Guide to Residential Concrete Construction

Reported by ACI Committee 332

ACI 332.1R-18

American Concrete Institute
Always advancing

First Printing
May 2018
ISBN: 978-1-64195-010-7

Guide to Residential Concrete Construction

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, 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 the ACI Collection of Concrete Codes, Specifications, and Practices.

American Concrete Institute
38800 Country Club Drive
Farmington Hills, MI 48331
Phone: +1.248.848.3700
Fax: +1.248.848.3701

www.concrete.org

Guide to Residential Concrete Construction

Reported by ACI Committee 332

James R. Baty II, Chair

James A. Farny, Secretary

Brent Anderson
William L. Arent
Chuck S. Bajnai
Joseph Stephen Balik
Claude J. Bergeron
Anthony J Candiloro
John P. Carr
Michael A. Carter
Michael W. Cook
Jerry D. Coombs
Barry A. Descheneaux
Timothy J. Dickson
Kelvin L. Doerr
Gary J. Ehrlich
Nader R. Elhajj
William A. Fennell
Jeff R. Filler
Augusta Gaertner
Robert L. Henry
Barry Herbert
Geoffrey Hichborn Sr.
Bret Houck
Morris Huffman
Said Iravani
Raj K. Jalla
James S. Jensen
Kirby Justesen
Ashok M. Kakade
Tarek S. Khan
Lionel A. Lemay
Kenneth A. Luttrell
David R. Maul
Warren E. McPherson Jr.
Jereme Montgomery
T. George Muste
Anil K. Patnaik
Dale A. Phillips
Luke R. Pinkerton
Dennis R. Purinton
Jorge L. Quiros Jr.
J. Edward Sauter
Sylvester B. Schmidt
Robert E. Sculthorpe
Christopher R. Tull
Michael H. Weber
Mary J. Wilson
Douglas C. Wittler

Consulting Members

Glen E. Bollin
Ron E. Colvin
Scott R. Humphreys
John M. Jaffee
Skip Reynolds
Royce J. Rhoads

This guide provides practical information about the construction of residential concrete that meets or exceeds code requirements. It covers concrete work for one- and two-family dwellings with a maximum height of three stories above grade and a basement that is either cast-in-place or placed as precast members. Information on materials, proportions, production, delivery, and testing is provided. Separate chapters on footings, walls, and slabs provide information on subgrade, forms, reinforcement, placement, consolidation, finishing, and curing. Special considerations regarding above-grade concrete systems (Chapter 6) and project considerations (Chapter 8) are included. Common problems and their repair are also addressed. Although the discussion of specific design provisions and all drawings provided by this guide are intended to offer illustrations of typical practice, they should be verified as to whether they meet the requirements of specific codes or project specifications. Applicable codes and construction documents take precedence over the information contained in this document.

Keywords: finish; footing; foundation; form; residential; slab; slab-on-ground; subgrade; tolerance; wall.

CONTENTS

ACI 332.1R-18 supersedes ACI 332.1R-06 and was adopted and published May 2018.

CHAPTER 1—INTRODUCTION

Concrete is the most widely used construction material throughout the world. Concrete is used in commercial structures, transportation, water and waste management, public works, farm construction, and utility and residential structures. Based on the amount of concrete produced for each of these categories, residential construction accounts for the second largest application of concrete (PCA MI451D).

1.1—Scope

This guide provides practical information about the construction of residential concrete that meets or exceeds code requirements, covering all concrete work within the scope defined in the "International Residential Code for One- and Two-Family Dwellings" (International Code Council 2018) and that of ACI 332. Provisions of these codes apply to detached one- and two-family dwellings and multiple single-family dwellings (townhomes) not more than three stories in height. These structures are no more than three stories above grade and may include a basement that is either cast-in-place or placed as precast members. Information on materials, proportions, production, delivery, and testing is provided. Separate chapters on footings, walls, and slabs provide information on subgrade, forms, reinforcement, placement, consolidation, finishing, and curing. Special considerations regarding above-grade concrete systems in Chapter 6 and project considerations in Chapter 8 are included. Common problems and their repair are also addressed. The discussion of specific design provisions and all drawings provided by this guide are intended to offer illustrations of typical practice and should not be interpreted as meeting the requirements of specific codes or project specifications. Applicable codes and construction documents take precedence over the information contained in this document.

Information excluded from this guide includes deep foundation systems (such as piles, drilled piers, or caissons), free-standing retaining walls (greater than 4 ft [1.2 m]), and post-tensioned slabs-on-ground. Limited information on the use of lightweight concrete is presented. This guide does not cover loading and design for seismic forces, with the exception of guidance on types of connections between the sill plate and foundation wall commonly used in higher seismic design categories. Additional information on seismic loading and design can be found in the "International Residential Code for One- and Two-Family Dwellings" (International Code Council 2018).

CHAPTER 2—DEFINITIONS

Please refer to the latest version of ACI Concrete Terminology for a comprehensive list of definitions. Definitions provided herein complement that resource.

anchor strap—metal connector with corrosion resistance designed to transfer uplift, lateral forces, or both, from wood framing members to concrete foundations.

bar diameter—proper designation of the sizes for reinforcement bars used in concrete construction, expressed as d_b.

fiber reinforcement—slender and elongated filaments in the form of bundles, networks, or strands of any natural or manufactured material that can be distributed throughout freshly mixed concrete.

fill—material placed to bring grade or subgrade to the desired elevation.

flowable fill—self-consolidating cementitious material used primarily as a backfill in place of compacted fill.

foundation walls—structural members of a foundation that transmit loads to the footing or directly to the subgrade.

hydrostatic pressure—pressure on a foundation wall due to water.

insulated concrete form—stay-in-place wall form made of foam plastic or other insulation materials that is filled with reinforced concrete; form remains in place to create fully insulated, reinforced concrete walls used for foundations, basements, and above-grade load-bearing walls.

moderately reinforced walls—structural concrete walls reinforced with an amount of steel reinforcement including reinforcing bar and welded wire reinforcement less than that required by ACI 332 or ACI 318 and shown to satisfy the design requirements for applied load without the need for additional steel reinforcement including reinforcing bar and welded wire reinforcement.

pad footing—isolated footing or column support that transfers vertical load from the structure above to the soil.

plain reinforced walls—structural concrete walls with no reinforcement required for design forces or with steel reinforcement including reinforcing bar and welded wire reinforcement for temperature, shrinkage, and crack control only.

reinforced walls—structural concrete walls reinforced with no less than the minimum amount of steel reinforcement including reinforcing bar and welded wire reinforcement required by ACI 332.

removable concrete form—removable wall form made of wood, aluminum, steel, or a combination of these materials that is set to the desired wall design and filled with concrete; the forms are then removed to reveal concrete walls used for foundations, basements, and above-grade load-bearing walls.

steel fiber—pieces of smooth or deformed cold-drawn wire, smooth or deformed cut sheet, melt-extracted fibers, or other steel fibers that are sufficiently small to be dispersed at random in a concrete mixture.

structural slab—concrete member that transfers load to supports through actions of flexure and shear; usually not supported by grade.

synthetic fiber—man-made fiber, commonly made of polypropylene, nylon, or polyester.

thickened slab—footing constructed as an integral part of a floor slab.

viscosity-modifying admixture—admixture that enhances concrete performance by modifying the viscosity and controlling the rheological properties of the concrete mixture; usually used in conjunction with high-range water-reducing admixtures to produce self-consolidating concrete mixtures.

web—mechanical connection in tension used in insulated concrete form systems to prevent forms from spreading due to the fluid pressure of fresh concrete; related to form ties used in removable forming systems.

CHAPTER 3—CONCRETE

3.1—Fundamentals

The main constituents for concrete used in residential construction include cementitious materials (portland cement and supplementary cementitious materials [SCMs]), coarse aggregate (stone or gravel), fine aggregate (sand), and water. Concrete mixtures have become much more complex in the range of additional components, as designers and contractors have been introduced to the benefits of performance-enhancing ingredients. These include a variety of chemical admixtures, fibers, and mineral pigments for such applications as decorative concrete. The ready mixed concrete producer can vary the proportions of ingredients to create a concrete mixture with specific properties to meet specific building code requirements, respond to specific or anticipated environmental conditions, and meet the purchaser's or contractor's requirements. The performance of the concrete should meet the requirements of ACI 332, ASTM C94/C94M, or C685/C685M; other applicable building code requirements; and the project specifications.

3.2—Materials

3.2.1 *Cementitious materials*—Cementitious materials include portland cement, blended cements, and supplementary cementitious materials (SCMs). A cementitious paste is formed by the combination of cementitious materials and water, and serves several functions: to coat and bond the aggregate particles together; to fill the void spaces between the aggregate; and to provide strength and durability to the hardened concrete. For any combination of materials, the strength of the resulting concrete mixture depends primarily on the water-cementitious materials ratio (*w/cm*). Increasing the amount of cementitious materials in relation to the amount of water in the mixture will generally increase the compressive strength. Using less water for a fixed amount of cementitious material results in a more viscous paste and stronger concrete. The amount of shrinkage in the hardened concrete is directly proportional to the amount of water in the mixture. Most cementitious materials for residential construction generally consist of a combination of portland cement and SCMs in the form of fly ash, slag, or both.

3.2.2 *Portland cement*—Portland cement is the most common type of cement used in concrete. ASTM C150/C150M defines five types of portland cement, but only four are typically used in residential construction. Type I is a general-purpose cement and is the most commonly used cement for residential concrete; Type II is a cement used where moderate sulfate exposure is anticipated; Type III is high-early-strength cement that is sometimes used to achieve faster setting and increased early strengths; and Type V is a cement that is used where severe exposure to sulfates is anticipated.

3.2.3 *Blended cements and hydraulic cement*—Blended cement, defined by ASTM C595/C595M, consists of preblended combinations of portland cement and SCMs. Hydraulic cements may or may not contain portland cement and are defined by ASTM C1157/C1157M. Both cement types are used in residential construction.

3.2.4 *Supplementary cementitious materials*—Natural pozzolans (ASTM C618 Class N), fly ashes (ASTM C618 Class C or F), and slag cements (ASTM C989/C989M Grades 80, 100, and 120), are some of the materials known as SCMs that are used in residential concrete. The benefits derived from the use of SCMs include functional or engineering benefits and environmental benefits. Some of the engineering benefits are decreased permeability, increased durability, improved workability, and higher ultimate compressive strength. The environmental benefits are reduced consumption of portland cement, which results in a lower carbon footprint for the concrete and a reduction in the amount of industrial by-products that are diverted to landfills. NRMCA CIP 30 provides further reference for SCMs and PCA EB001.

3.2.5 *Aggregates*—Aggregates are the major constituent in concrete, typically comprising 70 percent or more of the volume. They are an economical material that imparts volume stability, strength, and durability to concrete. Aggregates have significant influence on the properties and performance of both plastic (freshly mixed) and hardened concrete, depending on mineraology and physical characteristics. Aggregates used in concrete include coarse aggregate (gravel or crushed stone) and fine aggregate (natural sand or crushed stone). Other materials used for aggregate in concrete include lightweight processed shale or slate, air-cooled blast furnace slag, and other natural and manufactured materials.

3.2.5.1 *Coarse aggregate (gravel or crushed stone)*—Aggregate particles that are cubical or rounded facilitate better workability of the concrete, but higher compressive strength and bond comes from angularity and roughness. However, aggregate shape is often determined by the locally available sources. The aggregates should be clean and graded, with particle sizes ranging from 1/4 in. (5 mm) to 3/4 or 1 in. (19 or 25 mm) for most residential concrete. The applicable standard for coarse aggregates is ASTM C33/C33M.

3.2.5.2 *Fine aggregate (sand)*—ASTM C33/C33M sets limits for fine aggregates on impurities (organic materials, clay, and others) and soundness, as well as establishing gradation requirements. Fine aggregate particles range in size between 0.0118 in. (300 mm) and 1/4 in. (5 mm).

3.2.6 *Water*—The applicable standard for water used in mixing concrete is ASTM C1602/C1602M. Potable water from municipal or well sources is commonly used for batching concrete. Recycled water meeting ASTM C1602/C1602M can also be used. The suitability of any water is established by testing concrete or mortar for setting time and compressive strength relative to a control, with optional chemical limits for chlorides, sulfates, alkalis, and total dissolved solids.

3.2.7 *Chemical admixtures*—A variety of chemical admixtures are used to modify the placing and finishing characteristics of the concrete. The contractor and concrete producer should discuss the benefits of chemical admixtures and when their use is planned by the concrete producer. More information about chemical admixtures can be found in NRMCA CIP 15 and PCA EB001.

3.2.7.1 *Air-entraining agents*—Air-entraining agents may be used to provide air entrainment in concrete, which is an effective method for imparting freezing-and-thawing resistance to concrete (refer to 3.3.2.3 for more discussion on air entrainment). The applicable standard for air-entraining agents is ASTM C260/C260M.

3.2.7.2 *Water reducers*—Normal water reducers lower the amount of water required to achieve a given slump. The applicable standard for normal water reducers is ASTM C494/C494M Type A.

3.2.7.3 *Retarding water reducers*—Retarding water reducers extend the setting time in addition to reducing water requirements. These admixtures are normally used in hot weather. The applicable standard for retarding water reducers is ASTM C494/C494M Type D.

3.2.7.4 *Mid-range water reducers*—Mid-range water-reducing admixtures provide moderate water reduction without retardation associated with high dosages of conventional (normal) water reducers. These admixtures provide more water reduction than normal water reducers (5 percent), but less water reduction than high-range water-reducing admixtures (HRWRAs) (12 percent). This typically results in concrete with a slump range of 5 to 8 in. (125 to 200 mm). Mid-ranges will commonly meet ASTM C494/C494M Types A and F. These admixtures are commonly used in residential concrete.

3.2.7.5 *High-range water-reducing admixtures*—HRWRAs produce higher water reductions than normal water reducers. The applicable standard for HRWRAs is ASTM C494/C494M Type F (for normal setting) or Type G (for retarded set).

3.2.7.6 *Plasticizers*—Plasticizers are chemical admixtures that, when added to concrete, produce flowing concrete without further addition of water. These admixtures are not required to provide water reduction. The applicable standard for plasticizing admixtures is ASTM C1017/C1017M Type I (plasticizing) and Type II (plasticizing and retarding).

3.2.7.7 *Viscosity-modifying admixtures*—Viscosity-modifying admixtures are chemical admixtures that, when added to concrete, enhance the viscosity of the mixture, thus reducing aggregate segregation, settlement, and bleeding. These materials are used primarily with HRWRAs and SCMs to produce self-consolidating concrete (SCC) mixtures. More information on SCC can be found in NRMCA CIP 37 and PCA EB001.

3.2.7.8 *Accelerating water reducers*—Accelerating water reducers reduce set time in addition to reducing water requirements. These admixtures are normally used in cold weather. The applicable standard for accelerating water reducers is ASTM C494/C494M Type E.

3.2.7.9 *Accelerators*—Calcium chloride is an effective and commonly used accelerator in residential concrete. The amount used should not exceed 2 percent by weight of cementitious materials, where reinforced concrete is dry and protected from moisture in service conditions, or for plain (unreinforced) concrete in all service conditions. For reinforced concrete subject to other service condition, calcium chloride should not exceed 0.50 percent by weight of cementitious materials. Maximum allowable limits for the use of calcium chloride for residential applications are provided in Table 5.3.2 of ACI 332-14. Some specifications for prestressed concrete prohibit the use of calcium chloride due to the potential for corrosion problems with prestressing steel. Calcium chloride should not be used when dissimilar metals are embedded in concrete. Nonchloride accelerating admixtures are available for use in reinforced concrete that is wet in service. These nonchloride accelerators are effective for set acceleration and compressive strength development. The applicable standard for accelerating admixtures is ASTM C494/C494M Type C.