Chemical Admixtures for Concrete

American Concrete Pipe Association

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.

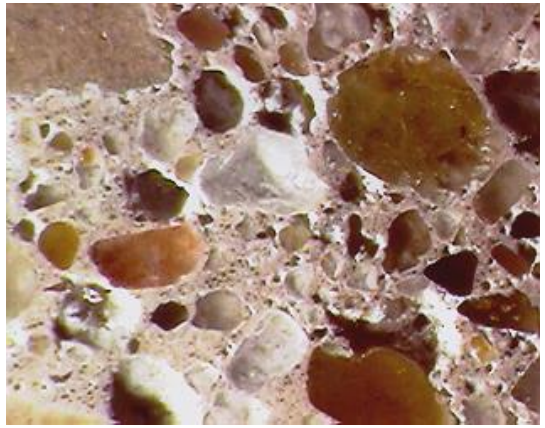
Admixtures What Are They?

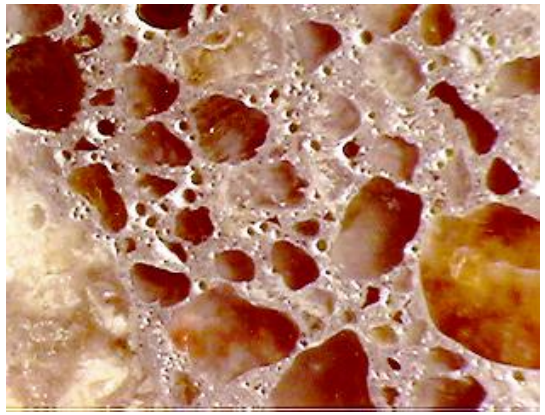
<u>Chemical Admixture</u> - a liquid, or dispersible powder, used as an ingredient in a cementitious mixture to improve its economy and/or properties in the plastic and/or hardened state.

(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.



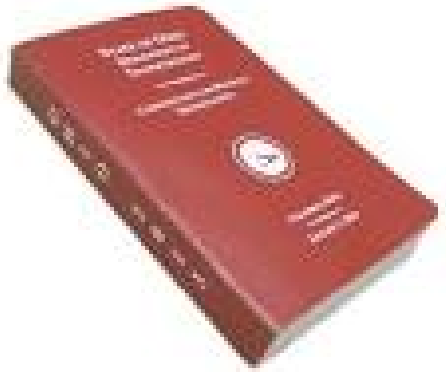


Air Void Systems

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

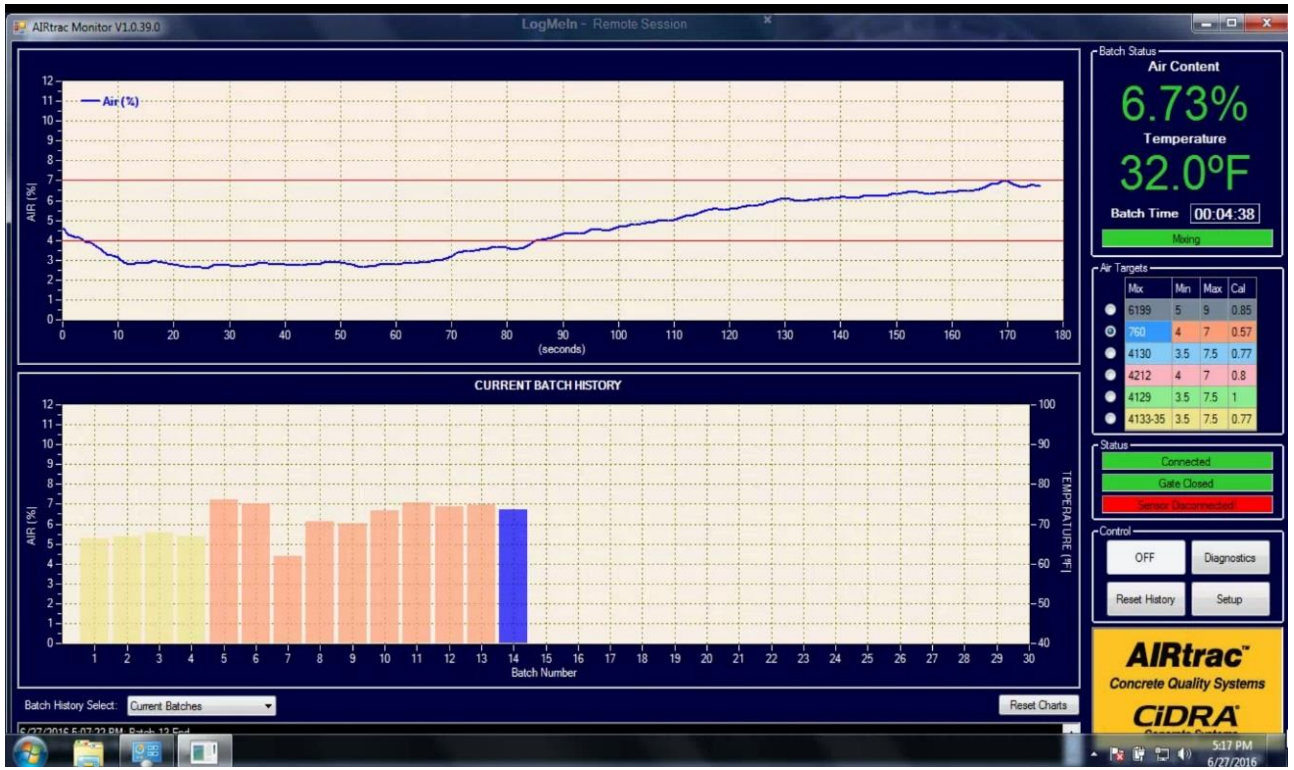
Challenges….

- 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
- 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:

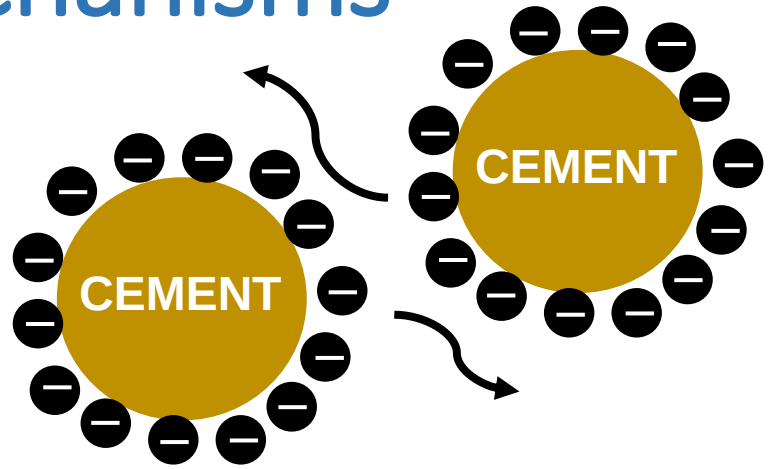
DIFFUSION:
Water miscibility

ADSORPTION:
Attraction to cement surface

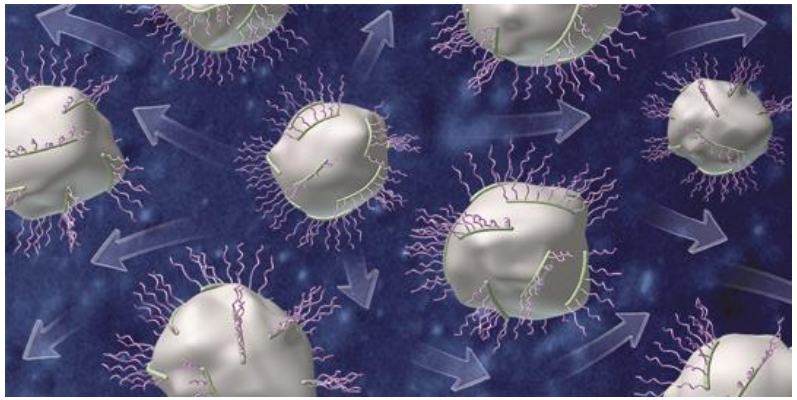
REPULSION:
Imparts a force that overcomes attractive forces between adjacent hydrating cement grains (dispersing ability)

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

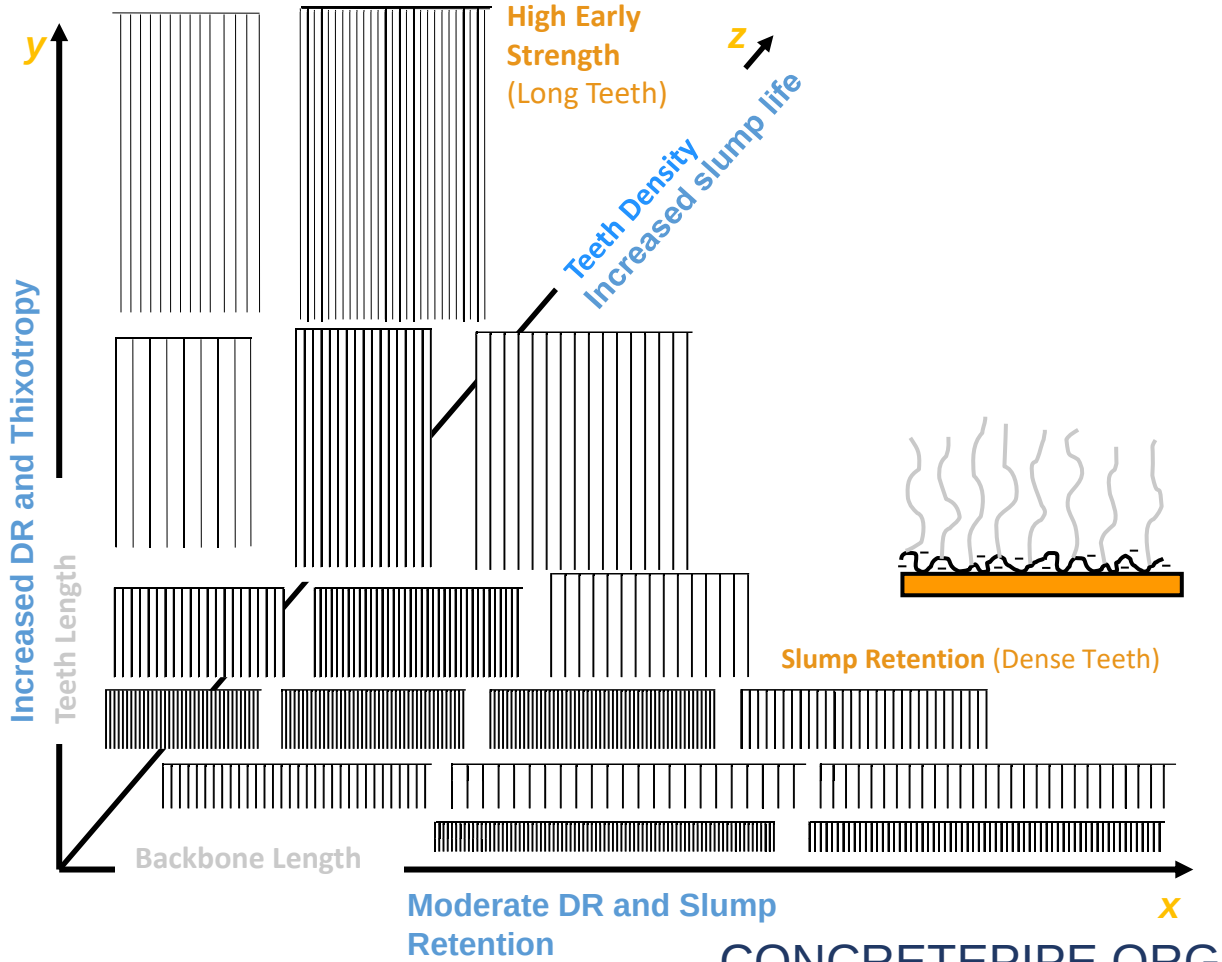


- Steric Repulsion
  - Physical force produced when two adsorbed polymers try to occupy same space in the pore water.
  - Overdose usually will not cause segregation in well designed concrete mixtures



Dispersant Mechanisms

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



Dispersant Mechanisms

No Admixture

Admixture

PC Structure and Applications

Applications of Different Polycarboxylate-based Admixtures				
Required Characteristics	Relative Chain Length of Backbone (trunk) Polymer	Relative Side Chain (graft) Length	Relative Number of Side Chains (grafts)	
Low Dispersibility and Short Dispersibility Retention	Long	Short	Large	
High Dispersibility	Short	Long	Small	
Long Dispersibility	Short	Long	Large	
	= Negative Charge	= Backbone	= Side Chain	

Ready Mix

PC/PS

Slump Retention

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

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

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

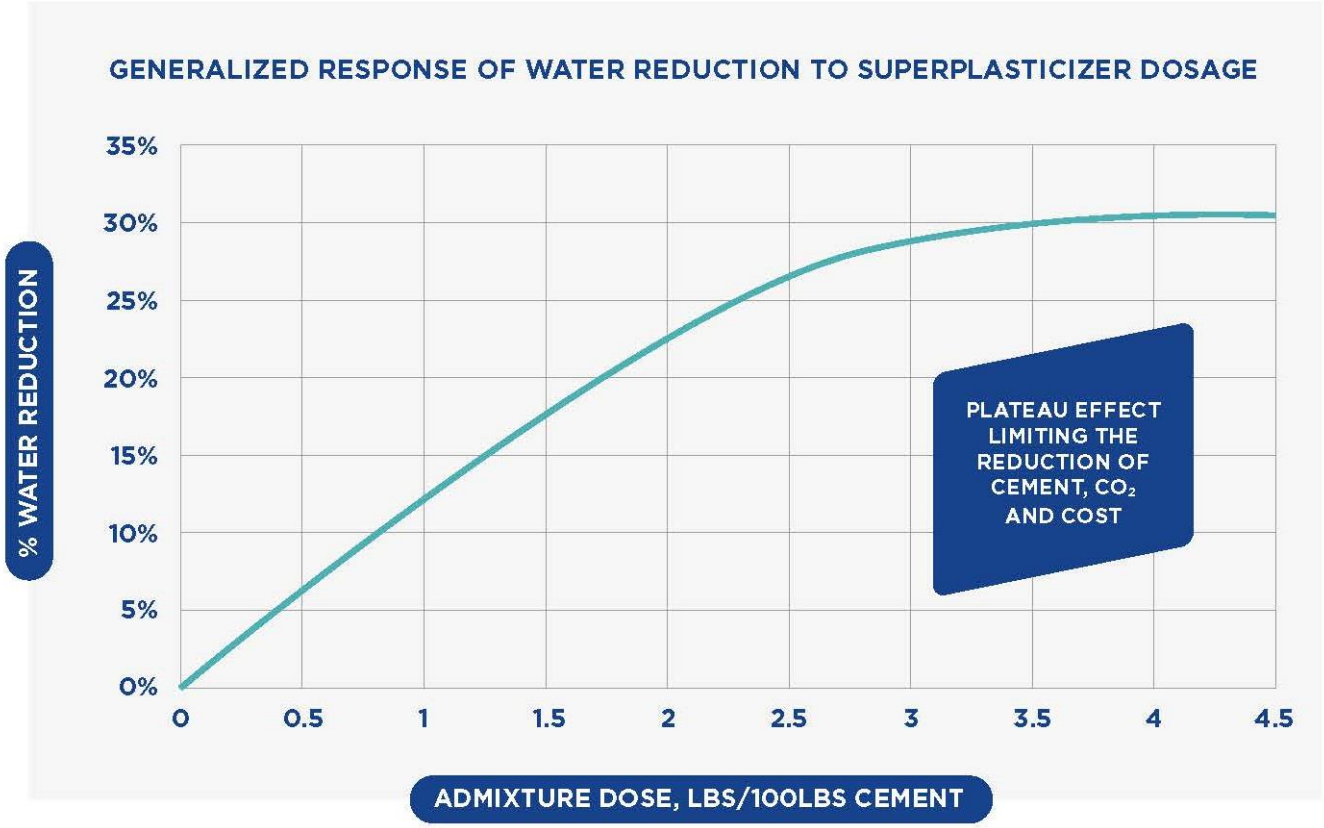
Strength Enhancing Admixtures

Sustainable Solutions

STRENGTH ENHANCERS

THE CHALLENGE:

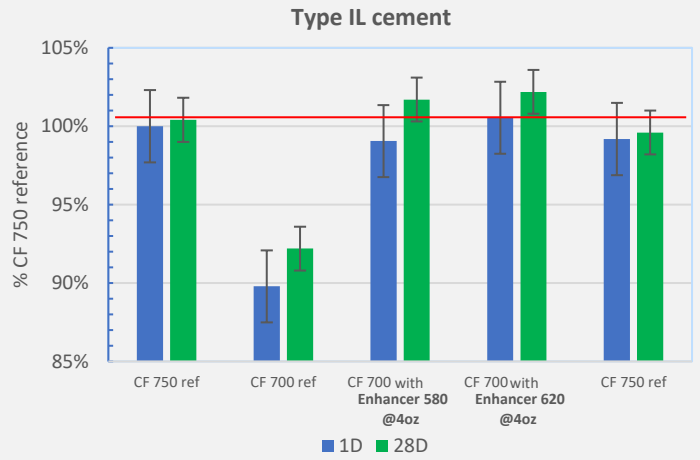
While water reducers are a powerful solution to reduce Cement Factor, their use can reach limits. Admixture researched solutions have been developed to further reduce the cement content without impacting concrete performance.



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

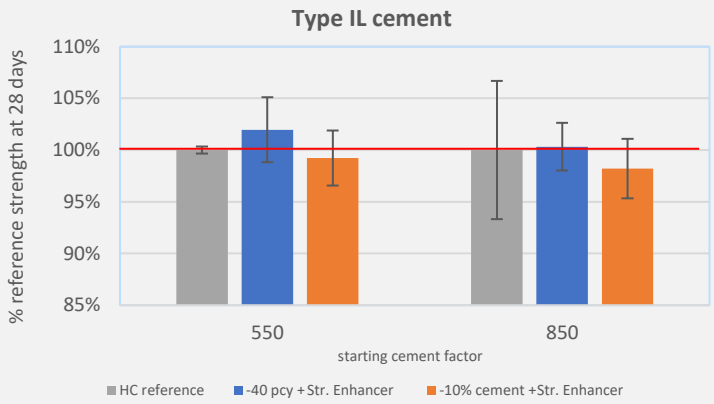
QUALITY SCHOOL

- **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_2/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_2/cu.yd.)
- Same strengths at 28 days

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

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 swipe
- 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
▪ decrease water content ▪ increase workability ▪ reduce segregation ▪ reduce the rate of slump loss ▪ improve pumpability ▪ improve placeability & finishability ▪ modify the rate of bleeding ▪ retard or accelerate setting time	▪ improve freeze / thaw resistance ▪ improve impact & abrasion resistance ▪ inhibit expansion due to ASR ▪ inhibit corrosion ▪ reduce shrinkage cracking ▪ reduce permeability ▪ produce colored concrete ▪ produce cellular concrete

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