Reinforcing Bar Layout for Two-Way Slabs

In this month's *Detailing Corner*, we examine the typical reinforcement layout of two-way slabs and present a number of suggestions for good detailing practices. A complete set of reinforcement details in a two-way slab is governed not only from a design aspect but other issues must also be considered, such as constructibility. It is also essential that the reinforcement is clearly shown on the structural drawings so the reinforcing bar detailer can prepare sufficiently complete placing drawings and minimize RFIs attributed to layout issues.

Common Methods of Detailing Two-Way Slab Reinforcement

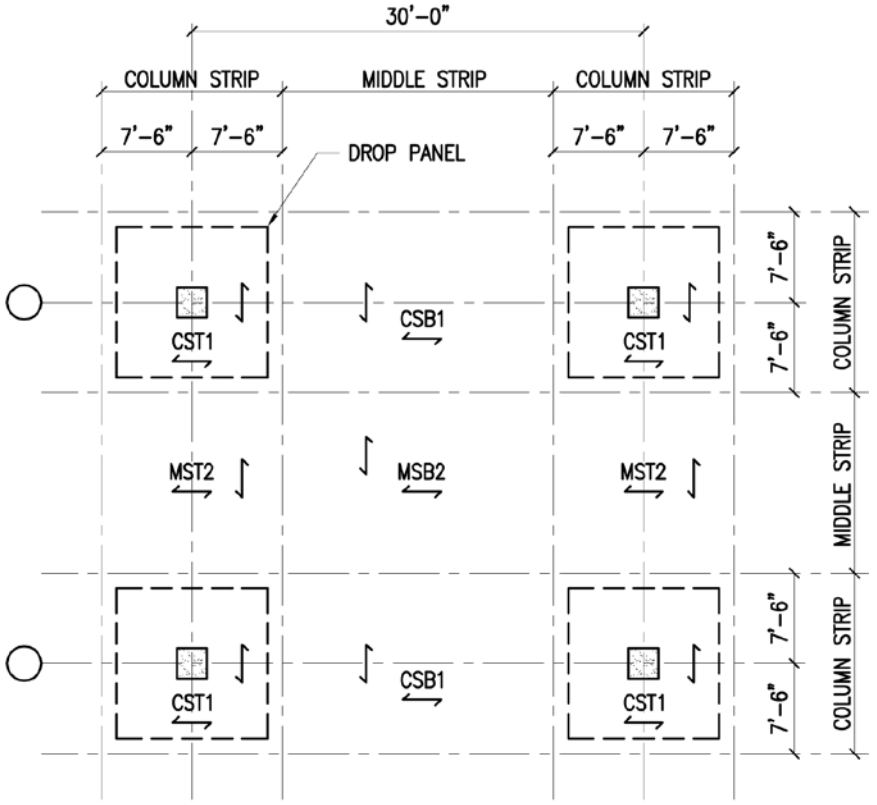
Two-way slabs are generally defined as suspended slabs whose ratio of long span to short span (bay length to width ratio) is less than two. Section 13.1.1 of ACI 318-11[1] identifies a two-way slab as a slab system designed for flexure in more than one direction. Normally, it is assumed the two directions are orthogonal and parallel to the rectangular grid of column lines. Two-way slabs are generally reinforced with two mats of reinforcing steel—a top mat and a bottom mat. The bottom mat is normally continuous over the entire slab area. This mat accommodates the positive design moments, as well as providing temperature and shrinkage reinforcement. The top mat is located at the supports (column strips) to resist the negative design moments. Top reinforcement is also provided between column lines to resist the negative design moments in the middle strips.

Two-way slabs can be detailed in different ways. Two of the commonly used methods are:

1. The structural drawings show the actual layout of the column and middle strips on a plan view. Then, for each design strip, both the top and bottom reinforcement is scheduled in tabular form (as shown in Fig. 1) or indicated directly on a plan view. The column and middle design strips are as defined in Section 13.2 of ACI 318-11, and shown in the plan view of Fig. 1; and
2. As shown in Fig. 2, the structural drawings will indicate a uniform bottom reinforcement quantity across the whole slab; this is generally equal to the greater of temperature and shrinkage reinforcement (0.0018 or 0.002 times the area of slab) or the calculated middle strip reinforcement demands. Any additional column strip reinforcement is called out as such on a plan view, in a slab schedule, or in both locations. The top reinforcement can be called out in a similar way by showing a uniform reinforcement for both the column and middle strips and then showing additional reinforcement for the column strips. In Fig. 2, note that the top and bottom reinforcement is designated as "T" and "B," respectively, whereas the additional reinforcement beyond the typical quantity is noted as "ADDN'L."

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."



SLAB REINFORCEMENT SCHEDULE	
TYPE	DETAIL
CSB1	(2)–#6x33'–0" IN COLUMN WIDTH PLUS (12)#6x33'–0" BARS. SPLICE 3'–1"
MSB2	(8)–#5x31'–0" PLUS (7)–#5x21'–0" (ALTERNATE)
CST1	(10)–#6x21'–0" PLUS (9)–#6x14'–0" (ALTERNATE)
MST2	#5@12"x9'–0"

NOTE: (B) INDICATES BOTTOM BARS, (T) INDICATES TOP BARS. CENTER TOP BARS AT CENTERLINE OF COLUMNS. ONLY REINFORCEMENT IN ONE DIRECTION HAS BEEN SHOWN FOR CLARITY.

Fig. 1: Two-way slab reinforcement with a bar schedule

Suggestions for Good Detailing Practices

Regardless of which method is used to show the required reinforcement in a two-way slab, the following guidelines are suggested or recommended as good detailing practices.

Layering: It is important to clearly show which reinforcing bars are going to be placed in outer layers and which reinforcing bars will be placed in the inner layers. The reinforcement in the direction of the higher design moments are generally placed in the outermost layers. Identifying the inner and outer layers of reinforcement can be accomplished by a note or a section cut detail on the structural drawings.

Column strip bars: In accordance with Section 13.3.8.5 of ACI 318-11, all of the column strip bottom bars or wires are to be continuous. This reinforcement shall be spliced at the column lines or in close proximity to them. At least two of these continuous bottom bars or wires must pass through the vertical column reinforcement; the Commentary terms these bars as "integrity steel." These bars should be specifically called out on the structural drawings or covered with a drawing note.

Spacing: If the reinforcing bar spacing is called out on the drawings, the engineer should ensure any additional bars have a spacing that is a multiple of the main bar spacing, rather than just calling out the number of additional bars. For example, if a mat of No. 4 (No. 13M) bars is called out at a spacing of 12 in. (300 mm), a spacing of 3, 6, or 12 in. (75, 150, or 300 mm) for any required additional bars in a region should be shown. Some designers prefer to use a slightly larger diameter for these additional bars, so their placement can be easily identified and checked in the field.

Hooks: The engineer needs to make sure standard hooks at the ends of the reinforcing bars will fit within the slab depth, while providing adequate concrete cover. If the hooks do not fit within the slab depth, then the following options should be considered:

- Use smaller-diameter bars (smaller bars results in smaller hooks);
- Use headed bars, as they typically take up less room than standard hooks;
- Use 180-degree hooks instead of 90-degree hooks, as the width/depth of a 180-degree hook is smaller than the projection of a 90-degree hook; or
- Tilting the hooks off vertical.

Punching shear: Closed stirrups for shear in thin slabs (thinner than

10 in. [250 mm]) should be avoided. Issues concerning the shear capacity at the column-slab connection are frequently resolved by either increasing the floor slab thickness, using a drop panel or a thicker panel, increasing the column plan size to provide a larger perimeter, increasing the floor slab's overall concrete strength, using shear stud rails or double-headed studs, or puddling higher-strength column concrete in the slab region around the column. Column capitals should only be used as a last resort because of the formwork costs.

Design provisions for headed shear stud reinforcement are provided in Section 11.11.5 of ACI 318-11. When puddling of high-strength concrete around the column perimeter is used, the diameter of the puddle must be specified. On most projects, the puddle is placed during placement of the column concrete and is integrated with the concrete placement for the floor slab to avoid cold joints and potential load-transfer issues. In some instances, stud shear rails and puddling have been used together. ACI 421.1R-08[2] provides additional guidance on designing two-way slabs for shear.

Offset columns: Where the columns are offset within the floor plate, the placement of bottom and top reinforcement should be clearly shown on the structural drawings. If possible, the bars should be placed orthogonally, as this minimizes constructibility and inspection issues when the slab is built. If skewed bars are required in the design for flexure demands, add these additional skewed bottom bars in a separate layer. Do not skew the top bars; rather, place them orthogonally similar to the bottom bars. The middle strip, top bars should be centered on a line connecting the column center lines, as shown on the right half of Fig. 3.

Negative moment reinforcement: The number and length of top reinforcing bars should be clearly scheduled on the drawings. If a closer spacing of bars is required at the columns, as per Section 13.5.3.2 of ACI 318-11, it should be clearly denoted on the structural drawings. The equivalent of closer-spaced, typical slab bars can be achieved by adding additional bars in the column strip directly over the column, while maintaining the typical bar arrangement.

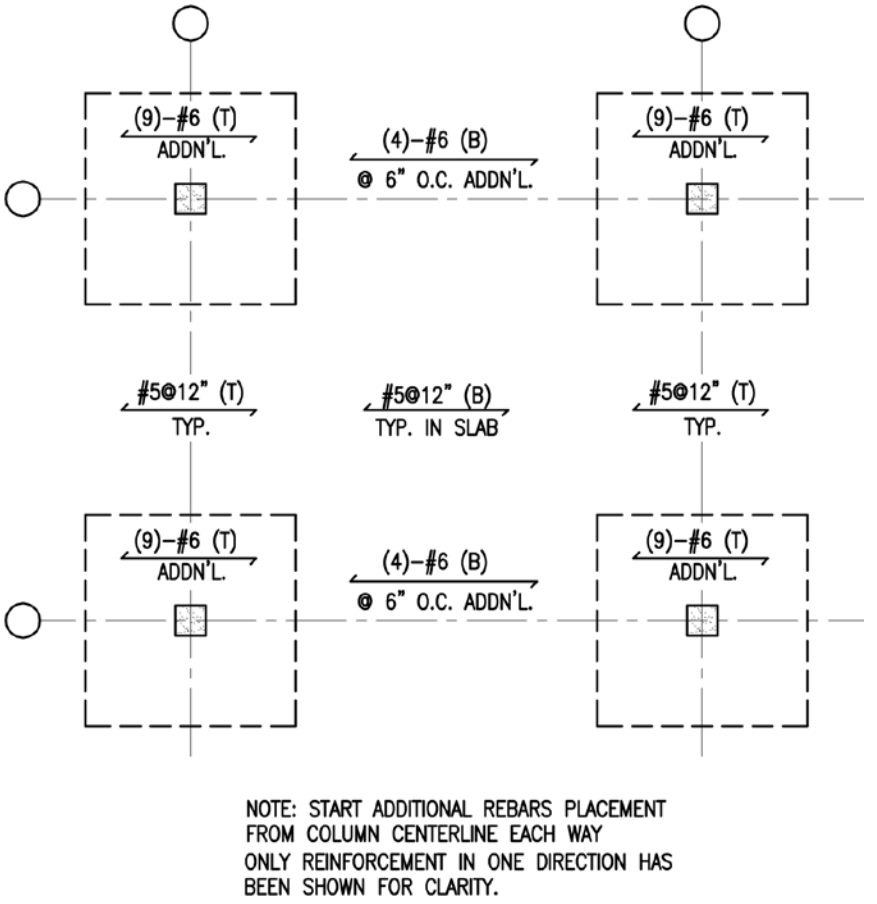


Fig. 2: Alternate method for showing two-way slab reinforcement

Beams: If beams are present along the column lines below the slab, the location of slab top reinforcement needs to be shown and differentiated with respect to the beam top reinforcement. Due to the smaller concrete cover of the reinforcement in the slab (3/4 in. [19 mm] minimum), these bars are typically placed atop the beam top bars for support, generally in the plane of the beam stirrups. Note that this may slightly reduce the negative reinforcement effective depth in the slab as shown in Fig. 4, which must be accounted for in the design.

Reinforcement support: When reviewing reinforcing placement drawings or performing a field inspection, the designer needs to be aware that the reinforcement supports are at the proper height to support the slab top and bottom reinforcement. The reinforcement should be properly tied to the supports so it remains in-place during concrete placement. A general note on the structural drawings that specifically warns against lifting the reinforcement during concrete placement should be provided. All reinforcement must be securely supported at the proper locations prior to concrete placement.

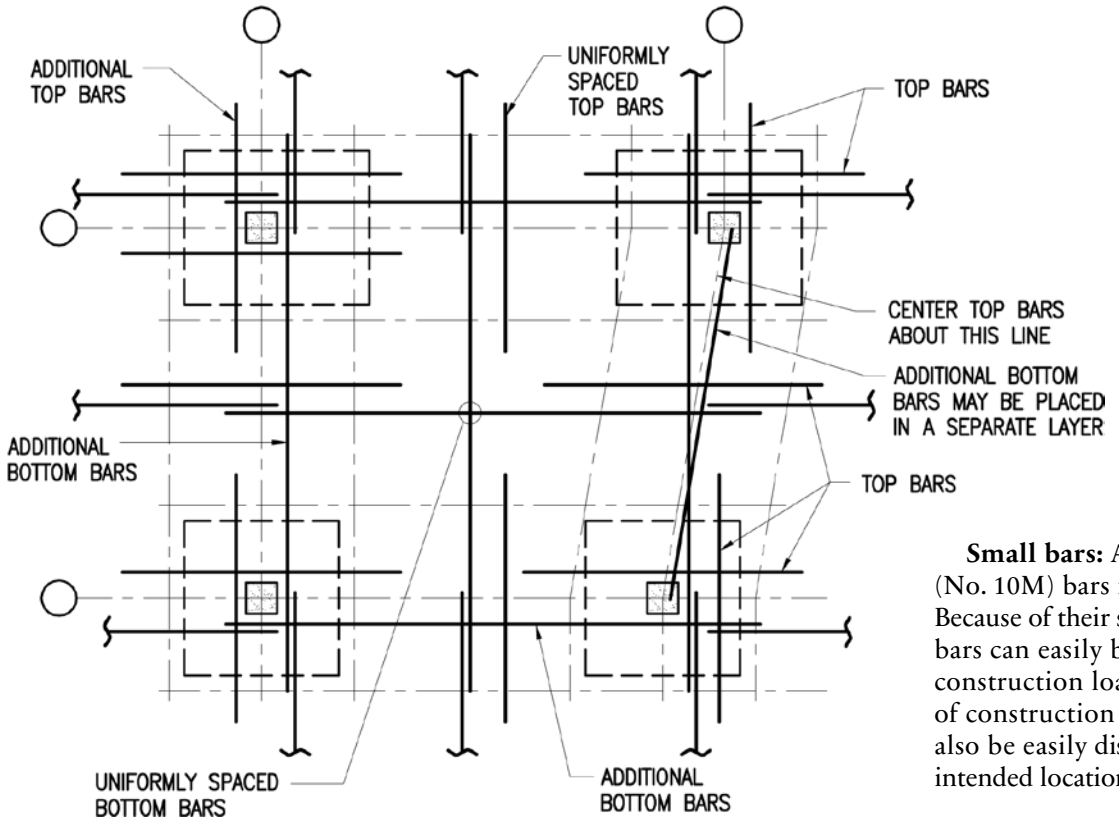


Fig. 3: Reinforcement placement when columns are offset

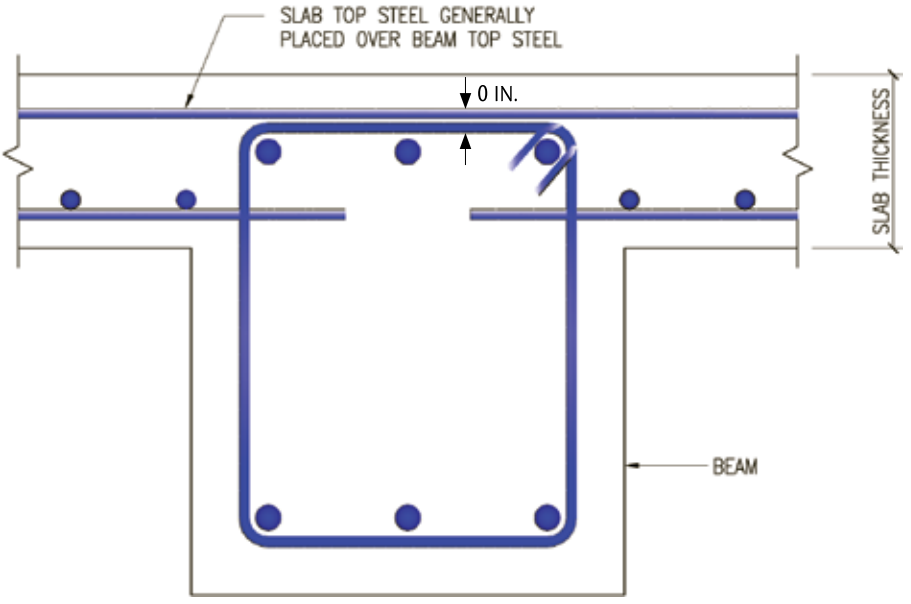


Fig. 4: Placement of slab reinforcement when beams are present

Small bars: Avoid using No. 3 (No. 10M) bars in two-way slabs. Because of their small diameter, these bars can easily be bent due to construction loads and the weight of construction personnel. They can also be easily displaced from their intended location.

Summary

The design of a reinforced concrete structure requires not only adherence to Code requirements but also consideration of such things as constructibility, clarity of the drawings, and practical field experience. All these facets work together to result in a successful project that is completed on time and under budget.

References

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

2. Joint ACI-ASCE Committee 421, "Guide to Shear Reinforcement for Slabs (ACI 421.1R-08)," American Concrete Institute, Farmington Hills, MI, 15 pp.

Thanks to Javed Malik of Jacobs Engineering Group and Neal Anderson of CRSI for providing the information in this article.

Selected for reader interest by the editors.