

# CHAPTER 10—COLUMNS

## CODE

## COMMENTARY

### **10.1—Scope**

**10.1.1** This chapter shall apply to the design of nonprestressed and prestressed columns, including reinforced concrete pedestals.

**10.1.2** Design of plain concrete pedestals shall be in accordance with [Chapter 14](#).

### **10.2—General**

#### **10.2.1 Materials**

**10.2.1.1** Design properties for concrete shall be selected to be in accordance with [Chapter 19](#).

**10.2.1.2** Design properties for steel reinforcement shall be selected to be in accordance with [Chapter 20](#).

**10.2.1.3** Materials, design, and detailing requirements for embedments in concrete shall be in accordance with [20.6](#).

#### **10.2.2 Connection to other members**

**10.2.2.1** For cast-in-place construction, joints shall satisfy [Chapter 15](#).

**10.2.2.2** For precast construction, connections shall satisfy the force transfer requirements of [16.2](#).

**10.2.2.3** Connections of columns to foundations shall satisfy [16.3](#).

### **10.3—Design limits**

#### **10.3.1 Dimensional limits**

**10.3.1.1** For columns with a square, octagonal, or other shaped cross section, it shall be permitted to base gross area considered, required reinforcement, and design strength on a circular section with a diameter equal to the least lateral dimension of the actual shape.

**10.3.1.2** For columns with cross sections larger than required by considerations of loading, it shall be permitted to base gross area considered, required reinforcement, and design strength on a reduced effective area, not less than one-half the total area. This provision shall not apply to columns in special moment frames or columns not part of the seismic-force-resisting system required to be designed in accordance with [Chapter 18](#).

**10.3.1.3** For columns built monolithically with a concrete wall, the outer limits of the effective cross section of the column shall not be taken greater than 1.5 in. outside the transverse reinforcement.

### **R10.1—Scope**

**R10.1.1** Composite structural steel-concrete columns are not covered in this chapter. Design provisions for composite columns are covered in [ANSI/AISC 360](#).

### **R10.3—Design limits**

#### **R10.3.1 Dimensional limits**

**R10.3.1.1** Explicit minimum sizes for columns are not specified to permit the use of reinforced concrete columns with small cross sections in lightly loaded structures. If small cross sections are used, [ACI SPEC-117](#) and [ACI ITG-7](#) specify more restrictive tolerances on reinforcement placement and member dimensions.

**R10.3.1.2** In some cases, the gross area of a column is larger than necessary to resist the factored load. In those cases, the minimum reinforcement percentage is given in 10.6.1.1 and may be calculated on the basis of the required area rather than the provided area, but the area of reinforcement cannot be less than 0.5 percent of the actual cross-sectional area.

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**10.3.1.4** For columns with two or more interlocking spirals, outer limits of the effective cross section shall be taken at a distance outside the spirals equal to the minimum required concrete cover.

**10.3.1.5** If a reduced effective area is considered according to 10.3.1.1 through 10.3.1.4, structural analysis and design of other parts of the structure that interact with the column shall be based on the actual cross section.

**10.4—Required strength****10.4.1 General**

**10.4.1.1** Required strength shall be calculated in accordance with the factored load combinations in **Chapter 5**.

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

**10.4.2 Factored axial force and moment**

**10.4.2.1**  $P_u$  and  $M_u$  occurring simultaneously for each applicable factored load combination shall be considered.

**R10.4—Required strength****R10.4.2 Factored axial force and moment**

**R10.4.2.1** The critical load combinations may be difficult to discern without checking each combination. As illustrated in Fig. R10.4.2.1, considering only the factored load combinations associated with maximum axial force (LC1) and maximum bending moment (LC2) does not necessarily provide a code-compliant design for other load combinations such as LC3.

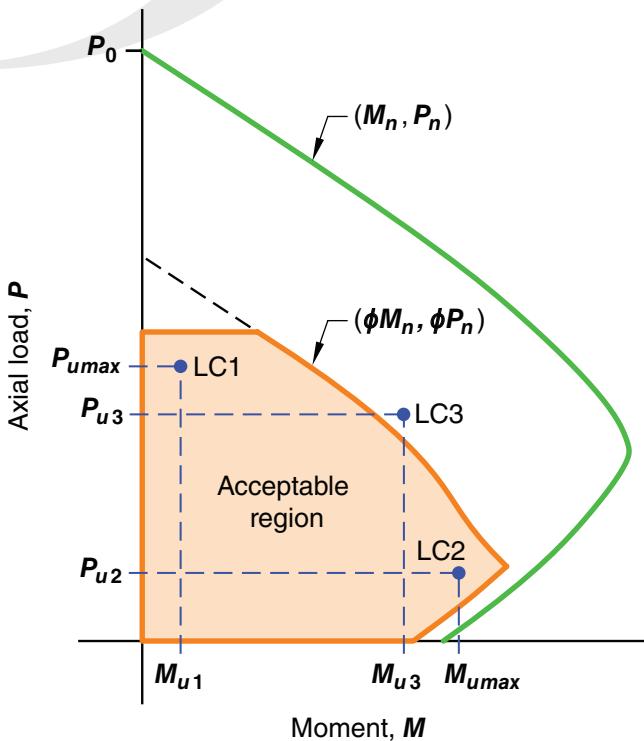


Fig. R10.4.2.1—Critical column load combination.

**CODE****COMMENTARY****10.5—Design strength****10.5.1 General**

**10.5.1.1** For each applicable factored load combination, design strength at all sections shall satisfy  $\phi S_n \geq U$ , including (a) through (d). Interaction between load effects shall be considered:

- (a)  $\phi P_n \geq P_u$
- (b)  $\phi M_n \geq M_u$
- (c)  $\phi V_n \geq V_u$
- (d)  $\phi T_n \geq T_u$

**10.5.1.2**  $\phi$  shall be determined in accordance with 21.2.

**10.5.2 Axial force and moment**

**10.5.2.1**  $P_n$  and  $M_n$  shall be calculated in accordance with 22.4.

**10.5.3 Shear**

**10.5.3.1**  $V_n$  shall be calculated in accordance with 22.5.

**10.5.4 Torsion**

**10.5.4.1** If  $T_u \geq \phi T_{th}$ , where  $T_{th}$  is given in 22.7, torsion shall be considered in accordance with Chapter 9.

**10.6—Reinforcement limits****10.6.1 Minimum and maximum longitudinal reinforcement**

**10.6.1.1** For non prestressed columns and for prestressed columns with an average compressive stress, due to effective prestress force only, less than 225 psi, area of longitudinal reinforcement shall be at least  $0.01A_g$  but shall not exceed  $0.08A_g$ .

**R10.5—Design strength****R10.5.1 General**

**R10.5.1.1** Refer to R9.5.1.1.

**R10.5.4 Torsion**

**R10.5.4.1** Torsion acting on columns in buildings is typically negligible and is rarely a governing factor in the design of columns.

**R10.6—Reinforcement limits****R10.6.1 Minimum and maximum longitudinal reinforcement**

**R10.6.1.1** Minimum longitudinal reinforcement is necessary to provide resistance to bending and axial load, and to reduce the effects of creep and shrinkage of the concrete under sustained compressive stresses. Creep and shrinkage effects cause force transfer from the concrete to the reinforcement, and the resultant increase in reinforcement stress becomes greater as the reinforcement ratio decreases. A minimum limit is placed on the reinforcement ratio to prevent reinforcement from yielding under sustained service loads (Richart 1933).

The maximum longitudinal reinforcement ratio is provided to ensure that concrete can be effectively consolidated around the bars and to ensure that columns designed according to the Code are similar to the test specimens by which the Code was calibrated. The 0.08 limit applies at all sections, including splice regions and joints, which may include dowels. Longitudinal reinforcement in columns should usually not exceed 4 percent if the column bars are required to be lap spliced, as the lap splice zone will have twice as much reinforcement if all lap splices occur at the same location.

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**10.6.1.2** For oversized columns, as permitted in 10.3.1.2, the minimum area of longitudinal reinforcement shall not be less than  $0.005A_g$ .

**10.6.2 Minimum shear reinforcement**

**10.6.2.1** A minimum area of shear reinforcement,  $A_v$ , shall be provided in all regions where  $V_u > 0.5\phi V_c$ .

**10.6.2.2** If shear reinforcement is required,  $A_{v,min}$  shall be the greater of (a) and (b):

$$(a) 0.75\sqrt{f'_c} \frac{b_{ws}}{f_{yt}}$$

$$(b) 50 \frac{b_{ws}}{f_{yt}}$$

**10.7—Reinforcement detailing****10.7.1 General**

**10.7.1.1** Concrete cover for reinforcement shall be in accordance with 20.5.1.

**10.7.1.2** Development lengths of deformed and prestressed reinforcement shall be in accordance with 25.4.

**10.7.1.3** Along development and lap splice lengths of longitudinal bars with  $f_y \geq 80,000$  psi, transverse reinforcement shall be provided such that  $K_{tr}$  shall not be smaller than  $0.5d_b$ .

**10.7.1.4** Bundled bars shall be in accordance with 25.6.

**10.7.2 Reinforcement spacing**

**10.7.2.1** Minimum spacing  $s$  shall be in accordance with 25.2.

**10.7.3 Longitudinal reinforcement**

**10.7.3.1** For nonprestressed columns and for prestressed columns with an average compressive stress, due to effective prestress force only, less than 225 psi, the minimum number of longitudinal bars shall be (a), (b), or (c):

- (a) Three within triangular ties
- (b) Four within rectangular or circular ties
- (c) Six enclosed by spirals or for columns of special moment frames enclosed by circular hoops

**10.7.4 Offset bent longitudinal reinforcement**

**10.7.4.1** The slope of the inclined portion of an offset bent longitudinal bar relative to the longitudinal axis of the

**R10.6.2 Minimum shear reinforcement**

**R10.6.2.1** The basis for minimum shear reinforcement is the same for columns and beams. Refer to R9.6.3 for more information.

**R10.7—Reinforcement detailing****R10.7.3 Longitudinal reinforcement**

**R10.7.3.1** At least four longitudinal bars are required when bars are enclosed by rectangular ties or circular ties. For other tie shapes, one bar should be provided at each apex or corner. For bars enclosed by spirals, at least six bars are required.

If the number of bars in a circular arrangement is less than eight, the orientation of the bars may significantly affect the moment strength of eccentrically loaded columns and should be considered in design.

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column shall not exceed 1 in 6. Portions of bar above and below an offset shall be parallel to axis of column.

**10.7.4.2** If the column face is offset 3 in. or more, longitudinal bars shall not be offset bent and separate dowels, lap spliced with the longitudinal bars adjacent to the offset column faces, shall be provided.

**10.7.5 Splices of longitudinal reinforcement****10.7.5.1 General**

**10.7.5.1.1** Lap splices, mechanical splices, butt-welded splices, and end-bearing splices shall be permitted.

**10.7.5.1.2** Splices shall satisfy requirements for all factored load combinations.

**10.7.5.1.3** Splices of deformed reinforcement shall be in accordance with 25.5 and, if applicable, shall satisfy the requirements of 10.7.5.2 for lap splices or 10.7.5.3 for end-bearing splices.

**COMMENTARY****R10.7.5 Splices of longitudinal reinforcement****R10.7.5.1 General**

**R10.7.5.1.2** Frequently, the basic gravity load combination will govern the design of the column itself, but a load combination including wind or earthquake effects may induce greater tension in some column bars. Each bar splice should be designed for the maximum calculated bar tensile force.

**R10.7.5.1.3** For the purpose of calculating  $\ell_d$  for tension lap splices in columns with offset bars, Fig. R10.7.5.1.3 illustrates the clear spacing to be used.

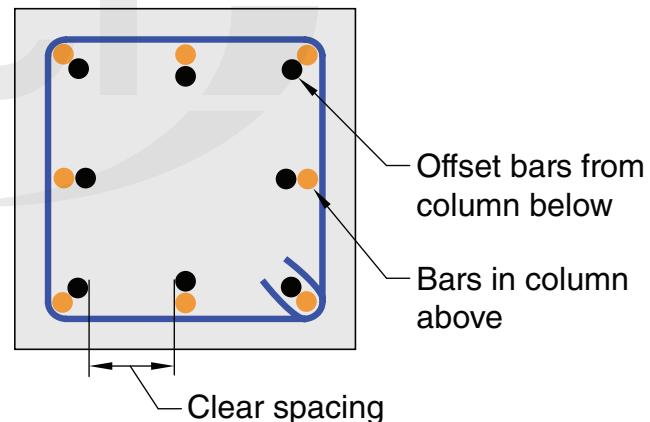


Fig. R10.7.5.1.3—Offset column bars.

**10.7.5.2 Lap splices****R10.7.5.2 Lap splices**

In columns subject to moment and axial force, tensile stresses may occur on one face of the column for moderate and large eccentricities as shown in Fig. R10.7.5.2. If such stresses occur, 10.7.5.2.2 requires tension splices to be used.

The splice requirements have been formulated on the basis that a compression lap splice has a tensile strength of at least  $0.25f_y$ . Therefore, even if column bars are designed for compression according to 10.7.5.2.1, some tensile strength is inherently provided.

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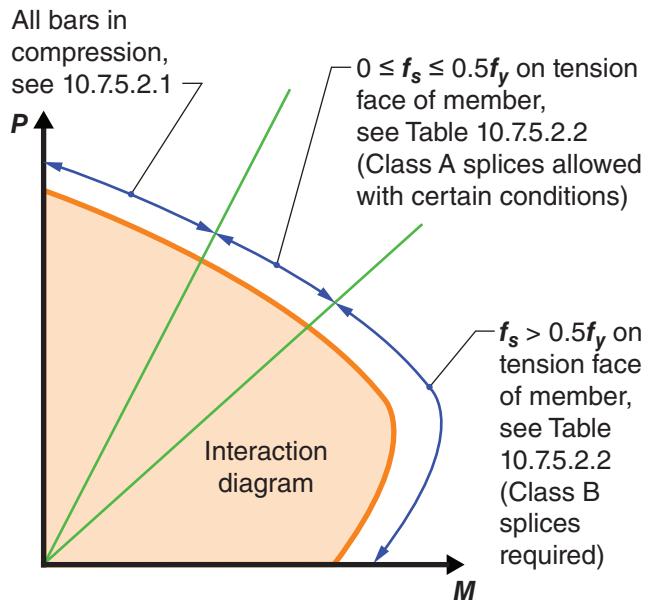


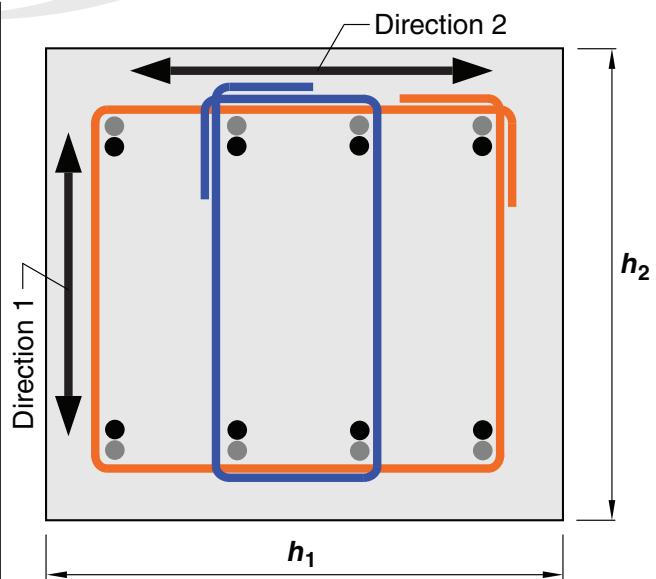
Fig. R10.7.5.2—Lap splice requirements for columns.

**10.7.5.2.1** If the bar force due to factored loads is compressive, compression lap splices shall be permitted. It shall be permitted to decrease the compression lap splice length in accordance with (a) or (b), but the lap splice length shall be at least 12 in.

- (a) For tied columns, where ties throughout the lap splice length have an effective area not less than  $0.0015hs$  in both directions, lap splice length shall be permitted to be multiplied by 0.83. Tie legs perpendicular to dimension  $h$  shall be considered in calculating effective area.
- (b) For spiral columns, where spirals throughout the lap splice length satisfy 25.7.3, lap splice length shall be permitted to be multiplied by 0.75.

**R10.7.5.2.1** Reduced lap lengths are permitted if the lap splice is enclosed throughout its length by sufficient ties. The tie leg areas perpendicular to each direction are calculated separately. An example is provided in Fig. R10.7.5.2.1, where four legs are effective in one direction and two legs in the other direction.

Compression lap lengths may also be reduced if the lap splice is enclosed throughout its length by spirals that provide increased splitting resistance.



$$\text{Direction 1: } 4A_b \geq 0.0015h_1s$$

$$\text{Direction 2: } 2A_b \geq 0.0015h_2s$$

where  $A_b$  is the area of the tie

Fig. R10.7.5.2.1—Example of application of 10.7.5.2.1(a).

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**10.7.5.2.2** If the bar force due to factored loads is tensile, tension lap splices shall be in accordance with Table 10.7.5.2.2.

**Table 10.7.5.2.2—Tension lap splice class**

Tensile bar stress	Splice details	Splice type
$\leq 0.5f_y$	$\leq 50\%$ bars spliced at any section and lap splices on adjacent bars staggered by at least $\ell_d$	Class A
	Other	Class B
$>0.5f_y$	All cases	Class B

**10.7.5.3 End-bearing splices**

**10.7.5.3.1** If the bar force due to factored loads is compressive, end-bearing splices shall be permitted provided the splices are staggered or additional bars are provided at splice locations. The continuing bars in each face of the column shall have a tensile strength at least  $0.25f_y$  times the area of the vertical reinforcement along that face.

**10.7.6 Transverse reinforcement****10.7.6.1 General**

**10.7.6.1.1** Transverse reinforcement shall satisfy the most restrictive requirements for reinforcement spacing.

**10.7.6.1.2** Details of transverse reinforcement shall be in accordance with 25.7.2 for ties, 25.7.3 for spirals, or 25.7.4 for hoops.

**10.7.6.1.3** For prestressed columns with an average compressive stress, due to effective prestress force only, greater than or equal to 225 psi, transverse ties or hoops need not satisfy the  $16d_b$  spacing requirement of 25.7.2.1.

**10.7.6.1.4** Longitudinal reinforcement shall be laterally supported using ties or hoops in accordance with 10.7.6.2 or spirals in accordance with 10.7.6.3, unless tests and structural analyses demonstrate adequate strength and feasibility of construction.

**COMMENTARY****R10.7.5.3 End-bearing splices**

**R10.7.5.3.1** Details for end-bearing splices are provided in 25.5.6.

**R10.7.6 Transverse reinforcement****R10.7.6.1 General**

**R10.7.6.1.4** All longitudinal bars in compression should be enclosed within transverse reinforcement. Where longitudinal bars are arranged in a circular pattern, only one circular tie per specified spacing is required. This requirement can be satisfied with a continuous circular tie (helix), that has a maximum pitch equal to the required tie spacing.

It is prudent to provide ties at each end of lap spliced bars, above and below end-bearing splices, and at minimum spacing immediately below sloping regions of offset bent bars.

Precast columns with cover less than 1-1/2 in., prestressed columns without nonprestressed longitudinal bars, columns constructed with concrete using coarse aggregate with a nominal maximum size of 3/8 in., wall-like columns, and other unusual columns may require closer spacing of transverse reinforcement.

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**10.7.6.1.5** If anchor bolts are placed in the top of a column or pedestal, the bolts shall be enclosed by transverse reinforcement that also surrounds at least four longitudinal bars within the column or pedestal. The transverse reinforcement shall be distributed within 5 in. of the top of the column or pedestal and shall consist of at least two No. 4 or three No. 3 ties or hoops.

**10.7.6.1.6** If mechanical couplers or extended bars for connection to a precast element are placed in the ends of columns or pedestals, the mechanical couplers or extended bars shall be enclosed by transverse reinforcement. The transverse reinforcement shall be distributed within 5 in. of the ends of the column or pedestal and shall consist of at least two No. 4 or three No. 3 ties or hoops.

**10.7.6.2 *Lateral support of longitudinal bars using ties or hoops***

**10.7.6.2.1** In any story, the bottom tie or hoop shall be located not more than one-half the tie or hoop spacing above the top of footing or slab.

**10.7.6.2.2** In any story, the top tie or hoop shall be located not more than one-half the tie or hoop spacing below the lowest horizontal reinforcement in the slab, drop panel, or shear cap. If beams or brackets frame into all sides of the column, the top tie or hoop shall be located not more than 3 in. below the lowest horizontal reinforcement in the shallowest beam or bracket.

**10.7.6.3 *Lateral support of longitudinal bars using spirals***

**10.7.6.3.1** In any story, the bottom of the spiral shall be located at the top of footing or slab.

**10.7.6.3.2** In any story, the top of the spiral shall be located in accordance with Table 10.7.6.3.2.

**Table 10.7.6.3.2 —Spiral extension requirements at top of column**

Framing at column end	Extension requirements
Beams or brackets frame into all sides of the column	Extend to the level of the lowest horizontal reinforcement in members supported above.
Beams or brackets do not frame into all sides of the column	Extend to the level of the lowest horizontal reinforcement in members supported above. Additional column ties shall extend above termination of spiral to bottom of slab, drop panel, or shear cap.
Columns with capitals	Extend to the level at which the diameter or width of capital is twice that of the column.

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**R10.7.6.1.5** and **R10.7.6.1.6** Confinement improves load transfer from the anchor bolts and mechanical couplers to the column or pedestal where concrete may crack in the vicinity of the bolts and mechanical couplers. Such cracking may occur due to unanticipated forces caused by temperature, restrained shrinkage, and accidental impact during construction.

**R10.7.6.2 *Lateral support of longitudinal bars using ties or hoops***

**R10.7.6.2.2** For rectangular columns, beams or brackets framing into all four sides at the same elevation are considered to provide restraint over a joint depth equal to that of the shallowest beam or bracket. For columns with other shapes, four beams framing into the column from two orthogonal directions are considered to provide equivalent restraint.

**R10.7.6.3 *Lateral support of longitudinal bars using spirals***

**R10.7.6.3.2** Refer to R10.7.6.2.2.

**CODE****COMMENTARY****10.7.6.4 Lateral support of offset bent longitudinal bars**

**10.7.6.4.1** Where longitudinal bars are offset, horizontal support shall be provided by ties, hoops, spirals, or parts of the floor construction and shall be designed to resist 1.5 times the horizontal component of the calculated force in the inclined portion of the offset bar.

**10.7.6.4.2** If transverse reinforcement is provided to resist forces that result from offset bends, ties, hoops, or spirals shall be placed not more than 6 in. from points of bend.

**10.7.6.5 Shear**

**10.7.6.5.1** If required, shear reinforcement shall be provided using ties, hoops, or spirals.

**10.7.6.5.2** Maximum spacing of shear reinforcement shall be in accordance with Table 10.7.6.5.2.

**Table 10.7.6.5.2—Maximum spacing of shear reinforcement**

$V_s$		Maximum $s$ , in.	
		Non prestressed column	Prestressed column
$\leq 4\sqrt{f'_c} b_w d$	Lesser of:	$d/2$	$3h/4$
		24	
$> 4\sqrt{f'_c} b_w d$	Lesser of:	$d/4$	$3h/8$
		12	

## Notes

