THE VOICE AND RECOGNIZED AUTHORITY FOR THE RESIDENTIAL CONCRETE INDUSTRY

TECH NOTE: TN-001

Codes for Residential Concrete Construction

Goal And Purpose

This edition of Tech Notes explains the three major consensus standards that cover residential concrete construction and the potential benefits of using them together.

A standard, while written in mandatory code language, does not become a code until it is adopted by a government jurisdiction responsible for enacting and adopting codes. State, provincial, city and county governments adopt a general standard document developed either by the International Codes Council (ICC), the National Research Council Canada (NRCC) or the National Fire Protection Association (NFPA). If a general standard is not adopted as a general code, a jurisdiction may have a consensus document developed by their own technical committee with reference to other standard documents produced by ANSI-approved consensus organizations such as the American Concrete Institute (ACI) or the Portland Cement Association (PCA) as well as other other standards developing organizations.

The three most relevant residential standards currently are:

- **International Residential Code (IRC)**

The IRC is a comprehensive residential code that sets minimum regulations for one- and two-family dwellings of three stories or less. It combines all building, plumbing, mechanical, fuel, gas, energy and electrical provisions for residences of this scope and superseded the three model codes in the United States (SBC, UBC and BOCA/NBC) beginning in 1997.

- **National Building Code of Canada (NBC)**

The NBC was first commissioned in 1947 and after 1960 has been updated or re-published every five years. This document governs all buildings in jurisdictions of adoption whereas the ICC separates its building code into commercial (IBC) and residential (IRC) standards. Several of the provinces have construction codes that are based on the majority of the NBC though not all have adopted it in its entirety.

- **ACI 332 Standard**

The ACI 332 Committee—Residential Concrete, developed a standard for concrete construction in residential applications. The complete title is Requirements for Residential Concrete Construction (ACI 332) and is given a date representing its most recent version. Originally published in 2004, this standard began as a prescriptive reference code to ACI 318 with modified strength provisions. Since then, the standard has continued to evolve with broadening applications across all forms of residential concrete construction. The 2019 version of the code is the first to present a full design methodology to residential concrete making it a stand-alone standard.

Instead of totally rewriting the general standard/code documents such as the IRC to include the provisions of ACI 332, the proponents of the document (CFA, NAHB, PCA, ACI, and NRMCA) have advocated for the addition of alternate reference to ACI 332 as an acceptable standard. This maintains a separation of the content and the authority of ACI 332 for enhanced detailing, design and prescriptive application as well as the autonomy of the standard with respects to the broader context of construction systems these general code documents must accommodate. An example of this can be found in section R404.1 of the 2015 IRC as follows:

> *R404.1 Concrete and masonry foundation walls. Concrete and masonry foundation walls shall be selected and constructed in accordance with the provisions of Section 404 or in accordance with the ACI 318, ACI 332, NCMA TR68-A or ACI 530/ASCE 5/TMS 402 or other approved structural standards. When ACI 318, ACI 332 or ACI 530/*

ASCE 5/TMS 402 or the provisions of Section R404 are used to design concrete or masonry foundation walls, project drawings, typical details and specifications are not required to bear the seal of the architect or engineer responsible for design, unless otherwise required by the state law of the jurisdiction having authority.

This simple reference enables a concrete foundation contractor in a jurisdiction that has adopted the IRC to use chapter 8 and its provisions ACI 332-14 for the design of residential foundation walls. A primary advantage is the Prescriptive Tables that offer greater flexibility and broader recognition for plain structural concrete. The tables offer concrete strengths ranging from 2500 psi to 4500 psi and wall heights up to 10 feet in height – a considerably wider range than IRC tables allow.

Below is a portion from one of the ten tables that are provided by 332. Each table combines both plain structural concrete requirements as well as reinforced concrete requirements to simplify the decision of wall design for the user.

One of the key areas of simplification and influence by ACI 332 is the combined tables referencing ares of "Plain", or in the IRC, "PC" and areas with a numerical value representing the spacing of vertical bars. "Plain" or "PC" refers to the term, "Plain Concrete" and is defined as concrete with no reinforcement bars required for structural performance, that is, to resist the external loads applied to the concrete structure. This effort by ACI 332, which led to the IRC combining separate tables for plain concrete and steel-reinforced concrete, results in an increased application of plain structural concrete due to the proven performance of concrete foundation walls under the relatively light loads of residential applications. The IRC values for required steel implements a term known as "Moderately Reinforced Design", which prescribes less steel than the minimum amount permitted by ACI 318. Versions of

RESIDENTIAL CODE REQUIREMENTS FOR STRUCTURAL CONCRETE (ACI 332-14) AND COMMENTARY

CODE COMMENTARY

Table 8.2.1.3d—Vertical reinforcing bar spacing for concrete basement walls

REBAR SPACING FOR SOLID CONCRETE FOUNDATION WALLS

MAXIMUM CLEAR WALL HEIGHT (FT)	f'c (PSI) = 3,500		MAXIMUM EQUIVALENT FLUID PRESSURE OF SOIL (PSF/FT)																									
	fy (PSI) = 60,000		30						45						60						100							
			WALL THICKNESS (IN.)																									
	UNBALANCED BACKFILL (FT)	REBAR	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 @ … inches	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 @ … inches	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 @ … inches	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 @ … inches	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 @ … inches	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 @ … inches	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 @ … inches	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 @ … inches	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 @ … inches	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC	37	21	48	27	PC	PC		
10	5	#4 @ … inches	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 @ … inches	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 @ … inches	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 @ … inches	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 @ … inches	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 @ … inches	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 @ … inches	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 @ … inches	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 @ … inches	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 @ … inches	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 @ … inches	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 @ … inches	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 @ … inches	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 @ … inches	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 @ … inches	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) The term "plain" refers to concrete where no vertical reinforcement is required other than reinforcement consistent with 8.2.10 and where horizontal reinforcement is required in accordance with 8.2.8 and 8.2.9.
b) 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.
c) This table is applicable only when the structure is not assigned to SDC D, E, or F.
d) Values in this table are derived in accordance with ACI 318 and 8.2.

ACI 332 prior to 332-19 prescribed an increase percentage of walls without structural steel, however, when the applied loads reached high enough to crack the section, a higher minimum steel was automatically calculated. Beginning with 332-19, "moderately-reinforced concrete" has been incorporated through a full design methodology (something that does not exist in the IRC) resulting in a lowering of the total steel required for structurally-reinforced foundation walls for these structures.

ADDITIONAL CODE REFERENCES

Beginning with the 2009 IRC, ACI 332 became a reference document in multiple chapters, in addition to R404.1. These include R402.2 for Concrete Materials, and R403.1 for Footings and R506.1 for Concrete Floors (On Ground). This broadens the application to address more of the advantageous information found in the evolving 332 Standard and greater control of constructibility issues for residential concrete contractors. The reference language is consistent such as:

Materials used to produce concrete and testing thereof shall comply with the applicable standards listed in Chapter 3 of 'ACI 318' or 'ACI 332'.

The most significant advantage to this reference for materials is the first code recognition for acceptance of contaminants on reinforcement not being deleterious to bond or affecting the strength performance of the embedded deformed reinforcement. ACI 332-14 states:

4.2.4 Surface conditions of reinforcement—At the time concrete is placed, deformed bar and welded wire reinforcement shall be free of materials deleterious to development.

R4.2.4 Surface contaminants such as concrete splatter, form oil or other release agents, will not prevent the reinforcing bars from achieving design values cited in the code requirements.

Where the IRC Section 403.1 references the footings chapter (currently chapter 7 in 332-14) with similar language:

Concrete footings shall be selected and constructed in accordance with the provisions of Section R403 or in accordance with 'ACI 332' or other approved structural standards.

Some of the relevant and important provisions that the inclusion of this chapter brings into the code include the acceptance of discontinuous footings, and the placement of footing dowels.

Discontinuous Wall Footings

ACI 332 states:

7.2.5 Discontinuous wall footings—A wall footing shall be permitted to be discontinuous at an abrupt elevation change according to 7.2.5.1 or 7.2.5.2.

7.2.5.1 A horizontal discontinuity of up to 4 ft shall be permitted by this code and conform to the reinforcement requirements of 8.2.9.

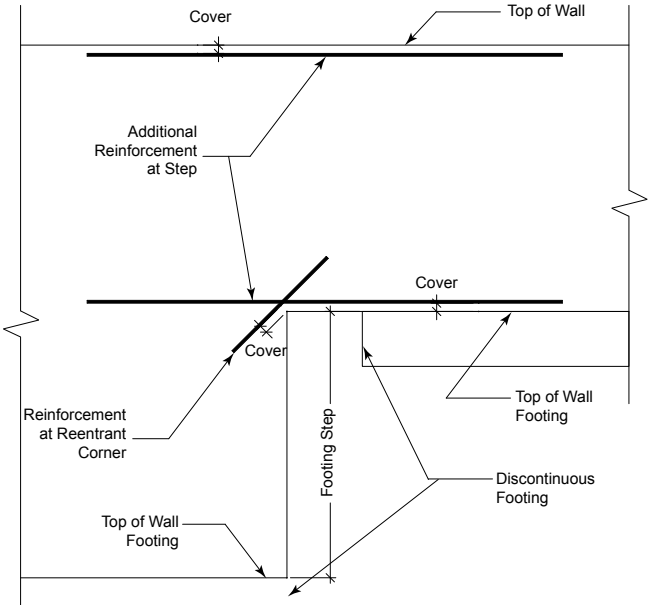

Fig. R7.2.5---Discontinuous wall footing and additional wall reinforcement.

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

R7.2.5 Abrupt 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. R7.2.5).

Wall-to-footing joint

The IRC recognizes that foundation walls need to be supported at the top and bottom in order to perform per the prescriptive design. However, unless the foundation referenced is located in a Seismic Design Category (SDC) of D_0, D_1 or D_2, the connections at the base of the foundation wall are not specified. These leaves a large gap in the interpretation of sufficient footing-to-wall connection design or whether the slab (not present at time of backfill) can be considered a point of restraint.

Here, ACI 332 brings clarification to the condition by stating:

7.3.4 Wall-to-footing joint—Wall-to-footing connections located in SDC A, B, or C shall be constructed in accordance with 7.3.4.1 or 7.3.4.2. Wall-to-footing connections located in SDC D, E, or F shall be constructed in accordance with 7.3.4.2.

7.3.4.1 A vertical No. 4 dowel shall extend at least 36db 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.

7.3.4.2 A continuous keyway shall be formed in the footing and shall be located within the middle 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.

Given that engineers are not generally supportive of wet-setting dowels into fresh concrete and the foundation to footing connection is imperative for performance of the foundation wall when it is backfilled, this section clarifies the construction operation for the contractor and improves the constructibility of the chosen footing connection detail.

Required Reinforcement

There are two structural concrete elements principally directed by the provisions of these residential building codes, the footing and the foundation wall. Jurisdictional differences for inspections place varying attentions to one over the other. Some jurisdictions will require inspections of the footing but not the wall, before placement of concrete. Likewise, the interpretation of the code documents varies based on the timing of these inspections. One of the key differences between ACI 332 and the IRC as it relates to reinforcement is found currently in the footings. The IRC presents general minimum requirements for footings in sections R403.1.1 and R403.1.4 thru R403.1.8.

However, sections R403.1.2 and R403.1.3 lie in the middle with specific reference to the higher SDCs of D_0, D_1 and D_2. Here continuous footings are required and reinforcement minimum requirements, including that for continuous longitudinal reinforcement are found. Contractors are often held to the standards of these two sections for footings in all SDCs incorrectly.

ACI 332 treats footing design and reinforcement differently by maintaining an organization of information from least specific to most specific. Therefore, information is presented for geometry and width or strength requirements, detailing of the geometry and finally reinforcement, which restricts longitudinal reinforcement requirements to the higher SDCs in step with the IRC but without the potential of confusion to lower SDCs.

When considering the minimum foundation wall reinforcement, ACI 332 introduces acceptance criteria for a greater percentage of wall conditions constructed with plain structural concrete. However, it also establishes a definitive position on the presence of horizontal reinforcement. In ACI 332-14, section 8.2.7 states that for all foundation walls, a minimum of one horizontal bar is to be located in each of the upper and lower 24 inches. Walls that exceed 6 feet in height are to have a minimum of three continuous bars and those exceeding 8 feet in height are to have a minimum of four continuous bars. This section also provides that in the higher SDCs, two horizontal bars are to be located in the upper 12 inches of all walls.

This is an important perspective for the residential concrete industry, since historically, as prescribed by the IRC, horizontal steel has been required for walls only in the higher SDCs. The reference to horizontal steel requirements changed in the 2015 IRC and as referenced in Table R404.1.2(1), all walls now have a similar prescriptive requirement for horizontal steel as found in ACI 332. Walls that are 8 feet or less in height are to have one horizontal bar in the top 12 inches and one near the mid-height while those greater than 8 feet in height are to have bars at the third points beyond the top horizontal bar.

www.cfawalls.org
PO Box 204,
Mount Vernon, IA 52314

Phone 319-895-6940 Fax: 320-213-5556