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. Finely divided mineral admixtures, such as fly ash or raw and processed natural pozzolans, are addressed in ACI 232.2R and ACI 232.1R, respectively.

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 1.2—Admixtures, their characteristics, and usage

Admixture type (Chapter number)	Effects and benefits	Materials
(5) Air-entraining (ASTM C260/C260M; AASHTO M 154M/M 154)	Improve durability in freezing and thawing, deicer, sulfate, and alkali-reactive environments. Improve workability.	Salts of wood resins, some synthetic detergents, salts of sulfonated lignin, salts of petroleum acids, salts of proteinaceous material, fatty and resinous acids and their salts, tall oils and gum rosin salts, alkylbenzene sulfonates, and salts of sulfonated hydrocarbons.
(6) Water-reducing (ASTM C494/C494M; AASHTO M 194M/M 194, Type A)	Reduce water content at least 5 percent.	Lignosulfonic acids and their salts. Hydroxylated carboxylic acids and their salts. Polysaccharides, melamine polycondensation products, naphthalene polycondensation products, and polycarboxylates.
(6) Mid-range water-reducing (ASTM C494/C494M, Type A)	Reduce water content by between 5 and 10 percent without retardation of initial set.	Lignosulfonic acids and their salts. Polycarboxylates.
(6) High-range water-reducing (ASTM C494/C494M; AASHTO M 194M/M 194, Type F or G)	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).	Melamine sulfonate polycondensation products, naphthalene sulfonate polycondensation products, and polycarboxylates.
(7) Accelerating (ASTM C494/C494M; AASHTO M 194M/M 194, Type C or E)	Accelerate setting and early strength development.	Calcium chloride (ASTM D98; AASHTO M 144), triethanolamine, sodium thiocyanate, sodium/calcium formate, sodium/calcium nitrite, calcium nitrate, aluminates, and silicates.
(8) Set-retarding (ASTM C494/C494M and AASHTO M 194M/M 194, Type D)	Reduce water content at least 5 percent. Delay set time.	Refer to water-reducing materials.
(9) Extended set-controllling (hydration control) (ASTM C494/C494M, Type B or D)	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.	Carboxylic acids. Phosphorus-containing organic acid salts.
(10) Workability retaining	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	Dispersants such as polycarboxylates.
(11) Viscosity- and rheology-modifying	Modify the rheological properties of plastic concrete.	Polyethylene oxides, cellulose ethers (HEC and HPMC), alginates (from seaweed), natural and synthetic gums, and polyacrylamides or polyvinyl alcohol.
(12) Shrinkage-reducing and shrinkage-compensating	Reduce drying shrinkage. Reductions of 30 to 50 percent can be achieved.	Polyoxyalkylene alkyl ether, propylene glycol, calcium sulfoaluminate, calcium-aluminate, calcium hydroxide- or magnesium oxide-based systems
(13) Corrosion-inhibiting (ASTM C1582/C1582M)	Significantly reduce the rate of steel corrosion and extend the time for onset of corrosion.	Amine carboxylates aminoester organic emulsion, calcium nitrite, and organic alkyidicarboxylic. Chromates, phosphates, hypophosphites, alkalis, and fluorides.
(14) Lithium admixtures to reduce deleterious expansions from alkali-silica reaction	Minimize deleterious expansions from alkali-silica reaction.	Lithium nitrate, lithium carbonate, lithium hydroxide, and lithium nitrite.
(15a) Permeability-reducing admixture: non-hydrostatic conditions (PRAN)	Water-repellent surface, reduced water absorption.	Long-chain fatty acid derivatives (stearic, oleic, caprylic capric), soaps and oils (tallows, soya-based), petroleum derivatives (mineral oil, paraffin, bitumen emulsions), and fine particle fillers (silicates, bentonite, talc).
(15b) Permeability-reducing admixture: hydrostatic conditions (PRAH)	Reduced permeability, increased resistance to water penetration under pressure.	Crystalline hydrophilic polymers (latex, water-soluble, or liquid polymer).
(16) Miscellaneous admixtures:		
(16a) Bonding	Increase bond strength.	Polyvinyl chloride, polyvinyl acetate, acrylics, and butadiene-styrene copolymers.
(16b) Coloring	Colored concrete.	Carbon black, iron oxide, phthalocyanine, raw burnt umber, chromium oxide, and titanium dioxide.
(16c) Flocculating	Increase interparticle attraction to allow paste to behave as one large flock.	Vinyl acetate-maleic anhydride copolymer.
(16d) Fungicidal, cermicidal, insecticidal	Inhibit or control bacterial, fungal, and insecticidal growth.	Polyhalogenated phenols, emulsion, and copper compounds.
(16e) Air-detraining	Reduce air in concrete mixtures, cement slurries, and other cementing applications.	Tributyl phosphate, dibutyl phosphate, dibutylphthalate, polydimethylsiloxane, dodecyl (lauryl) alcohol, octyl alcohol, polypropylene glycols, water-soluble esters of carbonic and boric acids, and lower sulfonate oils.
(16f) Expansive/gas forming	Control settlement and bleeding and improve the intrusion of grout and mortars.	Metallic aluminum, zinc or magnesium, hydrogen peroxide, nitrogen and ammonium compounds, and certain forms of activated carbon or fluidized coke.
(16g) Cellular	Air-generating admixtures for the production of flowable fill, lightweight concrete, insulation.	Protein and other synthetic surfactants.
(16h) Shotcrete	Shotcrete accelerators for wet and dry mixture applications.	Alkali-based and alkali-free materials.
(16i) MCP	Production efficiency, surface texture and strength.	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.