CHAPTER 15 — WALLS

Add the following definition to Chapter 2:

\[ M_{sa} = \text{maximum moment in wall due to service loads, excluding } P\Delta \text{ effects, in.-lb.} \]

Text highlighted in yellow denotes changes made.

15.1 — Scope

15.1.1 — Provisions of this chapter shall apply to the design of nonprestressed and prestressed walls including: 

- (a) Cast-in-place
- (b) Precast in-plant
- (c) Precast on-site including (tilt-up)

15.1.2 — Design of special structural walls shall be in accordance with Chapter 20.

15.1.3 — Design of plain concrete walls shall be in accordance with Chapter 25.

15.1.4 — Design of cantilever retaining walls shall be in accordance with 9.2 through 9.4, with minimum horizontal reinforcement according to 15.7.

15.2 — General

15.2.1 — Materials

15.2.1.1 — Design properties for concrete shall conform to Chapter 5.

15.2.1.2 — Design properties for steel reinforcement shall conform to Chapter 6.

15.2.2 — Connection to other members

15.2.2.1 — For precast walls, connections shall satisfy the force transfer requirements of 17.3.

15.2.2.2 — Connections of walls to foundations shall satisfy the force transfer requirements of 17.4.

15.2.3 — Load distribution

15.2.3.1 — Unless otherwise demonstrated by an analysis, the horizontal length of wall considered as effective for each concentrated load shall not exceed the smaller of the center-to-center distance between loads, and the bearing width plus four times the wall thickness.
15.2.4 — Intersecting elements

15.2.4.1 — Walls shall be anchored to intersecting elements, such as floors and roofs; or to columns, pilasters, buttresses, of intersecting walls; and to footings. <14.2.6>

15.3 — Design limits

15.3.1 — Minimum wall thickness

15.3.1.1 — Minimum wall thicknesses shall be in accordance with the requirements of Table 15.3.1.1. These requirements need not apply if structural analysis shows adequate strength and stability can be demonstrated by structural analysis. <14.2.7><14.5.3><14.6.1>

Table 15.3.1.1 — Minimum wall thickness, h

<table>
<thead>
<tr>
<th>Wall type</th>
<th>Minimum thickness, h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bearing*</td>
<td>4 in.</td>
</tr>
<tr>
<td>Greater of (a) and (b)</td>
<td>1/25 the lesser of unsupported length and unsupported height (b)</td>
</tr>
<tr>
<td>Nonbearing</td>
<td>4 in.</td>
</tr>
<tr>
<td>Greater of (c) and (d)</td>
<td>1/30 the lesser of unsupported length and unsupported height (d)</td>
</tr>
<tr>
<td>Exterior basement and foundation*</td>
<td>7.5 in.</td>
</tr>
</tbody>
</table>

* Only applies to walls designed in accordance with the simplified design method of 15.5.3.

15.4 — Required strength

15.4.1 - General

15.4.1.1 — Required strength shall be calculated in accordance with the factored load combinations defined in Chapter 7 and analysis procedures defined in Chapter 8. (<=>)

15.4.1.2 — Slenderness effects shall be calculated in accordance with 8.6.4, 8.7, or 8.8. Alternately, out-of-plane slenderness analysis shall be permitted using 15.8 for walls meeting the requirements of that section. <14.8.1>
15.4.1.3—Walls shall be designed for eccentric axial loads and any lateral or other loads to which they are subjected. <14.2.1>

15.4.2—Factored axial loadforce and moment

15.4.2.1—Walls shall be designed for the maximum factored moment that can accompany the factored axial loadforce for each applicable load combination. The factored axial force \( P_u \) at given eccentricity shall not exceed that \( \phi P_{n,\text{max}} \) where \( P_{n,\text{max}} \) shall be as given in 9.4.3.1 and strength reduction factor \( \phi \) shall be that for compression-controlled sections in Table 9.4.2.1. The maximum factored moment \( M_u \) shall be magnified for slenderness effects in accordance with 8.6.4, 8.7, or 8.8.<10.3.7>

15.4.3—Factored shear

15.4.3.1—Walls shall be designed for the maximum calculated factored in-plane and out-of-plane shear \( V_u \). <~>

15.5—Design strength

15.5.1—General

15.5.1.1—Design strength at all wall sections shall be in accordance with (a), (b), and (c) for each applicable factored load combination. <9.1.1> <10.3.6> <14.2.1> <11.1.1>

(a) \( \phi P_n \geq P_u \)
(b) \( \phi M_n \geq M_u \)
(c) \( \phi V_n \geq V_u \)

Interaction between axial load and flexure shall be considered.

15.5.2—Axial load and in-plane or out-of-plane flexure

15.5.2.1—For bearing walls, \( \phi P_n \) and \( \phi M_n \) (in-plane or out-of-plane) shall be calculated in accordance with 9.4. Alternatively, out-of-plane flexure may shall be permitted to be considered using 15.5.3. <14.2.2> <14.4> <10.3.6><10.3.7> <14.5.1>

15.5.2.2—For nonbearing walls, \( \phi M_n \) shall be calculated in accordance with 9.3.

15.5.3—Axial load and out-of-plane flexure—simplified design method

15.5.3.1—If the resultant of all factored loads is located within the middle third of the overall thickness of a solid wall with a rectangular cross-section, \( \phi P_n \) shall be permitted to be calculated by: <14.4> <14.5.1> <14.5.2>
\[ \phi P_n = \phi 0.55 f'_c A_g \left[ 1 - \left( \frac{k \ell_c}{32h} \right)^2 \right] \]  

\[(15.5.3.1)\]

**15.5.3.2** — Effective length factor \( k \) for use with Eq. (15.5.3.1) shall be in accordance with Table 15.5.3.2. <14.5.2>

**Table 15.5.3.2 — Effective length factor \( k \) for walls**

<table>
<thead>
<tr>
<th>Boundary conditions</th>
<th>( k )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walls braced top and bottom against lateral translation and</td>
<td></td>
</tr>
<tr>
<td>(a) Restrained against rotation at one or both ends (top, bottom, or both)</td>
<td>0.8</td>
</tr>
<tr>
<td>(b) Unrestrained against rotation at both ends</td>
<td>1.0</td>
</tr>
<tr>
<td>Walls not braced against lateral translation</td>
<td>2.0</td>
</tr>
</tbody>
</table>

**15.5.3.3** — Strength reduction factor \( \phi \) in Eq. (15.5.3.1) shall be that for compression-controlled sections in Table 9.4.2.1. <9.3.2.2>

**15.5.3.4** — Wall reinforcement shall not be less than that required by 15.6.

**15.5.4** — In-plane shear <14.2.3>

**15.5.4.1** — \( \phi V_n \) shall be calculated in accordance with 15.5.4.2 through 15.5.4.7. Alternatively, for walls with \( h_w \leq 2 \ell_w \), it shall be permitted to design for in-plane shear in accordance with the strut-and-tie procedure of 18.5. In all cases, 15.6, 15.7.2, and 15.7.3 shall apply. <11.9.1>

**15.5.4.2** — Strength reduction factor \( \phi \) shall be as given in Section 9.5.2.1. <~>

**15.5.4.3** — For in-plane shear design, \( h \) is thickness of wall and \( d \) shall be taken equal to 0.8\( \ell_w \). A larger value of \( d \), equal to the distance from extreme compression fiber to center of force of all reinforcement in tension, shall be permitted to be used when determined by a strain compatibility analysis. <11.9.4>

**15.5.4.4** — \( \phi V_n \) at any horizontal section shall not be taken greater than \( 10 \sqrt{f'_c h d} \). <11.9.3> <11.9.3>

**15.5.4.5** — \( \phi V_n \) shall be calculated by <11.1.1>

\[ \phi V_n = \phi V_c + \phi V_s \]  

\[(15.5.4.45)\]
15.5.4.56 Unless a more detailed calculation is made in accordance with 15.5.4.7, $V_c$ shall not be taken greater than $2\lambda f_c'hd$ for walls subject to axial compression or greater than the value given in 9.5.8 for walls subject to axial tension. <11.9.2><11.9.5>

Technical Change: 11.9.6 in 318-11 is being proposed for removal in an accompanying technical ballot. If the ballot fails, the contents of that section will be restored.

15.5.4.7 It shall be permitted to calculate $\phi V_c$ in accordance with Table 15.5.4.7, where $N_u$ is positive for compression and negative for tension and the quantity $N_u/A_g$ is expressed in psi. <11.9.5> <11.2.1.2> <11.9.6> <11.1.1> <11.2.2.3> <11.9.1> <11.9.2> <11.9.5>

Table 15.5.4.7 $V_c$: nonprestressed and prestressed walls

<table>
<thead>
<tr>
<th>Calculation Option</th>
<th>Axial Force</th>
<th>$V_c$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simplified</td>
<td>Compression</td>
<td>$2\lambda f_c'hd ^ {2\lambda f_c'hd}$</td>
</tr>
<tr>
<td></td>
<td>Tension</td>
<td>$2\left(1+\frac{N_u}{500A_g}\right)\lambda f_c'hd$</td>
</tr>
<tr>
<td></td>
<td>Greater of:</td>
<td></td>
</tr>
<tr>
<td>Detailed</td>
<td>Tension</td>
<td>$3.3\lambda f_c'hd ^ {3.3\lambda f_c'hd}$</td>
</tr>
<tr>
<td></td>
<td>Compression</td>
<td>$\ell_w \left[1.25\lambda f_c' + 0.2\frac{N_u}{\ell_w h}\right]$</td>
</tr>
<tr>
<td></td>
<td>Lesser of:</td>
<td>$0.6\lambda f_c' ^ {0.6\lambda f_c'}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$\frac{M_u}{V_u} - \ell_w^2$</td>
</tr>
</tbody>
</table>

Notes: *Equation (e) shall not apply if $(M_u/V_u - \ell_w/2)$ is negative.

15.5.4.8 Sections located closer to wall base than a distance $\ell_w/2$ or one-half the wall height, whichever is less, shall be permitted to be designed for the same value of $V_c$ calculated using the detailed calculation options in Table 15.5.4.7 at a distance $\ell_w/2$ or one-half the wall height, whichever is less. <11.9.7>
15.5.4.69 — $V_s$ shall be provided by transverse shear reinforcement, where $V_s$ shall be calculated by $\langle$11.9.9.1$\rangle$

$$V_s = \frac{A_f d_s}{s} V_s = \frac{A_f d}{s}$$  \hspace{1cm} (15.5.4.69)

15.5.5 — Out-of-plane shear $\langle$14.2.3$\rangle$

15.5.5.1 — $\phi V_n$ shall be calculated in accordance with 9.5.

15.5.5.2 — Strength reduction factor $\phi$ shall be as given in Section 9.5.2.1 or 9.6.2.1. $\langle$~$\rangle$

15.6 — Reinforcement limits

15.6.1 — If in-plane $V_u \leq 0.5 \phi V_c$, minimum $\rho_l$ and minimum $\rho_t$ shall be in accordance with Table 15.6.1. These limits need not apply if structural analysis shows adequate strength and stability.$\langle$11.9.8$\rangle$ $\langle$14.3.1$\rangle$ $\langle$14.3.2$\rangle$ $\langle$14.3.3$\rangle$ $\langle$16.4.1$\rangle$ $\langle$16.4.2$\rangle$$\langle$14.2.7$\rangle$$\langle$18.11.2.1$\rangle$$\langle$18.11.2.3$\rangle$

<table>
<thead>
<tr>
<th>Wall type</th>
<th>Type of nonprestressed reinforcement</th>
<th>Limits</th>
<th>$d_b$, Bar/wire size</th>
<th>$f_y$, psi</th>
<th>Minimum Longitudinal$^\dagger$, $\rho_l$</th>
<th>Minimum Transverse, $\rho_t$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cast-in-place</td>
<td>Deformed bars</td>
<td>$\leq$ No. 5</td>
<td>$\leq 60,000$</td>
<td>0.00120.0015</td>
<td>0.00250020</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$\geq$ No. 5</td>
<td>$\geq 60,000$</td>
<td>0.00150.0015</td>
<td>0.00200025</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Welded wire reinforcement</td>
<td>$\leq$ W31 or D31</td>
<td>AnyNot applicable</td>
<td>0.0012</td>
<td>0.0020</td>
<td></td>
</tr>
<tr>
<td>Precast$^*$</td>
<td>Deformed bars or welded wire reinforcement</td>
<td>AnyNot applicable</td>
<td>AnyNot applicable</td>
<td>0.0010</td>
<td>0.0010</td>
<td></td>
</tr>
</tbody>
</table>

$^*$In one-way precast, prestressed walls, not wider than 12 ft, and not mechanically connected to cause restraint in the transverse direction, the minimum reinforcement requirement in the direction normal to the flexural reinforcement need not be satisfied.

$^\dagger$Prestressed walls with an average effective compressive stress of at least 225 psi need not meet the
ACI 318-14 Chapter 15 Code, Approved Version, 2012-10-24

[requirement for minimum longitudinal reinforcement, \( \rho_L \)].

15.6.2 — If in-plane \( V_u \geq 0.5 \phi V_c \), (a) and (b) shall apply:

a) minimum \( \rho_t \) shall be the greater of the value calculated by Eq. (15.6.2) and 0.0025, but need not exceed \( \rho_t \) required by 15.5.74.9.

\[
\rho_t \geq 0.0025 + 0.5 (2.5 - \frac{h_w}{l_w}) (\rho_t - 0.0025)
\]  

(15.6.2)

b) minimum \( \rho_t \) shall be at least 0.0025.

15.7 — Reinforcement detailing

15.7.1 — General

15.7.1.1 — Concrete cover for reinforcement shall be in accordance with 6.11.1.

15.7.1.2 — Development lengths of deformed and prestressed reinforcement shall be calculated in accordance with 21.4.

15.7.1.3 — Splice lengths of deformed reinforcement shall be calculated in accordance with 21.5.

15.7.2 — Spacing of longitudinal reinforcement

15.7.2.1 — Maximum spacing, \( s \), of longitudinal bars in cast-in-place walls shall be the lesser of 3\( h \) and 18 in. If shear reinforcement is required for in-plane strength, spacing of longitudinal reinforcement shall not exceed \( l_w / 3 \).<7.6.5> <11.9.9.5> <14.3.5>

15.7.2.2 — Maximum spacing, \( s \), of longitudinal bars in precast walls shall be the lesser of:

(a) 5\( h \) and

(b) 18 in. for exterior walls or 30 in. for interior walls.

If shear reinforcement is required for in-plane strength, spacing of longitudinal reinforcement shall not exceed the smallest of 3\( h \), 18 in., and \( l_w / 3 \).<7.6.5> <10.6.4> <11.9.9.5> <14.3.5><16.4.2>
15.7.2.3 — For walls with \( h \) greater than 10 in., except basement walls and cantilever retaining walls, distributed reinforcement for each direction shall be placed in two layers parallel with wall faces in accordance with (a) and (b): <14.3.4>

(a) one layer consisting of a minimum of 1/2 and a maximum of 2/3 of total reinforcement required for each direction shall be placed within a minimum of 2 in. and a maximum of \( h/3 \) from the exterior surface;

(b) the other layer, consisting of the balance of required reinforcement in that direction, shall be placed within a minimum of 3/4 in. and a maximum of \( h/3 \) from the interior surface.

15.7.2.4 — Flexural tension reinforcement shall be well distributed and placed as close as practicable to the tension face. <18.8.3> <18.9.2.1> <10.6.3>

15.7.3 — Spacing of transverse reinforcement

15.7.3.1 — Maximum spacing, \( s \), of transverse reinforcement in cast-in-place walls shall be the lesser of \( 3h \) and 18 in.

If shear reinforcement is required for in-plane strength, spacing of transverse reinforcement shall not exceed \( t_w / 5 \). <7.6.5> <11.9.9.3> <14.3.5>

15.7.3.2 — Maximum spacing, \( s \), of transverse bars in precast walls shall be the lesser of:

(a) \( 5h \) and

(b) 18 in. for exterior walls or 30 in. for interior walls.

If shear reinforcement is required for in-plane strength, spacing of transverse reinforcement shall not exceed the smallest of \( 3h \), 18 in., and \( t_w / 5 \) <7.6.5> <11.9.9.3> <14.3.5> <16.4.2>

15.7.4 — Lateral support of longitudinal reinforcement

15.7.4.1 — Longitudinal reinforcement, if required as compression reinforcement or if \( A_{sc} \) exceeds \( 0.01A_g \), shall be laterally supported by transverse reinforcement ties. <14.3.6>

15.7.5 — Reinforcement around openings
15.7.5.1 — In addition to the minimum reinforcement required by 15.6, a minimum of two No. 5 bars in walls having two layers of reinforcement in both directions and one No. 5 bar in walls having a single layer of reinforcement in both directions shall be provided around window, door, and similarly sized openings. Such bars shall be anchored to develop $f_y$ in tension at the corners of the openings. <14.3.7>

15.8 — Alternate method for out-of-plane slender wall analysis

15.8.1 — General

15.8.1.1 — It shall be permitted to analyze out-of-plane slenderness effects using the requirements of this section for walls satisfying (a) through (e).

(a) The cross section is constant over the height of the wall. <14.8.2.2>

(b) The wall is tension-controlled for out-of-plane flexural effects. <14.8.2.3, 14.8.1>

(c) Reinforcement shall provide a design strength $\phi M_n$ not less than $M_{cr}$, where $M_{cr}$ is calculated using $f_y$ as provided in 5.2.3. <14.8.2.4>

(d) $P_n$ at the midheight section does not exceed $0.06f'_c A_g$. <14.8.2.6>

(e) The calculated out-of-plane deflection due to service loads, $\Delta_s$, including $PA$ effects, shall not exceed $l/c/150$. <14.8.4>

15.8.2 — Modeling

15.8.2.1 — The wall shall be analyzed as a simply-supported, axially-loaded member subject to an out-of-plane uniformly distributed lateral load, with maximum moments and deflections occurring at midheight. <14.8.2.1>

15.8.2.2 — Concentrated gravity loads applied to the wall above any section shall be assumed to be distributed over a width equal to the bearing width, plus a width on each side that increases at a slope of 2 vertical to 1 horizontal, but not extending beyond (a) or (b): <14.8.2.5>

(a) the spacing of the concentrated loads,

(b) the edges of the wall panel.

15.8.3 — Factored moment

15.8.3.1 — $M_n$ at midheight of wall due to combined flexure and axial loads shall include the effects of wall deflection in accordance with (a) or (b): <14.8.3>
(a) By iterative calculation using:

\[ M_u = M_{ua} + P_u \Delta_u \]  

(15.8.3.1a)

where \( M_{ua} \) is the maximum factored moment at midheight of wall due to lateral and eccentric vertical loads, not including \( PD \) effects.

\( \Delta_u \) shall be calculated by:

\[ \Delta_u = \frac{5M_u \ell_c^2}{(0.75)48E_c I_{cr}} \]  

(15.8.3.1b)

where \( I_{cr} \) shall be calculated by:

\[ I_{cr} = \frac{E_s}{E_c} \left( A_s + \frac{P_u h}{f_y 2d} \right) \left( d - c \right)^2 + \frac{P_u w_c^3}{3} \]  

(15.8.3.1c)

and the value of \( E_s / E_c \) shall not be taken less than 6.

(b) By direct calculation using:

\[ M_u = \frac{M_{ua} \ell_c^2}{1 - \frac{5P_u \ell_c^2}{(0.75)48E_c I_{cr}}} \]  

(15.8.3.1d)

15.8.4 — Out-of-plane deflection – service loads

15.8.4.1 — Out-of-plane deflection due to service loads, \( \Delta_s \), shall be calculated in accordance with Table 15.8.4.1, where \( M_a \) is calculated by 15.8.4.2. <14.8.4>

Table 15.8.4.1 — Calculation of \( \Delta_s \)

<table>
<thead>
<tr>
<th>( M_a )</th>
<th>( \Delta_s )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \leq (2/3)M_{cr} )</td>
<td>( \Delta_s = \left( \frac{M_a}{M_{cr}} \right) \Delta_{cr} )</td>
</tr>
<tr>
<td>( &gt; (2/3)M_{cr} )</td>
<td>( \Delta_s = \left( \frac{2}{3} \right) \Delta_{cr} + \left( \frac{M_a - (2/3)M_{cr}}{M_n - (2/3)M_{cr}} \right) \left( \Delta_n - (2/3) \Delta_{cr} \right) )</td>
</tr>
</tbody>
</table>
15.8.4.2 — The maximum moment \( M_a \) at midheight of wall due to service lateral and eccentric vertical loads, including \( P_s \Delta_s \) effects, shall be calculated by Eq. (15.8.4.2) with iteration of deflections <14.8.4>

\[
M_a = M_{sa} + P_s \Delta_s
\]  
(15.8.4.2)

15.8.4.3 — \( \Delta_{cr} \) and \( \Delta_n \) shall be calculated using Eq. (15.8.4.3a) and Eq. (15.8.4.3b). <14.8.4>

\[
\Delta_{cr} = \frac{5M_{cr} I_c^2}{48E_c I_{cg}}
\]  
(15.8.4.3a)

\[
\Delta_n = \frac{5M_n I_c^2}{48E_c I_{cr}}
\]  
(15.8.4.3b)

15.8.4.4 — \( I_{cr} \) shall be calculated by Eq. 15.8.3.1c. <14.8.3>
Notes:

1. Code shown in Ariel. **Code has been previously approved. However, the comments cast on the first ballot of the commentary necessitated changes to the code. Please comment if you disagree with the code changes.**

2. Commentary shown in Times New Roman in boxes. It is subject to the present ballot.

CHAPTER 15 — WALLS

Add the following definition to Chapter 2:

\[ M_{sa} = \text{maximum moment in wall due to service loads, excluding } P\Delta \text{ effects, in.-lb.} \]

15.1 — Scope

15.1.1 — Provisions of this chapter shall apply to the design of nonprestressed and prestressed walls including: <14.1.1> < R16.1.1> <10.1>

(a) Cast-in-place

(b) Precast in-plant

(c) Precast on-site, **such as including** tilt-up

**R15.1.1** — Chapter 15 applies generally to walls as vertical and lateral force-resisting members. Cantilever retaining walls are designed according to the flexural design provisions of Chapter 10. Walls designed to resist shear forces, such as shear walls, should be designed in accordance with Chapter 14 and 11.9 as applicable. Provisions for in-plane shear in ordinary structural walls (as opposed to special structural walls conforming to 20.9) are included in this chapter.

In the 1977 Code, walls could be designed according to Chapter 14 or 10.15. In the 1983 Code, these two were combined in Chapter 14. [<R14.1>](#)
15.1.2 — Design of special structural walls shall be in accordance with Chapter 20. <~>

R15.1.2 — Special structural walls are specially detailed according to the provisions of Section 20.10. ACI 318 uses the term structural wall as being synonymous with shear wall. The definition of a structural wall in 2.2 states: “A shear wall is a structural wall.” The term shear wall is not defined in this Code. ACI 318. ASCE 7 defines a structural wall as a wall that meets the definition for a bearing wall or a shear wall. A bearing wall is defined as a wall that supports vertical load beyond a certain threshold value. A shear wall is defined as a wall, bearing or nonbearing, designed to resist lateral forces acting in the plane of the wall. The ASCE 7 definitions are widely accepted.

15.1.3 — Design of plain concrete walls shall be in accordance with Chapter 25. <~>

15.1.4 — Design of cantilever retaining walls shall be in accordance with 9.2 through 9.4, with minimum horizontal reinforcement according to 15.7. <14.1.2>

R15.1.1 — Chapter 15 applies generally to walls as vertical and lateral load-carrying members. Cantilever retaining walls are designed according to the flexural design provisions of Chapter 10. Walls designed to resist shear forces, such as shear walls, should be designed in accordance with Chapter 14 and 11.9 as applicable. Shear provisions for in-plane shear in ordinary structural walls are included in this chapter.

In the 1977 Code, walls could be designed according to Chapter 14 or 10.15. In the 1983 Code, these two were combined in Chapter 14. <R14.1>
15.2.2.1 — For precast walls, connections shall satisfy the requirements of 17.3. <~>

15.2.2.2 — Connections of walls to foundations shall satisfy the requirements of 17.4. <14.2.8>

15.2.3 – Load distribution

15.2.3.1 — Unless otherwise demonstrated by an analysis, the horizontal length of wall considered as effective for each concentrated load shall be not exceed the smaller of the center-to-center distance between loads, and the bearing width plus four times the wall thickness. <14.2.4>

15.2.4 — Intersecting elements

15.2.4.1 — Where intersecting elements are required for support, walls shall be anchored to intersecting those elements, such as floors and roofs; or to columns, pilasters, buttresses, of intersecting walls; and to footings, where such elements are required for support. <14.2.6>

R15.2.4.1 — Walls that do not depend upon intersecting elements for support do not have to be connected to those elements. It is fairly not uncommon to separate massive retaining walls from intersecting walls to accommodate differences in deformations.

15.3 — Design limits

15.3.1 — Minimum wall thickness

15.3.1.1 — Minimum wall thicknesses shall be in accordance with Table 15.3.1.1. Thinner walls are permitted if adequate strength and stability can be demonstrated by structural analysis. <14.2.7><14.5.3><14.6.1>

Table 15.3.1.1 — Minimum wall thickness, h
R15.3.1.1 — The minimum thickness requirements need not be applied to bearing walls and exterior basement and foundation walls designed by 9.4.15.5.2 or analyzed by 15.8. <R14.5.3>

15.4 — Required strength

15.4.1 - General

15.4.1.1 — Required strength shall be calculated in accordance with the factored load combinations defined in Chapter 7 and analysis procedures defined in Chapter 8. <~>

15.4.1.2 — Slenderness effects shall be calculated in accordance with 8.6.4, 8.7, or 8.8. Alternatively, out-of-plane slenderness analysis shall be permitted using 15.8 for walls meeting
the requirements of that section. <14.8.1>.

15.4.1.3—Walls shall be designed for eccentric axial loads and any lateral or other loads to which they are subjected. <14.2.1>

R14.2—General
Walls should be designed to resist all loads to which they are subjected, including eccentric axial loads and lateral forces. Design is to be carried out in accordance with 14.4 unless the wall meets the requirements of 14.5.1. <<Just repeats the Code.>>

R15.4.1.3—The forces typically acting on a wall are illustrated in Fig. R15.4.1.3.

Fig. R15.4.1.3—In-plane and out-of-plane forces.

15.4.2—Factored axial force and moment

15.4.2.1—Walls shall be designed for the maximum factored moment that can accompany the factored axial force for each applicable load combination. The factored axial force $P_u$ at given eccentricity shall not exceed $\phi P_{n,\text{max}}$ where $P_{n,\text{max}}$ shall be as given in 9.4.3.1 and strength reduction factor $\phi$ shall be that for compression-controlled sections in Table 9.4.2.1. The maximum factored moment $M_u$ shall be magnified for slenderness effects in accordance with 8.6.4, 8.7, or 8.8.<10.3.7>

15.4.3—Factored shear
15.4.3.1 — Walls shall be designed for the maximum factored in-plane and out-of-plane shear $V_u$. 

15.5 — Design strength

15.5.1 — General

15.5.1.1 — Design strength at all wall sections shall be in accordance with (a), (b), and (c) for each applicable factored load combination. \( \langle 9.1.1 \rangle \) \( \langle 10.3.6 \rangle \) \( \langle 14.2.1 \rangle \) \( \langle 11.1.1 \rangle \)

(a) $\phi P_n \geq P_u$

(b) $\phi M_n \geq M_u$

(c) $\phi V_n \geq V_u$

Interaction between axial load and moment shall be considered.

15.5.2 — Axial load and in-plane or out-of-plane flexure

15.5.2.1 — For bearing walls, $\phi P_n$ and $\phi M_n$ (in-plane or out-of-plane) shall be calculated in accordance with 9.4. Alternatively, out-of-plane flexure shall be permitted to be considered using 15.5.3. \( \langle 14.2.2 \rangle \) \( \langle 14.4 \rangle \) \( \langle 10.3.6 \rangle \) \( \langle 10.3.7 \rangle \) \( \langle 14.5.1 \rangle \)

\( \langle \text{Commentary repeats the code} \rangle \)

R15.4.1.3 — Design is to be carried out in accordance with 14.4 unless the wall meets the requirements of 14.5.1. \( \langle R14.2 \rangle \)

15.5.2.2 — For nonbearing walls, $\phi M_n$ shall be calculated in accordance with 9.3.

R15.5.2.2 — Nonbearing walls, by definition, are not subject to any significant axial force; and, therefore, flexural strength is not a function of axial force.

15.5.3 — Axial load and out-of-plane flexure – simplified design method
178 15.5.3.1 — If the resultant of all factored loads is located within the middle third of the thickness of a solid wall with a rectangular cross section, $\phi P_n$ shall be permitted to be calculated by:

179 <14.4> <14.5.1> <14.5.2>

180 $\phi P_n = \phi 0.55 f'_c A_t \left[ 1 - \left( \frac{k \ell_c}{32h} \right)^2 \right] \quad (15.5.3.1)$

181

182 15.5.3.2 — Effective length factor $k$ for use with Eq. (15.5.3.1) shall be in accordance with Table 15.5.3.2. <14.5.2>

183

184 Table 15.5.3.2 — Effective length factor $k$ for walls

<table>
<thead>
<tr>
<th>Boundary conditions</th>
<th>$k$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walls braced top and bottom against lateral translation and (a) Restrained against rotation at one or both ends (top, bottom, or both) (b) Unrestrained against rotation at both ends</td>
<td>0.8</td>
</tr>
<tr>
<td>Walls not braced against lateral translation</td>
<td>2.0</td>
</tr>
</tbody>
</table>

185 15.5.3.3 — Strength reduction factor $\phi$ in Eq. (15.5.3.1) shall be that for compression-controlled sections in Table 9.4.2.1. <9.3.2.2>

186

187 15.5.3.4 — Wall reinforcement shall not be less than that required by 15.6.

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R15.5.3.1 — The empirical simplified design method applies only to solid rectangular cross sections; and all other shapes should be designed according to 14.4 15.5.2.

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Eccentric axial loads and moments due to lateral-out-of-plane forces are used to determine the maximum total eccentricity of the factored axial force $P_u$. When the resultant axial force for all applicable load combinations falls within the middle third of the wall thickness (eccentricity not greater than $h/6$) at all sections along the length of the undeformed wall, no tension is induced in the wall and the simplified design
method may be used. The design is then carried out considering $P_u$ as a concentric axial force. The factored axial force $P_u$ should be less than or equal to the design axial strength $\Phi P_n$ calculated by Eq. (14-15.5.3.1).

Historical.>

With the 1980 Code supplement, Eq. (14-1) was revised to reflect the general range of end conditions encountered in wall designs. The wall strength equation in the 1977 Code was based on the assumption of a wall with top and bottom fixed against lateral movement, and with moment restraint at one end corresponding to an effective length factor between 0.8 and 0.9. Axial strength values determined from the original equation were unconservative when compared to test results for walls with pinned conditions at both ends, as occurs with some precast and tilt-up applications, or when the top of the wall is not effectively braced against translation, as occurs with free-standing walls or in large structures where significant roof diaphragm deflections occur due to wind and seismic loads. Equation (14-1) gives the same results as the 1977 Code for walls braced against translation and with reasonable base restraint against rotation. Values of effective length factors $k$ are given for commonly occurring wall end conditions. The end condition “restrained against rotation” required for a $k$ of 0.8 implies attachment to a member having flexural stiffness $EI/\ell$ at least as large as that of the wall.

The slenderness portion of Eq. (14-1 15.5.3.1) results in relatively comparable strengths by 14.4 15.5.2 for members loaded at the middle third of the thickness with different braced and restrained end conditions. See Fig. R14.5 R15.5.3.1.

Note to ACI staff: Section nos. inside figure need to be updated.
15.5.4 — **In-plane shear** <14.2.3>

15.5.4.1 — \( \phi V_n \) shall be calculated in accordance with 15.5.4.2 through 15.5.4.6\(^7\). Alternatively, for walls with \( h_w \leq 2 \ell_w \), it shall be permitted to design for in-plane shear in accordance with the strut-and-tie procedure of 18.5. In all cases, 15.6, 15.7.2, and 15.7.3 shall apply. <11.9.1>

R15.5.4.1 — Shear in the plane of the wall is primarily of importance for shear structural walls with a small height-to-length ratio. The design of taller walls, particularly walls with uniformly distributed reinforcement, will likely be controlled by flexural considerations. <R11.9.1> Possible exceptions may occur in tall shear structural walls subject to strong earthquake excitation.

15.5.4.2 — Strength reduction factor \( \phi \) shall be as given in Section 9.5.2.1. <~>

15.5.4.3 — For in-plane shear design, \( h \) is thickness of wall and \( d \) shall be taken equal to \( 0.8 \ell_w \). A larger value of \( d \), equal to the distance from extreme compression fiber to center of force of all reinforcement in tension, shall be permitted to be used if determined by a strain compatibility analysis. <11.9.4>

15.5.4.4 — \( \phi V_n \) at any horizontal section shall not exceed \( \phi 10 \sqrt{f'_c h d} \). <11.9.3> <11.9.3>

R15.5.4.4 — This limit is imposed to control cracking under service loads and guard against diagonal compression failure in shear walls.

15.5.4.5 — \( \phi V_n \) shall be calculated by <11.1.1>

\[
\phi V_n = \phi V_c + \phi V_s
\]

(15.5.4.5)

15.5.4.6 — Unless a more detailed calculation is made in accordance with 15.5.4.7, \( V_c \) shall not be taken greater than \( 2 \lambda \sqrt{f'_c h d} \) for walls subject to axial compression or greater than the value given in 9.5.8 for walls subject to axial tension. <11.9.2> <11.9.5>
15.5.4.67 — It shall be permitted to calculate $V_c$ in accordance with Table 15.5.4.67, where $N_u$ is positive for compression and negative for tension and the quantity $N_u/A_g$ is expressed in psi.

Table 15.5.4.67 — $V_c$: nonprestressed and prestressed walls

<table>
<thead>
<tr>
<th>Calculation Option</th>
<th>Axial Force</th>
<th>$V_c$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simplified</td>
<td>Compression</td>
<td>$2\lambda \sqrt{f_c'} hd$ (a)</td>
</tr>
<tr>
<td></td>
<td>Tension</td>
<td>$2 \left(1 + \frac{N_u}{500A_g}\right) \lambda \sqrt{f_c'} hd$ (b)</td>
</tr>
<tr>
<td></td>
<td>Greater of:</td>
<td>$0$ (c)</td>
</tr>
<tr>
<td>Detailed</td>
<td>Tension or Compression</td>
<td>Lesser of:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$3.3\lambda \sqrt{f_c'} hd + \frac{N_u d}{4\ell_w}$ (d)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$0.6\lambda \sqrt{f_c'} + \frac{\ell_w \left(1.25\lambda \sqrt{f_c'} + 0.2 \frac{N_u}{\ell_w h}\right)}{M_u \frac{V_u}{V_u}}$ (e)</td>
</tr>
</tbody>
</table>

Notes: *Equation (e) shall not apply if $(M_u/V_u - \ell_w/2)$ is negative.

R15.5.4.67 — Equations (11-27) and (11-28) Expressions (d) and (a) through (e) in Table 15.5.4.67 may be used to determine $V_c$ at any section through a shear wall. Equation (11-27) Expression (d) corresponds to the occurrence of web shear cracking at a principal tensile stress of approximately $4\lambda \sqrt{f_c'}$ at the centroid of the shear wall cross section. Equation (11-28) Expression (e) corresponds approximately to the occurrence of flexure-shear cracking at a flexural tensile stress of $6\lambda \sqrt{f_c'}$ at a section $\ell_w/2$ above the section being investigated. As the term

$$\left(\frac{M_u}{V_u} - \frac{\ell_w}{2}\right)$$

Note to ACI staff: $l_w$ in equation needs to be consistent with $\ell_w$ elsewhere.

$M_u$ decreases, Expression (11-27) (ed) will control before this term becomes negative. When this term becomes negative, Expression (11-27) (d) should be used even when this term becomes negative. <R11.9.5 and R11.9.56>
15.5.4.7 — Sections located closer to the wall base than a distance $\ell_w/2$ or one-half the wall height, whichever is less, shall be permitted to be designed for the same value of $V_c$ calculated using the detailed calculation options in Table 15.4.6 at a distance $\ell_w/2$ or one-half the wall height, whichever is less. <11.9.7>

15.5.4.8 — The values of $V_c$ calculated from Eq. (11-27) and (11-28) (d) and (e) in Table 15.4.6 at a section located a distance above the base of $\ell_w/2$ or $h_w/2$, whichever is lesser, apply to that section and all sections between it and the base. However, the maximum factored shear force $V_u$ at any section, including the base of the wall, is limited to the upper bound on $\phi V_n$ in accordance with 11.9.3 15.5.4. <R11.9.7>

15.5.4.9 — $V_s$ shall be provided by transverse shear reinforcement, where $V_s$ shall be calculated by <11.9.9.1>

$$V_s = \frac{A_f f_y d}{s} \quad (15.5.4.9)$$

15.5.5 — Out-of-plane shear <14.2.3>

15.5.5.1 — $\phi V_n$ shall be calculated in accordance with 9.5.

15.5.5.2 — Strength reduction factor $\phi$ shall be as given in Section 9.5.2.1 or 9.6.2.1. <~>
15.6 — Reinforcement limits

15.6.1 — If in-plane $V_u \leq 0.5 \phi V_c$, minimum $\rho_{\ell}$ and minimum $\rho_t$ shall be in accordance with Table 15.6.1. These limits need not apply if structural analysis shows adequate strength and stability without less than the specified minimum reinforcement.\(<11.9.8> <14.3.1> <14.3.2> <14.3.3> <16.4.1> <16.4.2> <14.2.7> <18.11.2.1> <18.11.2.3>

<table>
<thead>
<tr>
<th>Wall type</th>
<th>Type of nonprestressed reinforcement</th>
<th>$f_y$, psi</th>
<th>Minimum Longitudinal$^\dagger$, $\rho_{\ell}$</th>
<th>Minimum Transverse, $\rho_t$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cast-in-place</td>
<td>Deformed bars</td>
<td>$\leq$ No. 5</td>
<td>$\geq 60,000$</td>
<td>0.0012</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>$&lt; 60,000$</td>
<td>0.0015</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$&gt; No. 5$</td>
<td>Any</td>
<td>0.0015</td>
</tr>
<tr>
<td></td>
<td>Welded wire reinforcement</td>
<td>$\leq W31$ or $D31$</td>
<td>Any</td>
<td>0.0012</td>
</tr>
<tr>
<td>Precast*</td>
<td>Deformed bars or welded wire reinforcement</td>
<td>Any</td>
<td>Any</td>
<td>0.0010</td>
</tr>
</tbody>
</table>

$^\dagger$Prestressed walls with an average effective compressive stress of at least 225 psi need not meet the requirement for minimum longitudinal reinforcement, $\rho_{\ell}$.

R15.6.1 — Both horizontal and vertical shear reinforcement are required for all walls. \(<Historical>\) The notation used to identify the direction of the distributed shear reinforcement in walls was updated in 2005 to eliminate conflicts between the notation used for ordinary structural walls in Chapters 11 and 14 and the notation used for special structural walls in Chapter 21. The distributed reinforcement is identified as being oriented parallel to either the longitudinal or transverse axis of the wall. Therefore, for vertical wall
segments, the notation used to describe the horizontal distributed reinforcement ratio is $\rho_t$, and the notation used to describe the vertical distributed reinforcement ratio is $\rho_\ell$. <R11.9.9>

<Now that the provisions of Chapter 11 and 14 are combined, this paragraph is no longer needed.>

The requirements of 14.3 are similar to those in previous codes. These apply to walls designed according to 14.4, 14.5, or 14.8. For walls resisting horizontal shear forces in the plane of the wall, reinforcement designed according to 11.9.9.2 and 11.9.9.4 may exceed the minimum reinforcement in 14.3.

<This commentary is a repeat of R11.9.9 which is shown above.>

The notation used to identify the direction of the distributed reinforcement in walls was updated in 2005 to eliminate conflicts between the notation used for ordinary structural walls in Chapters 11 and 14 and the notation used for special structural walls in Chapter 21. The distributed reinforcement is now identified as being oriented parallel to either the longitudinal or transverse axis of the wall. Therefore, for vertical wall segments, the notation used to describe the horizontal distributed reinforcement ratio is $\rho_t$, and the notation used to describe the vertical distributed reinforcement ratio is $\rho_\ell$. <R14.3>

Transverse reinforcement is not required in precast, prestressed walls equal to or less than 12 ft in width because this width is less than that in which shrinkage and temperature stresses can build up to a magnitude requiring transverse reinforcement. In addition, much of the shrinkage occurs before the members are connected into the structure. Once in the final structure, the members are usually not as rigidly connected transversely as monolithic concrete; thus the transverse restraint stresses due to both shrinkage and temperature change are significantly reduced.

This The minimum area of wall reinforcement for precast walls, instead of the minimum values in 14.3, has been used for many years and is recommended by PCI 16.4 and the Canadian Concrete Design Standard 16.20. Reduced minimum reinforcement and greater spacings in 15.7.2.2 are allowed recognizing that precast wall panels have very little restraint at their edges during early stages of curing and develop less shrinkage stress than comparable cast-in-place walls. <R16.4.2>

<This commentary repeats the code language.>

The minimum amounts of reinforcement in 14.3 need not apply to prestressed concrete walls, provided the average compressive stress in concrete due to effective prestress force only is 225 psi or greater and a
structural analysis is performed to show adequate strength and stability with lower amounts of reinforcement. <R18.11.2.3>

15.6.2 — If in-plane \( V_u > 0.5 \phi V_c \), (a) and (b) shall apply:

a) minimum \( \rho_e \) shall be the greater of the value calculated by Eq. (15.6.2) and 0.0025, but need not exceed \( \rho_t \) required by 15.5.4.9.

\[
\rho_e \geq 0.0025 + 0.5 (2.5 - \frac{h_w}{\ell_w}) (\rho_t - 0.0025) \quad (15.6.2)
\]

b) minimum \( \rho_t \) shall be 0.0025. <11.9.9.4> <11.9.8> <11.9.9.2>

R15.6.2 — For monotonically loaded walls with low height-to-length ratios, test data\(^{11.58}\) indicate that horizontal shear reinforcement becomes less effective for shear resistance than vertical reinforcement. This change in effectiveness of the horizontal versus vertical reinforcement is recognized in Eq. (11-30) (15.6.2); if \( h_w/\ell_w \) is less than 0.5, the amount of vertical reinforcement is equal to the amount of horizontal reinforcement. If \( h_w/\ell_w \) is greater than 2.5, only a minimum amount of vertical reinforcement is required (0.0025\( sh \)). <R11.9.9>

15.7 — Reinforcement detailing

15.7.1 — General

15.7.1.1 — Concrete cover for reinforcement shall be in accordance with 6.11.1. <~>

15.7.1.2 — Development lengths of deformed and prestressed reinforcement shall be calculated in accordance with 21.4. <~>
15.7.1.3 — Splice lengths of deformed reinforcement shall be calculated in accordance with 21.5. <~>

15.7.2 — Spacing of longitudinal reinforcement

15.7.2.1 — Maximum spacing, \( s \), of longitudinal bars in cast-in-place walls shall be the lesser of \( 3h \) and 18 in. If shear reinforcement is required for in-plane strength, spacing of longitudinal reinforcement shall not exceed \( \ell_w / 3 \). <7.6.5> <11.9.9.5> <14.3.5>

15.7.2.2 — Maximum spacing, \( s \), of longitudinal bars in precast walls shall be the lesser of:

(a) \( 5h \) and

(b) 18 in. for exterior walls or 30 in. for interior walls.

If shear reinforcement is required for in-plane strength, spacing of longitudinal reinforcement shall not exceed the smallest of \( 3h \), 18 in., and \( \ell_w / 3 \). <7.6.5> <10.6.4> <11.9.9.5> <14.3.5> <16.4.2>

R15.7.2.2 — See R15.6.1 for a discussion of the increased maximum reinforcement spacing for precast walls.

15.7.2.3 — For walls with \( h \) greater than 10 in., except basement walls and cantilever retaining walls, distributed reinforcement for each direction shall be placed in two layers parallel with wall faces in accordance with (a) and (b): <14.3.4>

(a) One layer consisting of not less than ½ and not more than 2/3 of total reinforcement required for each direction shall be placed not less than 2 in. nor more than \( h/3 \) from the exterior surface;

(b) The other layer, consisting of the balance of required reinforcement in that direction, shall be placed not less than 3/4 in. nor more than \( h/3 \) from the interior surface.

15.7.2.4 — Flexural tension reinforcement shall be well distributed and placed as close as practicable to the tension face. <18.8.3> <18.9.2.1> <10.6.3>
15.7.3 — Spacing of transverse reinforcement

15.7.3.1 — Maximum spacing, $s$, of transverse reinforcement in cast-in-place walls shall be the lesser of $3h$ and 18 in. If shear reinforcement is required for in-plane strength, spacing of transverse reinforcement shall not exceed $l_w/5$. <7.6.5> <11.9.9.3> <14.3.5>

15.7.3.2 — Maximum spacing, $s$, of transverse bars in precast walls shall be the lesser of:

(a) $5h$ and
(b) 18 in. for exterior walls or 30 in. for interior walls.

If shear reinforcement is required for in-plane strength, spacing of transverse reinforcement shall not exceed the smallest of $3h$, 18 in., and $l_w/5$. <7.6.5> <11.9.9.3> <14.3.5> <16.4.2>

R15.7.3.2 — See R15.6.1 for a discussion of the increased maximum reinforcement spacing for precast walls.

15.7.4 — Lateral support of longitudinal reinforcement

15.7.4.1 — Longitudinal reinforcement, if required as compression reinforcement or if $A_{sf}$ exceeds $0.01A_g$, shall be laterally supported by transverse ties. <14.3.6>

15.7.5 — Reinforcement around openings

15.7.5.1 — In addition to the minimum reinforcement required by 15.6, a minimum of two No. 5 bars in walls having two layers of reinforcement in both directions and one No. 5 bar in walls having a single layer of reinforcement in both directions shall be provided around window, door, and similarly sized openings. Such bars shall be anchored to develop $f_y$ in tension at the corners of the openings. <14.3.7>

15.8 — Alternate method for out-of-plane slender wall analysis

15.8.1 — General
15.8.1.1 — It shall be permitted to analyze out-of-plane slenderness effects using the requirements of this section for walls satisfying (a) through (e). <14.8.2>

(a) Cross section is constant over the height of the wall. <14.8.2.2>

(b) Wall is tension-controlled for out-of-plane flexural effects. <14.8.2.3> <14.8.1>

(c) Reinforcement provides a design strength $\phi M_n$, not less than $M_{cr}$, where $M_{cr}$ is calculated using $f_r$ as provided in 5.2.3. <14.8.2.4>

(d) $P_u$ at the midheight section does not exceed $0.06 f'_c A_g$. <14.8.2.6>

(e) Calculated out-of-plane deflection due to service loads, $\Delta_s$, including $P\Delta$ effects, does not exceed $\ell_c/150$ <14.8.4>

---

R15.8.1.1 — Section 14.8.15.8 was introduced in the 1999 edition and the provisions are based on requirements in the 1997 Uniform Building Code (UBC) and experimental research. Changes were included in the 2008 edition to reduce differences in the serviceability provisions and ensure that the intent of the UBC provisions is included in future editions of this Code and the International Building Code.

The procedure is presented as an alternative to the requirements of 10.10.15.4.1.2 for the out-of-plane design of slender wall panels, where the panels are restrained against overturning at the top.

Panels that have windows or other large openings are not considered to have constant cross section over the height of the panel. Such walls are to be designed taking into account the effects of openings.

Many aspects of the design of tilt-up walls and buildings are discussed in References 14.5 and 14.6.

<R14.8> Staff to update reference nos.
This The previous requirement that the reinforcement ratio should not exceed $0.6\rho_{bw}$ was replaced in the
2005 Code by the requirement that the wall be tension-controlled, resulting in approximately the same
reinforcement ratio. <R14.8.2.3>

15.8.2 — Modeling

15.8.2.1 — The wall shall be analyzed as a simply-supported, axially-loaded member subject to
an out-of-plane uniformly distributed lateral load, with maximum moments and deflections
occurring at midheight. <14.8.2.1>

15.8.2.2 — Concentrated gravity loads applied to the wall above any section shall be assumed
to be distributed over a width equal to the bearing width, plus a width on each side that
increases at a slope of 2 vertical to 1 horizontal, but not extending beyond (a) or (b): <14.8.2.5>

(a) the spacing of the concentrated loads,

(b) the edges of the wall panel.

15.8.3 — Factored moment

15.8.3.1 — $M_u$ at midheight of wall due to combined flexure and axial loads shall include the
effects of wall deflection in accordance with (a) or (b): <14.8>

(a) By iterative calculation using:

$$M_u = M_{ua} + P_u \Delta_u$$  \hspace{1cm} (15.8.3.1a)

where $M_{ua}$ is the maximum factored moment at midheight of wall due to lateral and
eccentric vertical loads, not including $P\Delta$ effects.

$\Delta_u$ shall be calculated by:
\[ \Delta_u = \frac{5M_u}{(0.75)48E_I c_{cr}} \]  
(15.8.3.1b)

where \( I_{cr} \) shall be calculated by:

\[
I_{cr} = \frac{E}{Ec} \left( A_s + \frac{P_u h}{2d} \right) (d - c)^2 + \frac{\ell w c^3}{3} 
\]  
(15.8.3.1c)

and the value of \( E_s / E_c \) shall not be taken less than 6.

(b) By direct calculation using:

\[
M_u = \frac{M_{ua}}{\left( 1 - \frac{5P_u \ell^2}{(0.75)48E_I c_{cr}} \right)} 
\]  
(15.8.3.1d)

R15.8.3.1 —

The neutral axis depth, \( c \), in Eq. (15.8.3.1c) corresponds to the following effective area of longitudinal reinforcement:-. <R14.8.3>

\[ A_{se,w} = A_s + \frac{P_u}{f_y} \left( \frac{h/2}{d} \right) \]

Note to staff: Add notation to Ch.2.

15.8.4 — Out-of-plane deflection – service loads

15.8.4.1 — Out-of-plane deflection due to service loads, \( \Delta_s \), shall be calculated in accordance with Table 15.8.4.1, where \( M_s \) is calculated by 15.8.4.2. <14.8.4>
Table 15.8.4.1 — Calculation of $\Delta_s$

<table>
<thead>
<tr>
<th>$M_a$</th>
<th>$\Delta_s$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\leq \left(\frac{2}{3}\right) M_{cr}$</td>
<td>$\Delta_s = \left(\frac{M_a}{M_{cr}}\right) \Delta_{cr}$</td>
</tr>
<tr>
<td>$&gt; \left(\frac{2}{3}\right) M_{cr}$</td>
<td>$\Delta_s = \left(\frac{2}{3}\right) \Delta_{cr} + \left(\frac{M_a - \left(\frac{2}{3}\right) M_{cr}}{M_n - \left(\frac{2}{3}\right) M_{cr}}\right) \left(\Delta_n - \left(\frac{2}{3}\right) \Delta_{cr}\right)$</td>
</tr>
</tbody>
</table>

R15.8.4.1 — Test data\textsuperscript{14,4} demonstrated that out-of-plane deflections increase rapidly when the service-level moment exceeds $2/3 M_{cr}$. A linear interpolation between $\Delta_{cr}$ and $\Delta_n$ is used to determine $\Delta_s$ to simplify the design of slender walls if $M_a > 2/3 M_{cr}$.

Service-level load combinations are not defined in Chapter 9 of ACI 318, but they are discussed in Appendix C of ASCE/SEI 7-10.\textsuperscript{14,7} Unlike ACI 318, however, appendixes to ASCE/SEI 7 are not considered to be mandatory parts of that standard. For calculating service-level lateral deflections of structures, Appendix C of ASCE/SEI 7-10 recommends using the following load combination

\[ D + 0.5L + W_a \]

in which $W_a$ is wind load based on serviceability wind speeds provided in the commentary to Appendix C of ASCE/SEI 7-10. If the slender wall is designed to resist earthquake effects, $E$, and $E$ is based on strength-level earthquake effects, the following load combination is considered to be appropriate for evaluating the service-level lateral deflections

\[ D + 0.5L + 0.7E \]

15.8.4.2 — The maximum moment $M_a$ at midheight of wall due to service lateral and eccentric vertical loads, including $P_s \Delta_s$ effects, shall be calculated by Eq. (15.8.4.2) with iteration of deflections <14.8.4>
576  \[ M_a = M_{sa} + P_s \Delta_s \] (15.8.4.2)

579  **15.8.4.3** — \( \Delta_{cr} \) and \( \Delta_n \) shall be calculated using Eq. (15.8.4.3a) and Eq. (15.8.4.3b). <14.8.4>

580  \[ \Delta_{cr} = \frac{5M_{cr} \ell_c^2}{48EI_c g} \] (15.8.4.3a)

582  \[ \Delta_n = \frac{5M_n \ell_c^2}{48EI_c \ell_{cr}} \] (15.8.4.3b)

584  **15.8.4.4** — \( l_{cr} \) shall be calculated by Eq. 15.8.3.1c. <14.8.3>