

## Recommended Details for Reinforced Concrete Construction

### Part 3: Columns

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This article is the third in a series (STRUCTURE: Part 1 – June 2019, Part 2 – July 2019) on recommended reinforcement details for cast-in-place concrete construction.

### Detailing Longitudinal Reinforcement

Once the size of the cross-section and the required area of longitudinal reinforcement have been determined for a reinforced

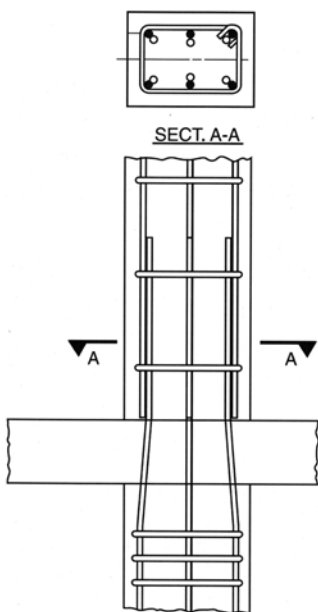


Figure 2. Lap splice location for reinforced concrete columns in buildings assigned to SDC A, B, or C.

concrete column based on strength requirements, the size and number of longitudinal reinforcing bars must be chosen to provide an area of reinforcement equal to or greater than the amount that is required, and satisfy the minimum and maximum spacing requirements in ACI 318-14, *Building Code Requirements for Structural Concrete and Commentary*. Columns that have longitudinal reinforcement ratios in the range of 1 to 2% are usually the most economical because concrete resists axial compression forces more cost-effectively than reinforcing steel. It is usually more economical to use larger column sizes with less longitudinal reinforcement.

The minimum number of longitudinal bars in a column based

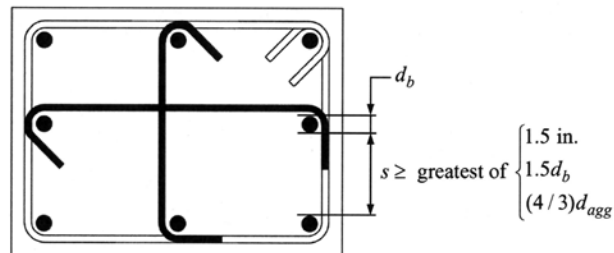


Figure 1. Minimum clear spacing between longitudinal bars.

on the type of transverse reinforcement is given in ACI 318 Section 10.7.3.1 (*Table 1*). Where longitudinal bars are in a circular arrangement, the orientation of the bars has an impact on the moment strength of a column where less than 8 longitudinal bars are provided; this must be considered in the design.

Minimum clear spacing between the longitudinal bars is given in ACI 318 Section 25.2 (*Figure 1*). In the figure,  $d_b$  is the diameter of the longitudinal bars and  $d_{agg}$  is the nominal maximum size of coarse aggregate in the mix. The longitudinal bars must be spaced far enough apart so that concrete can easily flow between the bars. Minimum bar spacing is especially critical at splice locations.

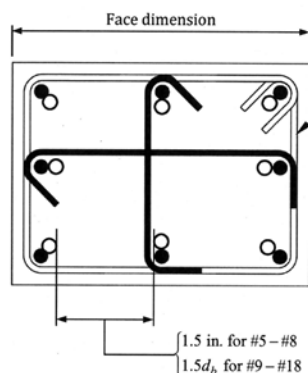
To facilitate the selection of the longitudinal bars, *Table 2* contains the minimum face dimension of rectangular tied columns with normal lap splices based on the minimum spacing requirements assuming 1.5-inch clear cover to #4 ties. The column face dimensions have been rounded to the nearest inch. Similar tables can be created for other tie bar sizes and circular longitudinal bar arrangements.

For columns in ordinary moment frames in buildings assigned to Seismic Design Category (SDC) A or B, or in intermediate moment frames in buildings assigned to SDC C, lap splices of the longitudinal

Table 1. Minimum number of longitudinal bars in a column.

Type of Transverse Reinforcement	Minimum Number of Bars
Triangular ties	3
Rectangular or circular ties	4
Spirals	6
Circular hoops for columns of special moment frames	6

Table 2. Minimum face dimension (inches) of rectangular tied columns with normal lap splices.



Bar Size	Number of bars per face												
	2	3	4	5	6	7	8	9	10	11	12	13	14
#5	8	10	12	14	17	19	21	23	25	27	29	31	34
#6	9	11	13	15	18	20	22	24	27	29	31	33	36
#7	9	11	14	16	18	21	23	26	28	30	33	35	37
#8	9	12	14	17	19	22	24	27	29	32	34	37	39
#9	10	13	16	18	21	24	27	30	33	35	38	41	44
#10	11	14	17	20	23	27	30	33	36	39	42	46	49
#11	11	15	18	22	25	29	33	36	40	43	47	50	54
#14	13	17	21	25	30	34	38	42	47	51	55	59	64
#18	16	21	27	32	38	44	49	55	61	66	72	78	83

bars are permitted to occur immediately above the top of the slab, which is the preferred location for ease of construction (Figure 2, page 31). The type of lap splice that must be used depends on the stress in the longitudinal bars due to the factored load combinations (see ACI 318 Section 10.7.5.2).

For columns that are part of special moment frames in buildings assigned to SDC D, E, or F, lap splices must be tension lap splices and located within the center half of the column length. These lap splices also must be located away from the ends of the column where spalling of the concrete shell surrounding the transverse reinforcement is likely to occur due to a seismic event (ACI 318 Section 18.7.4.3).

## Detailing the Transverse Reinforcement

Requirements for columns with tie reinforcement are given in ACI 318 Sections 10.7.6 and 25.7.2, and standard hook dimensions for ties are given in ACI Section 25.3.2. Tie spacing requirements for reinforced concrete columns in buildings assigned to SDC A and B are given in Figure 3. The clear spacing between ties must be at least  $(4/3)d_{agg}$ . Depending on the shear strength requirements, the required tie spacing may be less than that in the figure.

The provisions of ACI 318 Section 25.7.2.3, which pertain to rectilinear tie configurations and the maximum clear spacing permitted between laterally supported longitudinal bars, are illustrated in Figure 4 and ACI 318 Figure R25.7.2.3a. Lateral support must be provided for longitudinal bars that have a clear spacing greater than 6 inches from a laterally supported bar on each side along the tie.

There are numerous ways to arrange ties in a column, and some arrangements are preferred more than others. Consider the arrangements in Figure 5.

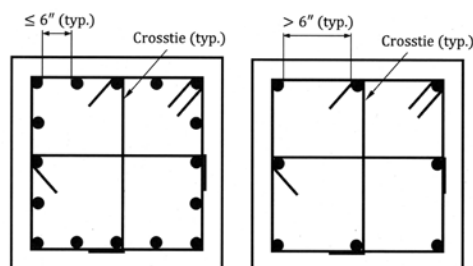
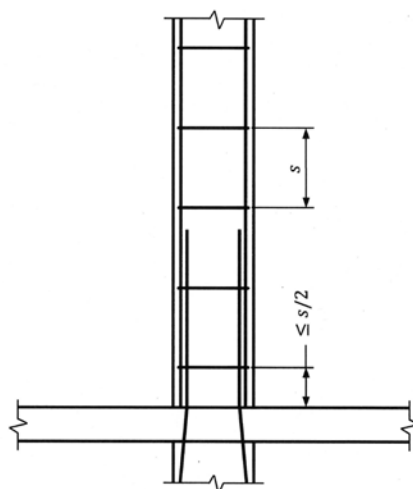


Figure 4. Lateral support requirements for longitudinal bars in tied columns.

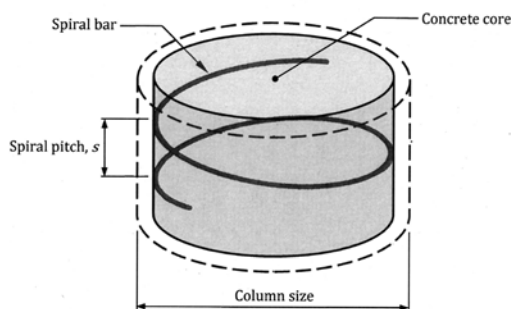


Tie Bar	Column Long. Bar	Max. s (in.)*
#3	#5	10
	#6	12
	#7	14
	#8	16
	#9	18
#4	#10	18
	#11	22
	#14	24
	#18	24

\*Max. s ≤ least column dimension

Figure 3. Tie requirements for reinforced concrete columns in buildings assigned to SDC A and B.

Table 3. Recommended standard spirals for circular columns.



$f'_c$ (psi)	Column Size (in.)	Spiral Size and Pitch
4,000	12 – 24	#3 @ 2"
	26 – 48	#3 @ 2 1/4"
7,000	12 – 16	#4 @ 2"
	18 – 48	#4 @ 2 1/4"
10,000	20 – 48	#5 @ 2 1/2"
14,000	36 – 48	#5 @ 1 3/4"

The arrangements in Figures 5a and 5b are preferred over the arrangement in Figure 5c because 1) the outer confinement tie acts as a template for the ironworker to place the longitudinal bars; 2) it is easier to maintain the required concrete cover using side-form spacers; 3) it is more efficient at preventing displacement of the longitudinal bars while the column cage is being moved into place by the crane; and (4) the tasks that are needed to be completed by the ironworker are simplified, which translates to increased productivity.

Transverse reinforcement requirements in columns that are part of intermediate and special moment frames are given in ACI 318 Sections 18.4.3 and 18.7, respectively.

Requirements for columns with spiral reinforcement are given in ACI 318 Sections 10.7.6 and 25.7.3. Standard spiral sizes are #3 to #5, and the clear spacing between consecutive turns on a spiral must not exceed 3 inches or be less than the greater of 1 inch or  $(4/3)d_{agg}$ . Recommended standard spirals for circular columns with Grade 60 reinforcement and various concrete compressive strengths are given in Table 3.

Additional recommendations and guidelines for detailing reinforced concrete columns in buildings assigned to any SDC can be found in the CRSI publications Design Guide for Economical Reinforced Concrete Structures and Design Guide for Reinforced Concrete Columns. ■



The online version of this article contains references. Please visit [www.STRUCTUREmag.org](http://www.STRUCTUREmag.org).

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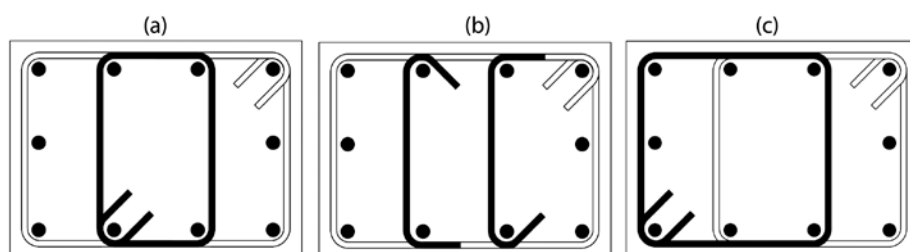


Figure 5. Column tie arrangements; a) With outer confinement tie and inner closed tie, b) With outer confinement tie and crosstie, c) With paired overlapping ties.

## References

- ACI (American Concrete Institute). 2014. *Building Code Requirements for Structural Concrete and Commentary*. ACI 318-14, Farmington Hills, Michigan.
- CRSI (Concrete Reinforcing Steel Institute). 2016. *Design Guide for Economical Reinforced Concrete Structures*. Schaumburg, IL.
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