PERFORMANCE ENGINEERED MIXTURES (PEM) FOR CONCRETE PAVEMENTS

Delivering Concrete To Survive The Environment
EVOlution

In The Art And Science Of Concrete Pavements

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National Concrete Pavement Technology Center
1909 – Eddyville, la Cemetery Road
Old State Highway

Response To A Need
County Pavement Constructed in 2009
The Journey Toward Performance Engineered Mixes (PEM)

• Near the millennium, concerns about concrete durability and poor pavement performance became a common topic of discussion in many concrete intensive states.
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
- ??????????????????
## What’s Changing?

<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>
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<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>
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</tbody>
</table>
The Journey Toward Performance Engineered Mixes (PEM)

- 2013 – NC² established an Expert Task Group (ETG) to further discuss and explore an action plan responsive to the concerns.
The PEM Initiative

- A partnership of agency and industry:
  - Understand what makes concrete “good”
  - Specify the critical properties and test for them
  - Design the paving mixtures to meet those specifications
Critical Properties for Durable Concrete

➢ Transport properties (everywhere)
➢ Aggregate stability (everywhere)
➢ Strength (everywhere)
➢ Cold weather resistance (cold locations)
➢ Shrinkage (dry locations)
➢ Workability (everywhere)
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

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Standard Practice for
Developing Performance Engineered Concrete Pavement Mixtures

AASHTO Designation: PP 84-17¹
Tech Section: 3c, Hardened Concrete
Release: Group 1 (April 2017)
Tech Brief working copy

American Association of State Highway and Transportation Officials
444 North Capitol Street N.W., Suite 240
Washington, D.C. 20001
<table>
<thead>
<tr>
<th>Mixture parameter</th>
<th>Traditional acceptance criteria</th>
<th>Property</th>
<th>Specification reference</th>
<th>Specified test</th>
<th>Selection details</th>
<th>Mixture qualification</th>
<th>Acceptance</th>
<th>Special notes</th>
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<tbody>
<tr>
<td>Aggregate stability</td>
<td>✓</td>
<td>D cracking</td>
<td>6.7.1</td>
<td>TMI1, ASTM C144</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Alkali aggregate reactivity</td>
<td>6.7.2</td>
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<td>Transport properties</td>
<td>✓</td>
<td>Water to cementitious materials (w/cm) ratio</td>
<td>6.6.1.1</td>
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<td>Choose only one</td>
<td>✓</td>
<td>✓</td>
<td>The required maximum water to cementitious ratio is selected based on freeze-thaw conditions</td>
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<td></td>
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<td>formation factor</td>
<td>6.6.1.2</td>
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<td>✓</td>
<td>Based on freeze-thaw conditions; other criteria could be selected</td>
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<td></td>
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<td>Ionic penetration, F factor</td>
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<td>Appendix K2</td>
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<td>✓</td>
<td>Determined using guidance provided in Appendix K2</td>
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<td>Durability of hydrated cement paste for freeze-thaw durability</td>
<td>✓</td>
<td>Water to cementitious materials (w/cm) ratio</td>
<td>6.5.1.1</td>
<td>—</td>
<td>Choose either 6.6.1.1 or 6.8.2.1</td>
<td>¡</td>
<td>✓</td>
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<tr>
<td></td>
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<td>Fresh air content</td>
<td>6.5.1.2</td>
<td>T152, T196, T918</td>
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<td>✓</td>
<td>✓</td>
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<td>Fresh air content-2AM</td>
<td>6.5.1.3</td>
<td>T152, T196, T918</td>
<td>Choose only one</td>
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<td>Time to critical saturation</td>
<td>6.5.2.1</td>
<td>“Bucket Test”</td>
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<td>Variation controlled with mixture proportion observation or F factor and porosity measures</td>
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<td>Drying salt damage</td>
<td>6.5.3.1</td>
<td>35% SCM</td>
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<td>Are calcium or magnesium chlorides used</td>
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<td>Drying salt damage</td>
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<td>✓</td>
<td>Are calcium or magnesium chlorides used; use specified sealers</td>
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<td></td>
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<td>Calcium sulfate limit</td>
<td>6.5.4.1</td>
<td>T 305-17</td>
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<td>Are calcium or magnesium chlorides used</td>
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<td>Hydrating cement paste cracking and shrinkage due to shrinkage</td>
<td>✓</td>
<td>Volume of paste (28%)</td>
<td>6.4.1.1</td>
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<td>Unstrained volume change</td>
<td>6.4.1.2</td>
<td>ASTM C157</td>
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<td>Restrained shrinkage</td>
<td>6.4.2.2</td>
<td>T3M</td>
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<td>Restrained shrinkage</td>
<td>6.4.2.3</td>
<td>TP 362-17 (Dual Ring)</td>
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<td></td>
<td>Probability of cracking</td>
<td>6.4.2.4</td>
<td>Appendix K1</td>
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<td>Quality control check</td>
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<td>Concrete strength</td>
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<td>Flexural strength</td>
<td>6.3.1</td>
<td>T 57</td>
<td>Choose either or both</td>
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<td>✓</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Compressive strength</td>
<td>6.3.2</td>
<td>T 22</td>
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<tr>
<td>Workability</td>
<td>✓</td>
<td>Sump</td>
<td>6.8.1</td>
<td>Appendix 2</td>
<td>Choose one</td>
<td>—</td>
<td>—</td>
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<td></td>
<td>V-Kelly test</td>
<td>6.8.2</td>
<td>Appendix 4</td>
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</table>
PEM Pooled Fund Partners
TPF-5(368)

17 States + FHWA + Industry
The PEM Team

- FHWA - Gina Ahlstrom, Mike Praul
- Researchers – Jason Weiss, Tyler Ley
- Consultants – Tom VanDam, Cecil Jones
- CP Tech – Peter Taylor, Gordon Smith, Jerod Gross
A Modernized Specification

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

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

✓ Conduct Shadow evaluations

✓ Later
  ➢ Guide/monitor Pilot projects
  ➢ Develop PWL models/PRS
  ➢ Guide in Q/C Programs
What is Concrete?

- Rock +
- Sand +
- Portland cement +
- Other grey powders +
- Water +
- Chemicals =

- Artificial rock
What is **Good Concrete**?

- Gray?
- Cracked?
- Hard?

- Strong
- Lasts forever

- Cheap
What is Good Concrete?

• Constructable (Workable)
• Dimensionally stable
  ✓ Aggregates
  ✓ Shrinkage
• Impermeable (Transport properties)
• Cold weather resistant
  ✓ Freeze thaw
  ✓ Salt attack
• Strong (enough)
How do we know it is good?

• Set the recipe
• Watch the process
• Poke it occasionally
• Break a sample
• Wait and see when it dies
The Perfect Test

• Fast
• Cheap
• Representative
• Repeatable
• Right
• Meaningful
The perfect test on a material that:

- Is mixed from variable ingredients
- Starts as a liquid and ends up holding up civilization
- Changes over time
- Changes with the weather
- Changes under load
- Changes when attacked

- Perfection is tricky
- “Good enough for engineering purposes” is not
But I have been doing it this way for 40 years…

• Current approaches
  ✓ May not measure critical parameters
  ✓ Are often built around previous failures – thereby introducing unintended consequences
  ✓ Limit innovation

Need to deliver mixtures that meet needs, reliably
How Do We Stay Safe?

- Some things we measure during prequalification
  - ✔ Workability
  - ✔ Aggregate stability
  - ✔ Shrinkage...

<table>
<thead>
<tr>
<th>Concrete property</th>
<th>Test description</th>
<th>Test method</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workability</td>
<td>Aggregate gradation</td>
<td>ASTM C 136 / AASHTO T 27, ASTM C 566 / AASHTO T 255</td>
<td>- Use the individual gradations and proportions to calculate the combined gradation.</td>
</tr>
<tr>
<td></td>
<td>Combined gradation</td>
<td>Tarantula curve</td>
<td>- Adjust combined gradation to achieve optimum workability.</td>
</tr>
<tr>
<td></td>
<td>Paste content</td>
<td>Batch chart</td>
<td>- Adjust paste content to find minimum paste needed while still workable. - Confirm that total is below maximum permitted for shrinkage.</td>
</tr>
<tr>
<td></td>
<td>VKelly or Box</td>
<td>T9120 / PP84 X2</td>
<td>- Confirm that the mixture responds well to vibration.</td>
</tr>
<tr>
<td></td>
<td>Slump at 0, 5, 10, 15, 20, 25, &amp; 30 minutes</td>
<td>ASTM C 143 / AASHTO T 119</td>
<td>- Look for excessive slump loss due to incompatibilities. This is more likely at elevated temperatures. - Determine approximate WRA dosage.</td>
</tr>
<tr>
<td></td>
<td>Segregation</td>
<td>-</td>
<td>- Look for signs of segregation in the slump samples.</td>
</tr>
<tr>
<td></td>
<td>Air void system</td>
<td>-</td>
<td>- Assess stability of the air void system for the cementitious / admixture combination proposed.</td>
</tr>
<tr>
<td></td>
<td>Foam drainage</td>
<td>-</td>
<td>- Determine approximate AEA dosage.</td>
</tr>
<tr>
<td></td>
<td>Air content</td>
<td>ASTM C 231 / AASHTO T 152, T196</td>
<td>- - 0.2 target.</td>
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<tr>
<td></td>
<td>SAM</td>
<td>AASHTO TP118</td>
<td>- - 0.2 target.</td>
</tr>
<tr>
<td></td>
<td>Clustering</td>
<td>Re collects a sample and uses optical microscopy to assess clustering</td>
<td>- Can assess strength. - Air content can also jump with remeasuring.</td>
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<tr>
<td></td>
<td>Hardened air</td>
<td>ASTM C 457</td>
<td>- Calibrate SAM limits.</td>
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<tr>
<td></td>
<td>Mortar content</td>
<td>Vibrate a container (air pot) for 5 minutes. Measure depth of mortar at the top surface</td>
<td>- Provides information on the coarse aggregate content - maximum is ~ 1/8”.</td>
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<tr>
<td></td>
<td>Unit weight</td>
<td>Unit weight</td>
<td>- Calibrate with test batch data.</td>
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<tr>
<td></td>
<td>Strength development</td>
<td>Compressive or flexural strength</td>
<td>ASTM C 39 / AASHTO T 22 and/or ASTM C 78 / AASHTO T 97 at 1, 3, 7, 28 &amp; 56 days</td>
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<tr>
<td></td>
<td></td>
<td>Maturity</td>
<td>ASTM C 1094</td>
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<tr>
<td></td>
<td>Transport</td>
<td>Resistivity / F factor</td>
<td>Soak store samples in salt solution</td>
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<td></td>
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<td>Sorption</td>
<td>ASTM C 1585</td>
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<td>w/cm</td>
<td>Microwave</td>
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<tr>
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<td>Other</td>
<td>Hydration</td>
<td>- Semi-adiabatic calorimetry</td>
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</table>
How Do We Stay Safe?

• Some things we measure during construction for acceptance
  ✓ Transport
  ✓ Air void system
  ✓ Strength

<table>
<thead>
<tr>
<th>Concrete property</th>
<th>Test description</th>
<th>Test method</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workability</td>
<td>Slump</td>
<td>ASTM C 143 / AASHTO T 119</td>
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<td>Air void system</td>
<td>SAM</td>
<td>AASHTO TP118</td>
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<td>Strength</td>
<td>Compressive or flexural strength</td>
<td>ASTM C 39 / AASHTO T 22 and/or ASTM C 78 / AASHTO T 97</td>
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<td>Transport</td>
<td>Resistivity / F factor</td>
<td>Soak samples in salt solution</td>
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<tr>
<td>Other</td>
<td>w/cm</td>
<td>Microwave</td>
<td></td>
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</tbody>
</table>
How Do We Stay Safe?

- Contractor also needs to watch how things are developing
  - Workability
  - Unit weight
  - Maturity…

<table>
<thead>
<tr>
<th>Concrete property</th>
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</tr>
</thead>
<tbody>
<tr>
<td><strong>Workability</strong></td>
<td>Aggregate gradation</td>
<td>ASTM C 136 / AASHTO T 27, ASTM C 566 / AASHTO T 255</td>
<td>Use the individual gradations and proportions to calculate the combined gradation.</td>
</tr>
<tr>
<td></td>
<td>Combined gradation</td>
<td>Tarantula curve</td>
<td>Monitor uniformity</td>
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<tr>
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<td>Aggregate moisture content</td>
<td>ASTM C 29</td>
<td>Affects w/cm and workability</td>
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<td>Slump</td>
<td>ASTM C 143 / AASHTO T 119</td>
<td>Indicates uniformity batch to batch</td>
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<tr>
<td><strong>Air void system</strong></td>
<td>SAM</td>
<td>AASHTO TP 118</td>
<td>Indicates uniformity batch to batch</td>
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<tr>
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<td>Unit weight</td>
<td>ASTM C 138 / AASHTO T 121</td>
<td>Indicates uniformity batch to batch</td>
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<td><strong>Strength development</strong></td>
<td>Compressive or flexural strength</td>
<td>ASTM C 39 / AASHTO T 22 and/or ASTM C 78 / AASHTO T 97</td>
<td>Indicates uniformity batch to batch</td>
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<td>Maturity</td>
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<td><strong>Transport</strong></td>
<td>Resistivity / F factor</td>
<td>Soak samples in salt solution</td>
<td>Monitor over time, Indicates uniformity batch to batch</td>
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<td><strong>Other</strong></td>
<td>Hydration</td>
<td>Semi-adiabatic calorimetry</td>
<td>Indicates uniformity batch to batch</td>
</tr>
</tbody>
</table>
Workability

- Not too wet
- Not too dry
Workability

• Slump
  ✓ Great for uniformity
  ✓ Cheap, fast and familiar
  ✓ Does not tell about response to vibration

✓ QC
Workability

- Box
  - ✅ Does tell about response to vibration
  - ✅ Adjust aggregate gradation and paste content to achieve desired numbers
  - ✅ Subjective

- ✅ Prequalification
- ✅ QC
Box Test

- The edges of the box are then removed and inspected for honey combing and edge slump.

<p>| | |</p>
<table>
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<tbody>
<tr>
<td>4</td>
<td>3</td>
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<tr>
<td>Over 50% overall surface voids.</td>
<td>30-50% overall surface voids.</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>10-30% overall surface voids.</td>
<td>Less than 10% overall surface voids.</td>
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</tbody>
</table>
Workability

• VKelly
  ✓ Does tell about response to vibration
  ✓ Adjust aggregate gradation and paste content to achieve desired numbers

✓ Prequalification
✓ QC
VKelly

- Measure initial slump (initial penetration)
- Start vibrator for 36 seconds at 8000 vpm
- Record depth every 6 seconds
- Repeat
- Plot on root time
- Calculate slope = VKelly Index

![Graph showing incremental penetration depth vs vibration duration]

\[ y = 2.1371x + 0.6778 \]
Workability

- What if it is bad?
  - ✓ Aggregate gradation (Tarantula)
  - ✓ Paste content
  - ✓ Admixture choice and dosage
  - ✓ Cementitious system

- ✓ Don’t add water!
Workability

• Better concrete!
Aggregate Stability

- If aggregates expand = damage

- Prequalification
Aggregate Stability

- Alkali aggregate reaction
  ✔ AASHTO R80 / ASTM C 1778
Aggregate Stability

• D-Cracking
  ✓ Iowa Pore Index Test
  ✓ Freeze thaw test
  ✓ Ledge control
  ✓ State practice

✓ Pick one…
Aggregate Stability

• What if it is bad?
  ✓ Change aggregates
  ✓ If alkali reactive, investigate SCM dosage
Shrinkage

• Influences cracking risk
• Controls warping
• Takes time

• Prequalification
**Shrinkage**

- Paste content (read the batch sheet)
  - Easy
  - Fast

<table>
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<tr>
<th>Mixture Proportions</th>
<th>Targets</th>
<th>Actual</th>
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<td>Cement Type I</td>
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<td>SCM 1 F Ash</td>
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<td>SCM 2 Slag</td>
<td>0</td>
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<td>Coarse Agg A85006</td>
<td>1753</td>
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<td>Fine Agg A25518</td>
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<td>2.66</td>
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<td>Intermediate A85007</td>
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<td>Water</td>
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<table>
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<th>Targets</th>
<th>Actual</th>
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<td>Cementitious</td>
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<td>428 pcy</td>
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<td>Volume of paste</td>
<td>24.0</td>
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<tr>
<td>Volume of aggs</td>
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<td>%</td>
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<tr>
<td>Volume of voids</td>
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<td>%</td>
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<td>125.0</td>
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<tr>
<td>w/cm</td>
<td>0.42</td>
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<tr>
<td>% SCM 1</td>
<td>20</td>
<td>20 %</td>
</tr>
<tr>
<td>% SCM 2</td>
<td>0</td>
<td>0 %</td>
</tr>
<tr>
<td>Mass aggs</td>
<td>3411</td>
<td>3411 pcy</td>
</tr>
<tr>
<td>Excess paste, %</td>
<td>4.8</td>
<td>%</td>
</tr>
</tbody>
</table>
Shrinkage

• What if it is bad?
  ✓ Reduce paste content
  ✓ Check clay content of aggregate
  ✓ Consider internal curing
  ✓ Consider shrinkage reducing admixtures
Transport Properties (Permeability)

• All deterioration mechanisms involve fluid movement
• Keep water out = longer life
• Measurement has been difficult

• Prequalification
• QC
• Acceptance
Formation Factor

• Resistivity
  ✓ Store a cylinder in a fixed salt solution
  ✓ Pull out at desired age
  ✓ Read and put back
  ✓ Repeat
  ✓ Calculate formation factor (x10)

\[ F = \frac{\text{Resistivity (bulk)}}{\text{Resistivity (solution)}} \]
Transport

• What if it is bad?
  ✓ Review w/cm
  ✓ Review SCM type and dose
Cold Weather

- Freeze-thaw
  - ✓ Saturation
  - ✓ Entrained air
- De-icing salts
  - ✓ Sufficient SCM
Is the Pressure Pot Sufficient?
Super Air Meter

- Reports air content and SAM number
- SAM number correlates with freeze-thaw testing
Super Air Meter

- Correlation with spacing factor is being reviewed
- Training and machine maintenance are critical

- Prequalification
- QC
- Acceptance (later)
• What if it is bad?
  ✓ Review AEA type and dose
  ✓ Review WRA interactions
  ✓ Review SCM interactions
Salts can cause chemical attack

- Calcium oxychloride
  ✓ Reaction between Ca(OH)$_2$ and calcium or magnesium chloride
  ✓ Expands 30%
  ✓ Forms above 32°F

- Prevention
  ✓ Enough SCM

CaCl$_2$ @ 40°F
Sutter Weiss
Tests for Oxychloride

- Low temperature differential scanning calorimetry (LT-DSC)
- Expansion
- Prequalification
Oxychloride

• What if it is bad?
  ✓ Review SCM type and dosage
**Strength**

- Strong enough to carry loads
  - ✓ Cylinders
  - ✓ Beams
  - ✓ Maturity

- Prequalification
Put it all together into
A Better Specification

✓ Measure the right things at the right time
  ➢ Prequalification
  ➢ Process control
  ➢ Acceptance
✓ Appropriate limits
✓ Appropriate remedial actions / bonuses
But…

• Too many tests!
  ✔ Acceptance testing is actually reduced
  ✔ QC testing is increased, but can you afford not to do it?

• That variability!!
  ✔ Use the data to watch trends and react early

• Too much change!!!
  ✔ OK please turn in your smart phone, flatscreen TV, and fuel efficient truck
But…

• My mixtures will be changed!!!!
  ✓ Most of the time:
    ➢ Quality aggregates
    ➢ w/cm = 0.42
    ➢ Air as you have been doing
    ➢ Enough SCM

• IA, PA, SD, MN, WI, MI, NC experience
Why We’re Excited

Concrete Evolution

- PEM: It’s our Superpave
- 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?”
- Collaboration with industry (It’s more than just the tests!)
Prescriptive vs. Performance Specifications

**Prescriptive**
- Agency dictates how the material or product is formulated and constructed
- Based on past experience
- Minimal/uncertain ability to innovate
- Requires agency to have proper manpower and skill set to provide oversight

**Performance**
- Agency identifies desired characteristics of the material or product.
- Contractor controls how to provide those characteristics
- Maximum ability to innovate
- Reduced oversight burden on the agency
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
Visit the PEM website:

www.cptechcenter.org/PEM

PEM Publications
One sheet test descriptions
Videos showing each test method
Progress Updates
Calendar of Open Houses/Demos

Performance Engineered Mixtures (PEM):
Delivering Concrete to Survive the Environment

About PEM
Test Methods
Schedule of Shadow Projects
For More Information

PEM has traditionally accepted, concrete based on
measurements too strength, curing, and air, these
measurements, in most cases, have very limited
relevance to future performance. Recent developments in
concrete testing technology have paved the way for
more accurate testing methods that will help them deliver
performance concrete products.

The goal of the PEM Transportation Paved Test Projects
is to bring these newer technologies to state agencies and
be used states in adoption of the test methods that will help them deliver
higher performing concrete products.

The Federal Highway Administration (FHWA), State
Highway Administrators, and the National Association
of State Transportation Officials (NASTO) formed a
consortium of testing agencies and laboratories, which
recently released its recommendations for the
Performance Engineered Mixtures (PEM) test program.

PEM Publications
One sheet test descriptions
Videos showing each test method
Progress Updates
Calendar of Open Houses/Demos
Resources

Ensuring that agencies can specify—and contractors can deliver—durable concrete pavements, every time

March 2017
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An Innovative Program for Pavement Reliability
The Performance Engineered Mixtures (PEM) program is designed to provide the tools for agencies to specify, and contractors to deliver, concrete mixtures that reliably and sustainably meet the needs for concrete infrastructure.

The PEM program will result in concrete pavements consistently achieving the performance life of the design. The program is based on the concept of measuring and controlling the concrete mixture around engineering properties that actually relate to performance:

- Identifying critical mixture properties for long-term durability specific to any climatic environment
- Achieving these properties through measuring the performance-related engineering parameters of the mixtures
- Developing a specification for mixtures
- Providing technical guidance and project-level support for preparing and delivering concrete mixtures that meet the specification

Iowa State University
Institute for Transportation
Performance Engineered Mixtures (PEM) for Concrete Pavements

Introduction
Concrete pavements are designed to perform for decades under harsh service conditions. Owners invest in them because of their ability to provide a safe, low-maintenance, long-life solution to a full range of needs, from low-volume secondary roads to the highest volume interstate applications in the country. With recent advancements in testing technologies, it is now possible to more directly measure the key properties of concrete paving mixtures that relate to performance and design them to perform with increased reliability in all climatic regions.

This tech brief will explain how concrete paving mixtures can be engineered to meet performance requirements and how to incorporate key performance parameters into a robust specification and quality process.

Why performance-engineered mixtures are needed
Concrete paving specifications have not kept pace with advancements in concrete science and innovations in testing technologies. Current specifications are still largely based on strength, slump, and air content and have been for over 50 years. While these are important parameters, there are other parameters that are not being measured that are equally or more important. Mixtures have become more complex with a growing range of chemical admixtures and supplementary cementitious materials (SCMs). Traffic is increasing, more aggressive winter maintenance practices are the norm, and demands are growing for systems to be built more quickly, less expensively, and with increased longevity.

Many local specifications are predominantly prescriptive, thus limiting the potential for innovation and not necessarily addressing current materials, environments, or construction methodologies.

Recognizing the need to advance concrete paving specifications, the Federal Highway Administration (FHWA), the American Concrete Pavement Association, the Portland Cement Association, and other industry partners, and member states of the National Concrete Consortium (NCC) are collaborating with the research and technical community to modernize the specifications for paving mixtures. This partnership formally began in April 2015 at the spring meeting of the NCC, with the formation of an Expert Task Group that included seven champion states (Indiana, Iowa, Minnesota, Michigan, Nebraska, South Dakota, Wisconsin, the Illinois Tollway, and Manitoba). FHWA shared vision was to have a provisional American Association of State Highway and Transportation Officials (AASHTO) specification by 2017. This vision has become a reality.

In April of 2017, AASHTO will publish PP 84-17, Developing Performance Engineering Concrete Pavement Mixtures (figure 1). The focus now shifts from this first step to technical education of agencies and industry on how to apply the PEM specification within an integrated framework that provides for innovation and local optimization.

The Long-Term Plan for Concrete Pavement Research and Technology (CP Road Map) is a national research plan developed and implemented by the concrete pavement stakeholder community. Publications and more information can be found at:
http://www.cproadmap.org

Moving Advancements into Practice (MAP) Briefs describe innovative research and promising technologies that can be used now to achieve concrete paving practices. The April 2017 MAP Brief provides information relevant to Track 1 of the CP Road Map: Materials and Mixes for Concrete Pavement.

The MAP Brief is available at:
www.cproadmap.org/publications/MAPs/MAP201704.pdf

Jana J. Jura

June 2017

ROAD MAP TRACK 1

PROJECT TITLE
Performance Engineered Mixtures for Concrete Pavements

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The Long-Term Plan for Concrete Pavement Research and Technology (CP Road Map) is a national research plan developed and jointly implemented by the concrete pavement stakeholder community. Publications and other support services are provided by the Operations Support Group and funded by the Federal Highway Administration.

Figure 1. AASHTO PP 84-17 specification

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Performance Engineered Mixtures for Contractors

Introduction
As the Performance Engineered Mixtures (PEM) program gains momentum, contractors are starting to ask about how to implement PEM in their daily work, and what impacts the program is going to have on them. This tech brief seeks to address those questions.

The program is based on the premise that if the right concrete is defined (or specified), developed, delivered, and placed for a pavement, the risk of rejection by the agency is reduced in the short term, and that maintenance is significantly reduced in the long term. This will lead to savings to contractors, agencies, and pavement users, as well as improvements in safety, because traffic cones need to be placed less often.

At the heart of the PEM program are three fundamental philosophies:

- We should specify and measure the things that matter for performance of the pavement for the anticipated service and the environmental conditions for which the pavement will be exposed.

- The bulk of the testing should be in the prequalification stage and testing at the point of delivery is simply to assure the agency that the material delivered is close to the prequalified mixture.

- The contractor can reduce costs by paying attention to the cut-off properties of the mixture, which will provide clues to likely acceptance of the mixture by the agency at a later age.

The American Association of State Highway and Transportation Officials (AASHTO) PP-84 is a guidance document for developing a concrete pavement specification that formulates this approach. AASHTO PP-84 addresses six fundamental properties:

- Transport properties
- Aggregate stability
- Strength
- Cold weather exposure
- Shrinkage
- Workability
PEM - DELIVERING CONCRETE TO SURVIVE THE ENVIRONMENT

• Performing to and beyond agency need/expectation

• A partnership of agency and industry

THANK YOU