Seismic Detailing of Special Shear Walls and Coupling Beams

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Detailing by BNBC-2020
Basis of Concrete Design Provisions of BNBC-2020

Updates of ACI 318-08
### Basis

**ACI 318-08 Chapter 21**: rest applies except where modified  
**BNBC-2017 Part 6**: STRUCTURAL DESIGN  
**Chapter 8**: DETAILING OF REINFORCEMENT IN CONCRETE STRUCTURES  
**Section 8.3**: EARTHQUAKE-RESISTANT DESIGN PROVISIONS  
**Chapter 6**: STRENGTH DESIGN OF REINFORCED CONCRETE STRUCTURES applies except where modified

### Section Numbers

- All section numbers that are not in blue are from ACI 318-08  
- All section numbers in blue are from BNBC-2020 Part 6, Chapter 8 or Chapter 6, unless otherwise noted.  
- ACI 318-14 changes are indicated in green.
Seismic Design

- Seismic design, in its very essence, is an exercise in trade-off between strength and inelastic deformation capacity.

- Inelastic deformation capacity is the ability of a structure to continue to carry full factored gravity loads as it deforms beyond the stage of elastic response.

- Inelastic deformation capacity comes from proper detailing of the structural members and the joints.

Seismic Design by the IBC/ BNBC-2020

- Chapter 16 (Part 6, Section 2.5) sets the design force level or strength.

- Detailing rules are given in the materials chapters: 19 (Pt 2, Ch 8) for concrete, 21 (Pt 2, Ch 7) for masonry, 22 (Pt 2, Ch 10) for steel, 23 (Pt 2, Ch11) for wood. The materials chapters reference materials standards: ACI 318 for concrete.

- Three levels of detailing are defined: ordinary, intermediate, special.

- R-value provides the link between design force level and level of detailing.
Seismic Design by the IBC/BNBC-2020

- SDC A: No seismic design required
- SDC B: Unrestricted trade-off between strength and inelastic deformability.
- SDC C: Intermediate detailing required as a minimum.
- SDC D, E, or F: Special detailing required as a minimum. [E or F does not exist in Bangladesh]

EARTHQUAKE FORCE-RESISTING STRUCTURAL SYSTEMS OF CONCRETE — ASCE 7-05 (BNBC-2020 Table 6.2.19)

<table>
<thead>
<tr>
<th>BASIC SEISMIC FORCE-RESISTING SYSTEM</th>
<th>DETAILING REF. SECTION</th>
<th>R</th>
<th>$\Omega_d$</th>
<th>$C_d$</th>
<th>SYSTEM LIMITATIONS AND BUILDING HEIGHT LIMITATIONS (m) BY SEISMIC DESIGN CATEGORY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bearing Wall Systems</td>
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<td></td>
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<td>B</td>
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<tr>
<td>Special reinforced concrete shear walls</td>
<td>14.2 and 14.2.3.6</td>
<td>5</td>
<td>$2^{1/2}$</td>
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<tr>
<td>Ordinary reinforced concrete shear walls</td>
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<tr>
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<tr>
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<tr>
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<tr>
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<td>3</td>
<td>$2^{1/2}$</td>
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<td>NL</td>
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</table>

¹Increase in height to 14 m is permitted for single-story storage warehouse facilities.
### Earthquake Force-Resisting Structural Systems of Concrete — ASCE 7-05 (BNBC-2020 Table 6.2.19)

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<thead>
<tr>
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<tbody>
<tr>
<td></td>
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<td>B</td>
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<tr>
<td><strong>Building Frame Systems</strong></td>
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<tr>
<td>Special reinforced concrete shear walls</td>
<td>14.2 and 14.2.3.6</td>
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<td>14.2 and 14.2.3.3</td>
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**Dual Systems with Special Moment Frames**

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**Dual Systems with Intermediate Moment Frames**

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<td>B</td>
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<tr>
<td>Special reinforced concrete shear walls</td>
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<td>5(\frac{3}{2})</td>
<td>2(\frac{3}{2})</td>
<td>4(\frac{3}{2})</td>
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**Shear Wall-Frame Interactive System with Ordinary Reinforced Concrete Moment Frames and Ordinary Reinforced Concrete Shear Walls**

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<td>2(\frac{3}{2})</td>
<td>4</td>
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</tr>
</tbody>
</table>
21.1.4, 21.1.5 – Materials

- **Concrete 8.3.3.3**
  - Compressive strength not less than 21 MPa
  - Lightweight – Not greater than 35 MPa

- **Reinforcement 8.3.3.4(b)**
  - Low-alloy – A706 Grade 420
    Alternatively,
  - Billet-steel – A615 (modified) Grades 275 and 420
  - BDS ISO 6935-2 Grades 300, 350, 400 and 420 or ASTM A615 Grades 275 and 420 *with supplementary requirements*

21.1.5 – Reinforcement

- The actual yield strength based on mill tests does not exceed $f_y$ by more than 125 N/mm² (*retests shall not exceed this value by more than an additional 20 N/mm²*); 8.3.3.4(b)(i)

- Minimum elongation in 200 mm shall be at least 14 percent for bar dia. 10 mm to 20 mm, at least 12 percent for bar dia. 22 mm through 36 mm, and at least 10 percent for bar dia. 40 mm to 60 mm. 8.3.3.4(b)(iii) *Added in ACI 318-14*
21.1.5, 8.3.3.4(b)(ii) – Reinforcement

BILLET STEEL REINFORCEMENT

ACI 21.1.5.4, 8.3.3.4(c) — The value of $f_{yt}$ used to compute the amount of confinement reinforcement shall not exceed 700 MPa.

- **ACI 21.1.5.5, 8.3.3.4(d)** — The value of $f_y$ or $f_{yt}$ used in design of shear reinforcement shall conform to 11.4.2, 6.4.3.2.

- **ACI 11.4.2, 6.4.3.2** — The values of $f_y$ and $f_{yt}$ used in design of shear reinforcement shall not exceed 420 MPa, except the value shall not exceed 550 MPa for welded deformed wire reinforcement.
18 Design of Special Shear Walls

Design requirements for special shear walls were changed in significant ways in ACI 318-14 in view of lessons learned from the Chile earthquake of 2010.
Shear Design of Special Shear Walls

\[ V_u \leq \phi V_n \]

**ACI 21.9.3 (8.3.6.3)**

\( V_u \) is to be obtained from lateral load analysis in accordance with factored load combinations.

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Shear Design of Special Shear Walls

\[ V_u \leq \phi V_n \]

**ACI 9.3.4 (6.2.3.3(a))**

For structures that rely on special reinforced concrete structural walls to resist earthquake force effects \( E \), \( \phi \) for shear for any structural member that is designed to resist \( E \) is to be 0.6 if the nominal shear strength of the member is less than the shear corresponding to the development of the nominal flexural strength of the member.
\[ V_n = A_{cv}(\alpha_c \sqrt{f'_c} + \rho_t f_y) \leq 0.66A_{cv}\sqrt{f'_c} \]

- \( \alpha_c \) varies linearly from 3.0 for \( h_w/l_w = 1.5 \) to 2.0 for \( h_w/l_w = 2.0 \)
- \( \alpha_c = 2 \) for \( h_w/l_w > 2.0 \)

21.9.4.2 (8.3.6.4(b))

The ratio of \( h_w/l_w \) used for determining \( V_n \) for segments of a wall is the larger of the ratios for

a. the entire wall, and

b. the segment of wall considered
### 21.9.2 (8.3.6.2) Special Shear Wall Reinforcement

- \( \rho_t \geq 0.0025, \ s \leq 450 \text{ mm.} \)
- \( \rho_t \geq 0.0025, \ s \leq 450 \text{ mm.} \)
- Two curtains of reinforcement required when \( V_u > 0.17A_{cv}\sqrt{f'_c} \) or when \( h_w/l_w \geq 2.0 \)
- When \( h_w/l_w \leq 2.0, \ \rho_t \geq \rho_t \)
- Min. reinforcement per 14.3 (11.6) when \( V_u \leq 0.08A_{cv}\sqrt{f'_c} \)

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### 18 Design of Special Shear Walls

**R18.10.2** …The requirement for two layers of vertical reinforcement in more slender walls is to improve lateral stability of the compression zone under cyclic loads following yielding of vertical reinforcement in tension.
SPECIAL SHEAR WALL DESIGN FOR FLEXURE AND AXIAL COMPRESSION

ACI 318-95

Boundary elements required to carry entire $P_u$ and $M_u$
ACI 318-95

Design for Flexure and Axial Load

- \( f_c = \left( \frac{P_u}{A_g} \right) + \left( \frac{M_u l_w}{2 I_g} \right) > 0.2 f'_c \)
- \( P_{u,\text{boundary}} = \left( \frac{P_u}{2} \right) \pm \left( \frac{M_u l_w}{l_c} \right) \)

ACI 318-95

Shortcomings

- Very large boundary elements with extremely large amounts of vertical reinforcement required
- Extensive amounts of required confinement reinforcement made construction very difficult
ACI 318-95

Shortcomings

• Flexural overstrength created high shear demand
• Unconservative shear design could result

Example

Seismic Zone 4
20 stories tall
Beams: 500 x 550 mm
Cols.: 500 x 500 mm
Walls: 300 mm thick
950 x 950 mm boundary elements
Example

Constructability?

21.9.5 (8.3.6.5)
Design for Flexure and Axial Loads

Design for flexural and axial loads

• Design in accordance with 10.2 (6.3.2) and 10.3 (6.3.3)
• 10.3.7 (6.3.3.7) (slenderness effects) and nonlinear strain requirements of 10.2.2 (6.3.2.2) shall not apply
21.9.5 (8.3.6.5)  
Design for Flexure and Axial Loads

Effective flange width

• Effective flange width shall extend from the face of the web a distance equal to the smaller of
  • $0.5 \times (\text{distance to adjacent wall web})$
  • $0.25 \times (\text{total wall height})$

21.9.6 (8.3.6.6)  
Boundary Elements of Special Structural Walls

Special boundary elements

• Two methods to determine need for special boundary elements
  • 21.9.6.2 (8.3.6.6(b))
  • 21.9.6.3 (8.3.6.6(c))
21.9.6.2 (8.3.6.6(b))
Displacement-Based Approach

Applicable to walls or wall piers that are

- Effectively continuous from the base of the structure to the top of the wall
- Designed to have a single critical section for flexure and axial loads

And have $h_w/l_w \geq 2.0$

---

21.9.6.2 (8.3.6.6(b))
Displacement-Based Approach

Compression zones shall be reinforced with special boundary elements when

$$c \geq \frac{l_w}{600(1.5\delta_u/h_w)}$$

$$\delta_u/h_w \geq 0.007 (0.005)$$

$\delta_u = $ design displacement; total lateral displacement expected for the design-basis earthquake
2.1 – Notation

- $c =$ distance from the extreme compression fiber to neutral axis
- Corresponds to the largest neutral axis depth calculated for the factored axial force and nominal moment strength consistent with the design displacement $\delta_u$.

R21.9.6.2
Displacement-Based Approach

The neutral axis depth $c$ is the depth calculated corresponding to development of nominal flexural strength of the wall when displaced by $\delta_u$. The axial load is the factored axial load that is consistent with the design load combination that produces the displacement $\delta_u$. 
21.9.6.2 (8.3.6.6(b))  
Displacement-Based Approach

- When special boundary elements are required by the displacement-based approach, the special boundary element reinforcement needs to extend vertically above critical section a distance at least the larger of
  - \( \ell_w \)
  - \( M_u/4V_u \)
- The same extension of the reinforcement is required below the critical section, except at the base of the wall, which is addressed in 21.9.6.4(d) (8.3.6.6(d)(iv))
When required, special boundary element reinforcement shall extend horizontally from the extreme compression fiber a distance not less than the larger of

- \( c - 0.1l_w \)
- \( c/2 \)

In flanged sections, the boundary element shall include the effective flange width in compression and shall extend at least 300 mm. into the web.

\[
\text{Effective flange width} \geq 300 \text{ mm.}
\]
### 21.9.6.4 (8.3.6.6(d)) Special Boundary Elements

At the wall base, the special boundary element reinforcement needs to extend into the support by

- \( \ell_d \), determined per 21.9.2.3 (8.3.6.2(c)) for the largest longitudinal reinforcement
- 300 mm. for footing, mat foundation or pile cap

### 18.10.6.4 Special Boundary Elements

Width of flexural compression zone \( b \) over the horizontal distance calculated by 18.10.6.4(a), including flange if present, shall be at least \( h_u/16 \);

\[
\text{Neutral Axis} \quad \downarrow \quad b \geq h_u/16
\]

\[
\text{PLAN} \quad \text{ELEVATION} \quad h_u = \text{laterally unsupported height at extreme compression fiber of wall or wall pier}
\]
18.10.6.4 Special Boundary Elements

For walls or wall piers where

- $h_w/l_w \geq 2.0$, and
- Effectively continuous from the base of structure to top of wall, and
- designed to have a single critical section for flexure and axial loads, and
- $c/l_w \geq 3/8$

width of the flexural compression zone $b$ over the length calculated in 18.10.6.4(a) shall be greater than or equal to 300 mm.
R18.10.6.4  
Special Boundary Elements

A value of $c/l_w \geq 3/8$ is used to define a wall critical section that is not tension-controlled according to 21.2.2. A minimum wall thickness of 300 mm is imposed to reduce the likelihood of lateral instability of the compression zone after spalling of cover concrete.

21.9.6.4 (8.3.6.6(d)) Special Boundary Elements Transverse Reinforcement

For boundary element transverse reinforcement requirements, 21.9.6.4(c) (8.3.6.6(d)(iii)) references:

- 21.6.4.2 (8.3.5.4(a)(iii)) – For configuration requirements (shape, arrangement, horizontal spacing, etc.).
- 21.6.4.3 (8.3.5.4(b)) – For maximum spacing along height of boundary element, with one exception.
- 21.6.4.4 (8.3.5.4(a)(i), (ii)) – For minimum amount of transverse reinforcement, with one exception.
21.9.6.4 (8.3.6.6(d)) Special Boundary Elements Transverse Reinforcement

Configuration requirements:

• Transverse reinforcement to comprise of single or overlapping spirals, circular hoops, or rectilinear hoops with or without crossties.

• Bends of rectilinear hoops and crossties to engage peripheral longitudinal reinforcing bars and to provide lateral support to them.

• Consecutive crossties to be alternated end for end along the longitudinal reinforcement and around the perimeter of the cross section.

• Reinforcement is to be arranged such that the spacing $h_x$ of legs of hoops or cross ties (longitudinal bars) laterally supported by the corner of a crosstie or hoop leg around the perimeter of the column do not exceed 350 mm. and two-thirds of the boundary element thickness.

$\text{Up to ACI 318-11: } x_i = \text{c/c spacing of consecutive ties}$

$\text{ACI 318-14: } x_i = \text{c/c spacing of consecutive supported bars}$

$h_x = \text{Max. value of } x_i \text{ on all faces } \\ \leq 350 \text{ mm and 2/3 of boundary element thickness}$
21.9.6.4 (8.3.6.6) Special Boundary Elements
Transverse Reinforcement

Spacing along the height of the boundary element:

Spacing shall not exceed the smallest of

- One-third of the minimum member dimension
- 6 times the diameter of smallest longitudinal bar
- 100 mm. ≤ \( s_o = 100 + \left( \frac{350 - h_x}{3} \right) \leq 150 \text{ mm.} \) (8.3.5.4)

21.9.6.4 (18.10.6.4) Special Boundary Elements Transverse Reinforcement

Minimum amount of transverse reinforcement:

<table>
<thead>
<tr>
<th>Transverse Reinforcement</th>
<th>Applicable expressions</th>
</tr>
</thead>
<tbody>
<tr>
<td>( A_{sh}/s_{bc} ) for rectilinear hoop</td>
<td>( 0.3 \left( \frac{A_g}{A_{ch}} - 1 \right) \frac{f_c}{f_{yt}} ) (a) |</td>
</tr>
<tr>
<td></td>
<td>0.09 ( \frac{f_c}{f_{yt}} ) (b)</td>
</tr>
<tr>
<td>( \rho_s ) for spiral or circular hoop</td>
<td>( 0.45 \left( \frac{A_g}{A_{ch}} - 1 \right) \frac{f_c}{f_{yt}} ) (c)</td>
</tr>
<tr>
<td></td>
<td>0.12 ( \frac{f_c}{f_{yt}} ) (b)</td>
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</tbody>
</table>
R21.9.6.4 Special Boundary Elements
Transverse Reinforcement

Minimum amount of transverse reinforcement:

For wall special boundary elements having rectangular cross section, $A_g$ and $A_{ch}$ in expressions (a) and (c) in Table 18.10.6.4(f) are defined as $A_g = t_{be}b$ and $A_{ch} = b_{c1}b_{c2}$, where dimensions are shown in Fig. R21.9.6.4. This considers that concrete spalling is likely to occur only on the exposed faces of the confined boundary element.

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21.9.6.4 Special Boundary Elements
Transverse Reinforcement

Fig. R21.9.6.4(a) - Development of wall horizontal reinforcement in confined boundary element.
21.9.6.2 – Displacement-Based Approach

21.9.6.4 – Special Boundary Elements

Special boundary elements required when

\[ c \geq \frac{l_w}{600(\delta_u/h_w)} \]

larger of

\[ \left\{ \begin{array}{l} \frac{l_w}{M_u/4V_u} \\ \text{c/2} \end{array} \right. \]

Special boundary element transverse reinforcement per 21.6.4.2 – 21.6.4.4 with 2 exceptions

8.3.6.6(b) – Displacement-Based Approach

8.3.6.6 – Special Boundary Elements

Special boundary elements required when

\[ c \geq \frac{l_w}{600(\delta_u/h_w)} \]

larger of

\[ \left\{ \begin{array}{l} \frac{l_w}{M_u/4V_u} \\ \text{c/2} \end{array} \right. \]

Special boundary element trans. reinf. per Sec 8.3.5.4, 8.3.5.4b(i)
21.9.6.3 (8.3.6.6(c))

Conventional Approach

- Applicable to any wall section
- Special boundary elements are required where the maximum extreme compressive stress $> 0.2f'_c$
- Special boundary elements may be discontinued where the calculated compressive stress $< 0.15f'_c$
- Stresses calculated based on factored forces using a linearly elastic model and gross section properties

Special boundary elements required when:

$$(P_u/A_y) + (M_u/l_w/2l_g) > 0.2f'_c$$

Special boundary elements may be discontinued where:

$$c - 0.1l_w, \quad c/2$$
21.9.6.4 (8.3.6.6) Special Boundary Elements

\[ A_{sh} \geq 0.09sb \cdot f'c / f_{ty} \]

0.3sb \cdot (A_g / A_{ch} - 1) f'c / f_{ty}

\[ s \leq \frac{6d_b}{s_o} \]

reinf. ratio \( \geq 0.0025 \)

\( s \leq 18" \)

6db 75 mm min.

21.9.6.4 (8.3.6.6) Special Boundary Elements

21.9.6.4(e) [8.3.6.6(d)(v)]

Horizontal web reinforcement, \( A_v \)

\( \leq 150 \text{mm} \)

\( \geq \ell_{ch} \) or \( \ell_{ct} \)
21.9.6.4 (18.10.6.4) Special Boundary Elements

21.9.6.4(e) [8.3.6.6(d)(v)]

21.9.6.5 (8.3.6.6(e)) “Non-Special” Boundary Elements

Reinforcement details where special boundary elements are not required

- If longitudinal reinforcement ratio at wall boundary > 2.8/f_y, provide boundary transverse reinforcement
  - That meets the geometric requirements within a cross-section per 21.6.4.2 [8.3.5.4(a)(iii), 8.3.5.4(c)], and
  - That extends horizontally from the extreme compression fiber per 21.9.6.4(a) [8.3.6.6(d)(i)], and

Continued....
21.9.6.5 *(8.3.6.6(e))
"Non-Special" Boundary Elements

Reinforcement details where special boundary elements are not required

- If longitudinal reinforcement ratio at wall boundary > 2.8/$f_y$, provide boundary transverse reinforcement
  - Where the maximum longitudinal spacing does not exceed (the lesser of) 200 mm (and 8$d_b$) (the lesser of 150 mm and 6$d_b$ over the greater of $t_w$ and $M/L/4V_u$ above the base).

21.9.6.5 *(18.10.6.5)
"Non-Special" Boundary Elements

\[ A_{sh} @ s \leq 200 \text{ mm and } 8d_b \text{ (or } 150 \text{ mm and } 6d_b) \]

\[ A_{cb} = b_w(2x + a) \]

\[ A_{cb} = s_b b_w \]

\[ A_{sh} \text{ to be provided over a length of } c - 0.1t_w \text{ or } c/2 \]
21.9.6.5 \((18.10.6.5)\)

“Non-Special” Boundary Elements

When \(V_u \geq A_{cv} f'_c\)

- Horizontal reinforcement terminating at ends of wall shall have a standard hook engaging the edge reinforcement, or

- Edge reinforcement shall be enclosed in U-stirrups having the same size and spacing as, and spliced to, the horizontal reinforcement

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### R18.10.6.5

“Non-Special” Boundary Elements

(a) Wall with \(h_w/l_w \geq 2.0\) and a single critical section controlled by flexure and axial load designed using 18.10.6.2, 18.10.6.4, and 18.10.6.5

**Fig. R18.10.6.4.2 - Summary of boundary element requirements for special walls.**
R18.10.6.5
“Non-Special” Boundary Elements

Fig. R18.10.6.4.2 - Summary of boundary element requirements for special walls.

Notes: Requirement for special boundary element is triggered if maximum extreme fiber compressive stress \( \sigma \geq 0.2f'_{c} \). Once triggered, the special boundary element extends until \( \sigma < 0.15f'_{c} \). Since \( h_{w} / f_{c} \leq 2.0 \), R18.10.6.4(c) does not apply.

(b) Wall and wall pier designed using 18.10.6.3, 18.10.6.4, and 18.10.6.5

21.9.2.3(d) [8.3.6.2(c)]
Reinforcement in Structural Walls

Mechanical and welded splices of longitudinal reinforcement of boundary elements shall conform to 21.1.6 and 21.1.7 (8.2), respectively
COUPLING BEAMS

High Seismic Risk – Coupling Beams

(21.9.7) (8.3.6.7)

- Aspect ratio $l_n/h \geq 4$
  - Satisfy requirements of 21.5 (8.3.7)
- Aspect ratio $l_n/h < 4$
  - Permitted to be reinforced with two intersecting groups of diagonal bars
- Aspect ratio $l_n/h < 2$ and $V_u > 0.33 f'c A_{cw}$
  - Must be reinforced with two intersecting groups of diagonal bars
(21.9.7) (8.3.6.7) Coupling Beams ($\ell_n / h < 4$)

$A_{wA} = \text{total area of bars in the group of bars forming one diagonal (min. 4 bars)}$ 

Bars to be developed for tension (typ.)

Min. per 11.7.4.1 [6.4.6.4]

Min. per 11.7.4.2 [6.4.6.5]
(21.9.7) (8.3.6.7) Coupling Beams

Source: http://nees.seas.ucla.edu/pankow
(21.9.7) (8.3.6.7) Coupling Beams

Source: http://nees.seas.ucla.edu/pankow

Coupling Beams

ACI 318-05

- Must have diagonal bars enclosed in transverse reinforcement

Source: http://nees.seas.ucla.edu/pankow

Diagonal Confinement
Coupling Beams

ACI 318-08, 318-11, 318-14

- Must either have diagonal bars enclosed in transverse reinforcement, or
- Must have entire beam cross-section enclosed in transverse reinforcement

Source: http://nees.seas.ucla.edu/pankow

Full Section Confinement

ACI 318-05 Detail

Source: http://nees.seas.ucla.edu/pankow

Confinement of Diagonal Bars
21.9.8 (8.3.6.8) – Wall Piers

Door and window openings in shear walls often lead to narrow vertical wall segments, many of which have been defined as wall piers in the IBC and in the UBC before it. Wall pier provisions are now included in Section 21.9.8 of ACI 318-11 (8.3.6.8). The dimensions defining wall piers are given in Section 2.2.
2.2 – Wall Piers

2.5 \leq \frac{t_{wp}}{h} \leq 6.0
h_{wp}/t_{wp} \geq 2.0

21.9.8 (8.3.6.8) – Wall Piers

Shear failures of wall piers have been observed in previous earthquakes. The intent of Section 21.9.8 (8.3.6.8) is to prescribe detailing that would result in flexural failure preceding shear failure in wall piers. The provisions apply to wall piers considered part of the seismic force-resisting system (SFRS). Wall piers considered not part of the SFRS need to be designed by Section 21.13 (8.3.12).
21.9.8 (8.3.6.8) – Wall Piers

Wall piers having \((l_w/b_w) \leq 2.5\) behave essentially as columns. Section 21.9.8.1 (8.3.6.8(a)) requires them to be detailed like columns. Alternative requirements are provided for wall piers having \((l_w/b_w) > 2.5\).

Table R21.9.1 – Governing Design Provisions for Vertical Wall Segments

<table>
<thead>
<tr>
<th>Clear height of vertical wall segment/length of vertical wall segment ((h_w/l_w))</th>
<th>Length of vertical wall segment/wall thickness ((l_w/b_w))</th>
<th>Wall pier required to satisfy specified column design requirements, see 21.9.8.1 (18.10.8.1)</th>
<th>Wall pier required to satisfy specified column design requirements or alternative requirements, see 21.9.8.1 (18.10.8.1)</th>
<th>Wall</th>
</tr>
</thead>
<tbody>
<tr>
<td>(h_w/l_w &lt; 2.0)</td>
<td>((l_w/b_w) \leq 2.5)</td>
<td>Wall</td>
<td>Wall</td>
<td>Wall</td>
</tr>
<tr>
<td>(h_w/l_w \geq 2.0)</td>
<td>((l_w/b_w) &gt; 6.0)</td>
<td>Wall</td>
<td>Wall</td>
<td>Wall</td>
</tr>
</tbody>
</table>

*\(h_w\) is the clear height, \(l_w\) is the horizontal length, and \(b_w\) is the width of the web of the wall segment.
21.9.8 (8.3.6.8) – Wall Piers

Wall piers at the edge of a wall are addressed in Section 21.9.8.2 (8.3.6.8(b)). Under in-plane shear, inclined cracks can propagate into segments of the wall directly above and below the wall pier. Shear failure within the adjacent wall segments can occur unless sufficient reinforcement is provided in those segments (Figure R21.9.8).
Questions?
Thank you