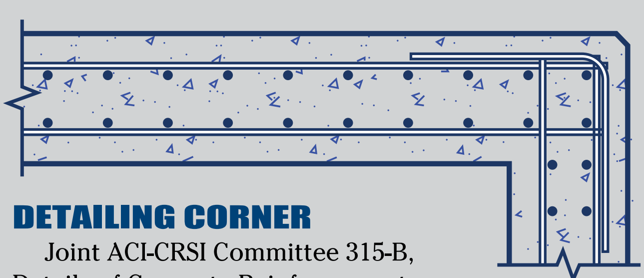
Concrete Cover at Rustications, Drip Grooves, and Formliners

Concrete cover is defined as the distance between the outermost surface of embedded reinforcement and the closest outer surface of the concrete. Section 7.7 of ACI 318-08[1] provides minimum concrete cover dimensions for reinforcement protection against weather effects, primarily due to moisture. Minimum concrete cover dimensions are also necessary for fire protection and providing a specified fire rating; these requirements are contained in Section 721 of the International Building Code.[2] Concrete cover has been shown to provide various structural benefits, including development length, but this issue is beyond the present discussion.

For flat or single-plane formwork, providing the proper cover is fairly straightforward considering the appropriate tolerances. The issue becomes more complex when considering architectural rustication, reveals, or drip grooves on the concrete surface. Architectural formliners further complicate the issue because of the multiple amplitudes likely present on the form surface. In all cases, the concrete cover to the embedded reinforcing steel must be properly considered on the concrete surface. This article examines these concrete cover issues as they affect some basic structural elements.



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."

WALLS

If reveals or rustications run along the entire length or height of the wall, there should not be a problem with the concrete cover over the reinforcing steel. It is assumed that the wall thickness does not include the rustication depth. A constant concrete cover is thus measured from the inside of the reveal, as shown in Fig. 1(a).

When the rustication influences only a specific region of the wall, there can be potential problems with the specified minimum concrete cover, as illustrated in Fig. 1(b). The designer should indicate or note on the design drawings the proper reinforcing steel details in the

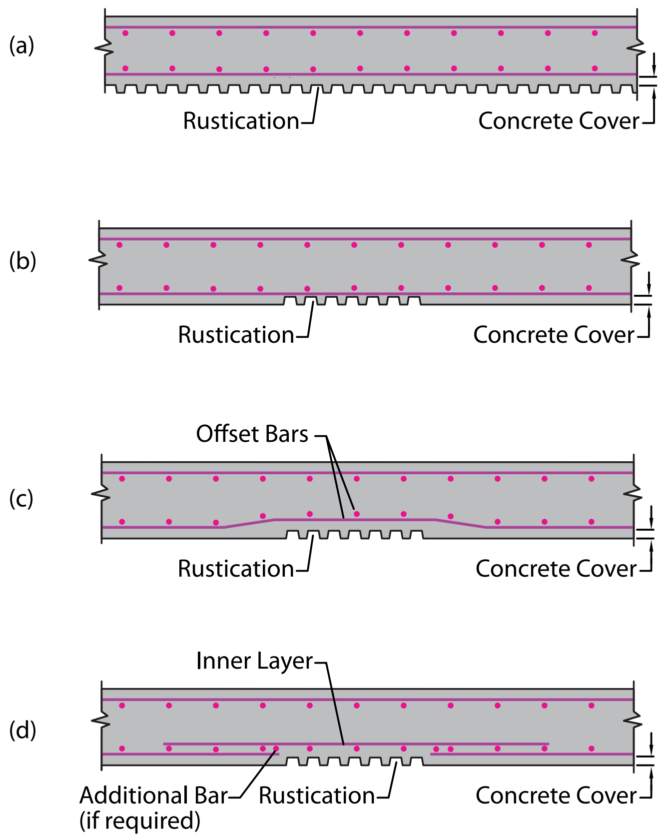


Fig. 1: Horizontal sections through walls with rustication: (a) rustication considered; (b) rustication not considered; (c) rustication considered using offset bars; and (d) rustication considered using inner layer of bars

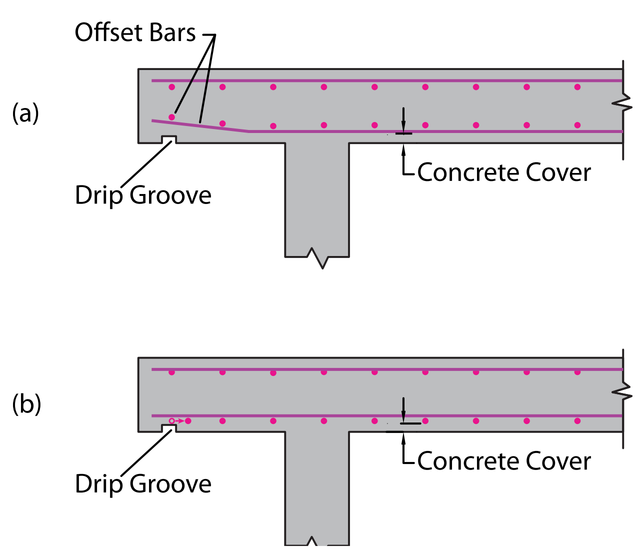


Fig. 2: Slab with drip groove at edge of soffit: (a) offset bars used to maintain cover at drip; and (b) relocated bars used to maintain cover at drip

rustication area with information on the minimum acceptable concrete cover. Two options typically exist for this situation:

- Run the bars straight through the rustication area, accepting the fact that less than the specified concrete cover will be provided in this area (Fig. 1(b)); or
- Offset the reinforcing bars in the localized area to maintain the specified concrete cover (Fig. 1(c)).

If the rustication area involves multiple small square or rectangular sections, the configuration of the reinforcing steel becomes more complex. If the reinforcement must be offset to provide the proper cover at each of these sections, then both the vertical and horizontal steel must be offset. This presents a significant detailing and placing challenge. If a rustication area is located near an opening, the issue becomes further complicated by the fact that the trim steel (additional bars) around the opening will have to be offset as well.

When a high percentage of the wall area has small rustication areas, a third option becomes more viable for the designer: treat the area as an opening and place an inner layer of reinforcing steel at the rustication with the proper clear cover. The inner reinforcing bar layer then extends a lap length beyond the area in all directions (Fig. 1(d)).

SLABS

While not as significant as the cover at wall rustications, the concrete cover at drip grooves or drip edges along the edge of a slab soffit should also be considered. These grooves are generally formed with a

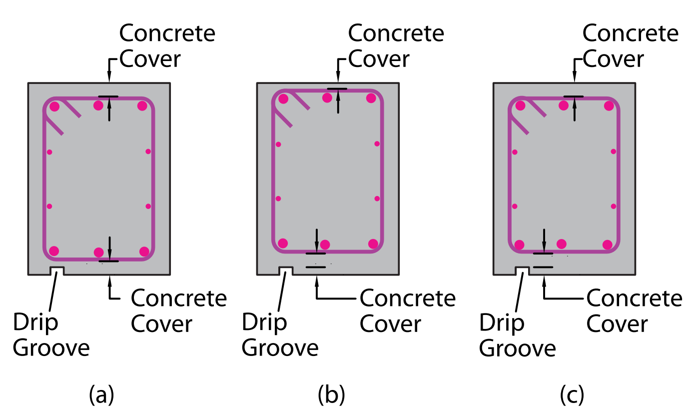


Fig. 3: Beam sections showing drip groove at bottom soffit: (a) inadequate cover at drip; (b) shifting reinforcing cage to maintain adequate cover at drip will cause top cover problems; and (c) to maintain adequate cover at all locations, stirrup sizes may need to be changed. The designer must consider the effects of shifting or changing the stirrups on beam capacity

piece of form chamfer strip or nominal 1 in. (25 mm) dimension lumber strip nailed to the formwork deck near the slab edge. Usually, the required concrete cover can be achieved by offsetting the bars crossing the groove (Fig. 2(a)). Alternatively, the transverse and longitudinal layers can perhaps be reversed and the affected reinforcing bar (open circle) can be moved away from the groove to achieve the proper concrete cover (Fig. 2(b)).

BEAMS

A drip groove or edge in a beam soffit oftentimes presents a concrete cover problem (Fig. 3(a)). Increasing the concrete cover in the beam soffit when the beam steel is placed isn't feasible. Raising the stirrups from the bottom to achieve the proper cover will decrease the concrete cover at the top (Fig. 3(b)). The only practical solution is to measure the concrete cover from the drip groove and detail the stirrups accordingly (Fig. 3(c)). This may impact the overall depth of the beam and should be accounted for in design.

FORMLINERS

Architectural formliners provide an inexpensive means of enhancing the visual characteristics of a concrete surface. When formliners are used, the specified concrete cover is generally measured from an interior working line, which represents the maximum

RFI ON WALL CORNER JOINTS

RFI 10-1: In the November 2009 Detailing Corner, I have concerns with two of the figures, Fig. 09-3.1(a) and (b) on p. 56. Unlike Fig. 09-3.1(c), (a) and (b) will provide inadequate anchorage for the compressive strut that will form across the diagonal in the corner under a large opening moment. My concern is the lack of support for the outward force component from the strut. The hooks need to be turned into the joint, not turned into the adjacent wall. The newly added diagonal bar helps, but not to anchor the strut.

Response: Point taken. The details shown in Fig. 09-3.1, in which a diagonal bar was added in the corner, were meant as improved details of those that originally appeared in Fig. 2 of the September 2009 Detailing Corner. As was noted in RFI 09-3, the details shown were intended for low levels of moment capacity in the wall and further detailing adjustments would be necessary for moderate or high levels of moment capacity.

To demonstrate the effect the reinforcement details have on the moment capacity of a corner, Fig. 10-1.1 presents various reinforcement details and their moment capacity ratings, which were calculated as the actual moment failure load divided by the calculated moment capacity.[1] As noted in the query, turning the hooks into the joint as well as adding the diagonal bar (Fig. 10-1.1(g)) results in a moment capacity that exceeds the corner's calculated capacity.

Reference

1. Nilsson, I.H.E., and Losberg, A., "Reinforced Concrete Corners and Joints Subjected to Bending Moment," *Journal of the Structural Division*, ASCE, V. 102, No. ST6, 1976, pp. 1229-1254.

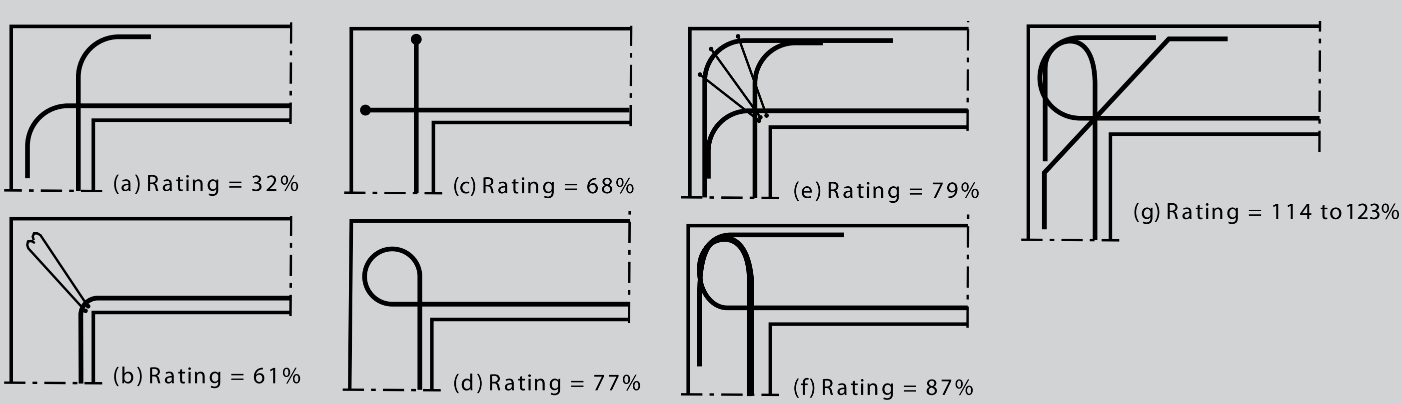


Fig. 10-1.1: Efficiency ratings (quotient of measured capacity and calculated capacity) for different reinforcement details (based on Reference 1)

Fig. 4: **Concrete wall cast using a formliner designed to simulate a masonry wall** *(photo courtesy of Gewalt Hamilton Associates)*

Fig. 5: View of formwork, formliner, and reinforcing showing side cover measured to the peak of the formliner

protrusion of the formliner into the form. The project drawings should be specific in the proper illustration of the concrete clear cover with respect to the formliner. The concrete used to create the textured surface is considered "extra" and may need to be accounted for in dead load computations, depending on the relief depth.

Figure 4 shows an example of a wall cast using a formliner that provides a random ashlar masonry pattern. The "masonry joints" are formed by ribs in the formliner. Because they have the largest amplitude of the features on the formliner, they set the interior working line of the wall. Figure 5 shows the reinforcing steel placement in the wall. For simplicity, straight lengths of vertical and horizontal wall bars were used. The wall thickness is based on the width from the near side to back side interior working lines, and the concrete cover is measured to the interior side of the working line.

DESIGN CONSIDERATIONS

It's important for the design engineer to clearly show rustications, reveals, and drip grooves on the design drawings. Details must show that members have sufficient thickness or depth to give the reinforcing steel the proper concrete cover but without compromising the design requirements of the member.

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. "International Building Code," International Code Council, Washington, DC, 2006, 664 pp.

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Selected for reader interest by the editors.