CHAPTER 14 — COLUMNS

14.1 — Scope

14.1.1 — Provisions of this chapter shall apply to the design of nonprestressed, prestressed, and composite columns. The provisions shall also apply to the design of reinforced concrete pedestals. <10.1>

(a) pedestals
(b) composite columns constructed of concrete and structural steel

14.1.2 — The provisions of Chapter 25 shall apply for the design of plain concrete pedestals, shall be designed according to Chapter 25. <22.2.1>

14.2 — General

14.2.1 — Materials

14.2.1.1 — Design properties for concrete shall conform to Chapter 5. <~>

14.2.1.2 — Design properties for steel reinforcement and structural steel used in composite columns shall conform to Chapter 6. <~>

14.2.1.3 — Design properties for structural steel used in composite columns shall conform to Chapter 6. <~>

14.2.2 — Composite columns

14.2.2.1 — Columns shall be designed as composite columns where a structural steel shape, pipe, or tubing is used as longitudinal reinforcement, the column shall be designed as a composite column. <10.13.1>

14.2.3 — Connection to other members

14.2.3.1 — For cast-in-place columns construction, beam-column and slab-column joints shall satisfy the requirements of 17.2. <10.12> Ref to 17.2 based on LB12-7

14.2.3.2 — For precast columns construction, connections shall satisfy the force transfer requirements of 17.3. <~> Ref to 17.3 based on LB12-7

14.2.3.3 — Connections of columns to foundations shall satisfy the requirements of 17.4. <~> Ref to 17.4 based on LB12-7
14.3 — Design limits

14.3.1 — Dimensional limits

14.3.1.1 — For columns of any cross-sectional shape with a square, octagonal, or other shaped cross section, it shall be permitted to base gross area considered, required minimum longitudinal reinforcement, and design strength on a circular section with a diameter equal to the least lateral dimension of the actual shape. <10.8.3>

14.3.1.2 — For columns with cross sections larger than required by considerations of loading, it shall be permitted to base gross area considered, minimum longitudinal reinforcement required, 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 designed in accordance with Chapter 20. <10.8.4>

14.3.1.3 — 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. <10.8.2>

14.3.1.4 — 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. <10.8.1>

14.3.1.54 — If a reduced effective area is considered as permitted by 14.3.1.1 through 14.3.1.4, 14.3.1.2, or 14.3.1.3 are used, structural analysis and design of other parts of the structure that interact with the column shall be based on the actual cross section the effects of the actual cross section on member stiffness shall be included in the structural analysis and considered in the design of the other parts of the structure that interact with the column. <R10.8.2, R10.8.3, R10.8.4>

14.3.1.6 — For composite columns with a concrete core encased by structural steel, the thickness of the steel encasement shall be at least (a) for rectangular sections or (b) for circular sections:

(a) \( b \sqrt{\frac{f_y}{3E_s}} \) for each face of width where \( b \) is the width of each face
(b) \( h \sqrt{\frac{f_y}{8E_s}} \) for circular sections of diameter where \( h \) is the section diameter
14.4 — Required strength

14.4.1 — General

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

14.4.2 — Factored axial force and moment

14.4.2.1 — Combined $P_u$ and $M_u$ shall be considered where $P_u$ is calculated considering loads on all floors or roof and $M_u$ is calculated considering loads on a single adjacent span of the floor or roof under consideration. Loading condition giving the maximum ratio of moment to axial load shall also be considered.

14.4.2.2 — Consideration shall be given to the effect of unbalanced floor or roof loads on both exterior and interior columns and of eccentric loading due to other causes.

14.4.3 — Factored shear

14.4.3.1 — When gravity load, wind, earthquake, or other lateral forces cause transfer of moment at connections of framing elements to columns, the shear resulting from moment transfer shall be considered.

14.5 — Design strength

14.5.1 — General

14.5.1.1 — Design strength at all sections along the column shall be in accordance with (a) through (c) satisfying $\phi S_n \geq U$, including (a) to (c), for each applicable factored load combination. Interaction between axial force and moment, as well as interactions between other load effects, shall be considered.

(a) $\phi P_n \geq P_u$

(b) $\phi M_n \geq M_u$
14.5.2 — Axial load-force and flexure moment

14.5.2.1 — $\phi P_n$ and $\phi M_n$ shall be calculated in accordance with 9.4. 

14.5.2.2 — For composite columns, forces shall be transferred between the steel section and concrete by direct bearing, shear connectors, or bond in accordance to the axial strength assigned to each component. 

The provision below has been rewritten to reflect composite design practice as presented above.

14.5.2.2 — For composite columns with a structural steel core, axial load strength assigned to concrete shall be transferred to the concrete by members or brackets in direct bearing on the composite column concrete. Axial load strength not assigned to concrete shall be transferred by direct connection to the structural steel shape, pipe, or tubing.

14.5.3 — Shear

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

14.5.4 — Torsion

14.5.4.1 — If $T_u \geq \phi T_{th}$ as defined in 9.7, torsion shall be considered in accordance with Chapter 13.

Commentary will be added to indicate that torsion rarely needs to be considered in column design.

14.6 — Reinforcement Limits

14.6.1 — Minimum and maximum longitudinal reinforcement

14.6.1.1 — For noncomposite columns with average $f_{pe} < 225$ psi, area of longitudinal reinforcement $A_{lr}$ shall not be less than $0.01 A_g$ or more than $0.08 A_g$, satisfy Eq. (14.6.1.1). 

Commentary will be added to indicate that torsion rarely needs to be considered in column design.
14.6.1.3 — For composite columns with a structural steel core, area of longitudinal reinforcing bars located within the transverse reinforcement shall not be less than \(0.01(A_g - A_{st})\) or more than \(0.08(A_g - A_{st})\), satisfy Eq. (14.6.1.1), where \(A_{st}\) is the area of longitudinal bars and \(A_g\) is the net area of the concrete section. <10.13.7.3> <10.13.8.5>

14.6.1.4 — For composite columns with a concrete core encased by structural steel, minimum longitudinal reinforcement shall not be required. <10.13.6>

14.6.2 — Minimum shear reinforcement

14.6.2.1 — A minimum area of shear reinforcement, \(A_{v,min}\), shall be provided in all regions where \(V_u > 0.5V_c\). <11.4.6.1>

14.6.2.2 — If shear reinforcement is required, \(A_{v,min}/s\) shall be the greater of (a) or (b). <11.4.6.3> <11.4.6.4>

\[
(a) \quad 0.75\sqrt{f_c} \frac{b_w s}{f_{yu}} \\
(b) \quad 50 \frac{b_w}{f_{yu}}
\]

in accordance with Table 14.6.2.2 <11.4.6.3> <11.4.6.4>

<table>
<thead>
<tr>
<th>Column type</th>
<th>(A_{v,min}/s)</th>
</tr>
</thead>
</table>
| Nonprestressed and Prestressed with effective prestress force < 40 percent of the tensile strength of the flexural reinforcement | Greater of: \[
0.75\sqrt{f_c} \frac{b_w}{f_{yu}} \quad (a)
\]
|                                                                             | Lesser of: \[
50 \frac{b_w}{f_{yu}} \quad (b)
\]
| Prestressed with effective prestress force ≥ 40 percent of the tensile strength of the flexural reinforcement | Greater of: \[
0.75\sqrt{f_c} \frac{b_w}{f_{yu}} \quad (e)
\]
|                                                                             | Lesser of: \[
50 \frac{b_w}{f_{yu}} \quad (d)
\]
|                                                                             | \[
\frac{A_{ps} f_{pu}}{80 f_{yu} d \sqrt{b_w}} \quad (e)
\]

14.7 — Reinforcement: detailing
14.7.1 — General

14.7.1.1 — Concrete cover for reinforcement shall be in accordance with 6.8.1. <~>

14.7.1.2 — Development lengths of deformed and prestressed reinforcement shall be calculated in accordance with 21.4. <~>

14.7.1.3 — Bundled bars shall be detailed in accordance with 21.6. <~>

14.7.1.4 — The most restrictive requirements for reinforcement spacing and placement shall apply. <11.5.3.8>

14.7.2 — Reinforcement spacing

14.7.2.1 — Minimum spacing shall be in accordance with 21.2. <~>

14.7.3 — Longitudinal reinforcement

14.7.3.12.2 — For non-prestressed columns and prestressed columns with average $f_{pe} < 225$ psi, the minimum number of longitudinal bars shall satisfy be in accordance with (a), (b), or (c):

\[(a) \text{ 3 within triangular ties; }\]
\[(b) \text{ 4 within rectangular or circular ties; }\]
\[(c) \text{ 6 enclosed by spirals or for columns of special moment frames enclosed by circular hoops.}\]

14.7.3 — Longitudinal reinforcement of composite columns with structural steel cores

14.7.3.12 — For composite columns with structural steel cores, A-a longitudinal bar shall be located at every corner of a rectangular cross section, with other longitudinal bars spaced not farther apart than one-half the least side dimension of the composite column. <10.13.8.6>

14.7.3.2 — Ends of structural steel cores shall be accurately finished to bear at end bearing splices, with positive provision for alignment of one core above the other in concentric contact. Bearing shall be considered effective to transfer not greater than 50% of the total compressive stress in the steel core. <7.8.2.1> <7.8.2.2>

14.7.4 — Offset bent longitudinal reinforcement

14.7.4.1 — The slope of the inclined portion of an offset bent longitudinal bar relative to the longitudinal axis of the column shall not exceed 1 in 6, with axis of column. Portions of bar above and below an offset shall be parallel to axis of column. <7.8.1.1> <7.8.1.2>
14.7.4.2 — If the column face is offset 3 in. or greater, longitudinal bars shall not be offset bent. Separate dowels, lap spliced with the longitudinal bars adjacent to the offset column faces, shall be provided. <7.8.1.5>

14.7.5 — Splices of longitudinal reinforcement

14.7.5.1 — General

14.7.5.1.1 — Lap splices, mechanical splices, butt-welded splices, and end-bearing splices shall be provided. <12.17.1>

14.7.5.1.2 — Splices shall satisfy requirements for all factored load combinations. <12.17.1>

14.7.5.1.3 — Splices of deformed reinforcement shall be in accordance with 21.5 in addition to 14.7.5.2 for lap splices or 14.7.5.3 for end-bearing splices. <~>

14.7.5.2 — Lap splices

14.7.5.2.1 — If the bar stress 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 not be less than 12 in. <12.17.2.1>

(a) For tied columns, where ties throughout the lap splice length have an effective area not less than 0.0015$hs$ in both directions, lap splice length shall be permitted to be multiplied by 0.83. Tie legs perpendicular to dimension $h$ shall be used in determining effective area. <12.17.2.4>

(b) For spiral columns, where spirals throughout the lap splice length satisfy 21.8.3, lap splice length shall be permitted to be multiplied by 0.75. <12.17.2.5> <R12.17.2.5>

14.7.5.2.2 — If the bar stress due to factored loads is tensile, tension lap splices shall be provided according to Table 14.7.5.2.2. <12.17.2.2> <12.17.2.3>

<table>
<thead>
<tr>
<th>Tensile Bar Stress</th>
<th>Splice Details</th>
<th>Splice Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\leq 0.5f_y$</td>
<td>$\leq 50%$ bars spliced at any section and alternate-lap splices on adjacent bars staggered by at least $\ell_d$</td>
<td>Class A</td>
</tr>
<tr>
<td></td>
<td>Other</td>
<td>Class B</td>
</tr>
<tr>
<td>$&gt; 0.5f_y$</td>
<td>All cases</td>
<td>Class B</td>
</tr>
</tbody>
</table>
14.7.5.3 — End-bearing splices

14.7.5.3.1 — If the bar stress 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 not less than \(0.25f_y\) times the area of the vertical reinforcement in that face. <12.17.4>

14.7.5.3.2 — For composite columns, ends of structural steel cores shall be accurately finished to bear at end-bearing splices, with positive provision for alignment of one core above the other in concentric contact. Bearing shall be considered effective to transfer not greater than 50 percent of the total compressive force in the steel core. <7.8.2.1> <7.8.2.2>

14.7.6 — Transverse Reinforcement

14.7.6.1 — General

14.7.6.1.1 — Transverse reinforcement shall be provided in accordance with this section. The most restrictive requirements for reinforcement spacing shall apply. <~>

14.7.6.1.2 — Details of transverse reinforcement shall be in accordance with 21.8.2 for ties, 21.8.3 for spirals, or 21.8.4 for hoops. <7.11.2>

14.7.6.1.3 — For prestressed columns with average \(f_{pe} \geq 225\) psi, transverse ties or hoops need not satisfy the \(16d_b\) spacing requirement of 21.8.2.1. <18.11.2.2>

14.7.6.1.4 — For composite columns with a structural steel core, transverse ties or hoops shall have a minimum \(d_b\) of 0.02 times the greater side dimension of the composite column but shall be at least No. 3 and need not be larger than No. 5. Spacing shall satisfy 21.8.2.1 but not exceed 0.5 times the least dimension of the composite column. Deformed wire or welded wire reinforcement of equivalent area shall be permitted. <10.13.8.3> <10.13.8.4>

14.7.6.1.3-5 — Longitudinal reinforcement shall be laterally supported using ties or hoops in accordance with 14.7.6.2 or spirals in accordance with 14.7.6.3 unless tests and structural analysis demonstrate adequate strength and feasibility of construction. <7.10.1> <7.10.2> <7.10.3>

14.7.6.1.64 — 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 bars. <7.10.5.7>

14.7.6.2 — Lateral support of longitudinal bars using ties or hoops

14.7.6.2.1 — 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. <7.10.5.5> <18.11.2.2(c)>
14.7.2.2 — 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. <7.10.5.5> <7.10.5.6> <18.11.2.2(c & d>)

14.7.2.3 — For prestressed columns with average $f_{pc} \geq 225$ psi, transverse reinforcement shall be at least No. 3 in size and center-to-center spacing shall not exceed the lesser of $48d_h$ of tie bar and least dimension of column. Deformed wire or welded wire reinforcement of equivalent area shall be permitted.

14.7.2.4 — For composite columns with a structural steel core, spacing of transverse reinforcement shall be in accordance with 21.8.2.1 but not to exceed 0.5 times the least dimension of the composite column. Transverse reinforcement shall have a minimum $d_h$ of 0.02 times the greater side dimension of the composite column but shall not be smaller than No. 3 and is not required to be larger than No. 5. <10.13.8.3> <10.13.8.4>

14.7.3 — Lateral support of longitudinal bars using spirals

14.7.3.1 — In any story, the bottom of the spiral shall be located at the top of footing or slab. <7.10.4.6>

14.7.3.2 — In any story, the top of the spiral shall be located as provided in Table 14.7.3.2.

Table 14.7.3.2 — Spiral extension requirements at top of column

<table>
<thead>
<tr>
<th>Framing at column end</th>
<th>Extension requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beams or brackets frame into all sides of the column</td>
<td>Extend to the level of the lowest horizontal reinforcement in members supported above. &lt;7.10.4.6&gt;</td>
</tr>
<tr>
<td>Beams or brackets do not frame into all sides of the column</td>
<td>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. &lt;7.10.4.7&gt;</td>
</tr>
<tr>
<td>Columns with capitals</td>
<td>Extend to the level at which the diameter or width of capital is twice that of the column. &lt;7.10.4.8&gt;</td>
</tr>
</tbody>
</table>

14.7.4 — Lateral support of offset bent longitudinal bars

14.7.4.1 — 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. <7.8.1.3>
14.7.6.4.2 — 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. <7.8.1.3>

14.7.6.5 — Shear

14.7.6.5.1 — If required, shear reinforcement shall be provided using ties, hoops, or spirals. <11.5.6.2> <11.5.4.1> <7.11.3> <7.11.2> <7.10.1>

14.7.6.5.2 — Maximum spacing of shear reinforcement shall be in accordance with Table 14.7.6.5.2. <11.4.5> <11.4.5.1> <11.4.5.3>

<table>
<thead>
<tr>
<th>$V_s$</th>
<th>Maximum $s$, in.</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\leq 4\sqrt{f_s b_n d}$</td>
<td>Lesser of: $\frac{d}{2}$, $\frac{3h}{4}$</td>
</tr>
<tr>
<td></td>
<td>24</td>
</tr>
<tr>
<td>$&gt; 4\sqrt{f_s b_n d}$</td>
<td>Lesser of: $\frac{d}{4}$, $\frac{3h}{8}$</td>
</tr>
<tr>
<td></td>
<td>12</td>
</tr>
</tbody>
</table>

Table 14.7.6.5.2 — Maximum spacing of shear reinforcement
CHAPTER 14—Columns  
COMMENTARY

Notes:
1. Written for the revision of Columns chapter available on the reorganization website as the Latest Version.
2. Purple highlights indicate reference numbers that will need to be updated.
3. Revisions of the 318-11 commentary relative to the first ballot are noted in red strikeout/underline.

Ballot History:
This commentary was balloted by Sub D on LB13D-2. Ballot results were Y-5, N-8, C-0, and A-0. There were a total of 111 comments of which 34 were negatives. All comments were addressed, and all negatives were resolved. This commentary was balloted for the first time by the main committee on this ballot, LB13-4. The comments from this ballot were subsequently addressed by Sub D at the summer meeting in San Antonio. This is the second ballot by the main committee on LB13-5.

R14.2 — General

R14.2.2 — Composite columns

R14.2.2.1 — Composite columns include both structural steel sections encased in concrete and hollow structural steel sections filled with concrete. Composite columns are defined without reference to classifications of combination, composite, or concrete-filled pipe column. Reference to other metals used for reinforcement has been omitted because they are seldom used in concrete construction. <R10.13.1>

R14.3 — Design limits

R14.3.1 — Dimensional Limits

R14.3.1 — With the 1971 Code, Explicit minimum sizes for columns are not specified were eliminated to permit the utilization use of reinforced concrete columns with small cross sections in lightly loaded structures, such as low-rise residential and light office buildings. When small cross sections are used, there is a greater need for careful workmanship and shrinkage stresses have increased significance. <R10.8>

For column design, the Code provisions for quantity of reinforcement, both vertical and spiral, are based on the gross column area and core area, and the design strength of the column is based on the gross area of the column section.

R14.3.1.2 — In some cases, however, the gross area of a column is larger than necessary to resist the factored load. In those cases, the minimum reinforcement percentage may be
calculated on the basis of the required area rather than the provided area but cannot be less than one-half percent of the actual cross sectional area.

The basis of 14.3.1.1 through 14.3.1.4 is that it is satisfactory to design a column of sufficient size (called “the reduced effective area” in 14.3.1) to carry the factored load and then simply add concrete around the designed section without increasing the reinforcement to meet the minimum percentages required by 14.6.1.1. The additional concrete should not be considered as carrying load; however, the effects of the additional concrete on member stiffness should be included in the structural analysis. The effects of the additional concrete also should be considered in design of the other parts of the structure that interact with the oversized member as is required by 14.3.1.5 <R10.8.2, R10.8.3, R10.8.4>

Note: the last part of the deleted commentary is no longer need as this has become a code provision in 14.3.1.5

R14.3.1.6 — Steel-encased concrete sections should have a steel metal wall thickness large enough to attain the longitudinal yield stress before buckling outward. <R10.13.6>

R14.4 — Required strength

R14.4.2 — Factored axial force and moment

R14.4.2.1 — The critical load combinations may be difficult to discern by inspection. As illustrated in Figure R14.4.2.1, only considering the factored load combinations with maximum axial force (P1) and with maximum bending moment (P2) does not ensure a safe design for all load combinations such as P3. <R8.10>

Section 8.10 has been developed with the intent of making certain that the most demanding combinations of axial load and moments be identified for design. <R8.10>
Fig. R14.4.2.1 – Critical column load combination

R14.5 — Design strength

R14.5.1 — General

R14.5.1.1 — The design conditions 14.5.1.1 (a) through (c) list the typical forces that need to be considered for a column. However, the general condition $\phi S_n \geq U$ indicates that all forces, such as torsion, that are relevant for a given structure need to be considered. <~>

R14.5.2 — Axial force and moment

R14.5.2.2 — Force transfer between structural steel and concrete can be accomplished using various resistance mechanisms. AISC 360 provides guidance regarding the calculation of force transfer capacity in composite columns.

While bond can be considered as a force transfer mechanism, it may not be appropriate for certain cases. For example, bond is typically considered for the strength of filled
composite columns. However, a concrete encasement around a structural steel shape may
stiffen a column, but not necessarily increase its strength. AISC 360 does not permit
bond to be considered for concrete encased steel columns and does not permit bond to be
combined with other transfer mechanisms. <R10.13.3><R10.13.4>

Add new reference:

XX. AISC 360-10, “Specification for Structural Steel Buildings”, American Institute of
Steel Construction, Chicago, IL, 2010.

NOTE: Relevant section to review in AISC 360-10 is I6.3.

R14.5.3 — Shear

NOTE: Request sent to Sub E to provide guidance in commentary of Section 9.5 on
calculation of \( d \) when all reinforcement is in compression. This will be balloted as new
business.

R14.5.4 — Torsion acting on columns in buildings is typically negligible; torsion is rarely
a governing factor in the design of columns.

R14.6 — Reinforcement limits

R14.6.1 — Minimum and maximum longitudinal reinforcement

R14.6.1.1 — Limits are provided for both the minimum and maximum longitudinal
reinforcement ratios.

This section prescribes the limits on the amount of longitudinal reinforcement for
noncomposite compression members. If the use of high reinforcement ratios would
involve practical difficulties in the placing of concrete, a lower percentage and hence a
larger column, or higher strength concrete or reinforcement (see R6.2.2) should be
considered. The percentage of reinforcement in columns should usually not exceed 4
percent if the column bars are required to be lap spliced. <R10.9.1>

Minimum reinforcement — Since the design methods for columns incorporate separate
terms for the load carried by concrete and by reinforcement, it is necessary to specify
some minimum amount of reinforcement to ensure that only reinforced concrete columns
are designed by these procedures. Reinforcement is necessary to provide resistance to
bending, which may exist whether or not computations show that bending exists
regardless of analytical results, and to reduce the effects of creep and shrinkage of the
concrete under sustained compressive stresses. Tests have shown that creep Creep and
shrinkage tend to transfer load from the concrete to the reinforcement, with a consequent
increase in stress in the reinforcement, and that this the resultant increase in
reinforcement stress is becomes greater as the reinforcement ratio decreases. Therefore, a
minimum limit is placed on the reinforcement ratio to prevent reinforcement from
yielding under sustained service loads. Unless a lower limit is placed on this ratio, the stress in the reinforcement may increase to the yield level under sustained service loads. This phenomenon was emphasized in the report of ACI Committee 105, and minimum reinforcement ratios of 0.01 and 0.005 were recommended for spiral and tied columns, respectively. However, in all editions of the Code since 1936, the minimum ratio has been 0.01 for both types of transversely reinforced columns. <R10.9.1>

Maximum reinforcement — The amount of longitudinal reinforcement must be limited 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. Extensive tests of the ACI column investigation included reinforcement ratios no greater than 0.06. Although other tests with as much as 17 percent reinforcement in the form of bars produced results similar to those obtained previously, it is necessary to note that the loads in these tests were applied through bearing plates on the ends of the columns and the problem of transferring a proportional amount of the load to the bars was thus minimized or avoided. Maximum ratios of 0.08 and 0.03 were recommended by ACI Committee 105 for spiral and tied columns, respectively. In the 1936 Code, these limits were made 0.08 and 0.04, respectively. In the 1956 Code, the limit for tied columns with bending was raised to 0.08. Since the 1963 Code, it has been required that bending be considered in the design of all columns, and the maximum ratio of 0.08 has been applied to both types of columns. This can also be considered a practical maximum for longitudinal reinforcement in terms of economy and requirements for placing. The percentage of 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. <R10.9.1>

R14.6.1.2 — Longitudinal and transverse reinforcement is necessary to prevent spalling and ensure that the concrete outside the structural steel core behaves as reinforced concrete. Limitations on longitudinal reinforcement are necessary for the reasons described in R14.6.1.1. Transverse reinforcement requirements are provided in 14.7.6.1.4. <~>

For composite columns with a concrete core encased by structural steel, no reinforcing bars are required. The minimum steel wall thickness of 14.3.1.6 inherently provides adequate reinforcement. <~>

R14.6.2 — Minimum shear reinforcement

R14.6.2 — The basis for the minimum shear reinforcement is the same for columns and beams. See R13.6.3 for more information.

R14.7 — Reinforcement detailing

R14.7.3 — Longitudinal reinforcement
R14.7.3.1 — Prestressed columns with average $f_{pe} \geq 225$ psi are exempted from this requirement based on a history of successful performance of prestressed members with fewer longitudinal bars than required by 14.7.3.1.

For compression members, a minimum of four longitudinal bars are required when bars are enclosed by rectangular or circular ties. For other shapes, one bar should be provided at each apex or corner and proper transverse reinforcement provided. For example, tied triangular columns require a minimum of three longitudinal bars, with one at each apex of the triangular ties. For bars enclosed by spirals, six bars are required.

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

R14.7.5 — Splices of longitudinal reinforcement

R14.7.5.1 — General

R14.7.5.1.2 — Note that the column splice should satisfy requirements for all load combinations for the column. Frequently, the basic gravity load combination will govern the design of the column itself, but a load combination including wind or seismic loads may induce greater tension in some column bars, and the column. Each bar splice should be designed for the maximum calculated bar tension force.

R14.7.5.2 — Lap splices

In columns subject to flexure-moment and axial force, tension stresses may occur on one face of the column for moderate and large eccentricities as shown in Fig. R14.7.5.2. When such tension stresses occur, 14.7.5.2.2 requires tension splices to be used, or an adequate tensile resistance to be provided. Furthermore, a minimum tension strength is required in each face of all columns even where analysis indicates compression only.
The 1989 Code clarifies this section. The splice requirements have been formulated on the basis that a compressive lap splice has a tension-tensile strength of at least one-quarter $0.25 f_y$, which simplifies the calculation requirements in previous Codes. Therefore, even if columns bars are designed for compression according to 14.7.5.2.1, nominal tensile strength is inherently provided. <R12.17>

**R14.7.5.2.1** — Reduced lap lengths are allowed-permitted when-if the splice is enclosed throughout its length by minimum sufficient ties. The tie leg areas perpendicular to each direction are computed separately and the requirement satisfied in each direction to apply the 0.83 reduction factor. This is illustrated. An example is provided in Fig. R14.7.5.2.1, where four legs are effective in one direction and two legs in the other direction. This calculation is critical in one direction, which normally can be determined by inspection. <R12.17.2.4>

Compression lap lengths may also be reduced when-if the lap splice is enclosed throughout its length by spirals because of due to increased splitting resistance. Spirals should meet requirements of 14.7.6.3 and 21.8.3.3. <R12.17.2.5>
R14.7.5.3 — End-bearing splices

R14.7.5.3.1 End-bearing splices used to splice column bars always in compression should have a tension strength of 25 percent of the specified yield strength of the steel area on each face of the column, either by staggering the end-bearing splices or by adding additional steel through the splice location. Details for end-bearing splices are provided in 21.5.6. The end-bearing splice should conform to 21.5.6. <R12.17.4>

R14.7.5.3.2 — The 50 percent limit on transfer of compressive load by end bearing on ends of structural steel cores is intended to provide some level of tensile strength at such splices (up to 50 percent) since because the remainder of the total compressive stress load in the steel core are is to be transmitted by dowels, splice plates, welds, etc. or other mechanisms. This provision should be intended to ensure that splices in composite compression members columns meet essentially the same tensile strength requirements as as required for conventionally reinforced concrete compression members columns. <R7.8.2>

R14.7.6 — Transverse Reinforcement

R14.7.6.1 — General

R14.7.6.1.4 — Research has shown that the required amount of tie reinforcement around the structural steel core is sufficient for the longitudinal steel bars to be included in the flexural stiffness of the composite column as permitted by Chapter 8. <R10.13.8>

R14.7.6.1.5 — All longitudinal bars in compression should be enclosed within transverse ties-reinforcement. Where longitudinal bars are arranged in a circular pattern, only one circular tie per specified spacing is required. This requirement can be satisfied by a continuous circular tie (helix) at a larger pitch than required for spirals under 10.9.3. the maximum pitch being equal to the required tie spacing (see also 7.10.4.3). <R7.10.5>
Unusual columns such as precast columns with cover less than 1-1/2 in., prestressed columns without longitudinal bars, columns smaller than minimum dimensions prescribed in earlier Code editions, columns of concrete with small size coarse aggregate, wall-like columns, and other unusual cases may require special designs for transverse reinforcement. Wire, W4, D4, or larger, may be used for ties or spirals. If such unusual columns are considered as spiral columns for load strength calculations in design, the volumetric reinforcement ratio for the spiral, $\rho_s$, is to conform to 21.8.3.3.

R14.7.6.1.6 — Provisions for confinement of anchor bolts that are placed in the top of columns or pedestals were added in the 2002 Code. Confinement improves load transfer from the anchor bolts to the column or pier for situations where the concrete cracks in the vicinity of the bolts. Such cracking can occur due to unanticipated forces caused by temperature, restrained shrinkage, and similar effects. <R7.10.5.7>

R14.7.6.2 — Lateral support of longitudinal bars using ties or hoops

R14.7.6.2.2 — For rectangular columns, beams or brackets framing into all four sides at the same elevation are considered to provide confinement 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. <~>

With the 1983 Code, the wording of this section was modified to clarify that ties may be terminated only when elements frame into all four sides of square and rectangular columns; for round or polygonal columns, such elements frame into the column from four directions. <R7.10.5.6>

R14.7.6.3 — Lateral support of longitudinal bars using spirals

R14.7.6.3.2 — See R14.7.6.2.2.