RC 2018 XVII Reunión del CONCRETO

El evento del Cemento, el Concreto y los Prefabricados

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El evento del Cemento, el Concreto y los Prefabricados

Quality as a Tool of Success in Infrastructure

Jim Grove
Conferencista #17
ATI Inc.
USA

Core Elements of Quality Assurance

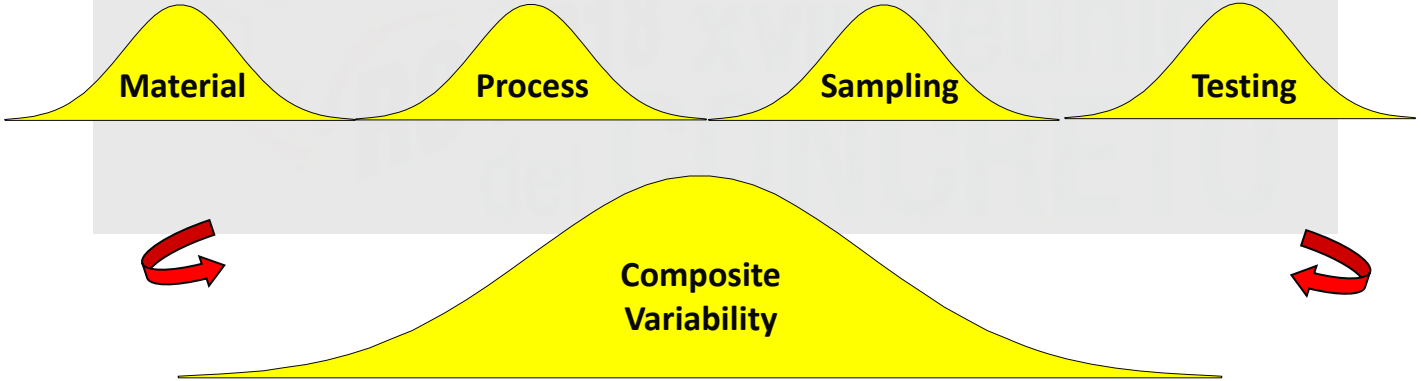
Sources of Variability

Material

Process

Sampling

Testing



Quality Measurement Tools

- Measure conformance with requirements:

Testing

Inspection

Agency Role

- Agency Acceptance
  - **Measure** the **Quality**
  - **Determine** the **payment**
  - Insure compliance with the QC plan

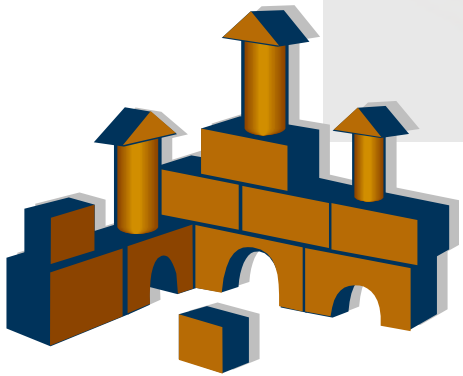
Agency Benefits

- QC Plan => specification compliance
- Saves inspection cost
  - Minimizes deficiency evaluation effort
  - Minimizes rework
  - Minimizes the construction time
- Improved project staffing scheduling

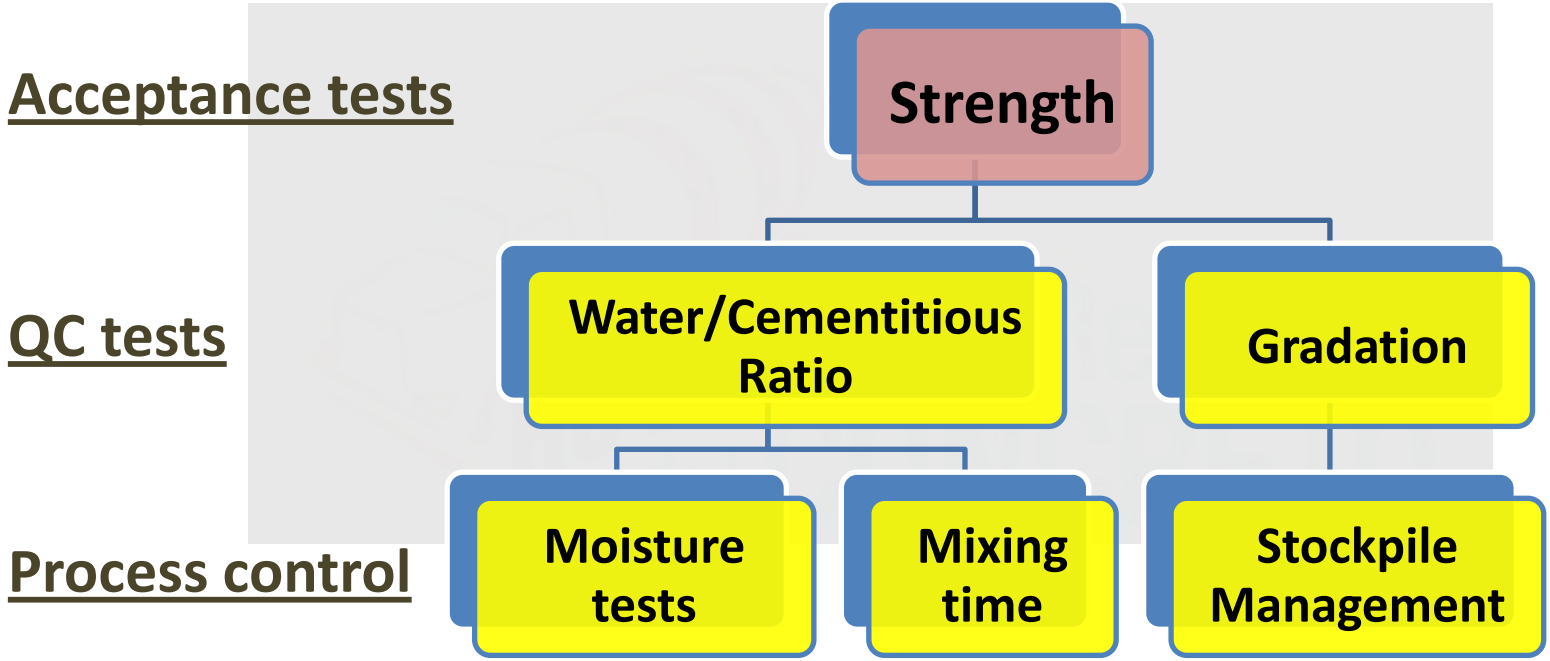
Quality Control

- Contractor Quality Control
  - What the contractor does
  - NOT more of what the agency does
  - Prepare a QC plan
  - Watching for change

Mixture design
↳ Mixture Evaluation
↳ Production



QC Tests are the Building Blocks for Acceptance



QC is NOT doing more of the what the Agency does for acceptance!

Scope of Quality Control Activities

- Contractor's QC system should address:
  - Materials production
  - Materials transportation and handling
  - Field placement procedures
  - Calibration and maintenance of equipment
  - Sampling, testing, and inspection to maintain each process "in control"
  - Use of QC information to make timely adjustments

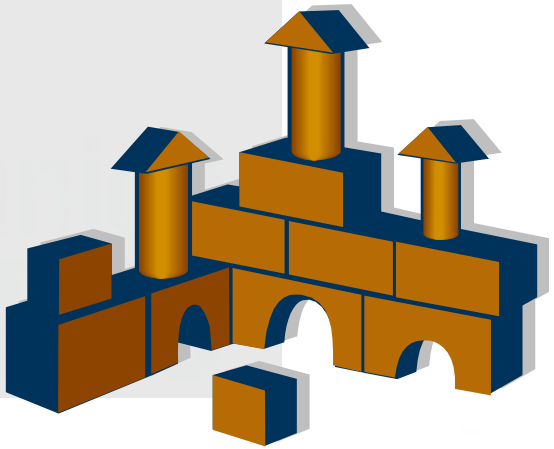
Contractor Benefits

- Competitive Advantage at the bidding table
  - Reduce construction costs
    - Avoid re-work
    - Safety implications
  - Reduce Disincentives
    - Saves costs
    - Increases profits
  - Increase Incentives
    - Know you will get full incentive
    - Use incentive to reduce bid amount

- Allows time for monitoring the process

Supporting Elements of Quality Assurance

- Qualified Laboratories
- Qualified Personnel
- Independent Assurance
- Dispute Resolution



Testing Variability

Three sources

- Technician
- Procedure
- Testing equipment

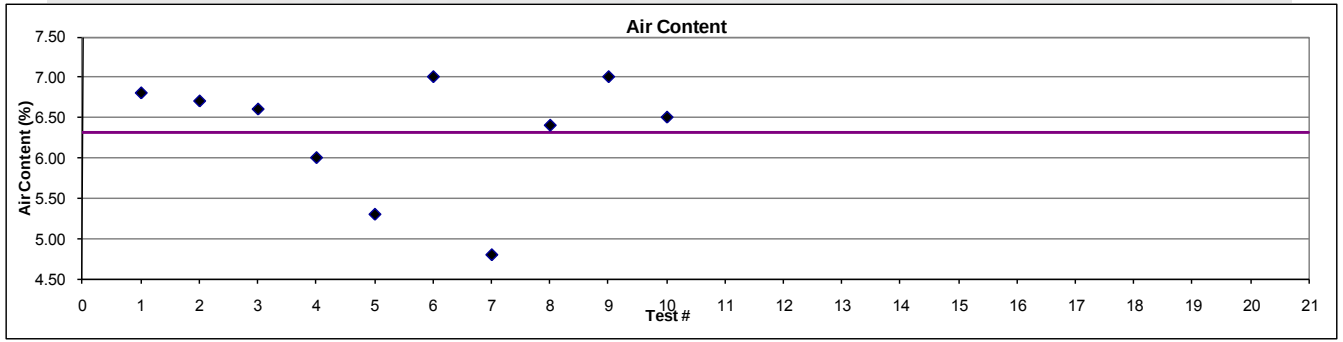
Validity of Sampling Data

- Required for Statistical analysis:

1. **Multiple** (n > 3) **samples** are used
2. All samples are **randomly** obtained
3. Samples are obtained under c**ontrolled conditions**

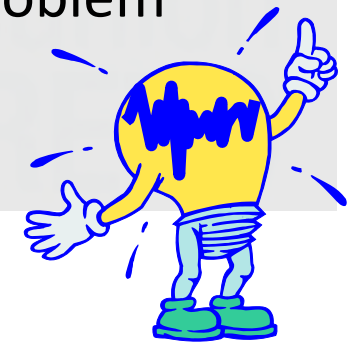
Statistical Process Control (SPC)

- Monitor QC measurements and react
  - Concentrate on identifying change
  - Do not focus on specification limits
  - Changes in materials and/or processes
    - Unusual test results



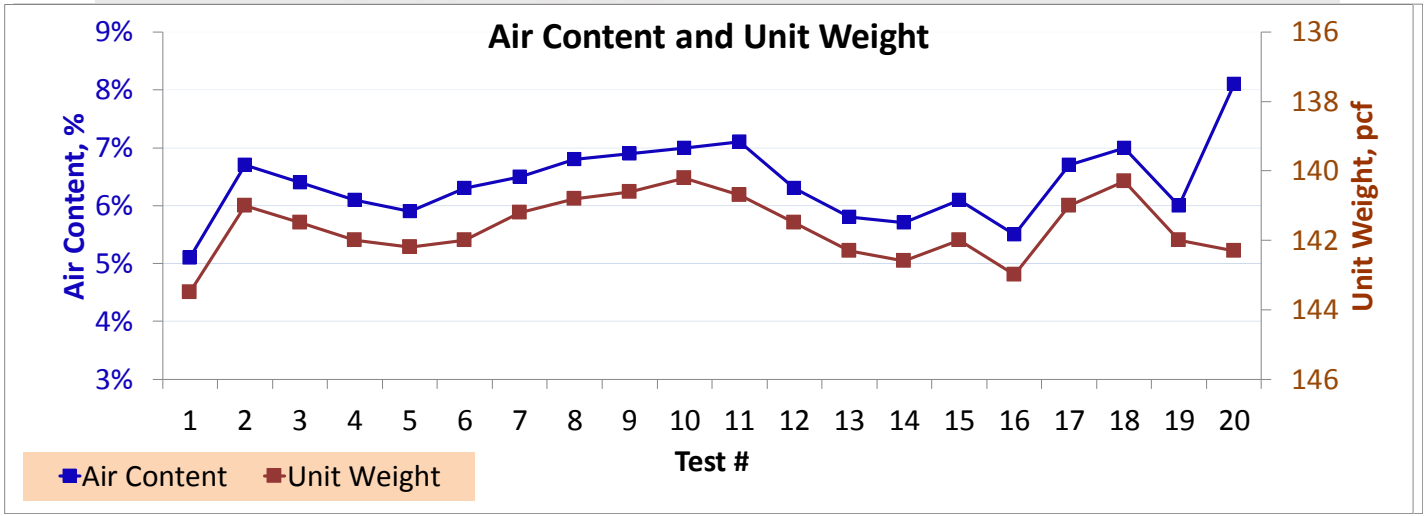
Control Charts

- Control charts **DO NOT**
  - Eliminate variability
  - Tell you where your problem lies
  - Tell you how to correct the problem

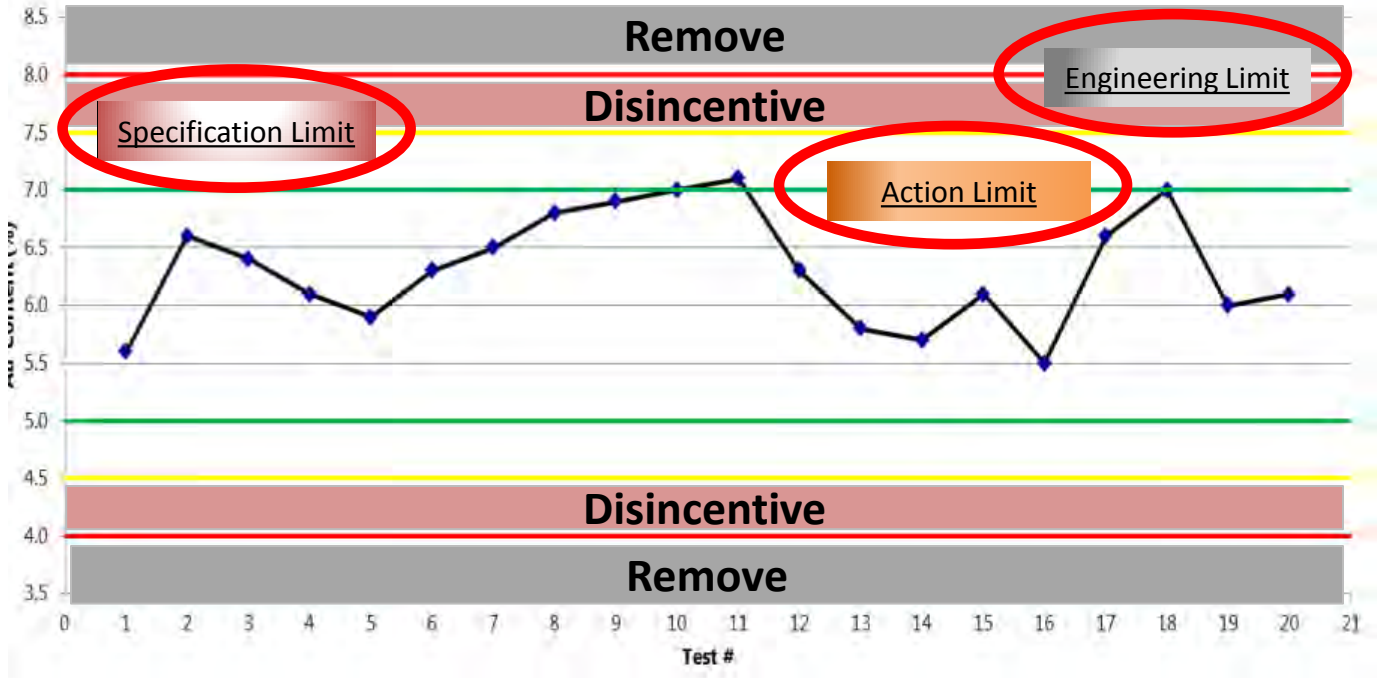


Dual Axis Plot Example

- Air content plotted on the left vertical axis
- Plot unit weight on the right vertical axis



Limits



Air Content Ahead of the paver

Performance Engineered Mixture (PEM) Concept

- Understand
  - What makes concrete last
  - What failure mechanisms we see
- Specify critical properties and test for them
- Prepare the mixtures to meet those specifications
- Starting point
  - For acceptance program for owner agencies

AASHTO PP 84-17

- AASHTO PP 84-17 is a part of the standard specification
- This is Provisional Practice
  - Intended to evolve based on field experience

This document seeks to provide agencies with tools to prepare a specification for concrete mixtures that moves closer to measuring and basing acceptance on parameters that are truly critical to the long-term performance of the system.

Strength

One-Man Band

In the past…

- We could measure it
- Best we had
- Thought to relate to long term performance
- If you mess it up, it always gets worse, not better
- ONE-MAN BAND!!

Performance Engineered Mixtures (PEM)

- Strength
- Cracking tendency
- Freeze-Thaw durability
- Permeability
- Aggregate stability
- Workability*

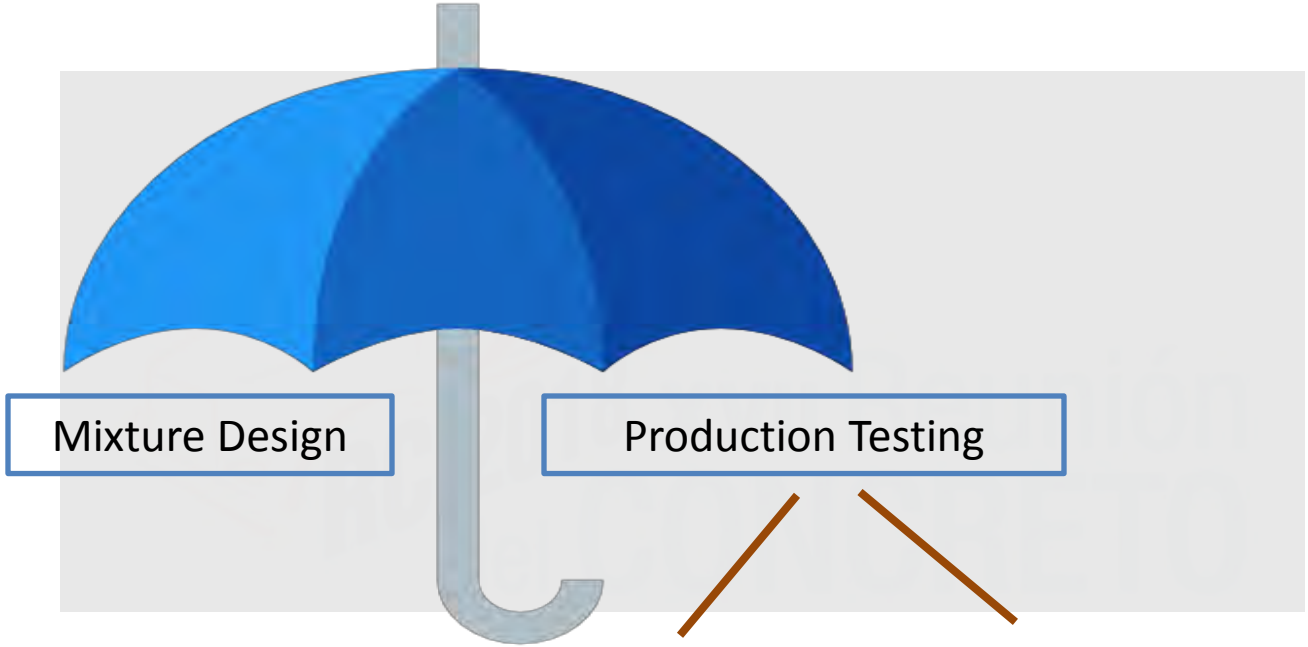
Six-Man Bands

Jefferson Airplane

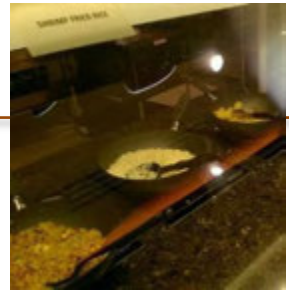
Iron Maiden

The Association

Performance Engineered Mixtures (PEM)



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	

*Prescriptive alternative

Freeze – Thaw Table

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			

Quality Control

- PP 84 acknowledges the key role of QC in a performance specification
- Requires QC testing and control charts
  - Unit weight
  - Water content
  - Air content/SAM
  - Strength
  - Formation Factor (via Surface Resistivity)
- Requires an approved QC Plan
  - Testing targets, frequency, and action limit
  - Equipment and construction inspection

Optimized Combined Gradation

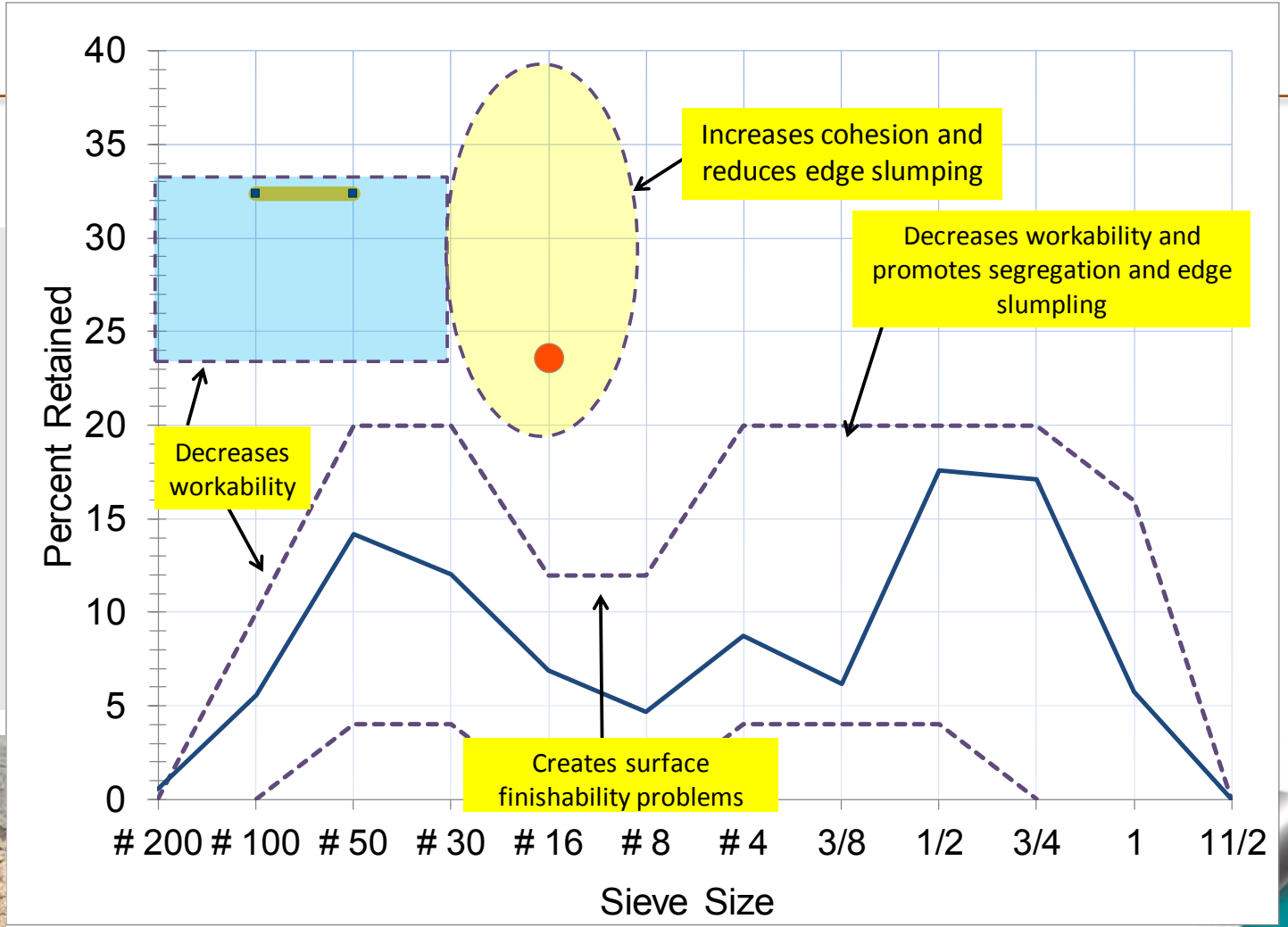
- Evaluate the combined aggregate gradation
- Often utilizes an intermediate size aggregate
- Maximize the filling of the space with aggregate
- Leads to minimizing paste content
  - Water and contaminates enter through paste
  - Reduces permeability

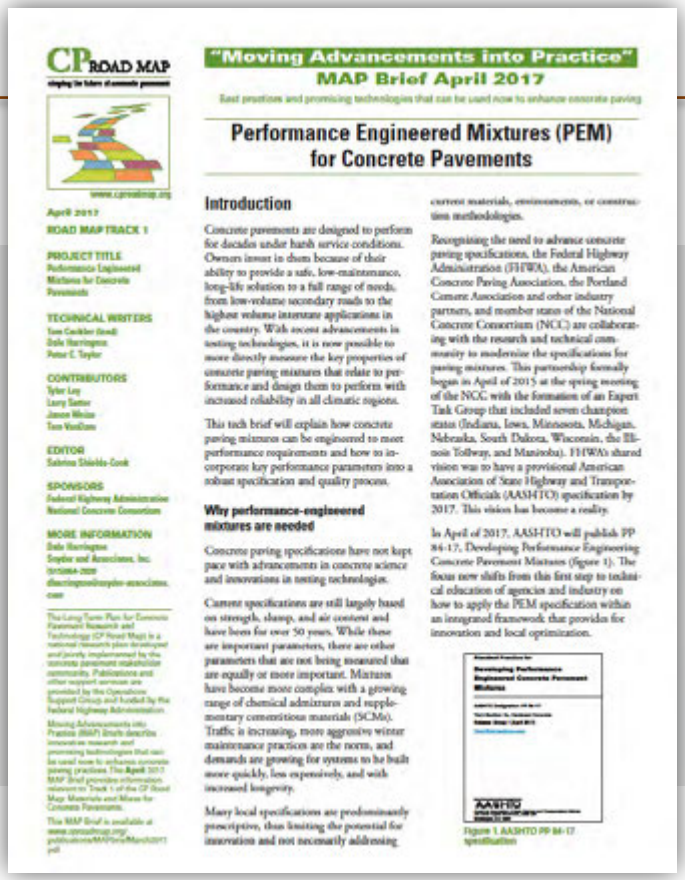

Gap graded


Well graded

Iowa DOT

Tarantula Curve





CP ROAD MAP

"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

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

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.

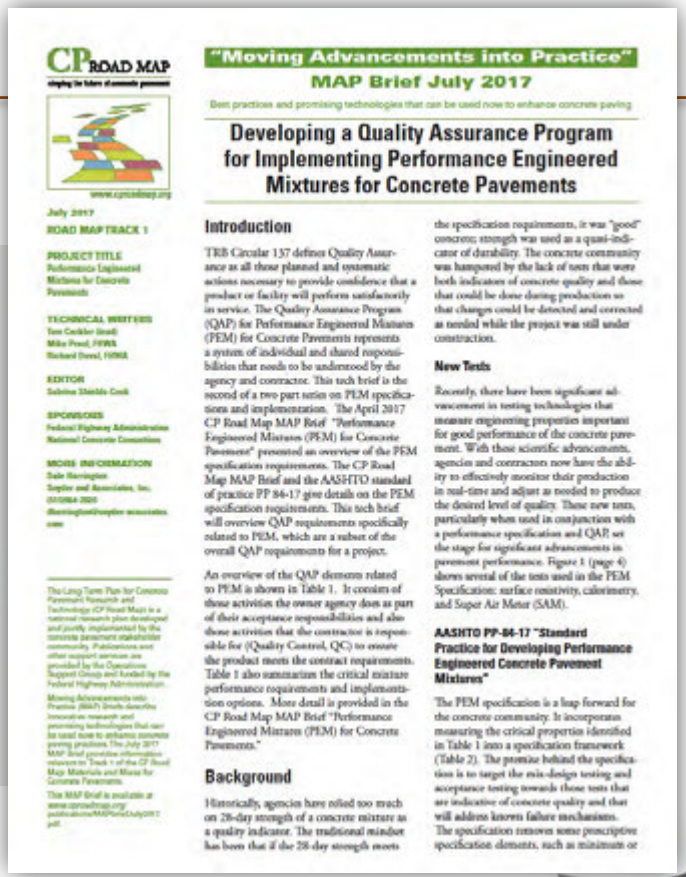
Current specifications are still largely based on strength, slump, and air content and have been for over 50 years. While these are important parameters, there are other parameters that are not being measured that are equally or more important. Mixtures have become more complex with a growing range of 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

"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

July 2017

ROAD MAP TRACK 1

PROJECT TITLE
Performance Engineered Mixtures for Concrete Pavements

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

Introduction

TEB 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 Pavements" 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 promise 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

One Pagers

- Effort to use FHWA Mobile Concrete Trailer data
- Narrowly focused
- Meant to stir interest and point reader to resources
  - 1st : Cement Content
  - 2nd: Optimized Mix Design
  - 3rd : Cores vs. Cylinders
  - 4th : NDT Pavement Thickness
  - 5th: Tining/Surface Texture
  - 6th: Surface Resistivity Test

www.fhwa.dot.gov/pavement/concrete/trailer/resources

Quality Fundamentals

- Using inspection & testing
- Insure materials quality
- Recognize inherent variability
- Utilizing testing targets and limits
- Insuring the validity of sampling data
  - Random sampling
- Testing
  - The right quality characteristics
  - Real time

Jim Grove

ATI Inc. / FHWA

2711 South Loop Drive, Suite 4502

Ames, Iowa 50010

Phone: 515-294-5988

Mobile: 515-450-3399

jim.grove@dot.gov