The location of foundation dowels for columns and boundary elements can have an impact on the ease of installation of preassembled reinforcing bar cages. As a cage is lowered over the protruding dowels, some of the dowels could interfere with the longitudinal bars in the cage or the tie hooks developed into the core of the column or boundary element. In a boundary element, other issues can arise with the horizontal wall reinforcing bars being developed into the core. These issues are addressed herein.

**Columns**

Figure 1 shows a 10-bar column section, including the dowels protruding from the foundation. Each tie set is made up of two closed ties and a crosstie in the center. The figure shows the ideal arrangement of the dowels for ease of installation of a preassembled reinforcement cage.

Other than at the central dowels at the crosstie, the dowel locations are offset from the longitudinal column bars at 45 degrees relative to the long sides of the column. This arrangement permits the 135-degree hooks of the ties to be located in any of the four corners without conflicting with the dowels. The dowels at the central crosstie location are shifted inboard 90 degrees relative to the long sides of the column. This arrangement permits crossties to be located on either side of the vertical bars without their hooks conflicting with the dowels.

Some engineers prefer that the dowels are located against the closed ties, along with the vertical bars. Using the same 10-bar arrangement as in Fig. 1, this would place the dowels along the longer faces of the column (Fig. 2) or along the long and short faces of the column (Fig. 3).

In the arrangement shown in Fig. 2, some of the dowels must be spaced apart from the longitudinal column bars to avoid interference with the 135-degree hooks of the ties. This will likely require some knowledge of where the tie hooks will be located in the pre-tied cage. Slight differences in the horizontal dimension between the dowel and longitudinal bars can usually be tolerated, however, because the ends of the hooks are relatively flexible and usually can be maneuvered around the dowels. With care, this arrangement can be quite manageable.

In the arrangement shown in Fig. 3, four dowels are located along the end faces and six dowels are located along the long faces of the column. Dowels along the long faces are located outboard of the inner hoop and crosstie. This arrangement has more potential for installation difficulty than the arrangement shown in Fig. 2. If a protruding dowel happens to be too close to the final position of a longitudinal column bar, lowering the preassembled cage over the dowels will be difficult because—unlike the hook
Furthermore, the location of some dowels must be considered in two directions rather than in only one direction. This arrangement requires much more care and is the least preferable option.

**Boundary Elements**

The arrangement of reinforcing bars for a boundary element in a shear wall is essentially the same as for a column. However, issues can arise due to embedment requirements of horizontal bars extending from the wall into the boundary element. Section 21.9.6.4(e) of ACI 318-11 requires the horizontal wall bars to be anchored to develop $f_y$ in tension within the confined core of the boundary element, using standard hooks or heads.

Figure 4 shows a 10-bar boundary element at the end of a shear wall; this detail is similar to Fig. 1 but with horizontal bars from a shear wall extending into the boundary element. In this illustration, the dowels have been located in the same positions as shown in Fig. 1. This dowel arrangement forces the horizontal bars to be positioned closer to the midplane of the wall, thus resulting in potentially greater side concrete cover to the wall reinforcement; the cover will likely exceed the typical cover in the 1-1/2 to 2 in. (40 to 50 mm) range, which may be considered as being excessive.

Figure 5 represents the same boundary element configuration, but with the dowels positioned as shown in Fig. 2. While this arrangement somewhat reduces the concrete cover in the wall, the side cover may still be construed as being excessive. Positioning the dowels as shown in Fig. 3 would not be an option due to the placement of the dowels at the ends (short faces) of the reinforcement cage.

Figure 6 represents a common solution to the issue of excessive ends—the ties will allow little flexibility.
Concrete cover to the horizontal bars. The horizontal bars are offset-bent to allow anchorage into the boundary element while still maintaining proper concrete cover in the wall. Unfortunately, the offset-bent horizontal bars now introduce two other potential issues that must be addressed.

Fig. 6: Ten-bar boundary element. Horizontal wall bars are offset-bent

Due to possible conflict between a tie hook and the hook on a horizontal bar, the horizontal bar hook may have to be rotated out of a horizontal plane. This, in turn, rotates the offset and decreases the offset distance in the horizontal plane, forcing the horizontal bar inwards and increasing the side cover. Additionally, vertical bars in the wall along the length of the offset slope (not shown in Fig. 6 for clarity) cannot be tied to the horizontal bars if a typical concrete

Fig. 7: Ten-bar boundary element with wall horizontal dowels
cover to the vertical wall bars is to be maintained.

Figure 7 shows a detail that minimizes constructibility issues. The reinforcement cage in the boundary element can be preassembled with the wall horizontal dowels in place. Once this cage is lowered into place, preassembled shear wall panels can be lowered into place. This method is less onerous than preassembling the boundary element and the shear wall together and placing them as a single unit, and it’s used extensively in the northwest United States. It’s allowed by Section 12.14.2.3 of ACI 318, which permits lapped bars to be spaced horizontally apart up to 6 in. (150 mm) or one-fifth the lap splice length, whichever is smaller. The wall horizontal bars would be limited to no larger than a No. 11 (No. 36) bar, however, as Section 12.14.2.1 of ACI 318 does not permit bars larger than No. 11 (No. 36) to be lap-spliced.

The options shown in Fig. 4 through 7 are based on the presumption that the shear wall will have a uniform thickness. If possible, the area of the boundary element could be made thicker (wider) than the rest of the shear wall, as shown in Fig. 8. This option serves to relieve congestion in the boundary element, and it will maintain concrete cover throughout the entire shear wall. This change will have structural and architectural repercussions that are outside the scope of this article.

The main difficulty in placing preassembled cages over the protruding foundation dowels is the interference of the dowels with the 135-degree tie hooks. In the 10-bar cages illustrated in the previous figures, there are six hook legs in each tie set to consider. Individual tie sets and single crossties may be replaced with a single tie with multiple bends to form consecutive closed shapes. This is known as a “uni-tie” or “multi-tie.” This tie detail is more common on the west coast of the United States because of the tie requirements for seismic design.

However, some fabrication shops may

Fig. 8: Ten-bar boundary element with increased boundary thickness

Fig. 9: Ten-bar column with dowels with “uni-ties”/“multi-ties”
not be suited to bend a multi-tie on their bending equipment because of safety concerns. If used, a one-piece tie for a 10-bar cage might look like the tie in Fig. 9. With this tie, there are only two hooks in each set to consider.

In Fig. 4 through 8, note that the 180-degree hooks in the wall horizontal bars are shown overlapping. This condition is common in heavily reinforced boundary elements. Because both bars are in the same plane, a necessary minor field adjustment would be to slightly rotate one bar (or both) so the hooks are out of plane.

Figures 4 through 8 also show the wall horizontal bars terminating with 180-degree standard hooks. This detail was used because the tension development length of a standard hook is shorter than the development length of a straight bar and is therefore easier to fit within the confines of a boundary element. Alternate details would be a 90-degree standard hook or a headed bar, which has a basic tension development length that’s 20% shorter than that of a standard hooked bar.

**Design Considerations**

Locating dowels to avoid interference with column bars is an important constructibility issue. Reinforcing bar cages for columns and boundary elements are rarely built in-place—they will generally be preassembled and hoisted into place over the dowels below. The designer should therefore consider how cages will fit over the dowels and manage the design with consideration for constructibility.

The reinforcing bar detailer is usually highly experienced with the ramifications of dowel location in any given situation. The designer should be flexible on dowel locations and defer to the experience of the detailer or placer unless there is some overriding structural reason to do otherwise.

**References**

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

Selected for reader interest by the editors.

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