>72</td>
</tr>
<tr>
<td>Fine Aggregates</td>
<td>634</td>
</tr>
<tr>
<td>Coarse Aggregates (#1 Stone; 40% Split)</td>
<td>454</td>
</tr>
<tr>
<td>Coarse Aggregate (#2 Stone)</td>
<td>682</td>
</tr>
<tr>
<td>Water – Cement Ratio</td>
<td>0.44</td>
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</tbody>
</table>
# Modulus of Rupture Test Results

<table>
<thead>
<tr>
<th>Age (Days)</th>
<th>Modulus of Rupture (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3.6</td>
</tr>
<tr>
<td>2</td>
<td>3.5</td>
</tr>
<tr>
<td>3</td>
<td>3.7</td>
</tr>
<tr>
<td>5</td>
<td>4.3</td>
</tr>
<tr>
<td>7</td>
<td>4.5</td>
</tr>
</tbody>
</table>
Initial Curing, the first 48 hours

Data Collection
- Slab Temperature using thermocouples
- Dipstick surveys
- LVDT Readings
- Vibrating Wire Strain Gauge readings

Concrete was placed at approximately 10:00AM. Data Collection started at 9:00 AM.
Dipstick Survey
Temperature Development in Slab Center within first 48 hours

![Graph showing temperature development](image-url)
Temperature Distribution in the Slab Center after Final Set

- Time of final setting
- 1.5 hours after final setting
- 3.0 hours after final setting
- 4.5 hours after final setting

Temperature in Celsius vs. Height of Measurement

- Time of final setting
- 1.5 hours after final setting
- 3.0 hours after final setting
- 4.5 hours after final setting
Shape of Slab after 48 hours

Slab ID: 6-13-840am (1), Deflection: 1.85 mm
LVDT Readings for initial 48 hours

Gauges Set at Zero
One Hour after Cutting Joints
Environmental Response: 24 hour period, 6 weeks after placement

- Readings were taken starting at 9:00 PM on the 37th day after placement
- Continued for a 24 hour period
- Data Collection included:
  - Temperature Readings
  - LVDT Data
  - Vibrating Wire Data
  - Dipstick Surveys
  - Falling Weight Deflectometer (FWD) Testing
Temperature in Slab Center and Air Temperature

Test Time (Hours)

Temperature (Degree Celsius)

- Thermocouple Top
- Thermocouple Bottom
- Air Temperature
Gradient in Slab Center vs. LVDT Readings

- Temperature Gradient
- LVDT Reading 2
- LVDT Reading 4
Dipstick Plot for Maximum Negative Gradient

Slab ID: 7-17-540am(1), Deflection: 4.97 mm
Dipstick Plot for Maximum Positive Gradient

Slab ID: 7-17-310pm(1), Deflection: 2.19 mm
Grid for FWD Testing
Deflections under FWD Testing at Greatest Negative Gradient
Deflections under FWD Testing at Greatest Positive Gradient
## Warping with Time at Varying Slab Locations

<table>
<thead>
<tr>
<th>LVDT</th>
<th>Reading on 2nd Day (mm)</th>
<th>Reading on 37th Day (mm)</th>
<th>Warping Difference (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LVDT 1</td>
<td>0.4</td>
<td>1.1</td>
<td>0.7</td>
</tr>
<tr>
<td>LVDT 2</td>
<td>1.5</td>
<td>3.2</td>
<td>1.7</td>
</tr>
<tr>
<td>LVDT 3</td>
<td>0.7</td>
<td>1.3</td>
<td>0.6</td>
</tr>
<tr>
<td>LVDT 4</td>
<td>0.7</td>
<td>1.6</td>
<td>0.8</td>
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</tbody>
</table>
Ideal Thermal Strain vs. Actual Strain Readings

VW Readings (Microstrain)
-300 -250 -200 -150 -100 -50 0

Test Time (Hours)
0 3 6 9 12 15 18 21 24

VW Reading Top
VW Reading Bottom
Ideal Thermal Strain Top
Ideal Thermal Strain Bottom
Conclusions

- PCC pavement placed during hot weather conditions develop positive built-in gradients.
  - This leads to significant upward deflections as early as the second day after placement.
- The influence of built-in curling must not be neglected in modeling.
- Pavement with positive built-in gradients experience high tensile stresses on top.
  - This will lead to top-down cracking under traffic loads.
Conclusions (cont.)

- Warping has a significantly greater influence on loss of support if PCC pavement is exposed to high air temperatures and radiation during curing.
- Warping can cause the pavement to experience a permanent loss of support which can not be reversed, even by extreme positive temperature gradients.
Conclusions (cont.)

- When a concrete shoulder is not attached to the driving lane, the outer edge experiences drastically more deformation than the other side.
- The result is permanent loss of support under the slab corners along the shoulder side.
- Tests with FWD deliver consistent data with regard to pavement deformation.
- Permanent loss of support can be determined with FWD.