IN-LB Inch-Pound Units

An ACI Standard

Code Requirements for Residential Concrete (ACI 332-20) and Commentary

Reported by ACI Committee 332

ACI 332-20

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Code Requirements for Residential Concrete and Commentary

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Code Requirements for Residential Concrete and Commentary

An ACI Standard

Reported by ACI Committee 332

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This code covers the design and construction of cast-in-place concrete for one- and two-family dwellings and multiple single-family dwellings (townhouses), and their accessory structures. Among the subjects covered are the design and construction requirements for plain and reinforced concrete footings; foundation walls; slabs-on-ground; and requirements for concrete, reinforcement, forms, and other related materials. The quality and testing of materials discussed in this document are covered by reference to the appropriate ASTM standards.

This code is written to allow for reference by adoption in a general building code without changing its language. Background details or suggestions for carrying out the requirements or intent of the code are provided in the commentary. The commentary discusses some of the considerations of the committee in developing the code with emphasis given to the explanation of provisions that may be unfamiliar to code users or where significant departure exists from other concrete codes.

Keywords: admixtures; aggregate; backfill; cement; compressive strength; cover; flexural strength; footings; formwork (construction); foundations; loads (forces); slabs; structural analysis; reinforcement.

ACI 332-20 supersedes ACI 332-14, was adopted July 6, 2020, and was published October 2020.

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PREFACE

The commentary of this code discusses some of the considerations of ACI Committee 332 in developing the provisions contained herein. Explanation of the departure of this code from ACI 318 is emphasized. Comments on specific provisions are made under the corresponding chapter and section numbers of this code.

The commentary is not intended to provide a complete historical background concerning the development of this code, nor is it intended to provide a detailed résumé of the studies and research data reviewed by the committee in formulating this document.

This code is meant to be used as part of a legally adopted building code and, as such, must differ in form and substance from documents that provide detailed specifications, recommended practices, or complete design procedures. This code was developed by an ANSI-approved consensus process.

This code is intended to cover all residential structures that fall within the scope of IRC-2018. Requirements more stringent than the code provisions may be desirable for large, complex, or irregular structures; high-hazard areas; and other unusual construction. This code cannot replace sound engineering knowledge, experience, and judgment.

A building code states only the minimum requirements necessary to provide for public health and safety; this code is based on that principle. For any structure, the owner or the designer may require the quality of materials and construction to be higher than the minimum requirements necessary to protect the public as stated herein. Lower standards, however, are not permitted. The commentary directs attention to other documents that provide suggestions for carrying out the requirements and intent of this code.

This code has no legal status unless adopted by government bodies having authority to regulate building design and construction. Where this code has not been adopted, it may serve as a reference to good practice even though it has no legal status.

This code provides a means of establishing minimum standards for acceptance of designs and construction by legally appointed building officials or their designated representatives. This document is not intended for use in settling disputes between the owner; engineer; architect; contractor; or their agents, subcontractors, material suppliers, or testing agencies. Therefore, this code cannot define the contract responsibility of each of the parties in construction. General references requiring compliance with this code in the project specifications should be avoided because the contractor is rarely in a position to accept responsibility for design details or construction requirements that depend on detailed knowledge of the design. Design-build construction contractors, however, typically combine the design and construction responsibility. Generally, the drawings, specifications, and contract documents should contain all the necessary requirements to ensure compliance with the code. In part, this can be accomplished by reference to specific code sections in the project specifications. Other ACI publications, such as ACI 301, are written specifically for use as contract documents for construction. Requirements for testing and certification programs should be provided for the individual parties involved with the execution of work performed in accordance with this code.

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CHAPTER 1—GENERAL

1.1—Scope

1.1.1 This chapter addresses (a) through (f):
(a) General requirements of this code
(b) Purpose of this code
(c) Applicability of this code
(d) Alternative systems
(e) Drawings and specifications
(f) Inspection

1.1.2 This code, when legally adopted as part of a general building code, provides minimum requirements for design and construction of residential concrete members. In areas without a legally adopted building code, this code defines minimum acceptable standards of design and construction practice.

1.1.3 This code supplements the general building code and governs matters pertaining to design and construction of cast-in-place concrete construction for one- and two-family dwellings and multiple single-family dwellings (townhouses), and their accessory structures, except wherever this code conflicts with requirements in the legally adopted general building code.

1.1.4 Where this code conflicts with requirements contained in other standards referenced in this code, this code shall govern.

1.1.5 This code is limited to design and construction of concrete footings, including thickened slab footings, wall footings, and isolated footings; concrete basement or foundation walls and above-grade walls constructed with removable forms or with flat insulating concrete forms; and concrete slabs-on-ground.

1.1.6 Where the scope of this code and the scope of ACI 318 coincide, design in accordance with ACI 318 shall be permitted for all buildings and structures, and all parts thereof, within the scope of this code.

1.1.7 *Seismic design*

1.1.7.1 The seismic risk level of a region, or seismic performance or design category of a structure, shall be regulated by the legally adopted general building code, of which this code forms a part, or determined by the local authority.

1.1.8 This code does not govern design and construction of insulating concrete form walls with a waffle or screen configuration; precast wall members; cantilevered walls or retaining walls; deep foundation systems, such as piles, drilled piers, or caissons; and elevated concrete slabs.

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CHAPTER R1—GENERAL

R1.1—Scope

R1.1.1 This Code includes provisions for the design of residential concrete used for structural purposes, including plain concrete and concrete containing mild reinforcement.

This chapter includes numerous provisions that explain where this Code applies and how it is to be interpreted.

R1.1.2 The user of this code should consult the applicable general building code for all applied loads to determine the applicable values for design requirements. In the absence of a governing code, the user should consider the use of ASCE/SEI 7 to determine applicable loads.

R1.1.4 IRC-2018 references this code. Where the design of a member is initiated with this code from reference by the IRC, the entire design of the member must be completed using the provisions of this code.

R1.1.5 The design and construction requirements for footings, foundation walls, and slabs-on-ground are included in this code, together with requirements for concrete, reinforcement, forms, and other related materials.

R1.1.7 *Seismic design*

Provisions for application of precast wall members are found in IRC-2018. The provisions for above-grade concrete walls are currently available in IRC-2018 based on PCA 100.03.

R1.1.8 Guidance on the type and application of systems for drainage, waterproofing, dampproofing, and radon gas ventilation are commonly found in the general building code.

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1.1.9 This code does not govern the design and application of methods for top lateral wall support, surface drainage, waterproofing, dampproofing, or the ventilation of radon gases.

1.1.10 When a building or structure contains concrete members that exceed the limits of this code or otherwise do not conform to this code, these concrete members shall be designed in accordance with ACI 318.

1.1.11 Where permitted by the statutes of the jurisdiction where the project is to be constructed, construction documents for residences designed by the provisions of this code need not be prepared by a licensed design professional. Where required by the statutes of the jurisdiction where the project is to be constructed, a licensed design professional shall prepare the construction documents for residences.

1.1.12 This code is intended to state only minimum requirements necessary to provide for public health and safety for the design of residences that fall within the scope of IRC-2018. The owner or the licensed design professional may require the quality of materials and construction to be higher than the minimum requirements stated in the code.

1.1.13 All references to minimum and maximum dimensions or values in the code refer to those dimensions or values as specified.

1.1.14 This code is not intended to define contractual responsibilities between all the parties involved in a project, nor is it intended to settle disputes regarding contractual responsibilities.

1.1.15 The commentary text, tables, figures, or illustrations shall not be used to interpret the code in a way that conflicts with the plain meaning of the code text, or to create ambiguity within the code that would not otherwise exist.

1.1.16 The English version in U.S. customary units is the official version of the code. In case of conflict between the official version and versions with SI units or in different languages, the official version governs.

1.2—Alternative systems

Sponsors of any system of design or construction or an alternative material to be applied within the scope of this code, the adequacy of which has been shown by successful use, analysis, or test, but which does not conform to or is not covered by this code, shall have the right to present the data on which their design is based to the building official or to a board of examiners appointed by the building official. This board shall have authority to investigate the data so submitted, to require tests, and to formulate rules governing design and construction of such systems to meet the intent of this code. These rules, if approved by the building official,

R1.2—Alternative systems

New methods of design, materials, and uses of materials should undergo a period of development before being specifically covered in a code. Hence, acceptable systems or components might be excluded from use by implication if means were not available to obtain acceptance. For systems considered under this section, specific tests, load factors, deflection limits, and other pertinent requirements should be set by the board of examiners and should be consistent with the intent of this document.

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and promulgated, shall be of the same force and effect as the provisions of this code.

1.3—Drawings and specifications

All designs for cast-in-place concrete construction not covered by the design provisions or prescriptive tables of this code shall require the seal of a licensed design professional.

1.4—Inspection

The construction of all concrete members covered by this code shall be inspected as required by the legally adopted general building code.

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CHAPTER 2—NOTATION AND DEFINITIONS

2.1—Notation

A_g = gross area of concrete section, in.^{2}
A_{st} = total area of longitudinal reinforcement, in.^{2}
A_v = effective area of all bar legs or wires (ties, stirrups, or crossties) within spacing s, in.^{2}
B_n = nominal bearing strength, psi
B_u = factored bearing strength, psi
b_w = web width, in.
d = distance from extreme compression fiber to centroid of tension reinforcement, in.
d_{agg} = nominal maximum size of coarse aggregate, in.
d_b = diameter of steel reinforcing bar, in.
D = effect of service dead load
E = effect of horizontal and vertical earthquake-induced forces
E_c = modulus of elasticity of concrete, psi
E_s = modulus of elasticity of reinforcement and structural steel, psi
f_c' = specified compressive strength of concrete, psi
f_r = modulus of rupture of concrete, psi
f_y = specified minimum yield strength of steel reinforcement, psi
H = effect of service load due to lateral earth pressure, groundwater pressure, or pressure of bulk materials, lb
L = effect of service live load
L_r = effect of service roof live load
M_n = nominal flexural strength at section, in.-lb
M_u = factored moment at section, in.-lb
P_n = nominal axial compressive strength at given eccentricity, psi
P_o = nominal axial load strength at zero eccentricity, psi
R = cumulative load effect of service rain load
S = effect of service snow load
S_m = elastic section modulus, in.^{3}
T = cumulative effects of service temperature, creep, shrinkage, differential settlement, and shrinkage compensating concrete
U = strength of a member or cross section required to resist factored loads or related internal moments and forces in such combinations as stipulated in this code
V_c = nominal shear strength provided by concrete, lb
V_n = nominal shear strength, lb
V_s = nominal shear strength provided by reinforcement, lb
V_u = factored shear force at section, lb
w_c = density, unit weight, of normalweight concrete, lb/ft^3
ϕ = strength reduction factor
ε_t = net tensile strain in extreme layer of longitudinal tension reinforcement at nominal strength, excluding strains due to effective creep, shrinkage, and temperature

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CHAPTER R2—NOTATION AND DEFINITIONS

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ε_{ty} = value of net tensile strain in the extreme layer of longitudinal tension reinforcement used to define a compression-controlled section

2.2—Definitions

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

above-grade walls—a wall that is more than 50 percent above grade and that encloses occupiable or conditioned space.

flat insulating concrete forms—insulating concrete forming system that produces a solid concrete wall of uniform thickness.

foundation walls—a wall that is more than 50 percent below grade and that encloses a crawl space or encloses occupiable or conditioned space such as a basement.

general residential code—code adopted in each jurisdiction; when adopted, this code supplements and forms part of the general residential code.

grade—the plane considered as the entrance surface to a structure which defines a structural member as exposed either to soil pressure and groundwater (below grade), or to wind and snow loads (above grade); also the prepared surface to receive a slab.

insulating concrete forms—concrete forming system using stay-in-place forms of rigid foam plastic insulation, a hybrid of cement and foam insulation, a hybrid of cement and wood chips, or other insulating material for constructing cast-in-place concrete walls.

macrofiber—fiber with an equivalent diameter greater than or equal to 0.012 in. for use in concrete.

plain concrete—structural concrete with no reinforcement other than as required for temperature and shrinkage.

reentrant corner—an internal or inside corner where a concrete member turns or wraps around on itself, creating an inside corner flanked by two outside corners or lengths of concrete.

reinforced concrete—structural concrete reinforced with no less than the minimum amount required by this code for strength-design capacity.

Seismic Design Category—classification assigned to a structure based on its occupancy category and the severity of the design earthquake ground motion at the site, as defined by the legally adopted general building code.

slump flow—measure of the unconfined flow potential of freshly mixed self-consolidating concrete or grout.

townhouse—single-family dwelling unit constructed in a group of three or more attached units in which each unit extends from foundation to roof and with open space on at least two sides.

unbalanced backfill height—difference between the heights of the finished grade on each side of a wall.

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R2.2—Definitions

unbalanced backfill height—Where an interior concrete slab is provided, the unbalanced backfill should be measured from the exterior finished grade level to the top of the interior concrete slab.

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wall height—distance from the top of the lower floor framing or slab to the bottom of the upper floor framing or slab.

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CHAPTER 3—REFERENCED STANDARDS

American Concrete Institute

ACI 318-19—Building Code Requirements for Structural Concrete and Commentary

American Society of Civil Engineers

ASCE/SEI 7-16—Minimum Design Loads for Buildings and Other Structures

ASTM International

ASTM A370-18—Standard Test Methods and Definitions for Mechanical Testing of Steel Products

ASTM A416/A416M-18—Standard Specification for Steel Strand, Uncoated Seven-Wire for Prestressed Concrete

ASTM A615/A615M-18—Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement

ASTM A706/A706M-16—Standard Specification for Low-Alloy Steel Deformed and Plain Bars for Concrete Reinforcement

ASTM A820/A820M-16—Standard Specifications for Steel Fibers for Fiber-Reinforced Concrete

ASTM A996/A996M-16—Standard Specification for Rail-Steel and Axle-Steel Deformed Bars for Concrete Reinforcement

ASTM C33/C33M-18—Standard Specification for Concrete Aggregates

ASTM C94/C94M-18—Standard Specification for Ready-Mixed Concrete

ASTM C150/C150M-19—Standard Specification for Portland Cement

ASTM C260/C260M-10(2016)—Standard Specification for Air-Entraining Admixtures for Concrete

ASTM C330/330M-17a—Standard Specification for Lightweight Aggregates for Structural Concrete

ASTM C494/C494M-16—Standard Specification for Chemical Admixtures for Concrete

ASTM C595/C595M-19—Standard Specification for Blended Hydraulic Cements

ASTM C618-19—Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete

ASTM C685/C685M-17—Standard Specification for Concrete Made by Volumetric Batching and Continuous Mixing

ASTM C989/C989M-18—Standard Specification for Slag Cement for Use in Concrete and Mortars

ASTM C1012/C1012M-18—Standard Test Method for Length Change of Hydraulic-Cement Mortars Exposed to a Sulfate Solution

ASTM C1017/C1017M-13—Standard Specification for Chemical Admixtures for Use in Producing Flowing Concrete

ASTM C1116/C1116M-10(2015)—Standard Specification for Fiber-Reinforced Concrete

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ASTM C1157/C1157M-17—Standard Performance Specification for Hydraulic Cement
ASTM C1218/C1218M-17—Standard Test Method for Water-Soluble Chloride in Mortar and Concrete
ASTM C1240-15—Standard Specification for Silica Fume Used in Cementitious Mixtures
ASTM C1579-13—Standard Test Method for Evaluating Plastic Shrinkage Cracking of Restrained Fiber Reinforced Concrete (Using a Steel Form Insert)
ASTM C1580-15—Standard Test Method for Water-Soluble Sulfate in Soil
ASTM C1602/C1602M-18—Standard Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete
ASTM C1798/C1798M-19—Standard Specification for Returned Fresh Concrete for Use in a New Batch of Ready-Mixed Concrete
ASTM D98-15—Standard Specification for Calcium Chloride
ASTM D422-63(2007)—Standard Test Method for Particle-Size Analysis of Soils
ASTM D516-16—Standard Test Method for Sulfate Ion in Water
ASTM D4130-15—Standard Test Method for Sulfate Ion in Brackish Water, Seawater, and Brines
ASTM D4318-17—Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils
ASTM D4829-11—Standard Test Method for Expansion Index of Soils
ASTM D7508/D7508M-10(2015)—Standard Specification for Polyolefin Chopped Strands for Use in Concrete

International Code Council
IRC-2018—International Residential Code

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CHAPTER 4—MATERIALS

4.1—Concrete

4.1.1 *Cementitious material*

4.1.1.1 Cement shall conform to ASTM C150/C150M, C595/C595M, or C1157/C1157M.

4.1.1.2 Fly ash and natural pozzolans shall conform to ASTM C618.

4.1.1.3 Slag cement shall conform to ASTM C989/C989M.

4.1.1.4 Silica fume shall conform to ASTM C1240.

4.1.2 *Aggregates*

4.1.2.1 Aggregates shall conform to ASTM C33/C33M or C330/C330M.

4.1.3 *Water*

4.1.3.1 Water used as mixing water in producing concrete shall conform to ASTM C1602/C1602M.

4.1.4 *Admixtures*

4.1.4.1 Air-entraining admixtures shall conform to ASTM C260/C260M.

4.1.4.2 Chemical admixtures shall conform to ASTM C494/C494M, except that admixtures for flowing concrete shall conform to ASTM C1017/C1017M.

4.1.4.3 Calcium chloride shall conform to ASTM D98.

4.1.5 *Recycled plastic concrete*

4.1.5.1 Recycled plastic concrete shall conform to ASTM C1798/C1798M.

4.2—Reinforcement

4.2.1 *Deformed reinforcement*

4.2.1.1 Deformed steel reinforcing bars shall conform to ASTM A615/A615M, A706/A706M, or A996/A996M. The yield strength of reinforcement shall be at least 40,000 psi.

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CHAPTER R4—MATERIALS

R4.2—Reinforcement

R4.2.1 *Deformed reinforcement*

Refer to Table R4.2.1 for bar information.

Table R4.2.1—Steel reinforcing bar information

Bar size, no.	Nominal diameter, in.	Nominal area, in.^{2}	Nominal weight, lb/ft	Hook size, in.	Development length, in.
				$6d_b$	$36d_b$
3	0.375	0.11	0.376	2.25	13.50
4	0.500	0.20	0.668	3	18.00
5	0.625	0.31	1.043	3.75	22.50
6	0.750	0.44	1.502	4.5	27.00

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4.2.2 *Prestressing steel*

4.2.2.1 Prestressing steel strand shall conform to ASTM A416/A416M.

4.2.3 *Surface conditions of reinforcement*

4.2.3.1 At the time concrete is placed, deformed bar and welded wire reinforcement shall be free of materials deleterious to development of bond strength between the reinforcement and the concrete.

4.2.4 *Fiber reinforcement*

4.2.4.1 Fiber-reinforced concrete shall conform to ASTM C1116/C1116M.

4.2.4.2 Macrofiber or microfiber shall conform to ASTM D7508/D7508M.

4.2.4.3 Steel fiber shall conform to ASTM C1116/C1116M and ASTM A820/A820M.

4.3—Formwork

4.3.1 Forms shall result in a final structure that conforms to shapes, lines, and dimensions of the members as required by the design drawings and specifications.

4.3.2 Forms shall provide a consistent surface and sufficiently tight joints so that leakage of concrete or mortar does not occur beyond the specified deviance for surface finish or which can be cleaned from the exposed concrete surface.

4.3.3 Forms shall be braced, tied, or secured together to maintain position and shape.

4.3.4 Forms and their supports shall be designed so as not to damage the previously placed structure.

4.3.5 Design of formwork shall include consideration of the following factors:
(a) Rate and method of placing concrete
(b) Construction loads, including vertical, horizontal, and impact loads
(c) Form requirements for construction of arches, blockouts, ledges, floor decks, or similar elements

4.4—Vapor retarder

4.4.1 A vapor retarder shall be installed under slabs that will receive a moisture-sensitive floor covering, coating, or adhesive, or where moisture-sensitive items will be stored in direct contact with a slab surface.

4.4.2 A 6 mil (0.006 in.) polyethylene or approved vapor retarder installed according to manufacturer's recommendations shall be placed between the concrete floor slab and

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R4.2.3 *Surface conditions of reinforcement*

Common surface contaminants such as concrete splatter, rust, form oil, or other release agents have been found not to be deleterious to bond (Taber et al. 2002; Suprenant and Malisch 1998).

R4.3—Formwork

R4.3.1 Refer to ACI 347R and ACI SP-4 for guidance on design and construction of formwork.

R4.4—Vapor retarder

R4.4.1 Vapor retarders are used to minimize moisture vapor transmission through slabs.

R4.4.2 Vapor retarder performance depends on its composition and the way it is installed. ASTM E1745 describes three classes of vapor retarders—Class A, B, and C—in

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base course or the prepared subgrade where no base course exists.

4.4.3 Vapor retarder shall be installed as follows:
(a) Base material shall be leveled and installed in a manner to minimize future settlement.
(b) Vapor retarder material shall be installed in an orientation to minimize joints/seams in the system.
(c) Vapor retarder shall be installed over footings and sealed to the foundation wall, grade beam, or slab, at an elevation consistent with the top of the slab.
(d) Vapor retarder shall be sealed around all penetrations using manufacturer's recommendations to create a continuous membrane between the bottom of the concrete slab and the base course or the prepared subgrade where no base course exists.
(e) Joints shall be lapped a minimum of 6 in. or as instructed by the manufacturer, and taped, sealed, or both, in accordance with manufacturer's recommendations.
(f) All damage to the vapor retarder shall be repaired prior to the concrete placement. Repairs shall conform to manufacturer's recommendations.

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order of highest to lowest requirements. Class C requirements are:
a) Water vapor permeance of 0.1 perms
b) Tensile strength of 13.6 lbf/in.
c) Puncture resistance of 475 g.

Membranes (greater than 6 mil) incorporating an adhesive layer to create a continuous bond to the concrete should be considered when there is possible settlement of the subgrade and loss of support of the membrane. Full adhesion of the membrane to the bottom of the slab prevents lateral vapor transmission.

R4.4.3 Vapor retarder placement requirements are intended to minimize the potential for water vapor to reach the concrete slab from the bottom or sides, when proper detailing is provided at slab edges and around isolated interior footing per manufacturer's recommendations, and when protected during concrete forming, placement, and finishing activities to help prevent damage to the membrane during construction. ASTM E1643 covers procedures for installing vapor retarders.

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CHAPTER 5—CONCRETE REQUIREMENTS

5.1—Exposure categories and classes

5.1.1 Exposure classes shall be assigned to concrete members based on the severity of the anticipated exposure for each category according to Table 5.1.1 or as determined by the local building official.

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CHAPTER R5—CONCRETE REQUIREMENTS

R5.1—Exposure categories and classes

R5.1.1 For Exposure Category RF, Exposure Class RF0 should be assigned to interiors and to footings, foundations, and basement walls that are constructed below grade. Concrete deteriorates when exposed to freezing-and-thawing cycles when any portion of the member is in a critically saturated condition during freezing weather. Basement and foundation walls that extend above grade less than 12 in. are unlikely to be saturated and could generally be assigned Exposure Class RF0. Exposure Class RF1 or RF2 should be assigned to vertical concrete members where excessive accumulation of ice and snow is not anticipated. Examples include above-grade walls, and columns. Exposure Class RF2 should be assigned to elevated or on-grade horizontal structurally reinforced concrete members that have a likelihood for prolonged contact with water to achieve a saturation state. Exposure class RF3 shall apply to nonstructurally reinforced soil-supported exterior slabs that are subject to freezeing-and-thawing cycling and deicing chemicals. Exposure Class RF4 should be assigned to the same type of structurally reinforced members as in Exposure Class RF2 but also when exposure to deicing chemicals is anticipated. Examples include above-grade columns and structural slabs exposed to salts in a marine environment. Depending on exposure conditions, garage floors can be classified as RF0 to RF3, but not RF4.

Exposure Category RS should be based on a measurement or knowledge of the concentration of soluble sulfates in soil or water that will be in contact with the relevant concrete member. The referenced test methods should be used to measure the sulfate concentrations. Other test methods can provide different results compared with the test methods referenced. Where the predominant soil sulfates are in the form of gypsum, the measured sulfate content will be higher, and these criteria will be conservative. In these cases, it is preferable that a test method that has a history of successful use in the geographic area of the project be permitted and approved by the local building official. Even though concentration of soluble sulfates in seawater will be high, members exposed to seawater should be assigned to Exposure Class RS1.

Exposure Category RC is only applicable to concrete members with structural reinforcement and not to plain concrete. The corrosion of the small amount of reinforcement used as temperature and shrinkage steel in plain or lightly reinforced (temperature and shrinkage steel) concrete members does not represent a problem whereby the structural safety of the member will be compromised.

The user of this document is encouraged to develop a table to assign exposure classes for each concrete member on a project as shown in Table R5.1.1.

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Table 5.1.1—Exposure categories and classes

Category	Severity	Class	Condition	
RF freezing and thawing	Not applicable	RF0	Concrete not exposed to freezing-and-thawing cycles	
	Moderate	RF1	Concrete exposed to moisture but not likely to be in a saturated condition when exposed to freezing-and-thawing cycles	
	Severe	RF2	Reinforced concrete exposed to moisture and with the potential of being in a saturated condition when exposed to freezing-and-thawing cycles	
	Very severe	RF3	Plain concrete exposed to moisture and deicing chemicals with the potential of being saturated when exposed to freezing-and-thawing cycles	
	Most severe	RF4	Reinforced concrete exposed to moisture and deicing chemicals with the potential of being saturated when exposed to freezing-and-thawing cycles	
RS sulfate			Water-soluble sulfate (SO_4) in soil, percent by mass*	Dissolved sulfate (SO_4) in water, ppm†
	Not applicable	RS0	$SO_4 < 0.10$	$SO_4 < 150$
	Moderate	RS1	$0.10 \leq SO_4 < 0.20$	$150 \leq SO_4 < 1500$ Seawater
	Severe	RS2	$0.20 \leq SO_4 \leq 2.00$	$1500 \leq SO_4 \leq 10,000$
	Very severe	RS3	$SO_4 > 2.00$	$SO_4 > 10,000$
RC‡ corrosion protection of reinforcement	Not applicable	RC0	Concrete dry or protected from moisture	
	Moderate	RC1	Concrete containing structural steel reinforcement and exposed to moisture but not to external sources of chlorides	
	Severe	RC2	Concrete containing structural steel reinforcement and exposed to moisture and an external source of chlorides from deicing chemicals, salt, brackish water, seawater, or spray from these sources	

*Percent sulfate by mass in soil shall be determined by ASTM C1580.

†Concentration of dissolved sulfates in water in ppm shall be determined by ASTM D516 or ASTM D4130.

‡Exposure Category RC applies to concrete members designed with reinforcing steel to resist loads. Does not apply to members with minimum steel reinforcement used for control of cracking due to temperature and shrinkage or to steel fiber-reinforced concrete.

The terms "plain concrete" and "reinforced concrete" refer to the use of structural reinforcement as found in 2.1 and 6.5.

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Table R5.1.1—Assigned exposure classes for concrete members

Concrete member*	Exposure class: RF freezing and thawing	RS sulfate	RC corrosion protection of reinforcement
Footings, foundations, and basement walls not exposed to weather	RF*†	RS*†	RC*†
Basement slabs and interior slabs on grade	RF*†	RS*†	RC*†
Footings, foundations, basement walls, and exterior walls exposed to weather	RF*†	RS*†	RC*†
Driveways, curbs, walks, patios, porches, steps, stairs, and unheated garage floors exposed to weather.	RF*†	RS*†	RC*†

*Depending on the project and or exposure conditions, fewer or additional concrete members may need to be defined for purposes of assigning exposure classes.

†For each concrete member, the corresponding exposure classifications should be placed in the appropriate cell and compared to determine the most restrictive requirements for concrete per 5.3.2.

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5.2—General requirements

5.2.1 The value of f_c' shall be the greatest of the values required by Table 5.1.1 based on exposure class or as required for structural strength. Concrete mixtures shall be proportioned to achieve the strength and to comply with the slump, air content, and cementitious materials limitations in this chapter.

R5.2—General requirements

R5.2.1 The specifier can require a higher specified strength than indicated in this code. The concrete supplier proportions concrete mixtures to achieve an average strength higher than the specified strength. The purchaser may request documentation demonstrating that the concrete being supplied will achieve the specified strength requirements. ACI 301 provides guidance for proportioning mixtures to meet specified compressive strength. If strength verification is required, cylinders shall be taken by an ACI Certified Field Technician or technician certified by an equivalent program during time of placement and shall be tested according ASTM C39/C39M. The concrete strength is considered satisfactory as long as averages of any three consecutive strength tests remain above the specified f_c' and no individual strength test falls below the specified f_c' by more than 500 psi.

5.3—Requirements for concrete mixtures

5.3.1 *Coarse aggregate size*—The nominal maximum size of coarse aggregate shall not exceed the smallest of (a), (b), and (c):

(a) one-fifth of the minimum wall thickness
(b) one-third of the cross-sectional dimension of a member
(c) three-fourths of the specified minimum clear spacing between reinforcing bars or clear cover

5.3.2 Based on the exposure classes assigned from 5.1.1, concrete mixtures shall comply with the most restrictive requirements according to Table 5.3.2.

R5.3—Requirements for concrete mixtures

R5.3.1 These aggregate size limitations do not apply (may be waived) if workability and consolidation methods facilitate the placement of concrete without honeycombs or voids. Selecting the largest maximum aggregate size consistent with workability and placement can reduce the paste and water content, resulting in reduced volume change, and typically results in a more economical mixture design.

R5.3.2 Concrete durability is improved by the introduction of air entrainment for resistance to freezing and thawing, the use of a *w/cm* less than or equal to 0.45 to reduce the permeability of concrete to water and deleterious chemicals, and proper curing (refer to 6.5).

The type and performance of water-reducing admixtures are selected based on the intended application and include both high-range water-reducing admixtures (HRWRAs) and mid-range water-reducing admixtures (MRWRAs). HRWRAs and MRWRAs result in large to moderate water reductions, respectively, in mixtures while maintaining greater workability (slump) without causing undue set retardation or increased air entrainment. If slump verification is required, slump testing shall be in accordance with ASTM C143/C143M. A traditional slump limit is not appropriate for self-consolidated concrete, where the consistency of the concrete is measured in terms of slump flow in accordance with ASTM C1611/C1611M. Slump flow in the range of 20 to 28 in. is generally used for residential concrete. Refer to ACI 237R for additional information.

For Exposure Class RS3, it is permitted to use cementitious materials in concrete mixtures that have a good service record in similar exposure conditions. When typical concrete mixtures used in the region have had good service history that exceeds approximately 5 years, testing mixtures in accordance with 5.4.2 to establish the additional quantity of pozzolans and slag cement is not necessary. The MS and HS designations for blended cements complying with ASTM C595/C595M and ASTM C1157/C1157M are tested to comply with the requirements of Table 5.4.2.

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Table 5.3.2—Concrete design requirements for exposure categories and classes

Exposure class	Maximum *w/cm*	Minimum f_c', psi*	Additional minimum requirements			
			Air content			Limits on cementitious materials
RF0	N/A	2500	N/A			N/A
RF1	0.55	3500	Table 5.4.1			N/A
RF2	0.45	4500	Table 5.4.1			N/A
RF3	0.45	4500	Table 5.4.1			Table 5.4.2
RF4	0.40	5000	Table 5.4.1			Table 5.4.2
			Cementitious materials†—types			Calcium chloride admixture
			ASTM C150/C150M	ASTM C595/C595M	ASTM C1157/C1157M	
RS0	N/A	2500	No type restriction	No type restriction	No type restriction	No restriction
RS1	0.50	2500	II	Types with (MS) designation	MS	No restriction
RS2	0.45	3000	V‡	Types with (HS) designation	HS	Not permitted
RS3	0.45	3000	V + pozzolan or slag§	Types with (HS) designation plus pozzolan or slag cement§	HS + pozzolan or slag cement§	Not permitted
			Maximum water-soluble chloride ion (Cl^-) content in concrete, percent by mass of cementitious materials‖ in reinforced concrete			
RC0	N/A	2500	1.00			
RC1	N/A	2500	0.30			
RC2	0.40	4000	0.15			

*Concrete compressive strength specified f_c' shall be based on 28-day tests per ASTM C39/C39M.

†Alternative combinations of cementitious materials of those listed in Table 5.4.2 shall be permitted when tested for sulfate resistance and meeting the criteria in 5.5.

‡Other available types of cement such as Type III or Type I are permitted in Exposure Classes RS1 or RS2 if the C_3A contents are less than 8 or 5 percent, respectively.

§The amount of the specific source of the pozzolan or slag to be used shall not be less than the amount that has been determined by service record to improve sulfate resistance when used in concrete containing Type V cement. Alternatively, the amount of the specific source of the pozzolan or slag to be used shall not be less than the amount tested in accordance with ASTM C1012/C1012M and meeting the criteria in 5.5.1.

‖Water-soluble chloride ion content that is contributed from the ingredients including water, aggregates, cementitious materials, and admixtures shall be determined on the concrete mixture by ASTM C1218/C1218M between 28 and 42 days.

Calcium chloride is a common and effective chemical admixture used to accelerate the setting time and rate of strength gain in cold weather construction. Its use is not permitted for members assigned with Exposure Classes RS2 and RS3 because of the potential for reducing the sulfate resistance of concrete. Its use may also be restricted for members with structural reinforcement assigned to Exposure Category RC. The limits for calcium chloride are stated in terms of chloride ions. When there is no other source of chlorides in the concrete ingredients, the limit on calcium chloride is approximately double the chloride ion limit (a 1 percent chloride ion limit is roughly equivalent to 2 percent calcium chloride). When calcium chloride use is restricted, non-chloride-based accelerating admixtures may be used for the same purpose.

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5.4—Additional requirements for freezing-and-thawing exposure

5.4.1 Normalweight concrete subject to Exposure Category RF1 through RF4 shall be air entrained with a total air content as indicated in Table 5.4.1. Tolerance on air content as delivered shall be ±1.5 percent. For f_c' greater than 5000 psi, reduction of air content indicated in Table 5.4.1 by 1.0 percent shall be permitted.

Table 5.4.1—Total air content for concrete assigned to exposure category RF

Nominal maximum aggregate size, in.*	Total air content, percent†	
	Exposure Class RF1	Exposure Classes RF2, RF3, and RF4
3/8	6	7.5
1/2	5.5	7
3/4	5	6
1	4.5	6
1-1/2	4.5	5.5
2	4	5
3	3.5	4.5

*Refer to ASTM C33/C33M for tolerance on oversized aggregate for various nominal maximum size designations.

†Tolerance on air content of ±1.5 percent shall be permissible.

5.4.2 The quantity of pozzolans, including fly ash and silica fume, and slag in concrete subject to Exposure Class RF3 shall not exceed the limits in Table 5.4.2.

Table 5.4.2—Requirements for concrete subject to exposure class RF3 and RF4

Cementitious materials	Maximum percent of total cementitious materials by weight*
Fly ash or other pozzolans conforming to ASTM C618	25
Slag conforming to ASTM C989/C989M	50
Silica fume conforming to ASTM C1240	10
Total of fly ash or other pozzolans, slag, and silica fume	50†
Total of fly ash or other pozzolans and silica fume	35†

*The total cementitious material also includes ASTM C150/C150M, C595/C595M, C845, and C1157/C1157M cement.

The maximum percentages above shall include:
(a) Fly ash or other pozzolans in Type IP blended cement, ASTM C595/C595M, or ASTM C1157/C1157M
(b) Slag used in the manufacture of an IS blended cement, ASTM C595/C595M, or ASTM C1157/C1157M
(c) ASTM C1240 silica fume present in a blended cement

†Fly ash or other pozzolans and silica fume shall constitute no more than 25 and 10 percent, respectively, of the total weight of the cementitious materials.

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R5.4—Additional requirements for freezing-and-thawing exposure

R5.4.1 Air-entrained concrete is essential for durability of concrete exposed to freezing-and-thawing cycles. A lower air content is justified for members assigned an Exposure Class RF1 because of the reduced likelihood that these members will be in a saturated condition when exposed to freezing and thawing cycles. Higher air contents than indicated in Table 5.4.1 will reduce strength and will not improve durability. If verification of air content is specified, testing shall be performed by an ACI Certified Field Technician or technician certified by an equivalent program and in accordance with ASTM C231/C231M or C173/C173M, as appropriate. If concrete fails to meet the required air entrainment at the lower end of the tolerance, steps should be taken to increase the air content.

R5.4.2 Table 5.4.2 establishes limitations on the amount of fly ash, other pozzolans, silica fume, and slag cement that can be included in concrete members assigned to Exposure Category RF3 and RF4. The quantity of these materials includes those in blended cements (ASTM C595/C595M and C1157/C1157M), separately added when batching concrete, or both. Exceeding these limitations may increase the potential for surface scaling. These limits on supplementary cementitious materials should not be applied to concrete members that are Class RF0, RF1, or RF2.

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5.5—Alternative cementitious materials for sulfate exposure

5.5.1 Alternative combinations of cementitious materials to those listed in Table 5.1.1 shall be permitted when tested for sulfate resistance and meeting the criteria in Table 5.5.1.

Table 5.5.1—Requirements for establishing suitability of cementitious materials combinations exposed to water-soluble sulfate

Exposure class	Maximum expansion when tested using ASTM C1012/C1012M		
	At 6 months	At 12 months	At 18 months
RS1	0.10 percent	—	—
RS2	0.05 percent	0.10 percent*	—
RS3	—	—	0.10 percent

*The 12-month expansion limit applies only when the measured expansion exceeds the 6-month maximum expansion limit.

5.6—Concrete cover

5.6.1 Concrete cover shall have a tolerance of ±3/8 in.

5.6.2 Concrete cover for slabs-on-ground shall be in accordance with 10.6.1.

5.6.3 Clear cover to reinforcement in concrete footings and walls shall be in accordance with 5.6.4 through 5.6.7.

5.6.4 Cover to reinforcement for concrete cast against earth shall be at least 3 in.

5.6.5 Cover to reinforcement for concrete not exposed to earth or weather shall be at least 3/4 in.

5.6.6 Cover to reinforcement, with a size not larger than a No. 5 bar or W31 or D31 wire, for concrete exposed to earth or weather shall be at least 1-1/2 in.

5.6.7 Cover to reinforcement, with a size not smaller than a No. 6 bar, for concrete exposed to earth or weather shall be at least 2 in.

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R5.5—Alternative cementitious materials for sulfate exposure

R5.5.1 Testing required to qualify cementitious materials in Table 5.5.1 takes considerable time and may not be possible with typical project schedules. It is permitted to use concrete mixtures with good service records in these circumstances. The expansion criteria for Exposure Classes RS1 and RS2 are the same as those for the MS and HS designations, respectively, for cements manufactured in accordance with ASTM C595/C595M and C1157/C1157M. Therefore, these blended cements may be an option in these exposure conditions.

R5.6—Concrete cover

R5.6.4 In some instances, it is advantageous or necessary for one or more sides of the formed concrete to be cast against an excavated earth surface. This section refers to these instances where the placing operation results in the concrete directly contacting the earth. Exceptions to this coverage limit include the placement of footing dowels in accordance with 8.2.2.1.1 when the dowels are not continuous as or are lap spliced with vertical reinforcement.

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CHAPTER 6—DESIGN OF STRUCTURAL CONCRETE

6.1—Scope

6.1.1 This chapter shall apply to design of structural concrete in structures or portions of structures defined in Chapter 1.

6.1.2 It shall be permitted to design a structural system comprising structural members not in accordance with this chapter, provided the structural system is approved in accordance with 1.2.

6.2—Materials

6.2.1 *Concrete design properties*

6.2.1.1 Modulus of elasticity, E_c, for concrete shall be permitted to be calculated as (a) or (b):

(a) For values of w_c between 90 and 160 lb/ft^3

$$E_c = w_c^{1.5} 33\sqrt{f_c'} \text{ (in psi)} \quad (6.2.1.1a)$$

(b) For normalweight concrete:

$$E_c = 57{,}000\sqrt{f_c'} \text{ (in psi)} \quad (6.2.1.1b)$$

6.2.1.2 Modulus of rupture, f_r, for concrete shall be calculated by

$$f_r = 7.5\lambda\sqrt{f_c'} \quad (6.2.1.2)$$

where, λ is 1 for normalweight concrete.

Alternatively, performance-based procedures may be employed as permitted in 1.2 to determine f_r.

6.2.2 *Steel reinforcement design properties*

6.2.2.1 Yield strength of bars and wires shall be determined by either (a) or (b):

(a) The offset method, using an offset of 0.2 percent in accordance with ASTM A370

(b) The yield point by the halt-of-force method, provided the bar or wire has a sharp-kneed or well-defined yield point

6.2.2.2 The stress below f_y shall be E_s times steel strain. For strains greater than that corresponding to f_y, stress shall be considered independent of strain and equal to f_y.

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CHAPTER R6—DESIGN OF STRUCTURAL CONCRETE

R6.1—Scope

R6.1.2 Some materials, structural members, or systems that may not be recognized in the provisions of the code may still be acceptable if they meet the intent of the code. Section 1.2 outlines the procedures for obtaining approval of alternative materials and systems.

R6.2—Materials

R6.2.2 *Steel reinforcement design properties*

R6.2.2.2 For deformed reinforcement, it is reasonably accurate to assume that the stress in reinforcement is proportional to strain below the specified yield strength f_y. The increase in strength due to the effect of strain hardening of the reinforcement is neglected for nominal strength calculations. In nominal strength calculations, the force developed in tension or compression reinforcement is calculated as:

if $\varepsilon_s < \varepsilon_y$ (yield strain)

$$A_s f_s = A_s E_s \varepsilon_s$$

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6.2.2.3 Modulus of elasticity, E_s, for steel reinforcement shall be taken as 29,000,000 psi.

6.3—Load factors and combinations

6.3.1 Required strength U shall be at least equal to the effects of factored loads in Table 6.3.1, with exceptions and additions in 6.3.3 through 6.3.7.

Table 6.3.1—Load factors and combinations

Load combination	Equation	Primary load
$U = 1.4D$	(6.3.1a)	D
$U = 1.2D + 1.6L + 0.5(L_r \text{ or } S \text{ or } R)$	(6.3.1b)	L
$U = 1.2D + 1.6(L_r \text{ or } S \text{ or } R) + (1.0L \text{ or } 0.5W)$	(6.3.1c)	L_r or S or R
$U = 1.2D + 1.0W + 1.0L + 0.5(L_r \text{ or } S \text{ or } R)$	(6.3.1d)	W
$U = 1.2D + 1.0E + 1.0L + 0.2S$	(6.3.1e)	E
$U = 0.9D + 1.0W$	(6.3.1f)	W
$U = 0.9D + 1.0E$	(6.3.1g)	E

6.3.2 The effect of one or more loads not acting simultaneously shall be investigated.

6.3.3 If applicable, L shall include (a) through (c):
(a) Concentrated live loads
(b) Vehicular loads
(c) Loads on handrails

6.3.4 If wind load W is based on allowable stress loads, $1.6W$ shall be used in place of $1.0W$ in Eq. (6.3.1d) and (6.3.1f), and $0.8W$ shall be used in place of $0.5W$ in Eq. (6.3.1c).

6.3.5 The structural effects of forces due to restraint of anticipated volume change and differential settlement T shall be considered in combination with other loads if the effects of T can adversely affect structural safety or performance. The load factor for T shall be established considering the uncertainty associated with the likely magnitude of T, the probability that the maximum effect of T will occur simultaneously with other applied loads, and the potential adverse consequences if the effect of T is greater than assumed. The load factor on T shall not have a value less than 1.0.

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if $\varepsilon_s \geq \varepsilon_y$

$$A_s f_s = A_s f_y$$

where ε_s is the value from the strain diagram at the location of the reinforcement.

R6.3—Load factors and combinations

The required strength U is expressed in terms of factored loads, or related internal moments and forces. The factor assigned to each load is influenced by the degree of accuracy to which the load effect usually can be calculated and the variation that might be expected in the load during the lifetime of the structure. Dead loads, because they are more accurately determined and less variable, are assigned a lower load factor than live loads. Load factors also account for variability in the structural analysis used to calculate moments and shears.

The code gives load factors for specific combinations of loads. In assigning factors to combinations of loading, some consideration is given to the probability of simultaneous occurrence. While most of the usual combinations of loadings are included, it should not be assumed that all cases are covered.

Due regard is to be given to the sign (positive or negative) in determining U for combinations of loadings, as one type of loading may produce effects of opposite sense to that produced by another type.

The load combinations with $0.9D$ are included for the case where a higher dead load reduces the effects of other loads. Consideration should be given to various combinations of loading to determine the most critical design condition.

If unusual circumstances require greater reliance on the strength of particular members than circumstances encountered in usual practice, some reduction in the stipulated strength reduction factors ϕ or increase in the stipulated load factors may be appropriate for such members.

R6.3.5 Several strategies can be used to accommodate movements due to volume change and differential settlement. Restraint of such movements can cause significant member forces and moments, such as tension in slabs and shear forces and moments in vertical members. Forces due to T effects are not commonly calculated and combined with other load effects. Rather, designs rely on successful past practices using compliant structural members and ductile connections to accommodate differential settlement and volume change movement while providing the needed resistance to gravity and lateral loads. Expansion joints and construction closure strips are used to limit volume change movements based on the performance of similar structures. Shrinkage and temperature reinforcement, which may exceed the required flexural reinforcement, is commonly

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proportioned based on gross concrete area rather than calculated force. Where structural movements can lead to damage of nonductile members, calculation of the predicted force should consider the inherent variability of the expected movement and structural response.

6.3.6 If lateral earth pressure H is present, it shall be included in the load combination equations of 6.3.1 in accordance with (a), (b), or (c):
(a) If H acts alone or adds to the primary load effect, it shall be included with a load factor of 1.6.
(b) If the effect of H is permanent and counteracts the primary load effect, it shall be included with a load factor of 0.9.
(c) If the effect of H is not permanent but, when present, counteracts the primary load effect, H shall not be included.

R6.3.6 The required load factors for lateral pressures from soil, water in soil, and other materials, reflect their variability and the possibility that the materials may be removed. The commentary of ASCE/SEI 7 includes additional useful discussion pertaining to load factors for H.

6.4—Strength reduction factors

6.4.1 Strength reduction factors ϕ shall be in accordance with Table 6.4.1a and 6.4.1b.

Table 6.4.1a—Strength reduction factors ϕ

	Action or structural member	ϕ
(a)	Moment, axial force, or combined moment and axial force	0.65 to 0.90 in accordance with Table 6.4.1b
(b)	Shear	0.75
(c)	Bearing	0.65
(d)	Plain concrete members	0.6

Table 6.4.1b—Strength reduction factors ϕ for moment, axial force, or combined moment and axial force

	Net tensile strain ε_t	Classification	ϕ*
(a)	$\varepsilon_t \leq \varepsilon_{ty}$	Compression-controlled	0.65
(b)	$\varepsilon_{ty} < \varepsilon_t < 0.005$	Transition†	$0.65 + 0.25(\varepsilon_t - \varepsilon_{ty})/(0.005 - \varepsilon_{ty})$
(c)	$\varepsilon_t \geq 0.005$	Tension-controlled	0.9

*Without spirals.

†For sections classified as transition, it shall be permitted to use ϕ corresponding to compression-controlled sections.

R6.4—Strength reduction factors

R6.4.1 The strength reduction factors in this code are compatible with the ASCE/SEI 7 load combinations, which are the basis for the required factored load combinations in 6.3.1.

6.5—Plain concrete

6.5.1 *General*

6.5.1.1 Plain concrete shall be permitted only in cases (a) through (c):
(a) Footings
(b) Walls
(c) Slabs supported on ground

R6.5—Plain concrete

R6.5.1 *General*

Because the strength and structural integrity of structural plain concrete members is based solely on the member size, concrete strength, and other concrete properties, use of structural plain concrete should be limited to members:
(a) That are primarily in a state of compression
(b) That can tolerate random cracks without detriment to their structural integrity
(c) For which ductility is not a performance requirement of design

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The tensile strength of concrete can be used in design of structural plain concrete members. Tensile stresses due to restraint from creep, shrinkage, or temperature effects are to be considered to avoid uncontrolled cracks or structural failure.

6.5.2 *Connection to other members*

6.5.2.1 Tension shall not be transmitted through outside edges, construction joints, contraction joints, or isolation joints of an individual plain concrete member.

6.5.2.2 Walls shall be braced against lateral translation.

6.5.3 *Required strength*

6.5.3.1 Required strength shall be calculated in accordance with the factored load combinations defined in 6.3.

R6.5.3 *Required strength*

R6.5.3.1 Plain concrete members are proportioned for adequate strength using factored loads and forces. When the design strength is exceeded, the cross section should be increased, the specified strength of concrete increased, or both, or the member designed as a reinforced concrete member in accordance with the code. An increase in concrete section may have a detrimental effect; stress due to load will decrease but stresses due to creep, shrinkage, and temperature effects may increase.

6.5.4 *Design strength*

6.5.4.1 *General*

6.5.4.1.1 For each applicable factored load combination, design strength at all sections shall satisfy (a) through (d). Interaction between load effects shall be considered.

(a) $\phi M_n \geq M_u$
(b) $\phi P_n \geq P_u$
(c) $\phi V_n \geq V_u$
(d) $\phi B_n \geq B_u$

R6.5.4 *Design strength*

R6.5.4.1 *General*

6.5.4.1.2 ϕ shall be determined in accordance with 6.4.

R6.5.4.1.2 The strength reduction factor ϕ for plain concrete design is the same for all strength conditions. Because both flexural tensile strength and shear strength for plain concrete depend on the variability of tensile strength characteristics of the concrete, with no reserve strength or ductility possible due to the absence of reinforcement, equal strength reduction factors for both bending and shear are considered appropriate.

6.5.4.1.3 Tensile strength of concrete shall be permitted to be considered in design.

R6.5.4.1.3 Flexural tension may be considered in design of plain concrete members to resist loads, provided the calculated stress does not exceed the permissible stress, and construction, contraction, or isolation joints are provided to relieve the resulting tensile stresses due to restraint of creep, shrinkage, and temperature effects.

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6.5.4.1.4 Flexure and axial strength calculations shall be based on a linear stress-strain relationship in both tension and compression.

6.5.4.1.5 No strength shall be assigned to shrinkage and temperature steel reinforcement.

6.6—Sectional strength of reinforced sections

6.6.1 *General*

6.6.1.1 This section shall apply to calculating nominal strength at sections of members, including (a) through (d):

(a) Flexural strength
(b) Axial strength or combined flexural and axial strength
(c) One-way shear strength
(d) Bearing strength

6.6.1.2 Design strength at a section shall be taken as the nominal strength multiplied by the applicable strength reduction factor ϕ given in 6.4.

6.6.2 *Design assumptions for moment and axial strength*

6.6.2.1 *Equilibrium and strain compatibility*

6.6.2.1.1 Equilibrium shall be satisfied at each section.

6.6.2.1.2 Strain in concrete and reinforcement shall be assumed proportional to the distance from neutral axis.

6.6.2.2 *Design assumptions for concrete*

6.6.2.2.1 Maximum strain at the extreme concrete compression fiber shall be assumed equal to 0.003.

6.6.2.2.2 Tensile strength of concrete shall be neglected in flexural and axial strength calculations.

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R6.5.4.1.5 Strength of reinforcement added to the plain concrete member to provide temperature and shrinkage cracking control should not be used.

R6.6—Sectional strength of reinforced sections

R6.6.1 *General*

The provisions in this chapter apply where the strength of the member is evaluated at critical sections.

R6.6.2 *Design assumptions for moment and axial strength*

R6.6.2.1 *Equilibrium and strain compatibility*

The flexural and axial strength of a member calculated by the strength design method of the code requires that two basic conditions be satisfied: 1) equilibrium; and 2) compatibility of strains. Equilibrium refers to the balancing of forces acting on the cross section at nominal strength. The relationship between the stress and strain for the concrete and the reinforcement at nominal strength is established within the design assumptions allowed by 6.6.2.

R6.6.2.1.2 Many tests have confirmed that it is reasonable to assume a linear distribution of strain across a reinforced concrete cross section (plane sections remain plane), even near nominal strength.

The strain in both reinforcement and in concrete is assumed to be directly proportional to the distance from the neutral axis. This assumption is of primary importance in design for determining the strain and corresponding stress in the reinforcement.

R6.6.2.2 *Design assumptions for concrete*

R6.6.2.2.1 The maximum concrete compressive strain at crushing of the concrete has been observed in tests of various kinds to vary from 0.003 to higher than 0.008 under special conditions. However, the strain at which strength of the member is developed is usually 0.003 to 0.004 for members of normal proportions, materials, and strength.

R6.6.2.2.2 The tensile strength of concrete in flexure (modulus of rupture) is a more variable property than the compressive strength and is approximately 10 to 15 percent

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of the compressive strength. Tensile strength of concrete in flexure is conservatively neglected in calculating the nominal flexural strength. The strength of concrete in tension, however, is important in evaluating cracking and deflections at service loads.

6.6.2.2.3 The relationship between concrete compressive stress and strain shall be represented by a rectangular, trapezoidal, parabolic, or other shape that results in prediction of strength in substantial agreement with results of comprehensive tests.

R6.6.2.2.3 At high strain levels, the stress-strain relationship for concrete is nonlinear (stress is not proportional to strain). As stated in 6.6.2.2.1, the maximum usable strain is set at 0.003 for design. The actual distribution of concrete compressive stress within a cross section is complex and usually not known explicitly. Research has shown that the important properties of the concrete stress distribution can be approximated closely using any one of several different assumptions for the shape of the stress distribution.

6.6.2.2.4 The equivalent rectangular concrete stress distribution in accordance with 6.6.2.2.4.1 through 6.6.2.2.4.3 satisfies 6.6.2.2.3.

R6.6.2.2.4 For design, the code allows the use of an equivalent rectangular compressive stress distribution (stress block) to replace the more detailed approximation of the concrete stress distribution.

6.6.2.2.4.1 Concrete stress of $0.85f_c'$ shall be assumed uniformly distributed over an equivalent compression zone bounded by edges of the cross section and a line parallel to the neutral axis located a distance a from the fiber of maximum compressive strain, as calculated by:

$$a = \beta_1 c \qquad (6.6.2.2.4.1)$$

R6.6.2.2.4.1 The equivalent rectangular stress distribution does not represent the actual stress distribution in the compression zone at nominal strength, but does provide essentially the same nominal combined flexural and axial compressive strength as obtained in tests (Mattock et al. 1961).

6.6.2.2.4.2 Distance from the fiber of maximum compressive strain to the neutral axis c shall be measured perpendicular to the neutral axis.

6.6.2.2.4.3 Values of β_1 shall be in accordance with Table 6.6.2.2.4.3.

R6.6.2.2.4.3 The values for β_1 were determined experimentally. The lower limit of β_1 is based on experimental data from beams constructed with concrete strengths greater than 8000 psi (Leslie et al. 1976; Karr et al. 1978).

Table 6.6.2.2.4.3—Values of β_1 for equivalent rectangular concrete stress distribution

f_c', psi	β_1	
$2500 \leq f_c' \leq 4000$	0.85	(a)
$4000 < f_c' < 8000$	$0.85 - (0.05(f_c' - 4000)/1000)$	(b)

6.6.3 *Flexural strength*

6.6.3.1 *General*

6.6.3.1.1 Nominal flexural strength M_n shall be calculated in accordance with the assumptions of 6.6.2.

6.6.3.1.2 M_n shall be calculated at the tension face:

$$M_n = f_r \times S_m \qquad (6.6.3.1.2)$$

where S_m is the corresponding elastic section modulus and M_n is the nominal flexural strength.

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6.6.4 *Axial strength or combined flexural and axial strength*

6.6.4.1 *General*

6.6.4.1.1 Nominal flexural M_n and axial strength P_n shall be calculated in accordance with the assumptions of 6.6.2.

6.6.4.2 *Maximum axial compressive strength*

6.6.4.2.1 Nominal axial compressive strength P_n shall not exceed $P_{n,max}$ in accordance with Table 6.6.4.2.1, where P_o is calculated by Eq. (6.6.4.2.1.2) for cast in place concrete members of plain concrete or reinforced concrete as defined in Section 2.2.

Table 6.6.4.2.1—Maximum axial strength

Member	Transverse reinforcement	$P_{n,max}$
Nonprestressed	Ties conforming to 6.6.4.3.2	$0.80P_o$

6.6.4.2.1.2 For cast-in-place concrete members and composite steel and concrete members, P_o shall be calculated by

$$P_o = 0.85f_c'(A_g - A_{st}) + f_yA_{st} \qquad (6.6.4.2.1.2)$$

where A_{st} is the total area of cast in place concrete longitudinal reinforcement.

6.6.4.3 Tie reinforcement for lateral support of longitudinal reinforcement in compression members shall satisfy 6.6.4.3.1 and 6.6.4.3.2.

6.6.4.3.1 *Lateral support of longitudinal bars using ties*

6.6.4.3.1.1 In any story, the bottom tie shall be located not more than one half the tie spacing above the top footing or slab.

6.6.4.3.1.2 In any story, the top tie shall be located not more than one-half the tie spacing below the lowest horizontal reinforcement in the slab. If beams frame into all sides of the column, the top tie shall be located not more than 3 in. below the lowest horizontal reinforcement in the shallowest beam.

6.6.4.3.2 *Ties*

6.6.4.3.2.1 Ties shall consist of a closed loop of deformed bar with spacing in accordance with (a) and (b):

(a) Clear spacing of at least $(4/3) \times d_{agg}$

(b) Center-to-center spacing shall not exceed the least of $16d_b$ of longitudinal bar, $48d_b$ of tie bar, and smallest dimension of member

(c) Rectilinear ties shall be arranged to satisfy (i) and (ii):

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R6.6.4 *Axial strength or combined flexural and axial strength*

R6.6.4.2 *Maximum axial compressive strength*

R6.6.4.2.1 To account for accidental eccentricity, the design axial strength of a section in pure compression is limited to 80 to 85 percent of the nominal axial strength. These percentage values approximate the axial strengths at eccentricity-to-depth ratios of 0.10.

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(i) Every corner and alternate longitudinal bar shall have lateral support provided by the corner of a tie with an included angle of not more than 135 degrees

(ii) No unsupported bar shall be farther than 6 in. clear on each side along the tie from a laterally supported bar

(d) Anchorage of rectilinear ties shall be provided by standard hooks that conform to ACI 318-19 Section 25.3.2 and engage a longitudinal bar. A tie shall not be made up of interlocking headed deformed bars.

6.6.4.3.2.2 Diameter of tie bar shall be at least (a) or (b):

(a) No. 3 enclosing No. 10 or smaller longitudinal bars

(b) No. 4 enclosing No. 11 or larger longitudinal bars

6.6.5 *One-way shear strength*

6.6.5.1 *General*

6.6.5.1.1 Nominal one-way shear strength at a section, V_n, shall be calculated by:

$$V_n = V_c + V_s \qquad (6.6.5.1.1)$$

6.6.5.1.2 Cross-sectional dimensions shall be selected to satisfy Eq. (6.6.5.1.2).

$$V_u \leq \phi(V_c + 8\sqrt{f_c'}\,b_w d) \qquad (6.6.5.1.2)$$

6.6.5.1.3 Effect of any openings in members shall be considered in calculating V_n.

6.6.5.2 V_c *calculation*

6.6.5.2.1 V_c shall be calculated by

$$V_c = 2\sqrt{f_c'}\,b_w d \qquad (6.6.5.2.1)$$

6.6.5.3 V_s *calculation*

6.6.5.3.1 Shear reinforcement satisfying (a) shall be permitted.

(a) Stirrups or ties perpendicular to longitudinal axis of member

6.6.5.3.2 For shear reinforcement in 6.6.5.5.3.1, V_s shall be calculated by

$$V_s = A_v f_y d/s \qquad (6.6.5.3.2)$$

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R6.6.5 *One-way shear strength*

R6.6.5.1 *General*

R6.6.5.1.1 In a member without shear reinforcement, shear is assumed to be resisted by the concrete. In a member with shear reinforcement, a portion of the shear strength is assumed to be provided by the concrete and the remainder by the shear reinforcement.

The shear strength provided by concrete, V_c, is assumed to be the same for members with and without shear reinforcement and is taken as the shear causing inclined cracking (Joint ACI-ASCE Committee 426 1973; MacGregor and Hanson 1969; Joint ACI-ASCE Committee 326 1962). After cracking, V_c is attributed to aggregate interlock, dowel action, and the shear transmitted across the concrete compression zone. The shear strength is based on an average shear stress over the effective cross section $b_w d$.

R6.6.5.1.2 The limit on cross-sectional dimensions in 6.6.5.1.2 is intended to minimize the likelihood of diagonal compression failure in the concrete and limit the extent of cracking.

R6.6.5.1.3 Openings in the web of a member can reduce its shear strength. The effects of openings are discussed in 4.7 of Joint ACI-ASCE Committee 426 (1973), Barney et al. (1977), and Schlaich et al. (1987).

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where s is the longitudinal spacing of the shear reinforcement, and A_v is given in 6.6.5.5.3.3.

6.6.5.3.3 For each rectangular tie, stirrup, or crosstie, A_v shall be the effective area of all bar legs or wires within spacings.

6.6.6 *Bearing*

6.6.6.1 Nominal bearing strength B_n shall be calculated in accordance with Table 6.6.6.1, where A_1 is the loaded area, and A_2 is the area of the lower base of the largest frustum of a pyramid, cone, or tapered wedge contained wholly within the support and having its upper base equal to the loaded area. The sides of the pyramid, cone, or tapered wedge shall be sloped 1 vertical to 2 horizontal.

Table 6.6.6.1—Nominal bearing strength

Geometry of bearing area	B_n		
Supporting surface is wider on all sides than the loaded area	Lesser of (a) and (b)	$\sqrt{A_1 + A_2}\,(0.85f_c'A_1)$	(a)
		$2(0.85f_c'A_1)$	(b)
Other cases		$0.85f_c'A_1$	(c)

6.7—Design limits

6.7.1 Design limits are specified in the respective member chapter.

6.8—Reinforcement detailing

6.8.1 Concrete cover for wall vertical reinforcement shall be in accordance with 5.6.

6.8.2 Development lengths of deformed reinforcement shall be in accordance with Table 6.8.2

Table 6.8.2—Required development lengths for deformed reinforcement

Spacing and cover	No. 6 and smaller bars and deformed wires	No. 7 and larger bars
Clear spacing of bars or wires being developed or lap spliced not less than d_b, clear cover at least d_b, and stirrups or ties throughout ℓ_d not less than the code minimum or Clear spacing of bars or wires being developed or lap spliced at least $2d_b$ and clear cover at least d_b	$f_y/25\sqrt{f_c'}d_b$	$f_y/20\sqrt{f_c'}d_b$
Other cases	$f_y/50\sqrt{f_c'}d_b$	$f_y/40\sqrt{f_c'}d_b$

6.8.3 Spacing of reinforcement shall be a maximum of 48 in.

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R6.6.6 *Bearing*

R6.6.6.1 The permissible bearing stress of $0.85f_c'$ is based on tests reported in Hawkins (1968). Where the supporting area is wider than the loaded area on all sides, the surrounding concrete confines the bearing area, resulting in an increase in bearing strength. A_1 is the loaded area but not greater than the bearing plate or bearing cross-sectional area.

Where the top of the support is sloped or stepped, advantage may still be taken of the condition that the supporting member is larger than the loaded area, provided the supporting member does not slope at too great an angle.

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CHAPTER 7—CONCRETE PRODUCTION AND PLACEMENT

7.1—Concrete

7.1.1 Ready mixed concrete shall be ordered, batched, mixed, and transported in accordance with ASTM C94/C94M.

7.1.2 Concrete produced by volumetric batching and continuous mixing shall be batched and mixed in accordance with ASTM C685/C685M.

7.1.3 Frozen materials or materials containing ice shall not be used.

7.2—Placement

7.2.1 Specified concrete properties in accordance with 5.3 and 5.4 shall be provided at point of delivery.

7.2.2 Concrete shall be placed by methods that maintain the properties specified in Chapter 5.

7.2.3 Concrete that is partially hardened or contaminated by foreign materials shall not be placed.

7.2.4 Areas prepared for the placement of concrete shall be free of debris and contaminants. Confined footing areas shall also be free of water.

7.2.5 Concrete shall be consolidated by suitable means during placement and shall be worked around embedded items, reinforcement, and into corners of the forms.

7.3—Form removal

Forms shall be removed in a manner that does not impair safety and serviceability of the structure. Concrete exposed by form removal shall have sufficient strength not to be damaged by the removal operation. Stay-in-place forms shall not be removed.

7.4—Finishing

Surface defects that expose reinforcement shall be repaired. Surface defects greater than 50 in.^{2} with depths greater than 0.5 in. shall be repaired.

COMMENTARY

CHAPTER R7—CONCRETE PRODUCTION AND PLACEMENT

R7.1—Concrete

R7.1.1 The user should refer to ACI 304R for additional recommendations for the measuring, mixing, transporting, and placing of concrete.

R7.1.2 The user should refer to ACI 304.6R for additional recommendations for volumetric batching and the continuous mixing of concrete.

R7.2—Placement

R7.2.1 Experience has shown that the 1-1/2-hour discharge time can be exceeded while maintaining the specified concrete properties during placing operations.

ASTM C94/C94M allows for the addition of water up to the allowable maximum *w/cm* or water-reducing admixtures, or both, before discharge.

R7.2.3 Partially hardened is in reference to plastic concrete, which has reached a state of rapid hydration, where initial set has begun, can no longer be delayed by chemicals, or both.

R7.2.4 Refer to 7.6 for the placement of concrete on frozen material. If the footing form permits water to exit, the hydraulic pressure of the concrete placement is sufficient to displace the water from the formed areas and prevent segregation.

R7.2.5 Recommendations for consolidation of residential concrete are given in detail in ACI 332.1R, and for all forms of concrete in ACI 309R. Usually, concrete with slump greater than 7 in. and self-consolidating concrete are not vibrated; however, minimal vibration may be required to minimize surface defects. Care should be taken to avoid segregation of the concrete due to over-vibration.

R7.4—Finishing

The general finishing standards for cast-in-place concrete are separated into three classifications based on application. These include structural concrete, non-air-entrained slabs,

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and air-entrained slabs. Generally, the surface of structural concrete is simply floated after placement. Slabs that are non-air-entrained can be finished per the request of the owner. Unless otherwise specified, final finishing can be a float, trowel, or broom finish. Where slabs are required to be air entrained, hard trowel finishing, either by hand or machine, is not recommended. Hard trowel finishing can reduce traction and may result in surface defects and poor durability under freezing-and-thawing conditions. Instead, final finishing may be obtained via a float, trowel, or broom. Most air-entrained slabs are struck off to grade, bull floated, and textured. The texture can be a broom, tine, burlap drag, or other texturing techniques.

7.5—Curing

After placement, concrete shall be protected to maintain proper moisture and temperature. Protection shall ensure that excessive water evaporation does not impair required strength or serviceability of the member. Sections 7.6 and 7.7 shall be followed in cold and hot weather conditions, respectively.

R7.5—Curing

Proper curing is required to produce the concrete's ultimate strength, durability, and other desirable properties of hardened concrete. The objectives of curing are to reduce the loss of moisture from concrete and, when needed, to supply additional moisture and maintain a favorable concrete temperature for a sufficient period of time to allow the concrete to reach initial critical strengths. Common methods include wet burlap, polyethylene sheets, blankets, foggers, and curing compounds. References to these methods and other curing techniques can be found in ACI 332.1R and ACI 308R. Note that wet curing methods can add substantial drying time to the project schedule and should be considered carefully where moisture-intolerant floor coverings are to be used.

7.6—Protection of concrete during cold weather

7.6.1 When cold weather is expected, damage to concrete due to early-age freezing shall be prevented to allow for proper strength development.

7.6.2 Concrete materials, reinforcement, forms, and any earth with which concrete is to come in contact shall be free from ice, snow, and frost.

R7.6—Protection of concrete during cold weather

R7.6.1 Cold weather is defined by ACI 306R to occur when air temperature has fallen to, or is expected to fall below 40°F during the protection period, and the protection period is defined as the time required to prevent concrete from being affected by exposure to cold weather. Concrete that is frozen before achieving a compressive strength of 500 psi will not achieve the compressive strength that it would have reached had it been protected. A maturity curve (ASTM C1074) for a particular mixture may be available from or can be developed by the concrete supplier and can be used to determine when the compressive strength of the concrete mixture can be expected to reach 500 psi. Further information demonstrating the effectiveness of maturity testing as an accurate prediction method for early-age in-place strength and mixture performance can be obtained from the Concrete Foundations Association (2004). Refer to ACI 306R and ACI 306.1 for further information regarding cold-weather concrete practices.

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7.7—Temperature limits for concrete as delivered in hot weather

7.7.1 Concrete materials and production methods shall be selected so that the concrete temperature at delivery complies with the specified temperature limits.

7.7.2 Handling, placing, protection, and curing procedures shall limit concrete temperatures or water evaporation that could reduce strength, serviceability, and durability of member or structure.

7.7.3 Use of synthetic macrofibers, synthetic microfibers, or both, shall be permitted to control plastic shrinkage cracking in hot weather.

COMMENTARY

R7.7—Temperature limits for concrete as delivered in hot weather

R7.7.1 ACI 301 and ACI 305.1 limit the maximum temperature to 95°F at the time of placement. Conditions such as wind, high ambient temperature, and low relative humidity can affect the evaporation rate and the workability and setting time of concrete. When high ambient temperatures exist, concrete should be delivered as cool as practical; the temperature of the concrete should not exceed 95°F. For more information on placing concrete in hot weather, refer to ACI 305R.

R7.7.2 Consult manufacturer's data for suggested dosage rates to reduce plastic shrinkage cracking when measured in accordance with ASTM C1579.

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CHAPTER 8—FOOTINGS

8.1—Scope

8.1.1 Provisions of this chapter shall apply to isolated footings and continuous wall footings of buildings within the scope of this code.

8.1.2 Design of concrete footings shall be in accordance with Chapter 6.

8.2—General

8.2.1 *Materials*

8.2.1.1 Design properties for concrete shall be selected in accordance with Chapter 5 and 6.2.1.

8.2.1.2 Design properties for steel reinforcement shall be selected to be in accordance with 6.2.2.

8.2.2 *Connection to other members*

8.2.2.1 *Wall-to-footing joint*

Wall-to-footing connections located in SDC A, B, or C shall be constructed in accordance with 8.2.2.1.1 or 8.2.2.1.2. Wall-to-footing connections located in SDC D, E, or F shall be constructed in accordance with 8.2.2.1.2.

8.2.2.1.1 A continuous keyway shall be formed in the footing and shall be located within the middle one-third of the wall. The keyway specified dimensions shall be at least 1-1/2 in. deep and 1-1/2 in. wide at the top.

8.2.2.1.2 A vertical No. 4 dowel shall extend at least $36d_b$ into the wall and 6 in. into the footing at a maximum of 24 in. on center along the footing. To facilitate positioning before concrete placement, vertical dowels are permitted to be driven into the grade in the bottom of the footing.

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CHAPTER R8—FOOTINGS

R8.1—Scope

Footings are provided under columns, also called piers, and walls when calculations show that omitting the footing will result in soil pressures that exceed the allowable soil-bearing pressures. Footings are also provided to facilitate the placement of forms. Soil-bearing pressures can be referenced in the general building code or obtained by conducting a geotechnical investigation where fill or otherwise unusual soil conditions are encountered.

R8.2—General

8.2.2 *Connection to other members*

8.2.2.1 *Wall-to-footing joint*

R8.2.2.1.1 Refer to Fig. R8.2.2.1.1.

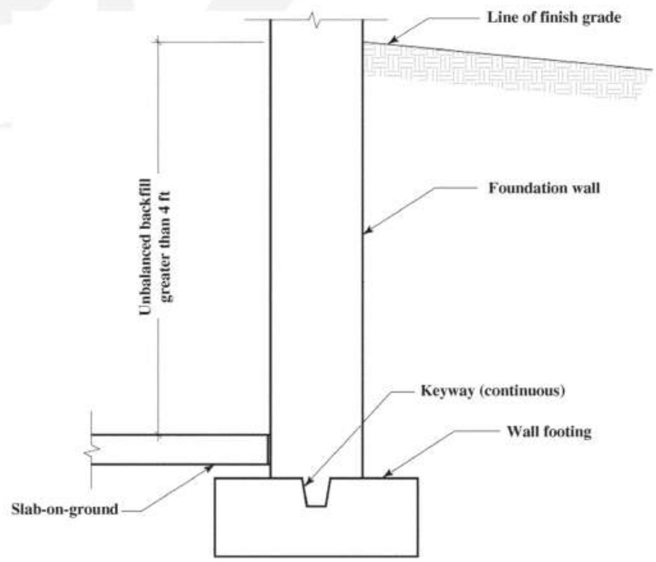

Fig. R8.2.2.1.1—Wall-to-footing joint with keyway.

R8.2.2.1.2 Refer to Fig. R8.2.2.1.2.

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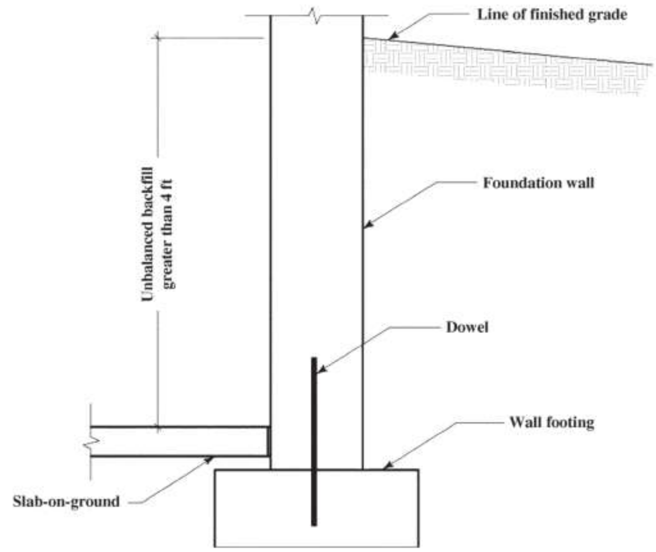

Fig. R8.2.2.1.2—Wall-to-footing joint with dowel.

8.2.3 *Longitudinal reinforcement in continuous footings in SDC D, E, and F*

8.2.3.1 *Continuous footings with stem walls*

8.2.3.1.1 Footings with stem walls shall contain at least two longitudinal No. 4 bars, one within 12 in. of the top of the stem wall and one located 3 to 4 in. from the bottom of the footing.

8.2.3.2 *Slabs-on-ground with turned-down footings*
(a) If a horizontal construction joint exists between the slab thickness and the footing thickness (Fig. R8.2.3.2), reinforcement shall consist of the following:

(i) A minimum of one No. 4 longitudinal bar shall be placed in the slab section and the footing section.

(ii) Vertical ties consisting of No. 3 or larger, spaced a maximum of 48 in. on center, shall pass through the construction joint. Vertical ties shall have hook ends to engage the longitudinal bars and be secured in place. Hooks shall have a minimum inside bend diameter of $6d_b$ and may be 90- or 180-degree in bend.

(iii) Minimum cover shall be in accordance with 5.6.

(b) If the slab and footing are cast monolithically, the footing shall be reinforced by one of the following:

(i) A minimum of two longitudinal No. 4 bars, one located at the top, and one located at the bottom of the footing

(ii) A minimum of two longitudinal No. 4 bars located in the middle one-third of the footing depth

(iii) A minimum of one longitudinal No. 5 bar located in the middle one-third of the footing depth

R8.2.3.2 *Slabs-on-ground with turned-down footings*
Refer to Fig. R8.2.3.2.

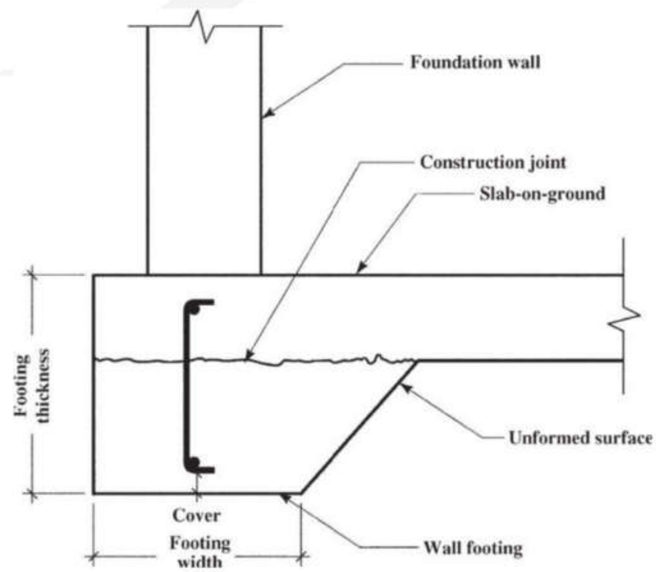

Fig. R8.2.3.2—Thickened slab footing with horizontal construction joint.

8.2.4 *Footings not continuously supported*

R8.2.4 *Footings not continuously supported*
Conditions where wall footings are not continuously supported are commonly found around sanitary or water

pipes where poorly compacted soil settles below the bottom surface of the footing. The backfill should be compacted by tamping or by use of a mechanical compactor to the level of the bottom surface of the footings to obtain adequate bearing and minimize the likelihood of detrimental settlement.

8.2.4.1 Trenches under footings shall be backfilled to prevent movement of the adjacent soil and compacted to match the adjacent soil conditions.

R8.2.4.1 Areas where soils have settled beneath existing continuous footing should be compacted using appropriate means for granular or cohesive soils where accessible. Thereafter, low-strength cementitious or flowable fill or other acceptable approaches can be used to reestablish full support beneath continuous footings. Critical difficult areas have also been underpinned.

There are conditions and situations when soil disturbance occurs beneath an existing, in place, continuous footing and foundation wall. Soil disturbance occurs during placement of utilities under footings, rain and wash-out events, high groundwater flows, over excavations, and similar conditions may cause loose/soft soil zone(s).

Soils that have settled beneath continuous footings must be probed to determine whether the soft zone is less than 36 in. deep and no more than 36 in. in length. Conditions meeting these criteria can be recompacted with handheld equipment; high frequency vibratory plates on granular soils and low frequency/high impact on cohesive soils. Optimum compaction results are achieved in 4 to 12 in. lifts depending upon soil moisture content and its characteristic. After soil recompaction is achieved, low-strength flowable fill or similar techniques can be placed under the footing to reestablish bearing capacity.

Settlement conditions whereby the soft soil zone is 36 in. or greater in depth and width, a geotechnical engineer should be consulted for guidance; underpinning or a similar engineered solution is commonly considered to reestablish continuous foundation support.

8.2.4.2 Where an unsupported wall footing section does not exceed a 3 ft span, at least two No. 4 reinforcing bars shall be securely positioned in the bottom of the footing and extend at least 18 in. into the supported sections on both sides. Reinforcing bars shall have a cover as specified in 5.6.4.

Unsupported wall footing spans exceeding 3 ft are beyond the scope of this code.

8.2.5 *Discontinuous wall footings*

A wall footing shall be permitted to be discontinuous where an elevation change occurs in continuous footings with stem walls (8.2.3.1) or slabs on ground with turned-down footings (8.2.3.2).

R8.2.5 *Discontinuous wall footings*

Elevation changes, commonly called steps, occur in locations such as walkout basements, grade changes, and transitions to garage foundations. At such locations, the wall spans the horizontal discontinuity of the footing (refer to Fig. R8.2.5).

8.2.5.1 A horizontal discontinuity of up to 4 ft shall be permitted and conform to the reinforcement requirements of 9.2.6.

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8.2.5.2 Horizontal footing discontinuities greater than 4 ft are beyond the scope of this code.

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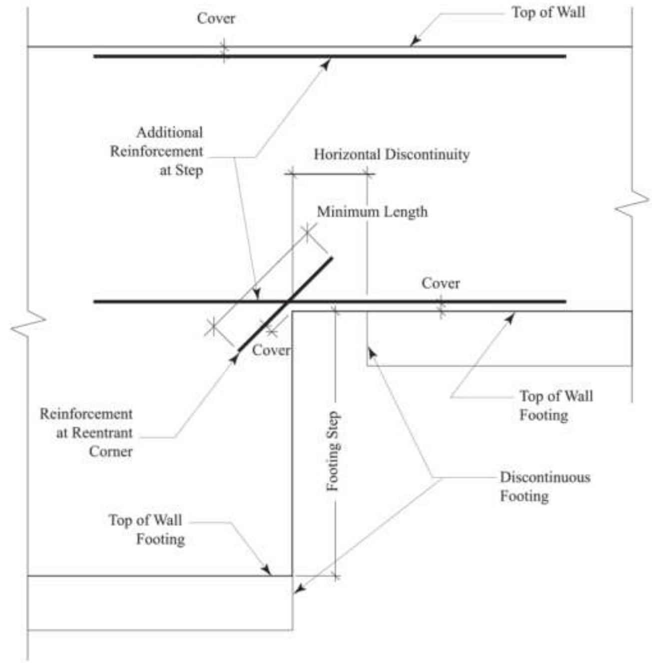

Fig. R8.2.5—Discontinuous wall footing and additional wall reinforcement.

8.3—Design limits

8.3.1 Continuous footings shall be at least 9.5 in. wide, with the wall positioned within designed tolerances on the footing.

R8.3—Design limits

R8.3.1 The minimum footing width of 9.5 in. is based on the minimum wall thickness permissible by this code of 5.5 in., as specified in 9.3.1, and the minimum extension beyond the wall thickness, as specified in 8.6.

8.3.2 Minimum depth of the footing shall be 6 in. The maximum projection of an unreinforced footing beyond the wall face shall not exceed the thickness of the footing unless transverse reinforcement is provided.

8.3.3 *Isolated footings*

8.3.3.1 Isolated footing dimensions shall be at least the applicable dimensions specified in 8.6.1.

R8.3.3 *Isolated footings*

Refer to Fig. R8.3.3 for typical locations of an isolated footing, also called pier or column footings. Tables 8.6.1g and 8.6.1h prescribe the minimum requirements for isolated footings with single or multiple spans defining the amount of tributary area that affects the load to the footing. A single span defines a footing loaded from one side only by a beam condition. A multiple span defines a footing supporting a member loaded two beam span conditions.

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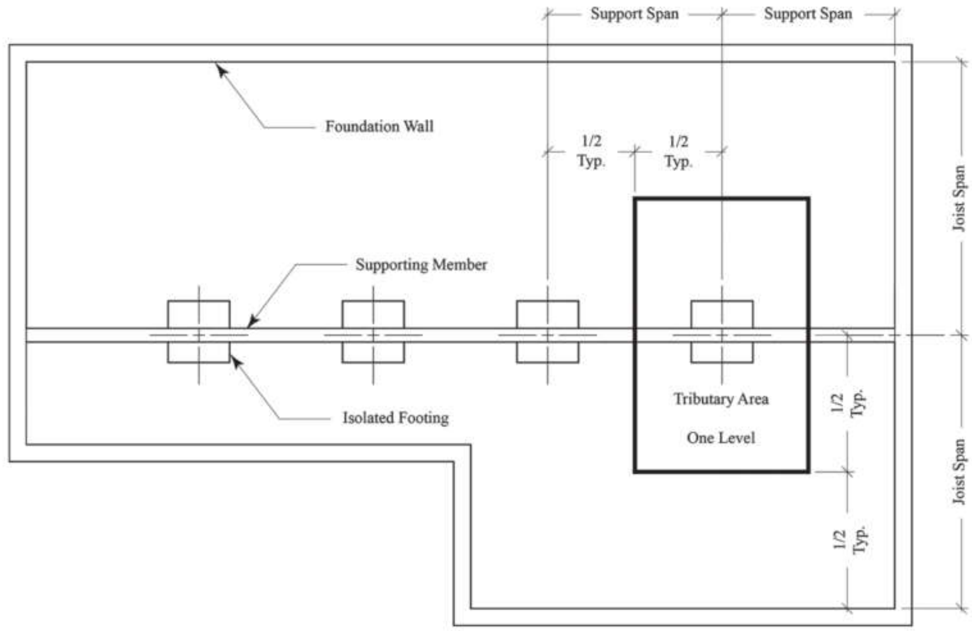

Fig. R8.3.3—Tributary area for isolated footing.

8.4—Required strength

8.4.1 Required strength shall be calculated in accordance with the factored load combination in 6.3.

8.4.2 Specified maximum attributes for design of prescriptive footings shall be as specified in Table 8.4.2.

Table 8.4.2—Specified maximum attributes for prescriptive design of footings

Attribute		Maximum limitation
General	Plan dimension	60 ft
	Ground snow load	70 lb/ft^2
Foundations	Equivalent fluid density of soil	100 lb/ft^3 (refer to Chapter 8)
	Presumptive soil-bearing value	1500 to 4000 lb/ft^2 (refer to 8.2.1.1)
Walls	Unsupported wall height, per story	10 ft
	Unbalanced backfill height	9 ft
Floor loads	Floor dead load	15 lb/ft^2
	First-floor live load	40 lb/ft^2
	Second- and third-floor live loads	30 lb/ft^2
Roof loads	Roof and ceiling dead load	15 lb/ft^2
	Roof snow load	70 lb/ft^2
	Attic live load	20 lb/ft^2
Maximum clear span	Floor span (unsupported)	32 ft
	Beam span (unsupported)	16 ft
	Roof span (unsupported)	40 ft

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8.5—Design

8.5.1 Footings shall be designed by one of the following methods:

(a) Design procedure of Chapter 6.

(b) Prescriptive tables in 8.6.

8.5.2 ϕ shall be determined in accordance with 6.4.

8.6—Prescriptive design tables

8.6.1 For footings that meet the requirements of 8.4.2, wall footing width shall be at least the greater of the applicable dimensions specified in Tables 8.6.1a through 8.6.1h or the supported wall thickness plus 4 in. Tables 8.6.1a through 8.6.1h are based on the following conditions:

(a) Maximum attic load: 20 psf

(b) Maximum second- and third-floor live load: 30 psf each

(c) Maximum foundation wall dead load: 100 psf (8 in. wall)

(d) Maximum floor dead load: 15 psf

(e) Maximum interior wall dead load: 15 psf (wood framing)

(f) Maximum first-floor live load: 40 psf

(g) Maximum roof and ceiling dead load: 20 psf

(h) Maximum floor-to-floor height: 10 ft

(i) Maximum foundation wall height: 10 ft

(j) Maximum roof overhang: 2 ft

(k) Minimum f_c': 2500 psi

(l) Minimum f_y: 60,000 psi

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R8.6—Prescriptive design tables

R8.6.1 Footing widths need to project a minimum of 2 in. on each side of the wall to support the forming system. The footing width projection is measured from the face of the concrete wall to the edge of the footing. The values in Tables 8.6.1a through 8.6.1h are consistent with light frame wood construction roof and floor with second and third floors used for sleeping areas.

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Table 8.6.1a—Minimum exterior footing width (in.) for clear span and interior supported footing for 15 psf wall dead load*

Wall dead load† = 15 psf		One-story/slab				One-story with basement				Two-story with basement				Three-story with basement			
Soil bearing capacity, psf	Roof and floor span, maximum, ft	Roof live load, psf				Roof live load, psf				Roof live load, psf				Roof live load, psf			
		20	30	50	70	20	30	50	70	20	30	50	70	20	30	50	70
1500	16	9.5	9.5	9.5	9.5	18	19	20	21	21	22	24	25	25	26	27	28
	24	9.5	9.5	10	11	21	22	24	26	26	27	29	30	30	32	33	35
	32	9.5	10	12	14	24	25	28	30	30	31	34	36	36	37	40	42
2000	16	9.5	9.5	9.5	9.5	14	14	15	16	17	17	18	19	19	20	21	21
	24	9.5	9.5	9.5	9.5	16	17	18	19	20	20	22	23	23	24	25	26
	32	9.5	9.5	9.5	11	18	19	21	22	23	24	25	27	27	28	30	31
3000	16	9.5	9.5	9.5	9.5	9.5	10	10	11	11	11	12	13	13	13	14	14
	24	9.5	9.5	9.5	9.5	11	11	12	13	13	14	15	15	16	16	17	18
	32	9.5	9.5	9.5	9.5	12	13	14	15	15	16	17	18	18	19	20	21
4000	16	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	10	10	10	11	11
	24	9.5	9.5	9.5	9.5	9.5	9.5	9.5	10	10	10	11	12	12	12	13	13
	32	9.5	9.5	9.5	9.5	9.5	10	11	11	12	12	13	14	14	14	15	16

*This table is applicable only when the structure is not assigned to Seismic Design Category D, E, or F.

†Wall dead load: light frame wood construction only.

Table 8.6.1.b—Minimum exterior footing width (in.) for clear span and interior supported footing for 45 psf wall dead load*

Wall dead load† = 45 psf		One-story/slab				One-story with basement				Two-story with basement				Three-story with basement			
Soil bearing capacity, psf	Roof and floor span, maximum, ft	Roof live load, psf				Roof live load, psf				Roof live load, psf				Roof live load, psf			
		20	30	50	70	20	30	50	70	20	30	50	70	20	30	50	70
1500	16	9.5	9.5	10	11	21	21	22	24	27	27	28	30	33	33	34	36
	24	9.5	10	12	14	24	25	26	28	31	32	33	35	38	39	41	42
	32	11	12	14	16	27	28	30	32	35	36	38	41	44	45	47	49
2000	16	9.5	9.5	9.5	9.5	16	16	17	18	20	21	21	22	25	25	26	17
	24	9.5	9.5	9.5	10	18	19	20	21	23	24	25	26	29	29	31	32
	32	9.5	9.5	11	12	20	21	23	24	26	27	29	31	33	34	35	37
3000	16	9.5	9.5	9.5	9.5	11	11	11	12	14	14	14	15	17	17	17	18
	24	9.5	9.5	9.5	9.5	12	13	13	14	16	16	17	18	19	20	21	21
	32	9.5	9.5	9.5	9.5	14	14	15	16	18	18	19	21	22	23	24	25
4000	16	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	10	11	11	11	13	13	13	13
	24	9.5	9.5	9.5	9.5	9.5	9.5	10	10	12	12	13	13	15	15	15	16
	32	9.5	9.5	9.5	9.5	10	11	12	12	13	14	15	15	17	17	18	19

*This table is applicable only when the structure is not assigned to Seismic Design Category D, E, or F.

†Wall dead load: light frame wood construction with brick veneer above the foundation.

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Table 8.6.1c—Minimum exterior footing width (in.) for clear span and interior supported footing for 100 psf wall dead load*

Wall dead load† = 100 psf		One-story/slab				One-story with basement				Two-story with basement				Three-story with basement			
Soil bearing capacity, psf	Roof and floor span, maximu m, ft	Roof live load, psf				Roof live load, psf				Roof live load, psf				Roof live load, psf			
		20	30	50	70	20	30	50	70	20	30	50	70	20	30	50	70
1500	16	12	13	14	15	25	26	27	28	35	36	37	38	46	46	48	49
	24	14	15	16	18	28	29	31	32	40	41	42	44	51	52	54	56
	32	15	16	19	21	31	32	34	37	44	45	47	49	57	58	60	62
2000	16	9.5	10	11	12	19	19	20	21	27	27	28	29	35	35	36	37
	24	10	11	12	14	21	22	23	24	30	31	32	33	39	39	41	42
	32	12	12	14	16	23	24	26	28	33	34	36	37	43	44	45	47
3000	16	9.5	9.5	9.5	9.5	13	13	14	14	18	18	19	19	23	23	24	25
	24	9.5	9.5	9.5	9.5	14	15	16	16	20	21	21	22	26	26	27	28
	32	9.5	9.5	10	11	16	16	17	19	22	23	24	25	29	29	30	31
4000	16	9.5	9.5	9.5	9.5	10	10	10	11	14	14	14	15	17	18	28	19
	24	9.5	9.5	9.5	9.5	11	11	12	12	15	15	16	17	20	20	20	21
	32	9.5	9.5	9.5	9.5	12	12	13	14	17	17	18	19	22	22	23	24

*This table is applicable only when the structure is not assigned to Seismic Design Category D, E, or F.

†Wall dead load: 8 in. grout-filled concrete masonry unit above the foundation wall.

Table 8.6.1d—Minimum interior footing width (in.) for clear span and interior supported footing for 15 psf wall dead load*

Wall dead load† = 15 psf		One-story/slab				One-story with basement				Two-story with basement				Three-story with basement			
Soil bearing capacity, psf	Roof and floor span, maximum, ft	Roof live load, psf				Roof live load, psf				Roof live load, psf				Roof live load, psf			
		20	30	50	70	20	30	50	70	20	30	50	70	20	30	50	70
1500	16	9.5	9.5	9.5	9.5	9.5	9.5	10	11	13	13	14	15	16	17	18	19
	24	9.5	9.5	9.5	10	12	13	14	16	17	17	19	20	22	22	24	25
	32	9.5	9.5	11	13	15	16	18	20	21	22	24	26	27	28	30	32
2000	16	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	10	10	11	11	12	13	13	14
	24	9.5	9.5	9.5	9.5	9.5	10	11	12	13	13	14	15	16	17	18	19
	32	9.5	9.5	9.5	10	11	12	14	15	16	17	18	19	20	21	22	24
3000	16	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5
	24	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	10	10	11	11	12	13
	32	9.5	9.5	9.5	9.5	9.5	9.5	9.5	10	11	11	12	13	14	14	15	16
4000	16	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5
	24	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	10
	32	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	10	10	11	11	12

*This table is applicable only when the structure is not assigned to Seismic Design Category D, E, or F.

†Wall dead load: light frame wood construction only.

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Table 8.6.1e—Minimum interior footing width (in.) for clear span and interior supported footing for 45 psf wall dead load*

Wall dead load† = 45 psf		One-story/slab				One-story with basement				Two-story with basement				Three-story with basement			
Soil bearing capacity, psf	Roof and floor span, maximum, ft	Roof live load, psf				Roof live load, psf				Roof live load, psf				Roof live load, psf			
		20	30	50	70	20	30	50	70	20	30	50	70	20	30	50	70
1500	16	9.5	9.5	9.5	10	14	14	15	16	20	20	21	22	26	26	27	28
	24	9.5	10	11	12	17	17	19	20	24	25	26	28	31	32	33	35
	32	10	11	13	15	20	21	23	25	28	29	31	33	37	28	39	41
2000	16	9.5	9.5	9.5	9.5	10	11	11	12	15	15	16	17	19	20	20	21
	24	9.5	9.5	9.5	9.5	13	13	14	15	18	19	20	21	23	24	25	26
	32	9.5	9.5	10	12	15	16	17	19	21	22	23	25	28	28	30	31
3000	16	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	10	10	11	11	13	13	14	14
	24	9.5	9.5	9.5	9.5	9.5	9.5	10	10	12	13	13	14	16	16	17	18
	32	9.5	9.5	9.5	9.5	10	11	12	13	14	15	16	17	19	19	20	21
4000	16	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	10	10	10	11
	24	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	10	10	11	12	12	13	13
	32	9.5	9.5	9.5	9.5	9.5	9.5	9.5	10	11	11	12	13	14	14	15	16

*This table is applicable only when the structure is not assigned to Seismic Design Category D, E, or F.

†Wall dead load: light frame wood construction with brick veneer above the foundation.

Table 8.6.1f—Minimum interior footing width (in.) for clear span and interior supported footing for 100 psf wall dead load*

Wall dead load† = 100 psf		One-story/slab				One-story with basement				Two-story with basement				Three-story with basement			
Soil bearing capacity, psf	Roof and floor span, maximum, ft	Roof live load, psf				Roof live load, psf				Roof live load, psf				Roof live load, psf			
		20	30	50	70	20	30	50	70	20	30	50	70	20	30	50	70
1500	16	12	12	13	14	23	23	24	25	33	33	34	35	43	44	45	46
	24	13	14	15	17	26	26	28	29	37	38	39	41	49	49	51	52
	32	15	16	18	20	29	30	31	33	41	42	44	46	54	55	57	59
2000	16	9.5	9.5	10	11	17	17	18	19	25	25	26	27	33	33	34	34
	24	10	11	12	13	19	20	21	22	28	29	30	31	37	37	38	39
	32	11	12	13	15	22	22	24	25	31	32	33	35	41	41	43	44
3000	16	9.5	9.5	9.5	9.5	11	12	12	13	17	17	17	18	22	22	23	23
	24	9.5	9.5	9.5	9.5	13	13	14	15	19	19	20	21	25	25	26	26
	32	9.5	9.5	9.5	10	15	15	16	17	21	21	22	23	27	28	29	30
4000	16	9.5	9.5	9.5	9.5	9.5	9.5	9.5	10	13	13	13	14	17	17	17	17
	24	9.5	9.5	9.5	9.5	10	10	11	11	14	14	15	16	19	19	19	20
	32	9.5	9.5	9.5	9.5	11	11	12	13	16	16	17	18	21	21	22	22

*This table is applicable only when the structure is not assigned to Seismic Design Category D, E, or F.

†Wall dead load: 8 in. grout-filled concrete masonry unit above the foundation wall.

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Table 8.6.1g—Minimum interior footing dimensions with single span*

		Soil bearing capacity, psf															
		1500				2000				3000				4000			
		Maximum roof load: live load or snow load, psf															
		20 and below	21 to 30	31 to 50	51 to 70	20 and below	21 to 30	31 to 50	51 to 70	20 and below	21 to 30	31 to 50	51 to 70	20 and below	21 to 30	31 to 50	51 to 70
Footing supporting only roof or single floor																	
Plain‡	L	2’-4”	2’-6”	2’-9”	3’-1”	2’-0”	2’-2”	2’-5”	2’-8”	1’-8”	1’-10”	2’-0”	2’-2”	1’-5”	1’-6”	1’-9”	1’-11”
	W	2’-4”	2’-6”	2’-9”	3’-1”	2’-0”	2’-2”	2’-5”	2’-8”	1’-8”	1’-10”	2’-0”	2’-2”	1’-5”	1’-6”	1’-9”	1’-11”
	D	1’-2”	1’-3”	1’-5”	1’-7”	1’-0”	1’-1”	1’-3”	1’-4”	1’-5”	1’-5”	1’-0”	1’-1”	1’-0”	1’-3”	0’-11”	1’-6”
Reinforced	L	2’-4”	2’-6”	2’-9”	3’-1”	2’-0”	2’-2”	2’-5”	2’-8”	1’-8”	1’-10”	2’-0”	2’-2”	1’-5”	1’-6”	1’-9”	1’-11”
	W	2’-4”	2’-6”	2’-9”	3’-1”	2’-0”	2’-2”	2’-5”	2’-8”	1’-8”	1’-10”	2’-0”	2’-2”	1’-5”	1’-6”	1’-9”	1’-11”
	D	0’-8”	0’-9”	0’-9”	0-’10”	0’-8”	0’-9”	0’-9”	0’-10”	0’-8”	0’-9”	0’-9”	0’-9”	0’-8”	0’-8”	0’-9”	0’-9”
	R§‖	(2)-#3	(2)-#3	(3)-#3	(3)-#3	(2)-#3	(2)-#3	(2)-#3	(2)-#4	(2)-#3	(2)-#3	(2)-#3	(3)-#3	(2)-#3	(2)-#3	(2)-#3	(2)-#3
Footing supporting combination of two levels (roof or floors)																	
Plain‡	L	3’-2”	3’-4”	3’-7”	3’-9”	2’-9”	2’-11”	3’-1”	3’-3”	2’-3”	2’-5”	2’-6”	2’-8”	1’-11”	2’-1”	2’-2”	2’-4”
	W	3’-2”	3’-4”	3’-7”	3’-9”	2’-9”	2’-11”	3’-1”	3’-3”	2’-3”	2’-5”	2’-6”	2’-8”	1’-11”	2’-1”	2’-2”	2’-4”
	D	1’-7”	1’-8”	1’-10”	1’-11”	1’-5”	1’-6”	1’-7”	1’-8”	1’-2”	1’-3”	1’-3”	1’-4”	1’-0”	1’-1”	1’-1”	1’-2”
Reinforced	L	3’-2”	3’-4”	3’-7”	3’-9”	2’-9”	2’-11”	3’-1”	3’-3”	2’-3”	2’-5”	2’-6”	2’-8”	1’-11”	2’-1”	2’-2”	2’-4”
	W	3’-2”	3’-4”	3’-7”	3’-9”	2’-9”	2’-11”	3’-1”	3’-3”	2’-3”	2’-5”	2’-6”	2’-8”	1’-11”	2’-1”	2’-2”	2’-4”
	D	0’-10”	0’-10”	0’-10”	0’-9”	0’-9”	0’-10”	0’-10”	0’-10”	0’-9”	0’-10”	0’-10”	1’-0”	0’-9”	0’-10”	0-10”	0’-10”
	R§‖	(2)-#4	(2)-#4	(3)-#4	(3)-#4	(3)-#3	(2)-#4	(2)-#4	(3)-#4	(3)-#3	(3)-#3	(3)-#3	(2)-#4	(2)-#3	(2)-#3	(2)-#3	(2)-#4
Footing supporting combination of three levels (roof or floors)																	
Plain‡	L	4’-0”	4’-2”	4’-4”	4’-6”	3’-6”	3’-7”	3’-9”	3’-11”	2’-10”	2’-11”	3’-1”	3’-3”	2’-6”	2’-7”	2’-8”	2’-9”
	W	4’-0”	4’-2”	4’-4”	4’-6”	3’-6”	3’-7”	3’-9”	3’-11”	2’-10”	2’-11”	3’-1”	3’-3”	2’-6”	2’-7”	2’-8”	2’-9”
	D	1’-0”	2’-2”	2’-2”	2’-3”	1’-9”	1’-10”	1’-11”	2’-0”	1’-5”	1’-6”	1’-7”	1’-8”	1’-3”	1’-4”	1’-4”	1’-5”
Reinforced	L	4’-0”	4’-2”	4’-4”	4’-6”	3’-6”	3’-7”	3’-9”	3’-11”	2’-10”	2’-11”	3’-1”	3’-3”	2’-6”	2’-7”	2’-8”	2’-9”
	W	4’-0”	4’-2”	4’-4”	4’-6”	3’-6”	3’-7”	3’-9”	3’-11”	2’-10”	2’-11”	3’-1”	3’-3”	2’-6”	2’-7”	2’-8”	2’-9”
	D	1’-0”	1’-0”	1’-0”	1’-0”	0’-10”	1’-0”	1’-0”	1’-0”	1’-0”	1’-0”	1’-0”	1’-0”	1’-0”	1’-0”	1’-0”	1’-0”
	R§‖	(3)-#4	(3)-#4	(3)-#4	(3)-#4	(3)-#4	(3)-#4	(3)-#4	(3)-#4	(2)-#4	(2)-#4	(2)-#4	(3)-#4	(2)-#4	(2)-#4	(2)-#4	(2)-#4

*This table is applicable only when the structure is not assigned to Seismic Design Category D, E, or F.

†Maximum tributary area = 320 ft^2.

‡The term plain refers to concrete where no structural reinforcement is required.

§R refers to minimum steel reinforcement.

‖Minimum reinforcement cover is 3 in.

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Table 8.6.1h—Minimum interior footing dimensions with multiple spans*†

		Soil bearing capacity, psf															
		1500				2000				3000				4000			
		Maximum roof load: live load or snow load, psf															
		20 and below	21 to 30	31 to 50	51 to 70	20 and below	21 to 30	31 to 50	51 to 70	20 and below	21 to 30	31 to 50	51 to 70	20 and below	21 to 30	31 to 50	51 to 70
Footing supporting only roof or single floor																	
Plain‡	L	3’-4”	3’-6”	4’-0”	4’-4”	2’-10”	3’-1”	3’-4”	3’-9”	2’-4”	2’-6”	2’-9”	3’-1”	2’-0”	2’-2”	2’-5”	2’-8”
	W	3’-4”	3’-6”	4’-0”	4’-4”	2’-10”	3’-1”	3’-4”	3’-9”	2’-4”	2’-6”	2’-9”	3’-1”	2’-0”	2’-2”	2’-5”	2’-8”
	D	1’-8”	1’-9”	2’-0”	2’-2”	1’-6”	1’-7”	1’-8”	1’-11”	1’-2”	1’-3”	1’-5”	1’-7”	1’-0”	1’-1”	1’-3”	1’-4”
Reinforced	L	3’-4”	3’-6”	4’-0”	4’-4”	2’-10”	3’-1”	3’-4”	3’-9”	2’-4”	2’-6”	2’-9”	3’-1”	2’-0”	2’-2”	2’-5”	2’-8”
	W	3’-4”	3’-6”	4’-0”	4’-4”	2’-10”	3’-1”	3’-4”	3’-9”	2’-4”	2’-6”	2’-9”	3’-1”	2’-0”	2’-2”	2’-5”	2’-8”
	D	0’-10”	0’-10”	1’-0”	1’-0”	0’-10”	0’-10”	1’-0”	1’-0”	0’-10”	0’-10”	1’-0”	1’-0”	0’-10”	0’-10”	1’-0”	1’-0”
	R§‖	(2)-#4	(2)-#4	(3)-#4	(4)-#4	(2)-#4	(2)-#4	(2)-#4	(3)-#4	(2)-#4	(3)-#3	(2)-#4	(3)-#4	(2)-#3	(3)-#3	(3)-#4	(2)-#4
Footing supporting combination of two levels (roof or floors)																	
Plain‡	L	4’-9”	4’-11”	5’-3”	5’-5”	4’-1”	4’-3”	4’-6”	4’-10”	3’-4”	3’-6”	3’-8”	3’-11”	2’-11”	3’-0”	3’-3”	3’-5”
	W	4’-9”	4’-11”	5’-3”	5’-5”	4’-1”	4’-3”	4’-6”	4’-10”	3’-4”	3’-6”	3’-8”	3’-11”	2’-11”	3’-0”	3’-3”	3’-5”
	D	2’-6”	2’-6”	2’-8”	2’-9”	2’-1”	2’-2”	2’-3”	2’-2”	1’-8”	1’-9”	1’-10”	2’-0”	1’-6”	1’-6”	1’-8”	1’-9”
Reinforced	L	4’-9”	4’-11”	5’-3”	5’-5”	4’-1”	4’-3”	4’-6”	4’-10”	3’-4”	3’-6”	3’-8”	3’-11”	2’-11”	3’-0”	3’-3”	3’-5”
	W	4’-9”	4’-11”	5’-3”	5’-5”	4’-1”	4’-3”	4’-6”	4’-10”	3’-4”	3’-6”	3’-8”	3’-11”	2’-11”	3’-0”	3’-3”	3’-5”
	D	1’-0”	1’-0”	1’-2”	1’-2”	1’-0”	1’-0”	1’-2”	1’-2”	1’-0”	1’-0”	1’-2”	1’-0”	1’-0”	1’-0”	1’-2”	1’-2”
	R§‖	(3)-#5	(3)-#5	(3)-#5	(3)-#5	(2)-#5	(2)-#5	(3)-#5	(3)-#5	(3)-#4	(3)-#4	(3)-#4	(4)-#4	(3)-#4	(3)-#4	(3)-#4	(3)-#4
Footing supporting combination of three levels (roof or floors)																	
Plain‡	L	5’-8”	5’-10”	6’-1”	6’-5”	4’-11”	5’-1”	5’-3”	5’-6”	4’-0”	4’-2”	4’-4”	4’-6”	3’-6”	3’-7”	3’-9”	3’-11”
	W	5’-8”	5’-10”	6’-1”	6’-5”	4’-11”	5’-1”	5’-3”	5’-6”	4’-0”	4’-2”	4’-4”	4’-6”	3’-6”	3’-7”	3’-9”	3’-11”
	D	2’-10”	2’-11”	3’-1”	3’-3”	2’-6”	2’-7”	2’-8”	2’-9”	2’-0”	2’-1”	2’-2”	2’-3”	2’-9”	2’-10”	1’-11”	2’-0”
Reinforced	L	5’-8”	5’-10”	6’-1”	6’-5”	4’-11”	5’-1”	5’-3”	5’-6”	4’-0”	4’-2”	4’-4”	4’-6”	3’-6”	3’-7”	3’-9”	3’-11”
	W	5’-8”	5’-10”	6’-1”	6’-5”	4’-11”	5’-1”	5’-3”	5’-6”	4’-0”	4’-2”	4’-4”	4’-6”	3’-6”	3’-7”	3’-9”	3’-11”
	D	1’-2”	1’-2”	1’-2”	1’-2”	1’-2”	1’-2”	1’-2”	1’-2”	1’-2”	1’-2”	1’-2”	1’-2”	1’-2”	1’-2”	1’-2”	1’-2”
	R§‖	(5)-#4	(4)-#5	(4)-#5	(5)-#5	(3)-#5	(3)-#5	(4)-#5	(4)-#5	(3)-#4	(3)-#5	(3)-#5	(4)-#5	(3)-#4	(3)-#4	(4)-#4	(3)-#5

*This table is applicable only when the structure is not assigned to Seismic Design Category D, E, or F.

†Maximum tributary area = 640 ft^2.

‡The term plain refers to concrete where no structural reinforcement is required.

§R refers to minimum steel reinforcement

‖Minimum reinforcement cover is 3 in.

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8.7—Construction requirements

8.7.1 *Unformed footings*

8.7.1.1 Unformed footings shall be permitted if the excavation remains stable to maintain dimensions and alignment before and during concrete placement.

8.7.2 *Formed footings*

8.7.2.1 Side forms shall be secured to maintain dimensions and alignment before and during concrete placement.

8.7.3 *Finishing*

8.7.3.1 Top surfaces of the footing shall be struck off level and prepared for keyway or dowel connection as required in 8.2.2.1.

COMMENTARY

R8.7—Construction requirements

R8.7.1 *Unformed footings*

Unformed footings are used frequently where frost depth is shallow or for interior load-bearing walls. Footings may be placed integrally with the floor slab. Refer to Fig. R8.7.1a for exterior unformed footings in slabs-on-ground. Refer to Fig. R8.7.1b for interior unformed footings in slabs-on-ground.

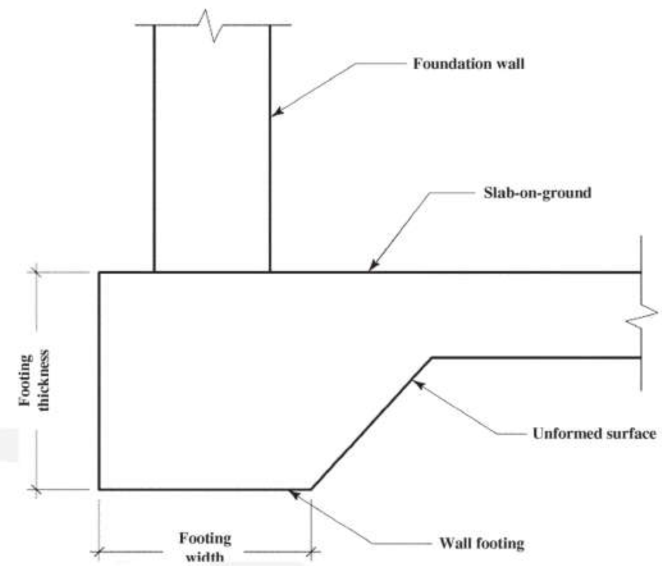

Fig. R8.7.1a—Exterior unformed thickened slab footing.

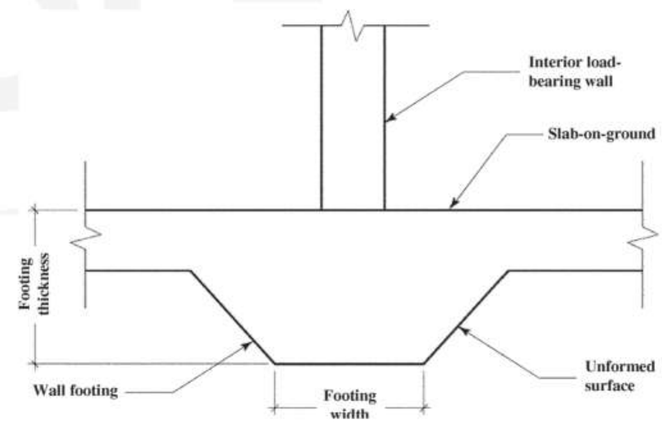

Fig. R8.7.1b—Interior unformed thickened slab footing.

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8.7.4 *Footing surfaces*

8.7.4.1 The bottom surface of footings shall not exceed a slope of 1 vertical in 10 horizontal. The top surface of footings shall be level within the tolerances of the project specifications.

8.7.5 *Foundation anchorage in SDC C, D, E, or F*

8.7.5.1 The following requirements shall apply to wood light-frame structures in SDC D, E, or F and wood light-frame townhouses in SDC C as defined by 1.1.3:

(a) Where braced wall panels exist, all anchor bolts shall have plate washers with dimensions of at least 0.229 x 3 x 3 in. for all between the sill plate and the nut. Properly sized cut washers shall be permitted for anchor bolts in wall lines not containing braced wall panels.

(b) For interior braced wall plates, the specified anchor bolt spacing shall not exceed 6 ft on center and is located within 12 in. of the ends of each plate section when supported on a continuous foundation.

(c) For interior bearing wall sole plates, the specified anchor bolt spacing shall not exceed 6 ft on center and is located within 12 in. of the ends of each plate section when supported on a continuous foundation.

(d) For buildings over two stories in height, anchor bolt spacing shall not exceed 4 ft on center.

COMMENTARY

R8.7.4 *Footing surfaces*

Common tolerances for residential concrete can be found in ACI 332.1R.

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CHAPTER 9—FOUNDATION WALLS

9.1—Scope

9.1.1 Provisions of this chapter shall apply to foundation walls of buildings.

9.2—General

9.2.1 Design of plain concrete walls and reinforced concrete walls shall be in accordance with Chapter 6.

9.2.2 Lateral support is required at the top and bottom of the wall. Wall-to-footing joints that comply with 8.2.2.1 are deemed to have satisfied the bottom lateral support requirement. The connection of the lateral support system to the top of the wall shall be in accordance with 9.6.1. The design of top lateral support is beyond the scope of this code.

9.2.3 *Material*

9.2.3.1 Design properties for concrete shall be selected to be in accordance with Chapter 5 and 6.2.1.

9.2.3.2 Design properties for steel reinforcement shall be selected to be in accordance with 6.2.2.

9.2.4 *Connection to other members*

9.2.4.1 Factored forces and moments at base of walls shall be transferred to supporting foundations by bearing on concrete and by reinforcement and dowels.

9.2.5 *Sections of reduced thickness*

9.2.5.1 The height of the reduced thickness section shall not exceed 24 in.

9.2.5.2 The reduced thickness section shall comply with (a) and (b):

(a) Reduced wall thickness shall not be less than 3.5 in.

(b) When the wall thickness is 4 in. or less, a minimum of one vertical No. 4 reinforcing bar shall be placed at 24 in. on center and comply with (i) through (iii);

(i) This bar shall extend at least 12 in. into the full thickness section.

(ii) This bar shall extend the full height into the reduced-thickness section.

(iii) Concrete cover shall be in accordance with 5.6.

COMMENTARY

CHAPTER R9—FOUNDATION WALLS

R9.2—General

R9.2.5 *Sections of reduced thickness*

The reduction of wall thickness is a common detail to accommodate brick veneer or a ledger for an interior floor deck (refer to Fig. R9.2.3).

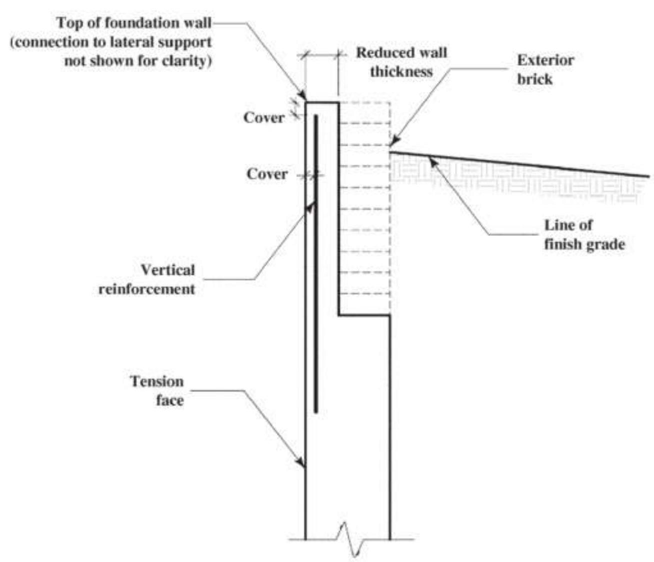

Fig. R9.2.5—Reduction of wall thickness.

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9.2.6 Lintel beams shall be designed in accordance with Chapter 11.

9.2.7 *Horizontal reinforcement*

9.2.7.1 For both reinforced and plain concrete walls, horizontal reinforcement shall be provided in accordance with (a) through (f). For SDC D, E, and F, the provisions of (g) shall also apply:

(a) Where walls exceed 6 ft in height, a minimum of three continuous, horizontal reinforcing bars shall be provided.

(b) Where walls exceed 8 ft in height, a minimum of four continuous, horizontal reinforcing bars shall be provided.

(c) For all wall heights, a minimum of one horizontal bar shall be located within the top 24 in. and a minimum of one in the bottom 24 in. The remaining required bars shall be spaced over the height of the wall as equally as practical.

(d) Horizontal reinforcement shall be secured as close as possible to the center of the wall or, where vertical reinforcement is present, shall be secured to the side of the vertical reinforcement closest to the center of the wall.

(e) Reinforcement lap length shall not be less than $30d_b$.

(f) At corners, horizontal reinforcement shall extend around corners and lap reinforcement a minimum of $30d_b$.

(g) Two No. 4 horizontal bars shall be located in the upper 12 in. of the wall.

9.2.8 *Additional wall reinforcement*

9.2.8.1 *Discontinuous wall footings*

Where wall footing elevation change is greater than twice the footing thickness, a minimum of two No. 4 horizontal reinforcing bars, one at the top and the other at the bottom of the wall, shall be provided in addition to other required wall reinforcement. These bars shall extend at each end at least 36 in. into the wall portion supported directly by the top and bottom wall footings. The bars shall be placed in the middle one-third of the wall thickness. Concrete cover shall be in accordance with 5.6.

9.2.8.2 *Reentrant corners*

Where a reentrant corner occurs, such as a wall opening or an elevation change greater than 8 in. between top and bottom of wall, at least one No. 4 reinforcing bar, 24 in. long, shall be secured diagonally as close as practical to the reentrant corner. Concrete cover shall be in accordance with 5.6.

COMMENTARY

R9.2.7 *Horizontal reinforcement*

Horizontal wall reinforcement is placed to reduce width of cracking that can result from restraint against volume changes due to shrinkage and temperature change. The serviceability requirements of residential concrete allow for crack development. The tension face is the inside face of a wall, assuming backfill is applied to the outside face.

R9.2.7.1 This reinforcement is placed to limit cracking. The code requires reinforcement to be provided in both plain and reinforced foundation walls (refer to Fig. R8.2.5).

R9.2.8.1 *Discontinuous wall footings*

Refer to Fig. R8.2.5.

R9.2.8.2 *Reentrant corners*

This reinforcement is placed to limit the width of wall cracks caused by a reentrant corner such as is formed by a window or a door (refer to Fig. R8.2.5, R9.2.8.2a, and R9.2.8.2b).

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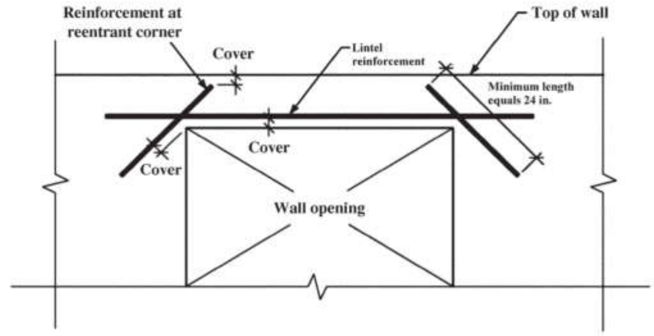

Fig. R9.2.8.2a—Lintel beam reinforcement.

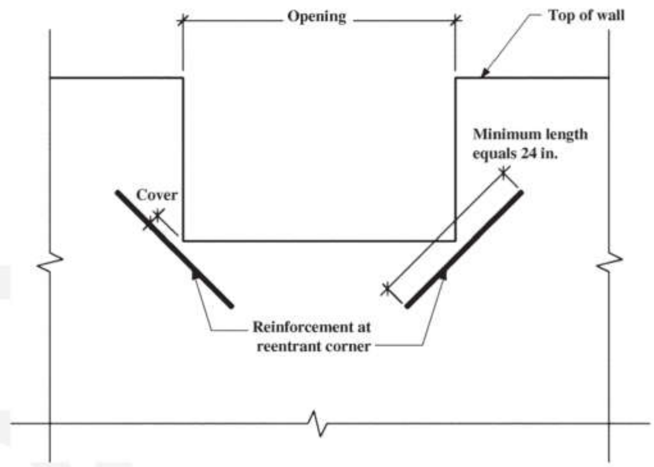

Fig. R9.2.8.2b—Reentrant corner reinforcement.

9.3—Design limits

9.3.1 The minimum specified wall thickness shall be in accordance with 9.3.1.1, 9.3.1.2, or 9.3.1.3.

9.3.1.1 The minimum specified thickness of reinforced concrete walls shall be the greater of 6 in. or 1/25 of the lesser of the unsupported length and unsupported height of the wall.

9.3.1.2 The minimum specified thickness of plain concrete walls shall be the greater of 7.5 in. or 1/24 of the lesser of the unsupported length and unsupported height of the wall.

9.3.1.3 A minimum specified wall thickness of 5.5 in. shall be permitted where the wall height does not exceed 4 ft and the unbalanced backfill height does not exceed 24 in.

9.3.1.4 A minimum wall thickness greater than 12 in. shall be designed by a licensed design professional in accordance with Chapter 6 of this code or the applicable section of ACI 318.

9.3.2 The equivalent fluid pressure of the backfill shall be determined in accordance with Table 9.3.2.

R9.3—Design limits

R9.3.1 This code provides for the minimum required thickness of a concrete wall based on a simply supported beam model consistent with traditional single-family residential foundations. In cases where the construction of a foundation may be more economical with a thickness greater than the minimum required, it is permissible.

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Table 9.3.2—Lateral soil load

Description of backfill material[*]	Unified soil classification	Design lateral soil load[†], lb/ft^2/ft of depth	
		Active pressure[‡]	At-rest pressure
Well-graded, clean gravels; gravel-sand mixtures	GW	30	60
Poorly graded clean gravels; gravel-sand mixtures	GP	30	60
Silty gravels, poorly graded gravel-sand mixtures	GM	40	60
Clayey gravels, poorly graded gravel-and-clay mixtures	GC	45	60
Well-graded, clean sands; gravelly sand mixtures	SW	30	60
Poorly graded clean sands; sand-gravel mixtures	SP	30	60
Silty sands, poorly graded sand-silt mixtures	SM	45	60
Sand-silt clay mixture with plastic fines	SM-SC	45	100
Clayey sands, poorly graded sand-clay mixtures	SC	60	100
Inorganic silts and clayey silts	ML	45	100
Mixture of inorganic silt and clay	ML-CL	60	100
Inorganic clays of low to medium plasticity	CL	60	100
Organic silts and silt clays, low plasticity	OL	§	§
Inorganic clayey silts, elastic silts	MH	§	§
Inorganic clays of high plasticity	CH	§	§
Organic clays and silty clays	OH	§	§

[*]The definition and classification of soil materials shall be in accordance with ASTM D2487.

[†]Design lateral soil loads are given for moist conditions for the specified soils at their optimum densities. Actual field conditions shall govern. Submerged or saturated soil pressures shall include the weight of the buoyant soil plus the hydrostatic loads.

[‡]For relatively rigid walls, as when braced by floors, the design lateral soil load shall be increased for sand and gravel type soils to 60 psf per foot of depth. Basement walls extending not more than 10 ft below grade and supporting light floor systems are not considered as being relatively rigid walls.

[§]Unsuitable as backfill material.

9.3.3 *Reduction of wall thickness*—The thickness of the top of a foundation wall shall be permitted to be reduced according to 9.2.3.1 and 9.2.3.2.

9.3.4 Construction and isolation joints shall be provided to divide structural plain concrete members into discontinuous elements. The size of each element shall be selected to limit stress caused by restraint to movements from creep, shrinkage, and temperature effects. The number and location of contraction or isolation joints shall be determined considering (a) through (f):

(a) Influence of climatic conditions
(b) Selection and proportioning of material
(c) Mixing, placing, and curing of concrete

COMMENTARY

R9.3.4 Joints in plain concrete construction are in important design consideration. In reinforced concrete, reinforcement is provided to resist the stresses due to restraint of creep, shrinkage, and temperature effects. In plain concrete, joints are the only means of controlling, and thereby relieving, the buildup of such a tensile stress.

A concrete member should therefore be small enough, or divided into smaller element by joints, to control the buildup of internal stresses. The joint maybe a contraction joint or isolation joint. A minimum 25 percent reduction of member

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(d) Degree of restraint to movement
(e) Stresses to which an element is subjected
(f) Construction techniques

COMMENTARY

thickness is typically sufficient for contraction joint activation. If applicable, the jointing should be such that no axial tension or flexural tension can be developed across a joint after cracking, a condition referred to as flexural discontinuity. Where random cracking due to creep, shrinkage, and temperature effects will not affect structural integrity and is otherwise acceptable (such as transverse cracks in a continuous wall footing), transverse contraction or isolation joints should not be necessary.

9.4—Required strength

9.4.1 Required strength shall be calculated in accordance with the factored load combination in 6.3.

9.4.2 Required strength shall be calculated in accordance with the analysis procedures in Chapter 6.

9.5—Design

Concrete design for expansive soils shall be in accordance with the provisions of Chapter 9.

9.5.1 Foundation walls shall be constructed from a design from one of the following methods:
(a) In accordance with the design procedures found in Chapter 6
(b) In accordance with the prescriptive tables in 9.5.3.

9.5.2 ϕ shall be determined in accordance with 6.4.

9.5.3 *Prescriptive design tables*

The design of walls conforming to this chapter shall be permissible in accordance with the parameters of 9.5.3.1. Interpolation is not permitted.

9.5.3.1 Tables 9.5.3.1a through 9.5.3.1j are based on the following conditions:
(a) Simply supported vertical flexural member
(b) Top and bottom laterally supported
(c) Axial force neglected
(d) Self-weight neglected
(e) No deflection limits considered because wall thickness and loading limits are specified
(f) The only loading considered is the equivalent fluid pressure of soil (use 30, 45, 60, and 100 psf/ft)
(g) Maximum unsupported wall height is 8, 9, and 10 ft, with maximum unbalanced backfill height of 7, 8, and 9 ft, respectively
(h) Range of concrete compressive strength f_c' considered is 2500 to 4500 psi
(i) Yield strength of reinforcement f_y is 40 or 60 ksi
(j) The building shall not be assigned to SDC D, E, or F, as defined in 1.1.7
(k) Plain concrete modulus of rupture specified in 6.2.1.2
(l) Minimum concrete cover to vertical reinforcement is 0.75 in.
(m) Walls constructed with removable forms
(n) Specified maximum vertical reinforcement spacing is 48 in.
(o) Specified minimum vertical reinforcement spacing is 6 in.

R9.5—Design

R9.5.3 *Prescriptive design tables*

R9.5.3.1 This minimum reinforcement and the maximum bar spacing of 48 in. corresponds to the extensive history of satisfactory performance. The tension face of the wall refers to the face that is opposite the side that is loaded laterally (supporting soil) (refer to Fig. R9.5.3.1 on p. 62).

Shaded areas of Tables 9.5.3.1a through 9.5.3.1j denote conditions where the lateral support system should be reviewed by a licensed design professional; for example, conditions with high soil pressures or tall walls, such as 60 lb/ft^2 soil pressure or a 10 ft wall height. Refer to footnote (g) of these tables.

CODE **COMMENTARY**

Table 9.5.3.1a—Vertical reinforcing bar spacing for concrete basement walls; f_c' = 2500 psi and f_y = 40,000 psi

Reinforcing bar spacing for solid concrete foundation walls																										
Maximum clear wall height, ft	f_c' (psi) = 2500; f_y (psi) = 40,000		Maximum equivalent fluid pressure of soil, psf/ft: 30												45											
			30						45						60						100					
			Wall thickness, in.						Wall thickness, in.						Wall thickness, in.						Wall thickness, in.					
	Unbalanced backfill, ft	Reinforcing bar	8		10		12		8		10		12		8		10		12		8		10		12	
			I	C	I	C	I	C	I	C	I	C	I	C	I	C	I	C	I	C	I	C	I	C	I	C
8	5	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
	6	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	16	9	PC	PC	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	24	14	PC	PC	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	34	19	PC	PC	PC	PC
	7	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	19	11	PC	PC	PC	PC	11	6	15	8	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	29	17	PC	PC	PC	PC	17	10	23	13	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	41	23	PC	PC	PC	PC	24	14	32	18	PC	PC
9	5	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
	6	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	15	8	PC	PC	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	23	13	PC	PC	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	32	18	PC	PC	PC	PC
	7	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	17	10	PC	PC	PC	PC	10	6	14	7	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	26	15	PC	PC	PC	PC	16	9	21	11	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	37	21	PC	PC	PC	PC	22	12	29	16	PC	PC
	8	#4 @ ... in.	PC	PC	PC	PC	PC	PC	17	10	PC	PC	PC	PC	13	7	17	9	PC	PC	8	NR	10	NR	13	7
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	27	15	PC	PC	PC	PC	20	11	26	14	PC	PC	12	6	16	8	19	10
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	37	21	PC	PC	PC	PC	28	16	37	20	PC	PC	16	9	22	12	27	15
10	5	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	22	12	PC	PC	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	33	19	PC	PC	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	47	27	PC	PC	PC	PC
	6	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	14	8	PC	PC	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	21	12	PC	PC	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	30	17	PC	PC	PC	PC
	7	#4 @ ... in.	PC	PC	PC	PC	PC	PC	21	12	PC	PC	PC	PC	16	9	PC	PC	PC	PC	9	NR	13	7	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	33	19	PC	PC	PC	PC	24	14	PC	PC	PC	PC	14	8	19	10	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	46	26	PC	PC	PC	PC	34	19	PC	PC	PC	PC	20	11	27	15	PC	PC
	8	#4 @ ... in.	PC	PC	PC	PC	PC	PC	16	9	PC	PC	PC	PC	12	6	15	8	PC	PC	7	NR	9	NR	11	6
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	24	14	PC	PC	PC	PC	18	10	24	13	PC	PC	11	6	14	7	18	9
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	34	19	PC	PC	PC	PC	25	14	34	18	PC	PC	15	8	20	11	25	13
	9	#4 @ ... in.	18	10	PC	PC	PC	PC	12	7	16	9	PC	PC	9	NR	12	6	15	8	5	NR	7	NR	9	NR
		#5 @ ... in.	28	16	PC	PC	PC	PC	19	10	25	13	PC	PC	14	8	18	10	23	12	8	NR	11	6	14	7
		#6 @ ... in.	40	23	PC	PC	PC	PC	26	15	35	19	PC	PC	20	11	26	14	32	17	11	6	15	8	19	10

Notes:

a) PC refers to plain concrete where no vertical reinforcement is required. All other reinforcement shall be consistent with 9.2.3.2, 9.2.4, 9.2.5, and 9.2.6.

b) NR refers to not recommended, where vertical reinforcement spacing drops below a practical field limitation of 6 in. on center for the given condition.

c) I refers to reinforcement placed near the tension face (inside) of the foundation wall as specified in 9.2.4.2(f).

d) C refers to reinforcement placed near the centerline of the foundation wall as specified in 9.2.4.2(g).

e) This table is applicable to walls of specified height, unbalanced backfill height, equivalent fluid pressure of soil, concrete strength, and the yield strength of reinforcement.

f) Values in this table are derived in accordance with Chapter 6 and 9.2.

g) Values under the thickened lines denote conditions where lateral loads at the top of the foundation wall exceed the capacity of the minimum provisions found in 9.6.1. A licensed design professional shall be consulted for the design of the connection between the floor framing and the foundation wall.

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Table 9.5.3.1b—Vertical reinforcing bar spacing for concrete basement walls; f_c' = 2500 psi and f_y = 60,000 psi

Reinforcing bar spacing for solid concrete foundation walls																										
Maximum clear wall height, ft	f_c' (psi) = 2500; f_y (psi) = 60,000		Maximum equivalent fluid pressure of soil, psf/ft																							
			30						45						60						100					
			Wall thickness, in.						Wall thickness, in.						Wall thickness, in.						Wall thickness, in.					
	Unbalanced backfill, ft	Reinforcing bar	8		10		12		8		10		12		8		10		12		8		10		12	
			I	C	I	C	I	C	I	C	I	C	I	C	I	C	I	C	I	C	I	C	I	C	I	C
8	5	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
	6	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	24	13	PC	PC	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	37	21	PC	PC	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	48	29	PC	PC	PC	PC
	7	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	29	16	PC	PC	PC	PC	17	9	22	12	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	44	25	PC	PC	PC	PC	26	14	35	19	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	48	35	PC	PC	PC	PC	37	20	48	27	PC	PC
9	5	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
	6	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	22	12	PC	PC	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	34	19	PC	PC	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	47	27	PC	PC	PC	PC
	7	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	26	14	PC	PC	PC	PC	15	8	20	11	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	40	22	PC	PC	PC	PC	24	13	31	17	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	48	32	PC	PC	PC	PC	33	18	44	24	PC	PC
	8	#4 @ ... in.	PC	PC	PC	PC	PC	PC	26	14	PC	PC	PC	PC	19	11	26	14	PC	PC	11	6	15	8	19	10
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	40	22	PC	PC	PC	PC	30	16	39	21	PC	PC	17	9	23	12	29	15
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	48	32	PC	PC	PC	PC	42	23	48	30	PC	PC	25	13	33	18	41	22
10	5	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	33	18	PC	PC	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	48	28	PC	PC	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	48	40	PC	PC	PC	PC
	6	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	21	11	PC	PC	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	32	18	PC	PC	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	44	25	PC	PC	PC	PC
	7	#4 @ ... in.	PC	PC	PC	PC	PC	PC	32	18	PC	PC	PC	PC	24	13	PC	PC	PC	PC	14	8	19	10	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	48	28	PC	PC	PC	PC	37	21	PC	PC	PC	PC	22	12	29	16	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	48	39	PC	PC	PC	PC	48	29	PC	PC	PC	PC	31	17	41	22	PC	PC
	8	#4 @ ... in.	PC	PC	PC	PC	PC	PC	24	13	PC	PC	PC	PC	18	10	23	13	PC	PC	10	NR	14	7	17	9
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	36	20	PC	PC	PC	PC	27	15	36	19	PC	PC	16	8	21	11	26	14
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	48	29	PC	PC	PC	PC	38	21	48	28	PC	PC	22	12	30	16	37	20
	9	#4 @ ... in.	28	15	PC	PC	PC	PC	18	10	24	13	PC	PC	14	7	18	10	22	12	8	NR	11	NR	13	7
		#5 @ ... in.	42	24	PC	PC	PC	PC	28	15	37	20	PC	PC	21	11	28	15	35	18	12	6	16	9	21	11
		#6 @ ... in.	48	34	PC	PC	PC	PC	39	22	48	29	PC	PC	29	16	39	21	48	26	17	9	23	12	29	15

Notes:

a) PC refers to plain concrete where no vertical reinforcement is required. All other reinforcement shall be consistent with 9.2.3.2, 9.2.4, 9.2.5, and 9.2.6.

b) NR refers to not recommended where vertical reinforcement spacing drops below a practical field limitation of 6 in. on center for the given condition.

c) I refers to reinforcement placed near the tension face (inside) of the foundation wall as specified in 9.2.4.2(f).

d) C refers to reinforcement placed near the centerline of the foundation wall as specified in 9.2.4.2(g).

e) This table is applicable to walls of specified height, unbalanced backfill height, equivalent fluid pressure of soil, concrete strength, and the yield strength of reinforcement.

f) Values in this table are derived in accordance with Chapter 6 and 9.2.

g) Values under the thickened lines denote conditions where lateral loads at the top of the foundation wall exceed the capacity of the minimum provisions found in 9.6.1. A licensed design professional shall be consulted for the design of the connection between the floor framing and the foundation wall.

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Table 9.5.3.1c—Vertical reinforcing bar spacing for concrete basement walls; f_c' = 3000 psi and f_y = 40,000 psi

Reinforcing bar spacing for solid concrete foundation walls																										
Maximum clear wall height, ft	f_c' (psi) = 3000 f_y (psi) = 40,000		Maximum equivalent fluid pressure of soil, psf/ft																							
			30						45						60						100					
			Wall thickness, in.						Wall thickness, in.						Wall thickness, in.						Wall thickness, in.					
	Unbalanced backfill, ft	Reinforcing bar	8		10		12		8		10		12		8		10		12		8		10		12	
			I	C	I	C	I	C	I	C	I	C	I	C	I	C	I	C	I	C	I	C	I	C	I	C
8	5	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
	6	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	16	9	PC	PC	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	25	14	PC	PC	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	35	20	PC	PC	PC	PC
	7	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	19	11	PC	PC	PC	PC	11	6	15	8	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	29	17	PC	PC	PC	PC	17	10	23	13	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	41	24	PC	PC	PC	PC	25	14	33	18	PC	PC
9	5	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
	6	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	15	8	PC	PC	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	23	13	PC	PC	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	32	18	PC	PC	PC	PC
	7	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	17	10	PC	PC	PC	PC	10	6	14	7	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	27	15	PC	PC	PC	PC	16	9	21	11	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	37	21	PC	PC	PC	PC	22	12	29	16	PC	PC
	8	#4 @ ... in.	PC	PC	PC	PC	PC	PC	17	10	PC	PC	PC	PC	13	7	PC	PC	PC	PC	8	NR	10	NR	13	7
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	27	15	PC	PC	PC	PC	20	11	PC	PC	PC	PC	12	6	16	8	19	10
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	37	21	PC	PC	PC	PC	28	16	PC	PC	PC	PC	16	9	22	12	27	15
10	5	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
	6	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	14	8	PC	PC	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	21	12	PC	PC	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	30	17	PC	PC	PC	PC
	7	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	16	9	PC	PC	PC	PC	9	NR	13	7	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	25	14	PC	PC	PC	PC	15	8	19	10	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	34	20	PC	PC	PC	PC	20	11	27	15	PC	PC
	8	#4 @ ... in.	PC	PC	PC	PC	PC	PC	16	9	PC	PC	PC	PC	12	6	16	8	PC	PC	7	NR	9	NR	11	6
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	24	14	PC	PC	PC	PC	18	10	24	13	PC	PC	11	6	14	8	18	9
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	34	19	PC	PC	PC	PC	25	14	34	19	PC	PC	15	8	20	11	25	13
	9	#4 @ ... in.	18	10	PC	PC	PC	PC	12	7	16	9	PC	PC	9	NR	12	6	PC	PC	5	NR	7	NR	9	NR
		#5 @ ... in.	28	16	PC	PC	PC	PC	19	10	25	14	PC	PC	14	8	19	10	PC	PC	8	NR	11	6	14	7
		#6 @ ... in.	40	23	PC	PC	PC	PC	26	15	35	19	PC	PC	20	11	26	14	PC	PC	12	6	15	8	19	10

Notes:

a) PC refers to plain concrete where no vertical reinforcement is required. All other reinforcement shall be consistent with 9.2.3.2, 9.2.4, 9.2.5, and 9.2.6.

b) NR refers to not recommended where vertical reinforcement spacing drops below a practical field limitation of 6 in. on center for the given condition.

c) I refers to reinforcement placed near the tension face (inside) of the foundation wall as specified in 9.2.4.2(f).

d) C refers to reinforcement placed near the centerline of the foundation wall as specified in 9.2.4.2(g).

e) This table is applicable to walls of specified height, unbalanced backfill height, equivalent fluid pressure of soil, concrete strength, and the yield strength of reinforcement.

f) Values in this table are derived in accordance with Chapter 6 and 9.2.

g) Values under the thickened lines denote conditions where lateral loads at the top of the foundation wall exceed the capacity of the minimum provisions found in 9.6.1. A licensed design professional shall be consulted for the design of the connection between the floor framing and the foundation wall.

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Table 9.5.3.1d—Vertical reinforcing bar spacing for concrete basement walls; f_c' = 3000 psi and f_y = 60,000 psi

Reinforcing bar spacing for solid concrete foundation walls																										
Maximum clear wall height, ft	f_c' (psi) = 3000; f_y (psi) = 60,000		Maximum equivalent fluid pressure of soil, psf/ft																							
			30						45						60						100					
			Wall thickness, in.						Wall thickness, in.						Wall thickness, in.						Wall thickness, in.					
	Unbalanced backfill, ft	Reinforcing bar	8		10		12		8		10		12		8		10		12		8		10		12	
			I	C	I	C	I	C	I	C	I	C	I	C	I	C	I	C	I	C	I	C	I	C	I	C
8	5	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
	6	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	24	13	PC	PC	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	37	21	PC	PC	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	48	29	PC	PC	PC	PC
	7	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	29	16	PC	PC	PC	PC	17	9	23	12	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	44	25	PC	PC	PC	PC	26	15	35	19	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	48	35	PC	PC	PC	PC	37	21	48	27	PC	PC
9	5	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
	6	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	22	12	PC	PC	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	34	19	PC	PC	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	48	27	PC	PC	PC	PC
	7	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	26	15	PC	PC	PC	PC	15	8	20	11	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	40	23	PC	PC	PC	PC	24	13	31	17	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	48	32	PC	PC	PC	PC	33	19	44	24	PC	PC
	8	#4 @ ... in.	PC	PC	PC	PC	PC	PC	26	15	PC	PC	PC	PC	19	11	PC	PC	PC	PC	11	6	15	8	19	10
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	40	23	PC	PC	PC	PC	30	17	PC	PC	PC	PC	18	10	23	13	29	16
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	48	32	PC	PC	PC	PC	42	24	PC	PC	PC	PC	25	14	33	18	41	22
10	5	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
	6	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	21	11	PC	PC	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	32	18	PC	PC	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	45	25	PC	PC	PC	PC
	7	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	24	13	PC	PC	PC	PC	14	8	19	10	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	37	21	PC	PC	PC	PC	22	12	29	16	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	48	29	PC	PC	PC	PC	31	17	41	22	PC	PC
	8	#4 @ ... in.	PC	PC	PC	PC	PC	PC	24	13	PC	PC	PC	PC	18	10	23	13	PC	PC	10	6	14	7	17	9
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	36	20	PC	PC	PC	PC	27	15	36	20	PC	PC	16	9	21	11	27	14
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	48	29	PC	PC	PC	PC	38	21	48	28	PC	PC	22	12	30	16	37	20
	9	#4 @ ... in.	28	16	PC	PC	PC	PC	18	10	24	13	PC	PC	14	7	18	10	PC	PC	8	NR	11	6	13	7
		#5 @ ... in.	43	24	PC	PC	PC	PC	28	16	37	20	PC	PC	21	11	28	15	PC	PC	12	6	17	9	21	11
		#6 @ ... in.	48	34	PC	PC	PC	PC	40	22	48	29	PC	PC	29	16	39	21	PC	PC	17	9	23	12	29	15

Notes:

a) PC refers to plain concrete where no vertical reinforcement is required. All other reinforcement shall be consistent with 9.2.3.2, 9.2.4, 9.2.5, and 9.2.6.

b) NR refers to not recommended where vertical reinforcement spacing drops below a practical field limitation of 6 in. on center for the given condition.

c) I refers to reinforcement placed near the tension face (inside) of the foundation wall as specified in 9.2.4.2(f).

d) C refers to reinforcement placed near the centerline of the foundation wall as specified in 9.2.4.2(g).

e) This table is applicable to walls of specified height, unbalanced backfill height, equivalent fluid pressure of soil, concrete strength, and the yield strength of reinforcement.

f) Values in this table are derived in accordance with Chapter 6 and 9.2.

g) Values under the thickened lines denote conditions where lateral loads at the top of the foundation wall exceed the capacity of the minimum provisions found in 9.6.1. A licensed design professional shall be consulted for the design of the connection between the floor framing and the foundation wall.

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Table 9.5.3.1e—Vertical reinforcing bar spacing for concrete basement walls; f_c' = 3500 psi and f_y = 40,000 psi

Reinforcing bar spacing for solid concrete foundation walls																										
Maximum clear wall height, ft	f_c' (psi) = 3500 f_y (psi) = 40,000		Maximum equivalent fluid pressure of soil, psf/ft																							
			30						45						60						100					
			Wall thickness, in.						Wall thickness, in.						Wall thickness, in.						Wall thickness, in.					
	Unbalanced backfill, ft	Reinforcing bar	8		10		12		8		10		12		8		10		12		8		10		12	
			I	C	I	C	I	C	I	C	I	C	I	C	I	C	I	C	I	C	I	C	I	C	I	C
8	5	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
	6	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	16	9	PC	PC	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	25	14	PC	PC	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	35	20	PC	PC	PC	PC
	7	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	11	6	15	8	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	18	10	23	13	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	25	14	33	18	PC	PC
9	5	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
	6	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	15	8	PC	PC	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	23	13	PC	PC	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	32	18	PC	PC	PC	PC
	7	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	17	10	PC	PC	PC	PC	10	6	14	7	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	27	15	PC	PC	PC	PC	16	9	21	11	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	37	21	PC	PC	PC	PC	22	13	29	16	PC	PC
	8	#4 @ ... in.	PC	PC	PC	PC	PC	PC	17	10	PC	PC	PC	PC	13	7	PC	PC	PC	PC	8	NR	10	NR	13	7
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	27	15	PC	PC	PC	PC	20	11	PC	PC	PC	PC	12	6	16	8	19	10
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	37	21	PC	PC	PC	PC	28	16	PC	PC	PC	PC	17	9	22	12	27	15
10	5	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
	6	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	14	8	PC	PC	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	21	12	PC	PC	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	30	17	PC	PC	PC	PC
	7	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	16	9	PC	PC	PC	PC	10	NR	13	7	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	25	14	PC	PC	PC	PC	15	8	19	11	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	35	20	PC	PC	PC	PC	21	12	27	15	PC	PC
	8	#4 @ ... in.	PC	PC	PC	PC	PC	PC	16	9	PC	PC	PC	PC	12	7	PC	PC	PC	PC	7	NR	9	NR	12	6
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	24	14	PC	PC	PC	PC	18	10	PC	PC	PC	PC	11	6	14	8	18	10
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	34	20	PC	PC	PC	PC	25	14	PC	PC	PC	PC	15	8	20	11	25	13
	9	#4 @ ... in.	19	10	PC	PC	PC	PC	12	7	PC	PC	PC	PC	9	NR	12	7	PC	PC	5	NR	7	NR	9	NR
		#5 @ ... in.	28	16	PC	PC	PC	PC	19	11	PC	PC	PC	PC	14	8	19	10	PC	PC	8	NR	11	6	14	7
		#6 @ ... in.	40	23	PC	PC	PC	PC	26	15	PC	PC	PC	PC	20	11	26	14	PC	PC	12	6	16	8	19	10

Notes:

a) PC refers to plain concrete where no vertical reinforcement is required. All other reinforcement shall be consistent with 9.2.3.2, 9.2.4, 9.2.5, and 9.2.6.

b) NR refers to not recommended where vertical reinforcement spacing drops below a practical field limitation of 6 in. on center for the given condition.

c) I refers to reinforcement placed near the tension face (inside) of the foundation wall as specified in 9.2.4.2(f).

d) C refers to reinforcement placed near the centerline of the foundation wall as specified in 9.2.4.2(g).

e) This table is applicable to walls of specified height, unbalanced backfill height, equivalent fluid pressure of soil, concrete strength, and the yield strength of reinforcement.

f) Values in this table are derived in accordance with Chapter 6 and 9.2.

g) Values under the thickened lines denote conditions where lateral loads at the top of the foundation wall exceed the capacity of the minimum provisions found in 9.6.1. A licensed design professional shall be consulted for the design of the connection between the floor framing and the foundation wall.

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CODE **COMMENTARY**

Table 9.5.3.1f—Vertical reinforcing bar spacing for concrete basement walls; f_c' = 3500 psi and f_y = 60,000 psi

Reinforcing bar spacing for solid concrete foundation walls																										
Maximum clear wall height, ft	f_c' (psi) = 3000 f_y (psi) = 60,000		Maximum equivalent fluid pressure of soil, psf/ft																							
			30						45						60						100					
			Wall thickness, in.						Wall thickness, in.						Wall thickness, in.						Wall thickness, in.					
	Unbalanced backfill, ft	Reinforcing bar	8		10		12		8		10		12		8		10		12		8		10		12	
			I	C	I	C	I	C	I	C	I	C	I	C	I	C	I	C	I	C	I	C	I	C	I	C
8	5	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
	6	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	24	14	PC	PC	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	37	21	PC	PC	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	48	30	PC	PC	PC	PC
	7	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	17	9	23	12	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	26	15	35	19	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	37	21	48	27	PC	PC
9	5	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
	6	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	22	12	PC	PC	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	34	19	PC	PC	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	48	27	PC	PC	PC	PC
	7	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	26	15	PC	PC	PC	PC	15	9	20	11	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	40	23	PC	PC	PC	PC	24	13	31	17	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	48	32	PC	PC	PC	PC	33	19	44	24	PC	PC
	8	#4 @ ... in.	PC	PC	PC	PC	PC	PC	26	15	PC	PC	PC	PC	19	11	PC	PC	PC	PC	12	6	15	8	19	10
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	40	23	PC	PC	PC	PC	30	17	PC	PC	PC	PC	18	10	23	13	29	16
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	48	32	PC	PC	PC	PC	42	24	PC	PC	PC	PC	25	14	33	18	41	22
10	5	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
	6	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	21	12	PC	PC	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	32	18	PC	PC	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	45	25	PC	PC	PC	PC
	7	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	24	13	PC	PC	PC	PC	14	8	19	10	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	37	21	PC	PC	PC	PC	22	12	29	16	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	48	30	PC	PC	PC	PC	31	17	41	23	PC	PC
	8	#4 @ ... in.	PC	PC	PC	PC	PC	PC	24	13	PC	PC	PC	PC	18	10	PC	PC	PC	PC	10	6	14	7	17	9
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	36	21	PC	PC	PC	PC	27	15	PC	PC	PC	PC	16	9	21	12	27	14
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	48	29	PC	PC	PC	PC	38	22	PC	PC	PC	PC	23	12	30	16	38	20
	9	#4 @ ... in.	28	16	PC	PC	PC	PC	18	10	PC	PC	PC	PC	14	8	18	10	PC	PC	8	NR	11	6	13	7
		#5 @ ... in.	43	24	PC	PC	PC	PC	28	16	PC	PC	PC	PC	21	12	28	15	PC	PC	12	7	17	9	21	11
		#6 @ ... in.	48	34	PC	PC	PC	PC	40	23	PC	PC	PC	PC	30	17	39	22	PC	PC	17	9	23	13	29	16

Notes:

a) PC refers to plain concrete where no vertical reinforcement is required. All other reinforcement shall be consistent with 9.2.3.2, 9.2.4, 9.2.5, and 9.2.6.

b) NR refers to not recommended where vertical reinforcement spacing drops below a practical field limitation of 6 in. on center for the given condition.

c) I refers to reinforcement placed near the tension face (inside) of the foundation wall as specified in 9.2.4.2(f).

d) C refers to reinforcement placed near the centerline of the foundation wall as specified in 9.2.4.2(g).

e) This table is applicable to walls of specified height, unbalanced backfill height, equivalent fluid pressure of soil, concrete strength, and the yield strength of reinforcement.

f) Values in this table are derived in accordance with Chapter 6 and 9.2.

g) Values under the thickened lines denote conditions where lateral loads at the top of the foundation wall exceed the capacity of the minimum provisions found in 9.6.1. A licensed design professional shall be consulted for the design of the connection between the floor framing and the foundation wall.

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Table 9.5.3.1g—Vertical reinforcing bar spacing for concrete basement walls; f_c' = 4000 psi and f_y = 40,000 psi

Reinforcing bar spacing for solid concrete foundation walls																										
Maximum clear wall height, ft	f_c' (psi) = 4000		Maximum equivalent fluid pressure of soil, psf/ft																							
	f_y (psi) = 40,000		30						45						60						100					
			Wall thickness, in.						Wall thickness, in.						Wall thickness, in.						Wall thickness, in.					
	Unbalanced backfill, ft	Reinforcing bar	8		10		12		8		10		12		8		10		12		8		10		12	
			I	C	I	C	I	C	I	C	I	C	I	C	I	C	I	C	I	C	I	C	I	C	I	C
8	5	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
	6	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	16	9	PC	PC	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	25	14	PC	PC	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	35	20	PC	PC	PC	PC
	7	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	11	6	PC	PC	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	18	10	PC	PC	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	25	14	PC	PC	PC	PC
9	5	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
	6	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	15	8	PC	PC	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	23	13	PC	PC	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	32	18	PC	PC	PC	PC
	7	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	17	10	PC	PC	PC	PC	10	6	14	7	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	27	15	PC	PC	PC	PC	16	9	21	12	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	37	22	PC	PC	PC	PC	22	13	30	16	PC	PC
	8	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	13	7	PC	PC	PC	PC	8	NR	10	6	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	20	11	PC	PC	PC	PC	12	7	16	9	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	28	16	PC	PC	PC	PC	17	9	22	12	PC	PC
10	5	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
	6	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	14	8	PC	PC	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	21	12	PC	PC	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	30	17	PC	PC	PC	PC
	7	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	16	9	PC	PC	PC	PC	10	NR	13	7	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	25	14	PC	PC	PC	PC	15	8	19	11	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	35	20	PC	PC	PC	PC	21	12	27	15	PC	PC
	8	#4 @ ... in.	PC	PC	PC	PC	PC	PC	16	9	PC	PC	PC	PC	12	7	PC	PC	PC	PC	7	NR	9	NR	12	6
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	24	14	PC	PC	PC	PC	18	10	PC	PC	PC	PC	11	6	14	8	18	10
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	34	20	PC	PC	PC	PC	26	15	PC	PC	PC	PC	15	8	20	11	25	14
	9	#4 @ ... in.	PC	PC	PC	PC	PC	PC	12	7	PC	PC	PC	PC	9	NR	12	7	PC	PC	5	NR	7	NR	9	NR
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	19	11	PC	PC	PC	PC	14	8	19	10	PC	PC	8	NR	11	6	14	7
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	27	15	PC	PC	PC	PC	20	11	26	14	PC	PC	12	6	16	8	19	10

Notes:

a) PC refers to plain concrete where no vertical reinforcement is required. All other reinforcement shall be consistent with 9.2.3.2, 9.2.4, 9.2.5, and 9.2.6.

b) NR refers to not recommended where vertical reinforcement spacing drops below a practical field limitation of 6 in. on center for the given condition.

c) I refers to reinforcement placed near the tension face (inside) of the foundation wall as specified in 9.2.4.2(f).

d) C refers to reinforcement placed near the centerline of the foundation wall as specified in 9.2.4.2(g).

e) This table is applicable to walls of specified height, unbalanced backfill height, equivalent fluid pressure of soil, concrete strength, and the yield strength of reinforcement.

f) Values in this table are derived in accordance with Chapter 6 and 9.2.

g) Values under the thickened lines denote conditions where lateral loads at the top of the foundation wall exceed the capacity of the minimum provisions found in 9.6.1. A licensed design professional shall be consulted for the design of the connection between the floor framing and the foundation wall.

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Table 9.5.3.1h—Vertical reinforcing bar spacing for concrete basement walls; f_c' = 4000 psi and f_y = 60,000 psi

Reinforcing bar spacing for solid concrete foundation walls																										
Maximum clear wall height, ft	f_c' (psi) = 4000 / f_y (psi) = 60,000		Maximum equivalent fluid pressure of soil, psf/ft																							
			30						45						60						100					
			Wall thickness, in.						Wall thickness, in.						Wall thickness, in.						Wall thickness, in.					
	Unbalanced backfill, ft	Reinforcing bar	8		10		12		8		10		12		8		10		12		8		10		12	
			I	C	I	C	I	C	I	C	I	C	I	C	I	C	I	C	I	C	I	C	I	C	I	C
8	5	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
	6	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	24	14	PC	PC	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	37	21	PC	PC	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	48	30	PC	PC	PC	PC
	7	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	17	10	PC	PC	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	26	15	PC	PC	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	37	21	PC	PC	PC	PC
9	5	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
	6	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	22	12	PC	PC	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	34	19	PC	PC	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	48	27	PC	PC	PC	PC
	7	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	26	15	PC	PC	PC	PC	16	9	20	11	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	40	23	PC	PC	PC	PC	24	13	31	17	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	48	32	PC	PC	PC	PC	33	19	44	25	PC	PC
	8	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	19	11	PC	PC	PC	PC	12	6	15	8	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	30	17	PC	PC	PC	PC	18	10	24	13	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	42	24	PC	PC	PC	PC	25	14	33	18	PC	PC
10	5	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
	6	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	21	12	PC	PC	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	32	18	PC	PC	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	45	26	PC	PC	PC	PC
	7	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	24	14	PC	PC	PC	PC	14	8	19	10	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	37	21	PC	PC	PC	PC	22	12	29	16	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	48	30	PC	PC	PC	PC	31	17	41	23	PC	PC
	8	#4 @ ... in.	PC	PC	PC	PC	PC	PC	24	13	PC	PC	PC	PC	18	10	PC	PC	PC	PC	11	6	14	8	17	9
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	36	21	PC	PC	PC	PC	27	15	PC	PC	PC	PC	16	9	21	12	27	14
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	48	29	PC	PC	PC	PC	38	22	PC	PC	PC	PC	23	13	30	17	38	20
	9	#4 @ ... in.	PC	PC	PC	PC	PC	PC	18	10	PC	PC	PC	PC	14	8	18	10	PC	PC	8	NR	11	6	13	7
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	28	16	PC	PC	PC	PC	21	12	28	15	PC	PC	12	7	17	9	21	11
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	40	23	PC	PC	PC	PC	30	17	39	22	PC	PC	18	10	23	13	29	16

Notes:

a) PC refers to plain concrete where no vertical reinforcement is required. All other reinforcement shall be consistent with 9.2.3.2, 9.2.4, 9.2.5, and 9.2.6.

b) NR refers to not recommended where vertical reinforcement spacing drops below a practical field limitation of 6 in. on center for the given condition.

c) I refers to reinforcement placed near the tension face (inside) of the foundation wall as specified in 9.2.4.2(f).

d) C refers to reinforcement placed near the centerline of the foundation wall as specified in 9.2.4.2(g).

e) This table is applicable to walls of specified height, unbalanced backfill height, equivalent fluid pressure of soil, concrete strength, and the yield strength of reinforcement.

f) Values in this table are derived in accordance with Chapter 6 and 9.2.

g) Values under the thickened lines denote conditions where lateral loads at the top of the foundation wall exceed the capacity of the minimum provisions found in 9.6.1. A licensed design professional shall be consulted for the design of the connection between the floor framing and the foundation wall.

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Table 9.5.3.1i—Vertical reinforcing bar spacing for concrete basement walls; f_c' = 4500 psi and f_y = 40,000 psi

Reinforcing bar spacing for solid concrete foundation walls																										
Maximum clear wall height, ft	f_c' (psi) = 4500	f_y (psi) = 40,000	Maximum equivalent fluid pressure of soil, psf/ft																							
			30						45						60						100					
			Wall thickness, in.						Wall thickness, in.						Wall thickness, in.						Wall thickness, in.					
	Unbalanced backfill, ft	Reinforcing bar	8		10		12		8		10		12		8		10		12		8		10		12	
			I	C	I	C	I	C	I	C	I	C	I	C	I	C	I	C	I	C	I	C	I	C	I	C
8	5	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
	6	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	16	9	PC	PC	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	25	14	PC	PC	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	35	20	PC	PC	PC	PC
	7	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	11	6	PC	PC	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	18	10	PC	PC	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	25	14	PC	PC	PC	PC
9	5	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
	6	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	15	8	PC	PC	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	23	13	PC	PC	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	32	18	PC	PC	PC	PC
	7	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	10	6	PC	PC	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	16	9	PC	PC	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	22	13	PC	PC	PC	PC
	8	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	13	7	PC	PC	PC	PC	8	NR	10	6	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	20	11	PC	PC	PC	PC	12	7	16	9	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	28	16	PC	PC	PC	PC	17	9	22	12	PC	PC
10	5	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
	6	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	14	8	PC	PC	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	21	12	PC	PC	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	30	17	PC	PC	PC	PC
	7	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	16	9	PC	PC	PC	PC	10	NR	13	7	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	25	14	PC	PC	PC	PC	15	8	19	11	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	35	20	PC	PC	PC	PC	21	12	27	15	PC	PC
	8	#4 @ ... in.	PC	PC	PC	PC	PC	PC	16	9	PC	PC	PC	PC	12	7	PC	PC	PC	PC	7	NR	9	NR	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	24	14	PC	PC	PC	PC	18	10	PC	PC	PC	PC	11	6	14	8	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	34	20	PC	PC	PC	PC	26	15	PC	PC	PC	PC	15	8	20	11	PC	PC
	9	#4 @ ... in.	PC	PC	PC	PC	PC	PC	12	7	PC	PC	PC	PC	9	NR	12	7	PC	PC	5	NR	7	NR	9	NR
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	19	11	PC	PC	PC	PC	14	8	19	10	PC	PC	8	NR	11	6	14	7
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	27	15	PC	PC	PC	PC	20	11	26	15	PC	PC	12	6	16	9	19	11

Notes:

a) PC refers to plain concrete where no vertical reinforcement is required. All other reinforcement shall be consistent with 9.2.3.2, 9.2.4, 9.2.5, and 9.2.6.

b) NR refers to not recommended where vertical reinforcement spacing drops below a practical field limitation of 6 in. on center for the given condition.

c) I refers to reinforcement placed near the tension face (inside) of the foundation wall as specified in 9.2.4.2(f).

d) C refers to reinforcement placed near the centerline of the foundation wall as specified in 9.2.4.2(g).

e) This table is applicable to walls of specified height, unbalanced backfill height, equivalent fluid pressure of soil, concrete strength, and the yield strength of reinforcement.

f) Values in this table are derived in accordance with Chapter 6 and 9.2.

g) Values under the thickened lines denote conditions where lateral loads at the top of the foundation wall exceed the capacity of the minimum provisions found in 9.6.1. A licensed design professional shall be consulted for the design of the connection between the floor framing and the foundation wall.

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Table 9.5.3.1j—Vertical reinforcing bar spacing for concrete basement walls; f_c' = 4500 psi and f_y = 60,000 psi

Reinforcing bar spacing for solid concrete foundation walls																										
Maximum clear wall height, ft	f_c' (psi) = 4500		Maximum equivalent fluid pressure of soil, psf/ft																							
	f_y (psi) = 60,000		30						45						60						100					
			Wall thickness, in.						Wall thickness, in.						Wall thickness, in.						Wall thickness, in.					
	Unbalanced backfill, ft	Reinforcing bar	8		10		12		8		10		12		8		10		12		8		10		12	
			I	C	I	C	I	C	I	C	I	C	I	C	I	C	I	C	I	C	I	C	I	C	I	C
8	5	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
	6	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	24	14	PC	PC	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	37	21	PC	PC	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	48	30	PC	PC	PC	PC
	7	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	17	10	PC	PC	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	26	15	PC	PC	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	37	21	PC	PC	PC	PC
9	5	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
	6	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	22	13	PC	PC	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	34	19	PC	PC	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	48	28	PC	PC	PC	PC
	7	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	16	9	PC	PC	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	24	13	PC	PC	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	34	19	PC	PC	PC	PC
	8	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	20	11	PC	PC	PC	PC	12	6	15	8	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	30	17	PC	PC	PC	PC	18	10	24	13	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	42	24	PC	PC	PC	PC	25	14	33	18	PC	PC
10	5	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
	6	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	21	12	PC	PC	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	32	18	PC	PC	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	45	26	PC	PC	PC	PC
	7	#4 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	24	14	PC	PC	PC	PC	14	8	19	10	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	37	21	PC	PC	PC	PC	22	12	29	16	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	48	30	PC	PC	PC	PC	31	18	41	23	PC	PC
	8	#4 @ ... in.	PC	PC	PC	PC	PC	PC	24	13	PC	PC	PC	PC	18	10	PC	PC	PC	PC	11	6	14	8	PC	PC
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	37	21	PC	PC	PC	PC	27	15	PC	PC	PC	PC	16	9	21	12	PC	PC
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	48	30	PC	PC	PC	PC	38	22	PC	PC	PC	PC	23	13	30	17	PC	PC
	9	#4 @ ... in.	PC	PC	PC	PC	PC	PC	18	10	PC	PC	PC	PC	14	8	18	10	PC	PC	8	NR	11	6	13	7
		#5 @ ... in.	PC	PC	PC	PC	PC	PC	28	16	PC	PC	PC	PC	21	12	28	15	PC	PC	13	7	17	9	21	11
		#6 @ ... in.	PC	PC	PC	PC	PC	PC	40	23	PC	PC	PC	PC	30	17	39	22	PC	PC	18	10	23	13	29	16

Notes:

a) PC refers to plain concrete where no vertical reinforcement is required. All other reinforcement shall be consistent with 9.2.3.2, 9.2.4, 9.2.5, and 9.2.6.

b) NR refers to not recommended where vertical reinforcement spacing drops below a practical field limitation of 6 in. on center for the given condition.

c) I refers to reinforcement placed near the tension face (inside) of the foundation wall as specified in 9.2.4.2(f).

d) C refers to reinforcement placed near the centerline of the foundation wall as specified in 9.2.4.2(g).

e) This table is applicable to walls of specified height, unbalanced backfill height, equivalent fluid pressure of soil, concrete strength, and the yield strength of reinforcement.

f) Values in this table are derived in accordance with Chapter 6 and 9.2.

g) Values under the thickened lines denote conditions where lateral loads at the top of the foundation wall exceed the capacity of the minimum provisions found in 9.6.1. A licensed design professional shall be consulted for the design of the connection between the floor framing and the foundation wall.

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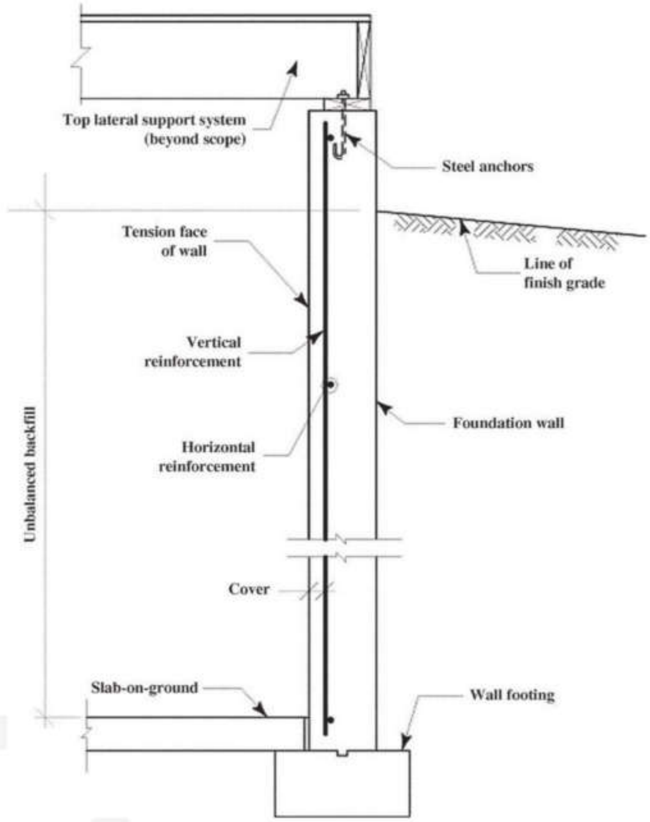

Fig. R9.5.3.1—Reinforced concrete foundation wall.

9.6—Connection to lateral support system

9.6.1 *Connection to floor framing system at top of wall*

A positive connection by means of bolts, or alternative anchors approved by the jurisdiction having authority, shall be required between the top of the wall and the floor framing system. The minimum size and spacing of the anchors that transmit the lateral force due to earth pressures to the floor framing system shall conform to (a) through (f):

(a) Anchor bolt diameter shall be at least 0.5 in.
(b) Embedment depth of anchor bolts shall be at least 7 in.
(c) Spacing of anchors bolts shall not exceed 6 ft.
(d) A minimum of one anchor shall be located within 12 in. of each change of wall direction, height, or termination.
(e) A minimum of one anchor shall be located within 12 in. of each side of each door or window opening.
(f) Other anchors or anchor straps shall be spaced as specified by the anchor manufacturer to provide an equivalent connection to anchor blots conforming with (a) through (c). Minimum anchor size and embedment shall be as specified by the anchor manufacturer.

9.6.2 Wall-to-footing joints that comply with 8.2.2.1 are deemed to have satisfied the bottom lateral support requirement.

9.7—Construction requirements

9.7.1 *Forms*

Foundation wall forms shall be properly braced during placement and vibration of concrete and shall result in a

R9.7—Construction requirements

R9.7.1 *Forms*

Bulkheads form the edge of a construction joint and are used at the end of a placement when an interruption is

ture that conforms to the shapes, lines, and dimensions within the tolerances specified as required by the design drawings and specifications. Block-outs, inserts, bulkheads, embedded items, and reinforcement shall be installed in the forms in such a manner that their final dimensions, alignments, and elevations are maintained within the tolerances specified.

planned or anticipated. Common tolerances for residential concrete can be found in ACI 332.1R.

9.7.2 *Construction joints*

R9.7.2 *Construction joints*

Construction joints may be required where there is an interruption in the placement of concrete.

9.7.2.1 The joint surface shall be clean and wetted immediately before concrete is placed.

R9.7.2.1 External waterproofing and internal waterstops are methods commonly used to provide watertight construction joints.

9.7.2.2 Construction joints shall be oriented vertically in plain concrete walls. Horizontal or vertical construction joints are permitted in reinforced concrete walls.

9.7.2.3 For vertical construction joints, a minimum of three horizontal reinforcing bars, equally spaced, shall extend through construction joints, with a minimum length of 24 in. on each side of the joint.

9.7.2.4 Construction joints shall be sealed in a manner to prevent seepage of water, paste, or mortar through the joint during concrete placement and consolidation.

9.7.3 *Surface irregularities*

9.7.3.1 Fins or projections of concrete greater than 0.5 in. shall be removed after stripping forms. Surface areas where voids in the concrete placement expose the reinforcement shall be repaired.

R9.7.3 *Surface irregularities*

It is important to remove fins or other projections from the exterior wall surface to prevent interference with dampproofing and waterproofing systems. It is also important to remove fins or other projections from the interior wall surface to prevent interference with interior finish systems where the wall surface encloses occupied space.

9.7.4 *Lateral restraint*

9.7.4.1 The foundation walls shall be restrained top and bottom against lateral movement. The top and bottom restraint for the foundation wall shall be in place before the introduction of backfill against the foundation wall. Temporary lateral restraint shall be permitted.

R9.7.4 *Lateral restraint*

A properly detailed connection between the wall and the interior slab or a wall-to-footing joint conforming to 8.2.2.1 should provide bracing to the wall bottom. Values for equivalent fluid pressure can be determined by using ASCE/SEI 7, the general building code, or geotechnical reports obtained locally.

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CHAPTER 10—ABOVE-GRADE WALLS

10.1—Scope

10.1.1 Provisions of this chapter shall apply to exterior above grade walls of buildings within the scope of this code.

10.2—General

10.2.1 *Material*

10.2.1.1 Design properties for concrete shall be selected to be in accordance with Chapter 5 and 10.2.1.

10.2.1.2 Design properties for steel reinforcement shall be selected to be in accordance with 10.2.2.

10.2.2 *Connection to other members*

10.2.2.1 Factored forces and moments at top and base of walls shall be transferred to supporting members by bearing on concrete and by reinforcement and dowels.

10.2.2.2 Lateral support is required at the top and bottom of the wall.

10.2.3 *Forming systems*

10.2.3.1 Removable forms and stay-in-place concrete forms shall be permitted.

10.3—Design limits

10.3.1 Minimum specified wall thickness shall be 4 in.

10.3.2 The maximum vertical steel reinforcement provisions shall be No. 4 at 48 in. on center.

10.4—Required strength

10.4.1 Required strength shall be calculated in accordance with the factored load combination in 6.3.

10.4.2 Required strength shall be calculated in accordance with the analysis procedures in Chapter 6.

10.5—Design

10.5.1 Above-grade wall design shall be designed in accordance with Chapter 6 and based on analyzing the wall as a simply supported vertical flexural member with the top and bottom laterally supported.

10.5.2 The structure shall be designed to resist the wind loads determined in accordance with ASCE/SEI 7.

10.5.3 *Connection to lateral support system at top of wall*

COMMENTARY

CHAPTER R10—ABOVE-GRADE WALLS

R10.3—Design limits

R10.3.2 Experience in the design of above-grade concrete residential walls demonstrates that most designs for a wind speed of 150 mph results in a vertical bar spacing of 48 in. on center when using No. 4 steel reinforcement bars.

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10.5.3.1 A positive connection by means of steel anchors shall be required between the top of the wall and the lateral bracing system.

10.6—Construction requirements

10.6.1 *Forms*

10.6.1.1 Above-grade wall forms shall be stable during placement of concrete and shall result in a structure that conforms to the shapes, lines, and dimensions within tolerances as required by the design drawings and specifications. Block outs, inserts, bulkheads, embedded items, and reinforcement shall be installed in the forms in such a manner that their final dimensions, alignments, and elevations are maintained within the tolerances specified.

10.6.2 *Construction joints*

10.6.2.1 The joint surface shall be clean and wetted and standing water removed from the forms immediately before concrete is placed.

10.6.2.2 Construction joints shall be oriented vertically in concrete walls.

10.6.2.3 For vertical construction joints, a minimum of three horizontal reinforcing bars, equally spaced, shall extend through construction joints, with a minimum length of 24 in. on each side of the joint.

10.6.2.4 Construction joints shall be sealed in a manner to prevent seepage of water, paste, or mortar through the joint.

10.6.3 *Surface irregularities*

10.6.3.1 Fins or projections of concrete greater than 0.5 in. shall be removed after stripping forms. Surface areas where voids in the concrete placement expose the reinforcement shall be repaired.

10.6.4 *Continuity of wall reinforcement between stories*

10.6.4.1 Vertical reinforcement shall be continuous between elements providing lateral support of the wall.

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R10.6—Construction requirements

R10.6.2 *Construction joints*

R10.6.2.1 It is important to remove fins or other projections from the exterior wall surface to prevent interference with exterior finish systems or exposed concrete performance. It is also important to remove fins or other projections from the interior wall surface to prevent interference with interior finish systems where the wall surface encloses occupied space.

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CHAPTER 11—LINTEL BEAMS

11.1—Scope

11.1.1 Provisions of this chapter shall apply to lintel beams of buildings within the scope of this code.

11.1.2 Design of reinforced concrete walls shall be in accordance with Chapter 9.

11.2—General

11.2.1 *Material*

11.2.1.1 Design properties for concrete shall be selected to be in accordance with 6.2.1.

11.2.1.2 Design properties for steel reinforcement shall be selected to be in accordance with 6.2.2.

11.2.2 Lintel beams shall be designed for gravity load bearing conditions only.

11.2.3 Lintel beams shall be designed to support uniform loads from roof, floor, and wall framing. Lintels supporting concentrated loads from roof or floor beams or girders or similar framing are beyond the scope of this section and shall be designed by a licensed design professional.

11.2.4 Lintel beams shall conform to (a) through (d):

(a) Steel reinforcement shall be provided in all lintel beams spanning openings equal to or greater than 2 ft in width

COMMENTARY

CHAPTER R11—LINTEL BEAMS

R11.2—General

R11.2.2 Arching action above opening should be considered. The lintel beam only supports the weight of the concrete and structure above the opening bounded by a triangular or trapezoidal shape having a base corresponding to the clear span of the lintel beam, and sides that start at the top edges of the opening, extending upward and inward toward the center of the opening at an angel of 45 degrees (refer to Fig. R11.2.2). In cases where significant uplift forces can occur, such as in high-wind events, lintel beams may be subjected to reversed loading conditions.

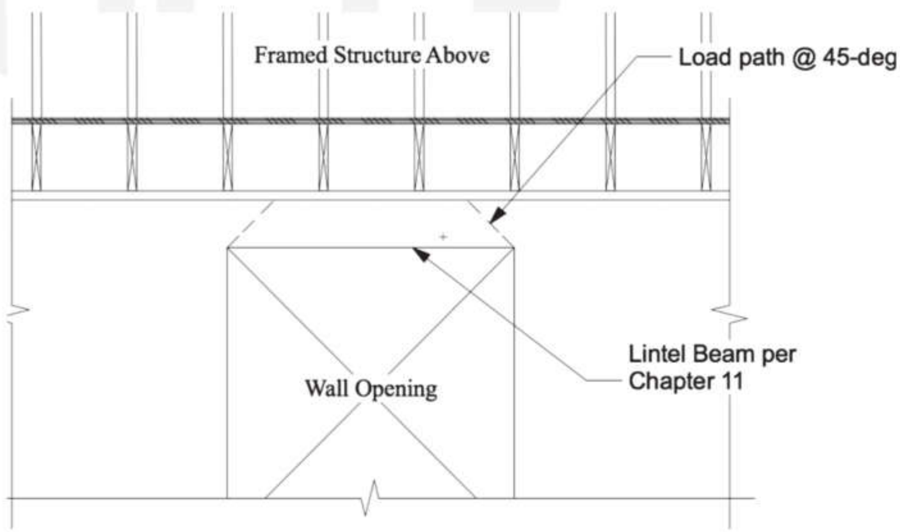

Fig. R11.2.2—Typical load path for lintel beam.

R11.2.3 Lintel beams are used to transfer wall, floor, roof, and attic dead loads; snow loads; and live loads above opening in walls to the sides of the opening.

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(b) Lintel beam span shall not exceed 72 in.
(c) Steel reinforcement shall extend at least 24 in. into the wall section at each end of the lintel beam.
(d) Concrete cover shall be in accordance with 5.6.

11.3—Design limits

11.3.1 Minimum depth of cast in place lintel beams shall be the greater of $\ell/16$ or 8 in.

11.3.2 For lintel beams with $P_u < 0.10f_c'A_g$, ε_t shall be at least 0.004.

11.3.3 Negative moment at the supporting ends shall govern and be based on $w\ell^2/12$.

R11.3—Design limits

R11.3.1 It is common in the residential concrete industry to have a standard assumption for a lintel condition in a cast-in-place concrete wall to use a simply supported beam model.

R11.3.3 Lintel beams have fixed end restraints because the walls and lintel beams are cast monolithically.

11.4—Required strength

11.4.1 Required strength shall be calculated in accordance with the factored load combination in 6.3.

11.4.2 Required strength shall be calculated in accordance with the analysis procedures in Chapter 6.

11.5—Design

11.5.1 Lintel beams shall be designed by one of the following methods:
(a) In accordance with Chapter 6
(b) According to the prescriptive method in 11.6.

11.5.2 ϕ shall be determined in accordance with 6.4

11.6—Prescriptive design

11.6.1 Lintel beams spanning openings ≤54 in. shall have a minimum of two No. 4 steel reinforcement bars.

11.6.2 Steel reinforcement bars shall be spaced evenly across the bottom of the lintel beam but no closer than 1 in. between bars.

11.6.3 Lintel beams spanning openings 54 in. and ≤72 in. shall have steel reinforcement bars in accordance with 11.6.3.1 through 11.6.3.3.

11.6.3.1 Lintel beams supporting structures of two-stories or less shall have three No. 4 steel bars.

11.6.3.2 Lintel beams supporting structures of three-stories with tributary spans less than 40 ft shall have three No. 4 steel bars.

11.6.3.3 Lintel beams supporting structures of three-stories with tributary spans of 40 ft shall have four No. 4 steel bars.

11.6.4 Reentrant corners at the lower boundary of lintel beams shall be reinforced in accordance with 9.2.6.2.

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CHAPTER 12—DESIGN FOR EXPANSIVE SOILS

12.1—Scope

Provisions of this chapter shall apply to footings and foundations constructed in areas known to contain expansive clays.

12.2—General

12.2.1 The design of footings and foundations for buildings and structures founded on expansive soil shall conform to 12.3.1 or 12.3.2.

12.2.2 Where expansive soil is removed to a depth that ensures constant moisture content in the remaining soil, or when the soil is stabilized in accordance with the general building code, the design of footings and foundations for buildings and structures need not conform to 12.3.1 or 12.3.2.

12.2.3 Fill material shall comply with the general building code and shall not contain expansive soils.

12.3—Expansive soil classification

Soils shall be considered expansive when the expansion index is greater than 20 as determined in accordance with ASTM D4829 or when soils tested meet with (a), (b), and (c):

(a) Plasticity index of 15 or greater, determined in accordance with ASTM D4318

(b) More than 12 percent of the soil particles are less than 75 μm (pass a No. 200 sieve), determined in accordance with ASTM D422

(c) More than 12 percent of the soil particles are less than 5 μm in size, determined in accordance with ASTM D422

12.4—Design

12.4.1 *Footings and foundations*

12.4.1.1 Footings or foundations placed on or within the moisture active zone of expansive soils shall be designed to resist differential volume changes and to prevent damage to the supported structure.

12.4.1.2 Foundations extending into or penetrating expansive soils shall be designed to prevent uplift of the supported structure and to resist forces exerted on the foundation due to soil volume changes or shall be isolated from the expansive soil.

12.4.2 *Slab-on-ground mat foundations*

12.4.2.1 Slab-on-ground and mat foundations on expansive soils shall be designed using moments, shears, and deflections derived from an analysis that accounts for the combined action of the deformed shape of the soil support, the plate or stiffened plate action of the slab, as well as both edge lift and edge drop conditions.

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CHAPTER R12—DESIGN FOR EXPANSIVE SOILS

R12.2—General

Plasticity index is the range of water content where the soil is plastic, which is an important consideration for engineering behavior of soil. For expansive soils, recommendations for an appropriate plasticity index comes from soil mechanics and geotechnical engineering, which are well established fields of study.

R12.4—Design

R12.4.1 *Footings and foundations*

For limits on deflection and cracking of the supported structure, refer to the general building code.

R12.4.2 *Slab-on-ground mat foundations*

The licensed design professional should design the slab on expansive soil. If a post-tensioned slab is considered, then the guidance on slab design can be obtained in ACI 360R and post-tensioned slabs-on-ground can be found in PTI DC10.1. The provisions for slabs-on-ground that are not on expansive soils are addressed in Chapter 13 of this code.

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CHAPTER 13—SLABS-ON-GROUND

13.1—Scope

13.1.1 Provisions of this chapter shall apply to concrete flatwork that is cast-in-place concrete with, and supported by, underlying soils.

13.1.2 Provisions in this chapter shall be limited to established residential loads and/or subjected to loads from vehicles with a passenger capacity of nine or fewer.

13.2—Design

13.2.1 Slabs-on-ground must meet the requirements (criteria) outlined in this chapter.

13.2.2 Concrete used for slabs-on-ground shall meet the requirements of Tables 5.2.1 and 5.3.2.

13.3—Support

Slabs-on-ground shall be continuously supported on undisturbed soil or with fill and base as described in 13.2.1 and 13.2.2.

13.3.1 *Fill*

13.3.1.1 The fill shall be compacted to provide uniform support to the slab and shall not contain deleterious quantities of organic or foreign material. Fill lifts shall not exceed 24 in. for clean sand or gravel and 8 in. for suitable soils, unless approved by the local building official.

13.3.2 *Base*

13.3.2.1 A 4 in. thick base course consisting of clean graded sand, gravel, crushed stone, crushed slag, or recycled crushed concrete passing a 2 in. sieve shall be placed on the prepared subgrade when the slab is below grade.

13.4—Forms

Forms for slabs-on-ground shall be braced to maintain horizontal and vertical alignment with sufficient strength to resist concrete pressure and applied loads from mechanical placing and finishing equipment.

13.5—Thickness

The minimum thickness of slabs-on-ground shall be 3.5 in.

13.6—Joints

13.6.1 *Construction joints*

COMMENTARY

CHAPTER R13—SLABS-ON-GROUND

R13.2—Design

These provisions apply to slabs placed on ground where the loads do not exceed those expected because of pedestrian traffic and passenger vehicles. Any slab placed on soil not suitable to support the imposed loads, located over voids, or otherwise not continuously supported should be designed and constructed as a structural slab. In addition, refer to the general building code for applicable requirements concerning vapor retarder, granular base drainage, waterproofing, and damp-proofing requirements.

R13.5—Thickness

Interior bearing walls on slabs-on-ground may require thickened slab footings for load distribution. Refer to Fig. R8.2.3.2a and 8.2.3.2c for unformed thickened slab footings.

R13.6—Joints

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13.6.1.1 Formed construction joints shall be provided when concrete placing operations are interrupted long enough for previously placed concrete to set.

13.6.2 *Contraction joints*

13.6.2.1 Contraction joints shall conform to (a) through (e). Alternatively, an isolation joint conforming to 13.6.3 is an acceptable contraction joint.
(a) Joints shall be formed, inserted, sawed, or tooled.
(b) Joint spacing shall not exceed the limits of Table 13.6.2.1
(c) Slab sections defined by contraction joints shall have an aspect ratio not greater than 1.5.
(d) For conventional, wet- or dry-cut, sawed joints in hardened concrete, joint depth shall be a minimum of one-fourth of the slab thickness.
(e) For mechanical inserts, tooled, or early-entry sawcuts, joint depth shall be a minimum of 1 in. or one-fifth of the slab thickness, whichever is greater.

Table 13.6.2.1—Specified maximum contraction joint spacing for slab-on-ground*

Slab thickness *h*, in.	Specified maximum size aggregate less than 3/4 in.	Specified maximum size aggregate 3/4 in. and larger
3.5	8 ft	10 ft
4.5	10 ft	13 ft
5.5	12 ft	15 ft

*Applies for slabs without steel reinforcement and slabs containing up to 0.1 percent reinforcement

13.6.3 *Isolation joints*

13.6.3.1 Isolation joints shall extend the full depth of the slab.

13.6.3.2 Where vehicular traffic crosses isolation joints, slab thickness shall be increased at least 25 percent at the joint and tapered back to thickness over a distance not less than 12 in. from the joint.

13.7—Reinforcement

Reinforcement shall consist of deformed bars conforming to 4.2.1.

13.7.1 *Steel reinforcement*

13.7.1.1 Steel reinforcement shall be placed and maintained in the upper one-half of the slab depth with a minimum cover of 3/4 in. for interior conditions and 1-1/2 in. for exterior conditions. Reinforcement shall be supported in a manner that maintains its position during concrete placement.

13.7.2 *Fiber reinforcement*

13.7.2.1 The dosage rate of synthetic microfibers used for plastic shrinkage crack control shall be determ

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R13.6.2 *Contraction joints*

Contraction joints are required because concrete shrinkage (shortening) occurs at a ratio of approximately 5/8 in. for each 100 ft based on empirical data.

Interior bearing walls should not bear directly on slabs-on-ground without considering the location of the contraction joint relative to the bearing wall. Also, the floor finish (such as carpeting or tile) manufacturer instructions should be consulted to determine the ability of the floor finish to span the contraction joint. The spacing of joints according to the provisions of Table 13.6.2.1 is intended to control location of cracks; however, it may not eliminate all random cracks in concrete slabs. For slab sections, with one or two sides restrained by connection to a footing, the aspect ratio limitations are waived. Experience has shown that the use of an early-entry concrete saw 1 to 4 hours after finishing or a conventional saw 4 to 12 hours after finishing tends to limit in-panel crack development. Refer to ACI 302.1R for more information on limiting slab-on-ground cracking.

R13.6.3 *Isolation joints*

Usually, isolation joints use at least 3/8 in. thick premolded joint filler. Isolation joints are provided where:
(a) Slab edges are adjacent to other slabs-on-ground or walls
(b) Rigid elements penetrate the slabs-on-ground

Isolation joints are formed at the rigid element penetrations by wrapping the element with a compressible filler material.

R13.7—Reinforcement

R13.7.2 *Fiber reinforcement*

Synthetic microfibers may be used to control plastic shrinkage cracking. Synthetic macrofibers, steel fibers, or both may be used to control drying shrinkage cracking and

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a licensed design professional. Macrofibers and steel fibers dosage rates shall be determined by a licensed design professional.

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provide post-crack load-carrying capacity in place of or in combination with steel reinforcement. Macrofiber and steel fiber dosage rates may be determined in accordance with ACI 544.4R. Building product evaluation reports published by an organization accredited by ISO/IEC 17065 may additionally be used. Currently, ICC AC reports exist for synthetic and steel fibers. Refer to Table R13.7.2 for the common descriptions and dosage rates for synthetic fibers.

Table R13.7.2—Fibers: properties and use

	Microfibers		**Macrofibers**
Fiber configuration	Monofilament	Fibrillated	Monofilament/fibrillated
Function	Plastic shrinkage settlement/ relaxation lessened	Plastic shrinkage settlement/ relaxation lessened	Settlement/relaxation lessened Temperature and shrinkage crack control
	Precrack	Precrack Post-crack	Precrack Post-crack
Fiber materials	Typical dosage*	Typical dosage*	Typical dosage*
Synthetics	0.5 to 1.0 lb/yd^3	1.5 to 3.0 lb/yd^3	3.0 to 7.5 lb/yd^3
Natural	0.5 to 1.0 lb/yd^3	—	—
Glass	0.5 to 1.0 lb/yd^3	3.0 to 6.0 lb/yd^3	6.0 to 30.0 lb/yd^3
Steel	—	—	6 to 40 lb/yd^3

*Dosages are for general guidance only. Consult manufacturers' recommendations.

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ACI 301-16—Specifications for Structural Concrete

ACI 302.1R-15—Guide to Concrete Floor and Slab Construction

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ACI 304.6R-09—Guide for Use of Volumetric-Measuring and Continuous-Mixing Concrete Equipment

ACI 305R-10—Guide to Hot Weather Concreting

ACI 305.1-06—Specification for Hot Weather Concreting

ACI 306R-16—Guide to Cold Weather Concreting

ACI 306.1-90(02)—Standard Specification for Cold Weather Concreting

ACI 308R-16—Guide to External Curing of Concrete

ACI (308-213)R-13—Report on Internally Cured Concrete Using Prewetted Absorptive Lightweight Aggregate

ACI 309R-05—Guide for Consolidation of Concrete

ACI 318-19—Building Code Requirements for Structural Concrete and Commentary

ACI 332.1R-18—Guide to Residential Concrete Construction

ACI 347R-14—Guide to Formwork for Concrete

ACI 360R-10—Guide to Design of Slabs-on-Ground

ACI 544.4R-18—Guide to Design with Fiber-Reinforced Concrete

ACI SP-4(14)—Formwork for Concrete (eighth edition)

American Society of Civil Engineers

ASCE/SEI 7-16—Minimum Design Loads for Buildings and Other Structures

ASTM International

ASTM C39/C39M-18—Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens

ASTM C94/C94M-18—Standard Specification for Ready-Mixed Concrete

ASTM C143/C143M-15—Standard Test Method for Slump of Hydraulic Cement Concrete

ASTM C173/C173M-16—Standard Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method

ASTM C231/C231M-17—Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method

ASTM C595/C595M-19—Standard Specification for Blended Hydraulic Cements

ASTM C1074-13—Standard Practice for Estimating Concrete Strength by the Maturity Method

ASTM C1157/C1157M-17—Standard Performance Specification for Hydraulic Cement

ASTM C1611/C1611M-18—Standard Test Method for Slump Flow of Self-Consolidating Concrete

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ASTM C1761/C1761M-17—Standard Specification for Lightweight Aggregate for Internal Curing of Concrete

ASTM E1643-18—Standard Practice for Selection, Design, Installation, and Inspection of Water Vapor Retarders Used in Contact with Earth or Granular Fill Under Concrete Slabs

ASTM E1745-17—Standard Specification for Plastic Water Vapor Retarders Used in Contact with Soil or Granular Fill under Concrete Slabs

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IBC-2018—International Building Code

IRC-2018—International Residential Code

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ISO/IEC 17065:2012—Conformity assessment - Requirements for bodies certifying products, processes and services

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PCA 100.03-2017—Prescriptive Design of Exterior Concrete Walls for One- and Two-Family Dwellings

Post-Tensioning Institute

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