UPDATE ON THE PERFORMANCE ENGINEERED MIXTURES (PEM) INITIATIVE

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Denver, CO

Gordon L. Smith, P.E.
Associate Director
CP Tech Center
The PEM Initiative

- A Partnership of Agency and Industry

- Specifications that call for what assures expected concrete pavement performance
- Based on measuring the things that matter
- At the right time
- Collecting data and evaluating tests nationwide
What should we measure to get **Good Concrete**?

1. **Shrinkage** - To reduce preventable cracking
2. **Transport (Permeability)** - To reduce transport of aggressive unwanted fluids in order to survive the environment
3. **Freeze/thaw durability** - To reduce expansive damage to the concrete pavement
4. **Aggregate Stability** - To eliminate reactive aggregate that destroys concrete pavements
5. **Workability** - To improve concrete placement that impacts concrete durability & improves rideability
6. **Strength** - To ensure concrete pavement carries intended vehicle loads without failure
Standard Practice for Developing Performance Engineered Concrete Pavement Mixtures (PP 84-17)

- Standard Practice – guidance for FHWA-State DOTs-Industry
- A dynamic “work-in-progress” that initiates our endeavor to embrace Performance Engineered Mixtures
How & when do we measure what matters?

<table>
<thead>
<tr>
<th>How do we measure?</th>
<th>Shrinkage</th>
<th>Transport</th>
<th>Freeze/Thaw Durability</th>
<th>Aggregate Stability</th>
<th>Workability</th>
<th>Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>How do we measure?</td>
<td>Paste content</td>
<td>Resistivity</td>
<td>w/cm ratio</td>
<td>ASR</td>
<td>Box Test</td>
<td>Flexural/Compressive.</td>
</tr>
<tr>
<td>Mix Design</td>
<td>Drying shrinkage</td>
<td>Formation Factor</td>
<td>Air content</td>
<td>D-Cracking</td>
<td>V-Kelly</td>
<td></td>
</tr>
<tr>
<td>Mix Design</td>
<td>Dual Ring</td>
<td></td>
<td>SAM</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>QC/Acceptance</td>
<td></td>
<td></td>
<td>CaOxychloride (LT-DSC)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Mix Design

QC/Acceptance
### What can we adjust to get Good Concrete?

<table>
<thead>
<tr>
<th>What can we adjust?</th>
<th>Shrinkage</th>
<th>Transport</th>
<th>Freeze/Thaw Durability</th>
<th>Aggregate Stability</th>
<th>Workability</th>
<th>Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>w/cm ratio</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Paste content</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Air void</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>SCM Type &amp; dose</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Aggregate gradation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
</tbody>
</table>
PEM Pooled Fund Participants
TPF-5(368)

17 States + FHWA + Industry
(October 2018)
The PEM Team

FHWA – Mike Praul, P.E.

Researchers – Dr. Jason Weiss; Dr. Tyler Ley, P.E.

Consultants – Dr. Tom VanDam, P.E.; Cecil Jones, P.E.

CP Tech – Dr. Peter Taylor, P.E; Gordon Smith, P.E.; Jerod Gross, P.E.
HOW DO WE GET THERE?

THE ROAD TO PEM

- Start
- Evaluate Process
- Shadow Projects
- Technical Assistance to State
- Performance Monitoring
- Technical Training for States
- PEM Test Refinement
- PEM Specification Refinement
- Pilot Projects with PEM Construction Specs
- Set Up Executive Task to Coordinate National Activities
- Implementation
PEM Activity 2018

- MCT/PEM Open House/Demo
  - CO, MN, IA (2018)
  - NC, KS, ID, IL (Planned 2019)

- FHWA Incentive Program Participation
  - MN, IA, NC, PA, NY, SD, WS, IL (Independent PEM work MI, KS)

- Shadow Testing
  - WI, MI, IA, SD, PA, NY

- Spec Requirements
  - WI, NY

- Test Refinement/Development

- Data Collection

- State Specification Reviews

- Training (WI, NY, MI, CO)

- Industry Collaboration
  - (ACPA-PCA-NRMCA-SCC)
Prescriptive vs Performance Specifications

• Goal of PEM is to understand how critical properties relate to performance.
• PP 84 provides a range of options for each property moving from prescriptive to performance choices.
• Initially, prescriptive options prevail while specification requirements are being confirmed for the more performance-based tests.
• Ultimately, the performance options will allow innovation and cost-effectiveness, with acceptable risk, for all parties as we understand how to set the tests limits.
 PEM Implementation Incentive Funding

- A, B, C, D
- A, B, D
- A, B
- Considering/Preparing
- No applicable project
## Category A: Incorporating two or more AASHTO PP 84-17 in the mix design/approval process (shadow testing acceptable)

<table>
<thead>
<tr>
<th>State</th>
<th>SAM</th>
<th>Box test</th>
<th>V-Kelly</th>
<th>Unit Weight</th>
<th>Bucket or CaOXY test</th>
<th>Surface resistivity</th>
<th>Additional tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Illinois</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><img src="astm_c157" alt="Illinois" /></td>
</tr>
<tr>
<td>Iowa</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td><img src="formation_factor" alt="Maturity for flexural strength" /></td>
</tr>
<tr>
<td>Minnesota</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td><img src="maturity" alt="Maturity for flexural strength" /></td>
</tr>
<tr>
<td>New York</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
<td><img src="compressive_strength" alt="Compressive strength" /></td>
</tr>
<tr>
<td>North Carolina</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Pennsylvania</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
<td>✓</td>
<td><img src="astm_c157" alt="ASTM C157, rate of flexural strength development" /></td>
</tr>
<tr>
<td>South Dakota</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Flexural strength, optimized aggregate gradation, concrete mix design</td>
</tr>
<tr>
<td>Wisconsin</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Category B: One or more new tests in the acceptance process (shadow testing acceptable)

<table>
<thead>
<tr>
<th>State</th>
<th>SAM</th>
<th>Box test</th>
<th>V-Kelly</th>
<th>Unit Weight</th>
<th>Bucket or CaOXY test</th>
<th>Surface resistivity</th>
<th>Additional tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Illinois</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td>strength</td>
</tr>
<tr>
<td>Iowa</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td>✓ formation factor</td>
<td>Plastic air, temperature</td>
</tr>
<tr>
<td>Minnesota</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>w/c with Phoenix, acceptance - optimized gradation and w/c ratio</td>
</tr>
<tr>
<td>New York</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓ formation factor</td>
<td>Exploring Payment factor for SAM, surface resistivity, f factor &amp; strength</td>
</tr>
<tr>
<td>North Carolina</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
<td>Comparing to limits proposed in PP-84 and UNC Charlotte Research</td>
</tr>
<tr>
<td>Pennsylvania</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td>✓ formation factor</td>
<td>Require slump, air, temperature, comp strength and w/c on tickets</td>
</tr>
<tr>
<td>South Dakota</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Fresh air content by SAM</td>
</tr>
<tr>
<td>Wisconsin</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Flexural strength (typically use compressive strength)</td>
</tr>
</tbody>
</table>
**Category C. Requiring a comprehensive QC Plan from the contractor that will be approved and monitored by the state**

<table>
<thead>
<tr>
<th>State</th>
<th>QC plan</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iowa</td>
<td>required</td>
<td>QC will be modified include SAM, formation factor, PWL for plastic air content and related corrective action.</td>
</tr>
<tr>
<td>Minnesota</td>
<td>required</td>
<td>QC will be modified to reflect PP 84, including unit weight, air content, water content, formation factor, flexural strength, moisture and gradation testing.</td>
</tr>
<tr>
<td>New York</td>
<td>developed</td>
<td>Currently, DOT has been performing the QC through their acceptance program.</td>
</tr>
<tr>
<td>Pennsylvania</td>
<td>required</td>
<td>Additional tests will add unit weight, SAM, water content, resistivity (f) and box test.</td>
</tr>
<tr>
<td>Wisconsin</td>
<td>Will be developed</td>
<td>WI requires a QMP plan currently. SPV will be developed requiring contractor to submit QC plan.</td>
</tr>
<tr>
<td>State</td>
<td>Intend to use</td>
<td>Currently required for</td>
</tr>
<tr>
<td>---------------</td>
<td>-------------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Iowa</td>
<td>• SAM test&lt;br&gt;• Box test&lt;br&gt;• Formation factor&lt;br&gt;• PWL for plastic air specification compliance</td>
<td>• Combined aggregate gradation&lt;br&gt;• Air content before and after paver&lt;br&gt;• Unit weight&lt;br&gt;• Moistures&lt;br&gt;• w/c ratio</td>
</tr>
<tr>
<td>Minnesota</td>
<td>• Unit weight&lt;br&gt;• SAM number&lt;br&gt;• Formation factor&lt;br&gt;• Flexural strength</td>
<td>• Air content before and after paver&lt;br&gt;• Composite gradations&lt;br&gt;• Moisture content (%)&lt;br&gt;• w/c ratio</td>
</tr>
<tr>
<td>New York</td>
<td>• w/c ratio&lt;br&gt;• Unit weight&lt;br&gt;• Air content</td>
<td>Plan includes producer and contactor to use control charts to monitor and track performance.</td>
</tr>
<tr>
<td>North Carolina</td>
<td>• Box test&lt;br&gt;• SAM test&lt;br&gt;• Resistivity test</td>
<td>• Air content&lt;br&gt;• Slump&lt;br&gt;• Unit weight&lt;br&gt;• Concrete temperature</td>
</tr>
<tr>
<td>Pennsylvania</td>
<td>• SAM test&lt;br&gt;• Air content&lt;br&gt;• Unit weight&lt;br&gt;• Water content&lt;br&gt;• Strength&lt;br&gt;• Formation factor from resistivity</td>
<td>Control chart is optional for concrete paving.</td>
</tr>
</tbody>
</table>
Iowa DOT Demonstration Project for Implementation of Performance Engineered Mixtures (PEM)/AASHTO PP 84

INTRODUCTION

The Iowa Department of Transportation applied for funds through the Performance Engineered Concrete Paving Mixtures pooled fund project (TPF-5(368)) to collect data and demonstrate the new tests. The FHWA approved the application for the full $100,000 with a 20% match for a total of $80,000. Application can be found in the Appendix.

The project location was on U.S. 20 in Woodbury County between Correctionville and Holstein. Ames Construction Inc. was awarded the $62.9 million contract for this stretch of U.S. 20, which is divided into 6 construction segments. Cedar Valley Corporation, LLC is the paving subcontractor responsible for the U.S. 20 paving. Grading and paving began in 2016 and was completed in 2018. All of the sampling and testing was performed in segment 4 westbound, roughly 11 miles within the U.S. 20 corridor between Holstein and Correctionville, Iowa. Figure 1 shows the project location.

![Figure 1: U.S. 20 Project Location](image-url)
United States
Department of Transportation

SUMMARY REPORT

US 20 Expansion
Holstein, IA
July, 2018

FHWA MCT Project # IA1802

Federal Highway Administration
Office of Preconstruction,
Construction, and Pavements
1200 New Jersey Avenue,
SE Washington, DC 20590
PEM Activity 2019

• MCT/PEM Open Houses/Demos
  ➢ NC, KS, CA
• FHWA Incentive Program Participation
  ➢ MN, WI, NY, IL, CO, ID
• Shadow Testing
  – MI, WI, NY, ID, IL, NC, KS, MN, CO
• Spec Requirements
  ➢ WI, NY
• Test Refinement/Development
• Data Collection/Analysis
• Industry Collaboration
  ➢ (ACPA-PCA-NRMCA-SCC)
PEM Activity 2019

- One-day engineering level PEM Workshops
  - Highlighting PEM Road to Implementation
- SHA assistance in establishing their PEM implementation strategy
- Technician training (ID, KS)
- Test refinements and new tests (AASHTO Task Force)
- PP-84-20 revision
- Construction specification development

- QC Guide for PEM (FHWA Co-Op)
- Precision and Bias for PEM Tests (FHWA Co-Op)
DELIVERING CONCRETE TO SURVIVE THE ENVIRONMENT

- The framework is in place
- Now we focus on the details of implementation

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