PERFORMANCE ENGINEERED MIXTURES (PEM) FOR CONCRETE PAVEMENTS

Delivering Concrete To
Survive The Environment

National Concrete Pavement
Technology Center
Tech Center

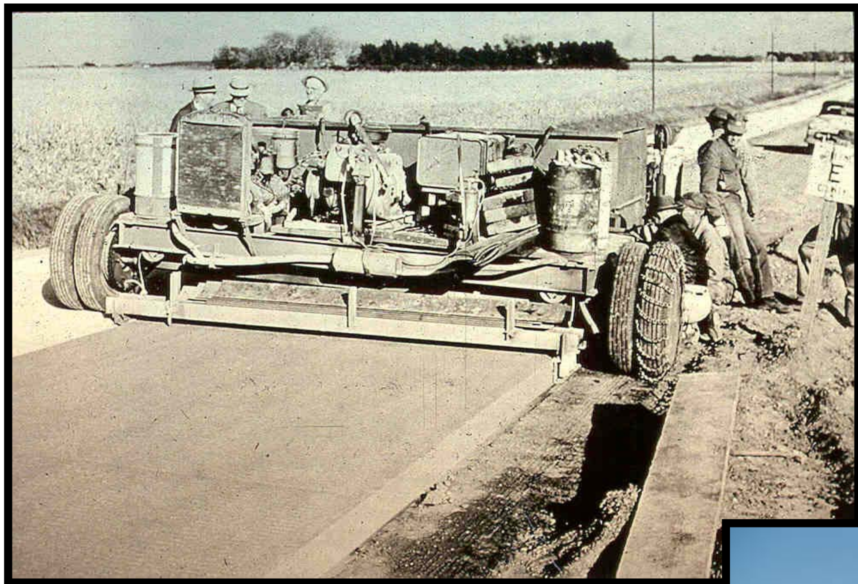
IOWA STATE UNIVERSITY
Institute for Transportation

EVOLUTION

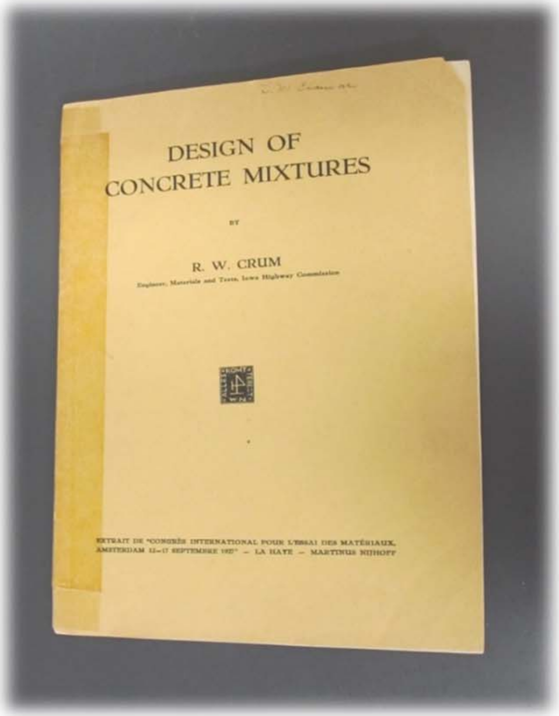
In The Art And Science Of Concrete Pavements

Gordon L. Smith, P.E.
Associate Director

National Concrete Pavement Technology Center






DESIGN OF
CONCRETE MIXTURES
BY
R. W. CRUM
Engineer, Materials and Tests, Iowa Highway Commission
EXTRAIT DE "CONGRÈS INTERNATIONAL POUR L'ESSAI DES MATÉRIAUX,
AMSTERDAM 12–17 SEPTEMBRE 1927" – LA HAYE – MARTINUS NIJHOFF

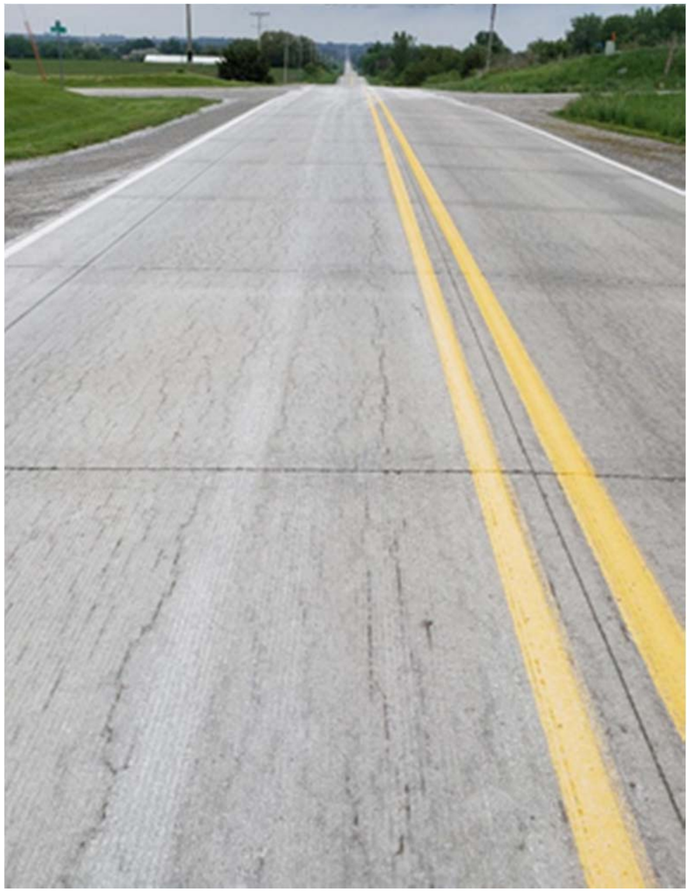

CONCRETE
MATURITY METER
SYSTEM 4101
SETUP
OFF
REC
EXIT
VIEW
ENTER
COM
ON
MADE IN CANADA
CH1
CH2
CH3
CH4
COMMUNICATION PORT
CHARGING PORT

1909 – Eddyville, Ia 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.

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National Concrete Consortium

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?

	1967	2017
No. of ingredients	Cement, water, rock, sand, AEA	Add SCMs, Non-Portland cements, admixtures, intermediate aggregates, limestone…
Opening	Weeks	Days (or hours)
Curing	Weeks	Days
De-icing	Sand, NaCl	Other chlorides, formates, acetates
Design life	20 years	50 years
Knowledge base	In house	Contracted out

The Journey Toward Performance Engineered Mixes *(PEM)*

- 2013 – NC^2 established an Expert Task Group (ETG) to further discuss and explore an action plan responsive to the concerns.

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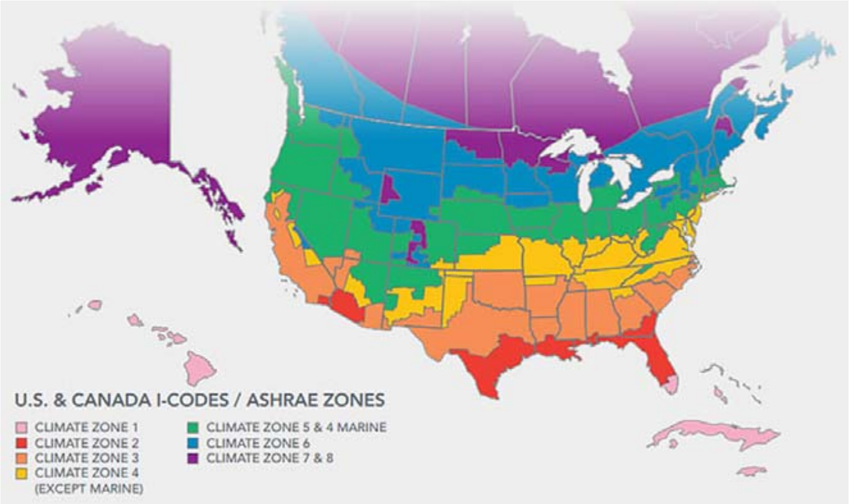
NATIONAL CONCRETE CONSORTIUM

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

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)

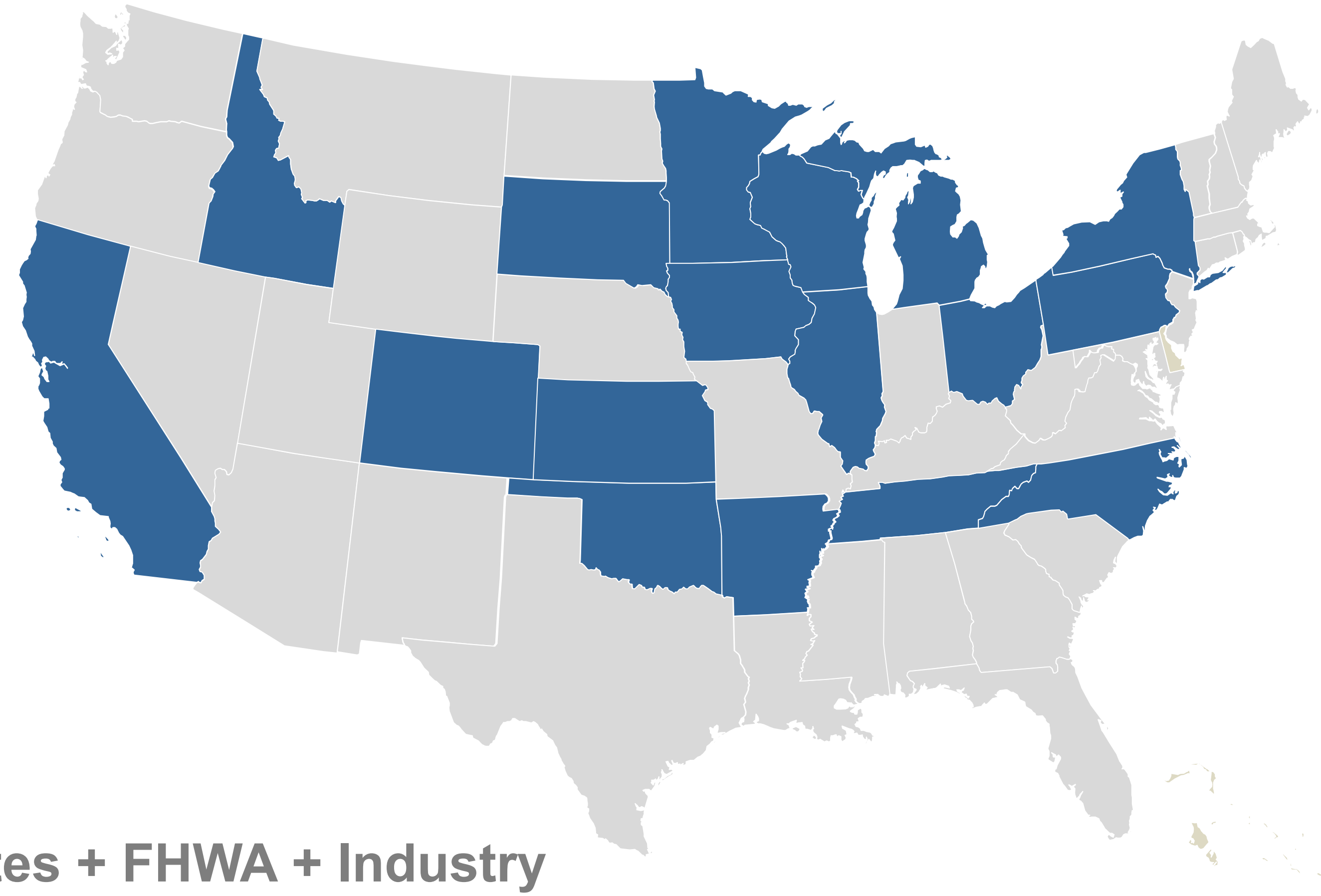
Tech Brief working copy

American Association of State Highway and Transportation Officials
444 North Capitol Street N.W., Suite 249
Washington, D.C. 20001

Tech Center

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			—	

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

Diversified
Engineering
Services, Inc

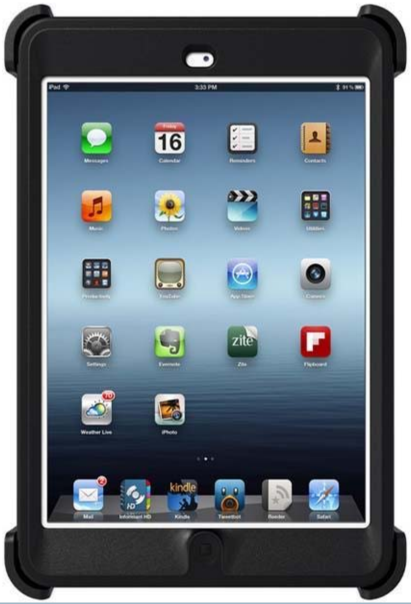
A Modernized Specification

✓ 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…

Concrete property	Test description	Test method	Comments
Workability	Aggregate gradation	ASTM C 136 / AASHTO T 27 ASTM C 566 /AASHTO T 255	• Use the individual gradations and proportions to calculate the combined gradation.
	Combined gradation	Tarantula curve	• Adjust combined gradation to achieve optimum workability
	Paste content	Batch sheet	• Adjust paste content to find minimum paste needed while still workable • Confirm that total is below maximum permitted for shrinkage
	VKelly or Box	TP129 / PP84 X2	• Confirm that the mixture responds well to vibration
	Slump at 0, 5,10,15, 20, 25, & 30 minutes	ASTM C 143 / AASHTO T 119	• Look for excessive slump loss due to incompatibilities. This is more likely at elevated temperatures. • Determine approximate WRA dosage
	Segregation		• Look for signs of segregation in the slump samples
Air void system	Foam drainage	-	• Assess stability of the air void system for the cementitious / admixture combination proposed
	Air content	ASTM C 231 / AASHTO T 152, T196	• Determine approximate AEA dosage
	SAM	AASHTO TP118	• < 0.2 target
	Clustering	Retemper a sample and use optical microscopy to assess clustering	• Can affect strength, • Air content can also jump with retempering
	Hardened air	ASTM C 457	• Calibrate SAM limits
	Mortar content	Vibrate a container (air pot) for 5 minutes. Measure depth of mortar at the top surface	• Provides information on the coarse aggregate content – maximum is ~ ¼"
Unit weight	Unit weight	ASTM C 138 / AASHTO T 121	• Indicates yield the mixture and a rough estimate of air content • Establish basis for QC monitoring
Strength development	Compressive or flexural strength	ASTM C 39 / AASHTO T 22 and/or ASTM C 78 / AASHTO T 97 at 1, 3, 7, 28 & 56 days	• Calibrate strength gain for early age QC • Calibrate flexural with compressive strengths
	Maturity	ASTM C 1074	• Calibrate the mixture so maturity can be used in the field to determine opening times
Transport	Resistivity / F factor	Soak /store samples in salt solution	• Determine development of F Factor over time
	Sorption	ASTM C 1585	• Determine time to critical saturation
	w/cm	Microwave	• Calibrate microwave test with batch data
Other	Hydration	Semi-adiabatic calorimetry	• Determine hydration rates of mixture.

AASHTO PP-84

How Do We Stay Safe?

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

Concrete property	Test description	Test method	Comments
Workability	Slump	ASTM C 143 / AASHTO T 119	•
Air void system	SAM	AASHTO TP118	•
Strength	Compressive or flexural strength	ASTM C 39 / AASHTO T 22 and/or ASTM C 78 / AASHTO T 97	•
Transport	Resistivity / F factor	Soak samples in salt solution	•
Other	w/cm	Microwave	•

How Do We Stay Safe?

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

Concrete property	Test description	Test method	Comments
Workability	Aggregate gradation	ASTM C 136 / AASHTO T 27 ASTM C 566 /AASHTO T 255	• Use the individual gradations and proportions to calculate the combined gradation.
	Combined gradation	Tarantula curve	• Monitor uniformity
	Aggregate moisture content	ASTM C 29	• Affects w/cm and workability
	Slump	ASTM C 143 / AASHTO T 119	• Indicates uniformity batch to batch
Air void system	SAM	AASHTO TP118	• Indicates uniformity batch to batch
	Unit weight	ASTM C 138 / AASHTO T 121	• Indicates uniformity batch to batch
Strength development	Compressive or flexural strength	ASTM C 39 / AASHTO T 22 and/or ASTM C 78 / AASHTO T 97	• Indicates uniformity batch to batch
	Maturity	ASTM C 1074	• Opening times
Transport	Resistivity / F factor	Soak samples in salt solution	• Monitor over time • Indicates uniformity batch to batch
Other	Hydration	Semi-adiabatic calorimetry	• Indicates uniformity batch to batch

Workability

- Not too wet
- Not too dry

Workability

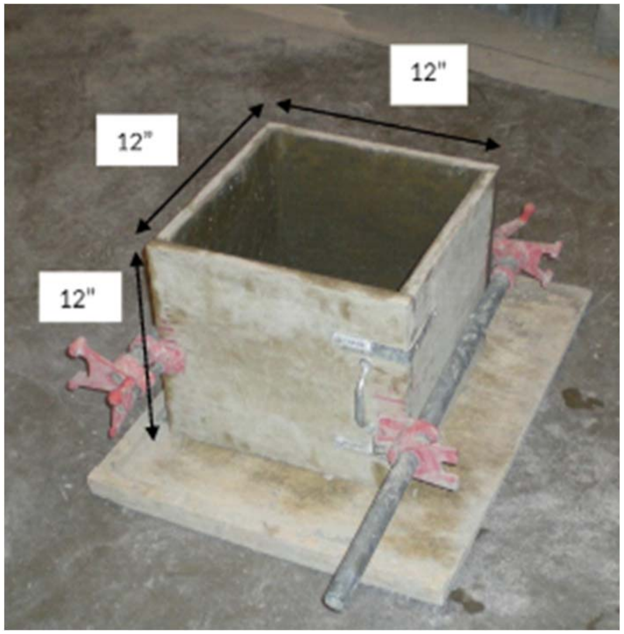
- Slump
  - ✓ Great for uniformity
  - ✓ Cheap, fast and familiar
  - ✓ Does not tell about response to vibration

  - ✓ QC

Workability

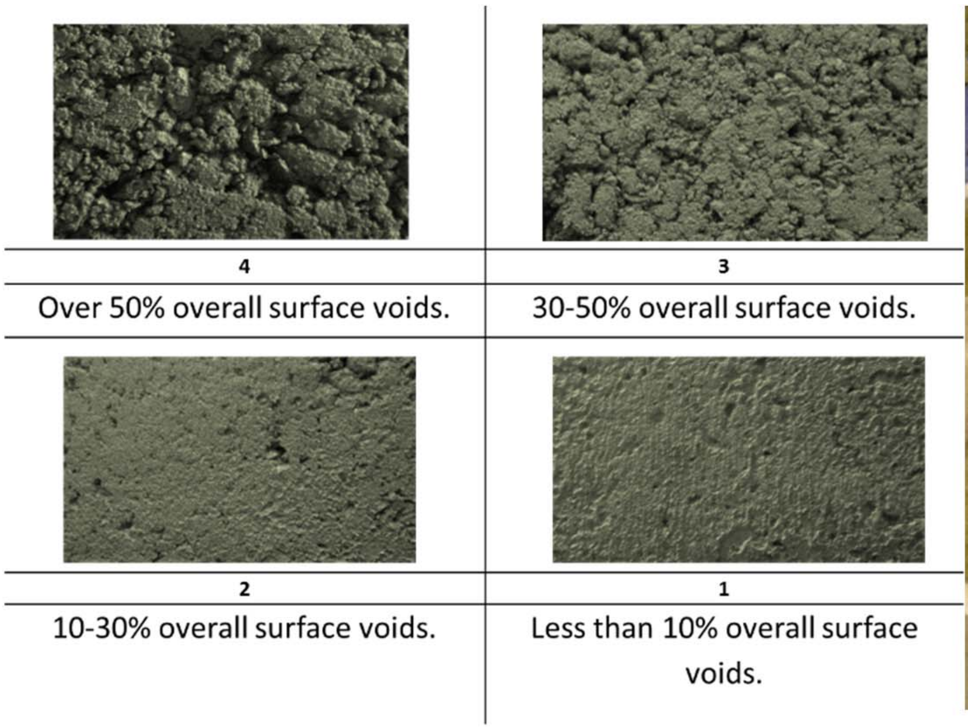
- Box
  - ✓ Does tell about response to vibration
  - ✓ Adjust aggregate gradation and paste content to achieve desired numbers
  - ✓ Subjective

  - ✓ Prequalification
  - ✓ QC



Box Test

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



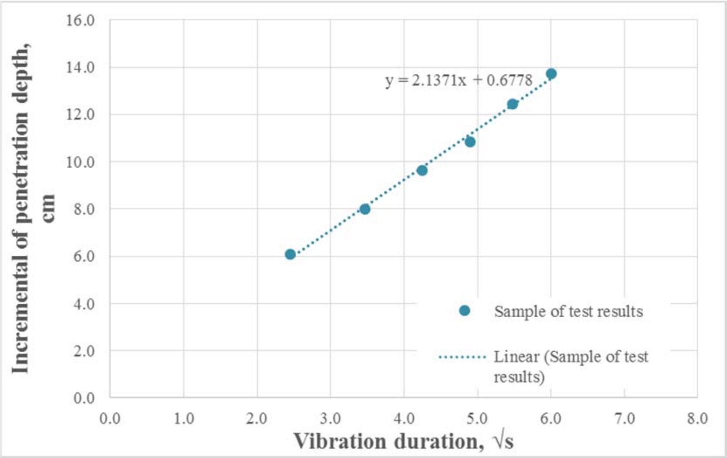
Workability

- 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



Workability

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

  - ✓ Don’t add water!

Workability

- Better concrete!

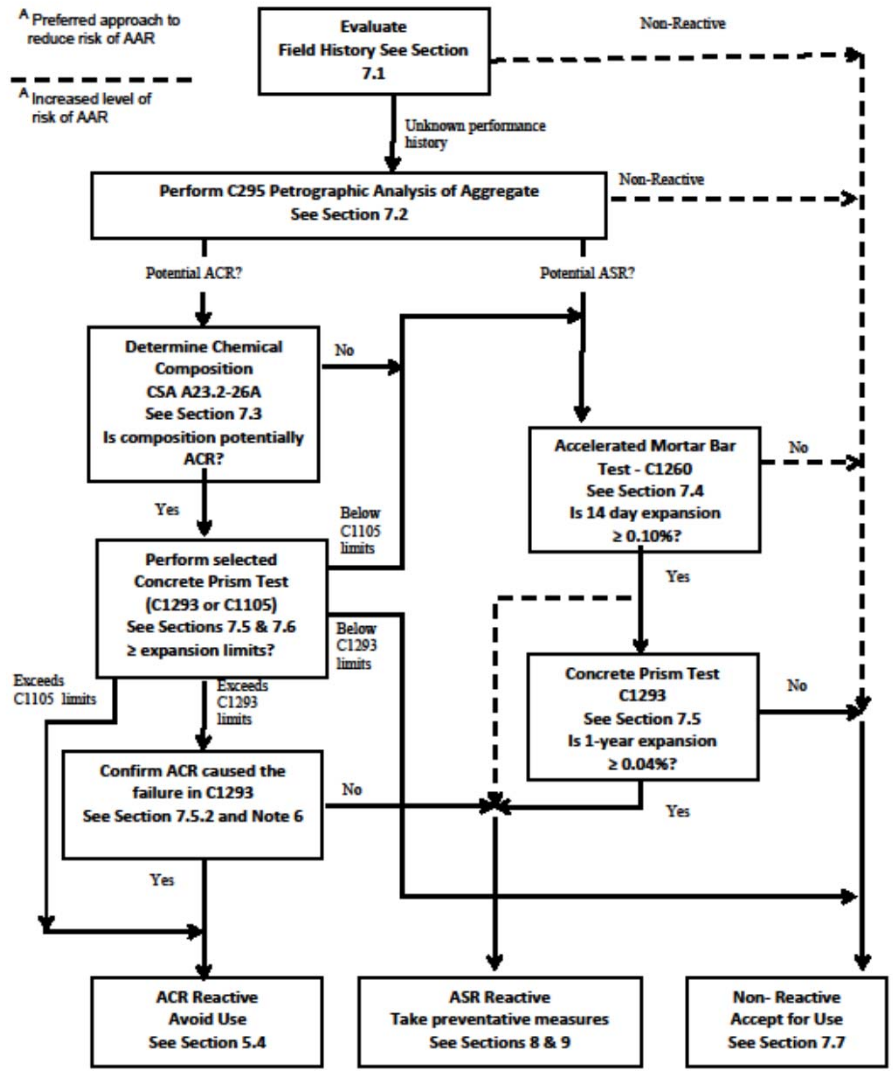
Aggregate Stability

- 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

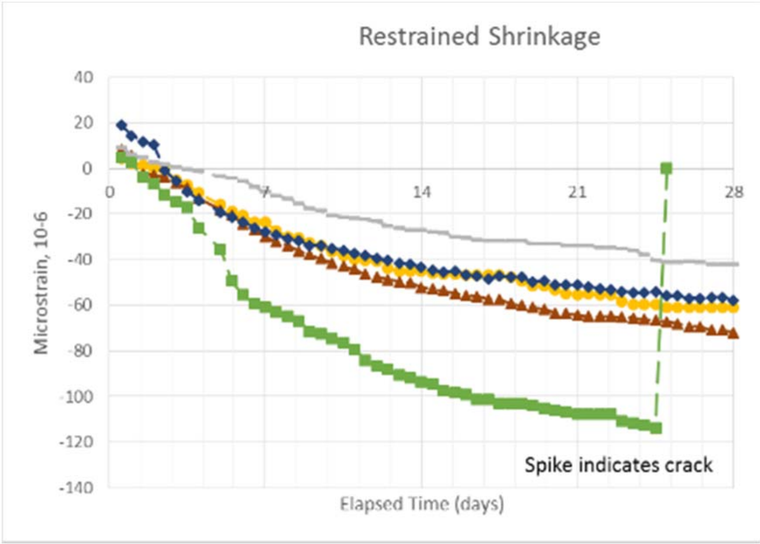
Shrinkage

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

Project	**Gravel 1"**		**5/15/2017**		
Mixture Proportions					
		Targets		**Actual**	
			Pounds	R.D.	Volume
Cement	Type I		342	3.15	1.74
SCM 1	F Ash		86	2.65	0.52
SCM 2	Slag		0	1.00	0.00
Coarse Agg	A85006		1753	2.72	10.33
Fine Agg	A25518		1318	2.66	7.94
Intermediate	A85007		340	2.43	2.24
Water			180	1.00	2.88
Air %			5.0		1.35
			4019		27.00
Cementitious		428	428	pcy	
Volume of paste			24.0	%	
Volume of aggs			76.0	%	
Volume of voids			19.2		
vp/vv		125	125.0		
w/cm		0.42	0.42		
% SCM 1		20	20	%	
% SCM 2		0	0	%	
Mass aggs		3411	3411	pcy	
Excess paste, %			4.8	%	

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)

➢ $$F = \frac{\text{Resistivity (bulk)}}{\text{Resistivity (solution)}}$$

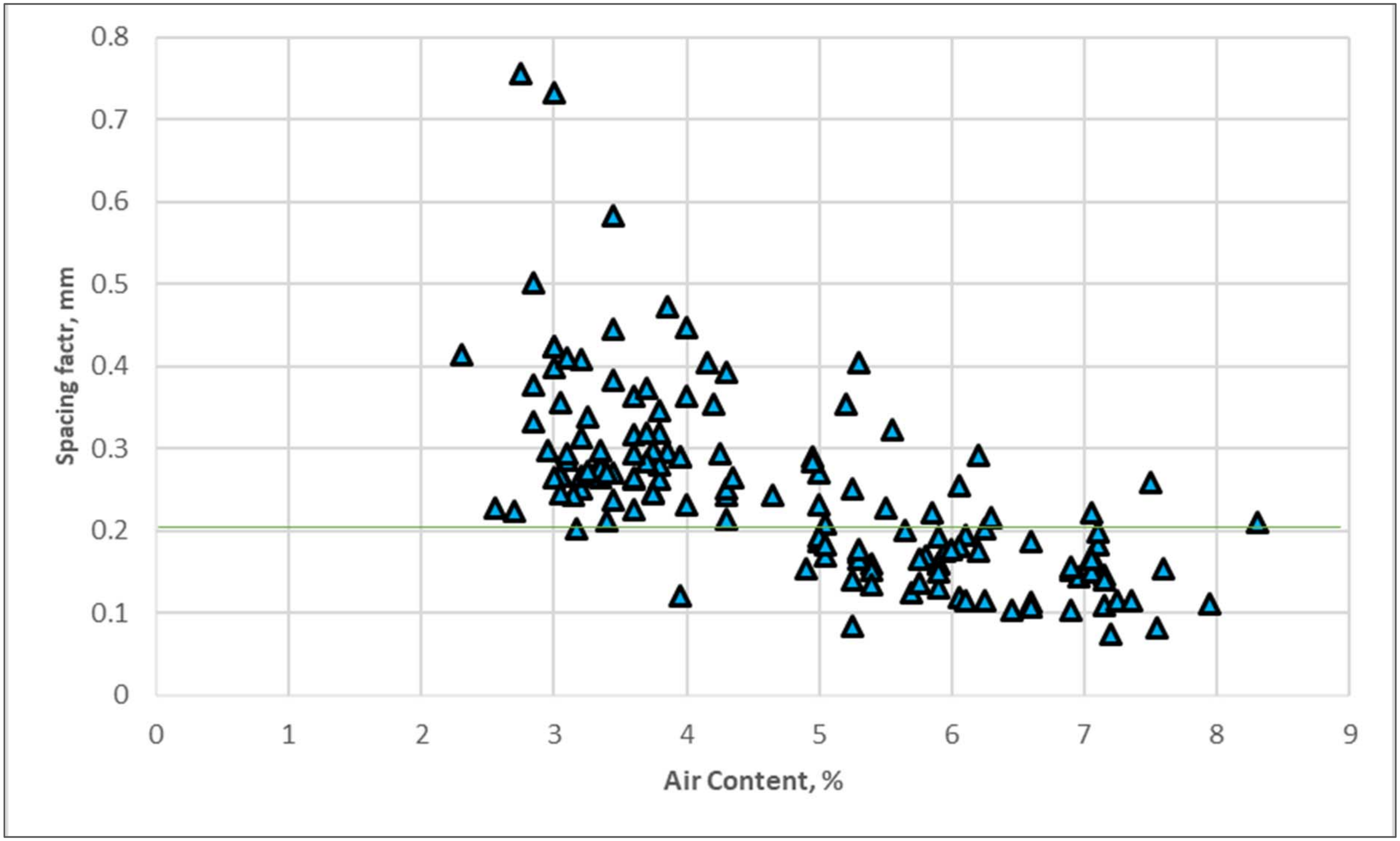
Transport

- What if it is bad?
  - ✓ Review w/cm
  - ✓ Review SCM type and dose

Cold Weather

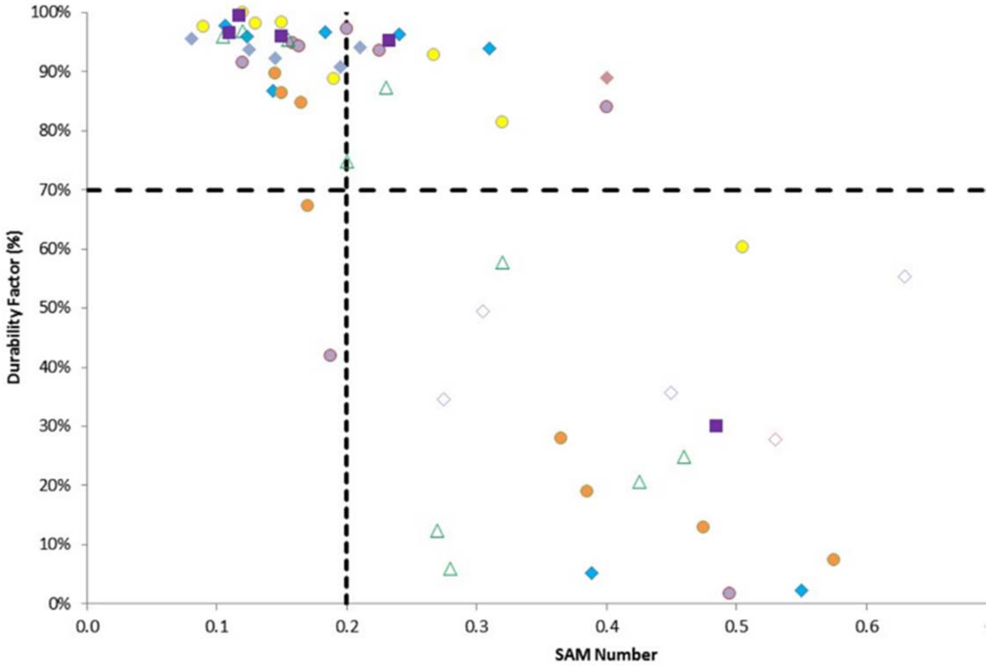
- Freeze-thaw
  - ✓Saturation
  - ✓Entrained air
- De-icing salts
  - ✓Sufficient SCM

Is the Pressure Pot Sufficient?



Super Air Meter

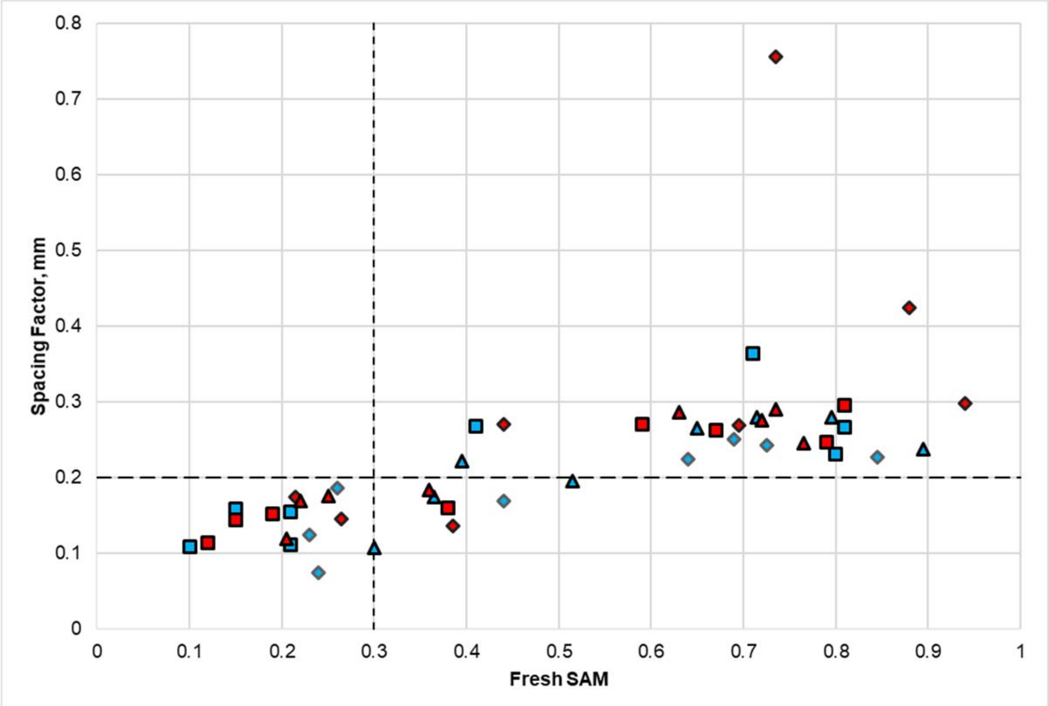
- Reports air content and SAM number
- SAM number correlates with freeze thaw testing



Super Air Meter

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

- Prequalification
- QC
- Acceptance (later)



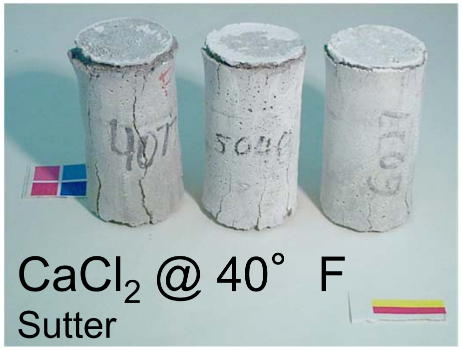
SAM

- 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 mag chloride
  - ✓ Expands 30%
  - ✓ Forms above 32F

- Prevention
  - ✓ Enough SCM



$CaCl_2$ @ 40° F
Sutter

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

Who We Are | Technical Library | Research | Events | Recorded Webinars | Search

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

Gordon Smith, glsmith@iastate.edu

John Cunningham, jcunningham@snyder-associates.com

Resources

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

March 2017

Peter Taylor, PhD, PE
Director

National Concrete Pavement
Technology Center

2711 S. Loop Drive,
Suite 4700
Ames, IA 50010-8664

515-294-9333
ptaylor@iastate.edu

National Concrete Pavement
Technology Center

IOWA STATE UNIVERSITY
Institute for Transportation

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

CP ROAD MAP

www.cproadmap.org

April 2017

ROAD MAP TRACK 1

PROJECT TITLE
Performance Engineered Mixtures for Concrete Pavements

TECHNICAL WRITERS
Tom Cackler (lead)
Dale Harrington
Peter C. Taylor

CONTRIBUTORS
Tyler Ley
Larry Sutter
Jason Weiss
Tom VanDam

EDITOR
Sabrina Shields-Cook

SPONSORS
Federal Highway Administration
National Concrete Consortium

MORE INFORMATION
Dale Harrington
Snyder and Associates, Inc.
(515)964-2020
dharrington@snyder-associates.com

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.

Figure 1. AASHTO PP 84-17 specification

CP ROAD MAP

www.cproadmap.org

July 2017

ROAD MAP TRACK 1

PROJECT TITLE
Performance Engineered Mixtures for Concrete Pavements

TECHNICAL WRITERS
Tom Cackler (lead)
Mike Praul, FHWA
Richard Duval, FHWA

EDITOR
Sabrina Shields-Cook

SPONSORS
Federal Highway Administration
National Concrete Consortium

MORE INFORMATION
Dale Harrington
Snyder and Associates, Inc.
(515)964-2020
dharrington@snyder-associates.com

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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

Coming Soon

TECH BRIEF November 2018

PERFORMANCE ENGINEERED MIXTURES FOR CONTRACTORS

PROJECT
Performance Engineered Concrete Paving Mixtures TPF-5(368) PEM

AUTHOR
Peter Taylor

PEM DEVELOPMENT/ IMPLEMENTATION TEAM
Jerod Gross
Cecil Jones
Tyler Ley
Mike Praul
Gordon Smith
Peter Taylor
Tom Van Dam
Jason Weiss

SPONSORS
Federal Highway Administration
Transportation Pooled Fund TPF-5(368)
Concrete Paving Industry

National Concrete Pavement Technology Center
2711 South Loop Drive, Suite 4700
Ames, IA 50010-8664
cptechcenter.org

Director, Peter Taylor
515-294-3230 / ptaylor@iastate.edu

National Concrete Pavement Technology Center

Iowa State University
Institute for Transportation

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 early-age 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 formalizes this approach. AASHTO PP 84 addresses six fundamental properties:

- Transport properties
- Aggregate stability
- Strength
- Cold weather exposure
- Shrinkage
- Workability

Angela James Folkestad, CO/WY Chapter, ACPA

Demonstration day in Colorado where the FHWA Mobile Concrete Trailer was present to illustrate new tests for the PEM program, including the VKelly test developed at the CP Tech Center

PEM - DELIVERING CONCRETE TO SURVIVE THE ENVIRONMENT

- Performing to and beyond agency need/expectation

- A partnership of agency and industry

THANK YOU