PEM: Where We Are Today

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All images FHWA unless otherwise noted
Performance Engineered Mixture (PEM) Concepts

- Get beyond slump, strength, and total air content as determinants of concrete quality
- Incorporate tests that correlate to service life durability
- Appropriately apply those tests in agency acceptance and contractor quality control programs
- Develop specifications and practices to leverage quality control
- Remove prescriptive restraints from specifications
  - Minimum cement content
  - Single aggregate gradation
  - Slump
Performance is NOT...

Performance Related Specifications (PRS)

Performance Based Specifications (PBS)
PEM is NOT...

All or nothing

A goal
Why PEM? Why Now?

- Increasing observations and documentation of premature concrete failures
- MAP-21 and FAST ACT focused on performance
- Industry motivation to innovate and produce longer-lasting, more economical concrete
- Concrete materials and service environment are changing (cements, SCMs, admixtures, de-icers)
- Promising new testing technologies (Super Air Meter, Surface Resistivity, Box Test, V-Kelly, etc.)
- Sustainability becoming a priority for State agencies
## Prescriptive vs. Performance Specifications

<table>
<thead>
<tr>
<th>Prescriptive/Method</th>
<th>Performance</th>
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<tbody>
<tr>
<td>Agency dictates how the material or product is formulated and constructed</td>
<td>Agency identifies desired characteristics of the material or product</td>
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<td>Based on past experience</td>
<td>Contractor controls how to provide those characteristics</td>
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<td>Minimal/uncertain ability to innovate</td>
<td>Maximum ability to innovate</td>
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<td>Involves agency capacity and skill set to provide oversight</td>
<td>More efficient use of agency resources</td>
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Better Assessment of Quality?

**Option 1**
- QC info: None
- Strength
- Slump
- Total Air

**Option 2**
- QC info:
  - Unit weight
  - Calorimetry
  - Water content (Phoenix)
- Strength
- Resistivity
- SAM number
Quality Control for Concrete Paving: A Tool for Agency and Industry

Developed under a cooperative agreement; use is not required by Federal statute or regulation.
## Technical Advisory Committee (TAC) Roster

<table>
<thead>
<tr>
<th>State Agencies</th>
<th>Contractors</th>
<th>Industry/Associations</th>
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<tbody>
<tr>
<td>Maine DOT – Rick Bradbury</td>
<td>Rieth-Riley – Pete Capon</td>
<td>ACPA – Leif Wathne, Gary Mitchell</td>
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<td>Michigan DOT – John Staton</td>
<td>Cedar Valley – Craig Hughes</td>
<td>NRMCA/RMCREF – Colin Lobo</td>
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<td>Ohio DOT – Dan Miller</td>
<td>AJAX – Hugh Luedtke</td>
<td>PCA – Paul Tennis</td>
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<td>Iowa DOT – Todd Hanson</td>
<td>Duit Construction – John Privat</td>
<td>WCPA – Kevin McMullen</td>
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<td>Minnesota DOT – Maria Masten</td>
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<td>Illinois Tollway – Cindy Williams</td>
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<td>Mike Praul, Bob Conway, Sam Tyson, Dennis Dvorak, Jeff Withee</td>
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19 States + FHWA + Industry (January 2022)

⭐ PEM Implementation Incentive Pilot Project
PEM approach typically is beneficial to State and industry

PEM mix tested better in all tests vs. Class C

2\textsuperscript{nd} supplier was reluctant to participate

- Determined QC requirements were not much more than the existing ones
- Mix looked and placed better than Class C

Needs

- Training in new tests
  - Understanding roles and responsibilities in a performance specification (including QC monitoring)
- Consider 56-day testing for resistivity

Four projects in progress. 2023: Full program!
New York Highlights

Class C SR vs. Class PEM SR

- Surface Resistivity (kΩ)
- 14 Day: 9.3, 9.9
- 28 Day: 10.7
- 42 Day: 14
- 56 Day: 15.9
- 70 Day: 18
- 84 Day: 20
- 91 Day: 20.9
- 98 Day: 21.8
- 112 Day: 22.8
- 126 Day: 23.5
- 140 Day: 24.6
- 154 Day: 26.8

*42 Day Class C point was averaged due to missing data*
North Carolina Highlights

- **Box Test**
  - Highly useful in mix development and evaluation. (contractor)
  - Simple, easy test. Potential to add to specification. (NCDOT)

- **Super Air Meter**
  - After some training, readily incorporated into QC. (contractor)
  - Doing more shadow testing and consider future use. (NCDOT)

- **Surface Resistivity**
  - Easy. Readily incorporated into QC. (contractor)
  - Easy. Affordable equipment. Will equip all State labs. (NCDOT)
  - UNC-Charlotte working to develop 28-day result to correlate with 56-day results.
North Carolina QC

Successive trial batches with mixture proportions changed to improve consistency.

Figure 6: Control chart showing 28-day resistivity for mixture 460SLNS during Phase 1 and Phase 2.
“Valuable experience.” (contractor and NCDOT)

“Due to project schedule, we were unable to apply the PEM criteria during the preliminary mix design phase. However, going forward, we intend to implement PEM guidelines on future PCCP (Portland Cement Concrete Pavement) projects.” (Contractor)

“The Department will continue to explore PEM to see how these tests and other AASHTO PP 84 provisions will work with our daily operations.” (NCDOT)

NCDOT will pilot PEM bridge project.
Colorado

- MCTC visit/Open House (2018)
- Spec revision (2019)
  - Removed max and min cement content
  - Allows optimized aggregate gradation
  - Box Test in mix design
  - Resistivity
  - Max shrinkage
- Industry support for PEM
Kansas

- Open house & shadow testing 2019
- Training Day – all DOT districts trained with SAM (2019)
- Considering requiring SAM in mix design
- Resistivity testing for 5 years
- Optimized aggregates for 10 years
PEM and Sustainability
Suggested Ways to Optimize Cement Content

- Move to performance-type specification language; eliminate mandatory cement content requirements
- Optimize aggregate gradation
- Use supplementary cementitious materials
- Use maturity testing to determine opening times
- Promote quality control in the plant to provide more consistent production
Change has already happened!

- Cements
- Widespread use of SCMs
- Advancements in chemical admixture technology
- De-icers
- Agency personnel and experience levels
- Industry knowledge base
PEM...

- It’s good concrete engineering
- It’s catching on
  - States beyond the PEM pooled fund
  - Federal Aviation Administration/Department of Defense
- It’s here to stay
- It’s evolving
“Live From the MCTC” Training/Workshops

- Super Air Meter (SAM)
- Surface/Bulk Resistivity
- Maturity
- Box Test/V-Kelly
- Semi-adiabatic calorimeter

- Phoenix (water content)
- Pulse induction
- Dowel bar measuring
- Performance software
- Optimized gradation software
Questions?

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