PEM is not over…

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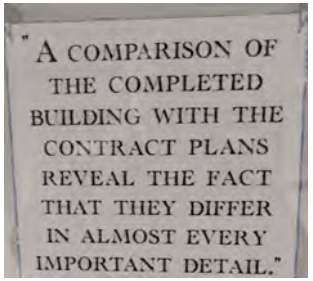
A Better Specification

- Require the things that matter
- Measure them at the right time
  - Prequalification
  - Process control
  - Acceptance



What do we need?

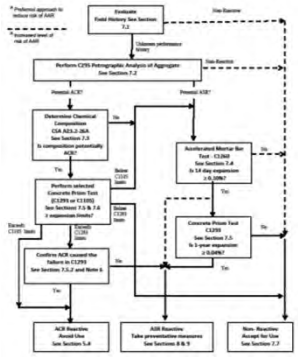
- Transport properties (permeability)
- Aggregate stability
- Cold weather resistance
- Strength
- Shrinkage
- Workability

Transport properties (permeability)

- All deterioration mechanisms involve fluid movement
- Keep water out = longer life
- Test using resistivity

Aggregate Stability

- Alkali aggregate reaction
  - AASHTO R80 / ASTM C 1778



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Cold Weather

- Freeze-thaw
  - Saturation
  - Entrained air (SAM)
- De-icing salts
  - Sufficient SCM

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Strength

- Strong enough to carry loads
  - Cylinders
  - Beams
  - Maturity
- Normally we get more than we need
- Not a substitute for the other properties

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Workability

- Not too wet
- Not too dry
- Test with VKelly or Box

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How do we proportion to achieve design goals?

		Workability	Transport	Strength	Cold weather	Shrinkage	Aggregate stability
Aggregate System	Type, gradation	✓✓	-	-	-	-	✓✓
Paste quality	Air, w/cm, SCM type and dose	✓	✓✓	✓✓	✓✓	✓	✓
Paste quantity	Vp/Vv	✓	-	-	-	✓✓	-

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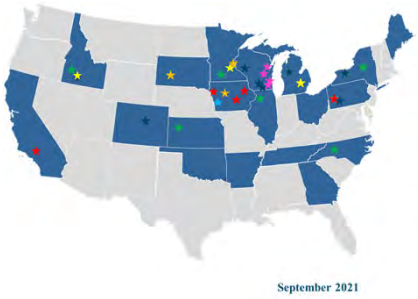
Implementation…



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Implementation

	Not a problem in our state	Haven't thought about it	A good spec already in place	Some interest	Considering change	Adopted change
Transport	1	3	3	8	3	1
Freeze thaw	2	2		10	5	
Oxychloride		15		3	1	
Aggregates	2	1	16			
Strength			19			
Shrinkage		11	3	1	3	1
Workability		4	6	6	1	2

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Steps to Long Life

Target performance
- Workability
- Durability
- Strength

Measure!

Design Levers
- Gradation
- Paste Volume
- Cementitious
- Admixtures

Batching
- Uniformity – Water
  - Cementitious system
  - Aggregates
- Mixing – Time
  - Energy

Measure!

Transportation
- Mixing
- Workability
  - Time and weather
  - Added water / admixtures
- Uniformity

Placement
- Handling / Vibration
  - Bleeding
  - Segregation
  - Air void system
  - Water movement

Measu

Finishing
- Surface finish
- Curing
- Sawing

Still working on..

- Tools in the lab:
  - Response to vibration
- Tools in the field:
  - Workability, air void stability, bleed, segregation
  - Feedback to the batch plant
  - Water content
  - Curing
  - Time to saw

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PEM: Where We Are Today

National Concrete Pavement Technology Center Webinar
September 14, 2021

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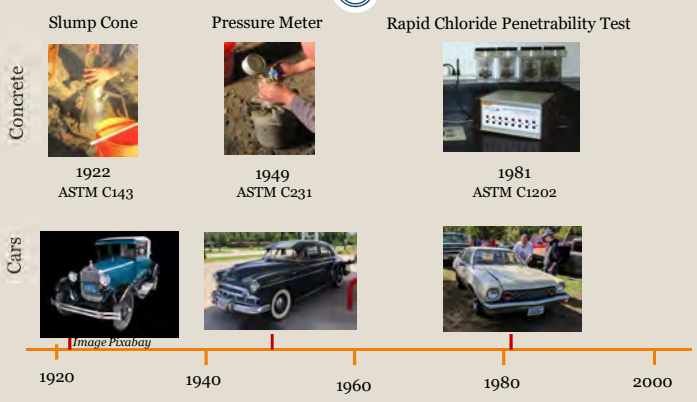
Office of Infrastructure

All images FHWA unless otherwise noted

Topics

- PEM and Performance Specification Background
- QC Tool
- PEM Project Highlights and States' Status
- Sustainability
- *Live From the MCTC*

Evolution of Concrete Acceptance Testing



New Technologies

Performance is NOT…

Performance Related Specifications (PRS)

Performance Based Specifications (PBS)

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

Better Assessment of Quality?

Option 1	Option 2
○ QC info: None ○ Strength ○ Slump ○ Total Air	○ QC info: ▪ Unit weight ▪ Calorimetry ○ Strength ○ Resistivity ○ SAM number

Jerry Voigt, ACPA Past President (ret.)

"It's the agency's responsibility to allow for innovation. It's the contractor's responsibility to deliver."

Image ACPA

How Do Contractors Deliver in a Performance Specification?

Image Pixabay

Prescriptive vs. Performance Specifications

Prescriptive/Method	Performance
○ 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	○ 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 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

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

QC Tool Overview

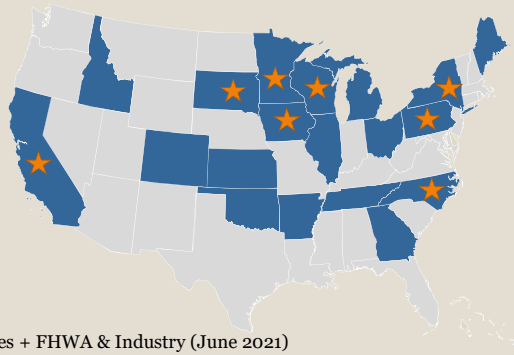
- Roles and responsibilities for agencies and industry under performance specifications
- Organizational and project-level QC
- PEM approach
- Mix design and production QC
- QC monitoring by both agency and industry
- Statistical tools, control charts, etc.

QC Tool References

- Review of Agency QC Requirements
  - Commonly and less-commonly specified QC requirements (from review of roughly 15 agencies)
- Example QC Plan Provisions
- QC Plan Outline
- Appendix D: Suggested Model QC Plan
  - Based on NorthEast Transportation Training and Certification Program (NETTCP) Model QC Plan

Developed under a cooperative agreement; use is not required by Federal statute or regulation. Material is included for informational purposes only and are not intended to reflect a preference, approval, or endorsement of any one product or entity by the Federal government.

PEM Implementation Incentive



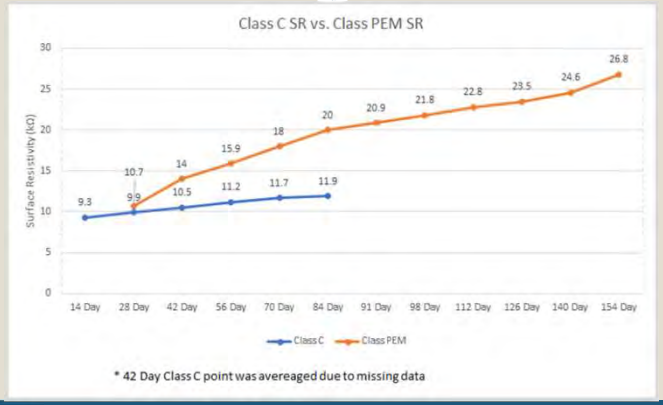
19 States + FHWA & Industry (June 2021)

★ PEM Implementation Incentive Pilot Project

New York Highlights

- PEM approach typically is beneficial to State and industry
- PEM mix tested better in all tests vs. Class C
- 2nd supplier was reluctant to participate
  - Determined QC requirements were not much more than they currently do
  - 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
- Developing next project in NYC area (structural)

New York Highlights



Iowa Highlights

- Box Test: 45#/cy reduction in cement
  - Contractor now using to develop mixes
- Super Air Meter notes
  - Need for technician training
  - Attention to detail for correlation testing
  - Concern with gauge durability
- Surface Resistivity
  - Invaluable information for agency and industry
  - Easy to perform, no changes needed
- Expanded typical QC requirements
- 2020 project use proposed by contractor. Approved!

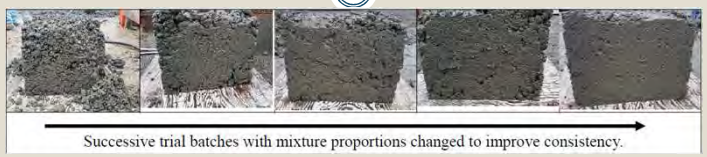
Iowa Highlights

"After dropping 45 pounds per cubic yard of cement out of our QMC mix and performing the Box Test, we were astonished and actually paved a considerable quantity with the PEM adjusted mix with very good results." (contractor)

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.

Image: Fred White, Lane Construction

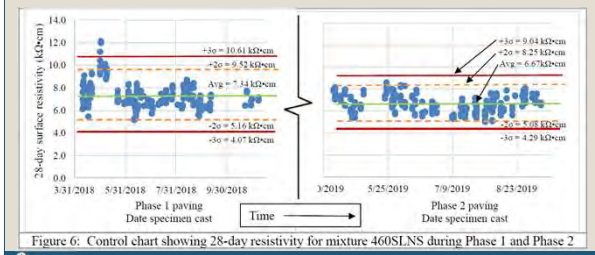


Figure 6: Control chart showing 28-day resistivity for mixture 460SLNS during Phase 1 and Phase 2

Image: Dr. Tara Cavalline, UNCC

North Carolina Highlights

- "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 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

- 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

Pennsylvania

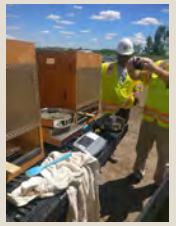
- 2 PEM projects (2018 & 2019)
- April 2020 spec lowered w/c ratio to 0.42
- Testing:
  - Shrinkage (bridge decks)
  - Resistivity
  - 4 SAMs
  - DOT plans to continue to evaluate the Box Test, resistivity, SAM
- Industry support for PEM

Kansas

- Open house & shadow testing 2019
- Training Day – all DOT districts trained with SAM (2019)
- Considering requiring SAM in mix design for 2022
- Resistivity testing for 5 years
- Optimized aggregates for 10 years

Minnesota

- Have optimized aggregate gradation
- 0.40 max w/c ratio with incentives
- Interested in SAM training
- Purchased Phoenix water content equipment
- Open house in 2019, shadow project in 2020



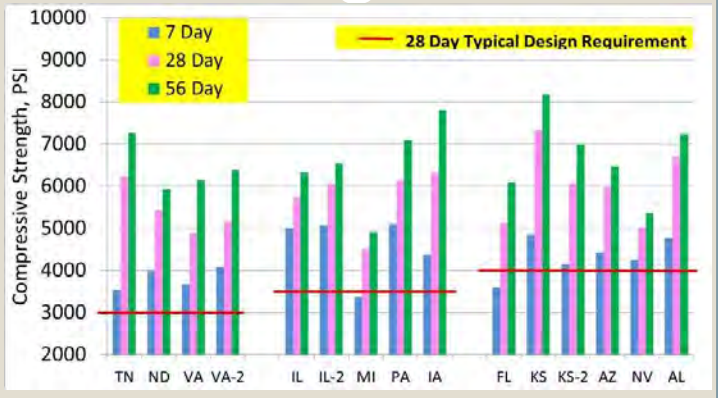
Michigan

- Considering SAM in mix design phase
- DOT purchased 19 SAMs
- Considering incentive for lower w/c ratios
- Optimized aggregates for > 20 years

Wisconsin

- SAM shadow testing in mix design phase (since 2017)
- Considering SAM for acceptance testing (2021)
- Incentive for aggregate gradation & cement reduction from 564 pcy to 520 pcy

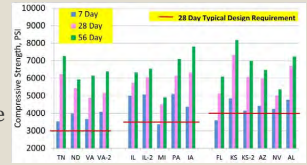
PEM and Sustainability



Observations From MCTC Data

- 28-day mix design strengths are being met in 7 days
- 28-day mix design strengths are exceeded by more than 60%
- 56 to 90-day strengths exceed the 28-day mix design strength by more than 80%

- High cement content is nearly always the primary cause
- Negative impacts of high cement content
  - Increased cracking potential
  - Higher permeability
  - Higher cost
  - Less workable concrete
  - Increased production of carbon dioxide

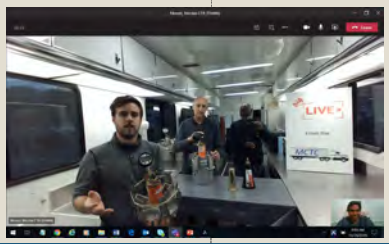


Ways to Reduce Cement Content

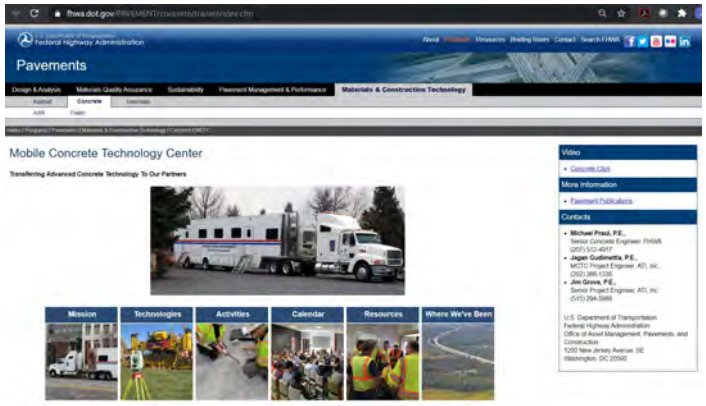
- Move to performance-type specification language; eliminate mandatory cement content requirements
- Optimize aggregate gradation
- Use supplementary cementitious materials
- Use maturity testing to determine opening times
- Promote quality control in the plant to provide more consistent production

"Live From the MCTC" Training/Workshops

- Super Air Meter (SAM)
- Surface/Bulk Resistivity
- Maturity
- Box Test/V-Kelly
- Semi-adiabatic calorimeter
- Phoenix (fresh water content)
- MIT SCAN-T3
- MIT Dowel Scan
- HIPERPAV
- Optimized Gradation software



MCTC Website



https://www.fhwa.dot.gov/MCTC

Questions?

Image Pixabay

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