Performance Engineered Mixtures and AASHTO PP 84: It's Time for a Change

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FHWA /ATI INC.

OFFICE OF PRECONSTRUCTION, CONSTRUCTION, & PAVEMENTS

QUALITY ASSURANCE WORKSHOP

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U.S. Department of Transportation
Federal Highway Administration
Office of Infrastructure

Unless otherwise noted, FHWA is the source of all images in this presentation.

We Are Horrible With Change

- Timeframe for widespread use of SCMs
- 28-day strength testing
- Slump test

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Evolution of Concrete Testing

Concrete

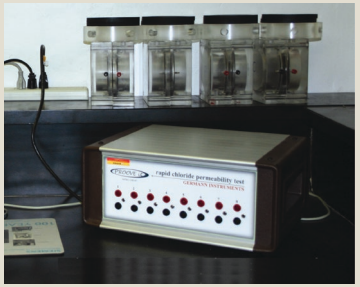
Slump Cone

1922
ASTM C143

Pressure Meter

1949
ASTM C231

Rapid Chloride Penetrability Test



1981
FHWA/PCA

Cars

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1920 1940 1960 1980 2000

Performance Engineered Mixture Concept

- Understand what makes concrete last and what failure mechanisms we see
- Specify critical properties to address those failure mechanisms and test for them
- Starting point for a performance-driven QA specification and acceptance program for owner agencies

What is PEM?

- AASHTO PP-84
- Development and integration of enhanced/robust Quality Control practices and oversight
- Specification changes—moving from prescriptive to performance
  - Slump
  - Minimum cement content
  - Single aggregate gradation requirements

AASHTO PP 84: A Better Specification

Require the things that matter

- Strength
- Shrinkage
- Freeze-thaw resistance
- Transport properties (Permeability)
- Aggregate stability
- Workability*

PEM

- PEM is like a buffet
- Pick what you like from the different groups
  - Salads
  - Bar B Que
  - Chinese
  - Dessert

Strength

Property	Mixture Qualification	Acceptance	Selection Details
Flexural Strength	Yes	Yes	Choose either or both
Compressive Strength	Yes	Yes	

Reduced Cracking

Property	Mixture Qualification	Acceptance	Selection Details
6.4 Reducing Unwanted Cracking Due to Shrinkage			
Volume of Paste	Yes	No	Choose only one
Unrestrained Volume Change	Yes	No	
Unrestrained Volume Change	Yes	No	
Restrained Shrinkage	Yes	No	
Restrained Shrinkage	Yes	No	
Probability of Cracking	Yes	No	

Freeze – Thaw

Property	Mixture Qualification	Acceptance	Selection Details	
6.5 Durability of Hydrated Cement Paste for Freeze-Thaw Durability				
Water to Cement Ratio	Yes	Yes	Choose Either 6.5.1.1 or 6.5.2.1	
Fresh Air Content	Yes	Yes		Choose only one
Fresh Air Content/SAM	Yes	Yes		
Time of Critical Saturation	Yes	No	Note 1	Note 2
Deicing Salt Damage	Yes	Yes	Choose one	
Deicing Salt Damage	Yes	Yes		
Calcium Oxychloride Limit	Yes	No		

Permeability

Property	Mixture Qualification	Acceptance	Selection Details	Special Notes
6.6 Transport Properties				
Water to Cement Ratio	Yes	Yes	Choose Only One	
RCPT Value	Yes	Yes		Other criteria could be selected
Formation Factor/Resistivity	Yes	through ρ		* Note this is currently based on saturated curing and an adjustment is needed to match with AASHTO Spec
Ionic Penetration, F Factor	Yes, F	through ρ		

Aggregate Stability

Property	Mixture Qualification	Acceptance	Selection Details		Special Notes
6.7 Aggregate Stability					
D Cracking	Yes	No			
Alkali Aggregate Reactivity	Yes	No			

Workability

Section	Property	Mixture Qualification	Acceptance	Selection Details		Special Notes
6.8 Workability						
6.8.1	Box Test	Yes	No			
6.8.2	Modified V-Kelly Test	Yes	No			

AASHTO PP 84

- A ***guide*** specification with tests completed either during mixture design or at placement or both that focus on concrete performance.
- Allows DOTs to take what they like from the document and make it their own.
- DOTs should not give up what they already know is important for them.

Remember…

The document is not designed to be used without modifying for local practice and experience!

Why We're Excited

Concrete Evolution

Image Pixabay

- PEM/PP 84: 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!)

CP ROAD MAP

www.cproadmap.org

April 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.

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

This MAP Brief is available at www.cproadmap.org/publications/MAPbriefMarch2017.pdf.

"Moving Advancements into Practice"

MAP Brief April 2017

Best practices and promising technologies that can be used now to enhance concrete paving

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 Paving 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 of 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's 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.

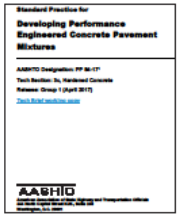
Standard Practice for
Developing Performance Engineered Concrete Pavement Mixtures
AASHTO

Figure 1. AASHTO PP 84-17 specification

CP ROAD MAP

www.cproadmap.org

July 2017

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"Moving Advancements into Practice"

MAP Brief July 2017

Best practices and promising technologies that can be used now to enhance concrete paving

Developing a Quality Assurance Program for Implementing Performance Engineered Mixtures for Concrete Pavements

Introduction

TRB Circular 137 defines Quality Assurance as all those planned and systematic actions necessary to provide confidence that a product or facility will perform satisfactorily in service. The Quality Assurance Program (QAP) for Performance Engineered Mixtures (PEM) for Concrete Pavements represents a system of individual and shared responsibilities that needs to be understood by the agency and contractor. This tech brief is the second of a two part series on PEM specifications and implementation. The April 2017 CP Road Map MAP Brief "Performance Engineered Mixtures (PEM) for Concrete Pavement" presented an overview of the PEM specification requirements. The CP Road Map MAP Brief and the AASHTO standard of practice PP 84-17 give details on the PEM specification requirements. This tech brief will overview QAP requirements specifically related to PEM, which are a subset of the overall QAP requirements for a project.

An overview of the QAP elements related to PEM is shown in Table 1. It consists of those activities the owner agency does as part of their acceptance responsibilities and also those activities that the contractor is responsible for (Quality Control, QC) to ensure the product meets the contract requirements. Table 1 also summarizes the critical mixture performance requirements and implementation options. More detail is provided in the CP Road Map MAP Brief "Performance Engineered Mixtures (PEM) for Concrete Pavements."

Background

Historically, agencies have relied too much on 28-day strength of a concrete mixture as a quality indicator. The traditional mindset has been that if the 28-day strength meets the specification requirements, it was "good" concrete; strength was used as a quasi-indicator of durability. The concrete community was hampered by the lack of tests that were both indicators of concrete quality and those that could be done during production so that changes could be detected and corrected as needed while the project was still under construction.

New Tests

Recently, there have been significant advancement in testing technologies that measure engineering properties important for good performance of the concrete pavement. With these scientific advancements, agencies and contractors now have the ability to effectively monitor their production in real-time and adjust as needed to produce the desired level of quality. These new tests, particularly when used in conjunction with a performance specification and QAP, set the stage for significant advancements in pavement performance. Figure 1 (page 4) shows several of the tests used in the PEM Specification: surface resistivity, calorimetry, and Super Air Meter (SAM).

AASHTO PP-84-17 "Standard Practice for Developing Performance Engineered Concrete Pavement Mixtures"

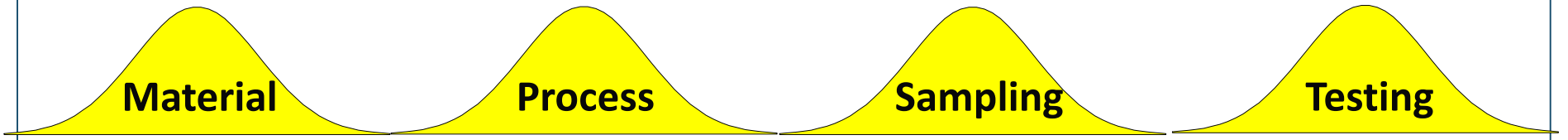
The PEM specification is a leap forward for the concrete community. It incorporates measuring the critical properties identified in Table 1 into a specification framework (Table 2). The premise behind the specification is to target the mix-design testing and acceptance testing towards those tests that are indicative of concrete quality and that will address known failure mechanisms. The specification removes some prescriptive specification elements, such as minimum or

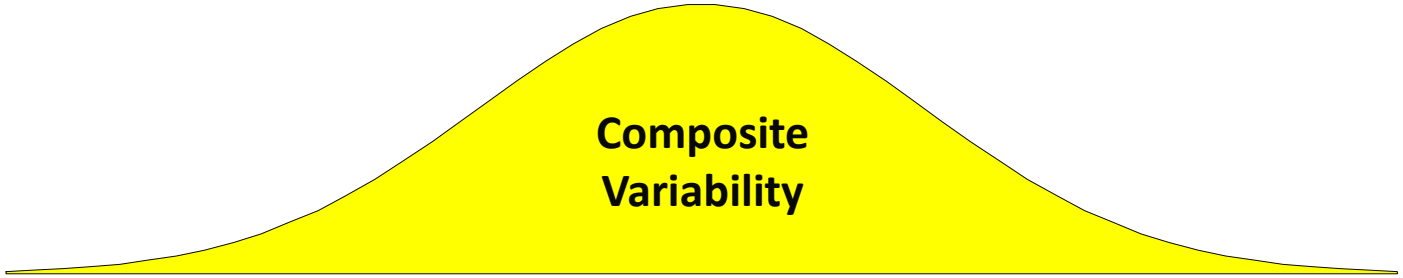
http://www.cproadmap.org/publications/MAPbriefApril2017.pdf

http://www.cproadmap.org/publications/MAPbriefJuly2017.pdf

Sources of Variability

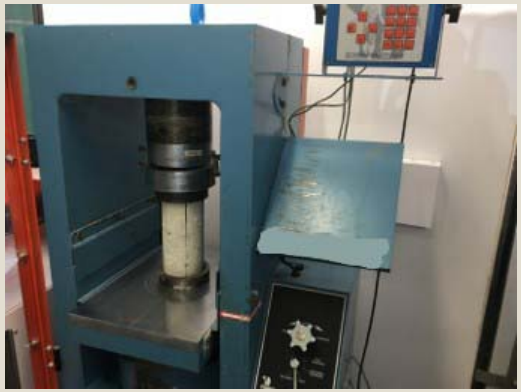
Material **Process** **Sampling** **Testing**





Controlling Sampling and Testing Variability

- Standard procedures (AASHTO, ASTM, state)
- Laboratory accreditation/qualification program
- Technician training and certification programs
- State Independent Assurance Program
- Calibrated equipment schedules



Testing Variability

Procedure	95% Lower Limit	Test Result	95% Upper Limit
Sieve analysis (% passing ½")	24%	28%	32%
Slump	2"	2 ½"	3"
Air content	4.9%	5.5%	6.1%
Rodded unit weight for aggregate	114.5 lb/ft^3	120 lb/ft^3	125.5 lb/ft^3
Compressive strength	3,390 lb/in^2	3,600 lb/in^2	3,810 lb/in^2
Flexural strength	602 lb/in^2	700 lb/in^2	798 lb/in^2

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 Assurance Defined: 23 CFR 637

- Agency Acceptance
- Contractor Quality Control
  - Qualified (certified) Personnel
  - Qualified Laboratories
  - Independent Assurance
  - Dispute Resolution for Test Results

} State processes, independent of material

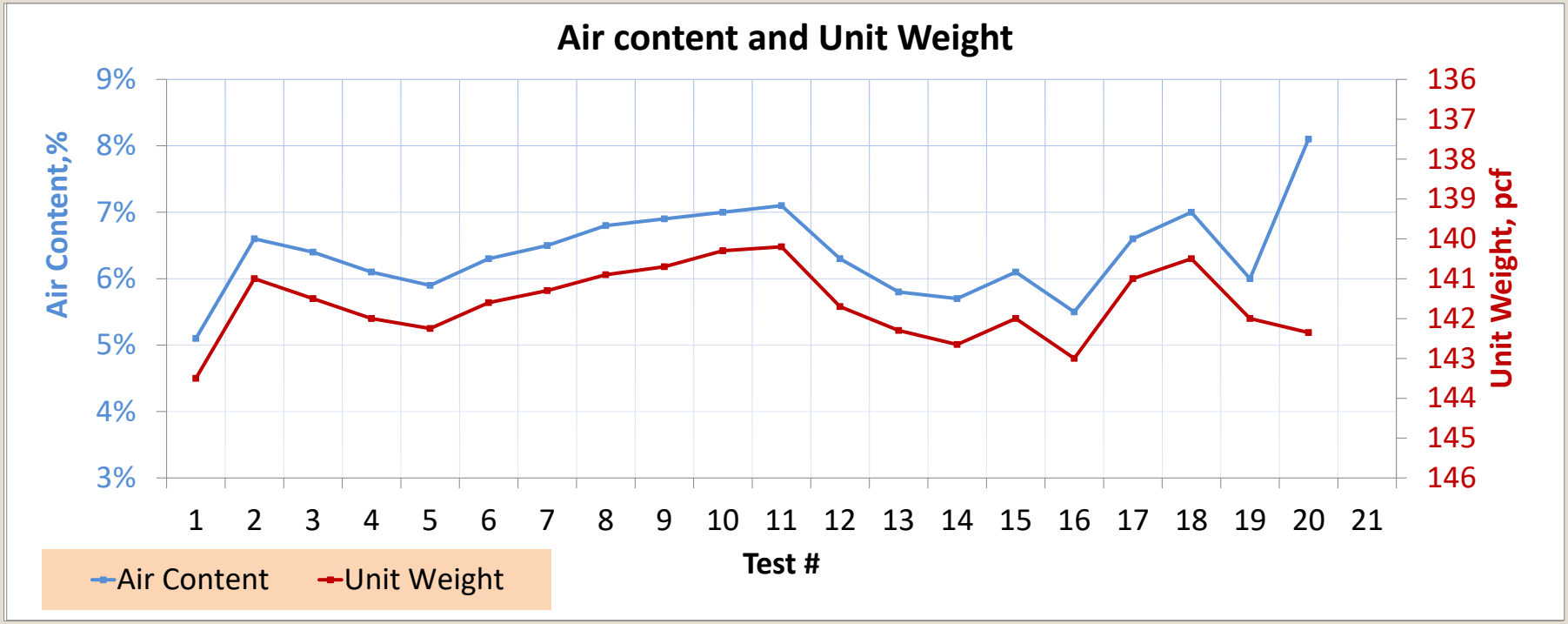
Quality Control

- PP 84 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

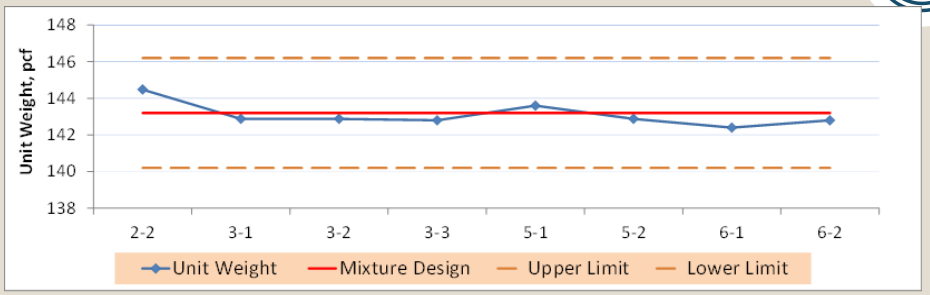
Image Pixabay

Dual Axis Plot Example

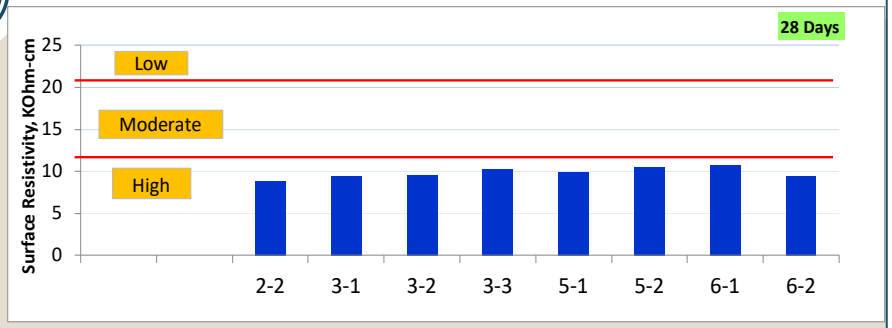
- Air content plotted on the left vertical axis
- Unit weight plotted on the right vertical axis



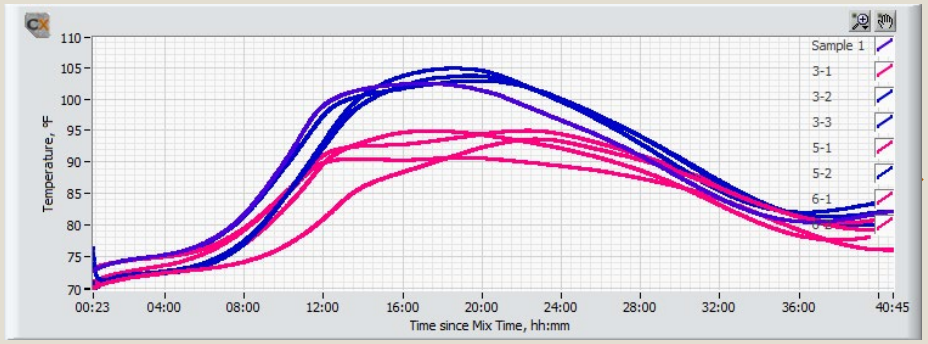
Unit Weight/Heat Signature/Permeability



Unit Weight – Real Time

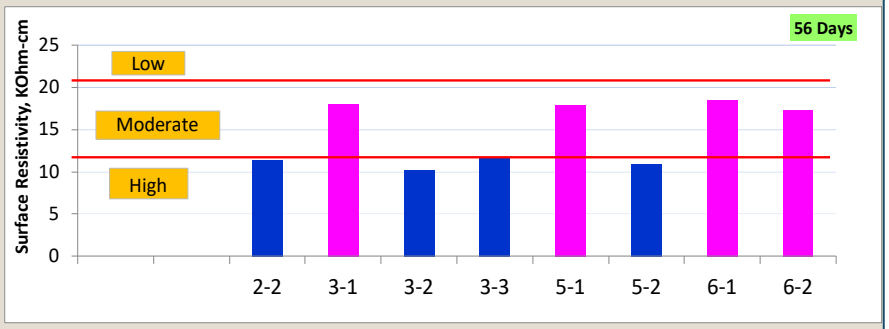


Surface Resistivity – 28 Days



Heat Signature – Info in a day

Real Time



Surface Resistivity – 56 Days

28 / 56 days

Field Data from an MCT project

"You're Asking for a Lot of Change"

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 Pooled Fund Partners

- FHWA
- State Departments of Transportation (DOTs)
- Industry
  - American Concrete Pavement Association
  - Portland Cement Association
  - National Ready Mixed Concrete Association
  - Others

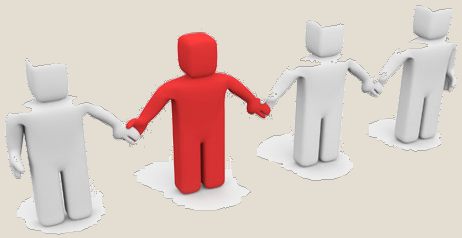
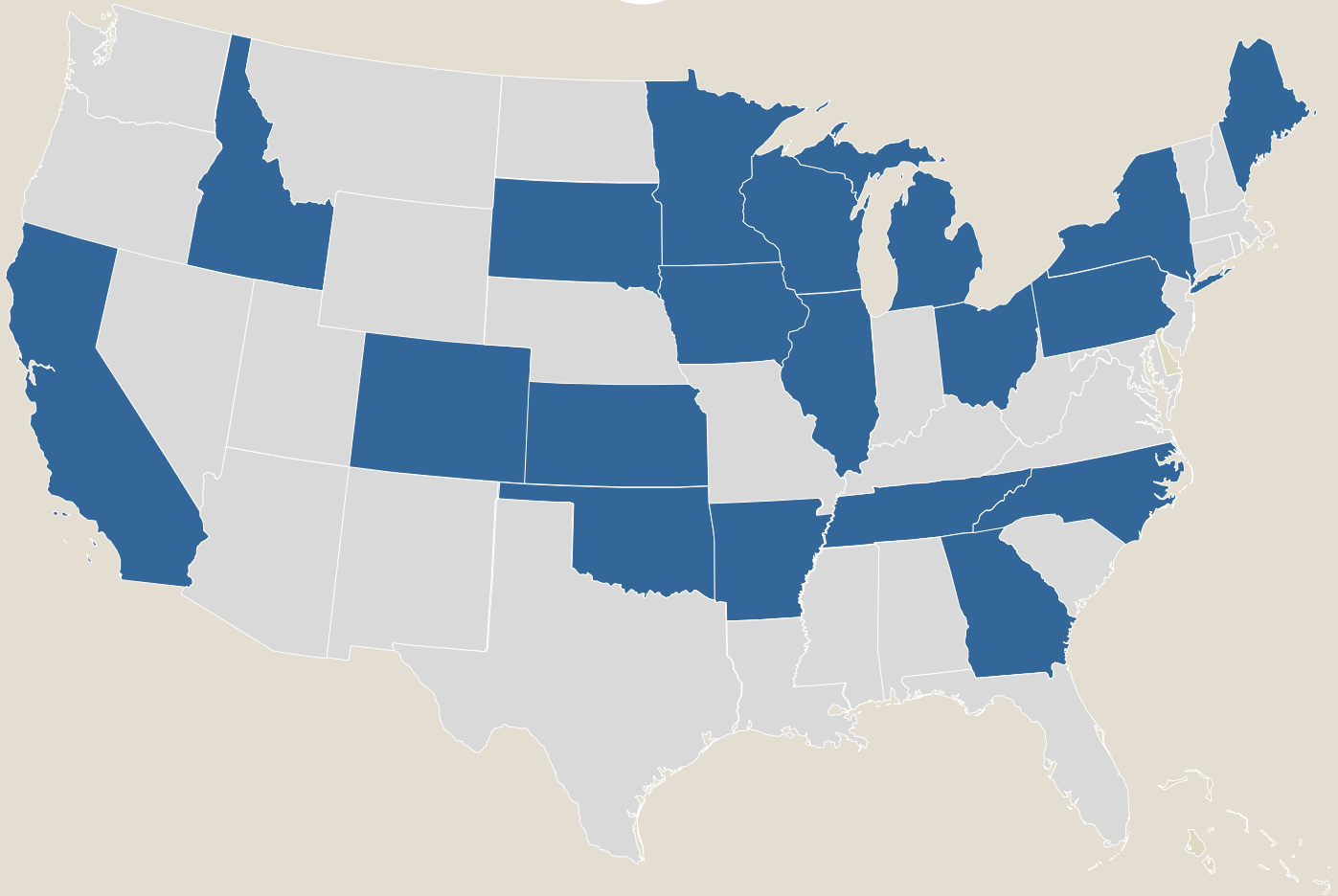


Image Pixabay

PEM Pooled Fund Participants

31



19 States + FHWA + Industry (December 2020)

Pooled Fund Emphasis

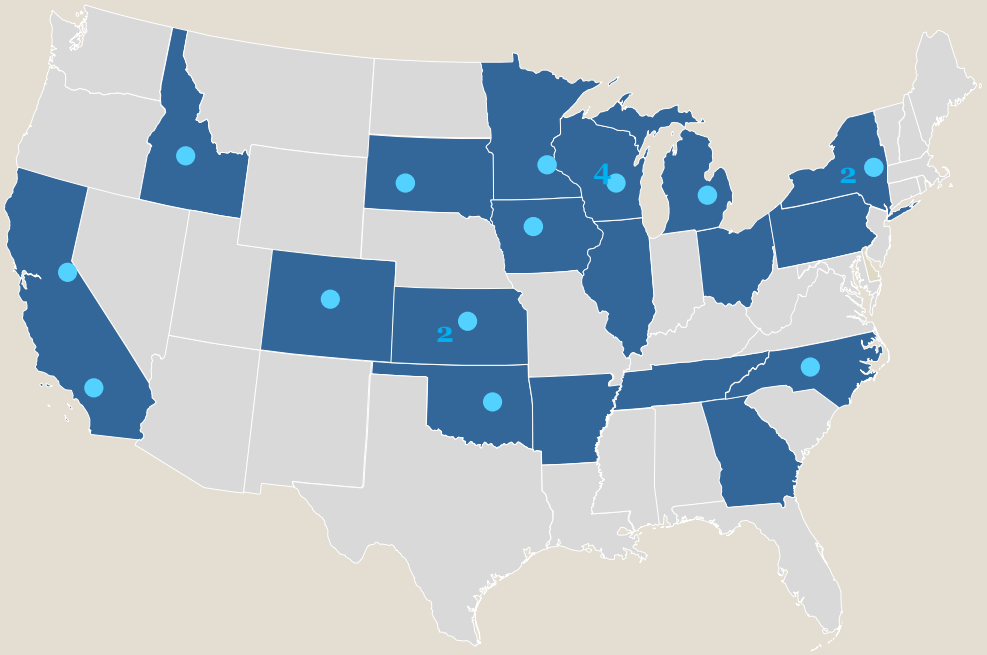
- Implementation
- Education and Training
- Adjustments in specifications based on field performance
- Continued development of a knowledge base relating early age properties to performances

Iowa Early Success Story

- FHWA PEM Implementation Incentive Funds
- "New" QC Plan?
- Box test experience
- Contractor moving forward

Images: Pixabay

Training



- Training Locations
  (CP Tech, MCTC, OSU, Industry)

PEM One Day Workshop

Purpose: Develop a state-specific plan to implement PEM principles

Target Audience: Specifiers and those involved with quality aspects of concrete pavement construction

Topics:

- Road to PEM –Why change things?
- Group discussion – What makes a good specification?
- AASHTO PP-84, philosophy and goals
- Group discussion – Barriers to performance evaluation
- Science and tests for PEM (Property-Test-Remedy)
- Group Discussion – What next?
- PEM in practice, Quality, Implementation, Training

Mobile Concrete Technology Center

Questions?

Image Pixabay

Contact information

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