

ACI 212.3R-16

Report on Chemical Admixtures for Concrete

Reported by ACI Committee 212



American Concrete Institute
Always advancing



Report on Chemical Admixtures for Concrete

Copyright by the American Concrete Institute, Farmington Hills, MI. All rights reserved. This material may not be reproduced or copied, in whole or part, in any printed, mechanical, electronic, film, or other distribution and storage media, without the written consent of ACI.

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 via the errata website at <http://concrete.org/Publications/DocumentErrata.aspx>. Proper use of this document includes periodically checking for errata 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.

Participation by governmental representatives in the work of the American Concrete Institute and in the development of Institute standards does not constitute governmental endorsement of ACI or the standards that it develops.

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
Phone: +1.248.848.3700
Fax: +1.248.848.3701

www.concrete.org

Report on Chemical Admixtures for Concrete

Reported by ACI Committee 212

Bradley K. Violetta*, Chair

Kari L. Yuers*, Secretary

James M. Aldred
Neal S. Berke*
Casimir J. Bognacki
Marshall L. Brown
Lewis J. Cook
Timothy Durning*
Roy Eller

Hamid Farzam
Dale Fisher*
Timothy S. Folks
Barney Heller*
Darmawan Ludirdja*
Ross S. Martin
Pierre-Claver Nkinamubanzi

William S. Phelan*
Michael F. Pistilli
Lawrence R. Roberts*
Ketan R. Sompura*
David B. Stokes*
Arthur T. Winters*

*Subcommittee members who prepared this report.

The committee would like to thank T. Harris, N. Treggar, and C. Talbot for their contributions to this report.

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.

ACI Committee Reports, Guides, and Commentaries are intended for guidance in planning, designing, executing, and inspecting construction. This document is 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. The American Concrete Institute disclaims any and all responsibility for the stated principles. The Institute shall not be liable for any loss or damage arising therefrom.

Reference to this document shall not be made in contract documents. If items found in this document are desired by the Architect/Engineer to be a part of the contract documents, they shall be restated in mandatory language for incorporation by the Architect/Engineer.

CONTENTS

CHAPTER 1—INTRODUCTION, p. 3

- 1.1—Introduction, p. 3
- 1.2—Scope, p. 3

CHAPTER 2—DEFINITIONS, p. 5

- 2.1—Definitions, p. 5

CHAPTER 3—GENERAL, p. 5

- 3.1—Admixture benefits, p. 5
- 3.2—Specifications for admixtures, p. 5
- 3.3—Sampling and testing, p. 5
- 3.4—Cost effectiveness, p. 6
- 3.5—Selection and evaluation, p. 6
- 3.6—Proportioning and batching, p. 6
- 3.7—Batching order for adding chemical admixtures in concrete, p. 7
- 3.8—Chapter reference chart, p. 8

CHAPTER 4—SUSTAINABILITY, p. 8

- 4.1—Sustainability of chemical admixtures, p. 8
- 4.2—Use of chemical admixtures in sustainable construction, p. 8

CHAPTER 5—AIR-ENTRAINING ADMIXTURES, p. 10

- 5.1—Introduction, p. 10
- 5.2—Materials for air entrainment, p. 10
- 5.3—Mechanism of entrained air, p. 11
- 5.4—Selection and evaluation, p. 12
- 5.5—Applications, p. 12

ACI 212.3R-16 supersedes ACI 212.3R-10 and was adopted and published March 2016.

Copyright © 2016, American Concrete Institute.

All rights reserved including rights of reproduction and use in any form or by any means, including the making of copies by any photo process, or by electronic or mechanical device, printed, written, or oral, or recording for sound or visual reproduction or for use in any knowledge or retrieval system or device, unless permission in writing is obtained from the copyright proprietors.

- 5.6—Dosage, p. 13
- 5.7—Proportioning concrete, p. 13
- 5.8—Effects on fresh and hardening concrete, p. 13
- 5.9—Effects on hardened concrete, p. 14
- 5.10—Quality assurance and batching, p. 14

CHAPTER 6—NORMAL, MID-, AND HIGH-RANGE WATER-REDUCING ADMIXTURES, p. 15

- 6.1—Introduction, p. 15
- 6.2—Materials, p. 15
- 6.3—Selection and evaluation, p. 15
- 6.4—Applications, p. 16
- 6.5—Dosage, p. 16
- 6.6—Proportioning concrete, p. 17
- 6.7—Effects on fresh and hardening concrete, p. 17
- 6.8—Effects on hardened concrete, p. 18
- 6.9—Quality assurance and batching, p. 19

CHAPTER 7—ACCELERATING ADMIXTURES, p. 19

- 7.1—Introduction, p. 19
- 7.2—Materials, p. 19
- 7.3—Selection and evaluation, p. 20
- 7.4—Applications, p. 21
- 7.5—Dosage and proportioning concrete, p. 21
- 7.6—Effects on fresh and hardening concrete, p. 21
- 7.7—Effects on hardened concrete, p. 22
- 7.8—Corrosion of metals, p. 22
- 7.9—Quality assurance and batching, p. 23

CHAPTER 8—SET-RETARDING ADMIXTURES, p. 24

- 8.1—Introduction, p. 24
- 8.2—Materials, p. 24
- 8.3—Selection and evaluation, p. 24
- 8.4—Applications, p. 25
- 8.5—Dosage, p. 25
- 8.6—Proportioning concrete, p. 25
- 8.7—Effects on fresh and hardening concrete, p. 25
- 8.8—Effects on hardened concrete, p. 26
- 8.9—Quality assurance and batching, p. 26

CHAPTER 9—EXTENDED SET-CONTROL ADMIXTURES, p. 26

- 9.1—Introduction, p. 26
- 9.2—Materials, p. 26
- 9.3—Selection and evaluation, p. 26
- 9.4—Applications, p. 26
- 9.5—Dosage and proportioning concrete, p. 27
- 9.6—Effects on fresh and hardening concrete, p. 27
- 9.7—Effects on hardened concrete, p. 27
- 9.8—Quality assurance and batching, p. 28

CHAPTER 10—WORKABILITY-RETAINING ADMIXTURES, p. 28

- 10.1—Introduction, p. 28
- 10.2—Materials, p. 28
- 10.3—Dosage and effect on fresh and hardened concrete, p. 29

- 10.4—Applications, p. 30
- 10.5—Quality assurance and batching, p. 31

CHAPTER 11—VISCOSITY- AND RHEOLOGY-MODIFYING ADMIXTURES, p. 31

- 11.1—Introduction, p. 31
- 11.2—Materials, p. 31
- 11.3—Selection and evaluation, p. 31
- 11.4—Applications, p. 32
- 11.5—Dosage and proportioning concrete, p. 32
- 11.6—Effects of fresh and hardened concrete, p. 32
- 11.7—Anti-washout admixtures, p. 32
- 11.8—Rheology-modifying admixtures, p. 32
- 11.9—Quality assurance and batching, p. 33

CHAPTER 12—SHRINKAGE-REDUCING AND SHRINKAGE-COMPENSATING ADMIXTURES, p. 33

- 12.1—Introduction, p. 33
- 12.2—Materials, p. 34
- 12.3—Mode of action, p. 34
- 12.4—Applications, p. 34
- 12.5—Dosage and proportioning concrete, p. 34
- 12.6—Effects on fresh and hardening concrete, p. 35
- 12.7—Effects on hardened concrete, p. 35
- 12.8—Quality assurance and batching, p. 35

CHAPTER 13—CORROSION-INHIBITING ADMIXTURES, p. 35

- 13.1—Introduction, p. 35
- 13.2—Materials, p. 36
- 13.3—Selection and evaluation, p. 38
- 13.4—Applications, p. 39
- 13.5—Dosage and proportioning concrete, p. 39
- 13.6—Effects on fresh and hardening concrete, p. 40
- 13.7—Effects on hardened concrete, p. 40
- 13.8—Quality assurance and batching, p. 41

CHAPTER 14—LITHIUM ADMIXTURES TO REDUCE DELETERIOUS EXPANSION FROM ALKALI-SILICA REACTION, p. 41

- 14.1—Introduction, p. 41
- 14.2—Materials, p. 41
- 14.3—Mechanism, p. 41
- 14.4—Dosage, p. 42
- 14.5—Effects on concrete properties, p. 42
- 14.6—Performance tests for effectiveness, p. 43
- 14.6—Quality assurance and batching, p. 43

CHAPTER 15—PERMEABILITY-REDUCING ADMIXTURES, p. 43

- 15.1—Introduction, p. 43
- 15.2—Materials, p. 44
- 15.3—Selection and evaluation, p. 46
- 15.4—Applications, p. 47
- 15.5—Dosage and proportioning concrete, p. 47
- 15.6—Effects on fresh and hardened properties, p. 48
- 15.7—Quality assurance and batching, p. 48

CHAPTER 16—MISCELLANEOUS ADMIXTURES, p. 48

- 16.1—Bonding admixtures, p. 48
- 16.2—Coloring admixtures, p. 49
- 16.3—Flocculating admixtures, p. 49
- 16.4—Fungicidal, germicidal, and insecticidal admixtures, p. 49
- 16.5—Air-detraining admixtures, p. 49
- 16.6—Expansive/gas forming admixtures, p. 50
- 16.7—Admixtures for cellular concrete/flowable fill, p. 50
- 16.8—Shotcrete admixtures, p. 50
- 16.9—Admixtures for manufactured concrete products, p. 51

CHAPTER 17—ADMIXTURES FOR FLOWING CONCRETE, p. 52

- 17.1—Introduction, p. 52
- 17.2—Materials, p. 52
- 17.3—Selection and evaluation, p. 52
- 17.4—Applications, p. 52
- 17.5—Proportioning concrete, p. 53
- 17.6—Effects on fresh and hardening concrete, p. 53
- 17.7—Effects on hardened concrete, p. 54
- 17.8—Quality assurance and batching, p. 55

CHAPTER 18—ADMIXTURES FOR SELF-CONSOLIDATING CONCRETE (SCC), p. 55

- 18.1—Introduction, p. 55
- 18.2—Materials for self-consolidating concrete admixtures, p. 55
- 18.3—Selection and evaluation, p. 58
- 18.4—Proportioning concrete, p. 58
- 18.5—Effects on fresh and hardening concrete, p. 58
- 18.6—Effects on hardened concrete, p. 59
- 18.7—Quality assurance and batching, p. 59

CHAPTER 19—ADMIXTURES FOR VERY COLD WEATHER CONCRETE, p. 59

- 19.1—Introduction, p. 59
- 19.2—Materials, p. 60
- 19.3—Selection and evaluation, p. 60
- 19.4—Proportioning concrete, p. 60
- 19.5—Batching, p. 60
- 19.6—Trial placement, p. 60
- 19.7—Placing and finishing, p. 61
- 19.8—Effects on fresh and hardening concrete, p. 61
- 19.9—Effects on hardened concrete, p. 61
- 19.10—Quality assurance, p. 61
- 19.11—Cost benefit, p. 62

CHAPTER 20—ADMIXTURES FOR VERY-HIGH-EARLY-STRENGTH CONCRETE, p. 62

- 20.1—Introduction, p. 62
- 20.2—Materials for very-high-early-strength concrete, p. 62
- 20.3—Selection and evaluation, p. 63
- 20.4—Proportioning concrete, p. 64
- 20.5—Effects on fresh and hardening concrete, p. 64
- 20.6—Effects on hardened concrete, p. 64

- 20.7—Quality assurance and batching, p. 64

CHAPTER 21—ADMIXTURES FOR PERVIOUS CONCRETE, p. 65

- 21.1—Introduction, p. 65
- 21.2—Materials, p. 65
- 21.3—Selection and evaluation, p. 65
- 21.4—Applications, p. 65
- 21.5—Proportioning, p. 65
- 21.6—Effects on fresh and hardening concrete, p. 65
- 21.7—Effects on hardened concrete, p. 66
- 21.8—Quality assurance and batching, p. 66

CHAPTER 22—REFERENCES, p. 66

- Authored documents, p. 67

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-controlling (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 alkydicarboxylic. 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.