Admixture Basics: An Overview

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Agenda

• Introduction
• Air Entraining Agents
• AASHTO M194 Admixtures
• Fibers
• Specialty Admixtures
• A few examples of what’s new
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.
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

Air Entraining Agents

1 mm
Air Void Systems

Standards

AASHTO
M 154 Standard Specification

ASTM
C 260 Standard Specification
C 233 Standard Test Methods
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 throughout the concrete.
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…
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

- **ASTM C 1017 – Flowing Concrete**
  - Type I – Plasticizing
  - Type II – Plasticizing & Retarding

- AASHTO M 194 includes a requirement for 56 day strengths
- No AASHTO equivalent for C 1017
Water-Reducing Admixtures

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
.40 w/c ratio
695lbs cement
NO ADMIXTURES

.40 w/c ratio
Water Reducer
3" Slump

.40 w/c ratio
Superplasticizer
7.5" Slump
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 (NSFC/MSFC/LS)**
  - 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 (PC)**
  - 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
General Effect of PC Structure on Performance

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

High Early Strength (Long Teeth)

Increased DR and Thixotropy

Teeth Length

Backbone Length

Moderate DR and Slump Retention

Teeth Density increased slump life

Slump Retention (Dense Teeth)
### Applications of Different Polycarboxylate-based Admixtures

<table>
<thead>
<tr>
<th>Required Characteristics</th>
<th>Relative Chain Length of Backbone (trunk) Polymer</th>
<th>Relative Side Chain (graft) Length</th>
<th>Relative Number of Side Chains (grafts)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Dispersibility and Short Dispersibility Retention</td>
<td>Long</td>
<td>Short</td>
<td>Large</td>
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<tr>
<td>High Dispersibility</td>
<td>Short</td>
<td>Long</td>
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- **Ready Mix**
- **PC/PS**
- **Slump Retention**
Type A

• Used in production of slump up to 5”
• Also used in combination with HRWR
• High dosages cease to add dispersion
• Small dosages adsorbed by the cement
• Many Type A’s become Type D’s at higher dosages
• Added at batch plant
• May be specified as Type A or F
  ▪ No specific ASTM category
• Typically provides ~ 8% to 12% water reduction
• Used in production of slumps of 5” to 8”
• Used in concretes with moderate/low w/cm
• Relatively neutral set times throughout a wide range of dosage rates
• Also used in combination with HRWR at low w/cm
• Consistent set times and minimize bleeding problems
• Improve overall quality of the paste
• Creamier paste easier to finish on concrete flatwork
• Provides for strength, durability, improvements
HRWR

Provide higher reductions in the water content

Flowing Concrete – 8” to 11” slump

Control Flow Concrete – 18” to 22” flow

Self Consolidating Concrete – 22” to 30” flow
HRWR

- Provide highest reductions in the water content
  - Water reduction minimum 12%
  - Water reduction > 20% routine
  - Low to very low W/CM
  - Increased compressive strength
  - Lower permeability
  - Improved durability
Other C 494 Admixtures

- Retarding admixtures
- Accelerating admixtures
- Slump extending admixtures
- Hydration stabilizing admixtures
**Micro Fibers**

- Diameters < 0.004” (0.1 mm)
- Polypropylene, Nylon, Carbon, Cellulose
- 0.03 – 0.1% volume (0.5-1.5#/cy)
- *Mainly control plastic shrinkage cracking*

**Macro Fibers**

- Diameters: 0.008 – 0.03”
- Synthetic, Steel
- 0.2 – 1.0% volume [3 - 15#/cy (Synthetic) or 20-100#/cy (Steel)]
- Improve concrete material characteristics
  - *Flexural toughness, Impact resistance, Fatigue resistance*
Specialty Admixtures

Corrosion Inhibitors
Shrinkage Reducing Admixtures
Micro Spheres
Water Repellants
Crystalline waterproofers
Additives for Controlled Low Strength fills
Specialty Admixtures

- Metakaolin
- ASR Mitigation
- Clay Mitigation
- Viscosity Modifiers
- Pervious Concrete Admixtures
- RCC Admixtures
An admixture (SR) that could be added to a number of existing admixtures (DR) at various doses to enhance slump retention of the base admixture while maintaining other key properties.

Two component system:
Base admixture (DR) + Booster Pack (SR)
What’s New
Slump Extending Admixtures

611 lbs/yd CM – 25% Fly Ash
W/CM = 0.42
Ambient Temperature = ~75°F.
Clay Mitigation Solutions

For Clay Mitigation
• Aggregate treatment at quarry
• Formulated as concrete admixtures (MRWR & HRWR)

For Clay Mitigation & Rheology Improvement
• Formulated as concrete admixtures (MRWR & HRWR)

Methylene Blue Test Kit
• Used to determine clay content of aggregates

Easier MBV test is used to assess clay content of aggregates
Common Issues at the Aggregate Quarry

• Issues due to source of aggregate
  • Depleted stock of high quality materials
  • Must resort to lower quality
  • New quarries can involve extensive regulatory hurdles (e.g. environmental)

• Issues due to poor quality aggregate
  • Decreased yield (due to poor gradation of manufactured sands)
  • Washing / separation required (due to poor cleanliness)
  • High variability in performance for end-user
Clay Mitigation for Aggregate Producer

Results

- **Problem Statement**
  - A customer quarry is producing manufactured sand with higher Deleterious Fines Index (DFI) than permitted in national standards
  - DFI is a measure of the amount of potentially harmful fine material present such as clay and organic material

- **Solution**
  - Treat manufactured sand at the quarry with the new clay mitigating admixture

- **Direct Benefits**
  - Higher quality aggregates
  - Additional yield and productivity
  - Eliminates quarry waste
  - No maintenance

- **Indirect Benefits**
  - Admixture dosage reductions
  - Potential for OPC reduction in concrete
  - Environmental Benefit
Mitigating Clay for Ready Mix Producer

The Challenge

Clays absorb large amounts of water and admixtures

- Poor admixture response
- Poor workability retention
- Slump and air control are made difficult

DR Efficiency Improvement vs Clay Content

Concrete Sand = 0.87% Na-Meq

Concrete Mix
w/c = 0.50
Slump = 2" (50 mm)

Concrete Mix w/ CMA
w/c = 0.50
Slump = 5" (125 mm)
Mitigating Clay for Ready Mix Producer

The Performance

- Dispersion capability over a wide range of clay bearing aggregates
- Increase quality of concrete by minimizing the negative effects of clay while achieving the benefits of polycarboxylate technology
  - Decreases water demand and admixture dosage
  - Increases slump and slump retention over time
  - Increases concrete strength
  - Decreases shrinkage
- Minimize production variability
Admixtures For Control Flow Concrete

• Simple, conventional mix designs taken to new performance levels
• Consistent high flowing concrete without segregation
• Improved flow around steel reinforcement
• Rapid discharge
• Fast pumping
• Easy placement & finishing
• Minimal vibration to consolidate
• Fast construction
Admixtures for Control Flow Concrete

Enables production of high flowing conventional concrete without segregation

- Excellent rheology control
- Excellent water tolerance
- Conventional mixes
  - **Simple**, Established mixture designs
  - **Consistent** performance day in and day out
  - **Easy** to place high flow concrete requires minimal vibration
  - **Faster** construction with no QC-related delays

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**Flowability of CFC**

- Minimum Target slump
- Mix “too tight”
- 1 gal
- 2-3 gal

**With CFA:**
**Without CFA:**

The window of acceptable mix designs to maintain cohesiveness is increased

Greater Flexibility in Mix Design
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