Detailing Concrete Columns

Designers of concrete structures are typically concerned about the final design and not necessarily about how a specific concrete element gets built. In other words, engineers tend to avoid issues that are traditionally contractor "means and methods." Yet, decisions made during the design process can have major impacts on the project cost, schedule, change orders, number of requests for information (RFIs), and overall constructibility. Knowledge of how a concrete element gets built can help ensure it matches the engineer's design so the listed impacts are minimized. From a reinforcing bar detailing and placing standpoint, understanding the constructibility aspects can perhaps expedite placing drawing review or reinforcing bar inspections in the field. (Note: detailed reinforcing bar drawings are known as "placing drawings," as opposed to "shop drawings.")

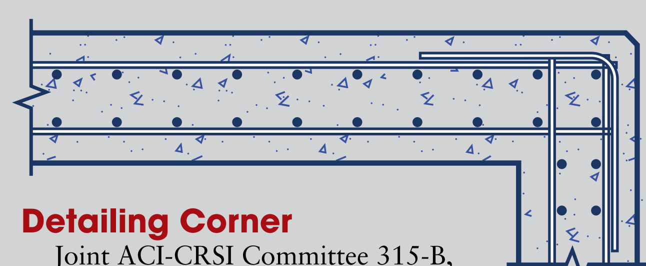
This Detailing Corner concerns various aspects of reinforced concrete column design and construction, including lap splicing of the longitudinal bars, placement of the column dowels, and offset bends. The recommendations presented herein are based on years of experience and they have proved helpful in keeping many a project on time and under budget.

Lap Splice Location

Section 1.2.1 of ACI 318-08[1] lists important informational items that must be included on design drawings, details, or specifications, including anchorage length of reinforcement and location and length of lap splices. One note concerning tension lap splices of longitudinal bars in a column: common industry practice is to categorize the bars as "other" types of bar, and not "top" bars.

A contract column schedule from the engineer may show the columns to be lap-spliced every floor. Depending on the size of the column vertical reinforcing bars for the particular project, the tension lap splices may be fairly lengthy. In some instances, the laps could approach the entire story height. This essentially results in a doubling of the column bars, which may unduly increase congestion in the column and make concrete placement more difficult. If the length of a lap splice is more than about one-third to one-half the story height, it may be more economical to save on laps and lap-splice the bars every other floor, if possible.

Ideally, the column cage should be stable enough to stand on its own so that cable guying or pipe bracing (Fig. 1) is avoided, because it can obstruct construction



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."

Fig. 1: Pipe bracing helps to stabilize tall column cages

activities. Inadvertent, "temporary" releases by other trades can result in instability, so coordination is required. A slightly more robust column cage design by the engineer may eliminate the need for guying or bracing. Certain factors will affect the stability of a column cage:

- Size of column—The larger a column is in cross section, the larger the moment of inertia of the reinforcement arrangement. The column cage is thus more stable as a freestanding unit.
- Quantity and size of bars—Larger bars are more rigid and stable than smaller bars. Similarly, a large number of bars arranged around the column perimeter would be more stable than a small number of bars (Fig. 2). Again, these factors influence the moment of inertia of the bar group.
- Floor-to-floor height—The greater the floor-to-floor height, the less stable the column cage becomes because the unbraced length is greater.

Bar Orientation and Location

A number of changes can occur to a specific longitudinal bar run as it traverses from the footing up to the roof;

Fig. 2: A column cage with many large vertical bars and crossties can be stable enough to eliminate the need for temporary bracing

the bar can change in size as it is spliced to another bar or it can be offset bent to a slightly different location. For these reasons, the reinforcing bar detailer (Detailer) will assign an identification or bar mark for every bar in the column. One way to maintain bar identification on a placing drawing is to assign a unique symbol for each bar, as shown in Details A and B in Fig. 3. In this figure, a unique circular mark representing a longitudinal bar run is shown in plan for pairs of bars (Detail B) and labeled below the footing in Detail A.

On the placing drawings, the Detailer will likely show a "North" orientation arrow on any plan views cut through rectangular columns (illustrated in Detail B in Fig. 3). The reference North arrow indicates the proper column orientation, which aids in the correct placement of the north-south face and east-west face reinforcing bars in the column cage by the ironworker. It also gives a point of proper reference in the column cross section should two opposite faces have a different quantity of bars than the other two sides. Although this may seem obvious, control points or column lines may not be yet established at the project site; thus, a "North" reference on the column cage may be the only sensible reference, given the point or stage of construction progress.

Erecting Column Cages

Although column cages are always shown on the design and placing drawings in their proper vertical orientation, they are almost always assembled horizontally on the ground on horses (Fig. 4). The cage is then hoisted into place. To ensure the ironworker properly constructs the cage, the first and last ties must be properly located at the ends of the cage while it's being fabricated on the ground. Referencing the tie location relative to a floor elevation or a beam soffit is meaningless to the ironworker at this stage because these control points are nowhere to be found on the cage while it's being built. The Detailer will thus provide distances from the end ties to the ends of the longitudinal bars, as shown in Detail A in Fig. 5. Once the location of these key end ties has been established, the remaining ties can be accurately placed along the length of the cage.

In spacing column ties, it's considered good practice to work with tie spacing, rather than the number of ties. Hence, this will be shown on a placing drawing by the Detailer. Multiplying the number of spaces by the spacing distance results in a hard dimension (from the first tie to the last), which is usable to the ironworker. Multiplying the number of ties by the tie spacing doesn't result in a usable dimension to the ironworker. Using tie spacing also allows the ironworker to mark or "tick off" the tie locations on the longitudinal column bars while building the cage.

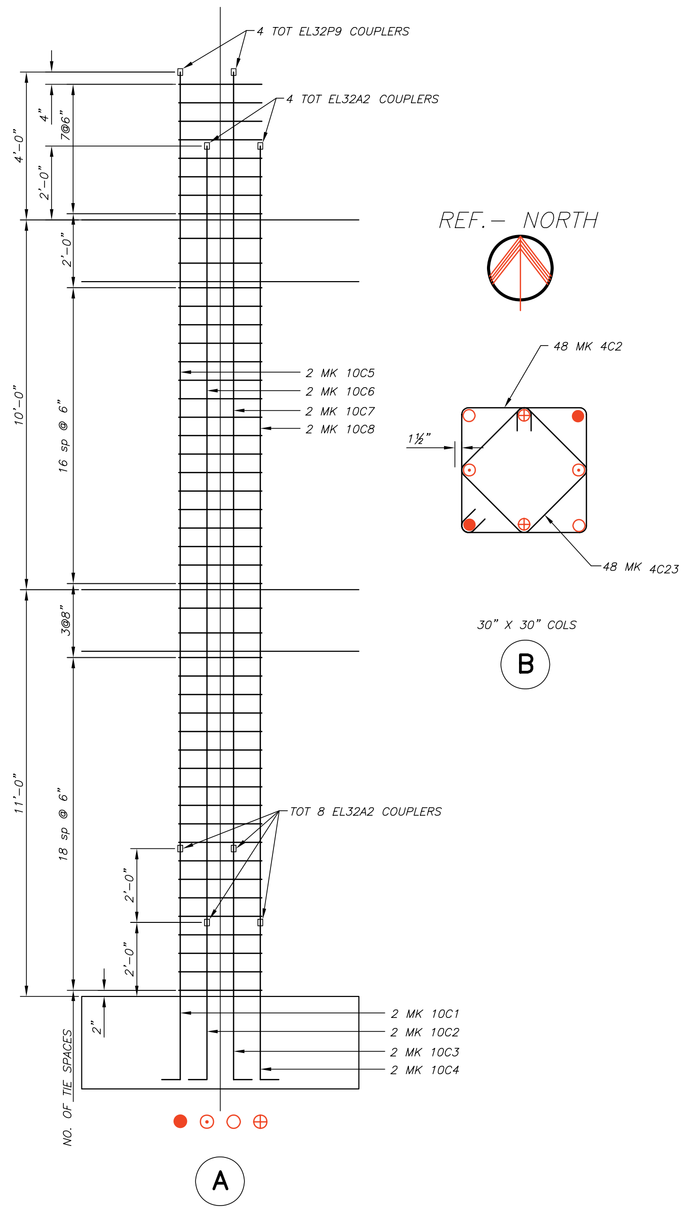


Fig. 3: Typical column details, showing specific bar identification marks and reference north for orientation (colored for emphasis). Column dowel bars are included to show relationship with other bars in the column (1 ft = 0.3048 m; 1 in. = 25.4 mm)

Mechanical Splices

Sheared reinforcing bars usually result in burrs or shear lips at the cut ends. Certain mechanical splices require special preparation at the bar end, such as a square saw cut, tapered thread, straight thread, or upset end. Other mechanical splices can couple bars without any special end preparation. A Detailer should be familiar with the numerous mechanical splice and headed bar systems on the market and make notes if special end preparations are required. The CRSI publication *Reinforcing Bars: Anchorages and Splices*[2] contains

Fig. 4: Horses are used to support a column cage during fabrication

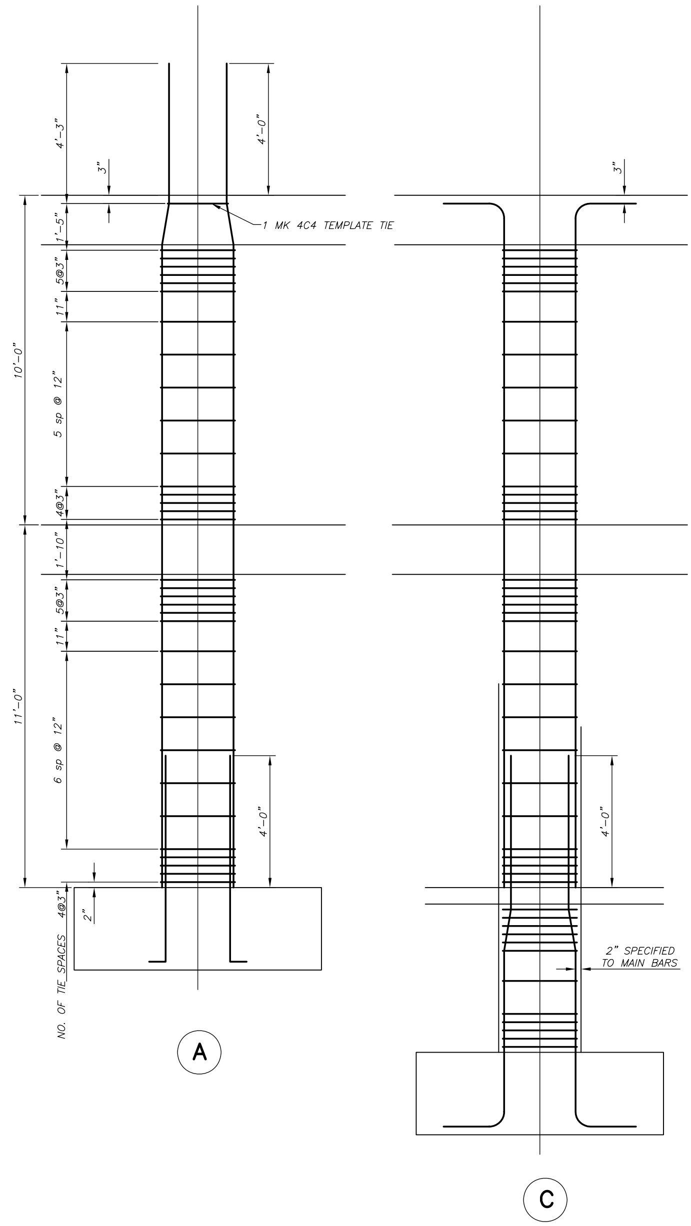
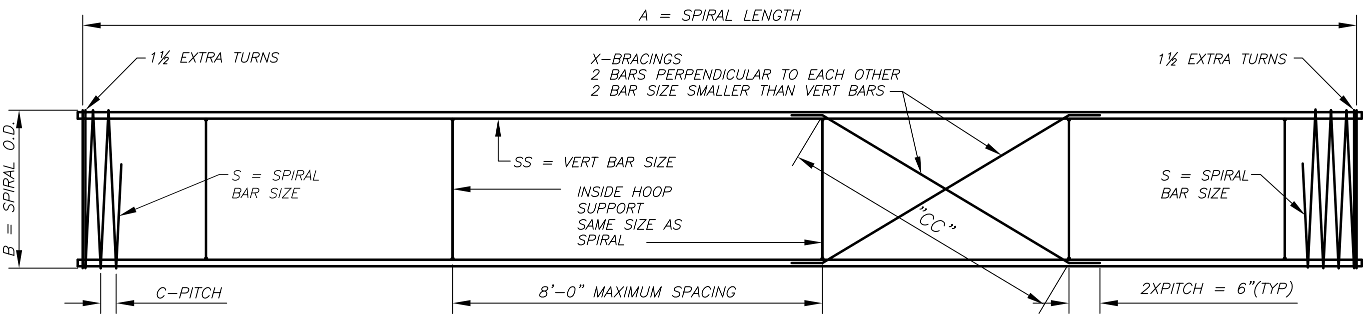


Fig. 5: Typical column details, showing bar offsets and distance from longitudinal bar ends to first and last tie (1 ft = 0.3048 m; 1 in. = 25.4 mm)

information on various types of mechanical splices, including those that require special end preparation.

Detail A of Fig. 3 depicts the required mechanical splices for this particular column. Each type of mechanical splice is properly located on the drawings by dimension lines and/or elevation references. Specific mark numbers are typically referenced back to a schedule, which may contain additional information on the splice device.

ACI 318-08[1] requires mechanical splices be staggered, which results in both short and long vertical bars in the column run. To reduce bar placement errors, the Detailer must properly indicate the placement of these short and long bars on the placing drawing with bar marks. As an example, consider an eight-bar column configured with three bars in each face, which reduces to a four-bar column higher up in building elevation; obviously the four bars would be in the corners of the column cage. It's incumbent on the Detailer to properly and clearly indicate the locations of the different length bars on the placing drawing through the bar mark numbers. If the drawings are unclear or ambiguous to this subtle length difference, the four vertical bars at the higher column elevation will be short should the ironworker accidently reverse the bar positions at the lower elevations.



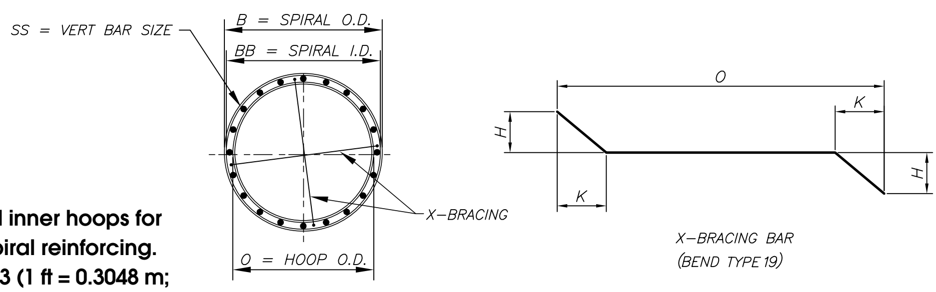


Fig. 6: Cross-bracing and inner hoops for a circular column with spiral reinforcing. Bar type is per Reference 3 (1 ft = 0.3048 m; 1 in. = 25.4 mm)

Mechanical splices can also pose a problem with the column tie locations. Typically, an engineer will show column tie spacing on a general elevation drawing coordinated with a column schedule. Mechanical splices may or may not be specifically located; rather, some general notes are provided as to their use and location.

When the Detailer lays out the actual column reinforcing bar details, a tie could be located at the same elevation as the mechanical splice. Because of the larger diameter of the mechanical splicing device, the tie won't fit or the tie would be forced to have a lower side concrete cover. For this reason, the Detailer will usually add two ties—one above and one below the splice—as a substitute for the single tie coincident with the splice device. Thus, there will be two ties above and two ties below the splice.

If the tie spacing is tight and the mechanical splice device length exceeds the tie spacing, shifting and/or adding column ties may not be practical; the engineer may be notified for an alternate design. Alternately, a different tie with a larger perimeter may be required, which will result in a reduction in the side concrete cover to the tie. Anticipating and noting this possible condition on the engineer's design drawings would give the Detailer advanced guidance and avoid the necessity for a future RFI.

Spiral Reinforcement for Columns or Caissons (Drilled Shafts)

If the spiral reinforcement for a column is sold F.O.B. (freight on board or sometimes known as free on board), cage assembly in the field is the buyer's responsibility and the spiral is shipped in a collapsed condition to the job site. When the column cage is built, the collapsed unit is expanded like an accordion and the spiral pitch (vertical spacing) is then established. After the cage is built on the ground, it will be necessary to pick it up with a crane and set it vertically in position. Without necessary precautions, the cage may deform in a serpentine manner, which can alter the bar spacings and bar layout in plan. For this reason, X-bracing and inner hoops are typically employed as constructibility aids to hold the column cage together. These "extra" bars are shown in Fig. 6.

Some project contracts or construction markets may have the fabricators shop-build the column cages because it's more economical and efficient. As such, the "extra" interior hoops and bracing will aid in hauling and handling the completed cages.

Shop practices will vary across fabricators and different markets, but inner hoops are usually used for column cages up to 36 in. (910 mm) outside diameter (OD). Inner hoops are usually the same bar diameter as the spiral and approximately spaced 8 ft (2.4 m) on center. They prevent the longitudinal (vertical) column bars from displacing inward and keep the cage from collapsing.

For larger column cages, greater than about 36 in. (910 mm) OD, X-bracing is added to supplement the inner hoops. The brace locations are usually provided by two reinforcing bars with a Type 19 bend pattern.[3] They are then placed perpendicular to one another in a three-dimensional fashion, located in the column cage interior. The bar size is usually two sizes smaller than the longitudinal bars, but this can vary by shop practice and experience.

The completed column cage will also have bars added to the pick or lift points to add local strength. Figure 7 shows a well-braced caisson (drilled shaft) cage with X-bracing, inner hoops, and lift point reinforcing, which makes it rigid enough to be picked without deforming.

Fig. 7: A well-braced drilled shaft cage is picked with minimal distortion *(photo courtesy of Dimension Fabricators, Inc.)*

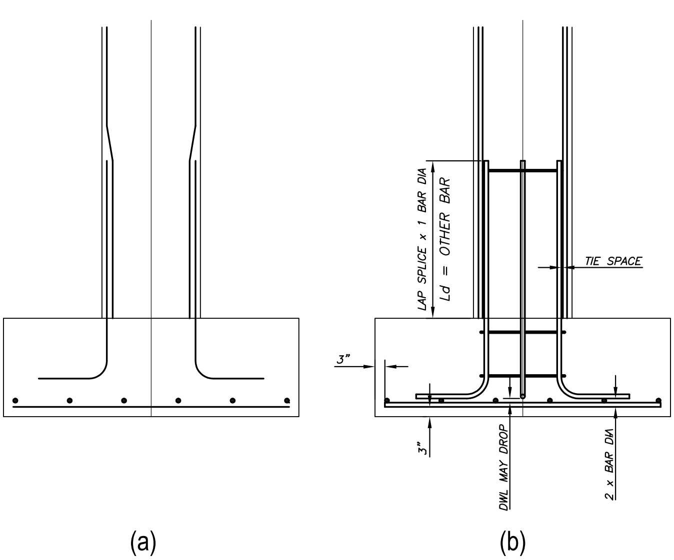


Fig. 8: Column and footing detail: (a) as shown in construction documents; and (b) as detailed for constructibility, with dowels supported on the footing reinforcing bars and straight column bars (no offsets) (1 in. = 25.4 mm)

Dowel Details

Column dowels are placed with the footing reinforcement and are shipped with the footing bars, not the column reinforcement. Engineers will sometimes show the dowel bars hooked into middepth of the footing, as if the concrete is cast already. From a practical standpoint and to facilitate placement, dowels should have a standard 90-degree hook, which will rest on the bottom mat of the footing bars (Fig. 8). Otherwise, additional bars and bar supports are required to position the dowel bars higher in the footing depth.

The dowels should be provided with template ties, which are normally not shown on the placing drawings. The main purpose of a template tie is to hold the column dowels into a relative position until the placed concrete has set. Figure 9 shows examples of various kinds of template ties. A minimum of two template ties are generally required to hold dowels in position.

It's poor practice to drive or push column dowels into position in wet concrete, as they are difficult to hold in proper alignment and depth. Depending on the concrete age when they are shoved in place, the bar development could be reduced because of consolidation damage to the partially set concrete around the bar perimeter. Moreover, adjustments in dowel location after the concrete has set can be costly.

Offset Bends

When a column changes in geometric size going up in elevation from one floor to the next, or when the longitudinal bars are lap spliced, there could be the need to offset bend the bars. This is necessary because of geometry or to avoid vertical bars being in the same location in section. Requirements for offset bent bars are presented in Section 7.8.1 of ACI 318-08[1] and include the following:

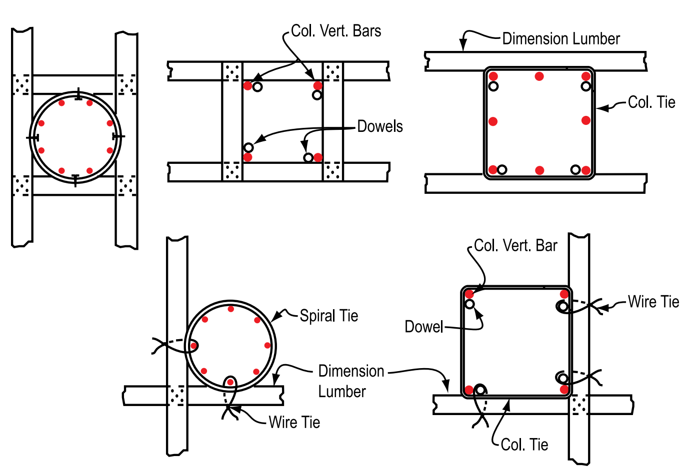


Fig. 9: Examples of templates and ties used for positioning column dowels

- The maximum slope of an offset bar must not exceed 1 in 6;
- Horizontal support at an offset bend must be provided by ties, spirals, or through part of the floor construction; and
- Per ACI 318-08, Section 7.8.1.5, the offset in a column face is limited to 3 in. (75 mm) or less to use offset bent bars. If the offset distance is 3 in. or greater, separate dowels or lap bars must be provided.

When bars in a rectangular column are spliced up the height of the column, the splice location will vary in plan for the corner bars and bars located on the face. In plan, the "second" or spliced bar will almost always be located on the inside portion of the bar (Fig. 10). For the side face bars, this is a simple inward offset following the Cartesian coordinates (x or y) of the column. The corner bar has the splice bar located inward on a diagonal, and thus the offset configuration will have a slightly different detail to accommodate the dimensional difference.

As shown in Detail C in Fig. 5, it's standard construction practice for the vertical bars in the column below to be offset bent into the column above. This is opposed to the bars in the column above being offset bent into the column below. One reason for this practice is to simplify fabrication of the top-most longitudinal bars in a column, which could have an offset bend at one end (the bottom end) and a 90-degree hook at the other end (the top end). Another reason is due to typical floor-to-floor construction techniques used to construct buildings. Once a floor slab is cast, it becomes easier to lower the larger diameter column cage over the small diameter offset cage protruding from the floor slab.

Figure 5 illustrates another way the Detailer can make construction easier. The top, offset point of the vertical column bars in Detail A is shown as being 3 in. (75 mm) below the finished floor slab elevation. This slight dimensional control below the floor allows room for the beam or slab reinforcing bars to pass in the column region.

One final comment on offset bends: if the engineer designing a connection or checking reinforcing bar placing drawings uses the longitudinal bar overall diameter (instead of the nominal bar diameter) in offset bend calculations, the fabricated bars will better accommodate the variables in reinforced concrete construction. Table 1 lists both bar diameters for typical vertical bars.

Summary

Many times, engineers leave the "nuts-and-bolts" of column reinforcing bar layout and configurations to the Detailer, using many "typical" details on the design drawings. Having an understanding of the actual details may help the engineer design them to be more constructible. Further, knowledge of column detailing issues can help expedite placing drawing review, minimize future RFIs, and aid in field inspection.

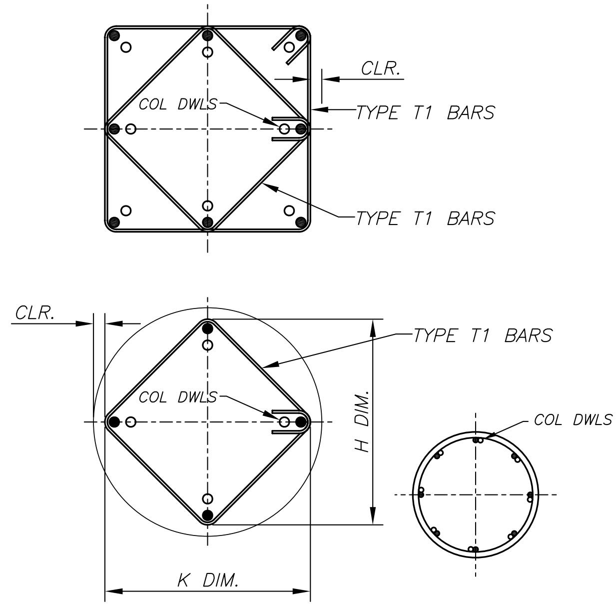


Fig. 10: Typical sections at longitudinal bar splices in columns with rectangular ties. Typical vertical bar splice locations in a circular column with circular ties or spiral are shown for reference. Bar types are per Reference 3

Table 1: Nominal and overall diameters for vertical reinforcing bars

Bar size, No.	Nominal diameter, in.	Overall diameter, in.
6	0.750	0.875
7	0.875	1.000
8	1.000	1.125
9	1.128	1.250
10	1.270	1.438
11	1.410	1.625
14	1.693	1.875
18	2.257	2.500

Note: Overall bar diameter includes the height of the bar deformations; 1 in. = 25.4 mm

References

1. ACI Committee 318, "Building Code Requirements for Structural Concrete (ACI 318-08) and Commentary," American Concrete Institute, Farmington Hills, MI, 2008, 473 pp.

2. *Reinforcing Bars: Anchorages and Splices*, Concrete Reinforcing Steel Institute, Schaumburg, IL, 2008, 70 pp.

3. ACI Committee 315, "Details and Detailing of Concrete Reinforcment (ACI 315-99)," American Concrete Institute, Farmington Hills, MI, 1999, p. 30.

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