AGENDA

Introduction:
Air Entraining Agents – AEA
Water Reducers/Dispersants
Retarders
Accelerators
Corrosion Inhibitors
Crystalline Waterproofers
Shrinkage Reducing Admixtures
ASR Control
Key Learning Objectives:

• ASTM C-494 is the specification that governs the performance of various admixture types in regards to % water reduction, compressive and flexural strength, set time, shrinkage, etc…

• ASTM C-260 is separate specification related to the performance of air entraining admixtures (AEA’s) in regards to relative durability, strength, set time, shrinkage, etc…

• Admixtures are typically dosed in liquid ounces per every 100#'s of cement or cementitious; for example many Type A Water Reducers are 3oz./cwt. ( cwt. = 100#'s of cementitious)

• An entrained air void system is extremely important for freeze/thaw durability.

• Water reduction is produced through the process of cement dispersion in the concrete mix.

• Time of set and strength gain is influenced significantly by the concrete temperature, the Rule of 20 F, in regards to cement hydration rate is either halved or doubled for every 20 F temperature change. EXAMPLE: 50 F concrete temperatures take twice as long as 70 F concrete temperatures to achieve set and gain strength.
Admixtures What Are They?

Material other than water, aggregates, hydraulic cement and fiber reinforcement used as an ingredient of concrete or mortar and added to the batch immediately before or during its mixing.

(ACI 116.R-2)
Concrete Admixtures... Why Use Them?
The 5 Functions of Concrete Admixtures

1. Can greatly extend the durability of concrete for the project owner
2. Can add aesthetic value to the designer and the owner.
3. Can reduce the cost of the concrete mix for the concrete producer.
4. Can reduce the cost to the contractor
5. Can improve concrete in the plastic state, making it more user friendly and efficient for the contractor.
Concrete Admixtures are similar to Rx Drugs for Humans

**Rx Drugs**
- Typically prescribed by a doctor or health professional
- Can be overused/abused/overdosed
- Can be underutilized
- Patient may not dose properly per prescriber guidelines
- Rx drugs can have side effects that you have to be aware of
- Rx drugs are not a cure all; they perform better with healthy lifestyle choices

**Chemical Admixtures**
- Typically prescribed by an engineer or concrete design professional
- Can be overused/abused/overdosed
- Can be underutilized
- Producer may not dose properly per prescriber guidelines
- Admixtures can have side effects, you need to be aware of... Test with your own materials
- Admixture are not a cure all, they help make well designed concrete perform better, they don’t cure bad in the field practices
What are some possible side effects of admixtures if not used properly or not tested prior to concrete production?

- Overdose of AEA, say over 8% air in concrete mix will lead to significant strength loss
- Overdose of AEA will lead to a stickier finishing concrete
- Overdose of a hydration stabilizer or a Type A water reducer could lead to retarded set time of concrete, causing delays at jobsite to finish, slow strength gain, etc.
- Overdose of a superplasticizer Type F & G water reducers could lead to segregation of the concrete mix, thus causing a rejection of the load of concrete.
- Lack of adequate mixing time can result in an insufficient air void system or lead to slump inconsistencies.
- Underdose of an concrete accelerator in cold weather could lead to set delay and prolonged concrete finishing times, slower strength gain....
Mix Design Professionals
Placing Professionals
Air Void Systems

Air Entraining Agents

1 mm
Why Use AEA’s?

• Absolutely necessary for freeze/thaw durability

• Other benefits
  ➢ improved workability
  ➢ reduced segregation and bleeding
  ➢ reduced permeability
  ➢ improved finishing with harsh sands
  ➢ Low cost way for a concrete producer to improve their yield
Specimens Subjected to 150 Cycles of Freezing and Thawing

- Non-air-entrained
- Air-entrained
• Create a system of safety relief valves to resist the destructive force of water when it turns to ice
• What is the expansion increase of freezing water?
Good entrained air void system: mostly entrained air

Poor entrained air void system: mostly entrapped air

(Both at the same magnification)
Parameters For A Good Air Void System

- **Air Content:** 5-8% for ¾” top aggregate size
- **Average Chord Length:** (distance across a bubble) 0.0065 inches
- **Specific Surface Area:** (bubble size) 600 in.² per cubic inch
- **Spacing Factor:** (distance between bubbles) < 0.008 inches
# Total Target Air Content for Concrete per ACI 318

<table>
<thead>
<tr>
<th>Nom. maximum size aggregate, (in.)</th>
<th>Air content, percent</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Severe exposure</td>
<td>Moderate exposure</td>
<td>Mild exposure</td>
<td></td>
</tr>
<tr>
<td>&lt; 3/8</td>
<td>9</td>
<td>7</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>3/8</td>
<td>7½</td>
<td>6</td>
<td>4½</td>
<td></td>
</tr>
<tr>
<td>1/2</td>
<td>7</td>
<td>5½</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>3/4</td>
<td>6</td>
<td>5</td>
<td>3½</td>
<td></td>
</tr>
<tr>
<td>1.00</td>
<td>6</td>
<td>4½</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>1.50</td>
<td>5½</td>
<td>4½</td>
<td>2½</td>
<td></td>
</tr>
<tr>
<td>2.00</td>
<td>5</td>
<td>4</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3.00</td>
<td>4½</td>
<td>3½</td>
<td>1½</td>
<td></td>
</tr>
</tbody>
</table>
• Entrained air is produced by a mixing action…the turning and mixing action of the drum. Not chemical or foam, but the AEA helps stabilize and retain micro size bubbles

• One Cubic Yard of Concrete contains: ~ 600 billion air bubbles
Challenges of managing an air void system

- Achieving the proper amount of air content
- Lower compressive and flexural strength if air content too high
- Lower abrasion resistance if air content too high
- High air content can make mixes feel sticky to finish
- Reduced and delayed bleeding effect, can cause finishing issues
- Testing inaccuracies of measuring air content in the field
Challenges

Loss of Compressive Strength

Compressive Strength & Air Content

28 Day Compressive Strength in PSI

Total Air Content %
A Few Factors That Can Affect Air Void Systems and Air Content

- Slump
- Other materials in the mixture
- Change in the other materials
- Temperature
- Mixing action
- Elapsed time from batching
- Transport and delivery
- Re-tempering
- Consolidation
- Finishing (surface effect)

Contractor Control
Quality Control Steps for minimizing air content variability from the concrete constituents

- Check for variations in fly ash LOI changes (Verify with Foam Index Test over time)
- Was there a change in cement brand or type?
- Examine coarse aggregate for excess fines or coatings
- Monitor fine aggregate gradation (Changes in the #16, #30 and #50 sieve can affect the air content, along with particle shape)
Quality Control steps for minimizing air content variability in the field

- Maximize allowed water content at the batch plant
- Avoid field retempering of slump with water
- Consider use of Slump Extending Admixture or Hydration Stabilizer Admixture to help retain slump in transit
- Use Hydration Stabilizers in hot weather and in long haul time situations
- Calibrate your air pressure meters
- **Always** run a unit weight test along with an air pressure meter... for normal weight concrete 6% air content ~ 142.00 lbs. per cubic ft.
Quality Control steps for minimizing air Variability At The Batch Plant

• Ensure AEA is **not** coming in contact with other admixtures at the point of discharge
• Ensure AEA is going in early in the batch process
• Consider AEA discharge point with water or on sand? (avoid AEA coming in direct contact with hot water)
• **Check mixing time and truck mixing efficiency** (condition of fins or built up hardened concrete on mixing fins)
• **Calibrate AEA dispenser** (usually AEA is a very low dose product, just a few fluid ozs.per cubic yard)
Testing:
Early and Often
In Summary of Controlling Air Void Systems

• Air Management is a complex process; with many variables that can affect the desired outcome.
• Run trial batches of 3 yards or more in truck…. Many times lab size batches do not correlate to the field
• Dosages may have to be adjusted fairly often… that is O.K.
• Testing must be done in the field on a consistent basis, … every xx yards
ASTM C-494

- 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 – Special Performance
Water Reducing Admixtures

- Type A
- Type F
- Type G
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…

ACI 116.R-2
Water-Reducing Admixtures
Why Use Them?

• Reduce mixing water required to produce a certain slump
• Reduce water-cement ratio
• Provide ability to reduce cement content, but able to maintain needed strength and durability performance
• Increase slump for more needed workability
# Water Reducers Types and Properties

<table>
<thead>
<tr>
<th>Products</th>
<th>Water Reduction</th>
<th>Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard Type A</td>
<td>5 - 10%</td>
<td>~ 10%</td>
</tr>
<tr>
<td>Mid-Range, Type A &amp; F</td>
<td>8 - 15%</td>
<td>~ 15%+</td>
</tr>
<tr>
<td>High-Range Type F &amp; G</td>
<td>10 - 20%</td>
<td>~ 15%+</td>
</tr>
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</table>
Raw Materials for Water Reducers/Dispersants

- Lignins – Byproducts of wood pulp processing
- Corn Syrup
- Sodium Gluconate
- Naphthalene Sulfonates
- Melamine Sulfonates
- T.E.A. – Tri Ethyl Alimenes
- Polycarboxlates
- Calcium Nitrates
- Calcium Nitrites
How Water Reducers / Dispersants Work

Flocculation – cement particles naturally attracted to each other electrostatically

Combined with loss of fluidity and workability, due to hydration reaction beginning.
How Water Reducers / Dispersants Work

Dispersant Molecules

Cement Dispersion by Electrostatic Repulsion, like magnets: opposite charges attract and like charges cause repulsion

Surface Adsorption = Surface Adhesion
Polycarboxylate Superplasticizers
Steric Repulsion
## RESULTS OF USE OF WATER REDUCERS

<table>
<thead>
<tr>
<th>Product Type</th>
<th>Class</th>
<th>Water Reduction</th>
<th>Typical Dosage</th>
<th>Strength Gain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Reducer</td>
<td>Low</td>
<td>4-7%</td>
<td>2-4 oz/cwt</td>
<td>~ 10%</td>
</tr>
<tr>
<td>Mid-Range</td>
<td>Mid</td>
<td>5-12%</td>
<td>6-12 oz/cwt</td>
<td>~ 15%+</td>
</tr>
<tr>
<td>HRWR (NSFC)</td>
<td>High</td>
<td>12-25%</td>
<td>10-18 oz/cwt</td>
<td>~ 20%+</td>
</tr>
<tr>
<td>HRWR (PC)</td>
<td>High</td>
<td>12-35%</td>
<td>3-8 oz/cwt</td>
<td>~ 20%+</td>
</tr>
</tbody>
</table>
An admixture, that typically that extends the slump life of a high range water reducer while maintaining other key properties

Two component system:

Base admixture (DR) + Booster Pack (SEA)
• Hydration- The chemical reaction that takes place between cement and water to turn to a solid and make concrete
• The temperature at which hydration occurs directly influences the rate of setting and strength gain
• Rule of 20- Chemical reaction time doubles or halves, for every 20F change in temperature
Set Retarding Admixtures

ASTM C 494
Type B
Type D
Set Retarding Admixtures

- Hot Weather Can:
  - Increase Water Demand
  - Decrease Set Times
  - Increase and Hasten Water Evaporation
  - Increase Potential for Plastic Shrinkage
  - Accelerate Slump Loss
Set Retarding Admixtures

- Allows concrete to be placed under hot conditions
- Large placements can be designed to set uniformly
- Alleviate interruptions in transport times
- Can be used to slow down set of high cement content mixtures
- Generally also help to reduce water
Set Retarding Admixtures

Hydration Stabilizers

- ASTM Type D
- Non-lignin technology
- Dosage depends on performance
- Overdoses can be very painful
Set Retarding Admixtures

Hydration Stabilizers

- Hydration Stabilizer - Extended Set Retarder
- 3 hour to >30 hour set extension
- Retardation is nearly linear

Graph:

- Equation: $REC = 86.051x + 368.14$
- $R^2 = 0.9975$

Ambient Temp 72° to 76°
• Caution:
  ➢ Longer set times provide more opportunity for moisture loss of concrete in the plastic state;
  ➢ Higher potential for plastic shrinkage cracking in flatwork, like slabs, sidewalks or paving;
  ➢ Increased need for protection against moisture loss… thus proper use of surface evaporation reducers
Time of Set with Hydration Stabilizer with 70F & 90F Concrete Temperatures

Initial time of set 70 and 90 Degrees
Hydration Stabilizer Dosage Rate oz/cwt

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Accelerating Admixtures

ASTM C 494
Type C
Type E
Accelerating Admixtures

• Some common names:
  - Calcium, CC, High Early… Generally these are calcium chloride based
  - Non-Chloride, NCA… These are non calcium chloride accelerators

• Allows concrete to be “used” faster
  - Finished Faster
  - Gain Strength Faster
  - Strip Forms Faster
  - Rapid Patching Mixes
  - Place Concrete in colder weather
Definition of Cold Weather Concreting Per ACI-306

- More than 3 consecutive days of the following:
  - Average daily air temperature is less than 40 F
  - Stays below 50 F for more than ½ of any consecutive 24 hour period
Accelerating Admixtures

Speed up both initial and final time of set

Important for finishing
The Rule of 20 for chemical reactions

Speed up strength development

• Important for form removal
• Fresh concrete needs to achieve min. 500 psi compressive strength to withstand 1 F/T cycle, 3500 psi to withstand multiple F/T cycles
Time of Set with Non-Chloride Accelerator at 50°F and 70°F

Initial Set Time at 50°F and 70°F

Dosage Rate of NCA oz/cwt

50°F Concrete Temp

70°F Concrete Temp
Accelerating Admixtures

Standard Concrete Set Times

<table>
<thead>
<tr>
<th>Temperature</th>
<th>4hrs</th>
<th>6hrs</th>
<th>8hrs</th>
<th>10hrs</th>
<th>12hrs</th>
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</thead>
<tbody>
<tr>
<td>40°F, 4°C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>⬤</td>
</tr>
<tr>
<td>50°F, 10°C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>⬤</td>
</tr>
<tr>
<td>60°F, 16°C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>70°F, 21°C</td>
<td></td>
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</tr>
</tbody>
</table>

- **12hrs**
- **10hrs**
- **8hrs**
- **6hrs**
- **4hrs**
Accelerating Admixtures

The graph illustrates the compressive strength (in PSI) of concrete over different ages in days. The compressive strength is measured on the y-axis, ranging from 0 to 7000 PSI. The age in days is on the x-axis, with values at 1, 7, 28, and 90 days.

Different admixtures are indicated by different colors and types of bars:
- Ref. (Referee) is represented by blue bars.
- A admixture is represented by light blue bars.
- B admixture is represented by dark green bars.

The graph shows a comparison of the compressive strength over time for all three admixtures, with B admixture generally showing the highest strength at all ages.
Specialty Admixtures

Type C - Corrosion Inhibitors…
  Calcium Nitrite
Type S - Shrinkage Reducing
  Admixtures -
Type S - Viscosity Modifiers – VMA’s
Type S – ASR Reducing… Lithium
  Nitrate