Integrated Materials and Construction Practices for Concrete Pavement

2nd Edition

IOWA STATE UNIVERSITY
Institute for Transportation

National Concrete Pavement Technology Center
CP Tech Center

Purpose

A resource to:

- Bridge the gap between research and practice
- Encourage good practices
- Provide practitioners with tools to design, build, and maintain concrete pavements
- Help practitioners improve communication between practice areas

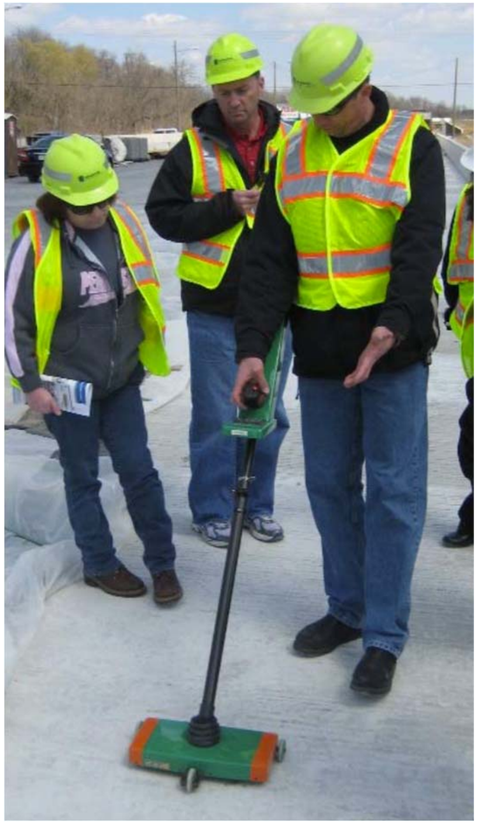
Learning objectives

- Understand concrete pavements as integrated systems
- Appreciate that constructing a concrete pavement project is a process involving interrelated practices
- Implement technologies to optimize performance
- Recognize and avoid factors leading to premature distress
- Access how-to and troubleshooting information

Audience

Anyone interested in optimizing concrete performance

- Engineers
- Quality control (QC) personnel
- Specifiers
- Contractors
- Materials and equipment suppliers
- Technicians
- Construction supervisors
- Tradespeople



What's New

This edition is an update:

- Sustainability
- MEPDG
- PEM
- RTS

Authors

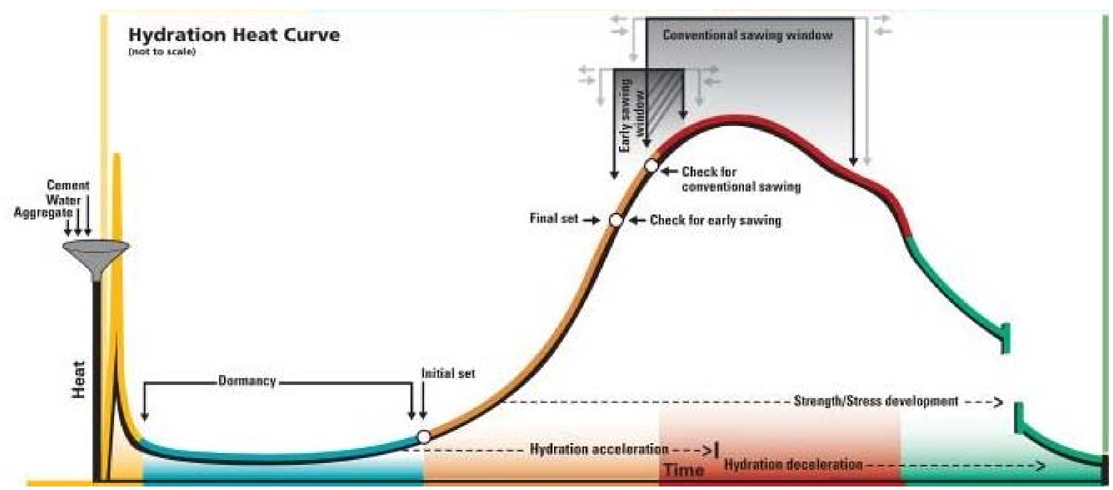
- Peter Taylor
- Tom Van Dam
- Larry Sutter
- Gary Fick

Review by

- TAC
- Previous authors

Overview

- 10 Chapters
  - Sustainability
  - Design
  - Materials and Mixtures
  - Construction
  - Quality
  - Troubleshooting



Contents

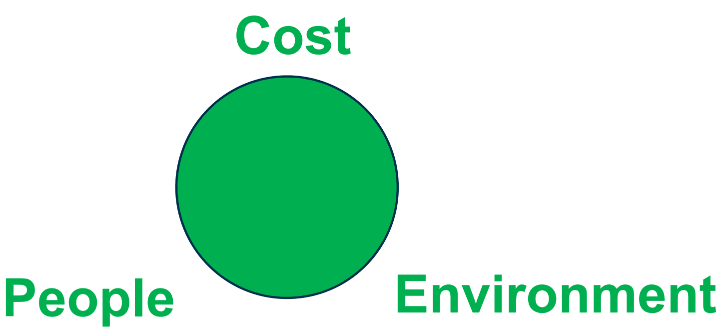
Chapter 2 Basics of Concrete Pavement Sustainability

- What is Pavement Sustainability?
- Concrete Pavement Design
- Materials
- Construction

What is Sustainability?

A sustainable pavement is one that achieves its specific engineering goals, while:

- It meets basic human needs
- Uses resources effectively
- Preserves/ restores surrounding ecosystems



"Meet[ing] the needs of the present without compromising the ability of future generations to meet their own needs"
[WCED 1987]

Strategies for Design

- Longevity
  - Reduced user impact
  - Durable mixtures
  - Increased Thickness
  - CRCP for heavy traffic
- Local and Recycled Materials
  - Use less fuel to haul it in
  - Avoid throwing away the old pavement

Sustainability and Materials

- Recycled, Coproduct, and Waste Materials
- Cementitious Materials and Concrete Mixtures
  - Portland Cement
  - Supplementary Cementitious Materials
  - Blended Cements
- Aggregate Materials
- Concrete Mixture Proportioning and Production
- Other Concrete Mixtures and Emerging Technologies

What About Operations?

- At least 80% of the energy and emissions associated with pavements is incurred during use
  - Fuel efficiency
    - Traffic flow
    - Rolling resistance
  - Albedo
    - Heat island
    - Lighting costs
  - Noise

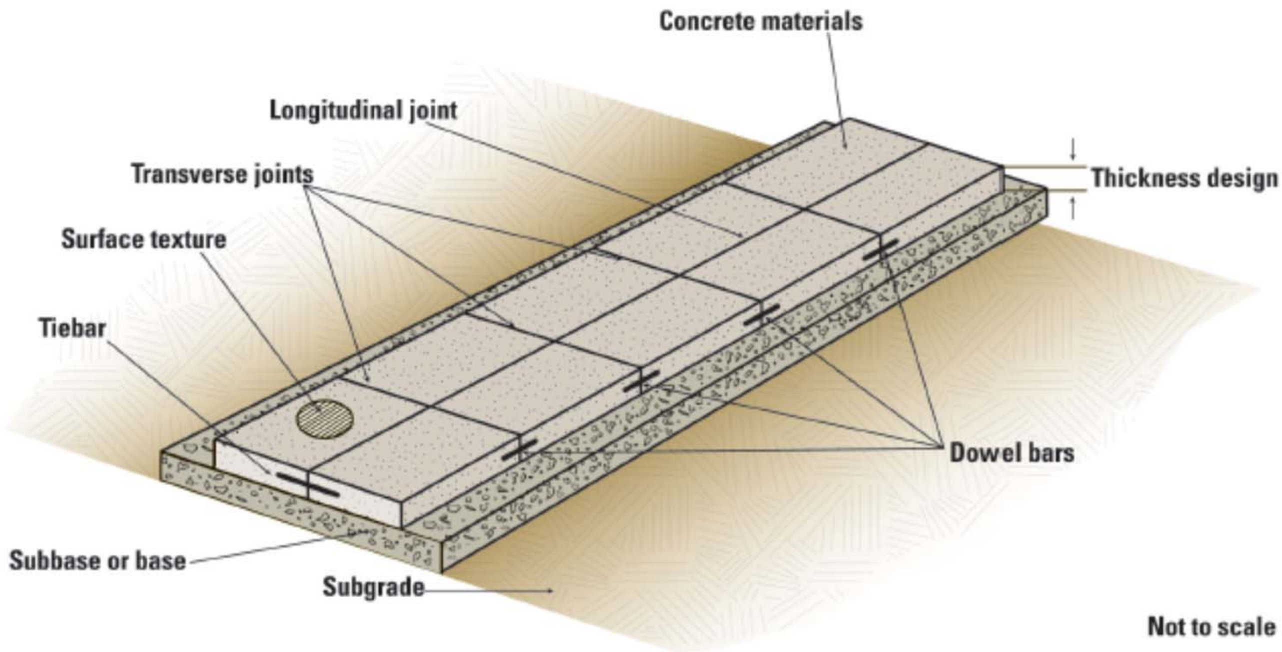
Which is more "sustainable"?

Contents

Chapter 3 Basics of Concrete Pavement Design

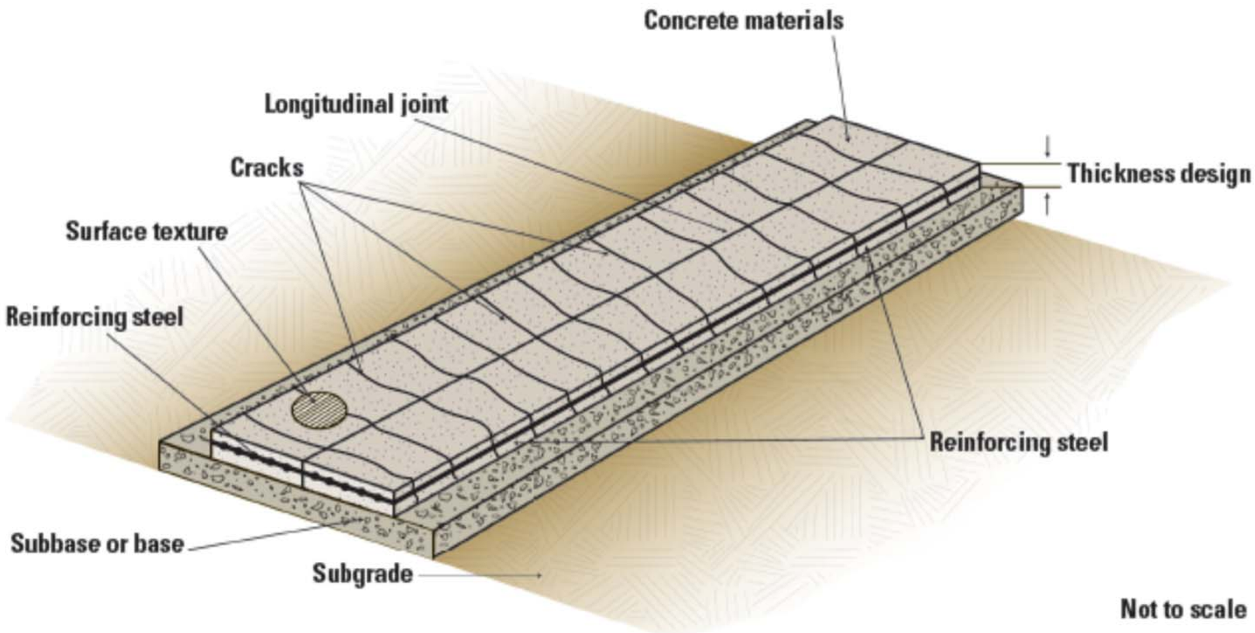
- Integrated Pavement Design
- Pavement Types
- What Do We Want?
- What Factors Do We Have to Accommodate?
- Getting What We Want
- Constructability Issues
- Concrete Overlays

It’s Not Just Thickness



Jointed Plain

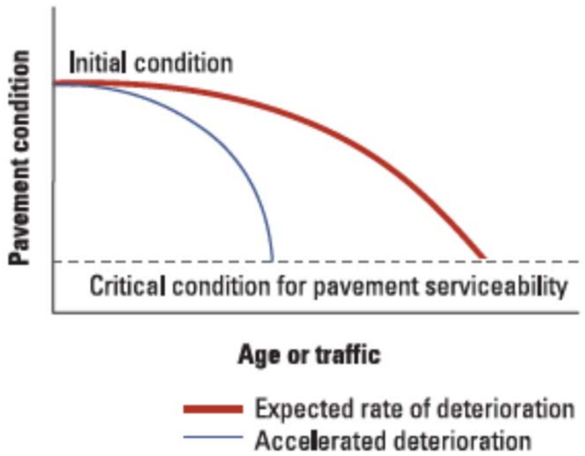
It’s Not Just Thickness



Continuously reinforced

What Do We Want?

- Service life
  - Structural models assume that materials will not fail
  - How long should it last?
- Performance:
  - Structural
  - Functional



What Do We Want?

- Structural – is it broken?

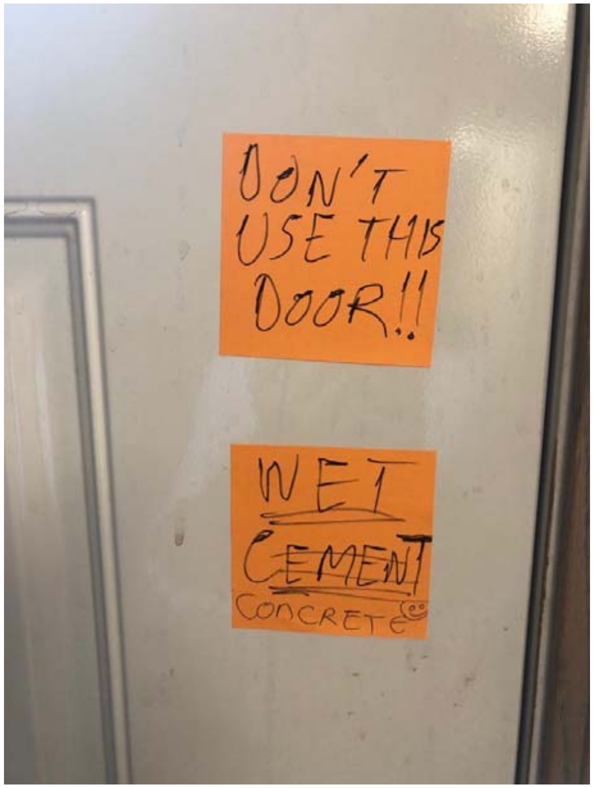
What Do We Want?

- Functional – do I want to drive on it?

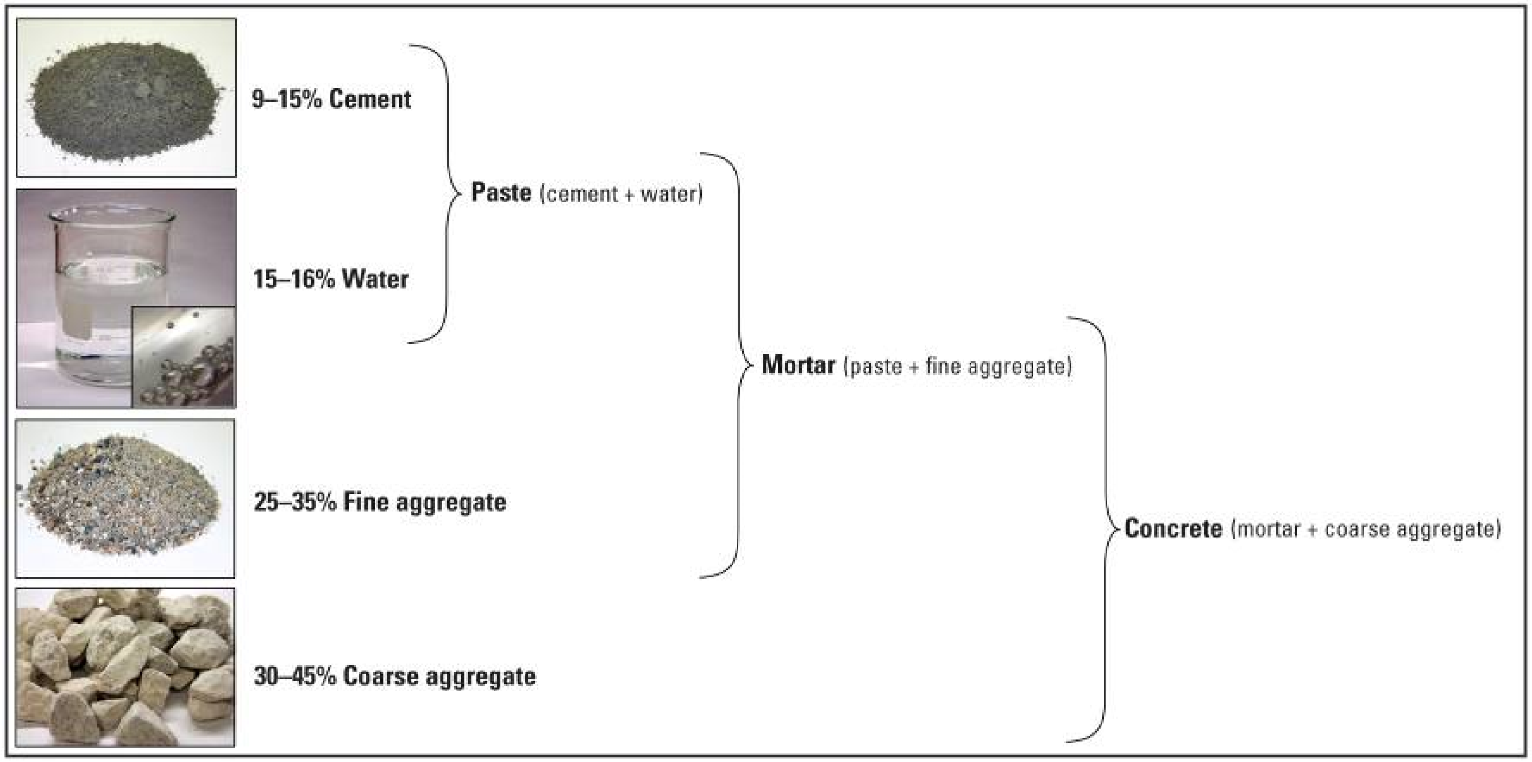
Contents

Chapter 4 Fundamentals of Materials Used for Concrete Pavements

- Cementitious Materials
- Aggregates
- Water
- Chemical Admixtures
- Dowel Bars, Tiebars, and Reinforcement
- Curing Compounds
- References



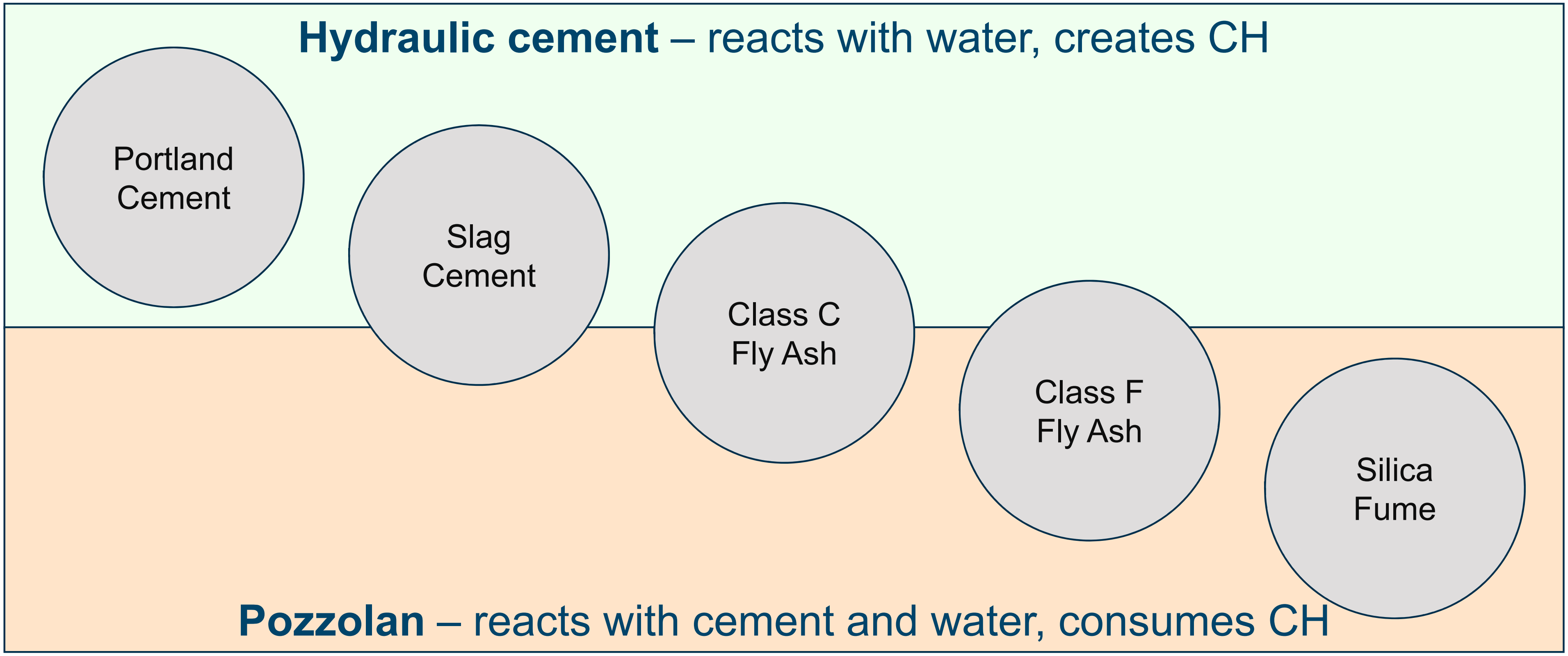
What do we have to work with



Aggregates

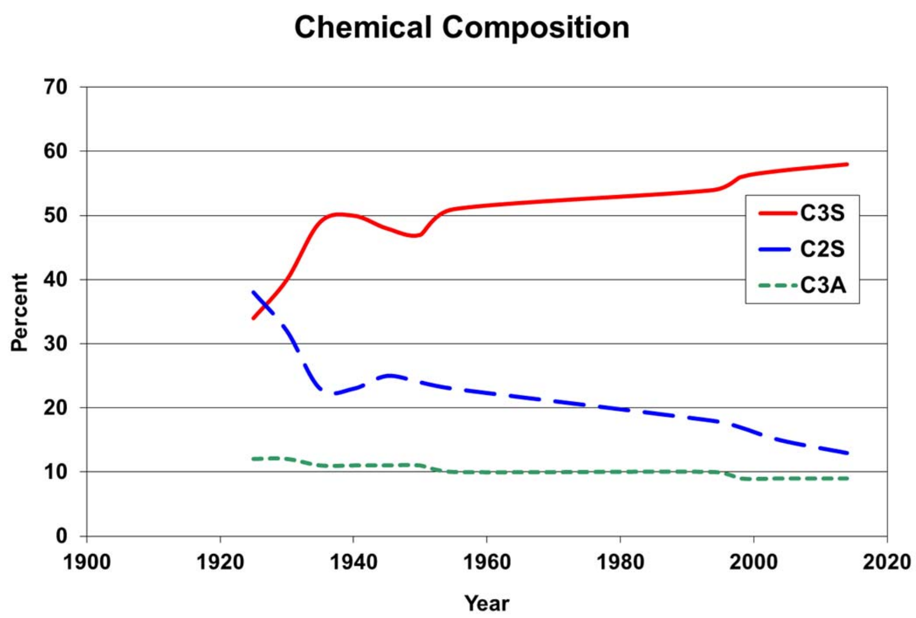
- Aggregates comprise ~70% of the volume of a concrete mix.
- Aggregate properties can have an influence on concrete properties:
  - Durability
  - Workability
  - Strength
  - Dimensional changes

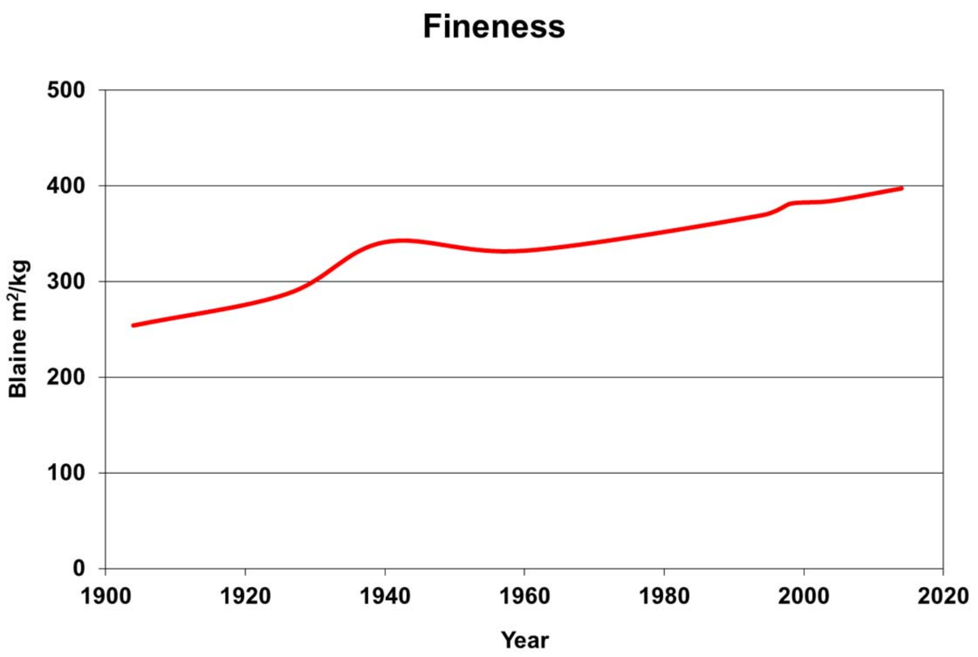
Cementitious Materials



Not to scale

Cement is Changing

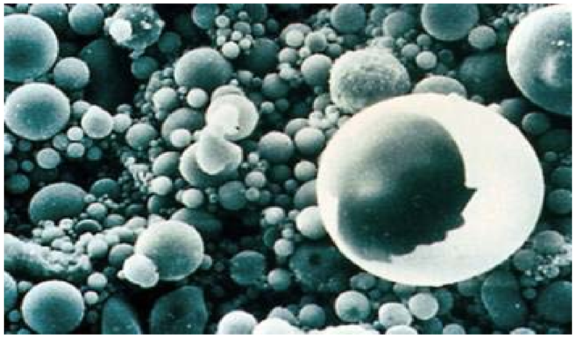


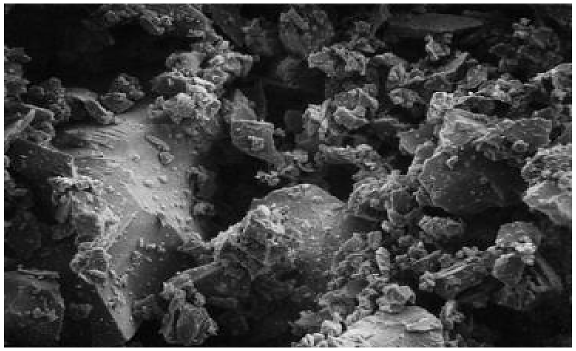


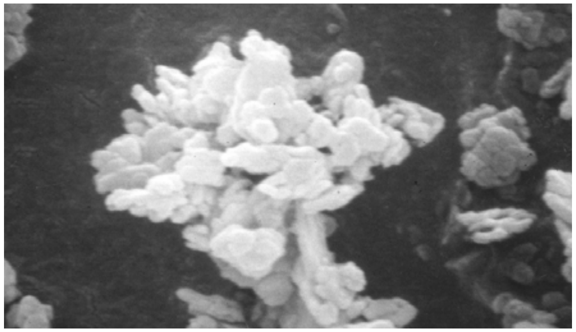
Supplementary Cementitious Materials

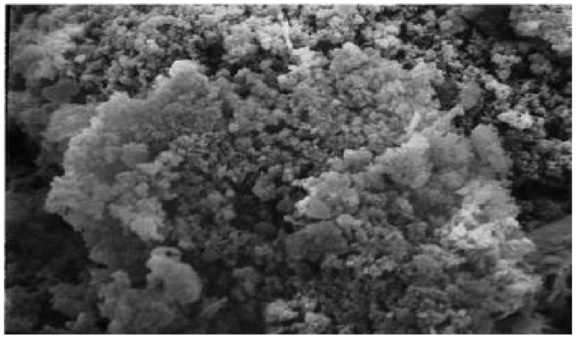
- Fly ash
- Slag
- Natural pozzolan
- Silica fume

"We deal with the negatives to get a positive"









Effects of Extra Water on Concrete

- Increases workability
- Lowers strength
- Increases drying shrinkage
- Increases permeability and reduces durability

Chemical Admixtures

- Air entraining admixtures (AEA)
- Water reducers
- Set modifying admixtures

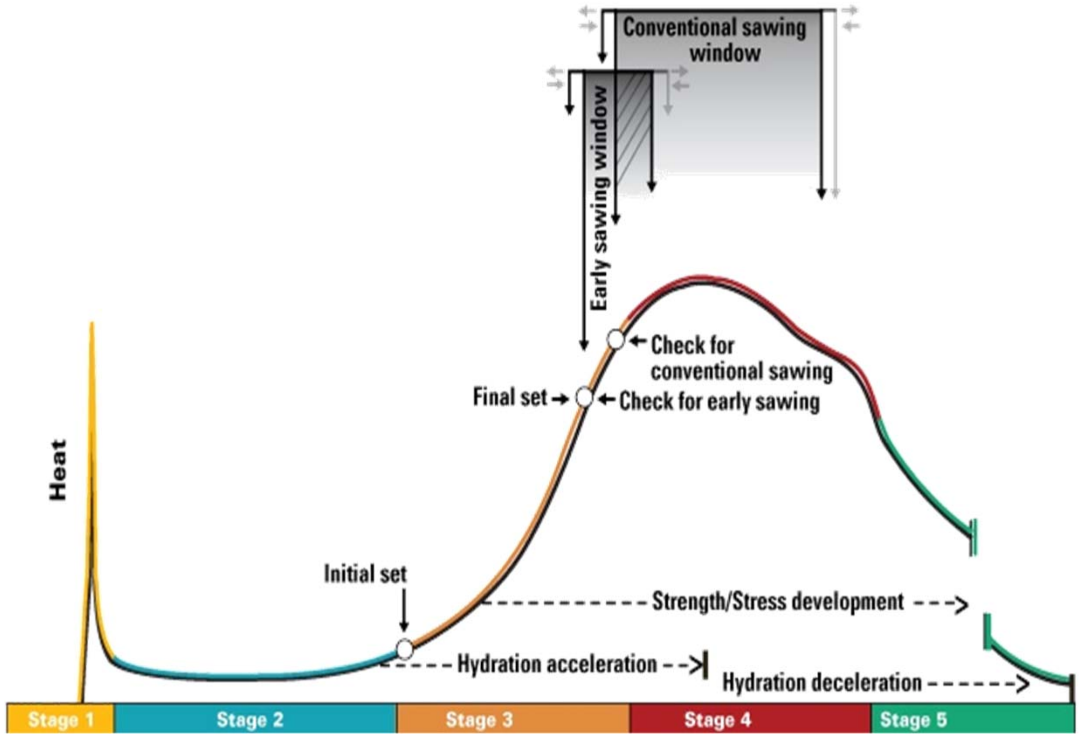
Don't use to fix a bad mixture,

use to Enhance!

Contents

- **Chapter 5 Hydration**
  - Stages of Hydration: Overview
  - Portland Cement
  - Supplementary Cementitious Materials
  - Impact of Hydration
  - Stages of Hydration: Details

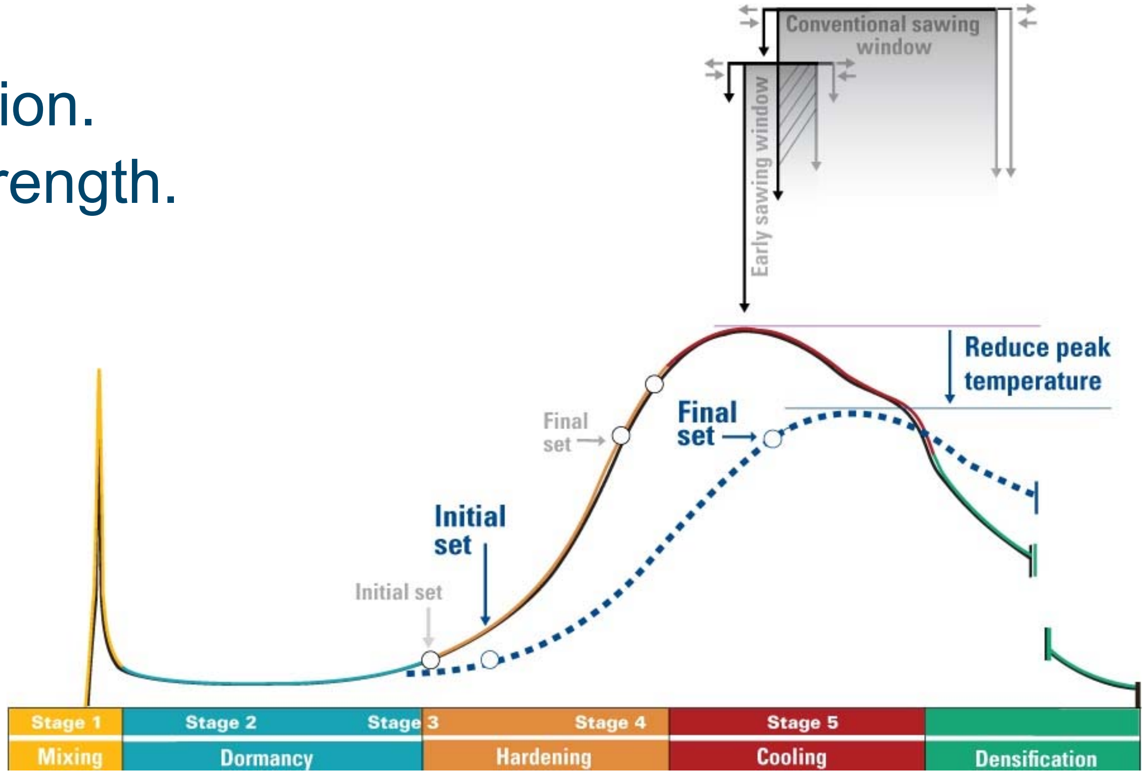
Five Stages of Hydration



1	2	3	4	5
Mixing	Dormancy	Hardening	Cooling	Densification

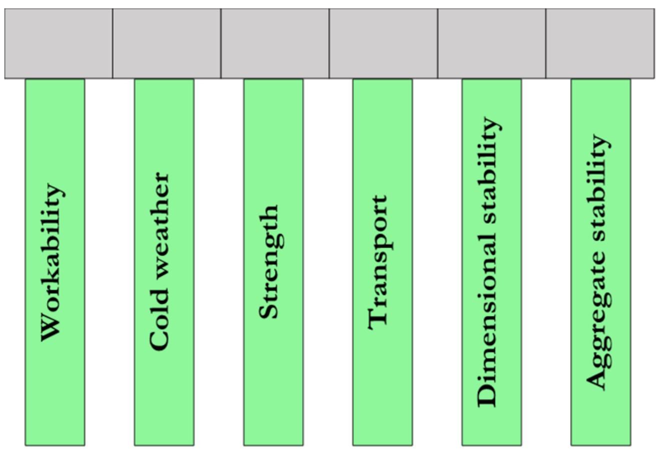
Effects of SCMs

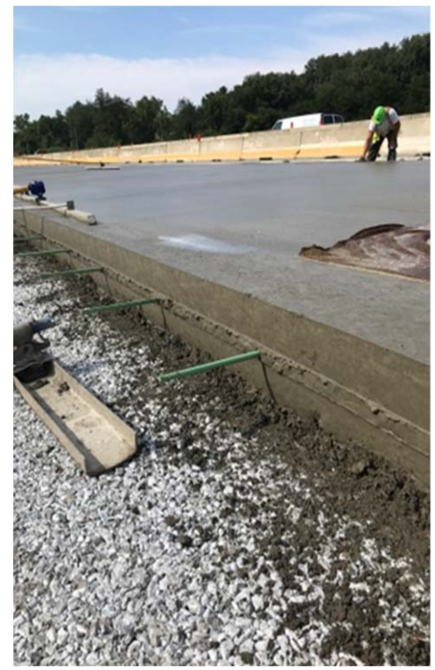
- Delayed final set.
- Reduced heat peak.
- Extended heat generation.
- Increased long-term strength.
- Reduced permeability.



Contents

- **Chapter 6 Critical Properties of Concrete**
  - Introduction
  - Fresh Properties
  - Mechanical Properties
  - Durability Related Properties





Fresh Properties

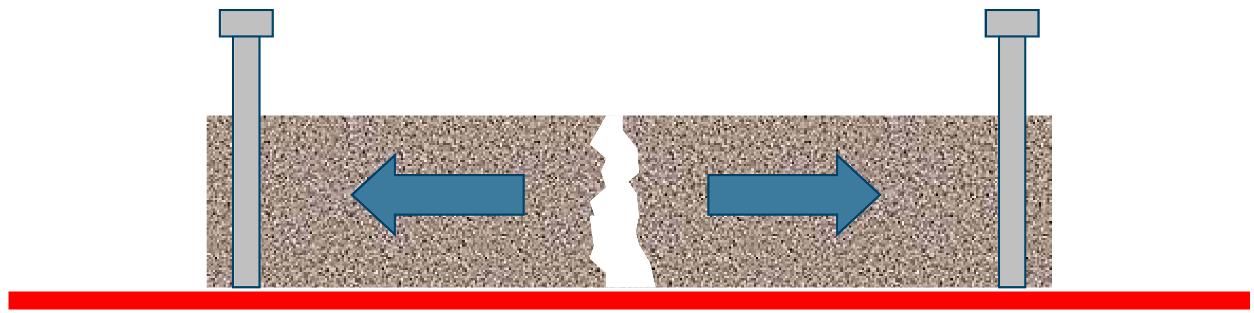
- Uniformity
- Workability
- Segregation
- Bleeding
- Setting
- Temperature effects

Mechanical Properties

- Strength
- Stiffness
- Shrinkage
- Polishing
- Cracking

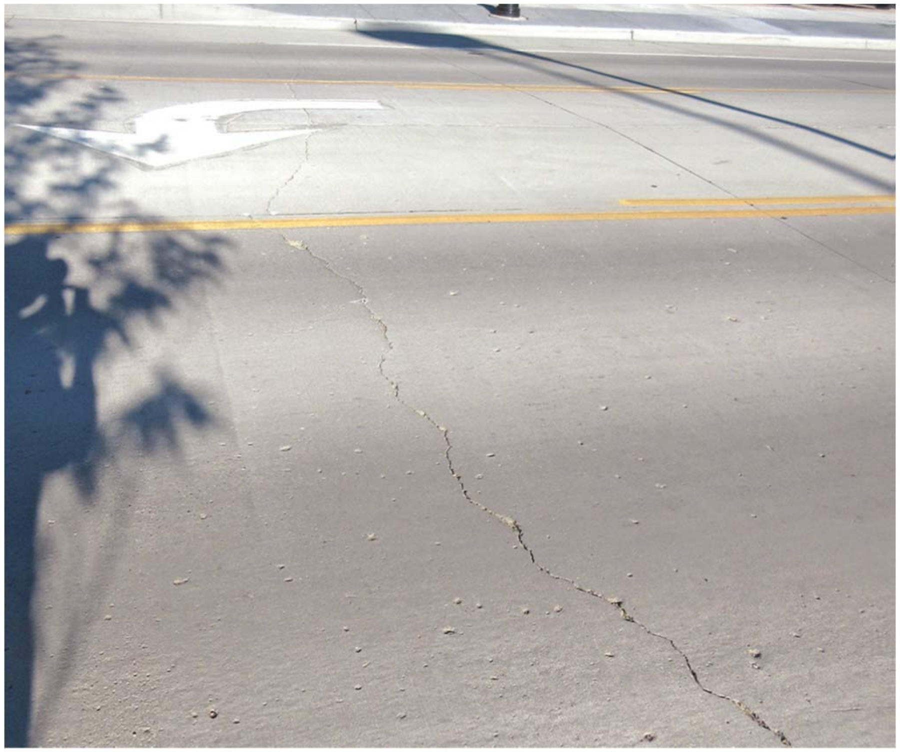
Early-Age Cracking

- Factors
  - Concrete moves (temperature and moisture gradients)
  - Movement + Restraint → Load
  - Loads + Stiffness → Stress
  - Stress > Strength = Cracks



Early Age Cracking

Discuss



Early Age Cracking

Discuss

Durability Properties

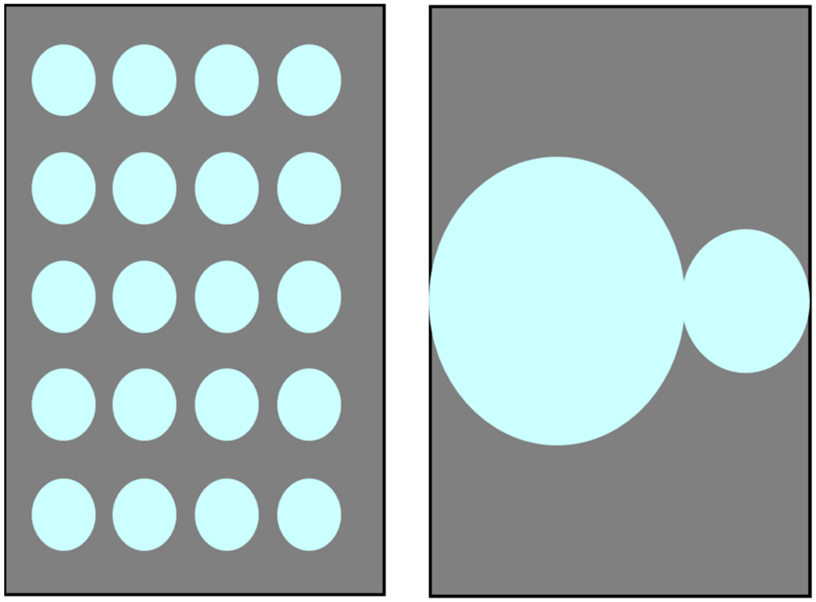
Ability of the concrete to survive the environment to which it is exposed:

- Transport
- Cold weather
- Sulfates
- AAR

Transport

The ease with which fluids can penetrate concrete

- Significance
  - All durability damage is governed by permeability
- Factors
  - w/cm
  - SCM type and dose
  - Hydration
  - Cracking



Cold Weather

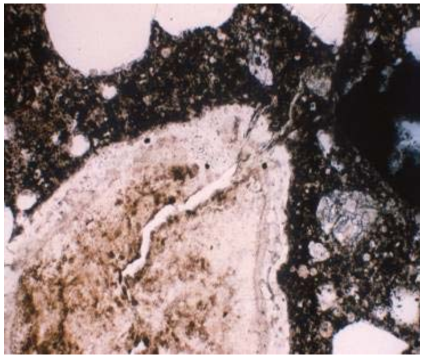
Two mechanisms:

- Saturated freeze thaw
- Oxychloride formation

Alkali-Silica Reaction

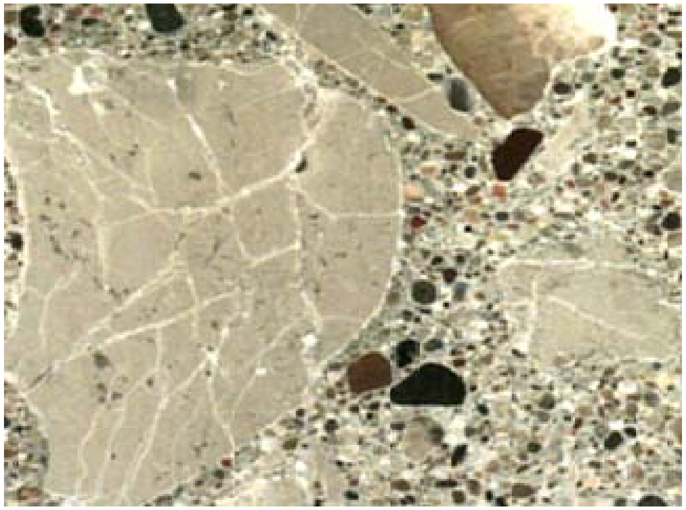
- Water + alkali hydroxide + reactive silicate aggregate $\rightarrow$ alkali silicates
- Alkali silicates + water $\rightarrow$ gel + expansion

- Silicates from aggregates
- Alkalis from cement (Na and K)



D-Cracking

- Certain calcareous aggregates absorb water
- Pore size prevents water leaving the system
- Freezing causes damage



Contents

- **Chapter 7 Mixture Design and Proportioning**
  - Introduction
  - Sequence of Development
  - Aggregate Grading Optimization
  - Calculating Mixture Proportions
  - Adjusting Properties

"The beast of interesting proportions"

Design

- Choosing what you need
  - Workability, setting time
  - Durability, strength, cracking risk

Proportioning

How do we proportion to achieve design goals?

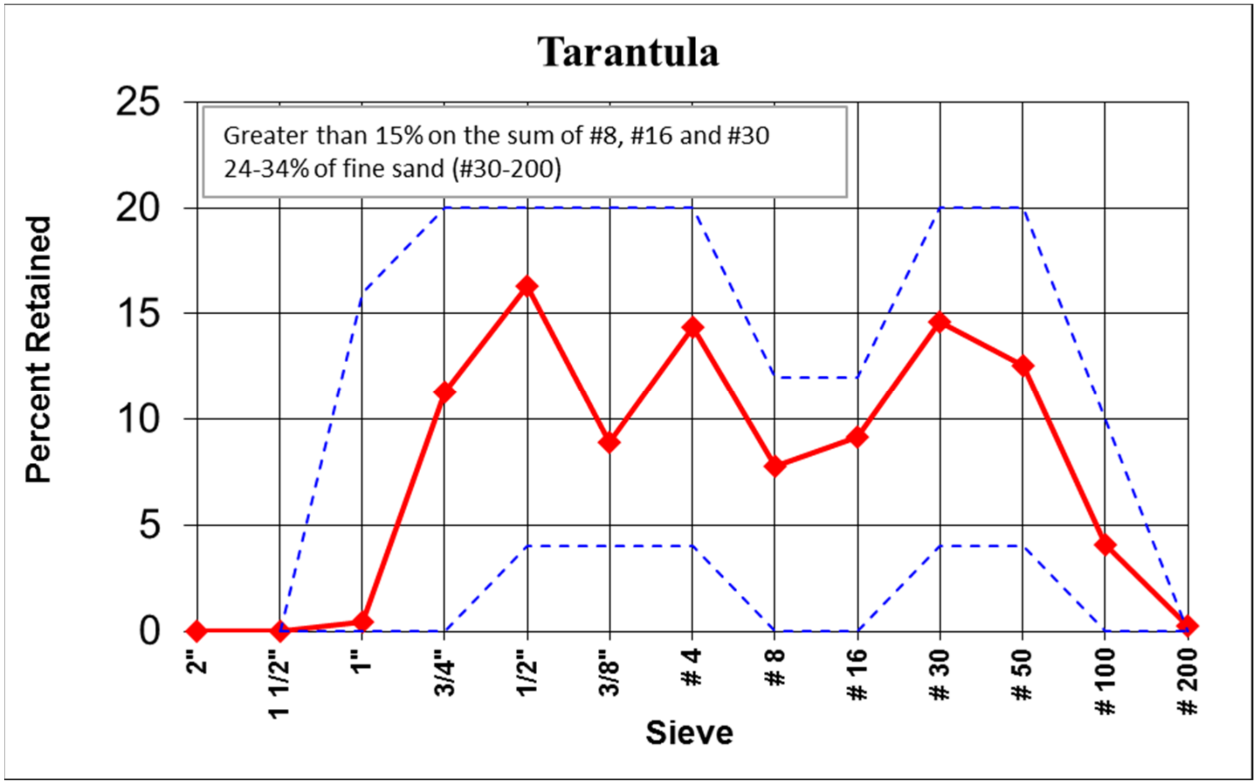
		Workability	Transport	Strength	Cold weather	Shrinkage	Aggregate stability
Aggregate System	**Type, gradation**	✓✓	-	-	-	-	✓✓
Paste quality	**Air, w/cm, SCM type and dose**	✓	✓✓	✓✓	✓✓	✓	✓
Paste quantity	**Vp/Vv**	✓	-	-	-	✓✓	-

Step 1 Paste Quality

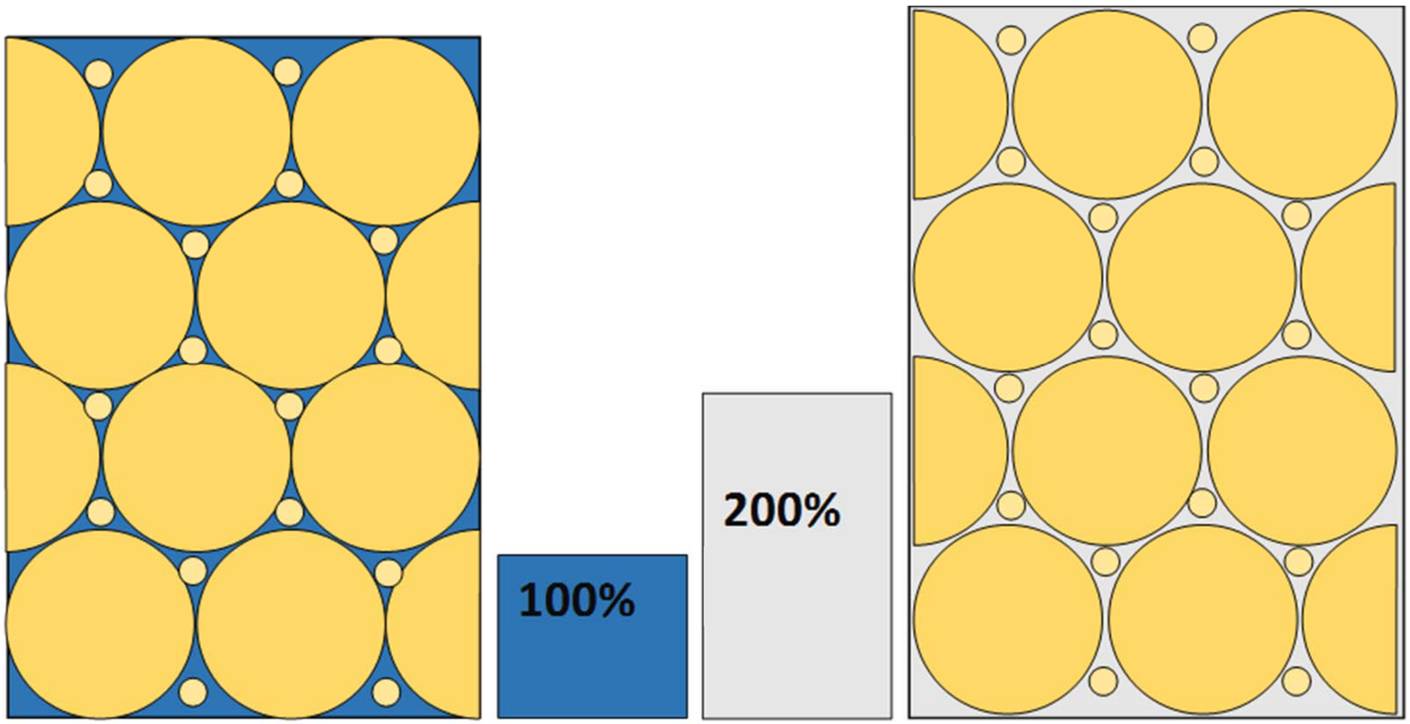
- Binder type
  - Cement type
  - SCM type and dosage
- w/cm
  - ~0.38-0.42
- Air void system
  - <0.2 SAM
  - <0.008 in. spacing factor
  - >5% in place
  - Stable

Step 2 Aggregate system

- Tarantula Curve



Step 3 Paste Content



Paste should be approximately 1.5x - 2x of voids

Contents

- **Chapter 8 Construction**
  - Subgrades
  - Bases
  - Concrete Paving

Support system should be stable and uniform with decent drainage

Contents

- **Chapter 9 Quality and Testing**
  - Quality Assurance
  - Monitoring the Mixture
  - Monitoring Construction Activities
  - Test Methods

"Delivering what is expected"

Defining Quality

- Simple Definition (Philip Crosby)
  - Quality: “Conformance to requirements”
  - Quality is defined by our customers

- QA = “Making sure the quality of a product is what it should be”

Why Should I Care

- Money!
  - Penalties vs Incentives

CONTRACTOR

Why Should I Care

- Better working environment
  - Project partners are qualified
  - Contractor knows how the Agency will accept/pay for the product
  - QC Plans remove some of the daily stress
- Product you paid for

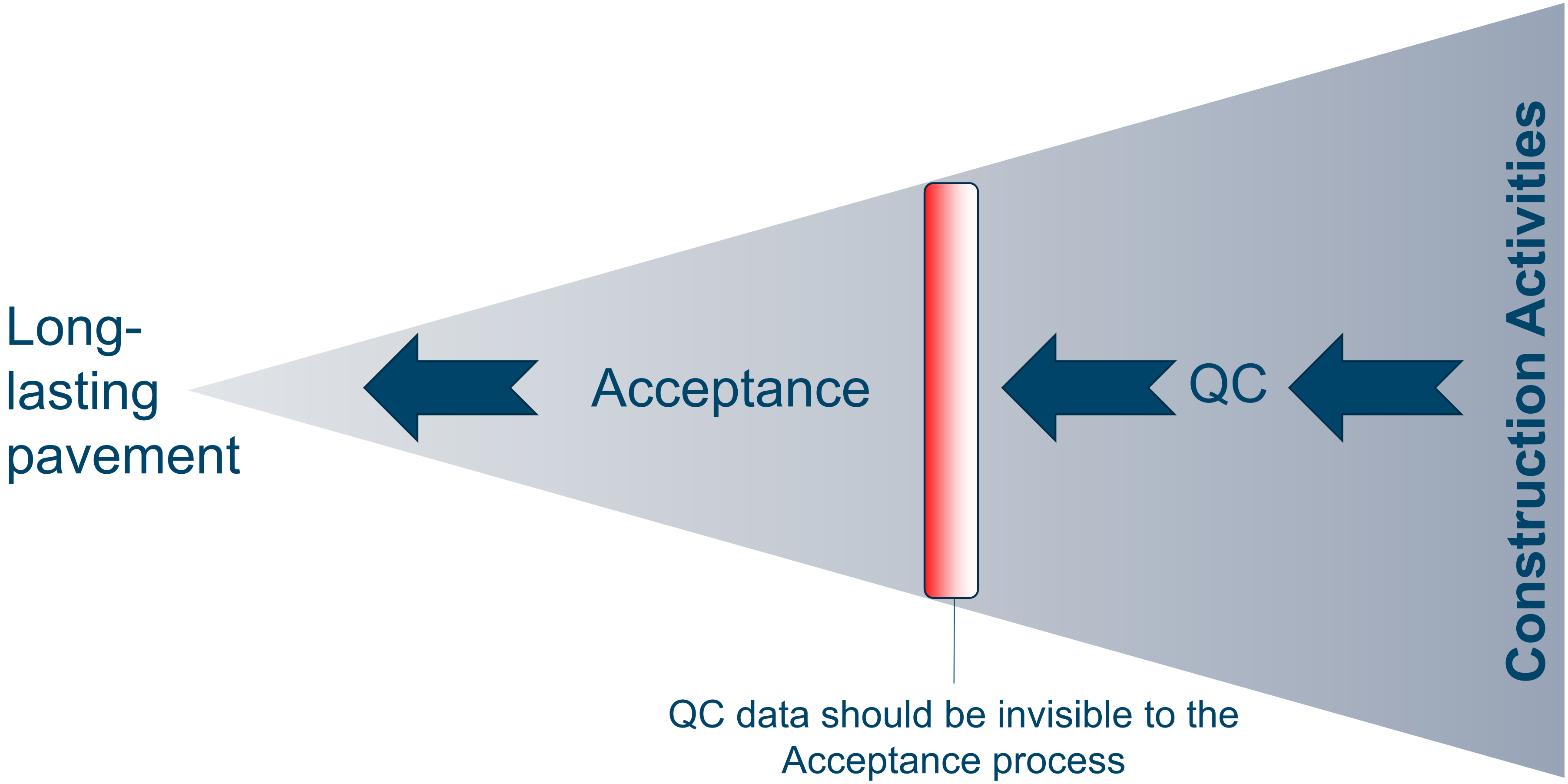
OWNER

Trick Question

- How do the following people affect quality?
  - Designer/Specifier
  - Agency Inspector
  - QC Technician
  - Loader Operator at the concrete plant
  - Truck Driver
  - Paver Operator
  - Concrete Finisher
  - Texture/Cure Machine Operator

Core Elements of an Agency QA Program

The Goal…



QC data should be invisible to the Acceptance process

How Do We Evaluate the Mixture?

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

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.

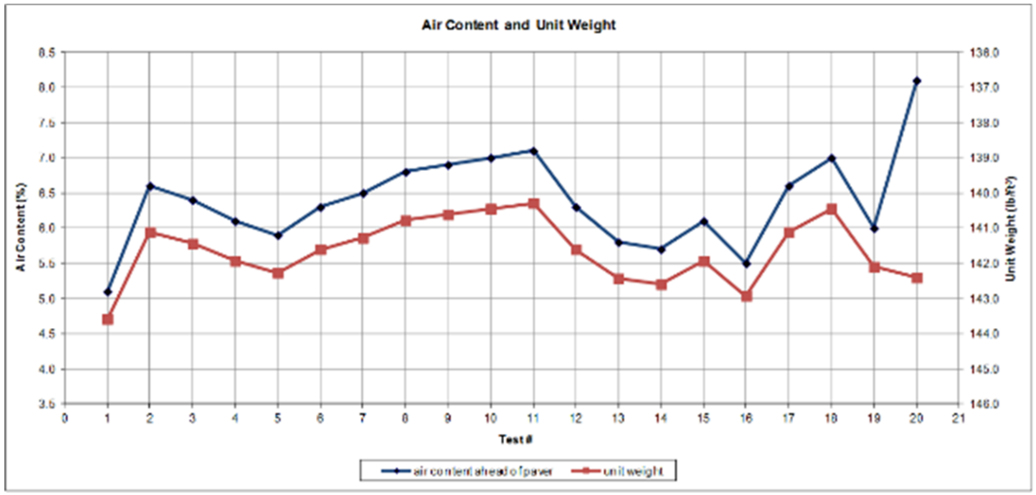
Quality Control

- QC should include
  - Unit weight
  - Calorimetry
  - Maturity
  - Strength development
  - Air void stability

  - And a response…

- Risk management

1. Get lab mix accepted
2. Ensure we are getting that mix



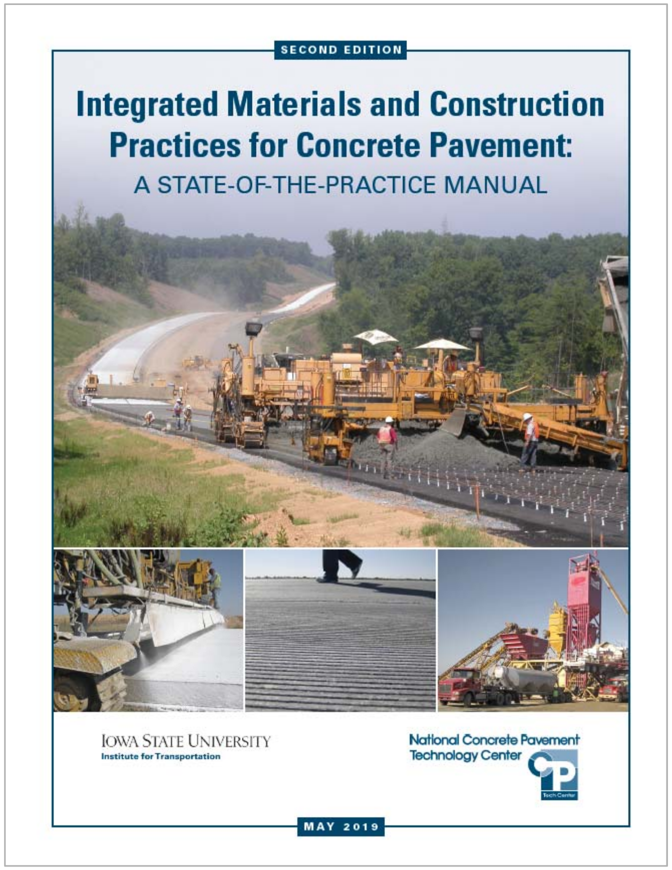
Contents

- **Chapter 10 Troubleshooting and Prevention**
    - Overview
    - Before the Concrete Has Set
    - After the Concrete Has Set
    - In the First Days after Placing
    - Some Time after Construction

IMCP 2nd Edition

- Format
  - Interactive pdf available to download
  - Limited printed copies
  - Dreaming of hotlinking with other publications

www.cptechcenter.org




National Concrete Pavement Technology Center
Tech Center
IOWA STATE UNIVERSITY
Institute for Transportation