Admixtures

Fig. 6-1. Liquid admixtures, from left to right: antiwashout admixture, shrinkage reducer, water reducer, foaming agent, corrosion inhibitor, and air-entraining admixture. (69795)
Admixtures are those ingredients in concrete other than Portland cement, water, and aggregates that are added to the mixture immediately before or during mixing (Fig. 6-1). Admixtures can be classified by function as follows:
1. Air-entraining admixtures
2. Water-reducing admixtures
3. Plasticizers
4. Accelerating admixtures
5. Retarding admixtures
6. Hydration-control admixtures
7. Corrosion inhibitors
8. Shrinkage reducers
9. Alkali-silica reactivity inhibitors
10. Colouring admixtures
11. Miscellaneous admixtures such workability, bonding, damp proofing, permeability reducing, grouting, gas-forming, and pumping admixtures
<table>
<thead>
<tr>
<th>Type of admixture</th>
<th>Desired effect</th>
<th>Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accelerators (ASTM C 494 and AASHTO M 194, Type C)</td>
<td>Accelerate setting and early-strength development</td>
<td>Calcium chloride (ASTM D 98 and AASHTO M 144), Triethanolamine, sodium thiocyanate, calcium formate, calcium nitrite, calcium nitrate</td>
</tr>
<tr>
<td>Air detainers</td>
<td>Decrease air content</td>
<td>Tributyl phosphate, dibutyl phthalate, octyl alcohol, water-insoluble esters of carbonic and boric acid, silicones</td>
</tr>
<tr>
<td>Air-entraining admixtures (ASTM C 260 and AASHTO M 154)</td>
<td>Improve durability in freeze-thaw, deicers, sulfate, and alkali-reactive environments</td>
<td>Salts of wood resins (Visol resin), some synthetic detergents, salts of sulfonated lignin, salts of petroleum acids, salts of proteinaceous material, fatty and resinous acids and their salts, alkybenzene sulfonates, salts of sulfonated hydrocarbons</td>
</tr>
<tr>
<td>Alkali-aggregate reactivity inhibitors</td>
<td>Reduce alkali-aggregate reactivity expansion</td>
<td>Barium salts, lithium nitrate, lithium carbonate, lithium hydroxide</td>
</tr>
<tr>
<td>Antiwashout admixtures</td>
<td>Cohesive concrete for underwater placements</td>
<td>Cellulose, acrylic polymer</td>
</tr>
<tr>
<td>Bonding admixtures</td>
<td>Increase bond strength</td>
<td>Polyvinyl chloride, polyvinyl acetate, acrylcs, butadiene-styrene copolymers</td>
</tr>
<tr>
<td>Coloring admixtures (ASTM C 979)</td>
<td>Colored concrete</td>
<td>Modified carbon black, iron oxide, phthalocyanine, umber, chromium oxide, titanium oxide, cobalt blue</td>
</tr>
<tr>
<td>Corrosion inhibitors</td>
<td>Reduce steel corrosion activity in a chloride-laden environment</td>
<td>Calcium nitrite, sodium nitrite, sodium benzoate, certain phosphates or fluosilicates, fluoaluminates, ester amines</td>
</tr>
<tr>
<td>Dampproofing admixtures</td>
<td>Retard moisture penetration into dry concrete</td>
<td>Soaps of calcium or ammonium stearate or oleate, Butyl stearate, Petroleum products</td>
</tr>
<tr>
<td>Foaming agents</td>
<td>Produce lightweight, foamed concrete with low density</td>
<td>Catonionic and anionic surfactants, Hydrolized protein</td>
</tr>
<tr>
<td>Fungicides, germicides, and insecticides</td>
<td>Inhibit or control bacterial and fungal growth</td>
<td>Polyhalogenated phenols, Dieldrin emulsions, Copper compounds</td>
</tr>
<tr>
<td>Gas formers</td>
<td>Cause expansion before setting</td>
<td>Aluminum powder</td>
</tr>
<tr>
<td>Grouting admixtures</td>
<td>Adjust grout properties for specific applications</td>
<td>See Air-entraining admixtures, Accelerators, Retarders, and Water reducers</td>
</tr>
<tr>
<td>Hydration control admixtures</td>
<td>Suspend and reactivate cement hydration with stabilizer and activator</td>
<td>Carboxylic acids, Phosphorus-containing organic acid salts</td>
</tr>
<tr>
<td>Permeability reducers</td>
<td>Decrease permeability</td>
<td>Latex, Calcium stearate</td>
</tr>
<tr>
<td>Pumping aids</td>
<td>Improve pumpability</td>
<td>Organic and synthetic polymers, Organic flocculents, Organic emulsions of paraffin, coal tar, asphalt, acrylics, Bentonite and pyrogenic silicas, Hydrated lime (ASTM C 141)</td>
</tr>
<tr>
<td>Retarders (ASTM C 494 and AASHTO M 194, Type B)</td>
<td>Retard setting time</td>
<td>Lignin, Borax, Sugars, Tartaric acid and salts</td>
</tr>
<tr>
<td>Shrinkage reducers</td>
<td>Reduce drying shrinkage</td>
<td>Polyoxyalkylene alkyl ether, Propylene glycol</td>
</tr>
<tr>
<td>Superplasticizers* (ASTM C 1017, Type 1)</td>
<td>Increase flowability of concrete</td>
<td>Sulfonated melamine formaldehyde condensates, Sulfonated naphthalene formaldehyde condensates, Lignosulfonates, Polycarboxylates</td>
</tr>
<tr>
<td>Type of admixture</td>
<td>Desired effect</td>
<td>Material</td>
</tr>
<tr>
<td>------------------------------------------</td>
<td>-----------------------------------------------------</td>
<td>--------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Superplasticizer* and retarder (ASTM C 1017, Type 2)</td>
<td>Increase flowability with retarded set Reduce water–cement ratio</td>
<td>See superplasticizers and also water reducers</td>
</tr>
<tr>
<td>Water reducer (ASTM C 494 and AASHTO M 194, Type A)</td>
<td>Reduce water content at least 5%</td>
<td>Lignosulfonates Hydroxylated carboxylic acids Carbohydrates (Also tend to retard set so accelerator is often added)</td>
</tr>
<tr>
<td>Water reducer and accelerator (ASTM C 494 and AASHTO M 194, Type E)</td>
<td>Reduce water content (minimum 5%) and accelerate set</td>
<td>See water reducer, Type A (accelerator is added)</td>
</tr>
<tr>
<td>Water reducer and retarder (ASTM C 494 and AASHTO M 194, Type D)</td>
<td>Reduce water content (minimum 5%) and retard set</td>
<td>See water reducer, Type A (retarder is added)</td>
</tr>
<tr>
<td>Water reducer—high range (ASTM C 494 and AASHTO M 194, Type F)</td>
<td>Reduce water content (minimum 12%)</td>
<td>See superplasticizers</td>
</tr>
<tr>
<td>Water reducer—high range—and retarder (ASTM C 494 and AASHTO M 194, Type G)</td>
<td>Reduce water content (minimum 12%) and retard set</td>
<td>See superplasticizers and also water reducers</td>
</tr>
<tr>
<td>Water reducer—mid range</td>
<td>Reduce water content (between 6 and 12%) without retarding</td>
<td>Lignosulfonates Polycarboxylates</td>
</tr>
</tbody>
</table>

* Superplasticizers are also referred to as high-range water reducers or plasticizers. These admixtures often meet both ASTM C 494 (AASHTO M 194) and ASTM C 1017 specifications.
The major reasons for using admixtures are:

1. To reduce the cost of concrete construction
2. To achieve certain properties in concrete more effectively than by other means
3. To maintain the quality of concrete during the stages of mixing, transporting, placing, and curing in adverse weather conditions
4. To overcome certain emergencies during concreting operations
Air-Entraining Admixtures

- used to purposely introduce and stabilize microscopic air bubbles in concrete. Air-entrainment will dramatically improve the durability of concrete exposed to cycles of freezing and thawing (Fig. 6-2). Entrained air greatly improves concrete's resistance to surface scaling caused by chemical de-icers
Frost damage at joints of a pavement
Frost induced cracking near joints
Scaled concrete surface resulting from lack of air entrainment, use of deicers, and poor finishing and curing practices.
The primary ingredients used in air-entraining admixtures are salts of wood resin (Vinsol resin), synthetic detergents, salts of petroleum acids, etc.

See Table 6-1 p.106 in the text for more details.
Water-Reducing Admixtures

• used to reduce the quantity of mixing water required to produce concrete of a certain slump, reduce water-cementing materials ratio, reduce cement content, or increase slump.

• Typical water reducers reduce the water content by approximately 5% to 10%.
Water-Reducing Admixtures

• Materials:
  – Lignosulfonates.
  – Carbohydrates.
  – Hydroxylated carboxylic acids.
Fig. 6-4. Slump loss at 23°C in mixtures containing conventional water reducers (ASTM C 494, Type D) compared with a control mixture (Whiting and Dziedzic 1992).
Water-Reducing Admixtures

• The effectiveness of water reducers on concrete is a function of their chemical composition, concrete temperature, cement composition and fineness, cement content, and the presence of other admixtures.
Superplasticizers (High-Range Water Reducers)

- These admixtures are added to concrete with a low-to-normal slump and water-cementing materials ratio to make high-slump flowing concrete.

- Flowing concrete is a highly fluid but workable concrete that can be placed with little or no vibration or compaction while still remaining essentially free of excessive bleeding or segregation.
Superplasticizers (High-Range Water Reducers)

• Applications where flowing concrete is used:
  1. thin-section placements,
  2. areas of closely spaced and congested reinforcing steel,
  3. pumped concrete to reduce pump pressure, thereby increasing lift and distance capacity,
  4. areas where conventional consolidation methods are impractical or can not be used, and
  5. for reducing handling costs.
Flowable concrete with high slump
Is easily placed
Even in areas of heavy reinforcing steel congestion
• Low water to cement ratio concrete with low chloride permeability---easily made with high-range water reducers— is ideal for bridge decks
• Plasticized, flowing concrete is easily placed in thin sections
Superplasticizers (High-Range Water Reducers)

- Typical superplasticizers include:
  - Sulfonated melamine formaldehyde condensates.
  - Sulfonated naphthalene formaldehyde condensate.
  - Lignosulfonates.
  - Polycarboxylates.
Superplasticizers (High-Range Water Reducers)

- bleed significantly less than control concretes of equally high slump and higher water content.
- High-slump, low-water-content, plasticized concrete has less drying shrinkage than a high-slump, high-water-content conventional concrete.
- has similar or higher drying shrinkage than conventional low-slump, low-water-content concrete.
- The effectiveness of the plasticizer is increased with an increasing amount of cement and fines in the concrete.
Retarding Admixtures

- used to retard the rate of setting of concrete at high temperatures of fresh concrete (30°C or more).
- One of the most practical methods of counteracting this effect is to reduce the temperature of the concrete by cooling the mixing water or the aggregates.
- Retarders do not decrease the initial temperature of concrete.
- The bleeding rate and capacity of plastic concrete is increased with retarders.
Retarding Admixtures

• The typical materials used as retarders are:
  – Lignin,
  – Borax,
  – Sugars,
  – Tartaric acid and salts.
Fig. 6-15. Slump loss at various temperatures for conventional concretes prepared with and without set-retarding admixture (Whiting and Dziedzic 1992).
Retarding Admixtures

- Retarders are used to:
  1. offset the accelerating effect of hot weather on the setting of concrete,
  2. delay the initial set of concrete when difficult or unusual conditions of placement occur,
  3. delay the set for special finishing processes such as an exposed aggregate surface.
Retarding Admixtures

- some reduction in strength at early ages (one to three days) accompanies the use of retarders.
- The effects of these materials on the other properties of concrete, such as shrinkage, may not be predictable.

Therefore, acceptance tests of retarders should be made with actual job materials under anticipated job conditions.
Accelerating Admixtures

- used to accelerate strength development of concrete at an early age.
- Typical Materials are:
  - Calcium chloride: most commonly used for plain concrete.
  - Triethanolamine.
  - Calcium formate.
  - Calcium nitrate.
  - Calcium nitrite.
Fig. 6-16. The damage to this concrete parking structure resulted from chloride-induced corrosion of steel reinforcement. (50051)
Corrosion Inhibitors

• The chlorides can cause corrosion of steel reinforcement in concrete.
• Ferrous oxide and ferric oxide form on the surface of reinforcing steel in concrete.
• Ferrous oxide reacts with chlorides to form complexes that move away from the steel to form rust. The chloride ions continue to attack the steel until the passivating oxide layer is destroyed.
Corrosion Inhibitors

- Corrosion-inhibiting admixtures chemically arrest the corrosion reaction.
- Commercially available corrosion inhibitors include:
  - calcium nitrite,
  - sodium nitrite,
  - dimethyl ethanolamine,
  - amines,
  - phosphates,
  - ester amines.
Shrinkage-Reducing Admixtures

- Shrinkage cracks, such as shown on this bridge deck, can be reduced with the use of good concreting practices and shrinkage reducing admixtures.
Chemical Admixtures to reduce Alkali-aggregate Reactivity (ASR Inhibitors)

- Expansion of specimens made with lithium carbonate admixture
Coloring admixtures (Pigments)

- Red and blue pigments were used to color this floor.