ACI 212.3R-10

Report on Chemical Admixtures for Concrete

Reported by ACI Committee 212

American Concrete Institute®

First Printing
November 2010

American Concrete Institute®
Advancing concrete knowledge

Report on Chemical Admixtures for Concrete

The technical committees responsible for ACI committee reports and standards strive to avoid ambiguities, omissions, and errors in these documents. In spite of these efforts, the users of ACI documents occasionally find information or requirements that may be subject to more than one interpretation or may be incomplete or incorrect. Users who have suggestions for the improvement of ACI documents are requested to contact ACI. Proper use of this document includes periodically checking for errata at **www.concrete.org/committees/errata.asp** for the most up-to-date revisions.

ACI committee documents are intended for the use of individuals who are competent to evaluate the significance and limitations of its content and recommendations and who will accept responsibility for the application of the material it contains. Individuals who use this publication in any way assume all risk and accept total responsibility for the application and use of this information.

All information in this publication is provided "as is" without warranty of any kind, either express or implied, including but not limited to, the implied warranties of merchantability, fitness for a particular purpose or non-infringement.

ACI and its members disclaim liability for damages of any kind, including any special, indirect, incidental, or consequential damages, including without limitation, lost revenues or lost profits, which may result from the use of this publication.

It is the responsibility of the user of this document to establish health and safety practices appropriate to the specific circumstances involved with its use. ACI does not make any representations with regard to health and safety issues and the use of this document. The user must determine the applicability of all regulatory limitations before applying the document and must comply with all applicable laws and regulations, including but not limited to, United States Occupational Safety and Health Administration (OSHA) health and safety standards.

Order information: ACI documents are available in print, by download, on CD-ROM, through electronic subscription, or reprint and may be obtained by contacting ACI.

Most ACI standards and committee reports are gathered together in the annually revised *ACI Manual of Concrete Practice* (MCP).

American Concrete Institute
38800 Country Club Drive
Farmington Hills, MI 48331
U.S.A.
Phone: 248-848-3700
Fax: 248-848-3701

www.concrete.org

ISBN 978-0-87031-402-5

Report on Chemical Admixtures for Concrete

Reported by ACI Committee 212

William S. Phelan*
Chair

Bradley K. Violetta*
Secretary

J. Floyd Best
Casimir Bognacki
Marshall L. Brown
Lewis J. Cook
Timothy Durning
Roy Eller*
Hamid Farzam
Charles J. Korhonen*
Darmawan Ludirdja
Ross S. Martin
Richard C. Mielenz
Pierre-Claver Nkinamubanzi*
Monique Page
Michael F. Pistilli
Kenneth B. Rear
Lawrence R. Roberts*
Arpad Savoly
Raymond J. Schutz
David B. Stokes*
Bruce R. Strickland*
Richard M. Wing
John B. Wojakowski*
Kari L. Yuers*

*Chairs of subcommittee that prepared this report.

The committee would like to thank Ketan R. Sompura* and Caroline M. Talbot* for their contributions to this report.

Chemical admixtures, which are primarily water-soluble substances, are discussed in detail and, in this report, are classified into 13 groups: air-entraining; accelerating; water-reducing and set-retarding; admixtures for flowing concrete; admixtures for self-consolidating concrete; cold weather admixture systems; admixtures for very high-early-strength concrete; extended set control; shrinkage-reducing; corrosion-inhibiting; lithium; permeability-reducing; and miscellaneous. Chemical admixtures are used on a daily basis in the cast-in-place and precast concrete industries. Twelve categories of admixtures are described in detail as to type, current usage, and their effect on concrete in the plastic and hardened state. Their benefits and common usage are outlined.

Each category of admixture addresses the benefits obtainable with their use in a properly proportioned concrete mixture, types of batching systems, control measures, and test placements for mixture design verification. Mixture designs using multiple chemical admixtures have become more common. Their successful usage requires proper compatibility and, often, setting times and early strengths that are proper for the placing environment. The potential benefits are highlighted to all members of the concrete team, concrete contractor, concrete producer, admixture supplier, and testing personnel.

Finely divided mineral admixtures are addressed by ACI 232.2R "Use of Fly Ash in Concrete," ACI 232.1R "Use of Raw or Processed Natural Pozzolans in Concrete" and ACI 234R "Guide for the Use of Silica Fume in Concrete."

Keywords: accelerating; admixture; admixture system; air-entraining; alkali-aggregate reaction; flowing concrete; high-range water-reducing admixture; permeability-reducing admixtures; self-consolidating concrete; shrinkage-reducing; water-reducing and set-retarding.

ACI 212.3R-10 supesedes 212.3R-04 and was adopted and published November 2010.

ADMIXTURES, THEIR CHARACTERISTICS, AND USAGE

Admixture type	Effects and benefits	Materials
Air-entraining (ASTM C260 and AASHTO M154)	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, salts of sulfonated hydrocarbons.
Accelerating (ASTM C494/C494M and AASHTO M194, Type C or E)	Accelerate setting and early-strength development.	Calcium chloride (ASTM D98 and AASHTO M144), triethanolamine, sodium thiocyanate, sodium/calcium formate, sodium/calcium nitrite, calcium nitrate, aluminates, silicates.
Water-reducing (ASTM C494/C494M and AASHTO M194, Type A)	Reduce water content at least 5%.	Lignosulfonic acids and their salts. Hydroxylated carboxylic acids and their salts. Polysaccharides, melamine polycondensation products, naphthalene polycondensation products, and polycarboxylates.
Water-reducing and set-retarding (ASTM C494/C494M and AASHTO M194, Type D)	Reduce water content at least 5%. Delay set time.	See water reducer, Type A (retarding component is added).
High-range water-reducing (ASTM C494/C494M and AASHTO M194, Type F or G)	Reduce water content by at least 12 to 40%, 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.
Mid-range water-reducing (ASTM C494/C494M, Type A)	Reduce water content by between 5% and 10% without retardation of initial set.	Lignosulfonic acids and their salts. Polycarboxylates.
Extended set control (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.
Shrinkage-reducing	Reduce drying shrinkage. Reductions of 30 to 50% can be achieved.	Polyoxyalkylene alkyl ether. Propylene glycol.
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, organic alkyidicarboxylic. Chromates, phosphates, hypophosphites, alkalis, and fluorides.
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.
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).
Permeability-reducing admixture: hydrostatic conditions (PRAH)	Reduced permeability, increased resistance to water penetration under pressure.	Crystalline hydrophilic polymers (latex, water-soluble, or liquid polymer).
Bonding	Increase bond strength.	Polyvinyl chloride, polyvinyl acetate, acrylics, and butadiene-styrene copolymers.
Coloring	Colored concrete.	Carbon black, iron oxide, phthalocyanine, raw burnt umber, chromium oxide, and titanium dioxide.
Flocculating	Increase interparticle attraction to allow paste to behave as one large flock.	Vinyl acetate-maleic anhydride copolymer.
Fungicidal, cermicidal, insecticidal	Inhibit or control bacterial, fungal, and insecticidal growth.	Polyhalogenated phenols, emulsion, and copper compounds.
Rheology/viscosity-modifying	Modify the rheological properties of plastic concrete.	Polyethylene oxides, cellulose ethers (HEC, HPMC), alginates (from seaweed), natural and synthetic gums, and polyacrylamides or polyvinyl alcohol.
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.

CONTENTS

CHAPTER 1—INTRODUCTION

1.1—Introduction

An admixture is defined as "a 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" (American Concrete Institute 2010; ASTM C125). Chemical admixtures are primarily water-soluble substances used to enhance the properties of concrete or mortar in the plastic and hardened state. These benefits include increased compressive and flexural strength at all ages, decreased permeability and improved durability, corrosion reduction, shrinkage reduction, initial set adjustments, 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; however, proper mixture designs are required for optimum benefits. In certain instances, a desired objective may be 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.

This report deals with commonly used admixtures other than those assigned to other ACI committees. Materials, such as mineral admixtures, used to produce concrete are not discussed in this report.

The chemical admixtures are classified generically or with respect to their characteristics. Information to characterize each class is presented with brief statements of the general purposes and expected effects of each group of materials. The wide scope of the admixture field, the continued entrance of new or modified materials into this field, and the variations of effects with different concreting materials and conditions preclude a complete listing of all admixtures and their effects on concrete. Summaries of the state of the art of chemical admixtures include Ramachandran and Malhotra (1984), Ramachandran and Mailvaganam (1992), Mather (1994), Nkinamubanzi and Aïtcin (2004), Collepardi and Valente (2006), and "Chemical Admixtures for Concrete," *ACI Education Bulletin* E4-03 (ACI Committee E703 2003).

CHAPTER 2—DEFINITIONS

2.1—Definitions

ACI provides a comprehensive list of definitions through an online resource, "ACI Concrete Terminology," http://terminology.concrete.org. Definitions provided herein complement that resource.

admixture—a material other than water, aggregates, cementitious materials, and fiber reinforcement, used as an ingredient of a cementitious mixture to modify its freshly mixed, setting, or hardened properties and that is added to the batch before or during its mixing.

admixture, accelerating—an admixture that causes an increase in the rate of hydration of the hydraulic cement and thus shortens the time of setting, increases the rate of strength development, or both.

admixture, air-entraining—an admixture that causes the development of a system of microscopic air bubbles in concrete, mortar, or cement paste during mixing, usually to increase its workability and resistance to freezing and thawing.

admixture, retarding—an admixture that causes a decrease in the rate of hydration of the hydraulic cement and lengthens the time of setting.

admixture, water-reducing—an admixture that either increases slump of a fresh cementitious mixture without increasing water content or maintains slump with a reduced amount of water, the effect being due to factors other than air entrainment.

admixture, water-reducing (high-range)—a water-reducing admixture capable of producing great water reduction, great flowability, or both, without causing undue set retardation or air entrainment in cementitious paste.

adsorption—development (at the surface of either a liquid or solid) of a higher concentration of a substance than exists in the bulk of the medium; especially formation of one or more layers of molecules of gases, of dissolved substances, or of liquids at the surface of a solid (such as cement, cement paste, or aggregates), or of air-entraining agents at the air-water interfaces; also the process by which a substance is adsorbed.

air, entrained—microscopic air bubbles intentionally incorporated in a cementitious paste during mixing, usually by use of a surface-active agent; typically between 0.0004 and 0.04 in. (10 and 1000 μm) in diameter and spherical or nearly so.