

# Better Specifications for Concrete

## A Users Guide to Performance Engineered Mixtures

Dr. Peter Taylor, PE (IL), FACI

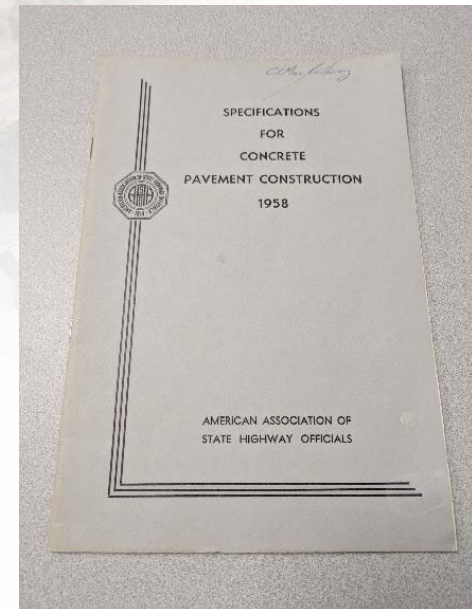
National Concrete Pavement  
Technology Center



# What is PEM?



- A program to develop a better specification for concrete mixtures
  - Understand what makes concrete “good”
  - Specify the critical properties and test for them
  - Prepare the mixtures to meet those specifications
- Ask for what is needed, and no more

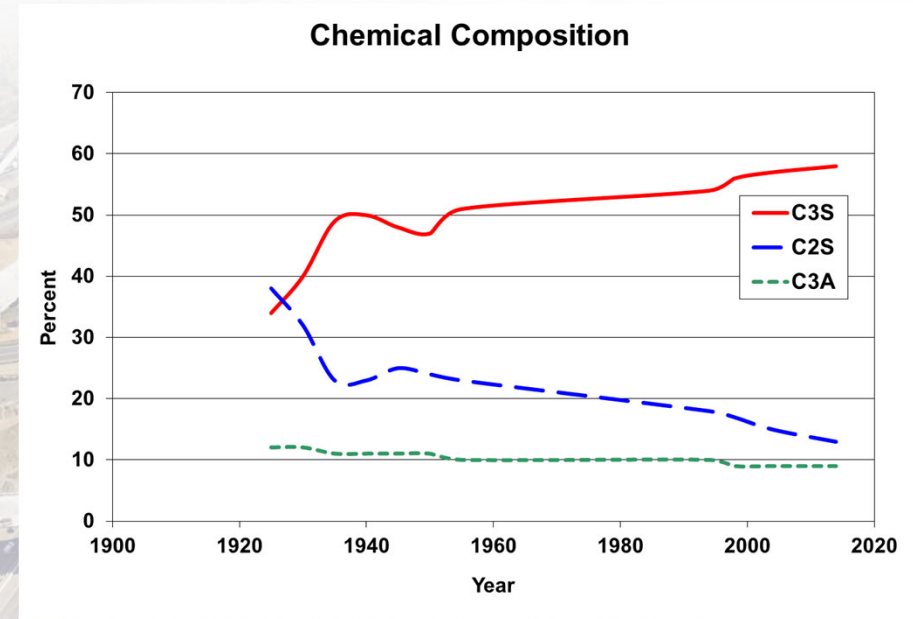


# What has changed?



- Cementitious chemistry

- $C_2S$  /  $C_3S$  balance
- Fineness
- Blended SCMs
- PLC
- (more to come)



- Other cementitious materials
- Chemical admixtures

# The way we were



- Quality Assurance

- Slump
- Strength
- Thickness



# The way we are



- Quality Assurance

- Slump
- Strength
- Thickness

- Air



# The way we were



- Equipment



# The way we are

## ConPaveStruc 2023



- Equipment



# The way we were



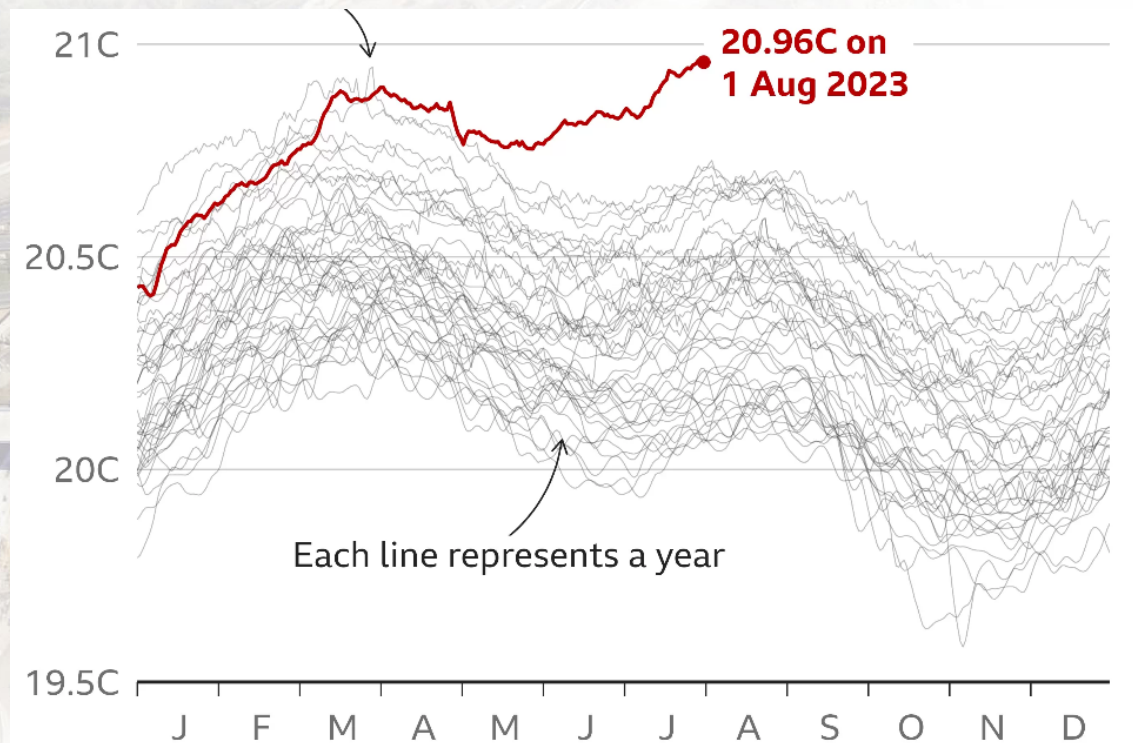
- Design Life
  - 20 years
  - ...
  - 40 years
  - ...





# Why Bother with Change?

- Sustainability
- Economics
- Materials
- Staffing
- Public perception

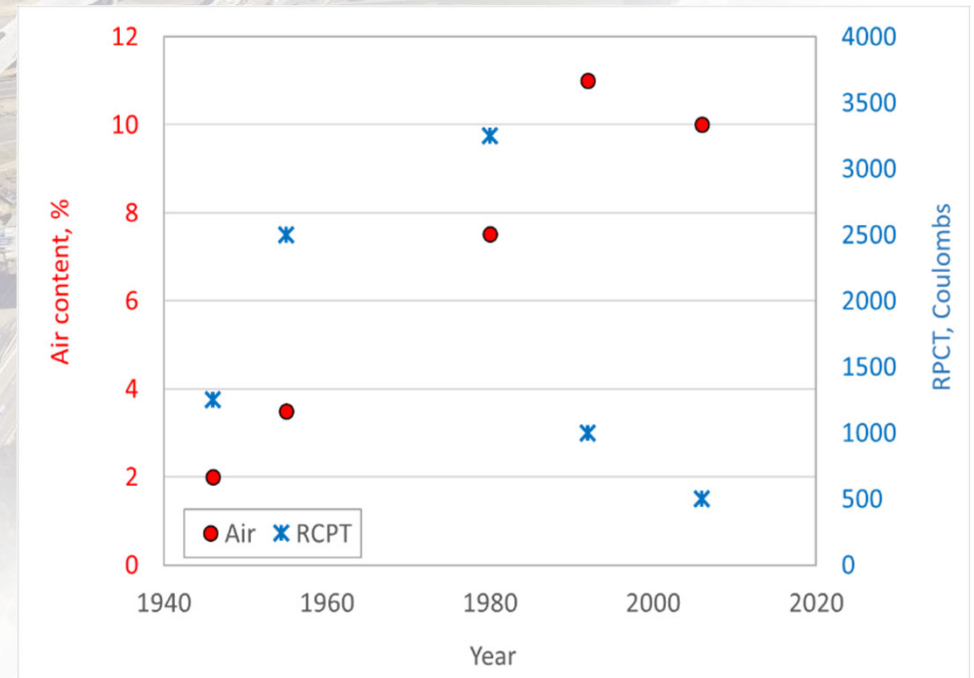


Source: ERA5, C3S/ECMWF

B B C

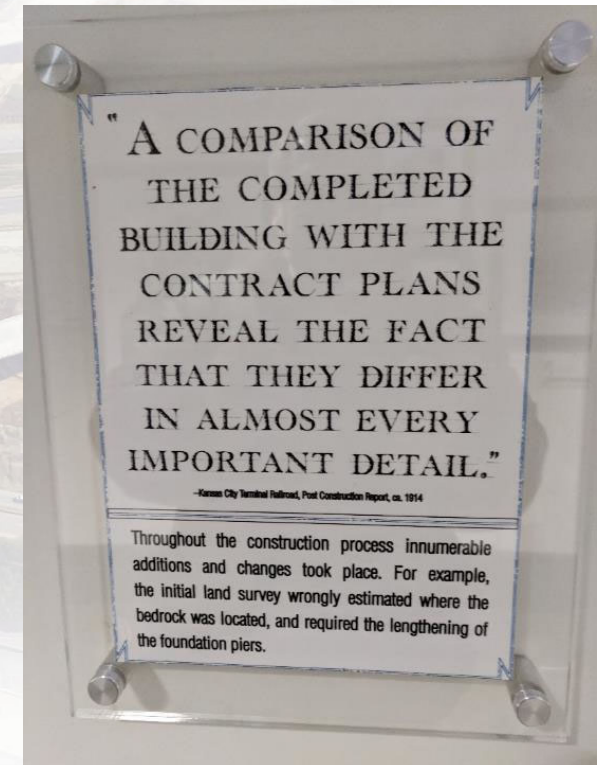
## What is Good concrete?

- Constructible (Workable)
- Dimensionally stable
  - Aggregates
  - Shrinkage
- Impermeable (Transport)
- Cold weather resistant
  - Freeze thaw
  - Salt attack
- Strong (enough)



## When do we test?

- Prequalification
  - Ensure the mix can meet spec.
  - Understand sensitivity to variations
- QC
  - Watch it develop
- Acceptance



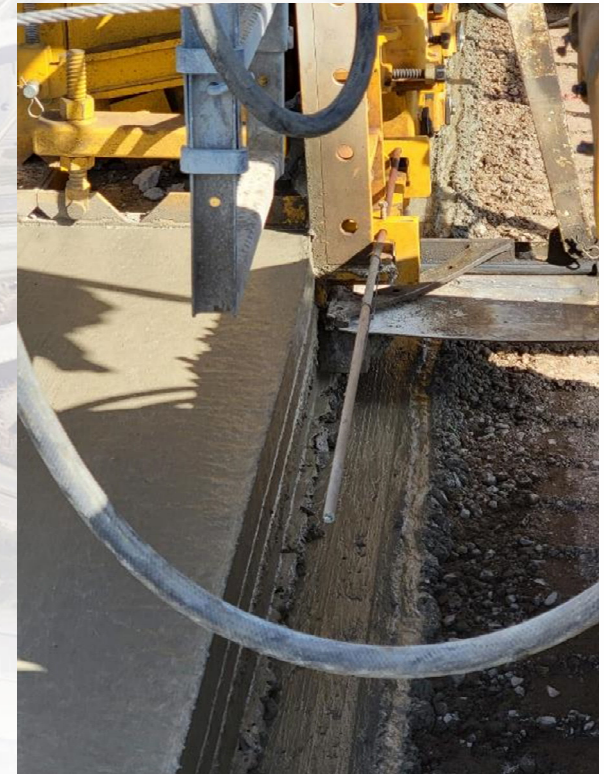
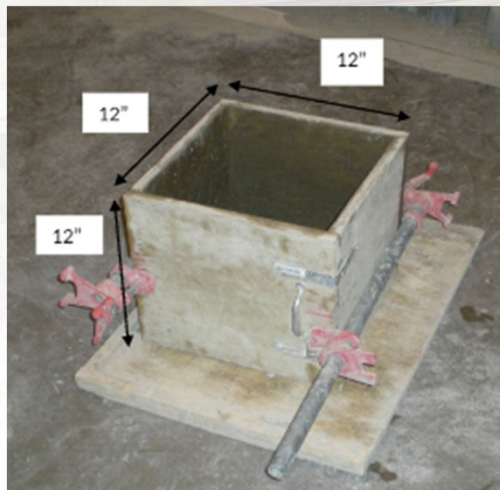
## Workability

- Not too wet / Not too dry
- Right for the equipment you are using
- Response to vibration
- Thixotropy
- VKelly and Box
- Prequalification



## Workability

- VKelly and Box



## Cold Weather

- Saturated Freeze-thaw
- De-icing salts
- Scaling
- Air void system
- SCM dose
- Prequalification
- QC
- Acceptance



## Aggregate Stability

- Aggregate growing due to
  - Alkali silica reaction
  - (Alkali carbonate reaction)
  - D-Cracking
- AASHTO R80
- Prequalification



## Shrinkage

- Influences cracking risk
- Warping in slabs on grade
- Paste Content
- Ring tests
- Prequalification





## Strength

- Strong enough to carry loads
  - (and not much more)
- Compression / Flexural
- Prequalification
- QC
- Acceptance



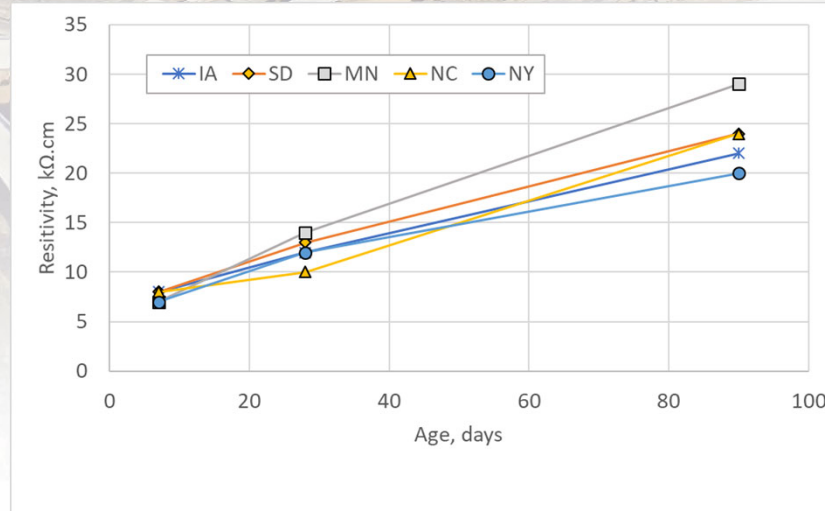
## Transport properties (permeability)

- All deterioration mechanisms involve fluid movement
- Keep water out = longer life
- Resistivity
- Prequalification
- QC
- Acceptance



## Resistivity

- Resistivity
  - Curing: Fog room
  - Pull out at desired age
  - Read and put back
  - Repeat



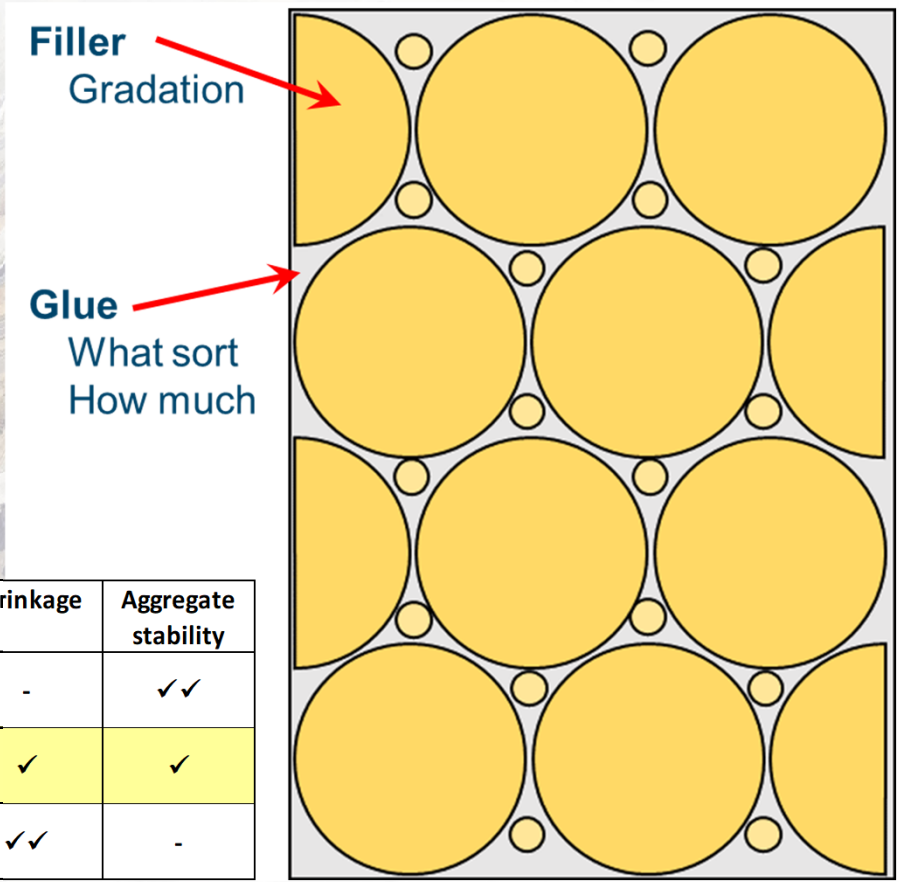
# The Mixture



- Can we make it:
  - Comply with the specification?
  - More sustainable?
  - Easier to work with?
  - People proof?



# The Mixture



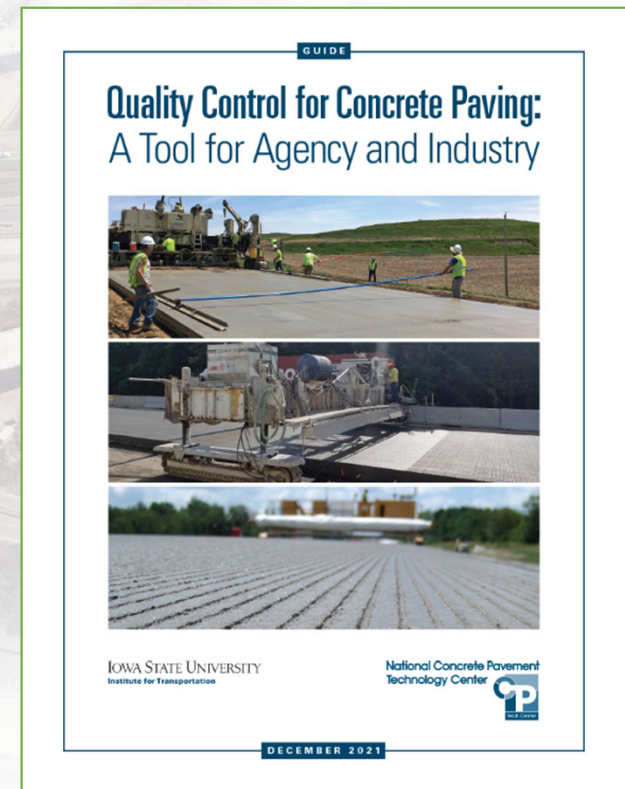
		Workability	Transport	Strength	Cold weather	Shrinkage	Aggregate stability
Aggregate System	Type, gradation	✓✓	-	-	-	-	✓✓
Paste quality	Air, w/cm, SCM type and dose	✓	✓✓	✓✓	✓✓	✓	✓
Paste quantity	Vp/Vv	✓	-	-	-	✓✓	-



# PEM So Far



- AASHTO R101
  - Guide to specifiers
    - What to ask for
    - How to measure it
    - When to measure it
- Commentary in development
- QC Manual available



# PEM So Far



- Tools available to help contractors and agencies
  - Tech briefs
  - Proportioning tool
  - Training

**TECH BRIEF** October 2018

## PERFORMANCE ENGINEERED MIXTURES FOR CONTRACTORS

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Federal Highway Administration  
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Performance Engineered Concrete Paving Mixtures

**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

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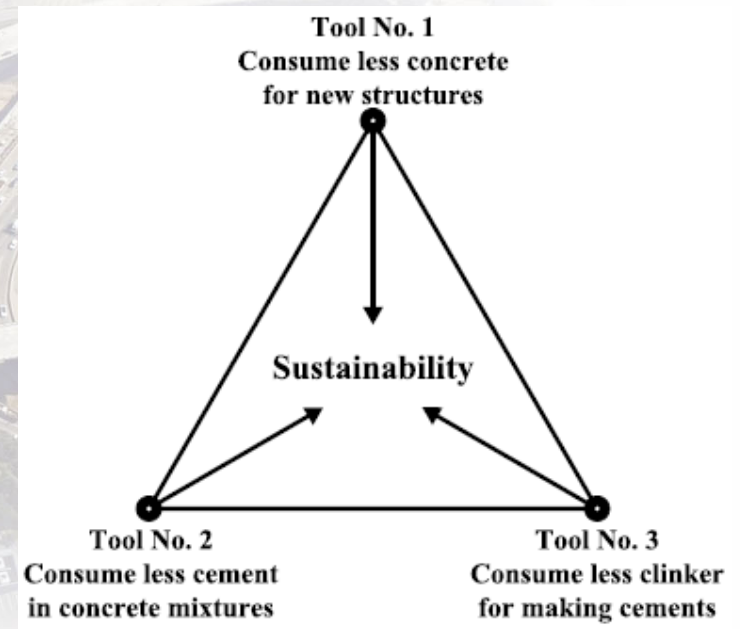


Angela James Folkstad, COWI Chapter - American Concrete Pavement Association  
Demonstration day in Colorado where the FHWA Mobile Concrete Trailer was present to illustrate new tests for the PEM program, including the Wkly test developed at the CP Tech Center

# What about Sustainability?

## What can we do?

- Use less concrete
- Use less binder in the concrete
- Use less clinker in the binder



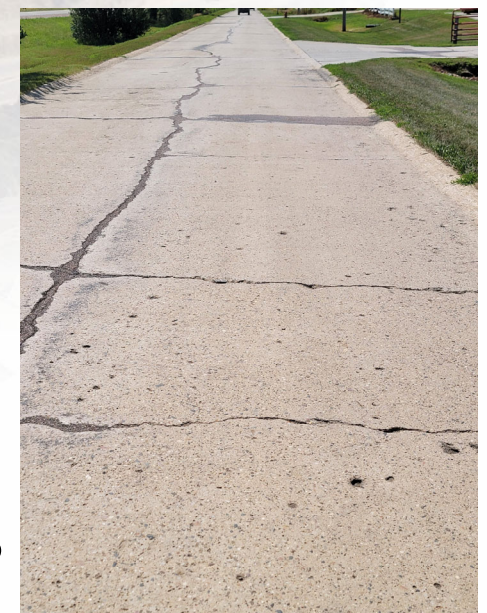
Mehta, CI Feb. 2009



# What about Sustainability?



	Sustainability	Longevity
Paste Content	✓	✓
w/cm	~	✓
SCM type and dose	✓	✓
Air void system	~	✓



# Closing



- Ask for what is needed, and no more
- Next:
- What happens after delivery?



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