Report on Chemical Admixtures for Concrete

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This report reviews several categories and types of chemical admixtures and their use in unique concrete technologies. They are classified into 12 groups: air-entraining; normal, mid- and high-range water-reducing; accelerating; set-retarding; extended set-control; workability-retaining; viscosity- and rheology-modifying, shrinkage-reducing and shrinkage-compensating, and corrosion-inhibiting; lithium admixtures to reduce deleterious alkali-silica reaction; permeability-reducing; and miscellaneous.

Chemical admixtures are used on a daily basis in the cast-in-place and precast concrete industries. Mixture designs using multiple chemical admixtures are more common today. Their successful use requires compatibility, setting times, and early strengths that are appropriate to the placing environment.

Each category of admixture addresses common use and the potential benefits of a properly proportioned concrete mixture to various professionals, including the concrete contractor, concrete producer, and design professional. The sustainability of chemical admixtures and their role in sustainable construction is addressed.

Keywords: accelerating; admixture(s); admixture system; air-entraining; alkali-aggregate reaction; batching order; cold weather concrete; corrosion-inhibiting; extended set control; flowing concrete; high-range water-reducing admixture; mid-range water-reducing admixture; permeability-reducing admixtures; pervious concrete; self-consolidating concrete; set-retarding; rheology-modifying; shrinkage-reducing; water-reducing; viscosity-modifying; workability-retaining.
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CHAPTER 1—INTRODUCTION
1.1—Introduction
Chemical admixtures are primarily water-soluble substances used to modify the properties of concrete, mortar, or grout in the plastic state, hardened state, or both. The effects include increased compressive and flexural strength at all ages, decreased permeability and improved durability, corrosion reduction, shrinkage reduction, initial set adjustments, extended set control, increased slump and workability, improved pumpability, finish and finishability, rheology modification, improved cement efficiency, alkali-silica reaction (ASR) reduction, and concrete mixture economy.

An admixture or combination of admixtures may be required to achieve the specific desired results. Proper mixture proportions, however, are required for optimum benefits. In some cases, a desired objective is best achieved by mixture changes in addition to proper admixture usage. Chemical admixtures are not a substitute for suitable concrete mixture proportions and acceptable construction practices.

1.2—Scope
This report deals with state-of-the-art and commonly used admixtures. Materials such as supplementary cementitious materials that are used to produce concrete are only referred to in regards to their interaction with chemical admixtures.

Chapters 1 through 4 address topics that typically apply to all admixtures, Chapters 5 through 16 categorize chemical admixtures generically or with respect to their performance characteristics, and Chapters 17 through 21 provide information on the use of multiple combinations of admixtures in the production of some unique concretes. Information characterizing each category is presented with brief statements of the general purposes and expected effects for each group of materials. The wide scope of admixture technology, the continued entrance of new or modified materials, and the variations of effects with different concreting materials and conditions preclude a complete listing of all admixtures and their effects on concrete. Table 1.2 lists the admixture types addressed in this document and summarizes their effects and benefits in concrete, and typical materials used in their manufacture.
<table>
<thead>
<tr>
<th>Admixture type (Chapter number)</th>
<th>Effects and benefits</th>
<th>Materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>(6) Mid-range water-reducing (ASTM C494/C494M, Type A)</td>
<td>Reduce water content by between 5 and 10 percent without retardation of initial set.</td>
<td>Lignosulfonic acids and their salts. Polycarboxylates.</td>
</tr>
<tr>
<td>(6) High-range water-reducing (ASTM C494/C494M; AASHTO M 194/M 194, Type F or G)</td>
<td>Reduce water content by at least 12 to 40 percent, increase slump, decrease placing time, increase flowability of concrete; used in self-consolidating concrete (SCC).</td>
<td>Melamine sulfonate polycondensation products, naphthalene sulfonate polycondensation products, and polycarboxylates.</td>
</tr>
<tr>
<td>(7) Accelerating (ASTM C494/C494M; AASHTO M 194/M 194, Type C or E)</td>
<td>Accelerate setting and early strength development.</td>
<td>Calcium chloride (ASTM D98; AASHTO M 144), triethanolamine, sodium thiocyanate, sodium/calcium formate, sodium/calcium nitrite, calcium nitrate, aluminates, and silicates.</td>
</tr>
<tr>
<td>(8) Set-retarding (ASTM C494/C494M and AASHTO M 194/M 194, Type D)</td>
<td>Reduce water content at least 5 percent. Delay set time.</td>
<td>Refer to water-reducing materials.</td>
</tr>
<tr>
<td>(9) Extended set-controlling (hydration control) (ASTM C494/C494M, Type B or D)</td>
<td>Used to stop or severely retard the cement hydration process. Often used in wash water and in returned concrete for reuse, and can provide medium- to long-term set retardation for long hauls. Retain slump life in a more consistent manner than normal retarding admixtures.</td>
<td>Carboxylic acids. Phosphorus-containing organic acid salts.</td>
</tr>
<tr>
<td>(10) Workability retaining</td>
<td>Provide workability (slump) retention when used in combination with normal-, mid-, or high-range water reducer with no effect on initial slump, set time, or strength gain.</td>
<td>Dispersants such as polycarboxylates.</td>
</tr>
<tr>
<td>(11) Viscosity- and rheology-modifying</td>
<td>Modify the rheological properties of plastic concrete.</td>
<td>Polyethylene oxides, cellulose ethers (HEC and HPMC), amines (from seaweed), natural and synthetic gums, and polycrylamides or polyvinyl alcohol.</td>
</tr>
<tr>
<td>(12) Shrinkage-reducing and shrinkage-compensating</td>
<td>Reduce drying shrinkage. Reductions of 30 to 50 percent can be achieved.</td>
<td>Polyoxyalkylene alkyl ether, propylene glycol, calcium sulfosalaluminate, calcium-aluminate, calcium hydroxide- or magnesium oxide-based systems.</td>
</tr>
<tr>
<td>(13) Corrosion-inhibiting (ASTM C1582/C1582M)</td>
<td>Significantly reduce the rate of steel corrosion and extend the time for onset of corrosion.</td>
<td>Amine carboxylates aminooester organic emulsion, calcium nitrite, and organic alkylcarboxylic.</td>
</tr>
<tr>
<td>(14) Lithium admixtures to reduce deleterious expansions from alkali-silica reaction</td>
<td>Minimize deleterious expansions from alkali-silica reaction.</td>
<td>Lithium nitrate, lithium carbonate, lithium hydroxide, and lithium nitrite.</td>
</tr>
<tr>
<td>(15a) Permeability-reducing admixture: non-hydrostatic conditions (PRAH)</td>
<td>Water-repellent surface, reduced water absorption.</td>
<td>Long-chain fatty acid derivatives (stearic, oleic, caprylic, capric), soaps and oils (tallow, soya-based), petroleum derivatives (mineral oil, paraffin, bitumen emulsions), and fine particle fillers (silicates, bentonite, talc).</td>
</tr>
<tr>
<td>(15b) Permeability-reducing admixture: hydrostatic conditions (PRAH)</td>
<td>Reduced permeability, increased resistance to water penetration under pressure.</td>
<td>Crystalline hydrophilic polymers (latex, water-soluble, or liquid polymer).</td>
</tr>
<tr>
<td>(16a) Bonding</td>
<td>Increase bond strength.</td>
<td>Polyvinyl chloride, polyvinyl acetate, acrylics, and butadiene-styrene copolymers.</td>
</tr>
<tr>
<td>(16b) Coloring</td>
<td>Colored concrete.</td>
<td>Carbon black, iron oxide, phthalocyanine, raw burnt umber, chromium oxide, and titanium dioxide.</td>
</tr>
<tr>
<td>(16c) Flocculating</td>
<td>Increase interparticle attraction to allow paste to behave as one large flock.</td>
<td>Vinyl acetate-maleic anhydride copolymer.</td>
</tr>
<tr>
<td>(16d) Fungicidal, cemicidal, insecticidal</td>
<td>Inhibit or control bacterial, fungal, and insecticidal growth.</td>
<td>Polyhalogenated phenols, emulsion, and copper compounds.</td>
</tr>
<tr>
<td>(16f) Expansive/gas forming</td>
<td>Control settlement and bleeding and improve the intrusion of grout and mortars.</td>
<td>Metallic aluminum, zinc or magnesium, hydrogen peroxide, nitrogen and ammonium compounds, and certain forms of activated carbon or fluidized coke.</td>
</tr>
<tr>
<td>(16g) Cellular</td>
<td>Air-generating admixtures for the production of flowable fill, lightweight concrete, insulation.</td>
<td>Protein and other synthetic surfactants.</td>
</tr>
<tr>
<td>(16h) Shotcrete</td>
<td>Shotcrete accelerators for wet and dry mixture applications.</td>
<td>Alkali-based and alkali-free materials.</td>
</tr>
<tr>
<td>(16i) MCP</td>
<td>Production efficiency, surface texture and strength.</td>
<td>Plasticizers such as soaps, surfactants, lubricants, and cement dispersants, accelerators both calcium chloride and non-chloride based, and water-repellent/efflorescence control admixtures such as calcium/aluminum stearates, fatty acids, silicone emulsions, and wax emulsions.</td>
</tr>
</tbody>
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