PERFORMANCE ENGINEERED MIXTURES (PEM) FOR CONCRETE PAVEMENTS

- *The Next Steps*

National Concrete Pavement Technology Center

Tech Center

IOWA STATE UNIVERSITY
Institute for Transportation

National Concrete Consortium Spring Meeting
Coeur d'Alene, Idaho
April 24, 2018

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THE PEM INITIATIVE

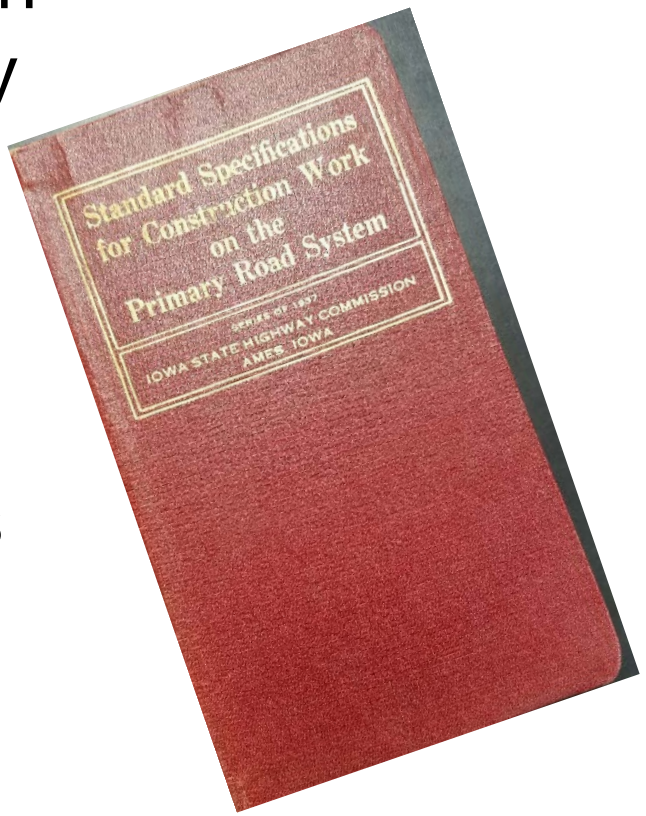
- A partnership of agency and industry to

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

RESPONDING TO A NEED

OUR CHALLENGE

- Today's concrete paving specifications need to be built upon engineering properties that directly relate to good field performance. With the recent advancements in research knowledge on failure mechanisms, and the paralleled development of better tests, this is possible.



A MODERNIZED SPECIFICATION

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

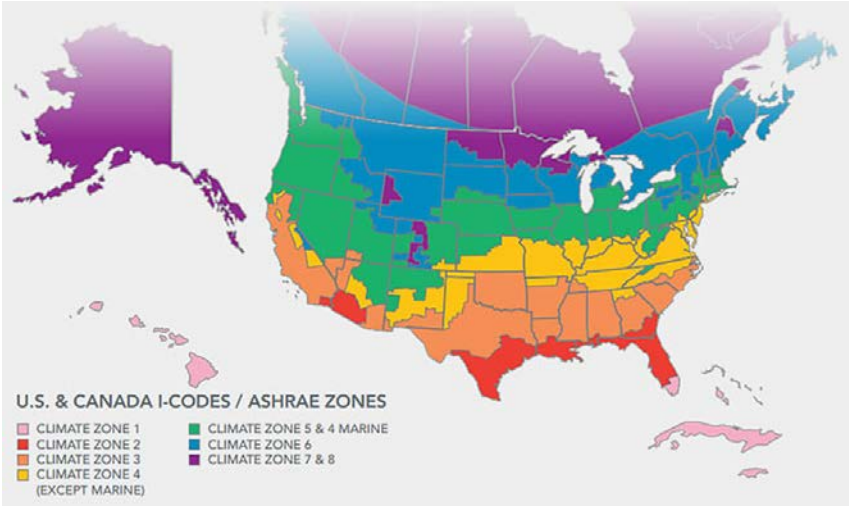
- ✓ Develop test methods
- ✓ Develop a “Guide Specification” (AASHTO’s PP-84)
- ✓ Develop tools to proportion mixtures

- ✓ Conduct Shadow evaluations

- ✓ Later
  - ➢ Guide/monitor Pilot projects
  - ➢ Develop PWL models
  - ➢ Guide in developing Q/C Programs

A SPECIFICATION THAT CONSIDERS:

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



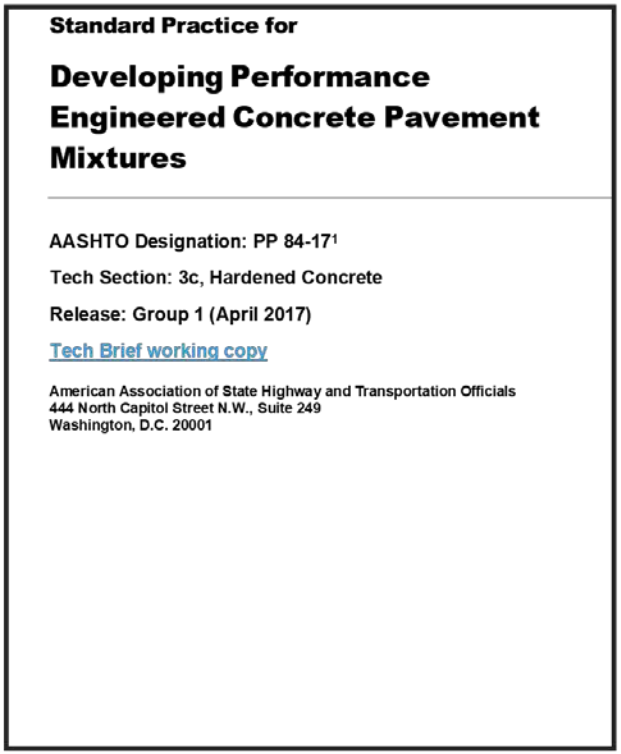
TEST METHODS

- Tests for those critical properties:

  - ➢VKelly *(Workability)*
  - ➢Box *(Workability)*
  - ➢Resistivity / Formation factor *(Transport)*
  - ➢Bucket / Sorptivity
  - ➢Dual ring *(Shrinkage)*
  - ➢SAM *(Cold Weather Resistance)*

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



Standard Practice for

Developing Performance Engineered Concrete Pavement Mixtures

AASHTO Designation: PP 84-17[1]

Tech Section: 3c, Hardened Concrete

Release: Group 1 (April 2017)

Tech Brief working copy

American Association of State Highway and Transportation Officials
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AASHTO PP84-17 test summary						Where is the test used?		
Mixture parameter	Traditional acceptance criteria	Property	Specification reference	Specified test	Selection details	Mixture qualification	Acceptance	Special notes
Aggregate stability	√	D-cracking	6.7.1	T161, ASTM C1646		√	—	
		Alkali aggregate reactivity	6.7.2	R80		√	—	
Transport properties		Water to cementitious materials (w/cm) ratio	6.6.1.1	–	Choose only one	√	√	The required maximum water to cementitious ratio is selected based on freeze–thaw conditions
		Formation factor	6.6.1.2	Table 1		√	√	Based on freeze–thaw conditions; other criteria could be selected
		Ionic penetration, F factor	6.6.2.1	Appendix X2		√	√	Determined using guidance provided in Appendix X2
Durability of hydrated cement paste for freeze-thaw durability		Water to cementitious materials (w/cm) ratio	6.5.1.1	—	Choose either 6.5.1.1 or 6.5.2.1	√	√	
	√	Fresh air content	6.5.1.2	T152, T196, TP118	Choose only one	√	√	
		Fresh air content/SAM	6.5.1.3	T152, T196, TP118		√	√	
		Time to critical saturation	6.5.2.1	"Bucket Test"		√	—	Variation controlled with mixture proportion observation or F factor and porosity measures
		Deicing salt damage	6.5.3.1	35% SCMs	Choose only one	√	√	Are calcium or magnesium chloride used
		Deicing salt damage	6.5.3.2	M224		√	√	Are calcium or magnesium chloride used; use specified sealers
		Calcium oxychloride limit	6.5.4.1	T 365-17		—	—	Are calcium or magnesium chloride used
Reducing unwanted slab warping and cracking due to shrinkage		Volume of paste (25%)	6.4.1.1	—	Choose only one	√	—	
		Unrestrained volume change	6.4.1.2	ASTM C157		√	—	Curing conditions
		Unrestrained volume change	6.4.2.1	ASTM C157		√	—	
		Restrained shrinkage	6.4.2.2	T 334		√	—	
		Restrained shrinkage	6.4.2.3	TP 363-17 (Dual Ring)		√	—	
		Probability of cracking	6.4.2.4	Appendix X1		√		Variation controlled with mixture proportion observation or F factor and porosity measures.
		Quality control check	Commentary			—	√	
Concrete strength	√	Flexural strength	6.3.1	T 97	Choose either or both	√	√	
		Compressive strength	6.3.2	T 22		√	√	
Workability	Slump	Box rest	6.8.1	Appendix 3	Choose one		—	
		V-Kelly test	6.8.2	Appendix 4			—	

A TRANSPORTATION POOLED FUND PROJECT

PERFORMANCE ENGINEERED
CONCRETE PAVING MIXTURES (***PEM***)

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THE PEM/TPF PARTNERS

- Federal Highway Administration (FHWA)
- State Departments of Transportation (DOTs)
- Industry (ACPA-PCA-NRMCA-SCA-Others)

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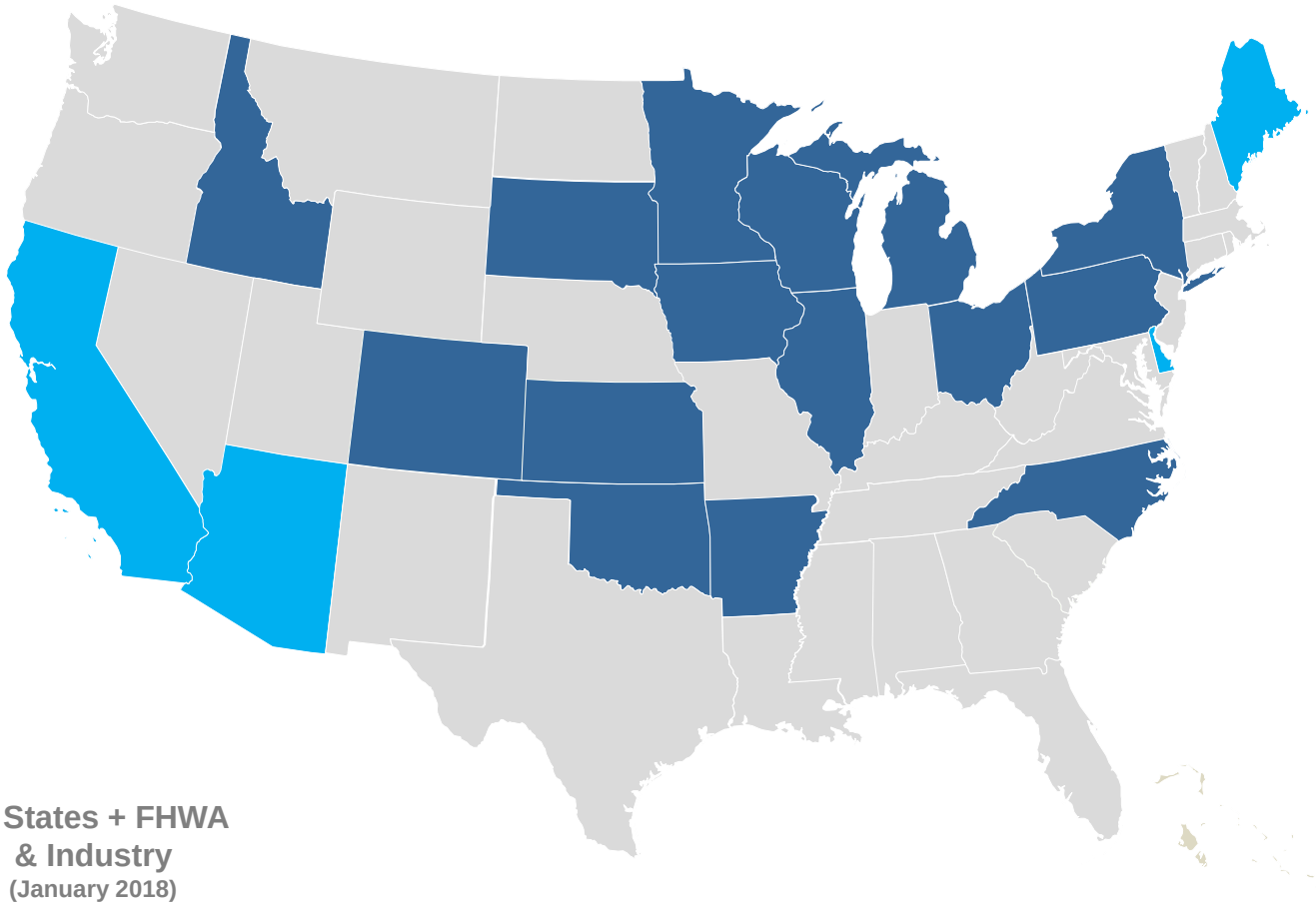
PEM POOLED FUND PARTICIPANTS
TPF-5(368)



15 States + FHWA & Industry
(January 2018)

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- Consultants – Tom VanDam, Cecil Jones
- CP Tech – Peter Taylor, Gordon Smith, John Cunningham

U.S.Department of Transportation
Federal Highway Administration

Oregon State University

OSU

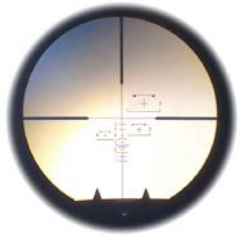
NCE

Diversified Engineering Services, Inc

CP Tech Center

PP 84 IMPLEMENTATION INCENTIVE FUNDS

SCOPE OF WORK



- Task 1 – Implementing what we know
- Task 2 – Performance Monitoring and Specification Refinement
- Task 3 – Measuring and Relating Early Age Concrete Properties to Performance.

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PROTOCOL FOR PEM SHADOW PROJECTS

- DOT Executive briefing
- Specification review
- Workshop for DOT office staff
- Construction, demonstrate tests, collect data, train field staff
- Review data and report findings / recommendations
- Ongoing data collection
- Data processing and storage
- Ongoing specification support
- Quality control plan guidance (w FHWA)

NOTES FROM THE 2018 PEM TAC MEETING - Chicago

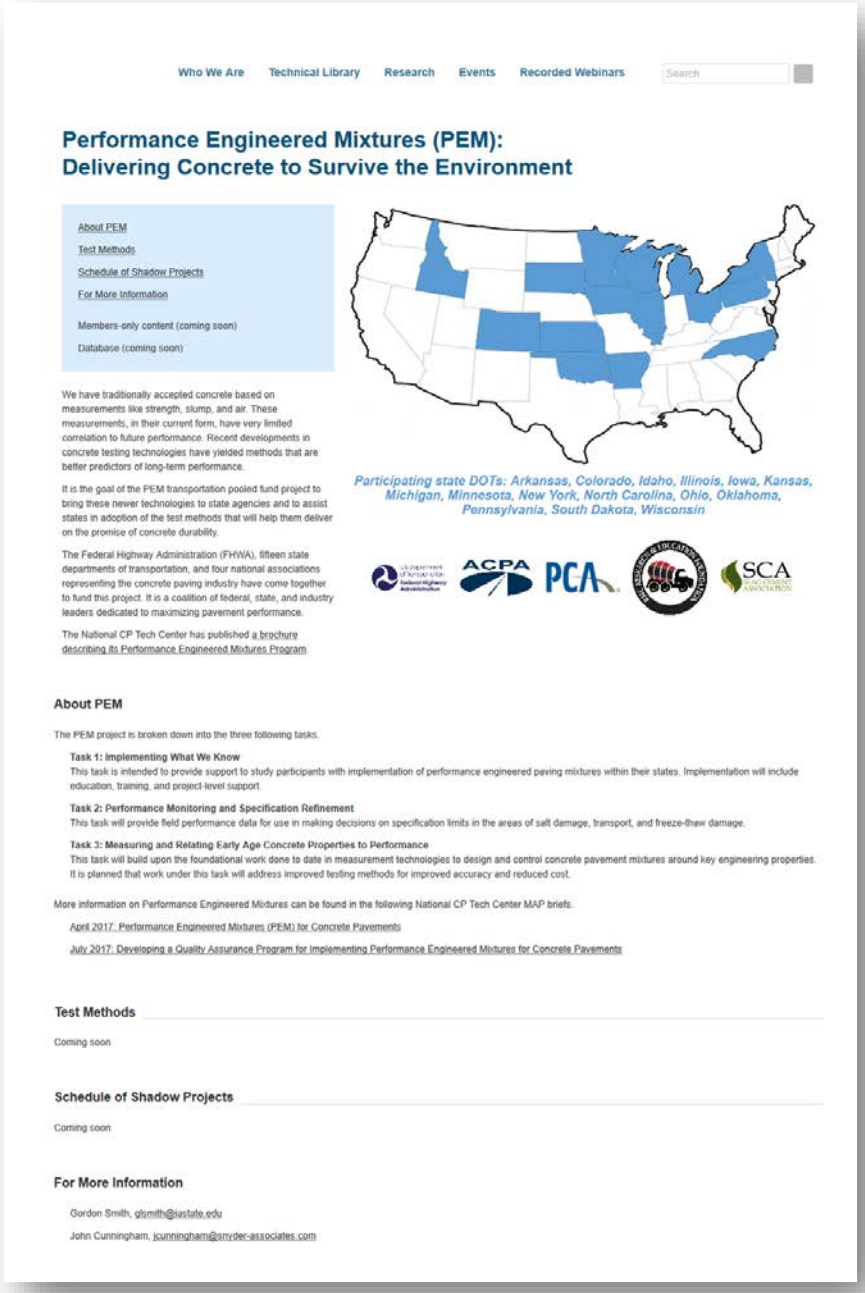
- Optimism for improvement of concrete performance by all.
- Recognition that testing methods need to be studied for reliability: precision and bias, certification
- Further discussion of acceptance/prequalification tests.
- Significant interest by participating states – FHWA will be in CO, IA and MN this paving season.
- Further work on the PP-84 Guide Spec ahead, based on shadow testing experience.

A WEBSITE DEDICATED TO PERFORMANCE ENGINEERED MIXTURES FOR CONCRETE PAVEMENTS

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

Visit the PEM website:

www.cptechcenter.org/PEM



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

About PEM
Test Methods
Schedule of Shadow Projects
For More Information

Members-only content (coming soon)
Database (coming soon)

We have traditionally accepted concrete based on measurements like strength, slump, and air. These measurements, in their current form, have very limited correlation to future performance. Recent developments in concrete testing technologies have yielded methods that are better predictors of long-term performance.

It is the goal of the PEM transportation pooled fund project to bring these newer technologies to state agencies and to assist states in adoption of the test methods that will help them deliver on the promise of concrete durability.

The Federal Highway Administration (FHWA), fifteen state departments of transportation, and four national associations representing the concrete paving industry have come together to fund this project. It is a coalition of federal, state, and industry leaders dedicated to maximizing pavement performance.

The National CP Tech Center has published a brochure describing its Performance Engineered Mixtures Program

Participating state DOTs: Arkansas, Colorado, Idaho, Illinois, Iowa, Kansas, Michigan, Minnesota, New York, North Carolina, Ohio, Oklahoma, Pennsylvania, South Dakota, Wisconsin

About PEM

The PEM project is broken down into the three following tasks.

Task 1: Implementing What We Know
This task is intended to provide support to study participants with implementation of performance engineered paving mixtures within their states. Implementation will include education, training, and project-level support.

Task 2: Performance Monitoring and Specification Refinement
This task will provide field performance data for use in making decisions on specification limits in the areas of salt damage, transport, and freeze-thaw damage.

Task 3: Measuring and Relating Early Age Concrete Properties to Performance
This task will build upon the foundational work done to date in measurement technologies to design and control concrete pavement mixtures around key engineering properties. It is planned that work under this task will address improved testing methods for improved accuracy and reduced cost.

More information on Performance Engineered Mixtures can be found in the following National CP Tech Center MAP briefs.

April 2017: Performance Engineered Mixtures (PEM) for Concrete Pavements

July 2017: Developing a Quality Assurance Program for Implementing Performance Engineered Mixtures for Concrete Pavements

Test Methods

Coming soon

Schedule of Shadow Projects

Coming soon

For More Information

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PERFORMANCE ENGINEERED MIXTURES PROGRAM

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

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CP ROAD MAP

shaping the future of concrete pavements

www.cproadmap.org

"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

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.

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

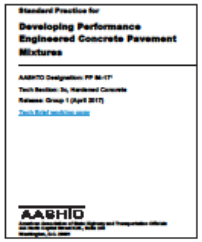
Concrete paving specifications have not kept pace with advancements in concrete science and innovations in testing technologies.

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

shaping the future of concrete pavements

www.cproadmap.org

"Moving Advancements into Practice"

MAP Brief July 2017

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

July 2017

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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

PEM –DELIVERING CONCRETE TO SURVIVE THE ENVIRONMENT

- The framework is in place
- Now we focus on the details and participation