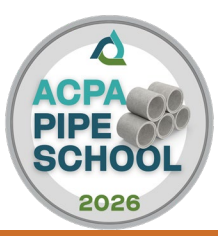


# Chemical Admixtures for Concrete



# Quality School



## Agenda

- Introduction
- Air Entraining Agents
- Water reducers
- Retarders
- Accelerators
- Strength Enhancers
- Corrosion Inhibitors
- Lubricants





## Admixtures for Concrete

- Modify and improve many of the properties of concrete.
- Make higher performance (engineered) concrete routinely possible.
- Admixtures make concrete more user friendly and a better value for both the owner and contractor.





## Admixtures What Are They?

**Chemical Admixture** - a liquid, or dispersible powder, used as an ingredient in a cementitious mixture to improve its economy and/or properties in the plastic and/or hardened state.

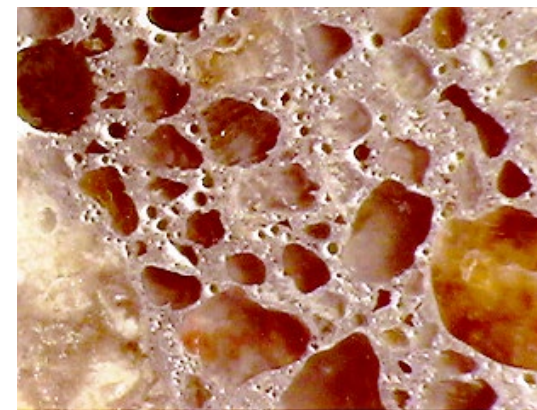
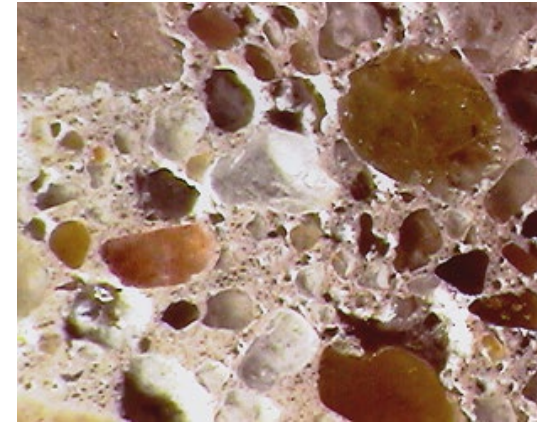
(ACI 212)





## Air Void Systems

- Discovered in the 1930's and is still considered one of the most significant improvements in concrete technology.
- Most standard specifications require that concrete be air entrained if exposed to freeze thaw cycles.
- Uses air entraining admixtures to create a network of small disconnected air voids distributed through out the concrete.





## Air Void Systems

### Standards

AASHTO

M 154 Standard Specification

ASTM

C 260 Standard Specification

C 233 Standard Test Methods





## Air Void Systems

- Absolutely necessary for F/T durability
- Other benefits
  - improved workability
  - reduced segregation and bleeding
  - reduced permeability
  - improved finishing with harsh mixtures
  - Increased yield





## Air Void Systems

### Challenges....

- Getting the right amount
- Dealing with variability
- Reduced strength
- “Sticky” mixtures
- Lower abrasion resistance
- Reduces bleeding time



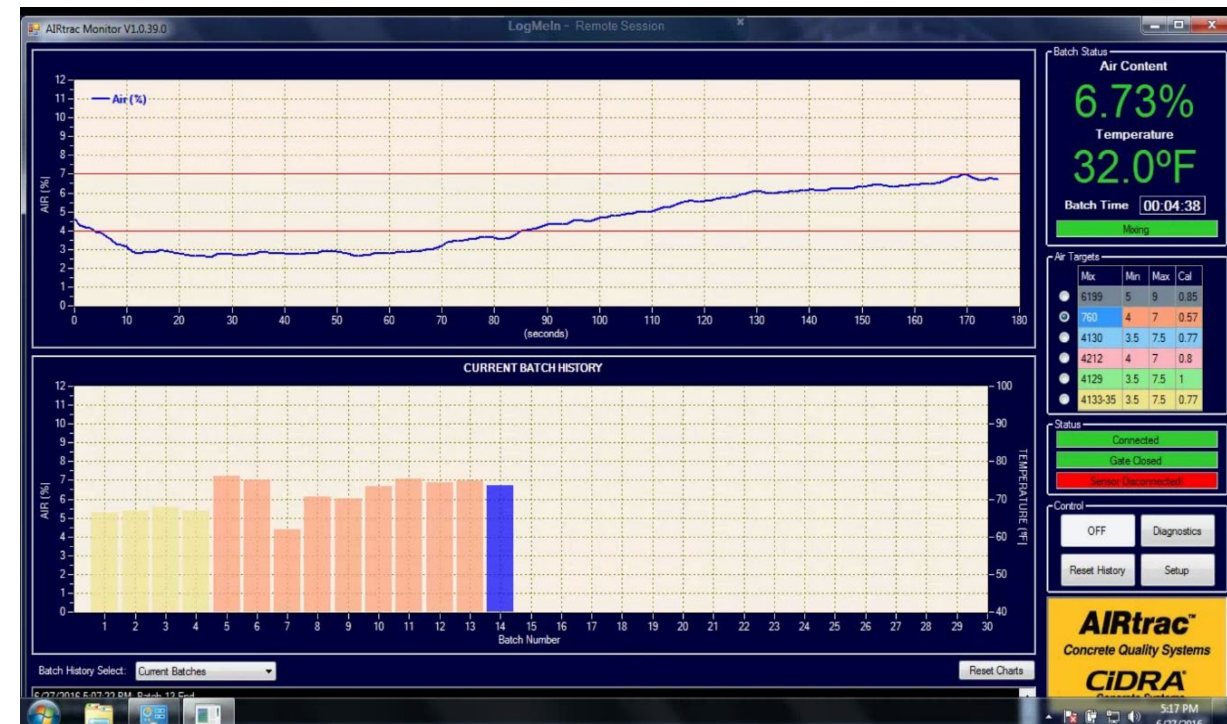


## Air Void Systems

### What impacts the Air Void System

- Amount & Type of OPC or Blended Cement
- Amount & Type of SCM
- Aggregates
- Water Content
- Concrete & Ambient Temperature
- Other Admixtures
- Mixing Variation
- Placing procedure
- Consolidation process...

*...and so on, and so on...*





# Water Reducers and High Range Water Reducers

(HRWR = Super Plasticizers)





## ASTM C 494 / AASHTO M 194\*

### • Standard Specification for Chemical Admixtures for Concrete

- Type A - Water Reducing
- Type B - Retarding
- Type C - Accelerating
- Type D - Water Reducing & Retarding
- Type E - Water Reducing & Accelerating
- Type F - High Range Water Reducing
- Type G - HRWR & Retarding
- **Type S – Specific Performance Admixture**
  - *AASHTO M 194 includes a requirement for 56-day strength*





## Water Reducing Admixtures: What Are They?

- Admixtures that either increase the slump of freshly-mixed mortar or concrete without increasing water content OR
- maintain slump with a reduced amount of water, the effect being due to factors other than air entrainment.



ACI - 212



## Water Reducing Admixtures

- Overview
  - Can be used to reduce water content, improve slump or both
  - Three groups: Type A, Mid-range, and High-range
- How they work
  - Reduces flocculation and improves hydration efficiency
- Effects on concrete
  - Increased strength
  - Increased slump and workability





## Water Reducing Admixtures

Water reduction/increased workability normally requires three processes:

**DIFFUSION:**  
Water miscibility

**ADSORPTION:**  
Attraction to cement surface

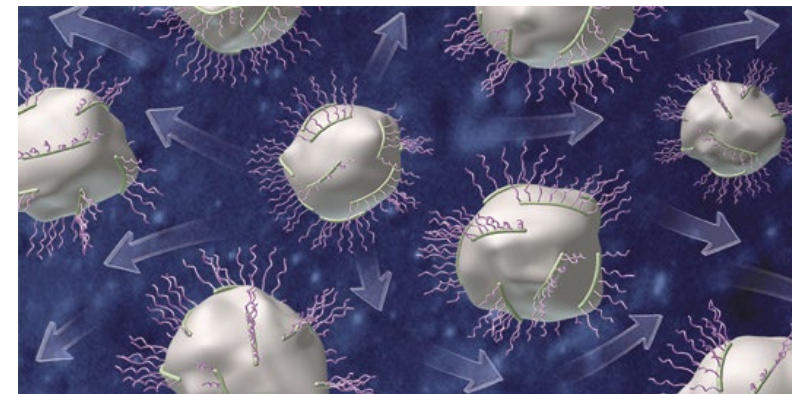
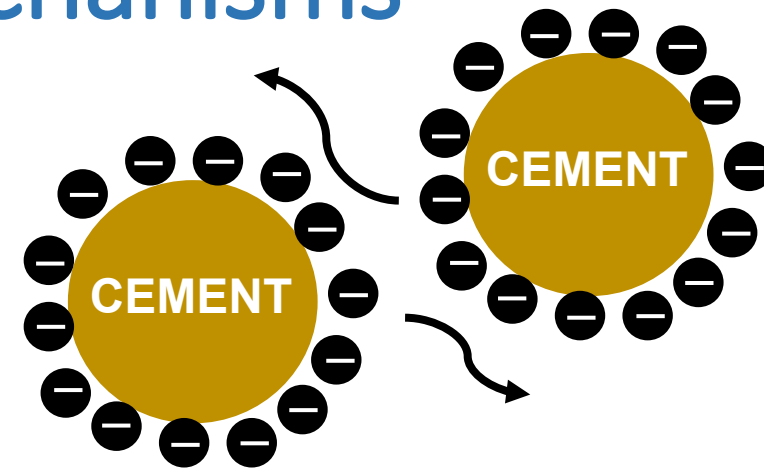
**REPULSION:**  
Imparts a force that overcomes attractive forces between adjacent hydrating cement grains (dispersing ability)





## Dispersant Mechanisms

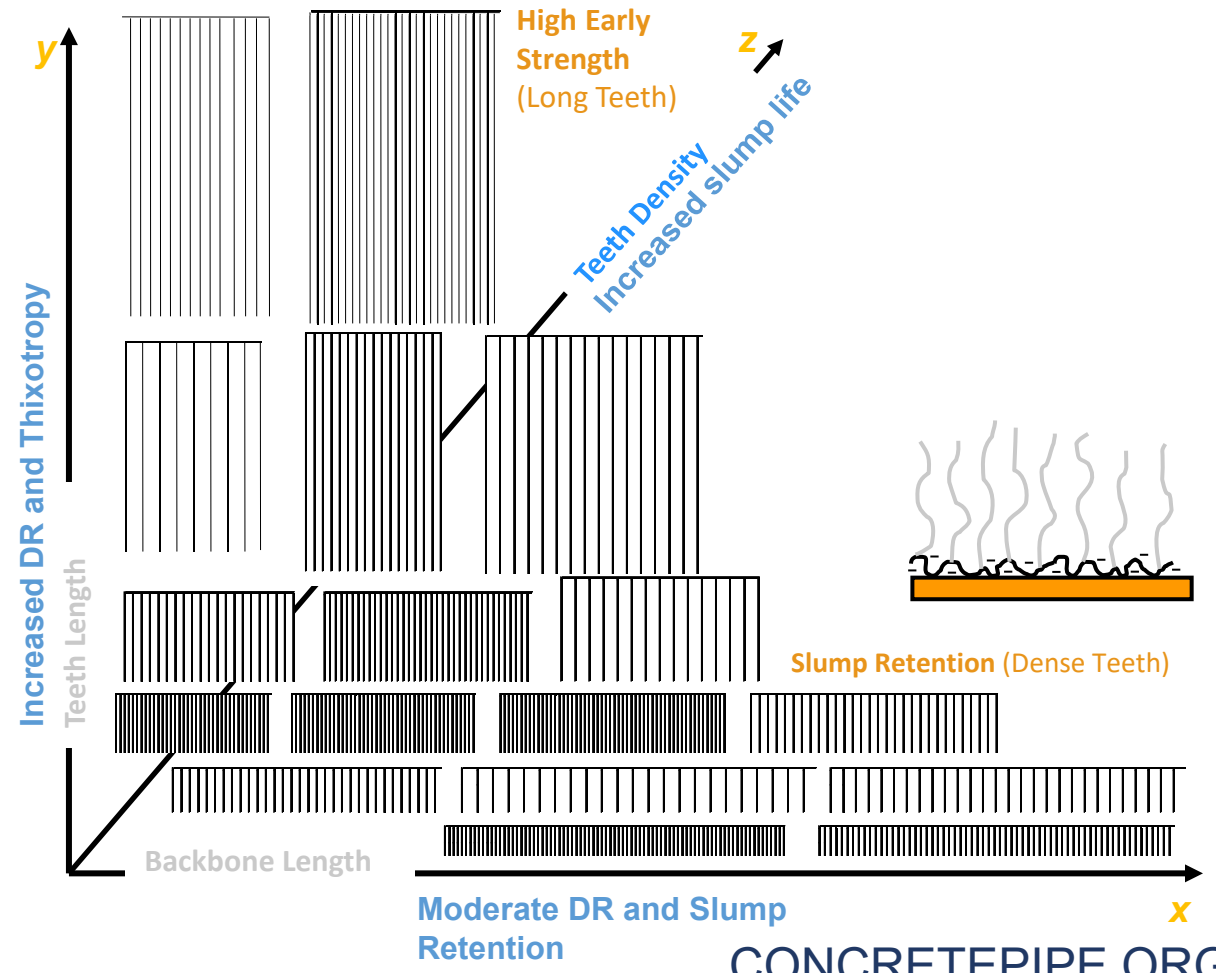
- **Electrostatic Repulsion**
  - Adsorbed charged molecules and polymers cause particle dispersion through repelling force of like charges on the surfaces of adjacent cement grains
  - Overdose can cause massive bleeding and segregation
- **Steric Repulsion**
  - Physical force produced when two adsorbed polymers try to occupy same space in the pore water.
  - Overdose usually will not cause segregation in well designed concrete mixtures





## Dispersant Mechanisms

- Understanding Polymer Structure vs. Concrete Performance critical to leverage value of PC Technology





## Dispersant Mechanisms



No Admixture



Admixture





## Water Reducing Admixtures

Product Type	Class	Water Reduction	Typical Dosage	Strength Gain
Water Reducer	Low	4-7%	2-4 oz/cwt	~ 10%
Mid-Range	Mid	5-12%	6-12 oz/cwt	~ 15%+
HRWR (NSFC)	High	12-25%	10-18 oz/cwt	~ 20%+
HRWR (PC)	High	12-35%	3-8 oz/cwt	~ 20%+





## Effects of HRWR on Properties of Fresh Concrete

- Increases workability
- Improves flow
- Improves placeability
- Improves finishability
- Improves formed surfaces (Swipe)
- Can have an effect on air content and setting





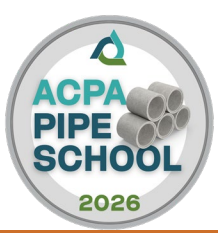
## Effects of HRWR on Properties of Hardened Concrete

- Improved Strength
- Improved Durability
  - Chloride resistance increases
  - Frost resistance improves
  - Increases sulfate resistance
  - Increases resistance to abrasion





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# Set Retarding Admixtures

Retarders / Hydration Stabilizers





## Why Use Set Retarding Admixtures?

- Hot Weather:
  - Increase water demand
  - Faster set times
  - Hasten evaporation rate
  - Increase potential for plastic cracking
  - Accelerate workability loss
- Use of retarders is not a substitute for adequate hot weather concreting procedures





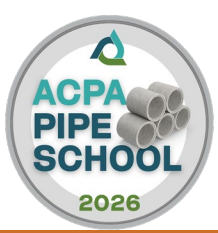
## Set Retarding and/or Hydration Stabilizing Admixtures

- How they work
  - Decreases the rate of cement hydration (C3S)
  - Admixture absorbs onto cement grains and temporarily inhibits crystal growth
- Effects on Concrete
  - Delays Initial set
  - Extends workability time
- Differences between Retarder and HS
  - Range of control over the variety of hydration processes at the surface of the cement grain
    - Retarders can slow, HS can stop





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# Set Accelerating Admixtures

Accelerators





## Accelerators

- Some common names:
  - Calcium, CC, NCA, non chloride & accelerator
- Allows concrete to be “used” faster





## Accelerators

- Speed up both initial and final time of set
- Speed up strength development
- General Categories: Chlorides and Non-Chloride





## Accelerators

- How they work
  - Increases rate of cement hydration
- Why accelerate concrete?
  - Shorten the setting time
  - Reduced curing time
  - Quicker early strength
  - Reduce bleeding
  - Earlier finishing
  - Improved initial protection against freezing
  - Reduction of protection time to achieve a given quality
- They are NOT anti-freeze agents





## Calcium Chloride

- Very effective & economical accelerator
- Cautions when using chloride-bearing admixture
  - DO NOT use in ANY reinforced concrete
  - high potential to cause corrosion
  - calcium chloride should not exceed 2% in non reinforced concrete
  - calcium chloride should not exceed 1% when concrete contains uncoated aluminum conduit
  - can cause discoloration issues (dark and light gray spots, especially on hard trowled finishes)
- Although often the most effective, non-liquid CC (pellets/flake) is not recommended





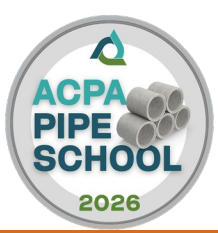
## Non-Chloride Accelerators (NCA)

- Non – corrosive
- Linear dosage
- NOT Anti-freeze





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# Strength Enhancing Admixtures

Sustainable Solutions



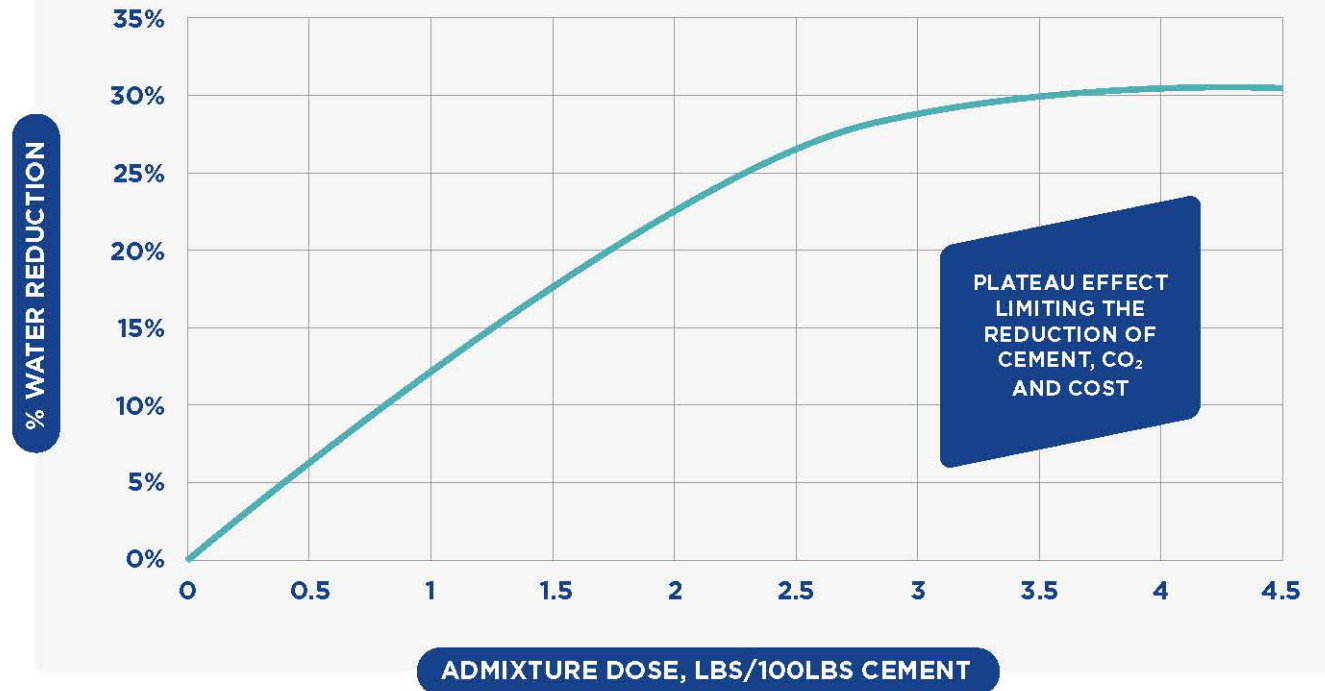


## STRENGTH ENHANCERS

### THE CHALLENGE:

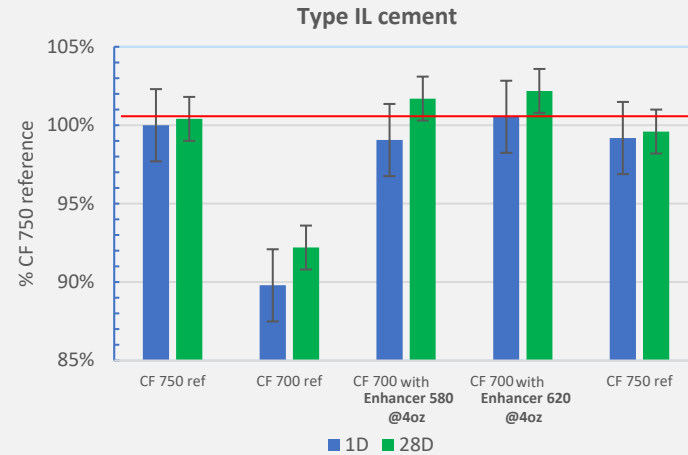
While water reducers are a powerful solution to reduce Cement Factor, their use can reach limits. Admixture researched solutions have been developed to further reduce the cement content without impacting concrete performance.

GENERALIZED RESPONSE OF WATER REDUCTION TO SUPERPLASTICIZER DOSAGE



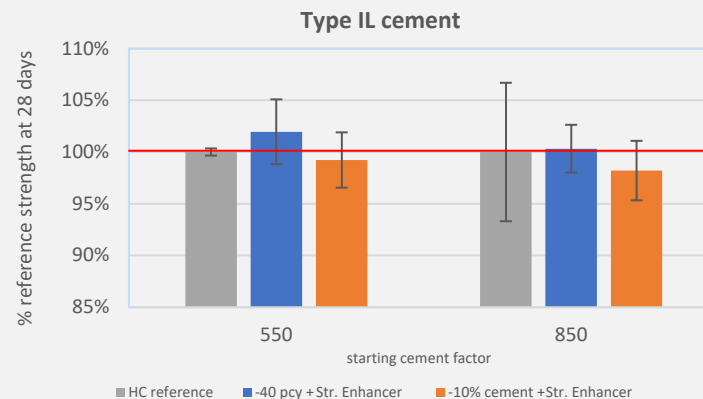
Source: J. Cheung, L. Roberts, J. Liu; Admixtures and sustainability; Cement and concrete research 114 (2018) 79-89

- **Accelerates** the hydration of cement and supplementary cementitious materials
  - Including Type I/II, Type IL, Fly-Ash
- **Enhances** early and late age strengths
- Allows to **reduce the cement factor** by up to 10%, while maintaining desired concrete quality and performance
- **Range of formulations** to meet the specific requirements of concrete producers
- **Simple to use:** no impact on fresh concrete properties; compatible with WRA admixtures



### Case Study 1 (Southeast US)

- Initial CF = 750 lbs./cu.yd.
- Cement reduction of 50 lbs (32 lbs CO<sub>2</sub>/cu.yd.)
- Comparable strength at 1 and 28 day

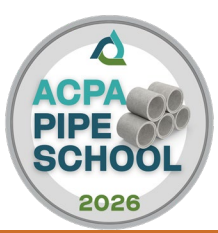


### Case Study 2 (South US)

- Initial CF = 550 lbs./cu.yd. and 850 lbs./cu.yd.
- Cement reduction of 40-85 lbs (25-50 lbs CO<sub>2</sub>/cu.yd.)
- Same strengths at 28 days



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# Corrosion Inhibitors





## Corrosion Inhibitors

- How they work
  - Passive film enhances the protection of reinforcing steel from corrosion in the concrete
  - Generally, corrosion inhibitors are not needed to protect steel reinforcing, due to the passivating effect of the high pH in the concrete.
- Effects on Concrete
  - May accelerate initial set
  - May improve early age strength





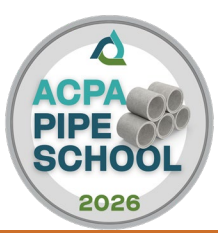
## Corrosion Inhibitors

- Control Corrosion of Steel Reinforcement
- Dosage dependent on anticipated chloride loading





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# Lubricants and Surfactants





## Lubricants & Surfactants (Drycast)

- How they work
  - Decreases surface friction and therefore aids in stripping forms
  - Increased reaction to vibration
  - Improved moisture retention
  - Improved production efficiency
- Effects on Concrete
  - Can improve appearance
  - Improved water tolerance
  - Increase in surface paste





## Dry Cast Admixtures

- Reduction in Cracking
- Improved surface swiipe
- Sharper joints
- Reduced repair





## Current Admixture Standards

- |               |                             |
|---------------|-----------------------------|
| ▪ ASTM C 494  | ▪ Chemical Admixtures       |
| ▪ ASTM C 260  | ▪ Air-entraining Admixtures |
| ▪ ASTM D 98   | ▪ Calcium Chloride          |
| ▪ ASTM C 869  | ▪ Foaming Agents            |
| ▪ ASTM C 1141 | ▪ Admixture for Shotcrete   |
| ▪ ASTM C 1017 | ▪ Flowing Concrete          |
| ▪ ASTM C 937  | ▪ Grout Fluidifier          |
| ▪ ASTM C 979  | ▪ Pigments                  |





## Admixtures can be used to modify various fresh and hardened concrete properties:

Fresh state	Hardened state
<ul style="list-style-type: none"><li>■ decrease water content</li><li>■ increase workability</li><li>■ reduce segregation</li><li>■ reduce the rate of slump loss</li><li>■ improve pumpability</li><li>■ improve placeability &amp; finishability</li><li>■ modify the rate of bleeding</li><li>■ retard or accelerate setting time</li></ul>	<ul style="list-style-type: none"><li>■ improve freeze / thaw resistance</li><li>■ improve impact &amp; abrasion resistance</li><li>■ inhibit expansion due to ASR</li><li>■ inhibit corrosion</li><li>■ reduce shrinkage cracking</li><li>■ reduce permeability</li><li>■ produce colored concrete</li><li>■ produce cellular concrete</li></ul>





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