Admixtures in Concrete

Admixtures

- A material other than water, aggregates, and hydraulic cements used as an ingredient of concrete or mortar and added to the batch immediately before or during mixing.

- Reason:
  - Improve or modify some or several properties of portland cement concrete.
  - Compensate for some deficiencies.
### A. Chemical Admixtures

- **Type A**: Water-reducing (WR)
- **Type B**: Set retarding (SR)
- **Type C**: Set accelerating (SA)
- **Type D**: WR + SR
- **Type E**: WR + SA
- **Type F**: High-range water-reducing (HRWR)
- **Type G**: HRWR + SR

### B. Mineral Admixtures

- **Class N**: Raw or calcined pozzolans
- **Class F**: Fly ash produced from burning bituminous coal
- **Class C**: Fly ash normally produced from burning lignite (subbituminous) coal. (both pozzolanic and cementitious)
1) Admixtures for Durability

- **Frost action**: Air-entraining agents
- **Sulfate and acidic solutions**: Pozzolans, polymer emulsions
- **Alkali-aggregate expansion**: Pozzolans
- **Thermal Strains**: Pozzolans

2) Admixtures for Increasing Strength

- **Water reducing agents**
- **Pozzolans**

To reduce the water content while maintaining a given consistency

- **Consistency**: Flowability, slump
- **Workability**: High cohesiveness and high consistency
  
  (Advantage of fine particle size cohesiveness)
Chemical Admixtures

Surfactants (Surface-Active Chemicals/Agents)

Air-entraining surfactants:

At the air-water interface the polar groups are oriented towards the water phase lowering the surface tension, promoting bubble formation and counteracting the tendency for the dispersed bubbles to coalesce.

At the solid-water interface where directive forces exist at the cement surface, the polar groups become bound to the solid with the non-polar groups oriented towards the water, making the cement surface hydrophilic so that air can displace water and remain attached to the solid particles as bubbles.
Air-Entrained Concrete

Mechanism of Frost damage in concrete

- Only concrete that is above the critical saturation is vulnerable to frost damage.
- Critical saturation occurs when more than 91.7% of pores in concrete is filled with water.
- Water Expands 9% on freezing.
Mechanism of Frost damage in concrete

- If 91.7% of the pores in concrete are filled with water prior to freezing, then all of the pores will be completely filled upon freezing.
- Water is forced ahead of the advancing freezing front.
- Internal hydrostatic pressure can disrupt the concrete.

Freeze-Thaw Deterioration
Mechanism of Protection by AE

Air-entrained concrete

Entrained Air Bubbles
10 to 100 microns
Saturation > 91.7%

Air bubbles provide space for water as freezing advances, relieving hydrostatic pressure in concrete
Mechanism of Protection by AE

Air bubbles provide space for water as freezing advances, relieving hydrostatic pressure in concrete.

As thawing occurs, water recedes from the air bubbles leaving them empty to accommodate the next freeze cycle.

Entrained Air Bubbles
10 to 100 microns

Saturation > 91.7%

Air Content Specifications

- ACI 318 – Building Code
- ASTM C 94 – Specs for Ready-Mixed Concrete

Specified Air Contents (tolerance ± 1.5 %)

<table>
<thead>
<tr>
<th>Exposure</th>
<th>Nominal Maximum Aggregate Size</th>
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<tbody>
<tr>
<td></td>
<td>9.5 mm</td>
</tr>
<tr>
<td></td>
<td>3/8 in.</td>
</tr>
<tr>
<td>Mild</td>
<td>4.5</td>
</tr>
<tr>
<td>Moderate</td>
<td>6.0</td>
</tr>
<tr>
<td>Severe</td>
<td>7.5</td>
</tr>
</tbody>
</table>

Notes: ACI 318 only specifies air for “Moderate” and “Severe” exposure.
ACI 318 allows air content to be reduced by 1% if concrete strength > 5000 psi (35 MPa)
Chemical Admixtures

**Surfactants** (Surface-Active Chemicals/Agents)

**Water-Reducing surfactants:**

When water is added to cement, a well-dispersed system is not achieved, because:

- The water has high surface tension.
- Cement particles tend to cluster together or form flocs.

When a surfactant with a hydrophilic chain is added to the cement-water system, the polar chain is adsorbed alongside the cement particle, and thus lowering the surface tension of the water, and making the cement surface hydrophilic.

**Surfactants**

**Water-Reducing surfactants:**
Mineral Admixtures

**Definition:** Mineral Admixtures are insoluble siliceous materials, used at relatively large amounts (15-20% by weight of cement).

- Fine particle size, siliceous material that can slowly react with CH at normal temperatures, to form cementitious products.

\[
\text{CH} + S \xrightarrow{\text{Aq Normal Temp.}} \text{C-S-H}
\]

- Low heat of hydration
- Transform large pores to fine pores
- Historically, mineral admixtures are volcanic ashes.
- Significance: Durability to thermal cracking, chemical attack, sulfate attack, workability.
By-Product Mineral Admixtures

- **Fly Ash (FA)** → 1-40 μm Particle Size; Surface Area=0.5 m²/g
- **Blast Furnace Slag (BFS)** → 1-40 μm; SA=0.5 m²/g
- **Condensed Silica Fume (SF)** → 0.1 μm; SA=20 m²/g
- **Rice Husk Ash (RHA)** → 10-20 μm; SA=60 m²/g

Internal bleeding is reduced ⇒ Reduced Microcracking

**Effect of Pozzolans:**
- It will reduce the available space for formation of large crystals
- Pozzolans will convert CH into C-S-H
Consistency of concrete is generally measured by the slump test (ASTM C143). This test is performed by measuring the slump (subsidence), in inches, of concrete after removal of the truncated cone mold in which the freshly mixed concrete was placed. Details of the test procedure and the dimensions of the cone and tamping rod are given in ASTM C143, and summarized in this figure: