Concrete Paving Field Inspection Inspector's Workshop

What is Concrete?

National Concrete Pavement Technology Center

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IOWA STATE UNIVERSITY

Institute for Transportation

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Concrete Paving Field Inspection Inspector's Workshop

1. Why are we here?
2. How do we achieve quality for PCC paving?
3. Got a project….Now what?
4. **What is concrete?**
5. What kinds of equipment are used?
6. What happens before you start paving?
7. What happens when you're finally paving?
8. What is the inspector's role?
9. What about all of the other road building stuff?
10. What do you look for in urban paving?
11. What paperwork?

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Instructor

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Representing the National Concrete Pavement Technology Center

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Q: WHAT IS CONCRETE?

A: It is not cement…..

What is Concrete?

- Concrete Materials
- Concrete Properties

Concrete Materials

What are the ingredients of concrete?

Concrete Materials

- 4 Basic Ingredients
  - Aggregates
  - Cement
  - Water
  - Air
- Other Stuff
  - Chemical Admixtures
  - SCM's

The proportion and properties of each determines the strength, workability, durability, and all other physical properties of concrete.

Concrete Materials

9 - 15%
Cement

15 - 16%
Water

Paste
(cement + water)

25 - 35%
Fine aggregate

Mortar
(paste + fine aggregate)

30 - 45%
Coarse aggregate

Concrete
(mortar + coarse aggregate)

Cement vs. Concrete

- (Portland) Cement
  Fine gray powder that reacts with water

- Concrete
  Mass of sand and rock held together by hydrated cement paste

Concrete Materials – Cement

- How is it made?
  - ➢ Limestone + Clay + Iron Ore + Heat ➔ Clinker
  - ➢ Clinker + Gypsum ➔ Portland Cement

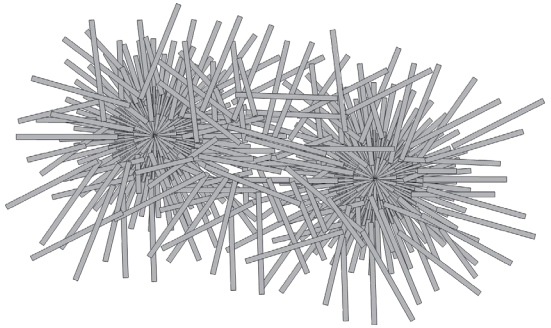
Portland Cement: Material made by heating a mixture of limestone and clay in a kiln at about 2700 F, then grinding to a fine powder with a small addition of gypsum.

Bricklayer Joseph Aspdin of Leeds, England first Portland cement in early 19th century

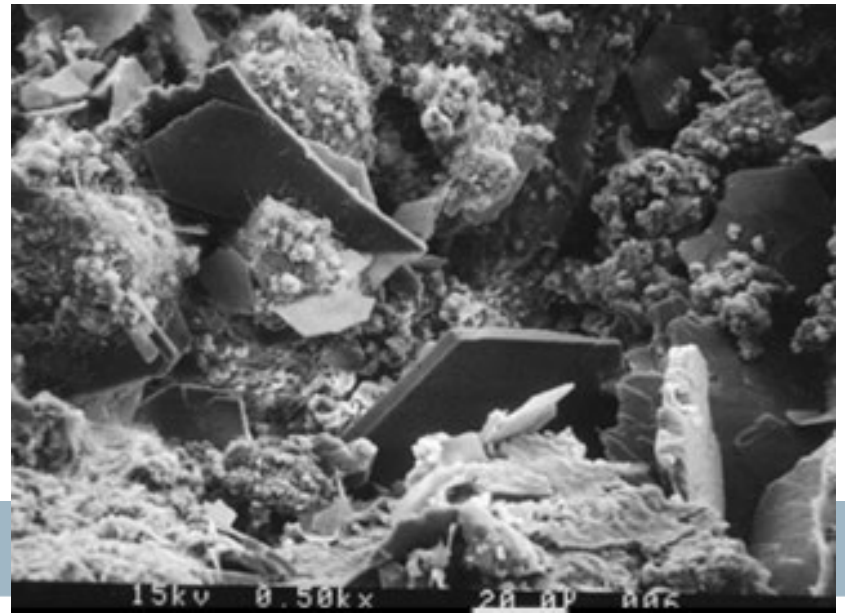
Concrete Materials – Cement

How does it work?

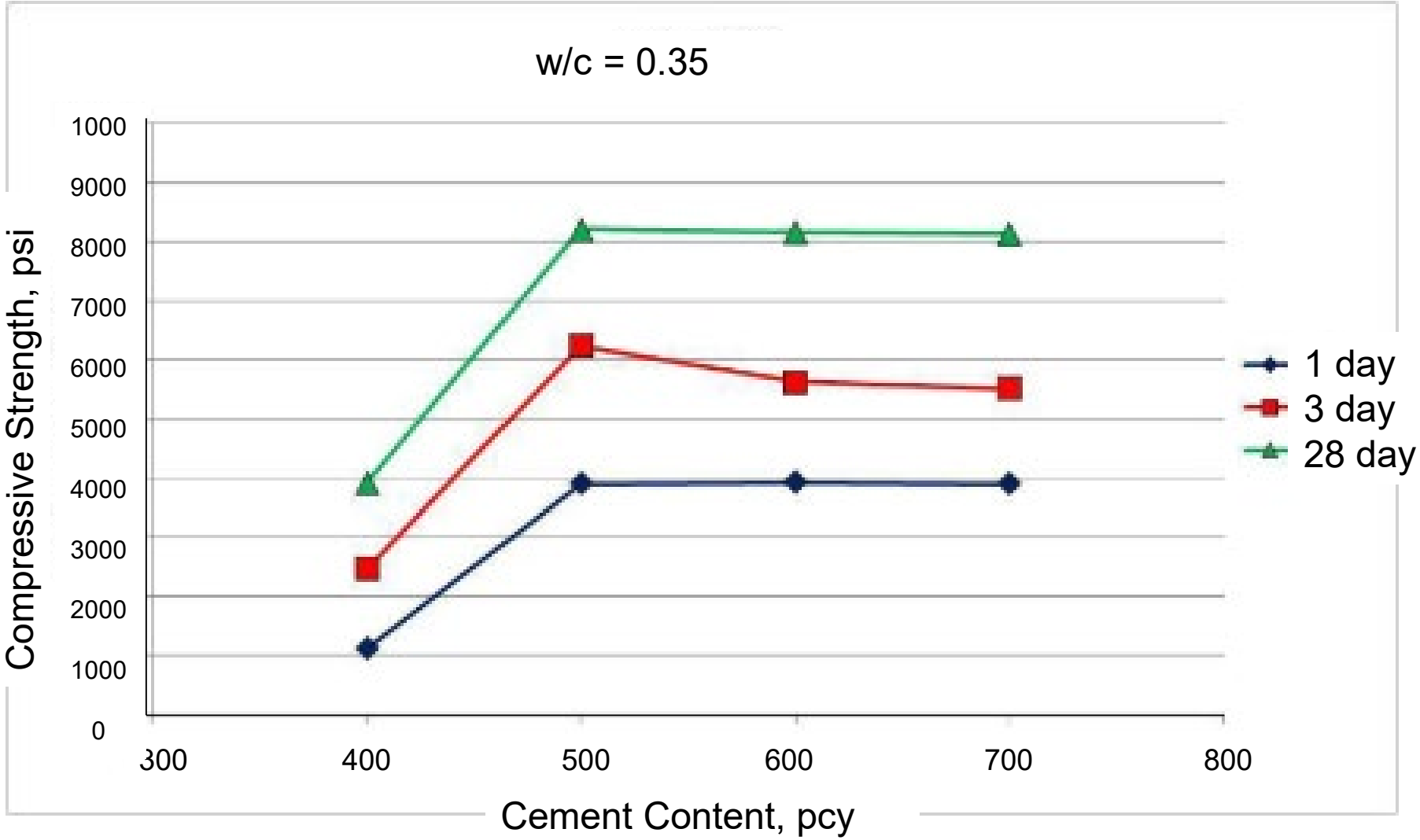
- Cement + Water ➔ Hydration ➔ Crystals + Heat
- Needle like crystals grow and stick together and form gel-like mass
  - C-S-H & C-H



- Longer Growth ➔ Stronger Concrete
  - ➢Needs water in mixture to continue growth
  - ➢Not too much—Not too little
  - ➢Keep water in mixture
    - –CURING



Concrete Materials – Cement



28 day strength = 32 Mpa (4641 psi)

Concrete Materials – Aggregates

Aggregates occupy most of the volume in a mix and have a significant effect on PCC properties

- Workability
  - Placement and consolidation
- Thermal expansion
- Cement content
- Water demand
- Strength

Concrete Materials – Aggregates

- Traditional Two Aggregate Mixtures
  - Fine Aggregate (Sand)
  - Coarse Aggregate (limestone & gravel)

- **Intermediate Aggregate**

- **Well Graded Mixtures**
  - Less Cement
  - Increased Workability
  - Decreased Shrinkage
  - Reduced Segregation

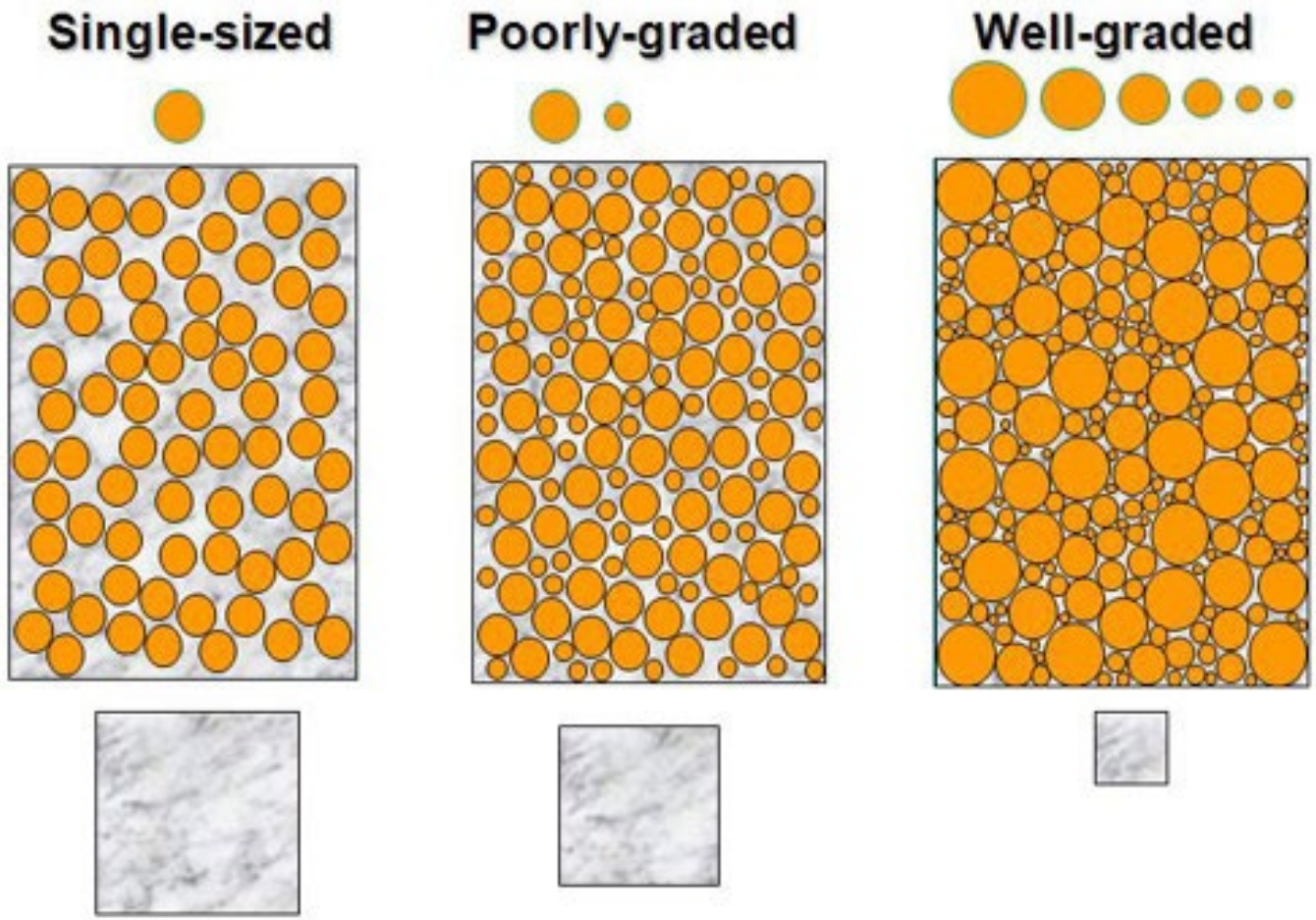
- Two Important Aspects of Aggregates
  - Gradation
  - Durability

Concrete Materials – Aggregates

Gradation

- Distribution of Particle Sizes
- “Well Graded”

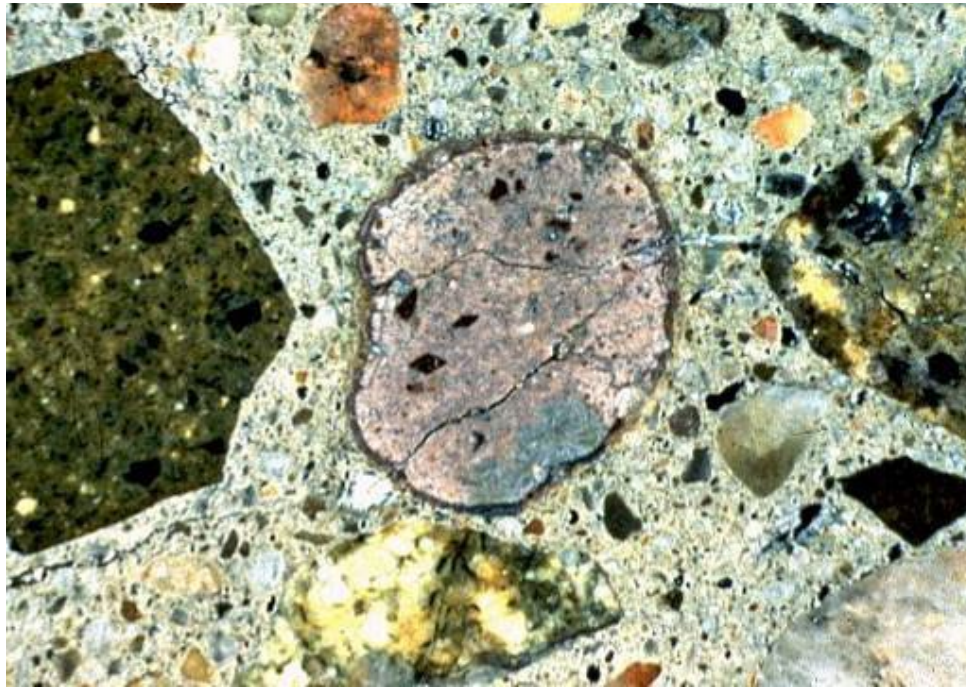
  Somewhat equal proportions



Concrete Materials – Aggregates

Durability

- How aggregates perform over time correlates to pavement life
- Geology
- Service Records
- Testing
  - Freeze/Thaw
  - Wetting/Drying
  - Absorption
  - MRD
    - D-Cracking
    - Alkali-Silicate Reactivity



Concrete Materials – Aggregates

- All types of rocks are used in concrete
- Particle shape can affect workability, but gravels to crushed aggregates can be used
- Most aggregates can be used
  - Reactive (ASR/ACR) calls for mitigation
  - D-Cracking prone should not be used
- The driving factor in aggregate selection is usually economics and source availability

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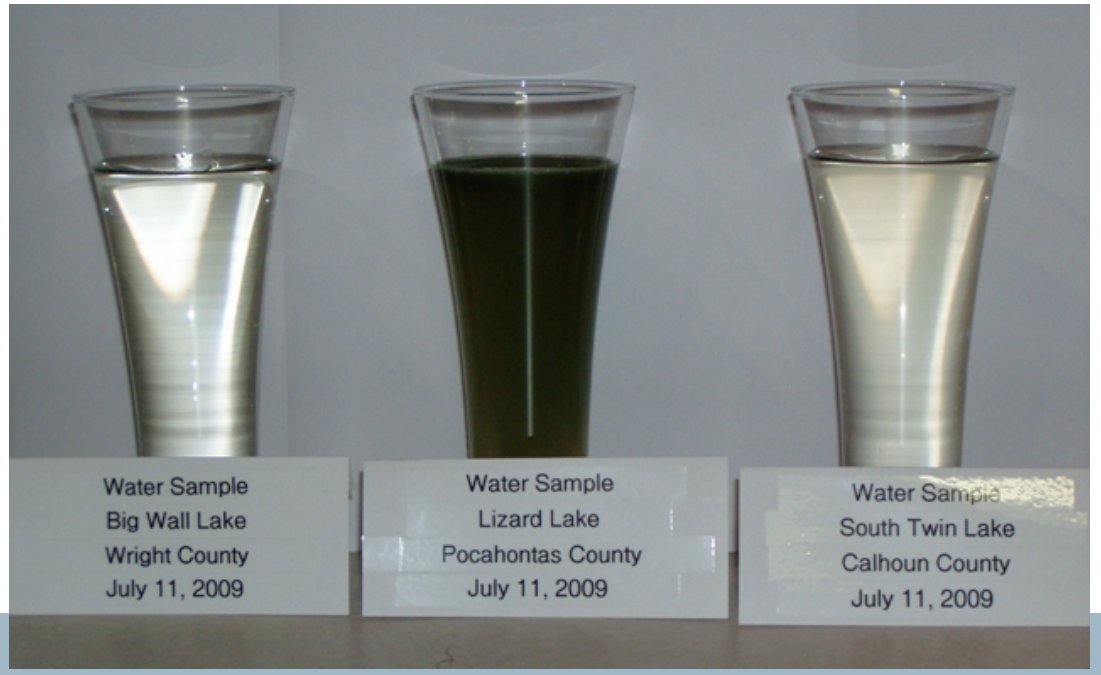
Concrete Materials – Water

Different Sources

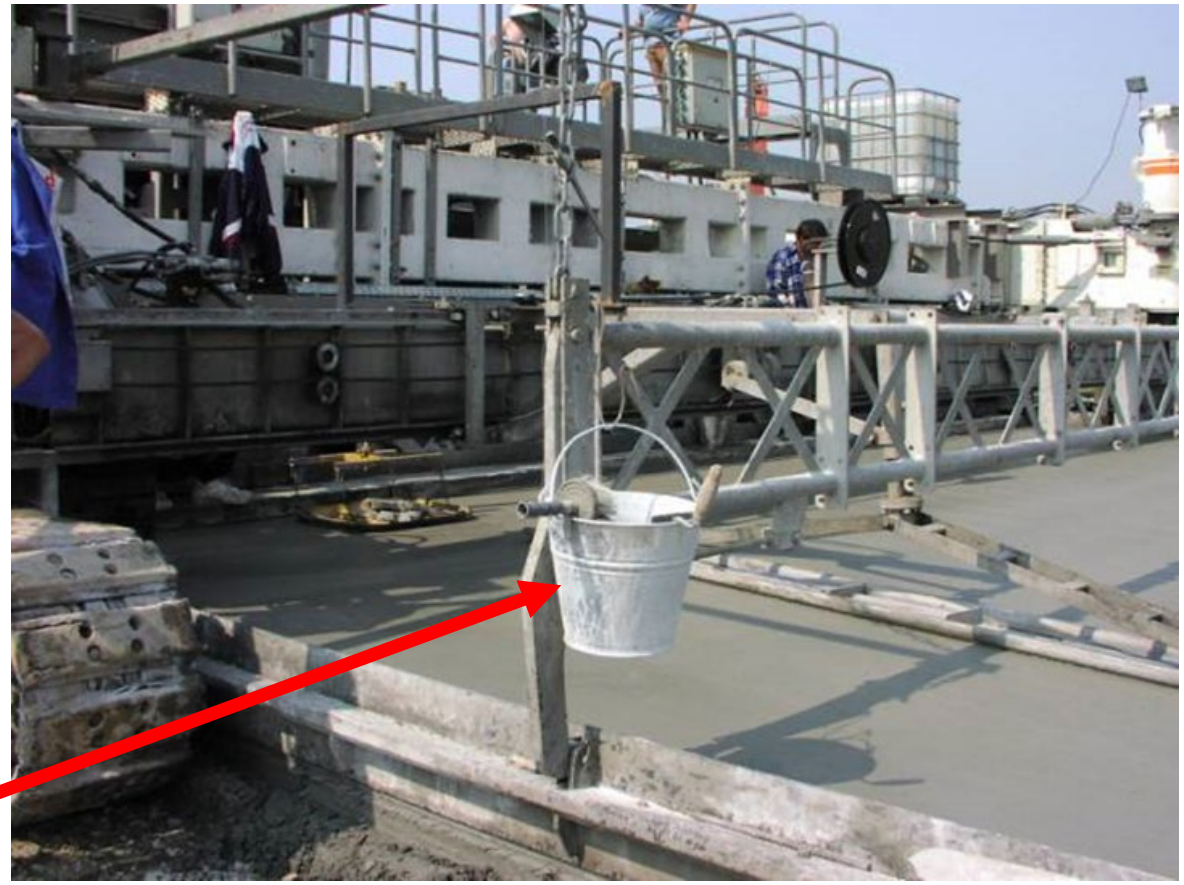
- Municipal (potable)

- Non-potable sources should be tested
  - Well
  - Lakes
  - Streams/Rivers



Concrete Materials – Water

- Water is necessary for the hydration reaction in portland cement to occur
- Quantity of water is based on cement content to meet strength, durability, and workability requirements



?

Adding 1 gallon / cu.yd

- Increases workability ~1”
- Lowers strength ~200 psi
- Increases drying shrinkage ~10%
- Increases permeability ~ 50%

A good concrete mix does not need excess water for finishing

Concrete Materials – SCMs

Supplementary Cementitious Materials
"Cement-like Stuff"

- Fly Ash
- Slag
- Silica Fume
- Ground Limestone

Concrete Materials – SCMs

Fly Ash

- By-product of burning coal in electricity generating power plants

- Pozzolanic

  Reacts with H_20 and $Ca(OH)_2$ to form cementing compounds

- Benefits of using fly ash
  - ➢Increased long term strength
  - ➢Increased workability
  - ➢Reduced heat of hydration
  - ➢Reduced permeability
  - ➢REDUCED COST

Concrete Materials – SCMs

Two Types of Fly Ash

Class C Fly Ash

- Increased compressive strength at all ages
- May slow hydration
- Pozzolanic and Cementitious

Class F Fly Ash

- Increased compressive strength
- Initially slow hydration, but goes on longer
- Pozzolanic
- Can help mitigate ASR

Concrete Materials – SCMs

Slag Cement

- By-Product of iron production
- “Cream” floating on top of iron furnace
- Quenched and ground into fine powder (white color)
- Blended at cement plant or at ready-mix / batch plant
- Benefits
  - Increased Strength
  - Increased Workability
  - Decreased Permeability
  - Increased Sulfate Resistance
  - Decreased Alkali Aggregate Reaction Potential

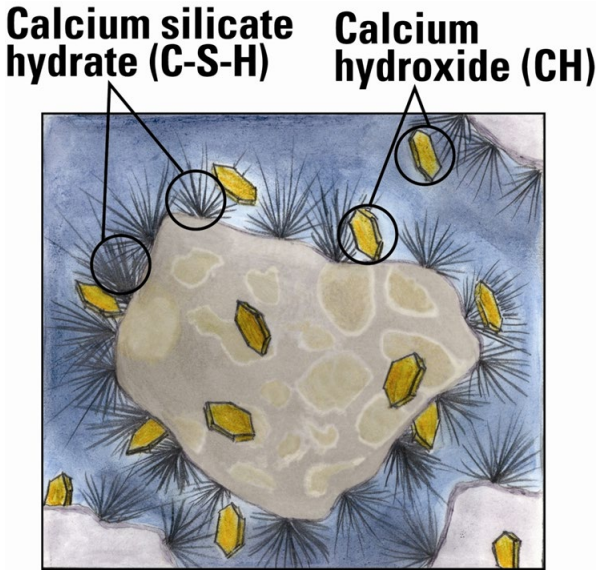
How Much SCM?

	% of total cementitious
• Class F fly ash:	15% - 25%
• Class C fly ash:	15% - 40%
• Slag:	25% - 50%

Too little – no benefit
Too much – slow setting, slow strength gain, cracking risk

Blended at the concrete batch plant, or blended or interground at the cement plant

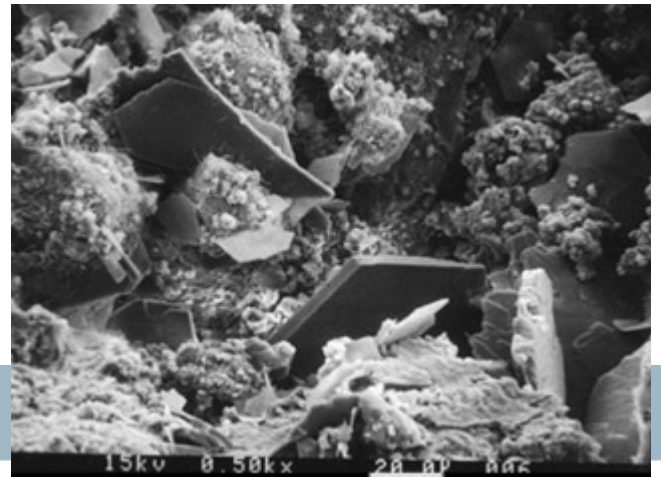
How Do SCMs Work?



Cement + Water = C-S-H +

SCM + Water + CH = more C-S-H

The use of SCMs also minimizes the potential of producing Calcium Oxychloride



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Concrete Materials - Admixtures

Types of Admixtures:

- Air Entraining
- High/Mid Range Water Reducing
- Retarding
- Accelerating

Concrete Materials – Admixtures

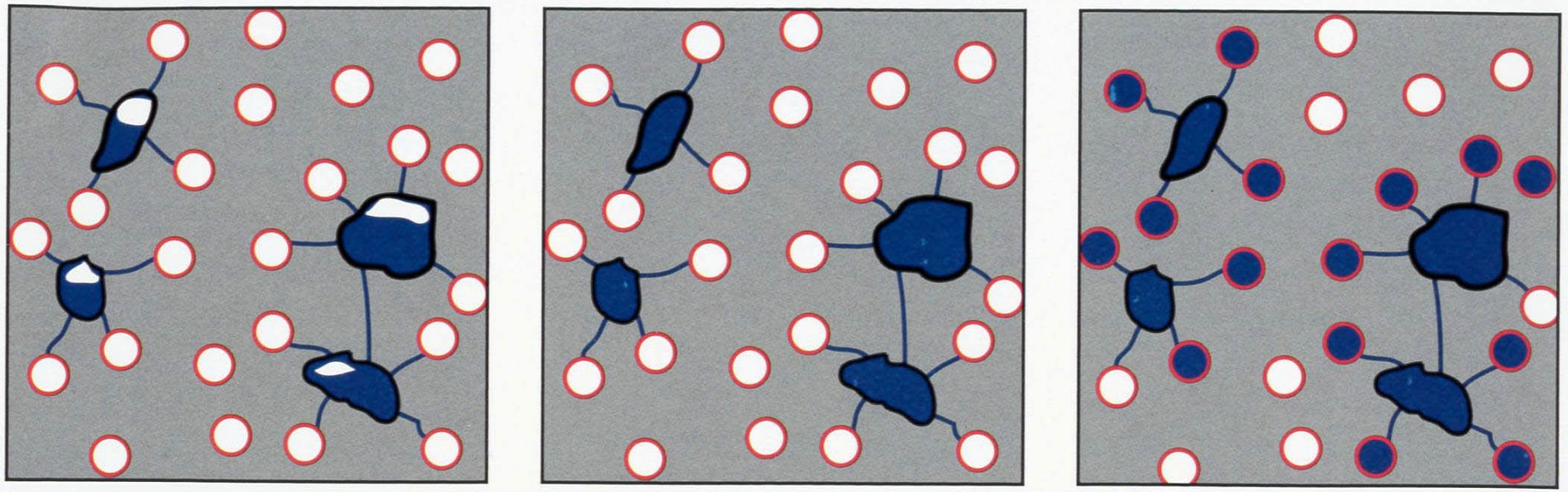
Admixtures are used to:

- Enhance concrete properties
- Change fresh concrete behavior
- Reduce overall cost
- NOT used to fix a bad mixture!

Chemical admixtures are added either at the time of batching or can be added at the job site when ready mix PCC is used. Note that blended cements combine SCMs and Portland cement at the time of manufacture.

Concrete Materials – Air Entraining

- Used to entrain small air bubbles in concrete
- Benefits of Air Entraining
  - Improve durability of concrete exposed to moisture during freeze/thaw
  - Improve concrete resistance to surface scaling caused by deicers
  - Reduce segregation and bleeding
  - Similar to dish soap



As temperatures drop, pores created by air entrainment allow the water a place to go as it freezes.

During freezing, water in the capillary pores expands; however, water is also going toward air-entrained pores.

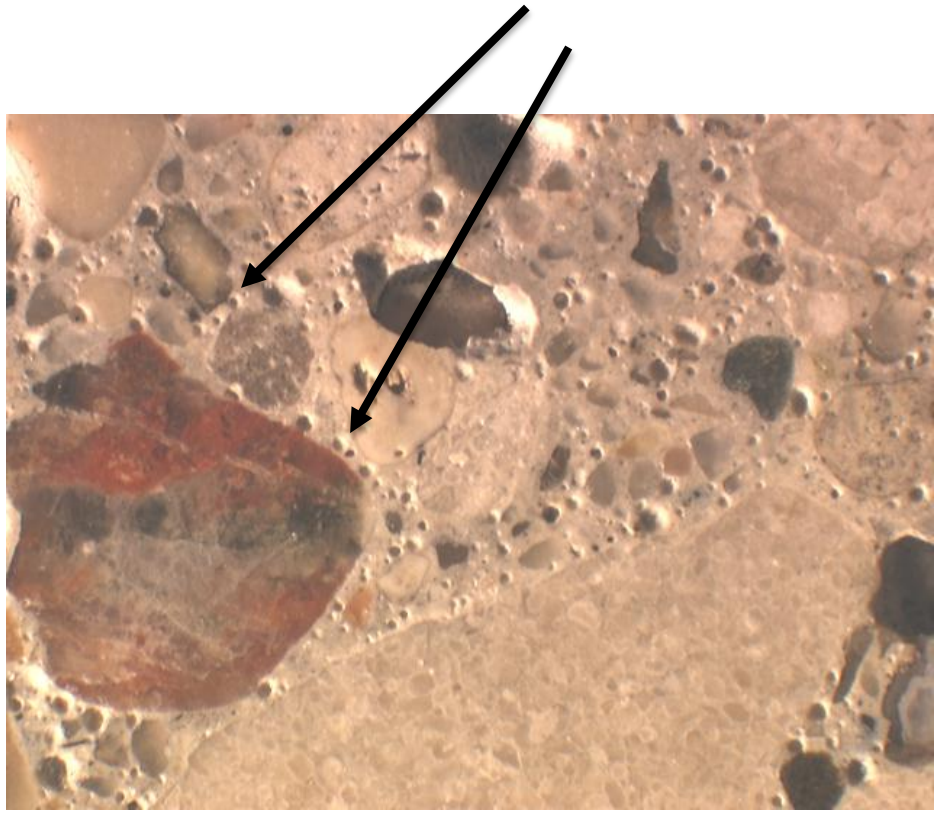
Under pressure, the water will be pushed into the air entrainment pores and not crack the concrete matrix.

Image: NPCA

Concrete Materials – Air Entraining

1% increase in air content ➔ ~5% decrease in compressive strength

Typical air content : 8% +/- 2% machine placed
7% +/- 1.5% hand placed



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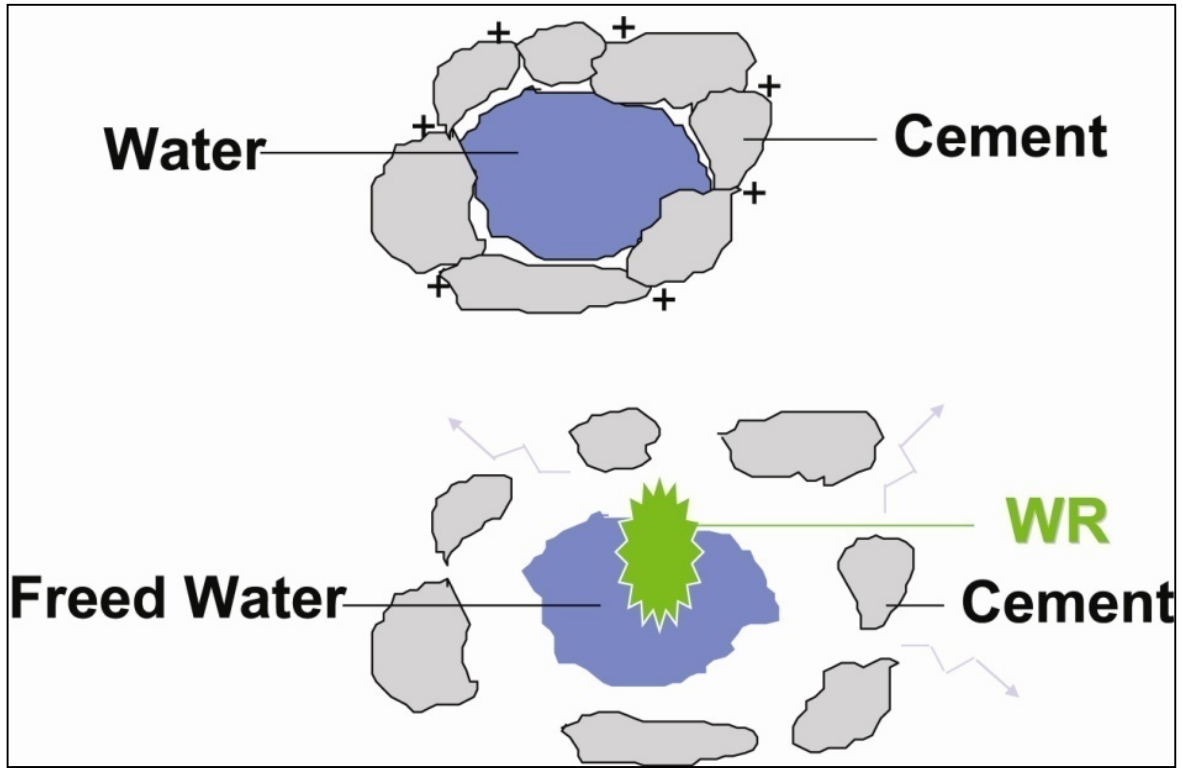
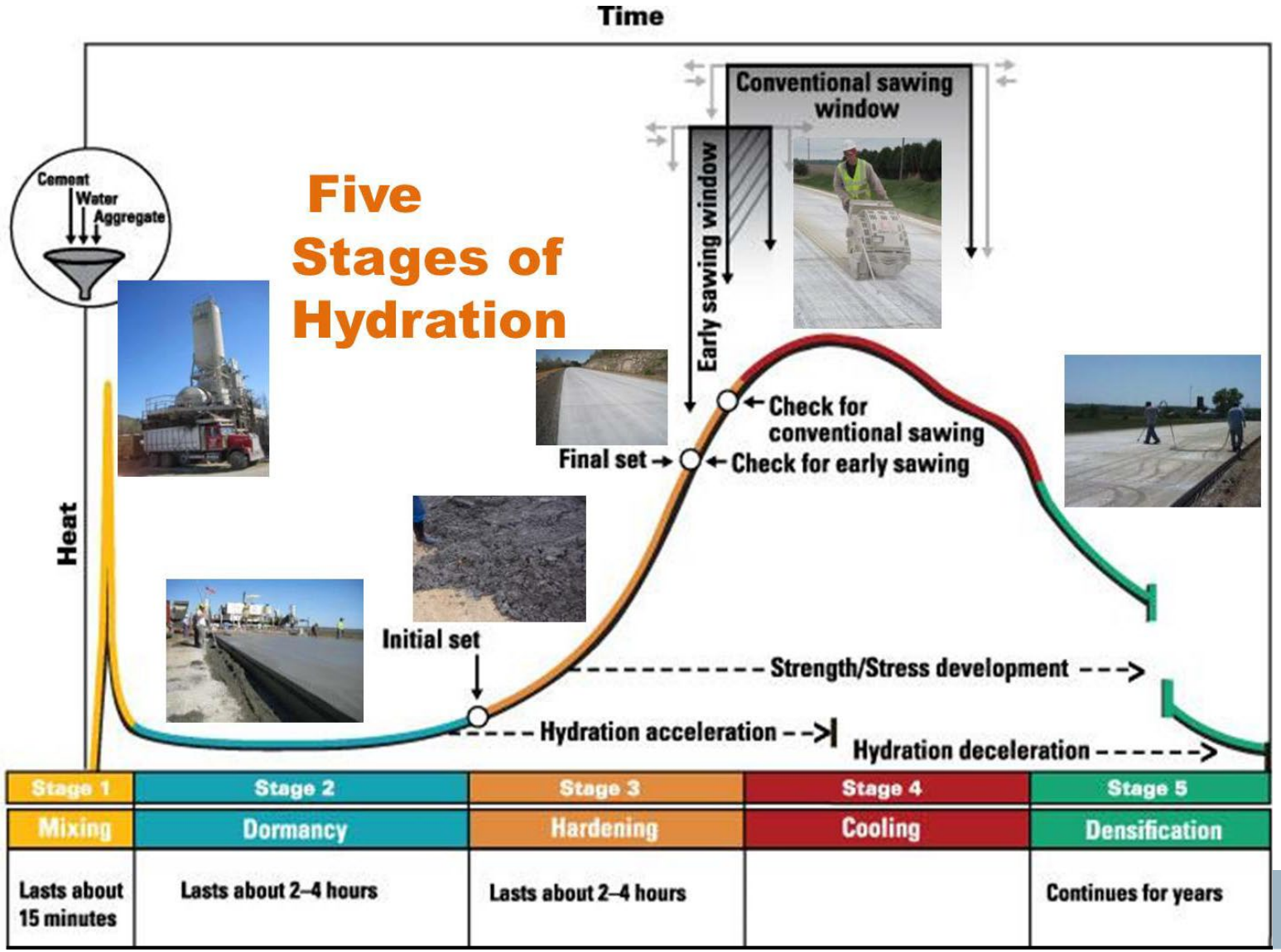
Concrete Materials – Water Reducers

- "FREE the Water"
- Changes electrical charges on cement particles
- Similar to anti-static laundry products
- Organic fingers force particles apart
- Typical water reducers can reduce water content by 7%-10%
- High range water reducers reduce water content by 12%-30%



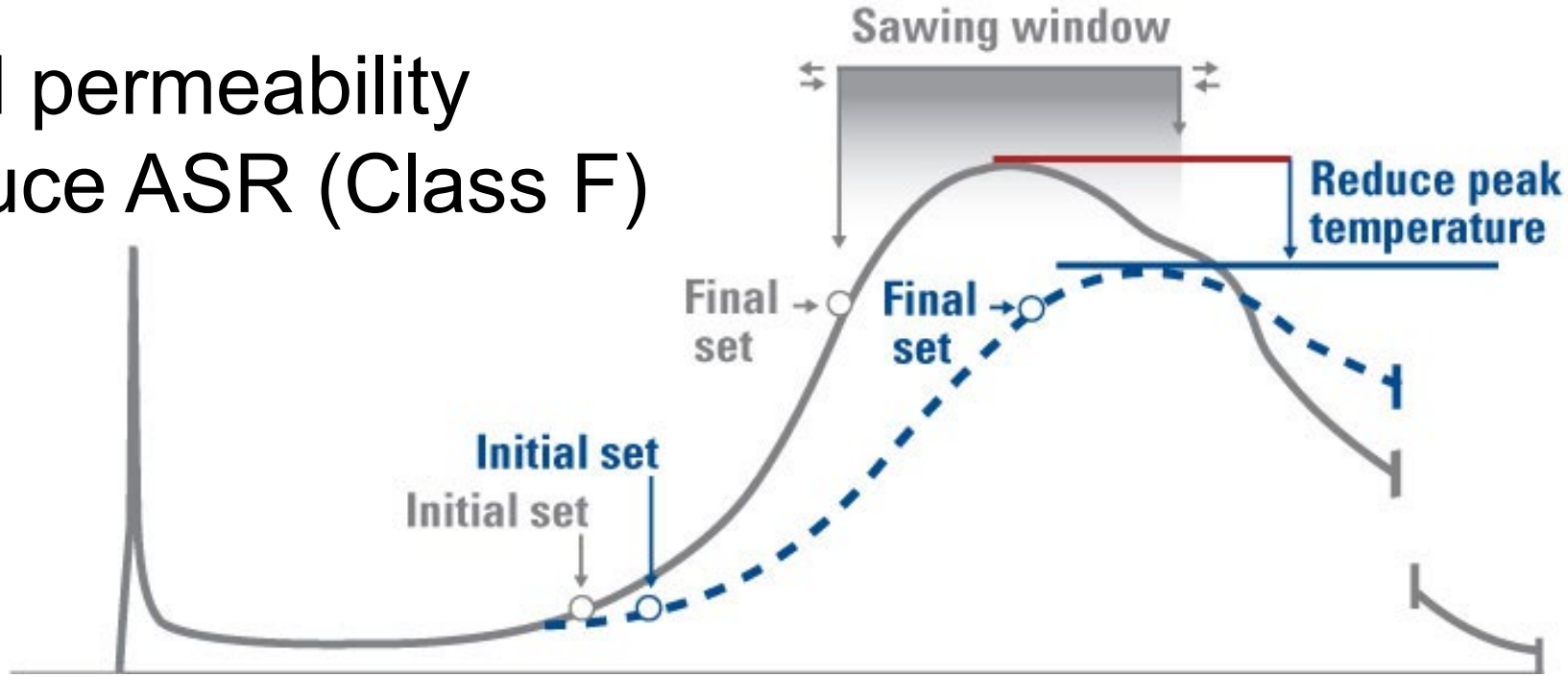
Concrete Production: Cement Hydration Process



SCM Effects

(IMCP—page 78)

- Delayed final set
- Reduced heat peak
- Extended heat generation
- Increased long-term strength
- Reduced permeability
- May reduce ASR (Class F)



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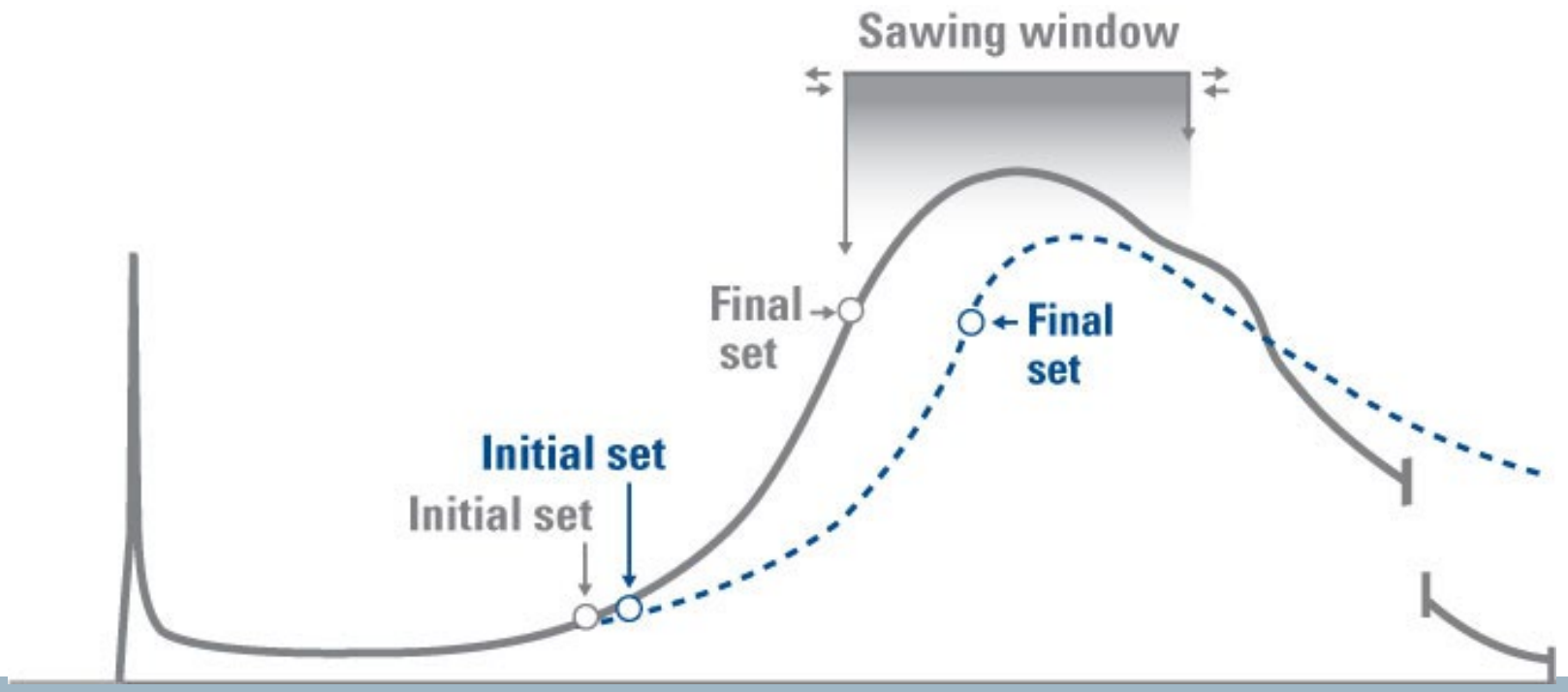
Water Reducers' Effects

(IMCP—pages 79, 99)

- Possibly slower strength gain (slows rate of alite reactions)
- Possibly faster aluminate reactions (and risk of flash set)
- More mix water available for hydration



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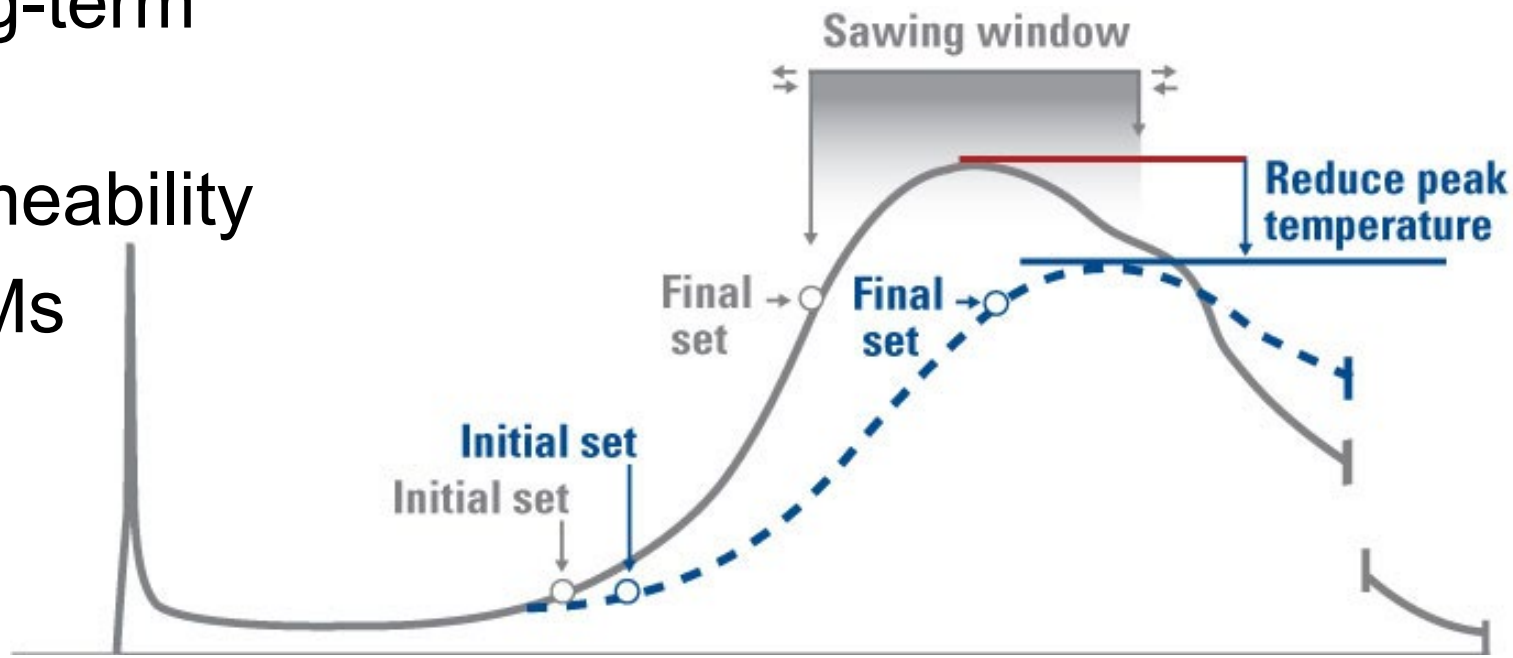
Retarders' Effects

(IMCP—page 79)

- Lengthened dormancy
- Slowed hydration
- Reduced heat peak
- Extended heat generation
- Increased long-term strength
- Reduced permeability
- Similar to SCMs



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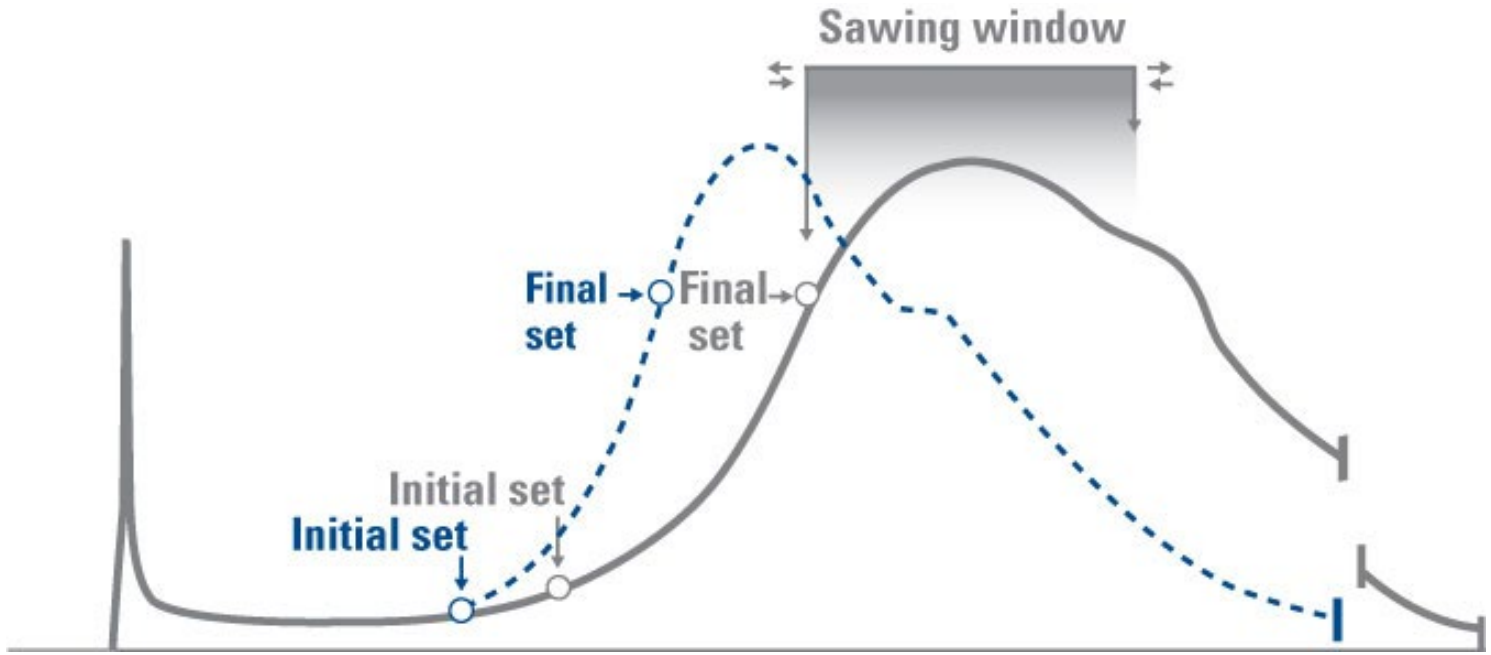
(IMCP—page 79)

Accelerators' Effects

- Calcium Chloride

- Shortened dormancy stage
- Earlier initial and final sets (steeper hydration curve)



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Concrete Properties

- Air Content
- Slump
- Workability
- Water/Cement Ratio
- Permeability-Unit Weight
- Temperature
- Strength

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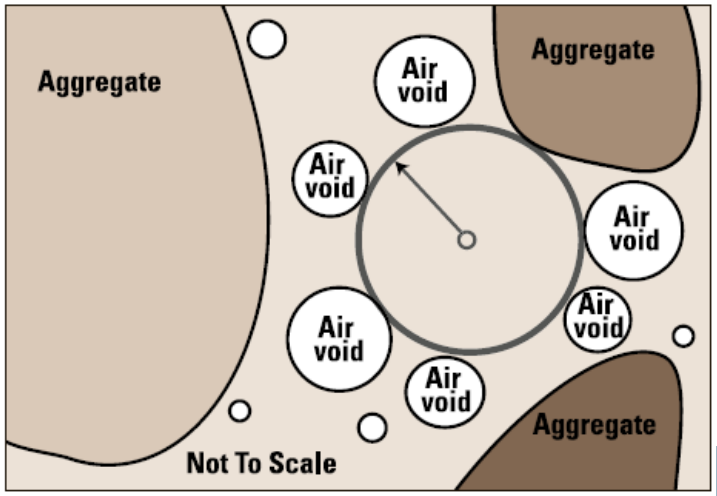
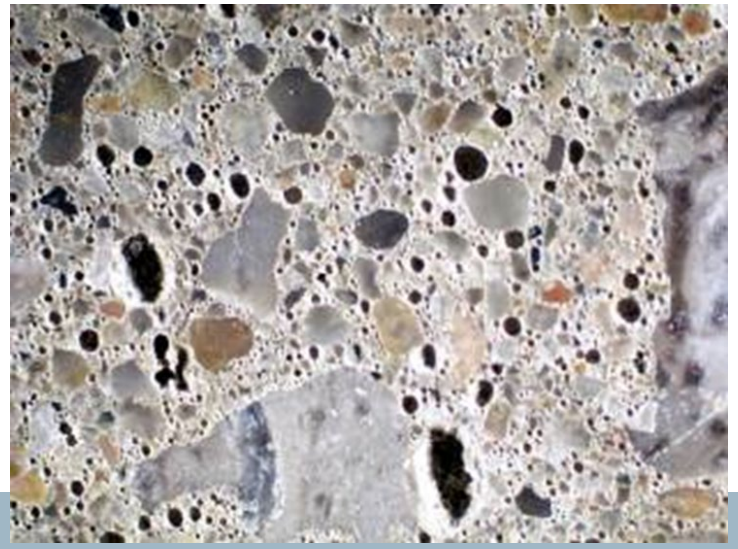
Concrete Properties – Air Content

- Pressure Meter
  Reports total air content – nothing about bubble sizes

- Super Air Meter (SAM) - Reports a number tied to freeze thaw resistance





Concrete Properties – Slump

- Test that was used to indicate water content in mixture
- No longer a good indicator of water content due to admixtures and SCMs
- Can indicate a change in the mix – CONSISTENCY!!

Concrete Properties - Workability

- Describes
  - How well concrete can be moved, molded, and shaped
  - Response to vibration
- Developing tests
  - V-Kelly Test
  - Box Test
- Affected by:
  w/cm ratio
  Aggregate gradation

V-Kelly Test

Box Test

Concrete Materials

What is the most important parameter affecting concrete performance?

W/CM Ratio

One of the most important elements affecting concrete performance is water to cementitious material ratio (w/cm) ratio

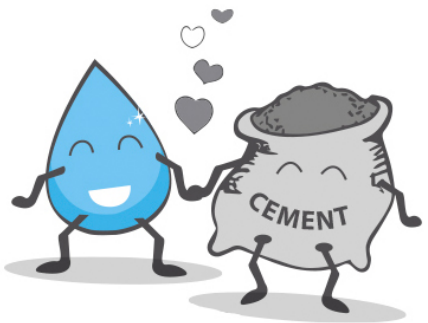


Table: Chloride Permeability Based on Charge Passed

Charge Passed (Coulombs)	Chloride Permeability	Typical of
>4,000	High	High W/C ratio (>0.60) conventional PCC
2,000–4,000	Moderate	Moderate W/C ratio (0.40–0.50) conventional PCC
1,000–2,000	Low	Low W/C ratio (<0.40) conventional PCC
100–1,000	Very Low	Latex-modified concrete or internally-sealed concrete
<100	Negligible	Polymer-impregnated concrete, Polymer concrete

W/CM Ratio

The Microwave Test – AASHTO TP 23

- Measures w/c ratio by “cooking out the water” using a min. 900 watt microwave
- Min. 3 heating cycles
- Mixing between cycles
- Takes approx. 15 min.

W/CM Ratio

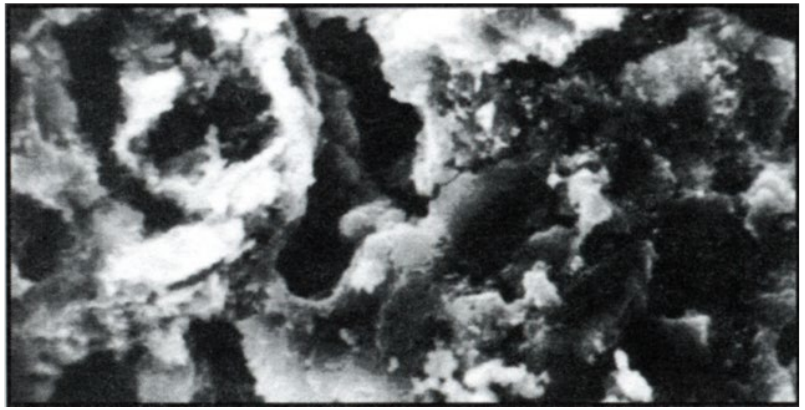
The “Phoenix Test”

- Measures w/c ratio by “cooking out the water” over high heat
- Requires large generator
- 30 minute test (currently)
- No mixing steps
- Heat & measure
- Very accurate

Concrete Properties – Water Cement Ratio

- Relationship between amount of water in mixture and amount of cement
- w/c ➔ water to cement
- w/cm ➔ water to cementitious material
- Has a huge impact on the ultimate strength/durability of concrete
- The more water in mix the farther apart the cement particles are

w/c ratio = 0.42



w/c ratio = 0.60

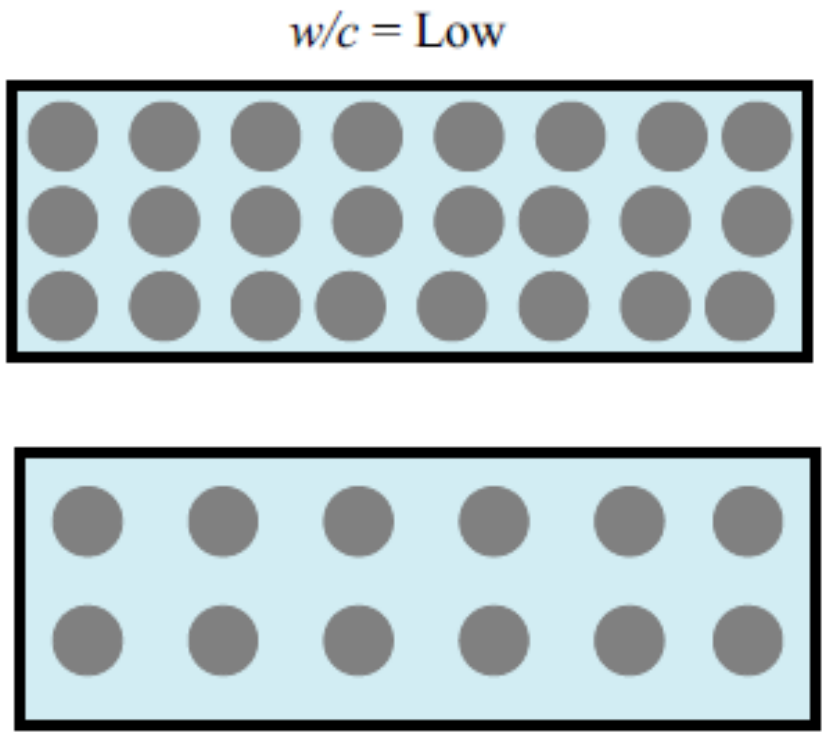
Concrete Properties – Permeability / Unit Weight

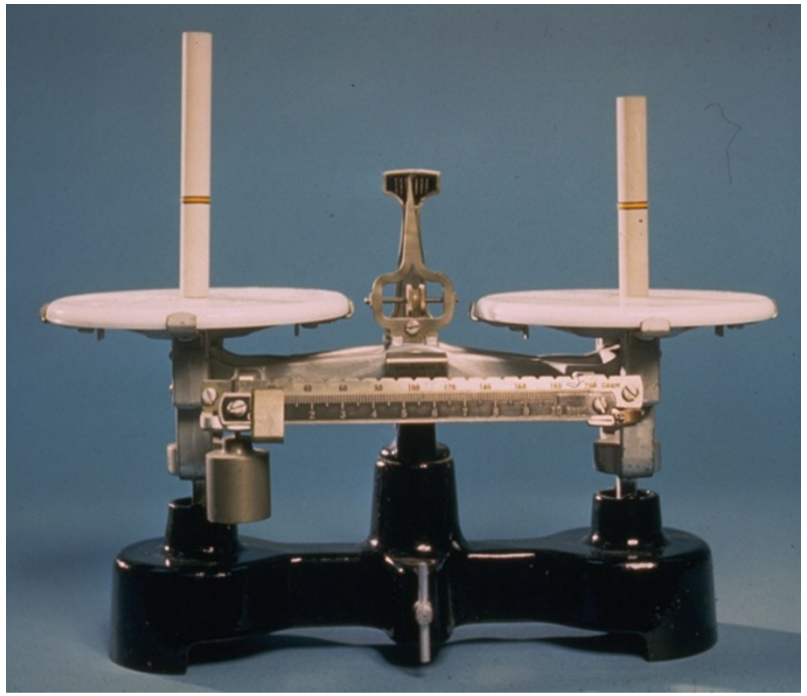
- Unit Weight = Mass of Concrete / Volume of Concrete
- Determined during mix design
- Field Unit Weight = Design Unit Weight ➔ Good
- Field Unit Weight ≠ Design Unit Weight ➔ Bad
  - ➢ Something is wrong

    Check these before you scream
    - –Scale (tare, calibration, etc.)
    - –Calculator (operator error)
    - –Math (1+1=3)

Concrete Properties - Permeability / Unit Weight

- More water – means more space between cement grains





Concrete Properties – Temperature

- When weather is cold…Is it warm enough for hydration to take place and the concrete will not be damaged?
  - Is the subbase/subgrade frozen?
  - Cold Weather Protection!

- When the weather is hot…Is it so hot the mix sets too quickly and the concrete is damaged?

- Follow your specifications

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Concrete Properties – Strength

- Many factors affect strength
  - Mix Design
  - Construction practice

- Many ways to measure strength
- Two most common:
  - Compressive Strength
  - Flexural Strength
    - Flexural ~10-20% Compressive

Concrete Properties - Strength

- Compressive Strength
  - Cylinders or Cores
  - Usually for commercial or structural work

- Flexural Strength
  - Beams cast during construction

    Preparation, curing, and handling are critical
  - Opening Strength
  - Two type of flexural test
    - Center Point
    - Third Point

Summary – What is Concrete?

- Ingredients
  - Cement, aggregate, water
  - SCMs
  - Admixtures

- Concrete Properties
  - Air Content
  - Slump
  - Workability
  - Water/Cement Ratio
  - Permeability-Unit Weight
  - Temperature
  - Strength

THANK YOU !

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