Column Tie Configurations

In the August 2011 *Detailing Corner*,[1] we focused on various aspects of reinforced concrete column design and construction, including lap splices of the longitudinal bars, placement of the column dowels, and offset bends. In this month's *Detailing Corner*, we examine ACI 318-11[2] requirements for column ties. We also present recommended tie configurations and call attention to an alternate form of tie: the "uni-tie." We thank those who have contacted us and encourage all readers to participate in this forum.

Code Requirements

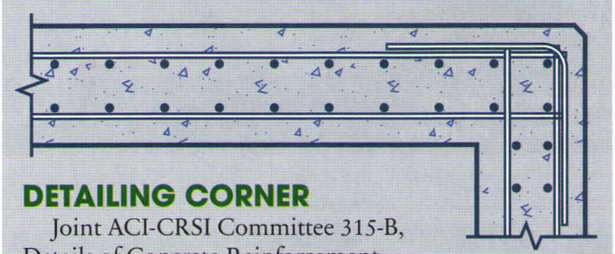
Basic requirements for column tie configurations are listed in Section 7.10.5 of ACI 318. They are summarized here:

- All longitudinal bars No. 10 (No. 32) or smaller must be enclosed by transverse ties at least No. 3 (No. 10) in size. Larger bars, No. 11, 14, and 18 (No. 36, 43, and 57), and bundled bars must be enclosed by transverse ties at least No. 4 (No. 13) in size;
- Vertical spacing of column ties must not exceed 16 longitudinal bar diameters, 48 tie bar or wire diameters, or the least dimension of the column;
- Ties must be arranged so that every corner bar and alternate longitudinal bar will be laterally supported by the corner of a tie with an included angle of not more than 135 degrees. No longitudinal bar can be farther than 6 in. (150 mm) clear on each side along the tie from a laterally supported bar; and
- When longitudinal bars are arranged around the perimeter of a circle, a complete circular tie is permitted. The ends of the circular tie must overlap at least 6 in. (150 mm) and terminate with standard hooks that engage (separate) longitudinal bars. Overlaps at ends of adjacent circular ties must be staggered around the entire perimeter of the column.

Table 1 summarizes maximum tie spacing based on Section 7.10.5.2. A new requirement in the ACI 318 Code, covered in Section 7.10.5.4, was discussed in the October 2011 *Detailing Corner*.[3]

Continuously wound bars or wires can be substituted for tie sets comprising multiple bars, as long as the spacing (pitch) and cross-sectional area meet the requirements stated in Section 7.10.5. The ends of the continuous reinforcement should be anchored by a standard hook or by an additional turn. Circular, continuous reinforcement is considered a spiral if it conforms to the requirements of Section 7.10.4 of ACI 318; otherwise, it's considered a continuous tie.

For structures in Seismic Design Category (SDC) C, D, E, or F, column ties must be "hoops." A hoop is defined as a closed tie or a continuously wound tie with seismic hooks at the ends. Closed tie hoops can be made up of several bars, each with seismic hooks on the ends. A seismic hook must have a hook extension of at least $6d_b$ or 3 in. (75 mm), project into the interior of the column (the column core), and engage a longitudinal bar. A seismic hook on a closed tie hoop must have a bend of at least 135 degrees. A seismic hook on a circular hoop must have a bend of at least 90 degrees.



DETAILING CORNER

Joint ACI-CRSI Committee 315-B, Details of Concrete Reinforcement-Constructibility, has developed forums dealing with constructibility issues for reinforced concrete. To assist the Committee with disseminating this information, staff at the Concrete Reinforcing Steel Institute (CRSI) are presenting these topics in a regular series of articles. If you have a detailing question you would like to see covered in a future article, please send an e-mail to Neal Anderson, CRSI's Vice President of Engineering, at nanderson@crsi.org with the subject line "Detailing Corner."

For SDC C, ACI 318, Section 21.3.5.2, limits the maximum hoop spacing to the smallest of:

- 8 times the diameter of the smallest enclosed longitudinal bar;
- 24 times the hoop bar diameter;
- One-half the minimum column dimension; and
- 12 in. (300 mm).

Table 2 summarizes these spacing requirements. Notice that the spacing limits in Table 2 are one-half the limits summarized in Table 1.

For SDC D, E, or F, hoop spacing limits are included in Section 21.6.4.3. The maximum hoop spacing is the smallest of:

- One-fourth the minimum column dimension; and
- 6 times the smallest longitudinal bar diameter.

Also, within a defined distance from a joint, hoop spacing is limited by a function of the maximum center-to-center horizontal spacing of crossties or hoop legs, h_x. The defined distance must be at least:

- The depth of the column at the joint face or at the section where flexural yielding is likely to occur;
- One-sixth the clear span of the column; or
- 18 in. (450 mm).

Within this distance, the hoop spacing can vary linearly from 4 to 6 in. (100 to 150 mm) as h_x varies from 14 to 8 in. (350 to 200 mm). Table 3 summarizes these spacing limits, with the maximum spacing conservatively assumed to be 4 in. (100 mm).

General Discussion

Standard arrangements of column ties are shown in Fig. 1 and 2 (Fig. 13 and 14 of ACI 315-99[4]). The arrangements of one-piece ties, as shown in Fig. 1, provide sufficient rigidity for column cages preassembled on the site before being lifted into place. Preassembly is preferred for common designs employing one-story-length longitudinal bars, which are all lap spliced at or near a consistent elevation above the floor line.

With staggered butt splices on large, two-story-length longitudinal bars, practical erection limitations usually require the column ties be assembled on free-standing vertical bars. Standard arrangements for two-piece column ties (Fig. 1 and 2) are recommended to facilitate field assembly. If access to the interior of a column is necessary, or if some other column tie pattern is preferred, the ACI 318 requirements listed previously must be met.

Table 1:
Maximum tie spacing (nonseismic)*

Tie bar size, No. (No. M)	3 (10)						4 (13)		
Longitudinal bar size, No. (No. M)	5 (16)	6 (19)	7 (22)	8 (25)	9 (29)	10 (32)	11 (36)	14 (43)	18 (57)
Minimum column diameter, in. (mm)	Maximum tie spacing, in. (mm)								
10 (250)	10 (250)	10 (250)	10 (250)	10 (250)	10 (250)	10 (250)	10 (250)	10 (250)	10 (254)
12 (310)	10 (250)	12 (310)	12 (310)	12 (310)	12 (310)	12 (310)	12 (310)	12 (310)	12 (310)
14 (360)	10 (250)	12 (310)	14 (360)	14 (360)	14 (360)	14 (360)	14 (360)	14 (360)	14 (360)
16 (410)	10 (250)	12 (310)	14 (360)	16 (410)	16 (410)	16 (410)	16 (410)	16 (410)	16 (410)
18 (460)	10 (250)	12 (310)	14 (360)	16 (410)	18 (460)	18 (460)	18 (460)	18 (460)	18 (460)
20 (510)	10 (250)	12 (310)	14 (360)	16 (410)	18 (460)	18 (460)	20 (510)	20 (510)	20 (510)
22 (560)	10 (250)	12 (310)	14 (360)	16 (410)	18 (460)	18 (460)	22 (560)	22 (560)	22 (560)
24 (610) and over	10 (250)	12 (310)	14 (360)	16 (410)	18 (460)	18 (460)	22.5 (570)	24 (610)	24 (610)

*Based on Section 7.10.5.2 of ACI 318-11[2]

In addition to calling out the column tie size and spacing on the structural drawings, the designer must clearly specify additional ties required for special conditions, such as confinement at splices or offset bends of the longitudinal bars. Refer to Section 7.8.1.3 of ACI 318 for column tie requirements at offset bars.

A one-legged, "candy cane" tie (called a "crosstie" in ACI 318), has a 90-degree hook at one end and a 135-degree hook at the other. The ACI 318 Code permits their use for column ties and hoops provided that the end hooks are alternated on successive ties.

Table 2:
Maximum tie spacing (SDC C)*

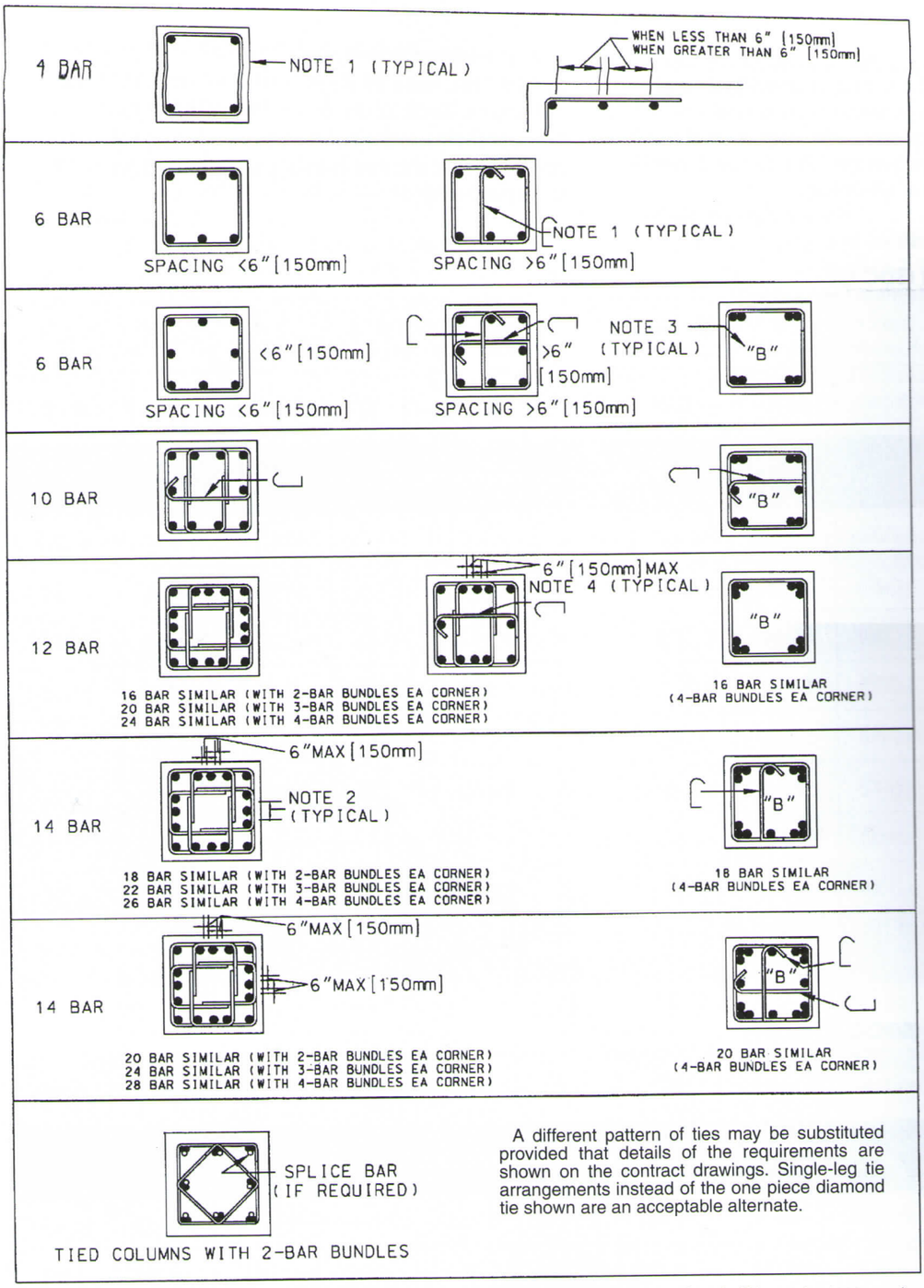
Hoop bar size, No. (No. M)	3 (10)						4 (13)		
Longitudinal bar size, No. (No. M)	5 (16)	6 (19)	7 (22)	8 (25)	9 (29)	10 (32)	11 (36)	14 (43)	18 (57)
Minimum column diameter, in. (mm)	Maximum tie spacing, in. (mm)								
10 (260)	5 (130)	5 (130)	5 (130)	5 (130)	5 (130)	5 (130)	5 (130)	5 (130)	5 (130)
12 (310)	5 (130)	6 (150)	6 (150)	6 (150)	6 (150)	6 (150)	6 (150)	6 (150)	6 (150)
14 (360)	5 (130)	6 (150)	7 (180)	7 (180)	7 (180)	7 (180)	7 (180)	7 (180)	7 (180)
16 (460)	5 (130)	6 (150)	7 (180)	8 (200)	8 (200)	8 (200)	8 (200)	8 (200)	8 (200)
18 (460)	5 (130)	6 (150)	7 (180)	8 (200)	9 (230)	9 (230)	9 (230)	9 (230)	9 (230)
20 (510)	5 (130)	6 (150)	7 (180)	8 (200)	9 (230)	9 (230)	10 (250)	10 (250)	10 (250)
22 (560)	5 (130)	6 (150)	7 (180)	8 (200)	9 (230)	9 (230)	11 (280)	11 (280)	11 (280)
24 (610) and over	5 (130)	6 (150)	7 (180)	8 (200)	9 (230)	9 (230)	11 (280)	12 (310)	12 (310)

*Based on Section 21.3.5.2 of ACI 318-11[2]

Table 3:
Maximum tie spacing (SDC D, E, and F)*

Longitudinal bar size, No. (No. M)	5 (16)	6 (19)	7 (22)	8 (25)	9 (29)	10 (32)	11 (36)	14 (43)	18 (57)
Minimum column diameter, in. (mm)	Maximum tie spacing, in. (mm)								
10 (250)	2.5 (60)	2.5 (60)	2.5 (60)	2.5 (60)	2.5 (60)	2.5 (60)	2.5 (60)	2.5 (60)	2.5 (60)
12 (310)	3 (80)	3 (80)	3 (80)	3 (80)	3 (80)	3 (80)	3 (80)	3 (80)	3 (80)
14 (360)	3.5 (90)	3.5 (90)	3.5 (90)	3.5 (90)	3.5 (90)	3.5 (90)	3.5 (90)	3.5 (90)	3.5 (90)
16 (410) and over	3.75 (100)	4 (100)	4 (100)	4 (100)	4 (100)	4 (100)	4 (100)	4 (100)	4 (100)

*Based on Section 21.6.4.3 of ACI 318-11,[2] with s_o conservatively set to 4 in. (100 mm)



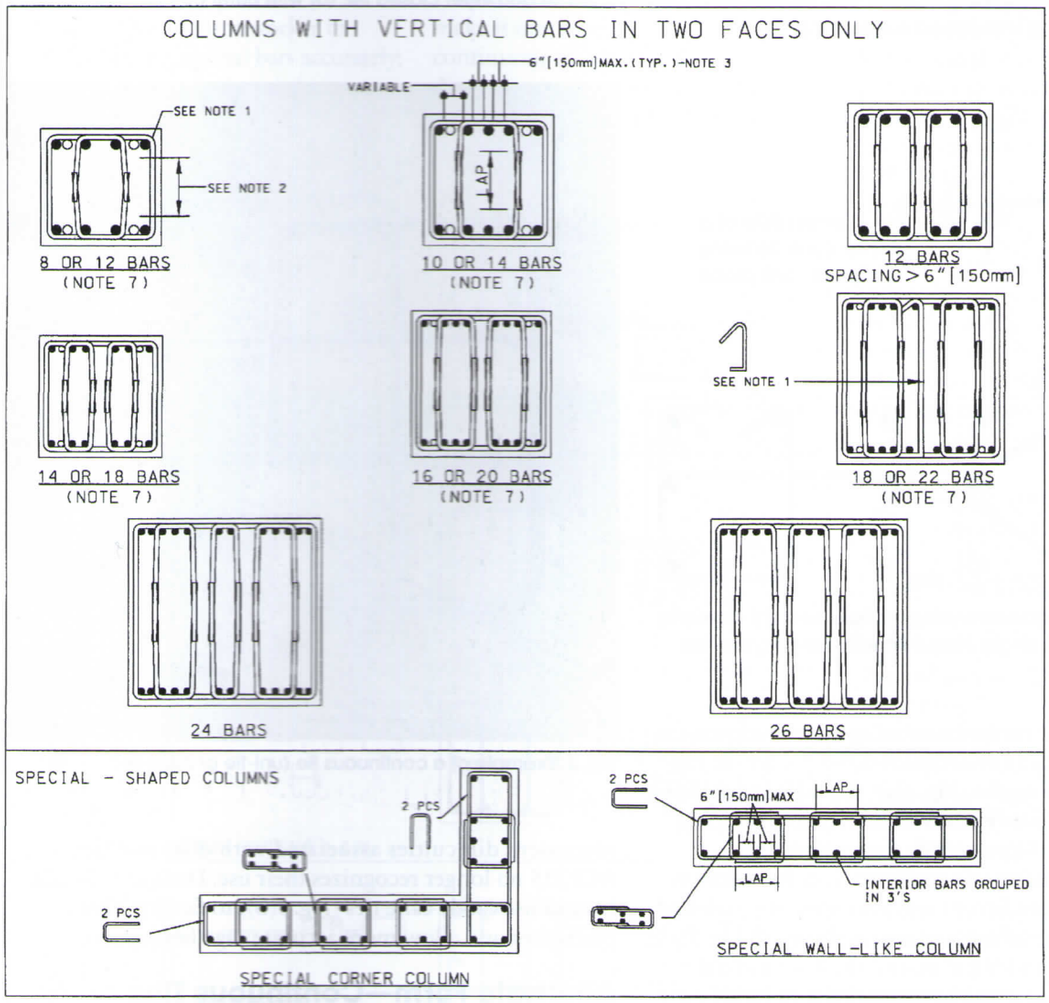
Notes: 1) Alternate position of hooks in placing successive sets of ties; 2) minimum lap shall be 12 in. (300 mm); 3) "B" indicates bundled bars. Bundles shall not exceed four bars; and 4) elimination of tie for center bar in groups of three limits clear spacing to be 6 in. (150 mm) maximum. Unless otherwise specified, bars should be so grouped.

Fig. 1: Standard column ties applicable for either preassembled cages or field erection (Fig. 13 in ACI 315-99[4])

Alternate Configurations

If a few key things are considered, column ties can be detailed in an "ironworker-friendly" way while still meeting design requirements. For example, when column tie configurations use multiple ties, known as tie sets, an outer confinement tie with one or more inner ties or candy cane ties, shown in Fig. 3(a) and (b), is generally preferred over paired overlapping ties, as shown in Fig. 3(c). The outer confinement tie offers these advantages:

- It acts as a template for the ironworker to place the column longitudinal bars accurately;
- It makes it easier to maintain the required concrete cover using side-form spacers;
- It's more efficient at preventing displacement of the longitudinal bars while the column cage is being flown into place by a crane; and
- It simplifies the work of the ironworker and therefore increases his or her productivity.



Notes: 1) Alternate position of hooks in placing successive sets of ties; 2) minimum lap shall be 12 in. (300 mm); 3) elimination of tie for center bar in groups of three limits clear spacing to be 6 in. (150 mm) maximum. Unless otherwise specified, bars should be so grouped; and 7) bars shown as open circles may be accommodated provided clear spaces between bars do not exceed 6 in. (150 mm). (Figure does not include Notes 3-6)

Fig. 2: Standard column ties applicable for either preassembled cages or field erection, special-shaped columns, and columns with bars in two faces only (Fig. 14 in ACI 315-99[4])

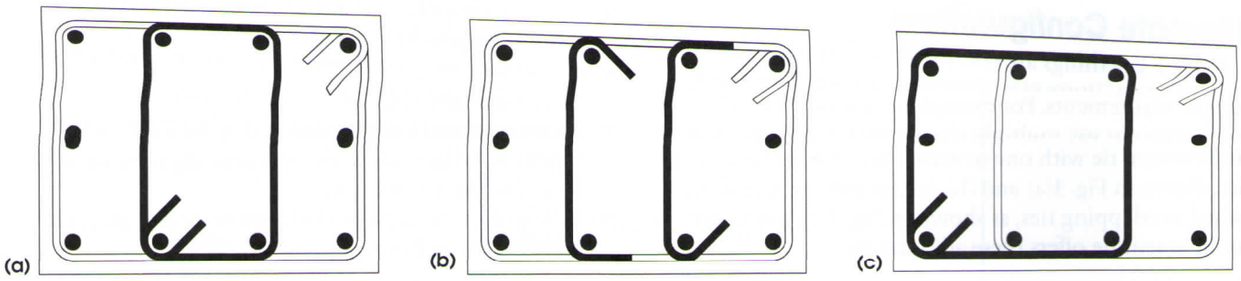


Fig. 3: Column tie sets comprising multiple ties: (a) with outer confinement tie and inner closed tie; (b) with outer confinement tie and candy cane ties; and (c) with paired overlapping ties

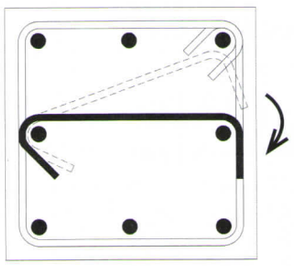


Fig. 4: Installation of a candy cane tie being "snapped" into place

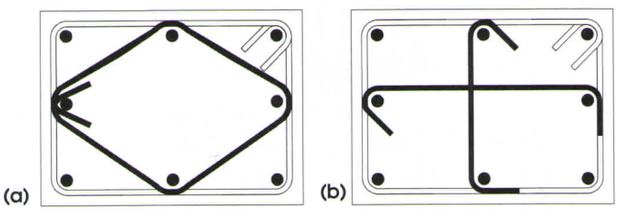


Fig. 5: Column tie configurations using multiple bars: (a) diamond tie (avoid use); and (b) single closed tie with candy cane ties

Fig. 6: Example of a continuous tie (uni-tie or multi-tie)

That being said, an exception to using outer confinement ties would be if the column is dimensionally large. In this case, paired overlapping ties (Fig. 3(c)) would be preferred, avoiding difficulties associated with fabricating, shipping, and placing ties with large outside dimensions.

Further, when detailing tie configurations for columns that require tie sets, candy cane ties (crossties) are preferred over closed ties. Generally, closed ties, as shown in Fig. 3(a), are difficult to place and align around the longitudinal bars. Designers should consider using single or candy cane ties, as shown in Fig. 3(b), to facilitate placement. Candy cane ties can be placed and "snapped" around the longitudinal bars after the column cage has been constructed with the outer confinement ties, as shown in Fig. 4.

Diamond ties, shown in Fig. 5(a), are difficult to accurately fabricate and difficult to place and align around the longitudinal bars; they should be avoided. Because of the placement difficulties associated with diamond ties, ACI 315 no longer recognizes their use. Designers should instead use candy cane ties (Fig. 5(b)) to facilitate bar placement and allow more accurate cage fabrication.

Alternate Form—Continuous Ties

In some markets in the western United States, column tie configurations are further simplified through the use of a single-piece, continuous wound tie that replaces a traditional tie set made up of multiple pieces. These continuous ties are also referred to as "uni-ties" or "multi-ties." The ties are manufactured from coiled stock ASTM A706/A706M[5] reinforcing bars on an automatic stirrup bending

machine. However, safety concerns may preclude some fabrication shops from bending this type of tie.

Figure 6 shows a photo of a continuous tie. Continuous ties offer these advantages:

- The number of pieces is reduced, while still providing an outer confinement tie;
- The one-piece tie provides a template for the ironworker to place the longitudinal bars accurately;
- Concrete cover to the reinforcement is maintained;
- Misplacement of the column reinforcement is reduced; and
- Reduction in the number of pieces increases the productivity of the ironworker.

Figure 7 shows some examples of traditional column tie sets and their comparable continuous tie configurations.

The size of the finished piece may make it impractical to fabricate a continuous tie with large outer dimensions on a stirrup bender with a limited working area. Also, the weight of the finished piece may make handling difficult for highly complex continuous tie patterns. Note also that as a continuous tie becomes more complex, safety concerns may require longer cycle times, as it must be fabricated at a slower rate than normal.

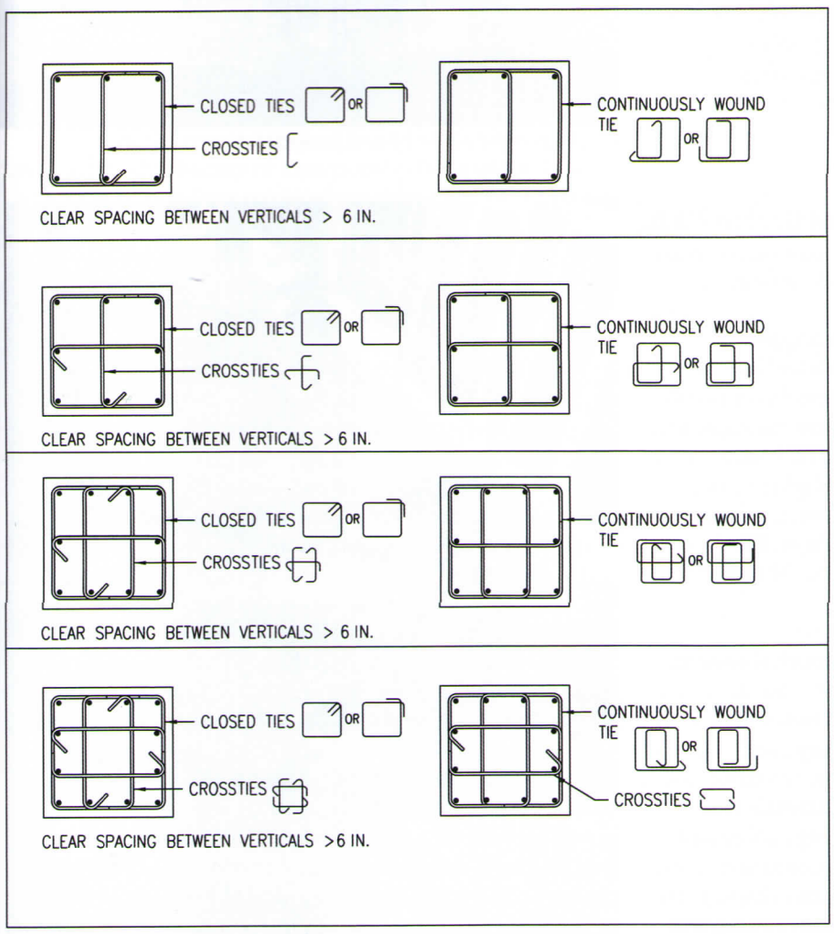


Fig. 7: Traditional column tie sets and continuously wound ties (uni-ties or multi-ties) alternates (Note: Uni-ties are not universally available or used) (Note: 1 in. = 25.4 mm)

Summary

The ACI 318 Building Code has many requirements for column longitudinal bars and ties. The perimeter tie is usually a straightforward, rectangular configuration. The reinforcing bar detailer and fabricator will usually select the interior tie configuration that satisfies Code requirements, yet is easiest to fabricate and tie in the field as the column cage is being laid out and constructed. Some fabricators have the option to bend one continuous tie piece, which can simplify the column cage tying operation.

References

1. CRSI Staff, "Detailing Concrete Columns," *Concrete International*, V. 33, No. 8, Aug. 2011, pp. 47-53.

2. ACI Committee 318, "Building Code Requirements for Structural Concrete (ACI 318-11) and Commentary," American Concrete Institute, Farmington Hills, MI, 2011, 503 pp.

3. CRSI Staff, "RFIs on Circular Ties, Rotating Hooks, Staggered Lap Splices, and Closure Strips," *Concrete International*, V. 33, No. 10, Oct. 2011, pp. 59-64.

4. ACI Committee 315, "Details and Detailing of Concrete Reinforcement (ACI 315-99)," American Concrete Institute, Farmington, Hills, MI, 1999, 44 pp.

5. ASTM A706/A706M-09b, "Standard Specification for Low-Alloy Steel Deformed and Plain Bars for Concrete Reinforcement," ASTM International, West Conshohocken, PA, 2009, 6 pp.

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