2020 Annual Virginia Concrete Conference

Count on Concrete For Value and Performance

February 27-28, 2020
The Westin Richmond
Richmond, VA

Brought to you by the ACI, Virginia Chapter, Virginia DOT, FHWA, ACPA, Mid-Atlantic Chapter, Precast Concrete Association of Virginia, Virginia Ready Mixed Concrete Association, and Southeast Cement Promotion Association
PERFORMANCE ENGINEERED MIXTURES (PEM) FOR CONCRETE PAVEMENTS

DELIVERING CONCRETE TO SURVIVE THE ENVIRONMENT

Gordon L. Smith, P.E.
Associate Director – CP Tech Center
An IOWA Story
Concrete Pavement Performance: An Old State Highway

Concrete Pavements
New challenges have to be addressed!

• Some pavement joints are deteriorating much faster than we would like!
Pavement Durability
US Highway in North Carolina
(Mid 1980s)
A County Road in the Midwest  (2009)
The discussions . . . .

- Aggregate Durability/Gradation
- Chemical Reactions ASR/ACR
- Poor Air Entrainment
- Poor Consolidation-Workability
- Sawing Practices
- Effects of Deicers and Deicing Practices
- SCM/Admixtures
- ????????????????????
“Endless conversation about CHANGE is the barrier. Actually committing to doing something and then acting is what is required.”
David Jakes
The PEM Initiative

- Understand what makes concrete “good”
- Specify the critical properties and test for them
- Design the paving mixtures to meet those specifications

The Concrete

- Gray
- Hard
- Cracked
Current Specs and Testing

• **Slump**
  √ No correlation with durability
  √ Does not measure quality

• **Air content**
  √ Poor correlation with durability
  √ Does not measure the system

• **Strength**
  √ No correlation with durability

*We have to do better to ensure durability!*
What has changed?

<table>
<thead>
<tr>
<th></th>
<th>1967</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of ingredients</td>
<td>Cement, water, rock, sand, AEA</td>
</tr>
<tr>
<td>Opening</td>
<td>Weeks</td>
</tr>
<tr>
<td>Curing</td>
<td>Weeks</td>
</tr>
<tr>
<td>De-icing</td>
<td>Sand, NaCl</td>
</tr>
<tr>
<td>Design life</td>
<td>20 years</td>
</tr>
<tr>
<td>Knowledge base</td>
<td>In house</td>
</tr>
</tbody>
</table>
### What has changed?

<table>
<thead>
<tr>
<th></th>
<th>1967</th>
<th>2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of ingredients</td>
<td>Cement, water, rock, sand, AEA</td>
<td>Add SCMs, Non-Portland cements, admixtures, intermediate aggregates, limestone…</td>
</tr>
<tr>
<td>Opening</td>
<td>Weeks</td>
<td>Days (or hours)</td>
</tr>
<tr>
<td>Curing</td>
<td>Weeks</td>
<td>Days</td>
</tr>
<tr>
<td>De-icing</td>
<td>Sand, NaCl</td>
<td>Other chlorides, formates, acetates</td>
</tr>
<tr>
<td>Design life</td>
<td>20 years</td>
<td>50 years</td>
</tr>
<tr>
<td>Knowledge base</td>
<td>In house</td>
<td>Contracted out</td>
</tr>
</tbody>
</table>
A modernized specification . . .

✓ Require the things that matter
✓ Measure them at the right time

✓ Develop test methods
✓ Develop “Guide Specification” (AASHTO’s PP-84)
✓ Develop tools to proportion mixtures

✓ Conduct Shadow evaluations

✓ Later
  ➢ Guide/monitor Pilot projects
  ➢ Develop PWL models
  ➢ Guide in Q/C Programs
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
Test Methods

• Tests for those critical properties
  ➢ VKelly  (Workability)
  ➢ Box    (Workability)
  ➢ Resistivity / Formation  (Transport) factor
  ➢ Bucket / Sorptivity
  ➢ Dual ring  (Shrinkage)
  ➢ SAM   (Cold Weather Resistance)
### How & when do we measure?

<table>
<thead>
<tr>
<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><strong>How do we measure?</strong></td>
<td>Paste content</td>
<td>Resistivity Forma</td>
<td>w/cm ratio Air content SAM CaOxychloride (LT-DSC)</td>
<td>ASR D-Cracking</td>
<td>Box Test V-Kelly</td>
</tr>
<tr>
<td>Mix Design</td>
<td>Drying shrinkage</td>
<td>Factor</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>QC/Acceptance</td>
<td>Dual Ring</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Mixture Proportioning

• Limited guidance on proportioning
  • w/cm
  • Paste content

• Allows contractor to work with their materials and equipment
• Tools available to help achieve performance

<table>
<thead>
<tr>
<th></th>
<th>Workability</th>
<th>Transport</th>
<th>Strength</th>
<th>Cold weather</th>
<th>Shrinkage</th>
<th>Aggregate stability</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aggregate System</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type, gradation</td>
<td>✓ ✓</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>✓ ✓</td>
</tr>
<tr>
<td><strong>Paste quality</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Air, w/cm, SCM type and dose</td>
<td>✓ ✓</td>
<td>✓ ✓</td>
<td>✓ ✓</td>
<td>✓ ✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td><strong>Paste quantity</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vp/Vv</td>
<td>✓ ✓</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>✓ ✓</td>
<td>-</td>
</tr>
</tbody>
</table>
Mixture Proportioning
**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>

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Standard Practice for Developing Performance Engineered Concrete Pavement Mixtures

- Standard Practice – guidance for FHWA-State DOTs-Industry
- A dynamic “work-in-progress” that initiates our endeavor to embrace Performance Engineered Mixtures
Performance Engineered Mixtures

• A broad initiative with a goal of implementing performance specifications for concrete, including an increased emphasis on durability.
The PEM Team

FHWA - Gina Ahlstrom, P.E., Mike Praul, P.E., Bob Conway 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.
PEM/TPF Project Emphasis

- Implementation
- Education and Training
- Adjustments in specification based on field performance
- Continued development of a knowledge base relating early age properties to performance
PEM Activity 2018

- MCT/PEM Open House/Demo in CO - May 2018
- MCT/PEM Open House/Demo in MN - July 2018
- MCT/PEM Open House/Demo in IA - July 2018
- Comparative Testing – SD/CP Tech – September 2018
- Demo/Open House(s) in PA - TBD
- FHWA Incentive Program Participation – MN, IA, NC, PA, NY, SD, WS, IL (Independent PEM work in MI, KS)
- PP-84 Guide Specification Update 2019
- Test Refinement/Development
- Equipment Loan Program from FHWA
- Shadow testing and data collection
- Industry Collaboration
  - (ACPA-PCA-NRMCA-SCC)
Why We’re Excited

**Concrete Evolution**

- PEM: Most significant field-level advancement in decades
- Answers the question “With our loss of staff and resources, how are we going to be able to get the job done in the future?”
- Requires collaboration with industry (It’s more than just the tests!)
Implementation Incentive Funding

FHWA PEM INCENTIVE PROJECTS

A - Incorporating 2 or more AASHTO P-84 tests in the mix design/approval process

B – Including one or more new tests in the acceptance process

C – Requiring a comprehensive QC plan from the contractor, monitored by the state

D – Requiring the use of control charts as called for in AASHTO) PP-84

A, B, C, D
A, B, D
A, B
Considering/Preparing
No applicable project
Image provided by CP Tech Center under FHWA contract.
Pract, Michael (FHWA), 2/1/2018
PEM Activity 2019

- One-day engineering level PEM Workshop
- Specification review and SHA assistance in establishing their PEM implementation strategy
- Technician training
- Shadow testing data collection
- QC/QA Plan (Co-Op)
- Test refinements and new tests (AASHTO Task Force)
- PP-84-20 revision
- Construction specification development
- FHWA Incentive/Shadow Testing Projects
- MCT/PEM Open House/Demos in NC, CA, KS
PEM Revisited
(November 2019 TAC Meeting)

• AASHTO PP84 is an overall guide to mix design development. The document includes a quality control program framework consistent with performance specifications
• Development and implementation of enhanced Quality Control programs, including agency specifications and oversight
• Changing from the historically prescriptive approach to concrete specifications to a performance type specifications. Typical specification changes include removing slump requirements, eliminating minimum cement content requirements, and removing single aggregate gradation requirements, eventually including construction oriented examples as well.
Quality Control

- PEM acknowledges the key role of QC in a performance specification
- Requires an approved QC Plan
  - Testing targets, frequency, and action limits
  - Equipment and construction inspection
    - Mirror design-build experience
- Requires QC testing and control charts
  - Unit weight
  - Air content/SAM
  - Water content
  - Formation Factor (via Surface Resistivity)
  - Strength
Looking Forward

• Collaboration with SHAs, FHWA and Industry along the road toward PEM implementation for concrete pavements – (Specs/Training/Questions)
• Shadow testing - shadow testing - shadow testing
• Data gathering/analysis/sharing for PEM test verification and a long term pavement performance record
• Training model for PEM tests (Who, When, How)
  ✓ Emphasis on a PEM QC guide/format
  ✓ Precision and Bias for PEM tests
  ✓ A PEM construction specification incorporating incentives/PRS
• Pilot projects WI & KS
THE ROAD TO PEM
PERFORMANCE ENGINEERED MIXTURES FOR CONCRETE PAVEMENTS

A POOLED FUND PROJECT FOR IMPLEMENTATION
WHAT MATTERS?
OUTREACH TO STATE DOTS/INDUSTRY

SHADOW TESTING/DATA COLLECTION

QC ENHANCED FOR PEM

DELIVERING CONCRETE TO SURVIVE THE ENVIRONMENT WITH PEM
PRS FOR PEM
A DEVELOPMENTAL SPECIFICATION FOR PILOT PROJECT
DELIVERING CONCRETE TO SURVIVE THE ENVIRONMENT

- The framework is in place
- Now we are focused on the details of confirmation and implementation

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