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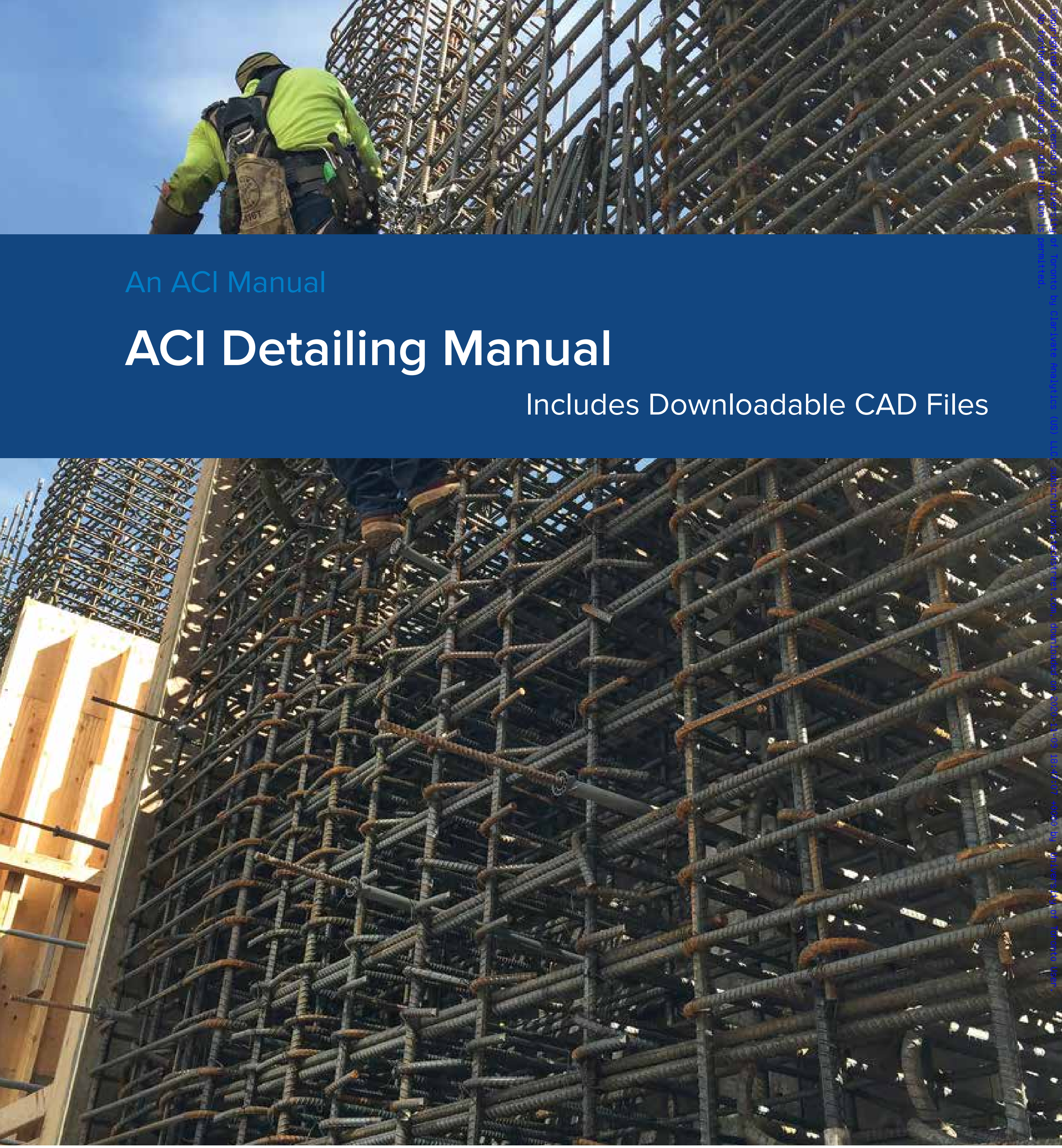

MNL-66(20)

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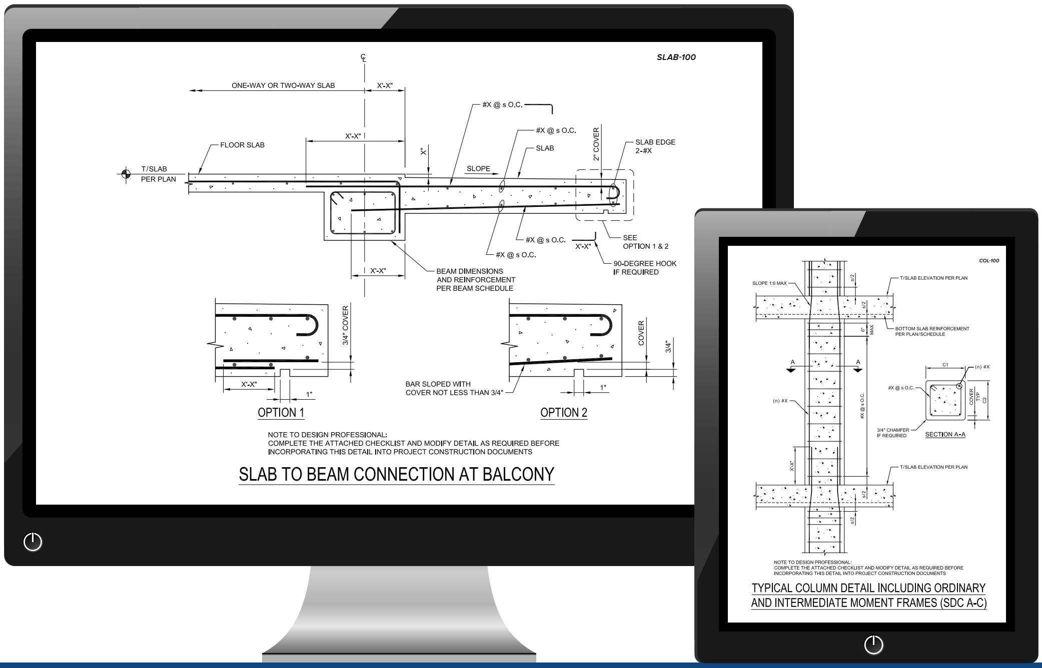

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MNL-66(20)

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ACI DETAILING MANUAL—MNL-66(20)

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ABOUT THIS BOOK

The 2020 edition of the *ACI Detailing Manual*, MNL-66, provides answers to many detailing questions asked by design engineers, architects, contractors, detailers, and engineering students. The Manual is divided in three sections: Section 1 includes a copy of ACI 315R-18, *Guide to Presenting Reinforcing Steel Design Details*; Section 2 includes individual details with corresponding checklists; and Section 3 includes a compilation of *Concrete International* articles chosen for their relevance to detailing reinforced concrete. Appendix A has tables to help the engineer in the detailing effort.

Section 1 guides designers of concrete structures in determining information and design details that are required to prepare reinforcing steel fabrication and placing drawings. The guide stresses the importance of this information to ensure that the reinforcing steel detailer effectively and accurately captures the intent of the designer, presenting it in a manner that is clear and unambiguous to the reinforcing steel fabricator and placer.

Section 2 illustrates methods for presenting necessary design information through over 100 individual details that provide examples of ways to communicate design information effectively and completely to the contractor. The details conform to "Building Code Requirements for Structural Concrete (ACI 318-19)" and were prepared with the assistance of a task group consisting of detailers, contractors, and practicing engineers. Each detail is placed on one page with dimensions and bar sizes left to be completed by the user. Alongside each detail, notes to the user are listed as a reminder of the main code requirements that need to be satisfied for that particular detail. This section is planned to be interactive with the engineering community. It is anticipated that engineers, architects, contractors, and detailers will not only submit comments to improve the details shown in this edition of the manual, but also submit other relevant details to be added to future editions at techinq@concrete.org.

Section 3 includes a collection of 37 articles published in *Concrete International* related to concrete detailing that were authored by detailers and practicing engineers. The articles identify constructability issues specific to reinforcing steel. Common problems found on engineering drawings are discussed along with solutions drawn from the experiences of knowledgeable practitioners in the industry. The article topics vary from describing the tolerance cloud to addressing constraints in reinforcing bar modeling to avoiding ambiguous callouts, among other topics. These solutions are not offered as official ACI-recommended practice.

Supporting reference data in Section 4 includes specific chapters on reinforcing bars, wires, bar supports, spirals, mathematical formulas and tables, and common symbols and abbreviations.

This guide is intended to provide examples and guidance for how licensed design professionals may satisfy the prescribed provisions of ACI 318-19, *Building Code Requirements for Structural Concrete*. It does not, however, purport to represent the only suitable way to satisfy the requirements for every project. Engineering judgment must be applied to the unique requirements of individual projects and the details should be modified accordingly before applying to a project.

ACKNOWLEDGMENTS

The development of MNL-66(20), "ACI Detailing Manual," is a must-have resource that provides answers to many detailing questions asked by design engineers, architects, contractors, detailers, and engineering students. The structural drawings conform to the "Building Code Requirements for Structural Concrete (ACI 318-19)."

ACI would like to thank the review group for this manual consisting of Chair Richard Birley, James Cornell, Jason Draper, John Hausfeld, Christopher Perry, and Tom Schaeffer. Their careful review and dedication to the project on top of all their other volunteer time made it possible to develop and revise this guide in a timely manner while maintaining the quality expected by the industry.

ACI would also like to thank Burns & McDonnell for providing examples of typical details that were used to develop the drawing in this detailing manual.

Khaled Nahlawi
Managing Editor

CONTENTS

SECTION 1

ACI 315R-18

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ACI 315R-18

Guide to Presenting Reinforcing Steel Design Details

Reported by Joint ACI-CRSI Committee 315

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*The Committee acknowledges P. Brienen, D. Fontenot, and C. Yokoyama for their contributions to this guide.

This document guides designers of concrete structures how to determine information and design details that are required to prepare reinforcing steel fabrication details and placing drawings. The guide stresses the importance of this information to ensure that the reinforcing steel detailer effectively and accurately captures the intent of the designer, presenting it in a manner that is clear and unambiguous to the reinforcing steel fabricator and placer. Recommendations are also provided concerning the review of placing drawings.

Keywords: concrete structures; design details; detailing; engineering drawings; fabrication details; placing drawings; reinforcement; reinforcing steel; tolerances.

CONTENTS

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ACI 315R-18 supersedes ACI 315-99 and was adopted and published January 2018.

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CHAPTER 1—INTRODUCTION AND SCOPE

1.1—Introduction

The purpose of this document is to guide the licensed design professional (LDP) in determining the information a reinforcing steel detailer requires to properly prepare reinforcing steel fabrication details and placing drawings. Guidance to the LDP is provided on how to present that information on their structural drawings so that the design intent is effectively and accurately conveyed.

The intent of this guide is to encourage clarity and consistency in reinforcing steel design details to help improve the quality and uniformity of steel reinforcement detailing, fabrication, and installation. It is intended to facilitate clear communication between LDPs, reinforcing steel detailers, fabricators, and placers by encouraging clear presentation of design details and information. Information presented is consistent with the requirements and recommendations of several ACI documents, including ACI 318, ACI 301, ACI 117, ACI 131.1R, and ACI 132R.

1.2—Scope

This guide provides general and specific information, as well as illustrative design details that are required for steel-reinforced concrete members such as slabs, beams, and columns. The importance of this information is emphasized to ensure that the reinforcing steel detailer effectively and accurately captures the intent of the LDP, and presents it in a manner that is clear and unambiguous to the reinforcing steel fabricator and placer. Recommendations are also provided concerning the review of placing drawings by the LDP.

CHAPTER 2—NOTATION AND DEFINITIONS

2.1—Notation

A_g = gross area of concrete section, in.^{2} (mm^2) where for a hollow section, A_g is the area of the concrete only and does not include the area of the void(s)

A_{st} = total area of nonprestressed longitudinal reinforcement, including bars or steel shapes and excluding prestressing reinforcement, in.^{2} (mm^2)

b = width of member, in. (mm)

d = distance from extreme compression fiber to centroid of tension reinforcement, in. (mm)

d_{agg} = nominal maximum size of coarse aggregate, in. (mm)

d_b = nominal diameter of bar or wire, in. (mm)

f_c' = specified compressive strength of concrete, psi (MPa)

f_y = specified yield strength for nonprestressed reinforcement, psi (MPa)

h = overall thickness, height, or depth of member, in. (mm)

ℓ_d = development length in tension of deformed bar, deformed wire, or plain and deformed welded wire reinforcement, in. (mm)

ℓ_{dh} = development length in tension of deformed bar or deformed wire with a standard hook, measured from outside end of hook, point of tangency, toward critical section, in. (mm)

ℓ_{ext} = straight extension at the end of a standard hook, in. (mm)

V_u = factored shear force

2.2—Definitions

ACI provides a comprehensive list of definitions through an online resource, ACI Concrete Terminology. The definitions provided herein complement that resource.

design details—drawings or other information presented by the licensed design professional (LDP) defining steel reinforcement sizes, locations, clearances, splices, geometry, points of termination, relationships, and tolerances.

detailer—person, firm, or corporation producing the reinforcing steel fabrication details and placing drawings based on the design drawings and design details for the structure.

detailing—the process of determining fabrication details based on design details.

fabrication details—dimensions and geometry of steel reinforcement determined for fabrication.

fabricator—person, firm, or corporation producing the reinforcing steel cut and bent to needed dimensions and geometry.

federated model—a building information model (BIM) that electronically links, but does not merge, single-discipline models together for analysis or presentation; the model databases remain distinct and are not combined into a single database.

placing drawings—detailed drawings that give the quantity, size, dimensions, spacing, locations, and other information required for reinforcement fabrication and installation.

CHAPTER 3—GENERAL CONSIDERATIONS

3.1—Building information modeling (BIM)

3.1.1 *Introduction to BIM*—Building information modeling is a three-dimensional process used to generate and manage digital models of buildings and other structures. This process is used by those who plan, design, and build structures, as well as those who manage these facilities. The process involves creating and maintaining intelligent models with attributes that represent characteristics of a facility and contain parametric data about the elements within the model. Many software packages exist that fall within the definition of BIM; each of these have distinct advantages to varying elements of the life cycle of a facility, from its design to construction through operation.

Although the focus of most BIM discussions center on the three-dimensional virtual model, the parametric data is of equal importance. The following is from the National BIM Standard-United States™ (NBIMS-US™ 2015):

> Building Information Model: Is the DIGITAL REPRESENTATION of physical and functional characteristics of a facility. As such it serves as a shared knowledge resource for information about a facility, forming a reliable basis for decisions during its life cycle from inception onwards.

In general, what makes BIM different than simple three-dimensional modeling is more information; not only is it a virtual mockup of a structure, but also a relational database of information.

A building information model is applied to the details of concrete reinforcement in the design and construction phases of a structure. In the design phase, BIM is often used by the design team to define the physical characteristics of the concrete to be reinforced by defining concrete edges in physical space, and reinforcement information using either data within the concrete elements or physical representations of the reinforcement. During the construction phase, concrete geometry is often further developed to the level required for construction, and reinforcement is defined to a level from which it can be fabricated and installed. The definition of the level of modeling, which is known as the Level of Development (LOD), is a key concept described as follows.

3.1.2 *Level of Development*—The content and reliability of a BIM is defined by an industry standard referred to as the Level of Development (LOD). The American Institute of Architects (AIA) and BIMForum have developed an LOD specification (2016) to standardize these definitions. The specification enables BIM stakeholders to specify and discuss with precision the content and reliability of models at different stages of the design and construction process. The LOD specification incorporates the AIA definition from the AIA G202™-2013 form and is organized in The Construction Specifications Institute (CSI) UniFormat™ (2010), which defines the important properties of model elements at various levels of development. This establishes a framework that allows model creators and users to establish reliable uses for the model. The intent of the specification is strictly to facilitate communication; it does not establish or prescribe what LOD is to be attained at any specific point in the project.

For example, in the construction phase, the concrete geometry is defined to a construction level of at least LOD 300 or 350, and the reinforcement is defined to LOD 350 to 400 to assure proper fabrication and placement (CSI UniFormat™ 2010). Many structural design models produced are not able to provide this level of detail for reinforcing steel.

3.1.3 *Benefits and challenges of BIM*—The technology of building construction and the preparation of documents for construction is rapidly evolving. All stakeholders should be aware of the potential benefits and wary of potential challenges in using new or evolving technology.

Licensed design professionals who are using BIM will, in most cases, be focused on developing models for the primary purpose of design rather than construction. Consequently, downstream users of design models should be wary that the information found in them might not be developed to the level required for their purposes.

The benefits of BIM accrue at all stages of a project to all stakeholders, including the owner, owner's representative, construction manager, contractors, subcontractors, material and equipment suppliers, and designers. The manner of BIM implementation can be tailored to the nature of the project, nature of the owner, delivery method, and delivery time available. Potential benefits include:

3.1.3.1 *Design and detailing*—

a) Better visualization, especially when dealing with complex structures

b) Improved coordination between trades through information sharing, which is one goal of a BIM process

c) Ability to rapidly compare alternatives

d) Improved communications and efficiency and reduced errors through:

1) Detecting and addressing issues earlier in the design process, thereby reducing the number of requests for information (RFIs) and issues in the field

2) Clearer communication of structural geometry and design intent from the LDP to the reinforcement detailer than what would be possible using traditional two-dimensional documents

3) Reinforcing details presented in three dimensions at a construction LOD

4) Better communication of reinforcement fabrication and placement information with downstream entities

3.1.3.2 *Construction*—Enhanced project visualization made possible by having full building models and related information readily available

a) More accurate material takeoffs, leading to less waste and reduced overall project costs

b) Improved project coordination, clash detection, and resolution achieved by combining three-dimensional models from various subcontractors into a single federated model

c) Validate the work sequence or progress with four-dimensional models created by the intelligent linking of individual three-dimensional components or assemblies with time- or schedule-related information

d) Increased change management so stakeholders better understand the impacts associated with them

3.1.3.3 *Operation*

a) Better 'as-built' documentation than conventional two-dimensional drawings, leading to easier remodels, rebuilds, and additions

b) Improved management of a building's life cycle achieved by using the three-dimensional model as a central database of all the building's systems and components

c) Enhanced tracking of building performance and maintenance needs

3.1.4 *IFC files and BIM file transfers*—Numerous BIM software packages exist that can define concrete geometry and data, detailing reinforcement, or both. Most BIM software is compatible with an open file format specification known as the Industry Foundation Classes (IFC) data models (ISO 16739:2013). This is an object-based file format that allows ease of interoperability between software platforms. Industry Foundation Classes files can be exported from, and imported into, most BIM software platforms, allowing model content and data created in different software to be viewed and used in other software.

In addition to IFC data file transfers, which can be brought directly into a building information model, there are many other electronic deliverable formats available for conveying model content to other stakeholders. Many programs share information-rich models securely, accurately, and in a relevant context that can be viewed on a variety of platforms—from desktop computers to hand-held tablets and smartphones. There are also various types of two- and three-dimensional PDF documents that can be used.

3.1.5 *State of the technology*—Building information modeling began in the late 1990s. One characteristic that makes BIM superior to past technologies is the ability to change and evolve with newly developing technologies that are providing an ever-increasing level of detail and volume of information. Building information modeling use varies with companies, industry segments, and regions, and is continually expanding. The introduction and development of technology for mobile access to data and the documentation of field conditions is shaping the development of BIM methods and capabilities for the future. A major focus for the evolution of BIM is improving the ability of different users applying different tools to readily use the database information. Although most BIM software packages are compatible with opening IFC format databases, each interprets the data differently, which leads to differences and errors when applying this method. The goal of improved access is not only intended for designer-to-designer transfer; there has also been much effort in developing processes for transferring data for downstream fabrication uses. Structural steel, pipe and duct, and reinforcing steel fabricators benefit from the ability to seamlessly use information from the building information model directly on the fabrication line of these elements.

Reinforcement placement in the field is being enhanced through technology in similar ways to others in the reinforcing market. Using devices such as tablets and smartphones makes access to BIM, fabrication information, placing drawings, three-dimensional PDFs, and a host of other electronic data available on the job site at the point of reinforcement placement. This easy access to information, which in many cases is bidirectional, is providing a real-time exchange of information that ensures the most up-to-date details are installed correctly, a better visual understanding, and more efficient tracking of work. From hand-held scanners to smart devices, field placement crews can also record important information in real-time by scanning a variety of data from fabrication tags and other identification markers to track receipt, installation, location, heat and mill cert information and production rates, as well as actual installation as-built conditions that can then be used for documentation, change management, coordination, and constructability reviews.

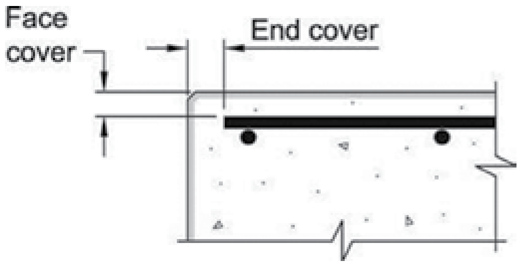


Fig. 3.2.2—Face cover and end cover for reinforcement.

3.2—Tolerance considerations

3.2.1 *Introduction and ACI 117*—ACI 301 requires that construction tolerances comply with ACI 117. ACI 117 provides tolerances for concrete construction, including tolerances for concrete forming, reinforcing bar fabrication, and placement. These tolerances, which can have an effect on cover, strength, constructability, and serviceability, are required to make concrete construction physically possible and economically practical. If more restrictive tolerances are required than those shown in ACI 117, they should be clearly indicated in the construction documents.

Note that while welded wire reinforcement (WWR) is not explicitly referenced in ACI 117, the fabrication tolerance information therein is normally applicable to WWR produced for concrete construction, and is enforced at the plant level accordingly. Fabrication of WWR styles is carried out in accordance with ASTM A1064/A1064M with due consideration for tolerances set forth in ACI 117. Refer to the Wire Reinforcement Institute manuals WWR-500-R-16 and WWR-600 for additional specifics.

In areas of potential reinforcement congestion, the LDP should consider combinations of tolerances— namely, reinforcing bar fabrication; reinforcing bar placement; clearance and congestion resulting from items such as couplers, headed bars, and other reinforcing bar accessories; and formwork. Combinations of tolerances can result in placement conflicts that are not readily resolved in the field. As an example, bars fabricated to the maximum positive (+) tolerance could create a conflict with required cover in some circumstances, or with an embedded element. The design/construction team should be aware of tolerances and work to identify and remove conflicts prior to construction.

3.2.2 *Concrete cover for reinforcement*—ACI 301 and ACI 318 define concrete cover requirements for reinforcement. Concrete cover as protection of reinforcement against weather and other effects is measured from the concrete surface to the outermost surface of the steel to which the cover requirement applies. ACI 117 defines tolerances for concrete cover (measured perpendicular to the concrete surface). There are two measurements for concrete cover, as shown in Fig. 3.2.2:

(1) Face cover – measured from the face or surface of a bar to the concrete surface

(2) End cover – measured from the end of a bar (straight or hooked) to the concrete surface

Cover values defined by ACI 301 and ACI 318 vary based on exposure conditions and the concrete element containing the reinforcement.

Where concrete cover is prescribed for a class of structural members, it is measured to the:

a) Outer edge of stirrups, ties, or spirals if transverse reinforcement encloses main reinforcement

b) Outermost layer of reinforcement if more than one layer is used without stirrups or ties

c) Metal end fitting or duct on post-tensioned prestressing steel

d) Outer edge of mechanical splices

e) Outermost part of the head on headed bars

The condition, "concrete surfaces exposed to earth or weather," in addition to temperature changes, refers to direct exposure to moisture changes. Slab or thin shell soffits are not usually considered directly exposed unless subject to alternate wetting and drying, including that due to condensation conditions or direct leakage from exposed top surface, run off, or similar effects.

3.2.3 *Spacing of reinforcement*—The spacing of reinforcement should comply with project drawings with some exceptions including one or more of the following:

(a) Field conditions

(b) Accumulating tolerances

(c) Coordination of concrete reinforcement

(d) Other embedded items

ACI 117 defines tolerances for the spacing of reinforcement.

The reinforcement spacing tolerance consists of an envelope with an absolute limitation on one side of the envelope determined by the limit on the reduction in distance between reinforcement. In addition, the allowable tolerance on spacing should not cause a reduction in the specified area of reinforcement used.

Designers are cautioned that selecting member sizes that exactly meet their design requirements might not allow for reinforcement placement tolerance. This can occur when laps or intersecting reinforcement elements take up extra space and, therefore, cannot accommodate the placement tolerance. Where reinforcement quantities and available space conflict with spacing requirements, the contractor and designer might consider bundling a portion of the reinforcement. Bundling of bars requires approval of the designer.

In the case of WWR, where reinforcement styles are prefabricated with electrical resistance welding, wire spacing and style squareness are also subject to tolerances prescribed in ASTM A1064/A1064M.

3.2.4 *Reinforcement placement*

3.2.4.1 *General information*—Just as there are tolerances in the fabrication of a bar or WWR style, there are also tolerances in the placement of reinforcement in a concrete member, creating potential placement tolerance clouds. Because LDPs and reinforcement detailers could overlook the impact of placement tolerances on constructability, a few examples are given herein.

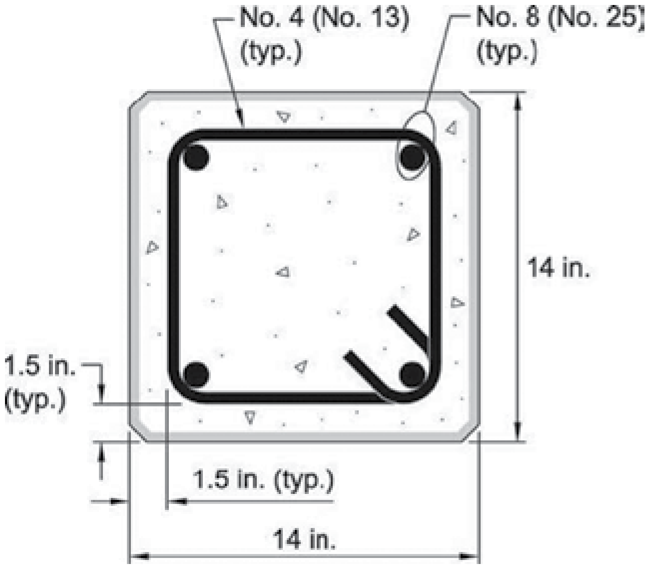


Fig. 3.2.4.2a—Column the designer defined. (Note: 1 in. = 25.4 mm.)

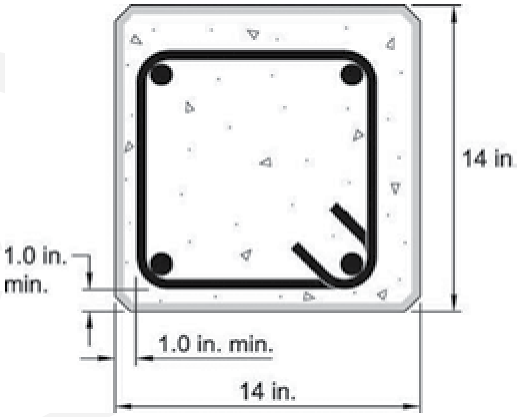


Fig. 3.2.4.2b—Column that could be placed within the specified tolerances. (Note: 1 in. = 25.4 mm.)

3.2.4.2 *Tolerance cloud*—The tolerances for reinforcement location are found in ACI 117. Cover tolerances vary from 1/4 in. (6 mm) for member sizes of 4 in. (100 mm) or less to 1 in. (25 mm) when member size is over 2 ft (0.6 m). The maximum reduction in cover is limited to one-third of the specified cover. In slabs and walls, the spacing tolerance is 3 in. (76 mm) for reinforcement other than stirrups and ties. For example, consider the simple 14 x 14 in. (355 x 355 mm) concrete column shown in Fig. 3.2.4.2a.

The column is reinforced with four No. 8 (No. 25) bars enclosed within No. 4 (No. 13) ties. Normally, concrete cover to the ties of this column would be 1-1/2 in. (38 mm). The cover tolerance is ±1/2 in. (13 mm). If the reinforcement was placed to the minimum tolerance in two directions, the column could appear as in Fig. 3.2.4.2b.

However, the reinforcement could be placed to minimum tolerance in any of the four directions. Thus, the placement tolerance clouds would appear as in Fig. 3.2.4.2c. This could be a significantly different image than the precise image envisioned at the outset.

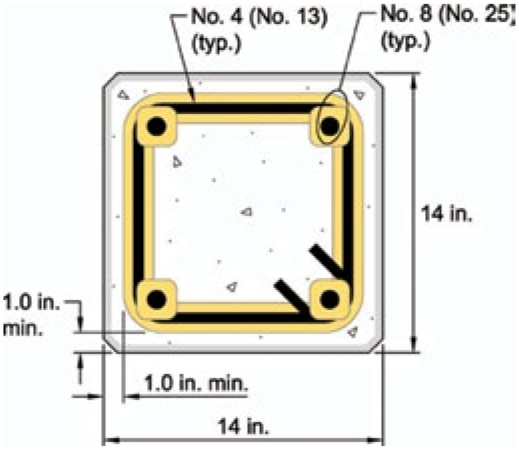


Fig. 3.2.4.2c—Column with placement tolerance clouds (1 in. = 25.4 mm).

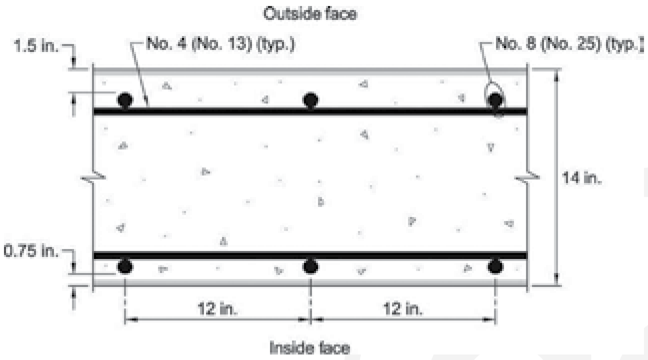


Fig. 3.2.4.2d—Wall the designer defined. (Note: 1 in. = 25.4 mm).

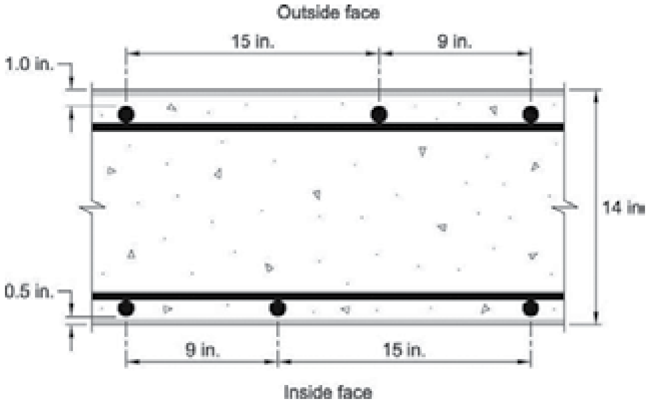


Fig. 3.2.4.2e—Wall that could be placed within the specified tolerances. (Note: 1 in. = 25.4 mm.)

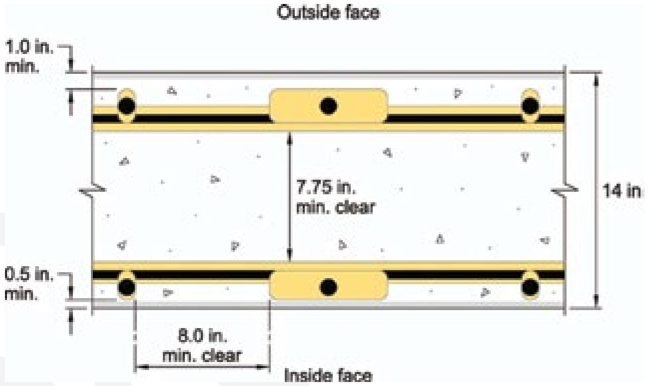


Fig. 3.2.4.2f—Wall with placement tolerance clouds. (Note: 1 in. = 25.4 mm.)

For a second example, consider the case of a simple 14 in. (355 mm)-thick wall reinforced with No. 8 (No. 25) vertical bars at 12 in. (300 mm) on center each face, and No. 4 (No. 13) horizontal bars at 12 in. (300 mm) on center each face (Fig. 3.2.4.2d).

The outside face cover is 1-1/2 in. (38 mm) and inside face cover is 3/4 in. (19 mm). The cover tolerance for the bars on the outside face is ±1/2 in. (13 mm). For the inside face cover, the maximum cover reduction is limited to one-third of the specified cover, resulting in a cover tolerance of +1/2 or –1/4 in. (+13 or – 6.5 mm). Thus, the outside face cover could be as little as 1 in. (25 mm) and the inside face cover as little as 1/2 in. (13 mm) (Fig. 3.2.4.2e).

Consider that any one of the vertical and horizontal bars can be located as far as 3 in. (76 mm) either way from its designated location; the tolerance cloud would appear as in Fig 3.2.4.2f.

3.2.4.3 *Design considerations*—Like the fabrication tolerance cloud of a single bar, the placement cloud of a group of placed bars presents a different image than the one probably envisioned by the designer or reinforcement detailer. If placement tolerances are factored into the design, they would realize the available space expected, which is to pass beam bars through a column or to place a vertical embed in a wall, might not be what is actually available, especially if the beam reinforcement and embed considered also have fabrication and placement tolerances of their own. Awareness of placement tolerance clouds can lead to design options that avoid tolerance issues.

3.2.5 *Reinforcing bar fabrication*

3.2.5.1 *General information*—The Concrete Reinforcing Steel Institute (CRSI) *Manual of Standard Practice* (2017) list properties of reinforcing bars. Practical limitations of equipment and production efficiency have led to the establishment of certain fabrication tolerances that can be met with standard shop equipment. These standard tolerances are shown in ACI 117 and the CRSI *Manual of Standard Practice* (2017) for both straight and bent bars. Where more restrictive tolerances are required than those shown in the referenced figures, they should be clearly indicated in the contract documents.

3.2.5.2 *Restrictive tolerances*—Tolerances more restrictive than those in ACI 117 should be used sparingly. If more restrictive tolerances are required, this is generally characterized as special bending by the reinforcing bar fabricator and requires special arrangements in the production shops. These special arrangements include, but are not limited to: additional equipment, modifications to existing equipment, additional staff, and inspection devices. Special bending is generally more time-consuming than normal bending, can be subject to additional costs, and could create delays in material deliveries to the job site.

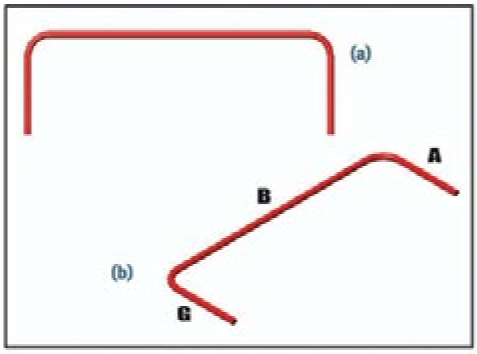


Fig. 3.2.5.3a: Standard (theoretical) hooked bar with Sides A, B, and G: (a) plan view, and (b) isometric view

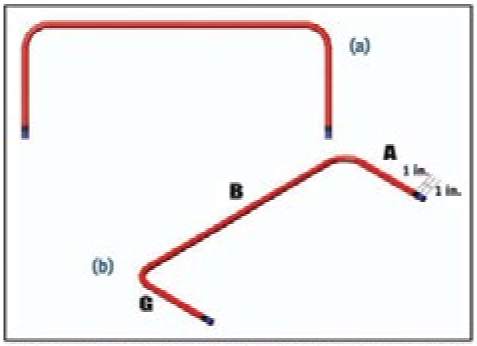


Fig. 3.2.5.3b: Hooked bar with ±1 in. tolerance envelope on Sides A and G

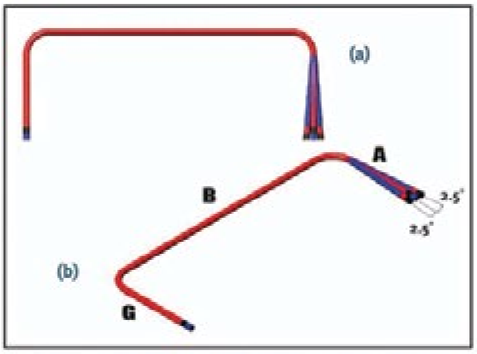


Fig. 3.2.5.3c: Hooked bar with ±1 in. tolerance envelope on Sides A and G and ±2.5 degrees in-plane angular tolerance envelope at Side A

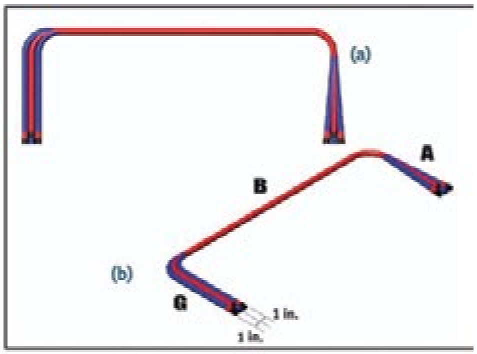


Fig. 3.2.5.3d: Hooked bar with ±1 in. tolerance envelope on Sides A and G, ±2.5 degrees in-plane angular tolerance envelope at Side A, and ±1 in. tolerance envelope on Side B

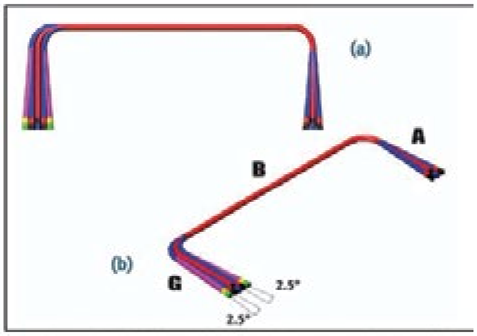


Fig. 3.2.5.3e: Hooked bar with ±1 in. tolerance envelope on Sides A, B, and G and ±2.5 degrees in-plane angular tolerance envelope at Sides A and G

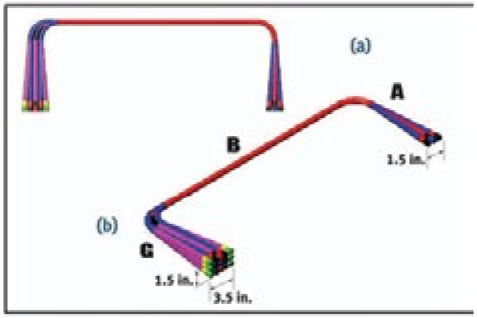


Fig. 3.2.5.3f: Hooked bar with ±1 in. tolerance envelope on Sides A, B, and G; ±2.5 degrees in-plane angular tolerance envelope at Sides A and G; and ±2.5 degrees out-of-plane angular tolerance envelope at Side G

Fig. 3.2.5.3—Hooked reinforcing bar tolerances (Birley 2005). (Note: 1 in. = 25.4 mm.)

3.2.5.3 *Fabrication tolerance clouds*—Licensed design professionals should be aware of the tolerance cloud that exists for fabricated reinforcing bar. As a simple example, consider the fabrication tolerances for a simple reinforcing bar with 90-degree bends at each end as given by Birley (2005) (Fig. 3.2.5.3(a)). For the purposes of this example, assume the bar is a No. 8 (No. 25) and Side A is anchored in the (idealized) plane ABG. For this bar size, the standard hook is 16 in. (400 mm) long, and the linear and angular tolerances are ±1 in. (±25 mm) and ±2.5 degrees, respectively.

Next, examine the potential effects of these tolerances (Fig. 3.2.5.3). First, note that Sides A and G can be as short as 15 in. (380 mm) (red to black zone interface), or as long as 17 in. (430 mm) (end of blue zone), and still be within allowable tolerances (Fig. 3.2.5.3(b)).

Because it is assumed Side A is anchored in ABG, there is no need to consider out-of-plane angular deviation for Side A. However, in-plane angular deviation will need to be considered. When this angular deviation of ±2.5 degrees is added to Side A, the tolerance envelope (cloud) will appear as shown in Fig. 3.2.5.3(c). Note that to simplify the illustrations, the effects of angular tolerances are shown as one-bar-diameter deviations in the position of the ends of the 16 in. (400 mm) hooks. Actual deviations will be about 70 percent of a bar diameter.

Next, add the dimensional tolerance of ±1 in. (±25 mm) for Side B as given in (Fig. 3.2.5.3(d)) and the in-plane angular deviation of ±2.5 degrees to Side G in (Fig. 3.2.5.3(e)). Finally, add the out-of-plane angular deviation of ±2.5 degrees to Side G. The resulting tolerance cloud is as shown in Fig. 3.2.5.3(f).

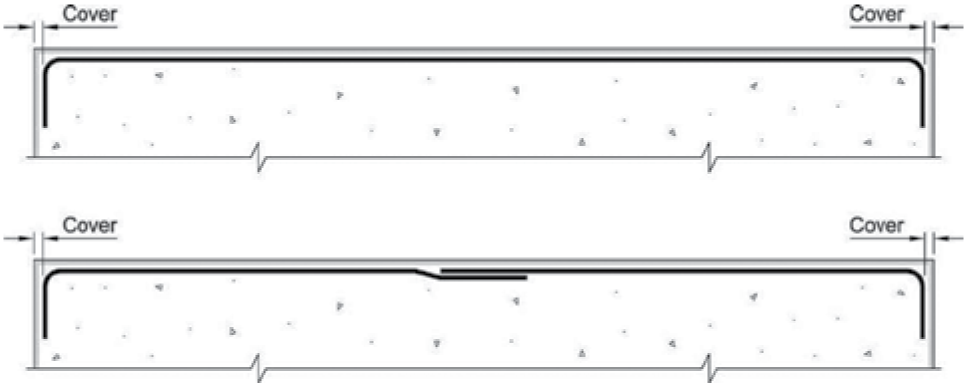


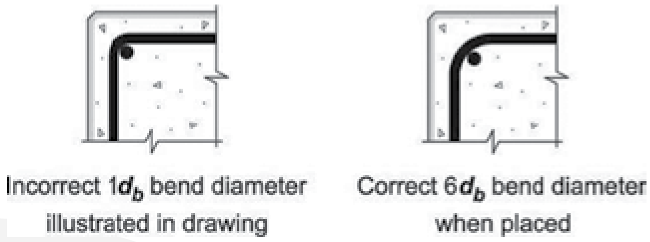
Fig. 3.2.5.4a—Reducing tolerance problems by replacing single bar with two lapped bars. Note that the lap splice shown offset is for clarity only.

3.2.5.4 *Design considerations*—The fabricated bar arriving at the construction site can be different from the bar the LDP or reinforcing bar detailer expected. Keeping this in mind during design could significantly reduce constructability problems. For instance, if our example bar was replaced with two hooked bars lapped in the middle (Fig. 3.2.5.4a), the only tolerance that might introduce problems would be in-plane angular deviation.

Because both hooks could be rotated, there would be no out-of-plane deviations. Further, because the lap length could be adjusted slightly in the field, there would be little chance of problems with the length of Side B.

Consideration of tolerances becomes even more of an issue when two or more bars are being assembled together in a structure. In this case, work with the accumulation of tolerances.

ACI 318-14 Section 25.3 restricts the minimum inside bend diameter of standard hook geometry for deformed bars in tension and the minimum inside bend diameters and standard hook geometry of stirrups, ties, and hoops. Primary factors affecting the minimum bend diameter are feasibility of bending without breakage and avoidance of crushing the concrete inside the bend. ACI 117 tolerance on these minimum inside bend diameters is –0 in. (–0 mm). Thus, bars cannot be requested, or expected, to be bent to a tighter diameter to solve a fit-up or congestion problem. Furthermore, there is not a + tolerance for minimum bend diameter, and the bend diameter can be larger than the minimum due spring-back and other factors. Design drawings sometimes illustrate hooks wrapping tightly around another bar with assumed bar positions based on the sum of the required cover, diameter of one bar, and half diameter of the other bar. A comparison of that incorrect assumption to the reality with a 6d_b minimum bend diameter is shown in Fig. 3.2.5.4b, and for larger bars, the minimum bend diameter could be 8d_b or 10d_b.


Incorrect 1d_b bend diameter illustrated in drawing

Correct 6d_b bend diameter when placed

Fig. 3.2.5.4b—Comparison of minimum bend diameter position effect for a No. 7 (No. 22) bar.

3.2.6 *Forming tolerances*

3.2.6.1 *General information*—The last two sections discussed tolerance clouds associated with fabrication and placement of reinforcing bars. While every builder strives to cast concrete to the precise dimensions indicated by the designer, reasonable constraints of time, technology, and economy make this impractical. Therefore, it is important for designers to understand the forming tolerances associated with concrete construction.

3.2.6.2 *Forming tolerance clouds*—Tolerances for forming concrete are found in ACI 117. The tolerances for cross-sectional dimensions of cast-in-place members vary with the overall dimension. Using the example from Section 3.2.4.2 of a 14 x 14 in. (355 x 355 mm) column, the tolerance is +1/2 in. or –3/8 in. (+13 mm or –10 mm). Ignoring vertical alignment, this produces the forming tolerance cloud shown in Fig. 3.2.6.2a, with a column having acceptable dimensions as large as 14-1/2 x 14-1/2 in. (368 x 368 mm) or as small as 13-5/8 x 13-5/8 in. (346 x 346 mm).

While it is highly unlikely that these small variations would create any constructability or design concerns with everything else being perfect, a different scenario arises when they are considered in conjunction with other possible tolerances.

With 1-1/2 in. (38 mm) cover, the design width for the column ties is 11 in. (280 mm), and the tolerance is ±1/2 in. (19 mm). Combining the maximum acceptable tie dimensions with the minimum acceptable column dimensions produces the configuration shown in Fig. 3.2.6.2b. With the reinforcing cage centered, the cover is reduced from the design value of 1-1/2 in. to 1-1/16 in. (38 mm to 27 mm) on all four sides. Recalling that the placement tolerances allow the cover to decrease to 1 in. (25 mm) minimum, the cage should be placed within ±1/16 in. (1.6 mm) of the center of the column in both directions if it is to meet tolerance requirements. Considering the straightness of the bars and forms, this could be difficult for the contractor.

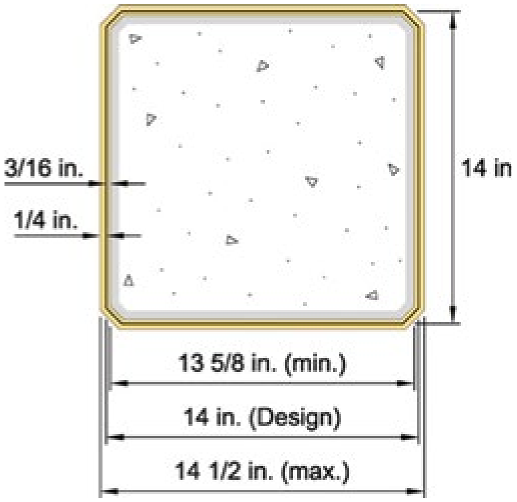


Fig. 3.2.6.2a—Forming tolerance cloud for the column. (Note: 1 in. = 25.4 mm.)

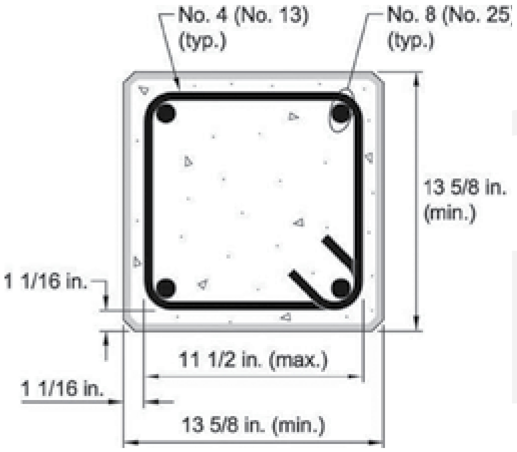


Fig. 3.2.6.2b—Combining the maximum acceptable tie dimensions with the minimum acceptable column dimensions effectively limits placing tolerances to ±1/16 in. (±2 mm). (Note: 1 in. = 25.4 mm.)

For the example of a 14 in. (355 mm)-thick wall that was discussed in previous sections, the situation is somewhat different because there are no tie tolerances to contend with. However, as seen in the following example, other issues arise that should be dealt with. The forming tolerance for the wall thickness allows the wall to be between 14-1/2 and 13-5/8 in. (368 and 346 mm) thick, as shown in Fig. 3.2.6.2c.

Reinforcement placement tolerances allow the 1-1/2 in. (38 mm) design cover on the outside face to be between 1 and 2 in. (25 and 50 mm) and the 3/4 in. (19 mm) design cover on the inside face to be between 1/2 and 1-1/4 in. (13 and 32 mm). The minimum wall thickness combined with the maximum cover on the outside face reinforcing is shown in Fig. 3.2.6.2d.

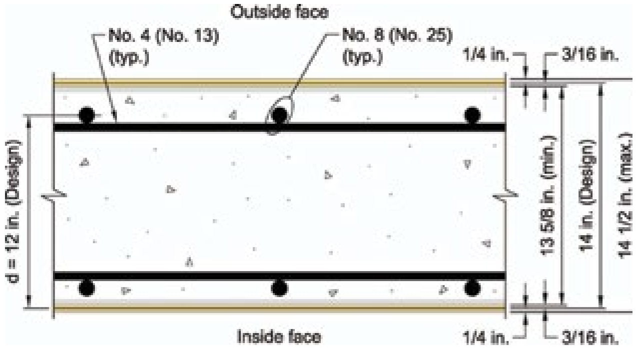


Fig. 3.2.6.2c—Forming tolerance cloud for the wall. (Note: 1 in. = 25.4 mm.)

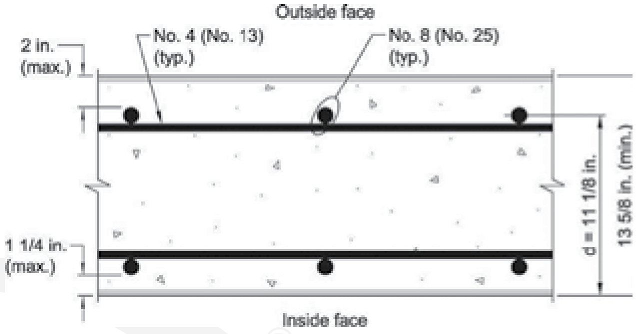


Fig. 3.2.6.2d—Minimum acceptable wall thickness and maximum acceptable cover combine to produce an effective depth for outside face vertical bars violating ACI 318 tolerances (1 in. = 25.4 mm).

In this case, the original effective depth of 12 in. (250 mm) for the vertical No. 8 (No. 25) bars on the outside face has decreased to only 11-1/8 in. (282 mm). Assuming 4000 psi (25.6 MPa) concrete and Grade 60 reinforcement, this reduction in effective depth would result in a decrease in nominal moment capacity from the original 45.1 kip·ft/ft (200 kNm/m) to 41.6 kip·ft/ft (185 kNm/m)—a 7.7 percent reduction due to forming and placement tolerances alone. The effect on moment strength would be even more drastic for thinner walls. To guard against this, Section 26.6.2.1(a) of ACI 318-14 places a tolerance on effective depth *d* of ±3/8 in. (10 mm) for $d \leq 8$ in. (200 mm) and ±1/2 in. (±13 mm) for $\underline{d} > 8$ in. (200 mm). These tolerances would produce a 4.4 percent reduction in nominal moment strength for the example wall considered herein; however, designers should realize that effective depth is not checked in the field. Reinforcement is placed and tolerances checked relative to the formwork surfaces.

3.2.7 *Confined reinforcing bars*—Confined reinforcing bars add one more level of complexity to the tolerance issues described in previous sections. In the context of detailing and placing reinforcing steel, a confined bar is one that is restricted by face cover requirements at both ends. The best example of a confined reinforcing bar is a bar with hooks at each end, as would be seen in an elevated beam as shown in Fig. 3.2.7a.

On the surface, this does not seem to be significant, other than the tolerance issues previously discussed. However, when considering that in most cases there is adjacent reinforcement for a beam, column, or wall, and that this double-hooked bar needs to fit within, the situation becomes much more complicated as shown in Fig. 3.2.7b.

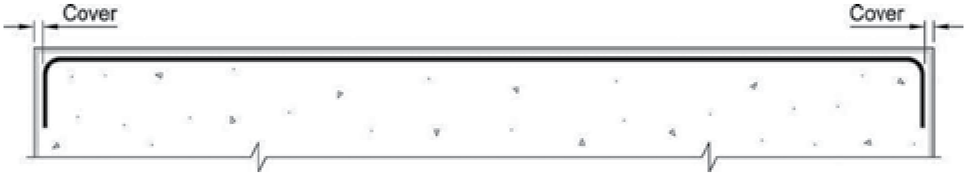
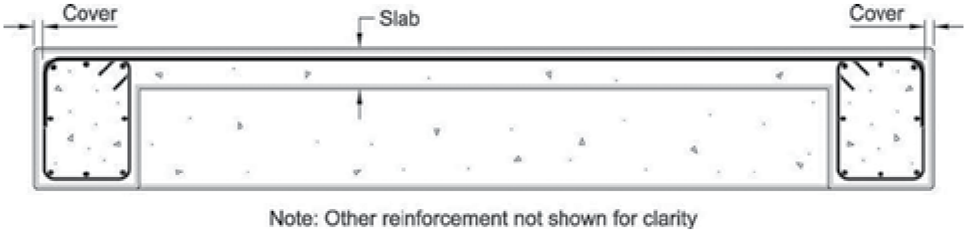
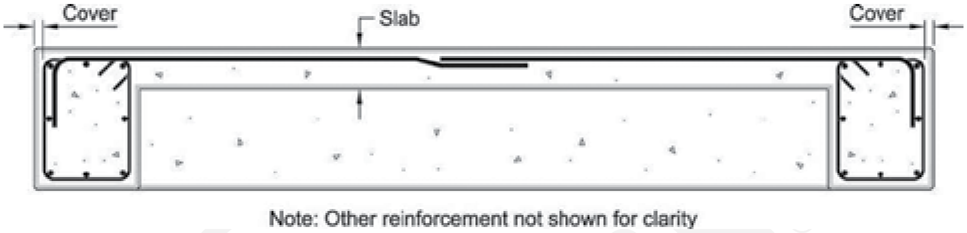


Fig. 3.2.7a—Single bar with hook at both ends.



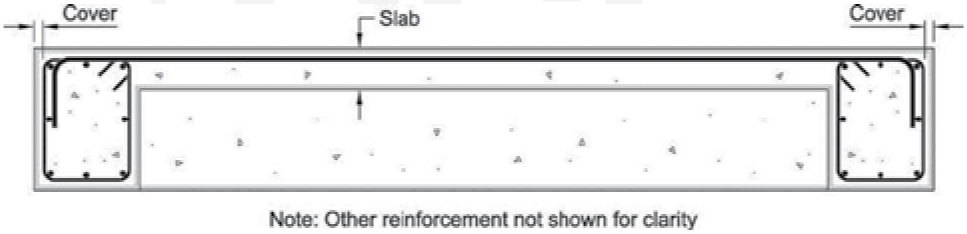
Note: Other reinforcement not shown for clarity

Fig. 3.2.7b—Single bar with hook at both ends and intersecting reinforcement.



Note: Other reinforcement not shown for clarity

Fig. 3.2.7c—Substitution of two hooked bars with lap splice (lap splice shown offset for clarity only).



Note: Other reinforcement not shown for clarity

Fig. 3.2.7d—Single bar with hook at both ends placed within beam cages.

The designer needs to consider that a bar with hooks at each end creates a situation where the bar is extremely restricted and should be exactly right; otherwise, the bar placer may not be able to place it. The reality is worse if the reinforcing bar detailer details the double hooked bars as shown in the design drawings with the correct concrete cover; it will almost never fit during field installation.

Because there is no flexibility with this bar, if it does not fit, it will most likely need to be replaced, causing delays on the job site. There are two options for addressing this situation. The first and most preferred is to allow the use of a lap splice, as shown in Fig. 3.2.7c. This gives the bar placer the flexibility to place the bars within the beam while avoiding conflicts with the adjacent steel.

If a lap splice is not permissible, a second option is for the designer to increase the end covers of the bar and place the hooks within the adjacent steel similar to Fig. 3.2.7c, as shown in Fig. 3.2.7d.

This situation needs to be addressed by the reinforcing bar detailer and shown in one of these two ways on the placing drawings. Notating this practice on the design drawings will provide clear direction to the detailer and bar placer, and avoid confusion during the detailing process and installation in the field.

These scenarios are commonly seen as shown in the following examples. In Fig. 3.2.7e, the left illustration shows the end of a confined bar where no adjacent steel is present; the right illustration shows the end of a confined bar with adjacent steel that should be accounted for in the design, detailing, and installation processes.

Figure 3.2.7f shows situations where the end position of a confined bar (in the last lift of a column or wall) with adjacent slab steel should be accounted for in the design, detailing, and installation processes.

3.2.8 *Accumulated (combined) tolerances*—The effects of tolerances on cover, strength, constructability, and serviceability of the structure should be considered by

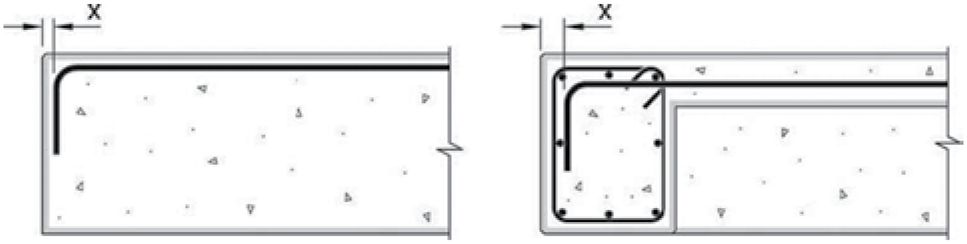


Fig. 3.2.7e—*Confined hooked bars in slabs and beams.*

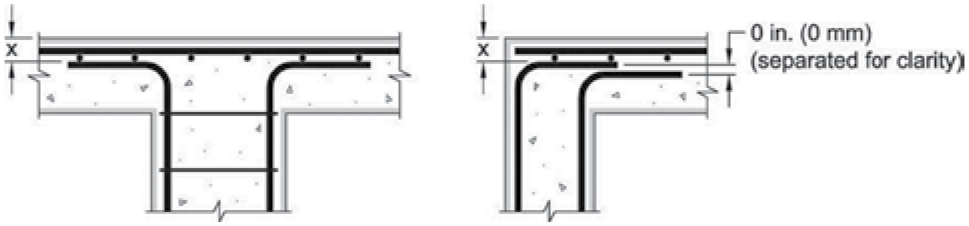


Fig. 3.2.7f—*Confined hooked bars in columns and walls.*

the LDP. Casting of concrete always involves the fabrication, placement, and formation of tolerance clouds. While these instances are not encountered every day, they occur frequently enough to create constructability problems. Any combination of tolerances as discussed in this section that are working against each other has the potential to create a constructability concern that often is difficult to reconcile, especially if it involves two different trades, each within their own acceptable tolerances. The designer should always assess the risk of this kind of problem arising in critical areas of the structure and consider options that mitigate or eliminate the possible constructability problem.

3.3—General cautions

3.3.1 *Revisions of drawings*—All revisions to drawings should be clouded. Be as specific as possible when putting a cloud on a drawing. Place a cloud around each revision, rather than a large cloud around several revisions. Remove all previous clouds from a drawing before initiating a new revision. Clearly annotate the revision on the revision list at the side of the drawing. It is good practice to identify revisions on pre-IFC drawings with letters, for example "Rev A, B, C," and on post-IFC drawings with numbers, for example, "Rev 1, 2, 3."

3.3.2 *Dimensioning*—Dimensioning of splice lengths should be clear and unambiguous so that the detailer and reviewer arrive at the same interpretation of the intent. Showing the anchorage and splice lengths on the drawing and sketches is the most certain way to convey intent. However, a well-prepared table of anchorage and splice lengths can work well. The table should include only the strengths of concrete and grades of reinforcement being used on the project and show development and splice lengths for bars in compression and bars in tension. For bars in tension, it should show development and splice lengths for top bars and other bars. The tables should be complete enough that the detailer and reviewer do not have to make calculations to arrive at the proper dimension. A brief sentence defining what constitutes a top bar is also good additional information.

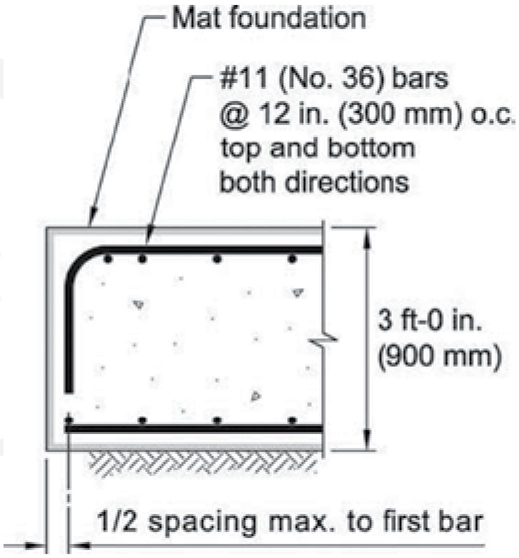


Fig. 3.3.2—*Effect of hooked bar confinement on first and last bars.*

Normally, the location of first and last reinforcing elements follows the general convention of one-half space from the face of a support for slab reinforcement or beam ties and one-half space from the top of a footing or slab for column ties or wall horizontals. Dimensioning the location of first and last reinforcing elements is not necessary in these situations unless there is a special situation that requires a nonconventional location. In such cases, dimensioning of the location should be clearly indicated.

First and last bars confined by transverse reinforcing elements with hooks at each end present a unique situation—for example, hooked top bars in a spread footing (Fig. 3.3.2). To maintain proper vertical elevation, the first and last bar in the upper layer of the mat should start at the beginning of the radius of the bend, not at the specified clearance from the concrete face. In such a case, one could question if the LDP intends that spacing be from the center lines of the first and last bars or from clearance-to-clearance. In this situation, it would be better for the LDP to give a quantity of reinforcing elements or area of steel required rather than spacing of the bars.

3.3.3 *Field cutting of bars*—Methods for field cutting any reinforcing steel, other than saw cutting, should be approved by the LDP. If the location is confined, the only practical alternative is to flame-cut the reinforcement. Bar placers are trained in the use of a cutting torch and can make the cut without any deleterious effect on the steel material. ACI 301 prohibits flame cutting of epoxy-coated bars. If the LDP has some compelling reason against flame-cutting uncoated reinforcement, this should be stated clearly in the general notes. In the absence of such an instruction, the bar placer will assume that flame-cutting uncoated reinforcement is permitted.

3.3.4 *Field bending of bars*—Field bending of embedded reinforcement may occasionally be required due to incorrect fabrication or placing, or due to a design change that requires the reinforcement to be reconfigured. ACI 301 specifies requirements for field bending. Small bars can usually be bent cold, especially if it is their first bend; that is, a straight wall vertical bar being bent into a slab. Large bars require preheating. Straightening and rebending of previously bent reinforcement should be approached cautiously. With caution, and if the bend radius is sufficiently large, the bars should not be affected. Other more extreme situations may require that the LDP set parameters for the process and ensure that the operation is supervised and executed by qualified personnel, subject to on-site inspector review.

3.3.5 *Mechanical connectors*—Mechanical connectors require similar considerations to those for splices. The LDP should indicate on the drawing where they are to be used. Specific limitations should be listed such as spacing, stagger, and clearance. The type of connector should be listed along with the manufacturer if this is critical.

3.3.6 *Mixing grades of steel on a project*—Frequently a project will require more than one grade of steel or more than one kind of coating. The LDP should be specific about where the various grades or coatings are to be used. This information can be given in the general notes and on the drawings to avoid any ambiguity about intent. Mixing grades or coatings in a single member should be avoided if possible. For example, do not call for coated top reinforcement in a beam while the remainder of the reinforcement is uncoated bar.

3.4—Drawing types and purposes

Design drawings for concrete structures are developed by LDPs. Those documents render the design and establish the design predicates for the construction. They include, at a minimum, building code required information for review by the pertinent code authority.

Design drawings are also contract documents. These form the contractual basis between the general contractor and owner. They should graphically show the scope, extent, and character of the construction work.

Placing drawings for reinforcement (and shop drawings for other trades) include graphics and schedules, and are specifically prepared by the contractor to illustrate specific portions of the construction work. These drawings, whether approved or not, do not become contact documents or design plans.

The normal process is for the designer to render the design and for the contractor (and subcontractors) to prepare trade-specific drawings extracted from the design plans that define the particular work. Usually the trade-specific drawings are submitted to the designer of record for review to confirm that contractor's interpretation of the design intent is correct.

Field construction is then conducted from the approved trade-specific drawings in conformance with the contract documents.

CHAPTER 4—STRUCTURAL DRAWINGS

4.1—Scope

This chapter describes information typically necessary to the structural design drawings, so the scope of the construction based on the design plans can be established. Normally, engineering offices develop an office standard suitable to their practice area for the presentation of design information. This guide, as an example, presents the project sheet order found in the United States National CAD Standard® (NCS-V6), as outlined in 4.3.

4.2—General

Structural drawings are prepared by a licensed design professional (LDP). The drawings, along with the project specifications, form the bulk of the contract documents. Structural drawings should contain an adequate set of notes, instructions, and information necessary to permit the reinforcing steel detailer to produce reinforcing steel placing drawings. Each sheet should have a title block, production data, and a drawing area as shown in Fig. 4.2.

The drawing area, which is the largest portion of the sheet, is where technical information is presented. Examples of technical information are the overall framing plan, sections, and details needed to illustrate information at specific areas, and additional notes as required.

The production data area is located in the left margin of the sheet and includes information such as the computer-aided design (CAD) filename and path to the file, default settings, printer/plotter commands, date and time of plot, overlay drafting control data, and reference files.

The title block area, which is located to the right side of the sheet, usually includes the designer's name, address, and logo; basic information about the project, including location of the work site, owner, and project name; an information block regarding issue type of this sheet, such as addendum, design development, bidding, and bulletin; a sheet responsibility block that indicates the project manager, engineer, draftsman, and reviewer of the information on the drawing; a sheet title block; and a sheet numbering block. The title block also contains space for a disclaimer, if it is a prelimi-

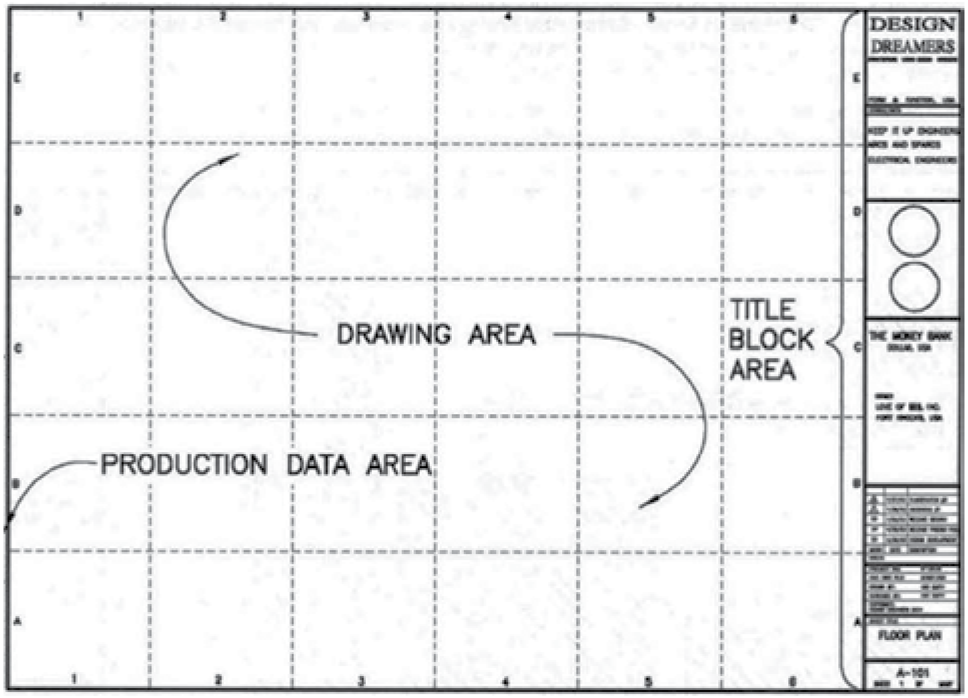


Fig. 4.2—United States National CAD Standard® (NCS-V6) overall sheet layout.

nary set of drawings, or a PE seal for the construction or permit set.

4.3—Order of sheets

The order of drawings shown in the United States National CAD Standard® (NCS-V6) is as listed in Table 4.3.

If more than one sheet is required within the listed order, then decimal sheet numbers are used, such as 5.0, 5.1, 5.2, 5.3. Often, the structural drawing order will be coordinated with the sheet order used by the other technical disciplines.

Table 4.3—NCS-V6 drawing sheet numbering

Sheet number	Sheet title	Information included
0	General notes	Symbols legend, general notes
1	Plans	Horizontal views of the project
2	Elevations	Vertical views
3	Sections	Sectional views, wall sections
4	Large-scale views	Plans, elevations, stair sections, or sections that are not details
5	Details	
6	Schedules and diagrams	
7	User defined	For types that do not fall in other categories, including typical detail sheets
8	User defined	For types that do not fall in other categories
9	Three-dimensional representations	Isometrics, perspectives, photographs

4.4—General notes sheets

A general notes sheet presents project design loads, the codes and standards that are the basis of design, material and product requirements, and construction directions. General notes can be the entire project structural specifications, act as an extension of the project structural specifications, or simply duplicate important aspects of the project structural specifications.

4.4.1 *Codes and standards*—The general building code, referenced standards, and authority having jurisdiction, or all these, require specific information be included on the construction documents and that the general notes sheet(s) present this information. ACI 318-14 also requires that all applicable information from Chapter 26 related to construction be provided in the construction documents. This includes design criteria, member information, concrete materials and mixture requirements, concrete production and construction, anchoring to concrete, embedments, precast and prestressed concrete requirements, formwork, concrete evaluation and acceptance, and inspection.

4.4.2 *Design loads*—Section 1603.1 of the International Building Code (IBC) (2015) requires the following design loads and other information pertinent to structural design be indicated on the construction documents.

(a) Floor live load
(b) Roof live load
(c) Roof snow load data
(d) Wind design data
(e) Earthquake design data
(f) Geotechnical information
(g) Flood design data
(h) Special loads
(i) Systems and components requiring special inspections for seismic resistance

Design loads are presented on the general notes sheet. Floor live loads, roof live loads, snow loads, and other simple gravity loads are commonly shown in a table. Basic wind load criteria assumptions and, when necessary, wind-loading diagrams are included. Earthquake design data are usually presented as a list of the different criteria used to develop the design earthquake loads. It is preferred to indicate if and where live load reductions were applied.

Geotechnical design information shown is usually supplied to the structural designer in a geotechnical report. This can be presented as a note when the soil and water table on-site is relatively consistent, or in a table format when there is significant soil or water table variability.

Flood design data and criteria used to determine the flood design loads are typically shown using notes.

Special loads not included in the code-required live loads are also noted in the table that includes live loads. Examples of such loads are architectural features, partition live loads, ceiling and hanging loads, and superimposed dead loads. A diagram might be needed for heavy pieces of equipment, such as forklifts, with their assumed wheel spacing and axle loads.

Showing the self-weight of the structure is not a requirement of the code. However, an indication of where lightweight, normalweight, and heavyweight concrete is used should be provided on the drawings so that the self-weight of the structure can be reasonably determined by the formwork engineer.

4.4.3 *Specifications*—The first concrete general note is commonly a reference to require construction be in accordance with ACI 301. The LDP ensures that the construction documents meet code provisions; therefore, requiring the contractor to conform to ACI 318 is not appropriate, as it provides code requirements to the LDP and not the contractor or materials supplier. By incorporating ACI 301 by reference into the construction documents and using the ACI 301 mandatory and optional checklists, the concrete materials and construction requirements will satisfy ACI 318. In addition, ACI 301 also specifies that fabrication and construction tolerances should comply with ACI 117.

ACI 301 contains the following three checklists: mandatory requirements, optional requirements, and submittals. The LDP is often also the specifier on a project and should go through these checklists and make necessary exceptions to ACI 301 in the construction documents. The general notes sheet is a convenient way to communicate any necessary exceptions to ACI 301.

4.4.4 *Concrete notes*—The Mandatory Requirements Checklist items in ACI 301 that are related to concrete can be specified in the general concrete notes and indicate that the construction documents include:

(a) Exposure class and specified compressive strength, f_c', for different concrete elements

(b) Handling, placing, and constructing requirements

(c) Designations and requirements for architectural concrete, lightweight concrete, mass concrete, post-tensioned concrete, shrinkage-compensating concrete, industrial floor slabs, tilt-up construction, and precast concrete

Concrete general notes can show this information in a table with each structural element type, along with its corresponding exposure class, specified compressive strength, and other requirements.

Construction documents should also indicate any exceptions to the default requirements of ACI 301. ACI 301 lists possible exceptions in the Optional Requirements Checklist. Concrete general notes often contain the following optional requirements checklist exceptions to ACI 301 default requirements:

(a) Air entrainment in percentage (%), along with the respective tolerance

(b) Slump in inches (in.), along with the respective tolerance

(c) When high-range water-reducing admixtures are allowed or required

(d) Additional testing and inspection services

4.4.5 *Reinforcement notes*—ACI 301 Mandatory Requirements Checklist items related to reinforcing steel can be specified in the general reinforcement notes and indicate that the construction documents include:

(a) Type and grade of reinforcing steel

(b) Bar development and splice lengths and locations

(c) Types of reinforcement supports and locations used within the structure

(d) Cover for headed shear stud reinforcement and headed reinforcing bars

Construction documents should indicate any exceptions to the default requirements of ACI 301. ACI 301 lists possible exceptions to the default requirements in the Optional Requirements Checklist. Some exceptions to ACI 301 default requirements can include the following:

(a) Weldability of bars

(b) Concrete cover to reinforcement

(c) Specialty item type and grade

(d) Coatings such as epoxy or zinc where applicable

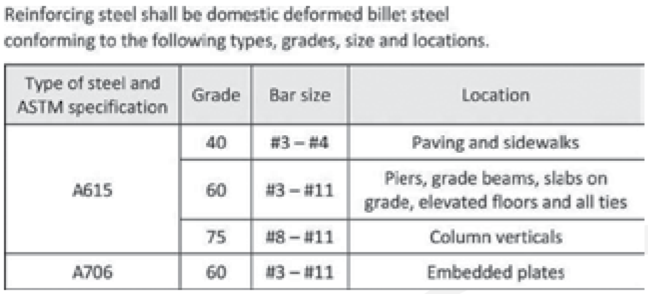
(e) Permitting field cutting of reinforcement and cutting methods

Reinforcement requires concrete cover to protect the steel from corrosion. ACI 301 Table 3.3.2.3 shows concrete cover requirements for specific members. The concrete cover requirements for a project are typically shown in a table or list showing the type of member, concrete exposure, type of reinforcement, and concrete cover requirements for each. If there are questionable locations on a specific project, the contract documents should indicate the specific concrete cover requirement controls at each location; an example is fire-rated elements.

When proprietary reinforcement products are required on a project, they can be specified in the general notes.

4.4.5.1 *ACI 318 reinforcement requirements*—Reinforcing bars, spirals, wires, and welded wire styles in conformance with ASTM International specifications are accepted for construction in the United States and are required by ACI 318. Type and grade of reinforcement are typically shown in a note. When there is more than one type, grade, or both of reinforcement used on a project, it is recommended to show this information in a table indicating the type and grade used in specific parts of the structure (Fig. 4.4.5.1).

4.4.5.2 *Development and splices*—ACI 318 requires that the development length/embedment of reinforcement, length of lap splices, and where critical to design, location of lap splices, be shown on the construction documents. Bar development and lap splice lengths and locations can be shown using tables, but the preferred method for showing development and lap splice length and location is graphically in plan, elevation, section, or detail with dimensions provided. This allows the fabrication detailer to more accurately read this information from the drawings. Where lap splice location and length have structural safety implications, the lap splice lengths should be shown graphically.



Reinforcing steel shall be domestic deformed billet steel conforming to the following types, grades, size and locations.

Type of steel and ASTM specification	Grade	Bar size	Location
A615	40	#3 – #4	Paving and sidewalks
	60	#3 – #11	Piers, grade beams, slabs on grade, elevated floors and all ties
	75	#8 – #11	Column verticals
A706	60	#3 – #11	Embedded plates

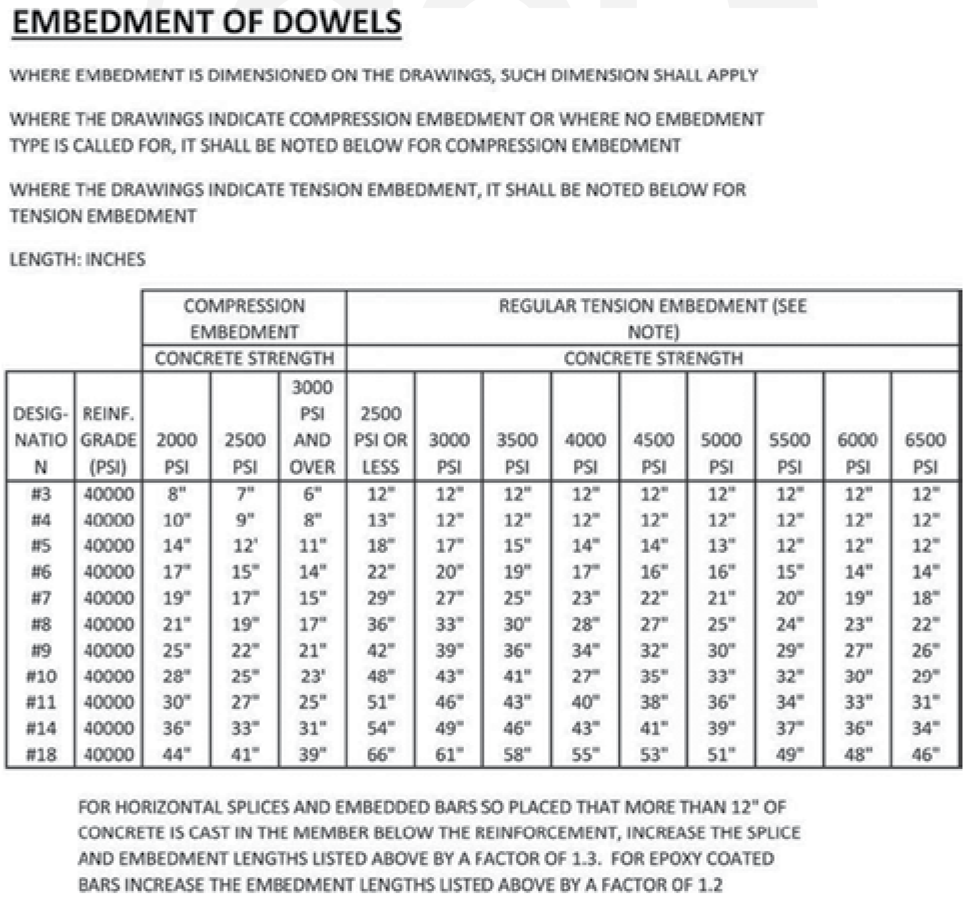
Fig. 4.4.5.1—Example table of reinforcing bar locations and grades.

When engineering judgment indicates that embedment and lap splice locations and length are less critical, a table can be used (Fig. 4.4.5.2a and 4.4.5.2b). Calculations should not be required of the fabrication detailer to determine the lap splice length or development lengths. Lap and development lengths calculated by the LDP should be shown on the design drawings. The LDP should verify that all possible bar development and lap splice length arrangements that are required on the project can be found on the drawings

If mechanical splices are permitted or required on a project, make a note of it on the general notes sheet or project specifications to permit them as well as the required type of splice. The LDP should also include a typical detail or specific details on where mechanical splices are required or permitted.

If headed bars are permitted or required on a project, make a note of it on the general notes sheet or project specifications to permit them. Make a note of the required bearing area, cover, and embedment lengths as well. The LDP should also include typical or specific details on where headed bars are required or permitted.

4.4.5.3 *Supports for reinforcing steel*—Before and during concrete placement, reinforcing steel should be supported and held firmly in place at the proper distance from the forms. The LDP specifies acceptable materials and corrosion protection for reinforcement supports, side form spacers, and supports or spacers for other embedded structural items or specific areas. ACI 301 specifies bar supports meeting



EMBEDMENT OF DOWELS

WHERE EMBEDMENT IS DIMENSIONED ON THE DRAWINGS, SUCH DIMENSION SHALL APPLY

WHERE THE DRAWINGS INDICATE COMPRESSION EMBEDMENT OR WHERE NO EMBEDMENT TYPE IS CALLED FOR, IT SHALL BE NOTED BELOW FOR COMPRESSION EMBEDMENT

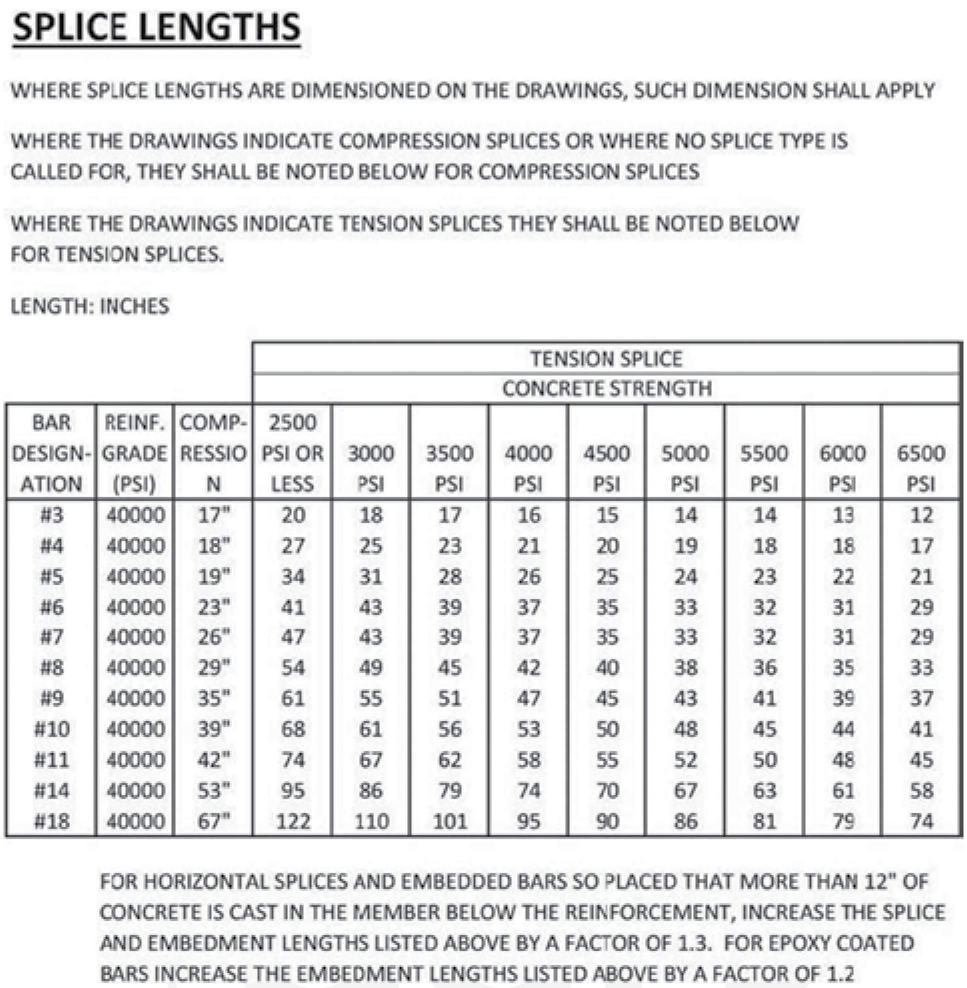
WHERE THE DRAWINGS INDICATE TENSION EMBEDMENT, IT SHALL BE NOTED BELOW FOR TENSION EMBEDMENT

LENGTH: INCHES

		COMPRESSION EMBEDMENT			REGULAR TENSION EMBEDMENT (SEE NOTE)								
		CONCRETE STRENGTH			CONCRETE STRENGTH								
DESIG-NATION	REINF. GRADE (PSI)	2000 PSI	2500 PSI	3000 PSI AND OVER	2500 PSI OR LESS	3000 PSI	3500 PSI	4000 PSI	4500 PSI	5000 PSI	5500 PSI	6000 PSI	6500 PSI
#3	40000	8"	7"	6"	12"	12"	12"	12"	12"	12"	12"	12"	12"
#4	40000	10"	9"	8"	13"	12"	12"	12"	12"	12"	12"	12"	12"
#5	40000	14"	12'	11"	18"	17"	15"	14"	14"	13"	12"	12"	12"
#6	40000	17"	15"	14"	22"	20"	19"	17"	16"	16"	15"	14"	14"
#7	40000	19"	17"	15"	29"	27"	25"	23"	22"	21"	20"	19"	18"
#8	40000	21"	19"	17"	36"	33"	30"	28"	27"	25"	24"	23"	22"
#9	40000	25"	22"	21"	42"	39"	36"	34"	32"	30"	29"	27"	26"
#10	40000	28"	25"	23'	48"	43"	41"	27"	35"	33"	32"	30"	29"
#11	40000	30"	27"	25"	51"	46"	43"	40"	38"	36"	34"	33"	31"
#14	40000	36"	33"	31"	54"	49"	46"	43"	41"	39"	37"	36"	34"
#18	40000	44"	41"	39"	66"	61"	58"	55"	53"	51"	49"	48"	46"

FOR HORIZONTAL SPLICES AND EMBEDDED BARS SO PLACED THAT MORE THAN 12" OF CONCRETE IS CAST IN THE MEMBER BELOW THE REINFORCEMENT, INCREASE THE SPLICE AND EMBEDMENT LENGTHS LISTED ABOVE BY A FACTOR OF 1.3. FOR EPOXY COATED BARS INCREASE THE EMBEDMENT LENGTHS LISTED ABOVE BY A FACTOR OF 1.2

Fig. 4.4.5.2a—Example reinforcement embedment schedule for a specific project.



SPLICE LENGTHS

WHERE SPLICE LENGTHS ARE DIMENSIONED ON THE DRAWINGS, SUCH DIMENSION SHALL APPLY

WHERE THE DRAWINGS INDICATE COMPRESSION SPLICES OR WHERE NO SPLICE TYPE IS CALLED FOR, THEY SHALL BE NOTED BELOW FOR COMPRESSION SPLICES

WHERE THE DRAWINGS INDICATE TENSION SPLICES THEY SHALL BE NOTED BELOW FOR TENSION SPLICES.

LENGTH: INCHES

			TENSION SPLICE								
			CONCRETE STRENGTH								
BAR DESIGNATION	REINF. GRADE (PSI)	COMPRESSION	2500 PSI OR LESS	3000 PSI	3500 PSI	4000 PSI	4500 PSI	5000 PSI	5500 PSI	6000 PSI	6500 PSI
#3	40000	17"	20	18	17	16	15	14	14	13	12
#4	40000	18"	27	25	23	21	20	19	18	18	17
#5	40000	19"	34	31	28	26	25	24	23	22	21
#6	40000	23"	41	43	39	37	35	33	32	31	29
#7	40000	26"	47	43	39	37	35	33	32	31	29
#8	40000	29"	54	49	45	42	40	38	36	35	33
#9	40000	35"	61	55	51	47	45	43	41	39	37
#10	40000	39"	68	61	56	53	50	48	45	44	41
#11	40000	42"	74	67	62	58	55	52	50	48	45
#14	40000	53"	95	86	79	74	70	67	63	61	58
#18	40000	67"	122	110	101	95	90	86	81	79	74

FOR HORIZONTAL SPLICES AND EMBEDDED BARS SO PLACED THAT MORE THAN 12" OF CONCRETE IS CAST IN THE MEMBER BELOW THE REINFORCEMENT, INCREASE THE SPLICE AND EMBEDMENT LENGTHS LISTED ABOVE BY A FACTOR OF 1.3. FOR EPOXY COATED BARS INCREASE THE EMBEDMENT LENGTHS LISTED ABOVE BY A FACTOR OF 1.2

Fig. 4.4.5.2b—Example reinforcement lap schedule for a specific project.

the requirements of the Concrete Reinforcing Steel Institute (CRSI) RB4.1.

If the construction documents only state that reinforcement needs to be accurately placed, adequately supported, and secured against displacement within permitted tolerances, the contractor selects the type, class, and spacing of wire supports, precast blocks, composite (plastic), or other materials to use for each area.

CRSI RB4.1 describes the various types of wire, composite, and precast bar supports. There are three common material types of bar supports: wire bar supports shown in Fig. 4.4.5.3a, precast concrete block bar supports shown in Fig. 4.4.5.3b, and composite (plastic) bar supports shown in Fig 4.4.5.3c.

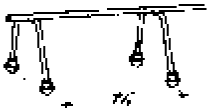
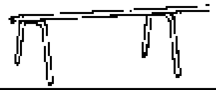
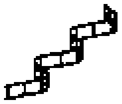
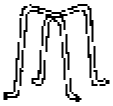
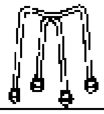
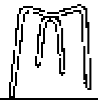
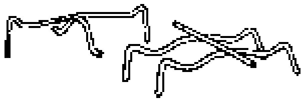
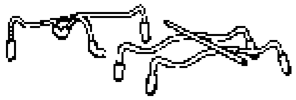
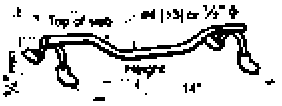
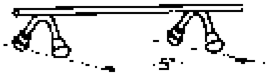
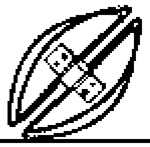
Certain reinforcement support types can cause aesthetic issues. For example, if precast blocks are used and the surface has a sand-blasted finish, the different texture and color between the precast blocks and the cast-in-place concrete might be objectionable. Also, Class 3 wire bar supports could leave rust stains on the exposed concrete surfaces due to corrosion. A common sub-type of wire bar supports is plastic-tipped wire bar supports that are often used when surface corrosion spots would be of concern. The LDP should clearly define areas on the drawings where specific types of supports are needed to avoid aesthetic problems and future repairs that can be costly.

Beam bolsters support bottom beam reinforcement and are placed in the beam form, usually perpendicular to the axis of the beam under the stirrups. Beams can also be supported with individual chairs or blocks placed under the beam stirrups.

Bar supports are furnished for bottom bars in grade beams or slabs-on-ground only if required in the construction documents. For a structural element, the LDP should specify bar supports for the bottom bars in grade beams or slabs-on-ground. Aesthetics are not a concern in the bottom of a slab-on-ground or grade beam, which allows the use of precast blocks for bar supports.

Side form spacers (Fig. 4.4.5.3d) can be specified for use, but are usually selected by the contractor.

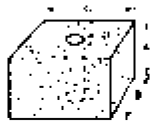
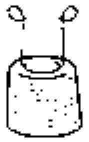
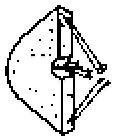
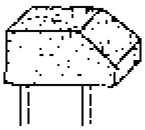
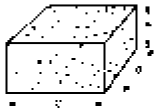
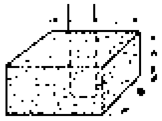
4.4.5.4 *Weldability of bars*—The weldability of steel is established by its chemical composition. The American Welding Society (AWS) D1.4 sets the minimum preheat and interpass temperatures and provides the applicable welding procedures. Carbon steel bars conforming to ASTM A615/A615M are weldable with appropriate preheating. Only reinforcing bars conforming to ASTM A706/A706M are preapproved for welding without preheating. Welding of rail-and

SYMBOL	BAR SUPPORT ILLUSTRATION*	BAR SUPPORT ILLUSTRATION PLASTIC TIPPED	TYPE OF SUPPORT	TYPICAL SIZES
BB			Beam Bolster	1, 1 ½, 2 to 5 in. heights in increments of ¼ in. in lengths of 5 ft
SBU**			Beam Bolster Upper	Same as BB
BC			Individual Bar Chair	¾, 1, 1 ½, 1 ¾, and 2 in. heights
CHC			Continuous High Chair	Same as HC in 5 ft and 10 ft
CHCM**			Continuous High Chair for Metal Deck	Up to 5 in. heights in increments of ¼ in.
CHCU**			Continuous High Chair Upper	Same as CHC
CS			Continuous Support	1 ½ to 12 in. in increments of ¼ in. in lengths of 6' – 8'
HC			Individual High Chair	2 to 15 in. heights in increments of ¼ in.
HCM**			High Chair for Metal Deck	2 to 15 in. heights in increments of ¼ in.
JC			Joist Chair	4, 5, and 6 in. widths and ¾, 1 and 1 ½ in. heights
JCU***			Joist Chair Upper	14 in. span; heights -1 in. thru +3 ½ in. vary in ¼ in. increments
SB			Slab Bolster	¾, 1, 1 ½, 2, and 3 in. heights in 5 ft and 10 ft lengths
SBC			Single Bar Centralizer (Friction)	6 in. to 24 in. diameter
SBU**			Slab Bolster Upper	Same as SB

*Illustrations are intended for informational purposes only.
**Usually available in Class 3 only, except on special order.
***Usually available with Class 3 only, with upturned or end-bearing legs.

1 in. = 25.4 mm
1 ft = 304.8 mm

Fig. 4.4.5.3a—Example wire bar supports (courtesy CRSI (CRSI RB4.1)).

z	BAR SUPPORT ILLUSTRATION	TYPE OF SUPPORT	TYPICAL SIZES, IN.	DESCRIPTION
CB		Combination Block	A – 1 ½ to 4 B – 2 to 4 C – 2 to 4 D – fits #3 to #5 [#10 to #16] bar	Commonly used on horizontal work.
DB		Dowel Block	A – 3 B – 3 to 5 C – 3 to 5 D – hole to accommodate a #4 [13] bar	Used to support top mat from dowel placed in hole. Block can also be used to support bottom mat.
DSBB		Bottom Bolster – Wired	Concrete cover, 3 to 6	Used to keep the reinforcing bar cage off the floor of the drilled shaft.* Support for 6 in. concrete cover is actually 8 in. in height with a 2 in. shaft cast in the top of the bolster to hold the vertical bar.
DSSS		Side-Form Spacer – Wired	Concrete cover, 2 to 6	Used to align the reinforcing bar cage in a drilled shaft.* Commonly 16-gauge tie wires are cast in the spacer. Supports for 5 in. to 6 in. cover have 9-gauge tie wires at top and bottom of the spacer.
DSWS		Side-form spacer for drilled shaft applications	Concrete cover, 3 to 6	Generally used to align reinforcing bar in a drilled shaft.* Commonly manufactured with two sets of 12-gauge annealed wires, assuring proper clearance from the shaft wall surface.
PB		Plain Block	A – ¾ to 6 B – 2 to 6 C – 2 to 48	Used when placing bars off grade and form work. When "C" dimension exceeds 16 in. the block should be cast with a piece of reinforcing bar inside the block.
WB		Wired Block	A – ¾ to 4 B – 2 to 3 C – 2 to 3	Generally, block is cast with embedded 16-gauge tie wire, commonly used against vertical forms or in positions necessary to secure the block by tying to the reinforcing bars.

* Also known as a pier, caisson or cast-in drilled hole

1 in. = 25.4 mm

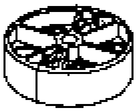
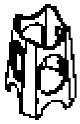
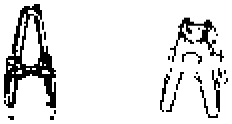
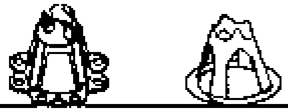
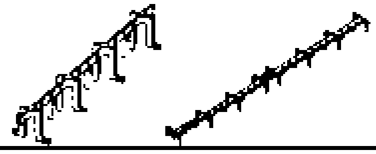
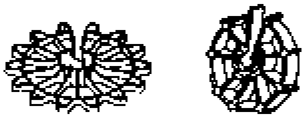
Fig. 4.4.5.3b—Example concrete supports (courtesy CRSI (CRSI RB4.1)).

axle-steel bars is not recommended. Welding of stainless-steel reinforcing bars is discouraged, but if necessary, done in accordance with AWS D1.6. Low-carbon chromium reinforcing bars should not be welded.

4.4.5.5 *Hooks and bends*—Standard practice is to show all bar dimensions as out-to-out and consider the bar lengths as the sum of all detailed primary dimensions, including Hooks A and G. Note the difference between "minimum" bend diameter and "finished" bend diameter. "Finished" bend diameters include a "spring-back" effect when bars straighten out slightly after being bent and are slightly larger than "minimum" bend diameters.

Standard bend shapes will have not more than six bend points in one plane, bent to normal tolerances. Shapes with more than six bends, or bent to special tolerances, or in more than one plane, involve greater difficulty and are subject to added costs.

Although bar hooks and bends are occasionally not shown on the drawings, a note should be placed stating that certain bars are required to end in a standard hook. Specifications that require a nonstandard hook should be used with caution because nonstandard hooks could be difficult to achieve. If the LDP shows a hook but does not dimension the hook, the reinforcing steel detailer will use an algorithm similar to the Block Flow diagram in Fig. 4.4.5.5 to determine the proper

SYMBOL	BAR SUPORT ILLUSTRATION	TYPE OF SUPPORT	TYPICAL SIZES, IN.	DESCRIPTION
BS		Bottom Support	Heights, ¾ to 6	Generally for horizontal work. Not recommended for ground or exposed aggregate finish.
BS-CL		Bottom Support	Heights, ¾ to 12	Generally for horizontal work, provides bar clamping action. Not recommended for ground or exposed aggregate finish.
DSBB		Bottom Bolster (Gripping)	Concrete cover, 3 Height, 6	Used to keep the reinforcing bar cage off of the bottom of a drilled shaft.** Fits #6 through #14 [#19 through #43] reinforcing bars.
DSWS		Side-Form Spacer for drilled shaft applications	Concrete cover, 2 ½ to 6	Generally used to align reinforcing bars in a drilled shaft.** Two-piece wheel that closes and locks on to the tie or spiral assuring proper clearance from the shaft wall surface.
HC		High Chair	Heights, ¾ to 6	For use in slabs or panels
HC-V		High Chair, Variable	Heights, 2 ¼ to 7 ¼	For horizontal and vertical work. Provides for different heights.
HDHC		Heavy Duty High Chair	Heights, 2 ¼ to 26	For use in slabs, or on grade with plate.
OGC		On Grade Chair	Heights, 1 ½ to 6 ¼	Used primarily on grade.
SB		Slab Bolster	Heights ¾ to 4 Lengths up to 60***	Commonly used in horizontal and vertical applications. When used as a side-form spacer in vertical work, slab bolster must be tied to the reinforcement.
SBU		Slab Bolster Upper	Heights, 1 to 5 Lengths up to 30	Commonly used in supporting the upper mat in a double mat application.
VLWS		Locking Wheel Side-Form Spacer for all vertical applications	Concrete cover, ¾ to 6	Generally used in both drilled shaft** and vertical applications where heavy loading occurs. Surface spines provide minimal contact while maintaining required tolerance.
WS		Wheel Side-Form Spacer	Concrete cover, ¾ to 3	Generally for vertical work. Bar clamping action and minimum contact with forms. Applicable for column reinforcing bars

*Illustrations are intended for informational purposes only.

**Also known as a pier, caisson, or cast-in drilled hole.

***Pieces can be locked together to form longer lengths.

1 in. = 25.4 mm

Fig. 4.4.5.3c—Example plastic supports (courtesy CRSI (CRSI RB4.1)).

Fig. 4.4.5.3d—Side form spacers to maintain reinforcement cover in a wall form.

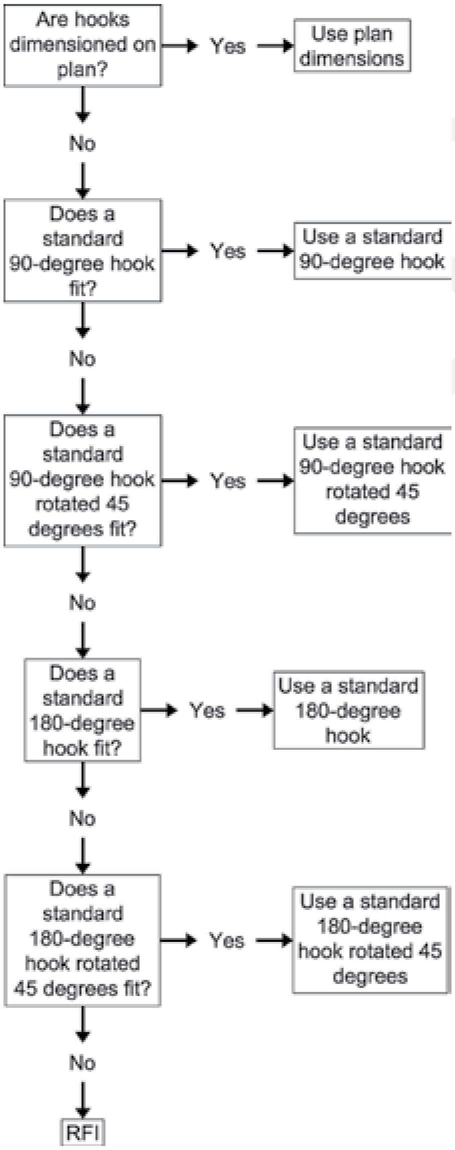
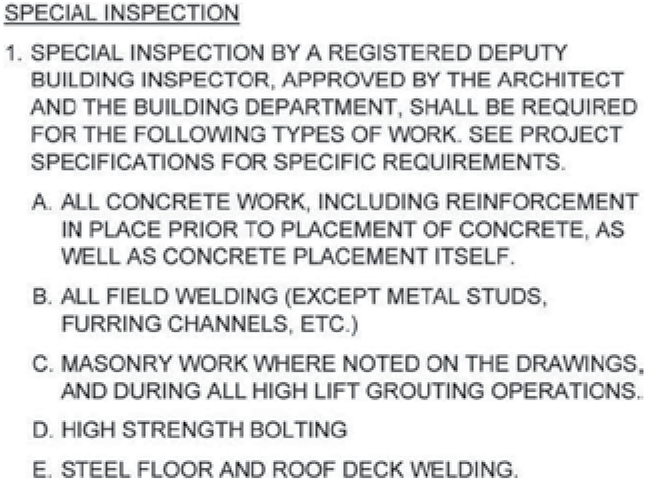


Fig. 4.4.5.5—Block flow diagram to determine hook type and size.



SPECIAL INSPECTION

1. SPECIAL INSPECTION BY A REGISTERED DEPUTY BUILDING INSPECTOR, APPROVED BY THE ARCHITECT AND THE BUILDING DEPARTMENT, SHALL BE REQUIRED FOR THE FOLLOWING TYPES OF WORK. SEE PROJECT SPECIFICATIONS FOR SPECIFIC REQUIREMENTS.
   - A. ALL CONCRETE WORK, INCLUDING REINFORCEMENT IN PLACE PRIOR TO PLACEMENT OF CONCRETE, AS WELL AS CONCRETE PLACEMENT ITSELF.
   - B. ALL FIELD WELDING (EXCEPT METAL STUDS, FURRING CHANNELS, ETC.)
   - C. MASONRY WORK WHERE NOTED ON THE DRAWINGS, AND DURING ALL HIGH LIFT GROUTING OPERATIONS.
   - D. HIGH STRENGTH BOLTING
   - E. STEEL FLOOR AND ROOF DECK WELDING.

Fig. 4.4.7—Example of special inspection notes.

hook to use. If the standard hook possibilities will not fit, a delaying request for information (RFI) becomes necessary. A standard hook only defines dimensions of the bend shape and is not an indicator of required development length.

4.4.5.6 *Wire and welded wire reinforcement (WWR)*—Welded wire reinforcement is produced by electrical resistance welding. In North America, it typically consists of a series of cold-drawn steel wires typically arranged at right angles to each other, although in other parts of the world it is produced at various angles besides right angles. Welded wire reinforcement can be used in slabs-on-ground, joist and waffle slab construction, walls, pavements, box culverts, and canal linings. The Wire Reinforcement Institute manuals WWR-500-R-16 and WWR-600 provide guidance on specification and development of design details.

General notes or the specifications will specify the WWR required. Welded wire reinforcement is produced in flat sheets called "styles" or in rolls. The wire may be plain or deformed.

Welded wire reinforcement in conformance with ASTM A1064/A1064M is most typically specified unless stainless or zinc-coated types are needed. Welded wire reinforcement can be fabricated in many configurations, ranging from 2 x 2-W1.4 x W1.4 to 16 x 16-D31 x D31, with many different combinations between. An example of one type of style is 3 x 12-D31 x W12.4. WWR-500-R-16 lists properties of common styles of WWR.

4.4.6 *Construction notes*—Construction notes are general notes that discuss many of the miscellaneous aspects of construction not covered by the other types of notes. These notes might include information pertinent to detailing, fabrication, and reinforcement placement.

4.4.7 *Inspection notes*—The general notes sheet should indicate the level of inspection required for the project. If the structure includes members that require special inspection, such as a special seismic-force-resisting system, they should be identified (Fig. 4.4.7).

4.5—Plan sheets

IBC (2015) Section 1603.1 requires construction documents to show the size, section, and relative locations of

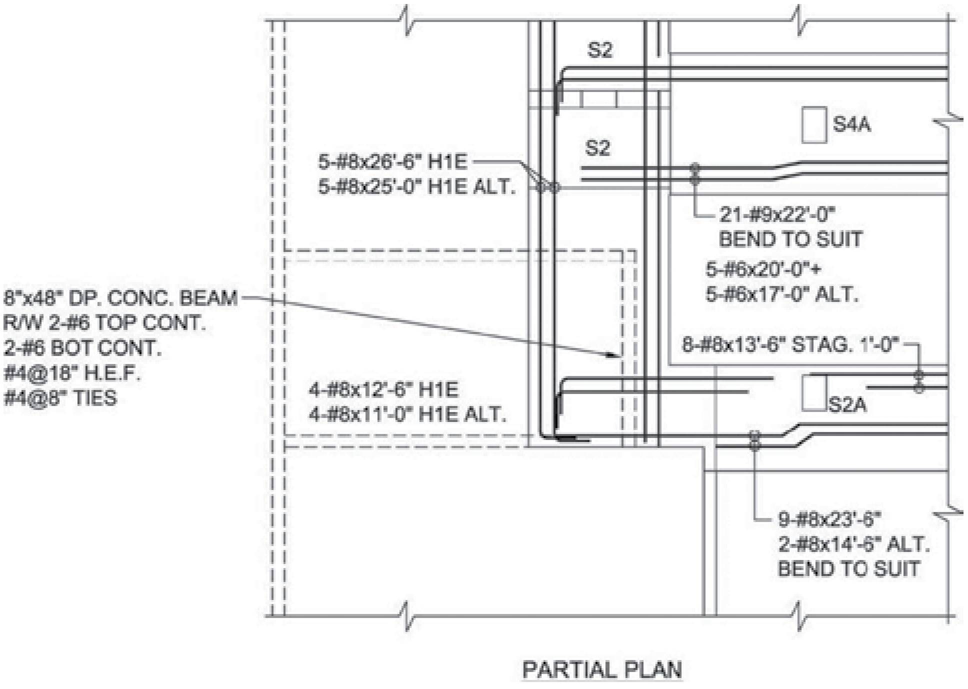


Fig 4.5a—Beam shown on plan.

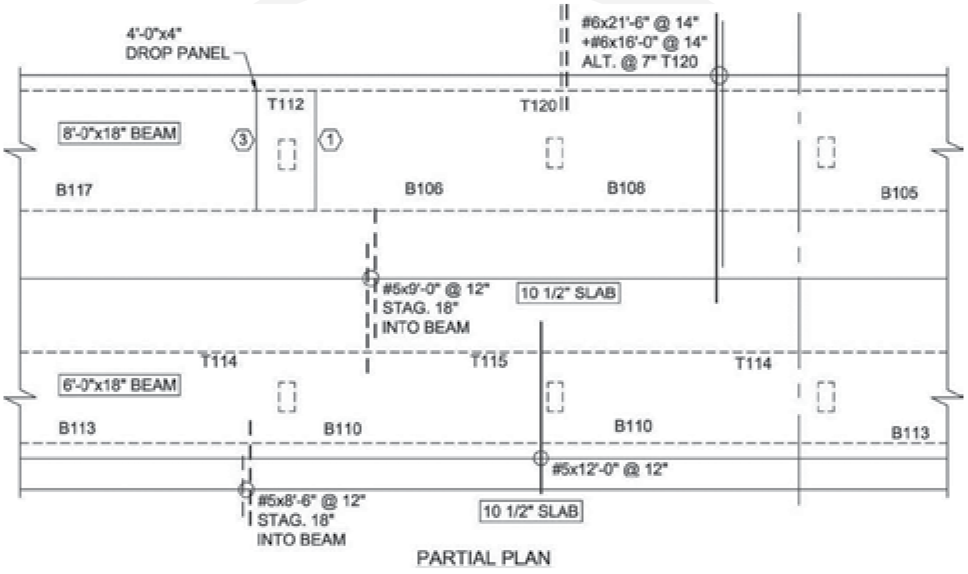


Fig 4.5b—Beam numbered on plan.

structural members with floor levels, column centers, and offsets dimensioned. A plan drawing provides information about an identified building floor, including overall geometry and dimensions, and concrete member width and thicknesses, either directly or by a designation keyed to a schedule, as well as reinforcement information for concrete members either directly, or by a designation keyed to a schedule. A plan drawing can include a general reference to other sheets, such as an elevation or detail sheet. A floor plan also includes orientation information, such as column line numbers, a north arrow, top of concrete relative to a datum, and general notes specific to the floor plan.

Member reinforcement such as beams, can be directly shown on the plan (Fig. 4.5a) or indirectly provided through use of schedule marks, such as beam numbers (Fig. 4.5b), which are listed on a corresponding beam schedule (Fig. 4.5c).

Plan drawings are usually drawn to 1/16 or 1/8 in. (1 mm = 100 to 200 mm) scale. For small floor plans larger scales can be used. The primary consideration for scale to be used is the complexity of the plan. Clarity should be maintained by using a larger scale if a large amount of information requires conveyance in a small area of the plan. If the designer needs to separate the plan into several parts for a floor, the designer should consider portions of the structure, assumed placement sequences, or some other easily readable way of

BEAM REBAR LEGEND

BEAM TOP REINFORCEMENT CENTER OVER SUPPORT U.N.O.		BEAM BOTTOM REINFORCEMENT STAG. 3" PAST CENTER OF SUPPORT U.N.O	
TYPE	REINFORCING 4-#6 CONT. BARS LAP 24" AT MID SPAN + FOLLOWING	TYPE	REINFORCING
T101	#6 6'-0" @6" H.1.E.	B101	8-#9 23'-3" 18-#9 20'-0" ALT. 6" INTO LINTEL
T102	8-#9 17'-0" 8-#9 14'-0" ALT.	B102	12-#8 18'-6" STAG.
T103	7-#9 17'-0" 6-#9 12'-0" ALT.	B103	13-#8 18'-6" STAG.
T104	8-#11 19'-6" 8-#11 14'-0" ALT.	B104	5-#8 11'-0" STAG. 5-#8 9'-0" 6" INTO WALL
T105	8-#8 17'-0" 7-#8 10'-6" ALT.	B105	14-#8 19'-6" STAG.
T106	7-#8 13'-0" 6-#8 10'-0" ALT.	B106	13-#8 18'-6" STAG.
T107	7-#8 13'-0" 6-#8 10'-0" ALT.	B107	12-#8 18'-6" STAG.
T108	8-#8 13'-0" 8-#8 10'-0" ALT.	B108	7-#8 15'-0" 7-#8 12'-6" ALT. 6" INTO WALL
T109	7-#9 14'-0" 6-#9 12'-0" ALT.	B109	10-#8 22'-6" STAG.
T110	5-#8 17'-6" 5-#8 11'-0" ALT.	B110	8-#8 18'-6" STAG.
T111	5-#8 19'-0" 5-#8 12'-0" ALT.	B111	8-#8 18'-6" STAG.
T112	7-#8 19'-0" 7-#8 12'-0" ALT.	B112	4-#8 11'-0" 4-#8 9'-6" ALT. 6" INTO WALL
T113	#6 12'-0" @ 6" center over wall	B113	9-#8 15'-0" 4-#8 12'-6" ALT. 6" INTO WALL
T114	5-#8 15'-0" 4-#8 10'-0" ALT.	B114U	14-#8 22'-6" STAG.
T115	3-#8 13'-0" 3-#8 10'-0" ALT.	B115	15-#8 18'-0" STAG.
T116	7-#9 17'-0" 7-#9 12'-0" ALT.	B116	5-#8 11'-0" STAG. 4-#8 9'-0" 6" ALT. INTO WALL
T117	6-#9 19'-6" 6-#9 12'-0" ALT.	B117	6-#8 20'-6" 6-#8 17'-6" ALT. 6" INTO WALL
T118	6-#11 19'-6" 6-#11 14'-0" ALT.	B118	7-#8 23'-3" 7-#8 19'-0" ALT. 6" INTO WALL
T119	8-#8 15'-0" 7-#8 10'-0" ALT.	B119	6-#8 19'-3" 6-#8 16'-6" ALT. 6" INTO WALL
T120	7-#8 13'-0" 7-#8 10'-0" ALT.	B120	12-#9 26'-0" STAG.
T121	7-#9 16'-0" 7-#9 12'-0" ALT.	B121	16-#8 26'-0" STAG.
T122	9-#11 19'-6" 9-#11 14'-0" ALT.	B122	14-#8 25'-6" STAG.
T123	7-#11 19'-6" 7-#11 14'-0" ALT.	B123	6-#8 19'-3" 5-#8 16'-6" ALT. 6" INTO WALL
T124	9-#11 18'-0" 8-#11 12'-6" ALT.	B124	9-#9 27'-0" 5-#9 23'-6" ALT. 6" INTO WALL
T125	6-#9 22'-0" 5-#9 18'-0" ALT. Over 2 walls	B125	5-#8 18'-6" 5-#8 16'-6" ALT. 6" INTO WALL

NOTE THE REBAR LENGTH SHOWN ABOVE ARE HORIZ. PROJECTED LENGTH ADD EXTRA FOR HOOK ONE END, BENT TO SUIT, ETC.

Fig 4.5c—Corresponding beam schedule for Fig. 4.5b.

breaking the plan into smaller parts. Match lines, indicating the adjacency of the separated parts, are typically used.

Because plans only provide information in the horizontal direction, use section cuts and elevations to clarify geometric and reinforcement information in the vertical direction. A section cut is indicated by a directional mark or cut drawn on the floor plan (Fig. 4.5d and 4.5e).

4.5.1 *Plan graphics and member geometry*—The assumed view point for a plan drawing is above the slab on each floor level of a structure (Fig. 4.5.1). Therefore, slab edges are shown as solid lines on the plan drawings. Concrete beams' and girders' locations are usually shown as hidden on the plan drawings because they are typically below the surface of the slab. Columns and walls above the slab are shown with solid lines.

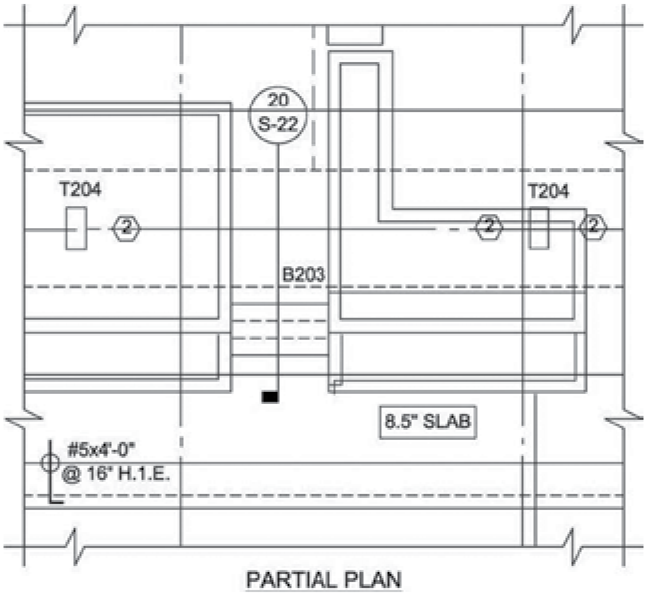


Fig 4.5d—Section cut through slab.

Columns and walls that are shown solid extend above the slab on the plan. These vertical members of the structure will be shown on all the plans from their lowest elevation in the structure, usually the foundation but occasionally a transfer girder or slab, to their highest elevation in the structure, usually the top tier where they will be drawn as hidden.

Foundations are drawn as hidden when they are below the slab-on-ground and solid when not covered by structural members or slab-on-ground concrete. Soil is not considered a structural member for this purpose.

4.5.2 *Reinforcement on plan views*—Reinforcement that is atypical, such as slab reinforcement required where a varied column layout or a large slab opening occurs, is often shown on the plan drawings instead of using slab marks (Fig. 4.5.2).

When the amount of slab reinforcement being shown on a plan drawing becomes so large that the plan is difficult to read, it is acceptable to make additional plans. These additional plan sheets can be used so that one shows the bottom reinforcement, the other the top reinforcement, and another that shows additional steel, such as that required around openings. Each plan should be properly labeled. Additional beam and girder reinforcement is not typically shown on plan drawings because it can cause confusion. If additional reinforcement is required for beams and girders, it is typically shown in a note or remark in the beam schedule, and a corresponding detail or section cut will be provided to show the additional reinforcement.

4.6—Elevation sheets

An elevation sheet contains drawing information about identified concrete members from an elevation view (Fig. 4.6a). Elevation drawings do not require a set scale, so an appropriate scale is chosen based on the height of the elevation being drawn and the level of detail needed. Similar to

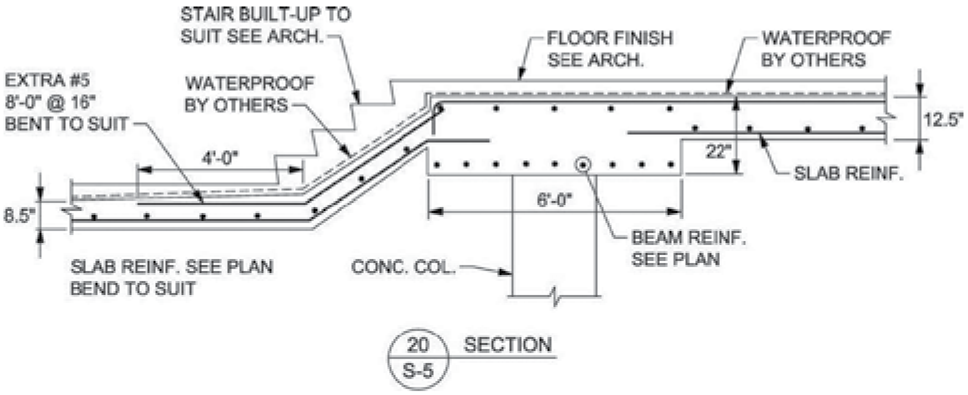


Fig 4.5e—Corresponding detail for Fig. 4.5d.

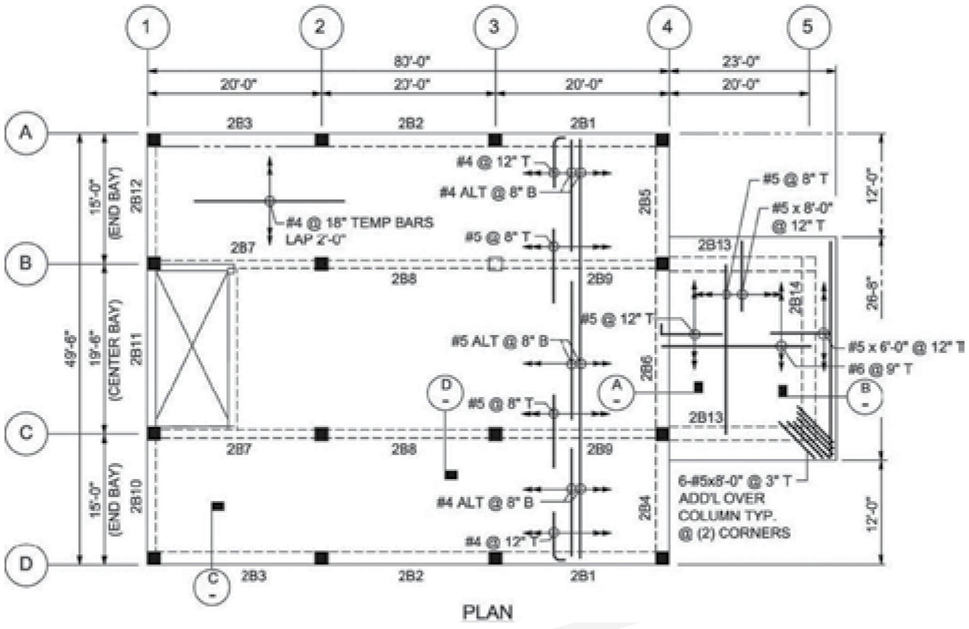


Fig. 4.5.1—Floor plan with beams with hidden lines and columns and walls with solid lines.

plan drawings, the scale is often based on the complexity of the structure. The elevation can be split into several drawings as required to show enough detail with match lines, as shown in Fig. 4.6a.

The elevation drawing provides orientation information, such as column lines or floor levels, and is connected to the plan drawings by noted concrete elevations relative to a datum, section references, and orientation information.

An elevation drawing that provides member dimensions can also provide member reinforcement. This information can be provided directly or by a designation referenced to a schedule.

When beams, columns, walls, or all are part of a seismic lateral-load-resisting system, elevations are often used to show all the reinforcement in the members that are part of that system (Fig. 4.6b). Ordinary moment frames, intermediate moment frames, and special moment frames and shear walls all have seismic detail requirements in ACI 318.

4.7—Section sheets

A section sheet is used for most projects. Sometimes, a single sheet combines sections, details, and schedules. Most sections are drawn at 3/4 in. = 1 ft (20 mm = 300 mm) scale, however, larger scales can be used if more detail is necessary for clarity. Sections are usually drawn from a point of view perpendicular to that of the drawing that calls out for the section, and is oriented by pointers on the section callout (Fig. 4.7). A section cut will show the geometry and reinforcement details at the cut plane, and may be drawn on a plan sheet, a sections sheet, or on a details sheet. The cut identifies the section number and the sheet number where the section is drawn.

4.8—Large-scale view sheets

Large-scale views are used if a dramatically increased scale of a section or detail is necessary to show additional clarity in an area of a structure. They are used to clarify reinforcement detailing in an unusual element, such as a curved staircase, complex elevator core, or heavily reinforced link

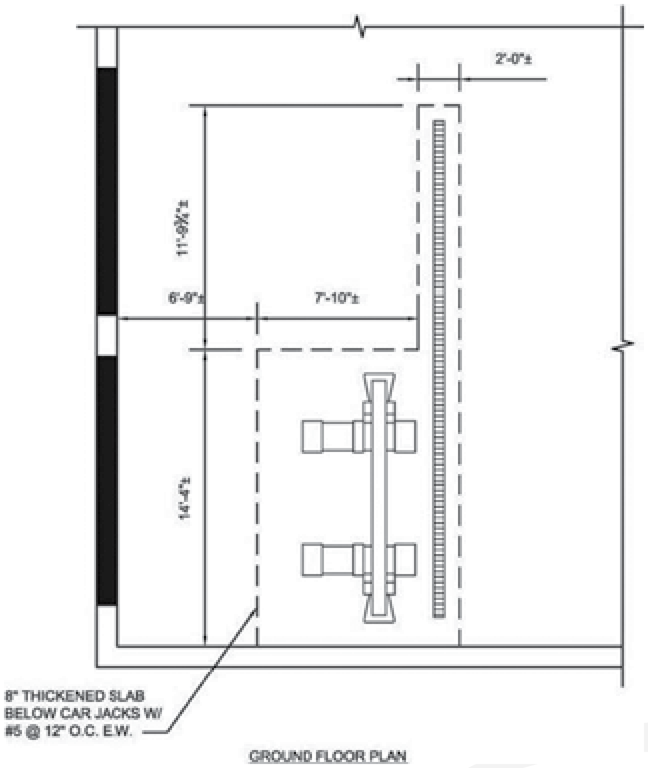


Fig. 4.5.2—Supplementary reinforcement shown on floor plan.

beam. These sheets are rarely titled "large-scale views," but instead, usually titled by what is being shown on the sheet. For example, "Stairs – Plans and Sections" could be an example title for a large-scale view sheet for a stair tower.

4.9—Detail sheets

Details are usually drawn from the same point of view as the drawing that calls out the detail (Fig. 4.9a).

A separate detail sheet is usually used on a project. However, small projects may have a single sheet that combines sections, details, and schedules. Many details are drawn at 3/8 to 1 in. = 1 ft (1 mm = 10 to 50 mm) scales, but larger scales are used if needed for clarity. In heavily congested areas, using full-scale drawings is suggested to help with checking constructability.

Details that are applicable to commonly encountered conditions are usually placed on "typical details" sheets. Often, the typical details are schematic only and are not exactly drawn. When the typical details are schematic only, the information regarding the detail is shown in a separate table or given in the notes. If not, it is typically shown simply as an example of what needs to be done, giving the contractor some freedom to choose the best means and methods for building the detailed item as shown.

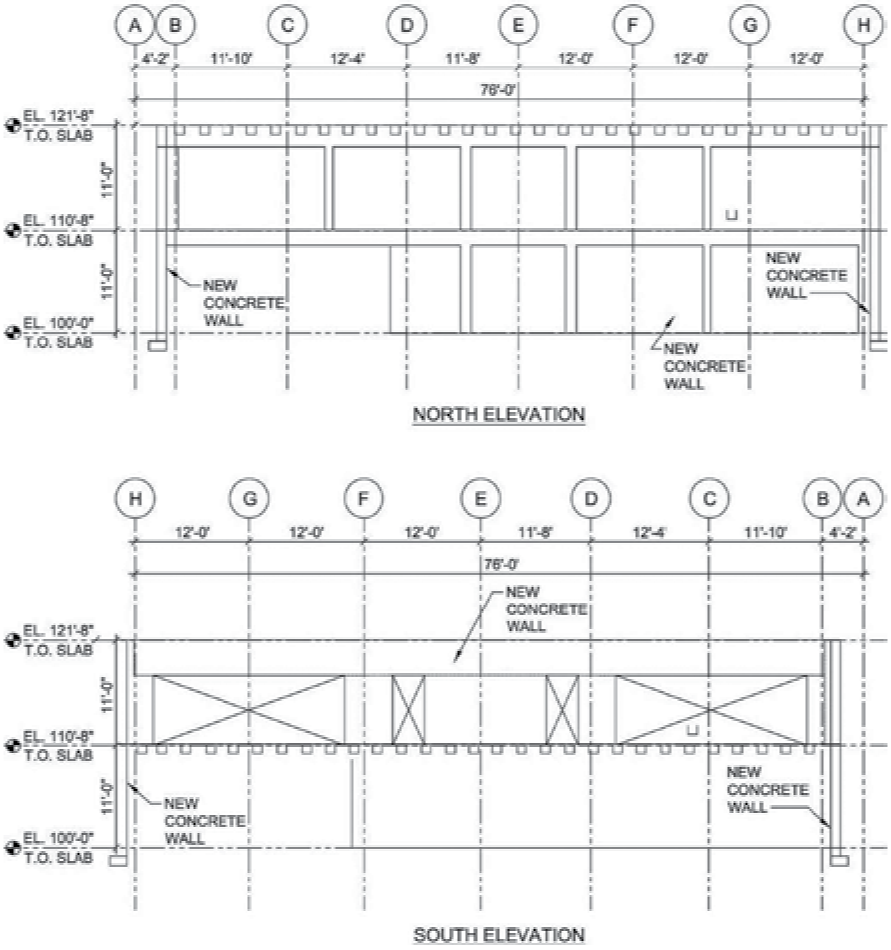


Fig. 4.6a—Building elevation with detail callouts.

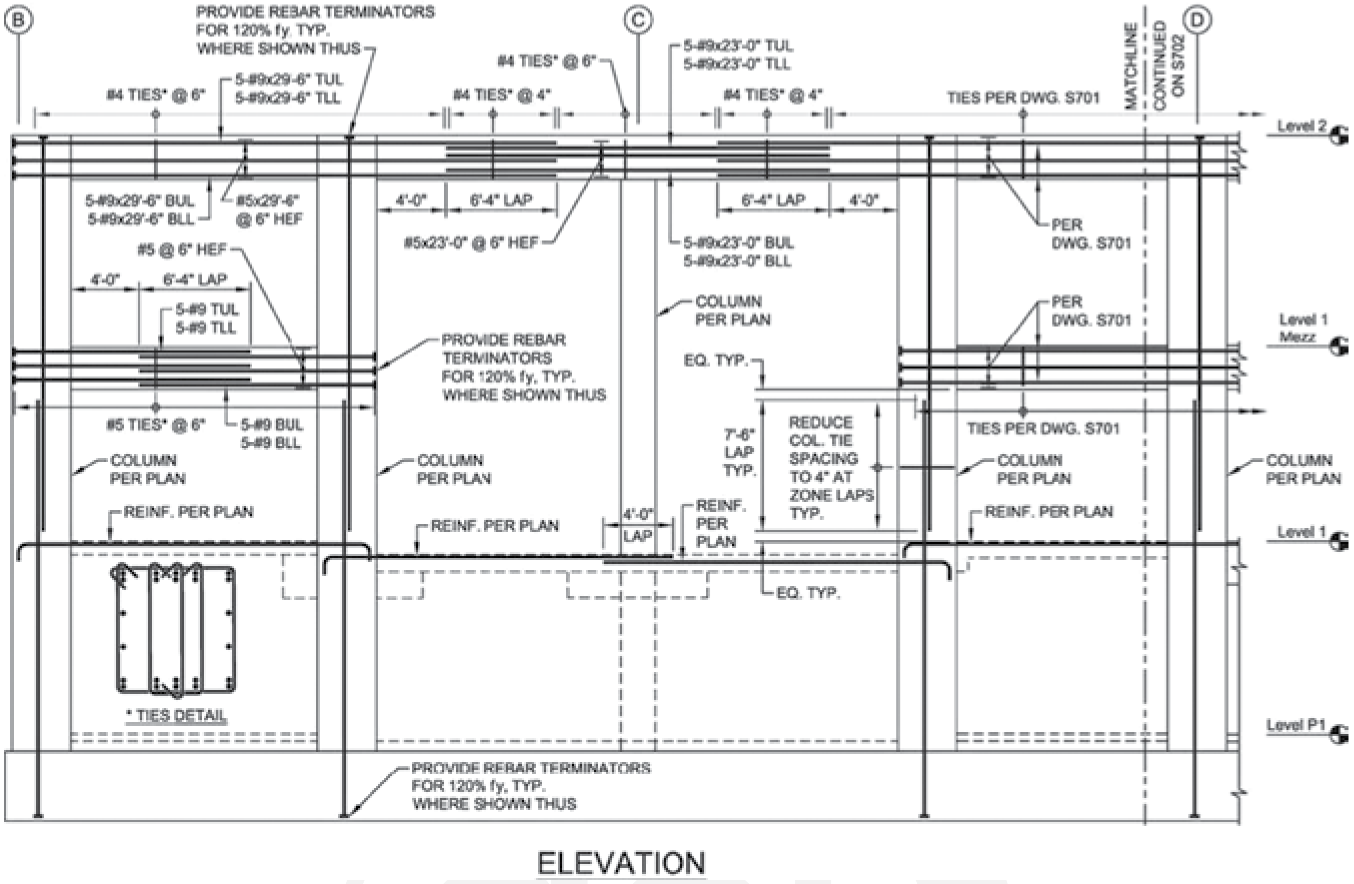


Fig. 4.6b—Building elevation with detail call-outs for lateral load-resisting system.

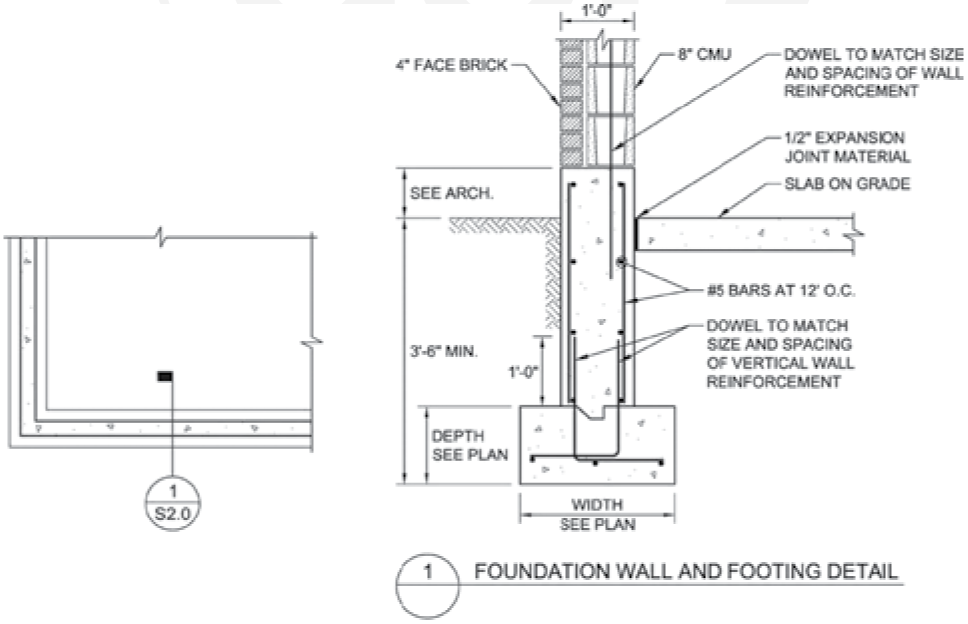


Fig. 4.7—Example plan sheet section cut call-out and section sheet section cut detail.

For example, trim reinforcement around a slab or wall opening is often standard for a certain range of opening sizes, and this arrangement shown in a typical detail. This allows the fabrication detailer to trim any opening within the stated range without asking the engineer for a specific solution. Other typical details include reinforcement around an in-slab conduit, a mechanical chase through a concrete slab, openings through a beam, reinforcement termination details at edges of concrete, contraction joints in slab-on-ground, and construction joints.

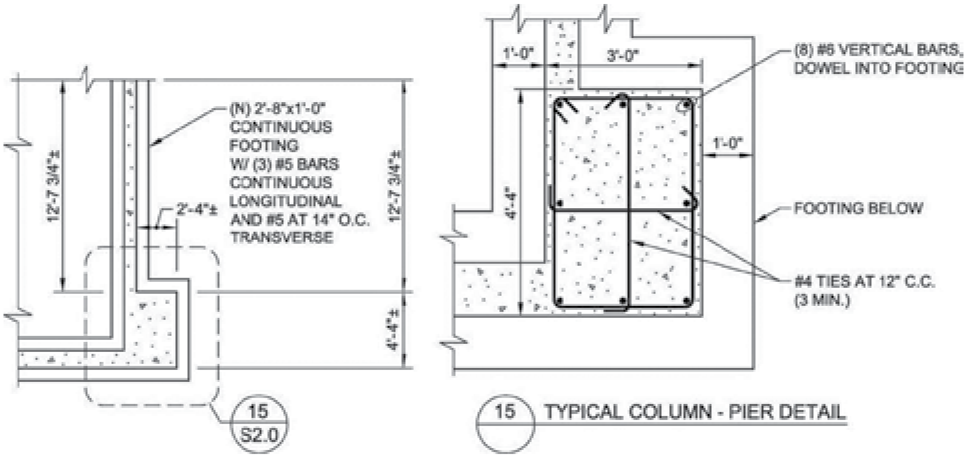
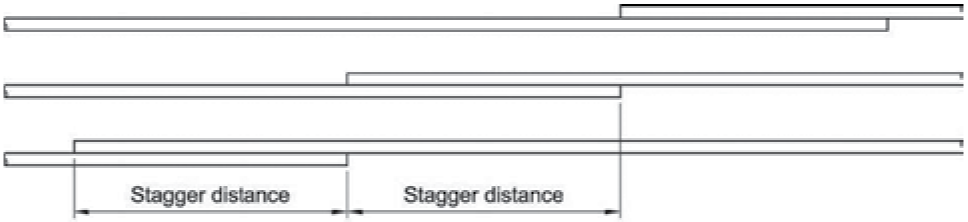
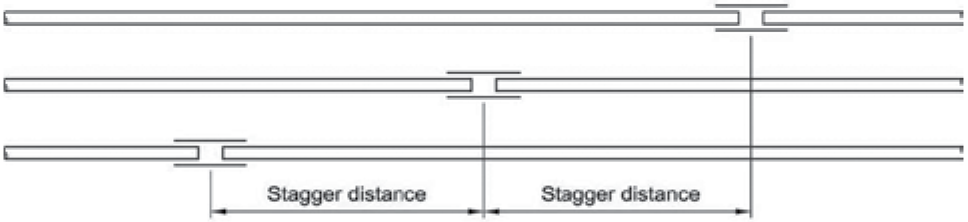


Fig. 4.9a—Example plan detail callout and detail on detail sheet.



Lap splices



Mechanical or welded splices

Fig. 4.9b—Staggered layout of splices in bundled bars.

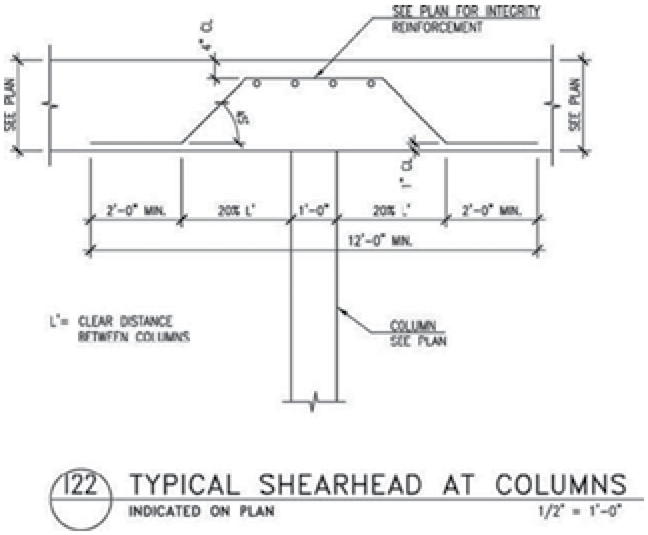


Fig. 4.9c—Example detail of a shear head.

Special member-specific information, such as bundled bar splices, or atypical splice lengths for beams, slabs, walls, and columns is best shown in typical details (Fig. 4.9b) or schedules on the respective member schedule sheets.

Shear reinforcement in a one-way slab is rarely used, but if it is, the shear reinforcement area is typically shaded or hatched on the plan drawing. A detail should be included, sometimes on the slab schedule sheet to indicate bar size, spacing of shear reinforcement, and shape of bent bar (Fig. 4.9c). Headed shear studs can also be a viable option, and a detail drawn if chosen.

4.10—Schedule and diagram sheets

Schedule sheets provide reinforcement information for various members, such as slabs, beams, columns walls, and foundations. A diagram to explain the schedule information is usually provided (Fig. 4.10).

Member schedules usually contain the following:

(a) Member mark that should have a standard naming convention and be identified on plans and elevations

(b) Member dimensions

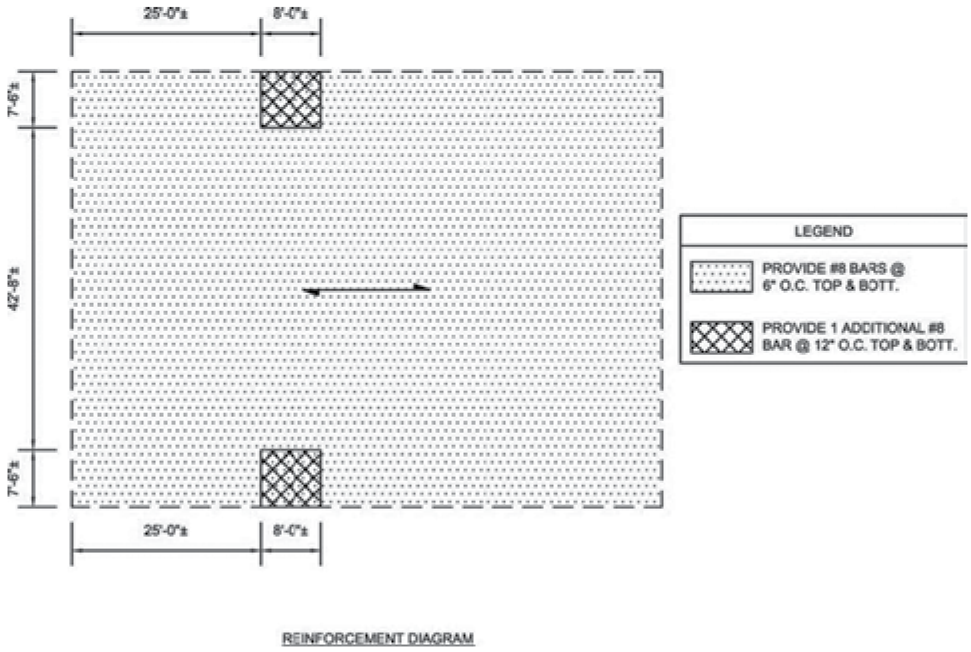


Fig. 4.10—Diagram provided to explain schedule information.

(c) Member reinforcement

(d) Remarks or notes describing to include atypical reinforcement patterns, elevation, and concrete strength

4.10.1 *Slab schedules*

Slab schedules usually contain the slab mark, thickness of slab, bottom and top reinforcement, and any notes or remarks necessary for that slab.

If the LDP choses to terminate some of the reinforcement short of the support in one-way slabs, it should be indicated in a detail similar to Fig. 4.10.1a.

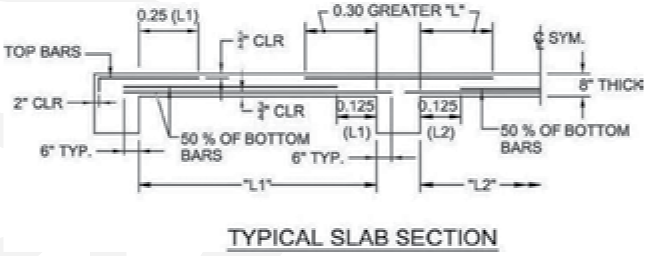


Fig. 4.10.1a—Example reinforcement terminations for a one-way slab.

Two-way slabs supported by edge walls or by edge-beams require reinforcement in the top and bottom of the slab at the intersection of the two-way slab and edge members. This reinforcement is shown using typical details if it occurs throughout the structure, or the information is shown right on the plan drawings if it is not a prevalent detail. Refer to Fig. 4.10.1b for an example.

Two-way slab structural integrity reinforcement requirements can be shown in different ways. The splicing requirements for structural integrity reinforcement can be shown on the slab schedule diagram. The requirement of two column strip bottom bars or wires that are required to go through the columns can also be shown on the plan or in a typical detail. The typical detail option is probably used most often because other information can be shown on the same detail if the designer wishes. Refer to Fig. 4.10.1c for an example.

Two-way shear reinforcement in slabs could be headed shear studs, typical stirrups, or structural steel members. Headed shear studs are used most often; a detail should be drawn to show the layout of the headed shear studs, especially at a column. When several different layouts of headed shear studs are needed in a structure, it may be clearer to use a series of headed shear stud diagrams, possibly in a table, to show their layouts as they vary throughout the structure (Fig. 4.10.1d). The plan drawings should be marked at each column to indicate which headed shear stud diagram should be used at that location.

While stirrups are not used as regularly as headed shear studs for two-way shear reinforcement, they are permitted by the ACI 318 Code. When stirrups are used for two-way shear reinforcement, they can be shown on a schedule similar to the schedule for headed shear studs (Fig. 4.10.1e). Structural steel members are rarely used; however, if they are used their locations should be identified and special details provided.

4.10.2 *Beam and girder schedules*—Beams and girders are often shown in the same schedule and the information presented is similar. For simplicity of wording, the terms "beam" and "beam schedule" will be used here to include both. Beam schedules contain the beam mark, beam width and depth, top and bottom reinforcement and extent, post-tensioning reinforcement when applicable, and stirrup size, and spacing (Fig. 4.10.2).

Along with the beam schedule, there should be a diagram to show the basic layout of the reinforcing steel in a beam. For clarity, this often requires two diagrams with one showing the longitudinal reinforcing steel and the other showing the shear reinforcing steel. The diagrams are often

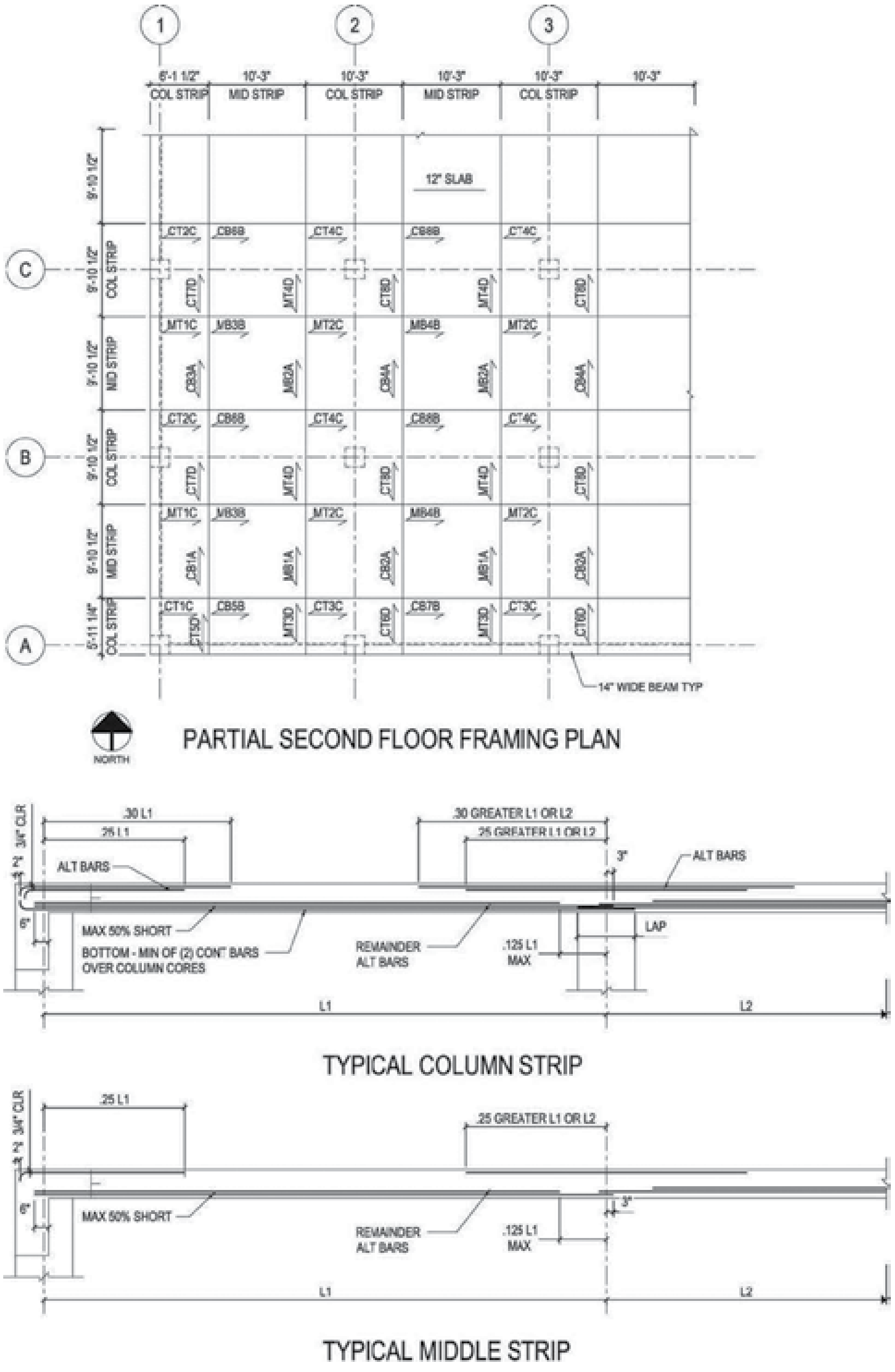


Fig. 4.10.1b—Termination rules for a two-way slab.

split into the following different types of beams: single span, multiple spans, and cantilever.

When applicable, the post-tensioning is typically specified using the assumed effective force that is expected to be applied to the beam, or using the number of tendons from the design. Typical shear reinforcing stirrup sizes and spacing are shown in the schedule by specifying each group of stirrups. For example, a beam might need six No. 4 (No.13) stirrups at 2 in. (50 mm) o.c., and then six No. 4 (No. 13) stirrups at 6 in. (150 mm) o.c. at each beam end, and the remainder along the length of the beam at 12 in. (300 mm) o.c.

Often, this type of shear reinforcement spacing at the ends of the beams or at other special shear reinforcing locations is shown in a typical diagram on the beam schedule sheet. The design drawings should provide a detail of stirrups showing the stirrup shape.

4.10.3 *Column schedules*—Column schedules usually contain the column mark, vertical reinforcement, and the

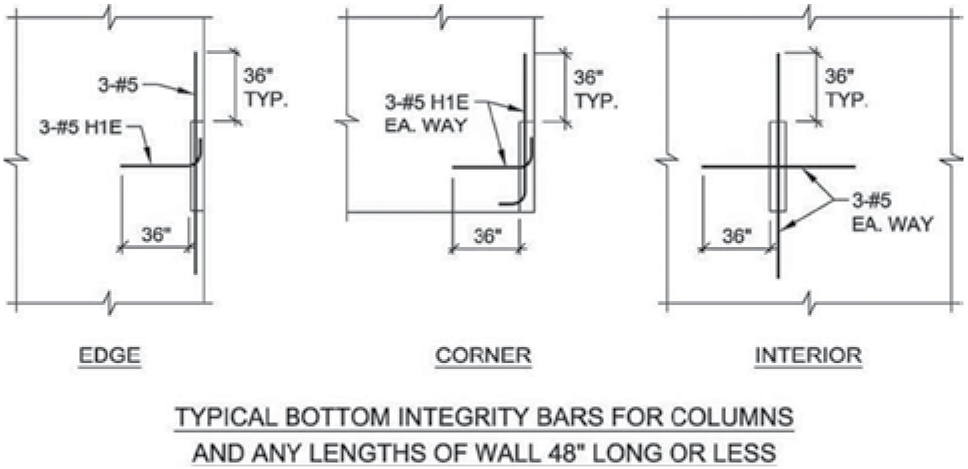
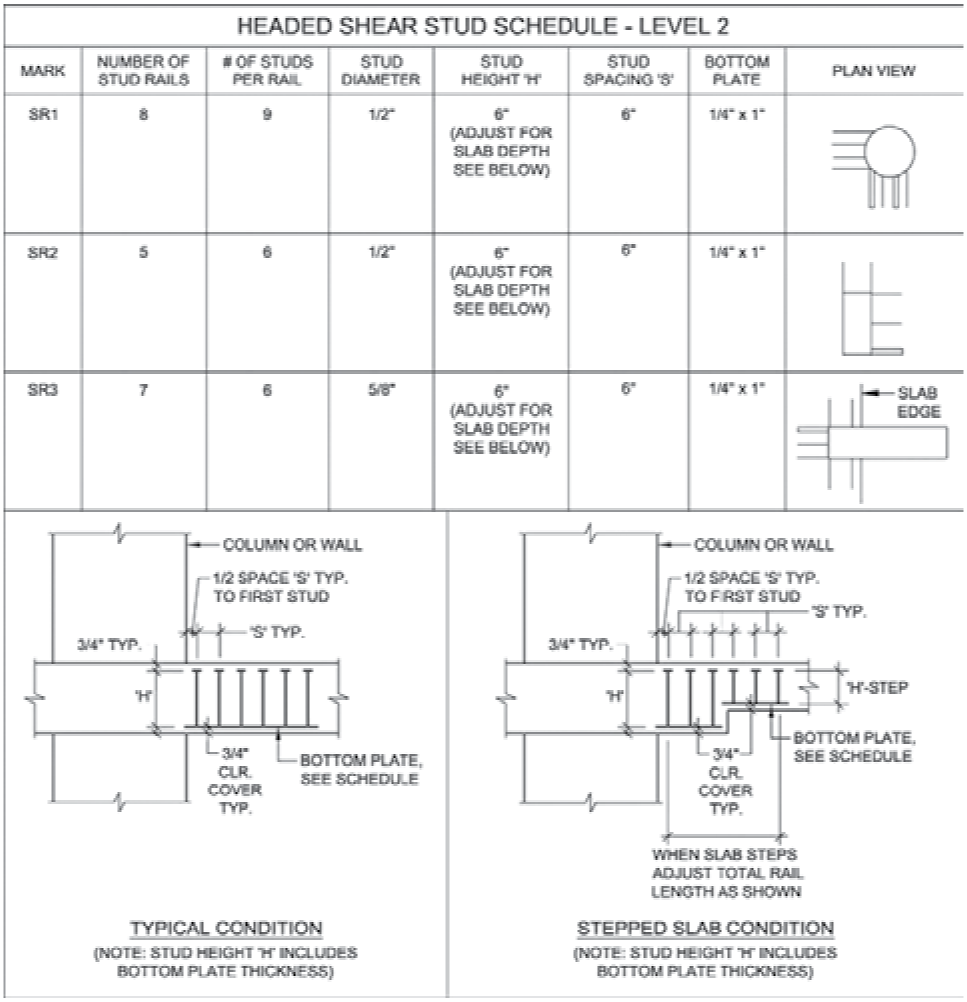


Fig. 4.10.1c—Typical column strip bottom integrity bars.

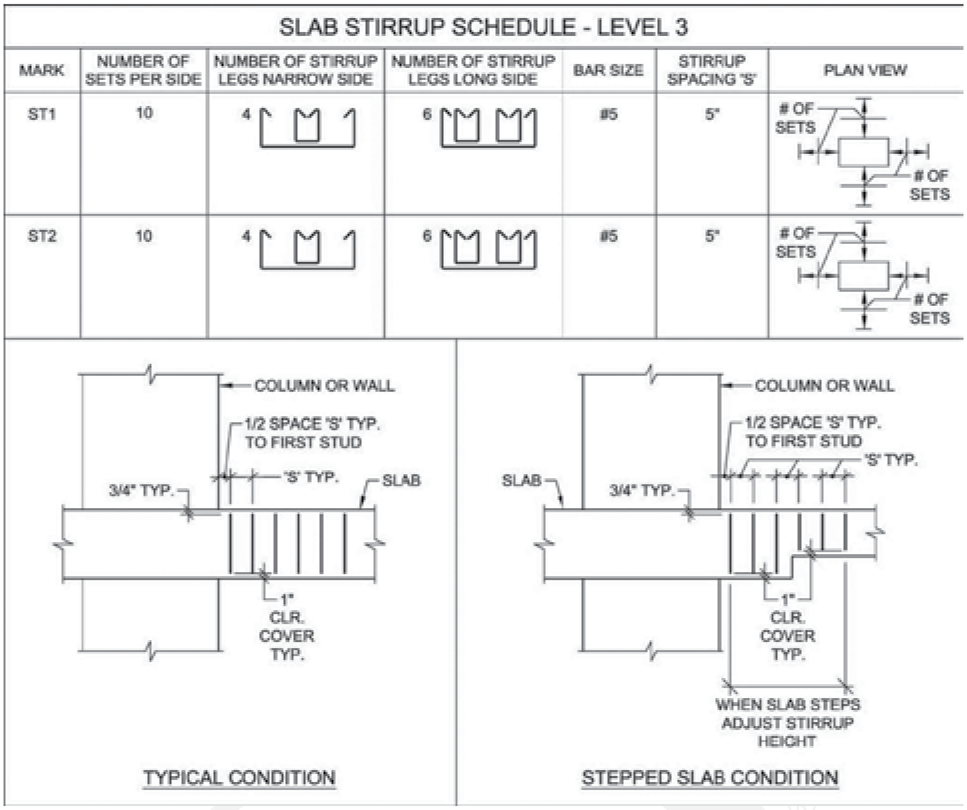


HEADED SHEAR STUD SCHEDULE - LEVEL 2

MARK	NUMBER OF STUD RAILS	# OF STUDS PER RAIL	STUD DIAMETER	STUD HEIGHT 'H'	STUD SPACING 'S'	BOTTOM PLATE	PLAN VIEW
SR1	8	9	1/2"	6" (ADJUST FOR SLAB DEPTH SEE BELOW)	6"	1/4" x 1"	
SR2	5	6	1/2"	6" (ADJUST FOR SLAB DEPTH SEE BELOW)	6"	1/4" x 1"	
SR3	7	6	5/8"	6" (ADJUST FOR SLAB DEPTH SEE BELOW)	6"	1/4" x 1"	SLAB EDGE

Fig. 4.10.1d—Headed shear stud schedule.

size and spacing of shear reinforcement (Fig. 4.10.3). Along with the column schedule, typical layout information for the column reinforcement from the bottom of one level to the bottom of the next or the top of the column, is often shown in section cuts or diagrams. These diagrams should show splice locations, including locations of staggered splices and reinforcement termination requirements. Often, spacing of the shear reinforcement at the tops and bottoms of columns varies and shown in a typical diagram on the column schedule sheet. If applicable, the following diagrams also should be included with the column schedule: basic transi-



SLAB STIRRUP SCHEDULE - LEVEL 3

MARK	NUMBER OF SETS PER SIDE	NUMBER OF STIRRUP LEGS NARROW SIDE	NUMBER OF STIRRUP LEGS LONG SIDE	BAR SIZE	STIRRUP SPACING 'S'	PLAN VIEW
ST1	10	4	6	#5	5"	# OF SETS # OF SETS
ST2	10	4	6	#5	5"	# OF SETS # OF SETS

Fig. 4.10.1e—Shear stirrup schedule.

Grade beam schedule

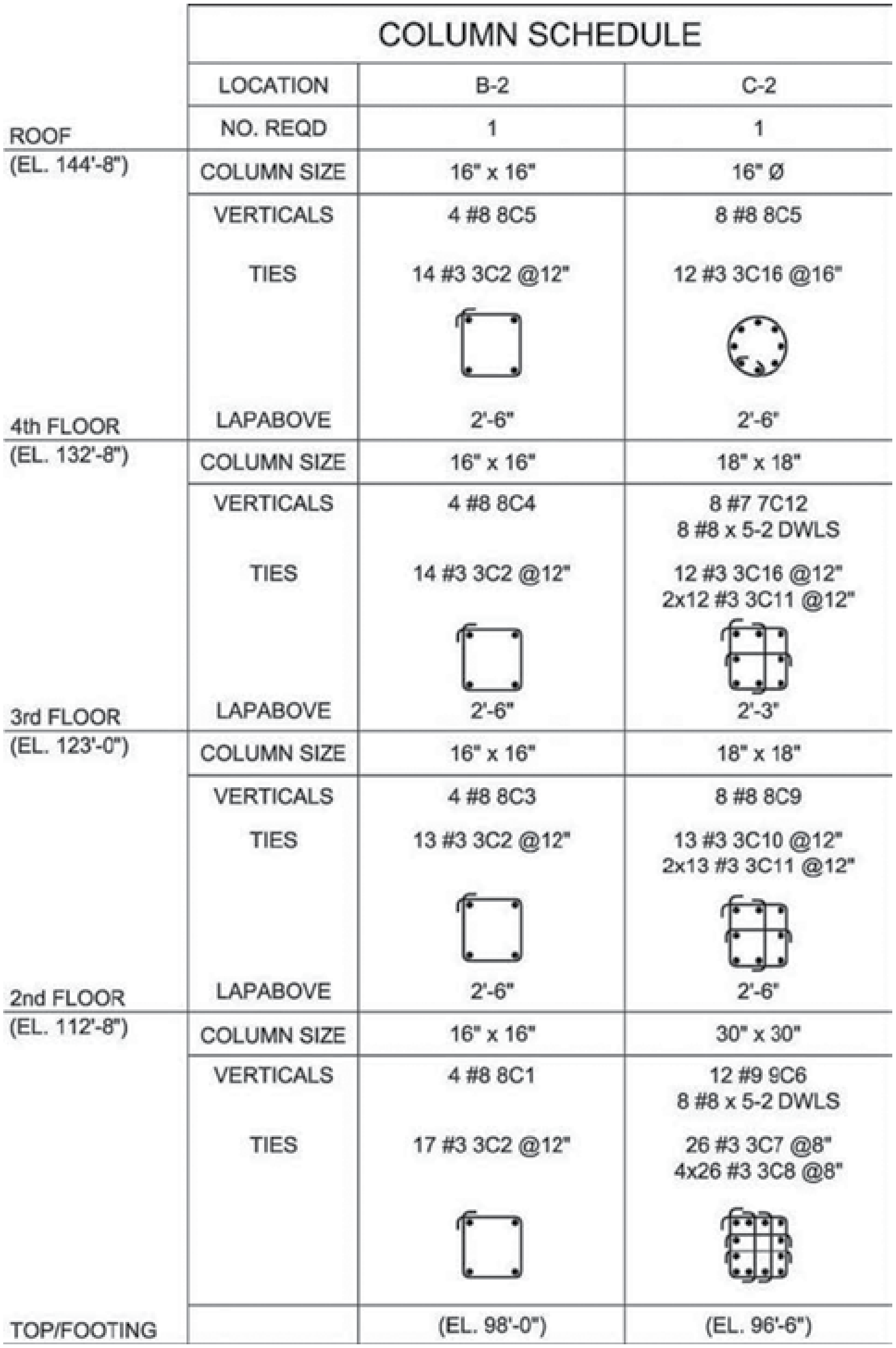
Mark	Size (in.) *b* x *h*	Reinforcing			Stirrups each end	Remarks
		Top bars	Bott. bars	Mid bars	Size & spacing	
GB1	30 x 42	(8) #10	(6) #7	(2) #5 E.F.	#4 @ 18 in. o/c	
GB2	48 x 36	(10) #8	(8) #8	(1) #5 E.F.	#4 @ 16 in. o/c	
GB3	24 x 36	(6) #9	(6) #9	(1) #5 E.F.	#4 @ 16 in. o/c	
GB4	24 x 36	(4) #9	(4) #9	(1) #5 E.F.	#4 @ 16 in. o/c	
GB5	24 x 30	(3) #6	(4) #8	(1) #5 E.F.	#4 @ 12 in. o/c	
GB6	30 x 36	(4) #8	(7) #8	(1) #5 E.F.	#4 @ 16 in. o/c	
GB7	24 x 28	(5) #8	(4) #5	(1) #5 E.F.	#4 @ 12 in. o/c	
GB8	34 x 28	(2) #6	(4) #6	(1) #5 E.F.	#4 @ 12 in. o/c	
GB9	24 x 16	(4) #6	(4) #9	-	#4 @ 12 in. o/c	

Fig. 4.10.2—Example grade beam schedule.

tion from floor-to-floor, offset transitions, sloped transitions, and top of column terminations.

4.10.4 *Wall schedules*—Wall schedules usually contain the wall mark and amount of vertical and horizontal reinforcement for each curtain of reinforcement required.

Along with the wall schedule, typically there will be a diagram of the wall from the bottom of the wall to the top of the wall, sometimes with section cuts showing the layout information for the wall reinforcement. These diagrams should show splice locations, including locations of staggered splices if necessary. Placing location of the rein-



COLUMN SCHEDULE

	LOCATION	B-2	C-2
ROOF (EL. 144'-8")	NO. REQD	1	1
	COLUMN SIZE	16" x 16"	16" Ø
	VERTICALS	4 #8 8C5	8 #8 8C5
	TIES	14 #3 3C2 @12"	12 #3 3C16 @16"
4th FLOOR (EL. 132'-8")	LAPABOVE	2'-6"	2'-6"
	COLUMN SIZE	16" x 16"	18" x 18"
	VERTICALS	4 #8 8C4	8 #7 7C12 8 #8 x 5-2 DWLS
	TIES	14 #3 3C2 @12"	12 #3 3C16 @12" 2x12 #3 3C11 @12"
3rd FLOOR (EL. 123'-0")	LAPABOVE	2'-6"	2'-3"
	COLUMN SIZE	16" x 16"	18" x 18"
	VERTICALS	4 #8 8C3	8 #8 8C9
	TIES	13 #3 3C2 @12"	13 #3 3C10 @12" 2x13 #3 3C11 @12"
2nd FLOOR (EL. 112'-8")	LAPABOVE	2'-6"	2'-6"
	COLUMN SIZE	16" x 16"	30" x 30"
	VERTICALS	4 #8 8C1	12 #9 9C6 8 #8 x 5-2 DWLS
	TIES	17 #3 3C2 @12"	26 #3 3C7 @8" 4x26 #3 3C8 @8"
TOP/FOOTING		(EL. 98'-0")	(EL. 96'-6")

Fig. 4.10.3—Example column schedule.

forcement should be clearly shown, such as VEF (Vertical Each Face), HIF (Horizontal Inside Face), HOF (Horizontal Outside Face), HFF (Horizontal Far Face), and HNF (Horizontal Near Face). Where not clear, inside and outside faces of walls should be identified on the drawings.

4.11—Foundation sheets and schedules

Foundations are sometimes treated separately from the remainder of the structural systems because of their unique characteristics and the fact that foundation systems are used for many superstructure types. Foundation drawings can be issued separately from the superstructure drawings, or could be the only reinforced concrete drawings on a project. Foundation sheets are commonly used for shallow foundations (Fig. 4.11) such as strip footings, isolated footings, combined footings, mat foundations, and grade beams. Foundation sheets are also used for deep foundation systems, including pile caps, piles, drilled piers, and caissons.

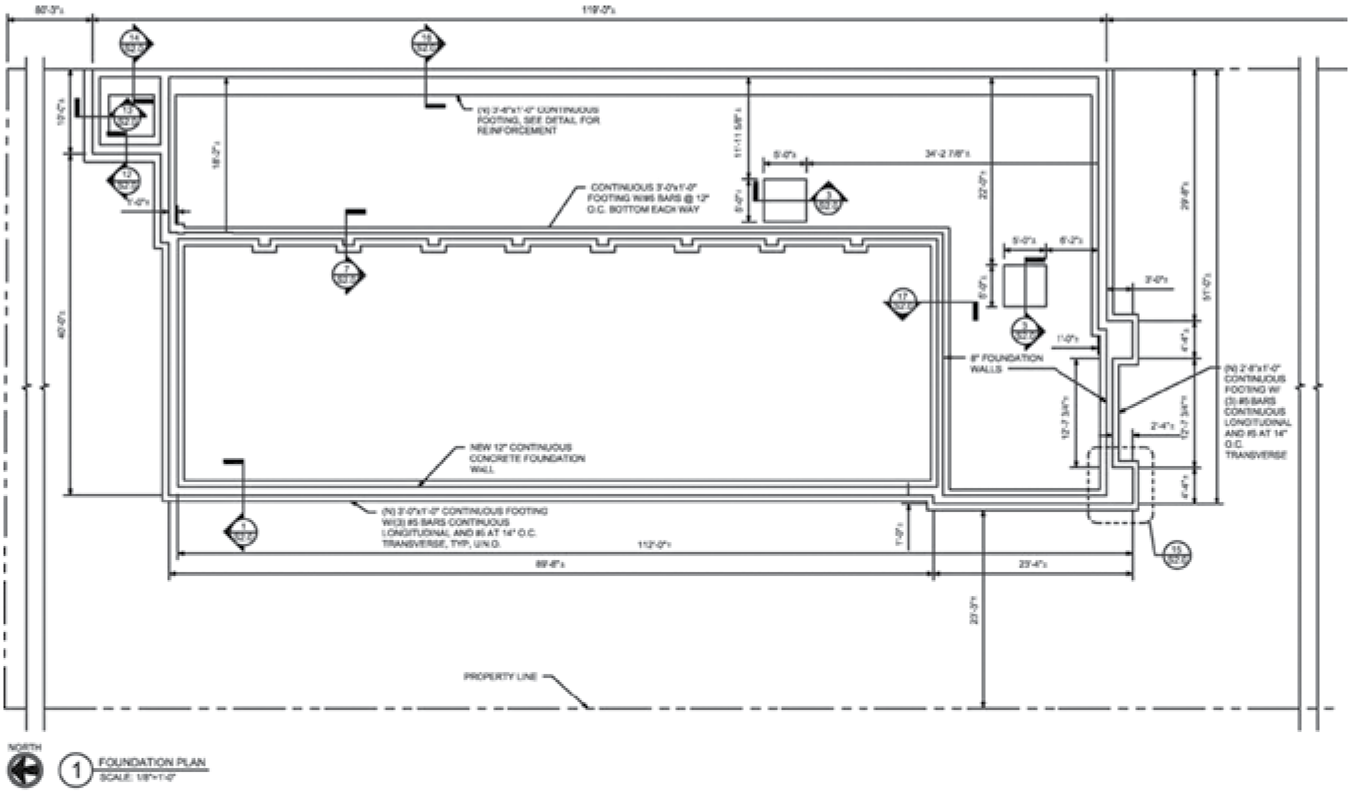


Fig. 4.11—Foundation plan drawing.

Foundation drawings can show foundation members with the reinforcement individually indicated or shown in a schedule. In a schedule, the member is identified by a letter or letters and a number. For example, P1 is usually related to a pile cap, F1 to a shallow footing, and GB1 to a grade beam. An Abbreviation and Notation Legend should always be included in the drawing sheet for clarity and ease of identification. Grade beam schedules are similar to elevated beam schedules; guidelines regarding beam schedules are shown in 4.10.2. Pile cap schedules should include dimensions of the pile cap and the required reinforcement in each one. Footing schedules are usually similar, with the schedule containing footing dimensions and the required reinforcement in each direction. Drilled piers are often not scheduled by mark, but by shaft and bell diameters. The schedule should include a listing of vertical reinforcement, tie reinforcement, and minimum distance that the reinforcement should extend into the top of the pier.

Each type of foundation element on the project should have a corresponding typical diagram that is referenced from the schedule. This typical diagram will show a typical layout of the member with typical locations of the reinforcement inside of it.

Although shear reinforcement in a foundation is not frequently used, when it is used, the design detail is presented in a manner similar to a beam. When stirrups are used for shear reinforcement, they should be shown on the foundation schedule and a separate detail or section considered.

4.12—User-defined sheets

User-defined sheets show information that is not presented on other sheets.

4.13—Three-dimensional representations

Although three-dimensional representations or isometric sketches are not commonly used, they can be helpful to show an especially complicated connection or joint, or to coordinate among different disciplines to prevent clashes among different systems

CHAPTER 5—DESIGNING FOR CONSTRUCTABILITY

Reinforcing steel design and detailing should conform to ACI 318-14. Minimum spacing of reinforcement should be in accordance with Section 25.2. Standard hook geometry should be in accordance with Section 25.3. Development lengths and splices of deformed reinforcement should be in accordance with Sections 25.4 and 25.5 respectively.

Code requirements often refer to minimum or maximum values. Good design practice should generally strive to avoid the indiscriminate use of minimum code values without considering constructability. For example, avoid or reduce constructability issues due to interference between overcrowding of steel reinforcement and loss of concrete cover or spacing problems between reinforcing bars due to incremental tolerance buildup. The licensed design professional (LDP) should render the design clearly. Clarity will assist the detailer and contractor in correctly interpreting the design intent. These considerations will help the process of producing good detailing for construction.

Design information can be represented with typical details, sections, or schedules containing the specific information for bar diameters, spacing, clearances and dimensions, construction and expansion joint locations, lap locations, and schedules. As reinforcement placement is essential to the strength of the structural members, a generic statement for reinforcement clearance might not be applicable in all cases. Therefore, critical clearances should also be shown on details when applicable so the LDP's intent is conveyed and followed. The LDP should minimize the use of multiple bar sizes when possible for ease of fabrication and placing. As this is not always achievable, the LDP should avoid specifying bar sizes less than 1/4 in. apart in diameter in a single element. Hook lengths and sizes that are different than standard hooks as defined by ACI 318-14 Section 25.3 should be specifically noted on the construction documents. Hook lengths not specified will be assumed to be standard hooks.

Clarity in identifying the different concrete and masonry elements and their corresponding reinforcement is important for the fabrication detailer to correctly detail the reinforcement in the placing drawings.

5.1—Defining requirements for concrete cover, clearance, development, and splices

During the process of preparing the detail drawings for a project, the reinforcing steel detailer performs many calculations. These calculations fall into two general categories. The first category includes calculations made for reinforcing steel quantities, lengths, and bending dimensions based on design requirements presented in the design drawings through typical specific sections, details, or both. These types of calculations generally fall under the responsibility of the reinforcing steel detailer. The second category includes calculations made from design data for dimensions such as concrete cover, development lengths, lap splice lengths, and hook lengths. These dimensions are particularly critical because they directly affect the integrity of the structure. These types of calculations are the responsibility of the LDP, should be completed and clearly presented in the design drawings, and should not be passed on as a responsibility of the reinforcing steel detailer.

5.1.1 *Calculations for reinforcement made by the reinforcing steel detailer*—Reinforcing steel detailers should review and understand all design requirements that are presented in the design documents so the reinforcing bars can be detailed correctly in terms of bar size, length, bending dimensions, quantity, and placement/location within each concrete element. If conflicting or missing information is identified, reinforcing steel detailers should ask questions or request clarifications via the request for information (RFI) process, or ask questions on the placing drawings that are submitted for approval.

The LDP may consider reviewing the quantities and bar spacings presented on the placing drawings for reasonableness and general conformance with the structural design.

5.1.2 *Calculations for reinforcement made by the LDP*—The LDP can reduce the amount of complex or critical calculations reinforcing bar detailers are required to make. For especially complex calculations or calculations requiring design data, the LDP can also consider presenting the calculated data on their design documents. For instance, a reinforcing bar detailer should not be expected to determine if a lap splice qualifies as Class A or Class B based on analyzing the ratio of the area of bars provided versus the area of bars required. In this case, the basis for calculation is only known by the LDP. Calculations such as this should be handled while completing the design, and presented clearly on the design documents in an effort to reduce the number of RFIs, speed up both the detailing and review process, and reduce the risk of error.

5.1.3 *Concrete cover*—The building code considers concrete cover to be a critical element of the structure. The design drawings should clearly enumerate the design required cover. Parametric cover requirements or delegating the assessment of particular environmental judgments to the nonprofessional should be avoided.

5.1.4 *Construction and expansion joints*—When construction and expansion joints are not specifically shown on the contract documents, the LDP should give guidance for construction and expansion joint locations and spacing, and should review joint locations provided by contractor for compliance.

5.2—Defining bar placing configuration

5.2.1 *Staggered laps*—General notes should never just state, "Stagger all laps." Staggering laps can add extra costs to a project in terms of detailing, greater number of different bar lengths, and placing. The LDP should note possible exceptions, such as for temperature steel and horizontal steel in walls.

The design documents should clearly indicate the type of stagger, such as if the stagger is a single or double lap length, or a specified dimension between the laps. A detail such as shown in Fig. 5.2.1 is a good way to show intent. Lap locations should be clearly indicated, as should those areas where laps are not allowed. Staggering of mechanical splices should be equally defined and indicated.

5.2.2 *Lap splice and development length tables*—Tables of lap splice and development length requirements are usually sufficient for most situations. Take care to clearly indicate special embedment locations development and appropriate instructions given to ensure they are correctly placed. The LDP should provide an appropriate table on the drawings. Examples are shown in Fig. 5.2.2.

5.2.3 *Bar dimensioning*—The most common bar dimensioning issue involves hooks. When the LDP indicates a dimension of a hooked bar on the drawing it should clearly indicate in the general notes or on the drawing if the dimension includes the hook length.

Reinforcing bar detailers will assume that all hooks are standard hooks unless indicated otherwise. Often, drawing sections of raft footings show the bottom and top bars hooked and lapping. If standard hooks are detailed there will

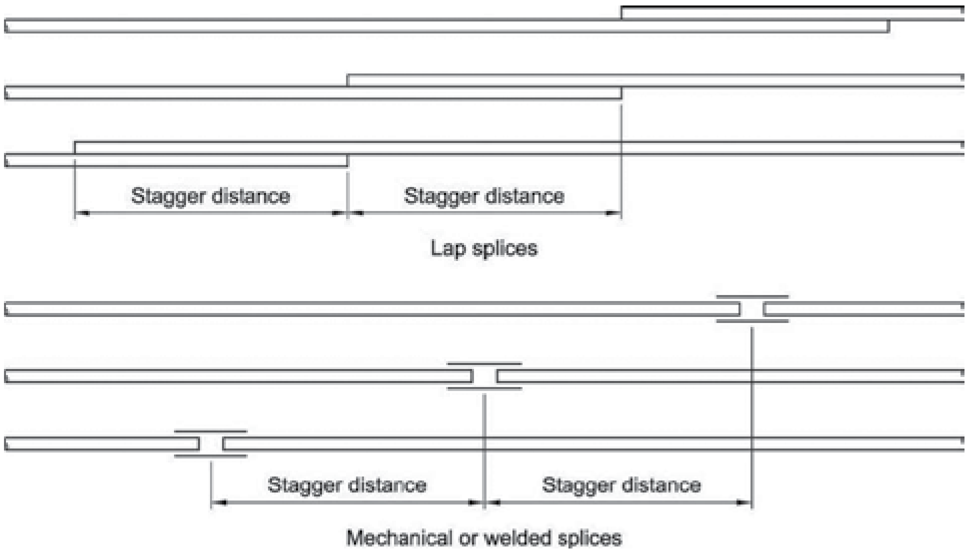


Fig. 5.2.1—Staggered lap splices and staggered mechanical splices.

be no lap. The design drawings should clearly indicate if a lap is intended and if so, dimension the lap (Fig. 5.2.3).

Where standard hooks would be too long to fit within the concrete member, the desired hook should be clearly dimensioned on the drawing.

5.2.4 *Skewed bars*—In plan views of trapezoidal-shaped slabs, the LDP should clearly indicate if the main bars are perpendicular to the parallel sides or parallel to the sloped sides (Fig. 5.2.4). Also indicate if the spacing of the bars is measured at right angles to the main bars or along the skew. These points should also be made clear for triangular or other irregular-shaped slabs.

Top steel over beams in skewed slabs can conflict with top bars from adjacent regular-shaped slabs and could cause layering and clearance problems. These conditions should be considered and addressed by the LDP.

5.2.5 *Termination of vertical bars*—The design drawings should always indicate how vertical bars are to be terminated. If the bars are to be hooked, there are several considerations as follows:

(a) If the hook is not a standard hook, the length should be indicated

(b) If the hook is located in either of the top layers or beneath both layers

(c) If the member into which the hook is to be embedded is sufficiently deep enough to accommodate the curvature of the bend

(d) If the direction of the hook is critical, it should be clearly indicated.

If nothing is indicated, hook direction will not be noted on the shop drawings and will likely be placed based on other field constraints. Member intersections can require additional consideration of bar interferences.

5.2.6 *Beam stirrups*—On a beam schedule, it should be clear whether a stirrup callout—for example, 3 @ 6 in.; 5 @ 9 in.; rem @ 12 in. (3 @ 150 mm; 5 @ 225 mm; rem @ 300 mm)—is referring to the number of stirrups or the number of spaces. If spacing of the first stirrup from a support is critical, it should be indicated, otherwise it will be located one-half space from the face of support.

In multiple tie sets, indicate if these are to be a series of nested stirrups or a series of interlocking stirrups. If open stirrups are indicated, if possible, try to provide a continuous top bar in each stirrup hook. Consider a greater quantity of smaller longitudinal bars rather than fewer larger bars.

In very narrow beams, determine if the stirrup hooks will allow the top bars to fit within the tie. If critical, indicate if longitudinal bars are to be lapped in a vertical or horizontal plane. At intersecting beams, indicate if the stirrups run through one beam or the other, or through both beams.

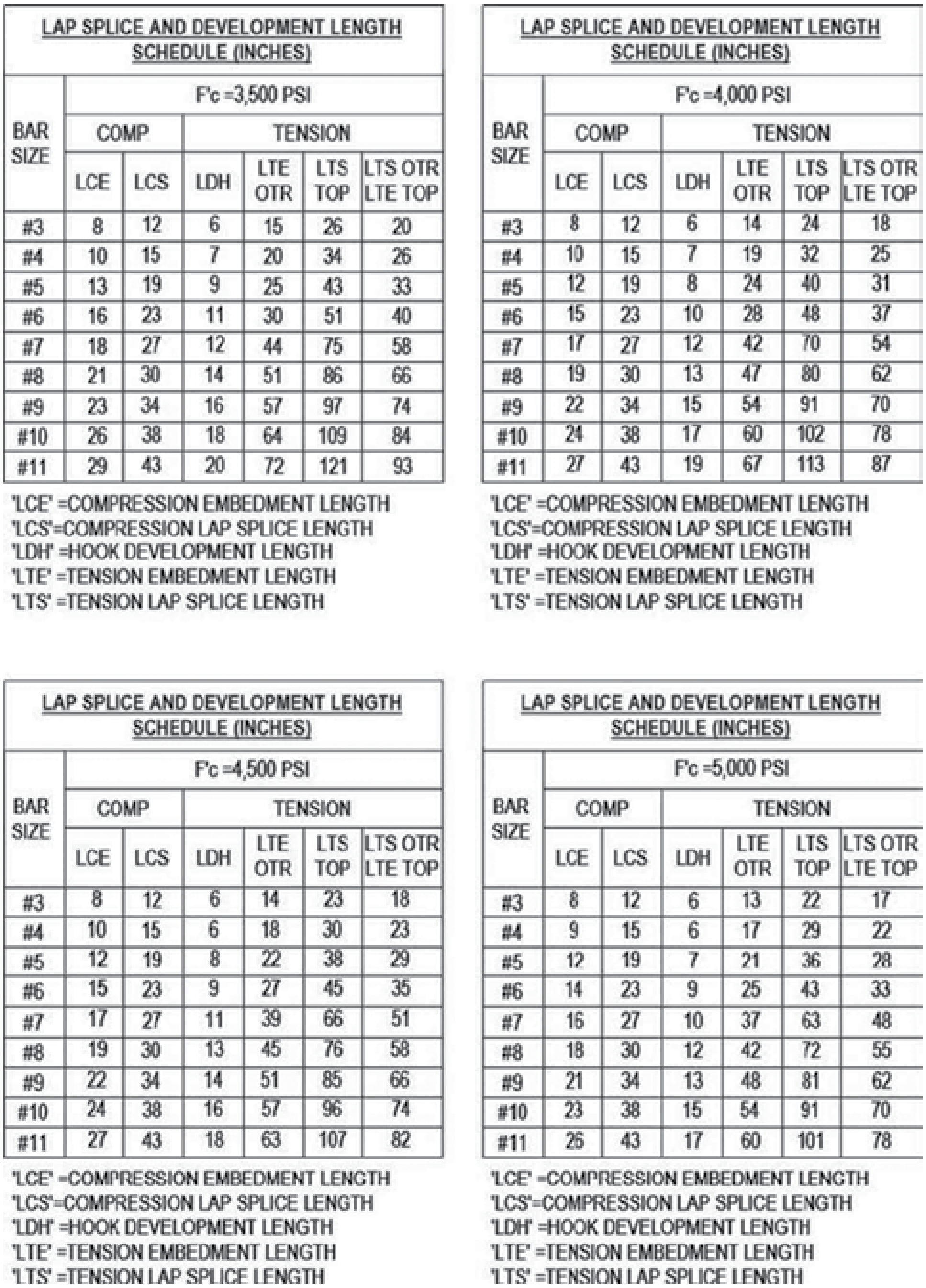
5.3—Foundations

This section applies to nonprestressed steel reinforcement of shallow and deep structural foundations as defined by ACI 318-14 Chapter 13 and includes piles, drilled piers, and caissons as further discussed in ACI 336.3R and ACI 543R. Refer to Section 5.5 of ACI 543R-12 for the supplemental details of deep foundations in structures assigned to Seismic Design Categories D, E, and F as prescribed by ACI 318-14 Section 18.13.4.

5.3.1 *Types*—Generally, foundation systems are categorized as either shallow foundations or deep foundations. Shallow foundations include such types as strip footings; isolated, spread, or pad footings; mat foundations; and grade beams. Caps are typically shallow elements transferring load to deep foundations.

5.3.2 *Bar arrangements*—Bar arrangements vary widely based on both the foundation type and the lateral, gravity, and torsional loadings imposed on the foundations. The example reinforcing details described in this section are common arrangements. The LDP should specify appropriate bar arrangements for the various conditions.

Shallow foundations such as strip, isolated, and mat foundations often have a bar arrangement similar to that of a slab with a bottom mat, a top mat, or both bottom and top mat of reinforcement with bars in each direction. In some instances,



LAP SPLICE AND DEVELOPMENT LENGTH SCHEDULE (INCHES)

BAR SIZE	F'c =3,500 PSI					
	COMP		TENSION			
	LCE	LCS	LDH	LTE OTR	LTS TOP	LTS OTR LTE TOP
#3	8	12	6	15	26	20
#4	10	15	7	20	34	26
#5	13	19	9	25	43	33
#6	16	23	11	30	51	40
#7	18	27	12	44	75	58
#8	21	30	14	51	86	66
#9	23	34	16	57	97	74
#10	26	38	18	64	109	84
#11	29	43	20	72	121	93

'LCE' =COMPRESSION EMBEDMENT LENGTH
'LCS'=COMPRESSION LAP SPLICE LENGTH
'LDH' =HOOK DEVELOPMENT LENGTH
'LTE' =TENSION EMBEDMENT LENGTH
'LTS' =TENSION LAP SPLICE LENGTH

LAP SPLICE AND DEVELOPMENT LENGTH SCHEDULE (INCHES)

BAR SIZE	F'c =4,000 PSI					
	COMP		TENSION			
	LCE	LCS	LDH	LTE OTR	LTS TOP	LTS OTR LTE TOP
#3	8	12	6	14	24	18
#4	10	15	7	19	32	25
#5	12	19	8	24	40	31
#6	15	23	10	28	48	37
#7	17	27	12	42	70	54
#8	19	30	13	47	80	62
#9	22	34	15	54	91	70
#10	24	38	17	60	102	78
#11	27	43	19	67	113	87

'LCE' =COMPRESSION EMBEDMENT LENGTH
'LCS'=COMPRESSION LAP SPLICE LENGTH
'LDH' =HOOK DEVELOPMENT LENGTH
'LTE' =TENSION EMBEDMENT LENGTH
'LTS' =TENSION LAP SPLICE LENGTH

LAP SPLICE AND DEVELOPMENT LENGTH SCHEDULE (INCHES)

BAR SIZE	F'c =4,500 PSI					
	COMP		TENSION			
	LCE	LCS	LDH	LTE OTR	LTS TOP	LTS OTR LTE TOP
#3	8	12	6	14	23	18
#4	10	15	6	18	30	23
#5	12	19	8	22	38	29
#6	15	23	9	27	45	35
#7	17	27	11	39	66	51
#8	19	30	13	45	76	58
#9	22	34	14	51	85	66
#10	24	38	16	57	96	74
#11	27	43	18	63	107	82

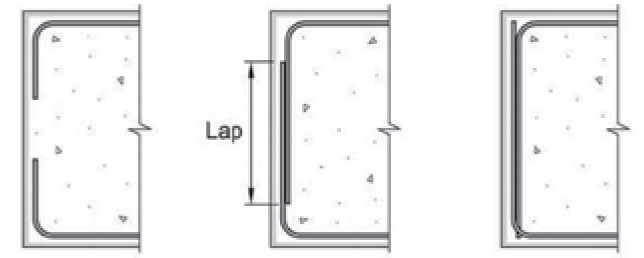
'LCE' =COMPRESSION EMBEDMENT LENGTH
'LCS'=COMPRESSION LAP SPLICE LENGTH
'LDH' =HOOK DEVELOPMENT LENGTH
'LTE' =TENSION EMBEDMENT LENGTH
'LTS' =TENSION LAP SPLICE LENGTH

LAP SPLICE AND DEVELOPMENT LENGTH SCHEDULE (INCHES)

BAR SIZE	F'c =5,000 PSI					
	COMP		TENSION			
	LCE	LCS	LDH	LTE OTR	LTS TOP	LTS OTR LTE TOP
#3	8	12	6	13	22	17
#4	9	15	6	17	29	22
#5	12	19	7	21	36	28
#6	14	23	9	25	43	33
#7	16	27	10	37	63	48
#8	18	30	12	42	72	55
#9	21	34	13	48	81	62
#10	23	38	15	54	91	70
#11	26	43	17	60	101	78

'LCE' =COMPRESSION EMBEDMENT LENGTH
'LCS'=COMPRESSION LAP SPLICE LENGTH
'LDH' =HOOK DEVELOPMENT LENGTH
'LTE' =TENSION EMBEDMENT LENGTH
'LTS' =TENSION LAP SPLICE LENGTH

Fig 5.2.2—Development and lap splice table.



Terminated with standard hooks

Terminated with lapped hooks

Terminated with full depth hooks

Fig. 5.2.3—Possible hook configurations at edge of raft footing.

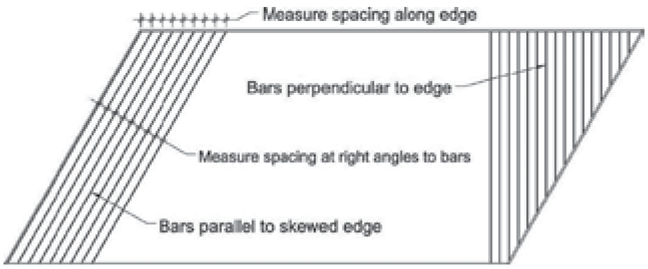


Fig. 5.2.4—Skewed slab.

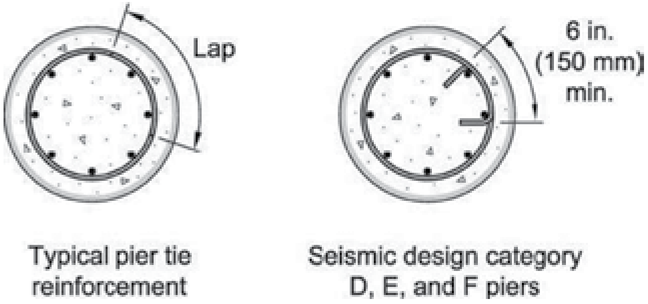


Fig. 5.3.2—Pier tie arrangements.

the bars can be required to be hooked at ends for development as prescribed by the LDP.

Grade beams and tie beams sometime span between foundation elements such as pile caps. Grade beams usually project above grade to support walls; tie beams are usually below grade and spread lateral loads to multiple deep foundations. Grade beams and tie beams have two primary reinforcement arrangements. The first is similar to a beam with reinforcing ties or stirrups, top and bottom longitudinal steel, and in some cases side longitudinal steel. The second arrangement is still similar to a beam; however, it might only have top and bottom reinforcement. Ties in the second arrangement may only be required for constructability as a method to support the top reinforcement.

Deep foundations are often round and have a bar arrangement similar to that of a round column with circular ties or a spiral around the perimeter and longitudinal steel spaced around the perimeter inside the tie. Smaller drilled piers might only have longitudinal steel that is centered in the drilled pier. In these cases, reinforcement can be added for constructability to keep the reinforcement centered in the shaft. Although reinforcement in piers is similar to that of columns, it is not fully prescribed by ACI 318 and, therefore, is often excluded from the ACI 318-14 Section 25.7.2.4.1 requirement for standard hooks at the ends of ties, except for the case of piers in Seismic Design Categories D, E, and F. Refer to Fig. 5.3.2 of this guide.

5.3.3 *Bar supports*—Special consideration should be given to mat foundations. Top steel support systems are commonly designed by the contractor, bar fabricator, or bar placer. Support systems for concrete foundations 4 ft (1.2 m) or more in depth should be approved by a licensed professional engineer. The supports should carry the weight of the steel and the forces created by movement of the concrete crew and others walking on the top mat. Contractors can request the use of WWR for worker safety on slabs and mat foundations, if a foot could slip between bars and fall 2 ft or more. At times, workers may have to work between the bottom and top mats. Bottom reinforcement of elements cast against the earth is usually supported on concrete or concrete blocks known as “dobies.”

Support systems can vary from simple standees to elaborate structural frames. Design of the support system should consider that the support/top mat structure is not freestanding, but requires lateral support by the formwork. The formwork for a thick mat foundation has been designed to withstand the lateral forces of a significant head of fresh concrete. While the vertical load of the top mat is significant, the lateral forces generated within the formwork are relatively small. Plastic or concrete spacers can secure the top mat against the formwork. The need for the formwork to restrain lateral movement of the support/top mat structure should be coordinated with the formwork engineer.

5.3.4 *Layering*—The direction of reinforcing steel layers in foundations primarily only applies to shallow foundations because grade beams are typically reinforced, similar to beams and deep foundations are typically reinforced similar to columns as noted in 5.3.2. For strip footings, the layering might be with transverse bars bottom-most for flexural strength, but for construction efficiency in placing reinforcement, it is better to locate the longitudinal bars bottom-most. Isolated pad footing layering most often depends on the geometry of the pad footing. For square pad footings, layering can go either way. For rectangular pad footings, reinforcement along the larger dimension usually runs in the bottom and top outer layers, and the reinforcement along the shorter dimension runs inside of the outer layers. For thick mat foundations not supported by deep foundations, the layering will be similar to that of rectangular pad footings. The cases discussed previously are typical layering conditions for foundations; however, each is also dependent on the design of the foundation. Always refer to the contract documents for specific requirements. Contract documents should specifically note the layering arrangement when it is critical to the design.

All reinforcement layering should be properly supported to keep the reinforcement at the correct location in the element.

5.4—Walls

ACI 318-14 Section 2.3 defines a wall as “A vertical element designed to resist axial load, lateral load, or both, with a horizontal length-to-thickness ratio greater than 3, used to enclose or separate spaces.” Concrete walls are structural elements that are generally used as vertical- and lateral-force-resisting members. Walls may be used in underground or aboveground tanks to contain liquids, as retaining walls, or for providing one-sided lateral confinement for soil or other materials, and for providing continuous support for floor or roof systems, in which case they should absorb and resist all reactions from these systems.

This section applies to steel reinforcement of nonprestressed ordinary structural walls, including: cast-in-place, precast in-plant and precast on-site, and tilt-up construction as defined in ACI 318-14 Chapter 11.

5.4.1 *General*—Steel reinforcement should be provided in walls to resist all in-plane and out-of-plane forces acting on ordinary structural walls, as shown in Fig. 5.4.1 of this guide (ACI 318-14 Chapter 11). Walls subjected to these forces will require longitudinal and transverse reinforcement, as well as additional reinforcement around openings. Design requirements are contained in ACI 318-14 Sections 11.3, 11.4 and 11.5.

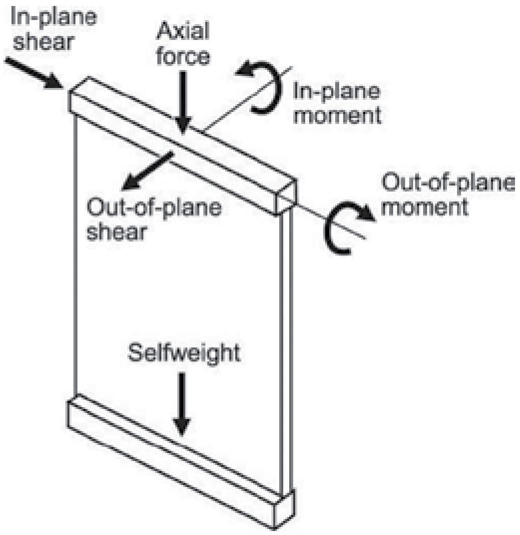


Fig. 5.4.1—In-plane and out-of-plane forces (ACI 318-14).

Cantilever retaining walls should be designed in accordance with ACI 318-14 Sections 22.2 through 22.4 with minimum horizontal reinforcement in accordance with Section 11.6.

5.4.2 *Reinforcement design considerations (ACI 318-14)*—Reinforcement limits for vertical and horizontal bars are indicated in Sections 11.6.1 and 11.6.2 for relative values of V_u (factored shear force). General bar design details should conform to Section 11.7. Concrete cover for reinforcement should conform to Table 20.6.1.3.1. Development lengths and splice lengths of reinforcement should be in accordance with Sections 25.4 and 25.5, respectively. Distribution and spacing of transverse and longitudinal reinforcement should conform to Sections 11.7.2 and 11.7.3. In ordinary structural walls, if longitudinal reinforcement is required for axial strength, or if A_{st} exceeds $0.01A_g$, longitudinal reinforcement should be laterally supported by transverse ties. In all walls, reinforcement is required around wall openings (ACI 318-14 Section 11.7.5).

5.4.3 *Best practices*—For constructability purposes as shown in Fig. 5.4.3, reinforcement on both faces of a wall should be equally spaced; or that spacing of bars on one face be a multiple of the bars on the other face; or that spacing of bars at each face be multiple of a common value, for example: 2, 3, or 4 in., (50, 75, or 100 mm). These practices facilitate formwork tie locations and installation.

For constructability, transverse or horizontal reinforcing bars are often placed closest to wall face and conform to cover limits mentioned in ACI 318-14 Table 20.6.1.3.1. Trim reinforcement is required in both directions around openings as well as diagonally at the corners of openings. As a rule of thumb, trim bars should be at least equal in area to the bars interrupted by the openings, and consist of at least two No. 5 (No. 16) bars, anchored to develop f_y in tension.

5.4.3.1 *Footing to wall connections*—In cantilever retaining walls, vertical projecting reinforcement should extend through the depth of the wall footing and be anchored on top of the footing bottom reinforcement. The footing thickness should be such as to permit the vertical reinforcing bar standard hooks to be correctly anchored a distance ℓ_{dh}.

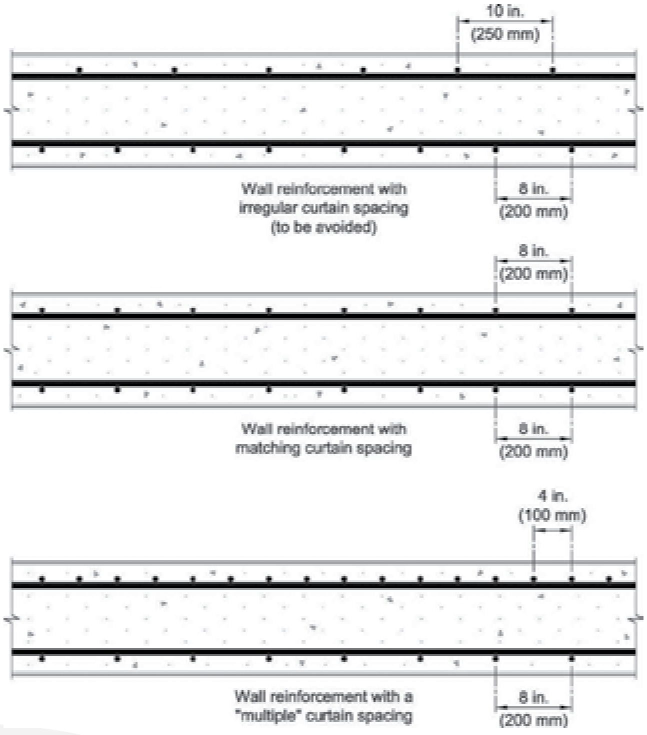


Fig. 5.4.3—Various spacing arrangements.

5.4.3.2 *Corners and intersections*—As shown in Fig. 5.4.3.2a, horizontal wall reinforcement should be anchored in vertical wall corners and intersections. To achieve proper anchorage, the bar should be extended across the intersection so that the end hook will be placed at the opposite (outer) face of the intersecting wall at corners and T-intersections.

Occasionally, additional diagonally placed horizontal reinforcement (Fig. 5.4.3.2b) is necessary to resist shear forces and help avoid opening of cracks at the corner or intersection. The additional bar is usually accommodated in a corner filet and should extend to the opposite face of each intersecting wall, terminating with a bar bend at least equal to the bar development length (ℓ_d).

A typical design detail of the correct bar arrangement at wall corners and midlength intersections will clarify the design intent. This information will help the detailer provide correct dimensioning and placing of reinforcing bars and avoid errors that could compromise the structural integrity of the walls.

5.4.3.3 *Steps and sectional transitions*—Steps and sectional transitions at base of walls should have design details showing the transitional reinforcement. Steel reinforcement across wall steps or sectional transitions should comply with ACI 318-14 Chapter 25. Attention should be given to providing continuous and correctly anchored reinforcement across any section change.

5.4.3.4 *Multiple curtains and layers*—Generally, walls are reinforced with a single curtain with two layers of steel at right angles to each other, or with two curtains of steel, one on each face, with each curtain consisting of two layers of

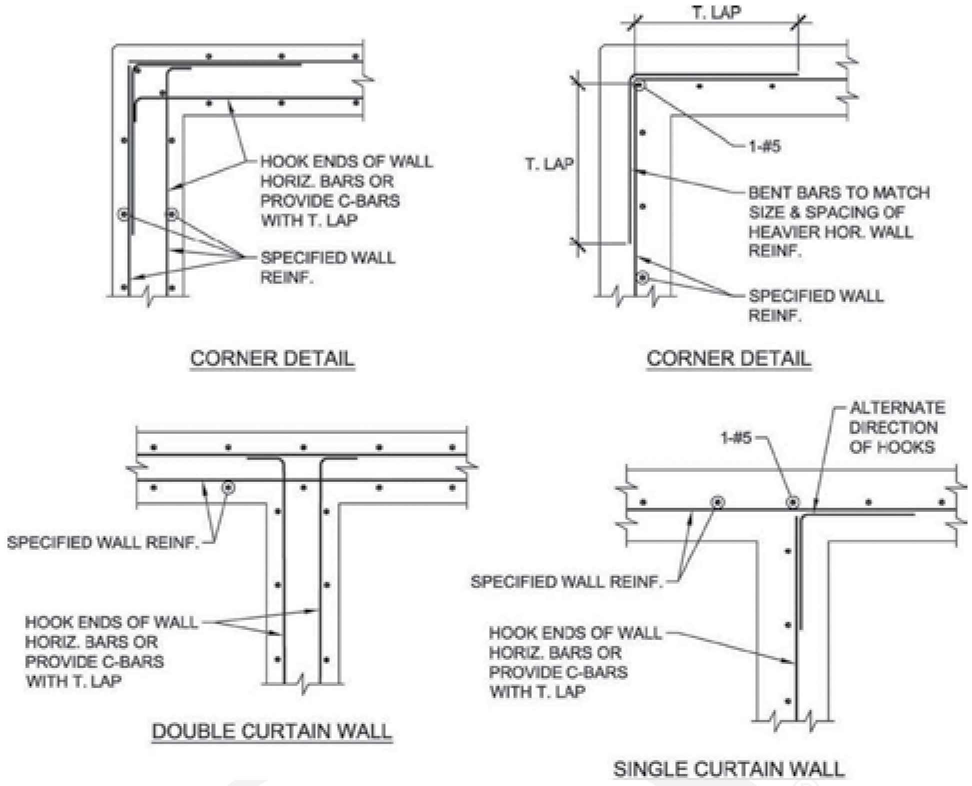


Fig 5.4.3.2a—Wall corner and intersection details.

steel at right angles to each other. Sometimes a curtain is made up of more than the usual two layers. In Fig. 5.4.3.4, Curtain A has the usual two layers of steel—one vertical, and one horizontal. Curtain B has three layers—two vertical and one horizontal. Curtain C has four layers of steel—two vertical and two horizontal.

When designing multiple layers of steel, such as in Curtains B and C, there are three considerations that will help to avoid concrete consolidation problems around and between the bars and the form:

(a) Place the larger bars in the outer layers of the member

(b) Space bars at the same dimension or multiples of that dimension in all layers

(c) Use only one bar size in a given layer

Frequently, designing curtains with more than the usual two layers of steel will cause spatial problems that affect clearances and constructability. Attention should be given to potential problems that can occur at wall corners and when staggering laps. The designer should consider using larger bar sizes, higher-strength steel, closer spacing, bundled bars, or a combination of these to avoid the need for multiple layers of reinforcing bars. Space between parallel bars should be adequate for the maximum size aggregate used and a vibrator to be inserted between the bars for consolidating the concrete.

5.4.3.5 *Design details at joints and waterstops*—The design details for reinforcement continuity or termination at wall joints with or without waterstops should be provided.

Construction joints are vertical or horizontal joints that are intentionally created between two successive placements of concrete. Shear keys can be used to increase the shear resistance at the joint. If keys are not used, the surface of the first pour should be cleaned and roughened as required per the construction documents before the next concrete pour. Keys are commonly formed in the wall base to give the stem more sliding resistance. Wall reinforcement is placed continuously across the joint (Fig. 5.4.3.5a).

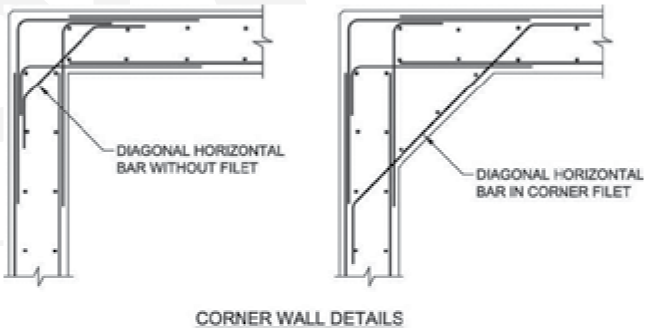


Fig 5.4.3.2b—Wall corner details.

Contraction joints are joints formed, sawed, or tool-grooved in a concrete structure to create a weakened plane to regulate the location of cracking resulting from the dimensional change of different parts of the structure. In walls, vertical contraction joints are usually about 1/4 in. (5 to 6 mm) wide and approximately 1/2 to 3/4 in. (12 to 20 mm) deep, and are provided at various intervals, depending on wall height, thickness, and amount of reinforcement, but usually not exceeding approximately 30 ft (9 to 10 m). Wall reinforcement is placed continuously across the joint (Fig. 5.4.3.5b).

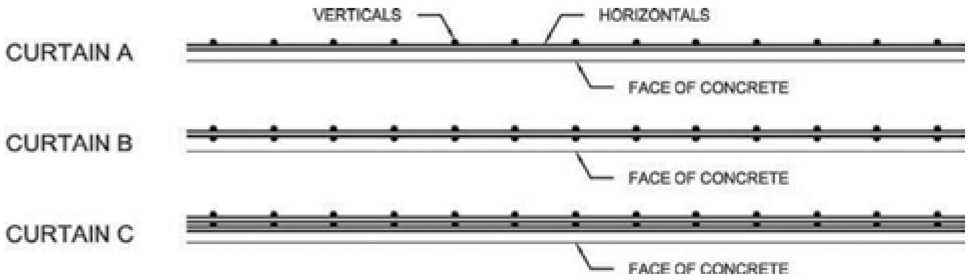


Fig. 5.4.3.4—Wall reinforcement curtain arrangements.

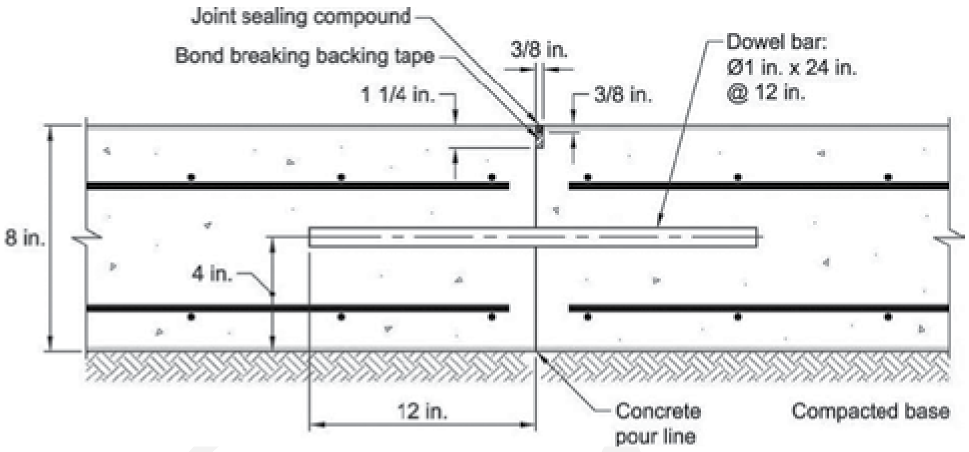


Fig 5.4.3.5a—Detail of a wall construction joint.

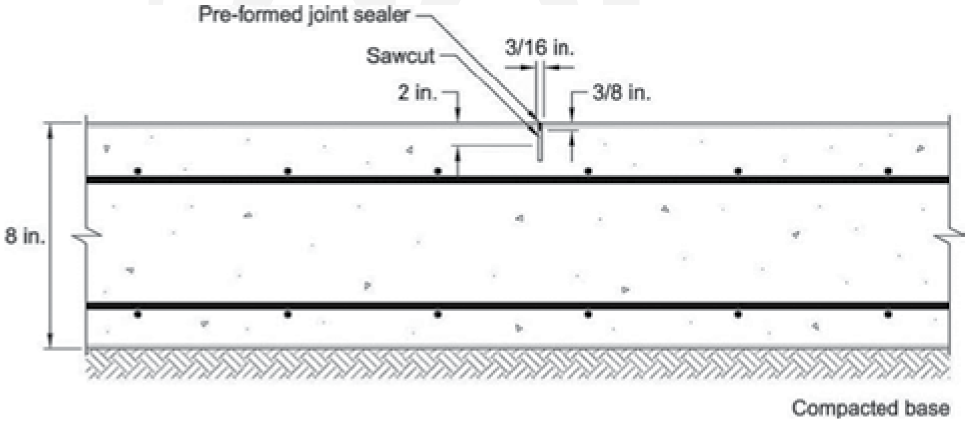


Fig 5.4.3.5b—Detail of a wall contraction joint.

Expansion joints are a separation provided between adjacent sections of a concrete structure to allow movement due to dimensional increases and reductions of the adjacent sections, and through which some or all the bonded reinforcement is interrupted. In walls, horizontal greased dowels are usually placed across vertical joints to tie adjacent sections together. Expansion joints are located at various intervals, depending on wall dimensions, but should not be spaced more than 75 to 90 ft (25 to 30 m) apart. Wall reinforcement is discontinuous across the joint, not placed across the joint but rather terminated at each joint face (Fig. 5.4.3.5c).

Waterstops are thin sheets of metal, rubber, plastic, or other material inserted across a joint to obstruct the seepage of water through the joint. They should be embedded equally in each side of the joint. There are various sections that can be used for the different types of joints named previously. In addition to molded waterstops that are embedded in concrete across the joint, there are adhesive-type waterstops that do not interfere with the reinforcement. These are strips of rubber and mastic that adhere to the surface of set concrete. The next placement of concrete compresses the rubber strip to form a watertight seal between the two placements of concrete. Steel reinforcement design details should be developed with consideration of the waterstop to be used in the joint. An example design detail for a waterstop and the effect of depressing the slab top reinforcement is shown in Fig. 5.4.3.5d.

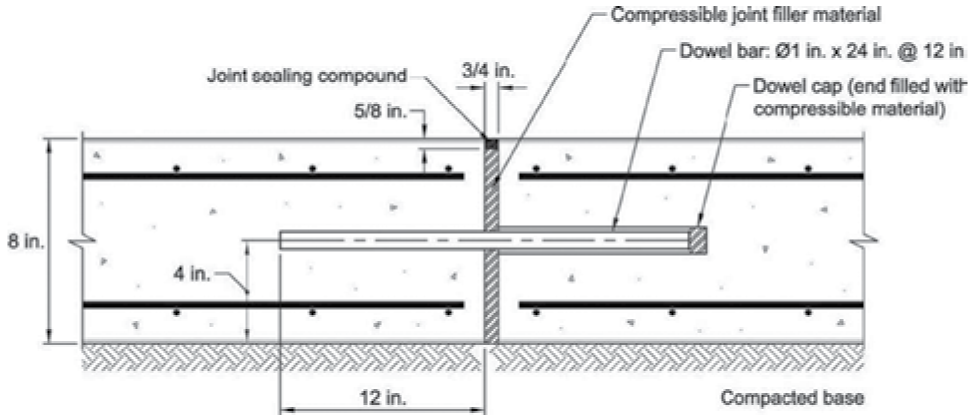


Fig 5.4.3.5c—Detail of a wall expansion joint.

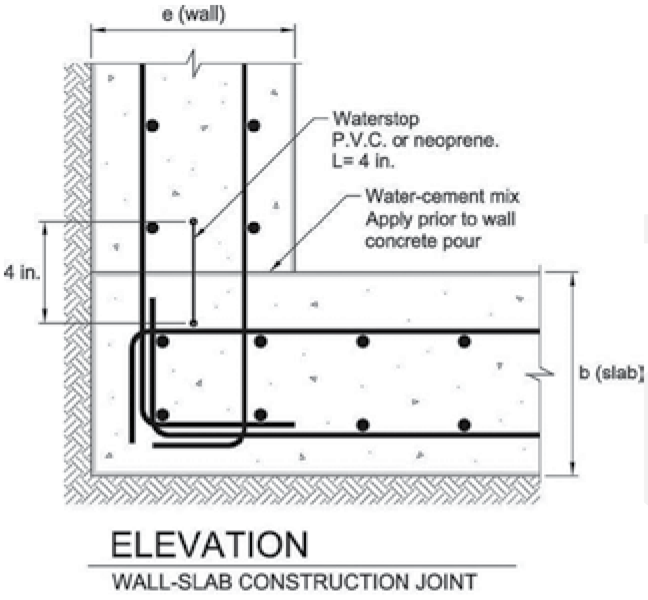


Fig 5.4.3.5d—Detail of wall-to-slab joint with waterstop.

5.5—Columns

This section applies to steel reinforcement of nonprestressed structural columns as defined by ACI 318-14 Chapter 10, and portions of deep foundations described by ACI 318-14 Section 13.4.3.1, as portions of deep foundation members in air, water, or soils not capable of providing adequate restraint throughout the member length to prevent lateral buckling.

5.5.1 *Vertical bar arrangement*—Vertical bar arrangement is prescribed by ACI 318-14 Section 10.7.3, requiring a minimum of three vertical bars with a triangular tie, four vertical bars within rectangular and circular ties, and six vertical bars enclosed by spiral ties or for columns in special moment frames enclosed by circular ties. Vertical reinforcement is most commonly arranged equally spaced around the perimeter of the column and enclosed by tie reinforcement, and includes at least a vertical bar in each corner of noncircular columns.

The LDP should provide clear tie arrangements for various numbers of longitudinal bars in a member (Fig 5.5.1).

5.5.2 *Ties*—Tie reinforcement is prescribed by ACI 318 Sections 10.7.6 and 25.7.2. As noted in ACI 318-14 Section 25.7.2, ties are required to have a minimum clear spacing of four-thirds the nominal maximum coarse aggregate size and a maximum of the lesser of 16 longitudinal bar diameters, 48 tie bar diameters, and the smallest dimension of the column. Spirals are required to be spaced continuously with the clear spacing being at least the greater of 1 in. (25 mm) and four-thirds the nominal maximum coarse aggregate size and a maximum of 3 in. (75 mm).

The smallest tie size should be No. 3 (No. 10) for longitudinal bars No. 10 (No. 32) and smaller, and No. 4 (No. 13) for ties enclosing No. 11 (No. 36) bars and larger. Alternatively, typical tie reinforcement can be replaced by welded wire reinforcement (WWR) of an equivalent area, except for spiral ties and special seismic systems. Deformed wire can be used for spiral ties. For rectangular ties, the tie arrangement should provide lateral support for every corner and alternate longitudinal bar with 135-degree hook. Additional tie reinforcement is required to provide lateral support for every longitudinal bar enclosed by a rectangular tie when the clear spacing between laterally supported longitudinal bars exceeds 6 in. (150 mm) on each side. Circular tie reinforcement should lap by a minimum of 6 in. (150 mm), terminate with standard hooks at each end that enclose a longitudinal bar, and be staggered around the perimeter.

Per ACI 318-14 Section 10.7.6, at member ends or transitions, the bottom tie is to be located, at most, one-half the tie spacing above the top of footing or slab. The top tie should also not be located more than one-half the tie or spacing below the lowest horizontal reinforcement in the slab, drop panel, or shear cap above. In the case of beams or brackets framing into all sides of a column, the top tie is to be located within 3 in. (75 mm) below the lowest horizontal reinforcement in the shallowest beam or bracket. For spiral reinforcement, the bottom of the spiral should be located at the top of the footing or slab, with the top conforming to ACI 318-14 Table 10.7.6.3.2.

5.5.3 *Detail at steps and transitions*—At steps and transitions (Fig. 5.5.3), the vertical reinforcement often is detailed with an offset bend, covered in ACI 318-14 Section 10.7.4. The slope of this transition should not exceed one (H) to six

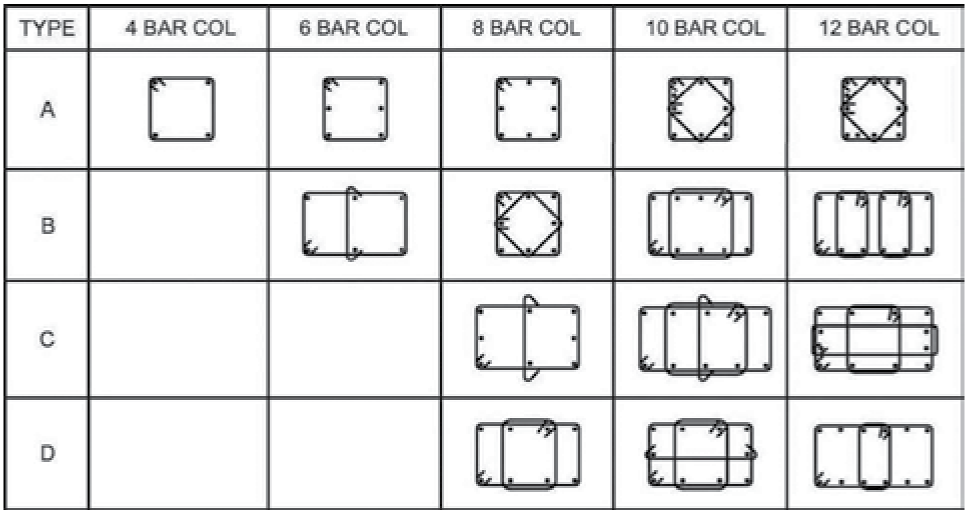


Fig. 5.5.1—Column tie arrangement schedule.

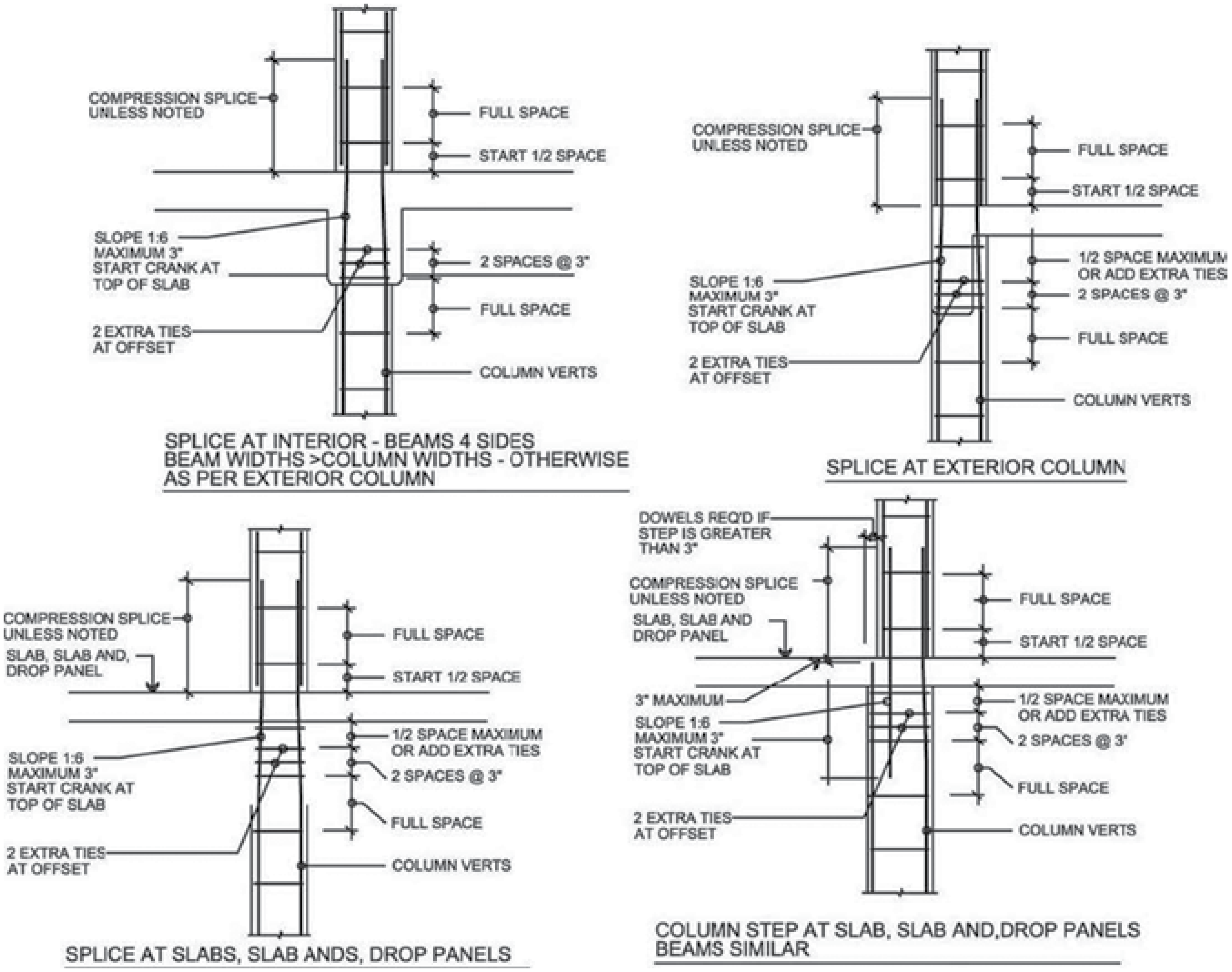


Fig. 5.5.3—Column details at steps and transitions.

(V). If there is a column offset greater than 3 in. (75 mm), a slope transition is not allowed and is to be made with separate dowels adjacent to the offset column faces. Where vertical bars are offset, horizontal support should be provided throughout by ties, spirals, or parts of the floor construction. If transverse reinforcement is provided, they should be

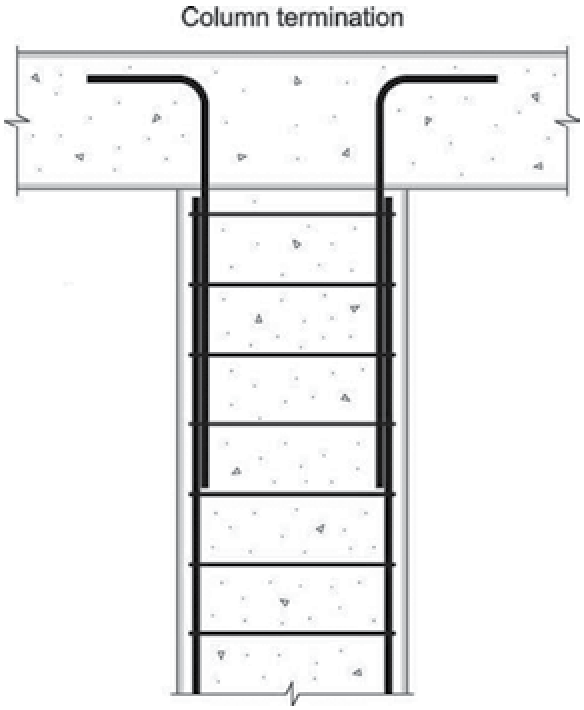


Fig. 5.5.5—Showing hooked bars spliced to vertical bars in a round column.

placed no more than 6 in. (150 mm) from the points of the bend per ACI 318-14 Section 10.7.6.4. Offset bend locations should be specified by the LDP as appropriate. If not noted, the offset bends will be located based on ease of construction and contractor preference.

5.5.4 *Laps*—Column reinforcement lap lengths should be specifically indicated in the design drawings. Guidance should be given through schedules, notes, or other methods to accurately prescribe lap requirements per column. Generally, compression laps can be allowed in gravity columns. These splices lengths can be factored by 0.83 when the effective area of tie reinforcement through the lap zone meets the requirements of ACI 318, 10.7.5.2.1(a), or can be factored by 0.75 when spiral reinforcement is provided in accordance to ACI 318-14 Section 25.7.3. Attention should be given to areas of laps due to congestion.

Spiral reinforcement laps are dictated by ACI 318-14 Table 25.7.3.6, where the most common lap length is 48-bar diameters. Spiral reinforcement is required to be anchored by 1-1/2 extra turns of the spiral bar per ACI 318-14 Section 25.7.3.4.

5.5.5 *Termination of vertical bars*—Termination of vertical column reinforcement into beams and slabs is prescribed by ACI 318-14 Chapter 15. Termination of vertical column reinforcement into foundations is prescribed by ACI 318-14 Section 16.3. In heavily congested areas, headed bars are an effective alternate to hooks.

Termination of vertical bars in round columns requires special consideration (Fig. 5.5.5). Many round columns are formed with laminated paper fiber tubes. If the column vertical bars are terminated with hooks, the tube form cannot be slipped down over the erected column, nor can the column reinforcement be installed if the tube is put in place first. The LDP should consider, if not subject to seismic provisions in ACI 318-14 Chapter 18, designing the termination with hooked bars spliced to the vertical bars after the tube form is in place.

5.6—Beams

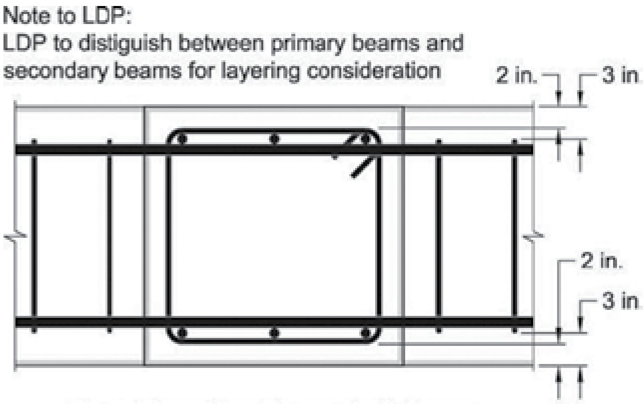
This section applies to steel reinforcement of nonprestressed beams, as defined in ACI 318-14 Section 9.1.1. General reinforcing bar design details should conform to ACI 318-14 Sections 9.6 and 9.7. Bundled bars should be in accordance with ACI 318-14 Section 25.6. Development lengths and splices of deformed reinforcement should be in accordance with ACI 318 Sections 25.4 and 25.5, respectively.

5.6.1 *Layering of beam bars at intersections*—ACI 318-14 Sections 15.2 and 15.4 provide requirements for steel reinforcement at beam-column joints. Longitudinal beam reinforcement in beam-to-beam connections should be designed in such a way that the secondary beam's top and bottom layers will be contained within the primary beam's top and bottom longitudinal layers. Consideration should be given to intersecting beam depth dimensions and concrete cover for each of the intersecting members. Attention should be given to ACI 318 Sections 9.7 and 25.4.

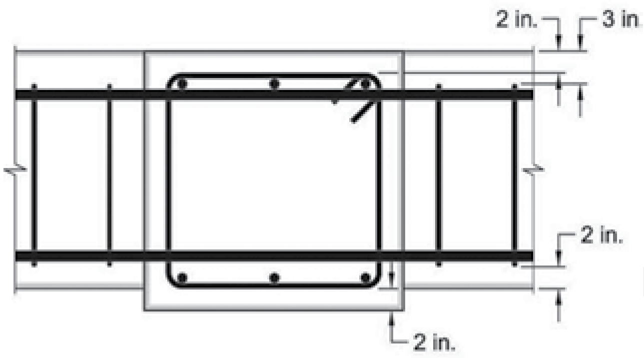
5.6.2 *Depth of beams at intersections*—Generally, primary beams will be dimensioned for greater loads than secondary intersecting beams and, thus, will normally be larger in both width and depth. Dimensioning different depths for members in beam-to-beam and beam-to-girder connections will facilitate passage of longitudinal reinforcing bar layers through the intersection without affecting specified concrete cover (Fig. 5.6.2). When dimensioning both beams to the same depth to facilitate formwork, the additional bottom soffit cover for the secondary beam should be defined to avoid interference.

5.6.3 *Tie arrangements*—ACI 318-14 Sections 25.7.1 and 25.7.2, respectively, provide requirements for stirrups and ties. Both should extend as close to the compression and tension surfaces of the member as cover requirements and proximity of other reinforcement permit, and are to be anchored at both ends. Stirrups can be used to resist shear and torsion forces in a beam member; they consist typically of deformed bars, deformed wires, or WWR either single leg or bent into L, U, or rectangular shapes, and located perpendicular to, or at an angle to, longitudinal reinforcement. Ties should consist of a closed loop of deformed bar with spacing in accordance with 25.7.2.1. Tie bar diameter should be at least No. 3 (No. 10) for enclosing bars No. 10 (No. 32) or smaller, and No. 4 (No. 13) for enclosing bars No. 11 (No. 36) or larger and bundled longitudinal bars. Rectilinear ties should be arranged to satisfy 25.7.2.3. Stirrups used for torsion or integrity reinforcement can be either closed stirrups placed perpendicular to the beam axis, as specified in 25.7.1.6, or can be made up of two pieces of reinforcement when conditions in 25.7.1.6.1 are met.

For large beams with long spans and heavy reinforcement, closed ties may reduce constructability. The long bars



Beam intersection at same depth beams



Beam intersection at different depth beams

Fig. 5.6.2—Primary beam–secondary beam connection.

would be threaded into the beams through column verticals and other obstructions. With open stirrups, the long bars are simply lifted and dropped into place without any threading required. Once the bars are installed, the stirrups can be capped as necessary.

If the LDP shows only the closed ties option on the design documents, the detailer will likely issue an RFI requesting a change of stirrup configuration to open/capped style (Fig. 5.6.3). This process may significantly delay the detailer, depending on turnaround time for RFIs. This is usually an unnecessary interruption; in most cases, the open/capped tie option is approved. Design documents that clearly show both options whenever open ties are acceptable speeds up the detailing process and reduces the document flow required by the designer, contractor, and detailer, and constructability is enhanced.

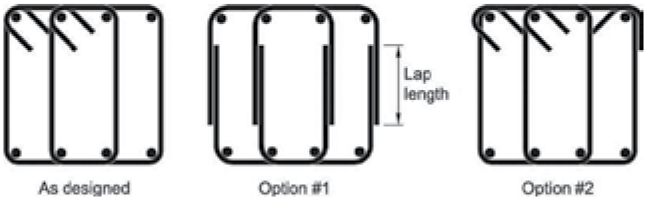


Fig. 5.6.3—Possible options for a tie set with closed design.

5.6.4 *Arrangement of longitudinal bars*—ACI 318 Chapters 9 and 25 provide requirements for longitudinal reinforcement in beams. Clear spacing between bars in a horizontal layer should be at least the greater of 1 in. (25 mm), $1.0d_b$, and $(4/3)d_{agg}$. For parallel nonprestressed reinforcement placed in two or more horizontal layers, reinforcement in the upper layers should be placed directly above reinforcement in the bottom layer with a clear spacing between layers of at least 1 in. (25 mm). Standard hooks for the development of deformed bars in tension should conform to ACI 318-14 Table 25.3.1. Reinforcement limits should be in accordance with ACI 318-14 Section 9.6. Attention should be given to ACI 318-14 Section 9.7.2.3, for detailing skin reinforcement in beams with depth h exceeding 36 in. (900 mm). Design of longitudinal reinforcement should comply with ACI 318-14 Section 9.7.3. Requirements for structural integrity are contained in ACI 318-14 Section 9.7.7.

In general, especially with multi-leg tie arrangements, numerous continuous longitudinal top and bottom bars should be placed to occupy the necessary positions required for every corner or leg of the tie set; the remaining bars will be spaced across the remaining space, in one or more layers. This will permit secure fastening in position of the ties in their correct shear-resisting position as well as provide lateral confinement for the longitudinal bars.

5.6.5 *Beam steps*—ACI 318 Chapters 9 and 25 provide requirements for steel reinforcement across beam steps or along beam section changes. Attention should be given to bar anchorage, development lengths, and providing continuous and correctly anchored reinforcement across any section change (Fig. 5.6.5).

5.6.6 *Special details*—Where nontypical conditions for steel reinforcement in beams, either geometrical or for other reasons, cannot be fully and correctly represented by elevations, sections, and schedules, specific design details should be presented for these conditions. The governing criteria should be to present clear and precise information for the detailer to help avoid misinterpretation of design drawings and delays in the detailing process.

5.6.7 *Beam schedules*—Beams with similar geometry and steel reinforcement distribution can be represented with typical details and a beam schedule (Fig. 5.6.7) containing the specific information for bar diameters and dimensions, development and cutoff lengths, continuity of structural integrity reinforcement, and other information. Clarity in identifying the different beams and their corresponding reinforcement is important for the detailer to be able to correctly detail steel reinforcement in the placing drawings.

5.7—Slabs

This section applies to steel reinforcement of nonprestressed slabs, as defined in ACI 318-14 Chapters 7 and 8, and ACI 421.1R-08.

5.7.1 *Bottom and top reinforcement*—Construction documents should include the minimum cover from the bottom, sides, and top of concrete in sections and details.

ACI 318-14 Section 25.5 provides reinforcement design requirements for embedment. Drawings should include the minimum embedment lengths into beams, columns, pilasters, or other supporting elements. These lengths should be shown in details, sections, plans, or schedules.

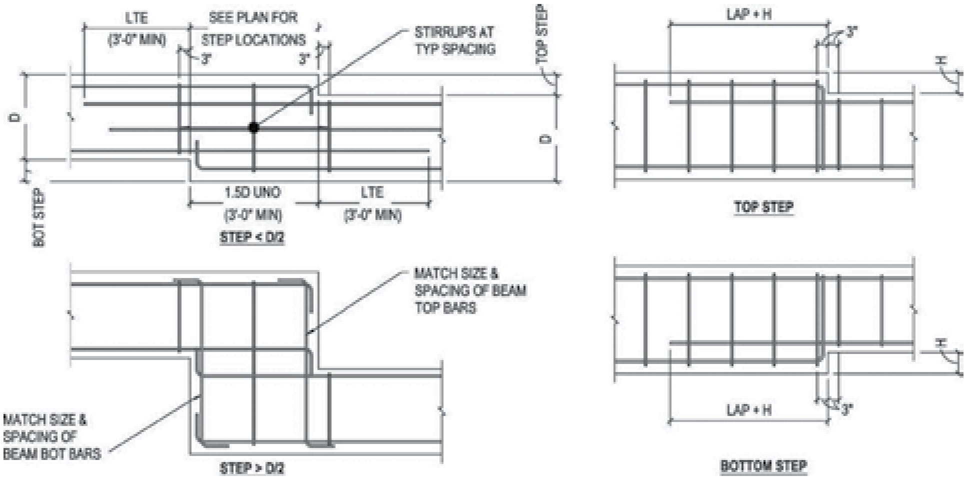
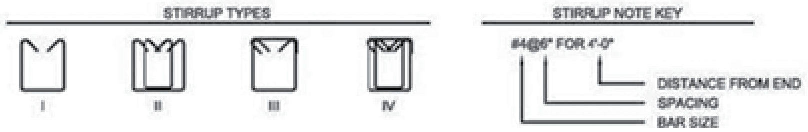


Fig. 5.6.5—Beam step details.

CIP BEAM SCHEDULE

MARK	W, WIDTH (IN)	D, DEPTH (IN)	LONGITUDINAL REINFORCEMENT				STIRRUPS				SIDE REINF.	REMARKS
			BOT	TL	TC	TR	TYPE	LEFT	BALANCE	RIGHT		
B1	24	48	(4) #9	(6) #9	(3) #9	(6) #9	I	#4@6" FOR 4'-0"	#4@12"	#4@6" FOR 4'-0"	#4@8"	-
B2	24	48	(4) #9	*	(3) #9	(6) #9	I	#4@6" FOR 4'-0"	#4@12"	#4@6" FOR 4'-0"	#4@8"	-

NOTE:
1. * = SEE ADJACENT SPAN



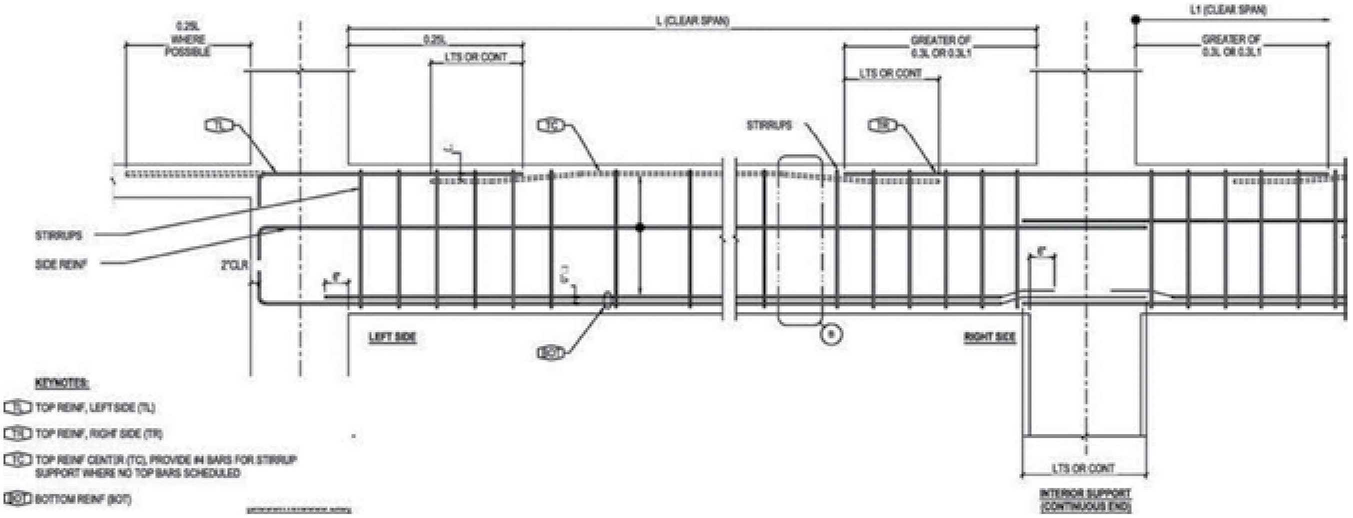
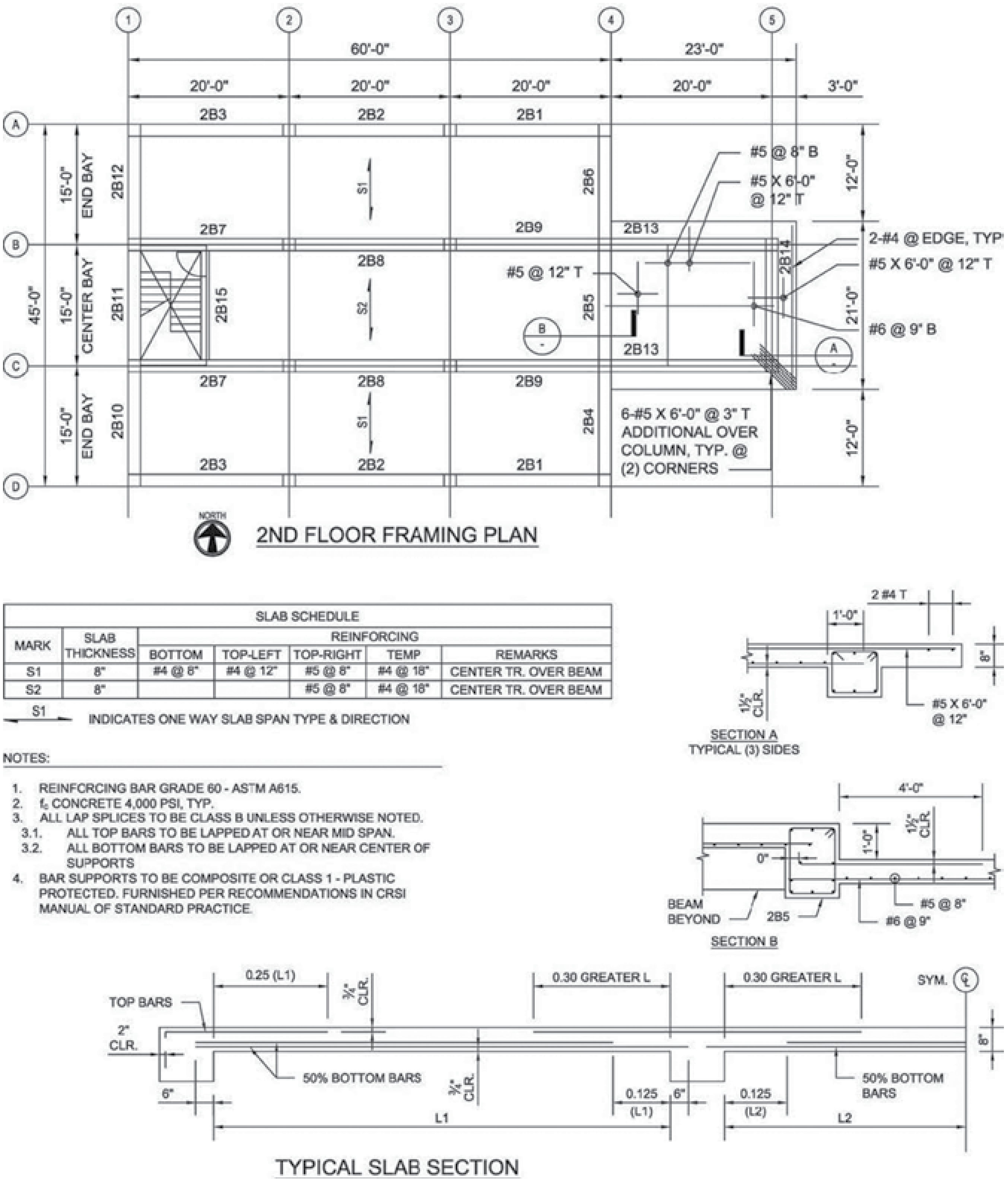


Fig. 5.6.7—Beam reinforcement schedule and diagram.

Standard hooks for the development of deformed bars in tension should conform to ACI 318-14 Table 25.3.1. If hooks are required at discontinuous ends, the LDP should verify the hook dimension can be placed within the specified slab thickness. If not, a sketch showing the accepted alternative should be provided.

5.7.2 *One-way slabs*—ACI 318-14 Chapter 7 provides reinforcement design requirements for one-way slabs. The amount of flexural bottom layer reinforcement required to run continuously across the span is anchored in the supporting member a minimum of 6 in. (150 mm). When a portion of the bars are terminated within the span, it is necessary to define the termination locations. For example, in Fig. 5.7.2,



SLAB SCHEDULE

MARK	SLAB THICKNESS	REINFORCING				
		BOTTOM	TOP-LEFT	TOP-RIGHT	TEMP	REMARKS
S1	8"	#4 @ 8"	#4 @ 12"	#5 @ 8"	#4 @ 18"	CENTER TR. OVER BEAM
S2	8"			#5 @ 8"	#4 @ 18"	CENTER TR. OVER BEAM

S1 ⟵ INDICATES ONE WAY SLAB SPAN TYPE & DIRECTION

NOTES:

1. REINFORCING BAR GRADE 60 - ASTM A615.
2. f_c' CONCRETE 4,000 PSI, TYP.
3. ALL LAP SPLICES TO BE CLASS B UNLESS OTHERWISE NOTED.
   - 3.1. ALL TOP BARS TO BE LAPPED AT OR NEAR MID SPAN.
   - 3.2. ALL BOTTOM BARS TO BE LAPPED AT OR NEAR CENTER OF SUPPORTS
4. BAR SUPPORTS TO BE COMPOSITE OR CLASS 1 - PLASTIC PROTECTED. FURNISHED PER RECOMMENDATIONS IN CRSI MANUAL OF STANDARD PRACTICE.

Fig. 5.7.2—One-way slab with bar schedule and top bar cutoff details.

50 percent of the bottom bars are terminated 0.125 of the clear span distance from the intermediate beam face, except in edge bays where 100 percent of the reinforcement should bear on the edge support.

Top layer flexural reinforcement is placed directly on the beam top layer reinforcement and is required to end with a standard hook at discontinuous ends. Support bar details with bar size and spacing or use of temperature bars should be included on the drawings.

Transverse temperature bars run continuously with the specified lap and are required to run through intermediate supporting members and at end supports are embedded a minimum of 6 in. (150 mm).

Terminations of top bars and bottom bars should be clearly dimensioned in the contract documents. Support members should be clearly marked. Calculations used for the top bar projections should be based on the clear distance between supports. Construction, contraction, isolation, and expansion joints should be located and dimensioned on the contract documents to ensure accurate placing of the reinforcement and required dowels. Standard hooks for the development of deformed bars in tension should conform to ACI 318-14 Table 25.3.1. Refer to Fig 5.7.2.

5.7.3 *Two-way slabs*—ACI 318-14 Chapter 8 provides reinforcement design requirements for two-way slabs (Fig. 5.7.3). Slab bottom layer flexural reinforcement is placed in both directions, runs continuously across the span, and is anchored in the support a minimum of 6 in. (150 mm).

Slab top layer reinforcement is placed in both directions directly on the top layer beam reinforcement and is required to terminate with a standard hook at discontinuous ends. Support bar details with bar size and spacing should be included on the drawings.

Specific details for bar layering at openings and varying span widths should be included in the contract documents. Construction, contraction, isolation, and expansion joints should be located and dimensioned on the contract documents to ensure accurate placing of the reinforcement and required dowels. Standard hooks for the development of deformed bars in tension should conform to ACI 318-14 Table 25.3.1.

5.7.4 *Edges and openings*—Standard hooks for the development of deformed bars in tension should conform to ACI 318 Table 25.3.1. If hooks are required at discontinuous end, the LDP should verify the hook dimension can be placed within the specified slab thickness. Details of bar conditions at slab edges and openings should be included in the contract documents. Trim bars should be shown in specific details on the drawings.

5.7.5 *Steps and depressions*—Design details for steps and depressions should be presented separately for different step dimensions (Fig. 5.7.5(a) and (b)). This should include directions for draping the main reinforcement, hooking and lapping, or furnishing a bent bar. Attention should be given to providing continuous and correctly anchored reinforcement across any section change. Dimensions of steps and depressions should be clearly shown on the structural drawings and located from grid lines or from concrete edge.

CHAPTER 6—REVIEW OF PLACING DRAWINGS

6.1—Scope

The information found in this chapter is intended to provide a general overview of the definition, purpose, review process, and use of reinforcing steel placing drawings. For more specific information and guidelines, refer to Chapter 6 of the CRSI *Manual of Standard Practice* (2017). Additionally, for a better understanding of the fundamentals and best practices in the preparation of reinforced concrete placing drawings, refer to CRSI *Reinforcing Bar Detailing* (2015).

6.2—Definition

Placing drawings are working documents that show the quantity, bar size, dimensions, and location of reinforcing steel as required for fabrication and placement. Placing drawings may comprise plans, details, elevations, schedules, material lists, and bending details. They can be prepared manually or by computer.

6.3—Overview

Placing drawings are the fabricator's interpretation of the licensed design professional's (LDP's) design intent as defined in the contract documents. The purpose is to assure proper fabrication and placement of reinforcing steel. The contract documents, plus changes issued by the LDP (per terms agreed upon in the contract if issued after the contract is made), constitute the sole authority for information in placing drawings. Because no new design intent is added during the creation of placing drawings, they do not require an engineer's seal. The LDP should furnish a clear statement of the design requirements in the project specifications and structural drawings, and should not refer the fabrication detailer to an applicable building code or other codes for information necessary to prepare the placing drawings. Such information should be provided by the LDP in the form of specific design details or notes.

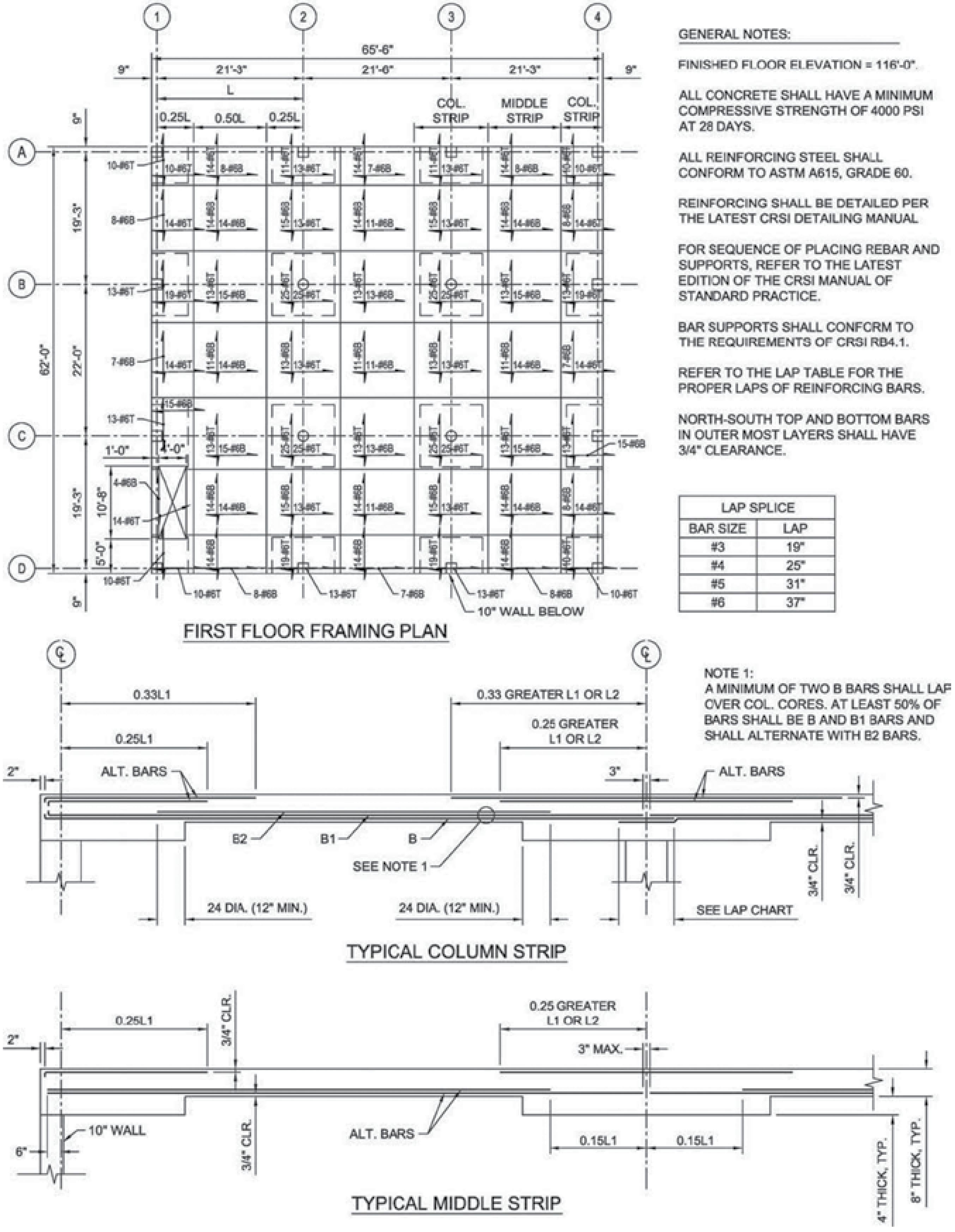
Necessary additional information such as field conditions, field measurements, location of construction joints, and sequence of placing concrete should be supplied by the contractor. Information supplied by the contractor should be provided in a timely manner so that complete placing drawings can be provided to meet deadlines required for reinforcement fabrication (Birley 2008). It is more important that placing drawings be prepared based on available information required by the reinforcing steel detailer to accurately complete the drawings. This includes shop drawings from other trades that are approved for construction. All parties need to work together to complete submittal, review, and approval processes in a timely manner that does not impact construction schedules. After review by the LDP, including necessary revisions, the drawings can be used for fabrication and placing of reinforcing steel.

6.4—Procedure

Placing drawings are most commonly prepared by a detailer, typically employed or contracted by the reinforcing steel fabricator. General steps for producing and using placing drawings are:

(1) Detailer prepares placing drawings based on information found in the project specifications and structural drawings, as well as information related to construction requirements obtained from the contractor.

(2) Placing drawings are submitted to the contractor or their designee for review and approval. On many projects, the contractor will also forward the placing drawings to the



GENERAL NOTES:

FINISHED FLOOR ELEVATION = 116'-0".

ALL CONCRETE SHALL HAVE A MINIMUM COMPRESSIVE STRENGTH OF 4000 PSI AT 28 DAYS.

ALL REINFORCING STEEL SHALL CONFORM TO ASTM A615, GRADE 60.

REINFORCING SHALL BE DETAILED PER THE LATEST CRSI DETAILING MANUAL

FOR SEQUENCE OF PLACING REBAR AND SUPPORTS, REFER TO THE LATEST EDITION OF THE CRSI MANUAL OF STANDARD PRACTICE.

BAR SUPPORTS SHALL CONFORM TO THE REQUIREMENTS OF CRSI RB4.1.

REFER TO THE LAP TABLE FOR THE PROPER LAPS OF REINFORCING BARS.

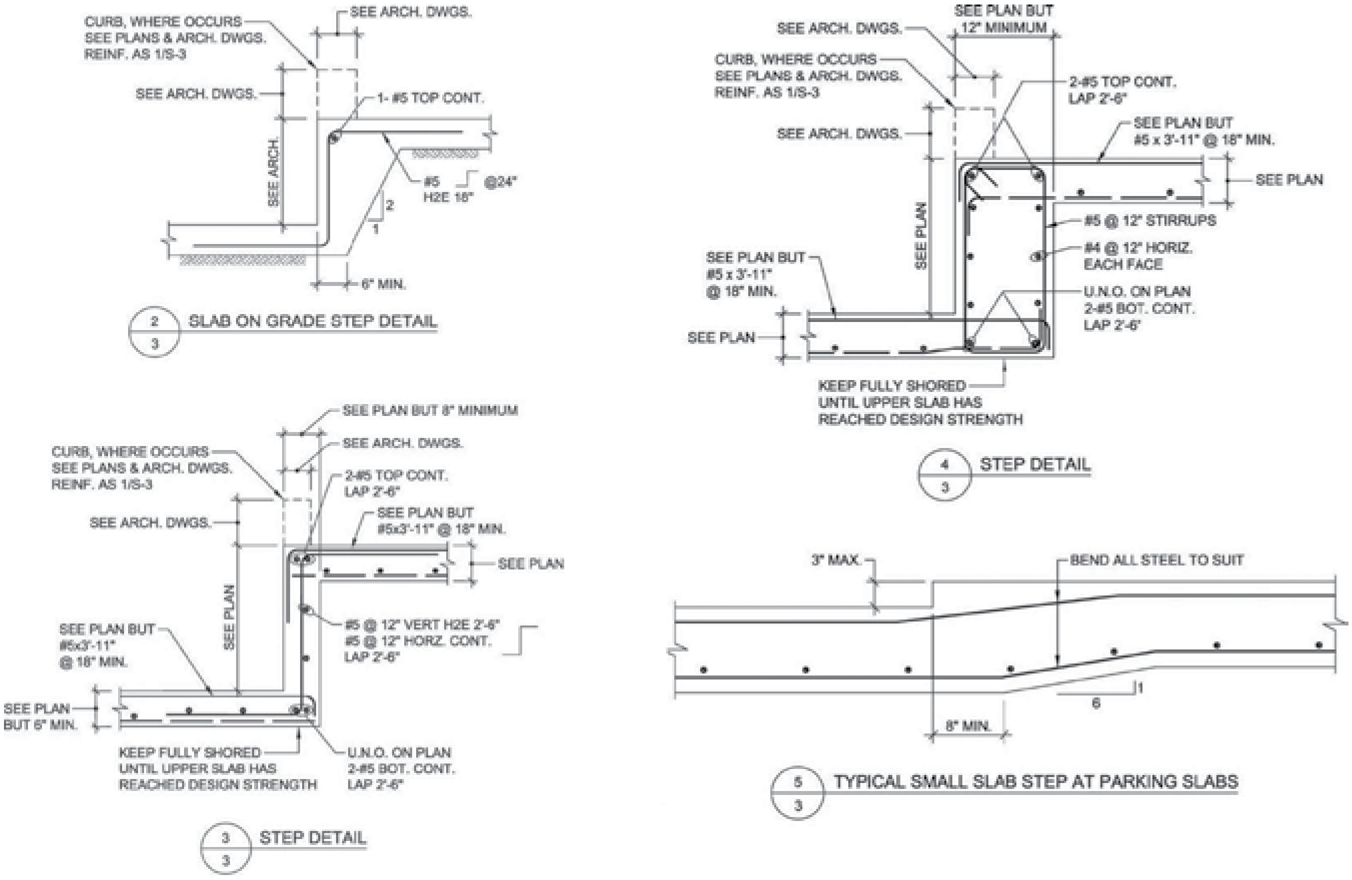
NORTH-SOUTH TOP AND BOTTOM BARS IN OUTER MOST LAYERS SHALL HAVE 3/4" CLEARANCE.

LAP SPLICE

BAR SIZE	LAP
#3	19"
#4	25"
#5	31"
#6	37"

NOTE 1:
A MINIMUM OF TWO B BARS SHALL LAP OVER COL. CORES. AT LEAST 50% OF BARS SHALL BE B AND B1 BARS AND SHALL ALTERNATE WITH B2 BARS.

Fig. 5.7.3—Two-way slab with bar schedule and top bar cutoff details.



(a) *(b)*

Fig. 5.7.5—Slab step details (a) and (b).

LDP for their review and approval. Refer to Sections 6.5 and 6.6 of this guide for detailed explanations of placing drawing review and approval processes.

(3) Once placing drawings have been approved, bar fabrication lists are prepared from the bar lists on the placing drawings, based on a delivery sequence agreed on between the fabricator and the contractor.

(4) Releases are submitted for fabrication in accordance with the current delivery schedule.

(5) Reinforcing steel is cut, bent, tagged, bundled, and delivered to the job site along with other material, such as bar supports, as specified in the contract.

(6) Reinforcing steel is installed based on details found on the placing drawings and in accordance with requirements of the contract documents.

6.5—Review of placing drawings

Practices and requirements for LDP review of placing drawings vary by geographic region, as well as by the nature of the project and client. In some geographic regions, it is customary for the LDP to review the placing drawings. In other regions, this is rarely done. For some types of projects—usually larger or publicly funded projects—review by the LDP is required by the owner. Review of the placing drawings by the LDP can reduce errors, lost production time, and rework during inspection, and is encouraged as a good practice.

6.5.1 *Benefits of review*—Review is deemed to have several worthwhile benefits, including:

(a) A tendency to include the LDP as part of the team effort

(b) Verification conformance with general design intent

(c) Verification that the most recent revised contract drawings have been used

(d) Catching and correcting small errors or omissions that would otherwise delay the project if left to be discovered during inspection in the field

(e) Providing assurance that the detailer understands the design concepts and is proceeding correctly

(f) Allowing reviewed placing drawings to form a large part of the "As-built" documents package

Most project specifications allow a given period of time for the LDP review of placing drawings—in most cases, 2 weeks. The detailer and construction team factor this review time into their schedules. Therefore, it is important for the LDP to work within this time constraint to help keep the project on schedule.

6.5.2 *Review process*—Ideally the process for submission and review of placing drawings should be outlined in the contract documents. Although the process varies from each project, it generally will include the following steps:

(1) Detailer submits the placing drawings to the contractor or their designee

(2) Contractor or their designee reviews the drawings and forwards them to the LDP

(3) LDP completes their review and returns the drawings to the contractor in a timely manner

(4) Reviewed drawings are returned to the detailer

(5) Detailer makes all necessary amendments and either resubmits if required, or authorizes the detailed reinforcing steel for fabrication

6.5.3 *Checklists for review of placing drawings*—Although the LDP will have an individual checklist, it generally will include at least the following items:

(a) Verification of the latest issue of contract drawings

(b) Verification of the latest issue of addenda and supplementary documents, such as requests for information (RFIs), design change notices (DCNs), and field change notices (FCNs)

(c) Verification of grades, coatings, and sizes of reinforcing steel

(d) Verification that all reinforcing steel has been included and properly located

6.6—Levels of approval

There are many variations of approval levels. Each LDP usually develops one that suits individual requirements. Although terms can vary, most will include, as a minimum, the following levels:

(a) *Approved*—These drawings meet all design requirements and are approved for fabrication and installation.

(b) *Approved as noted*—These drawings require small corrections that do not impact the design intent. Once corrections are completed they are approved for fabrication and installation. Resubmittal is not required.

(c) *Revise and resubmit*—These drawings have significant errors that impact the design intent or do not comply with the specifications. The LDP requires resubmittal.

(d) *Not approved*—These drawings do not meet the design intent. Alternately, perhaps, the LDP is aware that new or revised design documents are about to be issued that will supersede previous contract drawings. In either case, entirely new placing drawings are required and submitted.

The LDP normally reviews the placing drawings for general conformance with the contract documents, but does not materially change the design or make contract amendments in that review. Errors or omissions in the placing drawings are not generally the responsibility of the LDP.

CHAPTER 7—REFERENCES

ACI committee documents and documents published by other organizations are listed first by document number, full title, and year of publication followed by authored documents listed alphabetically.

American Concrete Institute

ACI 117-10(15)—Specification for Tolerances for Concrete Construction and Materials and Commentary

ACI 131.1R-14—Information Delivery Manual for Cast-in-Place Concrete

ACI 132R-14—Guide for Responsibility in Concrete Construction

ACI 301-16—Specifications for Structural Concrete

ACI 314R-16—Guide to Simplified Design for Reinforced Concrete Buildings

ACI 318-11—Building Code Requirements for Structural Concrete and Commentary

ACI 318-14—Building Code Requirements for Structural Concrete and Commentary

ACI 336.3R-14—Report on Design and Construction of Drilled Piers

ACI 421.1R-08—Guide to Shear Reinforcement for Slabs

ACI 543R-12—Guide to Design, Manufacture, and Installation of Concrete Piles

American Institute of Architects

AIA Document G202™-2013—Project Building Information Modeling Protocol Form

American Welding Society

AWS D1.4/D1.4M:2011—Structural Welding Code – Reinforcing Steel

AWS D1.6/D1.6M:2007—Structural Welding Code – Stainless Steel

ASTM International

ASTM A615/A615M-16—Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement

ASTM A706/A706M-16—Standard Specification for Deformed and Plain Low-Alloy Steel Bars for Concrete Reinforcement

ASTM A1064/A1064M-16—Standard Specification for Carbon-Steel Wire and Welded Wire Reinforcement, Plain and Deformed, for Concrete

BIMForum

LOD 2016—Level of Development (LOD) Specification

Concrete Reinforcing Steel Institute

CRSI—Manual of Standard Practice, 29th Edition, 2017

CRSI—Reinforcing Bar Detailing, Fifth Edition, 2015

CRSI RB4.1-2016—Supports for Reinforcement Used in Concrete

Construction Specifications Institute

CSI UniFormat™ 2010: A Uniform Classification of Construction Systems and Assemblies

International Code Council

IBC 2015—International Building Code

International Organization for Standardization

ISO 16739:2013—Industry Foundation Classes (IFC)

National Institute of Building Sciences

NBIMS-US™ 2015—National BIM Standard-United States, Version 3

NCS-V6—United States National CAD Standard®

Wire Reinforcement Institute®

WWR-500-R-16—Manual of Standard Practice—Structural Welded Wire Reinforcement

WWR-600—Structural Detailing Manual 2006

Authored documents

Birley, D., 2005, “The Tolerance Cloud,” *Concrete International*, V. 27, No. 6, June, pp. 61-63.

Birley, D., 2008, “Reinforcing Placing Drawings are not Shop Drawings,” *Concrete International*, V. 30, No. 12, Dec., pp. 48-50.

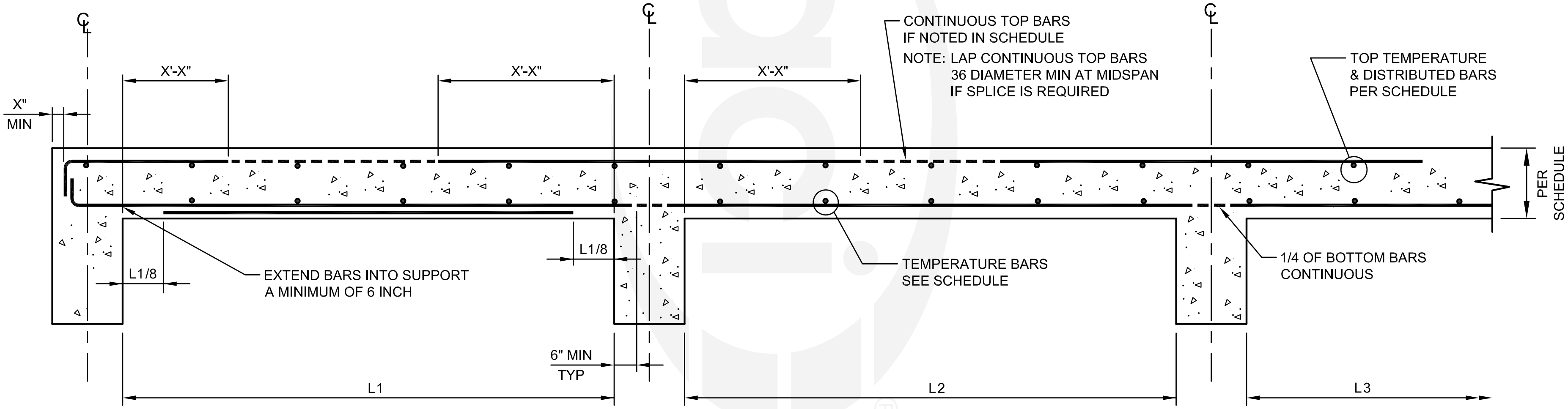
SECTION 2
DETAILS

SLAB
DETAILS

SLAB-1

ONE-WAY CONCRETE SLAB SCHEDULE

MARK	DEPTH	MAIN REINFORCEMENT			TEMPERATURE REINFORCEMENT		REMARKS
		TOP LEFT	TOP LEFT	TOP RIGHT	TOP	BOT	
S1	6"	#5 @ 12"	#5 @ 12"		-	#4 @ 18"	
S2	5"		#5 @ 18"		-	#4 @ 18"	
S3	4"	#5 @ 12"	#5 @ 12"	#5 @ 12"	#4 @ 18"	#4 @ 18"	



NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY SCHEDULE AS REQUIRED BEFORE INCORPORATING THIS SCHEDULE INTO PROJECT CONSTRUCTION DOCUMENTS

ONE-WAY CONCRETE SLAB SCHEDULE

FIGURE SLAB-1: ONE-WAY CONCRETE SLAB SCHEDULE

The design professional shall review the following checklist and
incorporate project-specific requirements into the details

INTENDED USE

Showing project one-way slabs reinforcement on one schedule

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Each one-way slab type is assigned with slab mark in the table and coordinated with slab marks on floor plan drawing
2. One-way slab bar sizes and locations are properly entered and coordinated in the table
3. Reinforcement resisting flexure are placed parallel to the main/short span
4. Minimum flexural reinforcement satisfies Section 7.6.1 and corresponding minimum and maximum spacing satisfies Sections 25.2 and 7.7.2.4, respectively, and Table 24.3.2
5. Flexural reinforcement is detailed per Section 7.7.3
6. Flexural reinforcement bar termination in slab satisfies Section 7.7.3.8
7. If shear reinforcement in slab is required, it is designed and detailed per Section 7.6.3 and 7.7.5
8. Minimum shrinkage and temperature reinforcement is provided perpendicular to the span and satisfies Sections 7.6.4, 24.4.1, and 7.7.6.1
9. Maximum shrinkage and temperature reinforcement spacing per Section 7.7.6.2.1
10. One-quarter of longitudinal reinforcement is continuous per Section 7.7.7.1
11. Main reinforcement develops fy at face of support at discontinuous ends per Section 7.7.7.2
12. Splices are provided near supports per Section 7.7.7.3
13. Cover for reinforcement in slabs satisfies Section 20.5.1
14. Remove “NOTES TO DESIGN PROFESSIONAL” before placing schedule and corresponding detail in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles[*]: 13, 16, 22

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[*] Refer to Section 3 for articles

SLAB-2_1

TWO-WAY CONCRETE SLAB SCHEDULE – COLUMN STRIP

MARK	DEPTH (INCHES)	TOP						BOTTOM				REMARKS
		A	B	C	D	I	J	E	F	G	H	
S1	6	#5 @ 12"	#5 @ 12"	#5 @ 12"	#5 @ 12"	#5 @ 12"	#5 @ 12"	#4 @ 18"	#4 @ 18"	#4 @ 18"	#4 @ 18"	
S2	6		#5 @ 18"									
S3	8	#5 @ 12"	#5 @ 12"									

TWO-WAY CONCRETE SLAB SCHEDULE – MIDDLE STRIP

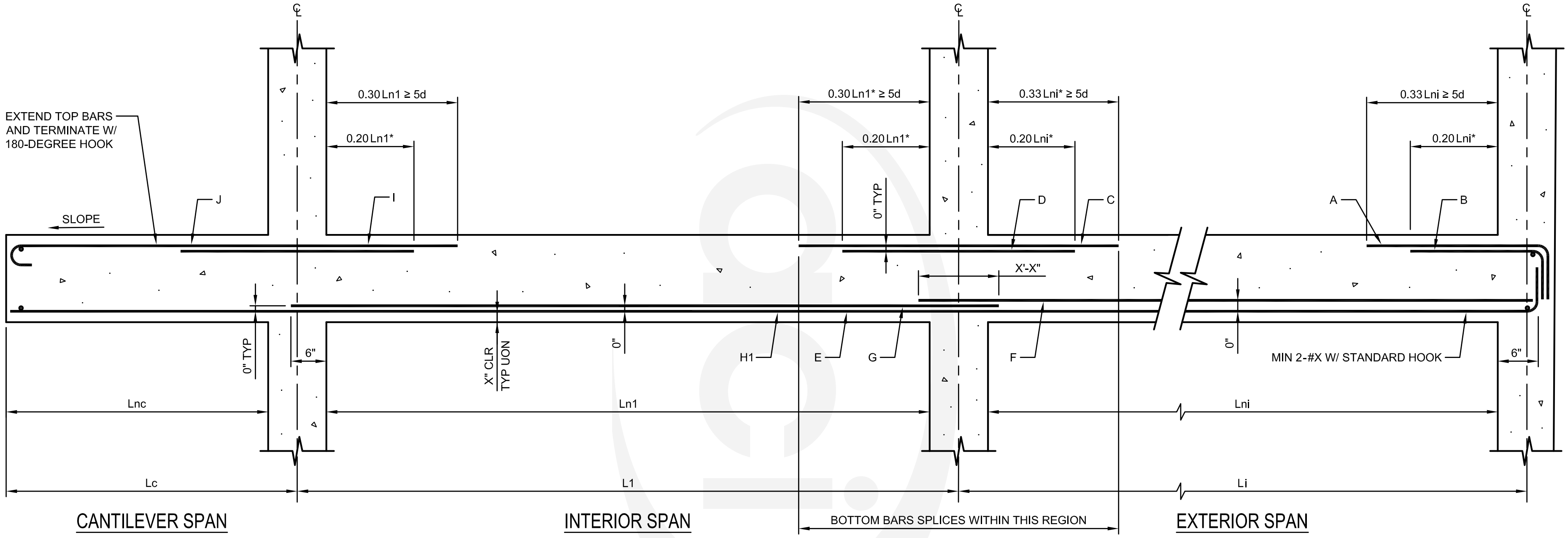
MARK	DEPTH (INCHES)	TOP				BOTTOM						REMARKS
		K	L	M	N	N	P	Q	R	U	V	
S1	6	#5 @ 12"	#5 @ 12"	#5 @ 12"	#5 @ 12"	#4 @ 18"	#4 @ 18"	#4 @ 18"	#4 @ 18"	#4 @ 18"	#4 @ 18"	
S2	6		#5 @ 18"									
S3	8	#5 @ 12"	#5 @ 12"									

NOTES TO DESIGN PROFESSIONAL:

- COMPLETE THE ATTACHED CHECKLIST AND MODIFY SCHEDULE AS REQUIRED BEFORE INCORPORATING THIS SCHEDULE INTO PROJECT CONSTRUCTION DOCUMENTS
- PROVIDE TEMPERATURE AND SHRINKAGE REINFORCEMENT
- WORK THIS SCHEDULE WITH FIGURES SLAB-2.2 AND SLAB-2.3

TWO-WAY CONCRETE SLAB SCHEDULE

SLAB-2_2

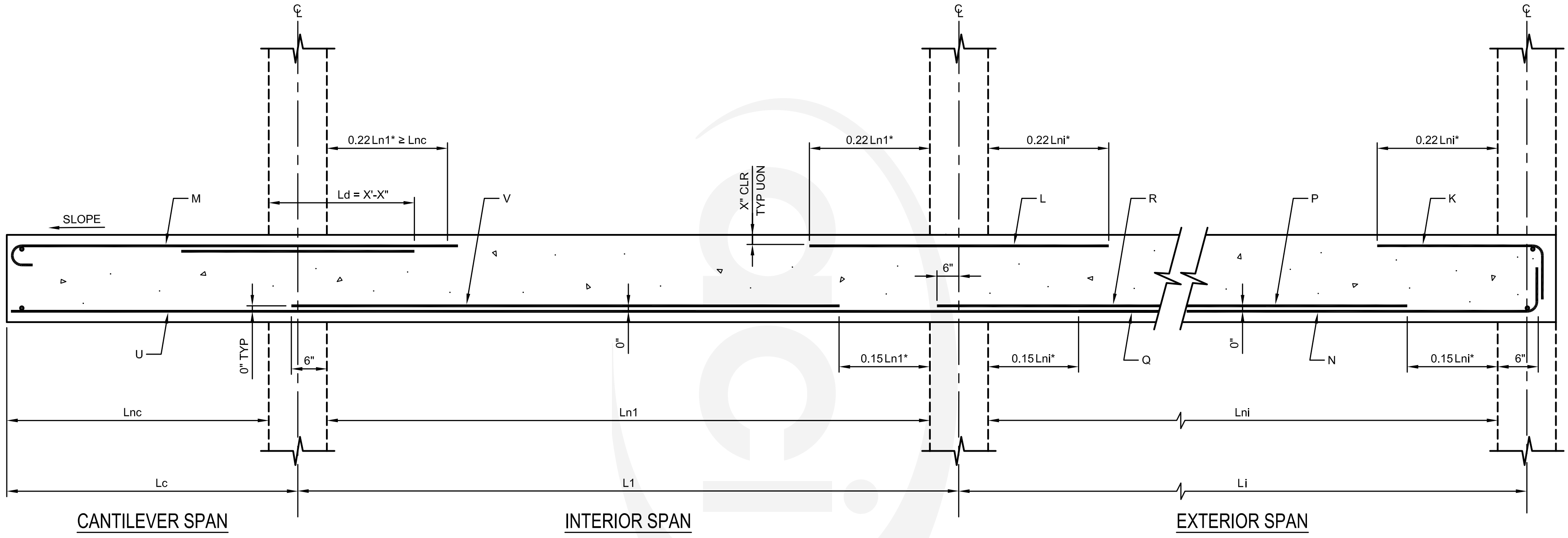


NOTES:

1. * EXTENSION OF BARS SHALL BE BASED ON THE LARGER OF THE TWO ADJACENT SPANS AND 5d
2. SPLICES SHALL BE MECHANICAL, WELDED, OR CLASS B LAP SPLICE
3. AT LEAST TWO BOTTOM BARS SHALL PASS WITHIN COLUMN BARS AND BE ANCHORED AT EXTERIOR SUPPORT
4. MINIMUM 50% OF TOP BARS SHALL EXTEND THE LONGER DISTANCE

NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

SLAB COLUMN STRIP



NOTES:

1. * EXTENSION OF BARS SHALL BE BASED ON THE LARGER OF THE TWO ADJACENT SPANS AND 5d
2. SPLICES SHALL BE MECHANICAL, WELDED, OR CLASS B LAP SPLICE

NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

SLAB MIDDLE STRIP

FIGURE SLAB-2_1, 2_2, AND 2_3: TWO-WAY CONCRETE SLAB SCHEDULE

The design professional shall review the following checklist and
incorporate project-specific requirements into the details

INTENDED USE

Showing all two-way slabs reinforcement on project on one schedule

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Each two-way slab type is assigned with slab mark in the table and coordinated with slab marks on floor plan drawing
2. Two-way slab bar sizes and locations are properly entered and coordinated in the table
3. Minimum flexural reinforcement satisfies Section 8.6.1 and corresponding minimum and maximum spacing satisfies Sections 25.2 and 8.7.2.2, respectively
4. Flexural reinforcement detailing and bar termination per Section 8.7.4.1
5. Structural integrity reinforcement is provided per Section 8.7.4.2
6. Shear reinforcement satisfies Section 8.7.6 or 8.7.7
7. Cantilever bars resisting flexure are placed parallel to the cantilever span
8. Development and spliced bars satisfy Sections 25.4 and 25.5
9. If bundled bars are used satisfy Section 25.6
10. Cover for reinforcement in slabs satisfies Section 20.5.1
11. Remove "NOTES TO DESIGN PROFESSIONAL" before placing schedule and details in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles[*]: 5, 13, 16, 36

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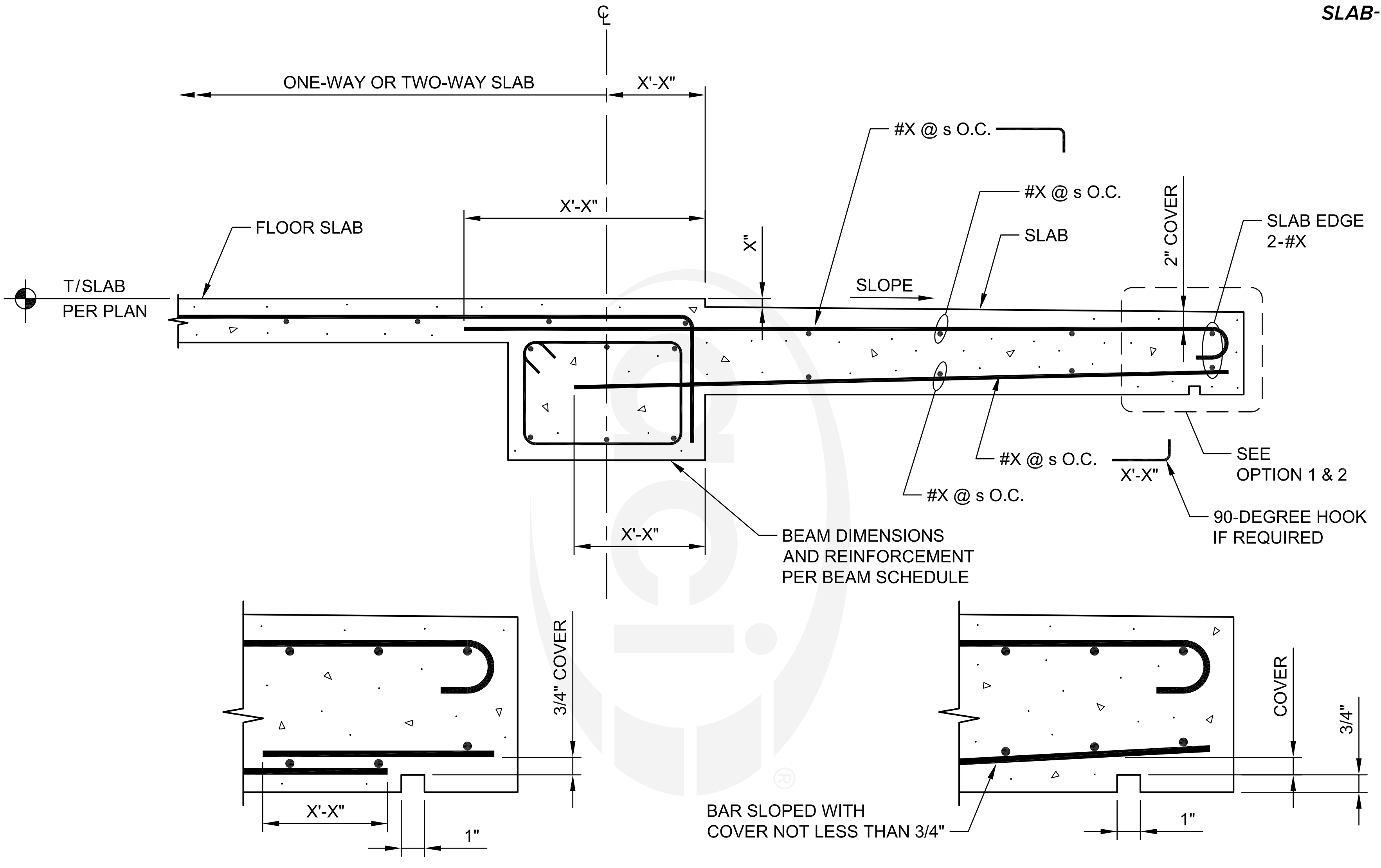
[*] Refer to Section 3 for articles

SLAB-100



OPTION 1

OPTION 2

NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE
INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

SLAB TO BEAM CONNECTION AT BALCONY

FIGURE SLAB-100: SLAB-TO-BEAM CONNECTION AT BALCONY

The design professional shall review the following checklist and incorporate project-specific requirements into the details

INTENDED USE

Solid nonprestressed one-way slab connection to beam with balcony

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Slab and cantilever depths, h, satisfy Section 7.3.1
2. Coordinate top of cantilever concrete elevation with architectural drawings
3. Cantilever bars resisting flexure are placed parallel to the cantilever span
4. Minimum cantilever flexural reinforcement satisfies Section 7.6.1 and corresponding minimum and maximum spacing satisfies Sections 25.2 and 7.7.2.4, respectively, and Table 24.3.2
5. Minimum shrinkage and temperature reinforcement is provided perpendicular to the span and satisfies Sections 7.6.4, 24.4.1, and 7.7.6.1
6. General reinforcement detailing per Section 7.7.1:
   a. Development length for deformed reinforcement satisfies Section 25.4
   b. Lap splices of deformed reinforcement satisfies Section 25.5
7. Beam resists torsion has closed ties designed and is detailed per Sections 9.5.4, 9.6.4, 9.7.5, and 9.7.6
8. Bars are properly detailed at the water drip strip location per Option 1 or 2. Note that detail shows Option 2. Modify detail if Option 1 is preferred
9. Cover for reinforcement in slabs satisfies Section 20.5.1
10. Balcony top surface slopes away from slab
11. Remove "NOTES TO DESIGN PROFESSIONAL" before placing detail in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles[*]: 5, 13, 16, 21, 22, 23

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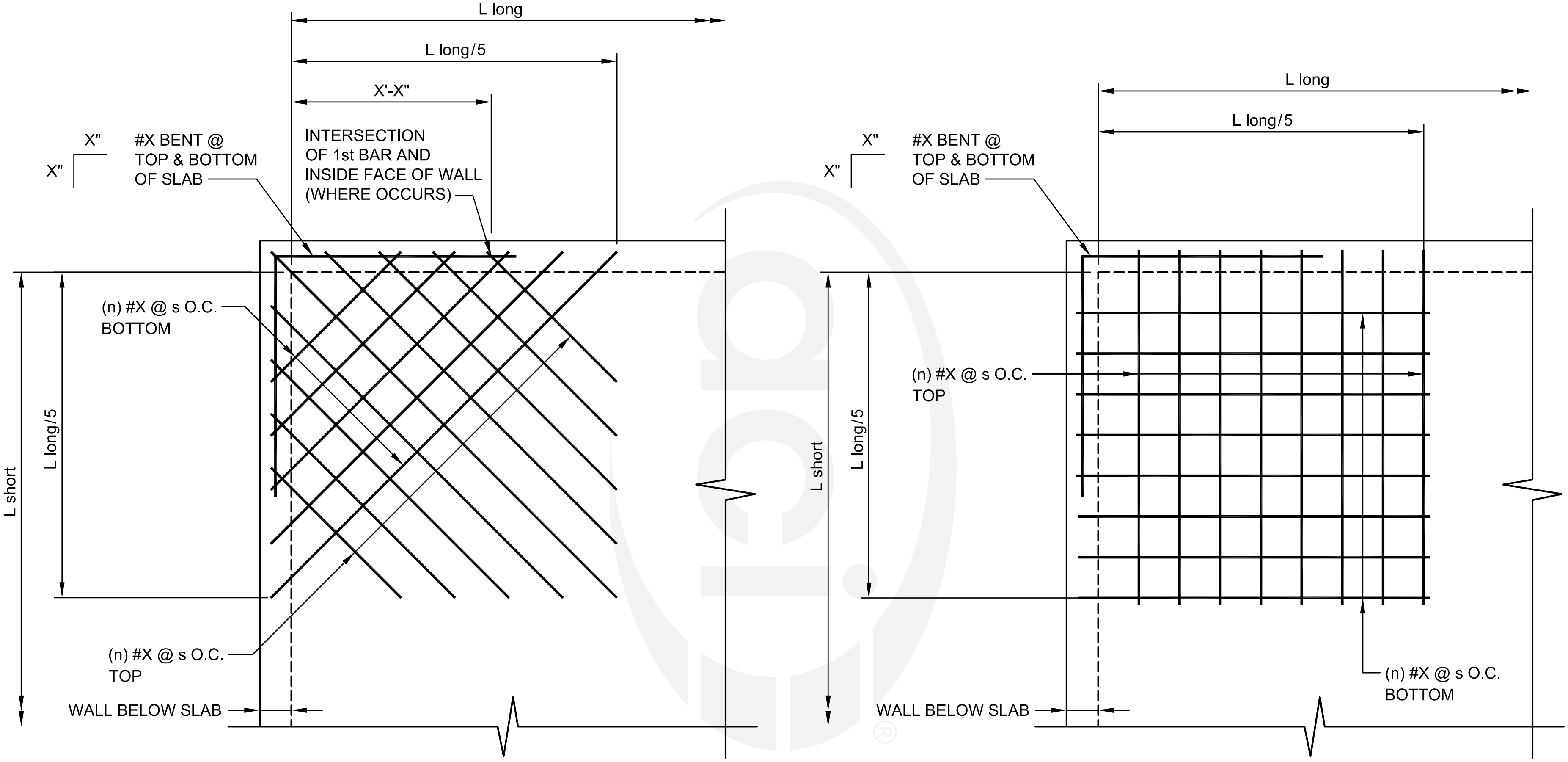
[*] Refer to Section 3 for articles

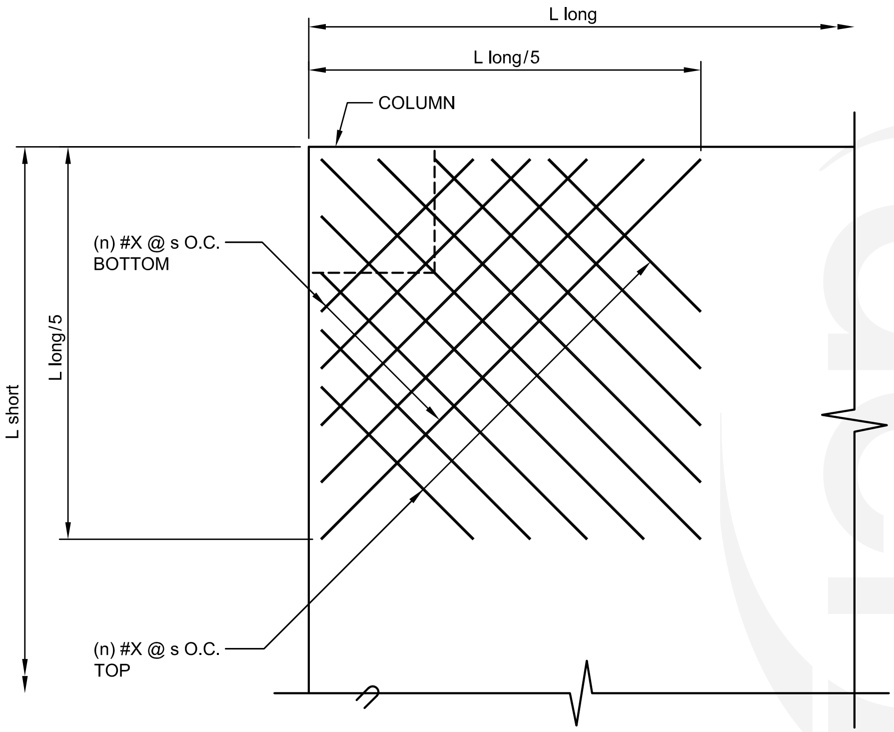


OPTION 1

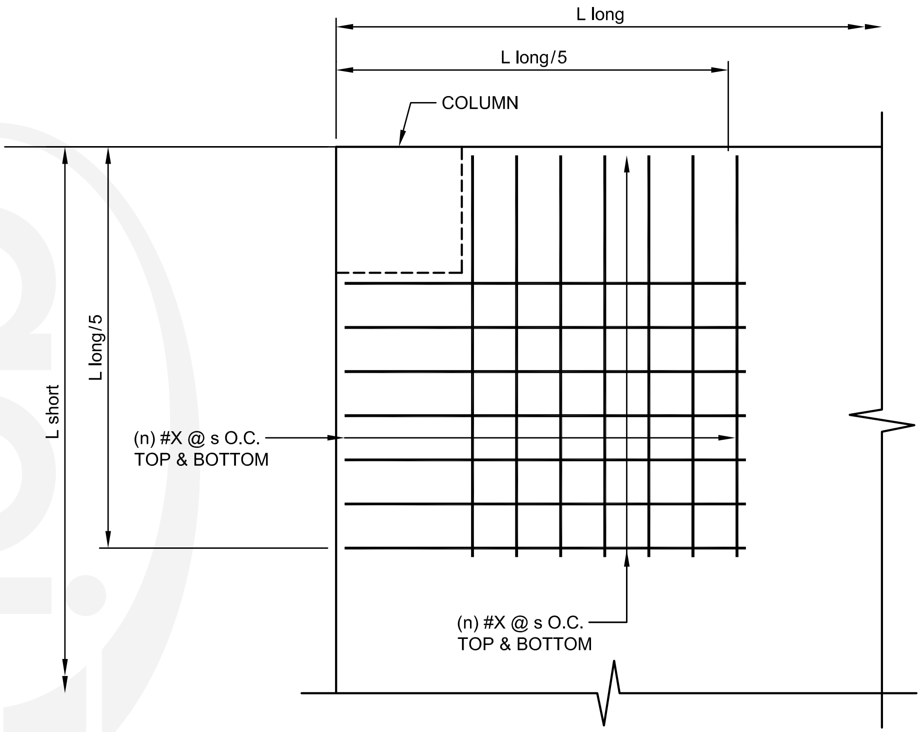
OPTION 2

NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE
INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

REINFORCEMENT AT SLAB CORNER / WALL



OPTION 1



OPTION 2

NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE
INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

REINFORCEMENT AT SLAB CORNER / COLUMN

FIGURE SLAB-200 AND SLAB-201: TWO-WAY SLAB CORNER REINFORCEMENT

The design professional shall review the following checklist and incorporate project-specific requirements into the details

INTENDED USE

Solid nonprestressed two-way slab corner restraint reinforcement

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. At exterior corners additional reinforcement is provided; Section 8.7.3.1
2. Use Option 1 or 2:
3. Option 1:
    a. Place top bars parallel to the diagonal from the corner of the slab
    b. Place bottom bars perpendicular to the diagonal from the corner of the slab
4. Option 2:
    a. Place bars in two layers parallel to the sides of the slab in both top and bottom of the slab
5. For both options, extend bars one-fifth of the longer span
6. Remove “NOTES TO DESIGN PROFESSIONAL” before placing detail in the Contract Documents

Note: Option 2 has the advantage of easier placement of the bars, but may result in congested reinforcement

RECOMMENDED REFERENCES

Concrete International articles[*]: 23, 33

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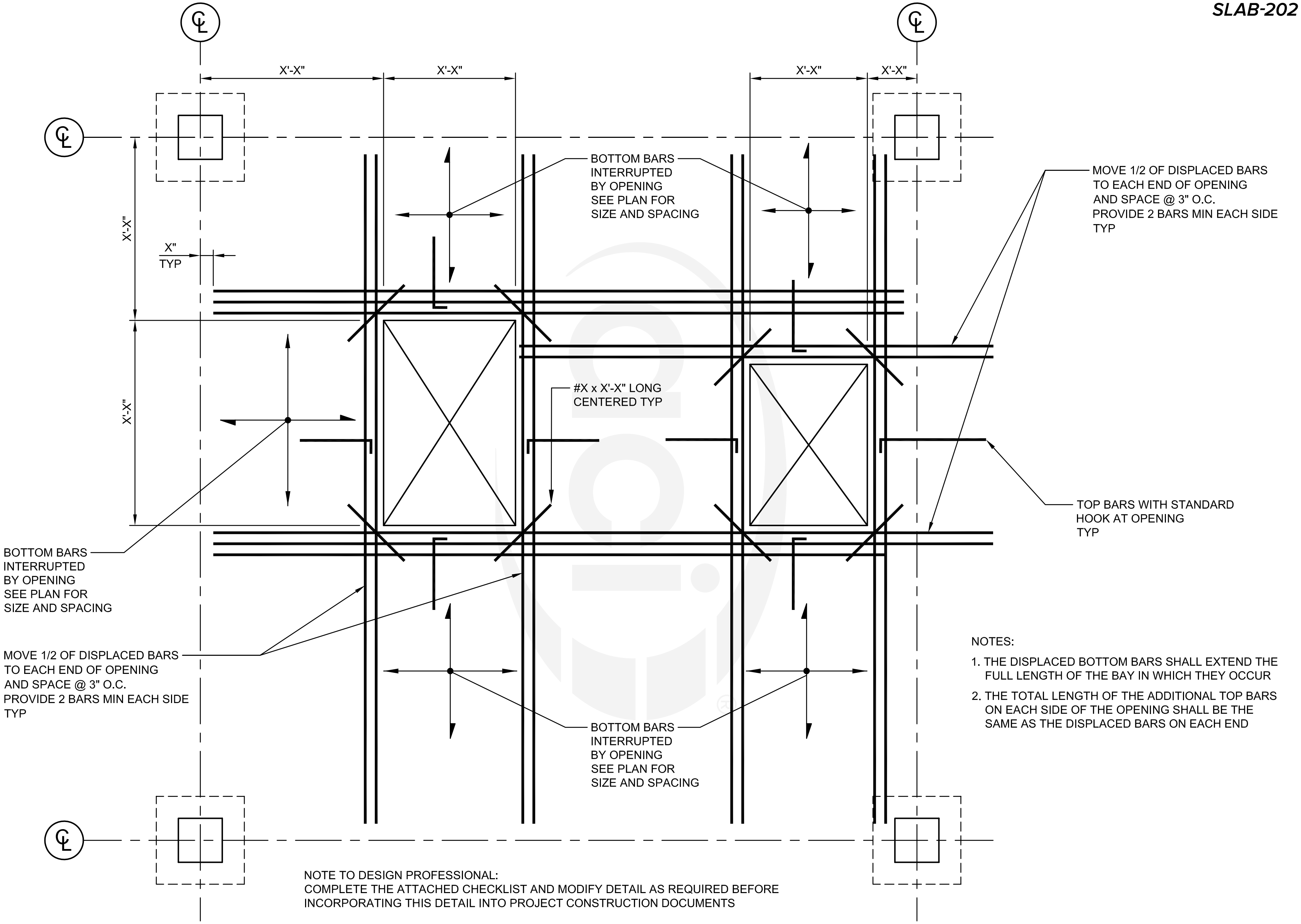
[*] Refer to Section 3 for articles

SLAB-202



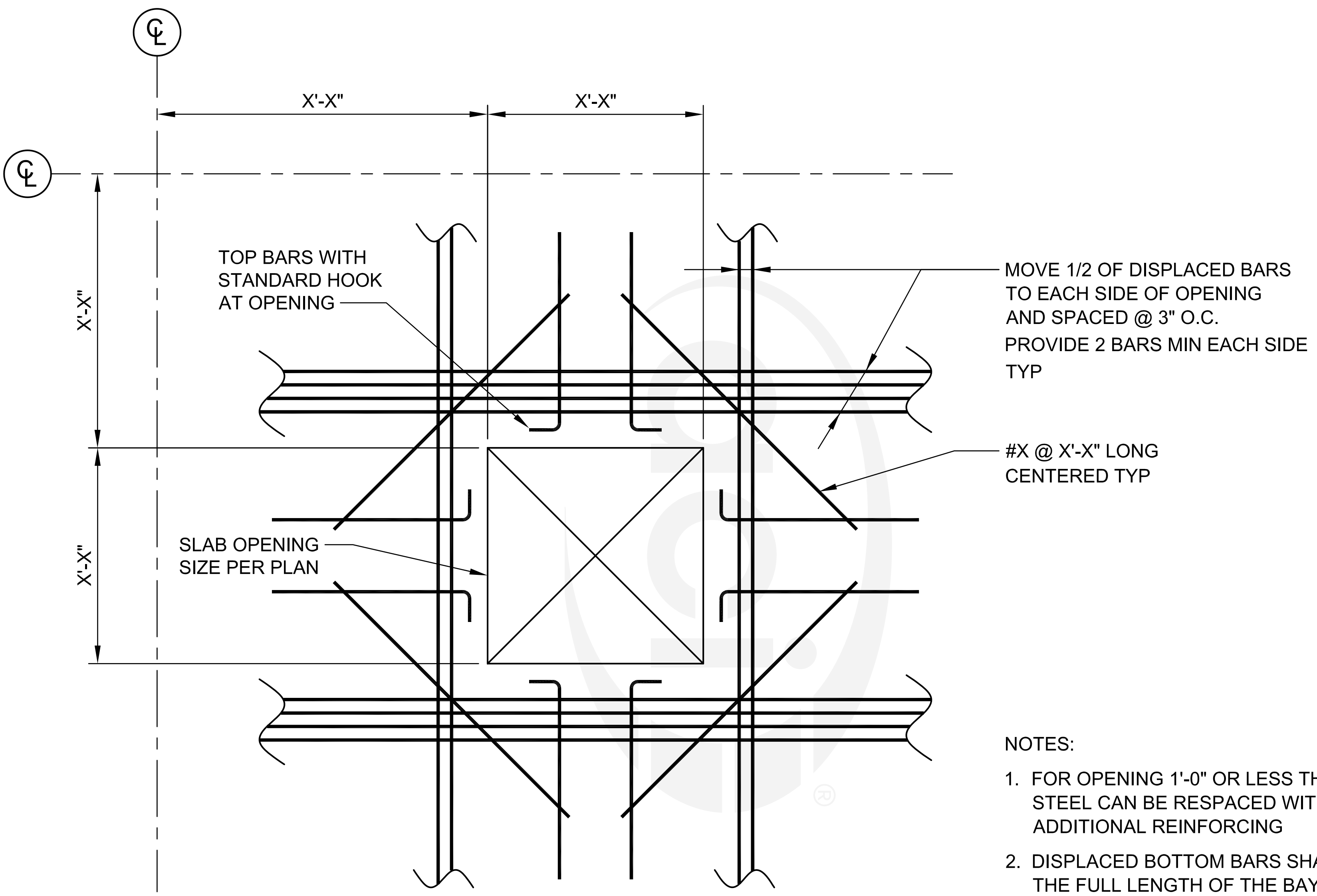
NOTES:

1. THE DISPLACED BOTTOM BARS SHALL EXTEND THE FULL LENGTH OF THE BAY IN WHICH THEY OCCUR
2. THE TOTAL LENGTH OF THE ADDITIONAL TOP BARS ON EACH SIDE OF THE OPENING SHALL BE THE SAME AS THE DISPLACED BARS ON EACH END

NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

TWO-WAY CONCRETE SLAB REINFORCEMENT AT OPENINGS

SLAB-203



NOTES:

1. FOR OPENING 1'-0" OR LESS THE SLAB STEEL CAN BE RESPACED WITHOUT ADDITIONAL REINFORCING
2. DISPLACED BOTTOM BARS SHALL EXTEND THE FULL LENGTH OF THE BAY IN WHICH THEY OCCUR
3. TOTAL LENGTH OF ADDITIONAL TOP BARS ON EACH SIDE OF OPENING SHALL BE SAME AS DISPLACED BARS ON EACH END

NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

CONCRETE SLAB REINFORCEMENT AT OPENING

FIGURE SLAB-202 AND SLAB-203: TWO-WAY CONCRETE SLAB REINFORCEMENT AT SLAB OPENINGS

The design professional shall review the following checklist and
incorporate project-specific requirements into the details

INTENDED USE

Openings in one-way and two-way slabs

Supplemental reinforcement at openings in concrete slabs

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Slab with opening(s) satisfy strength and serviceability requirements; Section 8.5.4
2. At the slab opening where slab reinforcement is terminated at opening, provide one-half of the interrupted longitudinal bars on each side and provide one-half of the interrupted transverse bars on each side of the corresponding opening
3. Longitudinal and transverse bars around openings to match slab reinforcement, but not less than one No. 5 bar centered
4. Additional bars are extended minimum development length beyond opening edge
5. Bars 4 ft long at 45 degrees are added and centered with respect to opening corners in slab each layer of reinforcement
6. If a distance is not available for the added bars to extend beyond opening edges a distance at least equal to the development length, then bars should be hooked
7. Cover for reinforcement in slabs satisfies Section 20.5.1
8. Remove “NOTES TO DESIGN PROFESSIONAL” before placing detail in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles*: 13, 16, 22, 24

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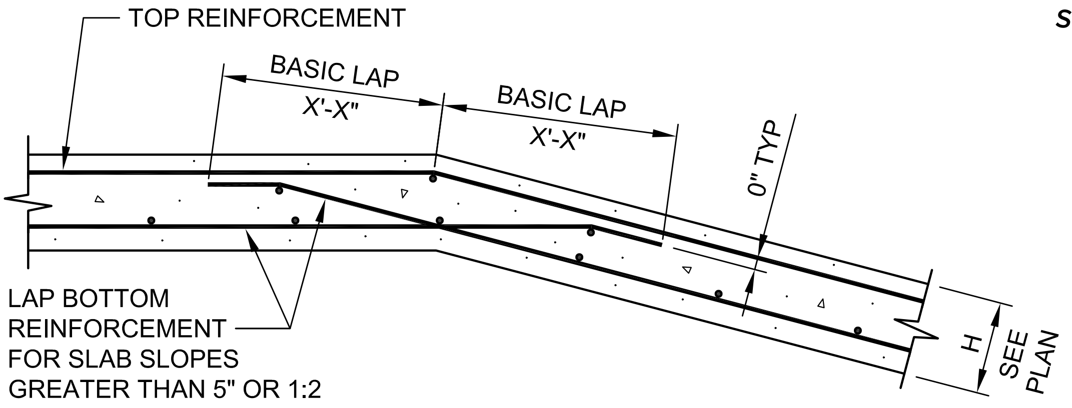
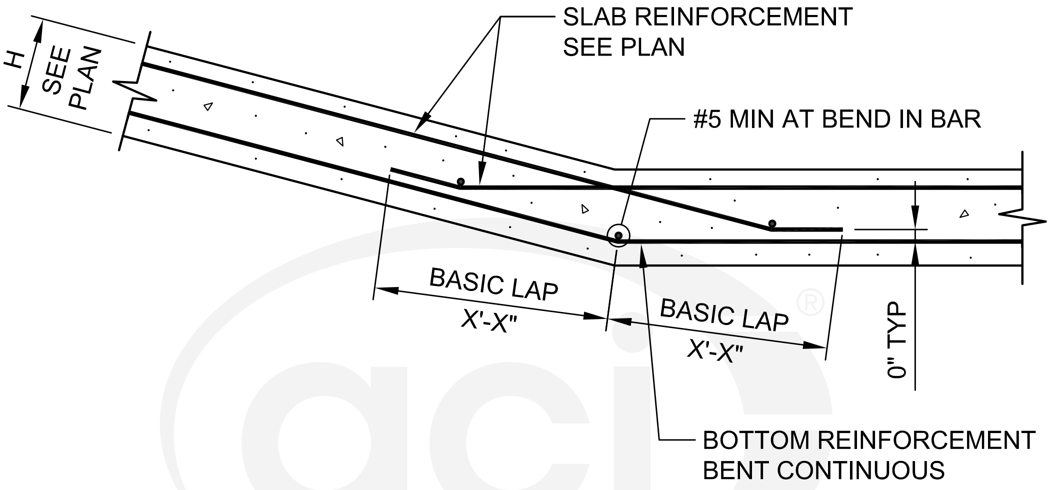
*Refer to Section 3 for articles

SLAB-204





NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

SLOPE IN ELEVATED SLAB

FIGURE SLAB-204: SLOPE IN ELEVATED SLAB

The design professional shall review the following checklist and
incorporate project-specific requirements into the details

INTENDED USE

Change in top of slab elevation from slope in solid nonprestressed one-way slab. Slope in slab occurs between slab supports at transition slab

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Slab depth in flat region and slab depth sloped region, H, satisfies Section 7.3.1
2. Reinforcement cover satisfies minimum required by Section 20.5.1
3. Flexural bars (bottom bars) of slab sloping upwards extend in flat region and sloped region of slab through slope point with tension embedment length beyond slope point of slab
4. Flexural bars (bottom bars) of slab sloping downward extend in flat region and sloped region of slab through slope point with tension embedment length beyond slope point of slab
5. General reinforcement detailing Section 7.7.1:
    a. Development length for deformed reinforcement satisfies Section 25.4
    b. Lap splices of deformed reinforcement satisfies Section 25.5
6. Remove “NOTES TO DESIGN PROFESSIONAL” before placing detail in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles[*]: 5, 16, 22

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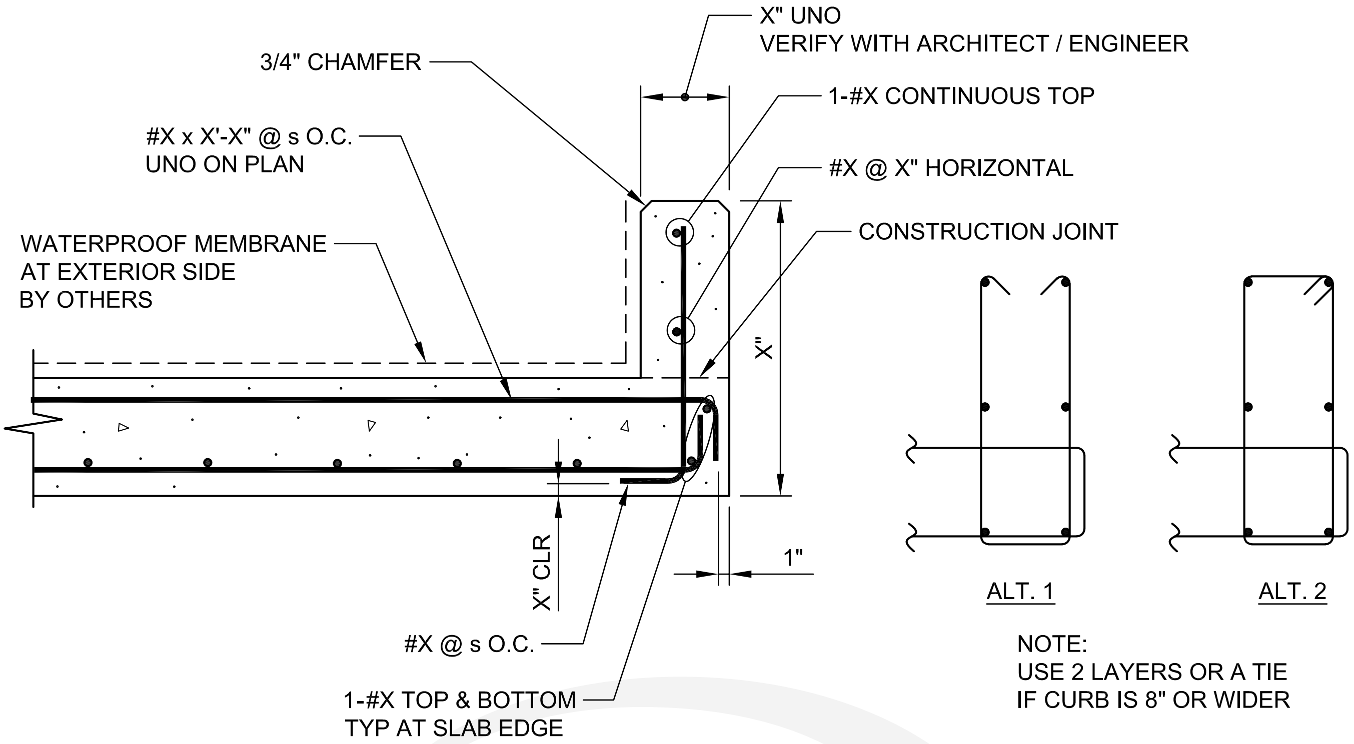
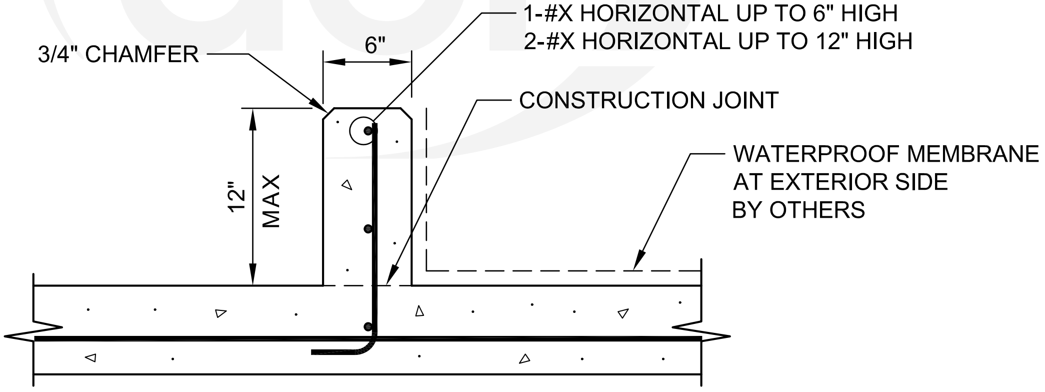
[*] Refer to Section 3 for articles

SLAB-205



CONCRETE CURB AT SLAB EDGE



NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

INTERIOR CONCRETE SLAB CURB

FIGURE SLAB-205: SLAB WITH A CONCRETE CURB INTERIOR/EDGE

The design professional shall review the following checklist and incorporate project-specific requirements into the details

INTENDED USE

Supported slab that terminates at edge with concrete curb

Concrete curb within supported slab span

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Slab depth, h, satisfies Section 7.3.1 or 8.3.1
2. Cover for reinforcement in slabs satisfies Section 20.5.1
3. Slab top and bottom reinforcement to terminate with 90-degree hook near edge of slab
4. At least one No. 5 bar is provided top and bottom at edge of slab
5. 90-degree bent bars are provided for curb reinforcement parallel to bottom slab flexural reinforcement. Bar lengths to exceed tension development length per Section 25.4. Tension lap splice 90-degree bars with bottom longitudinal slab reinforcement
6. Curb transverse reinforcement are provided
7. Construction joint assumptions are specified in the contract documents and satisfy Section 26.5.6
8. Remove "NOTES TO DESIGN PROFESSIONAL" before placing detail in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles[*]: 13, 16

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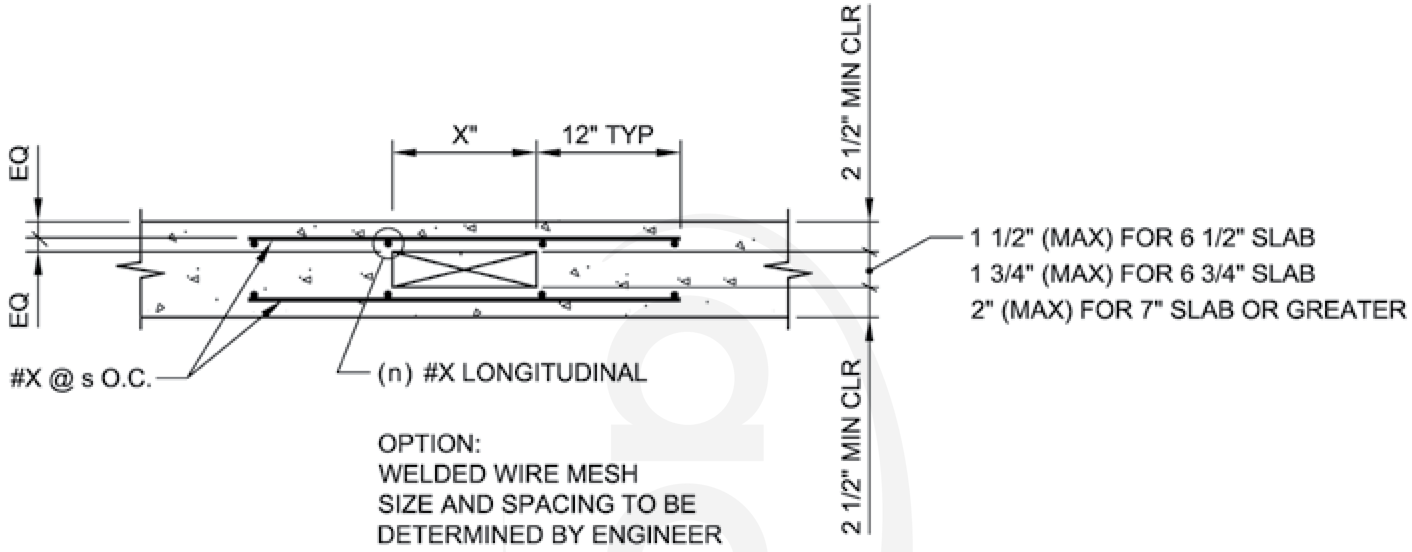
[*] Refer to Section 3 for articles



MINIMUM REINFORCING FOR SLAB AT DUCT

DUCT TO BE 30" (MIN) CLEAR OF ALL SLAB SUPPORTS
DUCT TO BE 24" (MIN) CLEAR OF OTHER DUCTS
FOR EXACT LOCATION, SIZE & EXTENT REFER TO MECHANICAL DRAWINGS

NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

CONCRETE ELEVATED SLAB WITH EMBEDDED DUCTWORK

FIGURE SLAB-206: CONCRETE ELEVATED SLAB WITH EMBEDDED DUCTWORK

The design professional shall review the following checklist and incorporate project-specific requirements into the details

---

INTENDED USE

Solid nonprestressed slab with embedded ductwork in slab

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Slab depth, *h*, satisfies Sections 7.3.1 and 8.3.1
2. Reinforcement cover satisfies minimum required by Section 20.5.1
3. Embedded duct material satisfies Section 20.6
4. Duct width should not exceed 12 in.
5. Minimum 2-1/2 in. concrete depth above and below embedded duct is provided
6. Spacing between floor reinforcement and embedded duct surface satisfies Section 25.2
7. Supplementary reinforcement is provided above and below embedded duct spanning beyond edges of duct work; terminate supplementary bars top and bottom a minimum tension development length beyond the edge of ductwork
8. Remove “NOTES TO DESIGN PROFESSIONAL” before placing detail in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles[*]: 10, 16

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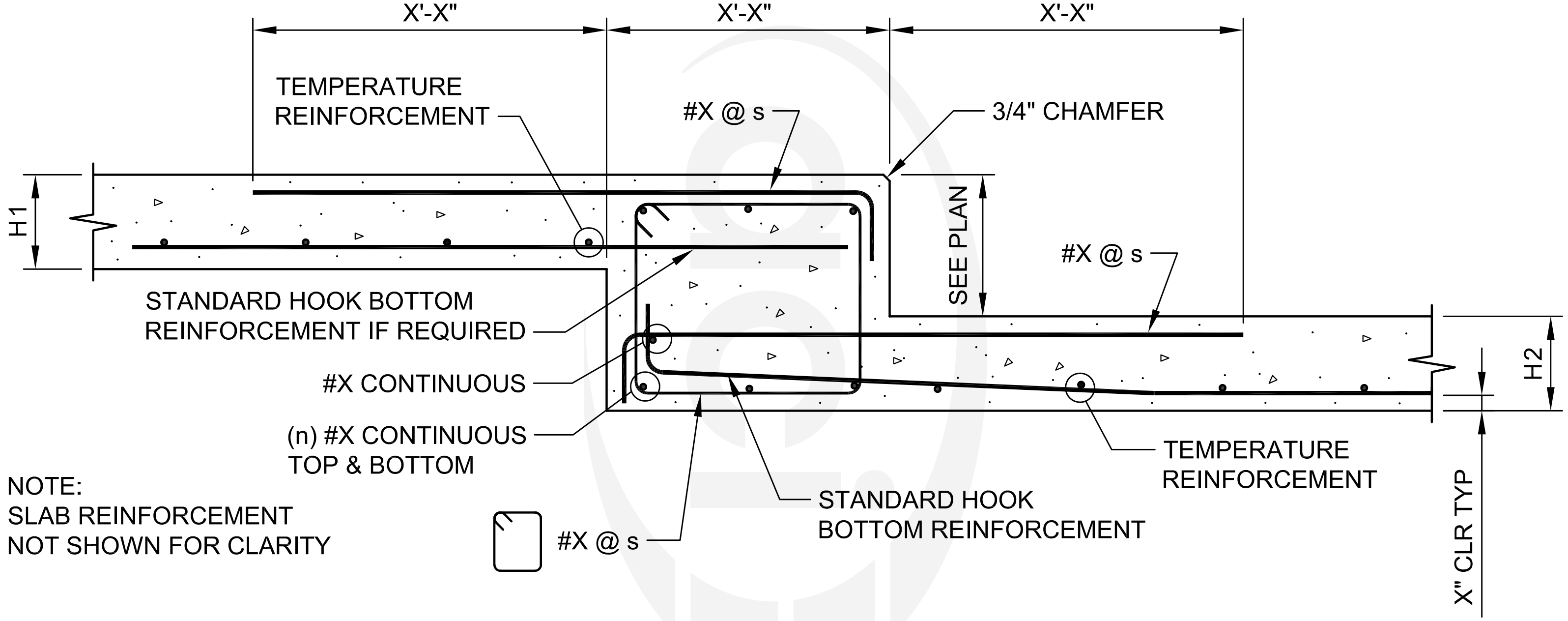
[*] Refer to Section 3 for articles



NOTE:
SLAB REINFORCEMENT
NOT SHOWN FOR CLARITY

NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

STEP IN ELEVATED SLAB

FIGURE SLAB-207: STEP IN ELEVATED SLAB

The design professional shall review the following checklist and incorporate project-specific requirements into the details

---

INTENDED USE

Change in top of slab elevation or step in solid nonprestressed one-way slab using a transition slab. Step in slab occurs between slab supports at transition slab

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Step location and height are identified in the floor plan and coordinated with architectural drawings
2. Slab depth upper region and slab depth lower region, H1 and H2, satisfy Section 7.3.1
3. Reinforcement cover satisfies minimum required by Section 20.5.1
4. Top slab edge may terminate in ¾ in. chamfer or steel edge angle
5. Flexural reinforcement bars in upper part and lower part of stepped slab extend into transition portion with tension embedment extending bars. Longitudinal bars extended into transition slab may be tension spliced with slab flexural reinforcement
6. Top reinforcement bars are added in upper and lower part of stepped slab and extend into transition region with standard hook near vertical surface. Terminate other end into slab with tension development length beyond transition edge
7. General reinforcement detailing per Section 7.7.1:
   a. Development length for deformed reinforcement satisfies Section 25.4
   b. Lap splices of deformed reinforcement satisfies Section 25.5
8. Top and bottom longitudinal bars are added in transition region with closed stirrups full length of region. Spacing of bars satisfies Sections 7.7.2. and 24.3
9. Longitudinal bars in the transition region extend a minimum distance equal to tension development length per Section 25.4.2
10. Remove "NOTES TO DESIGN PROFESSIONAL" before placing detail in the Contract Documents

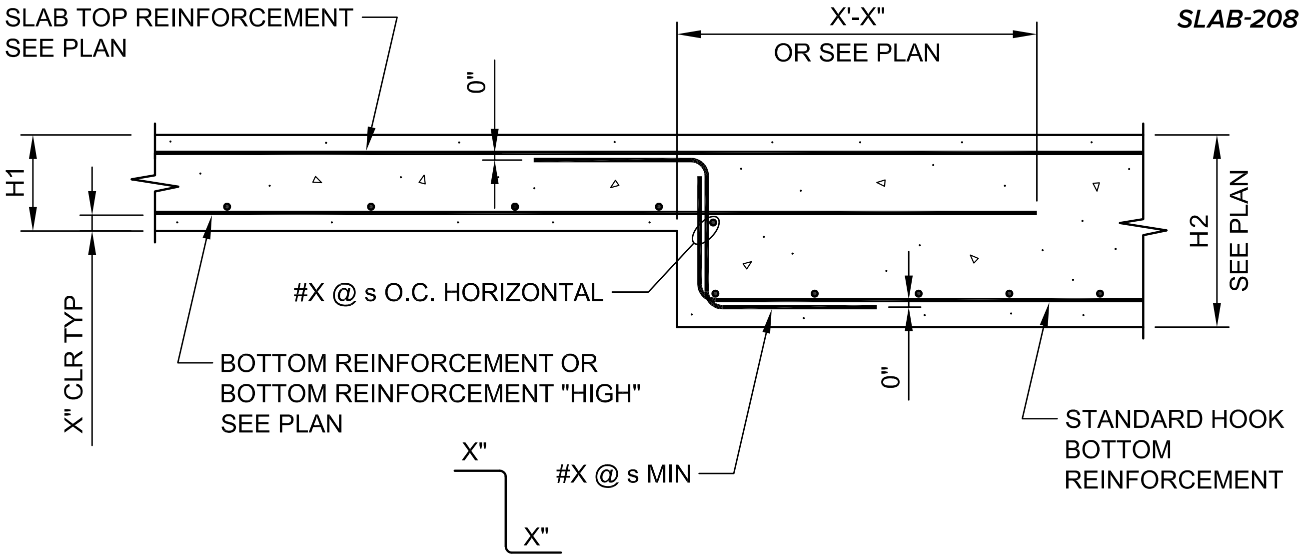
RECOMMENDED REFERENCES

Concrete International articles[*]: 13, 16, 20, 32

---

[*] Refer to Section 3 for articles

SLAB-208



NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

SLAB THICKNESS CHANGE - STEP IN BOTTOM OF ELEVATED ONE-WAY SLAB

FIGURE SLAB-208: SLAB THICKNESS CHANGE—STEP IN BOTTOM OF ELEVATED ONE-WAY SLAB

The design professional shall review the following checklist and
incorporate project-specific requirements into the details

INTENDED USE

Change in bottom of slab elevation/thickness in solid nonprestressed one-way slab

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Change in slab depth is identified in the floor plan and coordinated with architectural drawings
2. Slab depths, H1 and H2, satisfies Section 7.3.1
3. Reinforcement cover satisfies minimum required by Section 20.5.1
4. Bottom bars in lesser depth slab are extended into deeper depth slab with tension development length satisfying Section 25.4
5. Transition Z bars matching bottom bar size and spacing are added at the change in depth satisfying tension lap splice; Section 25.5
6. Transition Z bars are extended to top reinforcement with a tension lap splice length; Section 25.5
7. Remove “NOTES TO DESIGN PROFESSIONAL” before placing detail in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles[*]: 13, 16, 22, 32

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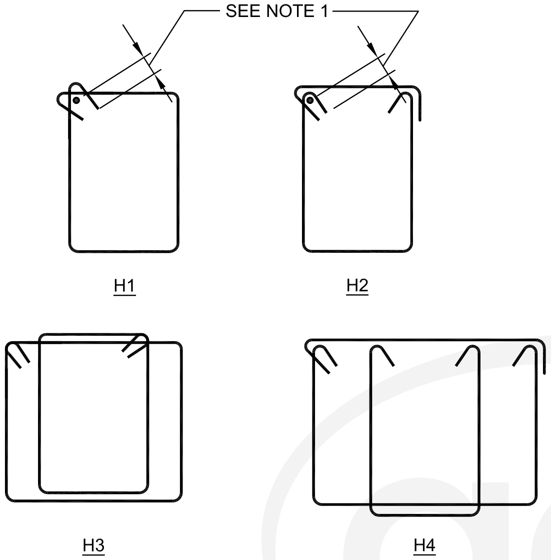
[*] Refer to Section 3 for articles

BEAM DETAILS

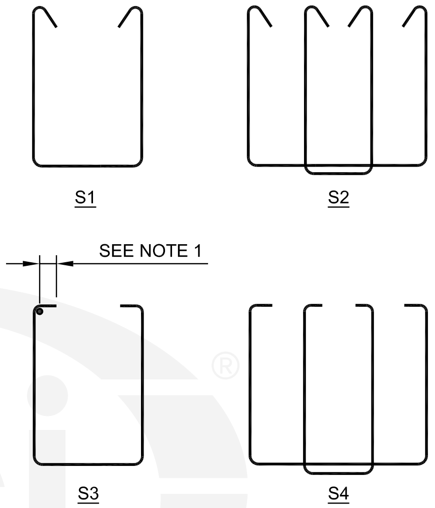
BM-1_1

REINFORCED CONCRETE BEAM SCHEDULE

MARK	SIZE	TYPE	MAIN HORIZONTAL REINFORCEMENT								TIES				REMARKS
	B x H		TOP					BOTTOM		SIDE BAR EACH	TR	TYPE	REST	TYPE	
			A	L4	B	C	L5	E	F						
B1	16 x 30	1	4 - #6	3'-0"	4 - #6	4 - #6	4'-0"	2 - #5	2 - #5		#4 @ 12"	H1	#4 @ 12"	S1	
B2	16 x 30	1	4 - #8	4'-0"			4'-6"	3 - #6			#4 @ 8"	S1	#4 @ 12"	S1	
B3	24 x 32	2	6 - #8	4'-0"			4'-6"	4 - #5		1 - #5		H3	#4 @ 12"	S4	



HOOP DETAILS



STIRRUP DETAILS

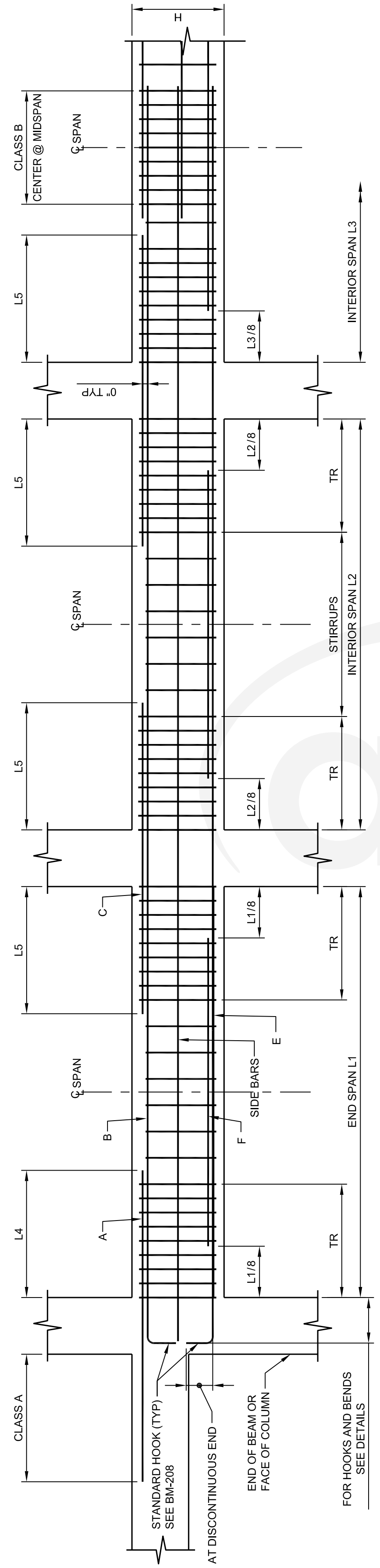
NOTES:

1. MINIMUM INSIDE BEND DIAMETER AND STANDARD HOOK GEOMETRY PER BM-209
2. WORK THIS SCHEDULE WITH FIG. BM-1_2 AND BM-1_3

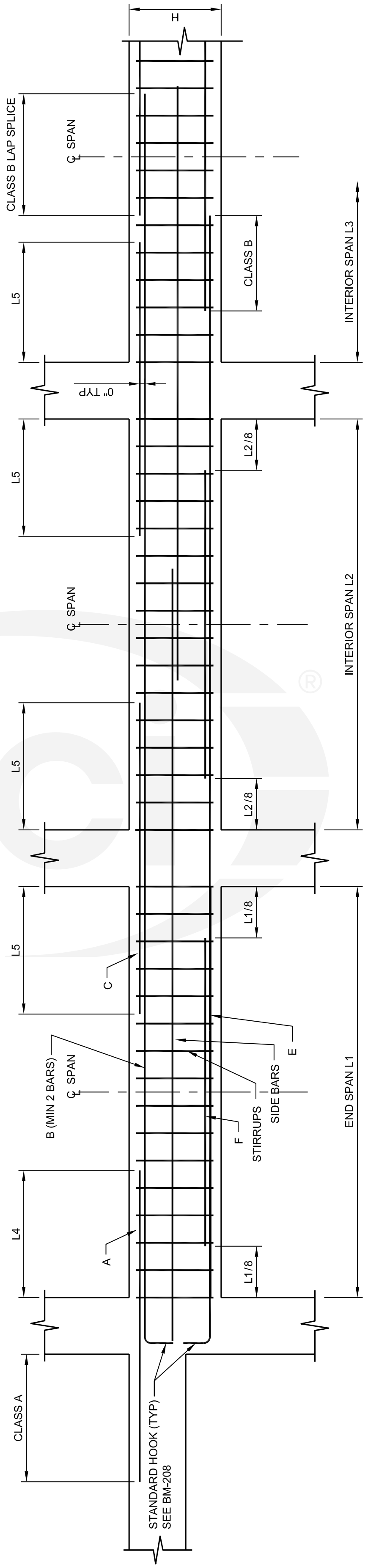
NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY TABLE AND DETAILS BEFORE
INCORPORATING THIS SCHEDULE INTO PROJECT CONSTRUCTION DOCUMENTS

REINFORCED CONCRETE BEAM SCHEDULE

BM-1_2



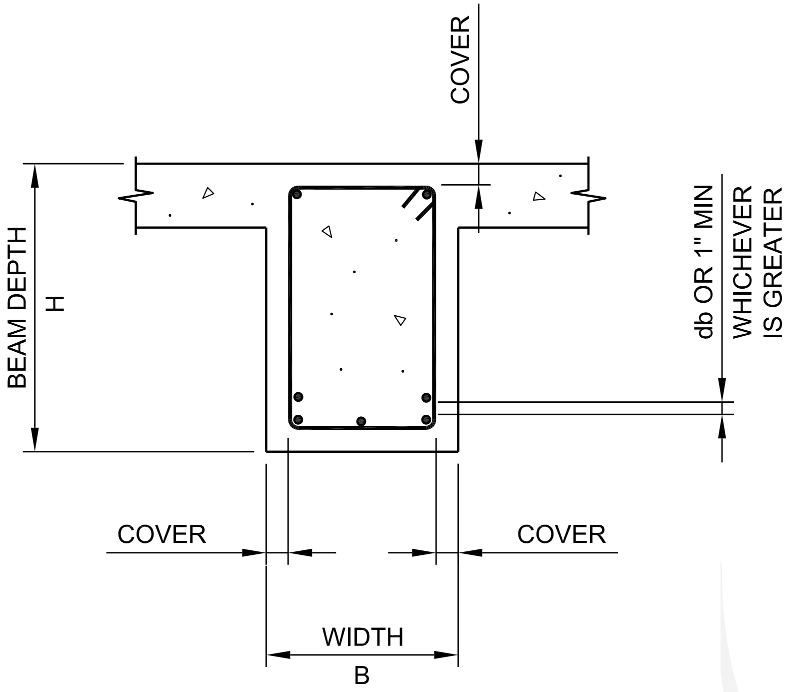
BEAM BARS PLACING DIAGRAM - TYPE I



NOTE:
WORK THIS FIGURE WITH SCHEDULE BM-1_1

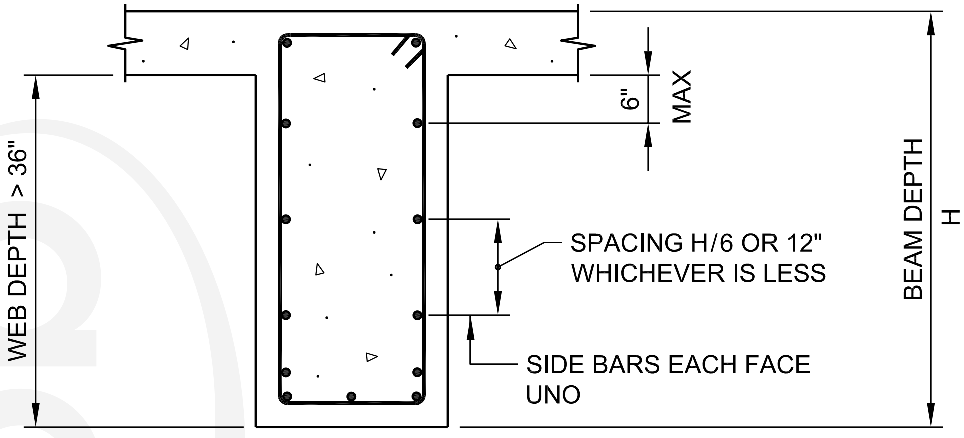
NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

BEAM BARS PLACING DIAGRAM - TYPE 2



TYPE 1

TYPICAL BEAM SECTION



TYPE 2

SKIN REINFORCEMENT FOR BEAM WITH WEB > 36"

NOTE:
WORK THIS FIGURE WITH SCHEDULE BM-1_1

NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

BEAM AND GIRDER REINFORCEMENT

FIGURE BM-1_1, 1_2, AND 1_3: TYPICAL BEAM SCHEDULE

The design professional shall review the following checklist and incorporate project-specific requirements into the details

INTENDED USE

Showing all reinforced concrete beams on project on one schedule

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Work Details BM-1_1 through BM-1_3 together
2. Beam is continuously laterally supported; Section 9.2.3.1
3. Each beam type is assigned with beam mark and coordinate beam marks on floor plan drawing
4. Beam schedule includes:
   a. Beam mark
   b. Beam dimensions
   c. Top and bottom bar sizes and types
   d. Development length of top bars L4 and L5
   e. Side bars if beams depth exceeds 36 in. or beam is subjected to torsion
   f. Size, spacing, and type of lateral reinforcement
5. Minimum flexural reinforcement area in nonprestressed beam satisfies Section 9.6.1
6. Longitudinal bar spacing satisfies the minimum spacing per Sections 9.7.2.1 and 25.2
7. Flexure reinforcement satisfies requirements of Sections 9.7.3.2 through 9.7.3.7
8. Minimum shear reinforcement satisfies Section 9.6.3
9. Maximum spacing of along length and across width of shear reinforcement per Section 9.7.6.2.2
10. Minimum shear reinforcement bar size satisfies Section 9.7.6.4.2
11. Minimum longitudinal torsional reinforcement satisfies Section 9.6.4
12. Transverse torsional reinforcement satisfies Section 9.7.6.3.3
13. For beams with depth exceeding 36 in., side bars, skin reinforcement is provided; Section 9.7.2.3
14. Concrete reinforcement cover satisfies Sections 9.7.1.1 and 20.5.1
15. Extend top negative reinforcement a minimum development length L4 and L5; Section 25.2
16. Remove "NOTES TO DESIGN PROFESSIONAL" before placing detail in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles[*]: 13, 16, 18, 19, 20, 23

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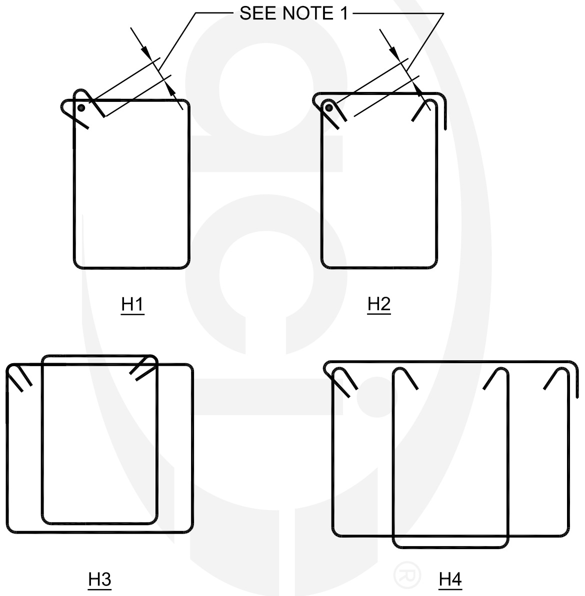
[*] Refer to Section 3 for articles

BM-2_1

REINFORCED CONCRETE PERIMETER BEAM SCHEDULE

MARK	SIZE	TYPE	MAIN HORIZONTAL REINFORCEMENT											TIES				REMARKS
	B x H		TOP						BOTTOM				SIDE BAR EACH	TR	TYPE	RESET	TYPE	
			A	L4	B	C	L5	D	E	F	G	H						
B1	16 x 30	1	4 - #6	3'-0"	4 - #6	4 - #6	4'-0"	2 - #6	4 - #5	2 - #5	4 - #5			#4 @ 12"	H1	#4 @ 12"	H1	
B2	16 x 30	1	4 - #8	4'-0"		6 - #6	4'-6"		3 - #6	2 - #6	2 - #6			#4 @ 8"	H1	#4 @ 12"	H1	
B3	24 x 38	2	6 - #8	4'-0"		4 - #6	4'-6"		4 - #6		4 - #6	2 - #6	1 - #5	#4 @ 10"	H3	#4 @ 12"	H3	



HOOP DETAILS

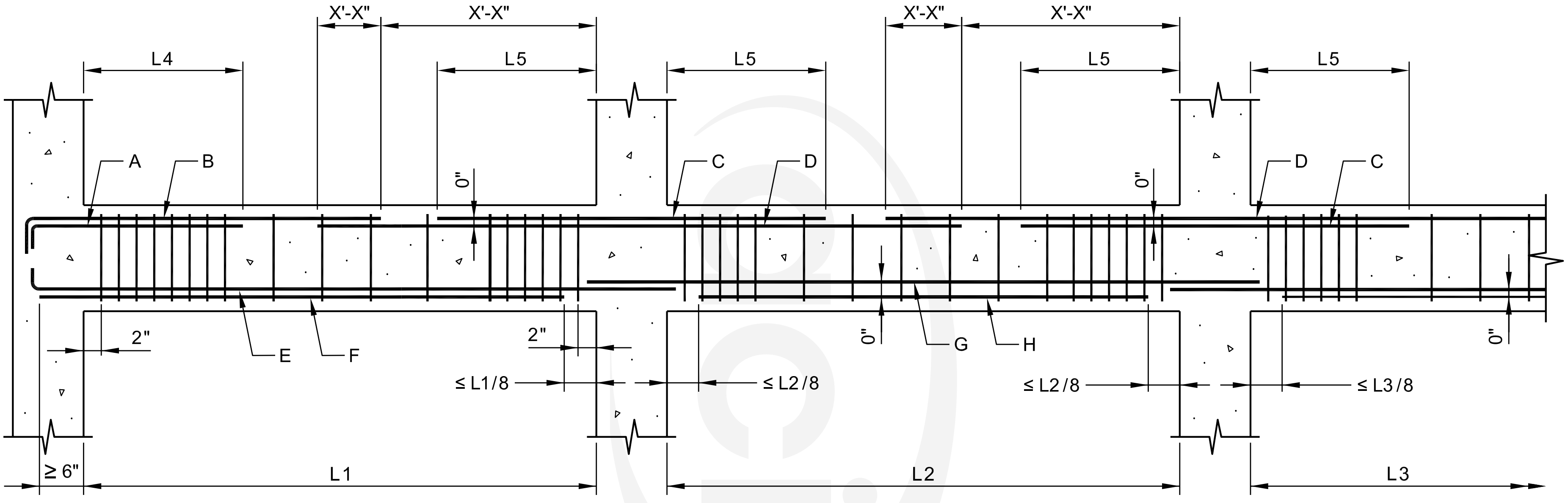
NOTES:

1. MINIMUM INSIDE BEND DIAMETER AND STANDARD HOOK GEOMETRY PER BM-209
2. WORK THIS SCHEDULE WITH FIG. BM-2_2 AND BM-2_3

NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY TABLE AND DETAILS BEFORE
INCORPORATING THIS SCHEDULE INTO PROJECT CONSTRUCTION DOCUMENTS

REINFORCED CONCRETE PERIMETER BEAM SCHEDULE

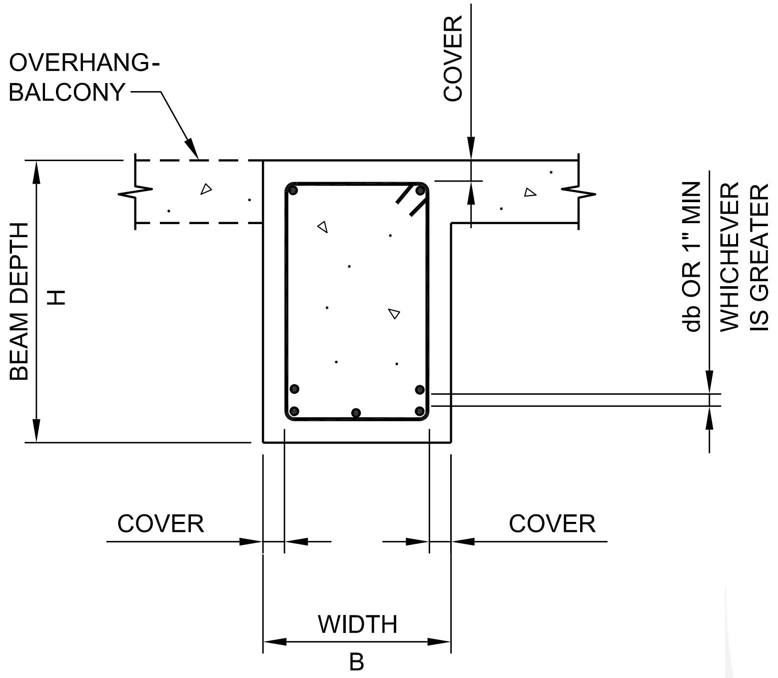
BM-2_2



NOTE:
WORK THIS FIGURE WITH SCHEDULE BM-2_1

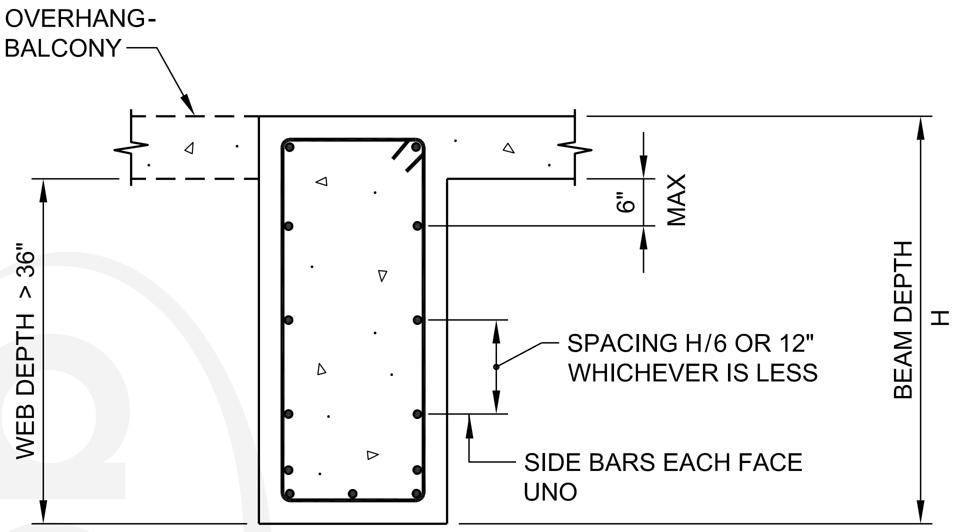
NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE
INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

REQUIRED INTEGRITY REINFORCEMENT - PERIMETER BEAM



TYPE 1

TYPICAL PERIMETER BEAM SECTION



TYPE 2

SKIN REINFORCEMENT FOR PERIMETER BEAM WITH WEB > 36"

NOTE:
WORK THIS FIGURE WITH SCHEDULE BM-2_1

NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE
INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

BEAM AND GIRDER REINFORCEMENT - PERIMETER BEAM

FIGURE BM-2_1, 2_2, AND 2_3: REQUIRED INTEGRITY REINFORCEMENT FOR PERIMETER BEAMS

The design professional shall review the following checklist and
incorporate project-specific requirements into the details

INTENDED USE

Typical beam along the perimeter of a building

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Work Details BM-2_1 through BM-2_3 together
2. Beam is continuously laterally supported; Section 9.2.3.1
3. Beam schedule includes:
    a. Beam mark (BM); each beam type is assigned with BM; coordinate BMs on floor plan drawing
    b. Beam dimensions
    c. Top and bottom bar sizes and types
    d. Development length of top bars L4 and L5
    e. Side bars if beams depth exceeds 36 in. or beam is subjected to torsion
    f. Size, spacing, and type of lateral reinforcement
4. Minimum flexural reinforcement area in nonprestressed beam satisfies Section 9.6.1
5. Longitudinal bar spacing satisfies the minimum spacing per Sections 9.7.2.1 and 25.2
6. Bars closest to the tension face satisfy Sections 9.7.2.2 and 24.3
7. For beams with $h \geq 36$ in., side bars, skin reinforcement is provided; Section 9.7.2.3
8. Flexural bars anchorage, development, extension, embedment, and termination requirements per Sections 9.7.3.2 through 9.7.3.7
9. At simple supports, at least 1/3 of $A_{s,max}^{+}$ but not less than two bars satisfy Section 9.7.3.8.1
10. At continuous supports at least 1/4 of $A_{s,max}^{+}$ but not less than two bars satisfy Section 9.7.3.8.2
11. At support at least 1/3 of A_s^{-} but not less than two bars satisfy Section 9.7.3.8.4
12. Top bars extend from face of supports a minimum development length; Section 9.7.1.2
13. Compression bars are laterally supported satisfying Section 9.7.6.4
14. Integrity reinforcement must satisfy the following; Section 9.7.7.1:
    a. At least 1/4 of maximum A_s^{+}, but not less than two bars are continuous
    b. At least 1/6 of A_s^{-} at support, but not less than two bars are continuous
    c. Longitudinal integrity reinforcement is enclosed by closed stirrups per Section 25.7.1.6
15. Longitudinal structural integrity bars pass through column bars; Section 9.7.7.3
16. Anchor integrity reinforcement at support to develop f_y; Section 9.7.7.4
17. Splices of positive moment bars must be located near support; Section 9.7.7.5(a)
18. Splices of negative moment bars must be located near midspan; Section 9.7.7.5(b)
19. Bars are spliced per Sections 9.7.1.3 and 25.5
20. Minimum shear reinforcement satisfies Section 9.6.3
21. Maximum spacing of shear reinforcement along length and across width of beam cross section per Section 9.7.6.2.2
22. Minimum shear reinforcement bar size satisfies Section 9.7.6.4.2
23. Concrete reinforcement cover satisfies Sections 9.7.1.1 and 20.5.1
24. Remove “NOTES TO DESIGN PROFESSIONAL” before placing detail in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles[*]: 2, 7, 13, 16, 18, 19, 20, 23

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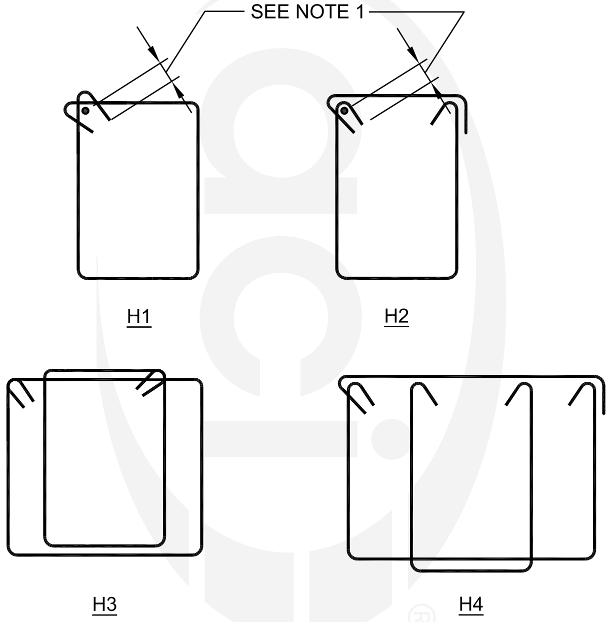
[*] Refer to Section 3 for articles

BM-3_1

REINFORCED CONCRETE NON-PERIMETER BEAM SCHEDULE

MARK	SIZE	TYPE	MAIN HORIZONTAL REINFORCEMENT									TIES				REMARKS
	B x H		TOP				BOTTOM				SIDE BAR EACH	TR	TYPE	RESET	TYPE	
			A	L4	C	L5	E	F	G	H						
B1	16 x 30	1	4 - #6	3'-0"	2 - #6	4'-0"	2 - #5	2 - #5	2 - #5	2 - #5		#4 @ 12"	H1	#4 @ 12"	H1	
B2	16 x 30	1	4 - #8	4'-0"		4'-6"	3 - #6	2 - #6	2 - #6			#4 @ 8"	H1	#4 @ 12"	H1	
B3	24 x 38	2	6 - #8	4'-0"		4'-6"	4 - #6		4 - #8		1 - #5	#4 @ 10"	H3	#4 @ 12"	H3	



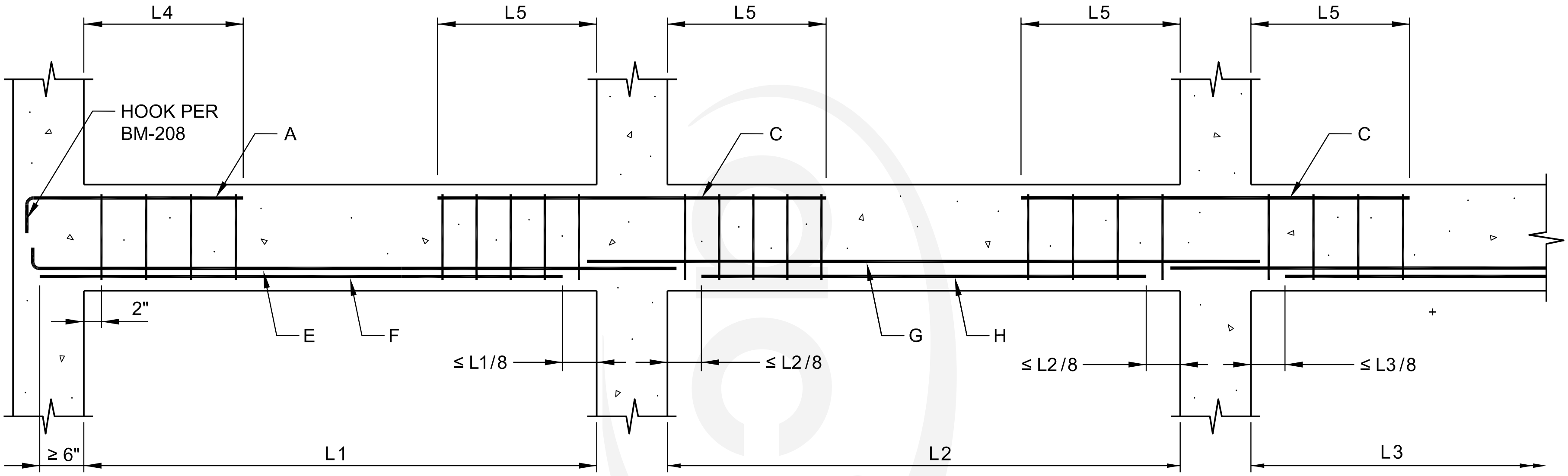
HOOP DETAILS

NOTES:
1. MINIMUM INSIDE BEND DIAMETER AND STANDARD HOOK GEOMETRY PER BM-209
2. WORK THIS SCHEDULE WITH FIG. BM-3_2 AND BM-3_3

NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY TABLE AND DETAILS BEFORE INCORPORATING THIS SCHEDULE INTO PROJECT CONSTRUCTION DOCUMENTS

REINFORCED CONCRETE NON-PERIMETER BEAM SCHEDULE

BM-3_2

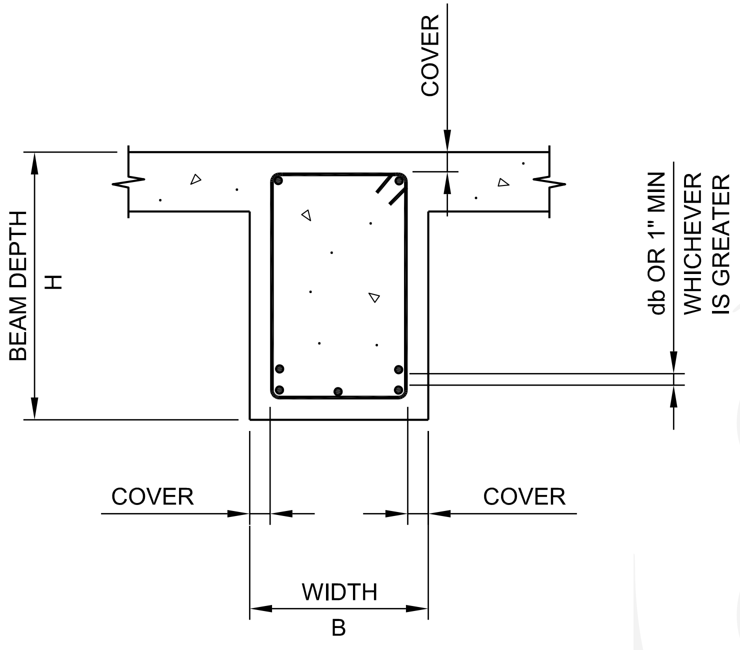


NOTE:
WORK THIS FIGURE WITH SCHEDULE BM-3_1

NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE
INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

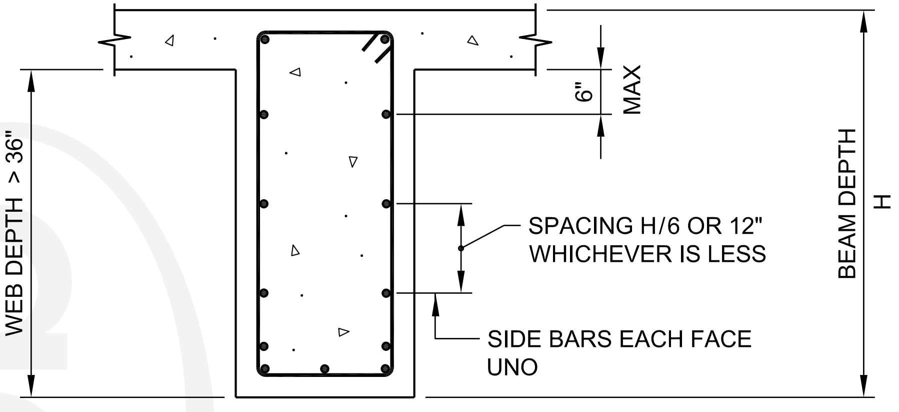
REQUIRED INTEGRITY REINFORCEMENT - OTHER THAN PERIMETER BEAMS

BM-3_3



TYPE 1

TYPICAL BEAM SECTION



TYPE 2

SKIN REINFORCEMENT FOR BEAM WITH WEB > 36"

NOTE:
WORK THIS FIGURE WITH SCHEDULE BM-3_1

NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

BEAM AND GIRDER REINFORCEMENT

FIGURE BM-3_1, 3_2, AND 3_3: REQUIRED INTEGRITY REINFORCEMENT FOR NONPERIMETER BEAMS

The design professional shall review the following checklist and
incorporate project-specific requirements into the details

INTENDED USE

Typical beam along the perimeter of a building

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Work Details BM-3_1 through BM-3_3 together
2. Beam is continuously laterally supported; Section 9.2.3.1
3. Beam schedule includes:
   a. Beam mark (BM); each beam type is assigned with BM; coordinate BMs on floor plan drawing
   b. Beam dimensions
   c. Top and bottom bar sizes and types
   d. Development length of top bars L4 and L5
   e. Side bars if beams depth exceeds 36 in. or beam is subjected to torsion
   f. Size, spacing, and type of lateral reinforcement
4. Minimum flexural reinforcement area in nonprestressed beam satisfies Section 9.6.1
5. Longitudinal bar spacing satisfies the minimum spacing per Sections 9.7.2.1 and 25.2
6. Bars closest to the tension face satisfy Sections 9.7.2.2 and 24.3
7. For beams with $h \geq 36$ in., side bars, skin reinforcement is provided; Section 9.7.2.3
8. Flexural bars anchorage, development, extension, embedment, and termination requirements per Sections 9.7.3.2 through 9.7.3.7
9. At simple supports, at least 1/3 of $A_{s,max}^+$ but not less than two bars satisfy Section 9.7.3.8.1.
10. At continuous supports, at least 1/4 of $A_{s,max}^+$ but not less than two satisfy Section 9.7.3.8.2
11. At support, at least 1/3 of A_s^- but not less than two bars satisfy Section 9.7.3.8.4
12. Top bars extend from face of supports a minimum development length; Section 9.7.1.2
13. Compression bars are laterally supported satisfying Section 9.7.6.4
14. Integrity reinforcement must satisfy the following; Section 9.7.7.1:
    a. At least 1/4 of maximum A_s^+, but not less than two bars are continuous
    b. At least 1/6 of A_s^- at support, but not less than two bars are continuous
    c. Longitudinal integrity reinforcement is enclosed by closed stirrups per Section 25.7.1.6
15. Longitudinal structural integrity bars pass through column bars, Section 9.7.7.3
16. Anchor integrity reinforcement at support to develop f_y; Section 9.7.7.4
17. Splices of positive moment bars must be located near support; Section 9.7.7.5(a)
18. Splices of negative moment bars must be located near midspan; Section 9.7.7.5(b)
19. Bars are spliced per Sections 9.7.1.3 and 25.5
20. Minimum shear reinforcement satisfies Section 9.6.3
21. Maximum spacing of shear reinforcement along length and across width of beam cross section per Section 9.7.6.2.2
22. Minimum shear reinforcement bar size satisfies Section 9.7.6.4.2
23. Concrete reinforcement cover satisfies Sections 9.7.1.1 and 20.5.1
24. Remove "NOTES TO DESIGN PROFESSIONAL" before placing detail in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles[*]: 2, 7, 13, 16, 18, 19, 20, 23

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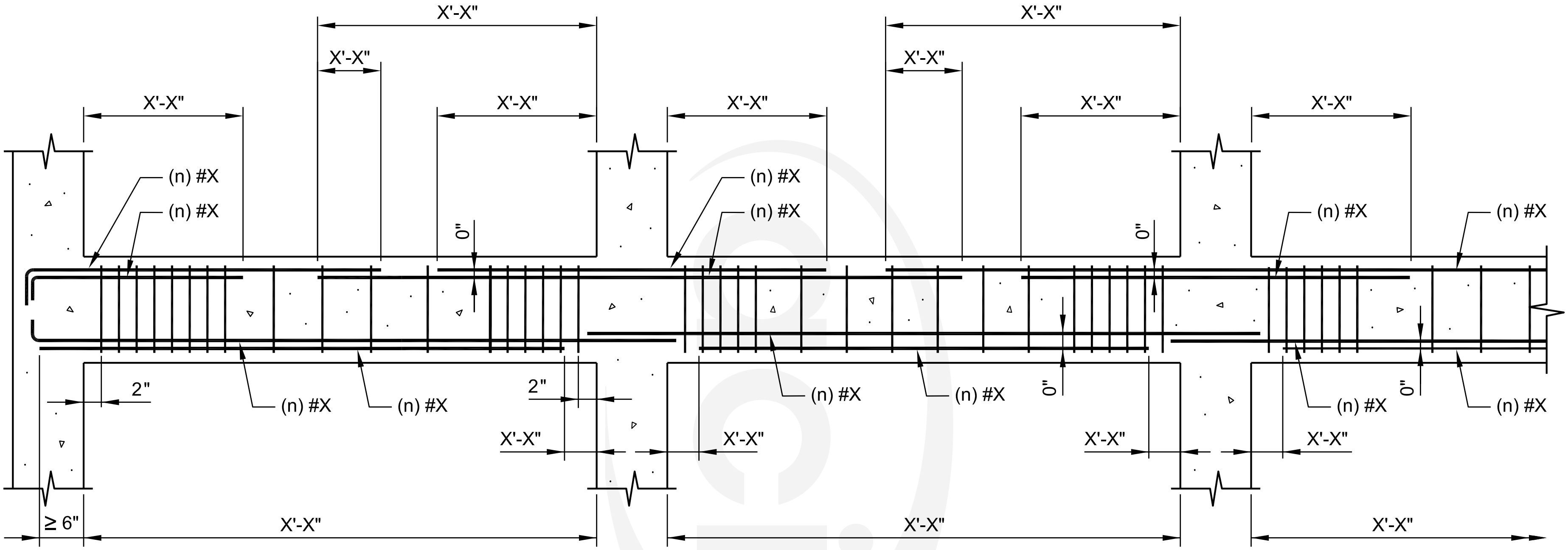
[*] Refer to Section 3 for articles



NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE
INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

REQUIRED INTEGRITY REINFORCEMENT - PERIMETER BEAM
(ALTERNATE)

FIGURE BM-100_ REQUIRED INTEGRITY REINFORCEMENT FOR PERIMETER BEAMS

The design professional shall review the following checklist and incorporate project-specific requirements into the details

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INTENDED USE

Typical beam along the perimeter of a building

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Coordinate beam detail with location on floor plan drawing
2. Beam is continuously laterally supported; Section 9.2.3.1
3. Minimum flexural reinforcement area in nonprestressed beam satisfies Section 9.6.1
4. Longitudinal bar spacing satisfies the minimum spacing per Sections 9.7.2.1 and 25.2
5. Bars closest to the tension face satisfy Sections 9.7.2.2 and 24.3
6. For beams with $h \geq 36$ in., side bars, skin reinforcement is provided; Section 9.7.2.3
7. Flexural bars anchorage, development, extension, embedment, and termination requirements per Sections 9.7.3.2 through 9.7.3.7
8. At simple supports, at least 1/3 of $A_{s,max}^+$ but not less than two bars satisfy Section 9.7.3.8.1
9. At continuous supports, at least 1/4 of $A_{s,max}^+$ but not less than two bars satisfy Section 9.7.3.8.2
10. At support at least 1/3 of A_s^- but not less than two bars satisfy Section 9.7.3.8.4
11. Top bars extend from face of supports a minimum development length; Section 9.7.1.2
12. Compression bars are laterally supported satisfying Section 9.7.6.4
13. Integrity reinforcement must satisfy the following; Section 9.7.7.1:
    a. At least 1/4 of maximum A_s^+ but not less than two bars are continuous
    b. At least 1/6 of A_s^- at support but not less than two bars are continuous
    c. Longitudinal integrity reinforcement is enclosed by closed stirrups per Section 25.7.1.6
14. Longitudinal structural integrity bars pass through column bars; Section 9.7.7.3
15. Anchor integrity reinforcement at support to develop f_y; Section 9.7.7.4
16. Splices of positive moment bars must be located near support; Section 9.7.7.5(a)
17. Splices of negative moment bars must be located near midspan; Section 9.7.7.5(b)
18. Bars are spliced per Sections 9.7.1.3 and 25.5
19. Minimum shear reinforcement satisfies; Section 9.6.3
20. Maximum spacing of shear reinforcement along length and across width of beam cross section per Section 9.7.6.2.2
21. Minimum shear reinforcement bar size satisfies Section 9.7.6.4.2
22. Concrete reinforcement cover satisfies Sections 9.7.1.1 and 20.5.1
23. Remove "NOTES TO DESIGN PROFESSIONAL" before placing detail in the Contract Documents

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Note: The design professional may use this detail or detail BM-2, table, to present the information in a table format if multiple types of perimeter beams are present in a project

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RECOMMENDED REFERENCES

Concrete International articles*: 2, 5, 7, 13, 16, 18, 19, 20, 23

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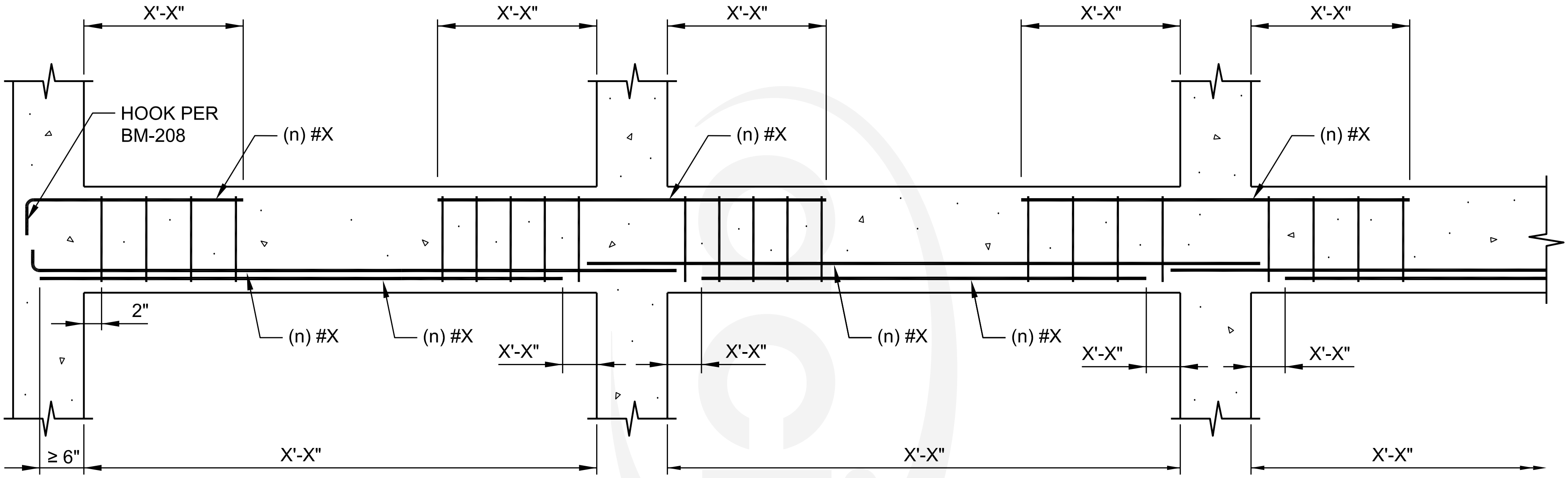
*Refer to Section 3 for articles



NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE
INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

REQUIRED INTEGRITY REINFORCEMENT - OTHER THAN PERIMETER BEAMS

(ALTERNATE)

FIGURE BM-101: INTEGRITY REINFORCEMENT FOR OTHER THAN PERIMETER BEAMS

The design professional shall review the following checklist and incorporate project-specific requirements into the details

INTENDED USE

Typical beam other than along the perimeter with integrity reinforcement

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Coordinate beam detail with location on floor plan drawing
2. Beam is continuously laterally supported; Section 9.2.3.1
3. Minimum flexural reinforcement area in nonprestressed beam satisfies Section 9.6.1
4. Longitudinal bar spacing satisfies the minimum spacing per Sections 9.7.2.1 and 25.2
5. Bars closest to the tension face satisfy Sections 9.7.2.2 and 24.3
6. For beams with $h \geq 36$ in., side bars, skin reinforcement is provided; Section 9.7.2.3
7. Flexural bars anchorage, development, extension, embedment, and termination requirements per Sections 9.7.3.2 through 9.7.3.7
8. At simple supports, at least 1/3 of $A_{s,max}^+$ but not less than two bars satisfy Section 9.7.3.8.1
9. At continuous supports at least 1/4 of $A_{s,max}^+$ but not less than two satisfy Section 9.7.3.8.2
10. At support at least 1/3 of A_s^- but not less than two bars satisfy Section 9.7.3.8.4
11. Top bars extend from face of supports a minimum development length; Section 9.7.1.2
12. Compression bars are laterally supported satisfying Section 9.7.6.4
13. Integrity reinforcement must satisfy the following; Section 9.7.7.1:
    a. At least 1/4 of maximum A_s^+ but not less than two bars are continuous
    b. At least 1/6 of A_s^- at support but not less than two bars are continuous
    c. Longitudinal integrity reinforcement is enclosed by closed stirrups per Section 25.7.1.6
14. Longitudinal structural integrity bars pass through column bars; Section 9.7.7.3
15. Anchor integrity reinforcement at support to develop f_y; Section 9.7.7.4
16. Splices of positive moment bars must be located near support; Section 9.7.7.5(a)
17. Splices of negative moment bars must be located near midspan; Section 9.7.7.5(b)
18. Bars are spliced per Sections 9.7.1.3 and 25.5
19. Minimum shear reinforcement satisfies Section 9.6.3
20. Maximum spacing of shear reinforcement along length and across width of beam cross section per Section 9.7.6.2.2
21. Minimum shear reinforcement bar size satisfies Section 9.7.6.4.2
22. Concrete reinforcement cover satisfies Sections 9.7.1.1 and 20.5.1
23. Remove "NOTES TO DESIGN PROFESSIONAL" before placing detail in the Contract Documents

Note: The design professional may use this detail or detail BM-1, table, to present the information in table format if multiple types of beams are present in a project

RECOMMENDED REFERENCES

Concrete International articles*: 2, 5, 7, 13, 16, 18, 19, 20, 23

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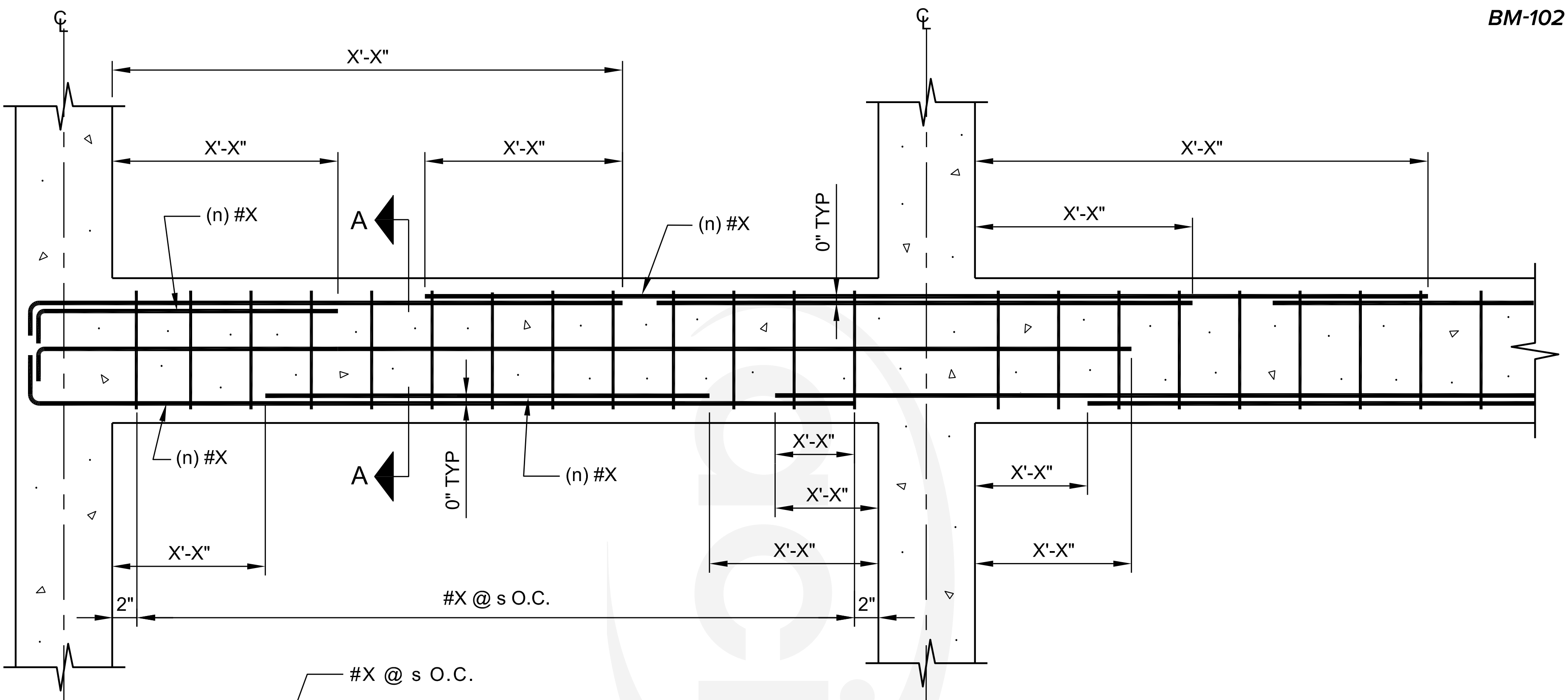
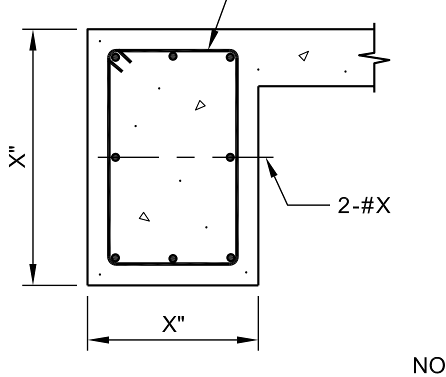
*Refer to Section 3 for articles

BM-102





SECTION A-A

NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

BEAM SUBJECTED TO TORSION

FIGURE BM-102: TYPICAL BEAM SUBJECTED TO TORSION

The design professional shall review the following checklist and incorporate project-specific requirements into the details

INTENDED USE

Beam subjected to torsional forces

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Refer to typical beam notes per corresponding seismic design category
2. The following torsional reinforcement requirements are satisfied:
   a. Transverse torsional reinforcement is closed stirrups satisfying Sections 25.7.1.6 and 25.7.1.6.1
   b. Transverse torsional reinforcement extends a distance of $b_t + d$ beyond point required by analysis per Section 9.7.6.3.2
   c. Transverse torsional reinforcement satisfies Section 9.7.6.3.3
   d. Develop longitudinal torsional reinforcement into support at both ends
3. Remove "NOTES TO DESIGN PROFESSIONAL" before placing detail in the Contract Documents

Note: The design professional may use this detail or detail BM-1, table, to present the information in a table format if multiple types of beams subjected to torsion are present in the project.

RECOMMENDED REFERENCES

Concrete International articles[*]: 2, 5, 7, 13, 16, 18, 19, 20, 23

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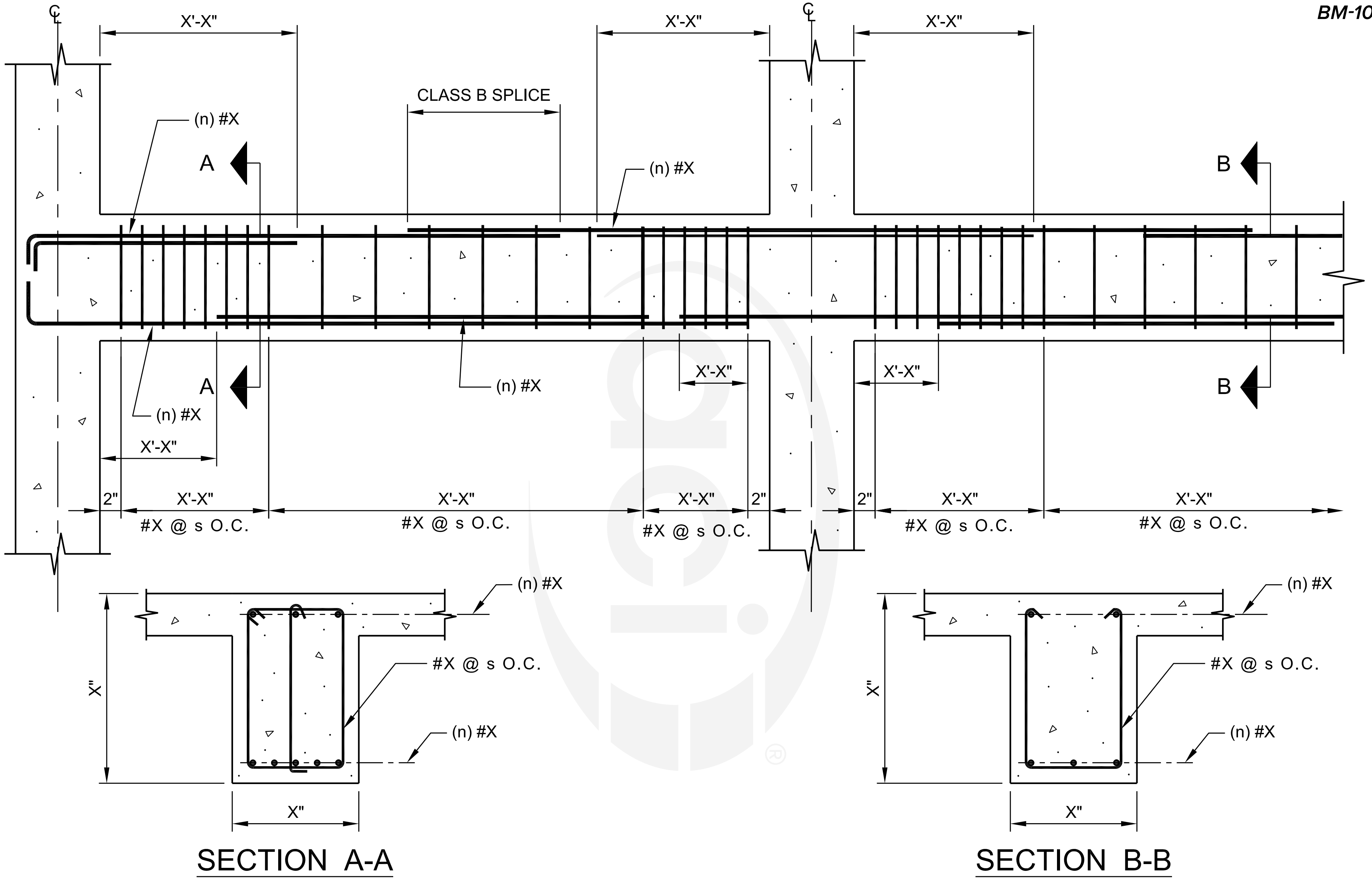
[*] Refer to Section 3 for articles

BM-103



SECTION A-A

SECTION B-B

NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE
INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

BEAM AS PART OF ORDINARY MOMENT FRAME, SDC B

FIGURE BM-103: BEAM AS PART OF ORDINARY MOMENT FRAME IN SDC B

The design professional shall review the following checklist and incorporate project-specific requirements into the details

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INTENDED USE

Typical beam part of intermediate moment frame

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Beam is continuously laterally supported; Section 9.2.3.1
2. Minimum flexural reinforcement area in nonprestressed beam satisfies Section 9.6.1
3. Minimum shear reinforcement satisfies Section 9.6.3
4. Concrete cover satisfies Section 9.7.1.1 and 20.5.1
5. Minimum bar spacing satisfies Section 9.7.2.1 and 25.2
6. Bars closest to the tension face satisfy Section 9.7.2.2 and 24.3
7. Skin reinforcement is provided over $h/2$ from the tension face for beam depths greater than 36 in. and complies with code requirements; Section 9.7.2.3
8. Flexure reinforcement satisfies requirements of Sections 9.7.3.2 through 9.7.3.7
9. At simple supports, at least 1/3 of $A_{s,max}^{+}$ but not less than two bars satisfy Section 9.7.3.8.1
10. At continuous supports, at least 1/4 of $A_{s,max}^{+}$ but not less than two bars satisfy Section 9.7.3.8.2
11. At support, at least 1/3 of A_s^{-} but not less than two bars satisfy Section 9.7.3.8.4
12. Minimum shear reinforcement bar size satisfies; Section 9.7.6.4.2
13. Maximum spacing of shear reinforcement along length and across width of beam cross section per Section 9.7.6.2.2
14. 1/4 of positive moment bars but not less than two bars must be continuous; Section 9.7.7.2a
15. Longitudinal compression bars are laterally supported satisfying Section 9.7.6.4.4
16. Splices of positive moment bars must be located near support; Section 9.7.7.5(a)
17. Splices of negative moment bars must be located near midspan; Section 9.7.7.5(b)
18. Bars are spliced per Sections 9.7.1.3 and 25.5
19. Minimum two continuous bars top and bottom are provided and anchored to develop f_y in tension at face of support; Section 18.3.2
20. Development lengths are calculated per Section 25.4.2
21. For integrity reinforcement refer to Detail BM-100 or BM-101
22. Remove “NOTES TO DESIGN PROFESSIONAL” before placing detail in the Contract Documents

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Note: The design professional may use this detail or detail BM-1, table, to present the information in table format if multiple types of beams are present in a project.

RECOMMENDED REFERENCES

Concrete International articles[*]: 2, 5, 7, 13, 16, 18, 19, 18, 20, 23

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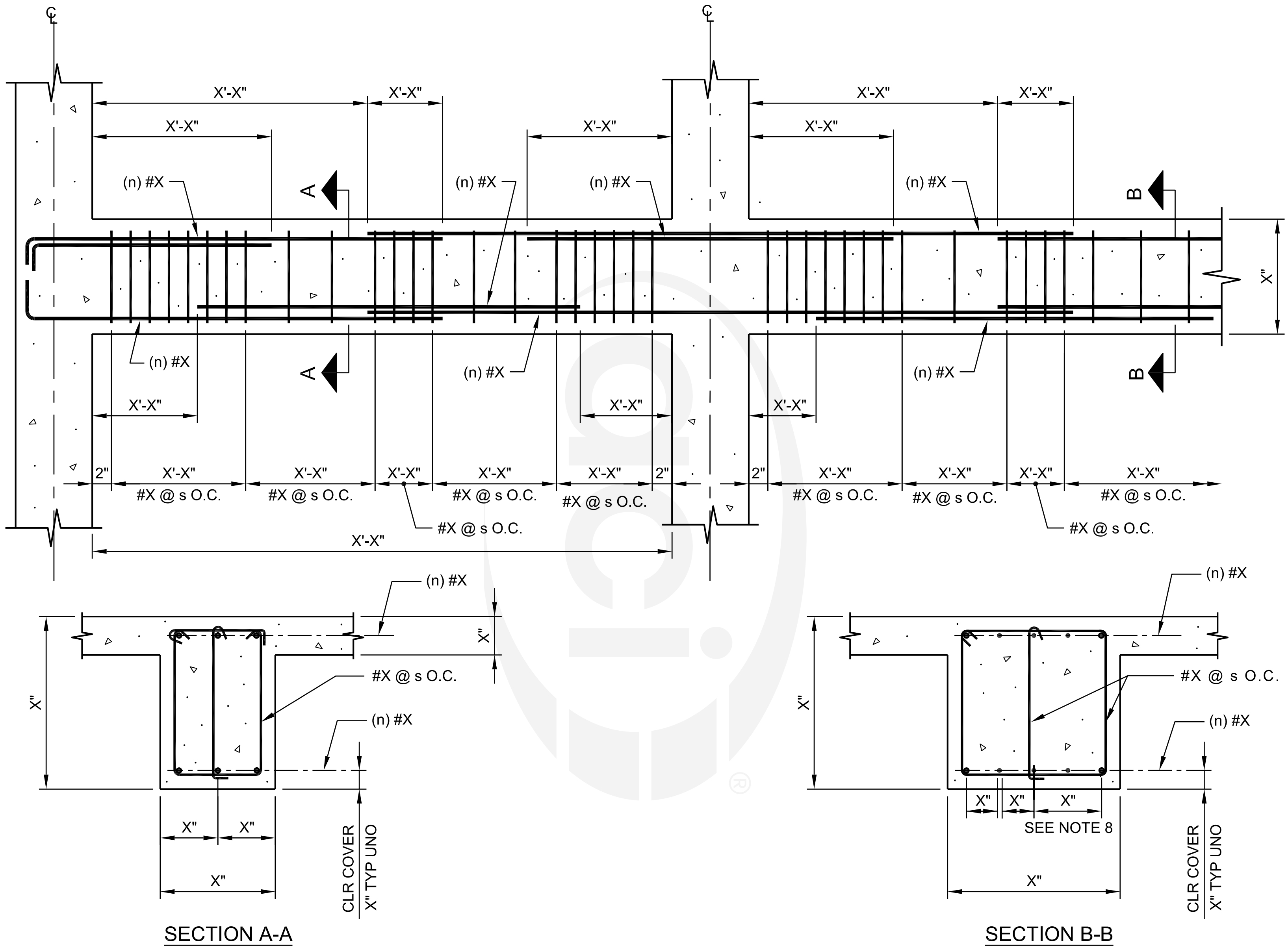
[*] Refer to Section 3 for articles

BM-104



NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE
INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

BEAM AS PART OF SPECIAL MOMENT FRAME, SDC D, E, F

FIGURE BM-104: TYPICAL BEAM IN A SPECIAL MOMENT FRAME, SDC D-F

The design professional shall review the following checklist and
incorporate project-specific requirements into the details

INTENDED USE

Beam part of a special moment resisting frame

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Coordinate beam detail with location on floor plan drawing
2. Beam is continuously laterally supported; Section 9.2.3.1
3. Minimum flexural reinforcement area in nonprestressed beam satisfies; Section 9.6.1
4. Longitudinal bar spacing satisfies the minimum spacing per Sections 9.7.2.1 and 25.2
5. Bars closest to the tension face satisfy Section 9.7.2.2 and 24.3
6. For beams with $h \geq 36$ in., side bars, skin reinforcement is provided; Section 9.7.2.3
7. Flexural bars anchorage, development, extension, embedment, and termination requirements per Sections 9.7.3.2 through 9.7.3.7 unless superseded by requirements in Chapter 18
8. At simple supports, at least 1/3 of $A_{s,max}^{+}$ but not less than two bars satisfy Section 9.7.3.8.1
9. At continuous supports at least 1/4 of $A_{s,max}^{+}$ but not less than two bars satisfy Section 9.7.3.8.2
10. At support at least 1/3 of A_s^{-} but not less than two bars satisfy Section 9.7.3.8.4
11. Provided shear reinforcement exceeds minimum required $A_v \geq A_{v,min}$; Section 9.6.3
12. Minimum shear reinforcement bar size satisfies Section 9.7.6.4.2
13. Concrete reinforcement cover satisfies Sections 9.7.1.1 and 20.5.1
14. Minimum two bars are continuous top and bottom; Section 9.7.7.1
15. Longitudinal bars must be enclosed by stirrups or hoops; Section 9.7.7.2b
16. Longitudinal compression bars are laterally supported satisfying Section 9.7.6.4.4
17. Splices of negative moment bars must be located near midspan; Section 9.7.7.5(b)

Seismic requirements below supersede any of the requirements above.

1. Beam satisfies the minimum dimensional requirements; Section 18.6.2.1
2. Maximum longitudinal reinforcement ratio satisfies Section 18.6.3.1
3. M_n^{+} at joint face $\geq$ ½ M_n^{-} at that face of joint; Section 18.6.3.2
4. M_n^{+} and M_n^{-} at any section along member length $\geq [1/4\ M_n^{-}]_{\max}$ at face of either joint; Section 18.6.3.2
5. Minimum two continuous bars top and bottom are provided and anchored to develop f_y in tension at face of support; Section 18.3.2
6. Continuous top and bottom bars with bottom bars having area not less than 1/4 $A^{+}_{s,max}$ and anchored at face of support; Section 18.4.2.1
7. Hoops are provided at each end of the beam over a length of $2h$ from the face of the support; Section 18.4.2.4
8. First hoop is located at 2 in. from face of support; Section 18.4.2.4
9. Hoop, shear reinforcement, spacing does not exceed Section 18.4.2.4
    - a. $d/4$
    - b. $8d_b$, smallest longitudinal bar enclosed
    - c. $24d_{hoop}$
    - d. 12 in.
    - e. Transverse spacing does not exceed $d/2$; Section 18.4.2.5
10. If factored axial compressive force > $A_g f_c'/10$, transverse reinforcement to conform to Section 25.7.2.2 and either Section 25.7.2.3 or 25.7.2.4; Section 18.4.2.6
11. At least two continuous bars at both top and bottom faces; Section 18.6.3.1

12. Locate splices at least two times the beam depth from column face or from critical sections where flexural yielding is likely to occur; Section 18.6.3.3
13. Splice distance must be enclosed by hoops or ties spaced the lesser of $d/4$ and 4 in.; Section 18.6.3.3
14. Hoops provided over $2h$ from the face of the support; Section 18.6.4.1a
15. Hoops provided over $2h$ on both sides from where flexural yielding is likely to occur, Section 18.6.4.1b
16. Laterally supported longitudinal bars must not be placed more than 14 in. apart; Section 18.6.4.2
17. Hoops are permitted to be made of two pieces; Section 18.6.4.3
18. Place first hoop 2 in. from face of support, then at maximum spacing satisfy Section 18.6.4.4
19. In the remaining regions, place stirrups with seismic hooks at maximum $d/2$; Section 18.6.4.6
20. Ties must have a hook with an angle not more than 135 degrees and extending the greater of $6d_b$ and 3 in.; Section 23.6.3.3 and 25.3.2
21. Remove “NOTES TO DESIGN PROFESSIONAL” before placing detail in the Contract Documents

Note: The design professional may opt to present the beam detailed information in a table format, especially if the project has multiple type of beams. The design professional may modify and use one of the tables, BM-1, or BM-2 to present the information

RECOMMENDED REFERENCES

Concrete International articles*: 2, 5, 7, 13, 16, 18, 19, 20, 23

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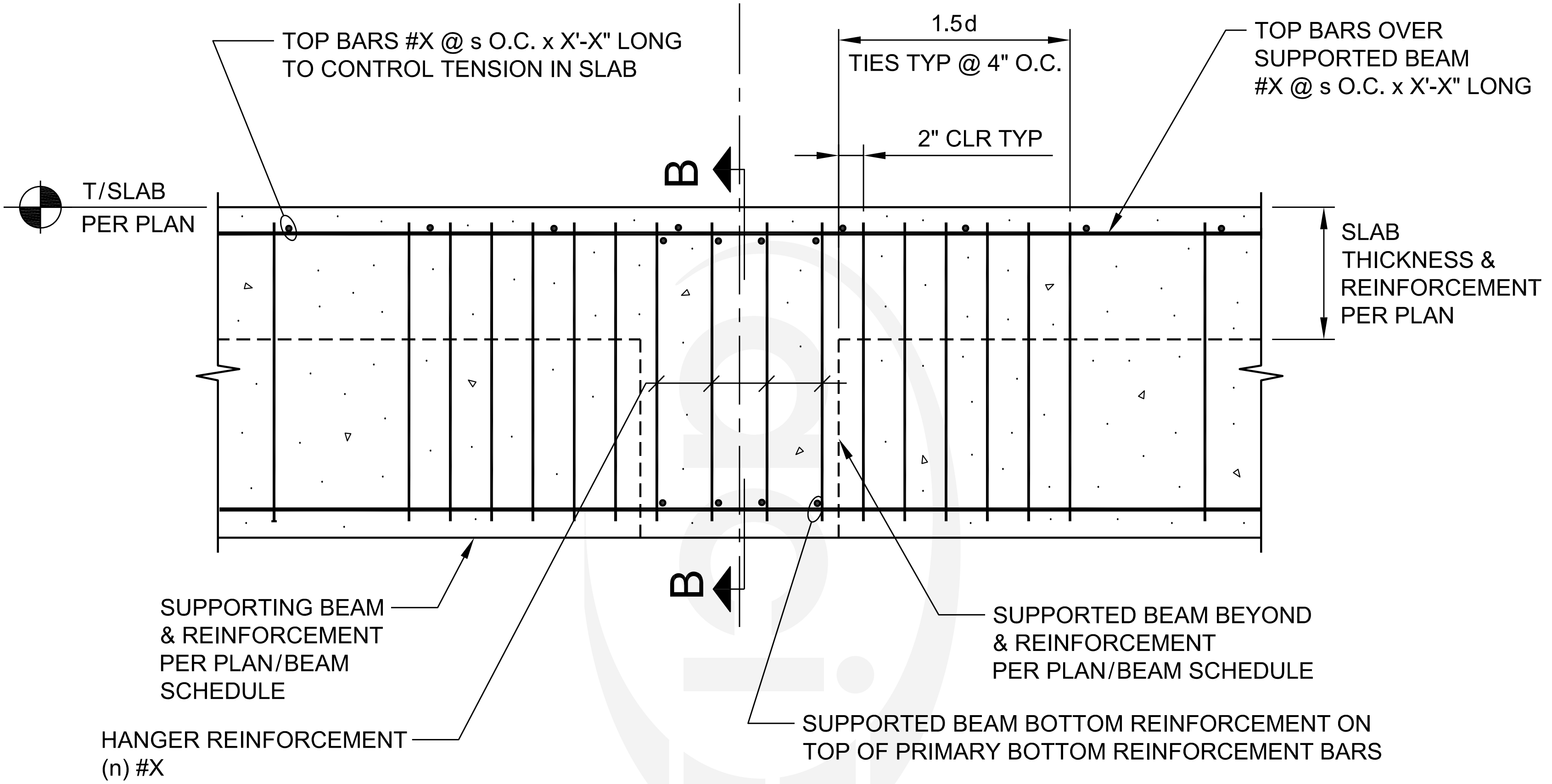
*Refer to Section 3 for articles

BM-200

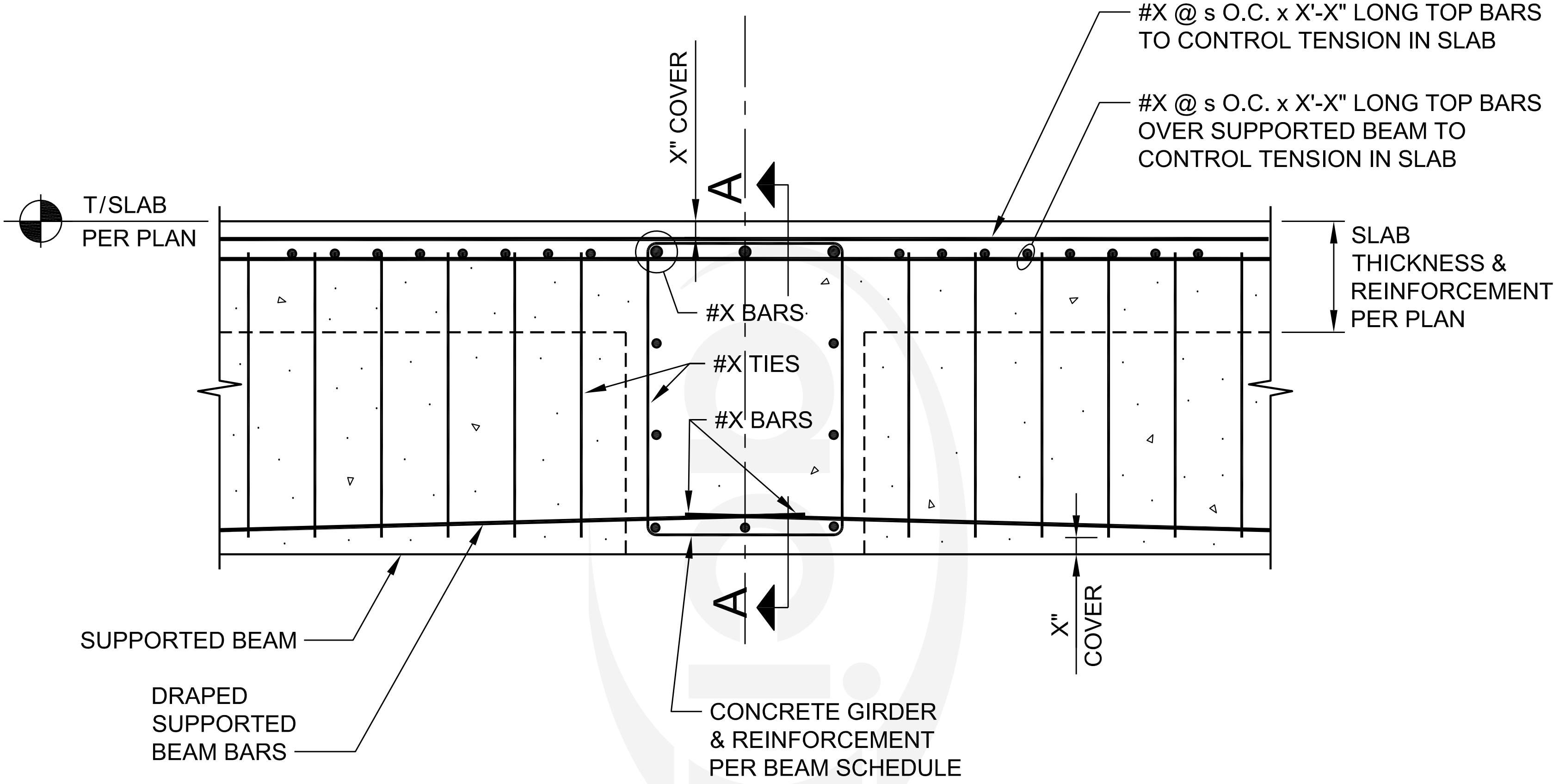


SECTION A-A

NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

SUPPORTED BEAM FRAMING INTO SUPPORTING BEAM

BM-201



SECTION B-B

NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE
INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

SUPPORTED BEAM FRAMING INTO SUPPORTING BEAM

FIGURE BM-200 AND BM-201: SUPPORTED BEAM FRAMING INTO SUPPORTING BEAM/GIRDER

The design professional shall review the following checklist and
incorporate project-specific requirements into the details

INTENDED USE

Beam to girder connection

Beam is continuous at girder

T-beams frame into opposite sides of girder (continuous beam)

Beams and girder placed monolithically

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Supported beam longitudinal reinforcing into girder:
   a. At least 1/4 of positive reinforcement (bottom bars) but not less than two bars to extend into supporting beam. Tension lap splice at or near girder centerline; Section 25.5.2.1
   b. Negative reinforcement (top bars) to extend into girder an embedment length at least tensile development length beyond the point where terminated tension reinforcement is no longer needed to resist flexure
2. Girder longitudinal reinforcement:
   a. If the bottom of the supported beam is below middepth of the supporting beam or if the factored shear transferred from the supported beam is equal to or greater than, provide additional stirrup reinforcement bars – referred to as hanger stirrups – placed minimum two within girder parallel with primary girder longitudinal bars. Anchor top of hanger stirrups with tensile development standard hook; Section 9.7.6.2.1
   b. Add secondary closed stirrups around girder longitudinal bars extending beyond face of secondary beam 1.5*d* (1.5 times the effective depth of the secondary beam)
3. Remove "NOTES TO DESIGN PROFESSIONAL" before placing detail in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles*: 2, 7, 18, 19, 20, 23

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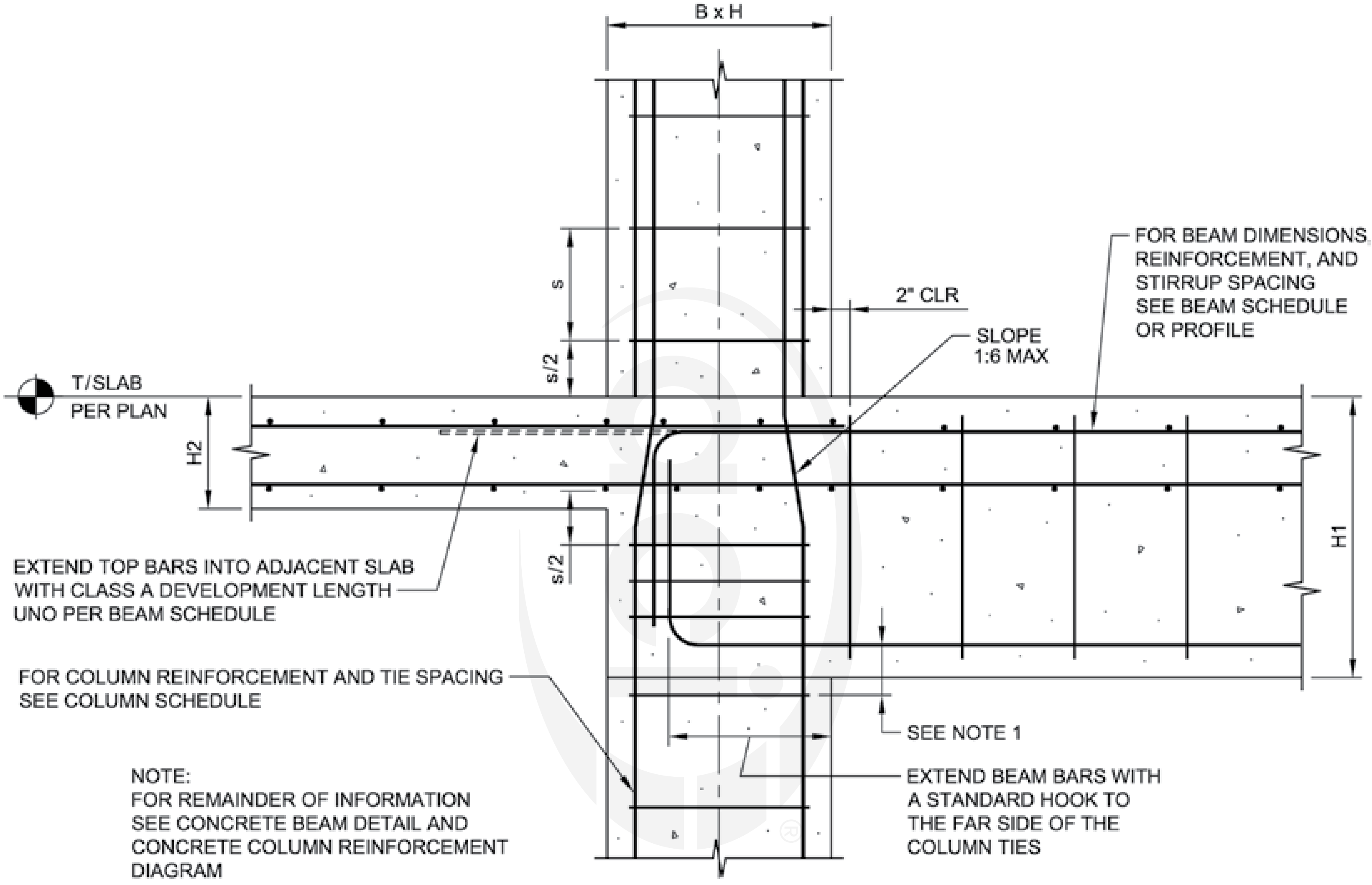
*Refer to Section 3 for articles

BM-202



NOTES TO DESIGN PROFESSIONAL:

1. ENGINEER TO PROVIDE MAX 3 IN. SEE NOTE 2d OF CHECKLIST. DELETE DIMENSION IF NOT APPLICABLE
2. COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

BEAM REINFORCING DEVELOPMENT AT COLUMN

FIGURE BM-202: BEAM REINFORCING DEVELOPMENT AT COLUMN

The design professional shall review the following checklist and incorporate project-specific requirements into the details

INTENDED USE

Beam-to-column connection – beam is discontinuous at column

T-beam frames into one side of column

Beam-column joint is not confined (fails to meet requirements of Section 15.2.8)

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. T-beam longitudinal reinforcing frames into column:
   a. Extend at least two positive reinforcement (bottom bars) into column with standard hook per Section 25.4.3
   b. Extend hook to far side of column and turn hook toward mid-depth of beam per Section 15.3.3.2
   c. Extend negative reinforcement (top bars) into column with an embedment length into column at least the tensile development length; extend bars to far side of column and provide standard hook turned toward mid-depth of beam per Section 15.3.3.2
   d. If slab is continuous beyond far side of column, then top bars could be extended into slab
2. Column longitudinal reinforcement:
   a. Provide transverse reinforcement within the intersecting column height not less than the deepest beam depth; at least two layers of transverse reinforcement per Section 15.3.1.3 and transverse reinforcement spacing shall not exceed 8 in. per Section 15.3.1.4
   b. First tie is placed one-half the tie or hoop spacing above slab; Section 10.7.6.2.1
   c. First tie is placed not more than one-half the tie or hoop spacing below lowest horizontal reinforcement in the slab, drop panel, or shear cap; Section 10.7.6.2.2
   d. Beams or brackets frame into all sides of column, place first tie not more than 3 in. below lowest horizontal reinforcement in the shallowest beam or bracket; Section 10.7.6.2.2
3. Remove “NOTES TO DESIGN PROFESSIONAL” before placing detail in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles*: 2, 5, 7, 13, 16, 19, 20, 23

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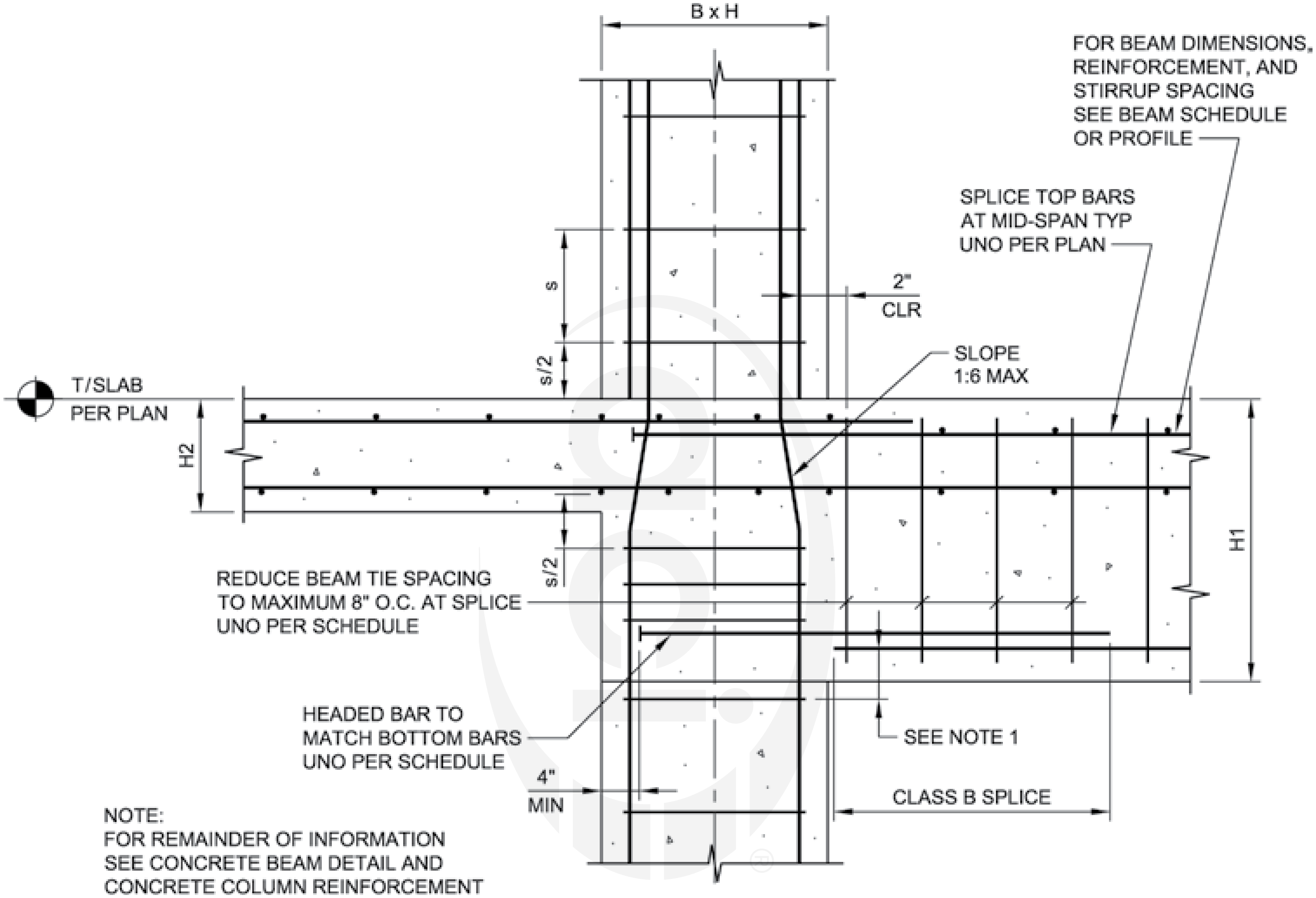
*Refer to Section 3 for articles



NOTE:
FOR REMAINDER OF INFORMATION
SEE CONCRETE BEAM DETAIL AND
CONCRETE COLUMN REINFORCEMENT
DIAGRAM

NOTES TO DESIGN PROFESSIONAL:

1. ENGINEER TO PROVIDE MAX 3 IN. SEE NOTE 2d OF CHECKLIST. DELETE DIMENSION IF NOT APPLICABLE
2. COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

BEAM REINFORCING DEVELOPMENT AT COLUMN (ALTERNATE)

FIGURE BM-203: BEAM REINFORCING DEVELOPMENT AT COLUMN (ALTERNATE)

The design professional shall review the following checklist and incorporate project-specific requirements into the details

INTENDED USE

Beam-to-column connection – beam is discontinuous at column

Beam supports floor slab. Top of floor slab and beam at same elevation. T-beam frames into one side of column

Beam-column joint is not confined fails to meet requirements of Section 15.2.8)

Longitudinal beam reinforcement is headed at column joint

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Beam (T-beam) longitudinal reinforcing with headed bars into column:
    a. Headed bar satisfies Section 25.4.4.1
    b. Extend at least two positive reinforcement (bottom bars) into column with standard hook per Section 25.4.3
    c. Extend headed bar to far side of column and ensure that bar satisfy the development length; Section 15.4.4.2
    d. Extend negative reinforcement (top bars) into column with an embedment length into column at least tensile development length; extend bars to far side of column and provide headed deformed bar in accordance with Section 25.4.4.6
    e. If slab is continuous beyond far side of column, then top headed bars could be replaced with typical bars and extended into slab
    f. Provide parallel tie reinforcement within specified dimension per Section 25.4.4.4
2. Column longitudinal reinforcement:
    a. Provide transverse reinforcement within the intersecting column height not less than the deepest beam depth; at least two layers of transverse reinforcement per Section 15.3.1.3 and transverse reinforcement spacing shall not exceed 8 in. per Section 15.3.1.4
    b. First tie is placed one-half the tie or hoop spacing above slab; Section 10.7.6.2.1
    c. First tie is placed not more than one-half the tie or hoop spacing below lowest horizontal reinforcement in the slab; Section 10.7.6.2.2
    d. Beams or brackets frame into all sides of column, place first tie not more than 3 in. below lowest horizontal reinforcement in the shallowest beam or bracket; Section 10.7.6.2.2
3. Remove "NOTES TO DESIGN PROFESSIONAL" before placing detail in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles[*]: 2, 7, 13, 16, 19, 20, 23

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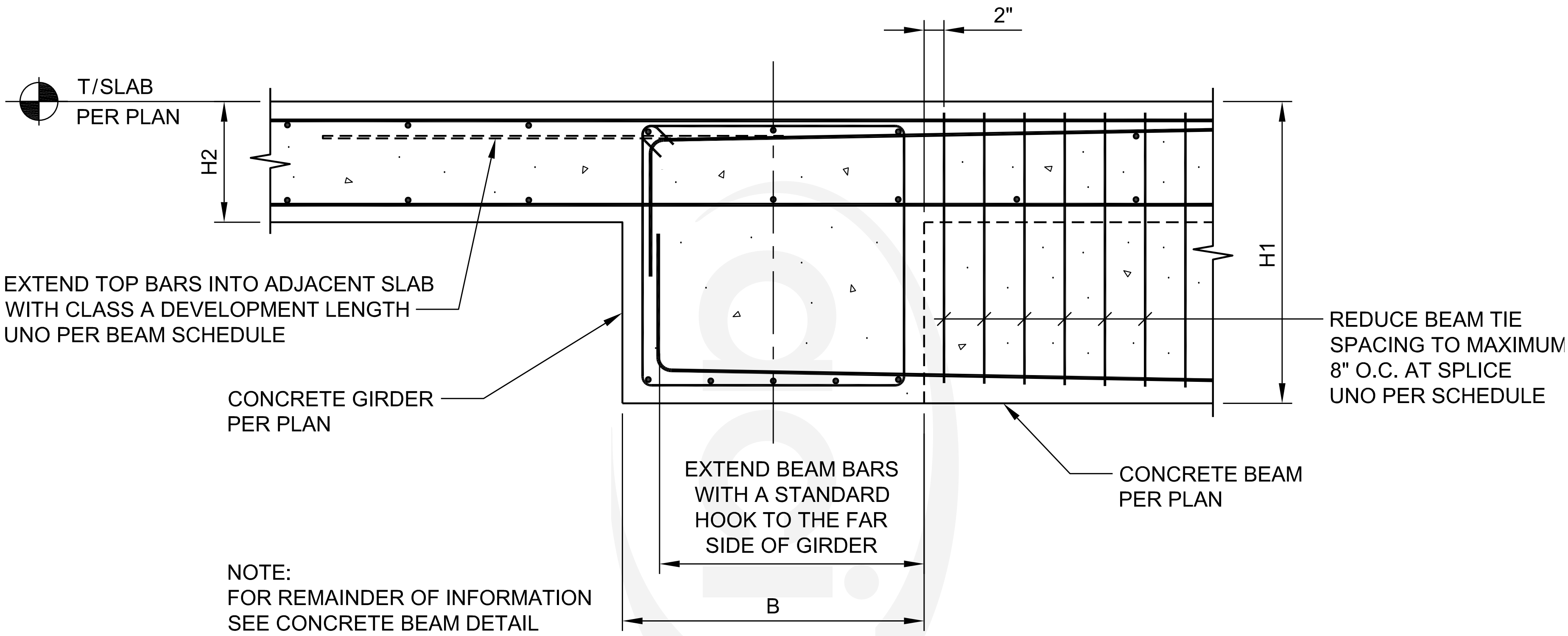
[*] Refer to Section 3 for articles

BM-204



NOTE:
FOR REMAINDER OF INFORMATION
SEE CONCRETE BEAM DETAIL

NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE
INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

CONCRETE BEAM TO GIRDER CONNECTION

FIGURE BM-204: CONCRETE BEAM-TO-GIRDER CONNECTION

The design professional shall review the following checklist and incorporate project-specific requirements into the details

---

INTENDED USE

Beam-to-girder connection in SDC A (or secondary beam to support beam connection)

Beam is not continuous at girder

T-beams frame into one side of girder (continuous beam – fixed end condition)

Beams and girder placed monolithically

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Secondary beam (T-beam) longitudinal reinforcing into girder:
   a. Extend at least two positive reinforcement (bottom bars) into the girder with tension development hook per Section 25.4.3
   b. Negative reinforcement (top bars) to have tension development into girder with tension embedment length achieved with tension standard hook per Section 25.4.3.1; extend hook to far side of girder
   c. If slab is continuous beyond the far side of the girder, then the top bars could be extended into slab
2. Girder longitudinal reinforcement:
   a. Provide additional stirrup reinforcement – referred to as hanger stirrups – place minimum four stirrups within girder parallel with girder longitudinal bars; Section 9.7.6.2.1 and Figure R9.7.6.2.1
3. Remove “NOTES TO DESIGN PROFESSIONAL” before placing detail in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles[*]: 2, 5, 7, 13, 16, 19, 20, 23

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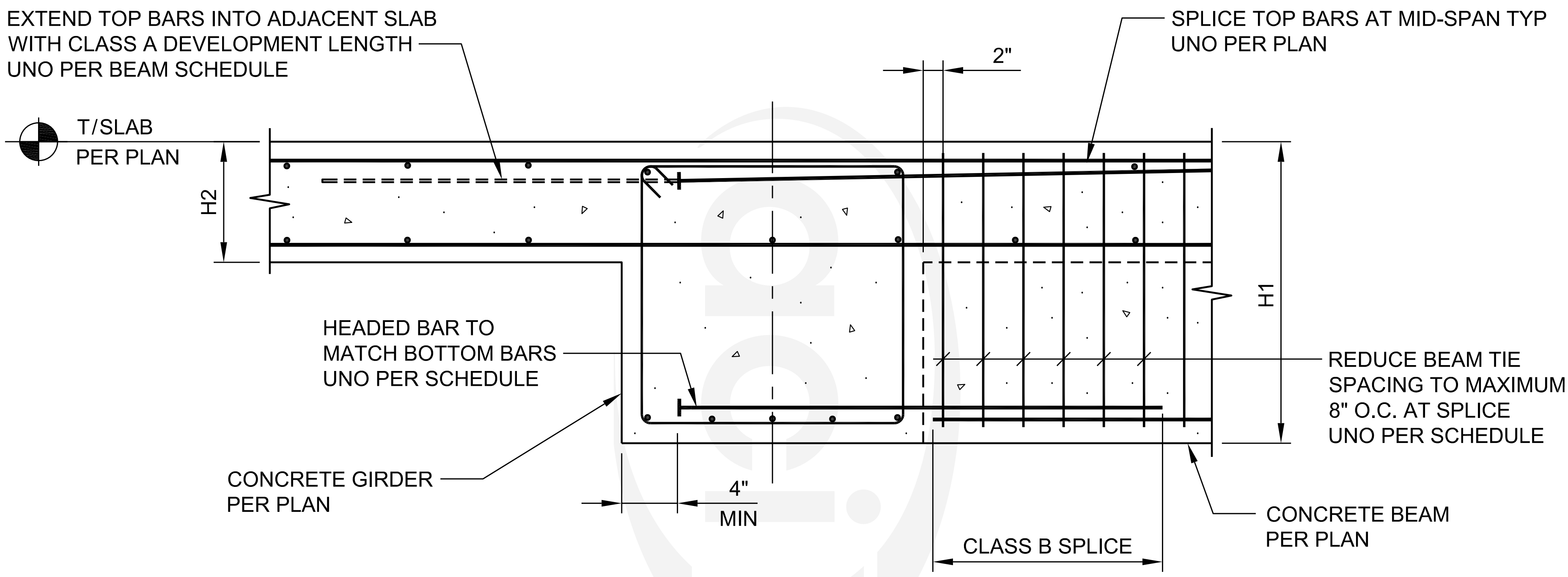
[*] Refer to Section 3 for articles

BM-205



NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE
INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

CONCRETE BEAM TO GIRDER CONNECTION (ALTERNATE)

FIGURE BM-205: BEAM-TO-GIRDER CONNECTION (ALT)

The design professional shall review the following checklist and incorporate project-specific requirements into the details

---

INTENDED USE

Beam-to-girder connection in SDC A (or secondary beam to support beam connection)

Beam is not continuous at girder

T-beams frame into one side of girder (continuous beam – fixed end condition)

Beams and girder placed monolithically

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Secondary beam (T-beam) longitudinal reinforcing into girder:
   a. Headed bar satisfies Section 25.4.4.1
   b. Extend at least two headed positive reinforcement (bottom bars) to far side of girder and satisfying Section 25.4.4
   c. Headed bars are to be continuous through beam and may be spliced with tension lap splice per Section 25.4.2 near girder
   d. Negative reinforcement (top headed bars) to have tension development into girder with tension embedment length per Section 25.4.4.6; extend headed bar to far side of girder
   e. If slab continuous beyond the far side of the column, then the top headed bars could be replaced with typical bars and extended into slab
   f. Provide parallel tie reinforcement within specified dimension per Section 25.4.4.4
2. Girder longitudinal reinforcement:
   a. Provide additional stirrup reinforcement – referred to as hanger stirrups – place minimum four stirrups within girder parallel with girder longitudinal bars; Section 9.7.6.2.1 and Figure R9.7.6.2.1
3. Remove "NOTES TO DESIGN PROFESSIONAL" before placing detail in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles*: 2, 7, 13, 16, 19, 20

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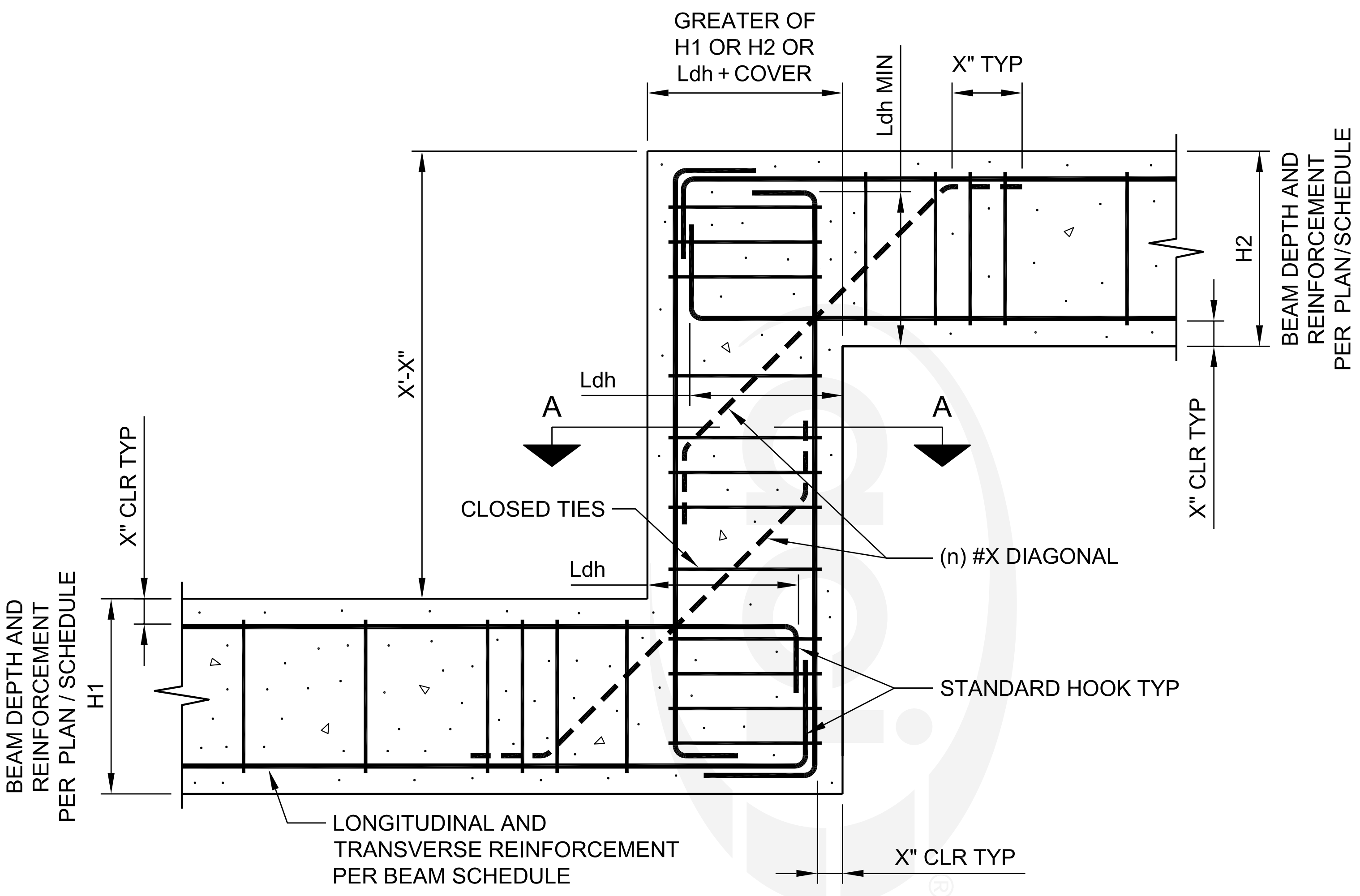
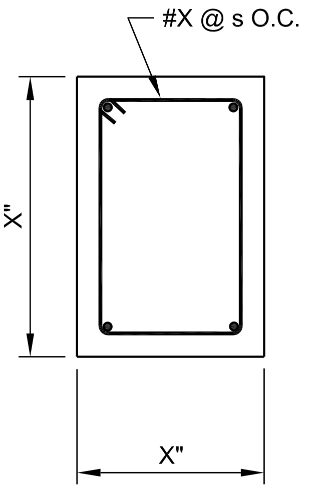
*Refer to Section 3 for articles

BM-206





NOTE:
DIAGONAL BARS NOT
SHOWN FOR CLARITY

SECTION A-A

NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE
INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

BEAM WITH LARGE STEP IN TOP OF SLAB

ELEVATION BETWEEN SUPPORTS

FIGURE BM-206: BEAM WITH LARGE STEP IN TOP OF SLAB ELEVATION BETWEEN SUPPORTS

The design professional shall review the following checklist and
incorporate project-specific requirements into the details

INTENDED USE

Beam with large step and change in top and bottom surface elevations greater than 24 in.

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. At higher top of beam surface elevation:
   a. Extend top and bottom longitudinal bars to far side of stepped slab and terminate with 90-degree hook
   b. Add stirrups or transverse reinforcement at hook ends; use minimum three stirrups spaced at 4 in. on center that provide tension anchorage of hooked ends
2. At lower top of beam surface elevation:
   a. Terminate ends of top and bottom longitudinal bars with standard hooks in tension development length beyond edge of thicker beam
   b. Add stirrups or transverse reinforcement at hook ends. Use minimum three stirrups spaced at 4 in. on center that provide tension anchorage of hooked ends
3. Add diagonal bars:
   a. Terminate ends of diagonal bars in tension development; Section 25.4
   b. Add stirrups at developed ends, minimum three stirrups spaced at 4 in.
4. Remove "NOTES TO DESIGN PROFESSIONAL" before placing detail in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles[*]: 2, 7, 20, 32

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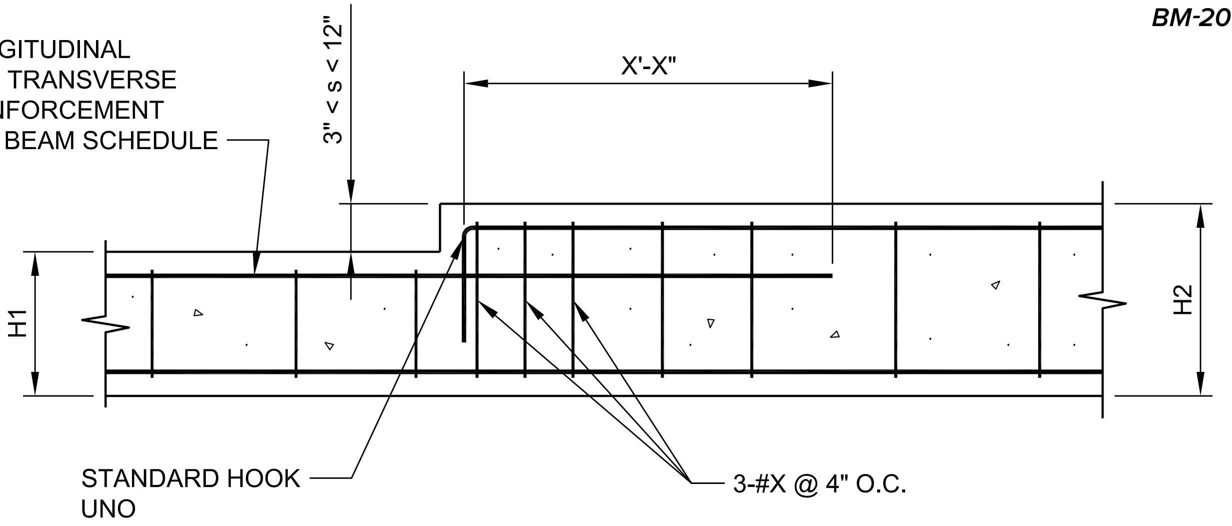
[*] Refer to Section 3 for articles

BM-207



NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

BEAM WITH SMALL STEP IN TOP OF SLAB ELEVATION BETWEEN SUPPORTS

FIGURE BM-207: BEAM WITH SMALL STEP IN TOP OF SLAB ELEVATION BETWEEN SUPPORTS

The design professional shall review the following checklist and incorporate project-specific requirements into the details

INTENDED USE

Beam with small step change in top surface elevations that occur between supports. Change in top surface elevation to be greater than 3 in. depth and less than 12 in.

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. At higher top of beam surface elevation:
    a. Extend top and bottom longitudinal bars to far side of stepped slab and terminate with 90-degree hook
    b. Add stirrups or transverse reinforcement at hook ends; use minimum three stirrups spaced at 4 in. on center that provide tension anchorage of hooked ends
2. At lower top of beam surface elevation:
    a. If top bars are not in tension, terminate ends of top longitudinal bars the tension development length beyond edge of deeper section
    b. If top bars are subjected to tension, then extend top reinforcement into the deeper section a distance at least equal to Class B tension splice; Section 25.5.2
3. Remove "NOTES TO DESIGN PROFESSIONAL" before placing detail in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles*: 2, 7, 20, 32

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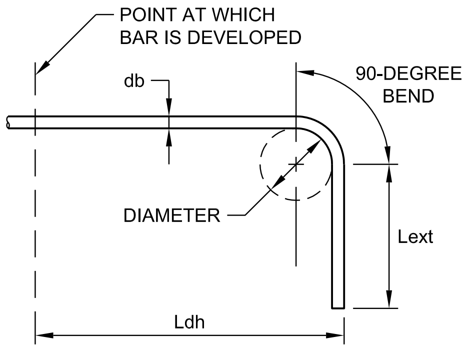
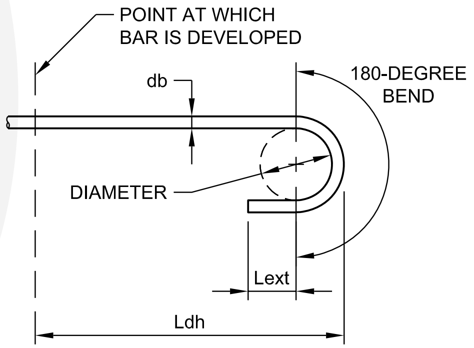
*Refer to Section 3 for articles

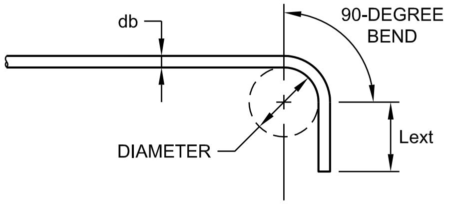
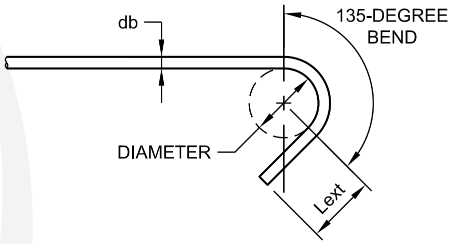
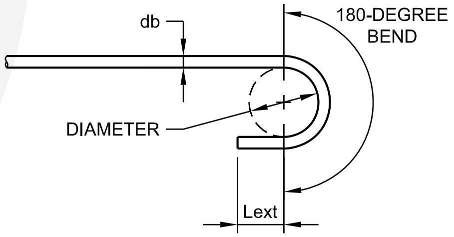
TYPE OF STANDARD HOOK	BAR SIZE	MINIMUM INSIDE BEND DIAMETER, IN.	STRAIGHT EXTENSION [1] Lext, IN.	TYPE OF STANDARD HOOK
90-DEGREE HOOK	#3 THROUGH #8	6db	12db	
	#9 THROUGH #11	8db		
	#14 AND #18	10db		
180-DEGREE HOOK	#3 THROUGH #8	6db	GREATER OF 4db AND 2.5"	
	#9 THROUGH #11	8db		
	#14 AND #18	10db		

[1] A STANDARD HOOK FOR DEFORMED BARS IN TENSION INCLUDES THE SPECIFIC INSIDE BEND DIAMETER AND STRAIGHT EXTENSION LENGTH. IT SHALL BE PERMITTED TO USE A LONGER STRAIGHT EXTENSION AT THE END OF A HOOK. A LONGER EXTENSION SHALL NOT BE CONSIDERED TO INCREASE THE ANCHORAGE CAPACITY OF THE HOOK.

NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY TABLE AS REQUIRED BEFORE
INCORPORATING THIS TABLE INTO PROJECT CONSTRUCTION DOCUMENTS

STANDARD HOOK GEOMETRY FOR DEVELOPMENT OF DEFORMED BARS IN TENSION

BM-209

TYPE OF STANDARD HOOK	BAR SIZE	MINIMUM INSIDE BEND DIAMETER, IN.	STRAIGHT EXTENSION [1] Lext, IN.	TYPE OF STANDARD HOOK
90-DEGREE HOOK	#3 THROUGH #5	4db	GREATER OF 6db AND 3"	
	#6 THROUGH #8	6db	12db	
135-DEGREE HOOK	#3 THROUGH #5	4db	GREATER OF 6db AND 3"	
	#6 THROUGH #8	6db		
180-DEGREE HOOK	#3 THROUGH #5	4db	GREATER OF 4db AND 2.5"	
	#6 THROUGH #8	6db		

[1] A STANDARD HOOK FOR STIRRUPS, TIES, AND HOOPS INCLUDES THE SPECIFIC INSIDE BEND DIAMETER AND STRAIGHT EXTENSION LENGTH. IT SHALL BE PERMITTED TO USE A LONGER STRAIGHT EXTENSION AT THE END OF A HOOK. A LONGER EXTENSION SHALL NOT BE CONSIDERED TO INCREASE THE ANCHORAGE CAPACITY OF THE HOOK.

NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY TABLE AS REQUIRED BEFORE
INCORPORATING THIS TABLE INTO PROJECT CONSTRUCTION DOCUMENTS

MINIMUM INSIDE BEND DIAMETERS AND STANDARD HOOK GEOMETRY FOR STIRRUPS, TIES, AND HOOPS

FIGURE BM-208 AND BM-209: STANDARD HOOK DETAIL FOR DEVELOPMENT OF BARS IN TENSION AND STANDARD HOOK GEOMETRY FOR STIRRUPS, TIES, AND HOOPS

The design professional shall review the following checklist and
incorporate project-specific requirements into the details

INTENDED USE

Showing all reinforced concrete beams on project on one schedule

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Standard hooks for the development of deformed bars in tension conforms to Table 25.3.1
2. Minimum inside bend diameters for bars used as transverse reinforcement and standard hooks for bars used to anchor stirrups, ties, hoops, and spirals conform to Table 25.3.2
3. Seismic hooks used to anchor stirrups, ties, hoops, and crossties conforms to:
    a. Minimum bend of 90 degrees for circular hoops and 135 degrees for all other hoops
    b. Hook engaging longitudinal bars and extension projects into the interior of the stirrup or hoop
4. Remove "NOTES TO DESIGN PROFESSIONAL" before placing detail in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles[*]: 5, 11, 28

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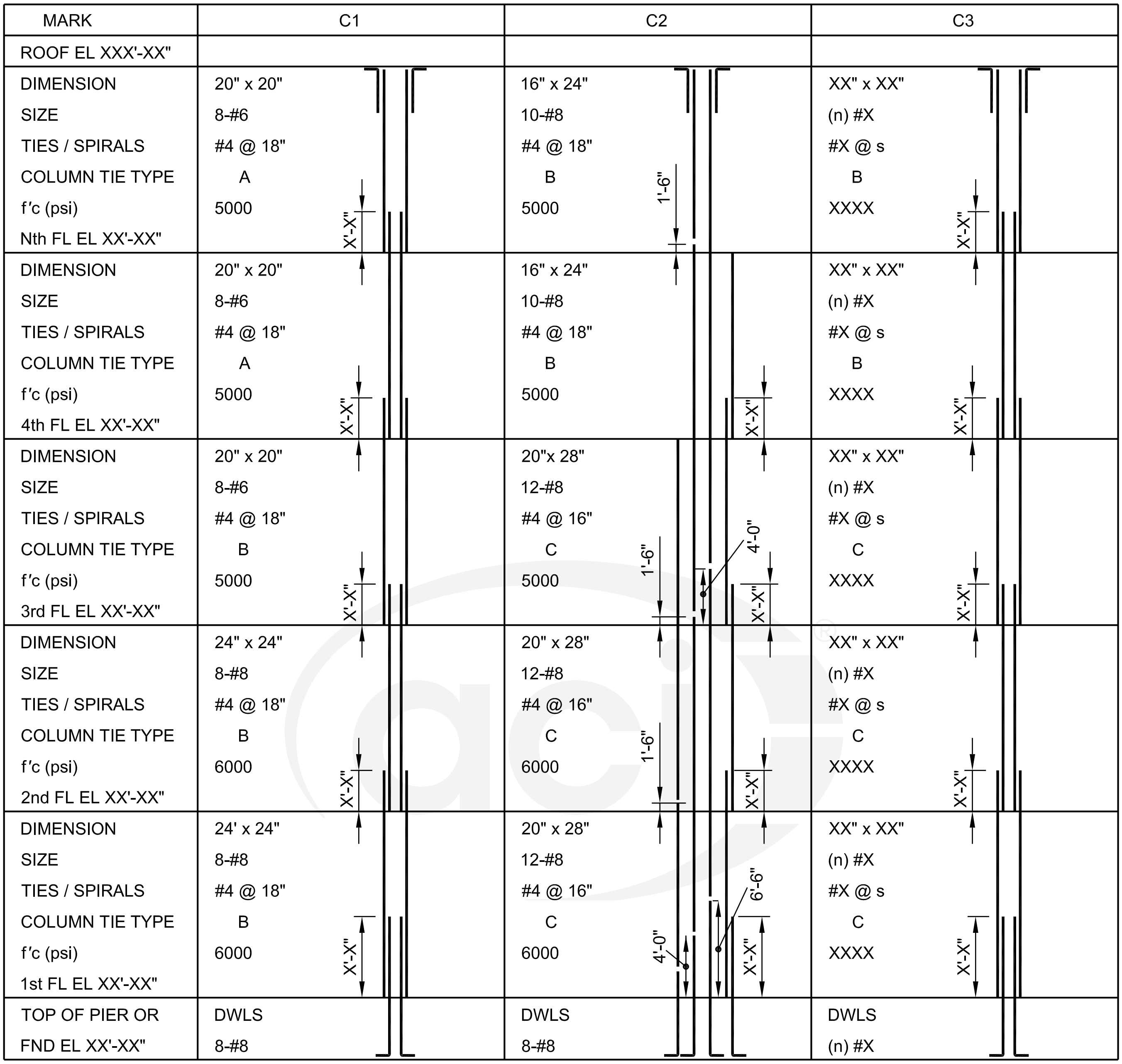
[*] Refer to Section 3 for articles

COLUMN
DETAILS

COL-1



MARK	C1	C2	C3
ROOF EL XXX'-XX"			
DIMENSION	20" x 20"	16" x 24"	XX" x XX"
SIZE	8-#6	10-#8	(n) #X
TIES / SPIRALS	#4 @ 18"	#4 @ 18"	#X @ s
COLUMN TIE TYPE	A	B	B
f′c (psi)	5000	5000	XXXX
Nth FL EL XX'-XX"			
DIMENSION	20" x 20"	16" x 24"	XX" x XX"
SIZE	8-#6	10-#8	(n) #X
TIES / SPIRALS	#4 @ 18"	#4 @ 18"	#X @ s
COLUMN TIE TYPE	A	B	B
f′c (psi)	5000	5000	XXXX
4th FL EL XX'-XX"			
DIMENSION	20" x 20"	20"x 28"	XX" x XX"
SIZE	8-#6	12-#8	(n) #X
TIES / SPIRALS	#4 @ 18"	#4 @ 16"	#X @ s
COLUMN TIE TYPE	B	C	C
f′c (psi)	5000	5000	XXXX
3rd FL EL XX'-XX"			
DIMENSION	24" x 24"	20" x 28"	XX" x XX"
SIZE	8-#8	12-#8	(n) #X
TIES / SPIRALS	#4 @ 18"	#4 @ 16"	#X @ s
COLUMN TIE TYPE	B	C	C
f′c (psi)	6000	6000	XXXX
2nd FL EL XX'-XX"			
DIMENSION	24' x 24"	20" x 28"	XX" x XX"
SIZE	8-#8	12-#8	(n) #X
TIES / SPIRALS	#4 @ 18"	#4 @ 16"	#X @ s
COLUMN TIE TYPE	B	C	C
f′c (psi)	6000	6000	XXXX
1st FL EL XX'-XX"			
TOP OF PIER OR	DWLS	DWLS	DWLS
FND EL XX'-XX"	8-#8	8-#8	(n) #X

NOTES TO DESIGN PROFESSIONAL:

- COMPLETE THE ATTACHED CHECKLIST AND MODIFY SCHEDULE AS REQUIRED BEFORE INCORPORATING THIS SCHEDULE INTO PROJECT CONSTRUCTION DOCUMENTS
- PROVIDE LAP SPLICE TYPE OR LENGTH - SEE NOTE 7

COLUMN SCHEDULE

FIGURE COL-1: COLUMN SCHEDULE

The design professional shall review the following checklist and incorporate project-specific requirements into the details

---

INTENDED USE

Showing all reinforced concrete columns on project on one schedule

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Column schedule includes:
   a. Column mark
   b. Top of suspended floor slab elevations and roof slab elevation
   c. Top of column formed pier elevation is provided
   d. Column longitudinal and transverse reinforcement
   e. Column tie configuration
   f. Specified concrete compressive strength f'_c
2. Coordinate diagrams in "Transverse Reinforcement Schedule" with each corresponding column's cross section view with longitudinal bar arrangement and transverse reinforcing bar (or tie) arrangement. Add other diagrams as needed
3. Each column type is identified with column mark and column marks are coordinated on column plan drawing (known as a column key plan)
4. Width and depth of column is stated between each floor level in the column schedule.
5. Area of longitudinal bars in column between floor level satisfies Section 10.6.1.1
6. Minimum shear reinforcement satisfies Section 10.6.2
7. Tension or compression lap splice of longitudinal bars immediately above finish supported floor elevations is identified per Section 25.5 for ordinary and intermediate moment frames (SDC A, B, or C)
8. Longitudinal bar arrangement in column is coordinated
9. Cover for columns satisfies Section 20.5.1
10. Remove "NOTES TO DESIGN PROFESSIONAL" before placing schedule in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles*: 13, 27, 28, 34

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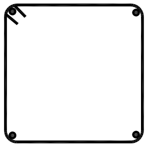
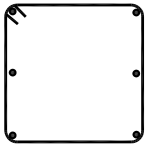
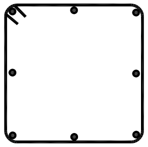
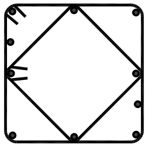
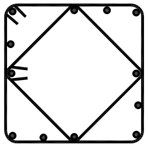
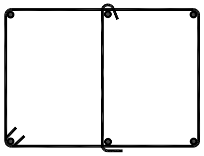
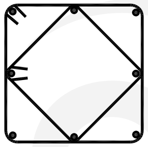
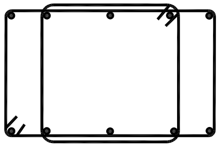
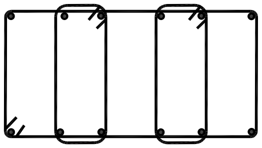
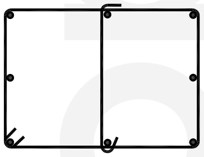
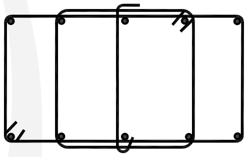
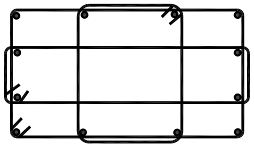
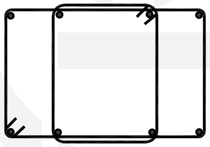
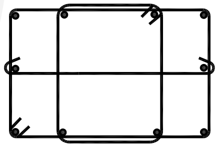
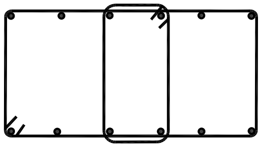
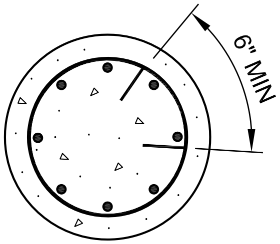
*Refer to Section 3 for articles

	4 BAR COL	6 BAR COL	8 BAR COL	10 BAR COL	12 BAR COL
A					
B					
C					
D					

NOTES TO DESIGN PROFESSIONAL:

- USE THIS TABLE W/COLUMN SCHEDULE COL-1 IDENTIFYING COLUMN TIE ARRANGEMENTS
- COMPLETE THE ATTACHED CHECKLIST AND MODIFY SCHEDULE AS REQUIRED BEFORE INCORPORATING THIS SCHEDULE INTO PROJECT CONSTRUCTION DOCUMENTS



HOOKS STAGGERED
AROUND PERIMETER

COLUMN TIE TYPE SCHEDULE

FIGURE COL-20: TRANSVERSE REINFORCEMENT SCHEDULE

The design professional shall review the following checklist and
incorporate project-specific requirements into the details

INTENDED USE

Tie configuration of different number of longitudinal column bars within a column cross section

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Include the appropriate tie arrangement from this schedule in the Column Schedule of COL-1
2. Column longitudinal bar spacing satisfies Section 25.2.3
3. Diameter of tie bar satisfies Section 25.7.2.2:
   a. Minimum No. 3 enclosing No. 10 or smaller longitudinal bars
   b. Minimum No. 4 enclosing No. 11 or larger longitudinal bars or bundled longitudinal bars.
4. Rectilinear ties are arranged such that each corner and alternate longitudinal bar are laterally supported by the corner of a tie with an included angle ≤ 135 degrees; Section 25.7.2.3(a)
5. No longitudinal bar is farther than 6 in. clear on each side along tie from laterally unsupported bar; Section 25.7.2.3(b)
6. Rectilinear ties are anchored per Section 25.3.2 engaging a longitudinal bar
7. Anchorage of individual circular ties satisfies Section 25.7.2.4.1:
   a. Ends overlap by at least 6 in.
   b. Ends terminate with standard hooks per Section 25.3.2
   c. Overlaps at ends of adjacent circular ties are staggered around perimeter
8. Consecutive crossties engaging same longitudinal bar have their 90-degree hooks on opposite sides of column
9. Remove "NOTES TO DESIGN PROFESSIONAL" before placing schedule in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles[*]: 13, 27, 28, 34

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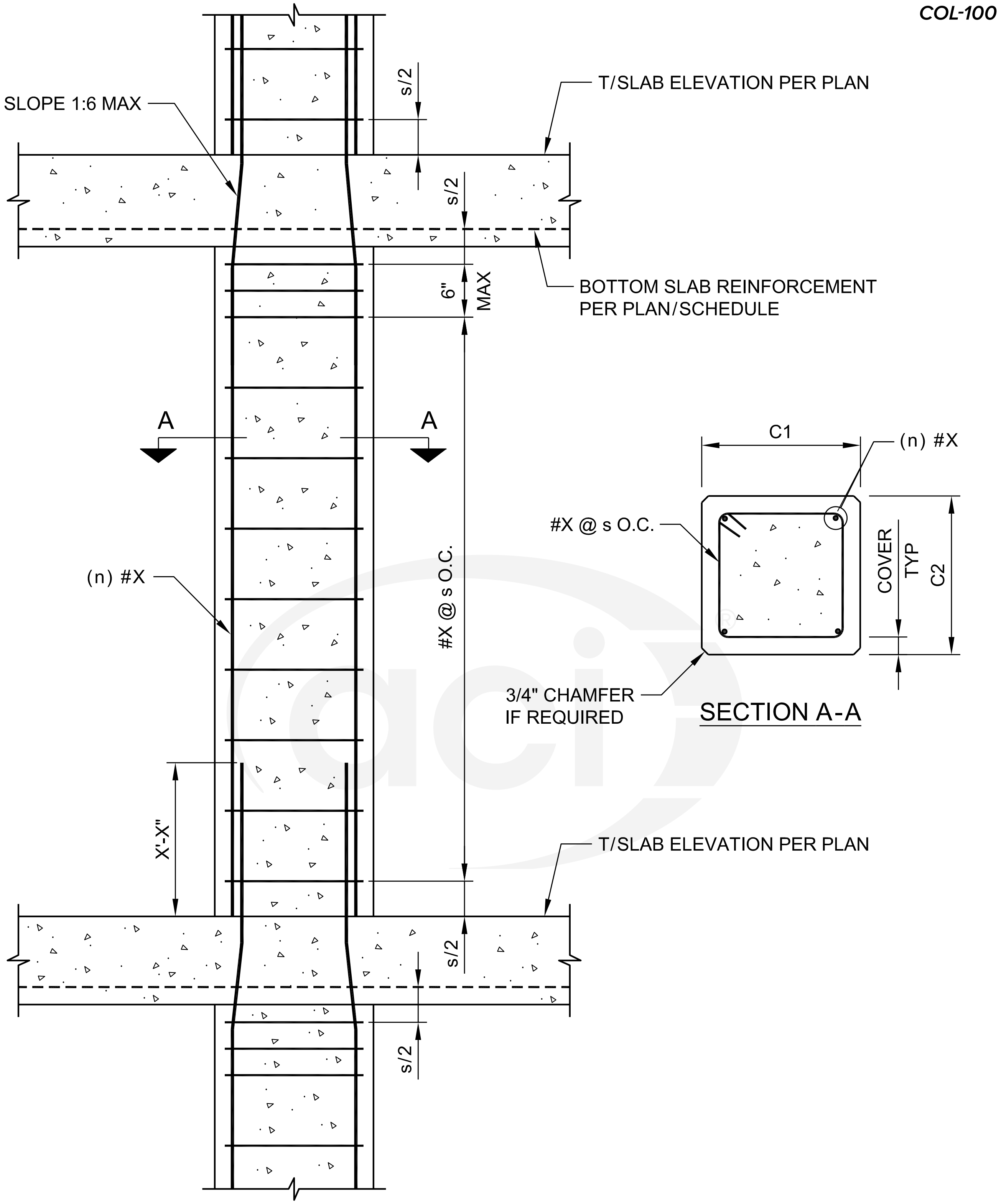
[*] Refer to Section 3 for articles

COL-100



NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

TYPICAL COLUMN DETAIL INCLUDING ORDINARY AND INTERMEDIATE MOMENT FRAMES (SDC A-C)

FIGURE COL-100: TYPICAL COLUMN DETAIL FOR ORDINARY AND INTERMEDIATE MOMENT FRAMES (SDC A, B, C)

The design professional shall review the following checklist and
incorporate project-specific requirements into the details

INTENDED USE

Multi-story column reinforcing for rectilinear and round columns

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Longitudinal reinforcement area satisfies Section 10.6.1.1
2. Minimum bar spacing satisfies Section 10.7.2 and 25.2
3. Minimum area of shear reinforcement has been provided in regions where $V_u > 0.5\phi V_c$; Section 10.6.2.1
4. Minimum number of longitudinal bars in a column per Section 10.7.3.1
5. Column faces offset by 3 in. or more, provide separate dowels; Section 10.7.4.2
6. Longitudinal reinforcement should not exceed 4 percent if bars are spliced at same location; Section R10.6.1.1
7. Determine type of bar splice per Section 10.7.5.1.1
8. Splices of deformed bars must satisfy Section 25.5
9. Compression lap splices are determined per Section 10.7.5.2.1
10. Tension lap splices are determined per Section 10.7.5.2.2
11. End bearing lap splices per Section 10.7.5.3
12. Transverse reinforcement satisfies Section 10.7.6 and Sections 25.7.2 through 25.7.4
13. In any story, bottom tie or hoop is placed not more than half the calculated tie or hoop spacing above slab or footing; Section 10.7.6.2.1
14. In any story, the top tie or hoop is placed not more than one-half the calculated tie or hoop spacing below the lowest slab, drop panel, or shear cap reinforcement; Section 10.7.6.2.2
15. Maximum spacing of column shear reinforcement satisfies Section 10.7.6.5.2
16. Column ties, rectangular, circular, or spiral satisfy requirements in Section 25.7.2
17. Bar splices are located at the bottom of columns at each floor or every other floor:
    a. Bar lap splices consists of offset bents into column above with maximum slope of bent being one horizontal to six vertical (slope of 1:6); Section 10.7.4.1
    b. Verify that minimum three transverse or hoop ties are added at offset bent locations that are no more than 6 in. from the point of the bend; space these three transverse or hoop ties at at 3 in.; Section 10.7.6.4.2
18. Mechanical couplers are enclosed by ties per Section 10.7.6.1.6
19. Concrete cover for reinforcement satisfies Section 20.5.1
20. Development lengths satisfy Section 25.4
21. Columns part of intermediate moment frame (SDC C) must satisfy requirements of Section 18.4.3
22. Remove "NOTES TO DESIGN PROFESSIONAL" before placing detail in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles[*]: 13, 27, 28, 34

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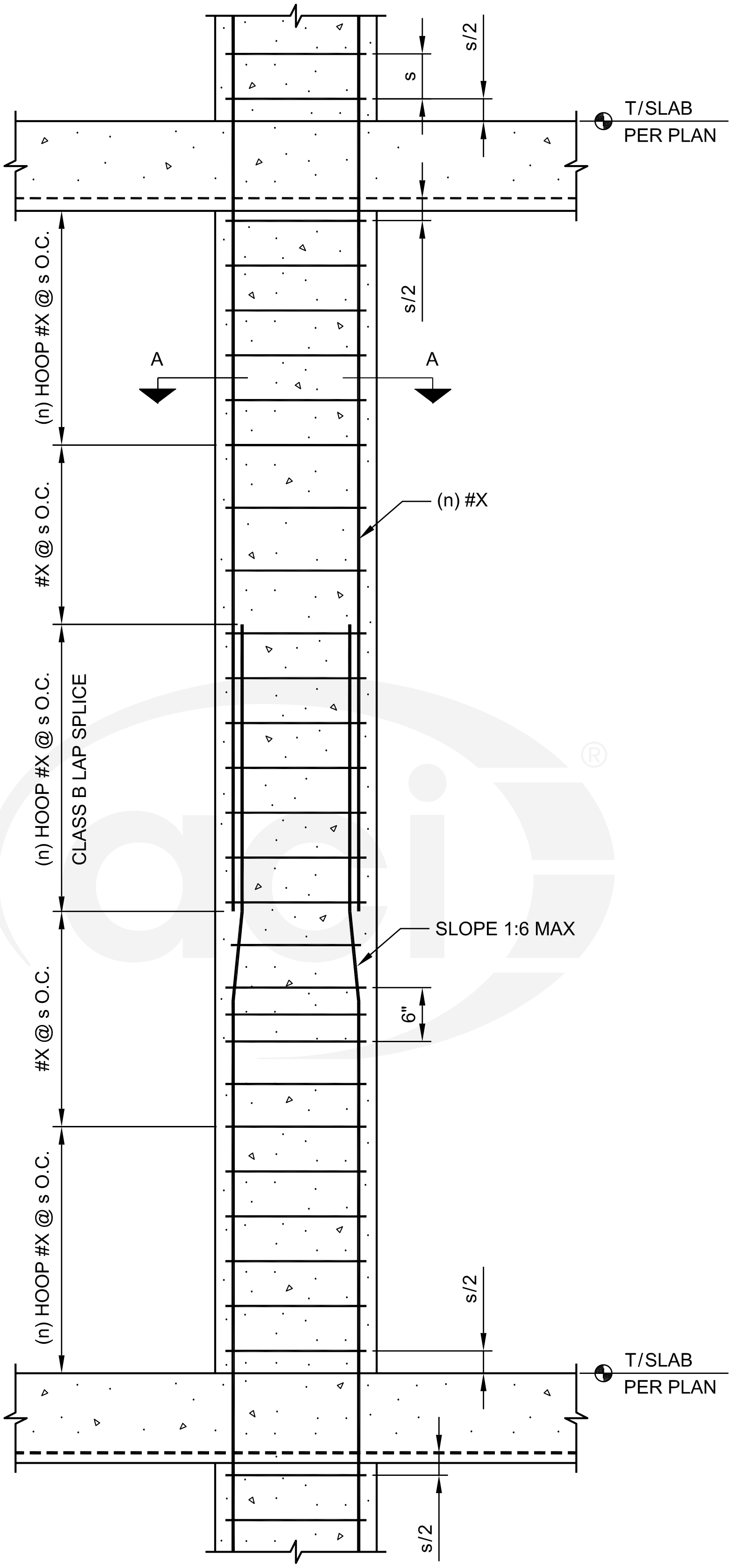
[*] *Refer to* Section 3 for articles

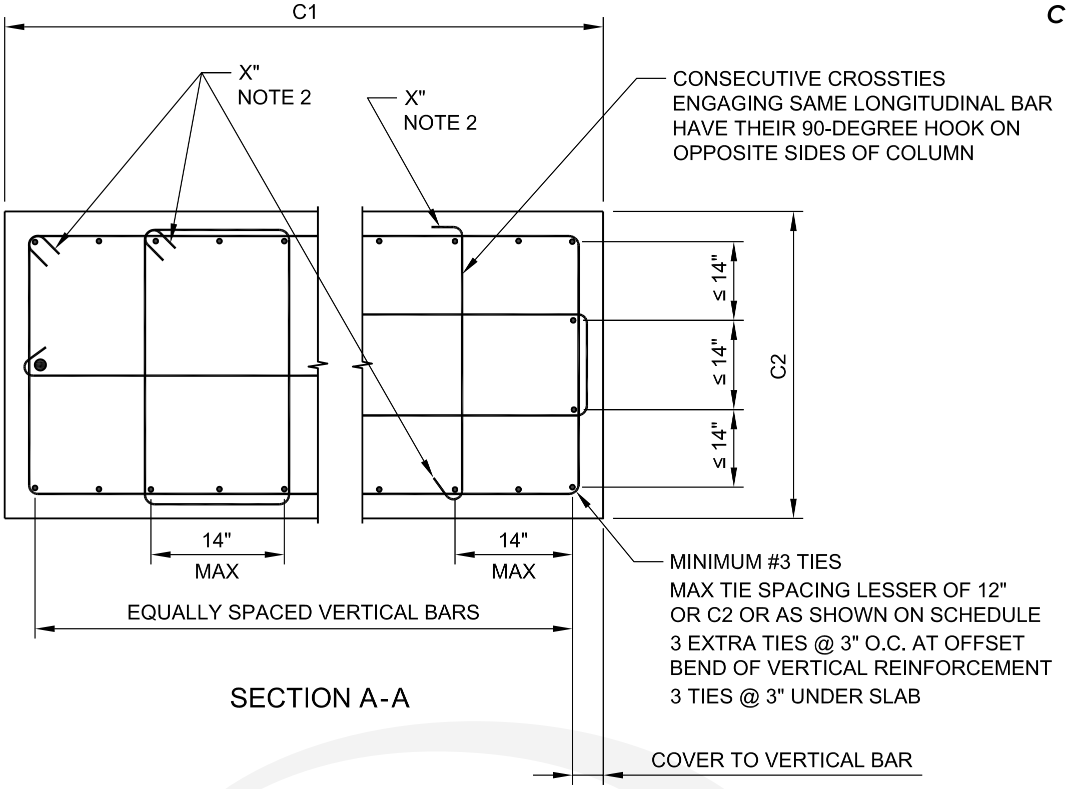
COL-101



NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE
INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

SPECIAL MOMENT FRAME COLUMN DETAIL (SDC D-F)

COL-102



CONSECUTIVE CROSSTIES
ENGAGING SAME LONGITUDINAL BAR
HAVE THEIR 90-DEGREE HOOK ON
OPPOSITE SIDES OF COLUMN

MINIMUM #3 TIES
MAX TIE SPACING LESSER OF 12"
OR C2 OR AS SHOWN ON SCHEDULE
3 EXTRA TIES @ 3" O.C. AT OFFSET
BEND OF VERTICAL REINFORCEMENT
3 TIES @ 3" UNDER SLAB

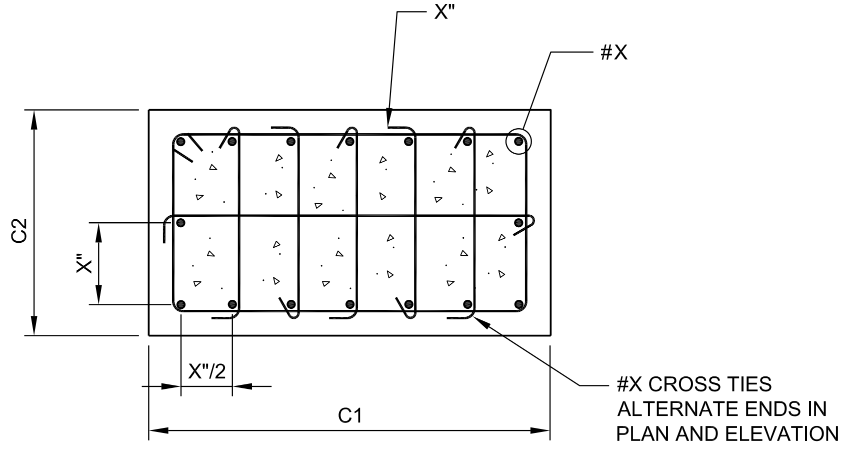
COVER TO VERTICAL BAR

SECTION A-A

NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE
INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

SPECIAL MOMENT FRAME COLUMN CROSS-SECTION TIE ARRANGEMENT - TYPE I

COL-103



SECTION A-A

NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE
INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

SPECIAL MOMENT FRAME COLUMN CROSS-SECTION TIE ARRANGEMENT - TYPE II

FIGURE COL-101 TO 103: SPECIAL MOMENT FRAME COLUMN DETAIL (SDC D, E, AND F)

The design professional shall review the following checklist and incorporate project specific-requirements into the details

INTENDED USE

Typical column reinforcement that are designated as part of the lateral-force-resisting system with hoops

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Specified concrete compressive strength, f'_c, satisfies requirements in Table 18.2.5
2. Specified yield strength and ASTM steel grade satisfy requirements in Section 18.2.6.1
3. Column minimum dimension and side ratio satisfies Section 18.7.2.1
4. Column cross-sectional dimensional ratio is at least 0.4; Section 18.7.2.1b
5. Minimum number of longitudinal bars in a column per Section 10.7.3.1
6. Area of longitudinal reinforcement ratio satisfies requirements in Section 18.7.4.1
7. Transverse reinforcement satisfies requirements of Section 18.7.5.2
8. Maximum bar spacing satisfies Section 18.7.5.2(e) and (f)
9. Maximum spacing of hoops is in conformance with Section 18.7.5.3
10. In any story, bottom tie or hoop is placed not more than half the calculated tie or hoop spacing above slab or footing; Section 10.7.6.2.1
11. In any story, top tie or hoop is placed not more than one-half the calculated tie or hoop spacing below the lowest slab, drop panel, or shear cap reinforcement; Section 10.7.6.2.2
12. Minimum bar spacing satisfies Section 10.7.2 and 25.2
13. Hoop sizes satisfy Section 25.7.2.2
14. Hook details satisfy Table 25.3.2
15. Select longitudinal reinforcement such that it satisfies Section 18.7.4.3
16. Plastic hinge zones length, at both ends of column, and on both sides of any section where flexural yielding is likely to occur satisfy the requirements in Section 18.7.5.1
17. Hoop spacing in regions outside plastic hinge region spacing defined in Section 18.7.5.5
18. Beam/slab-column reinforcement satisfies the requirements in Section 18.8.3
19. Splices of deformed bars must satisfy Section 25.5
20. Bar splices, except for No. 14 and No. 18 bars, Section 25.5.1.1, can be mechanical or welded splices
21. May replace Class B splice with mechanical splices or welded butt splice – refer to typical detail 203
22. Mechanical splices satisfy requirements in Section 18.2.7 and are tension splices; Section 18.7.4.4
23. Welded splices satisfy requirements in Section 18.2.8 and are tension splices; Section 18.7.4.4
24. Mechanical couplers are enclosed by ties per Section 10.7.6.1.6
25. Concrete cover for reinforcement satisfies Section 20.5.1
26. Development lengths satisfy Section 25.4
27. Type II cross section applies if $P_u > 0.3A_g f'_c$ or $f'_c > 10{,}000$ psi; Section 18.7.5.2(f)
28. Remove "NOTES TO DESIGN PROFESSIONAL" before placing schedule in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles[*]: 13, 27, 28, 34

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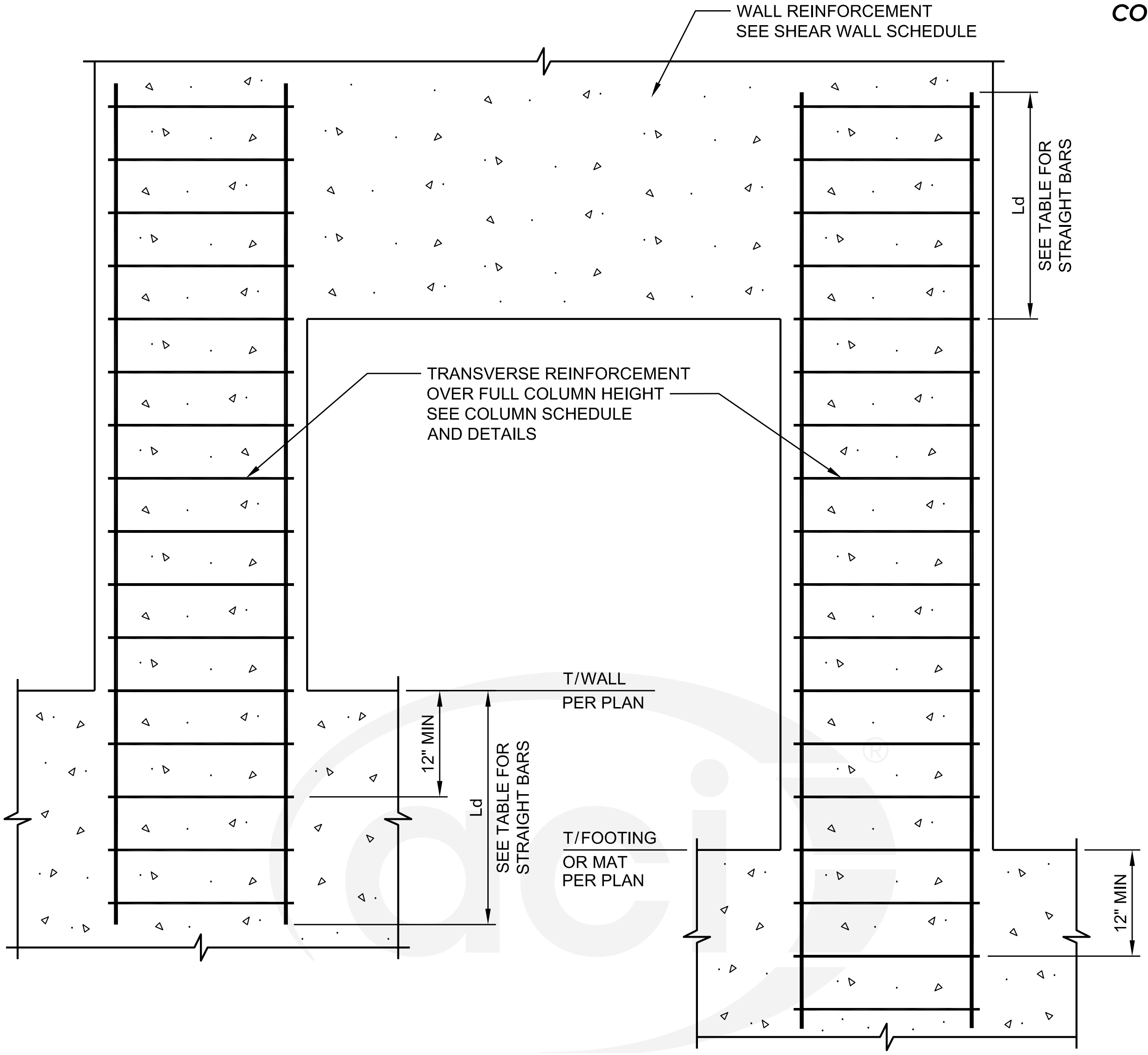
[*] Refer to Section 3 for articles

SECTION 2

COL-104



NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

SPECIAL MOMENT FRAME COLUMN SUPPORTING DISCONTINUED WALL

NOTES:

1. APPLICABLE TO NORMALWEIGHT CONCRETE (145 pcf) WITH UNCOATED GRADE 60 REINFORCING BARS
2. FOR LIGHTWEIGHT CONCRETE, MULTIPLY TABULATED VALUES BY 1.25
3. FOR EPOXY-COATED BARS, MULTIPLY TABULATED VALUES BY 1.5
4. FOR 80 ksi STEEL YIELD STRENGTH, MULTIPLY TABULATED VALUES BY 1.5
5. FOR 100 ksi STEEL YIELD STRENGTH, MULTIPLY TABULATED VALUES BY 2.2

MIN. DEVELOPMENT LENGTH Ld
STRAIGHT BARS

BAR SIZE	CONCRETE	
	4000 psi	5000 psi
#5	1' - 11"	1' - 9"
#6	2' - 4"	2' - 1"
#7	2' - 8"	2' - 5"
#8	3' - 1"	2' - 9"
#9	3' - 6"	3' - 1"
#10	3' - 11"	3' - 6"
#11	4' - 4"	3' - 11"

FIGURE COL-104: COLUMN SUPPORTING WALL – SDC D, E, AND F

The design professional shall review the following checklist and
incorporate project-specific requirements into the details

INTENDED USE

Columns supporting walls and columns terminate on walls or footing or mat

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Columns have transverse reinforcement per Section 18.7.5.2 over full height at all levels below discontinuity, per Section 18.7.5.6(a)
2. Column supporting a wall or column terminates on a wall:
   a. Verify that transverse reinforcement is extended into the wall at least the development length in tension, l_d, of the largest longitudinal column bar at the point of termination into the wall; Section 18.7.5.6(b)
   b. Verify that l_d is in accordance with Section 18.8.5
3. Column supporting a wall and supported on footing or mat:
   a. Verify that transverse reinforcement is extended into the footing/mat a minimum distance of 12 in.; Section 18.7.5.6(b)
4. Transverse reinforcement satisfies Section 18.7.5.2
5. For column longitudinal and transverse reinforcement requirements refer to DETAIL COL-101
6. Remove "NOTES TO DESIGN PROFESSIONAL" before placing schedule in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles[*]: 13, 27, 28, 34

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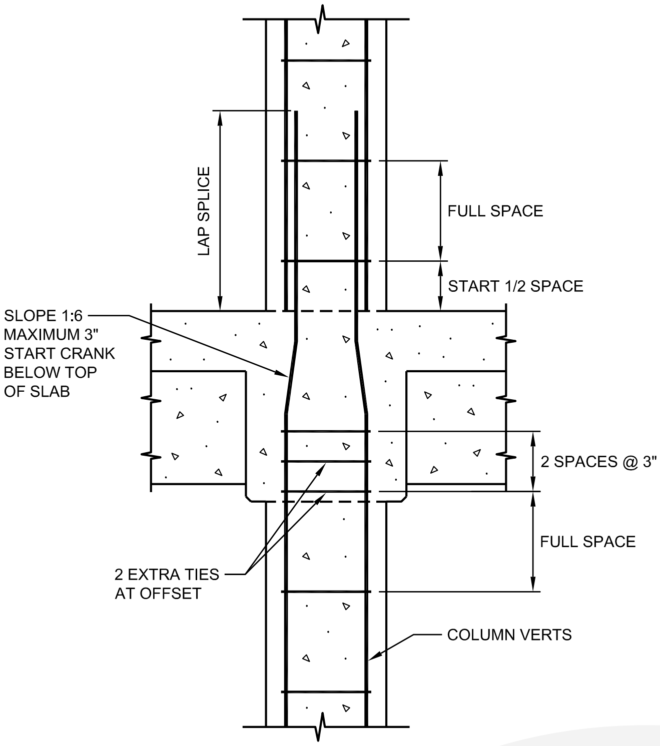
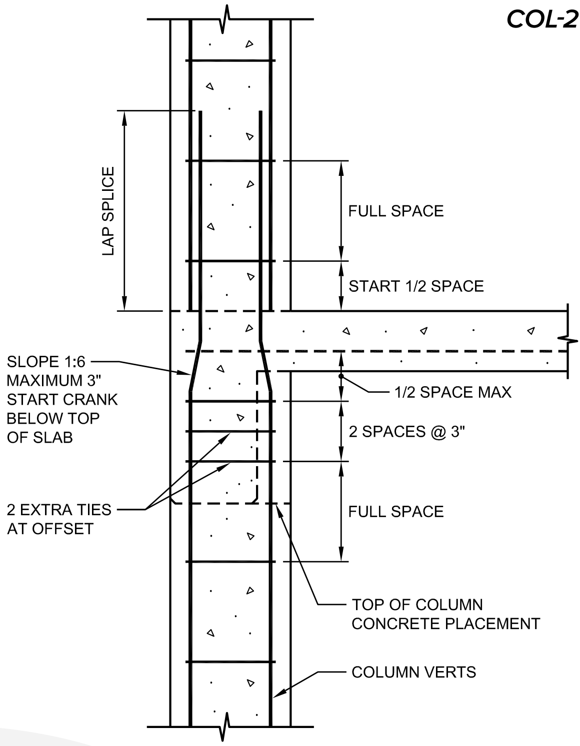
[*] Refer to Section 3 for articles

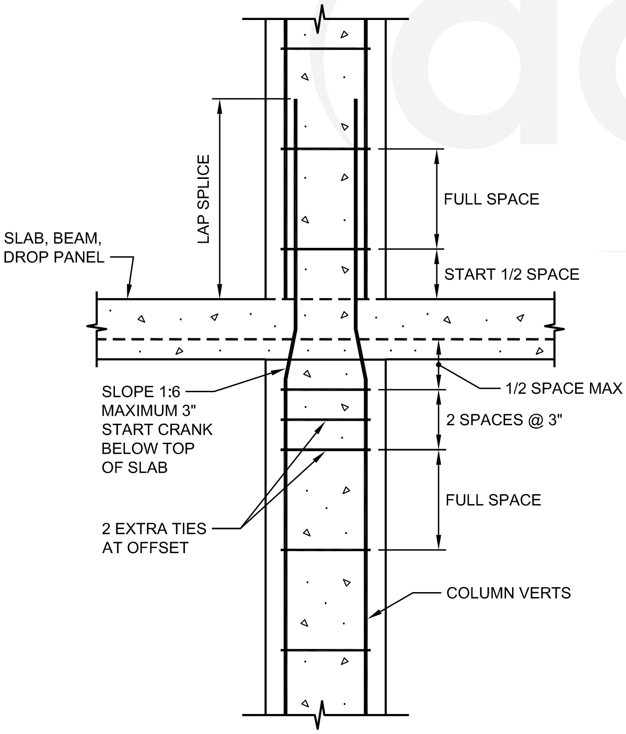
COL-200



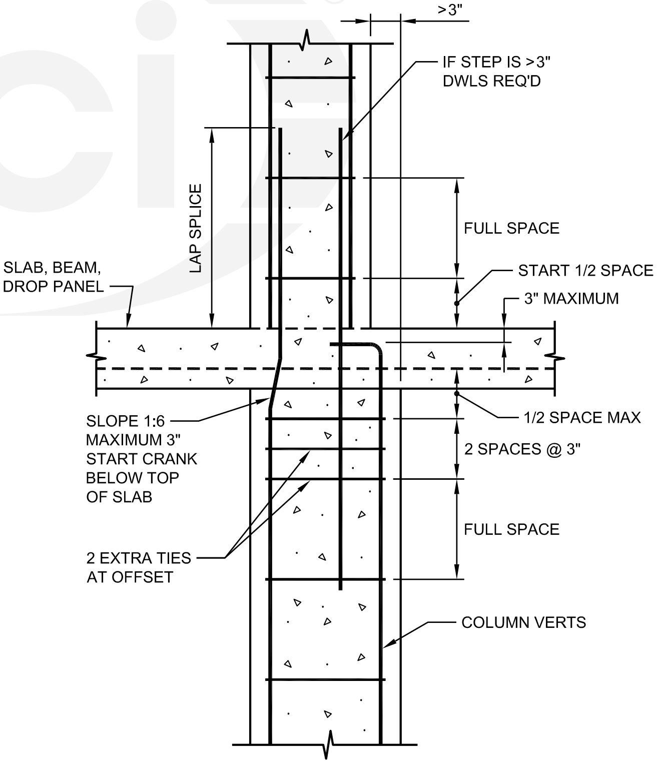
SPLICE AT INTERIOR - BEAMS 4 SIDES
BEAM WIDTHS > COLUMN WIDTHS
OTHERWISE AS PER EXTERIOR COLUMN



SPLICE AT EXTERIOR COLUMN



SPLICE AT SLABS, BEAMS, DROP PANELS



COLUMN STEP > 3" AT SLAB, BEAM, DROP PANELS
BEAM SIMILAR

NOTES TO DESIGN PROFESSIONAL:
- SPECIFY TYPE OF LAP SPLICE REQUIRED
- COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAILS AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

TYPICAL SPLICE DETAILS OF TYPICAL COLUMNS

FIGURE COL-200: TYPICAL COLUMN SPLICE DETAILS FOR NON-MOMENT FRAME COLUMNS IN ORDINARY-MOMENT FRAME

The design professional shall review the following checklist and incorporate project-specific requirements into the details

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INTENDED USE

Solid nonprestressed columns

Interior column supporting top slab with or without beams on all sides

Size of column at floor may change – column may be wider and deeper below slab

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Reinforcement cover satisfies Sections 10.7.1.1 and 20.5.1
2. Development lengths satisfy Sections 10.7.1.2 and 25.4
3. Slope longitudinal bar bents maximum 1 horizontal to 6 vertical; Section 10.7.4.1
4. Longitudinal bars compression lap splices satisfy Sections 10.7.5.2.1 and 25.5.5
5. Longitudinal bars tension lap splices satisfy Sections 10.7.5.2.2 and 25.5.2.1
6. Ties details for rectangular or square longitudinal bar orientation are per Section 25.7.2
7. Spirals or hoop ties for circular longitudinal bar orientation are per Sections 25.7.3 for spiral ties or 25.7.4 for hoop ties
8. Bottom tie or hoop, in any story, is placed per Section 10.7.6.2.1
9. Top tie or hoop, in any story, is placed per Section 10.7.6.2.2
10. If beam-column joint is not considered confined, part of the SFRS, or assigned to SDC D, E, or F in accordance with 15.3.1.1 (a) through (c); spacing of joint transverse reinforcement does not exceed 8 in., within the depth of the deepest beam framing into the joint; Section 15.3.1.4
11. If the column face is offset 3 in. or more, do not offset bent longitudinal bars; provide separate dowels lap spliced with the longitudinal bars adjacent to the offset column; Section 10.7.4.2
12. If joint is restrained on all four sides by beams satisfying Sections 15.2.8, 15.3.1.1a, and 15.3.2.1, then joint shear reinforcement is not required; delete ties or hoops from detail
13. If beam-column joint is not considered confined, and is part of the special force resisting system (SFRS), or assigned to SDC D, E, or F in accordance with 15.3.1.1 (a) through (c); at least two layers of horizontal reinforcement are provided within the depth of the shallowest beam framing into the joint; Section 15.3.1.3
14. Remove “NOTES TO DESIGN PROFESSIONAL” before placing schedule in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles[*]: 13, 27, 28, 34

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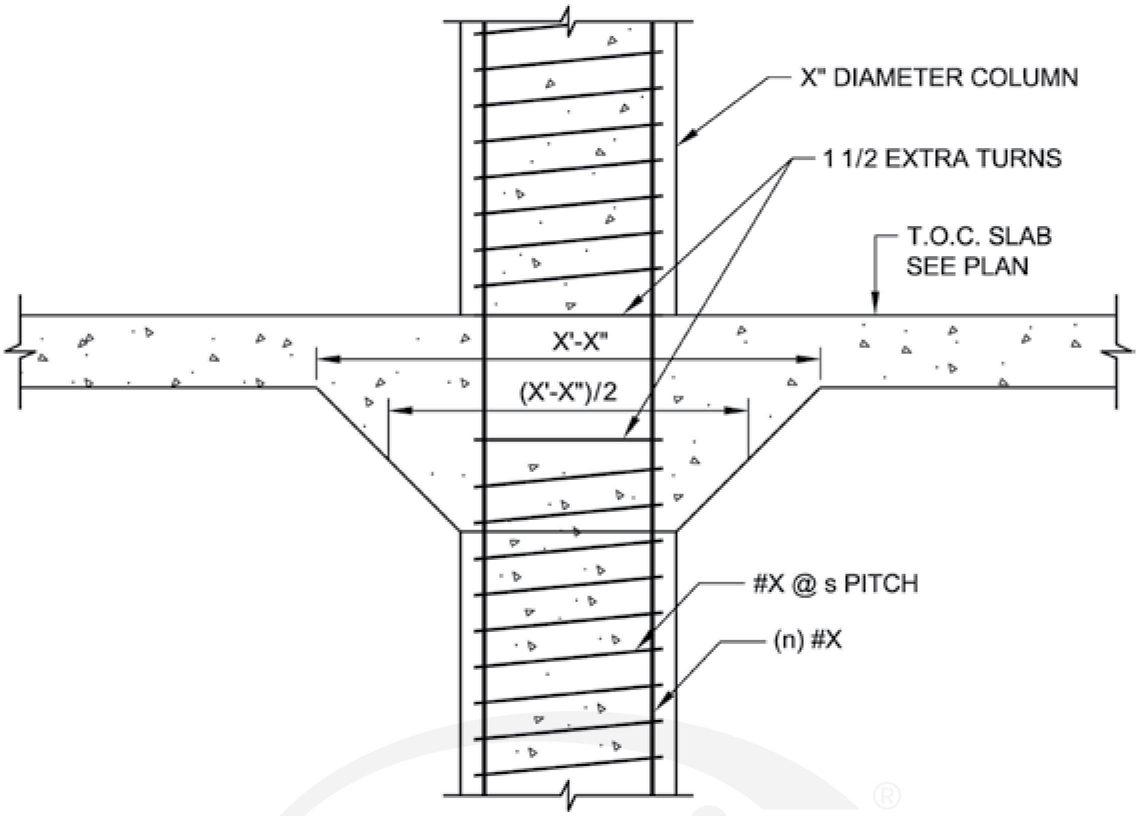
[*] Refer to Section 3 for articles

COL-201



NOTE:
SLAB AND CAPITAL REINFORCEMENT NOT SHOWN FOR CLARITY

NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

COLUMN WITH CAPITAL AND SPIRAL REINFORCEMENT

FIGURE COL-201: COLUMN WITH CAPITAL AND SPIRAL REINFORCEMENT

The design professional shall review the following checklist and incorporate project-specific requirements into the details

INTENDED USE

Determination of column spiral reinforcement termination with capital

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Capital is placed monolithically as part of the slab system; Section 26.5.7.2
2. Capital reinforcement with column spiral are coordinated
3. Column spiral reinforcement extends to minimum half the capital depth from top of column; Section 10.7.6.3.2
4. Spirals satisfy the requirements of Section 25.7.3
5. Remove "NOTES TO DESIGN PROFESSIONAL" before placing schedule in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles[*]: 27, 28

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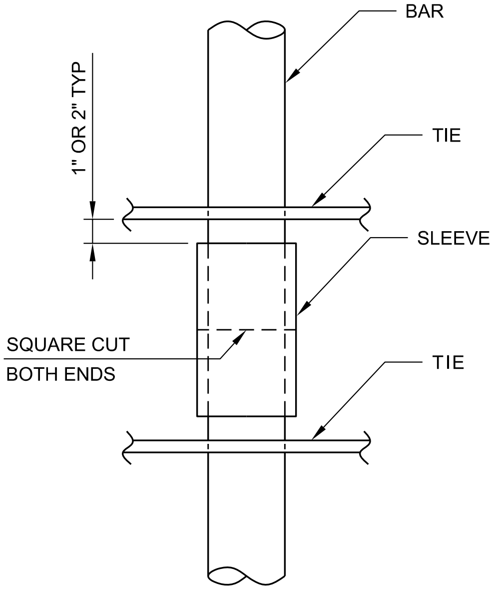
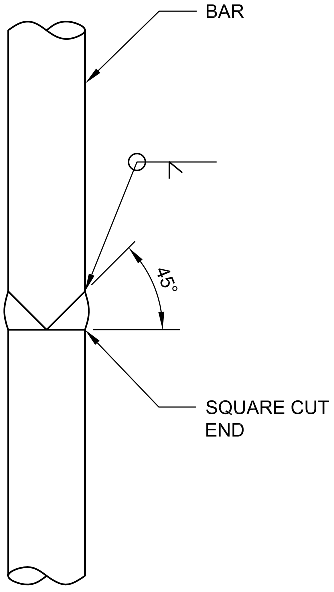
[*] Refer to Section 3 for articles

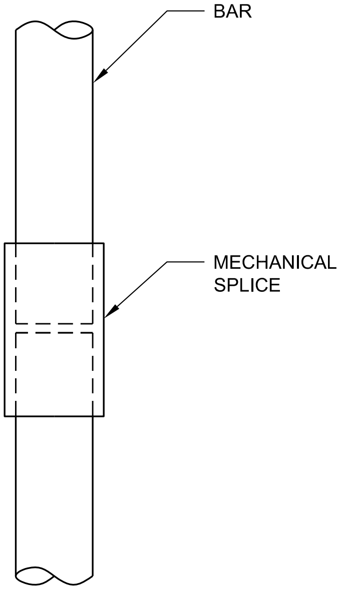
COL-202



END BEARING SPLICE



WELDED BUTT SPLICE



MECHANICAL SPLICE

NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE
INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

COLUMN BAR SPLICE DETAILS
END BEARING, MECHANICAL, WELDED

FIGURE COL-202: COLUMN BAR SPLICE DETAILS – END BEARING, MECHANICAL, WELDED

The design professional shall review the following checklist and
incorporate project-specific requirements into the details

INTENDED USE

Multi-story columns requiring longitudinal bar splicing – welded, mechanical, and end bearing splicing

NOT INTENDED FOR

Longitudinal bar splicing that are lap spliced

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Spliced bars or of same diameter
2. Welded splice:
   a. Square one end of joined longitudinal bars
   b. Full penetration weld all around
   c. Compression or tension splice to develop 1.25(f_y) of the bar yield strength
   d. Welding in accordance to AWS D1.4 (American Welding Society)
3. Mechanical splice:
   a. Compression or tension splice to develop 1.25(f_y) of the bar yield strength
   b. Proprietary steel splice fitted sleeve over joint; prepare longitudinal bar ends per splice manufacturer recommendations
4. End bearing (or butt) splice:
   a. Used for compression bar splicing
   b. Not used for tension bar splicing
   c. Square each end of joined longitudinal bars; bear upper bar on surface of lower bar
   d. Fitted steel sleeve over joint
   e. Provide a tie on either side of the end bearing splice
5. Remove “NOTES TO DESIGN PROFESSIONAL” before placing schedule in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles*:

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*Refer to Section 3 for articles

WALL DETAILS

WALL-1_1

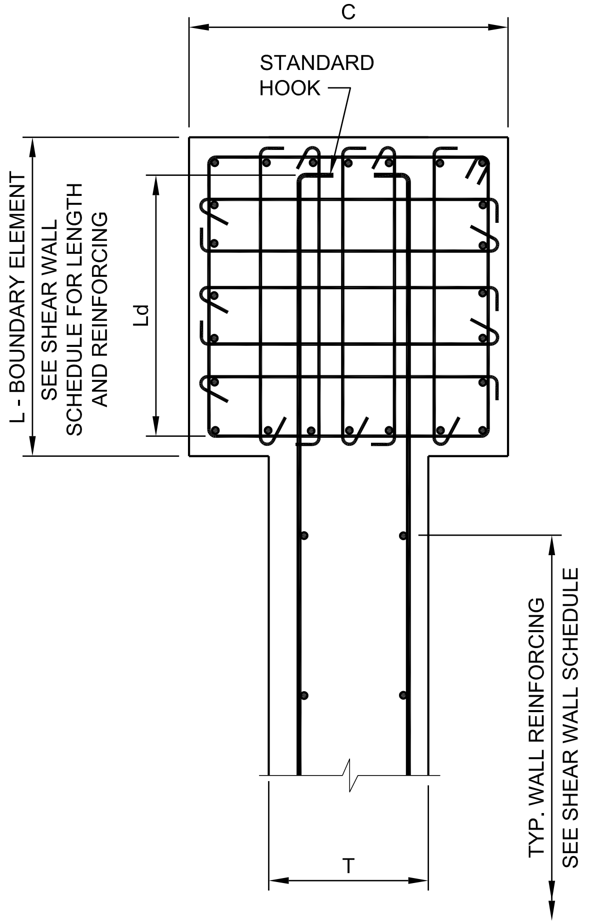
SHEAR WALL SCHEDULE

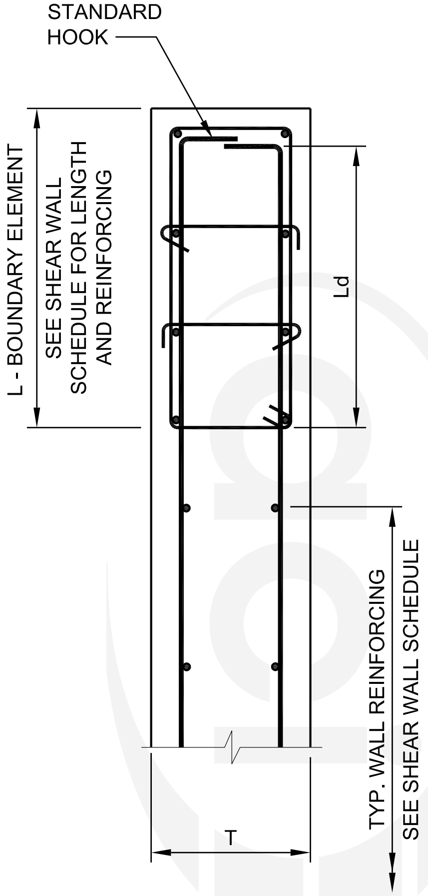
		SHEAR WALL SW-1							SHEAR WALL SW-2							SHEAR WALL SW-3						
SHEAR WALL MARK / FLOOR LEVEL		THICKNESS T	REINF EACH FACE		BOUNDARY ELEMENTS				THICKNESS T	REINF EACH FACE		BOUNDARY ELEMENTS				THICKNESS T	REINF EACH FACE		BOUNDARY ELEMENTS			
			VERT.	HORIZ.	C	L	REINFORCEMENT			VERT.	HORIZ.	C	L	REINFORCEMENT			VERT.	HORIZ.	C	L	REINFORCEMENT	
							VERT	HOOPS & CROSSTIES						VERT	HOOPS & CROSSTIES						VERT	HOOPS & CROSSTIES
T/ROOF																						
T/4TH FLOOR	f'_c=4000 PSI	16"	#5 @ 12"	#5 @ 12"	-	-	24-#10	#4 @ 8"	12"	#4 @ 12"	#4 @ 12"	-	-	8-#9	#4 @ 12"	12"	#4 @ 12"	#4 @ 12"	-	-	6-#9	#4 @ 12"
T/3RD FLOOR		16"	#5 @ 12"	#5 @ 12"	-	-	24-#10	#4 @ 8"	12"	#4 @ 12"	#4 @ 12"	-	-	8-#9	#4 @ 12"	12"	#4 @ 12"	#4 @ 12"	-	-	6-#3	#4 @ 12"
T/2ND FLOOR		16"	#5 @ 12"	#5 @ 12"	30	2'-6"	24-#10	#4 @ 8"	12"	#4 @ 12"	#4 @ 12"	-	2'-0"	8-#9	#4 @ 12"	12"	#4 @ 12"	#4 @ 12"	-	2'-0"	6-#9	#4 @ 12"
T/1ST FLOOR	f'_c=5000 PSI	18"	#5 @ 12"	#5 @ 12"	30	2'-6"	24-#11	#4 @ 6	12"	#4 @ 12"	#4 @ 12"	-	2'-0"	8-#10	#4 @ 8"	12"	#4 @ 12"	#4 @ 12"	-	2'-0"	6-#10	#4 @ 8"
T/FOUNDATION		18"	#5 @ 12"	#5 @ 12"	30	2'-6"	24-#11	#4 @ 6	12"	#4 @ 12"	#4 @ 12"	-	2'-0"	8-#10	#4 @ 8"	12"	#4 @ 12"	#4 @ 12"	-	2'-0"	6-#10	#4 @ 8"
REMARKS		SEE TYPICAL SHEAR WALL BASE DETAILS FOR SDC D AND HIGHER AND NOTE 1																				

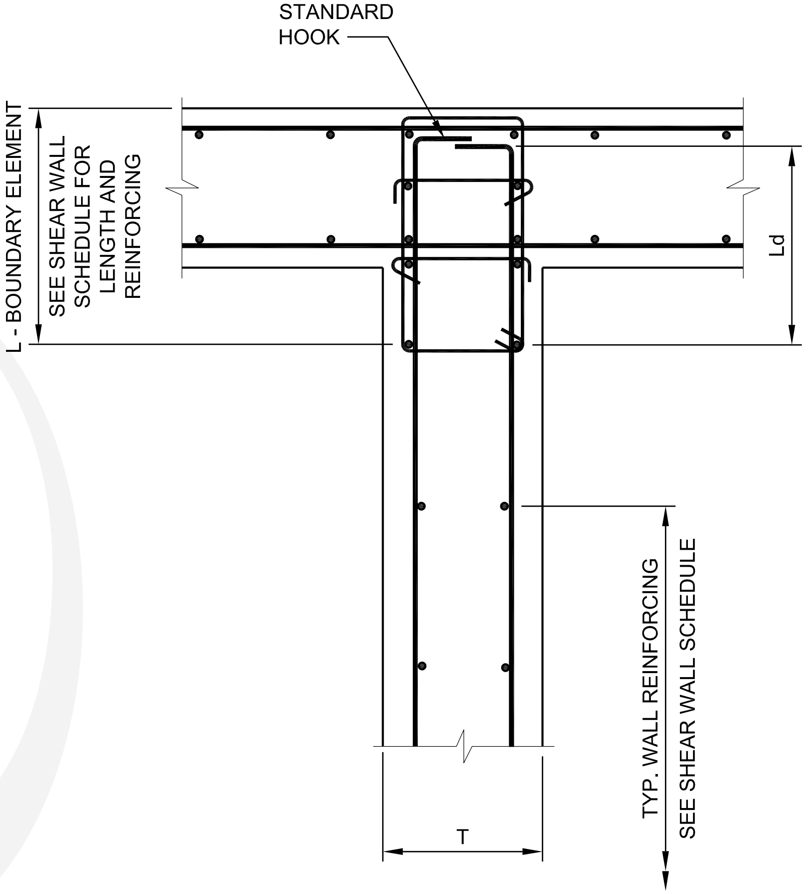
NOTES TO DESIGN PROFESSIONAL:
- USE NUMBERS AS EXAMPLES; MODIFY AS REQUIRED
- COMPLETE THE ATTACHED CHECKLIST AND MODIFY SCHEDULE AS REQUIRED BEFORE INCORPORATING THIS SCHEDULE INTO PROJECT CONSTRUCTION DOCUMENTS

WORK THIS SCHEDULE WITH WALL-1.2

WALL-1_2







NOTES TO DESIGN PROFESSIONAL:

1. HORIZONTAL REINFORCEMENT EXTENDING INTO BOUNDARY ELEMENT COULD BE STRAIGHT BARS, HOOKED, OR HEADED
2. CROSSTIES IN SPECIAL STRUCTURAL WALL (SDC D-F) BOUNDARY ELEMENT HAVE 135-DEGREE SEISMIC HOOKS AT BOTH ENDS
3. COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAILS AS REQUIRED BEFORE INCORPORATING THESE DETAILS INTO PROJECT CONSTRUCTION DOCUMENTS

SHEAR WALL SW-1

SHEAR WALL SW-2

SHEAR WALL SW-3

WORK THESE DETAILS WITH WALL-1.1 SCHEDULE

FIGURE WALL-1_1 AND WALL-1_2: SHEAR WALL SCHEDULE

The design professional shall review the following checklist and incorporate project-specific requirements into the details

INTENDED USE

Schedule for shear walls used on the project

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Each shear wall type is assigned with wall mark in the table and coordinated with wall marks on floor plan drawings
2. Shear walls of same reinforcement and dimensions may use same mark number
3. Shear wall schedule and shear wall typical details are coordinated
4. C and L dimensions are provided for special boundary member—Coordinate with Wall-1_2
5. Wall bar sizes and locations are properly entered and coordinated in the table
6. Horizontal bars are developed properly into the boundary elements; provide standard hook (90 degree) bars if space is not available or use headed bars
7. Special structural wall horizontal bars, straight, hooked, or headed, are extended to within 6 in. of the end of the wall; Section 18.10.6.4(k)
8. Hoops are provided around longitudinal bars in the boundary element
9. Standard hook (90-degree) are alternated on consecutive crossties
10. Ties for special structural walls (SDC D through F) supplemental crossties have 135-degree seismic hooks at both ends; Section 18.10.6.4(f)
11. Wall reinforcement ratios exceed the minimum required in Section 11.6
12. Wall longitudinal reinforcement spacing satisfies Sections 11.7.2
13. Wall transverse reinforcement spacing satisfies Sections 11.7.3
14. Longitudinal reinforcement is laterally supported per Section 11.7.4.1
15. Wall reinforcement and spacing requirements for special structural walls satisfy Sections 18.10 if special structural wall (SDC D through F) and supersede Sections of Chapter 11
16. Boundary elements satisfy Sections 18.10.6 if special structural wall (SDC D through F)
17. Cover for reinforcement satisfies Section 20.5.1
18. Remove "NOTES TO DESIGN PROFESSIONAL" before placing schedule and details in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles*: 5, 9, 13, 16, 17, 23, 24, 31, 33, 35

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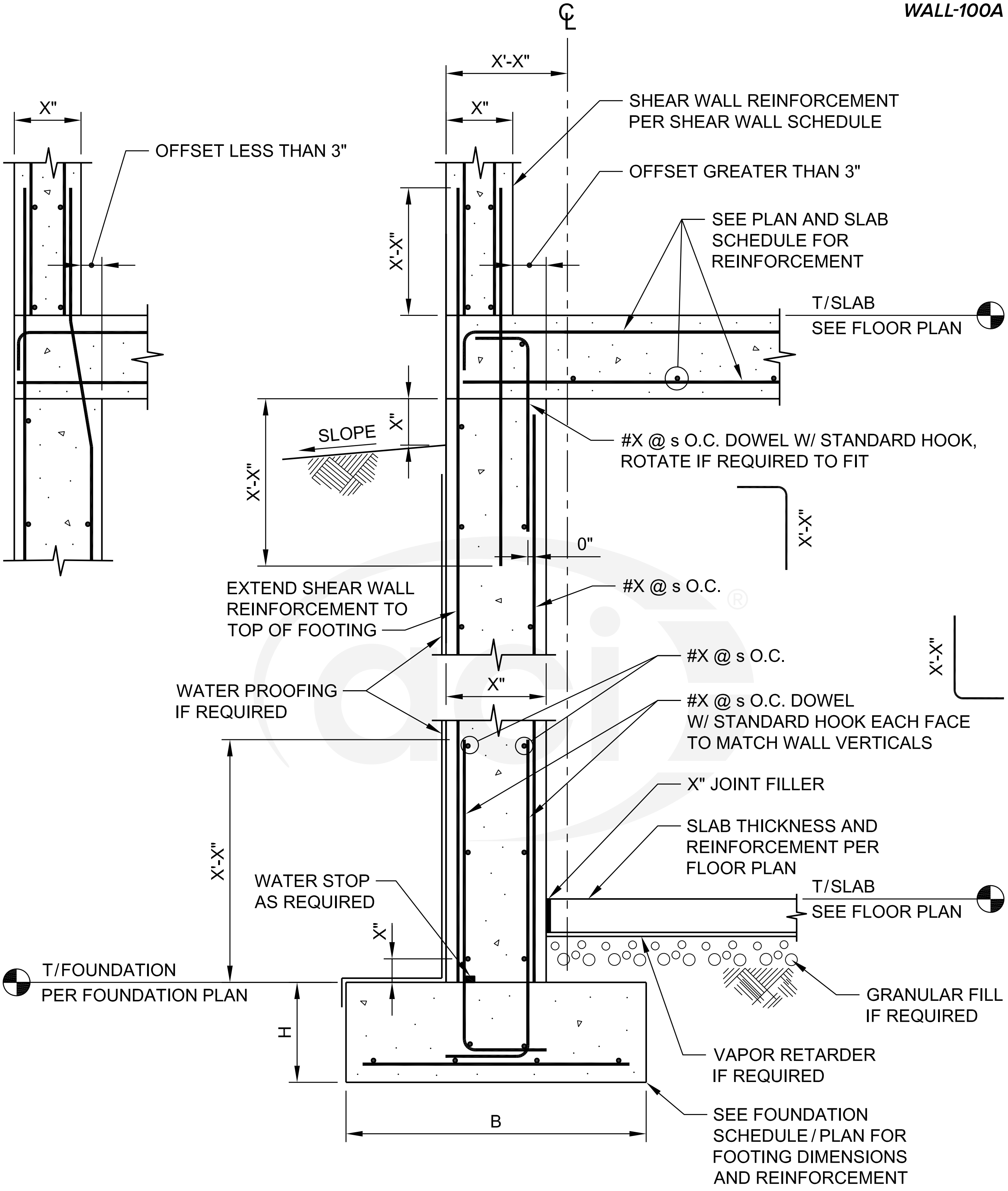
*Refer to Section 3 for articles

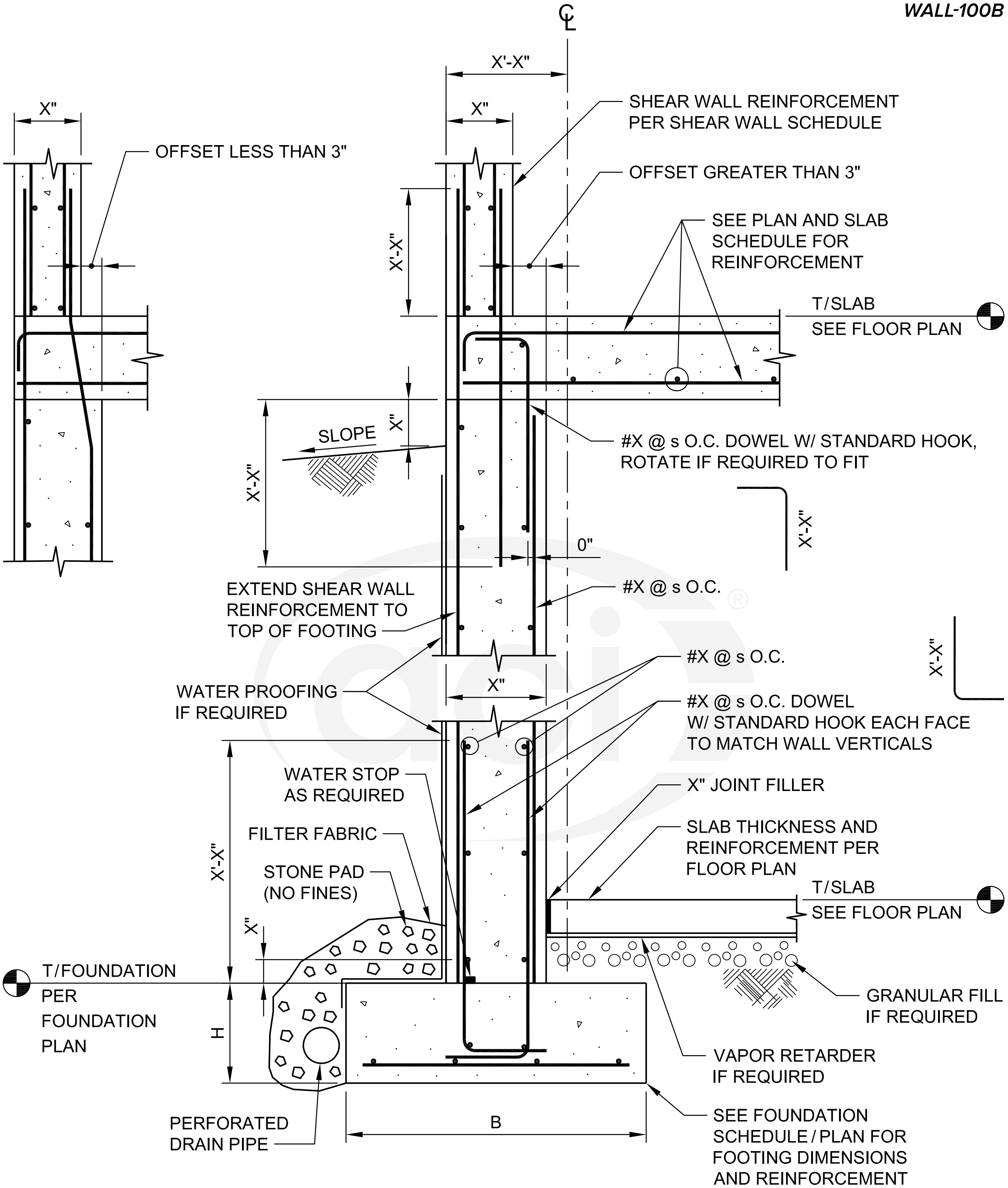
WALL-100A



NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

SHEAR WALL / BASEMENT WALL

WALL-100B



NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

SHEAR WALL / BASEMENT WALL WITH DRAINAGE

FIGURE WALL-100A AND WALL-100B: BASEMENT REINFORCED CONCRETE WALL TO FOUNDATION WITH SHEAR WALL ABOVE

The design professional shall review the following checklist and
incorporate project-specific requirements into the details

INTENDED USE

Basement reinforced concrete wall above ground and its connection to foundation and elevated slab

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Wall thickness satisfies Section 11.3.1.1 and provides adequate width to support elevated slab
2. Exterior wall face distance to column line is coordinated
3. Hooked bar is provided at ledge; size and spacing to match vertical wall bar size and spacing
4. Vertical dowels are provided from foundation into wall to match vertical wall reinforcement spacing
5. Basement wall vertical reinforcement is extended above finish grade and dowel into wall above per Section 25.5
6. Wall reinforcement ratios exceed the minimum required in Section 11.6
7. Wall longitudinal reinforcement spacing satisfies Sections 11.7.2
8. Wall transverse reinforcement spacing satisfies Sections 11.7.3
9. Longitudinal reinforcement is laterally supported per Section 11.7.4.1
10. Top of foundation and top of basement slab-on-ground elevation is coordinated
11. Detail reflects actual condition at ground level; slab-on-ground or finish grade slope away from wall
12. Wall reinforcement and spacing requirements for special structural walls (SDC D through F) satisfy Sections 18.10 and supersede Sections of Chapter 11
13. Boundary elements satisfy Sections 18.10.6 for special structural wall (SDC D through F)—see Figure WALL-1_2
14. Waterstop is provided if required. If adhesive waterstop type is used, then place next to the exterior vertical reinforcement layer. If bulb type waterstop is used, then place in the center of the wall
15. Vapor retarder applied to exterior face of wall below grade if required
16. Cover for reinforcement satisfies Section 20.5.1
17. Remove "NOTES TO DESIGN PROFESSIONAL" before placing detail in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles[*]: 5, 6, 16, 17, 23, 31, 33

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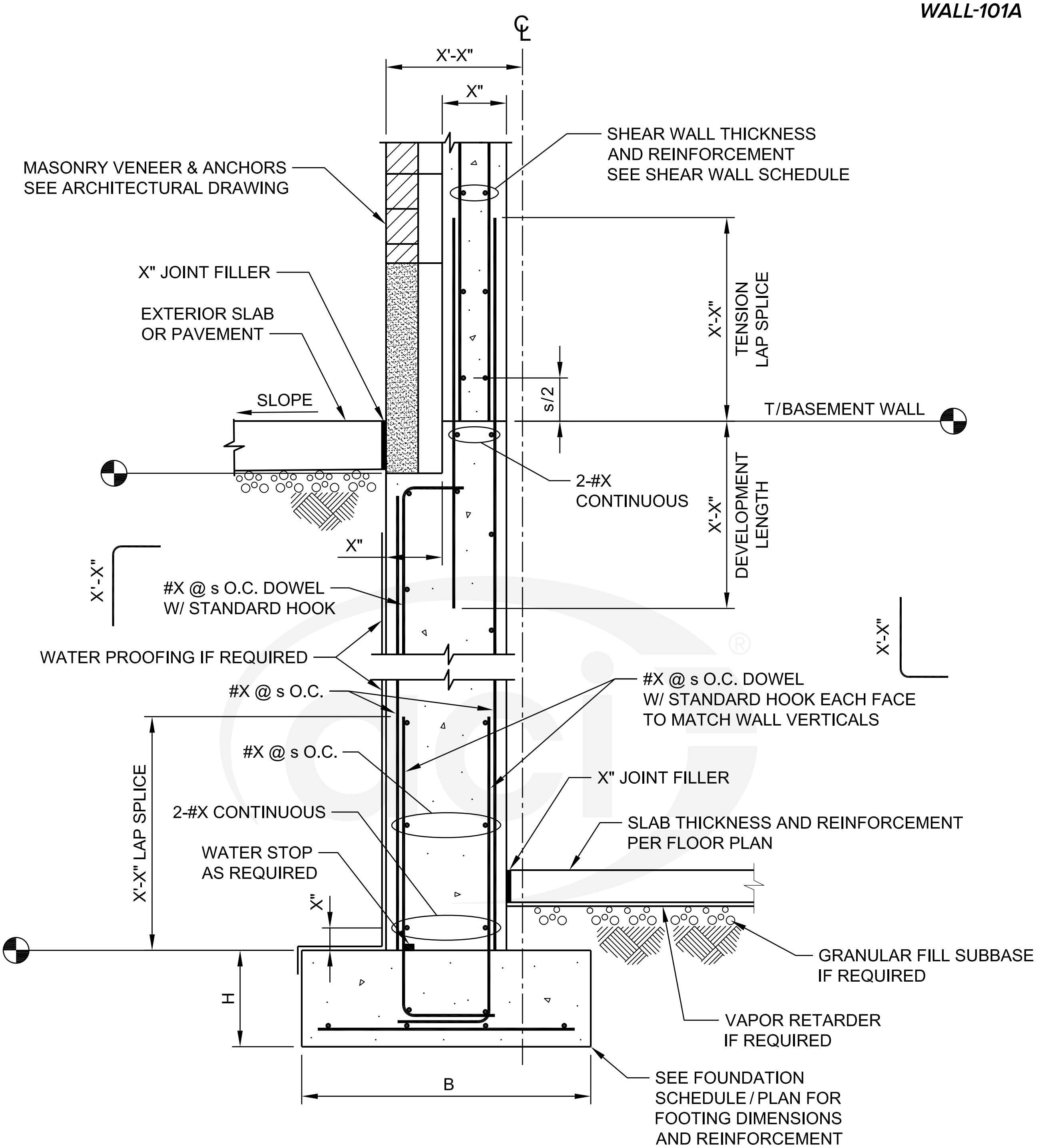
[*] Refer to Section 3 for articles

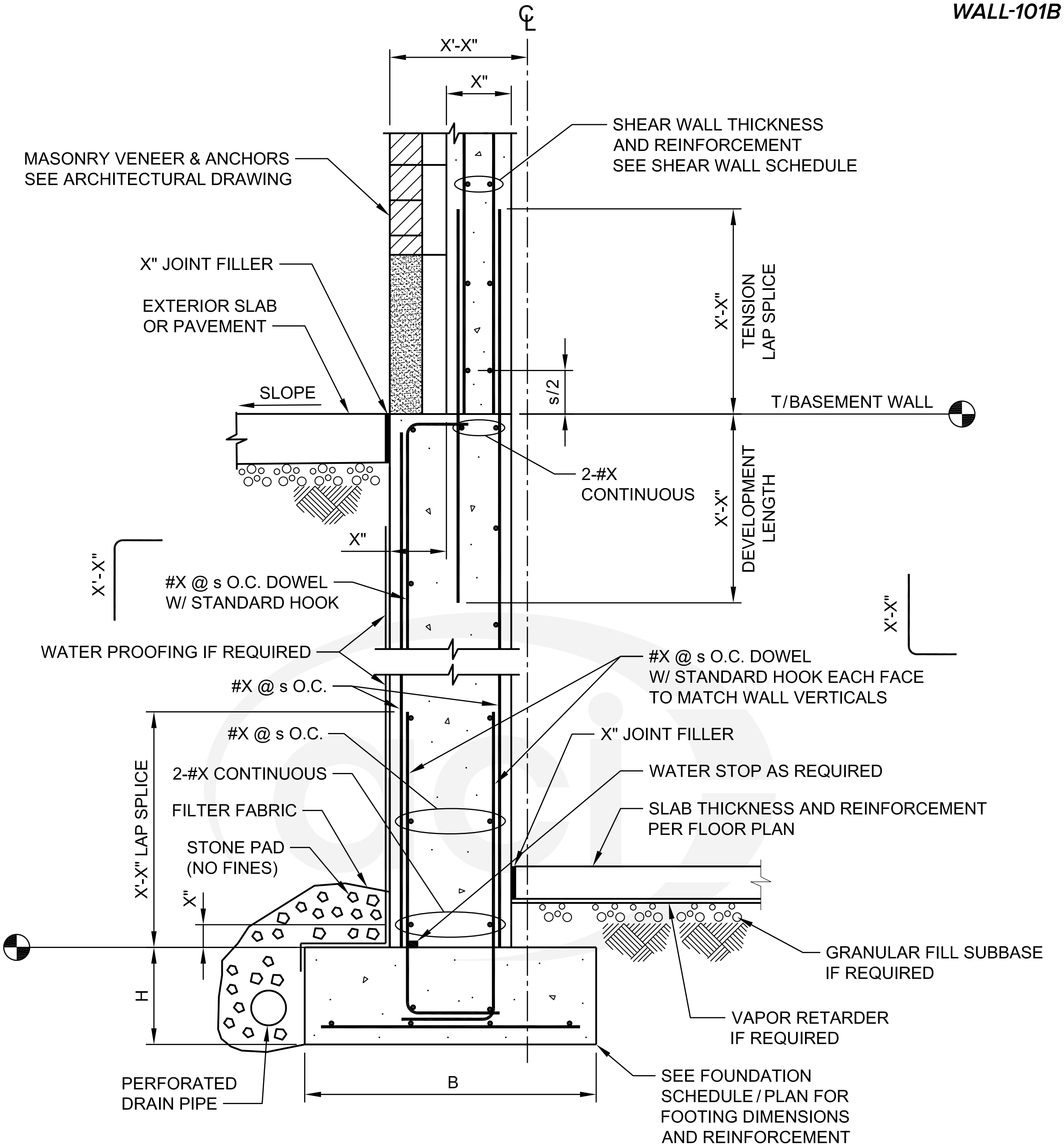
WALL-101A



NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE
INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

BASEMENT REINFORCED CONCRETE WALL TO FOUNDATION WITH SHEAR WALL AND BRICK VENEER ABOVE

WALL-101B



NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

BASEMENT REINFORCED CONCRETE WALL TO FOUNDATION WITH SHEAR WALL AND BRICK VENEER ABOVE WITH DRAINAGE

FIGURE WALL-101A AND WALL-101B: BASEMENT REINFORCED CONCRETE WALL TO FOUNDATION WITH SHEAR WALL AND BRICK VENEER ABOVE

The design professional shall review the following checklist and incorporate project-specific requirements into the details

---

INTENDED USE

Basement reinforced concrete wall reinforcement detail with exterior non-structural brick veneer

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Wall thickness satisfies Section 11.3.1.1 and provides adequate width to support elevated slab
2. Exterior wall face distance to column line is coordinated
3. Ledge is provided to support the veneer, or ledge may be eliminated and masonry block will start at ground level as shown in Figure WALL-101B
4. Hooked bar is provided at ledge; size and spacing to match vertical wall bar size and spacing
5. Vertical dowels are provided from foundation into wall to match vertical wall reinforcement spacing
6. Basement wall vertical reinforcement is extended above the joint and spliced with vertical wall reinforcement in accordance with section 25.5
7. Wall reinforcement ratios exceed the minimum required in Section 11.6
8. Wall longitudinal reinforcement spacing satisfies Sections 11.7.2
9. Wall transverse reinforcement spacing satisfies Sections 11.7.3
10. Longitudinal reinforcement is laterally supported per Section 11.7.4.1
11. Top of foundation and top of basement slab-on-ground elevation is coordinated
12. Detail reflects actual condition at ground level; slab-on-ground or finish grade; Slope away from wall
13. Wall reinforcement and spacing requirements for special structural walls (SDC D through F) satisfy Sections 18.10 and supersede sections of Chapter 11
14. Boundary elements satisfy Sections 18.10.6.4 for special structural wall (SDC D through F)—see Figure WALL-1_2
15. Waterstop is provided if required. If adhesive waterstop type is used, then place next to the exterior vertical reinforcement layer. If bulb type waterstop is used, then place in the center of the wall
16. Vapor retarder applied to exterior face of wall below grade if required
17. Cover for reinforcement satisfies Section 20.5.1
18. Remove "NOTES TO DESIGN PROFESSIONAL" before placing detail in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles*: 5, 6, 16, 17, 23, 31, 33

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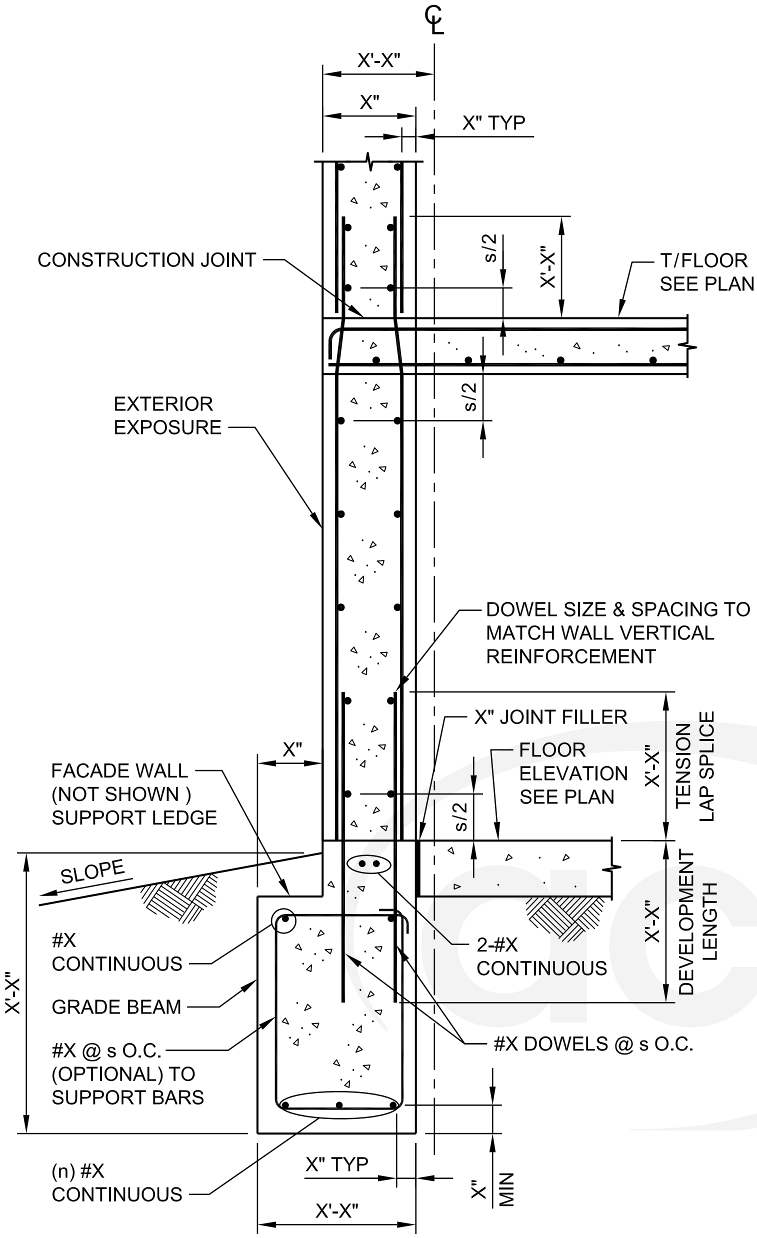
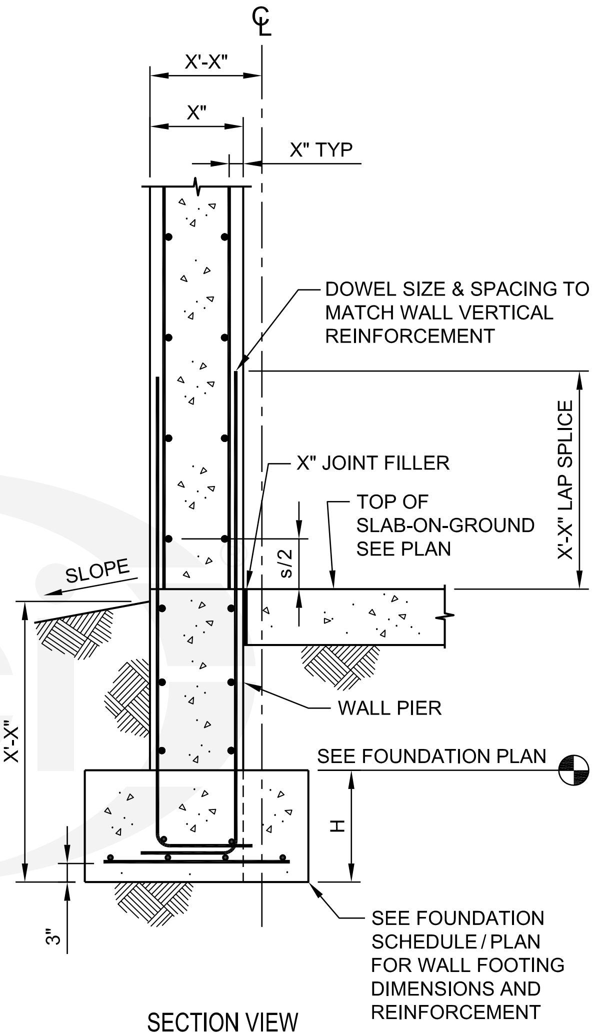
*Refer to Section 3 for articles

WALL-102



SECTION VIEW
AT GRADE BEAM



SECTION VIEW
AT WALL FOOTING (OPTIONAL)

NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

EXTERIOR WALL - WITHOUT BASEMENT

FIGURE WALL-102: EXTERIOR REINFORCED CONCRETE WALL – WITHOUT BASEMENT

The design professional shall review the following checklist and
incorporate project-specific requirements into the details

INTENDED USE

Exterior reinforced concrete wall without basement and its connection to shallow foundation and elevated slab

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Wall thickness satisfies Section 11.3.1.1 and provides adequate width to support elevated slab
2. Exterior wall face distance to column line is coordinated
3. Vertical dowels are provided from foundation into wall to match vertical wall reinforcement and spacing
4. Bottom of foundation is below frost line; coordinate with geotechnical report
5. Wall reinforcement ratios exceed the minimum required in Section 11.6
6. Wall longitudinal reinforcement spacing satisfies Sections 11.7.2
7. Wall transverse reinforcement spacing satisfies Sections 11.7.3
8. Longitudinal reinforcement is laterally supported per Section 11.7.4.1
9. Detail reflects actual condition at ground level; slab-on-ground or finish grade slope away from wall
10. Wall reinforcement and spacing requirements for special structural walls (SDC D through F) satisfy Sections 18.10 and supersede Sections of Chapter 11
11. Boundary elements satisfy Sections 18.10.6 for special structural wall (SDC D through F)
12. Expansion joint filled with sealant is provided between wall and basement slab-on-ground
13. Detail reflects actual condition at ground level; slab-on-ground or finish grade; slope away from wall
14. Cover for reinforcement satisfies Section 20.5.1
15. Remove "NOTES TO DESIGN PROFESSIONAL" before placing detail in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles[*]: 5, 13, 15, 16, 17, 23, 31, 33

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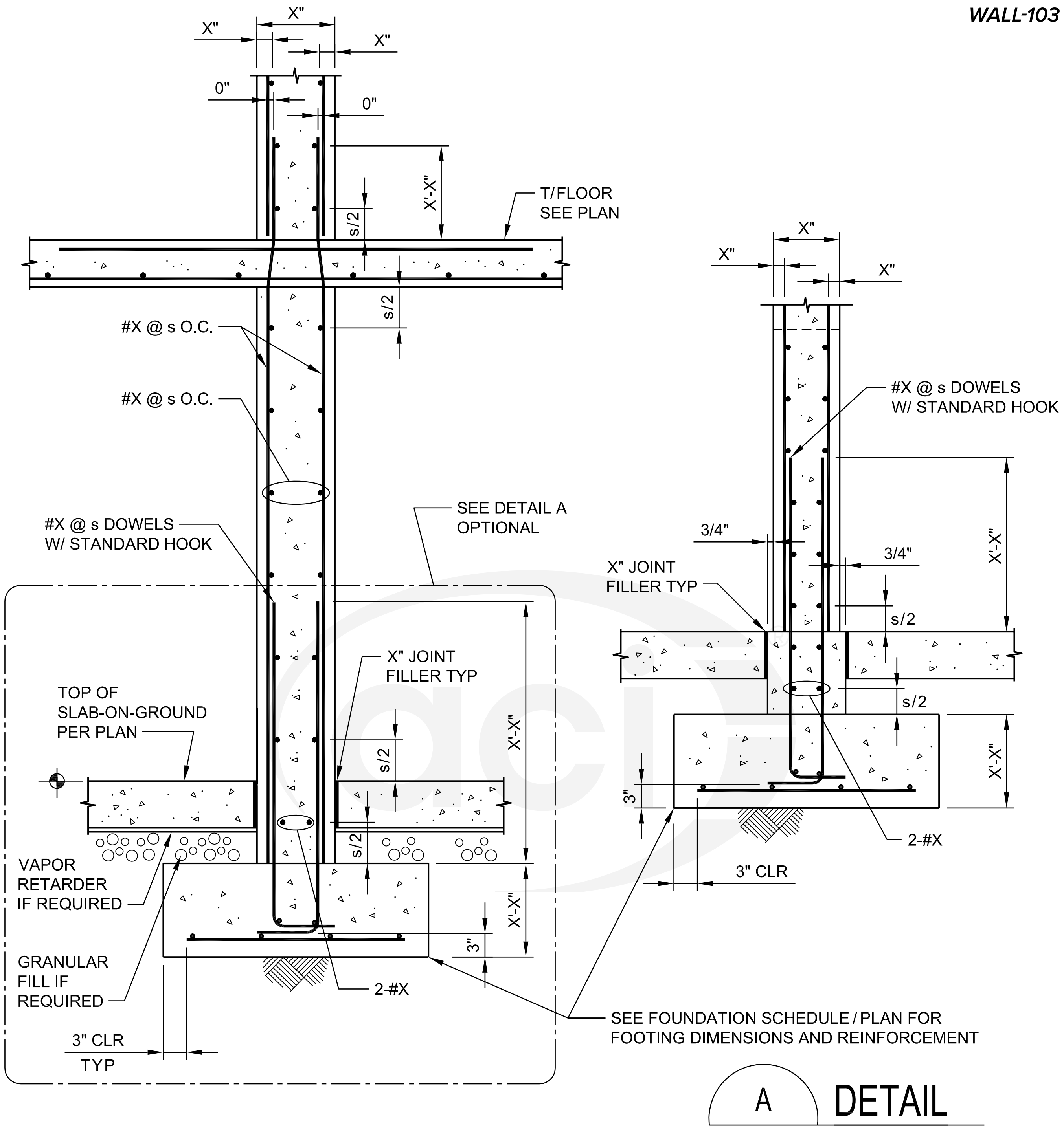
[*] Refer to Section 3 for articles

WALL-103



SECTION VIEW

(OPTIONAL FOOTING SECTION VIEW)

NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

INTERIOR REINFORCED CONCRETE WALL

FIGURE WALL-103: INTERIOR REINFORCED CONCRETE WALL

The design professional shall review the following checklist and incorporate project-specific requirements into the details

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INTENDED USE

Interior reinforced concrete wall and its connection to shallow foundation and elevated slab

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Wall thickness satisfies Section 11.3.1.1 and provides adequate distance to support elevated slab
2. Exterior wall face distance to column line is coordinated
3. Vertical dowels are provided from foundation into wall to match vertical wall reinforcement and spacing
4. Dowel hooks in foundation
5. Wall reinforcement ratios exceed the minimum required in Section 11.6
6. Wall longitudinal reinforcement spacing satisfies Sections 11.7.2
7. Wall transverse reinforcement spacing satisfies Sections 11.7.3
8. Longitudinal reinforcement is laterally supported per Section 11.7.4.1
9. Wall reinforcement and spacing requirements for special structural walls (SDC D through F) satisfy Sections 18.10 and supersede Sections of Chapter 11
10. Boundary elements satisfy Sections 18.10.6 for special structural wall (SDC D through F)
11. Expansion joint filled with sealant is provided between wall and slab-on-ground
12. Adequate distance is provided between top of foundation and bottom of slab-on-ground to run duct/pipes
13. Cover for reinforcement satisfies Section 20.5.1
14. Remove “NOTES TO DESIGN PROFESSIONAL” before placing detail in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles*: 5, 13, 16, 17, 23, 31, 33

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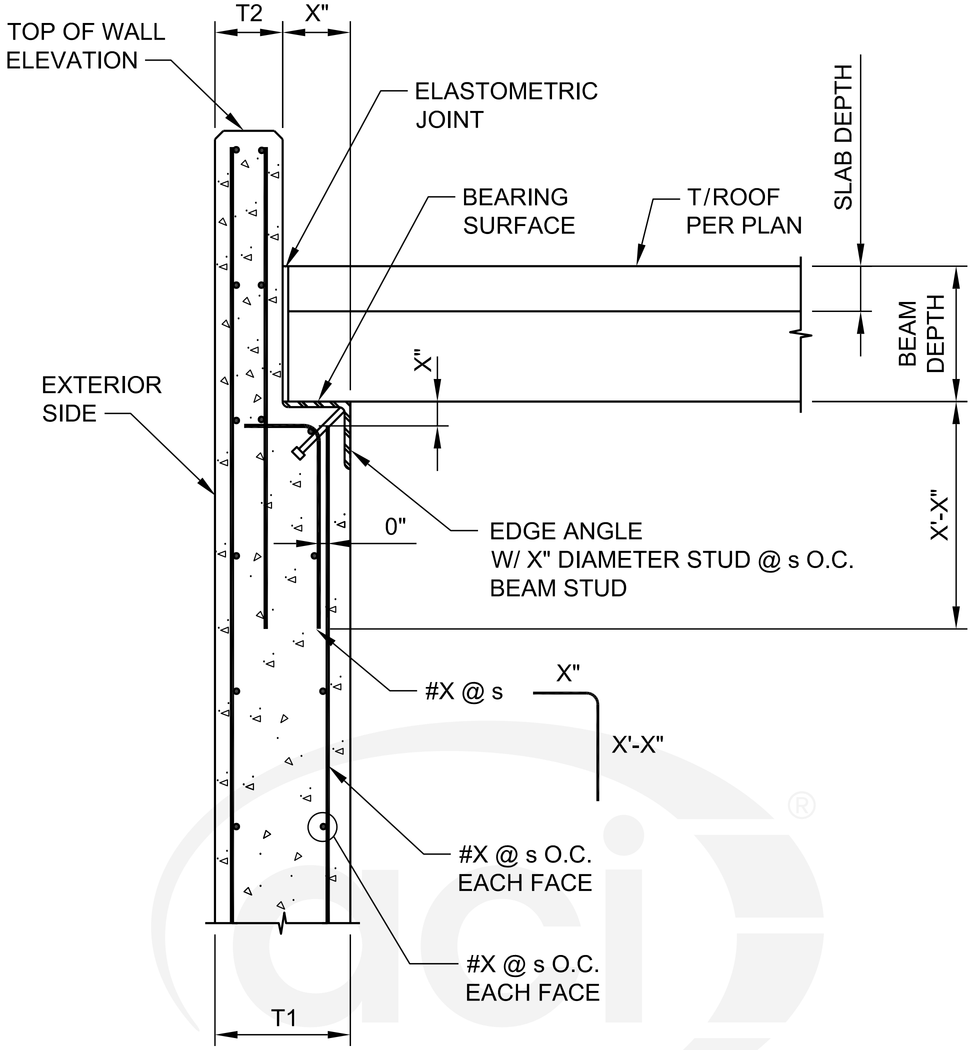
*Refer to Section 3 for articles



NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

EXTERIOR WALL SUPPORTING PRECAST BEAM AT TOP LEVEL

FIGURE WALL-104: EXTERIOR WALL – SUPPORTING PRECAST CONCRETE BEAM AT TOP LEVEL

The design professional shall review the following checklist and
incorporate project-specific requirements into the details

INTENDED USE

Cast-in-place reinforced concrete nonprestressed walls supporting precast concrete beam

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Wall thickness satisfies Section 11.3.1.1 and provides adequate width to support elevated slab
2. Wall reinforcement ratios exceed the minimum required in Section 11.6
3. Wall reinforcement and spacing requirements for special structural walls (SDC D through F) satisfy Sections 18.10
4. Wall longitudinal reinforcement spacing satisfies Sections 11.7.2
5. Wall transverse reinforcement spacing satisfies Sections 11.7.3
6. Longitudinal reinforcement is laterally supported per Section 11.7.4.1
7. Development lengths satisfy Sections 25.4
8. Bearing surface types, embedded steel plate, or angle with studs
9. Seat depth is defined, but is not less than 4 in.
10. An L-bar is placed below bearing area with size and spacing matching vertical wall reinforcement
11. Cover for reinforcement satisfies Section 20.5.1
12. Remove “NOTES TO DESIGN PROFESSIONAL” before placing detail in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles*: 5, 16, 17, 23, 31, 33

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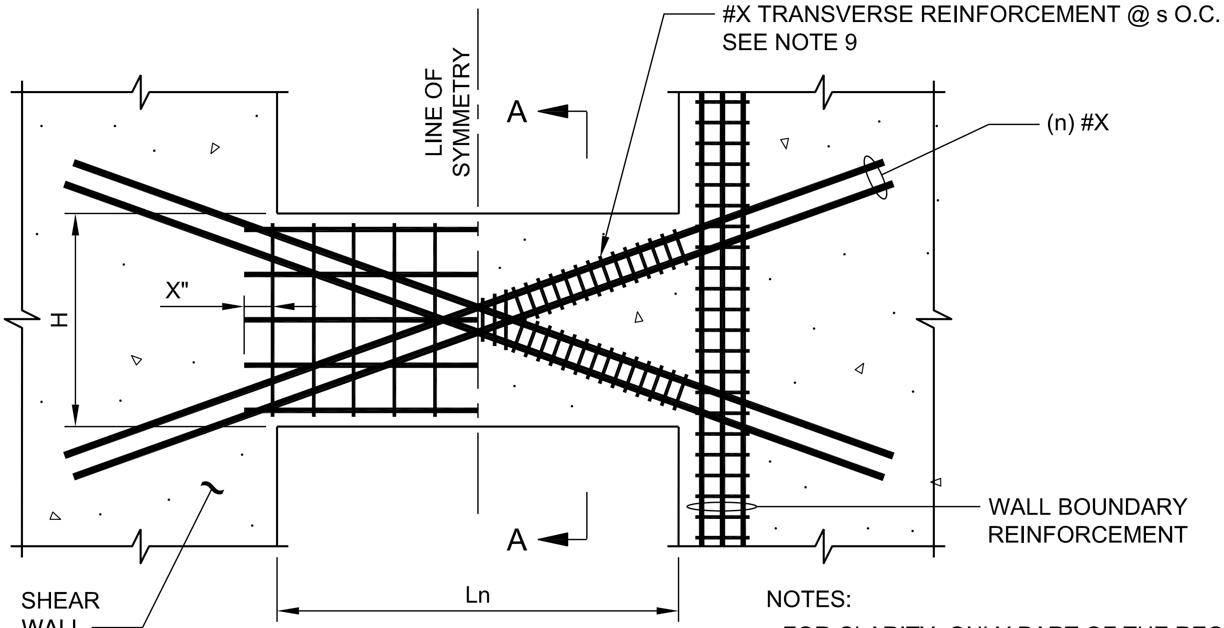
*Refer to Section 3 for articles

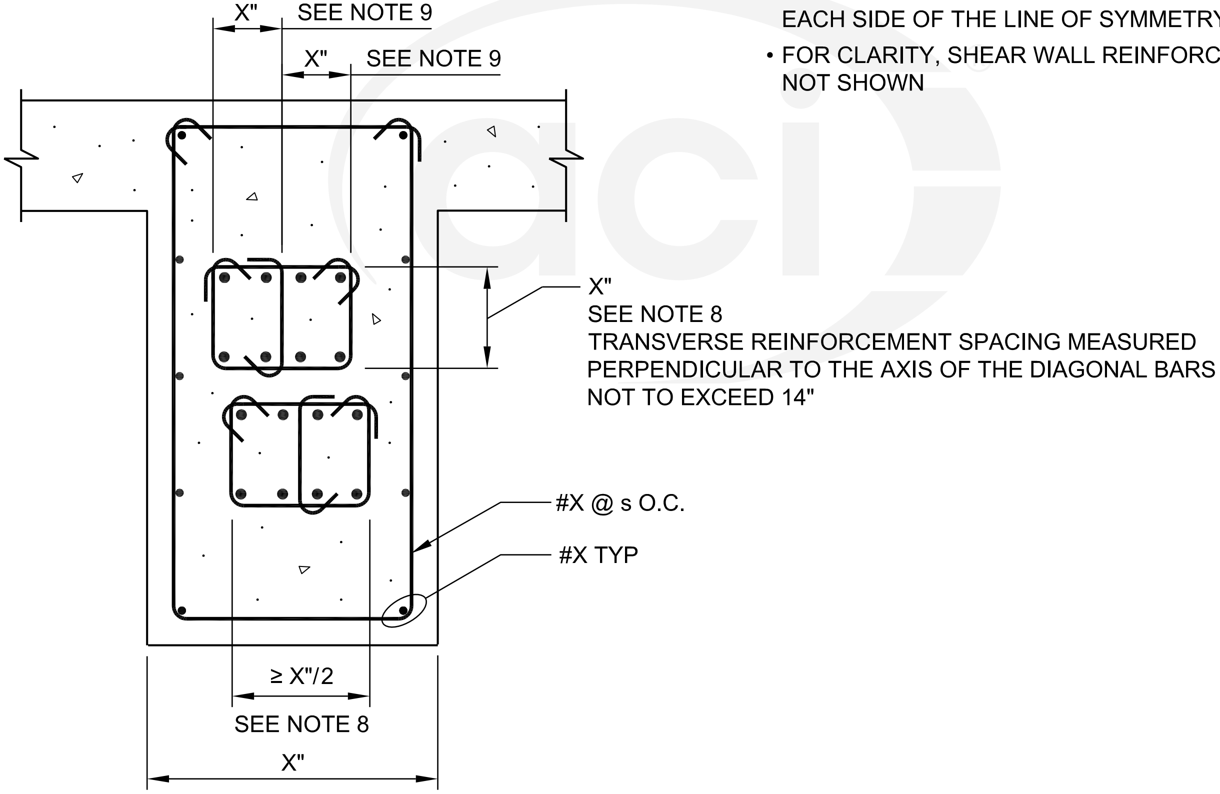
WALL-110



ELEVATION

NOTES:

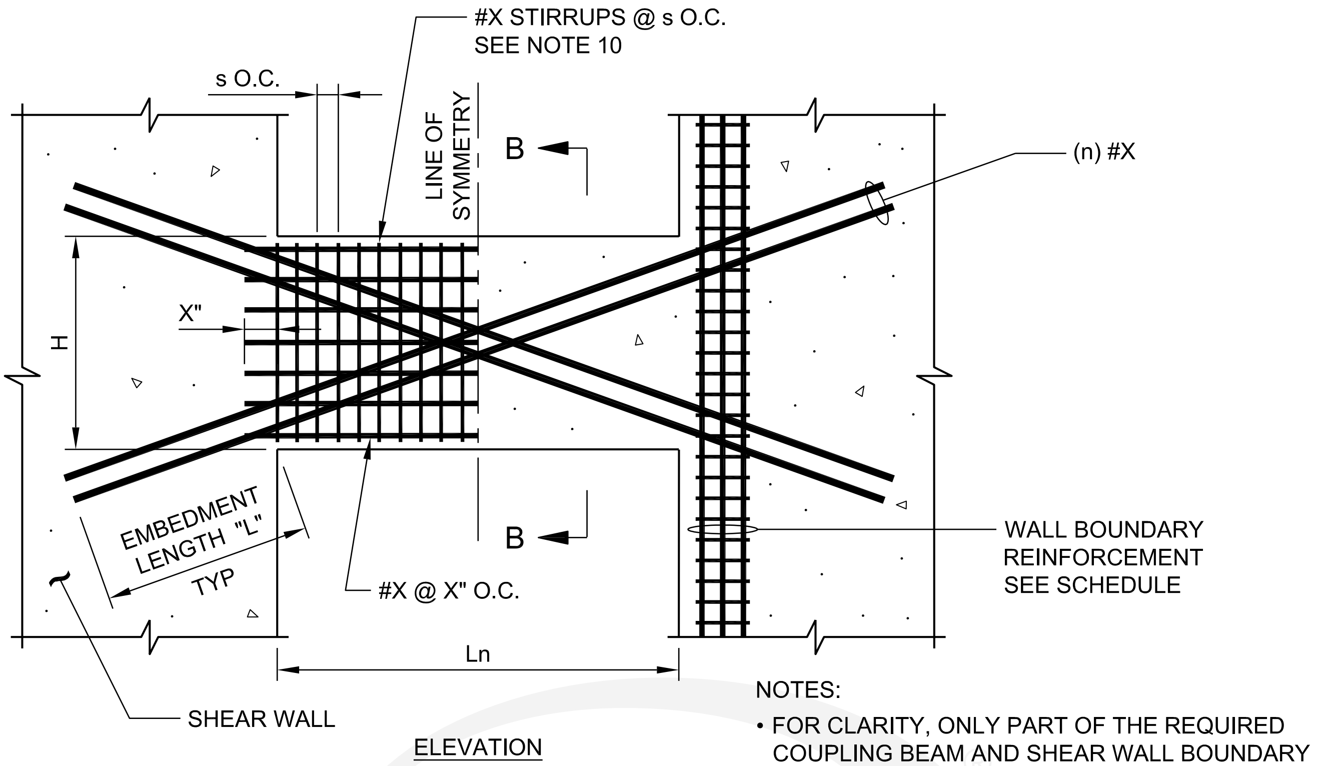
- FOR CLARITY, ONLY PART OF THE REQUIRED COUPLING BEAM AND SHEAR WALL BOUNDARY ELEMENT REINFORCEMENT IS SHOWN ON EACH SIDE OF THE LINE OF SYMMETRY
- FOR CLARITY, SHEAR WALL REINFORCEMENT NOT SHOWN



SECTION A-A

NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

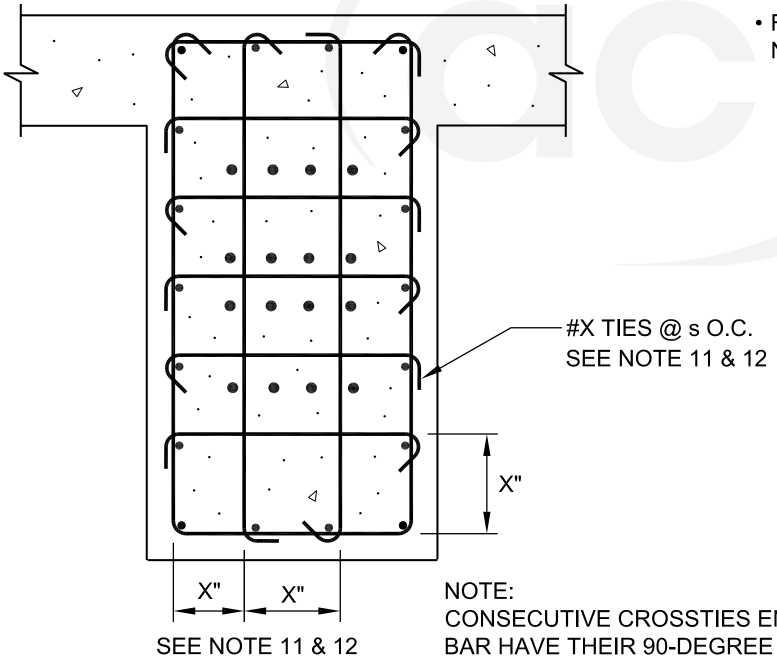
DIAGONALLY REINFORCED COUPLING BEAM - OPTION 1



ELEVATION

NOTES:

- FOR CLARITY, ONLY PART OF THE REQUIRED COUPLING BEAM AND SHEAR WALL BOUNDARY ELEMENT REINFORCEMENT IS SHOWN ON EACH SIDE OF THE LINE OF SYMMETRY
- FOR CLARITY, SHEAR WALL REINFORCEMENT NOT SHOWN



NOTE:
CONSECUTIVE CROSSTIES ENGAGING THE SAME LONGITUDINAL BAR HAVE THEIR 90-DEGREE HOOKS ON OPPOSITE SIDES OF BEAM

SECTION B-B

NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

DIAGONALLY REINFORCED COUPLING BEAM - OPTION 2

FIGURE WALL-110 AND WALL-111: DIAGONALLY REINFORCED COUPLING BEAM OPTIONS 1 AND 2

The design professional shall review the following checklist and incorporate project-specific requirements into the details

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INTENDED USE

Coupling beams used as part of the lateral-force-resisting system

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Coupling beam with $l_n/h \geq 4$, Section 18.10.7.1, satisfy the requirements of Section 18.6 with the exception of Sections 18.6.2.1(b) and (c) if it can be shown by analysis that the beam has adequate lateral support
2. Coupling beams with $l_n/h < 2$ and $V_n \geq$ must be reinforced with two intersecting groups of diagonally placed bars symmetrical about the midspan; Section 18.10.7.2
3. Maximum shear force does not exceed the limit in 18.10.7.4
4. Coupling beam reinforcement satisfies Section 18.10.7
5. Diagonal bars extend the development length into the wall or terminate in an end plate or headed bars where embedment length distance is not adequate; Section 25.4.2 and 25.4.4
6. Cover for reinforcement satisfies Section 20.5.1
7. Remove “NOTES TO DESIGN PROFESSIONAL” before placing detail in the Contract Documents

For Option 1:

8. Transverse reinforcement continues through the intersection of the diagonal bars. At the intersection, it is permitted to modify the arrangement of the transverse reinforcement provided the spacing and volume ratio requirements are satisfied per Section 18.10.7.4(c)
9. Each diagonal group is enclosed by rectilinear hoops having out-to-out dimensions of minimum $b_w/2$ along length of cross ties and $b_w/5$ and not exceeding 14 in. along the other side
10. Transverse reinforcement along parallel bars does not exceed $6d_b$ of smallest diagonal bar and spacing of crossties or hoop legs does not exceed 14 in.

For Option 2:

11. Longitudinal spacing of transverse reinforcement does not exceed the lesser of 6 in. or $6d_b$ of smallest diagonal bars
12. Spacing of crossties or legs of hoops both vertically and horizontally does not exceed 8 in.
13. Each crosstie each hoop leg engages a longitudinal bar

RECOMMENDED REFERENCES

Concrete International articles[*]: 9, 23, 35

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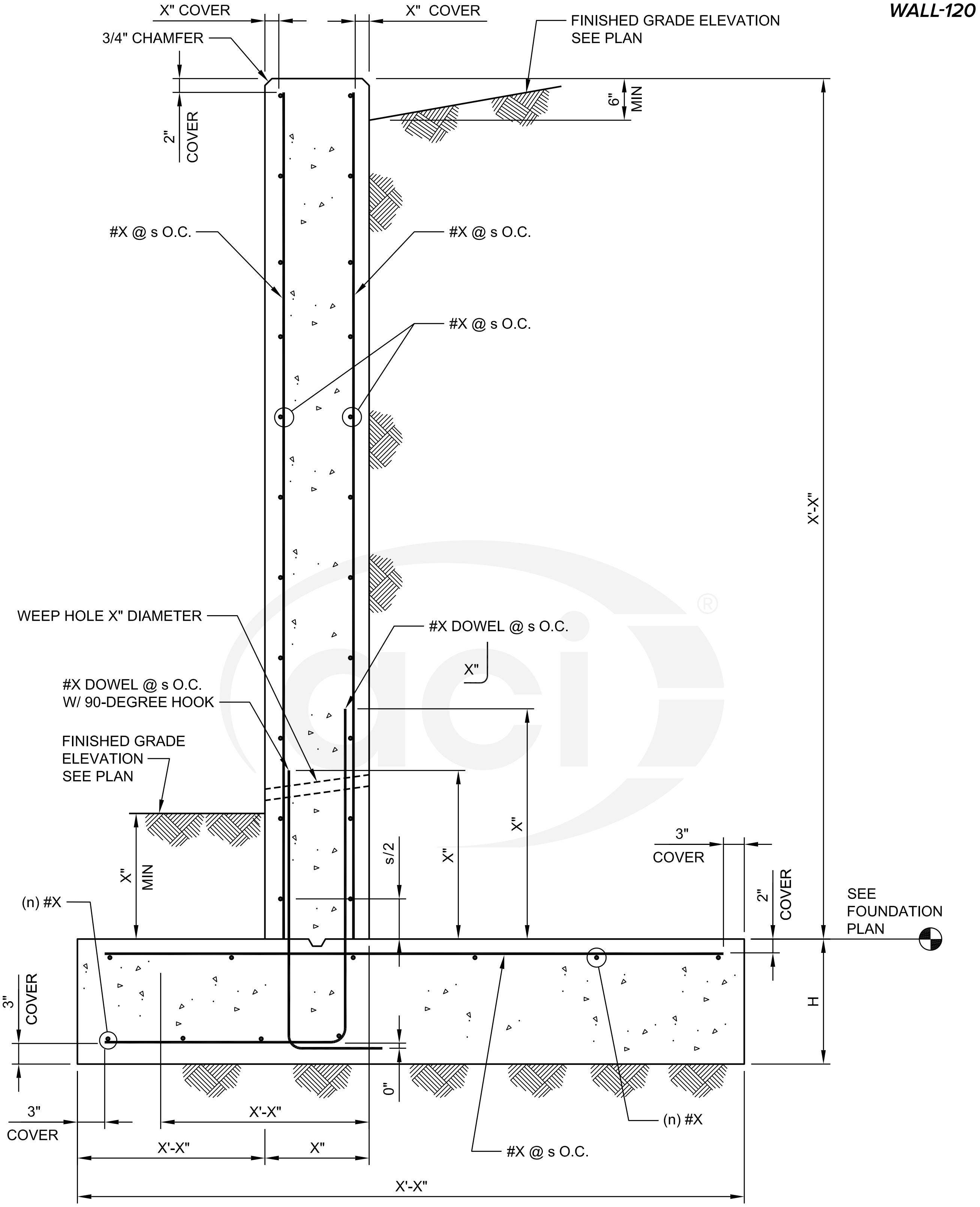
[*] Refer to Section 3 for articles

WALL-120



SECTION VIEW

NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

CANTILEVER RETAINING WALL

FIGURE WALL-120: CANTILEVER RETAINING WALL

The design professional shall review the following checklist and
incorporate project-specific requirements into the details

INTENDED USE

Cast-in-place reinforced concrete nonprestressed wall retaining earth on one side

Retained earth with horizontal or sloped fill

No positive top-of-wall support

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Stem is designed per Section 13.3.6
2. Dowel length from footing into wall for vertical bars on the tension side is the greater of the dowel development length, Section 25.4, and tension splice length, Section 25.5.2.1
3. Dowel length from the footing into wall for vertical bars on the compression side is the greater of the dowel development length, Section 25.4, and compression splice length, Section 25.5.5.1
4. Soil bearing pressure is within the limits specified in the geotechnical report
5. Reinforcement cover satisfies Section 20.5.1
6. For drainage use weep holes as shown in Figure WALL-120 or use a drainage system consisting of sloped drainpipe, crushed stones – no fines – and fabric to keep stone and soil separate as shown in Figure Wall-100B. Discuss with owner which drainage system to use
7. Remove "NOTES TO DESIGN PROFESSIONAL" before placing detail in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles[*]: 5, 16, 31

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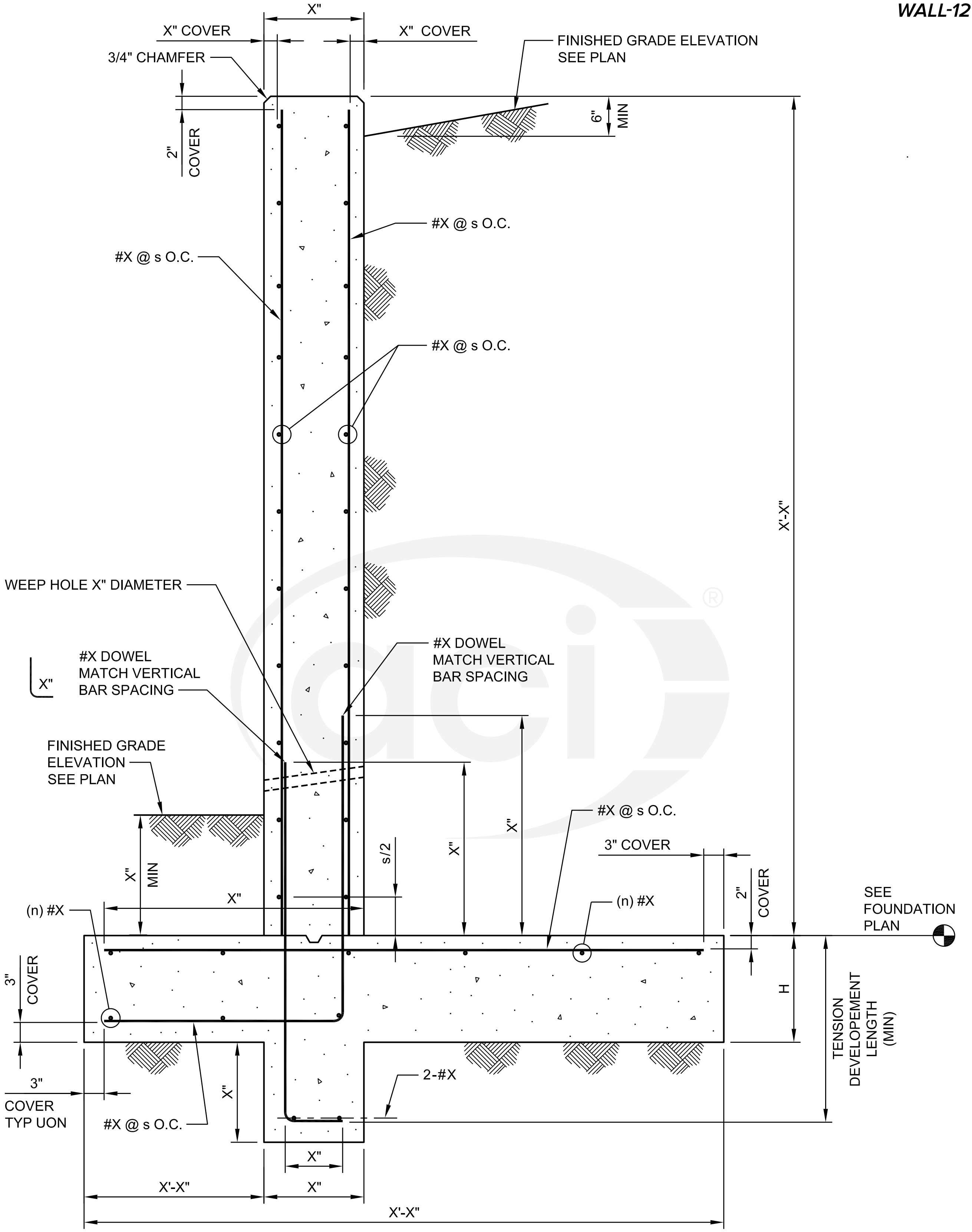
[*] Refer to Section 3 for articles

WALL-121



SECTION VIEW

NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE
INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

CANTILEVER RETAINING WALL WITH SHEAR KEY

FIGURE WALL-121: CANTILEVER RETAINING WALL WITH SHEAR KEY

The design professional shall review the following checklist and incorporate project-specific requirements into the details

---

INTENDED USE

Cast-in-place reinforced concrete nonprestressed wall retaining earth on one side

Retained earth with horizontal or sloped fill

No positive top-of-wall support

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Stem is designed per Section 13.3.6
2. Dowel length from footing into wall for vertical bars on the tension side is the greater of the dowel development length, Section 25.4, and tension splice length, Section 25.5.2.1
3. Dowel length from the footing into wall for vertical bars on the compression side is the greater of the dowel development length, Section 25.4, and compression splice length, Section 25.5.5.1
4. Soil bearing pressure is within the limits specified in the geotechnical report
5. Minimum two No. 5 horizontal bars are provided in the shear lug
6. Reinforcement cover satisfies Section 20.5.1
7. For drainage use weep holes as shown in Figure WALL-120 or use a drainage system consisting of sloped drainpipe, crushed stones – no fines – and fabric to keep stone and soil separate as shown in Figure Wall-100B. Discuss with owner which system to use
8. Remove “NOTES TO DESIGN PROFESSIONAL” before placing detail in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles[*]: 5, 16, 33

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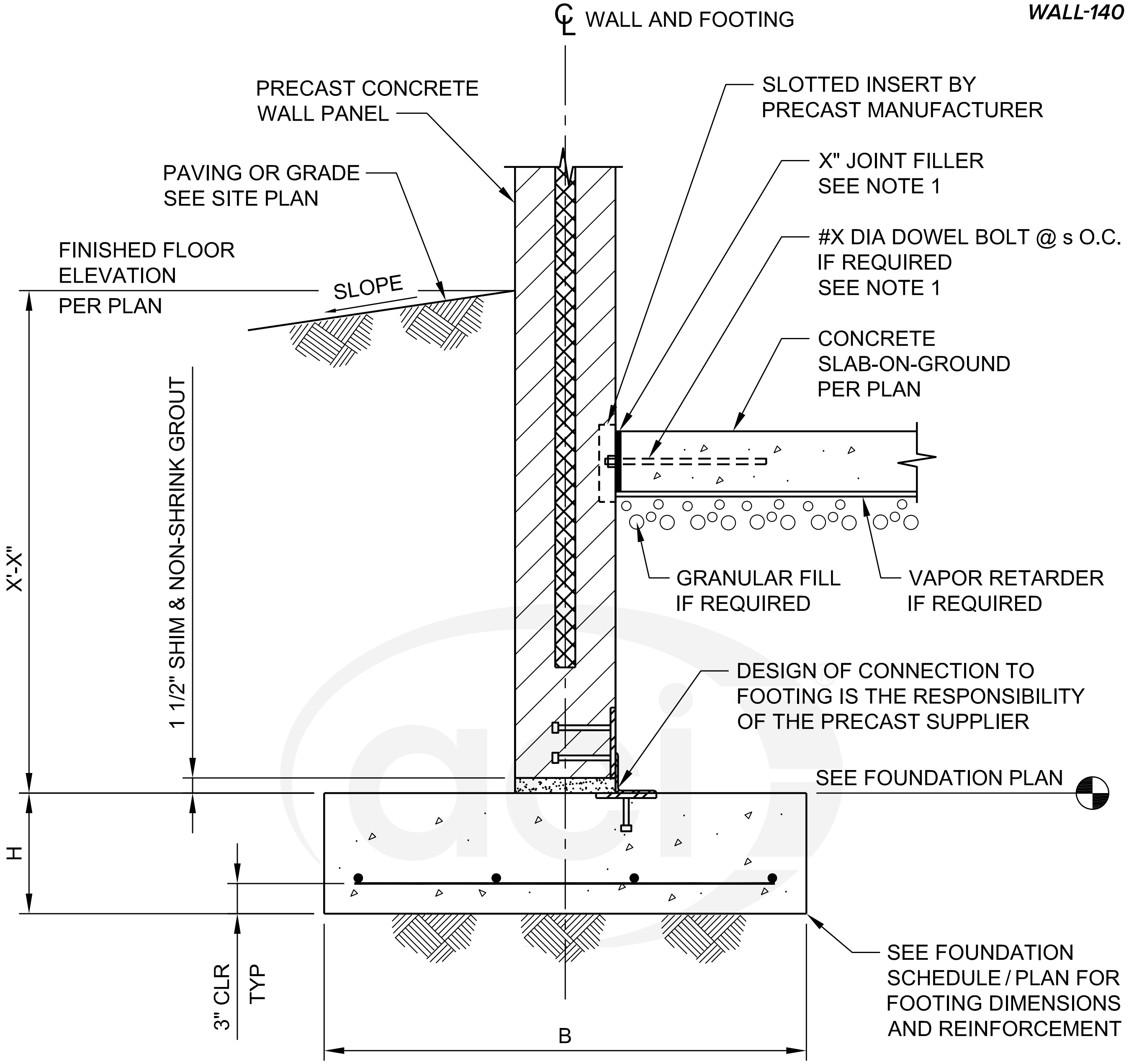
[*] Refer to Section 3 for articles

WALL-140



NOTES TO DESIGN PROFESSIONAL:

1. IF DOWEL BOLT IS USED THEN DELETE JOINT FILLER
2. COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

EXTERIOR PRECAST WALL AND FOOTING

FIGURE WALL-140: EXTERIOR PRECAST CONCRETE WALL AND FOOTING

The design professional shall review the following checklist and
incorporate project-specific requirements into the details

INTENDED USE

Exterior precast concrete wall panels to cast-in-place concrete footing with exterior grade above F/F elevation

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Precast concrete panels are centered on footing
2. Connection plate and angle are designed by precast contractor
3. Minimum 1-1/2 in. space between precast wall and foundation is filled with continuous nonshrink grout
4. Joint between precast wall and interior slab-on-ground is provided
5. Exterior finish grade is sloped away from precast wall
6. Show backfill depth on detail
7. Footing dimensions and reinforcement are called out on detail or refer to foundation plan or schedule
8. Cover for reinforcement satisfies Section 20.5.1
9. If slab-on-ground provides lateral support to the precast concrete panels, then provide dowels between precast concrete panels and slab-on-ground, delete the filler joint, and extend slab-on-ground to the precast concrete panel. Inserts are provided by the precast manufacturer
10. Design reinforcement in slab-on-ground to support the tensile force from the precast wall panels
11. Remove "NOTES TO DESIGN PROFESSIONAL" before placing detail in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles*: 23

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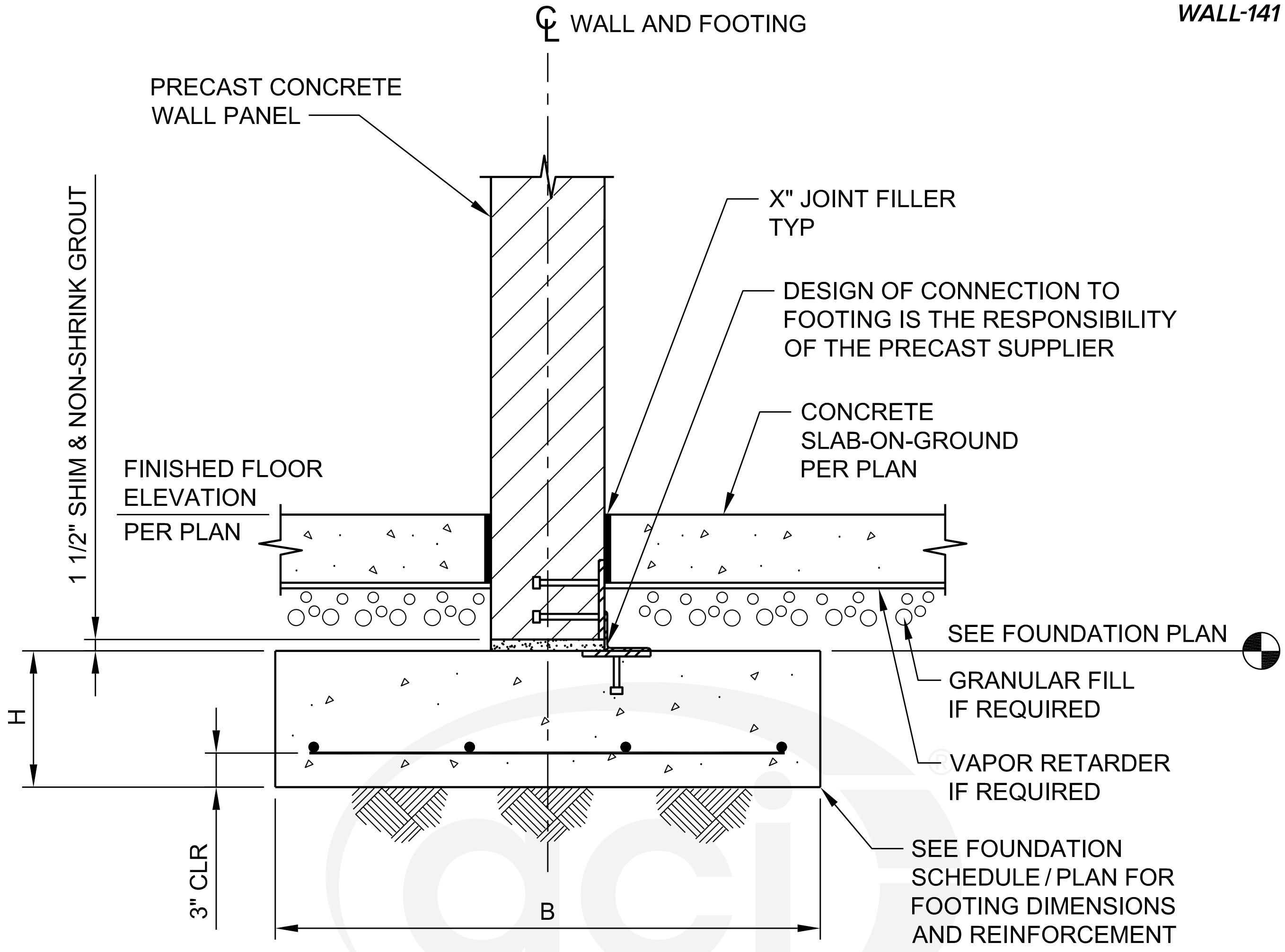
*Refer to Section 3 for articles

WALL-141



NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

INTERIOR PRECAST WALL AND FOOTING

FIGURE WALL-141: INTERIOR PRECAST WALL AND FOOTING

The design professional shall review the following checklist and
incorporate project-specific requirements into the details

INTENDED USE

Interior precast concrete wall panel to cast-in-place concrete footing connection

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Precast concrete panels are centered on footing
2. Connection plate and angle are designed by precast contractor
3. Minimum 1-1/2 in. space between precast wall and foundation is filled with nonshrink grout
4. Joint between precast wall and interior slab-on-ground is provided
5. Adequate spacing is provided between top of footing and bottom of slab-on-ground to place underground utilities per civil and mechanical drawings
6. Footing dimensions and reinforcement are called out on detail or refer to foundation plan or schedule
7. Cover for reinforcement satisfies Section 20.5.1
8. Remove “NOTES TO DESIGN PROFESSIONAL” before placing detail in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles[*]: 23

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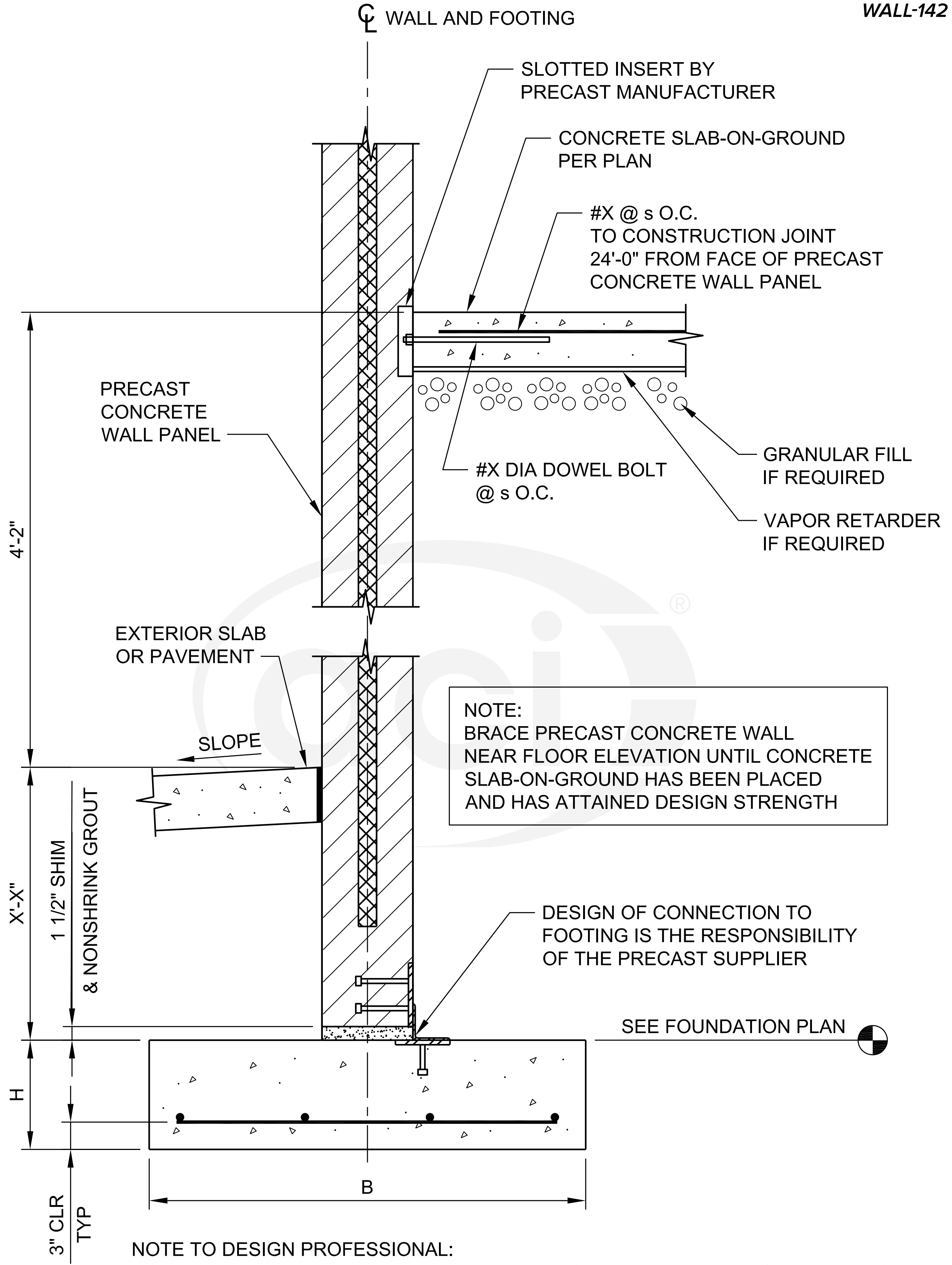
[*] Refer to Section 3 for articles

WALL-142



NOTE:
BRACE PRECAST CONCRETE WALL NEAR FLOOR ELEVATION UNTIL CONCRETE SLAB-ON-GROUND HAS BEEN PLACED AND HAS ATTAINED DESIGN STRENGTH

NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

PRECAST DOCK WALL AND FOOTING

FIGURE WALL-142: PRECAST DOCK WALL AND FOOTING

The design professional shall review the following checklist and
incorporate project-specific requirements into the details

INTENDED USE

Precast concrete dock wall panel to cast-in-place concrete footing connection

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Precast concrete panels are centered on footing
2. Connection plate and angle are designed by precast contractor
3. Minimum 1-1/2 in. space between precast wall and foundation is filled with nonshrink grout
4. Expansion joint between precast wall and interior slab-on-ground is provided
5. Adequate spacing is provided between top of footing and bottom of slab-on-ground to place underground utilities per civil and mechanical drawings
6. Footing dimensions and reinforcement are called out on detail or refer to foundation plan or schedule
7. Dowels are provided between precast wall and interior slab-on-ground as required but not more than 4 ft on center. Inserts are designed and provided by the precast manufacturer
8. Design reinforcement in slab-on-ground to support the tensile force from the precast wall panels
9. Height of truck dock is as required by owner; modify if required
10. Exterior slab-on-ground is sloped away from precast wall
11. Footing dimensions and reinforcement are called on detail or refer to foundation plan or schedule
12. Remove "NOTES TO DESIGN PROFESSIONAL" before placing detail in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles[*]: 23

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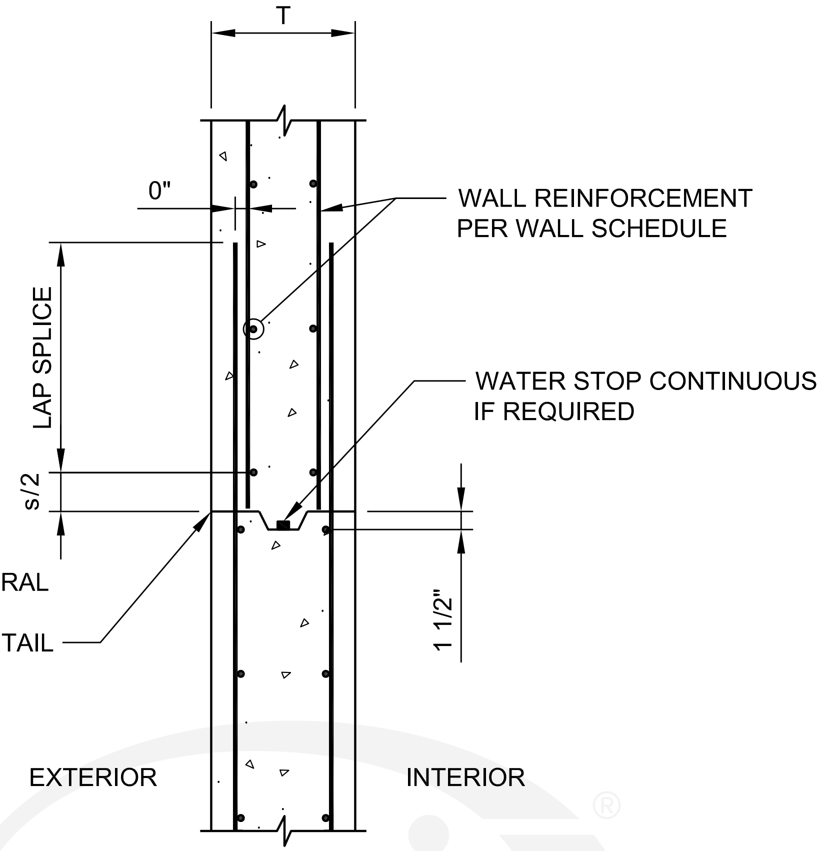
[*] Refer to Section 3 for articles

WALL-200



NOTES:

1. USE FOR VERTICAL AND HORIZONTAL CONSTRUCTION JOINTS IN STRUCTURAL AND ARCHITECTURAL CONCRETE WALL
2. SEE ARCHITECTURAL ELEVATIONS FOR REVEAL JOINT LAYOUT. LOCATE CONSTRUCTION JOINT AT REVEAL JOINTS WHEREVER POSSIBLE
3. SUBMIT PROPOSED WALL CONSTRUCTION JOINT LAYOUT FOR APPROVAL PRIOR TO FORMWORK ERECTION
4. LOCATION AND POSITION OF VERTICAL AND HORIZONTAL BARS MAY VARY, ENGINEER SHOULD MODIFY DETAIL AS REQUIRED FOR DESIGN

NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

WALL CONSTRUCTION JOINTS

FIGURE WALL-200: WALL CONSTRUCTION JOINT

The design professional shall review the following checklist and
incorporate project-specific requirements into the details

INTENDED USE

Vertical or horizontal contraction joint in an exterior retaining wall

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Concrete for exterior walls may need to be air-entrained. Engineer should determine proper mixture proportioning for project requirements
2. Construction joints are located at maximum spacing of 100 ft—modify as needed. Construction joints are either specifically shown in plan or elevation or noted for maximum spacing
3. Bars from the first placement are extended a minimum length equal to tension splice length satisfying Section 25.5
4. Add dumbbell type waterstop where specifically required
5. For retaining walls where water table is high, wall must be designed for additional lateral pressure
6. Reinforcement cover satisfies Section 20.5.1.3
7. Horizontal and vertical bars are shown correctly in each face for the vertical or horizontal joint detail
8. Remove "NOTES TO DESIGN PROFESSIONAL" before placing detail in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles*: 5, 6, 16, 31

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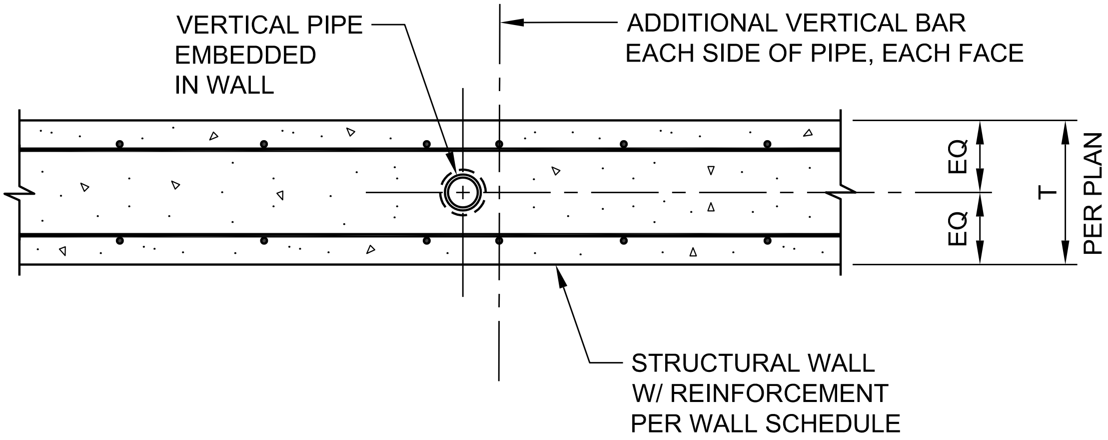
*Refer to Section 3 for articles

WALL-201



PLAN VIEW

NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

VERTICAL PIPE EMBEDDED IN STRUCTURAL WALL

FIGURE WALL-201: VERTICAL PIPE EMBEDDED IN STRUCTURAL WALL

The design professional shall review the following checklist and incorporate project-specific requirements into the details

INTENDED USE

Steel pipe embedded in concrete wall

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Material of pipe is:
    a. Not harmful to concrete and can be embedded without protection
    b. Aluminum or other reactive material, pipes must be effectively coated; that is, Styrofoam wrap, to prevent electrolytic reaction between aluminum and concrete
2. Pipe passing through wall does not impair significantly the strength of the wall
3. Pipe outside dimension do not exceed one-third the overall wall thickness
4. Pipe will fit within concrete wall allowing for bar placement and specified cover
5. If multiple pipes are embedded in a concrete wall, ensure that they are spaced not less than three times the larger pipe diameter
6. Concrete cover for pipes, conduit and fittings is not to be less than 1-1/2 in. for concrete exposed to earth or weather, or less than 3/4 in. for concrete not exposed to weather or in contact with earth
7. Place two additional vertical bars on either side of embedded pipe, each face
8. Reinforcement with area of 0.002 times the area of the concrete section to be provided perpendicular to the pipe; Section 20.7.4
9. Remove “NOTES TO DESIGN PROFESSIONAL” before placing detail in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles*: 16, 31

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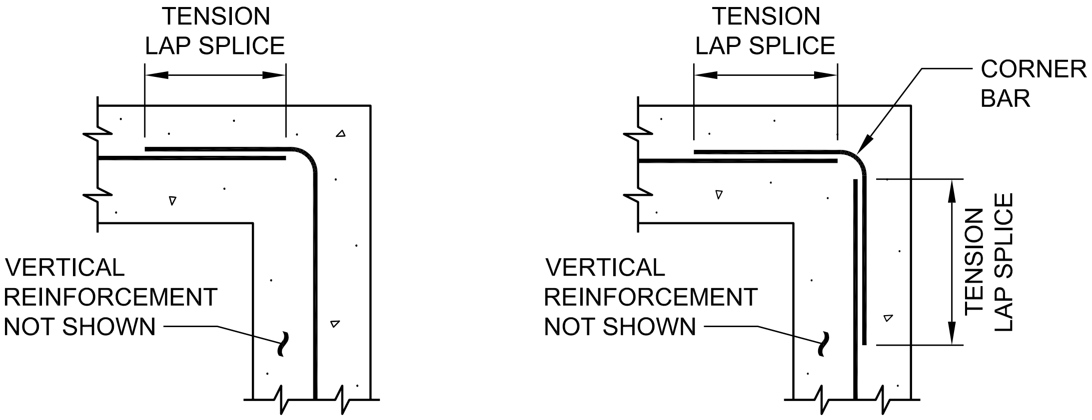
*Refer to Section 3 for articles

WALL-202



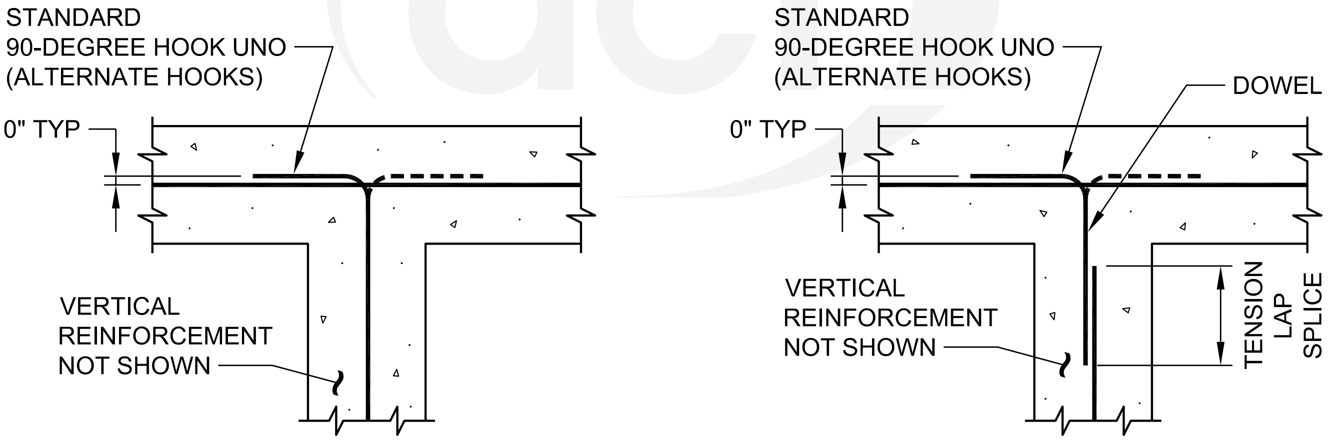
PLAN
OPTION #1

PLAN
OPTION #2

NOTE:
UNLESS OTHERWISE INDICATED, THE CONTRACTOR HAS THE OPTION OF REINFORCING CORNERS IN ACCORDANCE WITH OPTION #1 OR OPTION #2

NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAILS AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

SINGLE LAYER HORIZONTAL WALL REINFORCEMENT AT CORNERS



PLAN
OPTION #1

PLAN
OPTION #2

NOTE:
UNLESS OTHERWISE INDICATED, THE CONTRACTOR HAS THE OPTION OF REINFORCING CORNERS IN ACCORDANCE WITH OPTION #1 OR OPTION #2

NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAILS AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

SINGLE LAYER HORIZONTAL WALL REINFORCEMENT AT INTERSECTIONS

FIGURE WALL-202: SINGLE LAYER HORIZONTAL WALL REINFORCEMENT AT CORNERS AND WALL INTERSECTIONS

The design professional shall review the following checklist and incorporate project-specific requirements into the details

---

INTENDED USE

Horizontal corner wall-to-wall reinforcement detail with one curtain of bars

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Walls with one layer of reinforcement
2. Splice length is a tension lap splice that satisfies Section 25.5
3. L-corner bar/hooked bar/dowel to match the larger horizontal bar size in each of the framing walls
4. L-corner bar/dowel are placed in the same plane as wall reinforcement
5. If moment is transferred at the joint this detail may not be adequate and the joint must be designed
6. Remove "NOTES TO DESIGN PROFESSIONAL" before placing detail in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles[*]: 17, 18, 33

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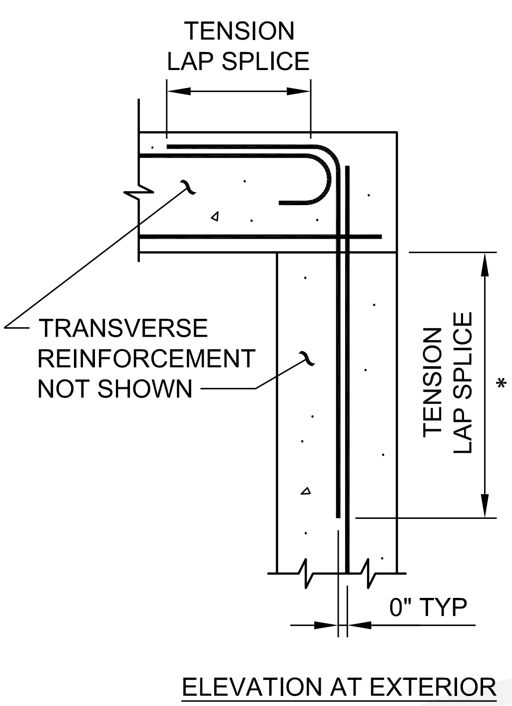
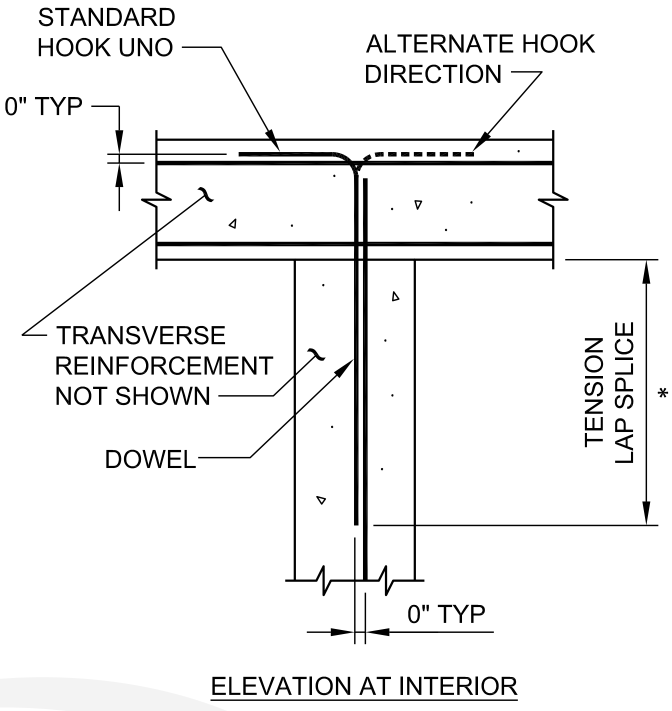
[*] Refer to Section 3 for articles

WALL-203



ELEVATION AT EXTERIOR



ELEVATION AT INTERIOR

NOTE:
* INDICATES CONTRACTOR OPTION: WITH OR WITHOUT LAP SPLICE AT THESE LOCATIONS

NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

CONCRETE SLAB AT TOP LEVEL ON WALL WITH SINGLE LAYER OF REINFORCEMENT

FIGURE WALL-203: CONCRETE SLAB AT TOP LEVEL ON WALL WITH SINGLE LAYER OF REINFORCEMENT

The design professional shall review the following checklist and incorporate project-specific requirements into the details

INTENDED USE

Cast-in-place reinforced concrete nonprestressed walls

Concrete wall connection to elevated top level concrete slab

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Walls with one layer of reinforcement
2. Corner L-bar size to match the larger of slab and wall bar sizes
3. Splice length satisfies Section 25.5
4. Place corner bar/dowel in the same plane as wall and floor slab/roof reinforcement
5. If moment is transferred at the joint, this detail may not be adequate and the joint must be designed
6. Remove "NOTES TO DESIGN PROFESSIONAL" before placing detail in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles[*]: 17, 18, 33

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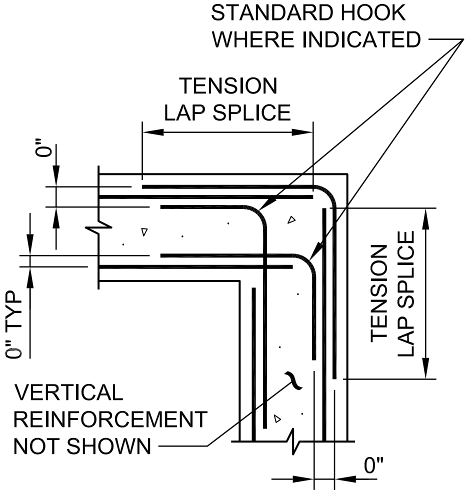
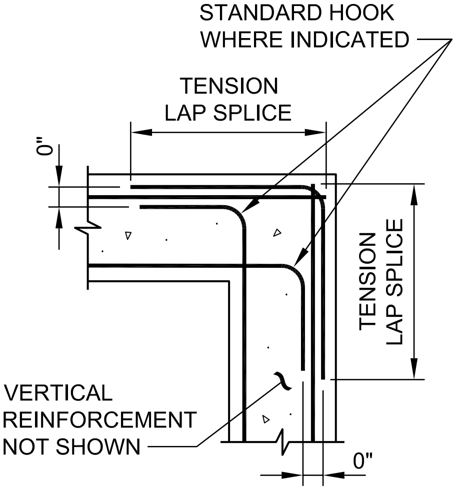
[*] Refer to Section 3 for articles

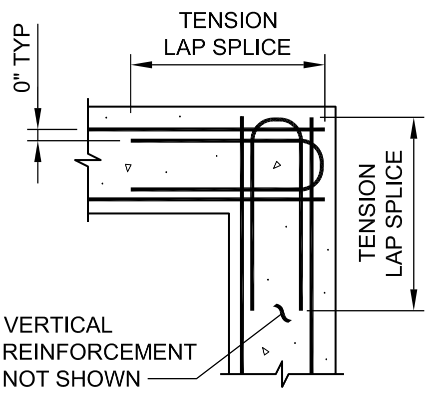
WALL-204



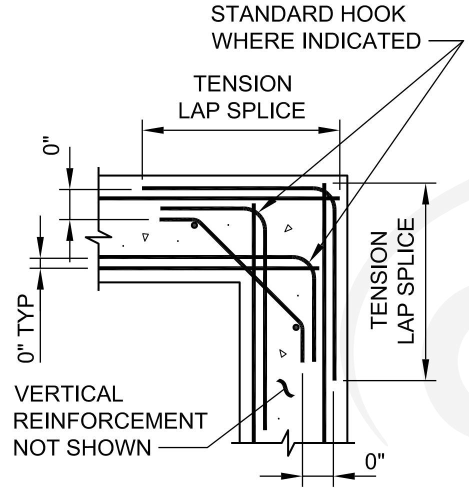
PLAN
OPTION #1



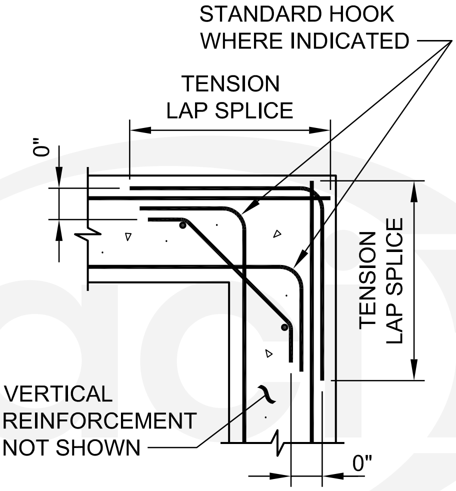
PLAN
OPTION #2



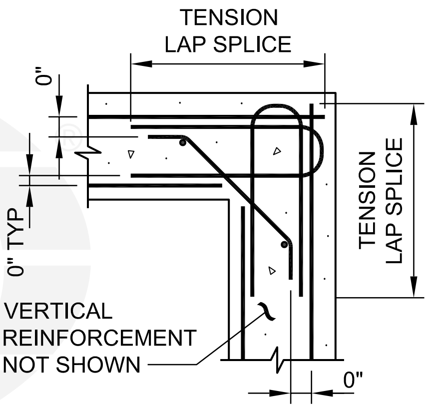
PLAN
OPTION #3



PLAN
OPTION #4



PLAN
OPTION #5



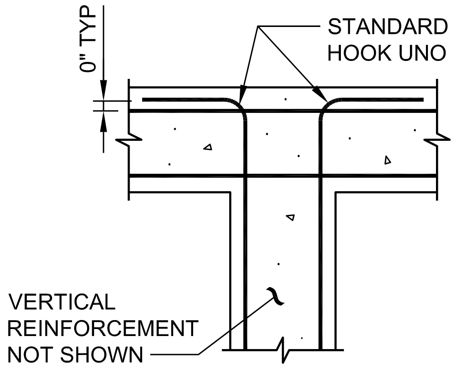
PLAN
OPTION #6

NOTE:
UNLESS OTHERWISE INDICATED, THE CONTRACTOR HAS THE OPTION OF REINFORCING CORNERS IN ACCORDANCE WITH H OPTION #1, OPTION #2, OPTION #3, OPTION #4, OPTION #5, OR OPTION #6

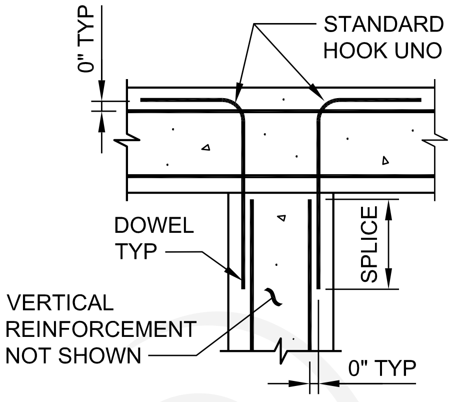
NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

DOUBLE LAYER HORIZONTAL WALL REINFORCEMENT AT CORNERS

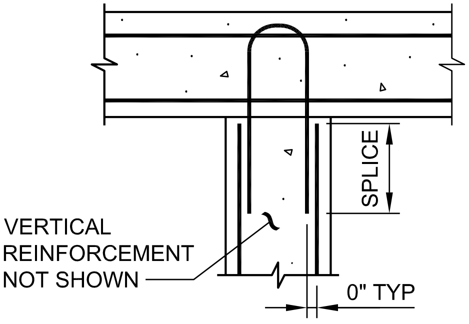
WALL-205



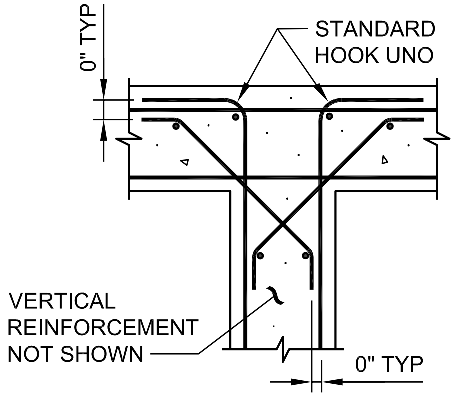
PLAN
WITHOUT CONSTRUCTION JOINT



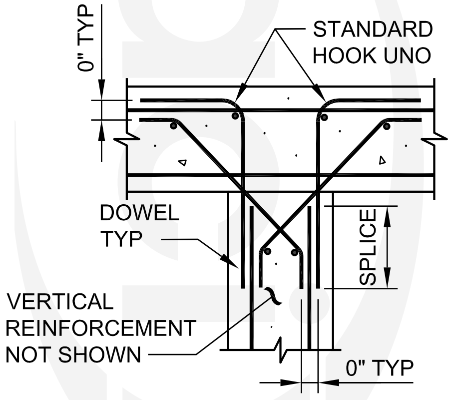
PLAN
WITH CONSTRUCTION JOINT



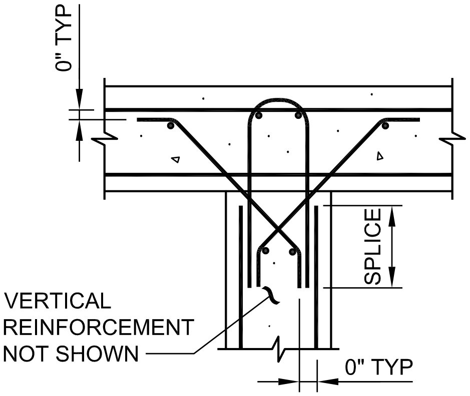
PLAN
WITH CONSTRUCTION JOINT



PLAN
WITHOUT CONSTRUCTION JOINT



PLAN
WITH CONSTRUCTION JOINT



PLAN
WITH CONSTRUCTION JOINT

NOTE:
UNLESS OTHERWISE INDICATED, THE CONTRACTOR HAS THE OPTION OF CONSTRUCTING INTERSECTIONS WITH OR WITHOUT CONSTRUCTION JOINTS. REINFORCE PER APPLICABLE DETAIL.

NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

DOUBLE LAYER HORIZONTAL WALL REINFORCEMENT AT INTERSECTIONS

FIGURE WALL-204 AND WAL-205: DOUBLE LAYER HORIZONTAL WALL TO WALL CORNER TYPICAL DETAILS

The design professional shall review the following checklist and
incorporate project-specific requirements into the details

INTENDED USE

Horizontal corner wall reinforcement detail of two curtain/layer of reinforcement

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Wall thicknesses are 10 in. or greater
2. L- and U bar sizes to match main horizontal wall bar size
3. Splice length measured from the inside face of walls and satisfies Section 25.5
4. L-corner bar/dowel are placed in the same plane as wall reinforcement
5. For liquid or granular retention (control corner opening), add diagonal bars per Set 2
6. If moment transfer at the joint is required, joint must be designed and diagonal bars can be used as shown
7. Remove "NOTES TO DESIGN PROFESSIONAL" before placing detail in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles[*]: 16, 17, 18, 31, 33

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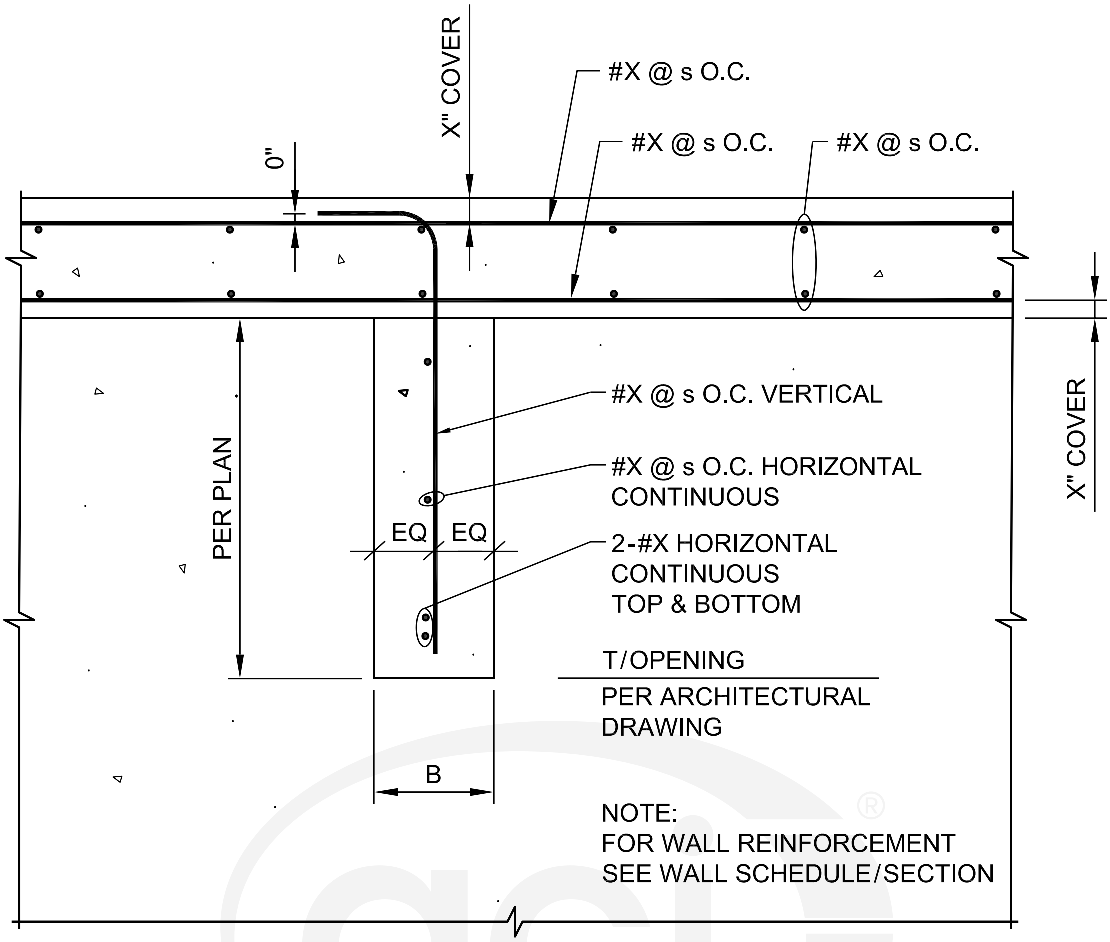
[*] Refer to Section 3 for articles

WALL-206



NOTE:
FOR WALL REINFORCEMENT
SEE WALL SCHEDULE/SECTION

NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

TYPICAL DOOR OR WINDOW OPENING IN WALL WITH SINGLE LAYER OF REINFORCEMENT

FIGURE WALL-206: DOOR OR WINDOW OPENING IN WALL WITH SINGLE LAYER OF REINFORCEMENT

The design professional shall review the following checklist and
incorporate project-specific requirements into the details

INTENDED USE

Wall with one layer of reinforcement above opening

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Wall with one layer of reinforcement
2. Opening elevation is coordinated with architectural drawings
3. Minimum No. 5 vertical and horizontal bars are provided in the wall section above opening
4. Minimum two No. 5 horizontal bars are placed above opening
5. Minimum No. 5 horizontal bars are provided below slab joint
6. Provide standard hook of vertical bars into top of slab
7. Minimum cover to bars is provided; Section 20.5.1
8. For reinforcement around openings refer to Section 11.7.5
9. Remove "NOTES TO DESIGN PROFESSIONAL" before placing detail in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles[*]: 23, 24

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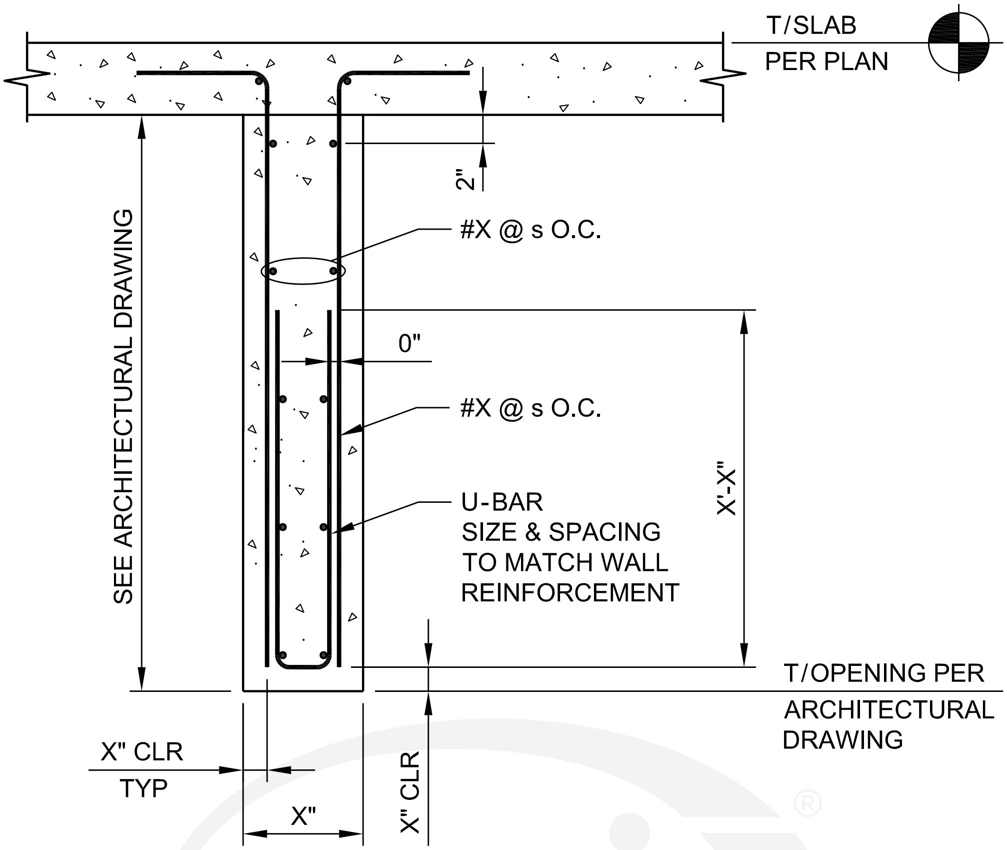
[*] Refer to Section 3 for articles

WALL-207



NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

DOOR OR WINDOW OPENING IN WALL WITH TWO LAYERS OF REINFORCEMENT

FIGURE WALL-207: DOOR/WINDOW OPENING IN WALL WITH TWO-LAYERS OF REINFORCEMENT

The design professional shall review the following checklist and incorporate project-specific requirements into the details

INTENDED USE

Wall with two layers of reinforcement above opening

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Opening elevation is coordinated with architectural drawings
2. Vertical reinforcement to match wall reinforcement on both sides of opening
3. U-shaped hairpin is provided above opening bar size to match vertical reinforcement
4. Horizontal reinforcement minimum No. 5 bars or as required by analysis are provided in the wall section above opening
5. Minimum two No. 5 horizontal bars are provided below slab joint
6. Provide standard hook of vertical bars into top of slab
7. Minimum cover to bars is provided; Section 20.5.1
8. Remove “NOTES TO DESIGN PROFESSIONAL” before placing detail in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles*: 23, 24

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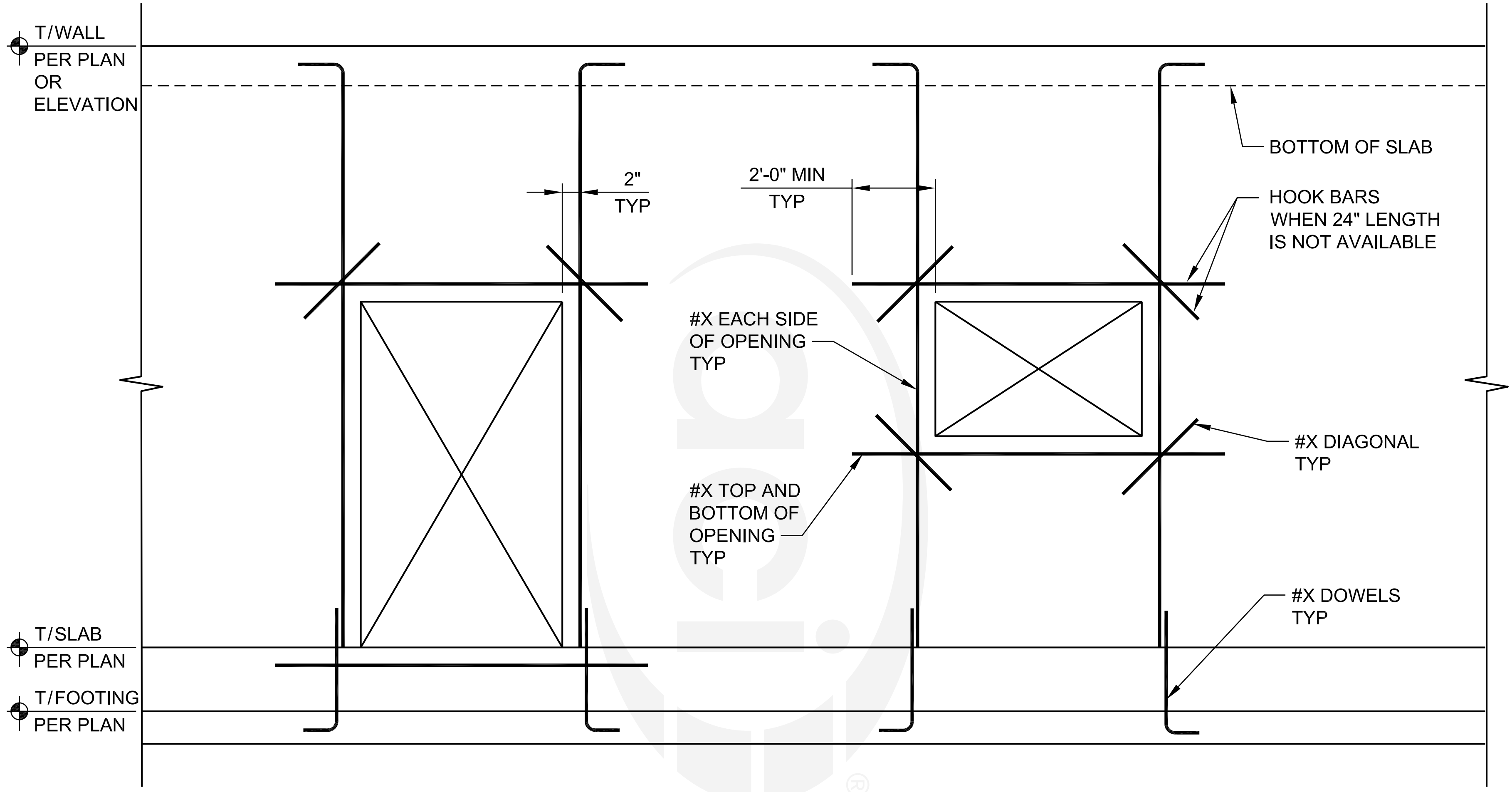
*Refer to Section 3 for articles

WALL-208



NOTES:

1. PROVIDE (1) #X x 48" DIAGONAL BAR IF THERE IS ONE LAYER OF REINFORCEMENT
2. PROVIDE (2) #X x 48" DIAGONAL BARS IF THERE ARE TWO LAYERS OF REINFORCEMENT
3. WALL REINFORCEMENT NOT SHOWN FOR CLARITY

NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

ELEVATION - CONCRETE WALL OPENING REINFORCEMENT

FIGURE WALL-208: CONCRETE WALL REINFORCEMENT AT OPENINGS

The design professional shall review the following checklist and
incorporate project-specific requirements into the details

INTENDED USE

Special reinforcement at doors and windows in concrete walls

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Vertical bars are placed on each side of opening equal to one-half of the interrupted wall bars due to the opening
2. Vertical bars are extended over full height of wall, floor/roof, but less than the required tension splice length
3. Horizontal bars are placed on each side of opening equal to one-half of the interrupted wall reinforcement due to the opening
4. Horizontal bars are extended a minimum of 2 ft 6 in. beyond opening but not less than the splice length of the bar
5. No. 5 bars 4 ft long at 45 degrees are added and centered with respect to opening corner
6. If a 2 ft length is not available for the added bars, then bars should be hooked
7. If wall has two layers/curtains of reinforcement, anchor transverse and longitudinal bars at edges of openings with U bars
8. At foundation provide dowels properly developed into wall and foundation per Sections 25.4 and 25.5
9. For reinforcement around openings refer to Section 11.7.5
10. Remove “NOTES TO DESIGN PROFESSIONAL” before placing detail in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles[*]: 5, 16, 24, 31, 33

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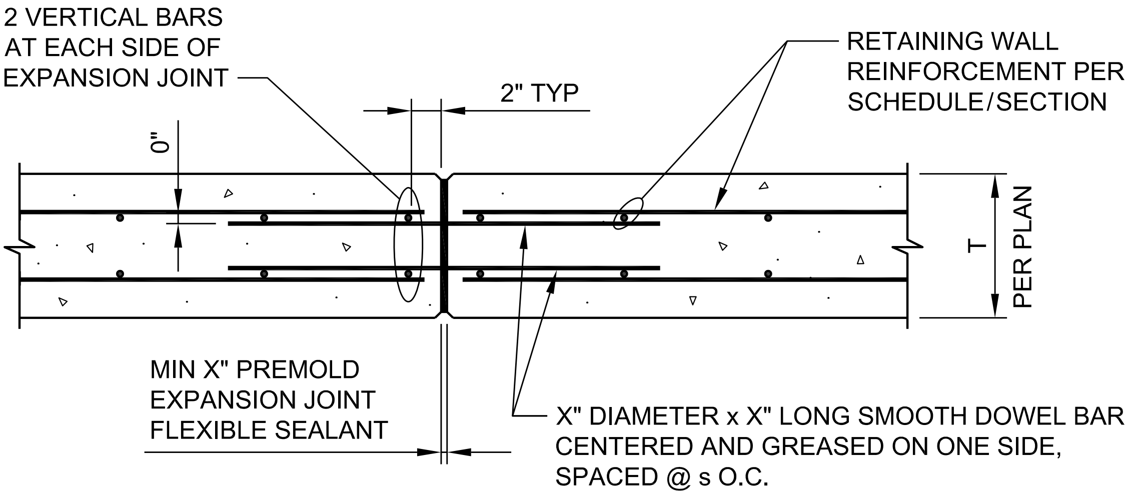
[*] Refer to Section 3 for articles

WALL-220



GENERAL NOTES:

1. ALL EXPOSED EDGES SHALL HAVE A 3/4" CHAMFER
2. ALL DISTANCE TO REINFORCING BARS REFER TO CLEAR CONCRETE COVER OF BAR UNLESS NOTED OTHERWISE
3. MINIMUM GRADE OF REINFORCING STEEL IS TO BE ASTM A615/A706 GRADE 60
4. MAXIMUM SPACING OF EXPANSION JOINTS SHALL BE X'-X" CENTER TO CENTER

NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

RETAINING WALL EXPANSION / SHRINKAGE JOINT

FIGURE WALL-220: RETAINING WALL EXPANSION/SHRINKAGE JOINT

The design professional shall review the following checklist and
incorporate project-specific requirements into the details

INTENDED USE

Vertical expansion joint to accommodate for expansion and shrinkage in an exterior retaining wall

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Concrete for all exterior walls should be air entrained
2. Expansion joints are located at maximum spacing of 75 to 90 ft—modify as needed. Expansion joints are either specifically shown in plan or elevation or noted for maximum spacing.
3. Called-out dowels are smooth and greased at one end only and are capable of transferring shear force
4. All exposed concrete edges to receive 3/4 in. chamfer
5. Expansive flexible material is provided at the expansion joint
6. Reinforcement cover satisfies Section 20.5.1
7. Remove “NOTES TO DESIGN PROFESSIONAL” before placing detail in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles*: 5, 16, 31

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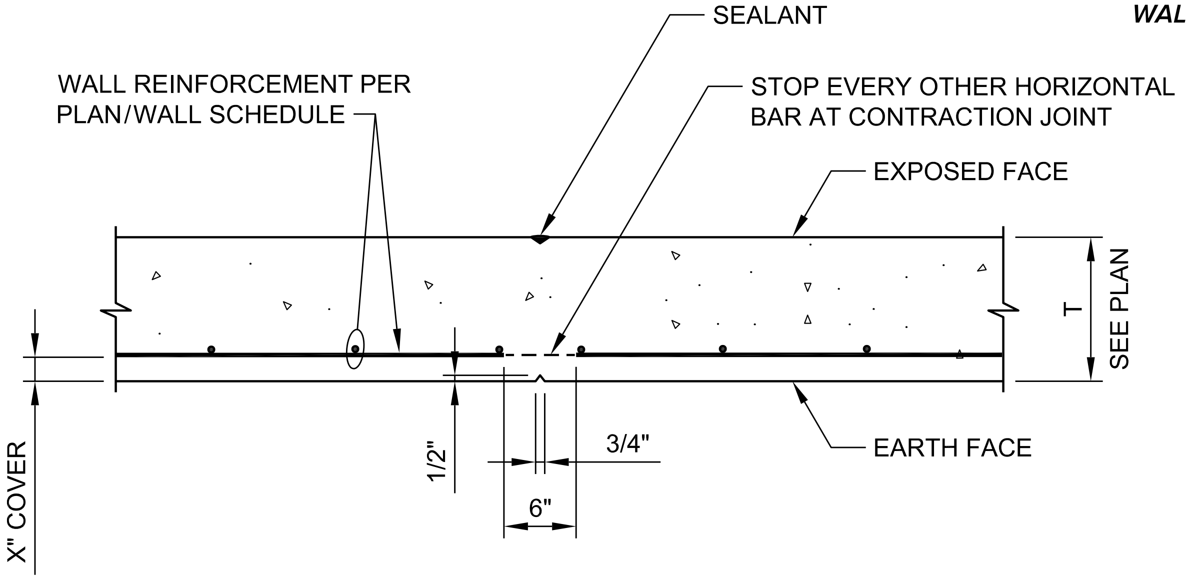
*Refer to Section 3 for articles

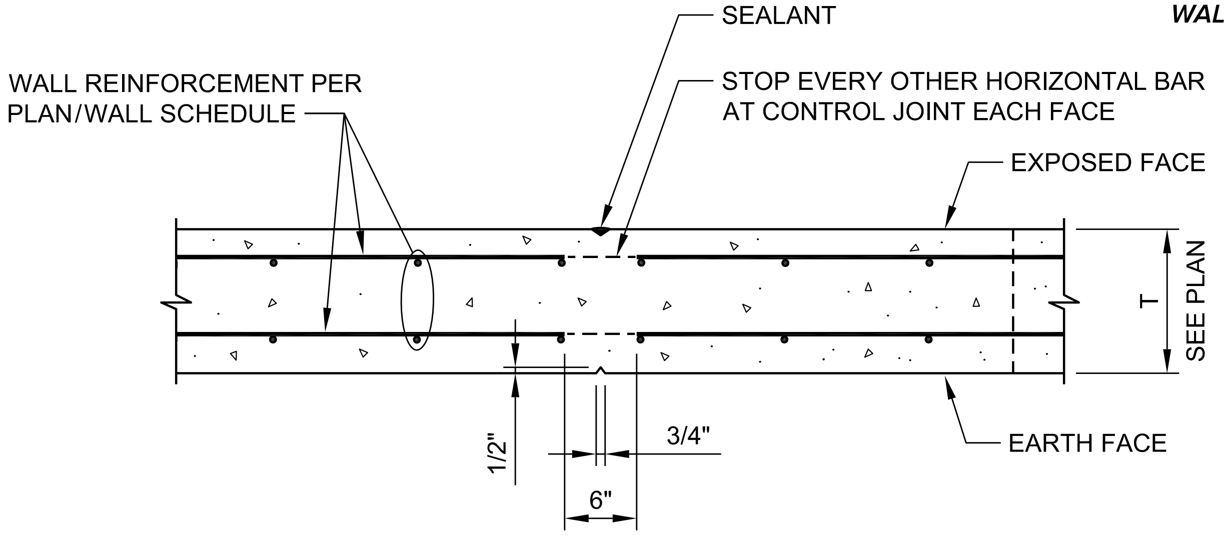
WALL-221



NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

RETAINING WALL CONTRACTION JOINT (SINGLE LAYER REINFORCEMENT)

WALL-222



NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

RETAINING WALL CONTRACTION JOINT (2 LAYER REINFORCEMENT)

FIGURE WALL-221 AND WALL-222: RETAINING WALL CONTRACTION JOINT – SINGLE AND TWO LAYERS

The design professional shall review the following checklist and
incorporate project-specific requirements into the details

INTENDED USE

Vertical contraction joint in an exterior retaining wall

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Concrete for all exterior walls should be air entrained
2. Contraction joints are located at maximum spacing of 20 ft—modify as needed. Contraction joints are either specifically shown in plan or elevation or noted for maximum spacing
3. Discontinue every other horizontal bar at contraction joints
4. A 1/2 in. or 3/4 in. notch is provided on both faces of wall at contraction. Fill the notch on the exterior face with sealant
5. Reinforcement cover satisfies Section 20.5.1
6. Remove "NOTES TO DESIGN PROFESSIONAL" before placing detail in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles*: 16, 31

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*Refer to Section 3 for articles

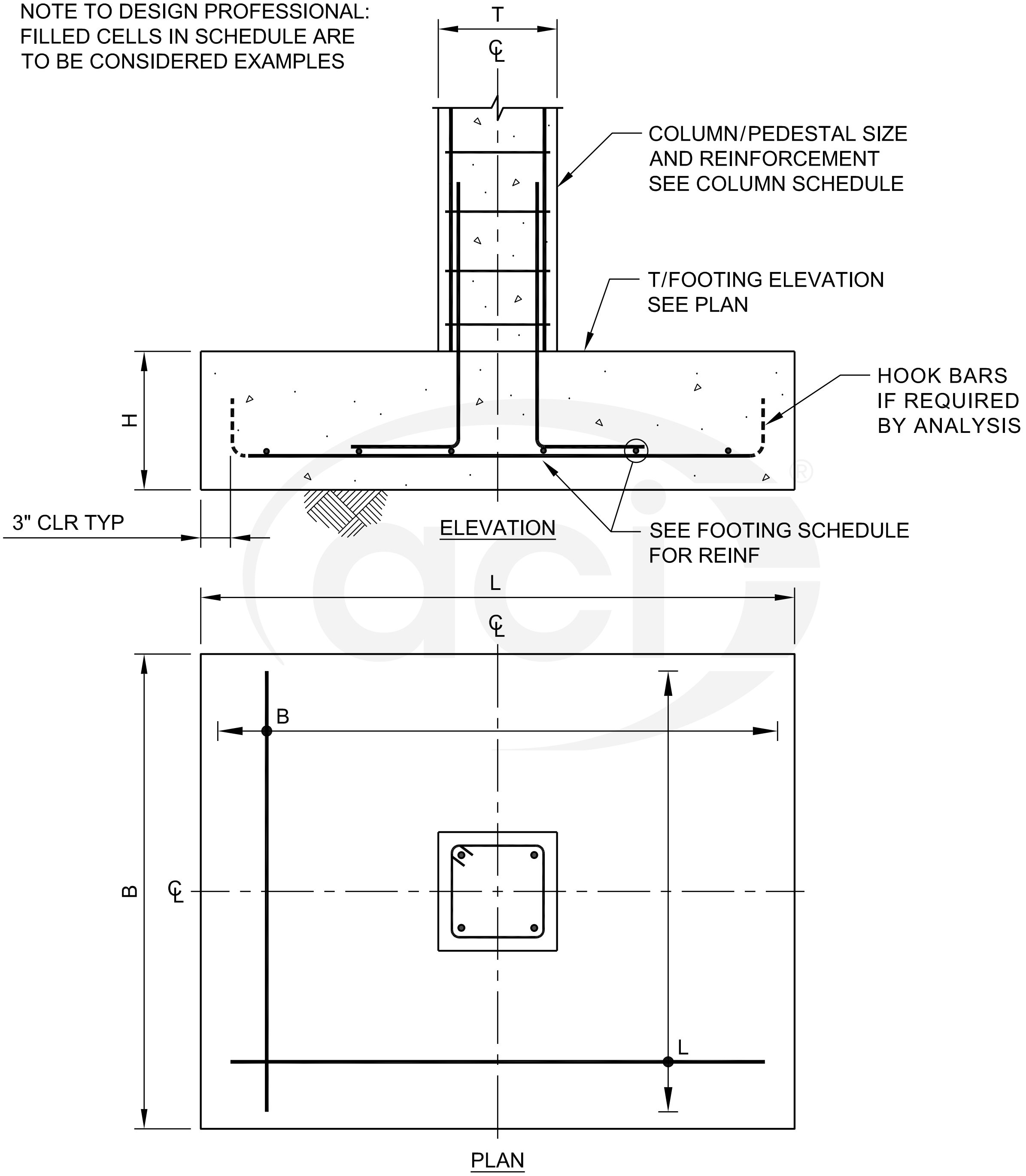
FOUNDATION DETAILS

FND-1

SQUARE AND RECTANGULAR FOOTING SCHEDULE

MARK	SIZE L x B x H	BOTTOM REINF		REMARKS
		L	B	
F1	4'-0" x 4'-0" x 1'-0"	5-#5	5-#5	
F2	4'-0" x 6'-0" x 1'-6"	5-#5	7-#5	

NOTE TO DESIGN PROFESSIONAL:
FILLED CELLS IN SCHEDULE ARE
TO BE CONSIDERED EXAMPLES



NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY SCHEDULE AND DETAIL AS REQUIRED BEFORE INCORPORATING THIS SCHEDULE AND DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

TYPICAL FOOTING DETAIL AND SCHEDULE

FIGURE FND-1: TYPICAL SHALLOW FOOTING SCHEDULE

The design professional shall review the following checklist and incorporate project-specific requirements into the details

---

INTENDED USE

Shallow rectangular or square footings for single interior or exterior columns and side-by-side columns at expansion joints

NOT INTENDED FOR

Deep foundations (such as drilled piers, piles)

Shallow footings used for SDC B through F for columns or pedestals designed as a fixed-end condition at the footing

Mat foundations

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Assigned footing type with footing marks on foundation plan is coordinated with schedule marks
2. Length, width, and depth of each footing type and mark is provided
3. Bottom bar sizes are provided in direction of the length and width of the footing for each footing type and mark
4. Top of footing elevations is shown on foundation plan drawings
5. Concrete column or formed pier dowels extend to bottom of footing supported on foundation reinforcement with 90-degree hooks
6. Place first tie in column at *s*/2 (half the spacing of required transvers reinforcing spacing in column) but not less than 2 in. above top of foundation; Section 10.7.6.2.1
7. Reinforcement cover satisfies Section 20.5.1.3
8. Refer to Foundation Figure 100 for additional information; Items 6 through 12
9. Remove "NOTES TO DESIGN PROFESSIONAL" before placing schedule in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles*: 5, 22, 23

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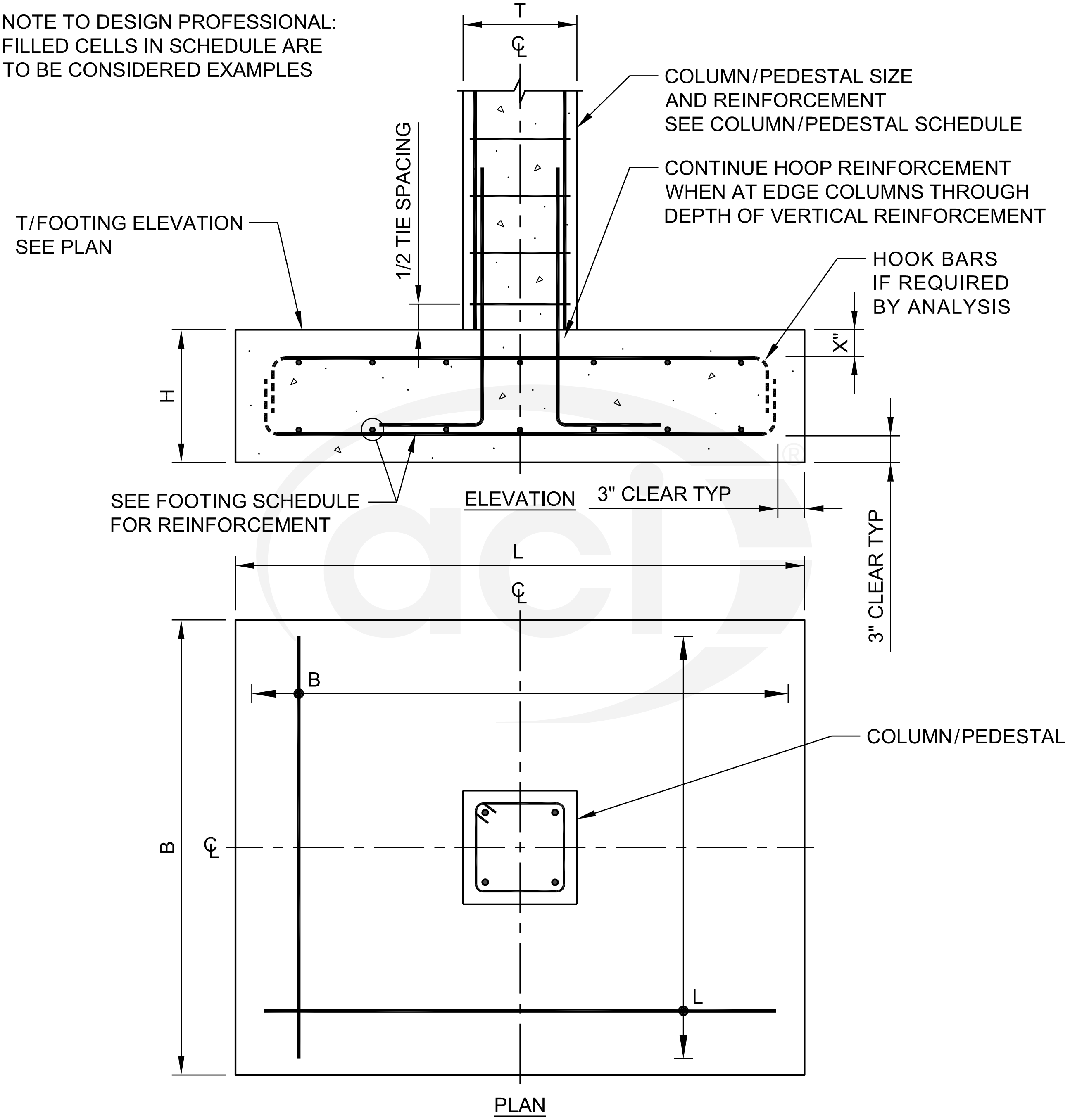
*Refer to Section 3 for articles

FND-2

SQUARE AND RECTANGULAR FOOTING SCHEDULE						
MARK	SIZE L x B x H	BOTTOM REINF		TOP REINF		REMARKS
		L	B	L	B	
F1	4'-0" x 4'-0" x 1'-0"	5-#5	5-#5	5-#5	5-#5	
F2	4'-0" x 6'-0" x 1'-6"	5-#5	7-#5	5-#5	7-#5	

NOTE TO DESIGN PROFESSIONAL:
FILLED CELLS IN SCHEDULE ARE
TO BE CONSIDERED EXAMPLES



NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY SCHEDULE AND DETAIL AS REQUIRED BEFORE INCORPORATING THIS SCHEDULE AND DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

TYPICAL FOOTING DETAIL AND SCHEDULE

FIGURE FND-2: SHALLOW FOOTING SCHEDULE FOR COLUMNS OR PEDESTALS IN SDC B THROUGH F DESIGNED WITH FIXED-END CONDITION

The design professional shall review the following checklist and
incorporate project-specific requirements into the details

INTENDED USE

Shallow rectangular or square footings for single interior or exterior columns and side-by-side columns at expansion joints

NOT INTENDED FOR:

Deep foundations (such as drilled piers, piles)
Shallow footings used for SDC A
Mat foundations

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Assigned footing type with footing marks on foundation plan is coordinated with schedule marks
2. Length width and depth of each footing type and mark is provided
3. Top and bottom bar sizes are provided in direction of the length and width of the footing for each footing type and mark
4. Top of footing elevations is shown on foundation plan drawings
5. Structures assigned to seismic design category (SDC) C, D, E, or F are designed per Section 18.13
6. Concrete column or formed pier dowels extend to bottom of footing with 90-degree hooks turned into pier; Section 18.13.2.3
7. Place first tie in column at $s/2$ (half the spacing of required transvers reinforcing spacing) but not less than 2 in. above top of foundation; Section 10.7.6.2.1
8. Transvers ties around pier dowels are provided over full depth of shallow foundation
9. Reinforcement cover satisfies Section 20.5.1.3
10. Refer to Foundation Figure 100 for additional information; Items 6 through 12
11. Remove "NOTES TO DESIGN PROFESSIONAL" before placing schedule in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles[*]: 5, 22

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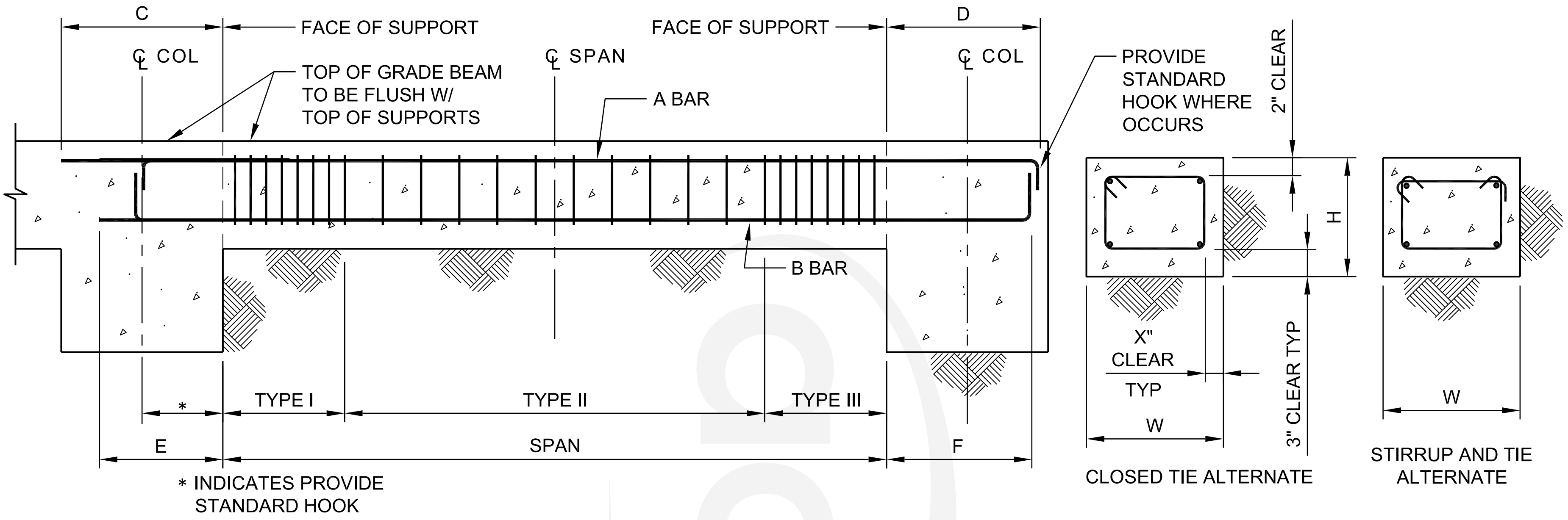
[*] Refer to Section 3 for articles

FND-3



MARK	SIZE		TOP BARS				BOTTOM BARS				STIRRUP			REMARKS
			A BARS				B BARS				TYPES			
	W	H	NO.	SIZE	C	D	NO.	SIZE	E	F	I	II	III	
GB1	36	18	8	#8	36	30	8	#8	36	30	#4 @ 6	#4 @ 6	#4 @ 6	
GB2	48	32	16	#8	96	84	12	#8	96	84	#5 @ 6 4 LEGS	#5 @ 6 4 LEGS	#5 @ 6 4 LEGS	
GB3	48	32	24	#11	84	70	14	#11	84	70	#5 @ 6 4 LEGS	#5 @ 6 4 LEGS	#5 @ 6 4 LEGS	TOP OF BARS IN 2 LAYERS

FILLED CELLS IN SCHEDULE ARE TO BE CONSIDERED EXAMPLES

NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY SCHEDULE AND DETAIL AS REQUIRED BEFORE INCORPORATING THIS SCHEDULE AND DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

SINGLE SPAN GRADE BEAM PROFILE AND SCHEDULE

FIGURE FND-3: GRADE BEAM PROFILE AND SCHEDULE

The design professional shall review the following checklist and
incorporate project-specific requirements into the details

INTENDED USE

Reinforced concrete grade beams, single span reinforcement

NOT INTENDED FOR:

Grade walls (supported by soil)

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Each assigned grade beam type with grade beam mark on foundation plan to match schedule mark
2. Length and width of each grade beam type and mark is provided
3. Minimum two longitudinal bars are provided top and bottom along full length of grade beam
4. Transverse bars are provided as required along length of beam span
5. Top bars are extended into support minimum tension development length beyond face of support
6. Bottom bars are extended into support minimum tension development length beyond face of support at end supports and compression development length at other supports or 6 in. minimum
7. Top of grade beam elevation is coordinated with slab-on-grade elevation
8. Bar cover is provided per Section 20.5.1.3
9. Grade beam in ordinary and intermediate moment frames (SDC A-C), a two-piece tie may be used, or as an alternate option is to use a two-piece tie in SDC D-F, but the cap tie having a 135-degree hook at each end instead of a 135-degree hook on one end and a 90-degree at the other end
10. Grade beams in special moment frames (SDC D-F), a closed tie must be used
11. Void forms are required under beam if determined by geotechnical report
12. Remove "NOTES TO DESIGN PROFESSIONAL" before placing schedule in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles*: 5, 15

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*Refer to Section 3 for articles

FND-4

PILE CAP SCHEDULE											
MARK	TYPE	SIZE (INCHES)			BOTTOM REINFORCING		TOP REINFORCING		TRANSVERSE NOTE 3 REINFORCING		REMARK
		N / S LENGTH "A" OR "B"	E / W LENGTH "A" OR "B"	THICKNESS H	N / S	E / W	N / S	E / W	N / S	E / W	
X		X	X	X	X	X	X	X	X	X	

NOTES TO DESIGN PROFESSIONAL:

1. USE THIS SCHEDULE WITH PILE CAP TYPE DETAILS 161 THROUGH 166
2. FOR TOP OF PILE CAP ELEVATION SEE FOUNDATION OR DRILLED PIER PLAN
3. PROVIDE TRANSVERSE REINFORCEMENT IF REQUIRED
4. IF REQUIRED, PROVIDE CARTON FORM OF THE SPECIFIED HEIGHT AND MASONITE UNDER THE PILE CAP
5. FOR COLUMN DOWELS REFER TO THE COLUMN SCHEDULE
6. CHANGE TITLE TO "PIER CAP SCHEDULE" IF PIERS ARE USED RATHER THAN PILES
7. FILLED CELLS IN SCHEDULE ARE TO BE CONSIDERED EXAMPLES

NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY SCHEDULE AS REQUIRED BEFORE INCORPORATING THIS SCHEDULE INTO PROJECT CONSTRUCTION DOCUMENTS

PILE CAP SCHEDULE

FIGURE FND-4: PIER/PILE CAP SCHEDULE

The design professional shall review the following checklist and
incorporate project-specific requirements into the details

INTENDED USE

Cast-in-place pile caps supported by pile or drilled pier deep foundations

Pile caps supporting single column or formed column pier

Pile caps supported by single pile or multiple piles

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Each pile cap is assigned with a pile cap mark. Marks shall be documented on drilled pier or pile foundation drawing. Pile cap marks should collect pile caps into similar sizes and depths and similar number of supporting piles
2. Top of pile cap elevations is provided on drawings
3. Length, width, and depth of pile cap is provided in the table. Coordinate length and width dimensions with north and south axis and east and west axis of the building site reference north axis. Enter length and width sizes parallel to corresponding axis
4. For three-pile pile cap made from 60-degree equilateral triangle shape, enter one length “A” in one column only
5. Longitudinal and transverse reinforcement size and spacing required in bottom reinforcement is provided; top reinforcement is provided, if required
6. Dowels from pile cap into formed column or formed column pier are added; provide number and size of column/column pier bars
7. Remove “NOTES TO DESIGN PROFESSIONAL” before placing schedule in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles[*]: 5, 22, 23

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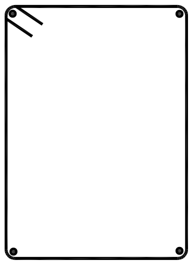
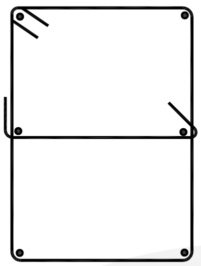
[*] Refer to Section 3 for articles

FND-10

REINFORCED CONCRETE PEDESTAL SCHEDULE						
MARK	SIZE		REINFORCEMENT		REINFORCEMENT CASE	REMARKS
			VERTICAL BARS	TIES		
P1	24	24	12 - #8	#4 @ 12"	7	
P2	18	18	8 - #8	#3 @ 12"	3	



CASE 1



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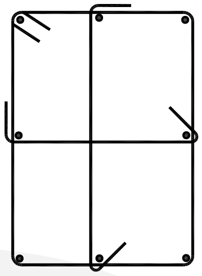
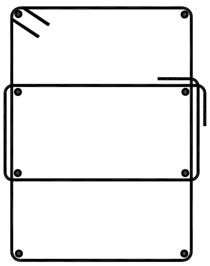


CASE 3



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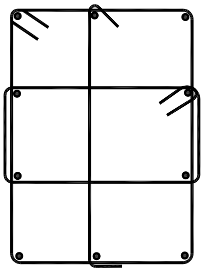
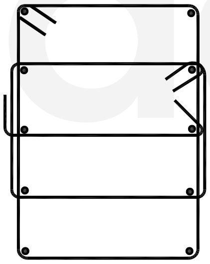
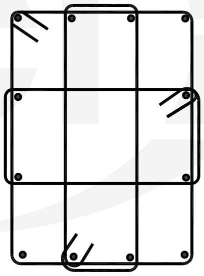


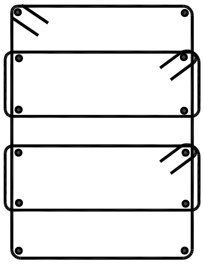
CASE 5



CASE 6



CASE 7



CASE 8

NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY SCHEDULE AND TIE CONFIGURATIONS AS REQUIRED BEFORE INCORPORATING THIS SCHEDULE AND TIE CONFIGURATIONS INTO PROJECT CONSTRUCTION DOCUMENTS

PEDESTAL REINFORCEMENT DETAILS

FIGURE FND-10: PEDESTAL REINFORCEMENT DETAILS

The design professional shall review the following checklist and
incorporate project-specific requirements into the details

INTENDED USE

Pedestal schedule and acceptable reinforcing pedestal tie pattern

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Pedestals marks on drawings match pedestal marks in the table
2. Entered pedestal dimensions in the table are coordinated with foundation plan
3. Minimum tie diameter satisfies Section 25.7.2.2
4. Ties are enclosed and provide lateral support to every corner and alternate longitudinal bar; Section 25.7.2.3
5. No vertical laterally unsupported bar is placed more than 6 in. from a laterally supported bar
6. Ties are spaced per Section 25.7.2.1
7. Minimum area of vertical pedestal steel is at least equal to 0.5% of gross pedestal area; Section 16.3.4.1
8. Remove “NOTES TO DESIGN PROFESSIONAL” before placing schedule in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles[*]: 34

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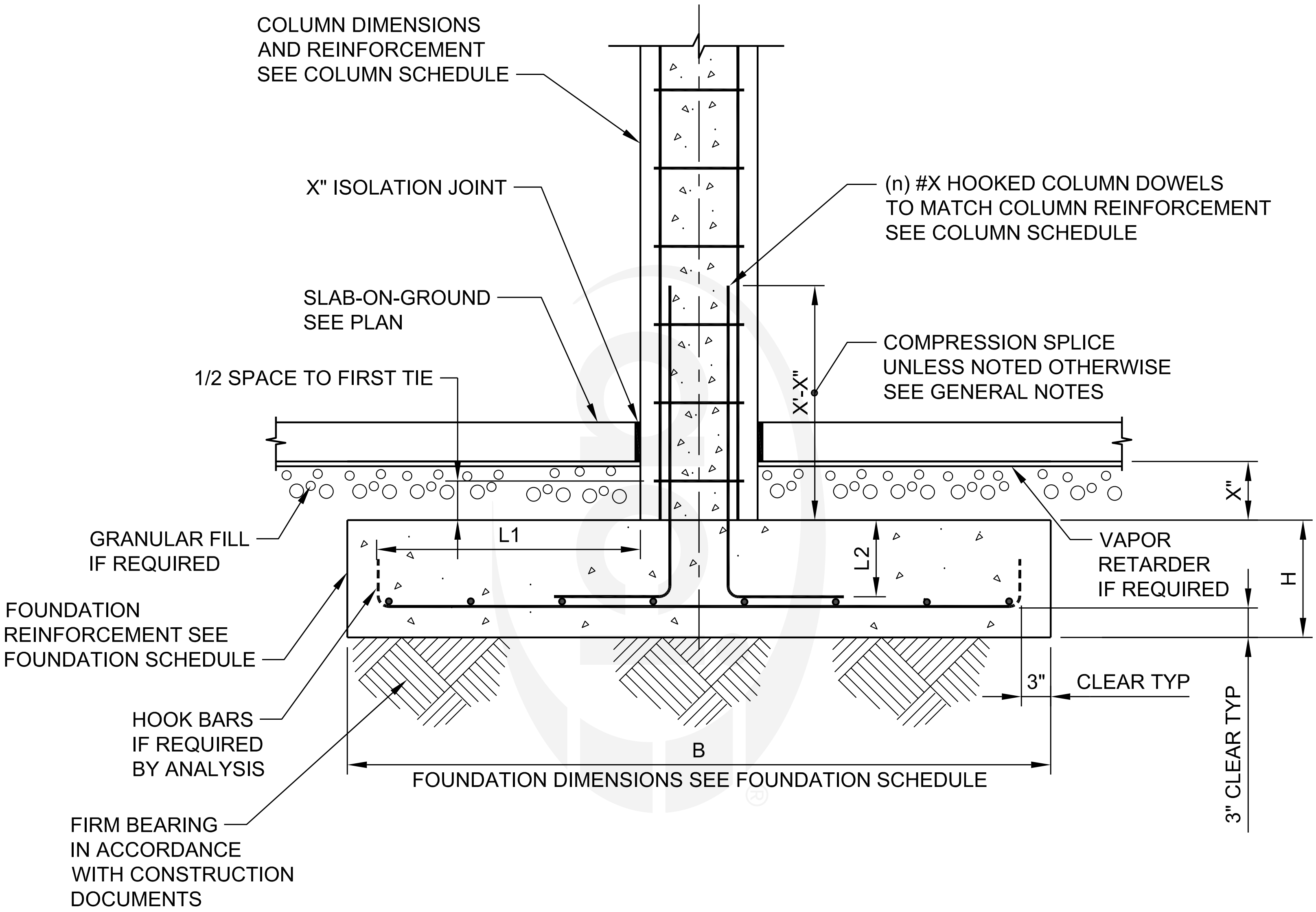
[*] Refer to Section 3 for articles

FND-100



NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

ISOLATED FOOTING SUPPORTING A COLUMN

FIGURE FND-100: ISOLATED FOOTING SUPPORTING COLUMN

The design professional shall review the following checklist and incorporate project-specific requirements into the details

INTENDED USE

Spread footing supported on medium to firm soil supporting single column

NOT INTENDED FOR (OPTIONAL)

Columns subjected to large moments and small axial forces producing uplift on part of footing

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Bar cover is provided per Section 20.5.1.3
2. Top of column footing elevation and bottom of slab-on-ground elevation are coordinated to avoid interference
3. Number and size of dowels to match number and size of column vertical reinforcement
4. It is permissible to rest column dowels on top of footing reinforcement
5. Columns dowels to be oriented toward the center, if column is part of special moment resisting frame, SDC D-F; Section 18.13.2.3
6. Extend dowels from footing into column a minimum length equal to the development length of the bar or equal to the tension splice length of the column bar if moment is transferred
7. Place first tie in column at $s/2$ (half the spacing of required transvers reinforcing spacing) but not less than 2 in. above top of foundation; Section 10.7.6.2.1
8. If the dowels are in tension, it is good practice to extend the hooks of the dowels under the top bars of the bottom mat reinforcement. Doing so engages the whole mat to resist the forces of dowels. Modify details accordingly
9. Footing to bear on material capable of achieving the minimum allowable bearing pressure as recommended by the geotechnical report
10. If footing bars cannot be developed, L1, beyond the face of the column, (B-T)/2, then provide hooks or extend footing dimensions
11. Ensure that required dowel bar development length, L2, in footing is less than the provided depth (H – 3 in. – $2d_b$)
12. If L2 > (H – 3 in. – $2d_b$) then consider the following:
    a. Increase footing thickness such that L2 < (H – 3 in. – $2d_b$)
    b. Use two dowels for every longitudinal bar in the column. The area of the two bars should not be less than the area of the bar in the column bar. Lap splice is provided per Section 25.5.5.4
13. Remove “NOTES TO DESIGN PROFESSIONAL” before placing schedule in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles[*]: 5, 22

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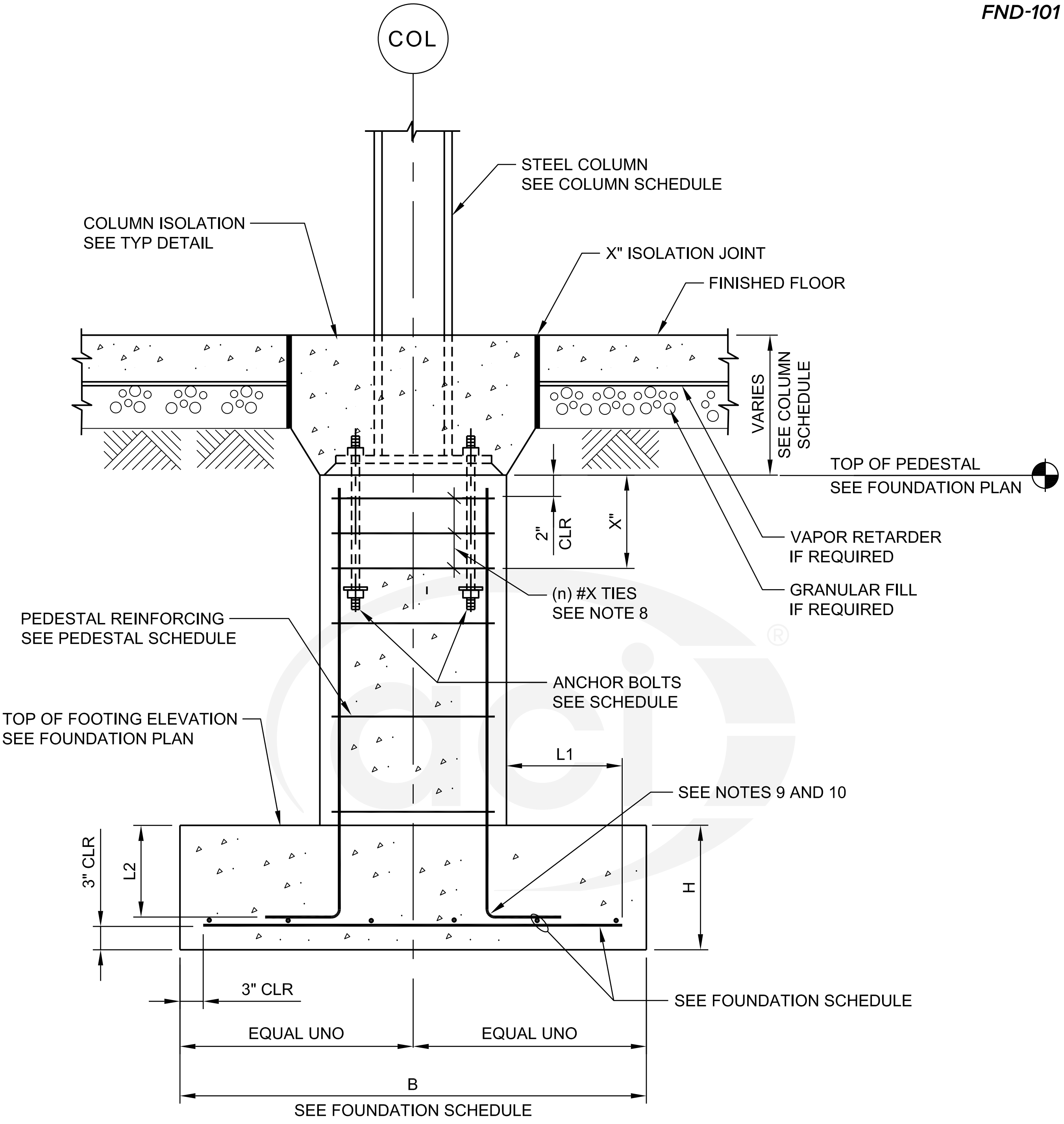
[*] Refer to Section 3 for articles

FND-101



NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

INTERIOR FOOTING WITH PEDESTAL SUPPORTING A STEEL COLUMN

FIGURE FND-101: INTERIOR FOOTING WITH PEDESTAL SUPPORTING A STEEL COLUMN

The design professional shall review the following checklist and
incorporate project-specific requirements into the details

INTENDED USE

For steel columns supported on isolated footing with pedestal

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Bar cover is provided per Section 20.5.1.3
2. Top of pedestal elevation and bottom of slab-on-ground elevation are coordinate to avoid interference
3. Top of footing elevation is coordinated with foundation plan
4. Pedestal dimensions can accommodate base plate and anchor bolts
5. Steel column anchor bolts have required embedment length within pedestal
6. Top of pedestal elevation provides for enough distance for anchor bolt extension to remain below top of slab-on-ground
7. Anchor bolts have enough extension above footing to accommodate grout, base plate thickness, nut thickness, and minimum 3/4 in. extension
8. The anchor bolts must be enclosed by minimum transverse reinforcement shown in accordance with Section 10.7.6.1.5; refer to Chapter 17 for possible additional requirements
9. Footing dimensions can accommodate the pedestal dimensions
10. It is permissible to rest column dowels on top of footing reinforcement
11. If the dowels are in tension, it is good practice to extend the hooks of the dowels under the top bars of the bottom mat reinforcement. Doing so engages the whole mat to resist the forces of dowels. Modify detail accordingly
12. Footing to bear on material capable of achieving the minimum allowable bearing pressure as recommended by the geotechnical report
13. If footing bars cannot be developed, L1, beyond the face of the column, (B-T)/2, then provide hooks or extend footing dimensions
14. Ensure that required dowel bar development length, L2, in footing is less than the provided depth $(H - 3 \text{ in.} - 2d_b)$
15. If L2 > $(H - 3 \text{ in.} - 2d_b)$ then consider the following:
    a. Increase footing thickness such that L2 < $(H - 3 \text{ in.} - 2d_b)$
    b. Use two dowels for every longitudinal bar in the column. The area of the two bars should not be less than the area of the bar in the column bar. Lap splice is provided per Section 25.5.5.4
16. Remove "NOTES TO DESIGN PROFESSIONAL" before placing detail in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles[*]: 5, 22, 34

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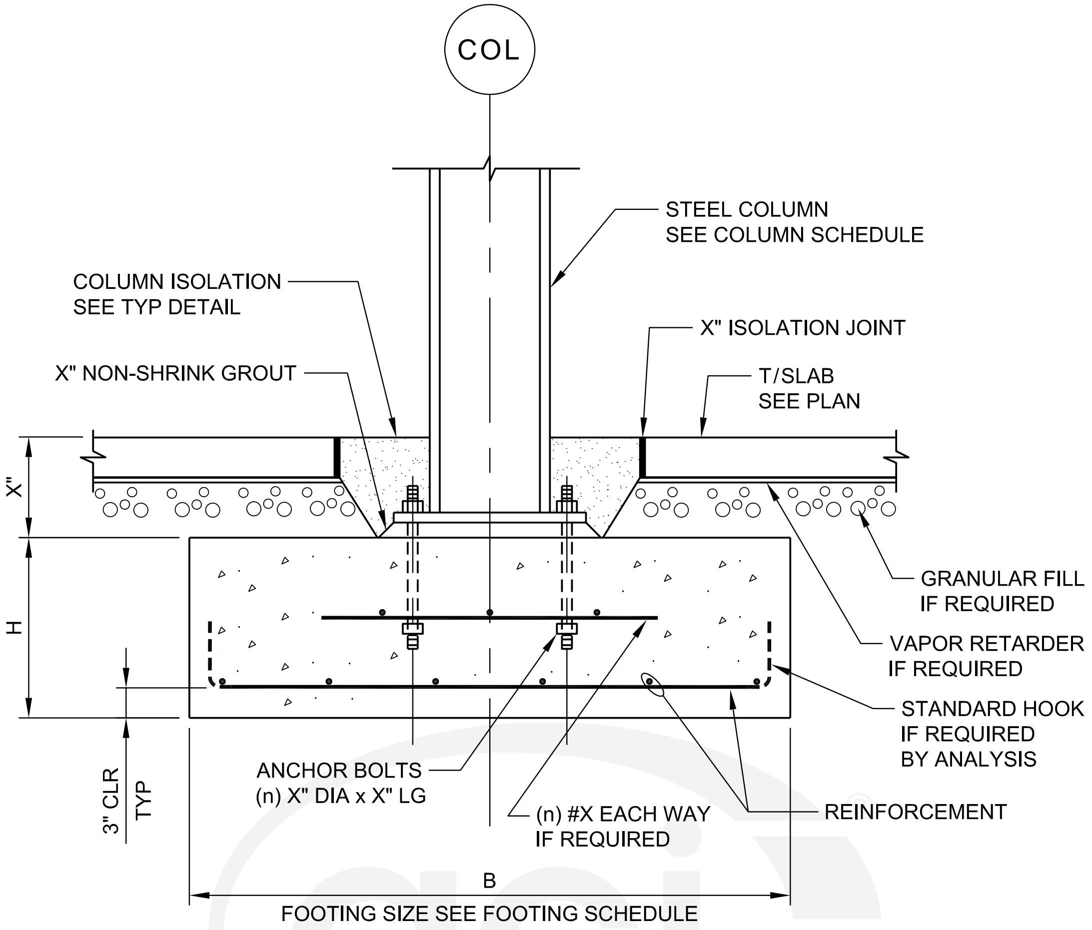
[*] Refer to Section 3 for articles

FND-102



NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

INTERIOR FOOTING SUPPORTING A STEEL COLUMN W/O PEDESTAL

FIGURE FND-102: INTERIOR FOOTING SUPPORTING A STEEL COLUMN WITHOUT PEDESTAL

The design professional shall review the following checklist and
incorporate project-specific requirements into the details

INTENDED USE

For steel columns supported on isolated footings

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Bar cover is provided per Section 20.5.1.3
2. Top of pedestal elevation and bottom of slab-on-ground elevation are coordinated to avoid interference
3. Top of footing elevation is coordinated with foundation plan
4. Footing depth is adequate to accommodate steel anchor bolt embedment plus cover
5. Anchor bolts have enough extension above footing to accommodate grout, base plate thickness, nut thickness, and minimum 3/4 in. extension
6. Top of foundation elevation provides for enough distance for anchor bolt extension to remain below top of slab-on-ground
7. Footing dimensions can accommodate the baseplate and anchor bolts
8. Footing to bear on material capable of achieving the minimum allowable bearing pressure as recommended by the geotechnical report
9. If footing bars cannot be developed, L1, beyond the face of the column, (B-T)/2, then provide hooks or extend footing dimensions
10. Remove “NOTES TO DESIGN PROFESSIONAL” before placing schedule in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles*: 5, 22, 34

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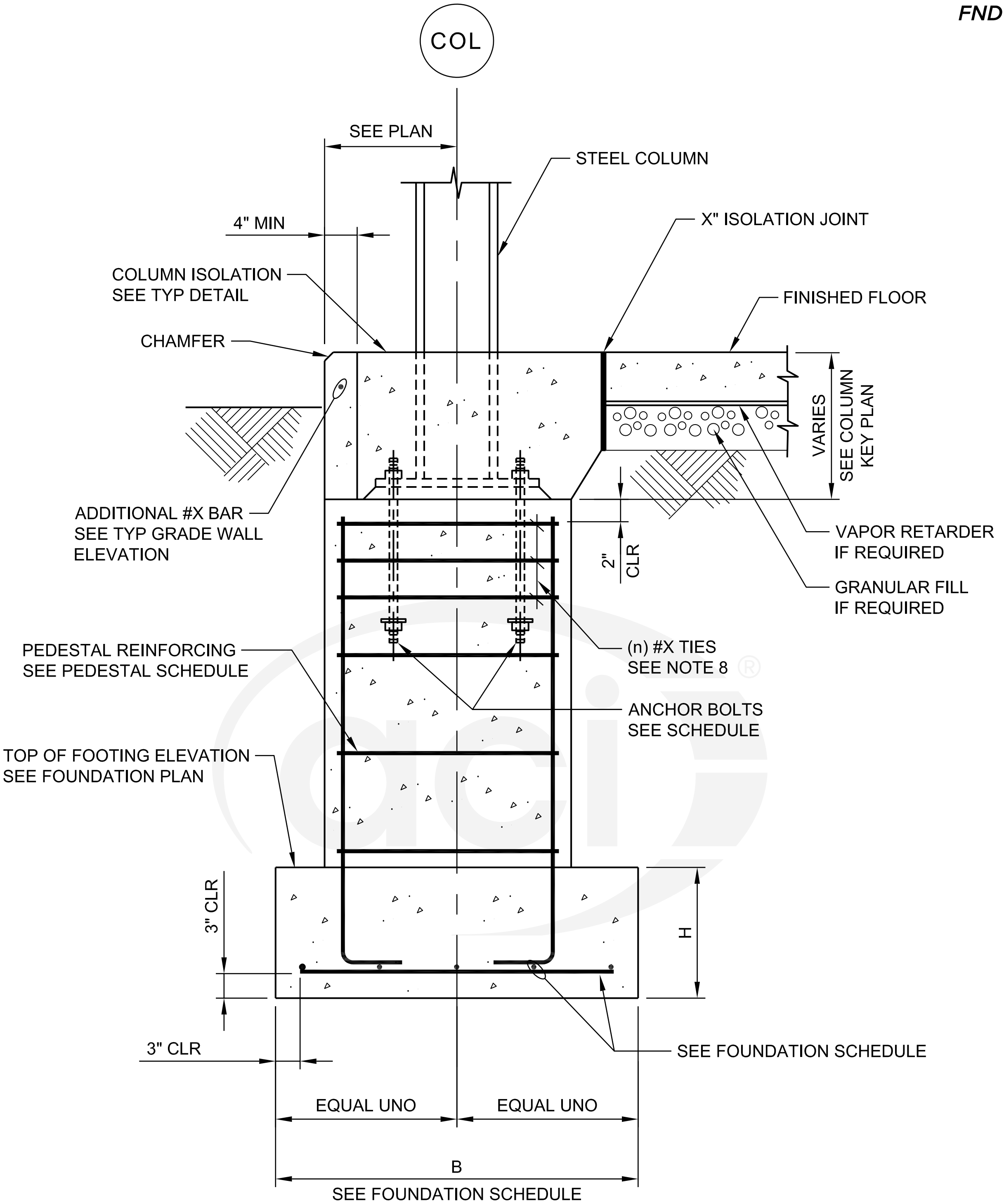
*Refer to Section 3 for articles

FND-103



NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE
INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

EXTERIOR FOOTING SUPPORTING A STEEL COLUMN WITH PEDESTAL AND GRADE WALL

FIGURE FND-103: EXTERIOR FOOTING SUPPORTING A STEEL COLUMN WITH PEDESTAL AND GRADE WALL

The design professional shall review the following checklist and
incorporate project-specific requirements into the details

INTENDED USE

For exterior steel column supported on footing with pedestal

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Bar cover is provided per Section 20.5.1.3
2. Top of pedestal elevation and bottom of slab-on-ground elevation are coordinated to avoid interference
3. Top of footing elevation is coordinated with foundation plan
4. Pedestal dimensions can accommodate base plate and anchor bolts
5. Steel column anchor bolts have required embedment within pedestal
6. Top of pedestal elevation including anchor bolts provides for enough distance for anchor bolt extension to remain below top of slab-on-ground
7. Anchor bolts have enough extension above footing to accommodate grout, base plate thickness, nut thickness, and minimum 3/4 in. extension
8. The anchor bolts must be enclosed by minimum transverse reinforcement shown in accordance with Section 10.7.6.1.5; refer to Chapter 17 for possible additional requirements
9. Where a column steel plate interferes with grade wall provide a pocket such that the exterior remaining width of grade wall is at least 4 in. thick
10. Footing dimensions can accommodate the pedestal dimensions
11. It is permissible to rest column dowels on top of footing reinforcement
12. If the dowels are in tension, it is good practice to extend the hooks of the dowels under the top bars of the bottom mat reinforcement. Doing so engages the whole mat to resist the forces of dowels. Modify detail accordingly
13. Footing to bear on material capable of achieving the minimum allowable bearing pressure as recommended by the geotechnical report
14. For footing reinforcement and pedestal dowels, refer to Detail 101, Notes 13, 14, and 15
15. Remove "NOTES TO DESIGN PROFESSIONAL" before placing schedule in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles[*]: 5, 22, 34

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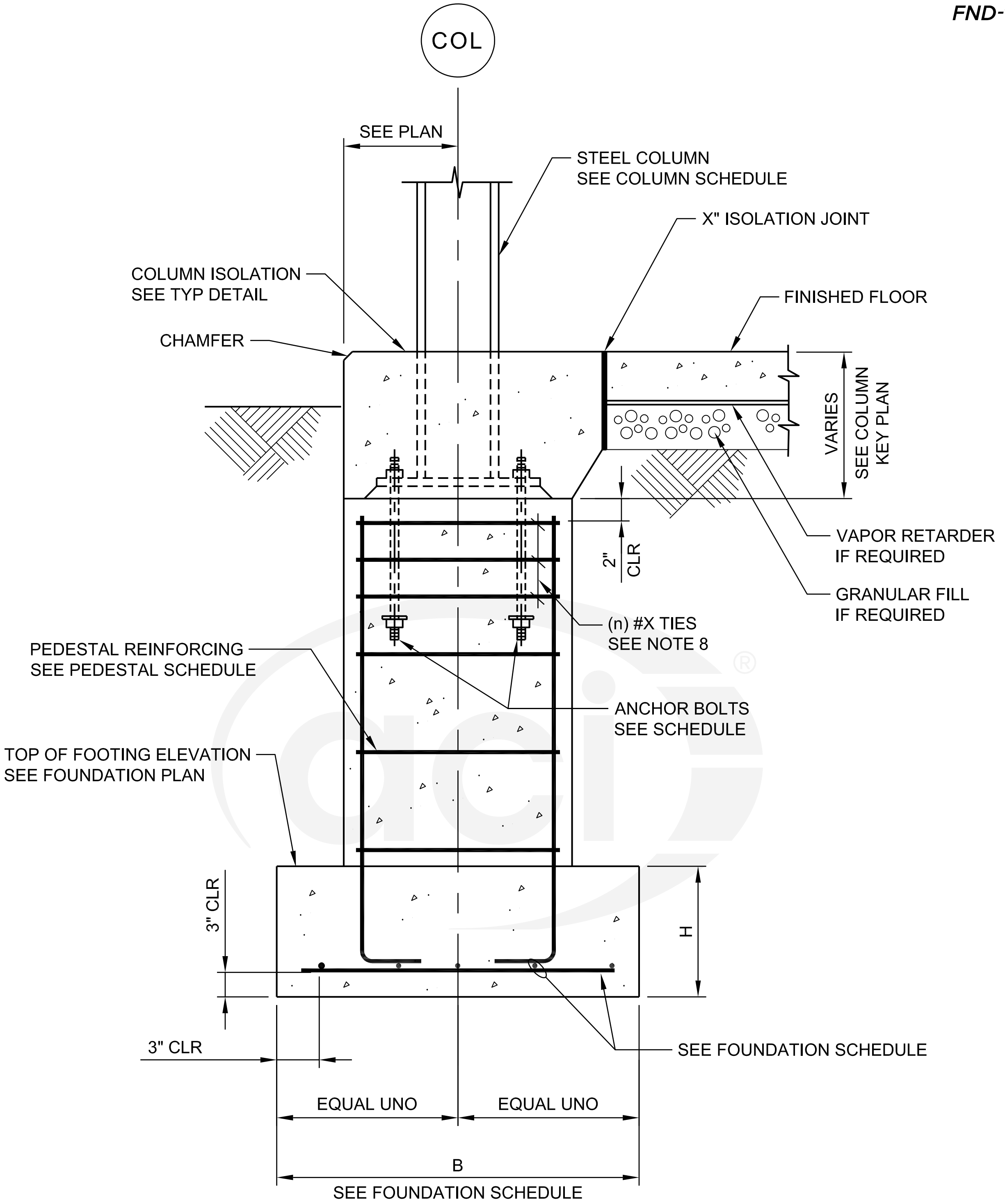
[*] Refer to Section 3 for articles

FND-104



NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

EXTERIOR FOOTING WITH PEDESTAL AND THROUGH POCKET SUPPORTING A STEEL COLUMN

FIGURE FND-104: EXTERIOR FOOTING WITH PEDESTAL AND THRU POCKET SUPPORTING A STEEL COLUMN

The design professional shall review the following checklist and
incorporate project-specific requirements into the details

INTENDED USE

For exterior steel columns supported on footing with pedestal

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Bar cover is provided per Section 20.5.1.3
2. Top of pedestal elevation and bottom of slab-on-ground elevation are coordinated to avoid interference
3. Top of footing elevation is coordinated with foundation plan
4. Pedestal dimensions can accommodate base plate and anchor bolts
5. Steel column anchor bolts have required embedment within pedestal
6. Top of pedestal elevation including anchor bolts provides for enough distance for anchor bolt extension to remain below top of slab-on-ground
7. Anchor bolts have enough extension above footing to accommodate grout, base plate thickness, nut thickness, and minimum 3/4 in. extension
8. The anchor bolts must be enclosed by minimum transverse reinforcement shown in accordance with Section 10.7.6.1.5; refer to Chapter 17 for possible additional requirements
9. Footing dimensions can accommodate the pedestal dimensions
10. It is permissible to rest column dowels on top of footing reinforcement
11. If the dowels are in tension, it is good practice to extend the hooks of the dowels under the top bars of the bottom mat reinforcement. Doing so engages the whole mat to resist the forces of dowels. Modify detail accordingly
12. Footing to bear on material capable of achieving the minimum allowable bearing pressure as recommended by the geotechnical report
13. For footing reinforcement and pedestal dowels refer to Detail 101, Notes 13, 14, and 15
14. Remove “NOTES TO DESIGN PROFESSIONAL” before placing schedule in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles[*]: 5, 22, 34

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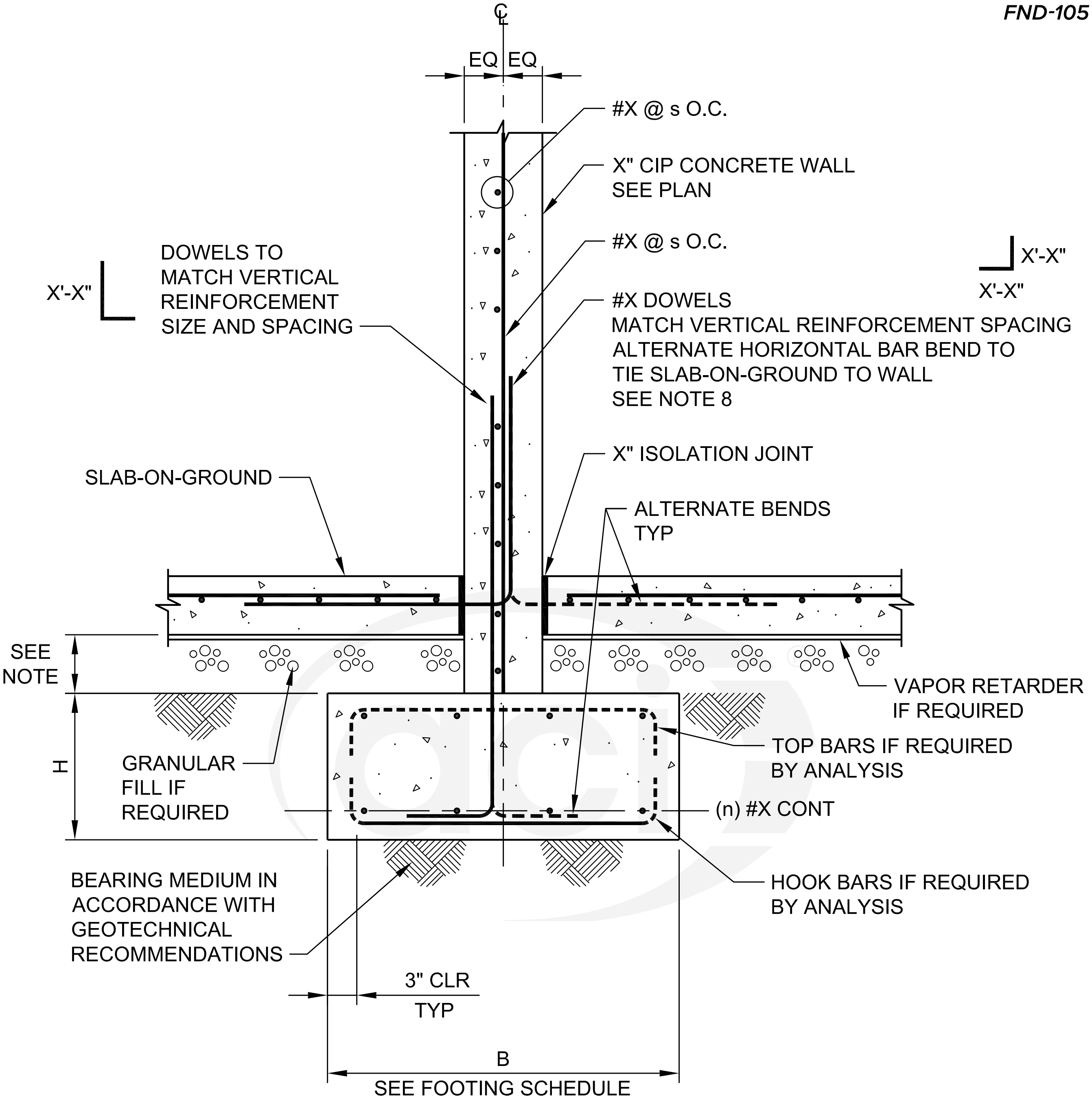
[*] Refer to Section 3 for articles

FND-105



NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE
INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

SPECIAL STRUCTURAL WALL ≤ 10" THICK ON CONTINUOUS FOOTING

FIGURE FND-105: SPECIAL STRUCTURAL WALL ≤10 IN. THICK ON CONTINUOUS FOOTING

The design professional shall review the following checklist and
incorporate project-specific requirements into the details

INTENDED USE

Wall footing for 10 in. or less thick cast-in-place concrete special structural wall (SDC D, E, and F)

NOT INTENDED FOR

Wall footing used in SDC A, B, and C
Wall footing for wall thickness greater than 10 in.
Wall footing for precast concrete wall

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Wall bars are placed in middle of wall thickness
2. Shear strength exceeds shear demand, otherwise provide two curtains of reinforcement or increase thickness; Section 18.10.2.2
3. Bar cover is provided per Section 20.5.1.3
4. Top of wall footing elevation and bottom of slab-on-ground elevation are coordinated to avoid interference
5. Dowels extended from footing into concrete wall matches wall reinforcement size and spacing
6. Dowel vertical length into wall is at least equal to the required tension lap splice
7. Contact area between foundation and wall is roughened
8. If slab-on-ground is designed to act as a diaphragm provide hooked reinforcing bars matching size and spacing of one set of vertical wall reinforcing bars, refer to 13.2.4. Length of bars to exceed tension lap splices of both slab and wall bars
9. If the dowels are in tension, it is good practice to extend the hooks of the dowels under the top bars of the bottom mat reinforcement as shown in the figure. Doing so engages the whole mat to resist the forces of dowels. Modify detail accordingly
10. If top of footing is in tension provide top reinforcement
11. For footing reinforcement and wall dowel requirements, refer to Detail 101, Notes 13, 14, and 15
12. Note that the detail may not apply exactly at boundary elements
13. Remove "NOTES TO DESIGN PROFESSIONAL" before placing schedule in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles[*]: 5, 22, 23, 31

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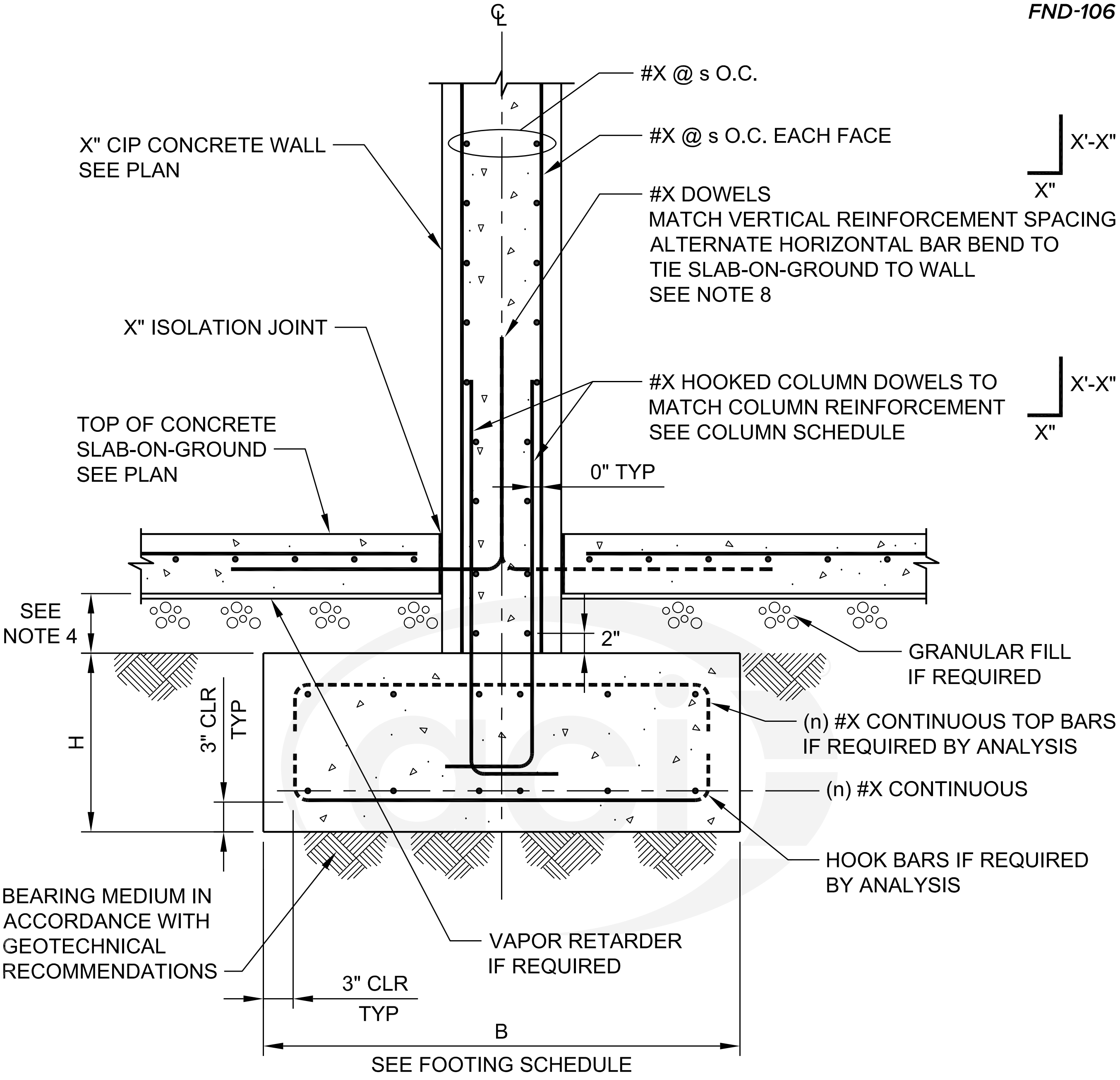
[*] Refer to Section 3 for articles

FND-106



NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

SPECIAL STRUCTURAL WALL > 10" THICK ON CONTINUOUS WALL FOOTING

FIGURE FND-106: SPECIAL STRUCTURAL WALL > 10 IN. THICK ON CONTINUOUS FOOTING

The design professional shall review the following checklist and
incorporate project-specific requirements into the details

INTENDED USE

Wall footing for cast-in-place concrete wall thicker than 10 in. used in SDC D, E, and F

NOT INTENDED FOR

Wall footing used in SDC A, B, and C
Wall footing for wall less or equal to 10 in. thick
Wall footing for precast concrete wall

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Two layers of reinforcement are provided in each direction near each face; Section 11.7.2.3
2. Distributed web reinforcement satisfies Section 18.10.2.1
3. Bar cover is provided per Section 20.5.1.3
4. Top of wall footing elevation and bottom of slab-on-ground elevation are coordinated to avoid interference
5. Dowels extended from footing into concrete wall matches wall reinforcement size and spacing
6. Dowel vertical length into wall is at least equal to the required tension lap splice
7. Contact area between foundation and wall is roughened
8. If slab-on-ground is designed to act as a diaphragm, provide hooked reinforcing bars matching size and spacing of one set of vertical wall reinforcing bars; Section 13.2.4. Length of bars to exceed tension lap splices of both slab and wall bars
9. If the dowels are in tension, it is good practice to extend the hooks of the dowels under the top bars of the bottom mat reinforcement as shown in the figure. Doing so engages the whole mat to resist the forces of dowels. Modify detail accordingly
10. If top of footing is in tension provide top reinforcement
11. For footing reinforcement and wall dowel requirements, refer to Detail 101, Notes 13, 14, and 15
12. Note that the detail may not apply exactly at boundary elements
13. Remove “NOTES TO DESIGN PROFESSIONAL” before placing schedule in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles[*]: 5, 22, 23, 31

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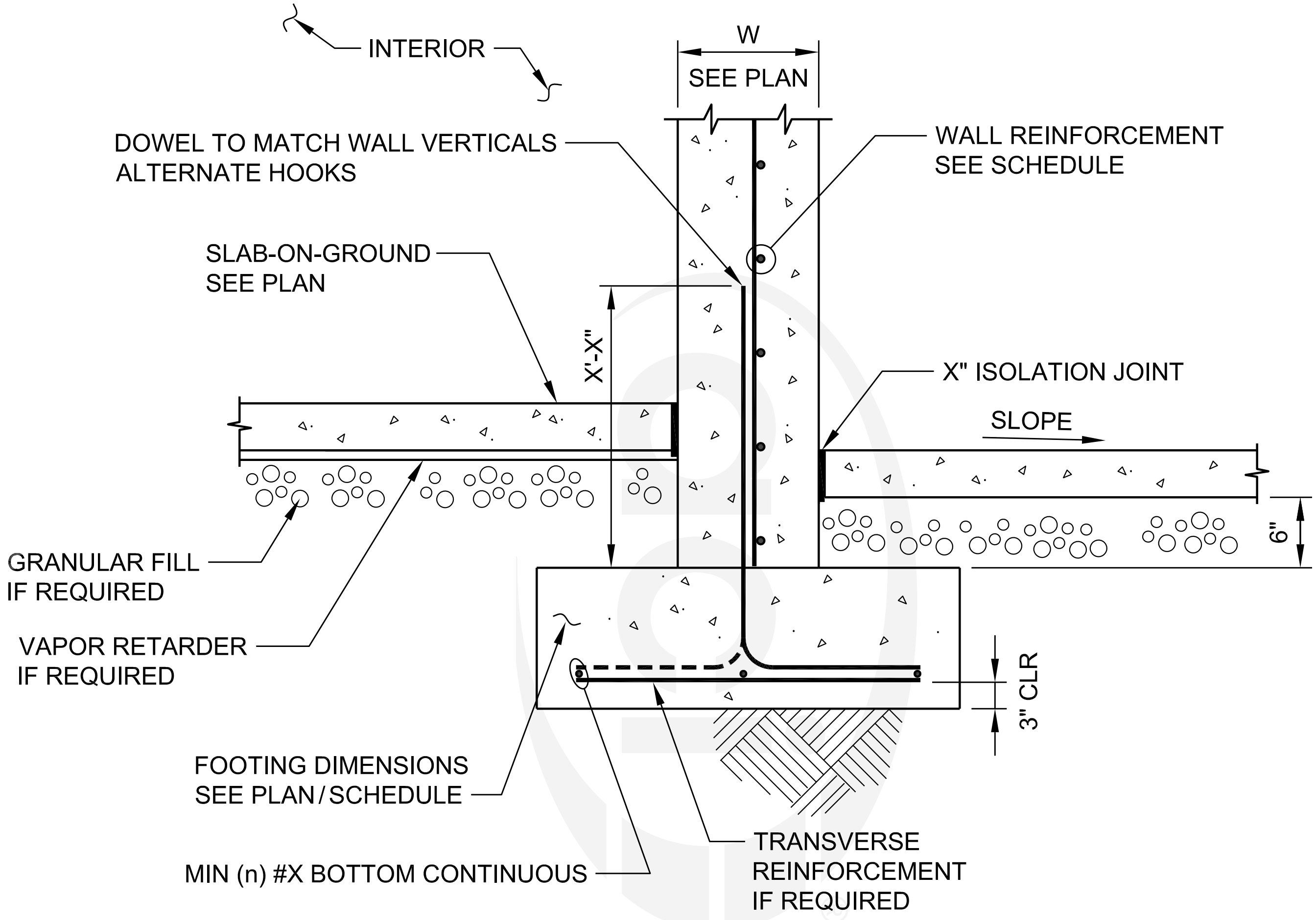
[*] Refer to Section 3 for articles



NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

EXTERIOR ORDINARY WALL SUPPORTED ON FOOTING

FIGURE FND-107: EXTERIOR ORDINARY WALL SUPPORTED ON FOOTING

The design professional shall review the following checklist and incorporate project-specific requirements into the details

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INTENDED USE

Exterior ordinary reinforced concrete wall connection at shallow foundation

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Footing to bear on material capable of achieving the minimum allowable bearing pressure as recommended in the geotechnical report
2. Wall-to-footing dowels to be same size and quantity as wall longitudinal reinforcing bars
3. Extend dowels from the footing into the wall a minimum length equal to the development length of the bar
4. Bar cover is provided per Section 20.5.1.3
5. Continuous footing is reinforced with longitudinal bars per schedule
6. Top of footing contact area with the wall shall be roughened
7. Wall bars can rest on top of the footing reinforcement
8. Top of wall footing elevation and bottom of slab-on-ground elevation are coordinated to avoid interference
9. For footing reinforcement and wall dowel requirements, refer to Detail 101, Notes 13, 14, and 15
10. Remove "NOTES TO DESIGN PROFESSIONAL" before placing schedule in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles[*]: 22, 23, 31

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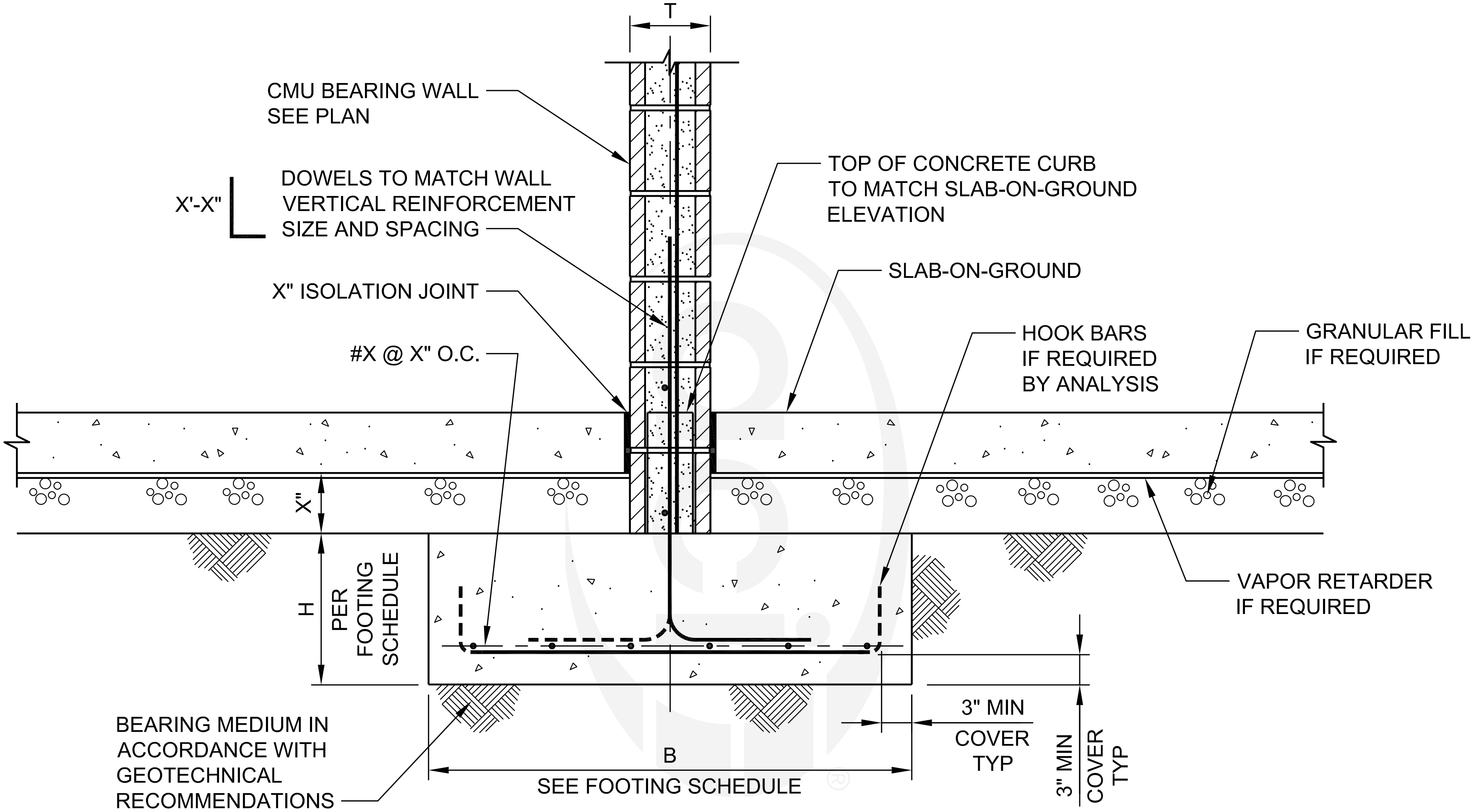
[*] Refer to Section 3 for articles



NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE
INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

CMU BEARING WALL ON CONTINUOUS FOOTING

FIGURE FND-108: CMU BEARING WALL ON CONTINUOUS FOOTING

The design professional shall review the following checklist and incorporate project-specific requirements into the details

---

INTENDED USE

Wall footings for CMU bearing walls

NOT INTENDED FOR (OPTIONAL)

Non-bearing-wall footings

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Footing to bear on material capable of achieving the minimum allowable bearing pressure as recommended in the geotechnical report
2. CMU wall to footing dowels to be same size and quantity as wall longitudinal reinforcing bars
3. Extend dowels from the footing into the wall a minimum length equal to the development length of the bar
4. Bar cover is provided per Section 20.5.1.3
5. Continuous footing is reinforced with longitudinal bars per schedule
6. Extend dowels from the footing into the CMU wall a minimum length equal to the development length of the bar
7. Top of CMU wall footing elevation and bottom of slab-on-ground elevation are coordinated to avoid interference and is adequate to run underground pipes
8. If footing bars cannot be developed, L1, beyond the face of the wall, (B-T)/2, then provide hooks
9. Remove “NOTES TO DESIGN PROFESSIONAL” before placing schedule in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles[*]: 5, 22

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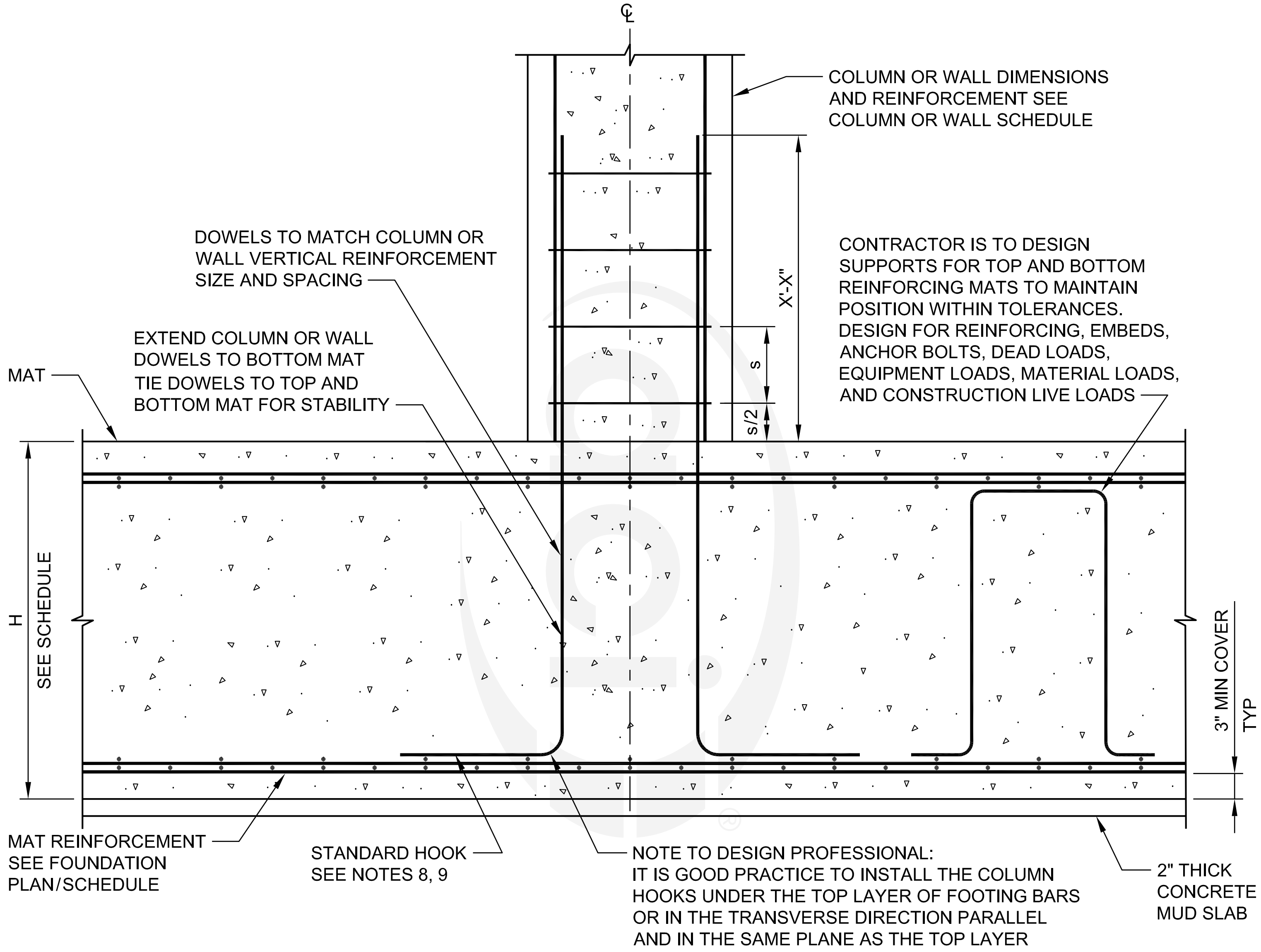
[*] Refer to Section 3 for articles

FND-109



NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

MAT FOUNDATION

FIGURE FND-109: MAT FOUNDATION TO CONCRETE COLUMN, COLUMN PIER, OR WALL CONNECTION

The design professional shall review the following checklist and incorporate project-specific requirements into the details

INTENDED USE

Construction of mat foundation supporting multiple columns, column piers, or concrete walls

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Mat bottom and side bar cover is provided per Section 20.5.1.3
2. Distribution of bearing pressure satisfies the geotechnical report; Section 13.3.4.3
3. Reinforcement exceeds the minimum required in Section 13.3.4.4
4. Concrete column or column pier dimensions and reinforcing is per concrete column or column pier schedule
5. Concrete wall dimensions and reinforcement is per wall schedule
6. Mat foundation reinforcement is per foundation schedule
7. Provided dowels match column or wall longitudinal bar size and spacing
8. Bars can be developed within mat foundation depth without hooks. Dowels are, however, extended to bottom of mat foundation with 90-degree standard hooks and tied to bottom mat foundation for stability
9. Column dowels may need to be oriented towards the center if column is part of a moment-resisting frame (SDC D-F) per Section 18.13.2.3
10. Dowels into columns, column piers, and wall members are extended with tension lap splice above mat foundation
11. Bottom tie or hoop is placed at maximum one-half the required tie or hoop spacing above mat foundation of the required member transverse reinforcement spacing; Section 10.7.6.2.1
12. Remove “NOTES TO DESIGN PROFESSIONAL” before placing schedule in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles*: 5, 13, 16, 19, 22, 30

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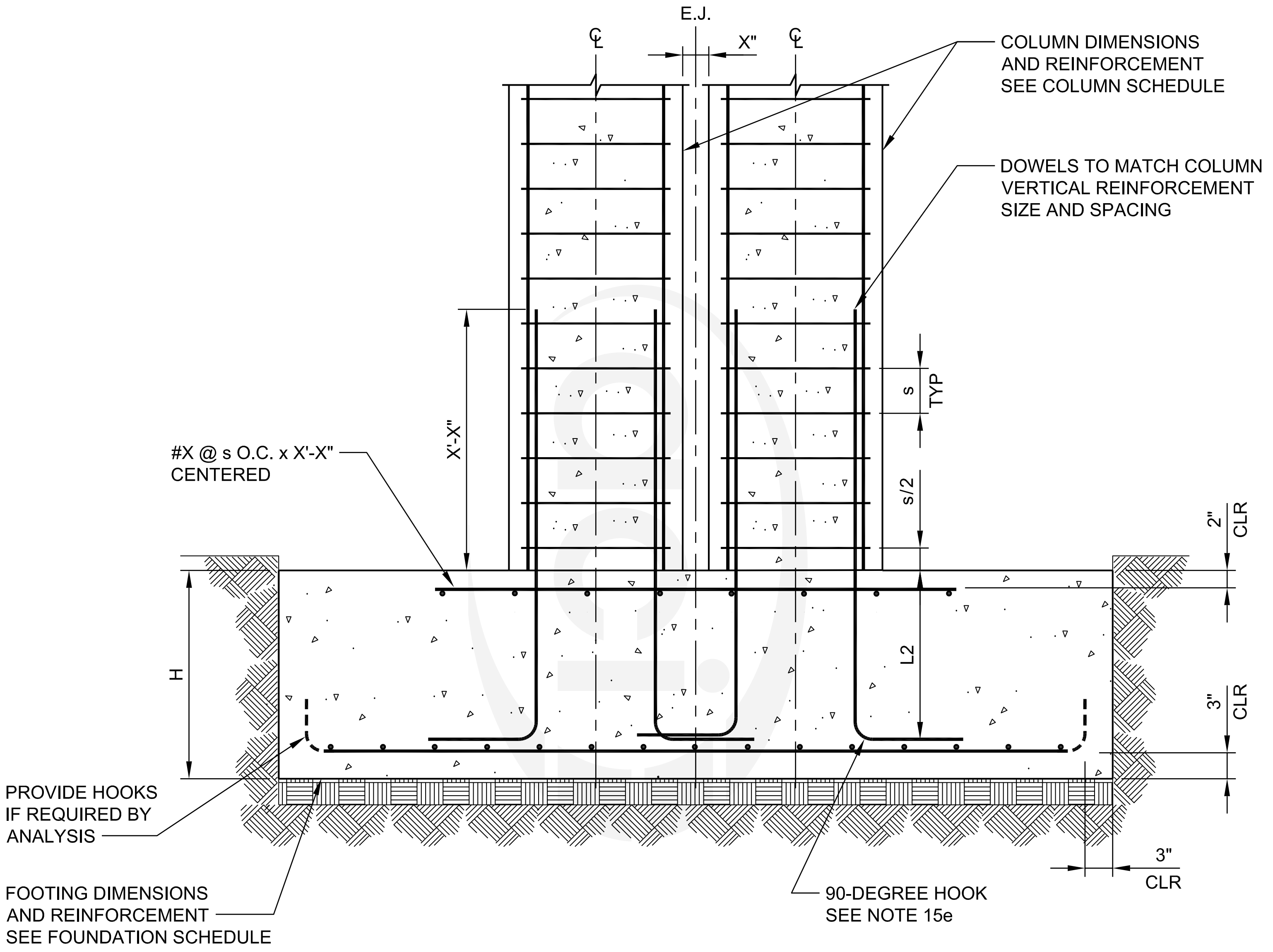
*Refer to Section 3 for articles

FND-110



NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

COMBINED FOOTING AT EXPANSION JOINT

FIGURE FND-110: COMBINED FOOTING AT EXPANSION JOINT

The design professional shall review the following checklist and
incorporate project-specific requirements into the details

INTENDED USE

Two-column combined shallow foundation at expansion joint

REVIEW BEFORE USE AND VERIFY THAT

1. The distance between column centerlines is greater than half the sum of the two column dimensions; coordinate distance between column with foundation plan
2. Distance between column faces is larger than the calculated lateral displacement at the top of the structure
3. Top of foundation elevation and bottom of slab-on-ground elevation are coordinated to avoid interference
4. Footing dimensions and reinforcement is coordinated with footing schedule
5. Top reinforcement in both directions is centered around columns and extends minimum 12 in. beyond exterior face of column at each end
6. Reinforcement cover satisfies Section 20.5.1.3
7. Maximum spacing of longitudinal bars closest to tension face meets Section 7.7.2.2 requirement
8. Bars in long direction are uniformly distributed across footing per Section 13.3.3.3
9. For rectangular footing, portion of the bars in the short direction are placed uniformly in a bandwidth centered on the column centerline per Section 13.3.3.3(b). The remaining bars are uniformly distributed equally on both sides of the bandwidth
10. Foundation bars are developed beyond face of column or column pedestal; otherwise provide hooks
11. Dowels between foundation and columns are properly developed per Section 25.4
12. Tensile splice length is provided for dowels in columns if moment is transferred
13. Bars between footing and concrete column or column pedestal are properly detailed:
    a. First tie is placed at maximum one-half the required tie or hoop spacing above mat foundation of the required member transverse reinforcement spacing; Section 10.7.6.2.1
    b. Footing dowel bar length, L2, satisfies L2 $\leq (h - 3\text{ in.} - 2d_b)$
    c. If L2 > $(h - 3\text{ in.} - 2d_b)$, then make one of the following changes:
        i. Increase foundation thickness such that L2 $\leq (h - 3\text{ in.} - 2d_b)$
        ii. Use two dowels for every longitudinal bar in the column. The area of the two bars should not be less than the area of the bar in the column bar. Lap splice is provided per Section 25.5.5.4
    d. Determine correction orientation of hooks at the bottom of the column dowels in the footing; Section 18.13.2.3
14. Remove “NOTES TO DESIGN PROFESSIONAL” before placing schedule in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles*: 5, 19, 22

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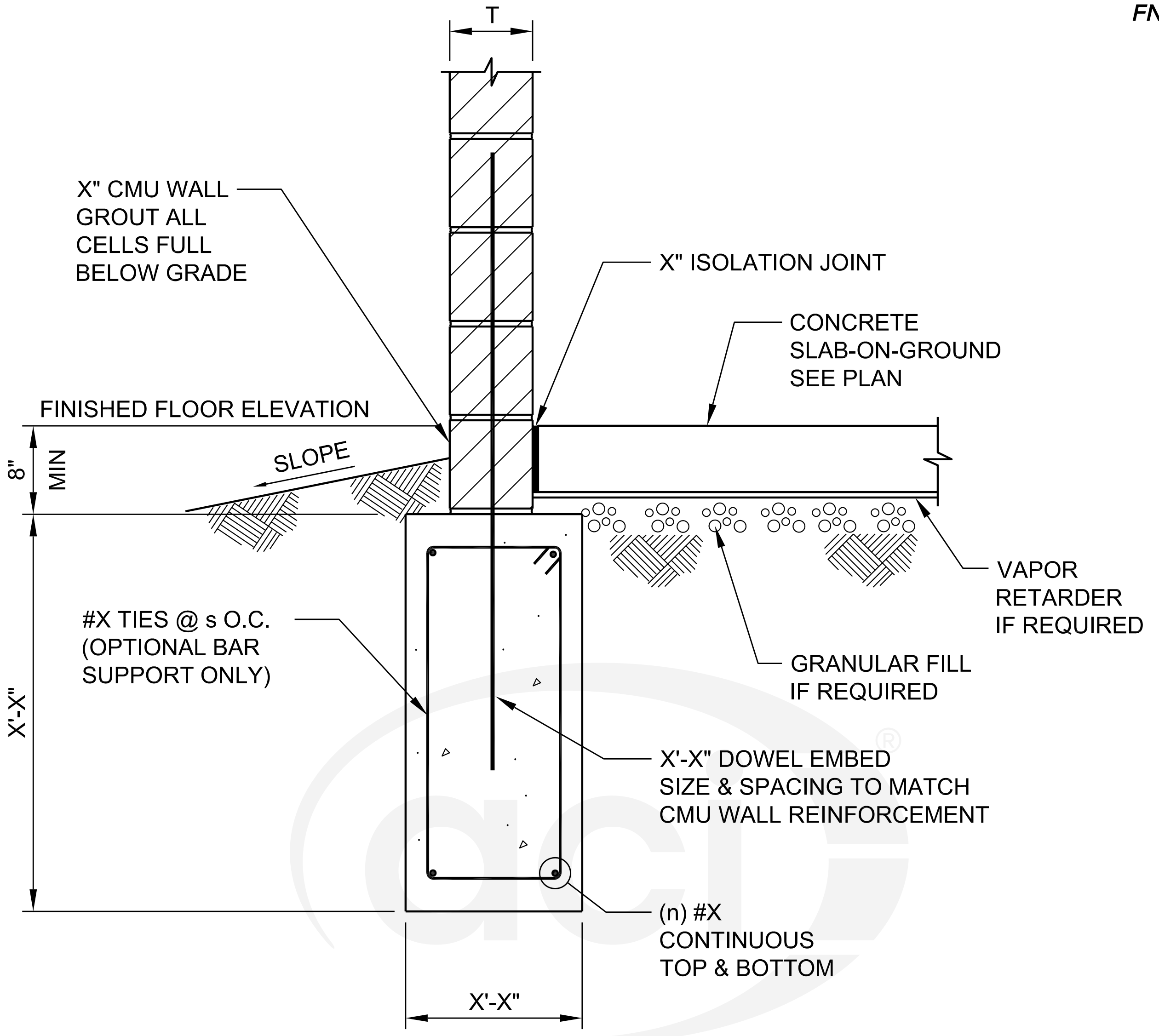
*Refer to Section 3 for articles

FND-111



NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

GRADE BEAM SUPPORTING CMU WALL

FIGURE FND-111: GRADE BEAM SUPPORTING CMU WALL

The design professional shall review the following checklist and incorporate project-specific requirements into the details

INTENDED USE

Grade beam supported by soil

Grade beam supports CMU bearing Wall

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. For stiff soil, excavation can be vertical; grade beam walls may be formed by soil
2. For soft soil, excavation is sloped to 2:1 (2 horizontal to 1 vertical)
3. Grade beam is reinforced with minimum two continuous bars top and bottom
4. Transverse ties are provided in grade beam to support top longitudinal bars (optional)
5. Dowels are provided between grade beam and CMU wall with adequate development and compression splice lengths, respectively. Bar sizes to match CMU wall bar size and spacing
6. Top of grade beam elevation does not interfere with bottom of slab-on-ground elevation
7. Exterior grade is sloped away from structure
8. Bar cover is provided per Section 20.5.1.3
9. Granular fill to be provided per geotechnical report
10. Check face of grade beam if face bars are necessary
11. Remove "NOTES TO DESIGN PROFESSIONAL" before placing schedule in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles*:

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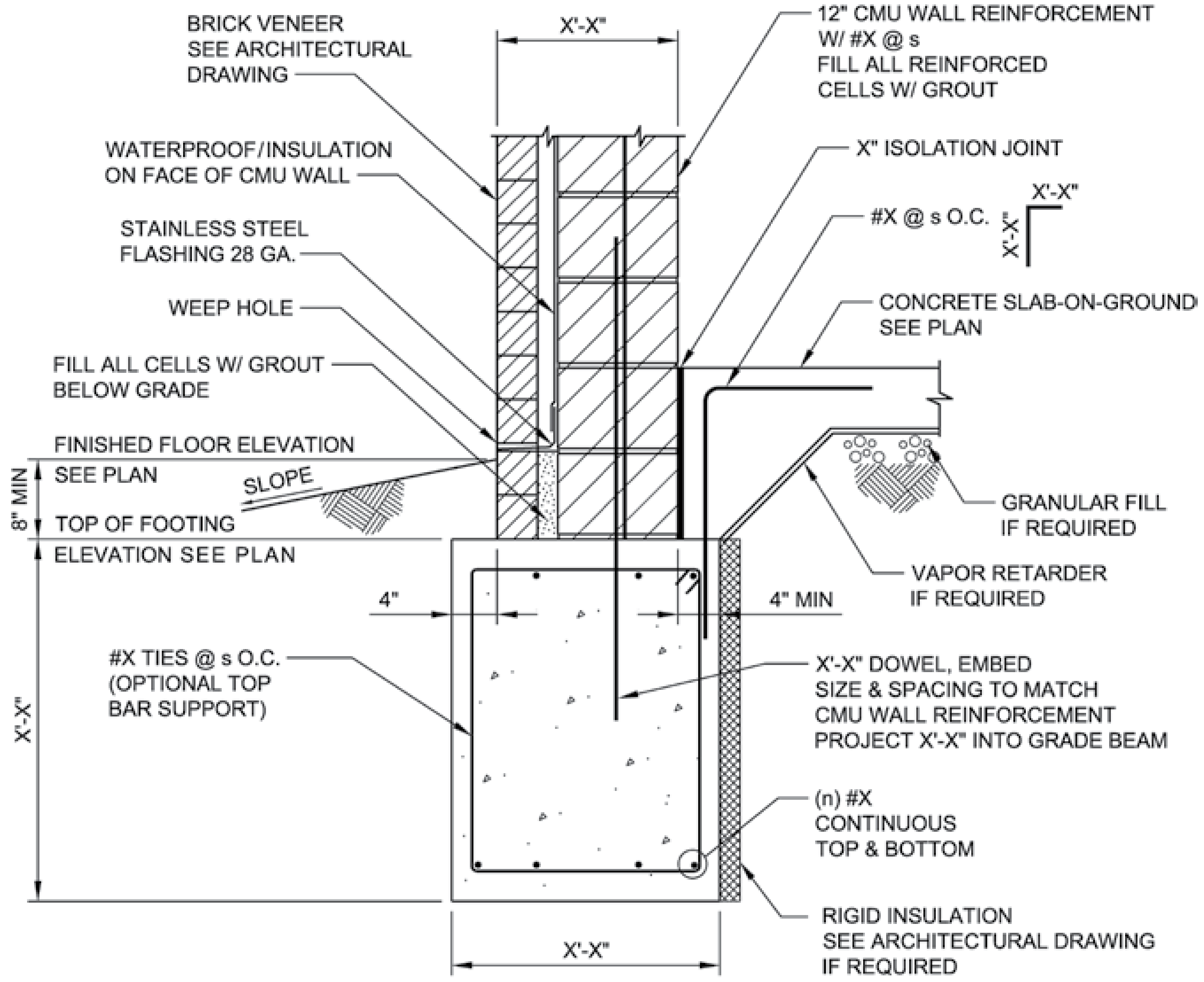
*Refer to Section 3 for articles

FND-112



NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

GRADE BEAM SUPPORTING CMU AND BRICK WALL

FIGURE FND-112: GRADE BEAM SUPPORTING CMU AND BRICK WALL

The design professional shall review the following checklist and
incorporate project-specific requirements into the details

INTENDED USE

Grade beam supported by soil

Grade beam supports CMU bearing plus brick wall

NOT INTENDED FOR (OPTIONAL)

Grade walls that are supported by adjacent column foundation or other foundation

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. For stiff soil, excavation can be vertical; grade beam walls may be formed by soil
2. For soft soil, slope excavation to 2:1 (2 horizontal to 1 vertical)
3. Grade beam is reinforced with minimum two continuous bars top and bottom
4. Transverse ties are provided in grade beam to support top longitudinal bars (optional)
5. Dowels are provided between grade beam and CMU wall with adequate development and compression splice lengths, respectively. Bar sizes to match CMU wall bar size and spacing
6. Top of grade beam elevation does not interfere with bottom of slab-on-ground elevation
7. Dowel length in the grade beam is identified in the detail
8. Exterior grade is sloped away from structure
9. Bar cover is provided per Section 20.5.1.3
10. Granular fill to be provided per geotechnical report
11. Check face of grade beam if face bars are necessary
12. Remove "NOTES TO DESIGN PROFESSIONAL" before placing schedule in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles[*]:

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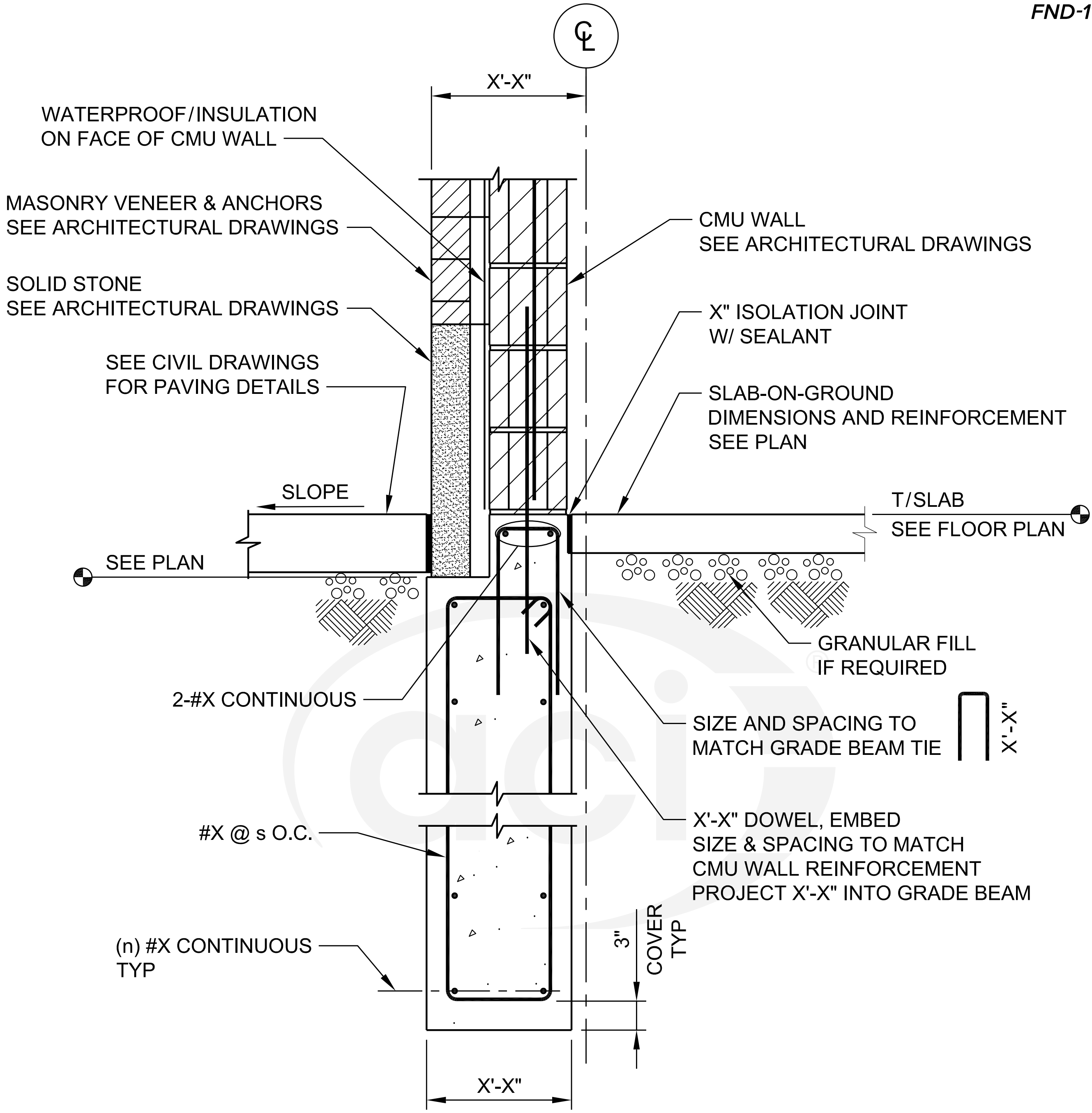
[*] Refer to Section 3 for articles

FND-113



NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

GRADE BEAM SUPPORTING CMU AND BRICK WALL

FIGURE FND-113: GRADE BEAM SUPPORTING CMU AND BRICK WALL

The design professional shall review the following checklist and incorporate project-specific requirements into the details

INTENDED USE

Grade beam supported by adjacent column foundations or other foundations

Grade beam supports flexural and shear loading supporting CMU and brick wall

Bottom elevation of CMU and brick walls are not the same; top of grade beam elevation has a step up in elevation

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. For stiff soil, excavation can be vertical; grade beam walls may be formed by soil
2. For soft soil, slope excavation to 2:1 (2 horizontal to 1 vertical)
3. Grade beam is reinforced with minimum two continuous bars top and bottom
4. Transverse ties are provided in grade beam to support top longitudinal bars (optional)
5. Dowels are provided between grade beam and CMU wall with adequate development and compression splice lengths, respectively. Bar sizes to match CMU wall bar size and spacing
6. Top of grade beam elevation does not interfere with bottom of slab-on-ground elevation
7. Dowel length in the grade beam is identified in the detail
8. Exterior grade/concrete sidewalk is sloped away from structure
9. Bar cover is provided per Section 20.5.1.3
10. Granular fill to be provided per geotechnical report
11. Check face of grade beam if face bars are necessary
12. Remove “NOTES TO DESIGN PROFESSIONAL” before placing schedule in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles*:

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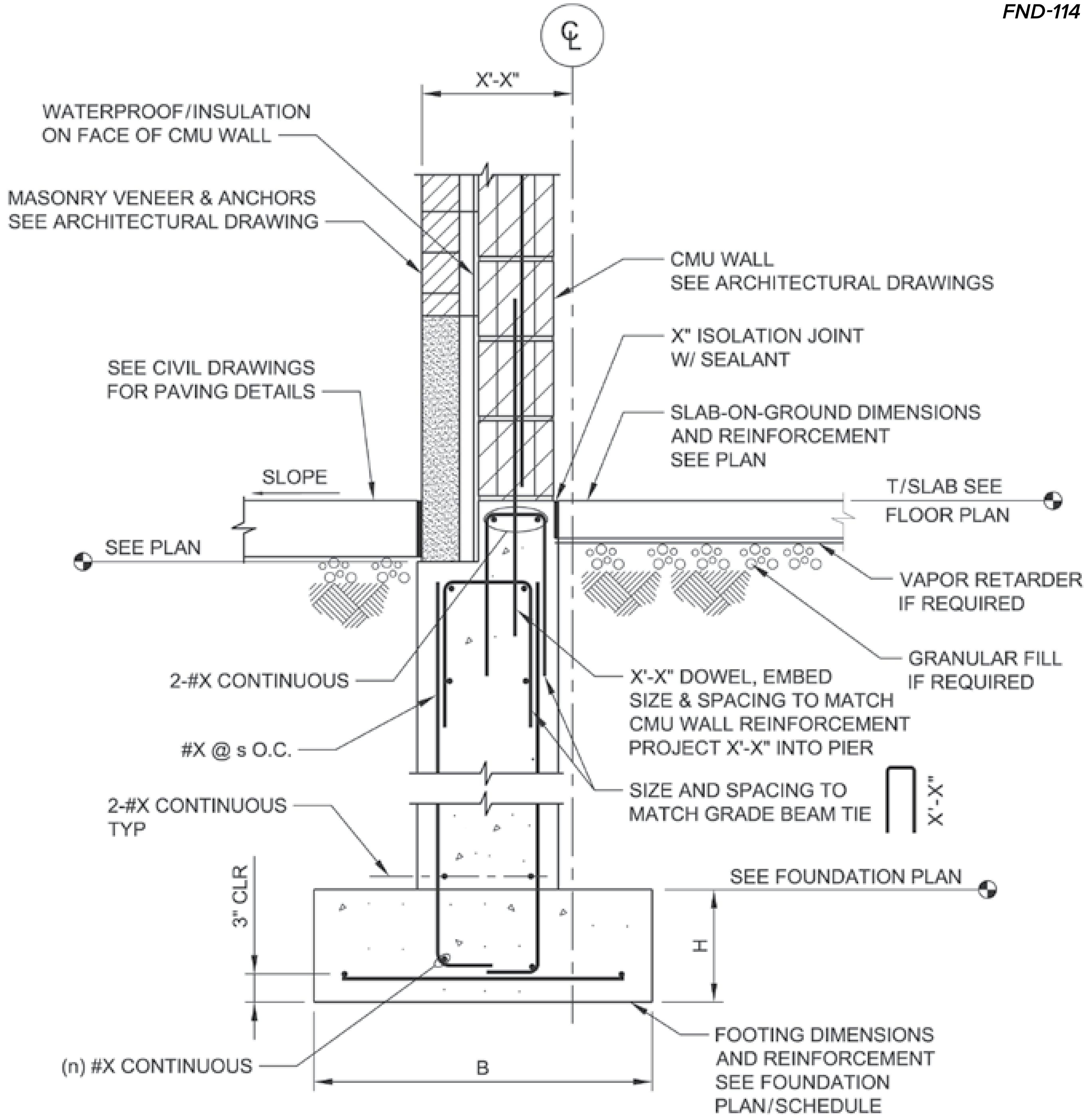
*Refer to Section 3 for articles

FND-114



NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

FOOTING SUPPORTING CMU AND BRICK WALL

FIGURE FND-114: FOOTING SUPPORTING CMU WALL AND BRICK

The design professional shall review the following checklist and incorporate project-specific requirements into the details

INTENDED USE

Concrete stem wall supported by soil

Concrete stem wall supports CMU wall and brick wall

Bottom elevation of CMU and brick walls are not the same; top of grade beam elevation has a step up in elevation

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. For stiff soil, excavation can be vertical
2. For soft soil, slope excavation to 2:1 (2 horizontal to 1 vertical)
3. Footing dimension and reinforcement per foundation plan or schedule
4. Dowels are provided between pier and CMU wall with adequate development length in each; dowel bar size to match CMU wall bar size and spacing
5. Dowel length in pier is identified in the detail
6. Pier reinforcement extends into footing and hooked below footing longitudinal bars as shown in the detail
7. Exterior grade/concrete sidewalk is sloped away from structure
8. Bar cover is provided per Section 20.5.1.3
9. Granular fill to be provided per geotechnical report
10. Check face of pier if face bars are necessary
11. Remove “NOTES TO DESIGN PROFESSIONAL” before placing schedule in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles*:

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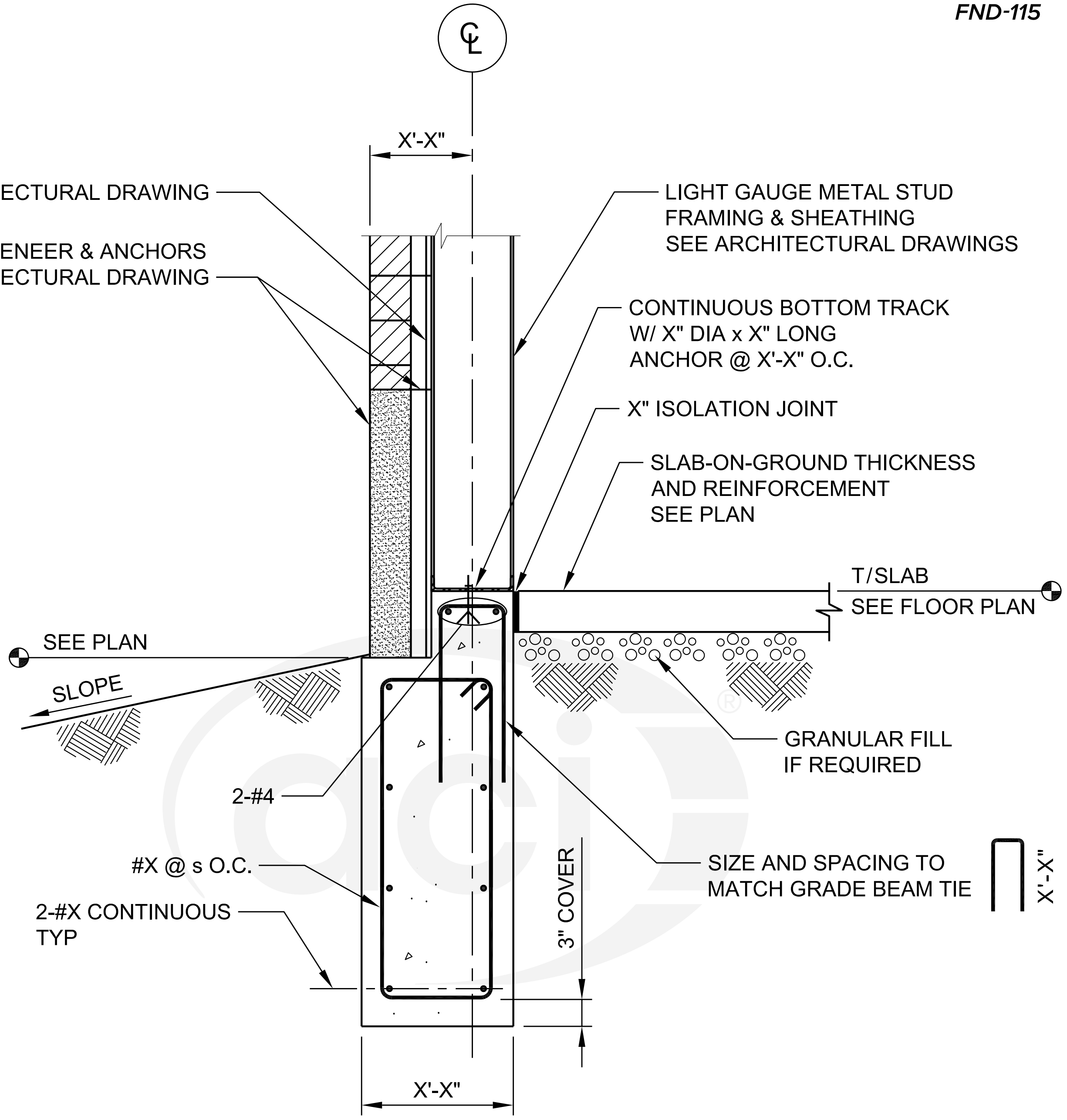
*Refer to Section 3 for articles

FND-115



NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE
INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

GRADE BEAM SUPPORTING LIGHT GAUGE METAL STUD FRAMING AND BRICK WALL

FIGURE FND-115: GRADE BEAM SUPPORTING LIGHT GAUGE METAL STUD FRAMING AND BRICK WALL

The design professional shall review the following checklist and incorporate project-specific requirements into the details

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INTENDED USE

Concrete stem wall supported by soil

Concrete stem wall supports stud wall and brick wall

Bottom elevation of stud and brick walls are not the same; top of grade beam elevation has a step up in elevation

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. For stiff soil, excavation can be vertical
2. For soft soil, slope excavation to 2:1 (2 horizontal to 1 vertical)
3. Grade beam is reinforced with minimum two continuous bars top and bottom
4. Transverse ties are provided in grade beam to support top longitudinal bars (optional)
5. Top of grade beam elevation does not interfere with bottom of slab-on-ground elevation
6. Exterior grade/concrete sidewalk is sloped away from structure
7. Bar cover is provided per Section 20.5.1.3
8. Granular fill to be provided per geotechnical report
9. Check face of grade beam if face bars are necessary
10. Remove “NOTES TO DESIGN PROFESSIONAL” before placing schedule in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles[*]: 15

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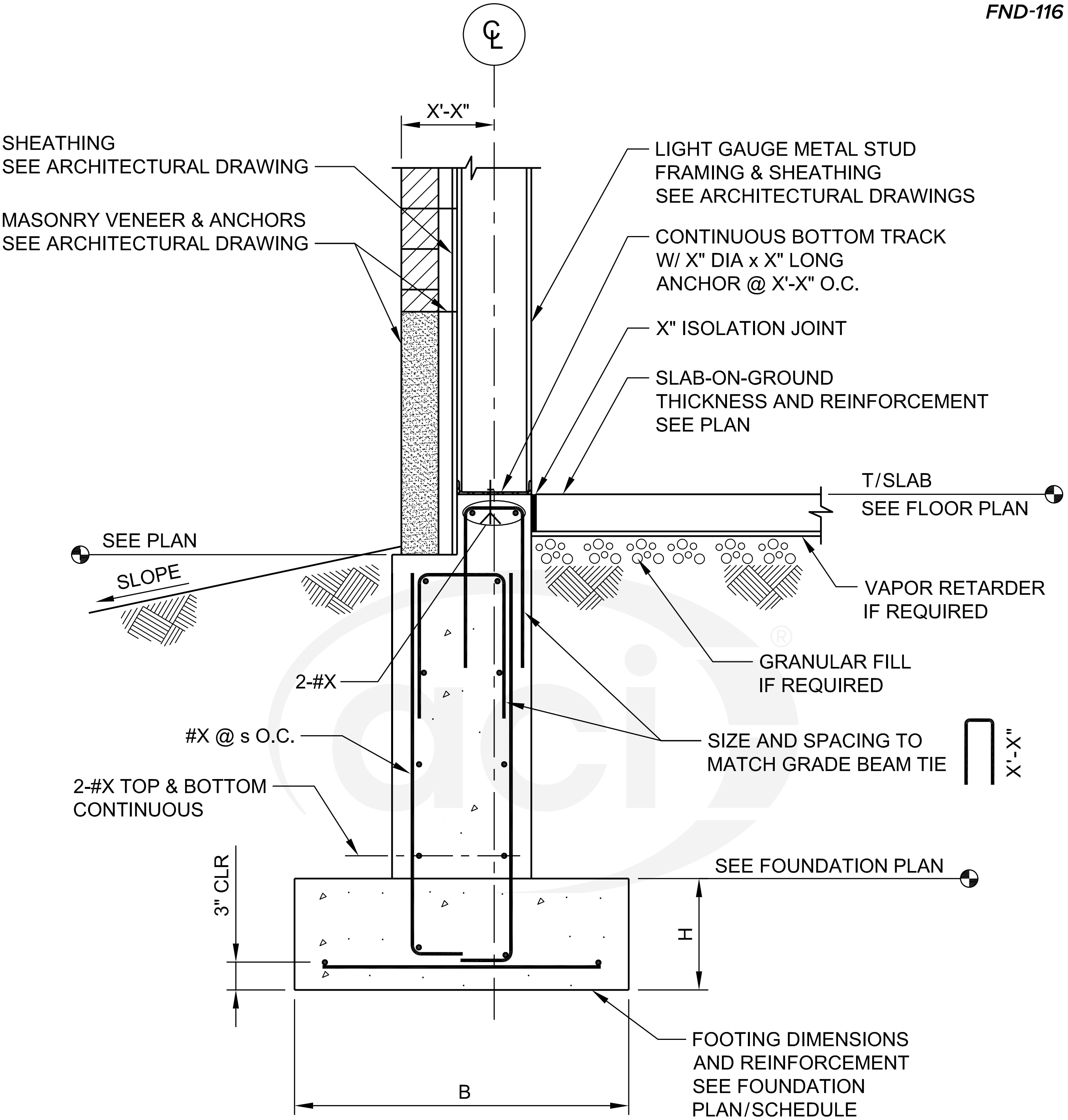
[*] Refer to Section 3 for articles

FND-116



NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

FOOTING SUPPORTING LIGHT GAUGE METAL STUD FRAMING AND BRICK WALL

FIGURE FND-116: FOOTING SUPPORTING LIGHT GAUGE METAL STUD FRAMING AND BRICK WALL

The design professional shall review the following checklist and
incorporate project-specific requirements into the details

INTENDED USE

Concrete stem wall supported by soil

Concrete stem wall supports stud and brick wall

Bottom elevation of stud and brick walls are not the same; top of grade beam elevation has a step-up in elevation

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. For stiff soil, excavation can be vertical
2. For soft soil, slope excavation to 2:1 (2 horizontal to 1 vertical)
3. Footing dimension and reinforcement per foundation plan or schedule
4. Pier reinforcement extends into footing and hooked below footing longitudinal bars as shown in the detail
5. Exterior grade/concrete sidewalk is sloped away from structure
6. Bar cover is provided per Section 20.5.1.3
7. Granular fill to be provided per geotechnical report
8. Check face of grade beam if face bars are necessary
9. Remove "NOTES TO DESIGN PROFESSIONAL" before placing schedule in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles[*]:

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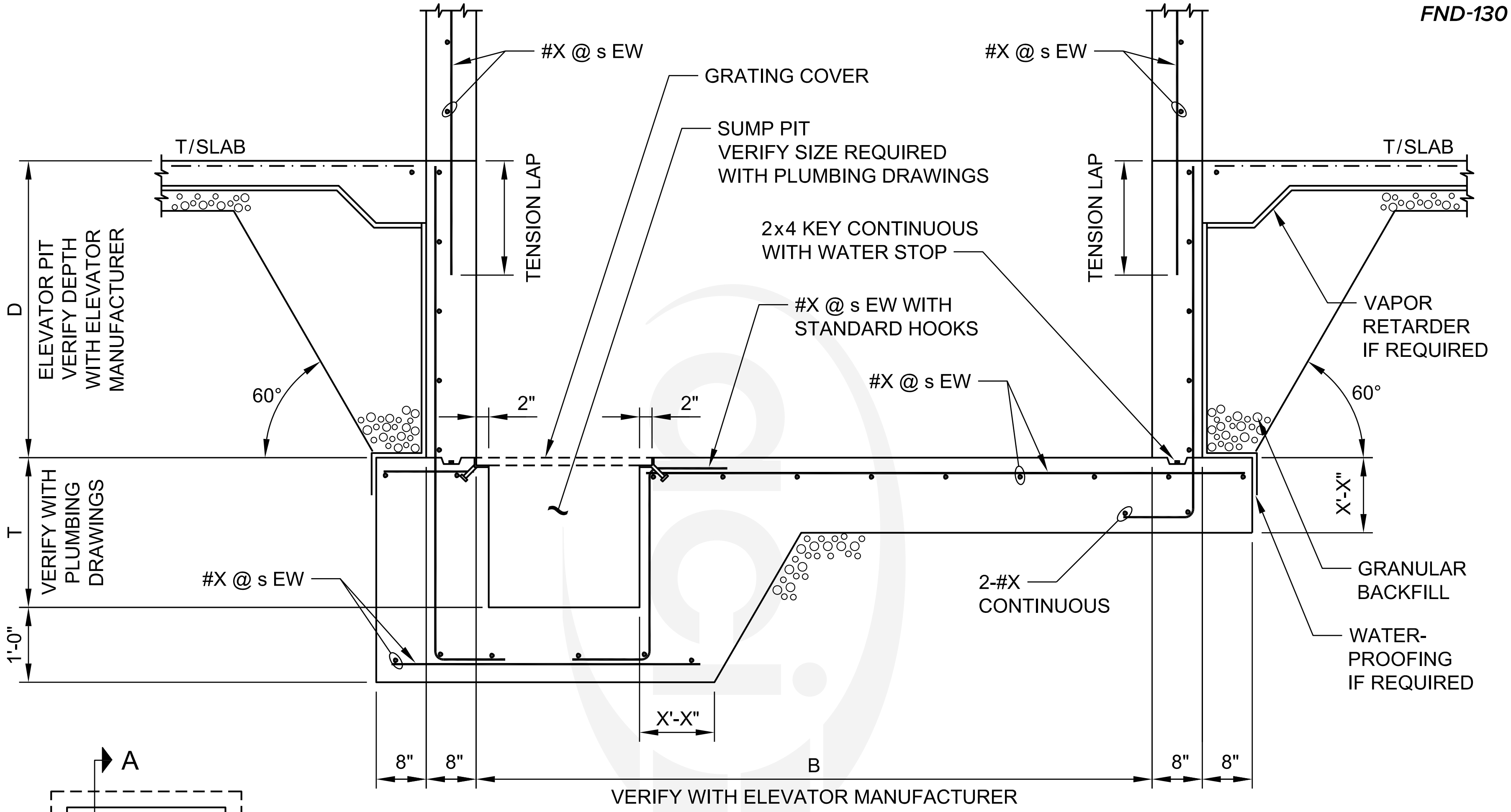
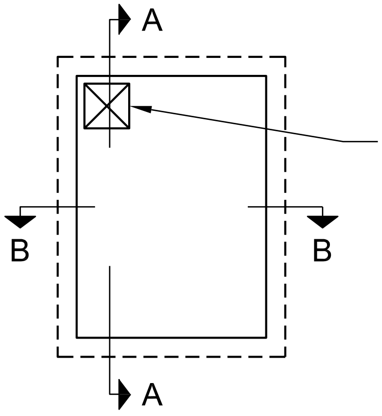
[*] Refer to Section 3 for articles



SECTION A-A



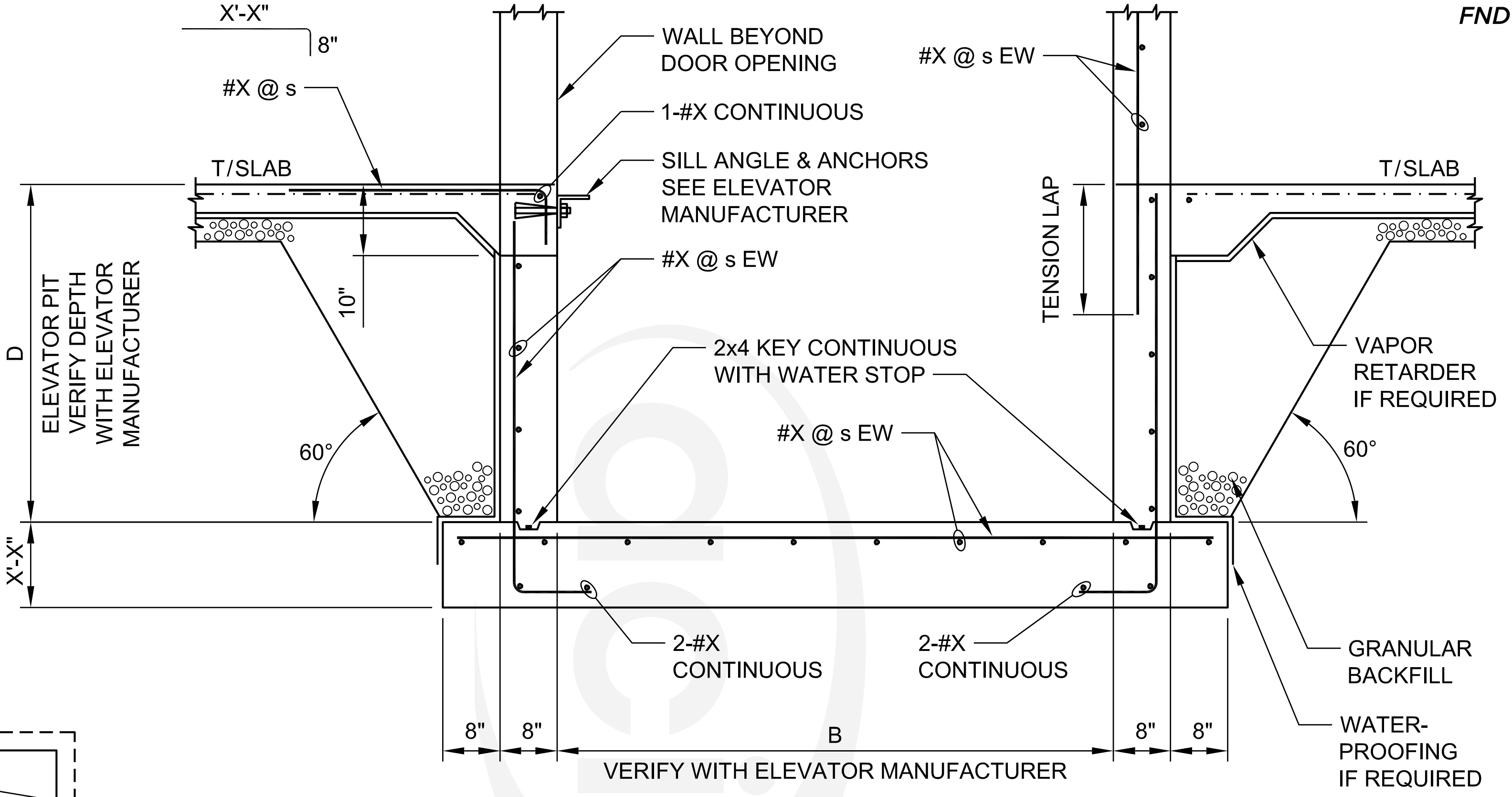
NOTE TO DESIGN PROFESSIONAL:
CONFIRM WITH PIT MANUFACTURER
FOR LOCATION

PLAN

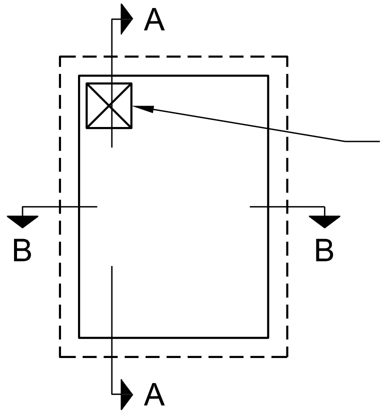
NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE
INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

ELEVATOR PIT WITH CONCRETE WALL

FND-131



SECTION B-B



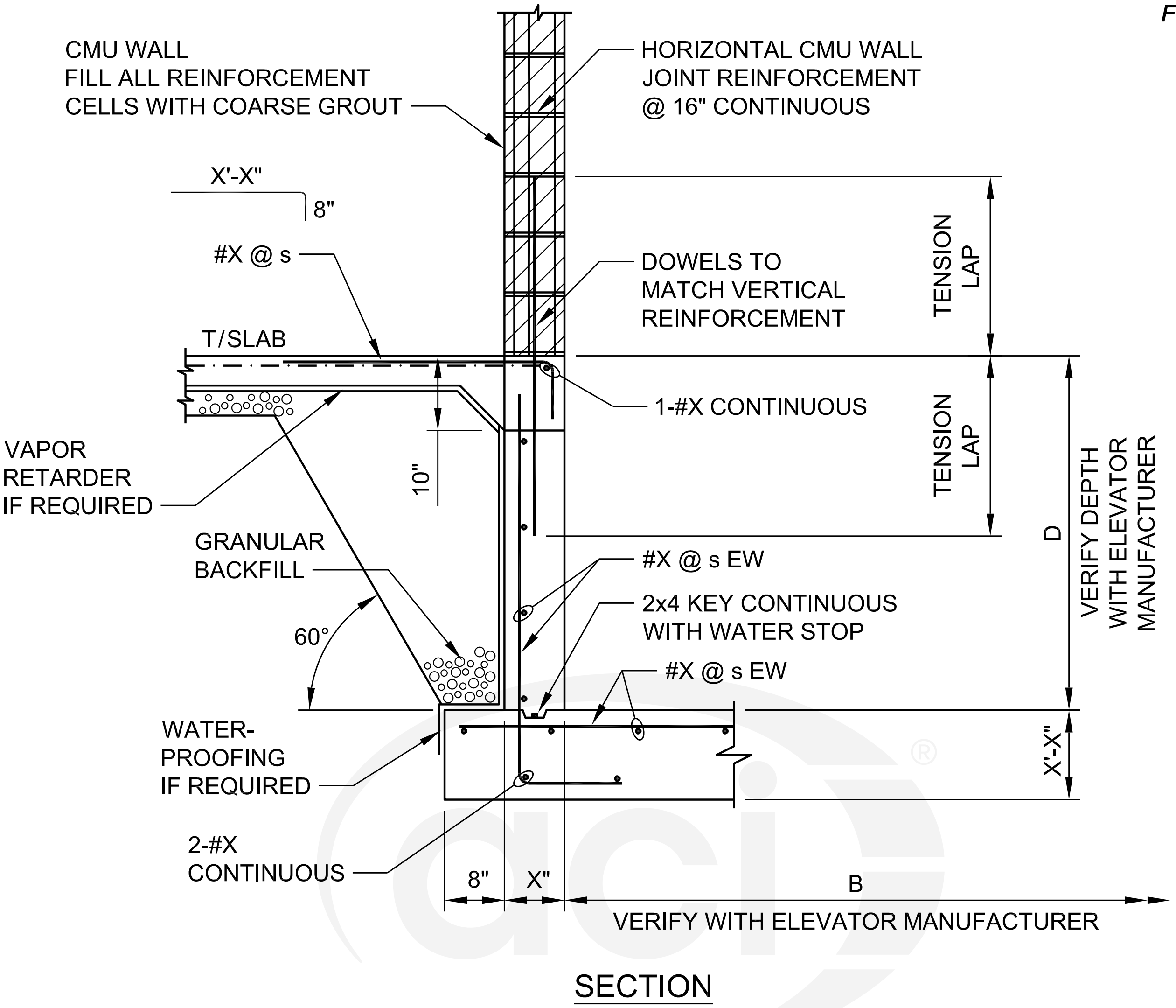
NOTE TO DESIGN PROFESSIONAL:
CONFIRM WITH PIT MANUFACTURER
FOR LOCATION

PLAN

NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

ELEVATOR PIT WITH CONCRETE WALL

FND-132



SECTION

NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

ELEVATOR PIT WITH CMU WALL

FIGURE FND-130, 131, AND 132: ELEVATOR PIT

The design professional shall review the following checklist and incorporate project-specific requirements into the details

INTENDED USE

Elevator pit cross section for hydraulically operated elevators

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Inside pit dimensions are coordinated with architectural drawings or elevator manufacturer's drawings
2. Adjacent foundations have been lowered or combined with pit mat to prevent surcharge on elevator pit or undermining of foundation
3. The elevator pit floor and walls have been designed to resist the forces from the elevator as provided by the elevator manufacturer. Additional steel support may be required to support the rails due to earthquake forces
4. Vertical elevator pit reinforcement is extended into the CMU or concrete elevator shaft wall
5. Sill requirements are coordinated with architectural drawings
6. Dowels between elevator shaft wall and slab-on-ground are needed
7. Bar cover is provided per Section 20.5.1.3
8. Remove "NOTES TO DESIGN PROFESSIONAL" before placing schedule in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles*: 5, 6

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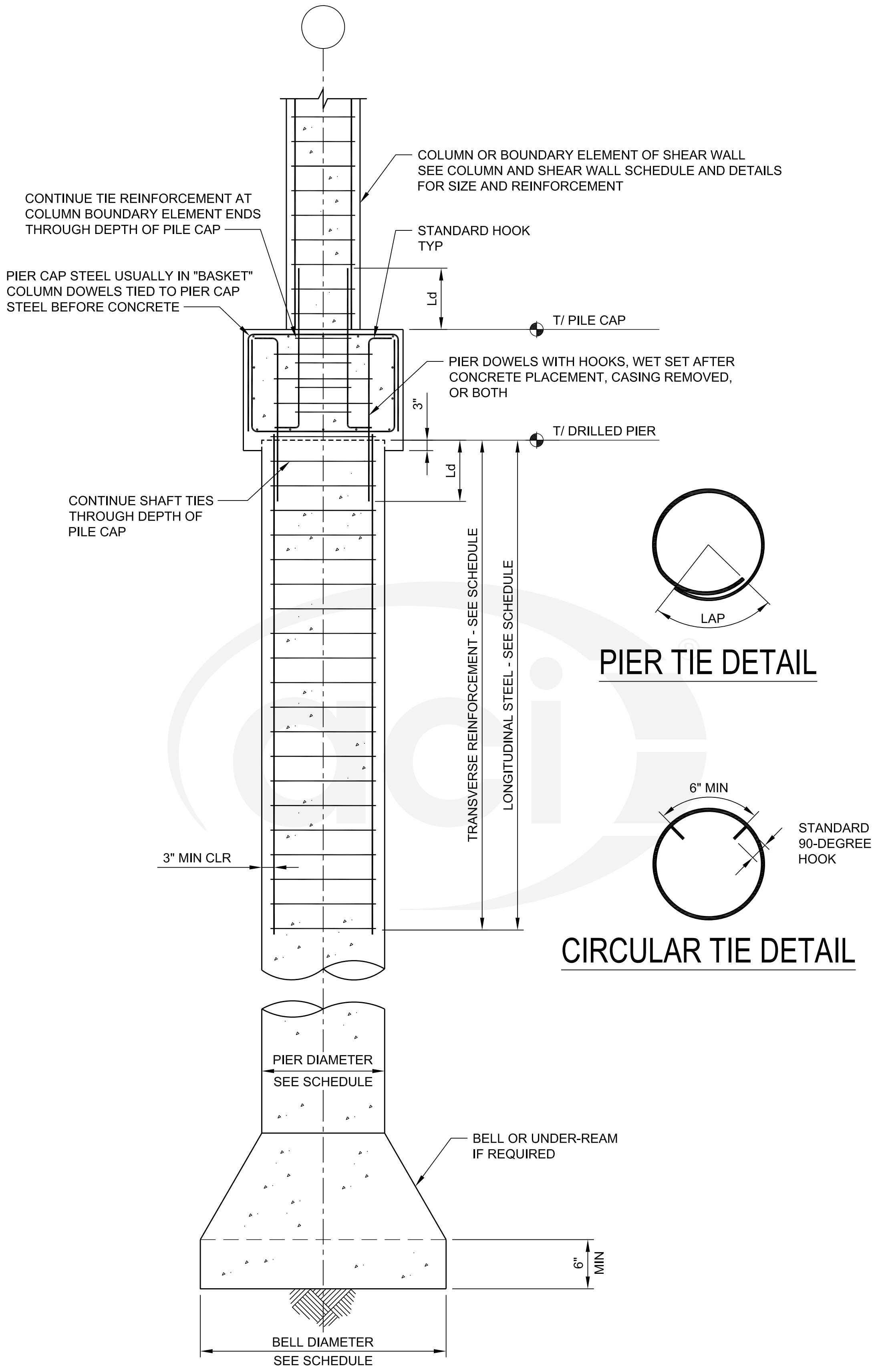
*Refer to Section 3 for articles



PIER TIE DETAIL

CIRCULAR TIE DETAIL

NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

DRILLED PIER

FIGURE FND-150: DRILLED PIER

The design professional shall review the following checklist and
incorporate project-specific requirements into the details

INTENDED USE

Single drilled pier or caisson cast-in-place with pile cap or formed pier

NOT INTENDED FOR (OPTIONAL)

Prestressed precast pile

Portions of deep foundation not in air, water, or soils not capable of providing adequate lateral restraint

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Column or pedestal may be doweled directly to drilled pier without a pile cap if round dimensions of driller pier work with the square or rectangular size of column. All of column cross section is to be supported by piers
2. Deep foundation is laterally supported over its entire height; see geotechnical report
3. Concrete side cover between longitudinal bars and side wall is per Section 20.5.1.3.4
4. Cut off top of longitudinal bars are developed in tension into pile cap in accordance with Section 18.13.6
5. Longitudinal bars are arranged in a symmetrical pattern
6. Longitudinal bars minimum spacing is the greater of 4 in. and four times maximum coarse aggregate size
7. Transverse reinforcement around shaft longitudinal bars are circular ties either with or without 90-degree hooks, spirals are also sometimes used
8. Lap splices for spiral transverse reinforcement is in accordance with Section 25.7.3.6
9. Place first transverse tie at top of deep foundation not less than 3 in. from top elevation
10. Determine if bell, or under-reamed, piers are to be used; show on contract documents
11. Determine and show detail if pier shaft is to embed into rock; define depth
12. Remove “NOTES TO DESIGN PROFESSIONAL” before placing schedule in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles[*]: 28

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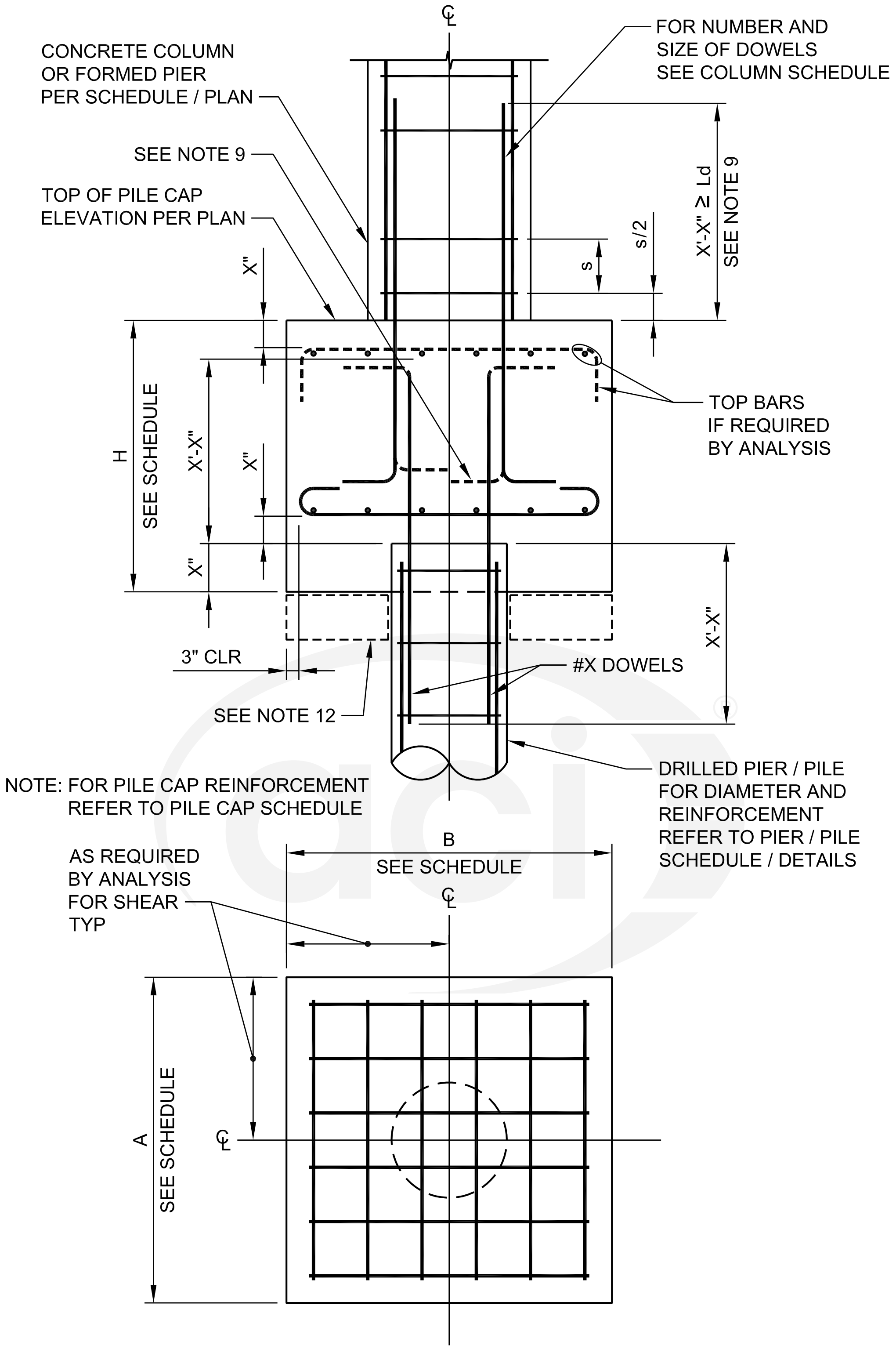
[*] Refer to Section 3 for articles

FND-161



NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST, MODIFY, AND DELETE REFERENCES TO NOTES
BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

TYPE I - ONE DRILLED PIER OR PILE CAP

FIGURE FND-161: ONE DRILLED PIER/PILE CAP

The design professional shall review the following checklist and
incorporate project-specific requirements into the details

INTENDED USE

Pile cap supporting column – pile cap supported by one drilled pier or pile

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Top of pile cap elevations is provided on drawings
2. Pile cap minimum depth satisfies Section 13.4.6.1
3. Bar cover is provided per Section 20.5.1.3
4. Bottom bars in pile cap matches bar sizes and spacing in pile cap schedule
5. Dowels from pile cap into formed column or formed column pier are shown
6. Extended dowels into column or formed pier above top surface of pile cap are the greater of tension development of dowels or tension lap splice of column bars if moment is transferred
7. Development lengths satisfy Section 25.4
8. Dowels between deep foundation (pile) member and pile cap are developed in tension, and for structures assigned to intermediate or special moment frames (SDC C through F), the anchorage to the pile cap is in accordance with Section 18.13.6
9. Column dowels are oriented toward the column center if located in SDC C through F per Section 18.13.2.3
10. Bar details between pile cap and concrete column or column pedestal:
    a. Top surface of pile cap contact area with column or column pedestal is roughened by float finish or vibrator finish. In areas not accessible for a float, such as between column dowels, a float finish is not needed and a vibrator finish is adequate
    b. Column or column pedestal longitudinal bars can be placed on top of pile cap
    c. For column or column pedestal ties, place first tie 1/2 calculated column or column pedestal tie spacing above top of pile cap
    d. Pile cap dowel bar length from column or column pedestal, l_2, satisfies $l_2 \leq (h - 3 \text{ in.} - 2d_b)$
    e. If $l_2 > (h - 9 \text{ in.} - 2d_b)$, then make one of the following changes:
        i. Increase pile cap thickness such that $l_2 \leq (h - 9 \text{ in.} - 2d_b)$
        ii. Hook bars (standard 90-degree hook)
        iii. For large size column or column pedestal longitudinal bars, use two dowels for every longitudinal bar in supporting column, d_1, such that the area of the two bars is greater than the original longitudinal bar in the column
11. As a good practice, top elevations of all pile or drilled pier extends into the bottom of the pile cap a minimum distance of 6 in. for steel piles and 4 in. for concrete pile and drilled pier
12. Provide void forms, if required
13. Remove "NOTES TO DESIGN PROFESSIONAL" before placing schedule in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles[*]: 5, 22, 23

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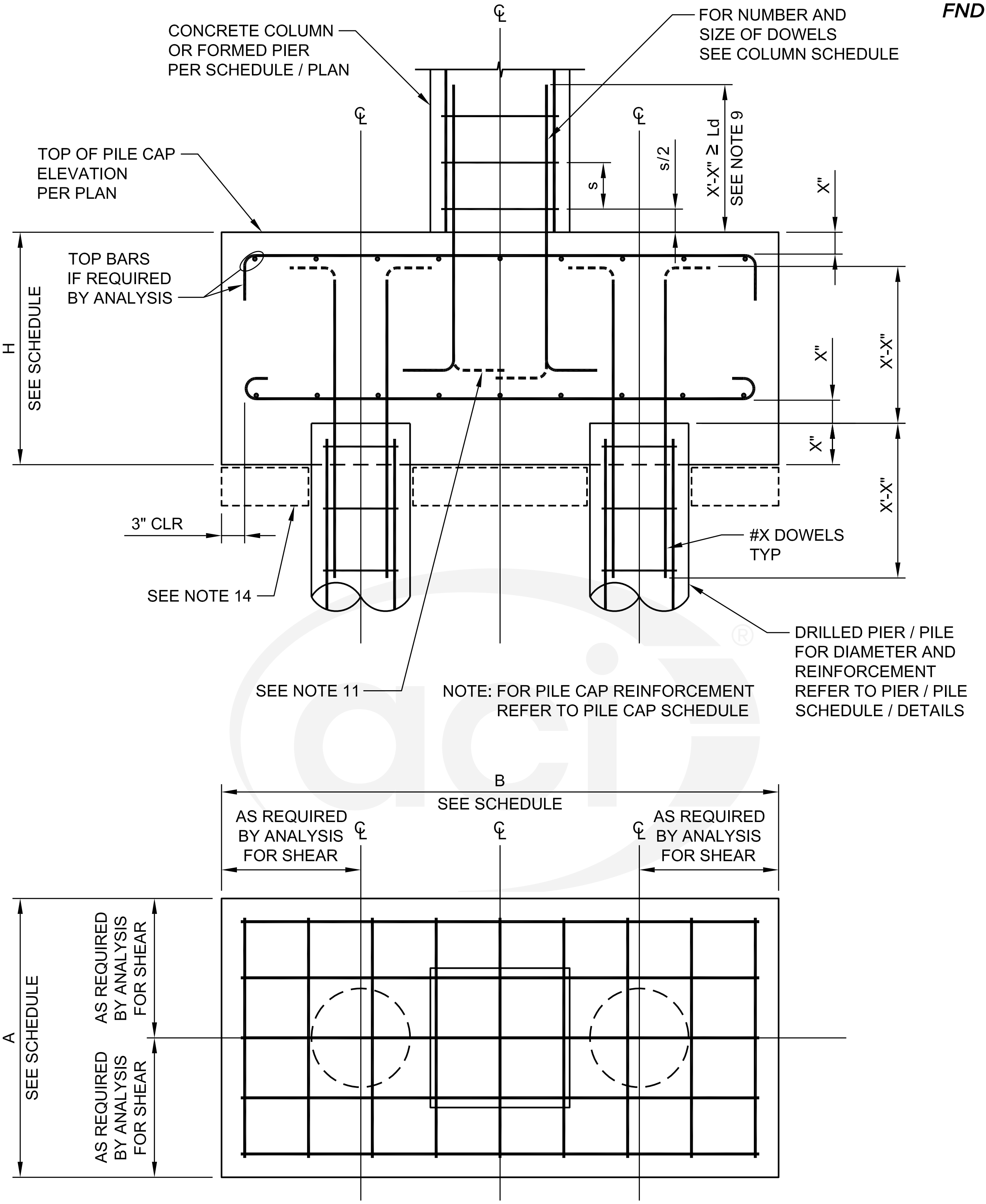
[*] Refer to Section 3 for articles

FND-162



NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST, MODIFY, AND DELETE REFERENCES TO NOTES
BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

TYPE II - TWO DRILLED PIER OR PILE CAP

FIGURE FND-162: TWO DRILLED PIER/PILE CAP

The design professional shall review the following checklist and
incorporate project-specific requirements into the details

INTENDED USE

Pile cap supporting column – pile cap supported by two drilled piers or piles

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Top of pile cap elevations is provided on drawings
2. Pile cap minimum depth satisfies Section 13.4.6.1
3. Bar cover is provided per Section 20.5.1.3
4. Bottom bars in pile cap matches bar sizes and spacing in pile cap schedule
5. Pile cap top bars are provided, if required
6. Dowels from pile cap into formed column or formed column pier are shown
7. Extended dowels into column or pier/pedestal above top surface of pile cap are the greater of tension development of dowels or tension lap splice of column bars if moment is transferred
8. Development lengths satisfy Section 25.4
9. Pile cap bars are developed beyond face of column or column pedestal; otherwise provide hooks
10. Dowels between deep foundation (pile) member and pile cap are developed in tension, and for structures assigned to intermediate or special moment frames (SDC C through F), the anchorage to the pile cap is in accordance with Section 18.13.6
11. Column dowels are oriented toward the column center if located in SDC C through F per Section 18.13.2.3
12. Bar details between pile cap and concrete column or column pedestal:
    a. Top surface of pile cap contact area with column or column pedestal is roughened by float finish or vibrator finish. In areas not accessible for a float, such as between column dowels, a float finish is not needed and a vibrator finish is adequate
    b. Column or column pedestal longitudinal bars can be placed on top of pile cap
    c. For column or column pedestal ties, place first tie 1/2 calculated column or column pedestal tie spacing above top of pile cap
    d. Pile cap dowel bar length from column or column pedestal, l_2, satisfies $l_2 \leq (h - 3 \text{ in.} - 2d_b)$
    e. If $l_2 > (h - 9 \text{ in.} - 2d_b)$, then make one of the following changes:
        i. Increase pile cap thickness such that $l_2 \leq (h - 9 \text{ in.} - 2d_b)$
        ii. Hook bars (standard 90-degree hook)
        iii. For large size column or column pedestal longitudinal bars, use two dowels for every longitudinal bar in supporting column, d_1, such that the area of the two bars is greater than the original longitudinal bar in the column
13. As a good practice, top elevations of all piles or drilled piers extend into the bottom of the pile cap a minimum distance of 6 in. for steel piles and 4 in. for concrete piles and drilled piers
14. Provide void forms if required
15. Remove "NOTES TO DESIGN PROFESSIONAL" before placing schedule in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles[*]: 5, 22, 23

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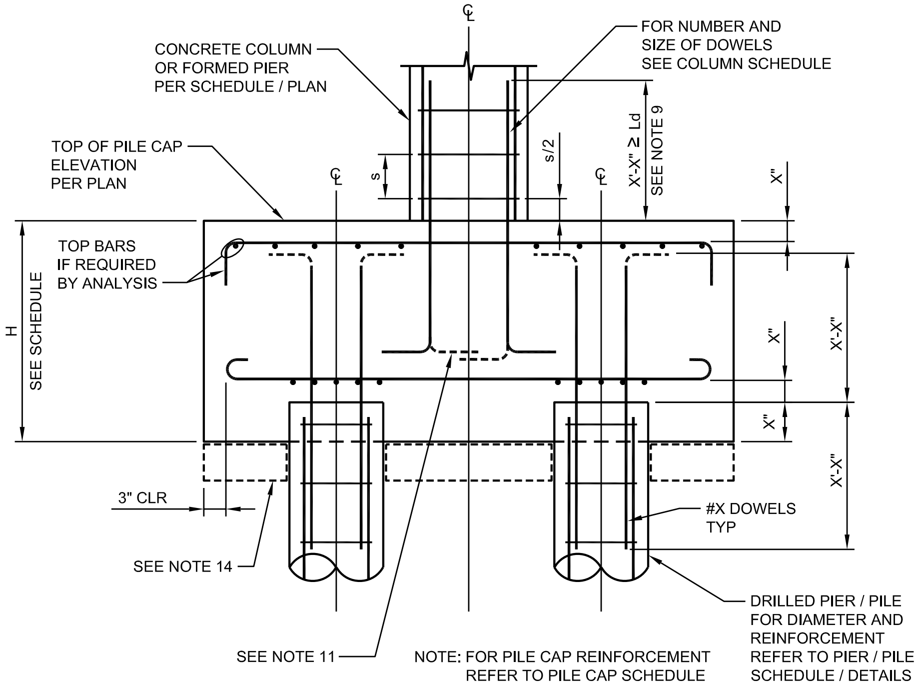
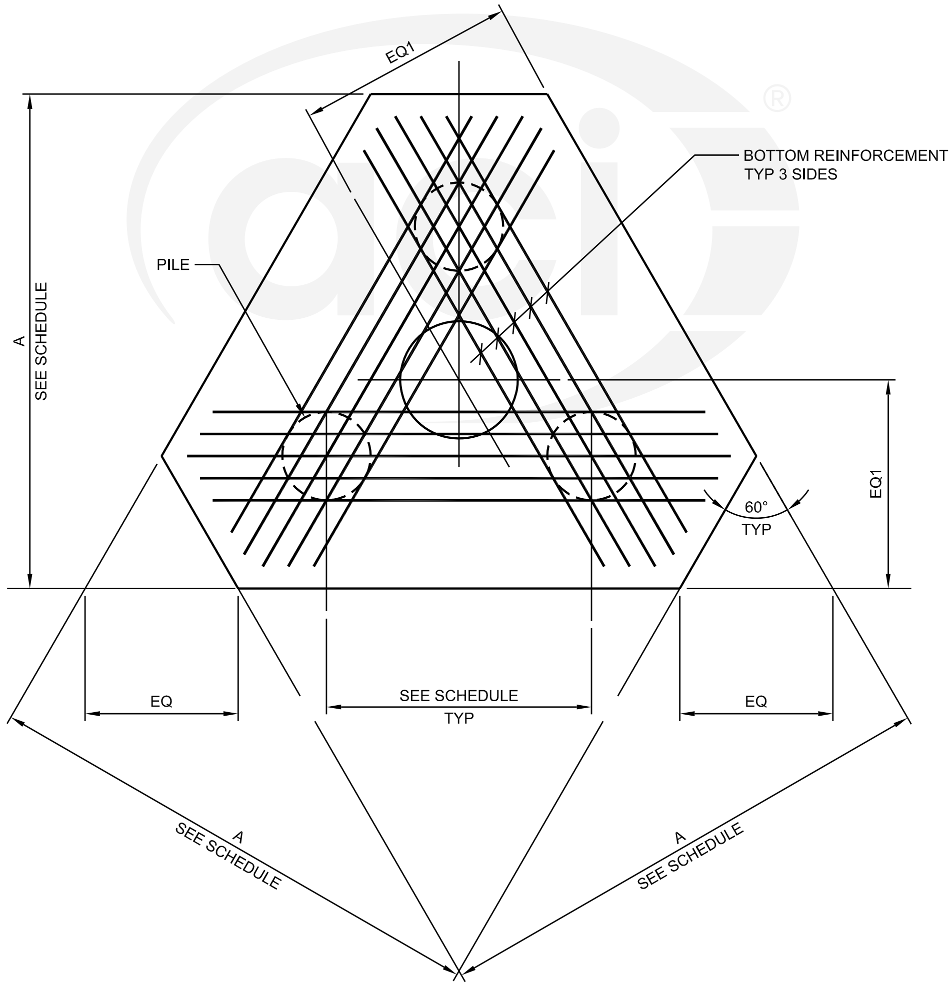
[*] Refer to Section 3 for articles

FND-163





NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST, MODIFY, AND DELETE REFERENCES TO NOTES
BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

TYPE III - THREE DRILLED PIER OR PILE CAP

FIGURE FND-163: THREE DRILLED PIER/PILE CAP

The design professional shall review the following checklist and
incorporate project-specific requirements into the details

INTENDED USE

Pile cap supporting column – pile cap supported by three drilled piers or piles

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Top of pile cap elevations is provided on drawings
2. Pile cap minimum depth satisfies Section 13.4.6.1
3. Bar cover is provided per Section 20.5.1.3
4. Bottom bars in pile cap matches bar sizes and spacing in pile cap schedule
5. Pile cap top bars are provided, if required
6. Dowels from pile cap into formed column or formed column pier are added
7. Extended dowels into column or formed pier above top surface of pile cap the greater of tension development of dowels or tension lap splice of column bars if moment is transferred
8. Development lengths satisfy Section 25.4
9. Pile cap bars are developed beyond face of column or column pedestal; otherwise provide hooks
10. Dowels between deep foundation (pile) member and pile cap are developed in tension, and for structures assigned to intermediate or special moment frames (SDC C through F), the anchorage to the pile cap is in accordance with Section 18.13.6
11. Column dowels are oriented toward the column center if located in SDC C through F per Section 18.13.2.3
12. Bar details between pile cap and concrete column or column pedestal:
    a. Top surface of pile cap contact area with column or column pedestal is roughened by float finish or vibrator finish. In areas not accessible for a float, such as between column dowels, a float finish is not needed and a vibrator finish is adequate
    b. Column or column pedestal longitudinal bars can be placed on top of pile cap
    c. For column or column pedestal ties, place first tie at 1/2 calculated column or column pedestal tie spacing above top of pile cap
    d. Pile cap dowel bar length from column or column pedestal, l_2, satisfies $l_2 \leq (h - 3\text{ in.} - 2d_b)$
    e. If $l_2 > (h - 9\text{ in.} - 2d_b)$, then make one of the following changes:
        i. Increase pile cap thickness such that $l_2 \leq (h - 9\text{ in.} - 2d_b)$
        ii. Hook bars (standard 90-degree hook)
        iii. For large size column or column pedestal longitudinal bars, use two dowels for every longitudinal bar in supporting column, d_1, such that the area of the two bars is greater than the original longitudinal bar in the column
13. As a good practice, top elevations of all piles or drilled piers extend into the bottom of the pile cap a minimum distance of 6 in. for steel piles and 4 in. for concrete piles and drilled piers
14. Provide void forms if required
15. Remove “NOTES TO DESIGN PROFESSIONAL” before placing schedule in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles[*]: 5, 22, 23

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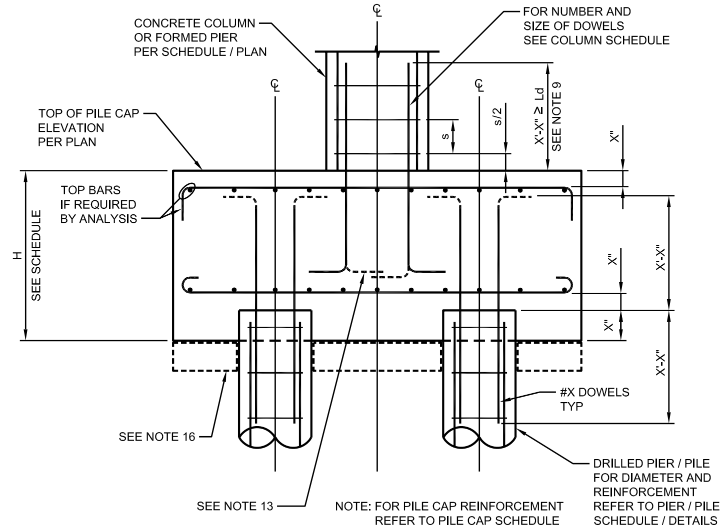
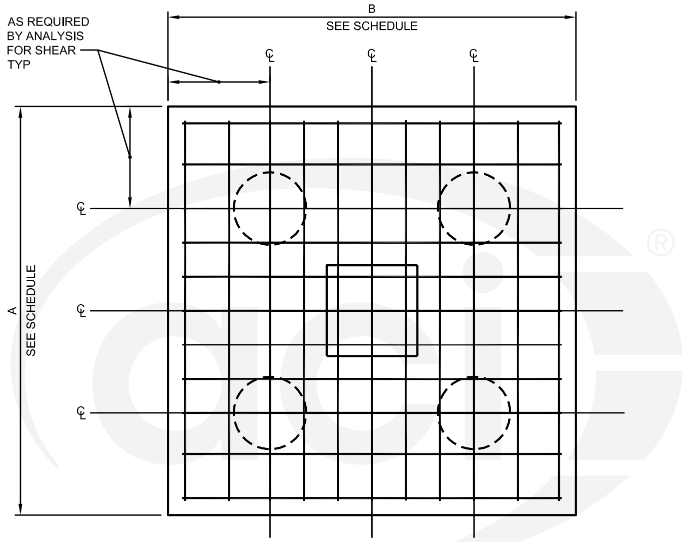
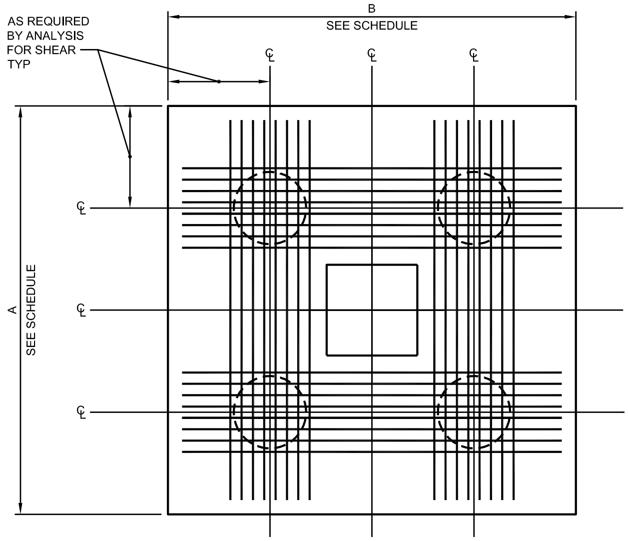
[*] Refer to Section 3 for articles

FND-164





TOP AND BOTTOM REINFORCEMENT



ALTERNATE BOTTOM REINFORCEMENT LAYOUT

NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST, MODIFY, AND DELETE REFERENCES TO NOTES BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

TYPE IV - FOUR DRILLED PIER OR PILE CAP

FIGURE FND-164: FOUR DRILLED PIER/PILE CAP

The design professional shall review the following checklist and
incorporate project-specific requirements into the details

INTENDED USE

Pile cap supporting column – pile cap supported by four drilled piers or piles

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Top of pile cap elevations is provided on drawings
2. Pile cap minimum depth satisfies Section 13.4.6.1
3. Bar cover is provided per Section 20.5.1.3
4. Bottom bars in pile cap matches bar sizes and spacing in pile cap schedule
5. Pile cap top bars are provided, if required
6. Dowels from pile cap into formed column or formed column pier are added
7. Extended dowels into column or formed pier above top surface of pile cap the greater of tension development of dowels or tension lap splice of column bars if moment is transferred
8. Development lengths satisfy Section 25.4
9. Pile cap bars can be uniformly distributed across pile cap, or
10. As an alternate, bottom bars can be centered and concentrated at piles. Ensure that spacing between bars is minimum 3 in., refer to alternate detail
11. Pile cap bars are developed beyond face of column or column pedestal; otherwise provide hooks
12. Dowels between deep foundation (pile) member and pile cap are developed in tension, and for structures assigned to intermediate or special moment frames (SDC C through F), the anchorage to the pile cap is in accordance with Section 18.13.6
13. Column dowels are oriented toward the column center if located in SDC C through F per Section 18.13.2.3
14. Bar details between pile cap and concrete column or column pedestal:
    a. Top surface of pile cap contact area with column or column pedestal is roughened by float finish or vibrator finish. In areas not accessible for a float, such as between column dowels, a float finish is not needed and a vibrator finish is adequate
    b. Column or column pedestal longitudinal bars can be placed on top of pile cap
    c. For column or column pedestal ties, place first tie at 1/2 calculated column or column pedestal tie spacing above top of pile cap
    d. Pile cap dowel bar length from column or column pedestal, l_2, satisfies $l_2 \leq (h - 3 \text{ in.} - 2d_b)$
    e. If $l_2 > (h - 9 \text{ in.} - 2d_b)$, then make one of the following changes:
        i. Increase pile cap thickness such that $l_2 \leq (h - 9 \text{ in.} - 2d_b)$
        ii. Hook bars (standard 90-degree hook)
        iii. For large size column or column pedestal longitudinal bars, use two dowels for every longitudinal bar in supporting column, d_1, such that the area of the two bars is greater than the original longitudinal bar in the column
15. As a good practice, top elevations of all piles or drilled piers extend into the bottom of the pile cap a minimum distance of 6 in. for steel piles and 4 in. for concrete piles and drilled piers
16. Provide void forms if required
17. Remove “NOTES TO DESIGN PROFESSIONAL” before placing schedule in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles[*]: 5, 22, 23

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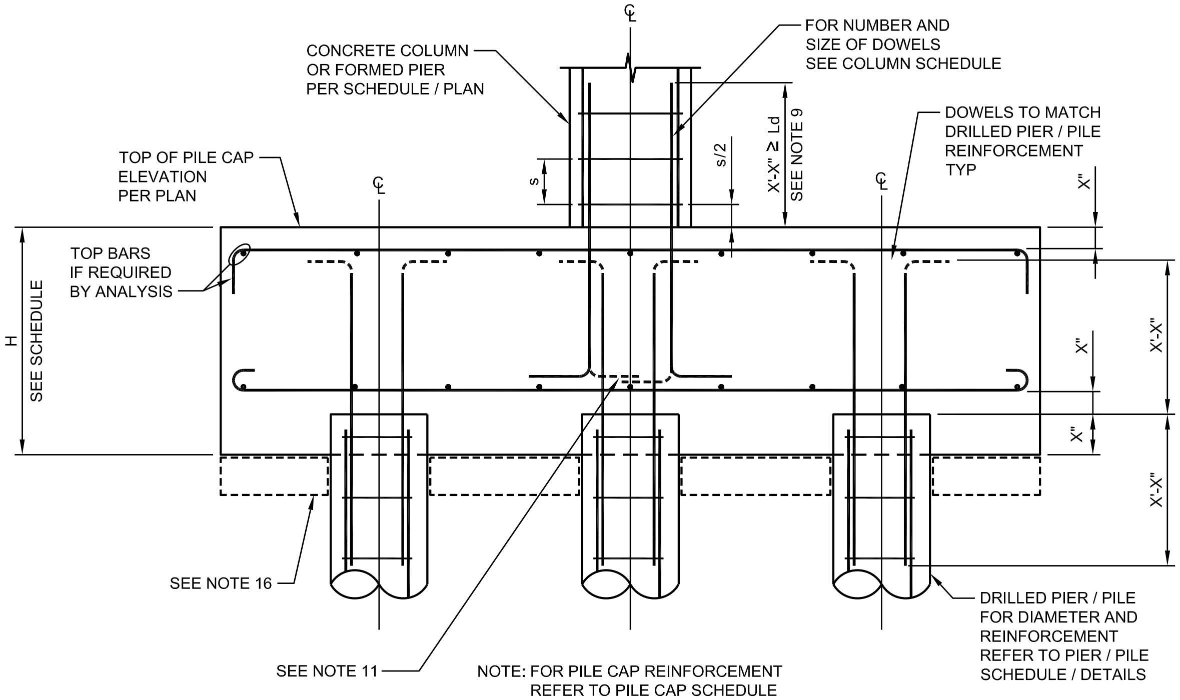
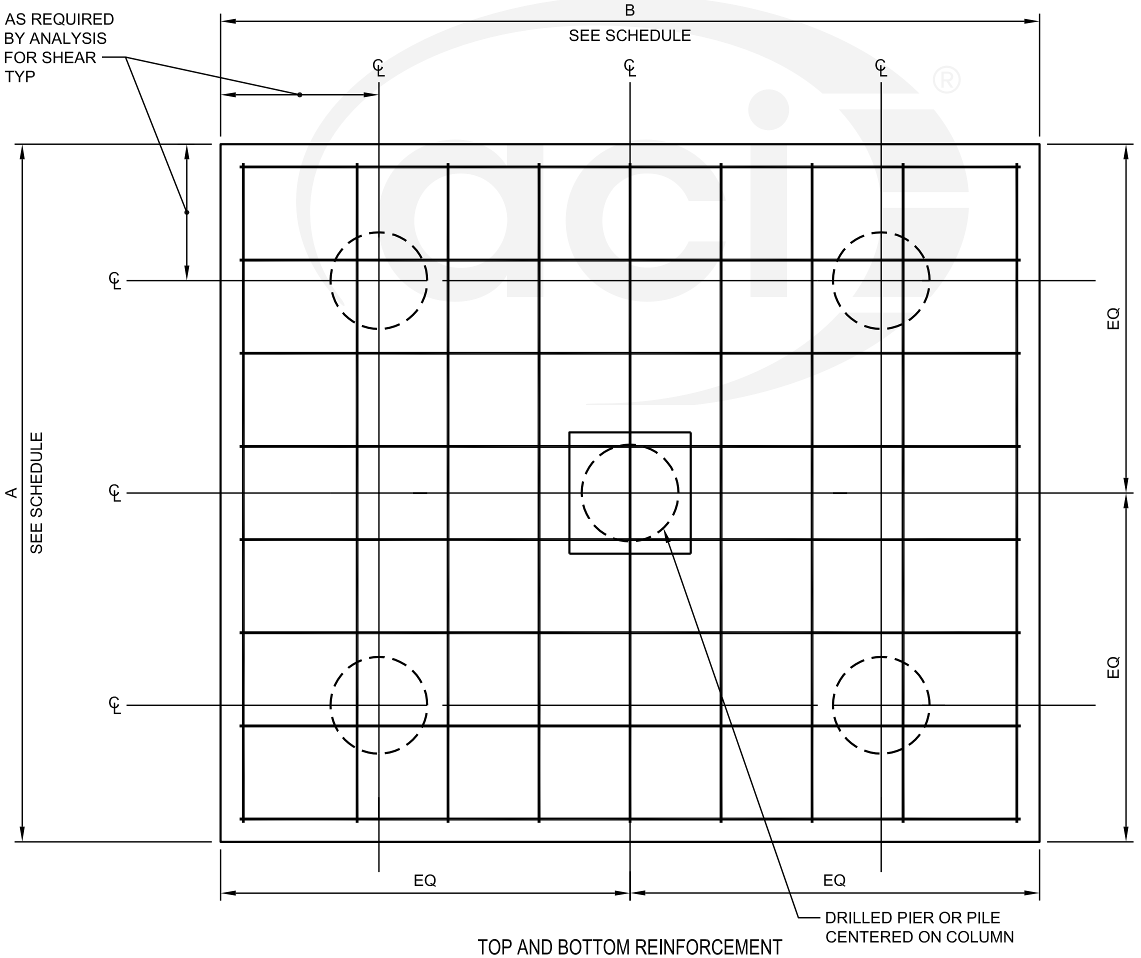
[*] Refer to Section 3 for articles

FND-165



NOTE: FOR PILE CAP REINFORCEMENT REFER TO PILE CAP SCHEDULE



TOP AND BOTTOM REINFORCEMENT

NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST, MODIFY, AND DELETE REFERENCES TO NOTES
BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

TYPE V - FIVE DRILLED PIER OR PILE CAP

FIGURE FND-165: FIVE DRILLED PIER/PILE CAP

The design professional shall review the following checklist and
incorporate project-specific requirements into the details

INTENDED USE

Pile cap supporting column – pile cap supported by five drilled piers or piles

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Top of pile cap elevations is provided on drawings
2. Pile cap minimum depth satisfies Section 13.4.6.1
3. Bar cover is provided per Section 20.5.1.3
4. Bottom bars in pile cap matches bar sizes and spacing in pile cap schedule
5. Pile cap top bars are provided, if required
6. Dowels from pile cap into formed column or formed column pier are added
7. Extended dowels into column or formed pier above top surface of pile cap the greater of tension development of dowels or tension lap splice of column bars if moment is transferred
8. Development lengths satisfy Section 25.4
9. Pile cap bars are developed beyond face of column or column pedestal; otherwise provide hooks
10. Dowels between deep foundation (pile) member and pile cap are developed in tension, and for structures assigned to intermediate or special moment frames (SDC C through F), the anchorage to the pile cap is in accordance with Section 18.13.6
11. Column dowels are oriented toward the column center if located in SDC C through F per Section 18.13.2.3
12. Bar details between pile cap and concrete column or column pedestal:
    a. Top surface of pile cap contact area with column or column pedestal is by float finish or vibrator finish. In areas not accessible for a float, such as between column dowels, a float finish is not needed and a vibrator finish is adequate
    b. Column or column pedestal longitudinal bars can be placed on top of pile cap
    c. For column or column pedestal ties, place first tie at 1/2 calculated column or column pedestal tie spacing above top of pile cap
    d. Pile cap dowel bar length from column or column pedestal, l_2, satisfies $l_2 \leq (h - 3 \text{ in.} - 2d_b)$
    e. If $l_2 > (h - 9 \text{ in.} - 2d_\text{b})$, then make one of the following changes:
        i. Increase pile cap thickness such that $l_2 \leq (h - 9 \text{ in.} - 2d_b)$
        ii. Hook bars (standard 90-degree hook)
        iii. For large size column or column pedestal longitudinal bars, use two dowels for every longitudinal bar in supporting column, d_1, such that the area of the two bars is greater than the original longitudinal bar in the column
13. As a good practice, top elevations of all piles or drilled piers extend into the bottom of the pile cap a minimum distance of 6 in. for steel piles and 4 in. for concrete piles and drilled piers
14. Provide void forms if required
15. Remove “NOTES TO DESIGN PROFESSIONAL” before placing schedule in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles*: 5, 22, 23

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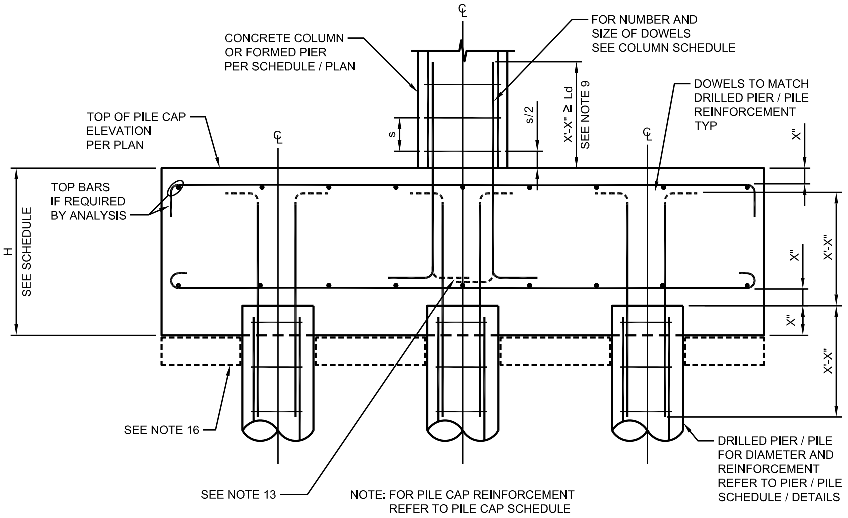
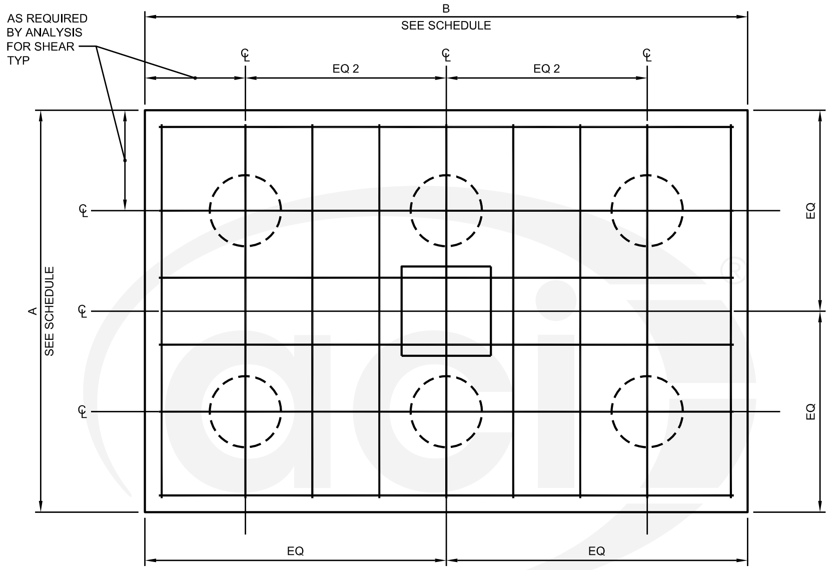
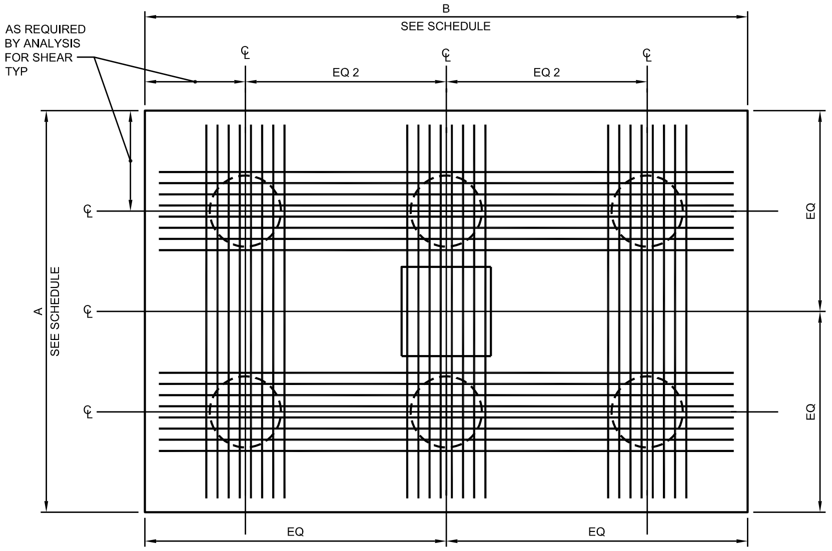
*Refer to Section 3 for articles

FND-166





TOP AND BOTTOM REINFORCEMENT



ALTERNATE BOTTOM REINFORCEMENT LAYOUT

NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST, MODIFY, AND DELETE REFERENCES TO NOTES BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

TYPE VI - SIX DRILLED PIER OR PILE CAP

FIGURE FND-166: SIX DRILLED PIER/PILE CAP

The design professional shall review the following checklist and
incorporate project-specific requirements into the details

INTENDED USE

Pile cap supporting column – pile cap supported by six drilled piers or piles

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Top of pile cap elevations is provided on drawings
2. Pile cap minimum depth satisfies 13.4.6.1
3. Bar cover is provided per Section 20.5.1.3
4. Bottom bars in pile cap matches bar sizes and spacing in pile cap schedule
5. Pile cap top bars are provided, if required
6. Dowels from pile cap into formed column or formed column pier are added
7. Extended dowels into column or formed pier above top surface of pile cap the greater of tension development of dowels or tension lap splice of column bars if moment is transferred
8. Development lengths satisfy Section 25.4
9. Pile cap bars can be uniformly distributed across pile cap, or
10. As an alternate, bottom bars can be centered and concentrated at piles. Ensure that spacing between bars is minimum 3 in., refer to alternate detail
11. Pile cap bars are developed beyond face of column or column pedestal; otherwise provide hooks
12. Dowels between deep foundation (pile) member and pile cap are developed in tension, and for structures assigned to intermediate or special moment frames (SDC C through F), the anchorage to the pile cap is in accordance with Section 18.13.6
13. Column dowels are oriented toward the column center if located in SDC C through F per Section 18.13.2.3
14. Bar details between pile cap and concrete column or column pedestal:
    a. Top surface of pile cap contact area with column or column pedestal is roughened by float finish or vibrator finish. In areas not accessible for a float, such as between column dowels, a float finish is not needed and a vibrator finish is adequate
    b. Column or column pedestal longitudinal bars can be placed on top of pile cap
    c. For column or column pedestal ties, place first tie 2 in. above top of pile cap
    d. Pile cap dowel bar length from column or column pedestal, l_2, satisfies $l_2 \leq (h - 3\text{ in.} - 2d_b)$
    e. If $l_2 > (h - 9\text{ in.} - 2d_b)$, then make one of the following changes:
        i. Increase pile cap thickness such that $l_2 \leq (h - 9\text{ in.} - 2d_b)$
        ii. Hook bars (standard 90-degree hook)
        iii. For large size column or column pedestal longitudinal bars, use two dowels for every longitudinal bar in supporting column, d_1, such that the area of the two bars is greater than the original longitudinal bar in the column
15. As a good practice, top elevations of all piles or drilled piers extend into the bottom of the pile cap a minimum distance of 6 in. for steel piles and 4 in. for concrete piles and drilled piers
16. Provide void forms if required
17. Remove “NOTES TO DESIGN PROFESSIONAL” before placing schedule in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles[*]: 5, 22, 23

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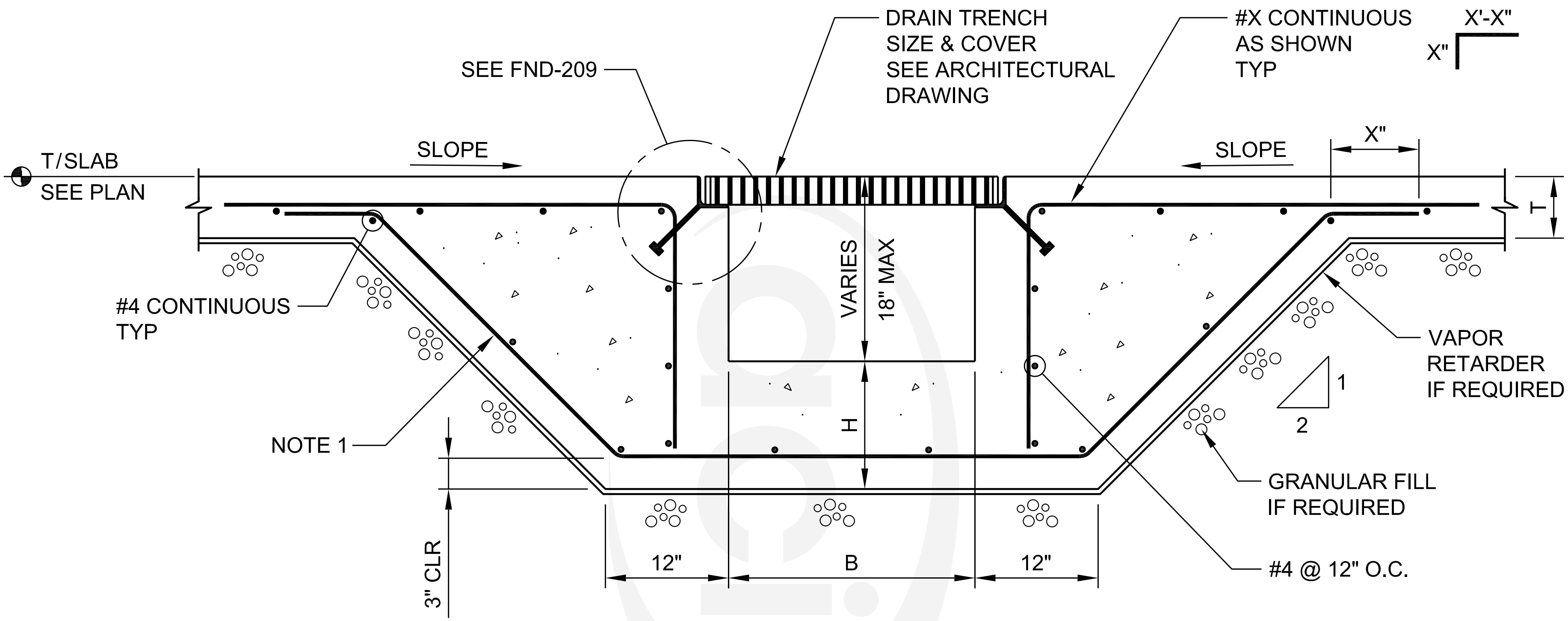
[*] Refer to Section 3 for articles

FND-200



NOTES:

1. BENT TRENCH REINFORCEMENT SHALL BE #X @ 12" O.C. TYP UNO
2. ADDITIONAL REINFORCEMENT SPACING BELOW TRENCH SHALL NOT EXCEED 12" O.C.

NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

TYPICAL SLAB-ON-GROUND TRENCH DETAIL

FIGURE FND-200: TYPICAL SLAB-ON-GROUND TRENCH DETAIL

The design professional shall review the following checklist and
incorporate project-specific requirements into the details

INTENDED USE

Slab-on-ground floor trench that slopes to drain

Slab-on-ground trench with constant elevation

Placed using single concrete placement

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. For 18 in. deep trench drain and less, slab-on-ground can be thickened
2. Width of floor trench matches that shown on floor plan
3. Trench cover size and depth can span the trench opening for the specified loading
4. Top of slab-on-ground slopes towards trench on both sides; specify slope minimum 1/8 in./ft
5. Trench floor finish elevations along full length slopes towards sump/outlet
6. Slab-on-ground bars are bent 90 degree at side walls of trench
7. Bars parallel to length of trench are provided on both sides of trench walls
8. Provide bottom bars below trench continuing along bottom trench walls. Develop into surrounding slab-on-ground using lap splice with slab-on-ground reinforcement
9. Provide edge angle(s) at trench cover plate with minimum 1/8 in. gap between edge angle and trench cover plate
10. Bar cover is provided per Section 20.5.1.3
11. Concrete thickness below trench (H) is minimum 6 in. deep if no vehicular traffic on trench
12. Width of trench side wall are minimum 12 in. thick
13. For ease of constructability it might be more economical to place trench bottom on one elevation, level for monolithic concrete placement. Then “later” install concrete or prepackage grout to achieve proper slope to drain
14. For grating support, coordinate with edge angle detail; see FND-209
15. Remove “NOTES TO DESIGN PROFESSIONAL” before placing schedule in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles[*]:

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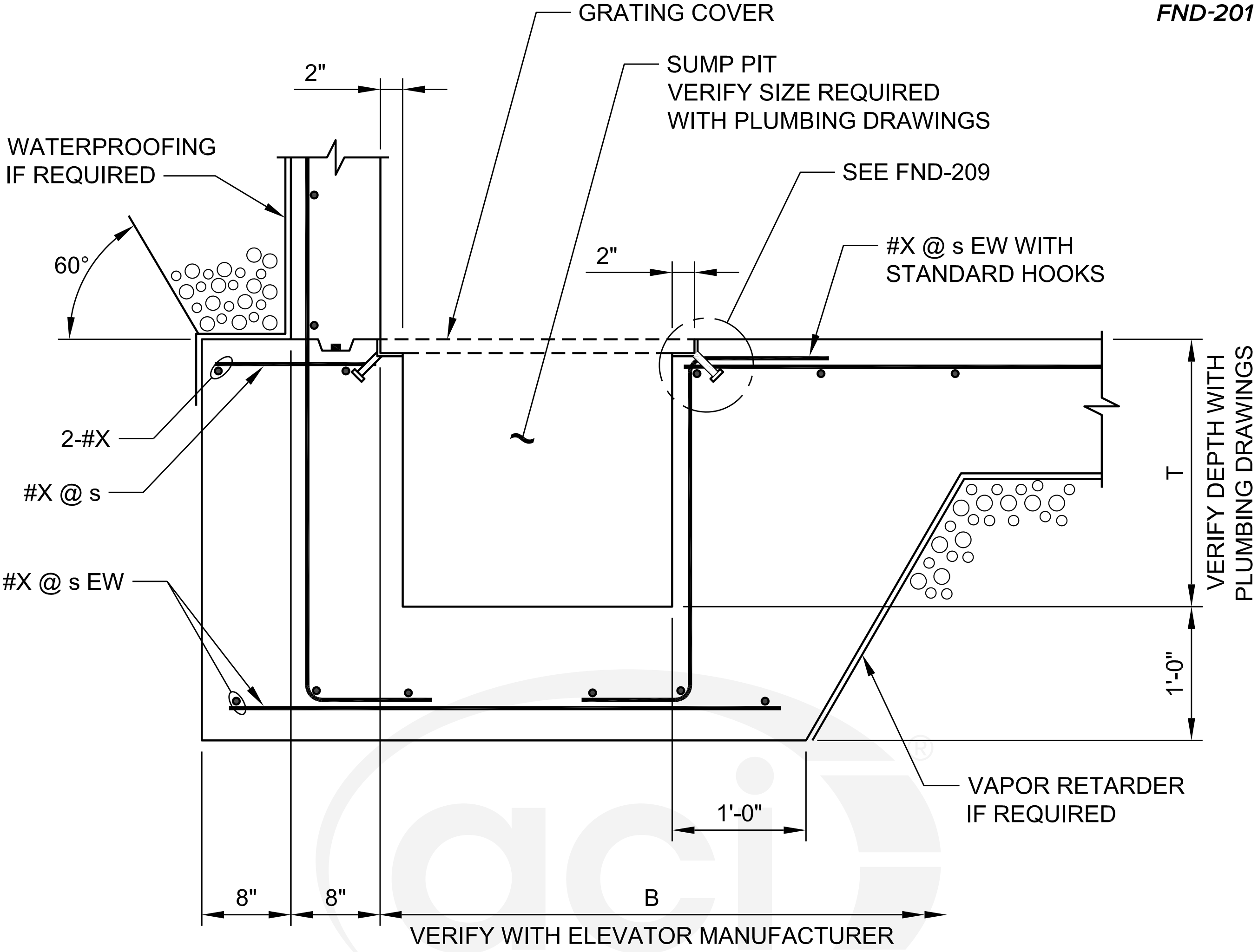
[*] Refer to Section 3 for articles

FND-201



NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

TYPICAL SUMP IN A PIT

FIGURE FND-201: TYPICAL SUMP IN A PIT

The design professional shall review the following checklist and incorporate project-specific requirements into the details

INTENDED USE

Sump in a pit

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Modify sump dimensions as required
2. Modify pit wall thickness as required
3. Reinforcing and bottom of sump thickness should be modified at mats
4. Bar cover is provided per Section 20.5.1.3
5. For grating support, coordinate with edge angle detail; see FND-209
6. Remove “NOTES TO DESIGN PROFESSIONAL” before placing schedule in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles[*]: 6

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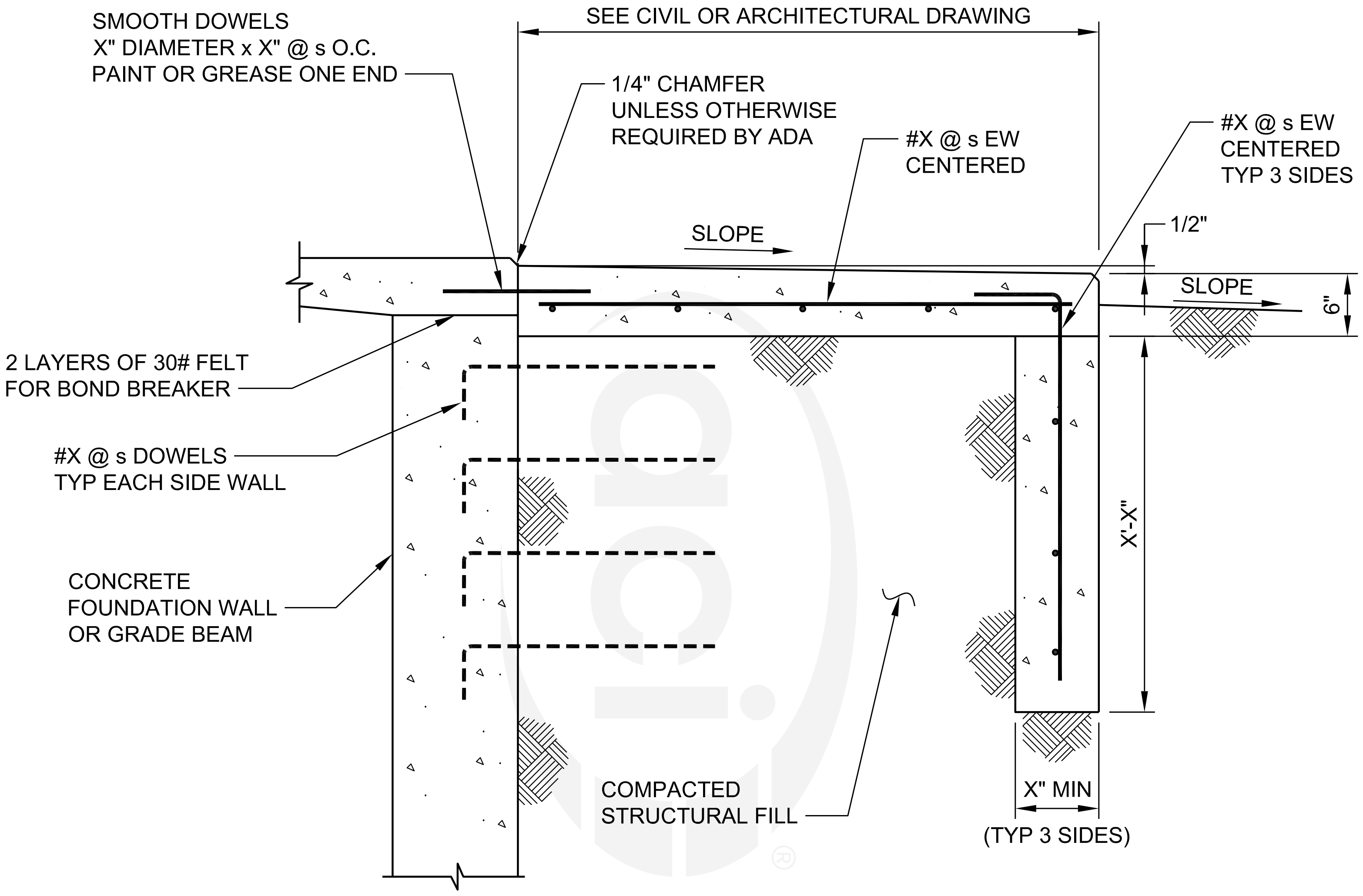
[*] Refer to Section 3 for articles

FND-202

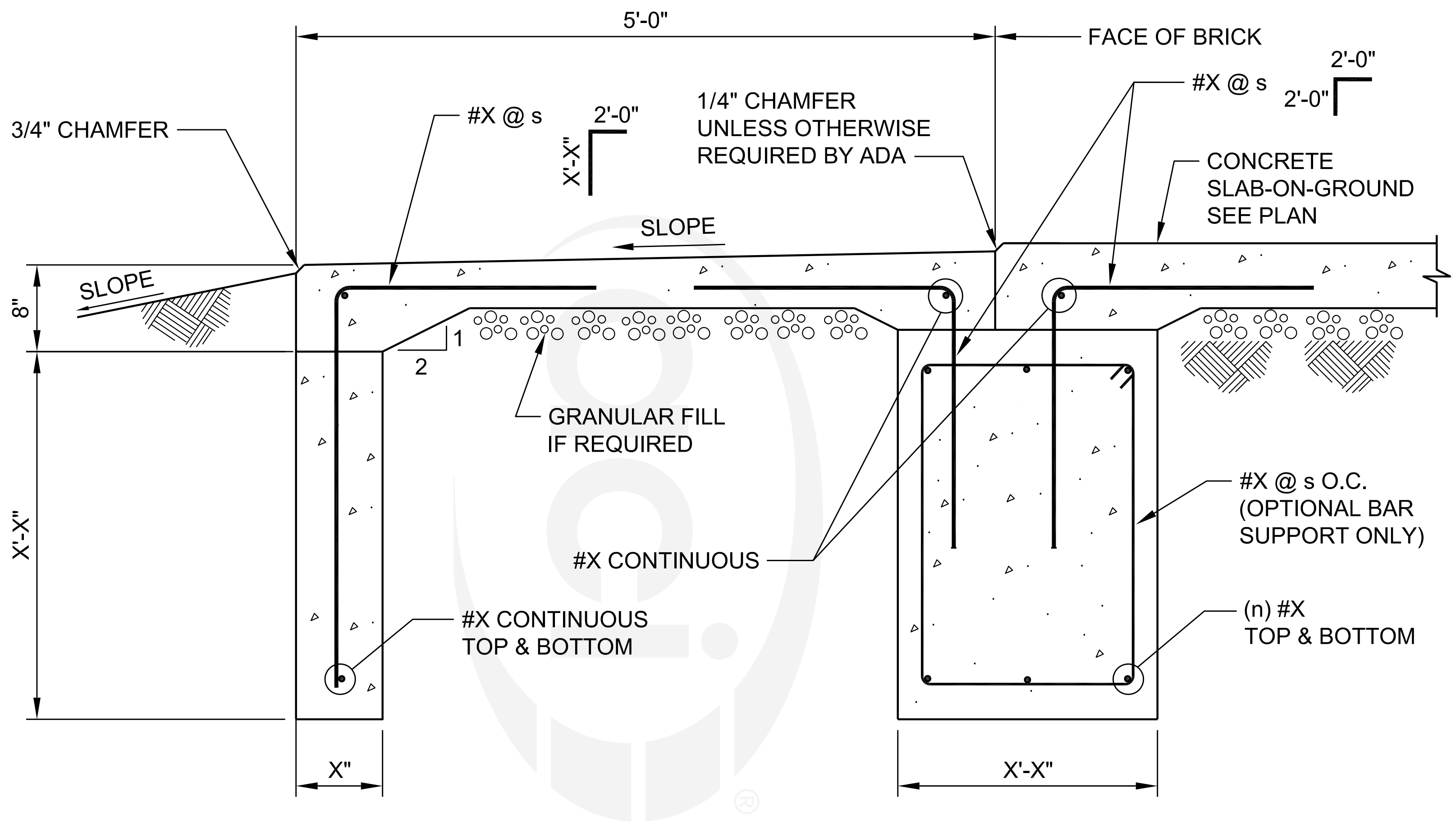


NOTE:
SEE CIVIL DRAWINGS FOR REQUIRED WIDTH

NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

EXTERIOR DOOR STOOP

FND-203



NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

EXTERIOR GRADE BEAM AT DOOR

FIGURE FND-202 AND 203: EXTERIOR DOOR STOOP AT MAN DOOR HOLD-DOWN (FROST PROTECTED)

The design professional shall review the following checklist and
incorporate project-specific requirements into the details

INTENDED USE

Door stoop at exterior grade beam man door

Door stoop meaning concrete pad supported typically on three sides by grade walls to frost protected depth

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Width of door hold-down location along top of grade beam is coordinated with architectural drawings
2. Depth of grade wall, frost depth, is coordinated with the geotechnical report or state requirements
3. Top of hold-down elevation is minimum 1/4 in. below interior top of slab elevation
4. Door pad slopes away from the door
5. Rigid insulation may be required under slab-on-ground; coordinate with architectural drawings
6. Door pad:
   a. Add concrete slab over hold-down width with hooked bars anchored into grade beam and embedded into slab
   b. Anchor pad to wall if pad movement is to be stabilized
   c. Indicate default length out from building and width beyond each side of door if not indicated on civil drawings
7. Bar cover is provided per Section 20.5.1.3
8. Granular fill to be provided per geotechnical report
9. Provide 1/4 in. chamfer at man door unless otherwise required by American with Disabilities Act (ADA)
10. Remove "NOTES TO DESIGN PROFESSIONAL" before placing schedule in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles*:

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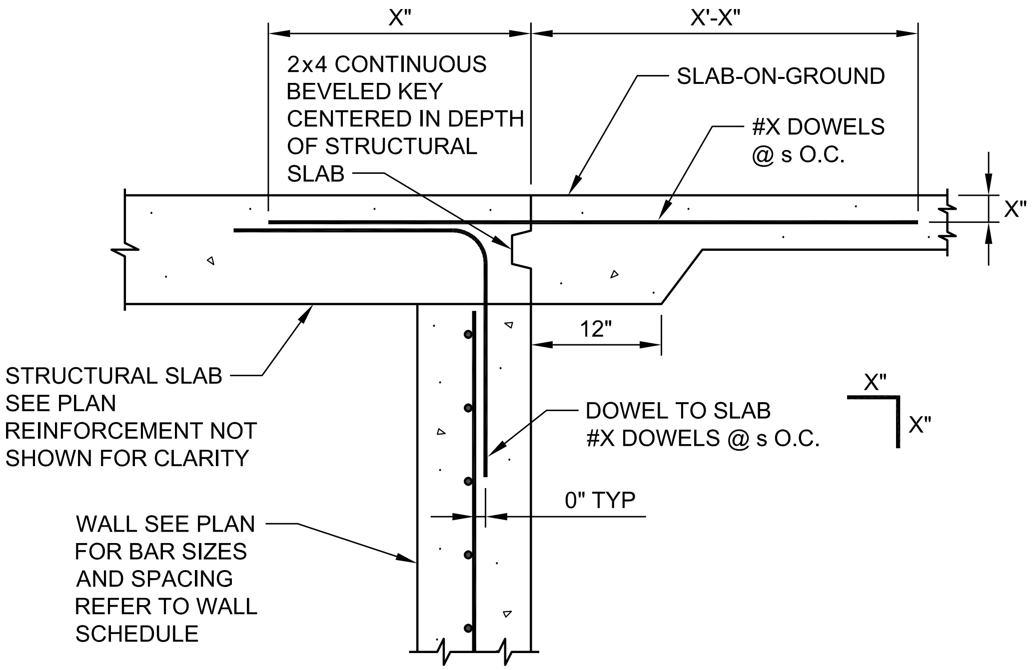
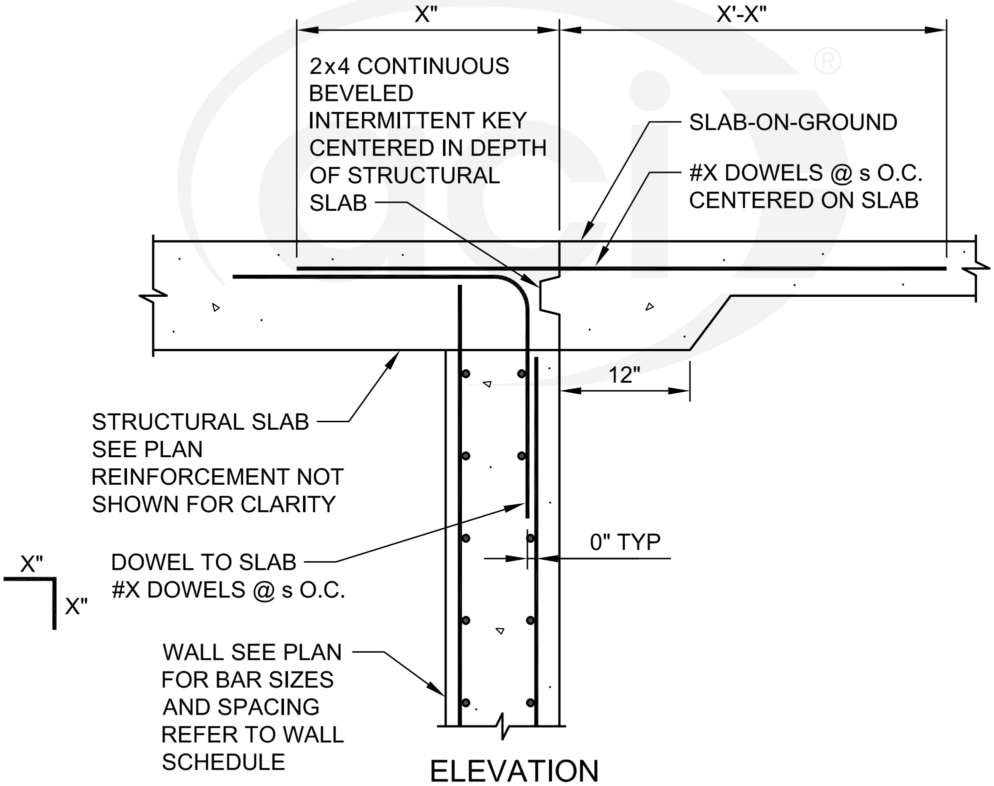
*Refer to Section 3 for articles

FND-204



ELEVATION



ELEVATION

NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

SLAB-ON-GROUND DOWELS AT STRUCTURAL SLAB

FIGURE FND-204: SLAB-ON-GROUND DOWELS AT SUPPORTED SLAB

The design professional shall review the following checklist and
incorporate project-specific requirements into the details

INTENDED USE

Solid nonprestressed slab to slab-on-ground dowel detail

Slab-on-ground at building edge to be anchored to slab

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Reinforcement cover satisfies minimum required by Section 20.5.1.3
2. Minimum spacing between longitudinal bars meets Sections 7.7.2.1 and 25.2
3. Dowels are placed in supported slab with end of dowel terminated in a tension embedment length from edge of supported slab. Extend dowel into slab-on-ground with end of dowel terminated in tension development length from edge of slab-on-ground
4. If slab-on-ground transfers only shear forces, grease dowel ends embedded maximum 12 in. into slab-on-ground
5. Maximum spacing of dowel bars satisfies Section 7.7.2.3
6. Remove “NOTES TO DESIGN PROFESSIONAL” before placing schedule in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles*:

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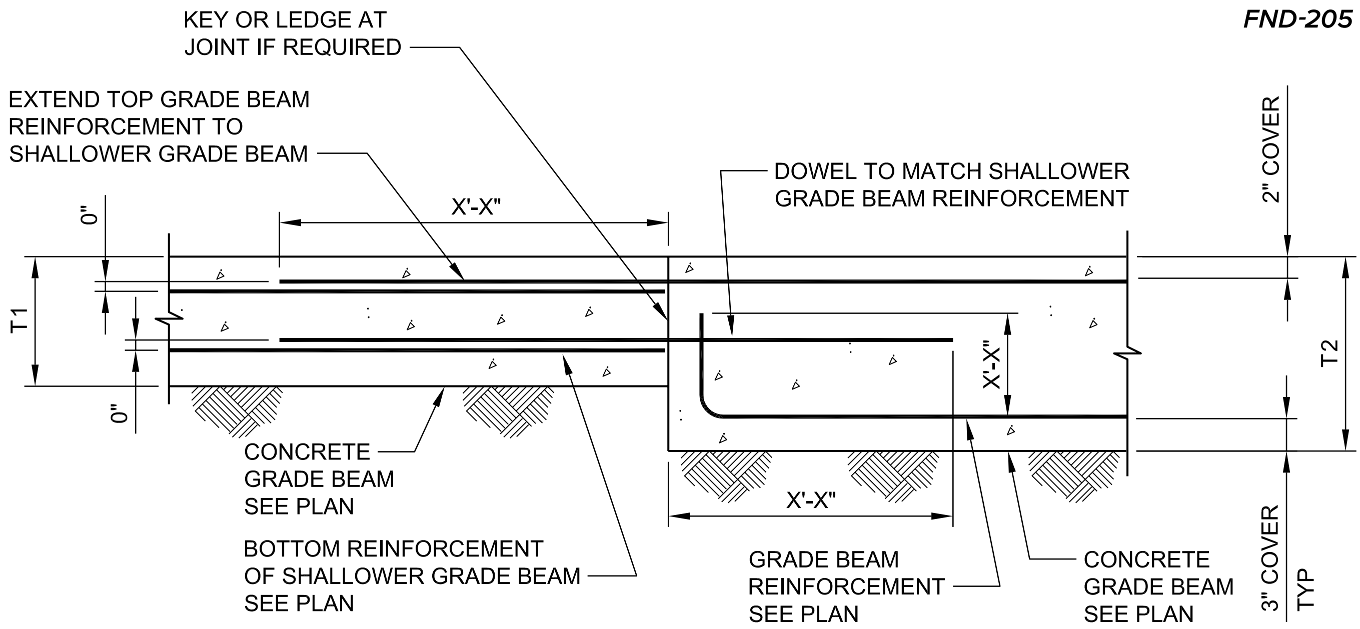
*Refer to Section 3 for articles

FND-205



NOTE:
TRANSVERSE REINFORCEMENT NOT SHOWN FOR CLARITY

NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

CONSTRUCTION JOINT DETAIL AT TRANSITION BETWEEN GRADE BEAMS OF DIFFERENT DEPTHS

FIGURE FND-205: CONSTRUCTION JOINT DETAIL AT TRANSITION BETWEEN GRADE BEAMS OF DIFFERENT DEPTHS

The design professional shall review the following checklist and
incorporate project-specific requirements into the details

INTENDED USE

Grade beams with differing thickness (top of grade beam elevations remains the same)

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Shallower grade beam top and bottom reinforcement bars are discontinued at transition joint
2. Top reinforcement bars of deeper grade beam is extended beyond transition joint a distance equal to or greater than a tension lap splice
3. Dowels are provided to match shallower grade beam bottom reinforcement that is embedded in deeper grade beam a distance equal to or greater than tension development length. Extend dowel into shallower grade beam a distance equal to or greater than a tension lap splice. Match dowel size with shallower grade beam reinforcement bar size
4. A standard hook is provided at transition joint in the deeper beam bottom reinforcement
5. Bar cover is provided per Section 20.5.1.3
6. Place a key or ledge at joint if required by analysis
7. If expansive soil is present, provide carton forms below grade beams
8. Remove “NOTES TO DESIGN PROFESSIONAL” before placing schedule in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles[*]: 5, 15

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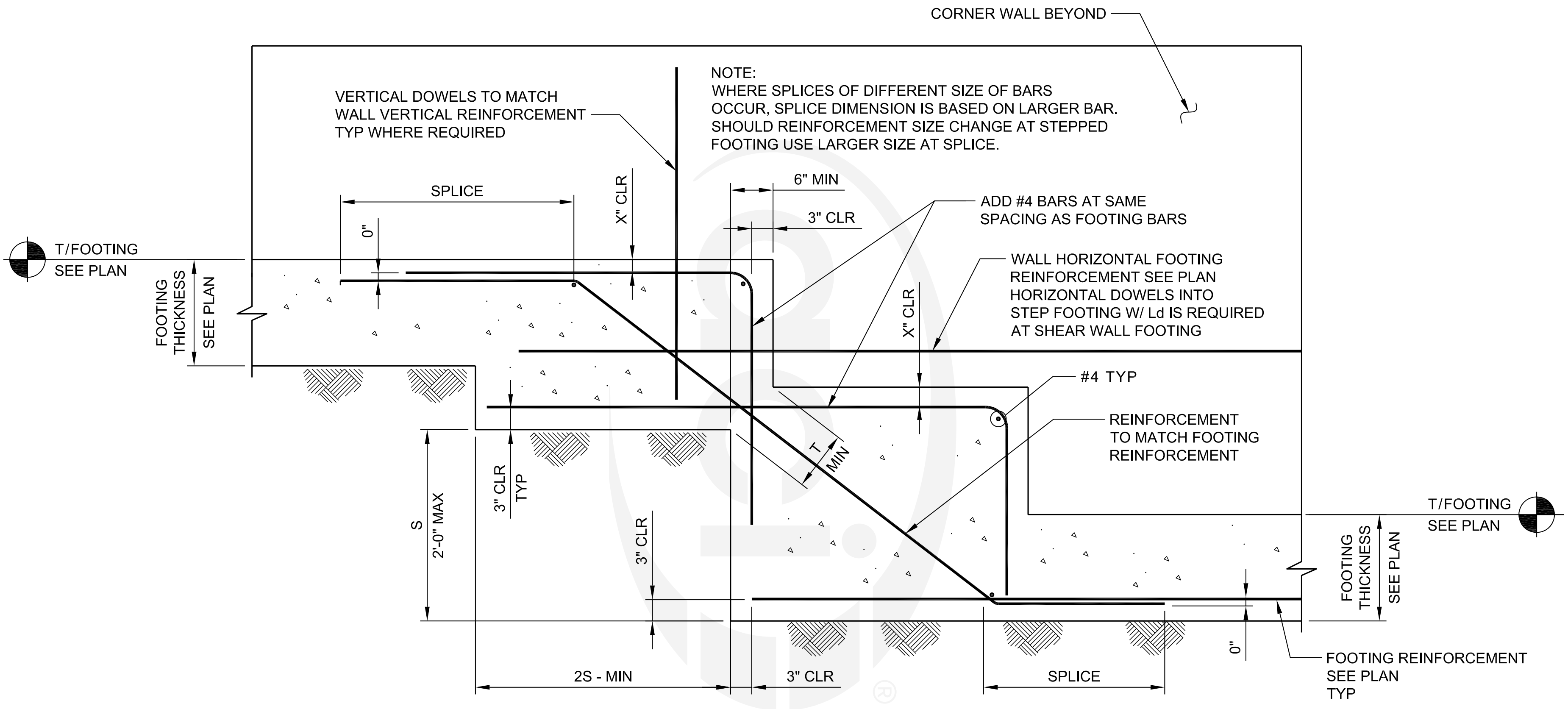
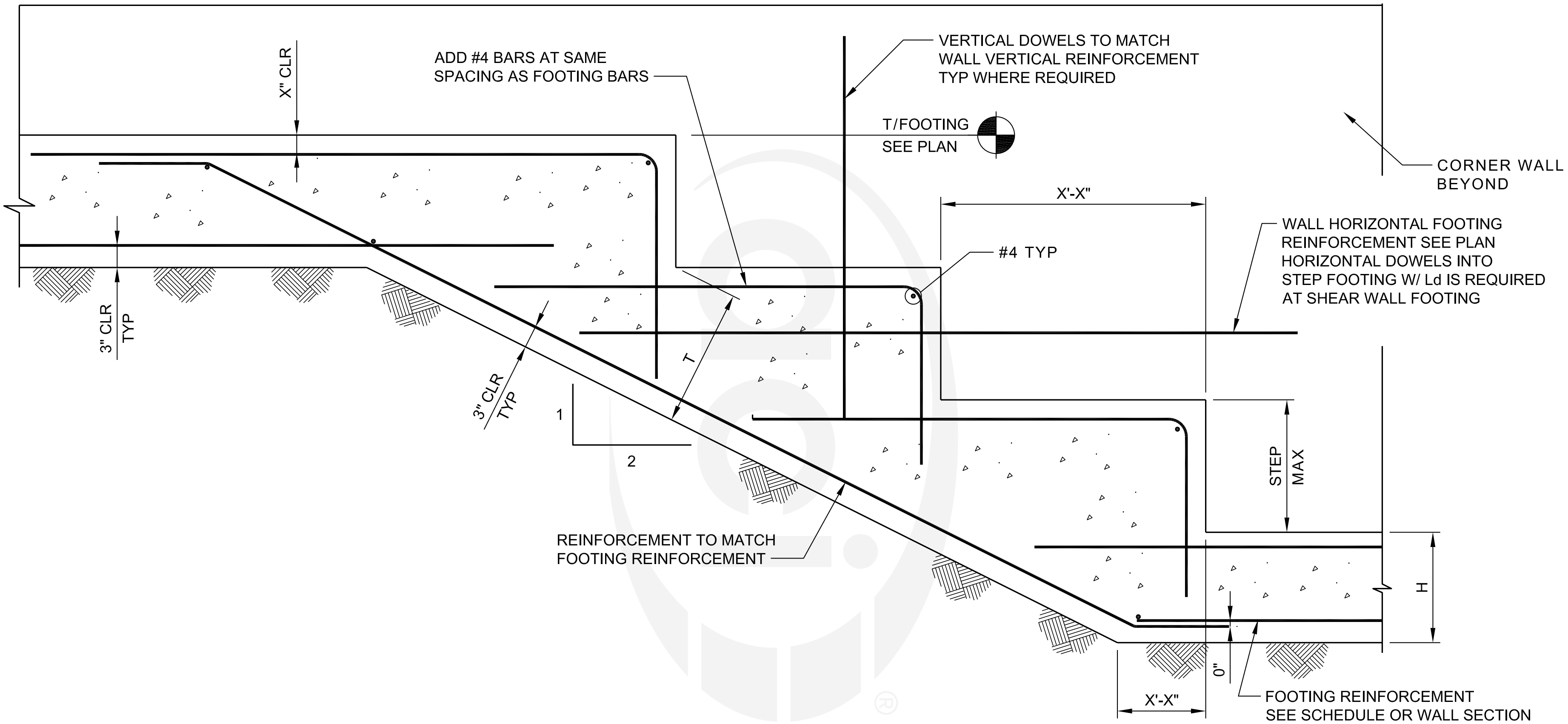
[*] Refer to Section 3 for articles



NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

STEP FOOTING DETAIL - OPTION 1



NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE
INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

STEP FOOTING DETAIL - OPTION 2

FIGURE FND-206 AND 207: STEP FOOTING DETAIL—OPTIONS I & II

The design professional shall review the following checklist and
incorporate project-specific requirements into the details

INTENDED USE

Continuous wall footings

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Total elevation change is a multiple of the footing thickness. If it is not, then the drop for each step must be smaller than the footing thickness. Contractor to determine
2. Stepped footing details are not overdetailed. Allow the contractor to determine the drop and length of each step
3. Step horizontal dimension is at least twice the vertical dimension of the step
4. No. 4 L-bars are provided at each step to match footing bars
5. Horizontal No. 4 nose bar is provided at tip of each step
6. Reinforcement cover satisfies Section 20.5.1.3
7. Wall horizontal bars are embedded minimum tension development length into the stepped footing
8. Wall vertical bars are embedded minimum tension development length into the stepped footing
9. The distance between front and back faces of an upper vertical step and lower vertical step is minimum 12 in.
10. Underside vertical face is sloped in the ratio of 2:1 two vertical and one horizontal
11. Sloped bars, matching footing reinforcement extending to lowest footing to the highest footing, are provided. Provide tension lap splices on each end of sloped bar that laps with footing reinforcement bars
12. Remove “NOTES TO DESIGN PROFESSIONAL” before placing schedule in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles*: 14

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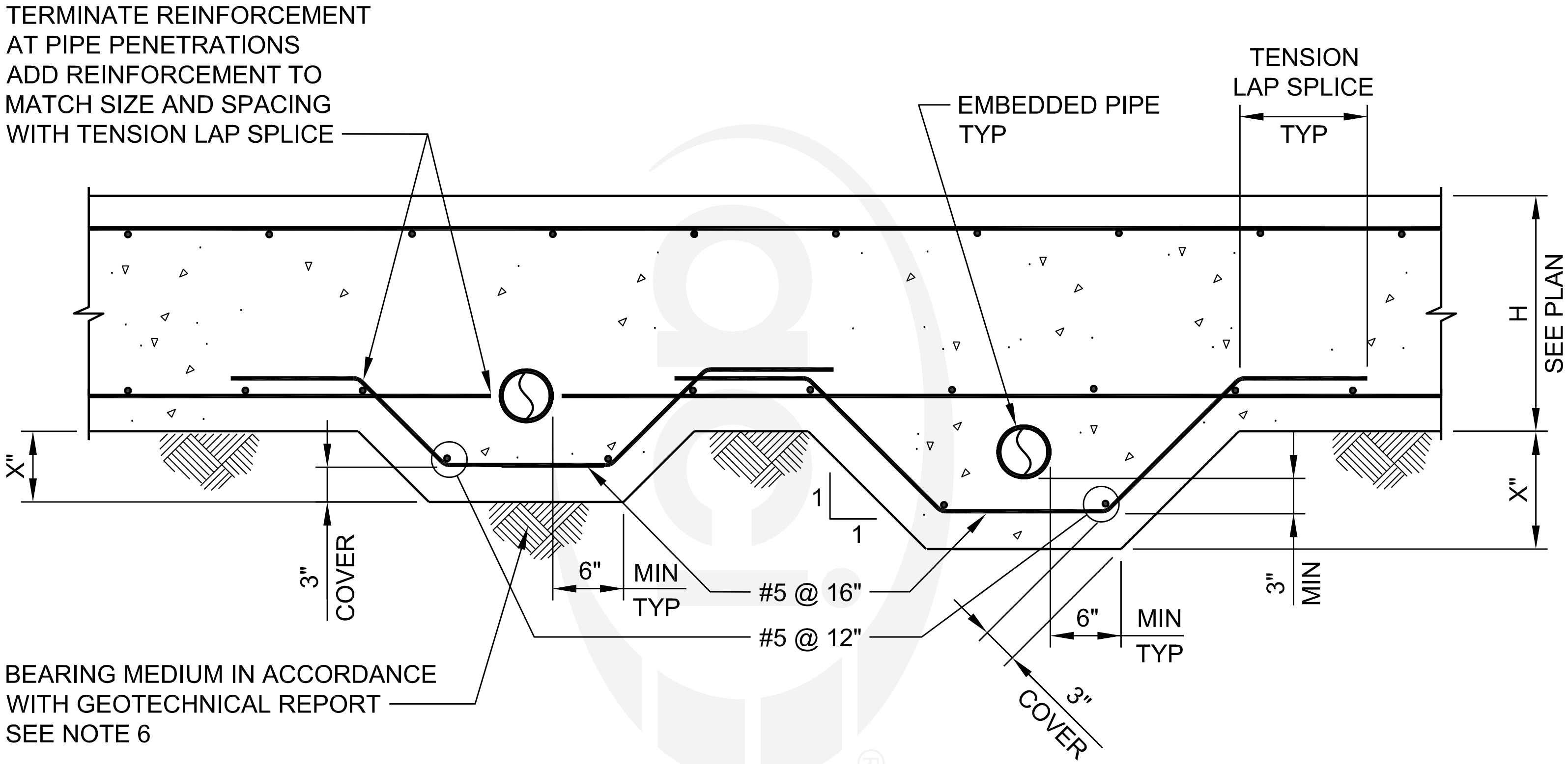
*Refer to Section 3 for articles



NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE
INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

PIPES IN FOOTING

FIGURE FND-208: PIPE EMBED IN FOOTING

The design professional shall review the following checklist and incorporate project-specific requirements into the details

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INTENDED USE

Pipe penetration located within footing depth

Pipe penetration located below or at bottom footing reinforcement layer

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Continuous footing is thickened at pipe locations
2. Width of thickened footing at pipe location is minimum 6 in. on each side of pipe plus outside pipe diameter
3. Where pipe penetration intersects footing reinforcement, terminate the reinforcement close as practical to the pipe. Add bent bars below the pipe penetration that are parallel to the footing reinforcement and match the size and spacing of the footing reinforcement. Add reinforcement below the pipe and parallel to the pipe as shown
4. Preferably 3 in. minimum spacing is provided between bottom of embedded pipe and bent bars
5. Cover is per Section 20.5.1.3
6. Columns dowels to be oriented toward the center, if in SDC D through F; Section 18.13.2.3
7. Remove "NOTES TO DESIGN PROFESSIONAL" before placing schedule in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles[*]:

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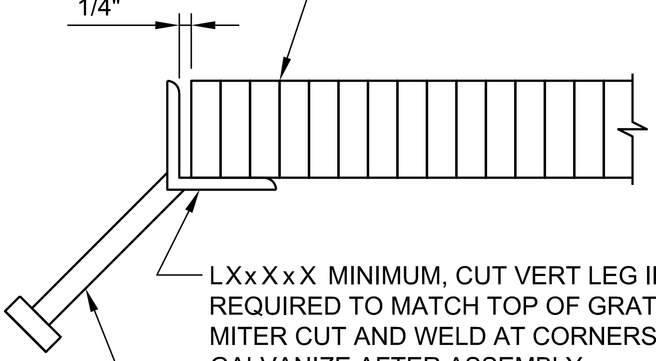
[*] Refer to Section 3 for articles

FND-209



GRATING, BAND ALL EDGES

LXxXxX MINIMUM, CUT VERT LEG IF REQUIRED TO MATCH TOP OF GRATING, MITER CUT AND WELD AT CORNERS, GALVANIZE AFTER ASSEMBLY, ADJUST ANGLE SIZE TO MATCH GRATING

1/2" DIA x 4" LONG HEADED STUD, 12" O.C., MINIMUM 2 PER SIDE

NOTE: WHEN PROVIDING ALUMINUM OR STAINLESS STEEL GRATING, ADD 1/8"x1" NEOPRENE, TEFLON OR UHMW POLYETHYLENE PAD. ADHERE TO ANGLE.

NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

GRATING ANGLE SUPPORT

FIGURE FND-209: GRATING ANGLE SUPPORT

The design professional shall review the following checklist and incorporate project-specific requirements into the details

INTENDED USE

Protection of exposed concrete corners

Support of an element bearing on concrete

NOT INTENDED FOR

Studs subjected to tension force, shear force, or both. For loaded stud anchors in tension, shear, or both, follow anchorage to concrete design per ACI 318-19, Chapter 17

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Stud length is coordinated with concrete member thickness; that is, slab or wall
2. For short length angles, 12 in. in length or less, use minimum two studs per element
3. Angles with greater dimensions, greater than 5 in., use two anchors at each location
4. Miter cut vertical leg to match grating thickness
5. When providing aluminum or stainless steel grating, add 1/8 in. x 1 in. neoprene, Teflon, or UHMW polyethylene pad; adhere separator to angle
6. Remove “NOTES TO DESIGN PROFESSIONAL” before placing schedule in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles[*]:

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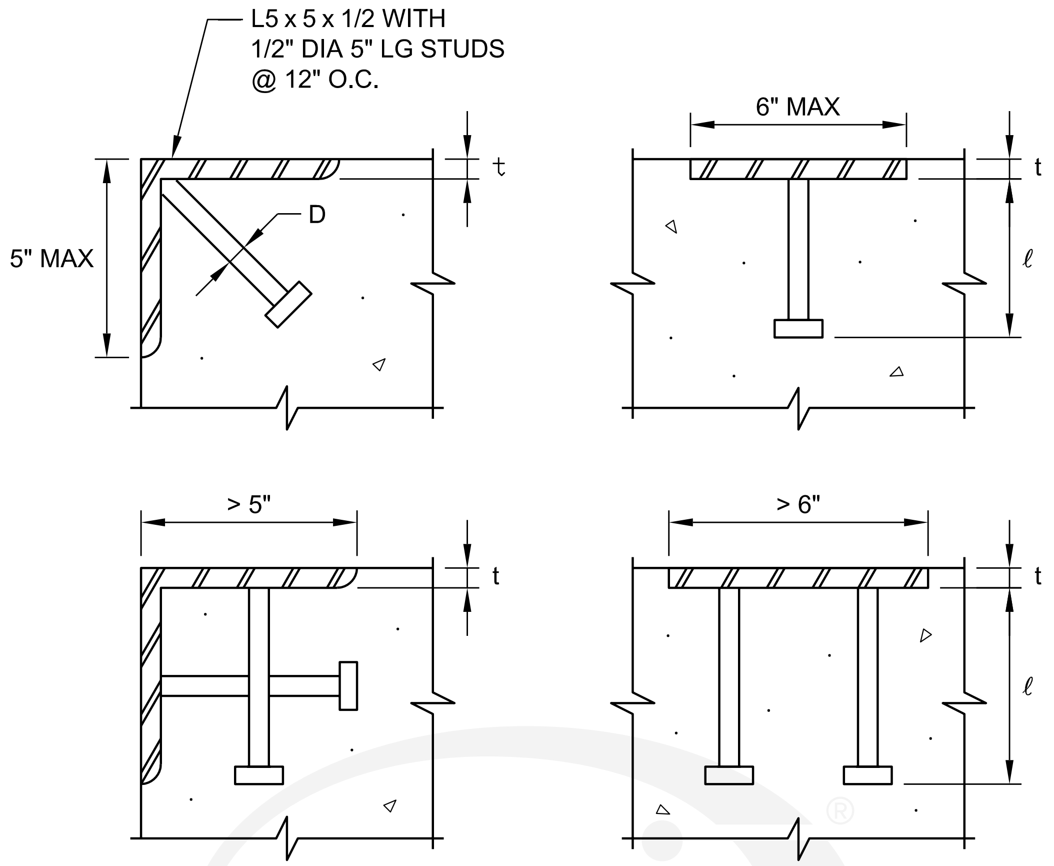
[*] Refer to Section 3 for articles



NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

STUD REQUIREMENTS FOR EMBEDDED STEEL ELEMENTS

FIGURE FND-210: STUD REQUIREMENTS FOR EMBEDDED STEEL ELEMENTS

The design professional shall review the following checklist and
incorporate project-specific requirements into the details

INTENDED USE

Protection of exposed concrete corners

Support of an element bearing on concrete

NOT INTENDED FOR

Studs subjected to tension force, shear force, or both. For loaded stud anchors in tension force, shear force, or both, follow anchorage to concrete design per ACI 318-19, Chapter 17

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. The stud anchor sizes and spacings are recommended for nonloaded applications
2. Coordinate stud length with concrete member thickness; that is, slab
3. For short length angles, plates, or channels, use minimum two studs per element
4. Angles/plates with greater dimensions (> 5 in. for angles and 6 in. for plates), use two anchors at each location
5. Remove “NOTES TO DESIGN PROFESSIONAL” before placing schedule in the Contract Documents

STUD ANCHOR RECOMMENDED APPLICATION

Stud anchor chart

Plate/angle thickness *t*, in.	Stud diameter *D*, in.	Nominal stud length ℓ, in.	Stud spacing *c/c*, in.
3/16	3/8	4	18
1/4	1/2	5	18
5/16	1/2	5	18
3/8	1/2	5	18
1/2	5/8	6	24
5/8	5/8	6	24
3/4	5/8	6	24
1	3/4	7	24

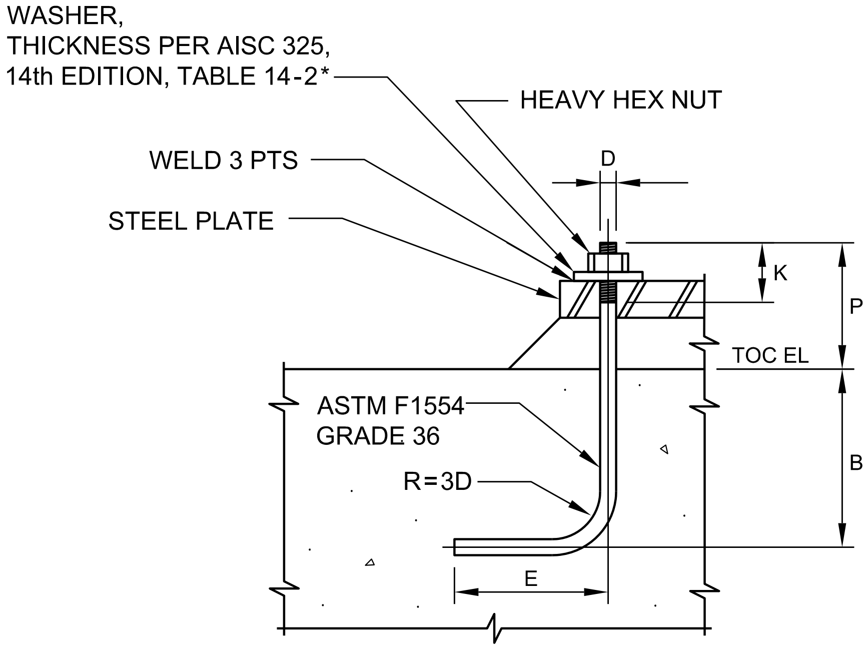
RECOMMENDED REFERENCES

Concrete International articles[*]:

---

[*] Refer to Section 3 for articles

FND-211



SCHEDULE		
D	B	E
3/8"	5"	1 5/8"
1/2"	6"	2 1/4"
5/8"	8"	2 7/8"
3/4"	10"	3 3/8"
7/8"	1'-0"	4"
1"	1'-2"	4 1/2"

B = EMBEDDED LENGTH
D = BOLT DIAMETER
E = HOOK LENGTH
K = THREADS (2D+2")
P = BOLT PROJECTION
= NONSHRINK GROUT THICKNESS + PLATE THICKNESS + WASHER THICKNESS + NUT THICKNESS + 3/4" ANCHOR PROJECTION

NOTES:

1. ALL EMBEDMENTS SHALL BE VERIFIED
2. BOLT PROJECTION SHALL BE VERIFIED

NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

EMBEDDED HOOKED BOLT IN CONCRETE

*NOTE: ENGINEER TO VERIFY EDITION AND TABLE NUMBERS

FIGURE FND-211: EMBEDDED HOOKED BOLT IN CONCRETE

The design professional shall review the following checklist and incorporate project-specific requirements into the details

INTENDED USE

Anchoring steel plate attachments to a concrete member

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Type of anchor is identified on plan/section; hooked bolt
2. Location of steel attachment on plan is shown
3. Size, embedment depth, and number and spacing of anchors per attachment verified in accordance with Chapter 17 and is identified in the documents
4. Number, sizes, and embedment depths of different anchor attachments is per table/schedule
5. Thickness of nonshrink grout between steel base plate and concrete is specified
6. Projection of anchor above concrete level is called out in table/schedule or on plan
7. Anchor has adequate edge distance (cover)
8. Anchor embedment depth is within concrete member thickness less cover
9. Anchor layout does not interfere with member reinforcement
10. Supplemental or anchor reinforcement is provided, if required, per Chapter 17
11. Hooked end is turned away from member edge
12. Remove "NOTES TO DESIGN PROFESSIONAL" before placing schedule in the Contract Documents

RECOMMENDED REFERENCES

Concrete International Articles[*]:

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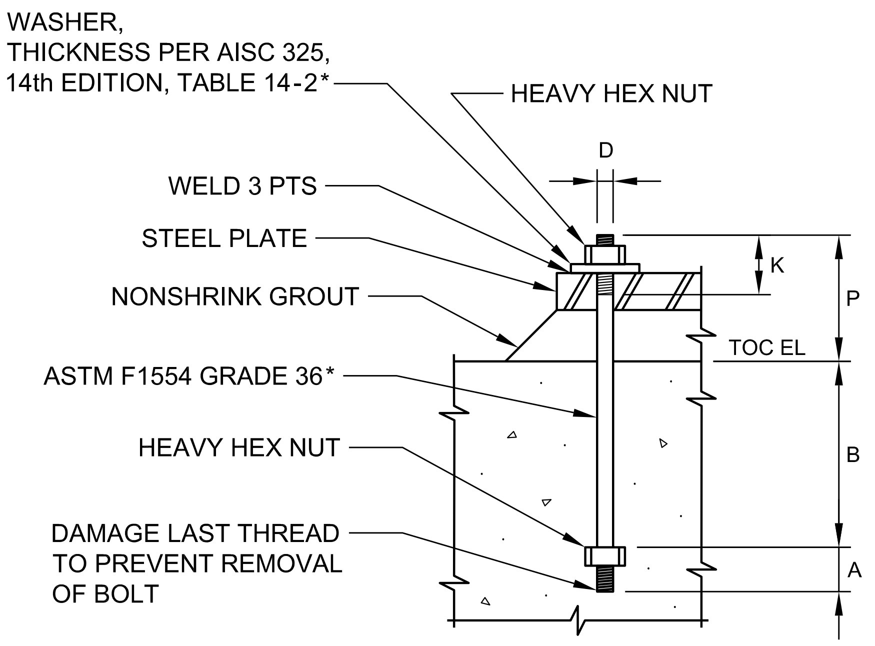
[*] Refer to Section 3 for articles

FND-212



SCHEDULE		
D	A[1]	B
3/8"	2"	6"
1/2"	2"	7"
5/8"	2"	10"
3/4"	2"	1'-0"
7/8"	3"	1'-2"
1"	3"	1'-4"
1 1/8"	3"	1'-6"
1 1/4"	3"	1'-8"
1 3/8"	4"	1'-10"
1 1/2"	4"	2'-0"
1 3/4"	4"	2'-5"
2"	4"	2'-10"

D = BOLT DIAMETER

K = THREADS (2D+3" SINGLE NUT)
THREADS (3D+3" DOUBLE NUTS)

P = BOLT PROJECTION
= NONSHRINK GROUT THICKNESS +
PLATE THICKNESS + WASHER THICKNESS +
NUT THICKNESS + 3/4" ANCHOR PROJECTION

NOTES:

1. NOT REQUIRED FOR HEADED MACHINE BOLTS
2. CONTRACTOR HAS OPTION OF USING HEADED MACHINE BOLTS IN LIEU OF THREADED RODS
3. FULLY THREADED RODS ARE NOT PERMITTED
4. MACHINE BOLTS SHALL CONFORM TO ASTM F1554 GRADE 36

NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

ANCHOR BOLT

THREADED ROD OR MACHINE BOLT

* ENGINEER TO VERIFY EDITION AND TABLE NUMBERS OF WASHER, AND ASTM NUMBER AND GRADE OF ANCHOR BOLT

FIGURE FND-212: ANCHOR BOLT—THREADED ROD OR MACHINE BOLT

The design professional shall review the following checklist and
incorporate project-specific requirements into the details

INTENDED USE

Anchoring steel plate attachments to a concrete member

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Type of anchor is identified on plan/section; headed bolt with heavy hex nut
2. Location of steel attachment on plan is shown
3. Size, embedment depth, and number and spacing of anchors per attachment verified in accordance with Chapter 17 and is identified in the documents
4. Number, sizes, and embedment depths of different anchor attachments is per table/schedule
5. Thickness of nonshrink grout between steel base plate and concrete is specified
6. Projection of anchor above concrete level is called out in table/schedule or on plan
7. Anchor has adequate edge distance (cover)
8. Anchor embedment depth is within concrete member thickness less cover
9. Anchor layout does not interfere with member reinforcement
10. Supplemental or anchor reinforcement is provided, if required, per Chapter 17
11. Anchor edge distance is adequate to prevent side face blowout for headed anchors
12. Remove “NOTES TO DESIGN PROFESSIONAL” before placing schedule in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles[*]:

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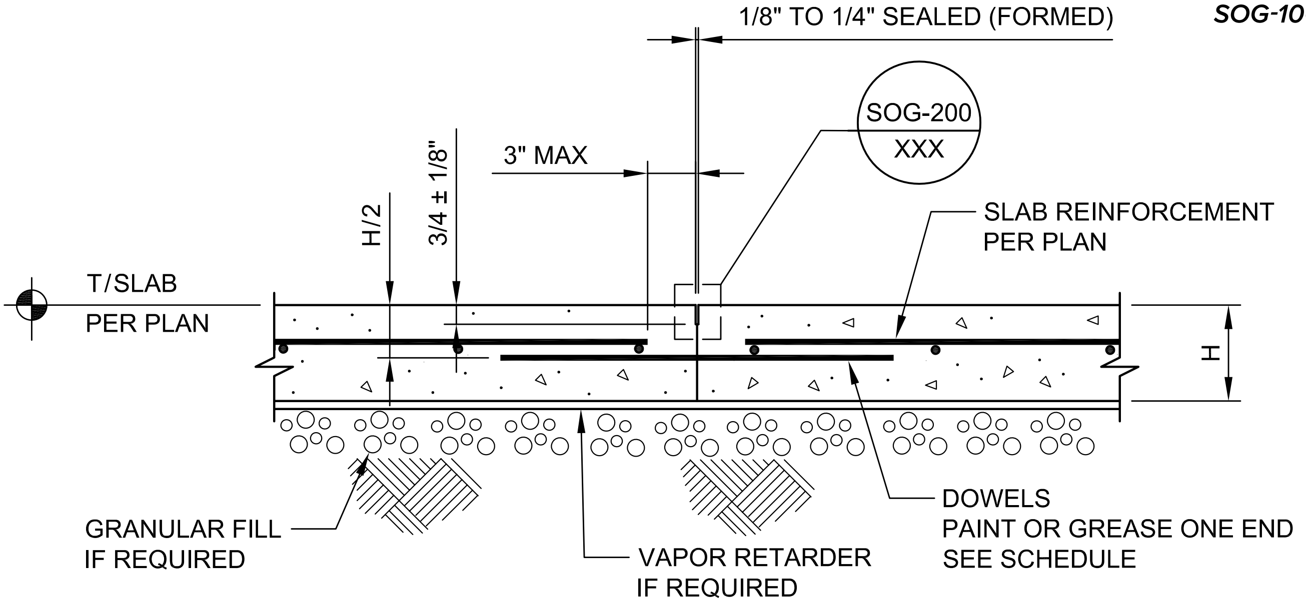
[*] Refer to Section 3 for articles

SLAB-ON-GROUND DETAILS

SOG-100



NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE
INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

SLAB-ON-GROUND CONSTRUCTION JOINT (CJ)

FIGURE SOG-100: SLAB-ON-GROUND CONSTRUCTION JOINT (CJ)

The design professional shall review the following checklist and incorporate project-specific requirements into the details

INTENDED USE

For office, commercial, and institutional buildings

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Defined slab-on-ground thickness matches with floor plan
2. Granular fill is per the geotechnical report recommendation
3. Reinforcing type, spacing, and elevation within slab-on-ground is specified
4. Vapor retarder is specified if moisture would affect building floor finish
5. Slab-on-ground reinforcement is not continuous at construction joint
6. Additional 3/4 in. diameter smooth dowel is centered at construction joint (optional – engineer to determine if it is required based on traffic load on slab-on-ground)
7. Dowels are greased or painted at one end
8. As an alternate to smooth bars as transfer mechanism, plate dowels (ACI 360R) can be used
9. Surface treatment application has been coordinated with owner and specifications
10. Construction joint is sealed per detail 200
11. Remove "NOTES TO DESIGN PROFESSIONAL" before placing detail in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles[*]:

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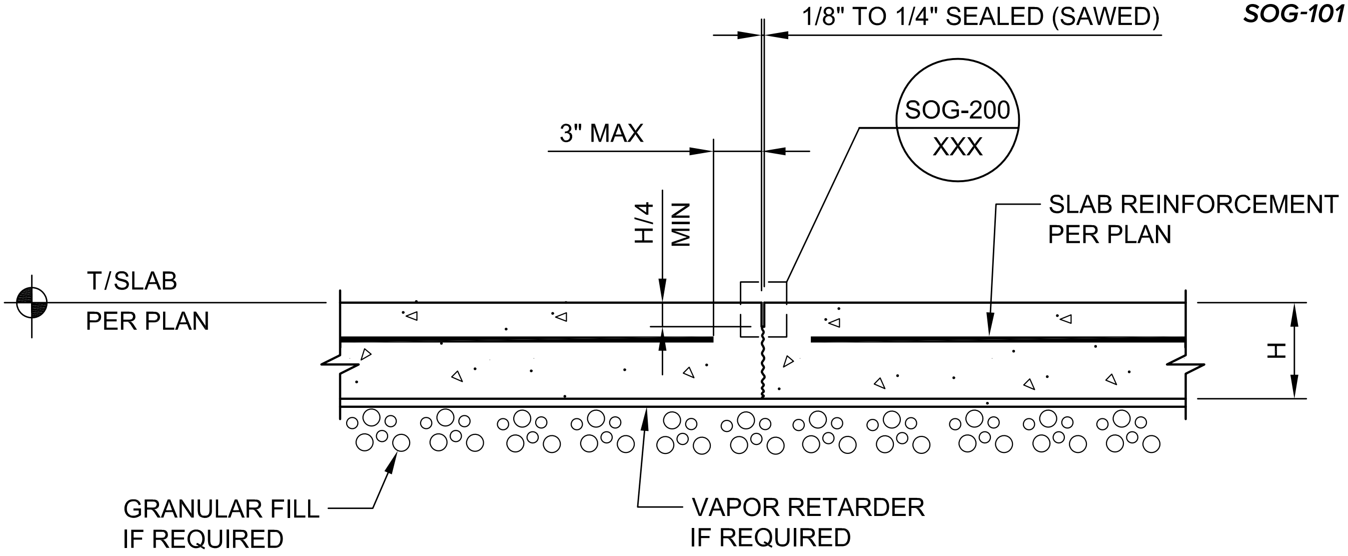
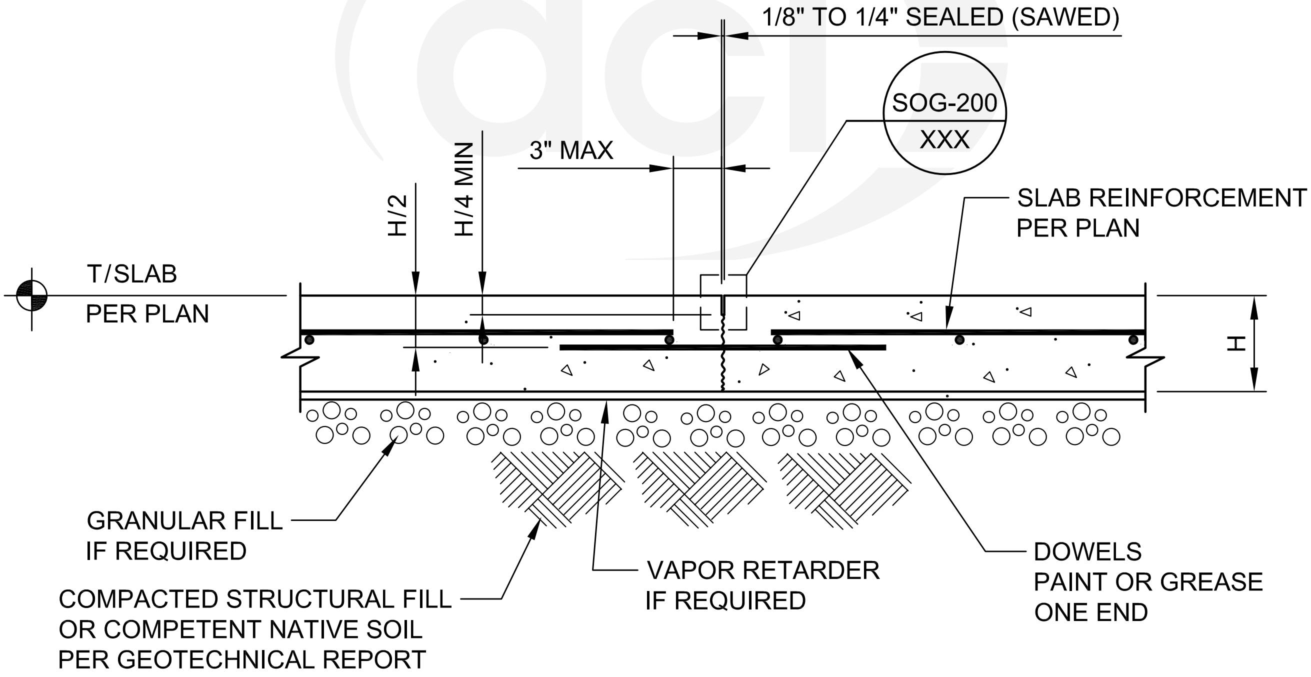
[*] Refer to Section 3 for articles

SOG-101



NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE
INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

CONTRACTION JOINT (CTJ)



NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE
INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

SLAB-ON-GROUND CONTRACTION JOINT

FIGURE SOG-101: SLAB-ON-GROUND CONTRACTION JOINT

The design professional shall review the following checklist and incorporate project-specific requirements into the details

INTENDED USE

Floor contraction joints for nonindustrial structures

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Defined slab-on-ground thickness matches with floor plan
2. Granular fill is per the geotechnical report recommendation
3. Reinforcing type, spacing, and elevation within slab-on-ground is specified
4. Vapor retarder is specified if moisture would affect building floor finish
5. Contraction joints may not be necessary if tile or carpeting is used
6. Early entry dry-cut saw is used as soon as possible without causing raveling of concrete edges; sawcut along short direction of placement first
7. Contraction joints are aligned with re-entrant slab corners, each way typical
8. Contraction joints enclose approximately square areas, 225 ft^2 maximum, with maximum panel aspect ratio of 1.5 to 1.0
9. Surface treatment application has been coordinated with owner and specifications
10. Contraction joints are sealed per detail 200
11. Remove "NOTES TO DESIGN PROFESSIONAL" before placing detail in the Contract Documents

RECOMMENDED CONTRACTION JOINT SPACING FOR CONCRETE SLAB-ON-GROUND

	Contraction joint spacing		
	Aggregate		
Slab thickness, in.	≤ 3/4 in.	>3/4 in.	Slump < 4 in.
4	8 ft	11 ft	12 ft
5	10	13	15
6	12	15	18
7	14	18	21
8	16	20	24
9	18	23	27
10	20	25	30

RECOMMENDED REFERENCES

Concrete International articles[*]:

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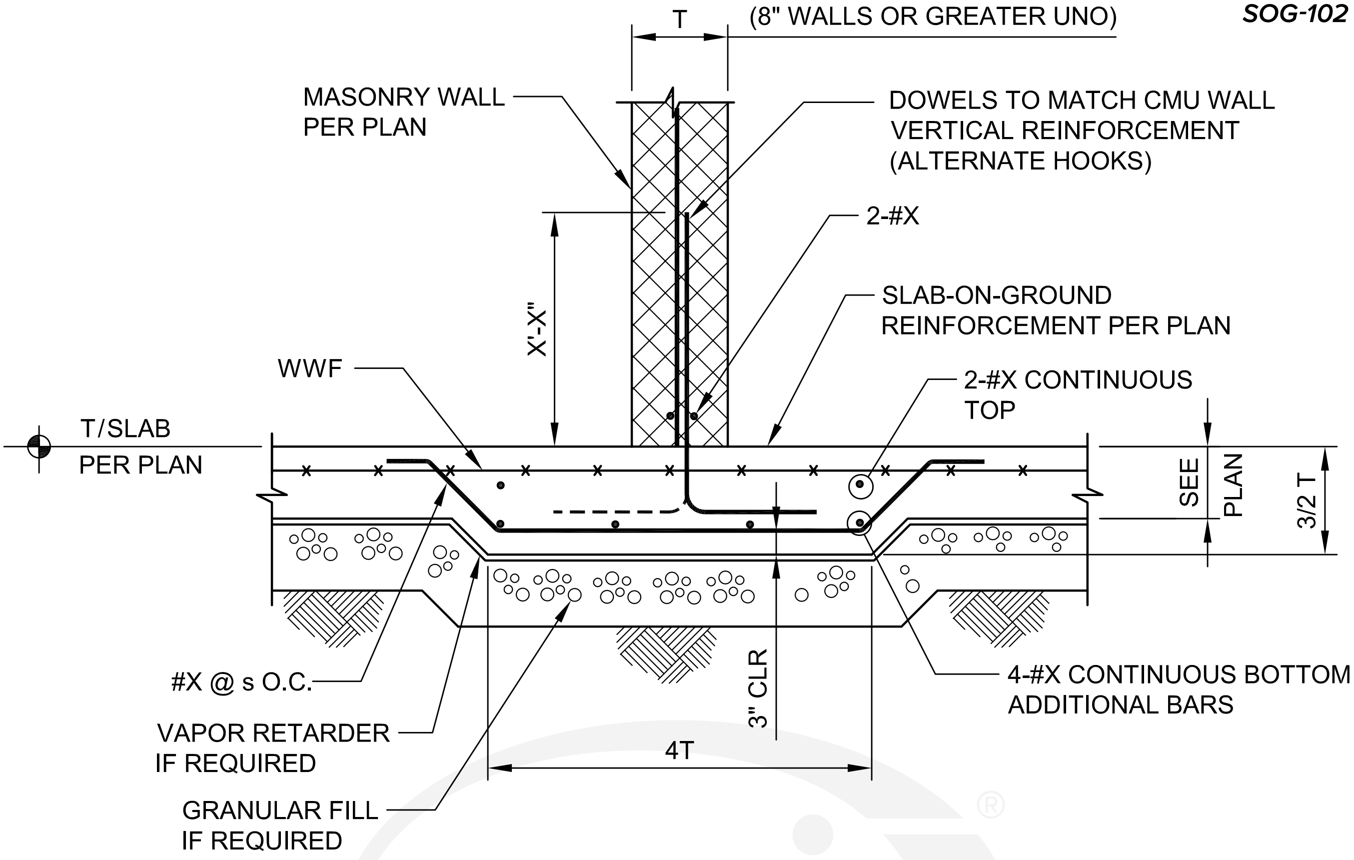
[*] Refer to Section 3 for articles

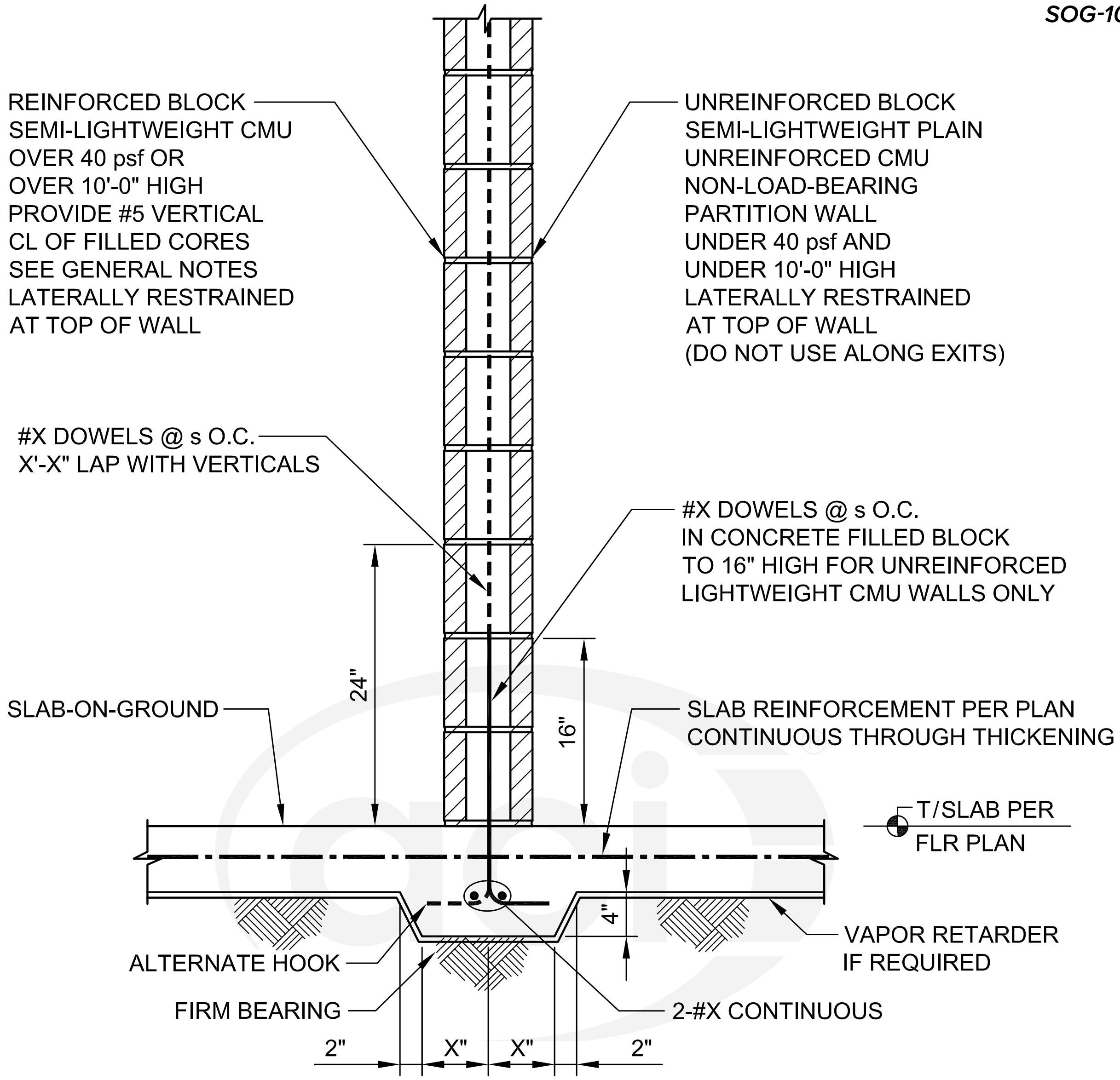
SOG-102



NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

INTERIOR THICKENED SLAB-ON-GROUND FOOTING AT CMU NONBEARING WALL - OPTION 1

SOG-103



NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

NON-STRUCTURAL MASONRY WALLS AND THICKENED SLAB-ON-GROUND - OPTION 2

FIGURE SOG-102 AND SOG-103: THICKENED SLAB-ON-GROUND SUPPORTING NON-STRUCTURAL BEARING WALL

The design professional shall review the following checklist and
incorporate project-specific requirements into the details

INTENDED USE

Partitions, single story enclosures, and light fire-partitions

NOT INTENDED FOR (OPTIONAL)

Load bearing walls

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Bar cover is provided per Section 20.5.1.3
2. Supported wall is 8 in. thick or less non-load-bearing wall
3. For walls greater than 8 in. thick, separate wall foundation may be required
4. Thickened slab-on-ground is identified and coordinated with joints parallel to the wall on the floor plan
5. Where joints run parallel or fall beneath wall, then:
    a. Revise layout of joints
    b. Eliminate control joints and allow for longer spacing between joints such that control joints do not fall below CMU wall, if possible
    c. Replace control joint with construction joint with the adjacent slab placement delayed 3 to 7 days, if possible. This will allow the first placement to shrink prior to next slab placement and for the reinforcement to be continuous. Coordinate slab-on-ground construction joints with CMI wall movement joint locations
6. For slab thicknesses 6 in. or less review slab-on-ground design for strength and capability of supporting the non-load-bearing wall
7. Drill vertical dowels for wall, if dowels are required and not preplaced during placement of concrete
8. Option 2 is used for non-load-bearing partition walls not more than 10 in. in height
9. For Option 2, thickened slab extends minimum 3 in. beyond face of wall and 4 in. thickness applies to slab-on-ground of 6 in. thick or less
10. Reinforcing type, spacing, and elevation within slab-on-ground is specified
11. Granular fill is per the geotechnical report recommendation
12. Vapor retarder is specified if moisture would affect building floor finish
13. Remove "NOTES TO DESIGN PROFESSIONAL" before placing detail in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles[*]:

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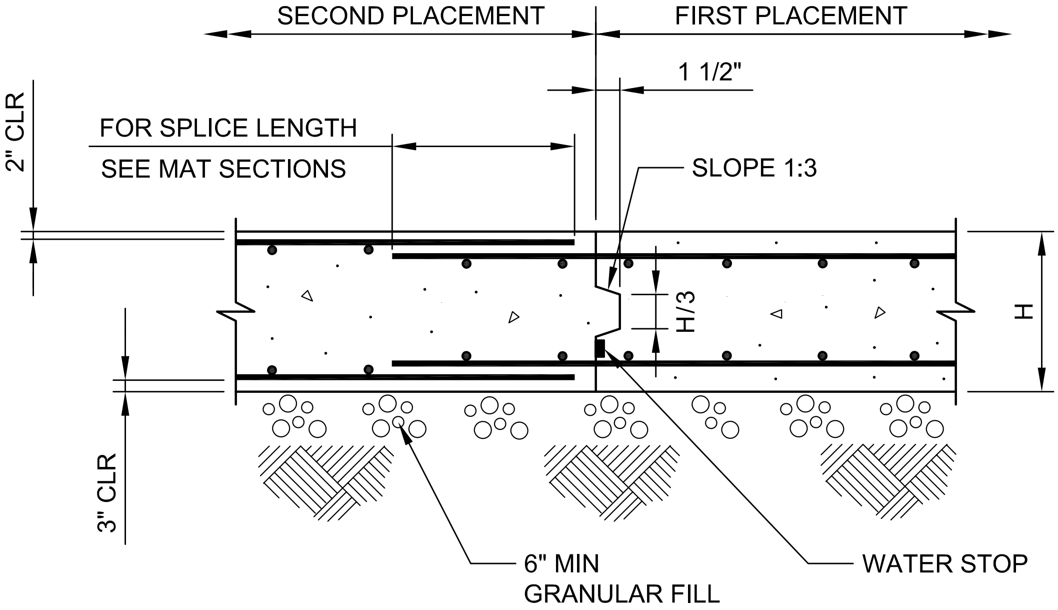
[*] Refer to Section 3 for articles

SOG-104



NOTE:
MAXIMUM 80 FEET BETWEEN CONSTRUCTION JOINTS
AND 72 HOURS MINIMUM BETWEEN ADJACENT PLACEMENTS

NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

MAT CONSTRUCTION JOINT

FIGURE SOG-104: MAT CONSTRUCTION JOINT

The design professional shall review the following checklist and incorporate project-specific requirements into the details

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INTENDED USE

Construction joint in foundation mat

NOT INTENDED FOR (OPTIONAL)

Slab-on-ground construction
Elevated slab construction

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Mat extent is identified on plan
2. If mat foundation is thicker than 18 in., then show multiple keyways
3. Joint locations and direction for large concrete placements are identified
4. Granular fill is per the geotechnical report recommendation
5. Reinforcing type, spacing, and elevation within slab is properly identified
6. Splice length at construction joints is called out
7. Waterstop is shown if required
8. Bar cover is provided per Section 20.5.1.3
9. Remove “NOTES TO DESIGN PROFESSIONAL” before placing detail in the Contract Documents

RECOMMENDED REFERENCES

Concrete International Articles[*]: 6

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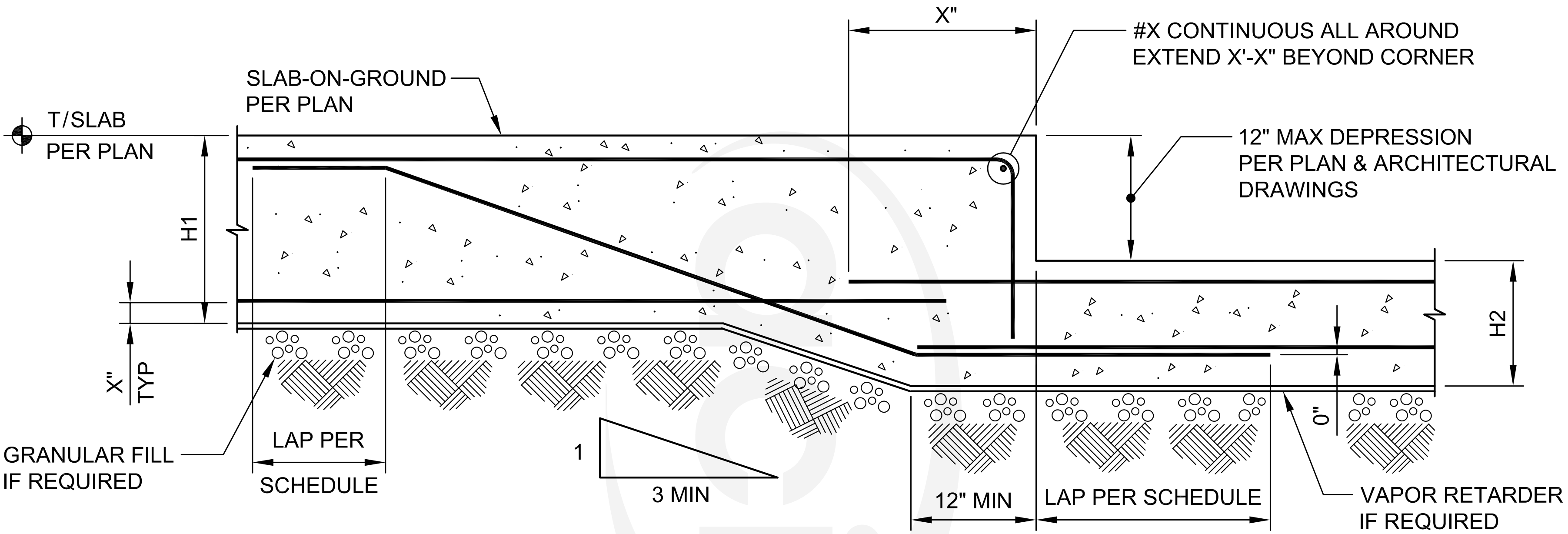
[*] Refer to Section 3 for articles

SOG-105

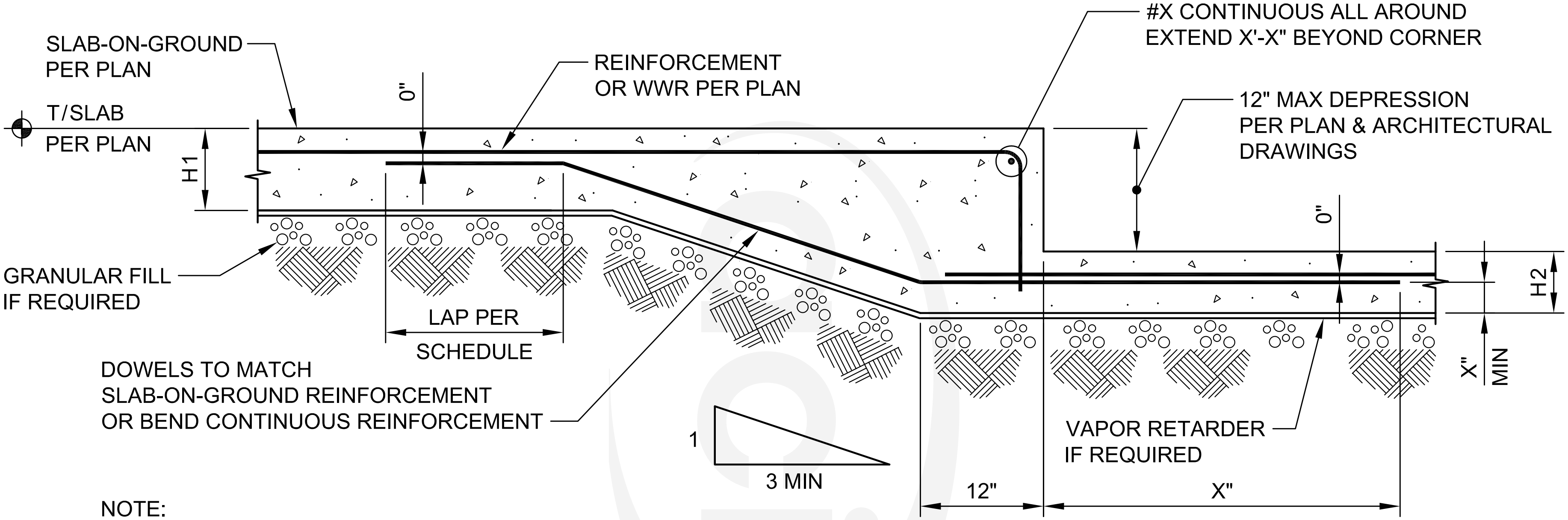


NOTE:
TRANSVERSE REINFORCEMENT NOT SHOWN FOR CLARITY

NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

SLAB-ON-GROUND WITH TOP AND BOTTOM REINFORCEMENT AND MAXIMUM 12 INCH DEPRESSION

SOG-106



NOTE:
TRANSVERSE REINFORCEMENT NOT SHOWN FOR CLARITY

NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE
INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

SLAB-ON-GROUND WITH MAX 12 INCH DEPRESSION

FIGURE SOG -105 AND SOG-106: SLAB-ON-GROUND WITH MAXIMUM 12 IN. DEPRESSION

The design professional shall review the following checklist and
incorporate project-specific requirements into the details

INTENDED USE

For drops in slab-on-ground not exceeding 12 in.

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Depth and extent of drop/depression in slab-on-ground is coordinated with floor plan
2. Granular fill is per the geotechnical report recommendation
3. Vapor retarder if required
4. Reinforcing type, spacing, and elevation is indicated within slab
5. Minimum No. 4 bar is provided at top edge of drop; extend ft beyond drop
6. Splice length of bars is called out
7. Depressed slab may require special sealer or coating
8. Remove “NOTES TO DESIGN PROFESSIONAL” before placing detail in the Contract Documents

RECOMMENDED REFERENCES

Concrete International Articles[*]:

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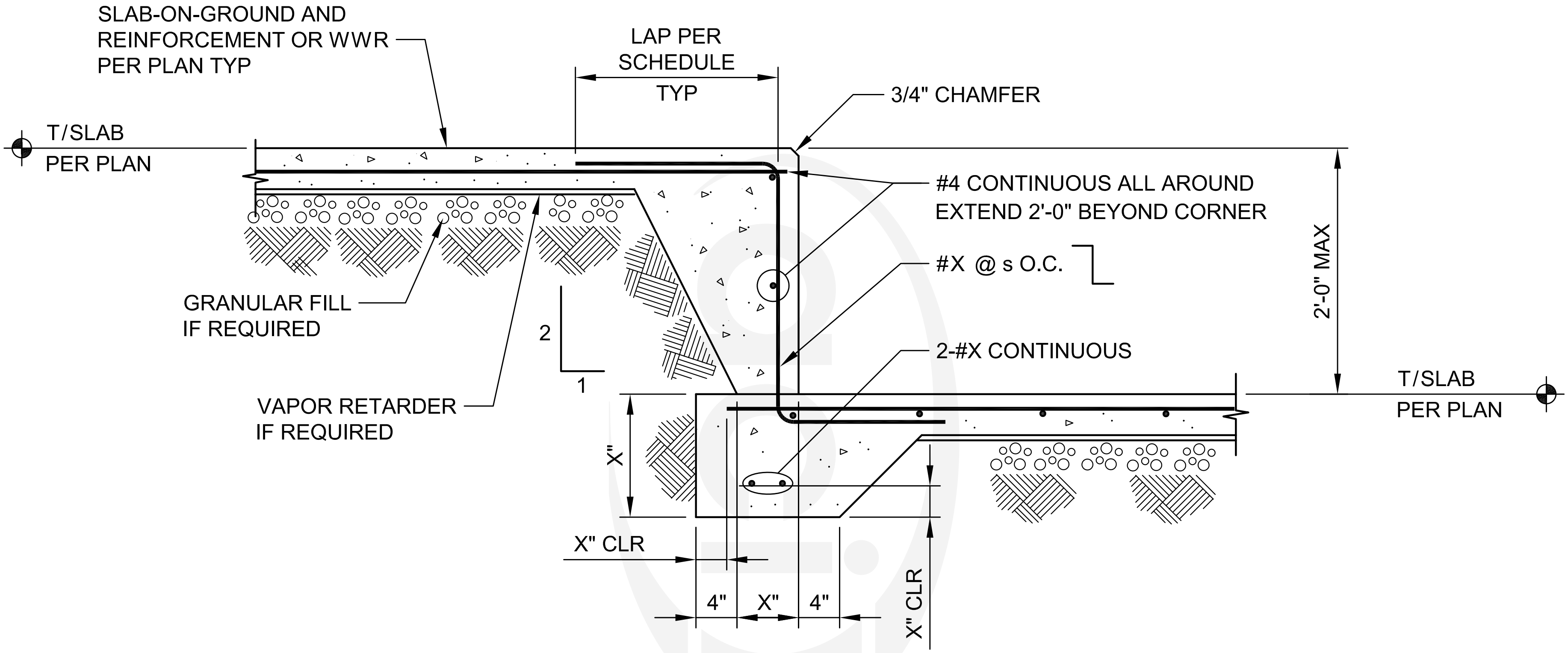
[*] Refer to Section 3 for articles

SOG-107



NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

SLAB-ON-GROUND WITH DEPRESSION BETWEEN 12- AND 24-INCH

FIGURE SOG-107: SLAB-ON-GROUND WITH DEPRESSION BETWEEN 12 AND 24 IN.

The design professional shall review the following checklist and
incorporate project-specific requirements into the details

INTENDED USE

For steps in slab-on-ground not exceeding 24 in.

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Depth and extent of step in slab-on-ground is coordinated with floor plan
2. Granular fill is per the geotechnical report recommendation
3. Vapor retarder if required
4. Reinforcing type, spacing, and elevation is indicated within slab
5. Minimum No. 4 horizontal bars are provided at edge of step; extend 2 ft beyond step
6. Vertical reinforcement is provided along the edge of the step and properly developed in the top and bottom slab-on-ground
7. Verify that thickened edge slab is provided below step-change in elevation
8. Minimum two No. 4 bars are provided in the thickened slab below the step
9. Depressed slab may require special sealer or coating
10. Remove “NOTES TO DESIGN PROFESSIONAL” before placing detail in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles[*]:

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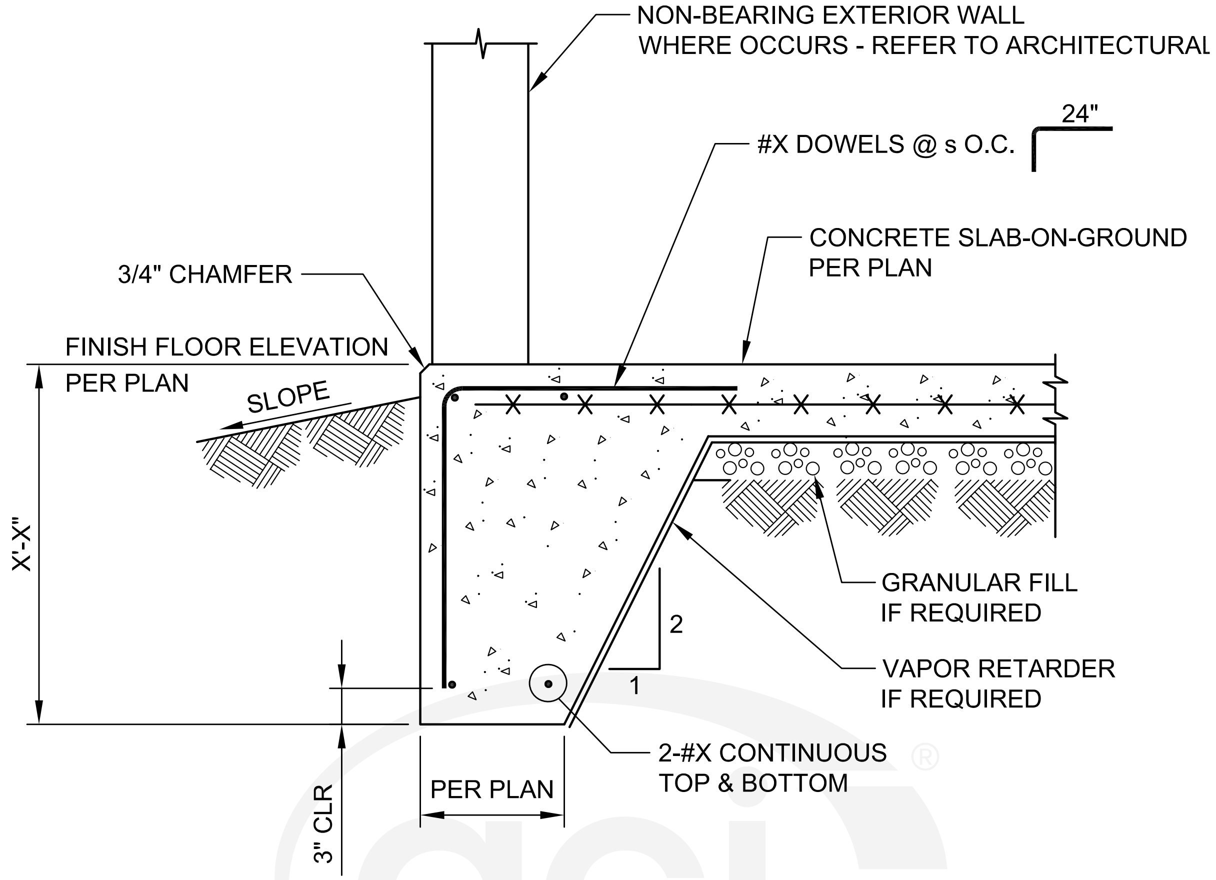
[*] Refer to Section 3 for articles

SOG-108



NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

THICKENED SLAB-ON-GROUND EDGE

FIGURE SOG-108: THICKENED SLAB-ON-GROUND EDGE DETAIL

The design professional shall review the following checklist and incorporate project-specific requirements into the details

INTENDED USE

Thickened edge slab where frost is not an issue or extended deep below frost line

Edge slab supporting light edge load

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Slab thickness and reinforcement with slab-on-ground plan are coordinated
2. Granular fill is per the geotechnical report recommendation
3. Two No. 5 minimum continuous bars are placed top and bottom of the thickened slab-on-ground
4. An L-shaped dowel is added to the edge of the slab
5. Remove “NOTES TO DESIGN PROFESSIONAL” before placing detail in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles[*]:

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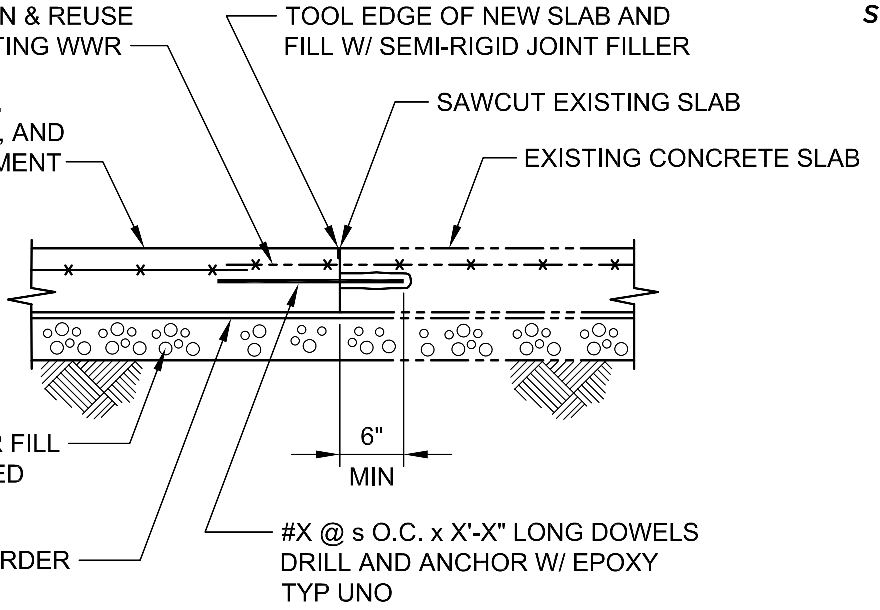
[*] Refer to Section 3 for articles

SOG-150



NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

JOINT AT EXISTING SLAB-ON-GROUND REINFORCED WITH WWF

FIGURE SOG-150: JOINT AT EXISTING SLAB-ON-GROUND REINFORCED WITH WWF

The design professional shall review the following checklist and
incorporate project-specific requirements into the details

INTENDED USE

Existing to new slab-on-ground joint detail reinforced with wire mesh

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Location of joint is identified on plan
2. Drilled hole into existing slab-on-ground is located at mid-depth
3. Diameter and depth of drilled hole is defined into existing slab-on-ground
4. Smooth dowel, not less than 5/8 in. in diameter and minimum 12 in. long are specified into new extension
5. Direction is given to the contractor to clean and protect existing wire mesh reinforcement from damage
6. Extension of existing wire mesh reinforcement into new slab-on-ground is identified
7. New wire mesh reinforcement in new addition matches existing wire mesh in existing slab-on-ground
8. Granular fill for new slab-on-ground extension is per the geotechnical report recommendation
9. Vapor retarder is specified for new slab-on-ground extension if moisture would affect building floor finish
10. Remove "NOTES TO DESIGN PROFESSIONAL" before placing detail in the Contract Documents

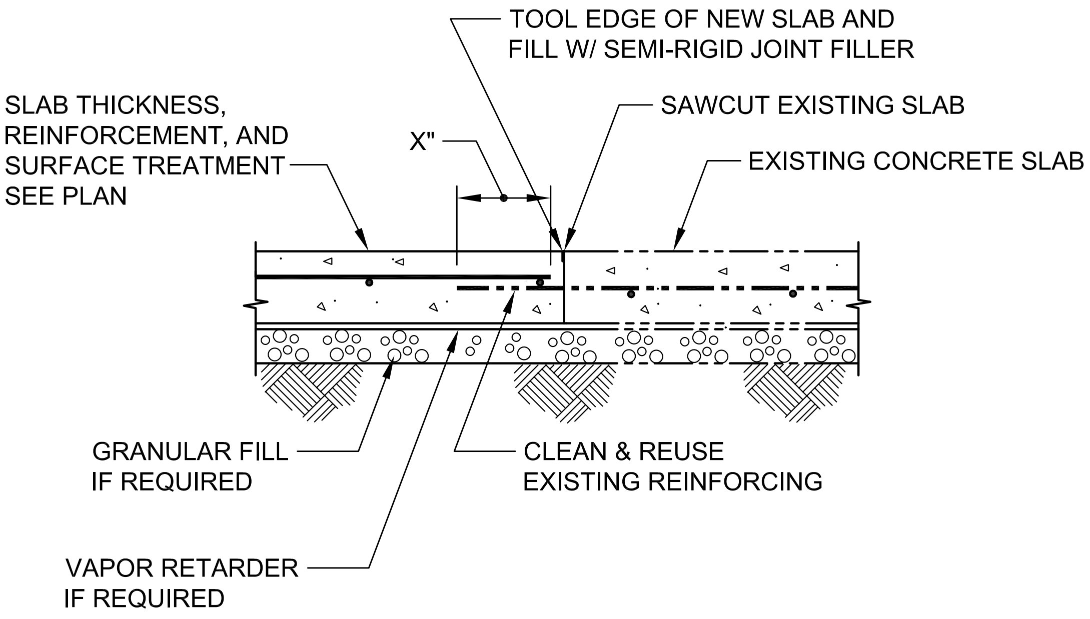
RECOMMENDED REFERENCES

Concrete International articles[*]:

---

[*] Refer to Section 3 for articles

SOG-151



NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

JOINT AT EXISTING SLAB-ON-GROUND REINFORCED WITH STEEL BARS

FIGURE SOG-151: JOINT AT EXISTING SLAB-ON-GROUND REINFORCED WITH STEEL BARS

The design professional shall review the following checklist and
incorporate project-specific requirements into the details

INTENDED USE

Existing slab-on-ground to new structural slab-on-ground joint detail reinforced with deformed bars

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Location of joint is identified on plan
2. Direction is given to the contractor to clean and protect reinforcement from damage
3. New bar diameter in new addition matches existing bar diameter in existing slab-on-ground
4. Existing bar length into new slab-on-ground exceeds its required splice length if flexure is transferred
5. If existing bars are cut, drill hole into existing slab-on-ground at mid-depth
6. Diameter and depth of drilled hole, if required, is defined into existing slab-on-ground
7. Smooth dowel, if required, not less than 5/8 in. in diameter and minimum 12 in. long are specified into new extension if only shear is transferred
8. Sawcut and joint filler are required
9. Granular fill for new slab-on-ground extension is per the geotechnical report recommendation
10. Vapor retarder is specified for new slab-on-ground extension if moisture would affect building floor finish
11. Remove "NOTES TO DESIGN PROFESSIONAL" before placing detail in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles*:

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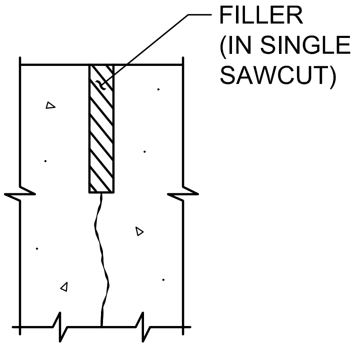
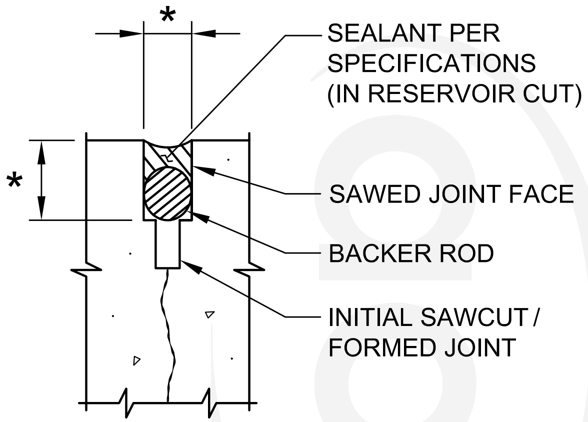
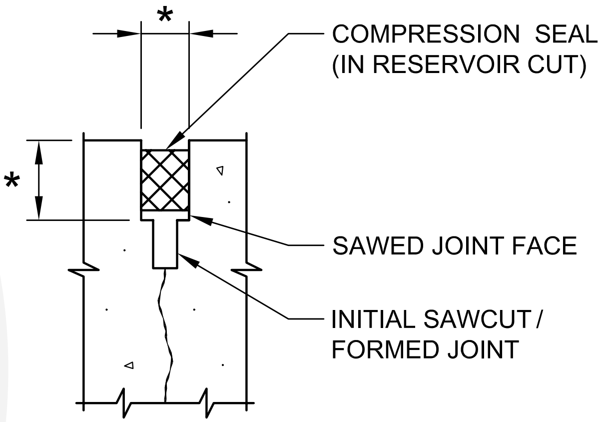
*Refer to Section 3 for articles





* SEE SLAB JOINT DETAIL



* SEE SLAB JOINT DETAIL

NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

TYPICAL SLAB JOINTS FILLER DETAIL

FIGURE SOG-200: TYPICAL SLAB JOINT FILLER DETAIL

The design professional shall review the following checklist and incorporate project-specific requirements into the details

INTENDED USE

To minimize infiltration of water and other material into a joint

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Type of sealant used on the project: hot-pour sealant, silicone sealant, or compression seal
2. Specify low-modulus sealant
3. Increase saw cut width at the top of the saw cut to accommodate backer rod and in-fill sealant
4. The recommended depth-to-width ratio of sealant above a backer rod is approximately 1.0 for hot-pour sealant and 0.5 for silicone sealant
5. Suggested minimum and maximum sealant width is 1/4 in. and 1/2 in., respectively
6. Remove "NOTES TO DESIGN PROFESSIONAL" before placing detail in the Contract Documents

SIZING RECOMMENDATIONS FOR BACKER RODS[1]

Reservoir width	Backer rod diameter
1/8 to 3/16 in.	1/4 in.
1/4 to 5/16 in.	3/8 in.
3/8 in.	1/2 in.
1/2 in.	5/8 in.
5/8 in.	3/4 in.
3/4 in.	7/8 in.
7/8 in.	1 in.
1 in.	1-1/4 in.
1-1/4 in.	1-1/2 in.
1-1/2 in.	2 in.

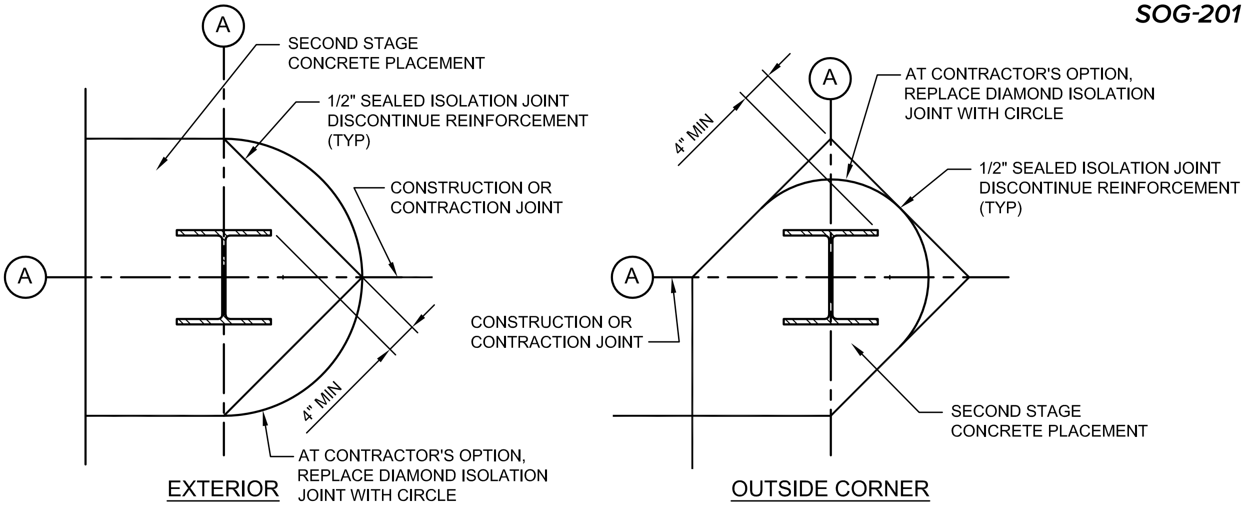
SIZING RECOMMENDATIONS FOR PREFORMED COMPRESSION SEALS[1]

Joint Spacing ft	Minimum Reservoir Width in.	Minimum Reservoir Depth in.	Relaxed Seal Width in.
15	1/4	1-1/2	7/16
20	5/16	1-1/2	5/8
25	3/8	2	11/16
30	1/2	2	1

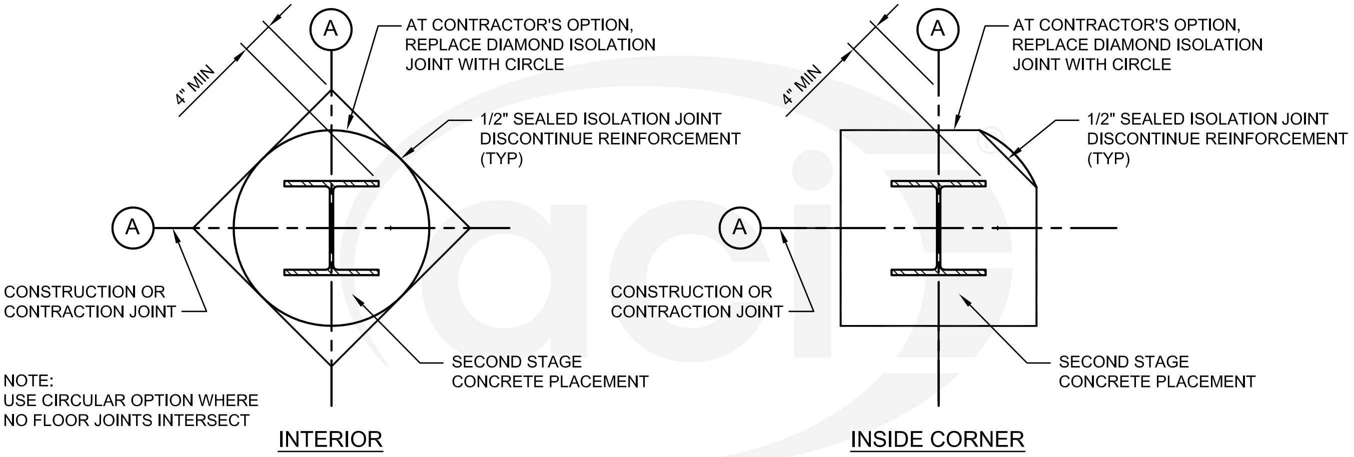
RECOMMENDED REFERENCES

[1] AASHTO, 2008, *Guide Specifications for Highway Construction*, American Association of Highway and Transportation Officials, Washington, DC

SOG-201



NOTE:
FOR EXTERIOR ISOLATION JOINT AT BRACED BAYS
SECOND STAGE CONCRETE PLACEMENT SHALL
ENCASE ALL GUSSET PLATES AND BRACING MEMBERS.



NOTE:
USE CIRCULAR OPTION WHERE
NO FLOOR JOINTS INTERSECT

NOTES:

1. USE "EARLY ENTRY DRY-CUT SAW" AS SOON AS POSSIBLE WITHOUT CAUSING RAVELING OF CONCRETE EDGES. SAWCUT ALONG SHORT DIRECTION OF PLACEMENT FIRST.
2. ALIGN A CONSTRUCTION OR CONTROL JOINT WITH RE-ENTRANT SLAB CORNERS, EACH WAY, TYPICAL.
3. CONSTRUCTION/CONTROL JOINT TO ENCLOSE APPROXIMATE SQUARE AREAS 225 SQUARE FEET MAXIMUM, WITH MAXIMUM PANEL ASPECT RATIO OF 1.5 TO 1.0.
4. CONTRACTOR TO SUBMIT CONSTRUCTION/CONTROL JOINT PLAN TO STRUCTURAL ENGINEER OF RECORD FOR REVIEW/APPROVAL.

NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE
INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

TYPICAL STEEL COLUMNS ISOLATION JOINT DETAILS

FIGURE SOG-201: TYPICAL STEEL COLUMN ISOLATION JOINT DETAILS

The design professional shall review the following checklist and incorporate project-specific requirements into the details

INTENDED USE

To isolate slab-on-ground from steel columns

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. The appropriate isolation shapes, circular, diamond, or rectangular are included on the plans that are relevant to the project
2. Joints are located at least 4 in. from the corners of the column
3. Joint sealant and premold joint material are specified
4. Premold joint is provided at isolation joint
5. At least two No. 4 x 3 ft long are placed top and bottom and to protect isolated joint re-entrant corners
6. Remove "NOTES TO DESIGN PROFESSIONAL" before placing detail in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles[*]:

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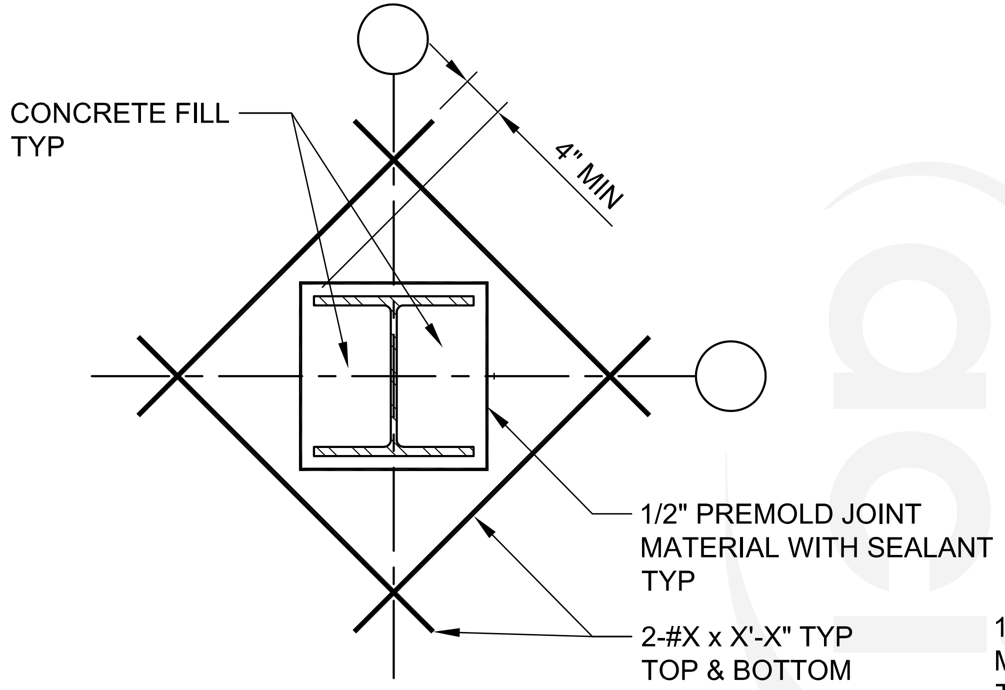
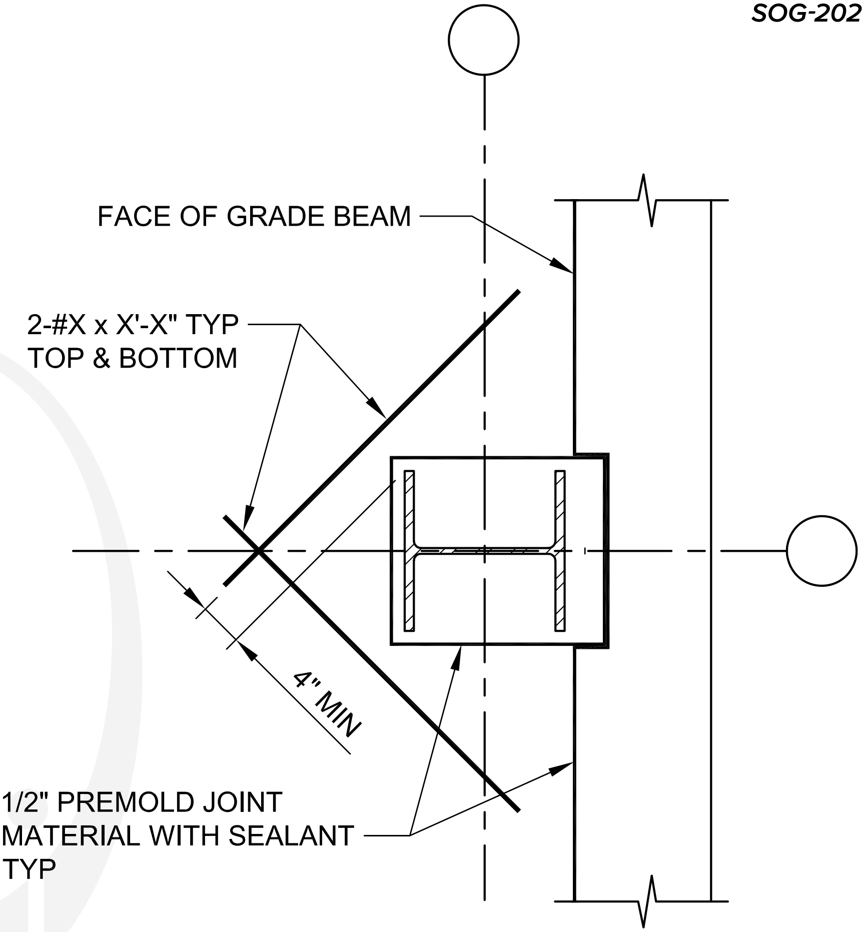
[*] Refer to Section 3 for articles

SOG-202



INTERIOR COLUMN



EXTERIOR COLUMN

NOTE TO DESIGN PROFESSIONAL:
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STEEL COLUMN ISOLATION JOINT

FIGURE SOG-202: TYPICAL STEEL COLUMN ISOLATION JOINT

The design professional shall review the following checklist and incorporate project-specific requirements into the details

INTENDED USE

To isolate slabs-on-ground from steel columns and concrete piers in office buildings

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Joint sealant and premold joint material are specified
2. Joints are located at least 4 in. from the corners of the column
3. If column fill is not full depth, use a bitumastic paint
4. Premold joint is provided at isolation joint
5. At least two No. 4 x 3 ft long are placed top and bottom and to protect isolated joint re-entrant corners
6. Remove "NOTES TO DESIGN PROFESSIONAL" before placing detail in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles[*]:

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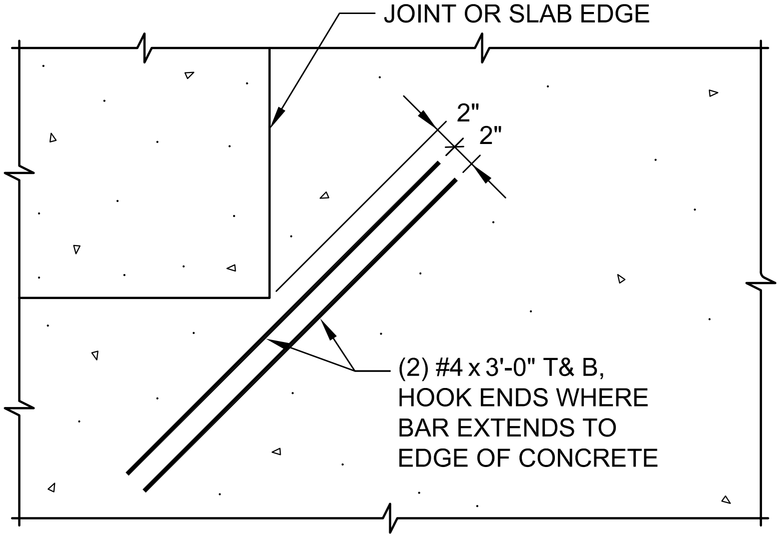
[*] Refer to Section 3 for articles

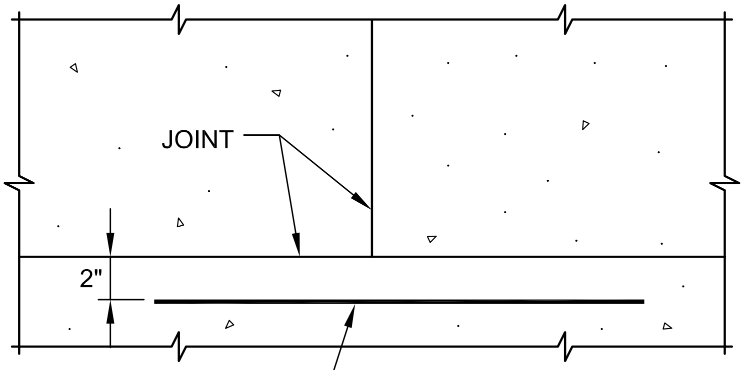
SOG-203



NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE
INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

RE-ENTRANT CORNER BARS IN SLAB-ON-GROUND

SOG-204



ADD (2) #4 x 3'-0" T&B CENTER
ON INTERSECTING JOINTS

NOTE TO DESIGN PROFESSIONAL:
COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAIL AS REQUIRED BEFORE INCORPORATING THIS DETAIL INTO PROJECT CONSTRUCTION DOCUMENTS

REINFORCEMENT AT DISCONTINUOUS SLAB-ON-GROUND CONTRACTION JOINT

FIGURE SOG-203 AND SOG-204: REINFORCEMENT AT DISCONTINUOUS SLAB-ON-GROUND CONTRACTION JOINT AND RE-ENTRANT CORNERS

The design professional shall review the following checklist and incorporate project-specific requirements into the details

INTENDED USE

Protection of slab at discontinuous joint from crack propagation

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Location of discontinuous slab joints is identified on plan
2. Bars are placed perpendicular to the discontinuous slab contraction joint
3. Bars are placed at 45 degrees at the intersection of two discontinuous joints
4. Two No. 4 x 3 ft long bars are placed per layer of slab reinforcement at 2 in. from continuous joint and spaced at 2 in. on center
5. Bars are centered at intersecting joints
6. Where discontinuous joint is close to an edge or obstruction, hook No. 4
7. Remove “NOTES TO DESIGN PROFESSIONAL” before placing detail in the Contract Documents

RECOMMENDED REFERENCES

Concrete International articles[*]:

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[*] Refer to Section 3 for articles

SECTION 3
REFERENCES

Designing for Constructibility: Perspectives on Reinforcing

The Tolerance Cloud

BY DICK BIRLEY

Design engineers often lack the practical field experience necessary to provide construction documents that reflect job-site requirements. Detailing and installation conflicts can therefore occur, leading to requests for information, delays, and additional costs. As a result, a variety of ad hoc, job-site solutions (“cowboy tricks”) have evolved. While many of these job-site remedies provide good, workable solutions, others could be improved through practical design review.

ACI Committee 315-B, Details of Concrete Reinforcement-Constructibility, has been identifying constructibility issues specific to reinforcing steel. With the hope that they will encourage discussion within the general construction community, the committee will publish a regular series of articles in *Concrete International*. In each case, committee members will discuss problems and provide solutions drawn from the experiences of knowledgeable practitioners in the industry. Of course, these solutions won’t (and can’t) be offered as official ACI-recommended practice. Even so, the committee hopes and believes that, by encouraging dialogue, the series will advance the interests of the industry. Further, when an adequate number of concerns have been published, discussed, and resolved, the committee plans to compile them into a formal publication. Interested parties are urged to join the committee.

To improve the constructibility of reinforced concrete structures, ACI Committee 315-B, Details of Concrete Reinforcement-Constructibility, is working to identify constructibility concerns; offer practical, job-site-based solutions; and solicit input and comments from the design community. As part of the committee’s efforts, I and other members will author a series of articles, with a primary focus on constructibility concerns that involve the assembly of reinforcing bar components. Further, we will address how other trades affect reinforcing bar installation, and we will attempt to identify design details that could be deficient, ambiguous, or simply missing. What better place to start our discussion of these issues than where the installation of reinforcing starts—with a single reinforcing bar and the tolerance envelope that exists at that single bar—what I call the tolerance cloud.

CONCERNS

Designers, reinforcing steel detailers, and software programmers often fail to factor the impact of fabrication

Designing for Constructibility: Perspectives on Reinforcing

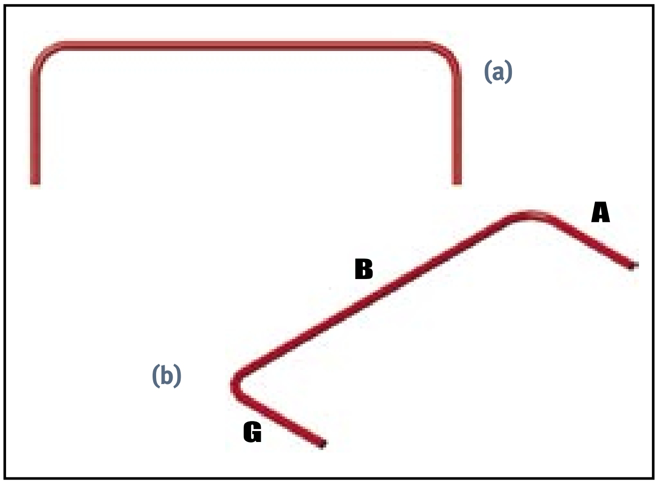

Fig. 1: Standard (theoretical) hooked bar with Sides A, B, and G: (a) plan view, and (b) isometric view

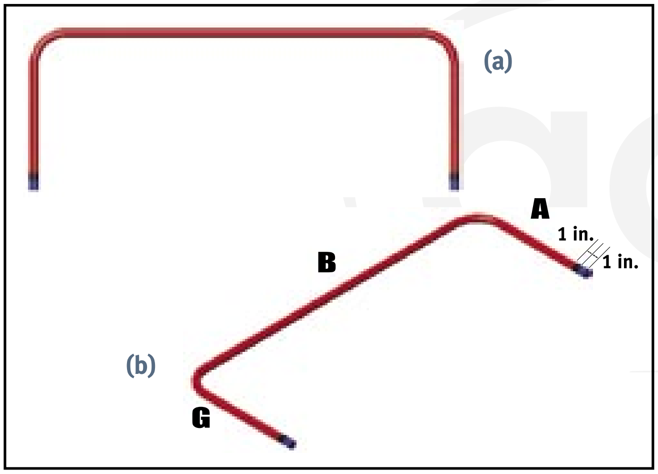

Fig. 2: Hooked bar with ±1 in. tolerance envelope on Sides A and G

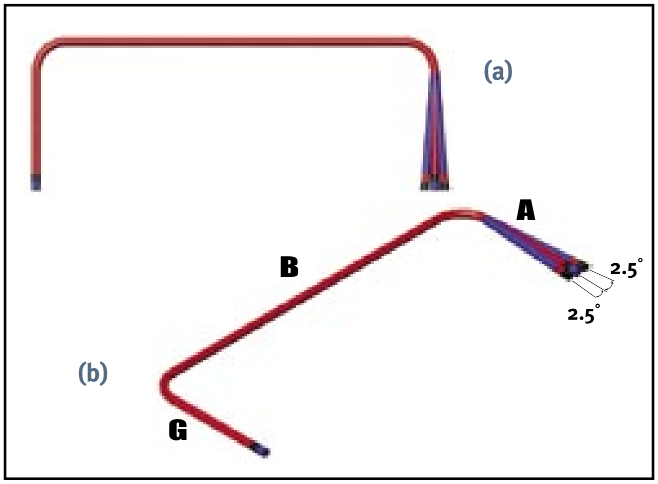

Fig. 3: Hooked bar with ±1 in. tolerance envelope on Sides A and G and ±2.5 degrees in-plane angular tolerance envelope at Side A

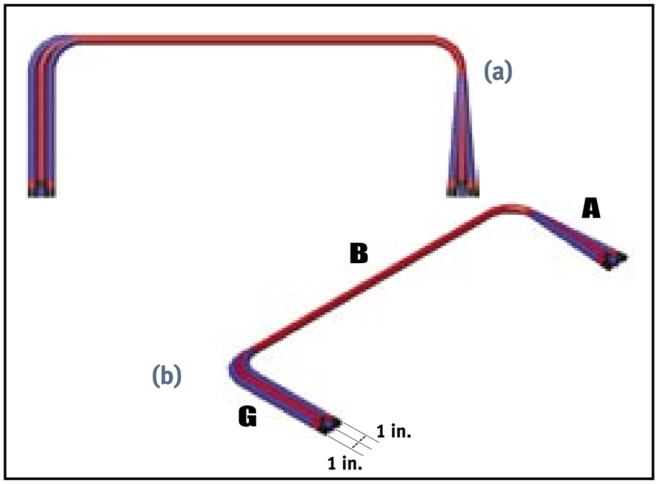

Fig. 4: Hooked bar with ±1 in. tolerance envelope on Sides A and G, ±2.5 degrees in-plane angular tolerance envelope at Side A, and ±1 in. tolerance envelope on Side B

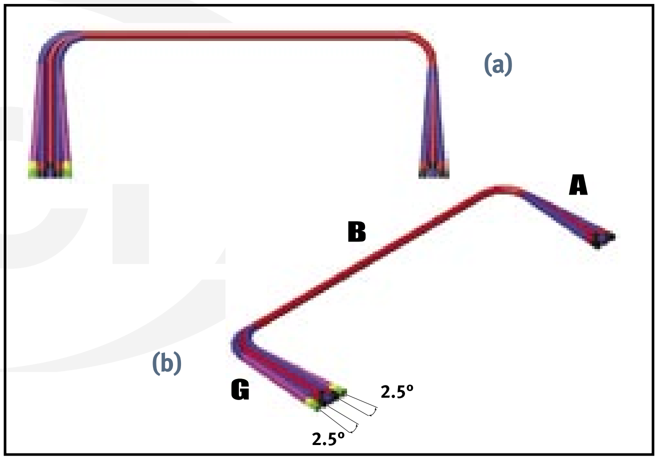

Fig. 5: Hooked bar with ±1 in. tolerance envelope on Sides A, B, and G and ±2.5 degrees in-plane angular tolerance envelope at Sides A and G

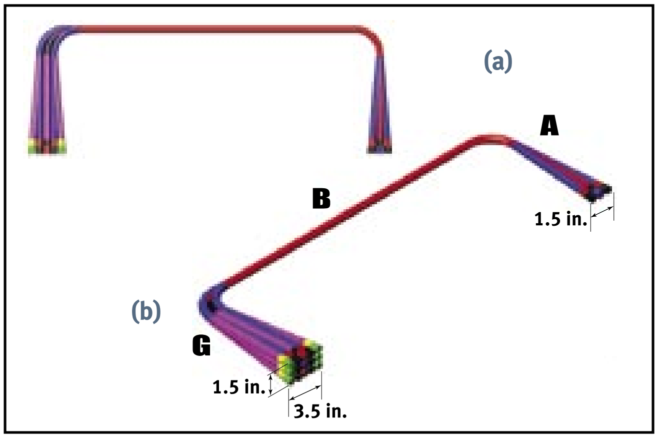

Fig. 6: Hooked bar with ±1 in. tolerance envelope on Sides A, B, and G; ±2.5 degrees in-plane angular tolerance envelope at Sides A and G; and ±2.5 degrees out-of-plane angular tolerance envelope at Side G

Designing for Constructibility: Perspectives on Reinforcing

tolerances into their work. As a simple example, let's consider the fabrication tolerances for a simple reinforcing bar with 90-degree bends (Fig. 1). For the purposes of our example, let's assume that the bar is a No. 8 (25 mm) bar and that Side A is anchored in the (idealized) plane ABG. For this bar size, the standard hook is 16 in. (400 mm) long, and the linear and angular tolerances are ±1 in. (±25 mm) and ±2.5 degrees, respectively.[1]

Now, let's examine the potential effects of these tolerances. First, note that Sides A and G can be as short as 15 in. (375 mm) (red to black zone interface) or as long as 17 in. (425 mm) (end of blue zone) and still be within tolerances (Fig. 2).

Because we have assumed Side A to be anchored in ABG, we will not need to consider out-of-plane angular deviation for Side A. However, we will need to consider in-plane angular deviation. When we add this angular deviation of ±2.5 degrees to Side A, the tolerance envelope (cloud) will appear as shown in Fig. 3. (***Note:*** *To simplify the illustrations, the effects of the angular tolerances are shown as one-bar-diameter deviations in the position of the ends of the 16 in. hooks. Actual deviations will be about 70% of a bar diameter.)*

Next, we add the dimensional tolerance of ±1 in. for Side B (Fig. 4) and the in-plane angular deviation of ±2.5 degrees to Side G (Fig. 5).

Finally, we add the out-of-plane angular deviation of ±2.5 degrees to Side G. The resulting tolerance cloud is as shown in Fig. 6.

DESIGN CONSIDERATIONS

Clearly, the fabricated bar arriving on the construction site can be quite different from the bar the designer or software programmer might have envisioned. Keeping this in mind during design could significantly reduce constructibility problems. For instance, if our example bar were replaced with two hooked bars lapped in the middle, the only tolerance that might introduce problems would be in-plane angular deviation. Because both hooks could be rotated, there would be no out-of-plane deviations. Further, because the lap could be adjusted slightly, there would be little chance of problems with the length of Side B.

Consideration of tolerances becomes even more of an issue when two or more bars are being assembled together in a structure. In such cases, one must deal with an accumulation of tolerances. Future articles in this series will examine these and other constructibility issues related to reinforcing steel.

References

1. ACI Committee 117, "Standard Specifications for Tolerances for Concrete Construction and Materials (ACI 117-90) and Commentary (117R-90)," American Concrete Institute, Farmington Hills, MI, 2002, 22 pp.

Selected for reader interest by the editors after independent expert evaluation and recommendation.

ACI member **Dick Birley** has more than 40 years of experience in the reinforcing steel industry, including working as an ironworker and owning a fabrication and placing company. He is currently the owner of Condor Rebar Consultants, Inc., a detailing company located in Vancouver, BC, that is involved in projects worldwide. He is a member of ACI Committees 315, Details of Concrete Reinforcement, and 439, Steel Reinforcement.

Designing for Constructibility: Perspectives on Reinforcing

Placement Tolerance Clouds

BY DICK BIRLEY

In my previous article "The Tolerance Cloud," I identified the potential tolerance envelopes for a single reinforcing bar fabricated with a 90-degree bend at each end.[1] Just as there are tolerances in the fabrication of a bar, there are also tolerances in the placement of a bar in a concrete member—creating potential "placement tolerance clouds." Because designers and software programmers may overlook the impact of placement tolerances on constructibility, it's worthwhile to use a couple of examples to take a brief look at what can occur.

CONCERNS

The tolerances for reinforcement location are found in Section 2.2 of ACI 117-90.[2] Cover tolerances vary from 1/4 in. (6 mm) for member sizes of 4 in. (100 mm) or less to 1 in. (25 mm) when member size is over 2 ft (600 mm). The maximum reduction in cover is limited to 1/3 of the specified cover. In slabs and walls, the spacing tolerance is 3 in. (76 mm) for reinforcement other than stirrups and ties.

As an example, let's consider the simple 14 x 14 in. (350 x 350 mm) concrete column shown in Fig. 1. The column is reinforced with four No. 8 (25 mm) bars enclosed within No. 4 (13 mm) ties. The normal concrete cover to the ties of this column would be 1-1/2 in. (40 mm). The cover tolerance is ±1/2 in. (±13 mm). If the reinforcement was placed to the minimum tolerance in two directions, the column could appear as in Fig. 2. However, the reinforcement could be placed to minimum tolerance in any of the four directions. Thus, the placement tolerance clouds would appear as in Fig. 3. This could be quite a different image than the precise image one might have had in mind at the outset.

For a second example, let's take the case of a simple 14-in.-thick (350 mm) wall reinforced with No. 8 (25 mm) vertical bars at 12 in. (300 mm) on center each face and No. 4 (13 mm) horizontal bars at 12 in. (300 mm) on center each face (Fig. 4). The outside face cover is 1-1/2 in. (40 mm) and inside face cover is 3/4 in. (19 mm).

The cover tolerance for the bars on the outside face is ±1/2 in. (±13 mm). For the inside face cover, the maximum cover reduction is limited to 1/3 of the specified cover, resulting in a cover tolerance of +1/2 or –1/4 in.

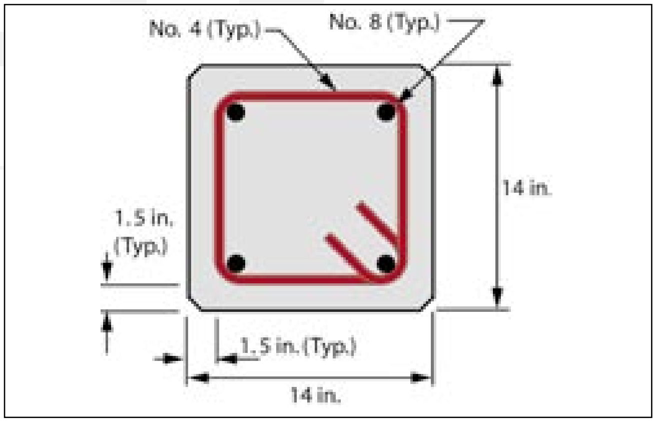

Fig. 1: The column the designer expects

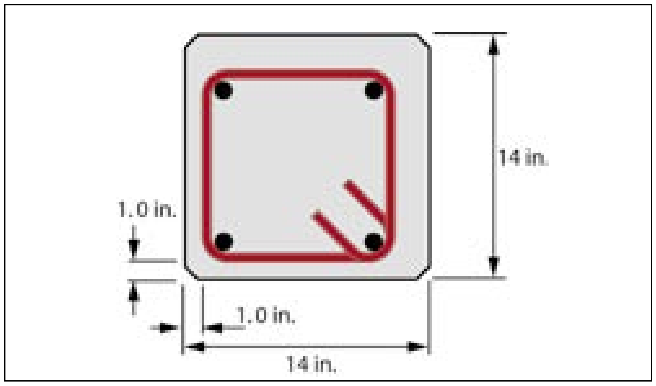

Fig. 2: The column that could be placed

(+13 or –6 mm). Thus the outside face cover could be as little as 1 in. (25 mm) and the inside face cover as little as 1/2 in. (13 mm) (Fig. 5). If we also consider that any one of the vertical and horizontal bars may be located as far as 3 in. (75 mm) either way from its designated location, the tolerance cloud would appear as in Fig 6.

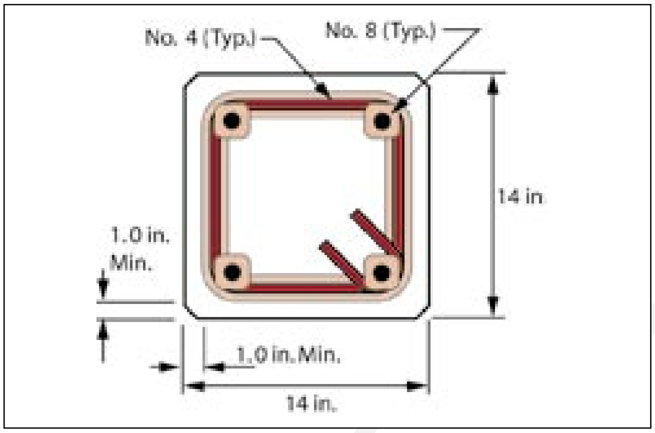

Fig. 3: The column with "Placement Tolerance Clouds"

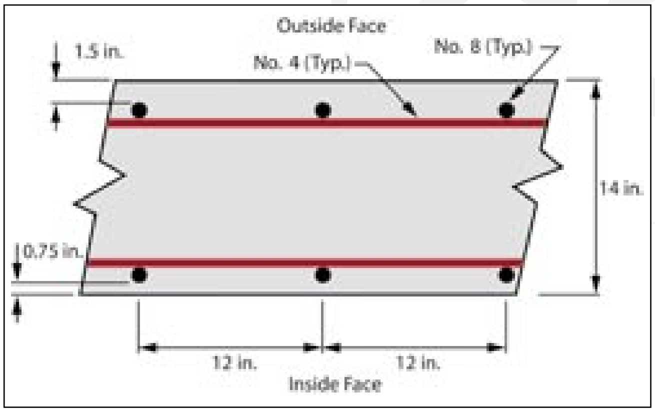

Fig. 4: The wall the designer expects

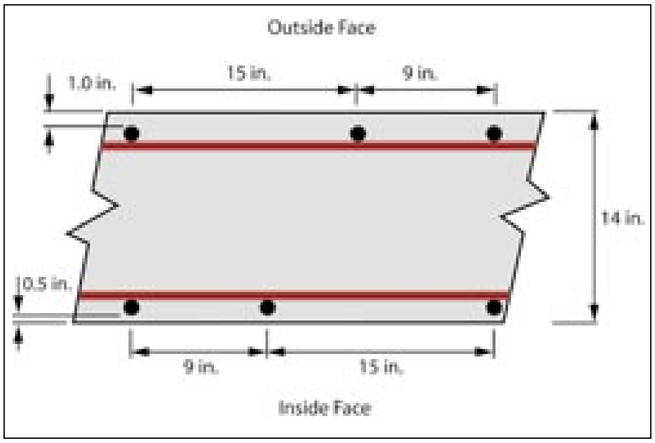

Fig. 5: The wall that could be placed

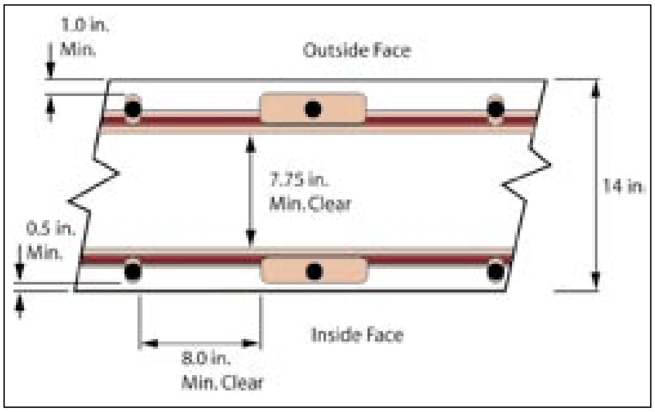

Fig. 6: The wall with "Placement Tolerance Clouds"

DESIGN CONSIDERATIONS

As in the instance of the fabrication tolerance cloud of a single bar, the placement cloud of a group of placed bars presents quite a different image than the one probably envisioned by the designer or software programmer. If the placement tolerances are factored into the design, they would realize that the available space they expected (to pass beam bars through a column or to place a vertical embed in a wall) might not be what is actually available, especially if they consider that the beam bars and the embed also have fabrication and placement tolerances of their own. Awareness of placement clouds may lead to design options that make these tolerances no longer a factor.

References

1. Birley, D., "The Tolerance Cloud," *Concrete International*, V. 27, No. 6, June 2005, pp. 61-63.

2. ACI Committee 117, "Standard Specifications for Tolerances for Concrete Construction and Materials (ACI 117-90) and Commentary (117R-90)," American Concrete Institute, Farmington Hills, MI, 1990, 22 pp.

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Designing for Constructibility: Perspectives on Reinforcing

The Forming Tolerance Cloud

BY DICK BIRLEY

In my last two articles, I discussed tolerance clouds associated with fabrication and placement of reinforcing bars.[1,2] While every builder strives to cast concrete to the precise dimensions indicated by the designer, the reasonable constraints of time, technology, and economy make this impractical. That's why I'd like to point out one more cloud associated with concrete construction—the forming tolerance cloud.

CONCERNS

Tolerances for forming concrete are found in Section 4 of ACI 117-90.[3] The tolerances for cross-sectional dimensions of cast-in-place members vary with the overall dimension (Table 1).

Using the example from my previous article of a 14 x 14 in. (350 x 350 mm) column, the tolerance is +1/2 in. (+13 mm) or –3/8 in. (–10 mm). Ignoring vertical alignment, this produces the forming tolerance cloud shown in Fig. 1, with a column having acceptable dimensions as large as 14-1/2 x 14-1/2 in. (363 x 363 mm) or as small as 13-5/8 x 13-5/8 in. (340 x 340 mm). While it is highly unlikely that these small variations would create any constructibility or design concerns with everything else being perfect, a very different picture arises when we consider them in conjunction with the other possible tolerances.

TABLE 1:
TOLERANCES FOR CROSS-SECTIONAL DIMENSIONS PER ACI 117-90[3]

Overall dimension	Tolerance
≤12 in. (300 mm)	+3/8 in. (+10 mm) –1/4 in. (–6 mm)
Over 12 to 36 in. (300 to 1000 mm)	+1/2 in. (+13 mm) –3/8 in. (–10 mm)
>36 in. (1000 mm)	+1 in. (+25 mm) –3/4 in. (–20 mm)

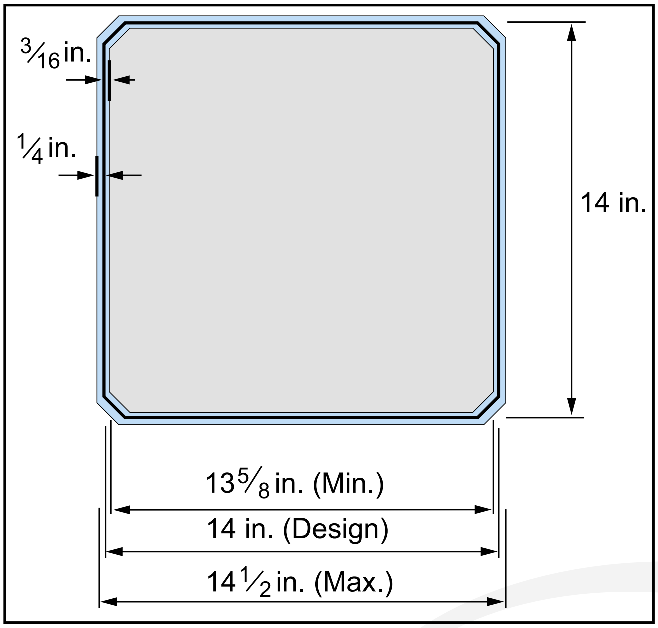

Fig. 1: "Forming Tolerance Cloud" for the column

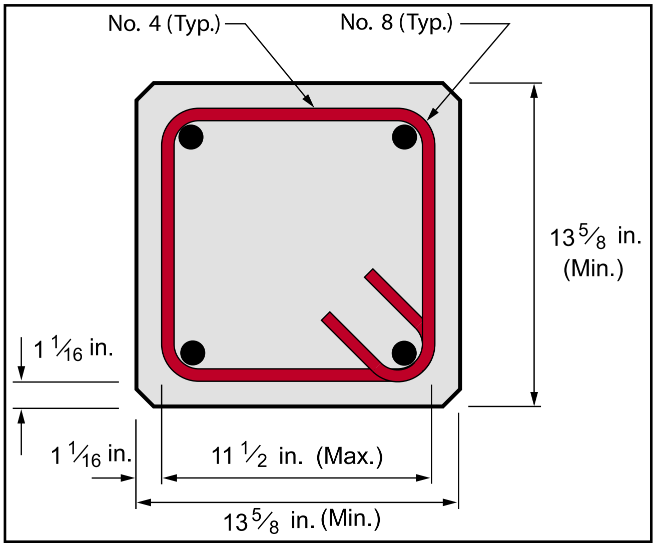

Fig. 2: Combining the maximum acceptable tie dimensions with the minimum acceptable column dimensions effectively limits placing tolerances to ±1/16 in. (±2 mm)

With 1-1/2 in. (40 mm) cover, the design width for the column ties is 11 in. (280 mm), and the tolerance is ±1/2 in (±13 mm). Combining the maximum acceptable tie dimensions with the minimum acceptable column dimensions produces the configuration shown in Fig. 2. With the reinforcing cage centered, the cover is reduced from the design value of 1-1/2 in. (38 mm) to 1-1/16 in. (27 mm) on all four sides. Recalling that the placement tolerances allow the cover to decrease to 1 in. (25 mm) minimum, the cage must be placed within ±1/16 in. (±2 mm) of the center of the column in both directions if it is to meet tolerance requirements. Considering the straightness of the bars and the straightness of the forms, this could be very difficult for the Contractor to do.

For the example of a 14-in.-thick (350 mm) wall that we previously examined, the situation is somewhat different because there are no tie tolerances to contend with. However, as we will see in the following example, other issues arise that must be dealt with.

The forming tolerance for the wall thickness allows the wall to be between 14-1/2 in. (363 mm) and 13-5/8 in. (340 mm) thick as shown in Fig. 3. Reinforcing placement tolerances allow the 1-1/2 in. (38 mm) design cover on the outside face to be between 1 and 2 in. (25 and 50 mm) and the 3/4 in. (19 mm) design cover on the inside face to be between 1/2 and 1-1/4 in. (13 and 32 mm). The minimum wall thickness combined with the maximum cover on the outside face reinforcing is shown in Fig. 4.

In this situation, the original effective depth of 12 in. (305 mm) for the vertical No. 8 (25 mm) bars on the outside face has decreased to only 11-1/8 in. (283 mm). Assuming 4000-psi (28-MPa) concrete and Grade 60

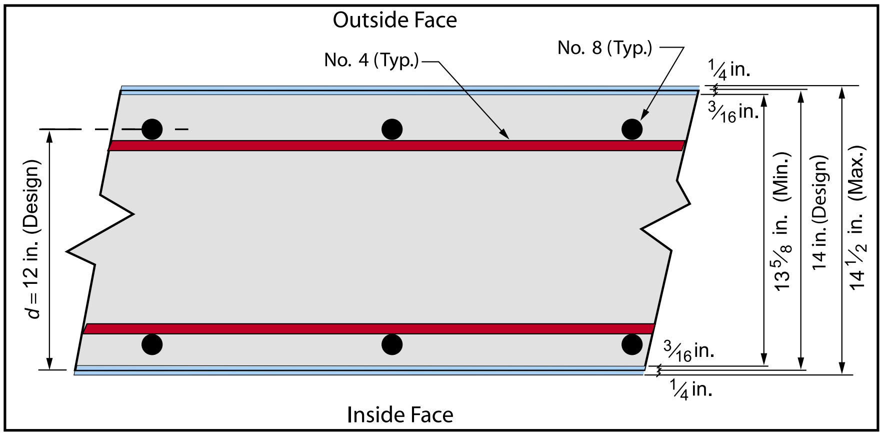

Fig. 3: "Forming tolerance cloud" for the wall

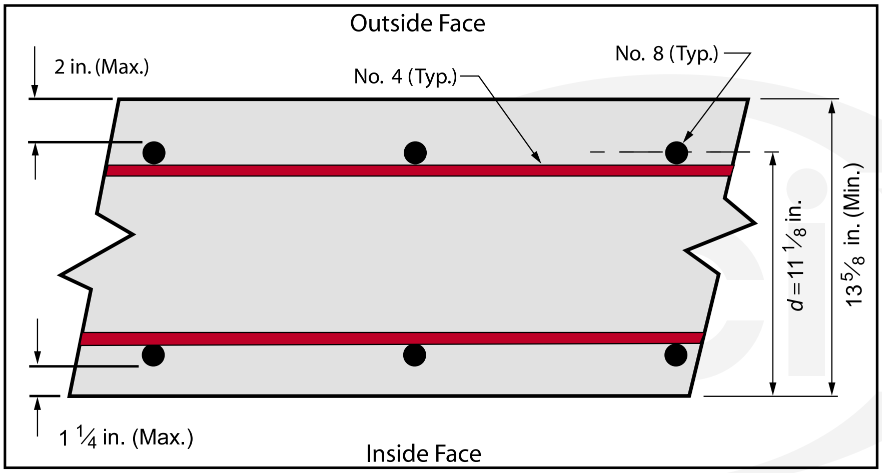

Fig. 4: The minimum acceptable wall thickness and maximum acceptable cover combine to produce an effective depth for the outside face vertical bars that violates ACI 318-05[4] tolerances. However, effective depth is usually not checked in the field

(Grade 420) reinforcement, this reduction in effective depth would result in a decrease in nominal moment capacity from the original 45.1 kip·ft/ft (201 kN·m/m) to 41.6 kip·ft/ft (185 kN·m/m)—a 7.7% reduction due to forming and placement tolerances alone. The effect on moment strength would be even more drastic for thinner walls. To guard against this, Section 7.5.2.1 of ACI 318-05[4] places a tolerance on effective depth d of ±3/8 in. (±10 mm) for $d \le 8$ in. (200 mm) and ±1/2 in. (±13 mm) for $d > 8$ in. (200 mm). These tolerances would produce a 4.4% reduction in nominal moment strength for the example wall considered here; however, designers should realize that effective depth is not checked in the field. Bars are placed and tolerances checked relative to the formwork surfaces.

DESIGN CONSIDERATIONS

Casting of concrete always involves the fabrication, placement, and forming tolerance clouds. While these instances are not encountered every day, they occur frequently enough to create constructibility problems. Any combination of these tolerance clouds working against each other has the potential to create a constructibility concern that quite often is difficult to reconcile, especially if it involves two different trades, each within their own acceptable tolerances. The designer must always assess the risk of this kind of problem arising in critical areas and consider options that mitigate or eliminate the possible constructibility problem.

Acknowledgments

Thanks to ACI member John H. Scarino for his contributions to this article.

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Designing for Constructibility: Perspectives on Reinforcing

Detailing and Fabrication Tolerances

Some practices can lead to problems

BY DICK BIRLEY

Because it's inherently difficult and expensive to fabricate reinforcing steel and formwork to precise dimensions, workers must place bars to avoid conflicts with items that simply can't be moved, such as openings and embedded hardware. Tolerances on placement, as well as fabricating and forming, are therefore needed to make concrete construction physically possible and economically practical.

AVOIDING CONFLICTS

In addition to this normal interplay of tolerances in the field, detailers sometimes use tolerances to avoid conflicts. For example, to simplify formwork construction, beams and girders are commonly designed with a common soffit elevation. However, if the engineering drawings don't show how to avoid crossing the beam and girder reinforcing bars in the same planes (Fig. 1), there will be a constructibility problem. In such a case, detailers might detail the girder stirrups to the maximum vertical dimension and the beam stirrups to the minimum vertical dimension. While this won't completely eliminate the problem, it can mitigate it significantly. Of course, the detailer must "flag" these dimensions as critical, and the fabricator must exercise special care to fabricate the stirrups precisely to the detailed dimensions (normal fabricating tolerances wouldn't be acceptable).

Occasionally, ironworkers find a run of lapped temperature bars in a slab that doesn't terminate with the proper embedment at the end support. Rather than trying to find some extra bars to extend the run, ironworkers may opt to adjust the splices within the run to their minimum length. Quite often, this will extend the run the few inches required to achieve proper embedment at the support.

I've seen fabricators, especially during times of steel shortages, adjust the length of certain bars by the plus or minus tolerance to get exact cuts out of stock bars. For instance, to obtain 13 ft 5 in. bars from a 40 ft bar, a fabricator would need to make two cuts—producing two 13 ft 5 in. bars and one 13 ft 2 in. crop bar (Fig. 2). If the fabricator adjusts the bar length to 13 ft 4 in., however, two cuts would produce three 13 ft 4 in. bars, and there would be no crop bar. If the ironworker installing the bars cooperates and adjusts the end locations of the bars by 1/2 in., everything will be within tolerance.

In my opinion, these examples are acceptable, practical uses of tolerances to solve specific constructibility issues. They do, however, require mutual cooperation among the trades involved and are recognized as one-off instances. Therefore, they should not be considered acceptable common practice.

CAUTIONS

Unfortunately, I've also seen practices that I consider to be abuses of tolerances. While these practices may be followed because of a perceived economic gain, such practices are often detrimental to other trades involved (and even to their own trade).

Although it might seem that routinely cutting all reinforcing bars to an acceptable tolerance of 1 in. less than the detailed length would save thousands of feet of

Designing for Constructibility: Perspectives on Reinforcing

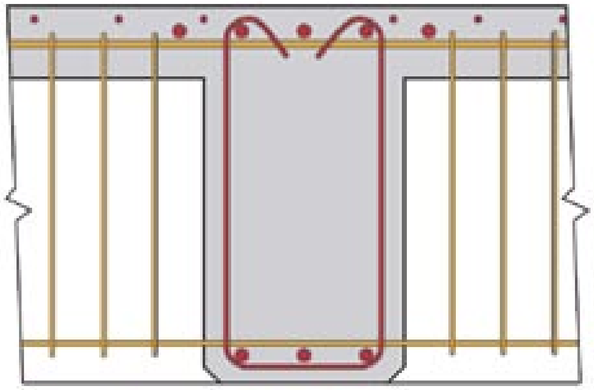


Fig. 1: To avoid conflicts between longitudinal bars at beam-to-girder connections, detailers sometimes dimension the beam stirrups to the minimum dimension within tolerances and the girder stirrups to the maximum dimension

Fig. 2: A practical use of tolerances is to increase the number of usable bars that can be fabricated from stock lengths

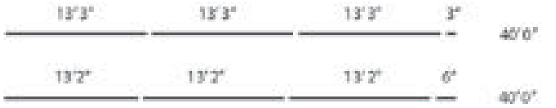


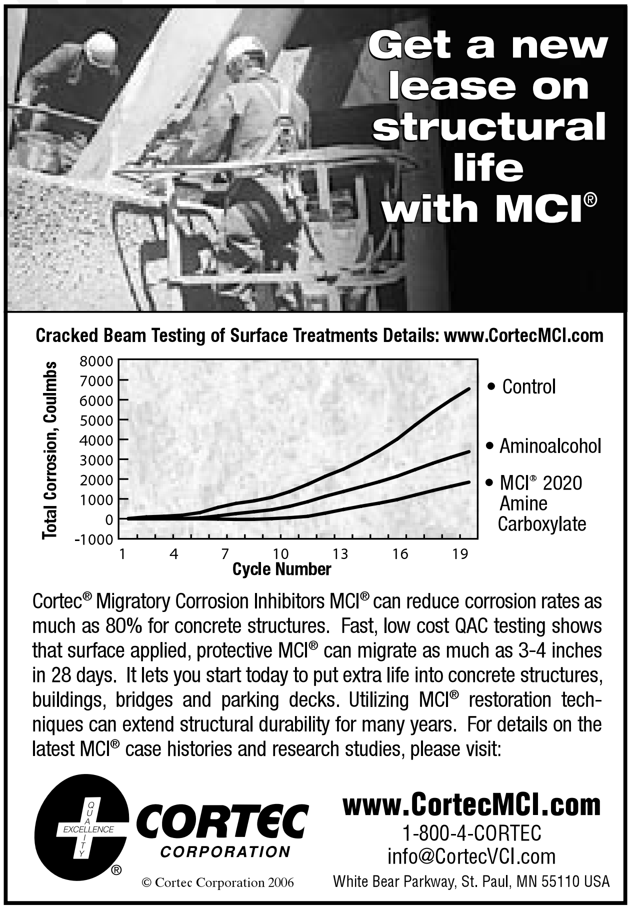
Fig. 3: Routine shortcutting of bars often just results in more crop bar, rather than an actual saving of steel

reinforcement each year, this really isn't the case. Many of those 1 in. savings would actually lead to longer pieces of crop bars, and produce no real "savings." For instance, if 13 ft 3 in. bars were required and cut to the proper length, the fabricator would get three usable bars plus a 3 in. crop bar out of a standard 40 ft bar (Fig. 3). If the lengths were reduced by an inch to 13 ft 2 in., the fabricator would get three usable bars plus a 6 in. crop bar—nothing would be gained.

Apart from a perceived economic benefit, others argue that cutting bars to the detailed length inevitably produces some bars that are longer and that these longer bars cause clearance problems for the ironworker. It's a poor argument. It's true that the ironworker would have to be more careful while placing the longer bars than if they had been cut to the detailed dimension. However, if the fabricator is cutting the bars to the minimum dimension, normal variation will cause some bars to be shorter. These shorter bars will create excessive clearance problems that are not easily rectified.

In fact, the practice of cutting bars to the minimum length can actually turn out to be very costly. A few years ago, I toured a large construction project and noticed some ironworkers coupling 8 in. pieces of No. 14 bar to the tops of a number of column bars. I inquired, and found that these were the last of four lifts of reinforcement for the columns. Because the fabricator had cut each lift of No. 14 vertical bars short by the minus tolerance (2 in.), and because No. 14 bar splices must be coupled rather than lapped, the full run of each vertical bar was 8 in. short of the required embedment into the supported beam. Because the short run required additional short bars, field labor for end-preparation to install extra couplers, and the cost of the couplers themselves, the potential "savings" turned into major additional costs.

During my years as an ironworker, I occasionally encountered contractors who routinely used tolerances to reduce the thickness of slabs. As Fig. 1 illustrates, even with a full-thickness slab, the multiple layers of crossing reinforcing at beam-to-girder connections may force the ironworker



to use the minimum cover. However, if the contractor has already formed the slab to the minimum thickness, even the minimum cover may not be possible, and problems such as surface cracking along the length of the bars can result. What was thought to be a savings in concrete often increased costs required for ironworkers as well as finishers.

DESIGN CONSIDERATIONS

Fabricating bars to minimum dimensions within tolerances frequently creates annoying or even significant problems for the unsuspecting ironworker. Because detailers calculate the lengths of bars, they are usually the first ones faulted for the problem and must present calculations to prove that their dimensions are correct. Detailers quickly get to know which fabricators are involved in the practice of shortcutting bars. To reduce or eliminate potential problems in critical situations, many detailers will dimension bars to maximum tolerances (or even longer).

Unfortunately, the person reviewing the detailing for the designer often spots these longer dimensions and marks them for correction. Of course, this presents a dilemma for detailers: do they correct the dimensions to satisfy the designer, or do they ignore the designer in the interest of better constructibility? Perhaps the best course of action for a designer is to allow longer dimensions, provided they will not cause a structural problem.

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Calculating the Length of Bent Reinforcing Bars

Tight tolerances lead to some interesting observations

BY DICK BIRLEY

When reinforcing bars are fabricated with bends, the straight bar is initially cut to a length that is less than the sum of the specified dimensions of the bent bar. The difference between the detailed length and the cut length is the "bend curvature deduction" and may be known in the trade by other names such as gain, creep, and gyp. Generally, fabricators and programmers obtain the bend curvature deduction from a bend deduction table, such as the one shown in Table 1, that lists the deductions for 45- and 90-degree bends of common bar sizes.

Figure 1 shows a No. 8 (No. 25) bar with a standard hook and sides measuring 1 ft 4 in. and 4 ft (400 and 1220 mm). The detailed length of this bar would be the sum of the two sides, or 5 ft 4 in. (1620 mm). From Table 1, the deduction for a 90-degree bend on a No. 8 (No. 25) bar is 2-1/2 in. (65 mm). Thus, in this case, the cut length of the bar would be 5 ft 1-1/2 in. (1555 mm).

The usual standard for measuring the cut length of a bar is along the actual centerline of the bar, which corresponds to the neutral axis of the bar cross section prior to bending. The cut length of a bent bar is shorter than the sum of the finished dimensions for two reasons. The first reason is obvious—the fillets created at the bend points have an arc length that is shorter than the sum of the intersecting tangents. This component of the bend deduction can be found with a simple mathematical calculation. The second reason isn't so obvious. While the outer fibers of the bar are free to elongate, the inner fibers of the bar are restrained by friction against the bending mandrel—the neutral axis therefore shifts inward toward the mandrel. This component cannot be easily calculated. Fortunately, however, the discrepancy resulting from calculating lengths based on the actual centerline is rarely a concern.

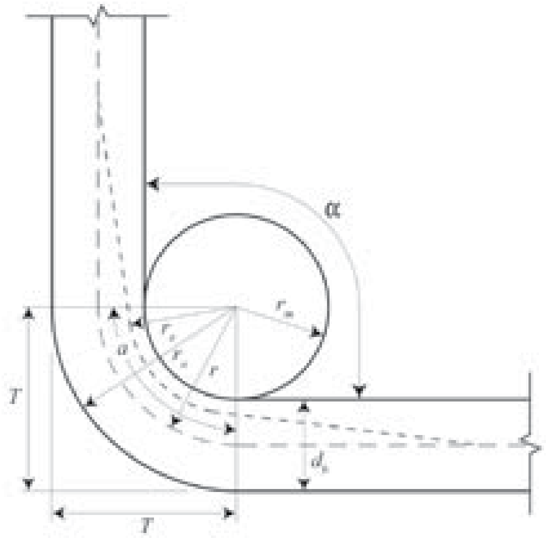
A few years ago, some interesting surprises were found while detailing

Fig. 1: Using the bend deduction value from Table 1 of 2-1/2 in. (65 mm), the length of straight bar cut to form the bent bar shown would be 5 ft 1-1/2 in. (1555 mm)

TABLE 1:
BEND DEDUCTION VALUES

Bar size	45-degree bend, in. (mm)	90-degree bend, in. (mm)
No. 3 (No. 10)	1/4 (5)	1 (25)
No. 4 (No. 13)	1/4 (5)	1-1/4 (30)
No. 5 (No. 16)	1/4 (10)	1-1/2 (40)
No. 6 (No. 19)	1/2 (10)	1-3/4 (50)
No. 7 (No. 22)	1/2 (15)	2-1/4 (55)
No. 8 (No. 25)	1/2 (15)	2-1/2 (65)
No. 9 (No. 29)	3/4 (20)	3-1/2 (90)
No. 10 (No. 32)	3/4 (20)	3-3/4 (100)
No. 11 (No. 36)	1 (25)	4-1/4 (110)
No. 14 (No. 43)	1-1/4 (30)	6 (150)
No. 18 (No. 57)	1-1/2 (40)	8 (200)

the reinforcing for a large precast segmental bridge. There were more than 200 different bar shapes, of which most were multi-sided, closed stirrups with varying angles. The client insisted that the cut length of the bars had to be within a tolerance of 10 mm (3/8 in.), regardless of the number of bends on the bar or the angles. Obviously, this could not be accomplished by using a chart. The ability to calculate the precise bend deduction for each bend at any angle on each bar size had to be introduced into the detailing software.



α = bend angle
d_b = bar diameter
r = radius to actual centerline of bar
r_m = radius of mandrel
r_o = radius to outside of bar = $r_m + d_b$
f = friction factor $1 < f < 0$
r_e = radius to effective centerline of bar = $f(d_b/2) + r_m$
a = arc along effective centerline of bar = $r_e(\pi - \alpha)$
T = tangent to radius at outside of bar = $r_o/(\tan \alpha/2)$
d = bend curvature deduction = $2T - a$
= $2r_o/(\tan \alpha/2) - r_e(\pi - \alpha)$

Fig. 2: Calculation of bend deduction values including friction factor

To meet this challenge, the calculations had to include a term that would allow the effective centerline of the bend to shift inward from the actual centerline. One way to include this effect in the arc length calculations is to use an effective centerline located a distance $f(d_b/2)$ from the inside of the bend, where f is a variable labeled the friction factor. With zero friction, $f = 1$ and the effective centerline is located at the actual centerline. With zero slip, $f = 0$ and the effective centerline is located at the inside face of the bend.

For a given bar size and mandrel, a calibration for the f value can be made by carefully measuring the lengths of straight bars, bending them to the same angle, measuring and summing the dimensions of the two resulting sides, deducting the original straight length from this sum to find the total bend curvature deduction, and solving the equations defined in Fig. 2.

Many factors, including bar size, steel grade, angle of the rib to the mandrel, the mandrel material, the amount of wear on the mandrel, the bending speed, and the bar temperature (the shop operated through winter and summer), were found to affect the value of f. There were four bending machines in the shop, and each one was assigned a value for f for each bar size. Bending speed was set at a constant prescribed rate for each bender, and the whole process was rechecked every couple of weeks. The 10 mm (3/8 in.) tolerance could be successfully met, provided the client could successfully control the various factors affecting f.

Surprisingly, the value of f was usually about 0.2 to 0.25 and rarely approached 0.3. If the bending speed was increased, f would drop to as low as 0.1. There was a small amount of Grade 75 (520 MPa) bar on the project for which f had to be set to zero. This seemed to indicate that friction with the mandrel was so high (due to the force required to bend the bar) that there was no slip along the inner curve and that all of the elongation was along the outside curve of the bar.

DESIGN CONSIDERATIONS

Considering the values for f, it became apparent that, when a bar was bent, there was much more elongation along the outside of the bend than anticipated. If the mandrel was new and very smooth, there seemed to be less friction with the mandrel, which increased the value of f. Increasing the bending speed seemed to increase friction against the mandrel, which decreased the value of f. In the case of Grade 75 (520 MPa) bars with an f of 0, the difference between elongations along the outside and inside of the bend was extreme.

As an aside, the client found the task of monitoring the factors affecting the bending so onerous that the requirement for the 10 mm (3/8 in.) cutting tolerance was quietly dropped, and the shop gradually returned to normal fabricating practices.

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Designing for Constructibility:
Perspectives on Reinforcing

Interference between Reinforcing Bars and Mechanical Waterstops

Constructible solutions to a common problem

BY JAVED B. MALIK

Waterstops are commonly used at cold joints in concrete structures, such as water tanks, water treatment plants, and below-grade structures, to prevent the seepage of fluids through the joint. Although they come in several forms and shapes, the two most commonly used types are adhesive and mechanical waterstops as shown in Fig. 1 and 2, respectively. Adhesive waterstops can be hydrophilic or hydrophobic. Hydrophilic waterstops prevent the seepage of fluids by swelling when they come in contact with moisture, hydrophobic waterstops act as internal joint sealants, and mechanical waterstops rely on embedment into the concrete on both sides of a joint to form a diaphragm that seals off liquids.

Because they are typically smaller than mechanical waterstops and don't have to be embedded on both sides of a joint, adhesive waterstops can generally be installed without conflicting with the reinforcing bars. Mechanical waterstops, however, can often conflict with reinforcement when their size and location are not properly taken into account during design and detailing.

CONFLICTS

The most common conflict between mechanical waterstops and reinforcement occurs at the joint between a slab or mat and a wall, as shown in Fig. 3. The waterstop is generally embedded into the slab 3 in. (75 mm) or more, producing the potential for interference with the top layer of reinforcing bars in the slab. If this conflict isn't addressed on the contract drawings, the steel detailer will specify the height of the reinforcing bar supports based on the cover requirements shown on the drawings, and the iron worker will place the bars accordingly. Because the waterstop is typically the last item installed before the concrete is placed, the workers will either curl the waterstop so it lies above the steel, or cut notches in the waterstop so it clears the bars. Neither of these remedies is acceptable practice.

Potential conflicts become even more pronounced when the contract documents call for shear keys at wall-to-slab joints (Fig. 2). Not only does the shear key effectively increase the embedment of the waterstop in the slab, the concrete contractor must split the form for the shear key and install the shear key between the resulting form components. After the concrete hardens, it's difficult to remove the form pieces without damaging the waterstop. It's therefore a good idea to consider the use of alternate means for shear transfer at the cold joint, such as roughening the surface of the slab.

Designing for Constructibility: Perspectives on Reinforcing

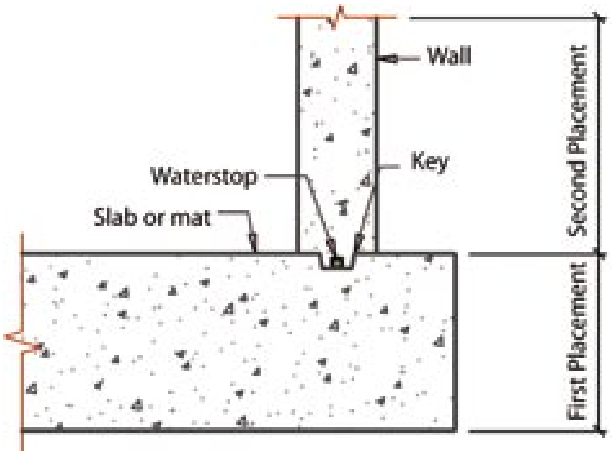

Fig. 1: Typical adhesive waterstop installation at the base of a wall (reinforcing steel not shown for clarity)

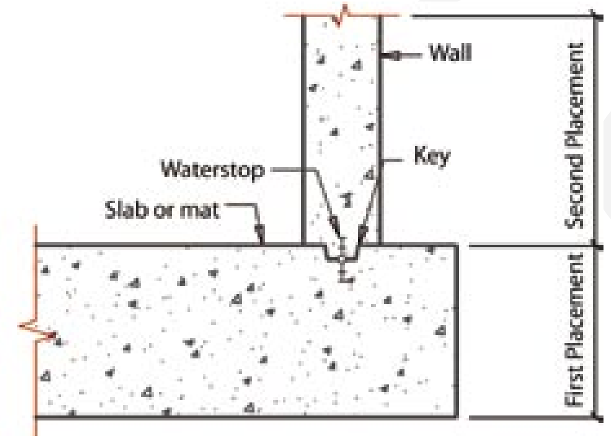

Fig. 2: Typical mechanical waterstop installation at the base of a wall (reinforcing steel not shown for clarity)

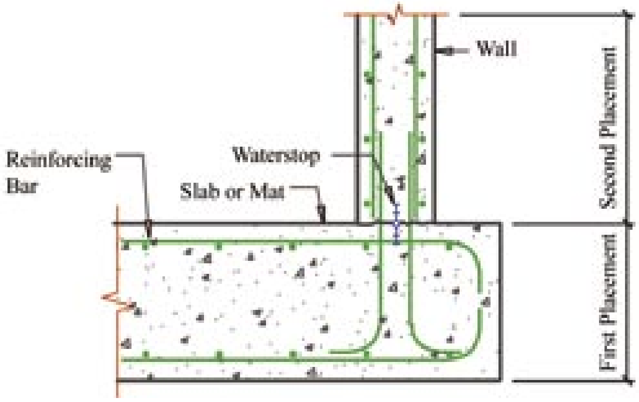

Fig. 3: Even when shear keys are not used, interference between a mechanical waterstop and the top layer of reinforcing bars is possible

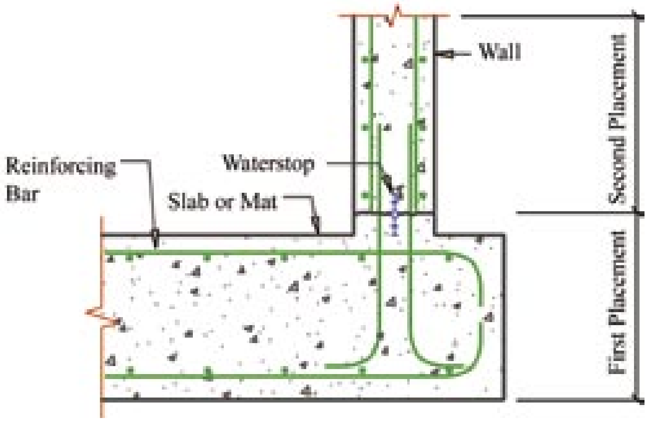

Fig. 4: A short starter wall can be used to lift the waterstop away from the top slab bars

COMMON SOLUTIONS

The three most common solutions to the interference are:

- Form a “starter” wall that raises the waterstop clear of the top slab bars;
- Deflect the top slab bars so they pass below the waterstop; and
- Lower the top slab bars to clear the waterstop.

The first option, shown in Fig. 4, is to form and place a small portion of the wall (called a starter wall) monolithically with the bottom slab, thus raising the waterstop sufficiently clear of the top steel in the slab. This may be the ideal solution from a designer’s viewpoint. Many builders consider it problematic, but others like having the starter wall to tighten the wall forms against.

The second option, shown in Fig. 5, is to deflect the top slab bars below the waterstop. For smaller-diameter bars, this can be accomplished by pushing the bars down at the waterstop location, but larger bars need to be bent by the fabricator in the shop. Because the moment capacity of the slab is reduced due to a smaller lever arm, this option works best if the negative moment in the slab is small. The end of the deflected top bar will be very low in the slab if it’s deflected at a steep angle or over a long distance. Therefore, this solution becomes less practical the farther the wall is from the slab edge, and it’s not practical at interior walls.

The third option, shown in Fig. 6, is to lower the top mat of steel to clear the waterstop. If the depth of the slab is not increased, this solution may require additional top bars in the slab because of the reduced effective steel depth. However, if the reinforcing quantity is controlled by creep and shrinkage or temperature requirements, the

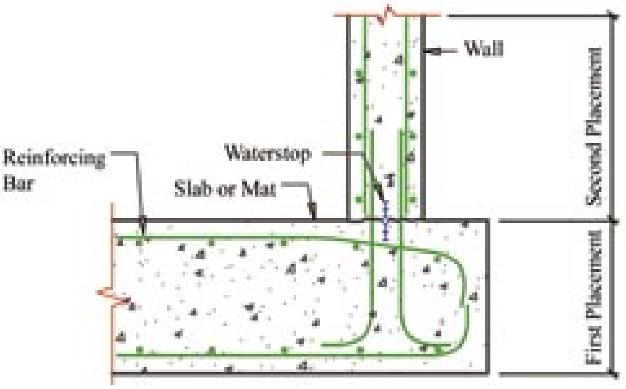

Fig. 5: The top bars in the slab can be deflected to clear the waterstop

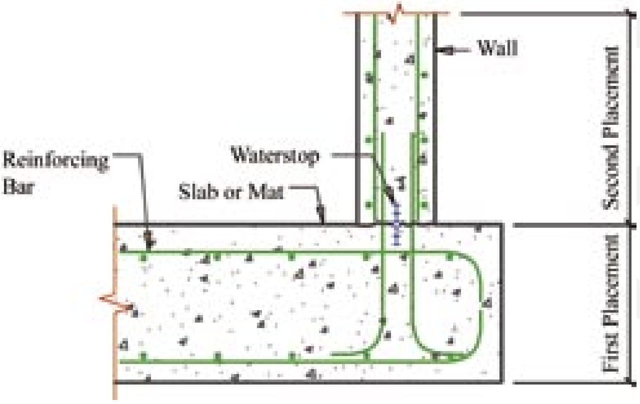

Fig. 6: The top bars in the slab can be dropped to increase the cover throughout the slab and clear the waterstop

reduced moment capacity may not be a concern. For either the second or third option, a shear key will increase the required correction.

WHICH OPTION WORKS BEST

From a constructibility point of view, forming a starter wall is the best option when the slab has a large amount of top reinforcing bars, or when the wall is an interior wall. Forming the starter wall incurs a certain amount of cost, but can be offset by the savings due to better constructibility. If creep and shrinkage criteria control the steel quantity, or the bars are of a relatively large diameter and closely spaced, lowering the top layer of reinforcement in the slab to clear the waterstop may be a good option. For slabs with smaller-diameter bars, deflecting the top bars to clear the waterstop should only be considered if the reduced moment capacity of the slab is not a concern. No matter which option is selected, it's best if the design engineer addresses the condition before the construction phase and indicates the preferred method on the contract documents.

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Designing for Constructibility:
Perspectives on Reinforcing

Beam-Column Joints

Alternative bottom beam reinforcement layouts can reduce congestion

BY DICK BIRLEY

Beam-column joints are frequently areas of congestion in reinforced concrete construction. Several factors can contribute to beam-column joint congestion, such as column verticals that terminate in the beam with hooks and excessive top steel over the column. By far the most common problem, however, is the lapping of bottom beam bars at a column to meet the structural integrity requirements in Section 7.13 of ACI 318-05,[1] especially if the column and beam are the same width.

When the bottom beam bars are lapped at the column, the number of bottom bars that must pass through the joint doubles. The resulting congestion can contribute to poor consolidation of the concrete at a critical location where the concrete is under a complex state of stress and may also cause clearance problems with the column ties or beam stirrups. This congestion can be significantly reduced by using alternative splice locations and bar arrangements.

The following discussion presents four general splice arrangements, along with the advantages and disadvantages of each from a constructibility point of view. Designers must also consider structural issues when selecting among the alternative locations for the bottom bar splices. Only continuous bottom beam bars are shown. All other bars are omitted for clarity.

ARRANGEMENT #1—SPLICES LOCATED AT SUPPORTS

The most common arrangement is to locate all bottom bar splices at the supports as shown in Fig. 1, but this arrangement also produces the most congestion in the joint.

Advantages:

- Simplest to detail;
- Good arrangement where beams are wider than the supporting columns; and
- No additional steel is required.

Disadvantages:

- Causes heavy congestion, especially if the column and beam are the same width or a large amount of reinforcement must be continuous;
- Installation of single-bay preassembled beam cages is difficult; and
- Installation of multiple-bay preassembled beam cages is almost impossible.

ARRANGEMENT #2—50% OF SPLICES ON EACH SIDE OF SUPPORTS

To ease congestion in the joints, half of the continuous bottom beam bars can be spliced on one side of the joint

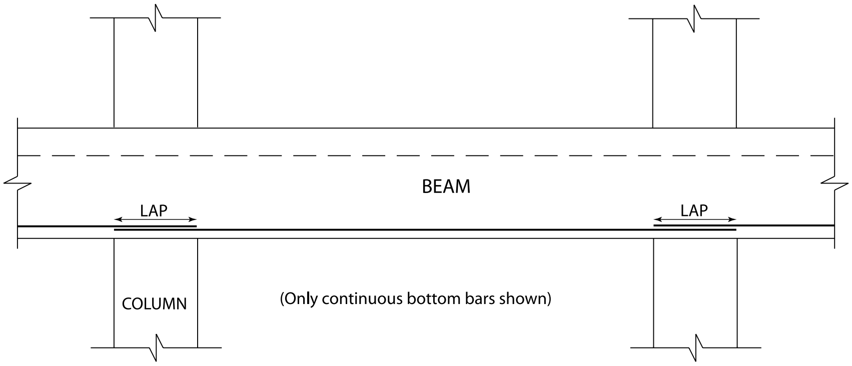

Fig. 1: Arrangement #1—All bottom bar splices located at the supports

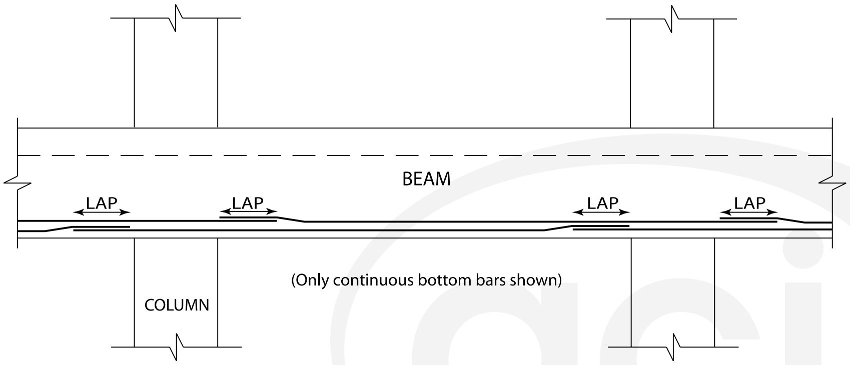

Fig. 2: Arrangement #2—50% of splices located on each side of the supports

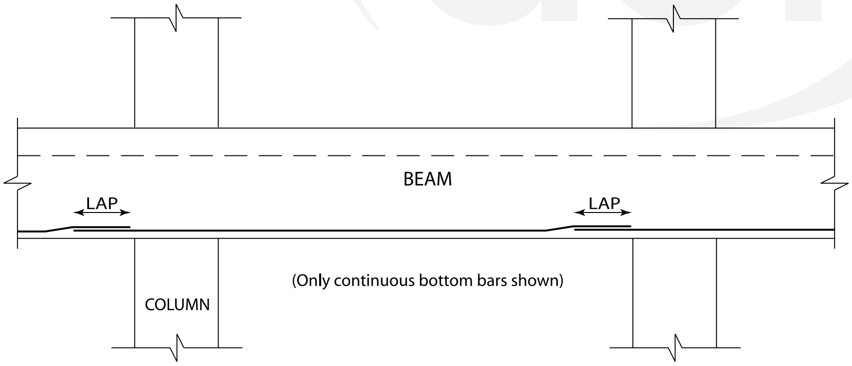

Fig. 3: Arrangement #3—All bottom bar splices located on one side of support

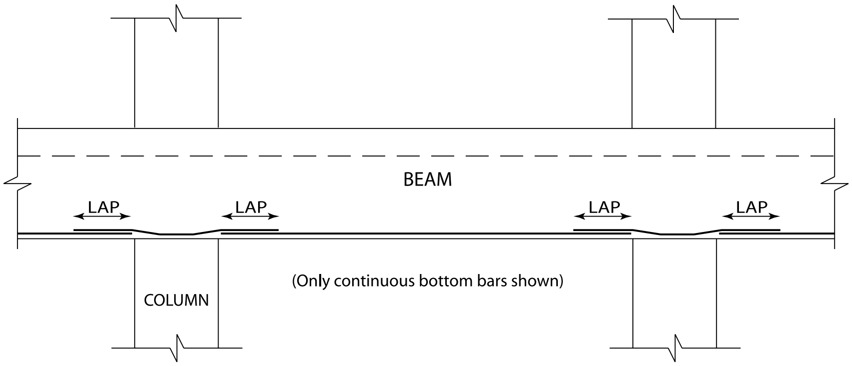

Fig. 4: Arrangement #4—Splice bars added through columns

and the other half on the other side of the joint, as shown in Fig. 2. This arrangement eliminates half of the bars passing through the joint compared to Arrangement #1.

Advantages:

- With no splices over the supports, congestion is eased; and
- No additional steel is required.

Disadvantages:

- Detailing and preassembled cages are slightly more complex;
- Preassembled beam cages are longer and more awkward to install; and
- Installation of multiple-bay preassembled cages is very difficult.

ARRANGEMENT #3—100% OF SPLICES LOCATED ON ONE SIDE OF SUPPORTS

The third alternate arrangement is similar to Arrangement #2 except that all of the splices are located on one side of the joint, as shown in Fig. 3.

Advantages:

- Detailing and preassembled cages are relatively simple;
- Preassembled cages are the same length as in Arrangement #1, but easier to install because they pass through only one joint; and
- No additional steel is required.

Disadvantages:

- Care must be taken to ensure that the cages are oriented correctly if installation begins at the center of the beam and progresses both ways.

ARRANGEMENT #4—SPLICE BARS ADDED THROUGH SUPPORTS

The fourth alternate arrangement is to add splice bars passing through the joint that are spliced to the bottom beam bars on both sides of the joint. This arrangement is shown in Fig. 4.

Fig. 5: A multiple-bay, preassembled reinforcing cage can minimize the amount of work that must be done "in the air" and decrease the time required to install reinforcing steel

Advantages:

- No congestion at columns because splice bars through columns are added later;
- Preassembled cages are shorter than any of the previous options;
- Very easy to install preassembled cages because no bottom bars pass through the columns during installation; and
- Best option for installation of multiple-bay preassembled cages.

Disadvantages:

- Additional steel required.

DESIGN CONSIDERATIONS

Congestion should be considered when choosing the location of continuous bottom beam bar splices. Arrangements #2, #3, and #4 address this issue to varying extents.

Even though Arrangement #4 increases the amount of steel required, it may be the most cost-effective in certain situations. The cost of the extra steel may be more than offset by the savings in labor or other costs. By permitting preassembly of the reinforcing steel cages on the ground, rather than "in the air," Arrangement #4 increases safety and eliminates the need for special scaffolding to support bundles of steel while the cages are being assembled in place.

The advantages of preassembled cages are illustrated by the example shown in Fig. 5, where the bottom steel in the preassembled beam cage was configured per Arrangement #4. The total time required to hook up to the cage, position the cage in the forms, and install the splice bars was only 30 minutes for two ironworkers. Safety was also increased by requiring only two ironworkers "in the air" during installation.

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1. ACI Committee 318, "Building Code Requirements for Structural Concrete (ACI 318-05) and Commentary (ACI 318R-05)," American Concrete Institute, Farmington Hills, MI, 2005, 430 pp.

Selected for reader interest by the editors.

ACI member **Dick Birley** has more than 40 years of experience in the reinforcing steel industry, including working as an ironworker and owning a fabrication and placing company. He is currently the owner of Condor Rebar Consultants, Inc., a detailing company located in Vancouver, BC, Canada, that is involved in projects worldwide. He is a member of ACI Committees 315, Details of Concrete Reinforcement, and 439, Steel Reinforcement.

Designing for Constructibility: Perspectives on Reinforcing

Designing to Minimum Concrete Dimensions

Focusing on member size can defeat the purpose

BY JAVED B. MALIK

Structural engineers generally strive to optimize the cost of structures, often by minimizing the sizes of structural members. An emphasis on minimizing the size of concrete members, however, can lead to unintended consequences that may defeat the global goal of minimizing the construction cost for the overall project. In short, it's important to step back to consider how the individual components interact. Although this may seem rather basic, I've observed that problems occur often enough to warrant a reminder, especially for younger engineers and detailers.

ISSUES

Concrete members sized purely on the basis of applied loads may not be large enough to accommodate the required amount of reinforcing steel with the proper spacing between bars. Conflicts can be created by the reinforcement for the member in question, reinforcing bars from adjacent members, and embedded anchor bolts or headed studs. These conflicts can potentially lead to honeycombs and voids in the concrete, inadequate cover, and inadequate embedment.

Designing individual members to minimum dimensions can also create a large number of similar, but not identical, members. This can significantly impact cost by limiting reuse of the formwork and reducing the efficiencies of workers and inspectors.

EXAMPLES

The following are some common examples where designing to minimum overall dimension can create problems. Addressing these and similar issues during the design phase saves time, reduces requests for information as well as change orders, and avoids headaches for both the contractor and the engineer.

Piers and pier caps

Sizing lightly loaded piers considering only the applied loads and allowable soil bearing capacity can result in relatively small piers. For piers supporting steel columns, this can create a conflict such as shown in Fig. 1(a), where the anchor bolts or bearing plates will not fit inside the steel cage for the pier. Obviously, this can be resolved by increasing the pier diameter as shown in Fig. 1(b), or a wider pier cap at top of piers can be installed to accommodate the anchor bolts as shown in Fig. 1(c).

To minimize the number of pier sizes installed at a site, it's preferable to change the shaft diameters in increments of at least 6 in. (150 mm) and the bell or under-ream diameters in increments of at least 12 in. (300 mm).

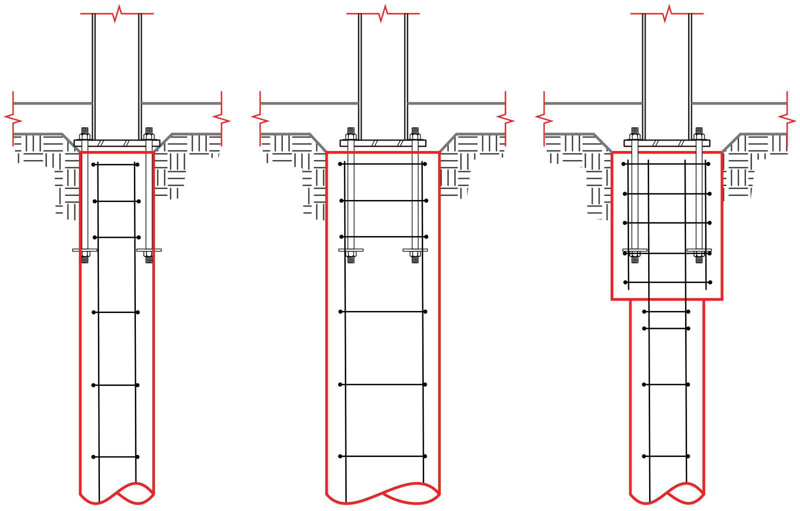
Spread footings

To minimize the number of different footing types, the length or width should be changed in minimum increments of 12 in. (300 mm). Before finalizing the footing thickness, the depth required to develop the column dowels or embed anchor bolts for steel columns should be checked because it may control the footing thickness (Fig. 2). An alternative to thickening the entire footing is to locally thicken it at the column location. For practical reasons, a minimum thickness of 12 in. (300 mm) is suggested.

Designing for Constructibility: Perspectives on Reinforcing

Grade beams

To eliminate formwork, the sides of grade beams are often placed against earth, requiring a clear concrete cover of at least 3 in. (75 mm). To accommodate bend diameters at the corners of stirrups in grade beams, it's good practice to use a minimum grade beam width of 12 or 15 in. (300 or 380 mm) as shown in Fig. 3. If the sides of the grade beams are formed, clear cover on the stirrups can be reduced to 1-1/2 in. (40 mm), and the grade beam can be made narrower. In these cases, a note should be added on the drawings requiring the contractor to increase the beam width by 1-1/2 in. (40 mm) on each side if the decision is made to eliminate forms.



(a) (b) (c)

Fig. 1: The diameter of piers supporting steel columns should be checked to ensure the anchor bolts and anchor plates will fit within the reinforcing cage: (a) small piers may not be large enough to contain the anchor bolts; (b) the pier size can be increased; or (c) a larger pier cap can be added to accommodate the bolts

Designing for Constructibility: Perspectives on Reinforcing

Columns

It's good practice to standardize column sizes on a job as much as possible. Ideally, all interior columns should be of one size and exterior columns of another size, if necessary. This will simplify the formwork and steel placement. It's generally economical to keep the same column sizes for as many floors as possible and use higher strength concrete and more longitudinal reinforcement on the lower floors.

Beams

Beam dimensions, especially depth, should also be standardized on a job. It's generally economical to use the same depth for all beams at a floor except for heavily loaded girders or spandrel beams. As shown in Fig. 4, making the beams slightly wider or narrower than the columns can help prevent interference between beam bars and vertical column bars. Although beams that are wider than the columns may be preferred to simplify formwork, the designer must also check the beam-column joint for any special reinforcement required in special moment frames for seismic applications.

Walls

Designing to the minimum thickness for walls can produce several problems. Walls are not only reinforced with vertical and horizontal steel, but sometimes have ties enclosing the vertical steel such as at boundary elements. In addition, bars from slabs, floor beams, and link beams terminate in the walls. As shown in Fig. 5, link beam bars placed in several planes can further complicate the placement and congestion of the reinforcement. If these issues are not carefully considered during design, the wall can become heavily congested at locations where

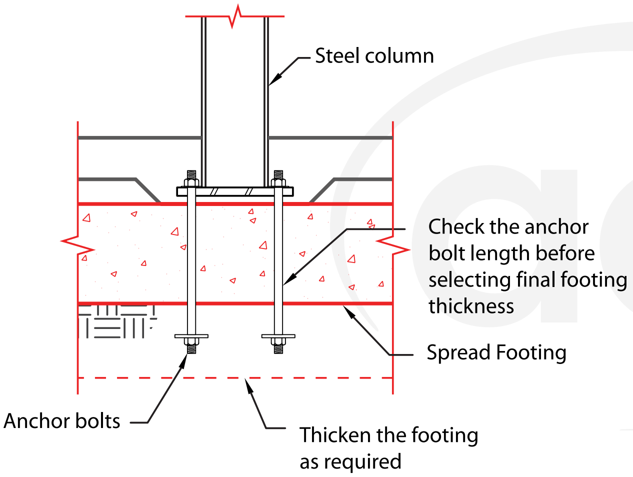


Fig. 2: Spread footings must be thick enough to accommodate the anchor bolt embedment for steel columns

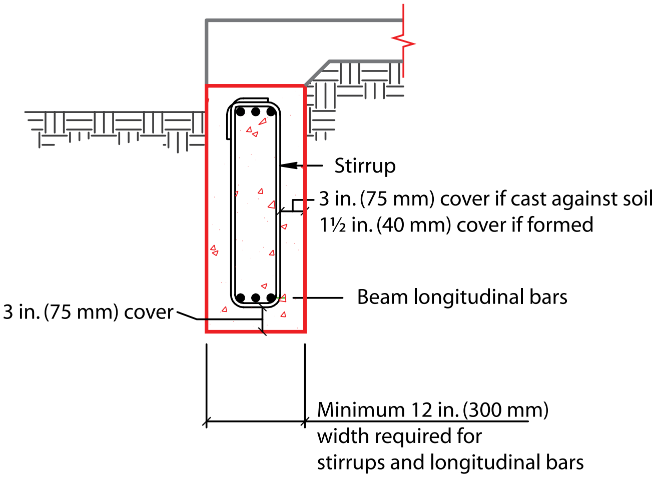


Fig. 3: Earth-formed grade beams should be wide enough to accommodate standard stirrup bend diameters and the 3 in. (75 mm) cover required over the stirrups

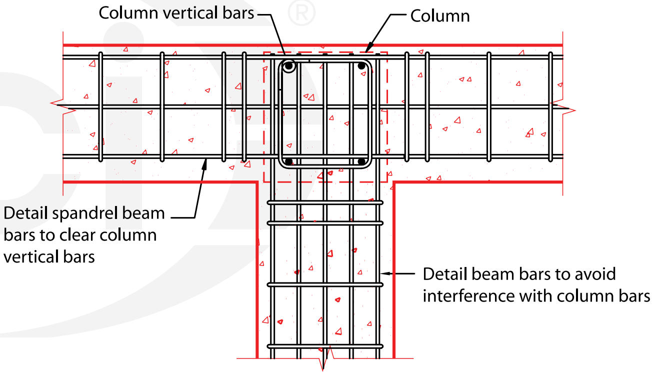


Fig. 4: Making beams a different width than the columns reduces interference between beam and column longitudinal reinforcement

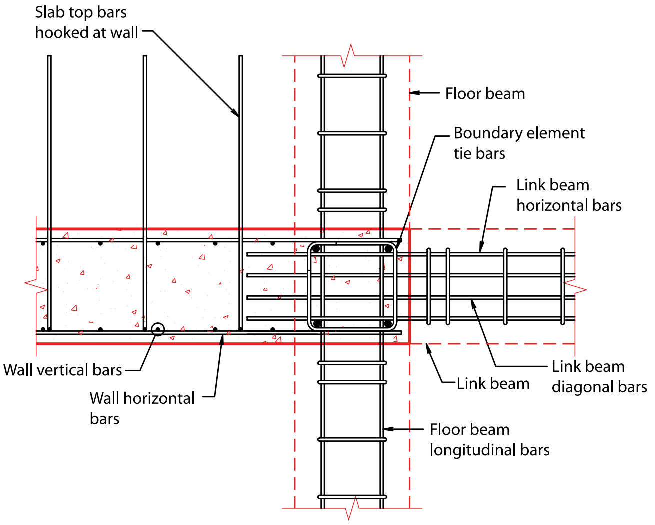


Fig. 5: Plan view of a wall/beam intersection showing steel from several members that terminate into a wall

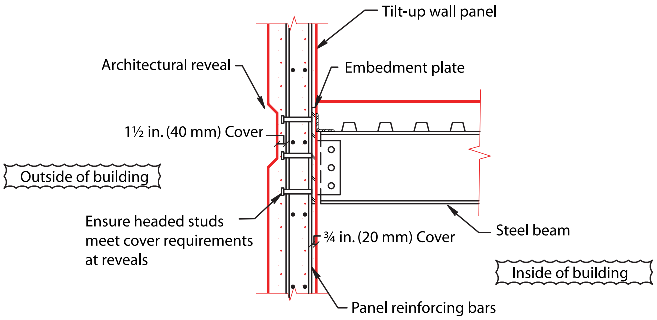


Fig. 6: Section through a tilt-up wall panel. Shear stud lengths should be checked considering the depth of reveals and the plate thickness

several elements intersect and make it very difficult to place the bars and consolidate the concrete properly.

Tilt-up wall panels

For tilt-up walls, panel thickness is often set at about 1/48th the vertical span of the wall.[1] It's important to note, however, the effect of architectural reveals on the net wall thickness. This is needed not only for design, but also for detailing. For example, to ensure that the wall is thick enough for embedment plates with headed studs, designers must verify that sum of the plate thickness, the stud length, and the cover on the end of the studs doesn't exceed the net wall thickness (Fig. 6).

Using double mats of reinforcing can significantly increase the moment capacity as well as the cracked moment of inertia (and thus, the axial capacity of slender wall elements). For panels thinner than 6 in. (150 mm), however, double mats of reinforcement are not preferred as they will be located nearly on top of each other. Finally, note that a standard hook may not fit well in a thin wall panel, so it may be necessary to place the hook in the plane of the wall or use welded-bar mats.

STEPPING BACK

Although the size of structural members must be appropriate for the applied loads and material properties, this should only be considered the starting point. By simply taking a step back and looking at how various elements interface with one another, the issues discussed in this article and other, similar issues can often be easily found and corrected. Making this a continuous process during design and detailing can help avoid having to redesign elements when conflicts are found, and it can lead to a better understanding of how the structural elements interact as a whole.

Acknowledgments

The author is thankful to the members of ACI Committee 315-B, Details of Concrete Reinforcement—Constructibility, for their valuable suggestions and contributions.

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1. "Tilt-Up Construction and Engineering Manual," 6th Edition, Tilt-Up Concrete Association, Mount Vernon, IA, Aug. 2006, p. 9-2.

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Designing for Constructibility: Perspectives on Reinforcing

Shearwalls and Boundary Elements

Critical intersections require critical review

BY JAVED B. MALIK

Boundary elements are the heavily-reinforced, critical zones of shearwalls normally located close to the edges of the wall or next to large wall openings (Fig. 1). In the depth of the floor system, where floor beams and link beams must frame into the wall, boundary elements can become very congested. As Fig. 2 shows, the horizontal reinforcement for two floor beams as well as the horizontal and diagonal reinforcement for the link beam must be threaded between:

- Vertical reinforcement for the boundary element and the wall;
- Horizontal reinforcement for the wall; and
- Ties needed to confine the boundary element vertical reinforcement.

Some of this reinforcement may be located in several layers and some of the bars may be hooked, making the congestion even more severe.

If the walls are sized without proper consideration of the potential conflicts, two problems typically occur. First, it becomes very difficult to fit all the bars in the allotted space—bars may interfere with each other and may not fit. Even if there is enough room for all of the bars to fit in their final positions, however, congestion may make it difficult, if not impossible, to assemble the reinforcing bar cages. Hooked bars can be particularly challenging to place in their final position when having to thread them through a congested area of reinforcement.

The second problem is that concrete placement is very difficult around congested areas. Not only is it difficult to get the concrete into these areas, it is also difficult to insert the vibrators properly. If not properly vibrated, voids can be created in the wall at the most critical locations. If undetected, these voids may jeopardize the structural performance of the wall.

SUGGESTIONS FOR CONSTRUCTIBILITY

A short time spent during the schematic design and construction document phases can save a lot of time and trouble during construction. The following suggestions

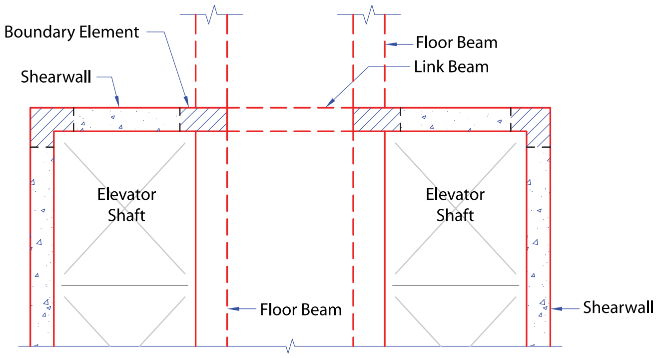

Fig. 1: Plan view of core, showing shearwalls, boundary elements, and beams

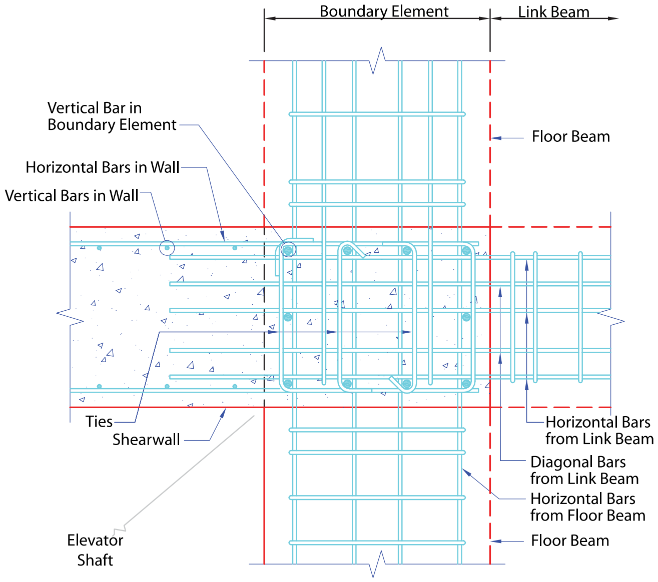

Fig. 2: Joint between a boundary element, floor beams, and a link beam

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will help ensure a constructible design. When considering these suggestions, designers should keep in mind that they are made strictly from a constructibility point of view. Their impact on structural performance should be carefully evaluated by the designer. Reference 1 deals with some of these issues in detail.

The starting point for the designer should be to draw a sketch of the critical areas to scale, study the clearances, and make sure that all of the reinforcement can fit. With modern software, critical joints can be drawn and studied in three dimensions.

An obvious way to reduce congestion is to increase the thickness of the wall, creating more room for concrete and reinforcing bars. This may not always be possible however, due to architectural constraints and loss of precious lease space. An alternative is to thicken only the boundary elements. Making the boundary elements only a few inches thicker than the wall can greatly reduce congestion in the joint by moving the boundary element vertical reinforcement outside of the link beam horizontal reinforcement, as shown in Fig. 3. If the boundary element is thickened, the link beam can also be easily widened to provide additional room for link beam reinforcement. Because it may pose problems with space planning, the option of thickened boundary elements should be carefully studied, particularly where they encroach into elevator shafts.

Similar to increasing the thickness of a boundary element, increasing the length of boundary elements can help spread the vertical bars apart, leaving more room for floor beam reinforcement perpendicular to the wall. This, however, may also increase the quantity of the vertical reinforcing steel required for the design.

Splices for both vertical and horizontal bars should be moved outside of the joint, if possible. As shown in Fig. 4, this reduces the number of bars taking up space in the highly congested area of the joint. Similarly, terminating the longitudinal link beam reinforcement with a straight development length instead of a hook can reduce congestion but also makes the bars much easier to install. When hooks are required at each end of a bar in a floor beam perpendicular to a wall, splicing the bar in the middle of the beam allows much easier installation than placing a single bar with hooks on both ends in a congested

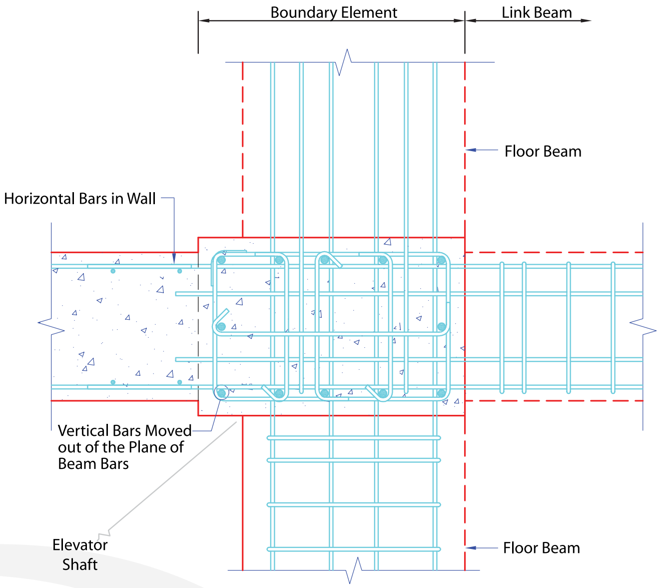

Fig. 3: Boundary elements can be thickened to reduce congestion of reinforcement at joints

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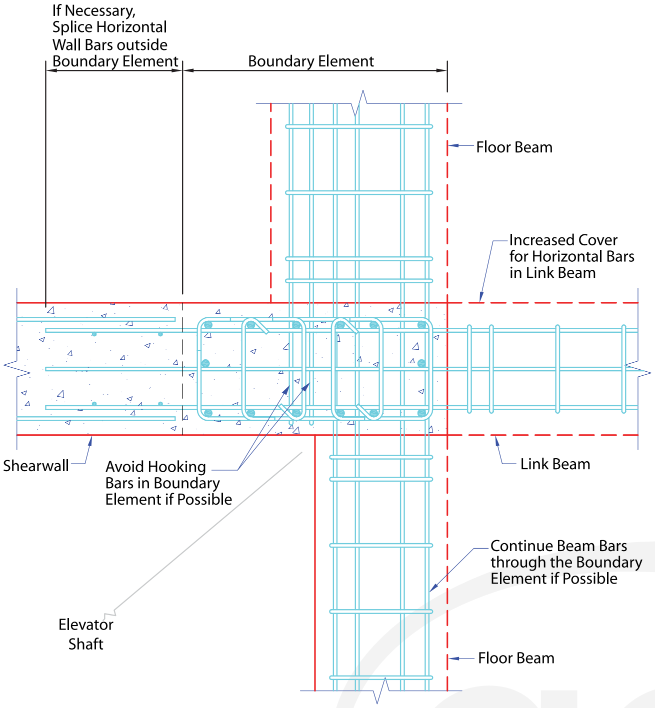

Fig. 4: Relocating splices outside of boundary elements will aid constructibility

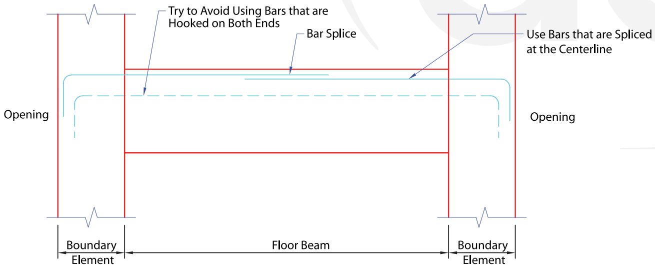

Fig. 5: Bars with hooks on both ends are especially difficult to place. A splice at midspan makes placement much simpler

joint (Fig. 5). The savings in placement time can easily offset the increased steel quantity. Another option may be to use headed bars instead of hooks.[2]

Diagonal bars for link beams can be especially difficult to properly coordinate with other reinforcement. It's important to keep in mind that each bar is located in a separate layer and to be certain that the wall or the boundary element is wide enough to accommodate all these bar layers. Another location that can be difficult for installing diagonal bars is where they extend into the wall or boundary element. Often, this location is also where longitudinal bars from floor beams perpendicular to the wall enter the joint. This may require moving the floor beam bars to clear the diagonal bars from the link beam.

Another issue to look for is when the floor beams and link beams are of the same depth. The floor beam bars will have to be raised or lowered to clear the longitudinal bars from the link beam. This will change the height of the beam stirrups.

Similarly, if the link beams and the shearwall are the same width, the link beam horizontal bars will be located inside of the wall vertical bars. This will increase the clear cover for the link beams and make the stirrups narrower. This needs to be brought to the attention of the steel detailer by a section cut through the floor beams. If not addressed properly, the detailer would probably deduct 3 in. (75 mm) from the overall width and depth of the beam to get the stirrup dimension.

Some other suggestions for keeping these joints constructible include placing the horizontal wall bars and boundary element ties in the same plane and using mechanical splices. Placing the horizontal bars and the ties in the same plane reduces the number of reinforcement planes and increases clearances. Vertical wall bars will thus be located inside the horizontal bars. Mechanical splices can be especially helpful in alleviating congestion at splices located in joints, but relocating the splice to another location is often an even better choice.

As a final note, remember that the actual bar diameter for calculating clearances is larger than the nominal diameter due to the deformations. Similarly, the curvature of column ties, beam stirrups, and hooks should be taken into account because these also reduce clearances.

Acknowledgments

The author is thankful to the members of ACI Committee 315-B, Details of Concrete Reinforcement—Constructibility, for their valuable suggestions and contributions.

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Designing for Constructibility: Perspectives on Reinforcing

Avoiding the Dead Zone

Constructibility concerns at intersections of curved and tangential members

BY DICK BIRLEY

Constructibility issues aren't always the result of members that are heavily reinforced—geometry can also be a culprit. The connection of a beam with a circular column (Fig. 1) and the tangential intersection of a straight beam (or wall) with a curved wall (Fig. 2) are common examples. The curvilinear layout of the vertical bars in the column or wall results in slight offsets that can create "dead zones" through which horizontal bars cannot pass.

This problem is most serious in large heavily reinforced columns such as those found on many highway structures. Bridge bents, for instance, often have very heavily reinforced caps sitting on round columns with the same diameter as the cap width. The problem is compounded when the cap has multiple sets of stirrups that allow little, if any, lateral adjustment of the longitudinal beam bars. Double or triple layers of vertical bars can make the dead zone even worse.

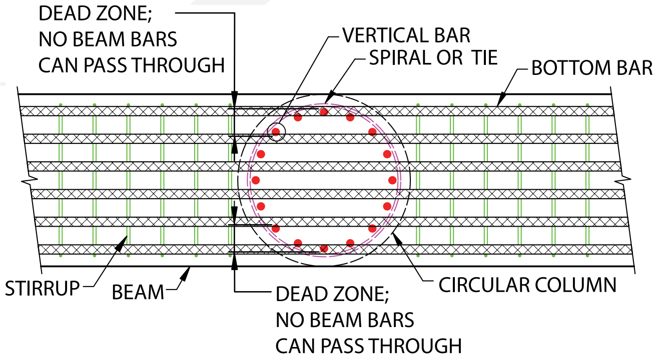

Fig. 1: The intersection of a beam and a round column of the same width creates areas near the edges of the beam where reinforcement cannot pass through the column. This situation can occur even when the column and beam are not heavily reinforced

POSSIBLE SOLUTIONS

The following are some of the best methods for dealing with this problem. For each individual case, however, the best solution will depend on the specific layout of the reinforcement as well as structural design issues:

- Often, the best solution is to design the beam to be wider than the supporting member so the outer continuous bars of the beam pass outside of the dead zone. Additionally, the inner continuous beam bars can then be arranged so they are clear of the dead zone. If the beam has extra bars shorter than the span between supports, they can be located at the dead zones;
- Prior to placing the wall or column concrete, it's sometimes possible to deflect the problem vertical bars so they don't interfere with the beam bars.

Designing for Constructibility: Perspectives on Reinforcing

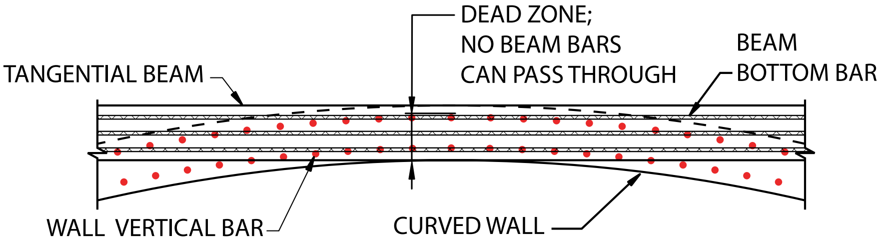

Fig. 2: The tangential intersection of a straight beam with a curved wall can create a very large area where the curvilinear layout of the vertical bars interferes with the beam longitudinal bars

Placing a spacer such as a wooden 2x4 on edge along the top of the forms exactly where the beam bars will be located works well. Unfortunately, large-diameter vertical bars may make it impractical to achieve the needed amount of deflection;

- Stop the problem vertical bars at the soffit of the beam and install appropriate and properly located dowels to maintain member integrity; or
- Stop the beam bottom bars at the faces of the supporting member and install appropriate splice bars. This is practical only if the column or wall stops at the beam and does not rise above it because, in such a case, the vertical bars will terminate below the top bars. The top bars cannot be cut at the faces of the supporting member, so if the verticals must pass through the beam to the member above, another solution must be found.

ADVANTAGES AND DISADVANTAGES

Advantages and disadvantages for the solutions presented herein depend on the specifics of each case. Bar conflicts should immediately come to mind in all curvilinear-tangential situations and should be thoroughly thought out at the design stage—the best time to look for a solution.

The cost differences among the possible solutions are usually not significant, but any additional up-front cost—for example, for extra splices—will be minor compared to the cost of trying to correct the situation after concrete in the supporting member is cast. Structural issues such as selecting which reinforcement to splice and splice locations will often be the determining factors when choosing a design solution.

DESIGN CONSIDERATIONS

Any congestion issue is clearly one that is best solved prior to construction. Unfortunately, people tend to overlook the potential difficulties that can arise at curvilinear-tangential connections. If a problem isn't solved before it's discovered in the field, it's often perceived as a typical situation of too many bars in too small of a space, rather than as a problem caused by the arrangement of the bars along a curve.

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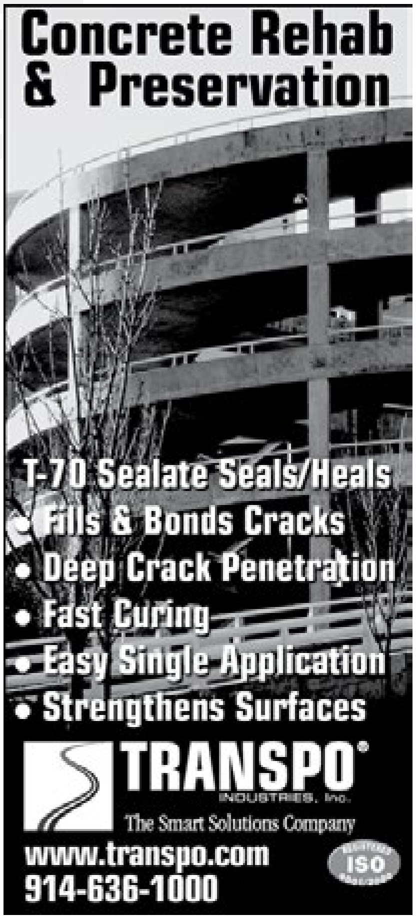

Detailing Corner

Constraints on Reinforcing Bar Modeling

In a three-dimensional (3-D) model, structural, mechanical, electrical, and architectural components can be brought together to form a composite, digital prototype. These models can be used to resolve conflicts and interference issues between components earlier in the design phase more than ever before.

The greatest success with 3-D modeling is usually found for components with very precise tolerances. For instance, the tolerance for the outside diameter of steel pipe is measured in thousandths of an inch, and the pipe can be located in the field to within fractions of an inch. If a pipe is accurately modeled, it can be a reasonably true representation of the real pipe in the structure. Software that can analyze a composite model and find interferences produces the greatest benefit in terms of conflict analysis and resolution when the 3-D model contains these types of components with tight tolerances on dimensions and location.

Given their successful experience with these elements, modelers often assume they will have similar success with 3-D modeling of reinforcing bars. Unfortunately, this is not necessarily the case.

DETAILING CORNER

Joint ACI-CRSI Committee 315-B, Details of Concrete Reinforcement—Constructibility, has developed forums dealing with constructibility issues for reinforced concrete. Staff at the Concrete Reinforcing Steel Institute (CRSI) are presenting these topics in a regular series of articles. If you have a detailing question for 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."

3-D BAR MODELING PROBLEMS

Reinforcing bar models are great for illustrating the general layout of the bars, especially in congested areas, and are useful for identifying possible problem areas that might require special attention from the detailer, fabricator, or placer. The range of tolerances for the manufacture, fabrication, and placement of reinforcing bars, however, is larger than for most other components in the construction industry. Therefore, current reinforcing bar models tend to be only general representations of the bars, not accurate or realistic representations. A 3-D model using precise dimensions for reinforcement without considering tolerances, therefore, cannot be used in the same manner as models for other components.

MANUFACTURING TOLERANCES

Reinforcing bars are manufactured to dimensions specified in ASTM standards. The nominal bar diameter excludes the deformations and is used to calculate the cross-sectional bar area for design and weight calculations. When considering constructibility, the important dimension

Detailing Corner

is the overall diameter of the bar, which is measured to the outside of the deformations. Overall reinforcing bar diameters from the CRSI *Manual of Standard Practice*[1] are shown in Fig. 1.

Using a No. 11 (No. 36) bar as an example, the nominal diameter is 1.41 in. (35.8 mm), but the overall diameter is 1.625 in. (40 mm) or 15% larger than the nominal diameter. The overall diameter, however, is also approximate for at least two reasons. First, if the reinforcing bar was rolled at a mill using worn rolls, the overall bar diameter will tend to be larger. Second, deformation patterns used by some mills have higher deformations and, therefore, larger overall diameters, than other patterns. For the No. 11 (No. 36) bar in this example, at least another 1 or 2% difference between nominal and overall diameter should be allowed to accommodate for these possibilities.

Some modelers use the nominal diameter for the bar size. Clearly, those models are not as accurate as a model that uses the overall diameter relative to the actual bar being represented.

Bar Size	Approximate Diameter Outside Deformations, in. [mm]
#3 [#10]	7/16 [11]
#4 [#13]	9/16 [14]
#5 [#16]	11/16 [18]
#6 [#19]	7/8 [22]
#7 [#22]	1 [25]

Bar Size	Approximate Diameter Outside Deformations, in. [mm]
#8 [#25]	1-1/8 [28]
#9 [#29]	1-1/4 [32]
#10 [#32]	1-7/16 [36]
#11 [#36]	1-5/8 [40]
#14 [#43]	1-7/8 [48]
#18 [#57]	2-1/2 [63]

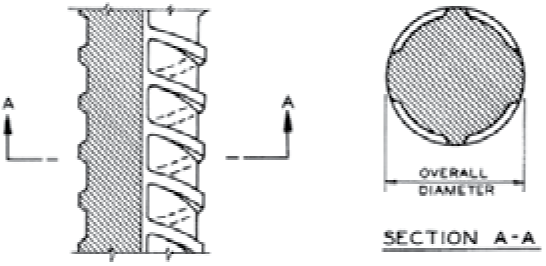

Fig. 1: Overall reinforcing bar diameters (from Reference 1)

REINFORCING BAR FABRICATION TOLERANCES

Reinforcing bar fabrication and placement is not precise. This is reflected by the liberal fabrication and placing tolerances specified by ACI Committees 318, Structural Concrete Building Code, and 117, Tolerances.[2,3] Trying to model bars in a structure without incorporating these tolerances will produce a graphic model with much less precision than expected.

Here are a few of the tolerances that, if not considered, can affect the accuracy of the model:[3]

- Sheared length:
  No. 3 to No. 11 = ±1 in.;
  (No. 10 to No. 36 = ±25 mm);
  No. 14 and No. 18 = ±2 in.;
  (No. 43 and No. 57 = ±50 mm);
- Overall length of bars bent at each end:
  No. 3 to No. 11 = ±1 in.;
  (No. 10 to No. 36 = ±25 mm);
  No. 14 = ±2.5 in.;
  (No. 43 = ±65 mm);
  No. 18 = ±3.5 in.;
  (No. 57 = ±90 mm); and
- Angular deviation on 90-degree bends:
  ±2.5 degrees.

The designer cannot assume that the dimensions of the modeled 3-D bar will be the same as those for the actual bar in the structure. If an adjustment is made to a particular bar to solve an interference problem in the graphical model, it will not necessarily translate to the actual placed bar.

Reinforcing bar bends are also difficult to accurately model. Bends are typically modeled with a constant

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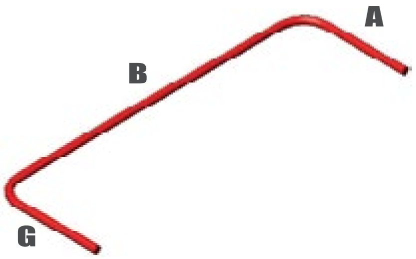

Fig. 2: Hooked bar with Sides A, B, and G as detailed (from Reference 4)

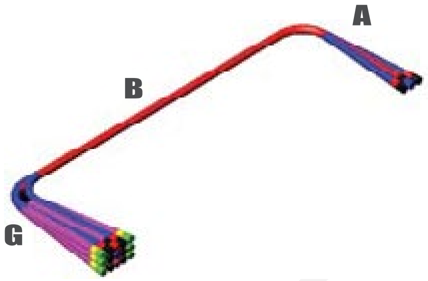

Fig. 3: Tolerances applied to the hooked bar from Fig. 2: ±1 in. (±25 mm) tolerance envelope on Sides A, B, and G; ±2.5 degree in-plane angular tolerance envelope at Sides A and G; and ±2.5 degree out-of-plane angular tolerance envelope at Side G (from Reference 4)

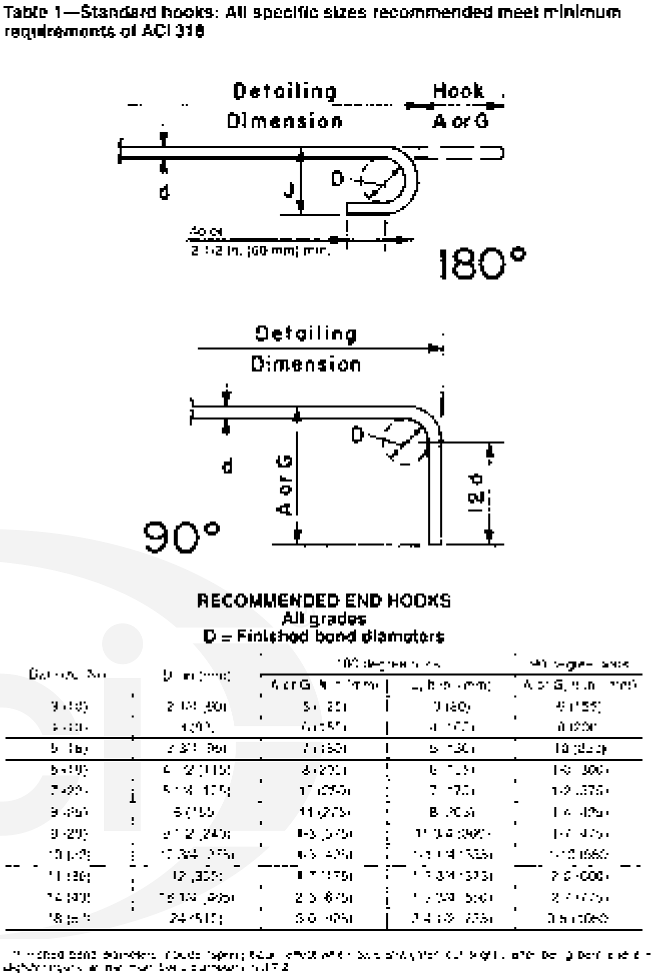
Table 1—Standard hooks: All specific sizes recommended meet minimum requirements of ACI 318

RECOMMENDED END HOOKS
All grades
D = Finished bend diameters

Fig. 4: Recommended minimum dimensions for standard end hooks (from Reference 5)

radius. For the actual bar, the bend radius varies depending on whether the bar is bent normal to the plane of the main longitudinal ribs or parallel to the plane of the longitudinal ribs. Many other factors affect the curvature of bends, such as the speed of the bending machine or the state of wear of the mandrel that the bar is bent around.

The variation in bending of a group of supposedly identical bars can be significant. For example, consider the No. 8 (No. 25) bar with standard hooks at each end. Figure 2 represents the perfect bar case.[4] Figure 3 shows the possible geometric variations for the bar in Fig. 2 that are within acceptable fabrication tolerances. Based on the potential variations shown in Fig. 3, Fig. 2 is not an accurate representation of reality.

The issue of finished bend diameter is another concern for the reinforcing bar modeler. The ACI *Detailing Manual–2004*[5] contains the recommended end hook dimensions shown in Fig. 4. The "D" dimension is the finished bend diameter for various bar sizes. A spring-back effect is mentioned that will produce a finished bend diameter slightly larger than the pin that the bar was bent around.

As an example, the finished bend diameter for a No. 11 (No. 36) bar is 12 in. (305 mm). A reinforcing bar modeler could reasonably be expected to use this dimension to model bent No. 11 (No. 36) bars. The finished bend diameters listed, however, are minimum dimensions. To ensure their bars are bent to the proper minimum diameter, many fabricators use the "D" dimension as the actual size of their mandrels. If the 3-D model is used to investigate interferences, this potential dimensional difference can be significant, especially for larger bars.

The longitudinal ribs on reinforcing bars present another complicating issue. First, when bars are rolled in the mill, they pass through the rolls onto the rolling (cooling) bed, gradually twisting to the right or left. The result is that the longitudinal ribs tend to spiral around the longitudinal axis of the bar. This spiraling of the longitudinal ribs can have an effect on fabrication.

A bend made at right angles to the plane of the main ribs will be tighter than a bend made parallel to the plane of the main ribs. The difference can be significant. The first bend on a bar can always be bent at right angles to

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the plane of the main ribs, but due to the spiraling of the ribs, there is no guarantee subsequent bends on the same bar will be at right angles to the plane of the longitudinal ribs. In fact, there is a high probability that they won't. Thus, there can be two different bend diameters on the actual bar, while identical bend diameters would be assumed in the 3-D model.

PLACING TOLERANCES

Per ACI 117-06,[3] the tolerance on cover varies from –1/4 to –1/2 in. (–6 to –13 mm), depending on the member thickness. This is unlikely to be included in a reinforcing bar 3-D model. The tolerance for bar spacing in slabs and walls is ±3 in. (±76 mm). Moving bars in a model fractions of an inch to avoid a perceived interference in the model doesn't accurately reflect field conditions. A journeyman ironworker has the knowledge, tools, and skill to solve in the field almost all of the minor interferences encountered in a model.

USE WITH CAUTION

Reinforcing bar 3-D modeling is a beneficial tool for providing a general perspective of the bar arrangement in a structure, and how the bars may interface with the other components. While many components are reflected in a relatively precise manner, reinforcing bar fabrication and placement typically is not. Software that detects and identifies interface conflicts is useful for resolving problems in most components because the model closely reflects reality. Because many bar models don't accurately depict real conditions, however, resolving bar fabrication and placement problems in a graphical computer model is not recommended and should be used with caution.

References

1. Committee on Manual of Standard Practice, *Manual of Standard Practice*, 27th edition, Concrete Reinforcing Steel Institute, Schaumburg, IL, 2001, p. 6-2.

2. ACI Committee 318, "Building Code Requirements for Structural Concrete (ACI 318-08) and Commentary," American Concrete Institute, Farmington Hills, MI, 2008, pp. 89-90.

3. ACI Committee 117, "Specifications for Tolerances for Concrete Construction and Materials and Commentary (ACI 117-06)," American Concrete Institute, Farmington Hills, MI, 2006, 70 pp.

4. Birley, D., "The Tolerance Cloud," *Concrete International*, V. 27, No. 6, June 2005, pp. 61-63.

5. ACI Committee 315, *ACI Detailing Manual—2004*, SP-66(04), American Concrete Institute, Farmington Hills, MI, 2004, p. 43.

Selected for reader interest by the editors.

Thanks to ACI Committee 315 member Dick Birley, President of Condor Rebar Consultants, Inc., in Vancouver, BC, Canada, for providing the information in this article.

Providing constructible details is an important step in the design process. Since 2005, *Concrete International* has published a number of articles dealing with these issues in the "Designing for Constructibility: Perspectives on Reinforcing" article series by Joint ACI-CRSI Committee 315-B, Details of Concrete Reinforcement—Constructibility. As part of a cooperative initiative between the Concrete Reinforcing Steel Institute (CRSI) and ACI, CRSI staff have volunteered to assist the committee by authoring a regular series of constructible detailing articles that address common problems and are based on solutions developed by the committee. This "Detailing Corner" article is the first in this series. Current plans are to publish the series bimonthly.

Point of View

Reinforcement Placing Drawings are not Shop Drawings

Requirements for early submittal can be detrimental

BY DICK BIRLEY

> *"Contractor will be required to have engineering such as submittals, shop drawings, and samples submitted for approval within one hundred (100) calendar days from written engineering notice to proceed."*

Statements similar to this quote from the specifications for a new stadium proposed several years ago appear in many project specifications. In today's environment of ever-shortening design and construction schedules, it's understandable that specification writers feel it's necessary to impose tight time constraints on the delivery of shop drawings.

Although reinforcing bar placing drawings are often assigned to the "shop drawings" category, it's important to note that bar placing drawings are quite different from the fabrication and installation drawings required for other construction trades. In fact, the constraints placed on the production of bar placing drawings may make it impossible to comply with such a contract demand in a manner that's productive for the detailer or the contractor.

This point of view article is presented for reader interest by the editors. However, the opinions expressed are not necessarily those of the American Concrete Institute. Reader comment is invited.

GATHERING THE INFORMATION

There are many items on a construction project that require shop drawings, including structural steel, precast concrete, miscellaneous metal, mechanical and electrical systems, and finish items such as doors and windows. There is, however, a fundamental difference between shop drawings for most items and reinforcing bar placing drawings. Except for relatively minor embedded pieces in concrete, most items detailed in shop drawings are installed as self-contained systems or as attachments to in-place systems. In contrast, reinforcing steel is an integral part of a much larger system assembled during the concrete placing process, and proper detailing depends on how that process is carried out.

There are two reasons why many items need shop drawings prepared as quickly as possible after the project begins. Most importantly, most items are manufactured products with relatively long delivery times. They must be ordered as soon as possible to ensure that they arrive on site at the proper moment in the construction process. The second reason is that concrete cannot be placed until final concrete dimensions are determined. Although the architect and engineer prepare the initial concrete dimensions, these dimensions are fine-tuned during preparation of shop drawings for the other items, including mechanical and electrical equipment, windows and doors, and concrete formwork, required to suit the particular requirements of the project.

Rapid, early preparation of shop drawings is normally not problematic for most of these other items because they have relatively little interdependence with each other or casting concrete. For the most part, the data needed for production of these shop drawings are not dependent on the work performed by other trades.

A reinforcing bar placing drawing is, however, an entirely different matter.

First of all, reinforcing steel is fabricated and installed as part of the concrete placing process. The builder cannot begin to cast concrete until the final dimensions are known. Likewise, reinforcing bar detailers cannot complete their detailing until they have the final dimensions. Basically, detailers cannot complete their placing drawings until most of the other trades have completed their drawings.

Furthermore, they cannot complete placing drawings for many parts of the structure, especially slabs and walls, until concrete contractors have completed their formwork drawings and defined all of the relevant construction joints. In addition, there are often requests-for-information that will have to be answered before placing drawings for the areas in question can be completed. Because of these issues, detailers are often left with very little lead time before the steel is needed. As a result, they will have to know in considerable detail the precise construction sequence so they deal with the most urgent items first. The construction sequence is also necessary so the detailer can properly arrange for necessary dowel projections from one placement into the succeeding ones.

Fortunately, there is almost always ample time for delivery of reinforcing bars, even if the placing drawings are prepared and approved only a couple of weeks before the steel is needed in the field. Because reinforcing bars are readily stockpiled and ready for almost immediate cutting and bending, production can be quite rapid. For all of these reasons, there is no compelling need to prepare placing drawings "within one hundred (100) calendar days from written engineering notice to proceed."

To complete their jobs properly, detailers must have at hand a great deal of data that often doesn't come until it becomes critical—in other words, until the lead time is gone and they are in danger of not completing their work in time for a placement. This is why the reinforcing bar detailers always seem to be behind schedule—they are the last people to get all the information they need to complete their jobs. Those that don't understand this may assume that detailers are submitting their placing drawings at the last moment due to poor planning or incompetence, but that's simply not a fair assumption.

WHAT'S BEST FOR THE PROJECT?

If the reinforcing steel for a project is detailed within 100 days after notice to proceed, or simply ahead of the availability of proper data, it's almost certain that a great deal of the detailing will have to be revised. A detailer details on the basis of a unit price per ton of steel that is included in the bid price. Revising detailing is usually done at an hourly rate. The cost for redetailing in such a situation can be enormous and can be as much or more than the cost of the original detailing. This is a significant and needless cost to be passed on to the client or the client's client.

Awareness of these issues makes clear that the request for detailing to be completed far ahead of the required schedule is unreasonable. The issue at hand is to try to get all the necessary information to the reinforcing bar detailers as quickly as possible so they can keep ahead of construction. Reinforcing bar placing drawings are simply not the same as other shop drawings, and care should be taken to treat them as distinct and separate.

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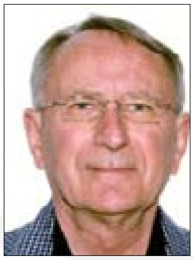

ACI member **Dick Birley** has more than 40 years of experience in the reinforcing steel industry, including working as an ironworker and owning a fabrication and placing company. He is the owner of Condor Rebar Consultants, Inc., a detailing company located in Vancouver, BC, Canada, that is involved in projects worldwide. He is a member of ACI Committees 315, Details of Concrete Reinforcement, and 439, Steel Reinforcement.

Detailing Corner

Reinforcing Bars Exceeding Stock Lengths

Steel mills supply reinforcing bars in standard stock lengths, commonly known as mill lengths. Fabricators supply reinforcing bars in cut or detailed lengths. Normally, No. 5 (No. 16) and larger bars are available in standard mill lengths of up to 60 ft (18 m), and No. 4 (No. 13) and smaller bars are available in mill lengths of up to 40 ft (12 m). Some fabricators, however, may stock a small quantity of larger bar sizes, usually No. 11 (No. 36) and larger, in lengths over 60 ft (18 m).

Although splices are typically used to overcome stock-length limitations, there are occasional situations where splices would be inconvenient or unacceptable. There are also situations where it would be more efficient to have the steel mill fabricate bars that are longer or shorter than the standard stock lengths. Fortunately, within certain limitations, it's possible to vary the length of the bar produced at the mill.

LIMITATIONS

Before reinforcing bars that exceed the standard mill length are detailed or scheduled on design documents, there are a few important limitations to consider. First, check availability. Fabricators and mills may have some flexibility, so given enough lead-time and sufficient quantity, bars of any specific length (longer or shorter than stock length) may be ordered directly from the mill. There are regional differences in the availability of special-length bars, however, so again—check with fabricators and mills.

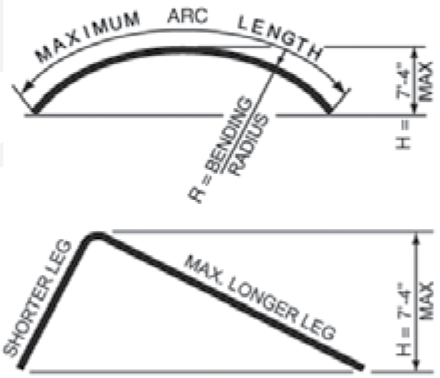

Fig. 1: An 8 ft wide truck bed can limit the total bar length for arc or longer leg of L-shaped bars (from Reference 1) (1 ft = 0.3 m)

If overlength reinforcing bars are required on a project, the designer should try to avoid using overlength bars with hooks or bends. Bending overlength bars may present difficulties for the fabricator, and the required special accommodations in the fabrication shop could be costly.

Issues may also arise over the shipping of overlength bars. The standard length of a rail car is about 65 ft (20 m). The lengths of flatbed semitrailers used on U.S. highways can range from 48 to 60 ft (15 to 18 m), but length restrictions vary by state. Access to the site may also be an issue. Although long tractor-semitrailer combinations can usually maneuver with relative ease on large industrial sites, they may have difficulty accessing tight urban sites.

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The transportation of overlength reinforcing bars bent in an arc or an L-shape must also be considered. Standard trailer bed widths range from 8 ft 0 in. to 8 ft 6 in. (2.4 to 2.6 m). Figure 1 illustrates a 7 ft 4 in. (2.2 m) maximum reinforcing bar width for a common 8 ft 0 in. bed width (the 8 in. [200 mm] difference accounts for the bundling of several bars in a shipment). For an arc-shaped bar, the maximum bar length is a function of the bending radius R and the maximum reinforcing bar width H of 7 ft 4 in. (2.2 m):

$$\text{Maximum arc length} = 2R\cos^{-1}\left(1 - \frac{H}{R}\right) \qquad (1)$$

For an L-shaped bar, the maximum longer leg length is a function of H and the length of the shorter leg S:

$$\text{Maximum longer leg length} = SH/\sqrt{S^2 - H^2} \qquad (2)$$

Typical results for Eq. (1) and (2) are tabulated in Reference 1.

Overlength reinforcing bars can strain the limits of on-site lifting equipment. Bar bundles may have to be split to reduce the weight of each lift, and special chokers or spreader beams may be needed to prevent excessive bending of the bars under self-weight. Maneuvering bar bundles around onsite obstacles and placing bars in the forms can also be issues, and placed bars themselves can create obstacles if they extend past a construction joint.

GOING TO GREAT LENGTHS

Using overlength reinforcing bars can have both benefits and drawbacks. Designers need to determine the best option, taking into consideration the affected mills, fabricators, transportation systems, and site conditions. Even if it can be done, it may be better to find an alternate solution.

References

1. ACI Committee 315, *ACI Detailing Manual*, SP-66, American Concrete Institute, Farmington Hills, MI, 2004, 175 pp.

Thanks to ACI Committee 315 member Dick Birley, President of Condor Rebar Consultants, Inc., in Vancouver, BC, Canada, for providing the information in this article.

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Detailing Corner

RFI ON GRADE 40 STEEL

RFI 09-1: I'm a research engineer and occasionally need to use Grade 40 (Grade 280) steel in test specimens. I just noticed that my stock of Grade 40 (Grade 280) bars is getting low. Is Grade 40 (Grade 280) steel still produced and available? Also, how can I be sure the mechanical properties aren't closer to Grade 60 (Grade 420). I can't afford to experiment with rejected Grade 60 (Grade 420) steel. Its yield strength may be too high.

Response: The majority of bars used in the U.S. meet ASTM A615/A615M[1] requirements for carbon-steel reinforcing bars. Low-alloy reinforcing bars meeting ASTM A706/A706M[2] requirements are also used in high-seismic regions of the country or where welding of the bar is required. Rail-steel and axle-steel reinforcing bars per ASTM A996/A996M[3] are not used extensively.

Most reinforcing bars used in the U.S. are Grade 60 (Grade 420), with a specified minimum yield strength f_y of 60,000 psi (420 MPa). Grade 75 (Grade 520) bars are sometimes specified to help alleviate congestion in heavily reinforced members, and a designer or researcher like yourself will occasionally specify Grade 40 (Grade 280) reinforcing bars for certain applications.

While it's generally true that reinforcing bar mills can produce bars of any grade, each mill normally produces only those grades that are ordered on a regular basis. In the summer of 2008, CRSI conducted a survey of all mills, and Fig. RFI 09-1.1 indicates the states with mills producing Grade 40, 60, and 75 (Grade 280, 420, and 520) reinforcing bars. As you can see, Grade 40 (Grade 280) reinforcing bars are still produced and available in most U.S. states. In fact, one of the mills in the northwest U.S. confirmed that Grade 40 (Grade 280) is indeed the target for their bar production. Depending on the steel chemistry, recent production heats from this specific mill exhibited yield strengths varying from 42 to 54 ksi (290 to 375 MPa). Availability of Grade 40 (Grade 280) bars will depend on the local mill and warehouse facilities in your particular area of the country, so contact the CRSI technical department as soon as specific quantities are known.

References

1. ASTM A615/A615M-08b, "Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement," ASTM International, West Conshohocken, PA, 2008, 6 pp.

2. ASTM A706/A706M-08a, "Standard Specification for Low-Alloy Steel Deformed and Plain Bars for Concrete Reinforcement," ASTM International, West Conshohocken, PA, 2008, 5 pp.

3. ASTM A996/A996M-06a, "Standard Specification for Rail-Steel and Axle-Steel Deformed Bars for Concrete Reinforcement," ASTM International, West Conshohocken, PA, 2006, 5 pp.

4. ASTM A1035/A1035M-07, "Standard Specification for Deformed and Plain, Low-Carbon, Chromium, Steel Bars for Concrete Reinforcement," ASTM International, West Conshohocken, PA, 2007, 5 pp.

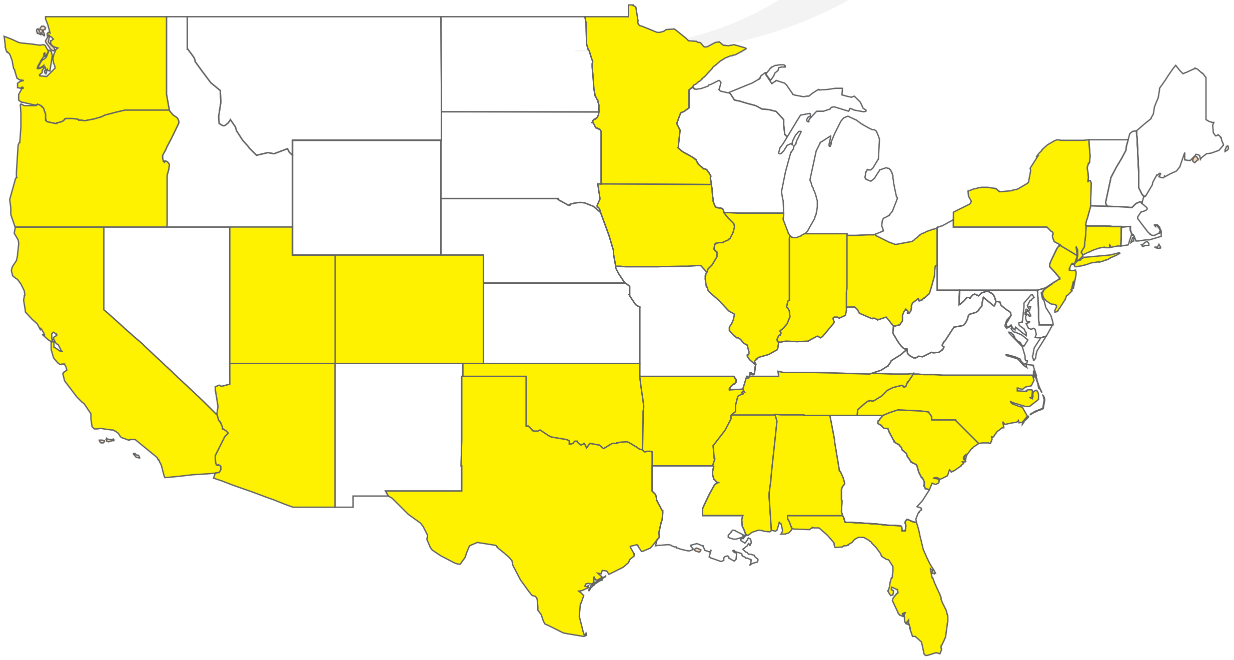

Fig. RFI 09-1.1: States with reinforcing bar mills are highlighted in yellow. All of the indicated states have mills producing Grade 60 (Grade 420) bars, and most have mills producing Grade 40 and 75 (Grade 280 and 520) bars. The exceptions: Indiana doesn't have a mill producing Grade 40 (Grade 280) bars, and North Carolina doesn't have a mill producing Grade 75 (Grade 520) bars. At press time, Grade 100 (Grade 690), ASTM A1035 bars[4] are produced only in Oregon

Detailing Corner

Sloped Versus Stepped Footings for Walls

Generally, it's most economical to place wall footings at a constant elevation. If the site or finished grade slopes along the length of the wall, however, the footing may end up a considerable distance below finished grade. This is clearly not economical, as it requires extra excavation and material. Two other options are therefore preferred (Fig. 1):

- Slope the footing with the site so its depth below the finished grade is nearly constant along its length; or
- Step the footing so its depth below finished grade is not excessive at any point along its length.

SLOPED FOOTING ISSUES

The sloped footing option may seem appealing because of the simple geometry and apparent ease in formwork construction. It does, however, create the following construction issues (Fig. 2):

- Vertical wall bars above the footing will have different lengths, creating major challenges in the fabrication plant and on the job site. Two of these—managing the inventory and placing the bars in their correct locations—can be eased by detailing the bars with variable lap splice lengths. This will, however, increase the quantity of vertical reinforcement;
- Horizontal reinforcing bars in the lower portion of the wall will also have different lengths because they are interrupted by the sloped footing. If constant length horizontal bars are used at the wall base, they can be fanned out, but this will create a variable vertical spacing of the reinforcing bars;
- Sloped footings will require trapezoidal formwork. This will require modifications to standard rectangular formwork;
- A sloped footing could be unstable, particularly on a very steep slope; and
- Concrete placement and finishing could be difficult, and a stiff concrete mixture might be required to prevent the concrete from flowing downhill, which may lead to segregation. Alternatively, the top of the form may have to be closed.

Because of these challenges, most engineers and contractors prefer to use stepped footings instead of sloped footings.

CONSIDERATIONS FOR STEPPED FOOTINGS

As with any aspect of a design, cost should be considered before a system is selected. If the slope of the finished grade is less than 2 ft (0.6 m) for a 20 to 30 ft (6 to 9 m) long wall, a lower but constant bottom bearing

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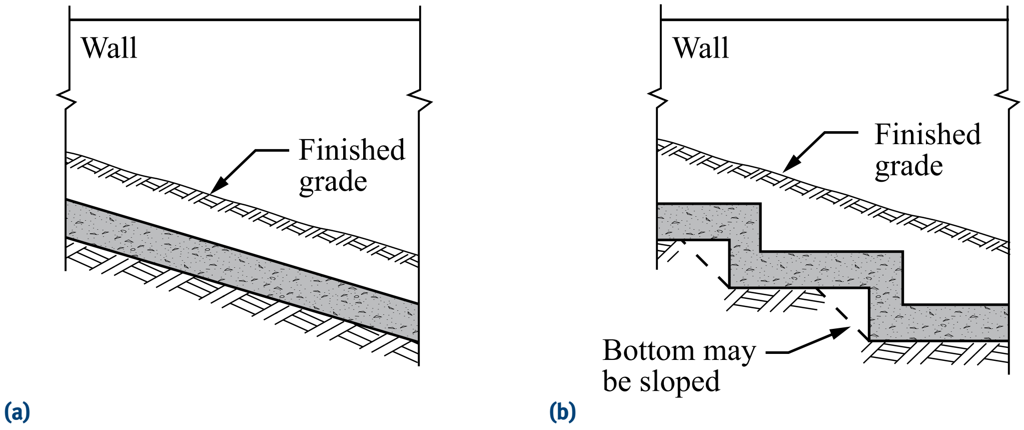

Fig. 1: There are two ways to construct footings for walls built at sloping grades: (a) slope the footing to match the change in finished grade elevation; or (b) step the footing at intervals that maintain the minimum footing depth

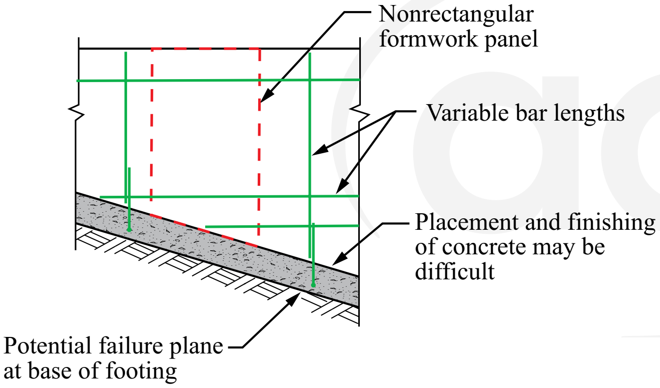

Fig. 2: Construction issues for sloped footings

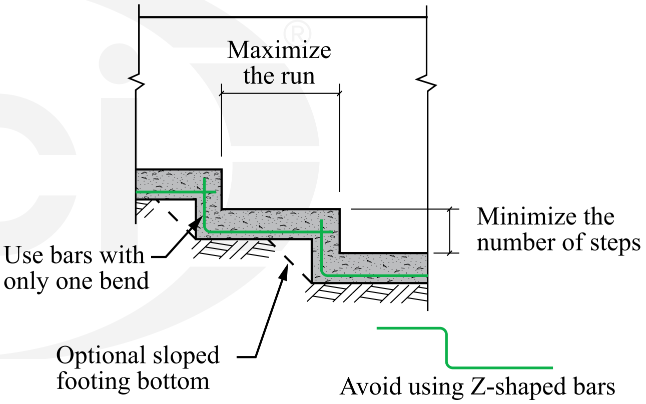

Fig. 3: Preferred details for stepped footings

elevation may be more economical than a stepped footing. For a very long wall, however, even a 1 ft (0.3 m) variation in the site elevation may make a stepped footing more economical. Communication with the contractor during the design phase regarding the number and length of steps can be very helpful.

It's generally more cost effective to minimize the number of steps. For example, it may be more economical to design for a 6 ft (1.8 m) change in elevation using three 2 ft (0.6 m) steps or two 3 ft (0.9 m) steps rather than six 1 ft (0.3 m) steps. This minimizes the number of wall sections to be detailed and formed. Before deciding on the footing step locations, however, consider the horizontal distance between them. Distances should preferably be multiples of available or standard form lengths.

Before completing a design, it's a good idea to communicate with area formwork contractors. The horizontal runs should be dimensioned in 2 or 4 ft (0.6 or 1.2 m) increments to conform to standard plywood or form system dimensions. Unless the site slopes drastically, try to keep a minimum horizontal run of 10 ft (3 m) for each step, if possible.

Keep the detailing simple. Avoid using Z-shaped bars (Fig. 3). Their geometry may make it necessary to slant the riser out of plane to meet cover requirements for the treads.

It's also prudent to evaluate other footing options. For example, the individual spread footings or piers supporting grade beams shown in Fig. 4 may be more economical than a continuous spread footing option. Because the wall can span between footings or piers, similar configurations can be constructed without the grade beam.

Situations can vary along the wall length, so it's prudent to show specific details rather than generic details. This will expedite placing drawing preparation and perhaps minimize requests for information (RFIs).

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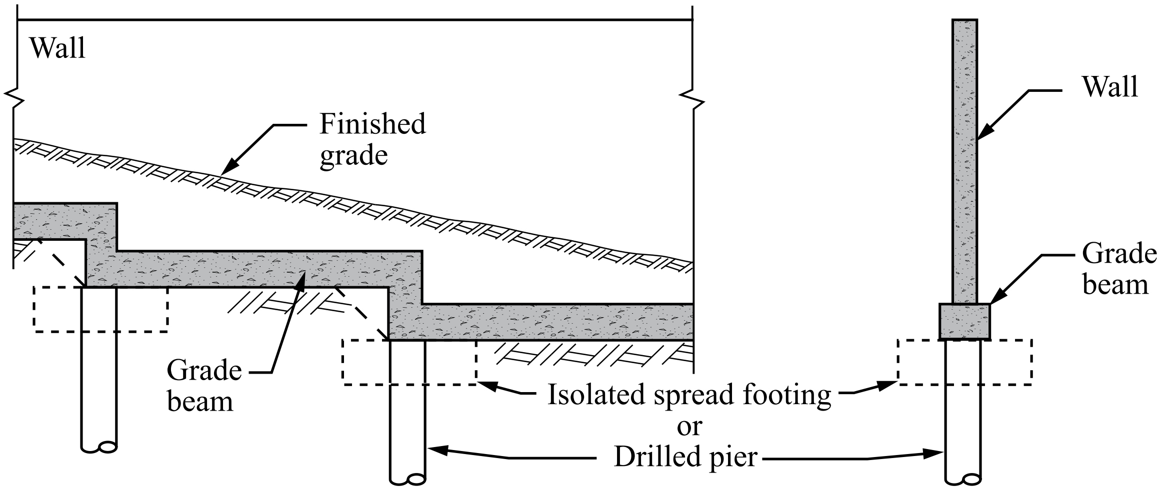

Fig. 4: Isolated spread footings or drilled piers, with or without a grade beam connecting them, are an alternative to sloped or stepped footings

CLOSURE

The use of sloped or stepped footings depends on site conditions, finished grade elevations, finished wall slope, and various reinforcing bar placement and construction issues. Regardless of the footing system selected, the engineer is required to follow the design requirements of Section 15.9 in ACI 318-08.[1] Section 15.9.1 requires that the angle of slope or depth and location of steps be such that the design requirements are satisfied at every section. Additionally, Section 15.9.2 requires footings designed as a unit to be constructed to ensure they act as a unit.

References

1. ACI Committee 318, "Building Code Requirements for Structural Concrete (ACI 318-08) and Commentary," American Concrete Institute, Farmington Hills, MI, 2008, 465 pp.

Thanks to Joint ACI-CRSI Committee 315 member Javed Malik, Jacobs Engineering Group, Houston, TX, for providing the information in this article.

Selected for reader interest by the editors.

Detailing Corner

Grade Beam Depth and Dowel Embedment

Shallow grade beams can cause congestion problems at the tops of drilled pier foundations or pile caps. Achieving proper embedment of the column vertical reinforcing bars, dowels projecting from the foundation, or both often requires that the reinforcement be hooked in the grade beam. The resulting congestion may make it very difficult for the grade beam longitudinal bars to pass unobstructed over the foundation. The problem is compounded if two grade beams intersect over a foundation element.

OPTIONS

Figure 1 shows an example of a grade beam-drilled pier connection as originally detailed. The drilled pier is 18 in. (460 mm) in diameter with eight No. 8 (No. 25) vertical bars. The grade beam is 2 x 2 ft (0.6 x 0.6 m) with No. 11 (No. 36) top and bottom longitudinal bars and No. 5 (No. 16) stirrups. The dowels for the columns are eight No. 8 (No. 25) bars.

As shown in Fig. 1, the reinforcing bars can barely fit—even with ideal placement. If there were more bars in

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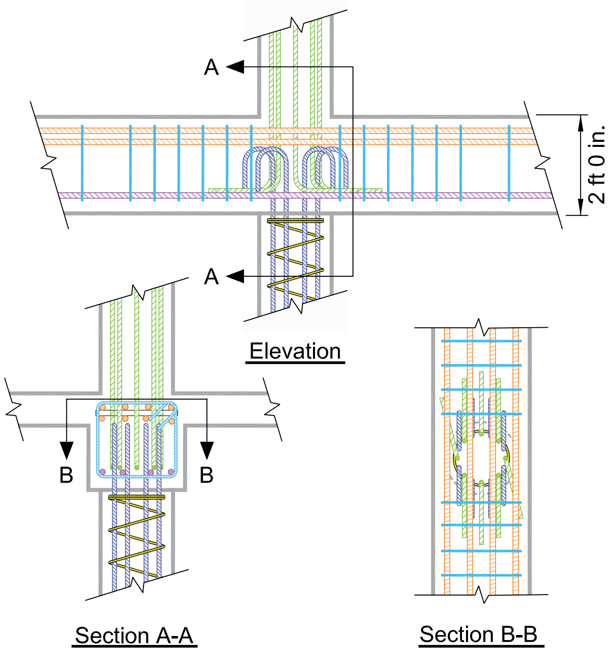

Fig. 1: Drilled pier to grade beam connection, as designed

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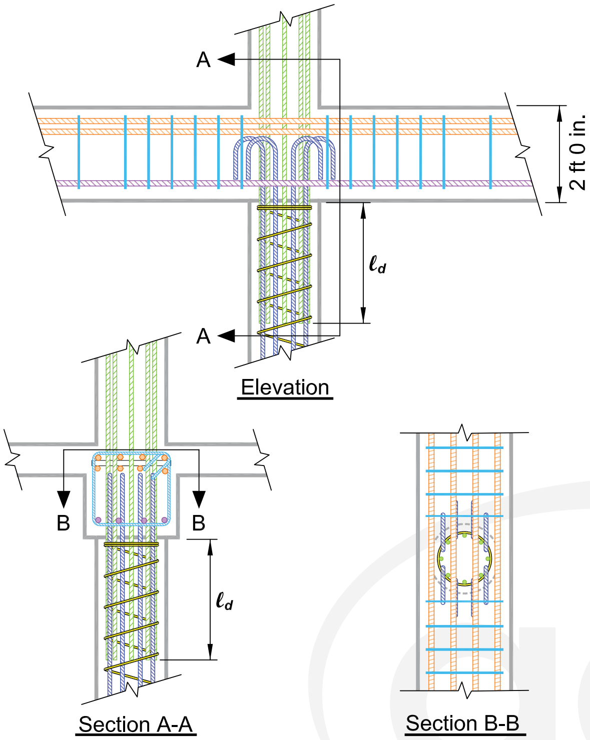

Fig. 2: Option 1—Column dowels extended straight into the drilled pier

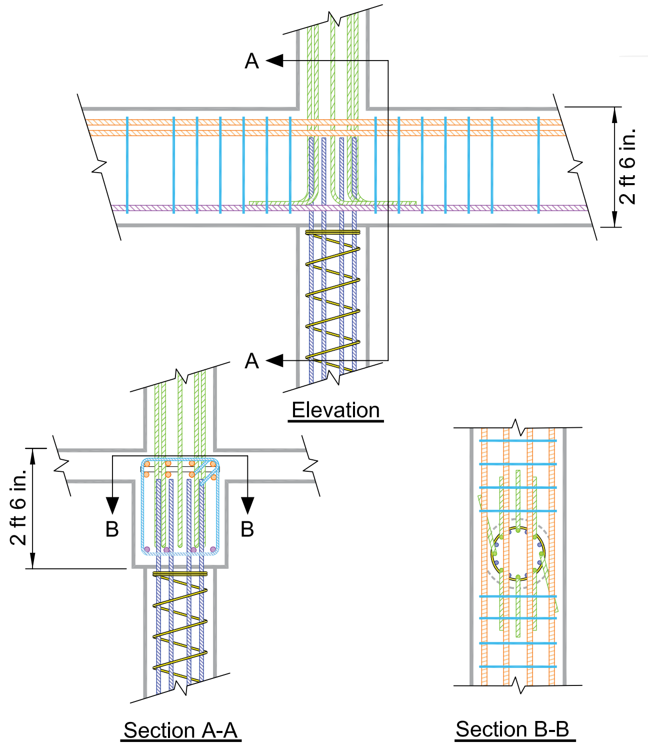

Fig. 3: Option 2—Increase grade beam depth

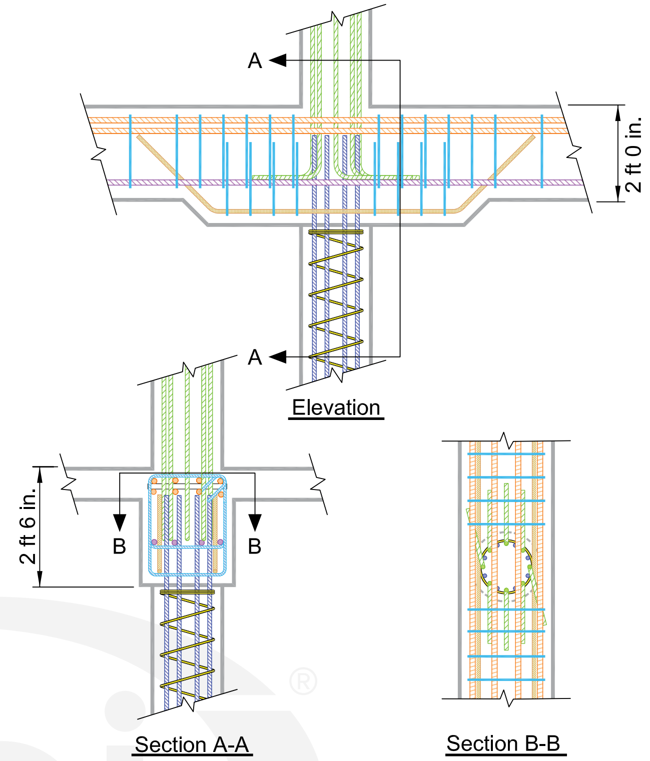

Fig. 4: Option 3—Increase grade beam depth only at the drilled pier

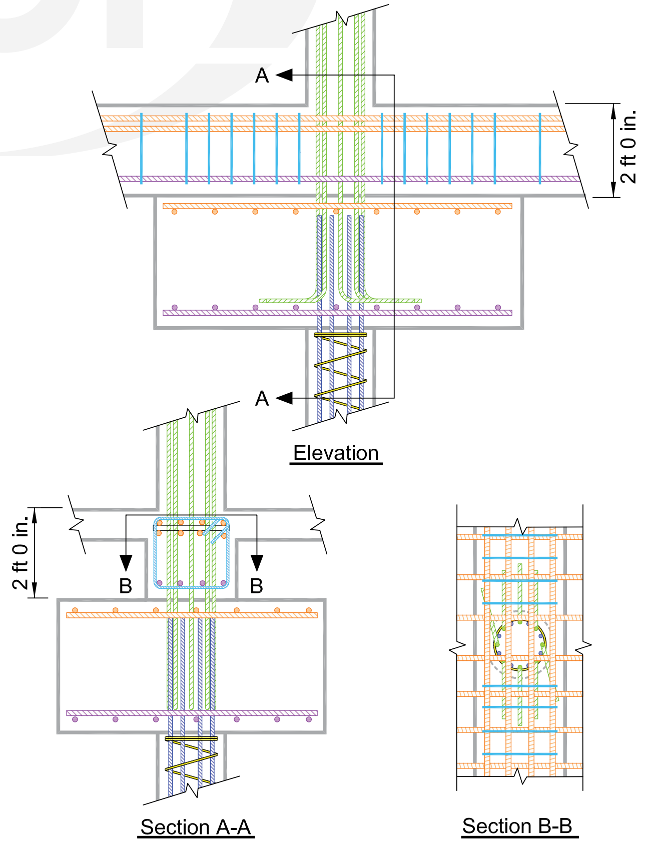

Fig. 5: Option 4—Add a pile cap under the grade beam

Detailing Corner

the beam, drilled pier, or column or if the bars were larger, it would be impossible to fit all of the bars in the cross section. Moreover, if there was an intersecting beam, there would be no room to install the bars.

One option would be to extend the column dowels straight into the drilled pier as shown in Fig. 2. This option, however, presents some difficulties:

- In many parts of the country, the contract for installation of piles and drilled piers is separate from the contract for construction of the remaining building structure, so different contractors normally execute each portion. While the foundation contractor's workers will place the steel in the drilled piers, union rules may not allow them to place the column dowels. This would require coordination at a time when the building concrete contractor may not be on site yet;
- If they are cast in the drilled pier, the column dowels can't be moved or adjusted to accommodate beam reinforcement or column locations;
- For large diameter drilled piers, the tolerance on pier location is much larger than that for the column location. If the column dowels are installed according to the foundation tolerances, they may be located farther away from their intended location than the tolerances for column location can accommodate; and
- If the dowels are out of tolerance, who is responsible for corrective actions—the building concrete contractor or the foundation contractor?

A second option would be to design a deeper grade beam as shown in Fig. 3. Deepening the beam may eliminate the need for the drilled pier vertical reinforcing bars to be hooked, which eases the congestion to a large extent. Without the hooks, it's possible to accommodate an intersecting grade beam. Although this option increases the volume of concrete, it may reduce the amount of steel required in the grade beam.

A third option would be to deepen the grade beam only at the drilled pier as shown in Fig. 4. This thickened section would be placed concurrently with the grade beam concrete and gives results similar to Option 2. It eliminates the need for hooks on the drilled pier vertical bars, easing congestion. This option only slightly increases the volume of concrete and adds a slight amount of steel at each drilled pier. It does not significantly affect the reinforcing steel required in the grade beam.

A fourth option would be to add a pile cap under the grade beam at the drilled pier as shown in Fig. 5. This would likely require a separate placement, independent of the grade beam work.

In the options shown in Fig. 3 to 5, there is enough depth to achieve straight embedment of the column dowels. This would be acceptable to most designers. Some designers, however, insist on hooked dowels because they feel this provides more accurate placement of the dowels, ensuring proper lap length projecting above the grade beam. For that reason, the column dowels are shown hooked in those figures. Another consideration may center on whether or not any moment is transferred into the foundation.

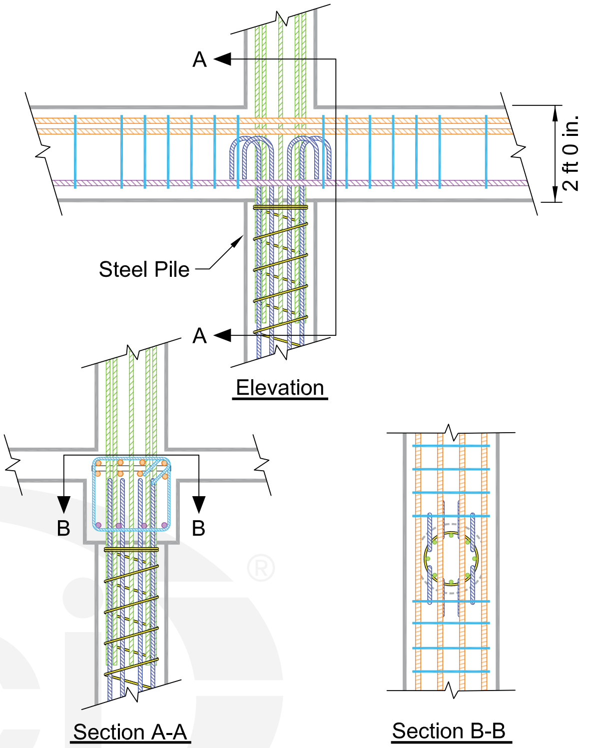

Fig. 6: Option 5—Hold back the concrete from the pile top

A fifth option could be used if the grade beam is supported by a concrete-filled steel pile or casing, as shown in Fig. 6. In this case, the steel jacket is filled with concrete to an elevation sufficiently below the top so the column dowels could project into the pile to give the proper embedment length. This option is similar to Option 1 in Fig. 2, except in this case the column dowels are placed with the grade beam. This allows a certain amount of adjustment in placing the dowels. The top of the pile is filled with concrete when the concrete for the grade beam is placed.

A sixth option would be to place a blockout in the top of the drilled pier as shown in Fig. 7. This option has advantages similar to those of Option 6. There is room for adjusting the location of the dowels for more accurate placement. As in Option 6, the blockout is filled with the grade beam concrete placement. Yet another option may be to use headed bars.

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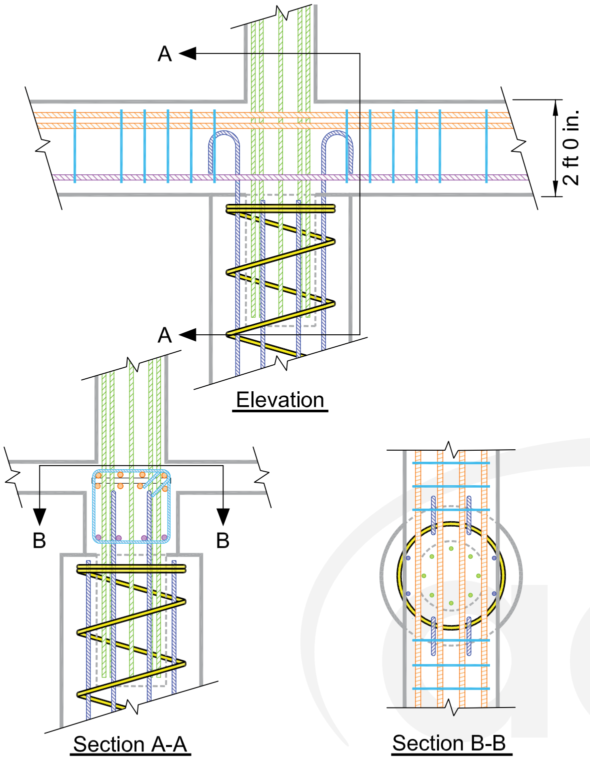

Fig. 7: Option 6—Form a blockout in the top of the drilled pier

DESIGN CONSIDERATIONS

Designers should always look carefully at the embedment lengths of the reinforcing bars passing from one member into another. The possibility of congestion should be reviewed whenever the drilled pier vertical reinforcing bars have to be hooked. Frequently, the difference between requiring a hooked bar rather than a straight bar is a matter of only a few inches. Wherever it's possible without jeopardizing the integrity of the structure, the designer should opt for a straight bar embedment to minimize congestion.

Relative advantages and disadvantages of the options discussed depend on the specifics of each case. The cost impact is usually not significantly different from one to the other if the deeper beam in Option 2 allows a reduction in the amount of beam reinforcement required.

Thanks to Joint ACI-CRSI Committee 315 member Dick Birley, President of Condor Rebar Consultants, Inc., in Vancouver, BC, Canada, for providing the information in this article.

Selected for reader interest by the editors.

RFI ON STAINLESS STEEL REINFORCING BARS

RFI 09-2: I'm considering the use of stainless steel reinforcing bars on a project where I need the level of corrosion resistance this material provides. What are some of the issues that I need to understand about stainless steel?

Response: Stainless steel reinforcing bars are not stocked in quantities as large as for traditional reinforcing bars. Therefore, it's recommended that the contractor coordinate early with the stainless steel reinforcing bar supplier to ensure timely delivery to the job site. The bars are typically only available in lengths up to 40 ft (12.2 m), which may require detailing changes to accommodate lap splice locations. Also, keep in mind that bar supports have to be made of stainless steel or plastic. Similarly, tie wire has to be stainless steel or plastic-covered carbon steel. Mechanical couplers, if needed, will also have to be stainless steel.

Reinforcing bar fabricators and contractors need to recognize that stainless steel reinforcing bars are pickled. Pickling (cleaning with an acid mixture) is required by ASTM A955[1] to remove mill scale and iron particles. This prevents the particles from corroding and damaging the stainless steel, but the bars must be handled in such a way that the surface is not recontaminated with carbon steel during fabrication, storage, transportation, and placement. In practice, this means the stainless steel bars cannot be fabricated using the same pieces of equipment used to fabricate traditional reinforcing bars, have to be handled with nylon slings, and should be stored inside or under a protective cover. For additional information, see "Stainless Steel Rebar Guidelines for Shipping, Handling, Fabrication and Placement."[2]

References

1. ASTM A955/A955M-07a, "Standard Specification for Deformed and Plain Stainless-Steel Bars for Concrete Reinforcement," ASTM International, West Conshohocken, PA, 2007, 11 pp.

2. "Stainless Steel Rebar Guidelines for Shipping, Handling, Fabrication and Placement," Nickel Development Institute, Toronto, ON, Canada, and Specialty Steel Industry of North America, Washington, DC, 6 pp.

Detailing Corner

Alternating Bar Sizes

Designers often use alternating bar sizes for reinforcement in walls and slabs. While at first glance this may seem to be a simple method to enhance design efficiency in terms of total steel weight, it usually doesn't optimize the overall cost of the project. Before the decision is made to specify alternating bar sizes, several issues should be considered.

ISSUES

Which bar starts a run?

Whether to start a run of bars with the larger or smaller bar (Fig. 1) may seem like a trivial issue, but this

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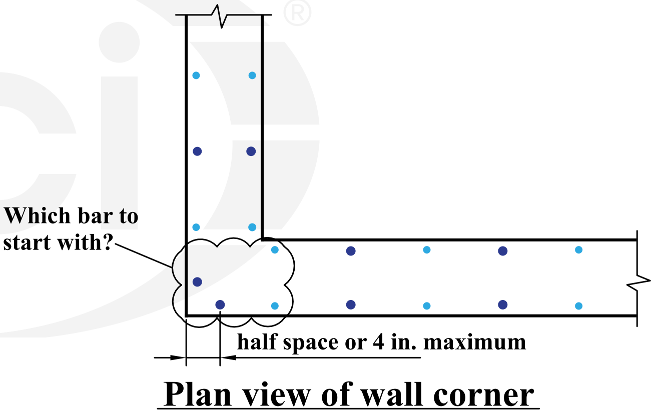

Fig. 1: Should a run of bars start with the larger or smaller bar? (Note: 1 in. = 25.4 mm)

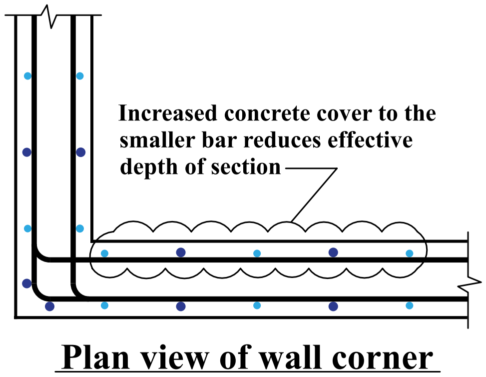

Fig. 2: Cover thickness will vary if alternating bar sizes are used in the outside layer of wall or slab reinforcement, and the effective depth of the section may be smaller than anticipated

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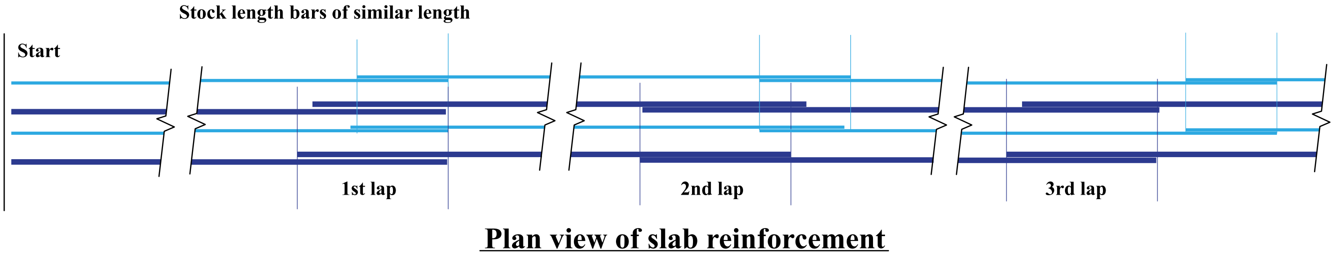

Fig. 3: The difference in splice lengths for the different bar sizes causes the location of splices to change relative to one another when stock length bars are used

simple decision has been the root of countless disagreements between inspectors and contractors, especially when there are an odd number of bars. Designers and inspectors naturally prefer to maximize the amount of steel and tend to start with the larger bar, while fabricators and placers prefer to minimize steel congestion and tend to start with the smaller bar. Consequently, the size of the starting bar in the run becomes a matter of debate and needs to be coordinated in advance.

Concrete cover may vary

The vertical bars in a wall are tied to the horizontal bars. If the horizontal bars are inside the vertical bars and the vertical bars alternate in size, the specified cover must be met on the larger bar and the cover on the smaller bars will be larger (Fig. 2). If the bars differ by two bar sizes, the smaller bars will have 1/4 in. (6 mm) greater concrete cover than the larger bars. Designers must be aware that this situation will result in a smaller effective depth to the reinforcement and, therefore, a smaller nominal moment capacity than would occur if both bar sizes had the same cover.

Lap locations can shift

Alternating bar sizes can create problems with lap locations, particularly in long runs of horizontal wall bars or temperature reinforcement in a slab (Fig. 3). If stock length bars are used, the difference in lap length for the two bar sizes will cause the lap locations to move apart relative to each other. This means the final bar in the run is a different length for each of the bar sizes.

How are trim bars allocated?

Typically, half of the reinforcing bars interrupted by a slab or wall opening must be placed as trim or framing bars on each side of the opening. If the bar sizes alternate and six bars are interrupted by an opening, for example,

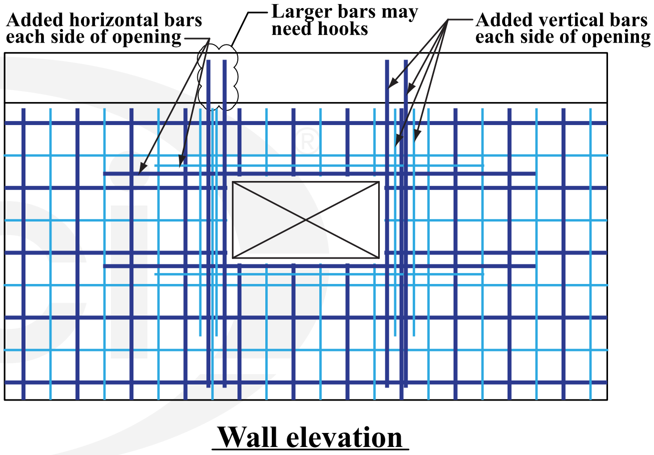

Fig. 4: Alternating bar sizes can complicate the distribution of reinforcing steel around openings

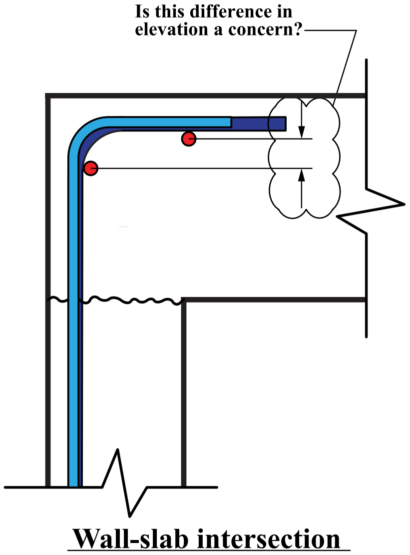

Fig. 5: The difference in hook dimensions for vertical wall bars with different bar sizes affects the location of the outermost slab or beam reinforcement

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three large bars and three small bars must be distributed at the sides of the opening. The configuration and layout could be issues for dispute, so the “field fix” shown in Fig. 4 could result in the need for even more bars.

Hook dimensions will vary

If the tops of vertical bars with different sizes are terminated with standard hooks, the bend diameters will be different for the two bar sizes, as shown in Fig. 5. Very often, especially along perimeter walls, the designer requires a continuous bar tied in the corner of the vertical hook. The continuous bar touches only every other vertical bar and appears to be too low, causing concern from some inspectors. Additionally, if the vertical bars are hooked into a continuous beam at the top of the wall, the different arcs of the hooks may result in one or more bars positioned lower in the cross section than expected. This may become an issue concerning the effective depth of the member.

Maintaining accurate installation is more difficult

Slab bars are typically placed on supports known as slab bolsters. When the bottom bars are tied in place, the smaller bars are lifted off the slab bolsters and secured against the layer of bars above, as depicted in Fig. 6. Later, as workers walk on the reinforcing steel to place conduits, inserts, and other embedded items or during concrete placement, the ties holding the small bars could be stretched or broken so the bars are no longer secured against the reinforcing steel mat. They must be re-tied or they are likely to be displaced by the concrete as it is placed.

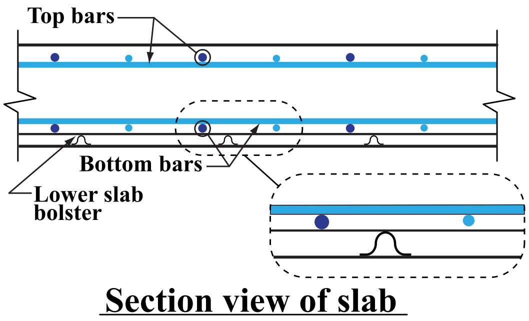

Fig. 6: Alternating slab bar sizes can lead to broken or loose tie wires

Fabrication expense can increase

It’s more economical to cut a quantity of bars of a single bar size than it is to cut half the quantity for each of two different bar sizes. Furthermore, if the designer used only the larger bar with a wider spacing or an intermediate bar size with a wider spacing, there would be fewer total bars required, thus reducing fabrication costs.

Placing expense can also increase

Sorting and placing bars of alternating sizes requires extra labor and handling. To avoid getting the alternating bars out of sequence, ironworkers must start placing the reinforcing bars at a single point on a slab or wall, rather than in several locations simultaneously. The previously mentioned tendency for lap locations to shift will also increase labor costs.

TOTAL COST IS MORE THAN A FUNCTION OF WEIGHT

Designers should understand that what they may perceive as cost efficiency might actually add to the overall cost of a project. While they may be trying to save reinforcing steel, they are increasing the potential difficulties for the placers and the inspectors. Even better cost efficiencies and reduced potential for placing and inspection difficulties can often be achieved simply by adjusting the bar spacing and using a single size.

Thanks to Joint ACI-CRSI Committee 315 member Dick Birley, President of Condor Rebar Consultants, Inc., in Vancouver, BC, Canada, for providing the information in this article.

Selected for reader interest by the editors.

Detailing Corner

Corner Details for Wall Horizontal Bars

Continuity of horizontal reinforcing steel at corners and wall intersections can be ensured in several ways. While the designer's first concern must be to provide connections that satisfy safety and serviceability requirements, the designer must also be aware that some reinforcement details may be more constructible than others.

ISSUES

In general, long horizontal reinforcing bars with hooks at one or both ends should be avoided. For the ironworker, lifting long horizontal bars and tying them into place can be problematic, especially if they are positioned overhead. If the bars have hooks, they'll tend to sag and twist, making them even more awkward to handle. Positioning long hooked bars in the proper location is difficult, and once installed, there are few means to adjust their locations.

Long horizontal bars with hooks at each end also require the ironworker to line up the bars in two planes. This is quite difficult, so the placed bars may violate concrete cover requirements at one or both ends. Even if all bars are correctly positioned at one end, however, the bars at the other end will usually be very uneven. The designer should keep these issues in mind and provide appropriate corner and intersection arrangements.

Wall bars are often assembled in curtains or mats that are lifted into position in the wall form. If the reinforcement curtains are to be preassembled in the shop or field, hooks would complicate preassembly, transportation, storage, and handling as well as make placement more difficult. Providing separate bars at intersections enhances constructibility by allowing adjacent panels to be installed without interference. The curtains can then be adjusted to maintain precise concrete cover as the independent hooked bars are being tied in place.

While the extra bar length and weight needed for lap splices may appear to be an inefficient use of material, the associated costs are usually more than offset by the increased production, handling, and installation efficiencies associated with preassembled curtains.

Single layer reinforcing layout

Figure 1 shows sectional plan views of intersections of walls reinforced with single layers of horizontal bars. Details a), b), and d) show bars with corner hooks on long horizontal bars. If possible, these hook arrangements

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should be avoided. As indicated previously, they can hinder installation or make it difficult to preassemble and install reinforcement curtains. Details c) and e) show the preferred solutions, with separate hooked bars at the wall intersections.

Double layer reinforcing layout

Figure 2 shows sectional plan views of intersections of walls reinforced with double layers of horizontal bars. For the 90-degree corner, Details a) and b) are examples of horizontal bars with hooks in both reinforcement planes. If possible, these schemes should be avoided, as they make it difficult to use preassembled curtains of bars. Although Detail c) is fairly common, Detail d) is preferred. Separate 90-degree hooked bars lapped with two preassembled double-bar curtains is generally considered to be very constructible. Detail e) provides an alternate layout that is also ideal for preassembled reinforcing bar curtains or precast wall panels. However, this detail can only be used in wall panels that are thick enough to accommodate the width of the hairpin or U bars. Keeping in mind that the minimum width of a 180-degree hook is eight bar diameters for No. 8 (No. 25) and smaller bars and 10 bar diameters for No. 9, 10, and 11 (No. 29, 32, and 36) bars, and noting as well that the detail should allow for a +1 in. (+25 mm) fabrication tolerance, this limitation can be significant.

For tee-intersections, Detail f) is similar to Details a) and b) for the 90-degree corner. Again, this detail should be avoided if possible. Detail g) illustrates the preferable reinforcing bar layout, showing separate hooked bars lapped with preassembled bar curtains. If the wall is thick enough, Detail h) is a potential variation of

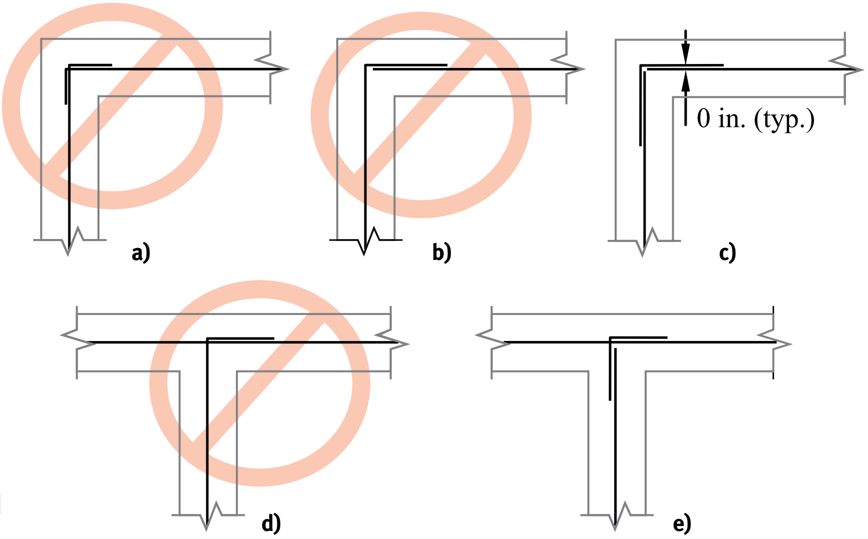

Fig. 1: Sectional plan views showing intersections of walls reinforced with single layer of horizontal bars

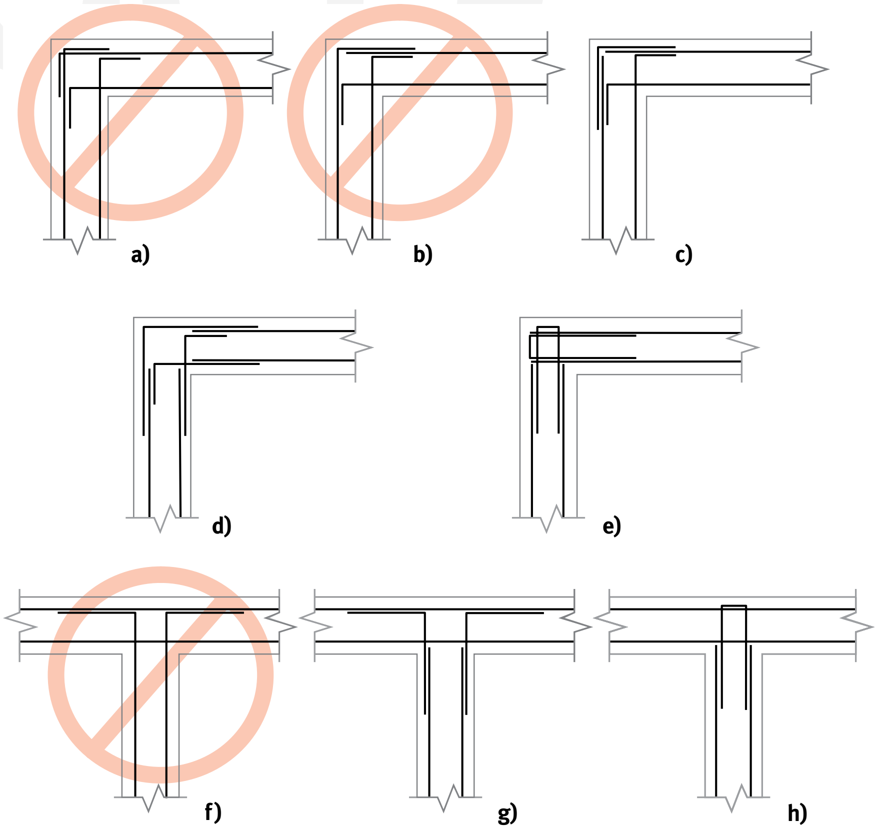

Fig. 2: Sectional plan views showing intersections of walls reinforced with double layers of horizontal bars

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Detail e), where a hairpin or U bar is lap-spliced with the double-bar curtain of the terminated wall section.

Horizontal hooks can be good

Ironically, there are certain situations where hooks on the horizontal bars provide advantages. In Fig. 3, Details a) and b) illustrate ideal horizontal bar arrangements for small concrete structures, where the bar length is in the 8 to 10 ft (2.4 to 3 m) range. Detail a) would be typical of a catch basin or sump detail. Detail b) is an example of a grease pit or acid pit. Because these structures are small, dimensions can be easily measured and the reinforcing steel precisely located as it is being assembled.

In Detail a), the dimension is fixed in one direction and can be adjusted in the other direction. If the structure is square, the bar arrangement can be alternately rotated 90 degrees to fix the dimensions in both directions. In Detail b), the dimensions are adjustable for all four walls and bars can be precisely adjusted for proper concrete cover. In some instances, the tails on the 90-degree hook can be extended beyond the normal 12-bar-diameter dimension to provide added adjustability to meet tolerances. In both Details a) and b), care must be taken to ensure that the dimensions of the bars do not exceed shipping limitations, as discussed in an earlier Detailing Corner article.[1]

SUMMARY

When long runs of horizontal bars are required, end hooks should be avoided if possible. To facilitate necessary tolerance and cover requirements, separate 90-degree (corner) hooked bars should be used and lapped with straight lengths of horizontal bars. For structures requiring only short runs of horizontal bars, however, hooks at one or both ends can be advantageous, as the installed dimensions can be better controlled and the reinforcing bars are more easily assembled.

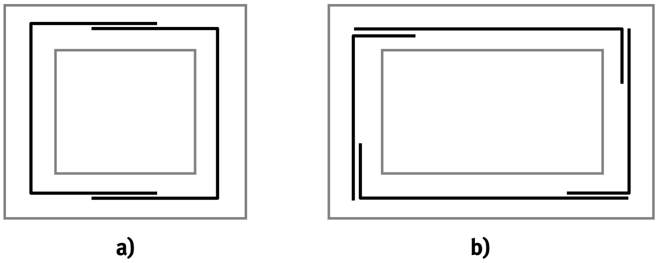
a) b)

Fig. 3: For small concrete structures such as basins, sumps, or pits, hooks at the ends of horizontal bars can provide advantages

Reference

1. "Reinforcing Bars Exceeding Stock Lengths," *Concrete International*, V. 31, No. 1, Jan. 2009, pp. 50-51.

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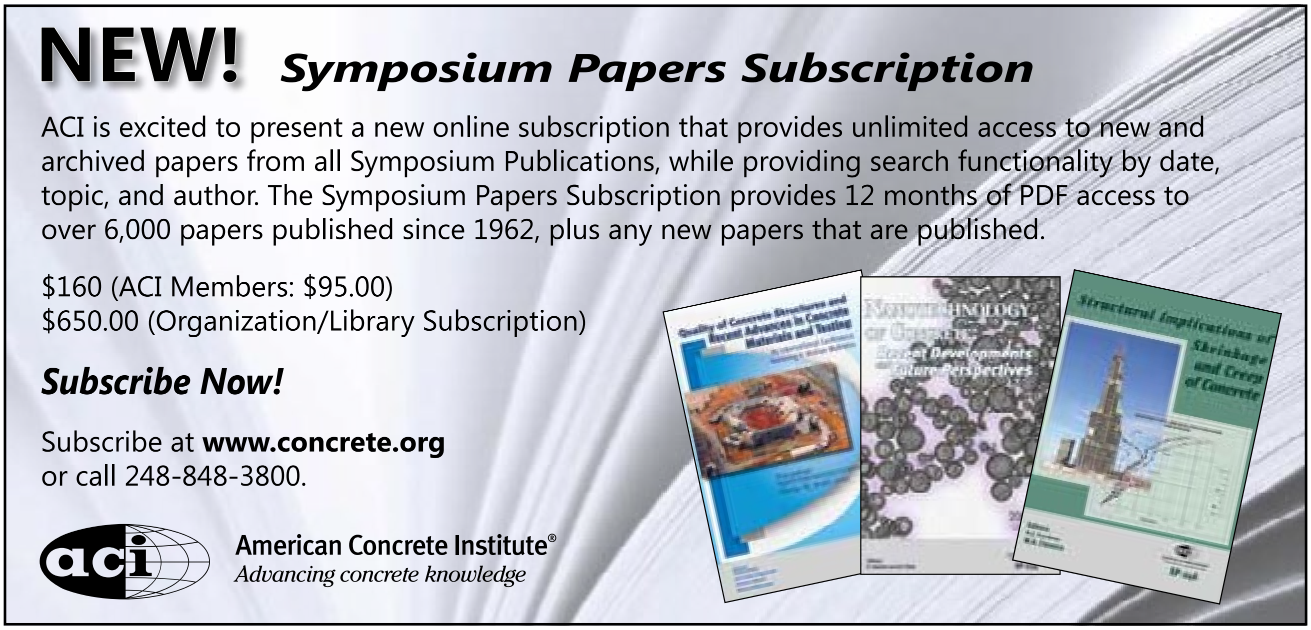

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Detailing Corner RFIs 09-3, 09-4, and 09-5

Alternate joint details to transfer large moments, the “0 in.” dimension, and lap splicing hooks

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The material published in the last Detailing Corner (V. 31, No. 9, Sept. 2009, pp. 43-45) spawned requests for information from our readers. This month’s Detailing Corner provides responses as well as additional information. We thank those who contacted us and encourage all readers to participate.

RFI 09-3: In the September 2009 Detailing Corner, a number of wall corner joints were illustrated with preferred means of detailing reinforcement to accommodate pretied curtains of wall reinforcement. Most of the details appeared to be reinforced for low or minimal horizontal moment transfer at the joint. Could you please comment on alternate joint details that can better transfer large moments?

Response: Yes, you are correct that the corner reinforcement illustrations in the September 2009 Detailing Corner were intended for low levels of moment capacity in the wall. When we define “low moment” capacity, we are considering a wall with a low percentage of horizontal flexural reinforcement, likely conforming to minimum temperature and shrinkage requirements. A buried tank would be one example; two perpendicular shear walls joined together at their intersection with negligible corner moment transfer would be another example.

For large horizontal moments at a corner joint, the loading would likely be applied by a liquid or granular material in a tank structure. In this instance, frame joint detailing concepts become applicable. Research has shown that the addition of diagonal bars in the corner significantly enhances the flexural capacity.[1,2] The diagonal bars are intended to resist the opening (prying) moment, which causes tension and potential cracking in the inside corner of the joint. Figure RFI 09-3.1 illustrates the addition of the diagonal bars. These bars would be detailed at every horizontal bar elevation in the wall. Because the maximum moment occurs in the inside corner projected along a diagonal line (potential crack plane), these bars are then developed beyond this point

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of maximum moment by extending them into the compression zone in each wall.

For a T-joint in a tank or retaining wall structure, corner moment capacity can be enhanced in two fashions. Where moment reversal at the joint is possible, the detail shown in Fig. 2(g) of the September 2009 Detailing Corner can be improved by increasing the extensions on the two 90-degree bent bars and placing the hooks so the extensions cross through the joint, as in Fig. RFI 09-3.2(a). At the T-joint shown, the bars should be spliced in the discontinuous wall, but standard hooks should be acceptable in the continuous wall. Figure RFI 09-3.2(b) shows a further enhancement of the T-joint with the addition of two series of diagonal bars. This figure is similar to Fig. 15 of the ACI 315 Detailing Manual.[3]

If only moment in one direction can occur at the T-joint, only one series of diagonal bars need be detailed. Figure RFI 09-3.3 illustrates an example of this detail for a T-joint on a retaining wall from Chapter 14 of the CRSI Design Handbook.[4]

RFI 09-4: Often when checking reinforcement placing drawings, I come across the dimension “0 in.” indicating some bar spacing. Coincidentally, this was also shown in the September 2009 Detailing Column in Fig. 1. Can you provide an interpretation of this dimension, as I have had some disagreements with contractors and inspectors in years past?

Response: The “0 in.” dimension is commonly used on a two-dimensional (2-D) drawing for reinforcing bars to indicate the presence of two bars that are in the same plane. If shown in true drafting convention, the second bar would be hidden and consequently not visible or clearly

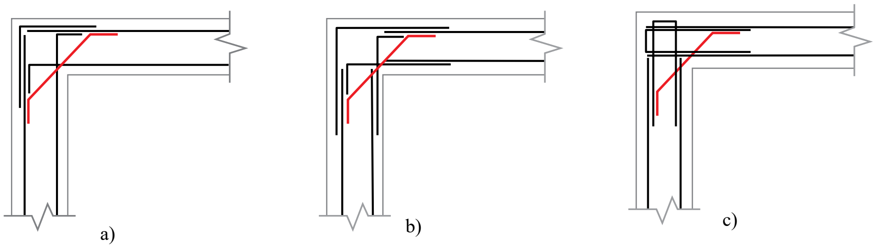


Fig. RFI 09-3.1: Diagonal bars (red) provide increased flexural resistance against opening of joints

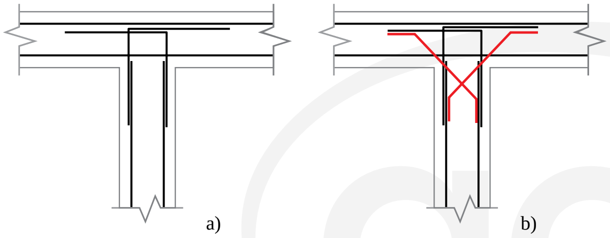


Fig. RFI 09-3.2: The detail shown in Fig. 2(g) of the September 2009 Detailing Corner can be improved by: (a) increasing the extensions on the hook bars and overlapping the extension at the joint; (b) adding two diagonal bars (red)

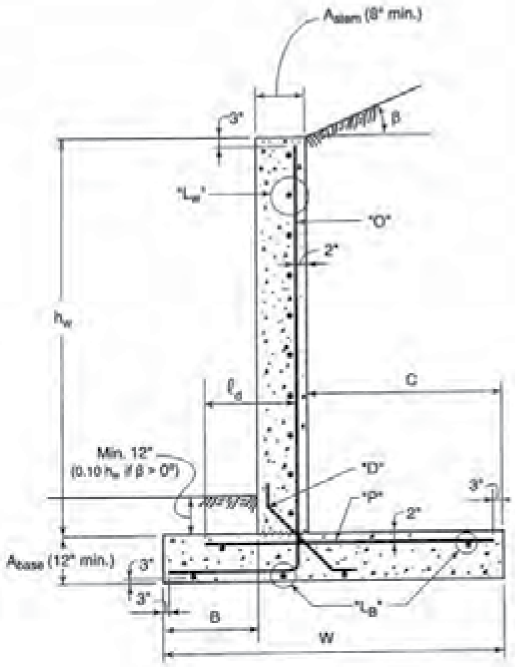
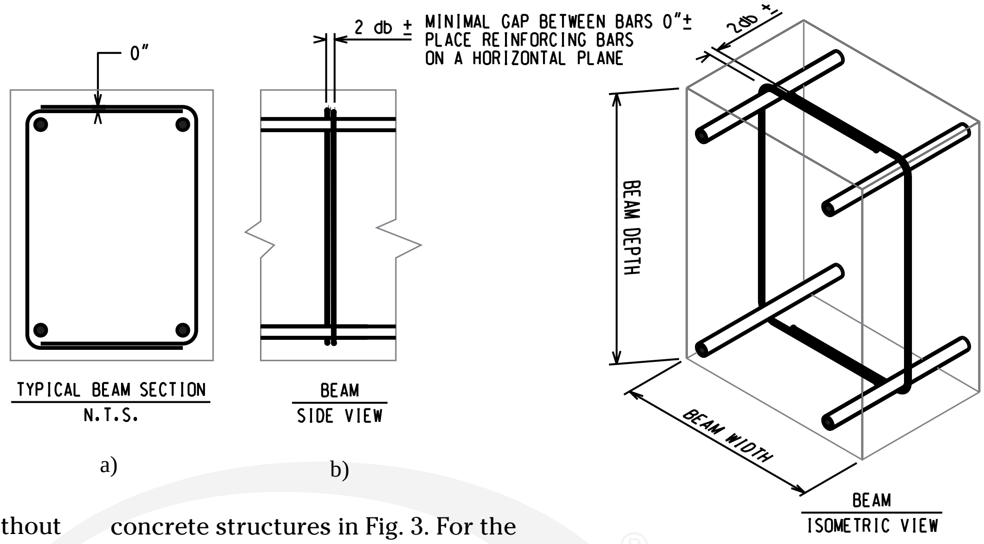


Fig. RFI 09-3.3: Example of the diagonal “D” bar at the base of a retaining wall to enhance the flexural capacity of the T-joint (Fig. 14-1, CRSI Design Handbook, 2008)

Detailing Corner

Fig. RFI 09-4.1: Example of a 0 in. dimension, here indicating that hook extensions on the stirrup bars are lapped in the horizontal plane: (a) section through beam at stirrup; (b) elevation view of a beam section with a stirrup; and (c) isometric view of the beam section and stirrup



a) b) c)

evident on the 2-D drawing. Without showing the bars with a “0 in.” dimension, the risk is that it would be missed or misplaced if provided.

In Fig. 1(c) of the September 2009 Detailing Corner, the 90-degree bent bar shown in the sectional plan was intended to be located above or below the horizontal bars, and in contact with the horizontal bars. Thus, the bars would be located in the same vertical plane. This is what the “0 in.” dimension refers to in this illustration—these two bars are in the same plane.

To illustrate the point further, consider the beam in Fig. RFI 09-4.1(a), with a 0 in. dimension shown at the top of the stirrup. As shown in elevation view in Fig. RFI 09-4.1(b) or in the 3-D view of Fig. RFI 09-4.1(c), the two bars are located in the same horizontal plane, one behind the other. The note does not indicate that two bars are stacked on top of one another with a “0 in.” spacing between them. This incorrect placement would likely violate the clear cover requirements or (because the stirrup bars are hooked at each end) require shifting the longitudinal bar toward the beam centerline.

RFI 09-5: The September 2009 Detailing Corner showed some reinforcement details for small concrete structures in Fig. 3. For the detail in Fig. 3(b), the article notes the 90-degree hook only needs a 12-bar diameter ($12d_b$) dimension. Shouldn’t the bars be long enough to develop the tension lap splice rather than just hooked?

Response: The length of the extensions shown in Fig. 3(b) must be at least the distance required for a tension lap splice, with a minimum length of 12 in. (305 mm). The $12d_b$ length referred to in the article is the length of the minimum extension for a 90-degree hook, as required in Section 7.1.2 of the ACI 318-08 Building Code.[5] Assuming there will be horizontal moment at the corner, the hook extension length must also be long enough to provide a full lap splice length and the necessary adjustability. The fourth sentence in the second full paragraph on page 45 should have read:

“Note that the length of the extensions on the 90-degree hooks shown in Fig. 3(b) must be long enough to not only meet the $12d_b$ requirement of Section 7.1.2 of the Code, but must also provide the length required for a full tension lap splice (but not less than 12 in.), plus an allowance to provide adjustability to meet tolerances.”

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Thanks to Joint ACI-CRSI Committee 315 Chair Dennis Hunter and H.V. Nawlin of Gerdau Ameristeel, in Tampa, FL, for the Fig. RFI 09-4.1 illustrations.

Selected for reader interest by the editors.

Detailing Corner

Layering Reinforcing Bars

Many walls and slabs are reinforced with a single curtain of reinforcing bars comprising two orthogonal layers. An example of a two-layer curtain is Curtain A in Fig. 1. Thicker walls or slabs are usually reinforced with a two-layer curtain at each face.

From the perspectives of detailing and installation, a two-layer curtain is the most desirable. In many structures, if structural requirements call for increased reinforcement area, the bar size can be increased while maintaining the two-layer arrangement. In heavy industrial and nuclear construction, however, it may be impractical to increase the bar size. So, three- or four-layer curtains (Curtains B and C in Fig. 1, respectively) may be needed.

ISSUES AND CONCERNS

General

When designing multiple-layer curtains such as Curtains B and C in Fig. 1, there are several issues to consider:

- Clear spacing for parallel reinforcement must meet the requirements of Section 7.6.1 of ACI 318-08 (clear spacing ≥ d_b or 1 in.). Normally, when using multiple-layer curtains (three or more layers), the bar would likely be at least a No. 8 bar and, thus, the 1 in. (25 mm) dimension would not control;
- The nominal maximum size of coarse aggregate must comply with the limitations in Section 3.3.2 of ACI 318-08;
- The same bar size should be used in each direction to avoid installation errors;
- Bars should be placed at a consistent spacing or using multiples of a given spacing to simplify reinforcement placing; and
- Staggering the bar spacing between parallel layers should be avoided as this can effectively halve the clear spacing between bars (see Fig. 2(a)).

It should also be noted that using curtains with more than the normal two layers will cause spatial issues that can affect concrete cover and constructibility at wall corners, staggered lap splices, and slab top steel over intersecting beams.

Wall corners

When multiple-layer curtains of reinforcing bars are required, a common problem area is the corner region of two intersecting walls. In walls with typical two-layer curtains, there is usually space available to maneuver the bars to make them fit. With three- or four-layer curtains, however, bar placement becomes much more difficult. If the wall curtains are preassembled, it becomes very challenging to get the inner horizontal or diagonal corner bars in place. When the wall curtains are site-built (“stick” built in place), the placer can encounter sequencing difficulties when installing the reinforcing bars. As illustrated in Fig. 3, the heavily reinforced thick walls (for example, 4 to 6 ft [1.2 to 1.8 m] thick) present difficulties in placing the corner bars, and sequencing the bar placement is critical.

To assist in placing the curtains of reinforcement in the corner shown in Fig. 3, note that the horizontal bars

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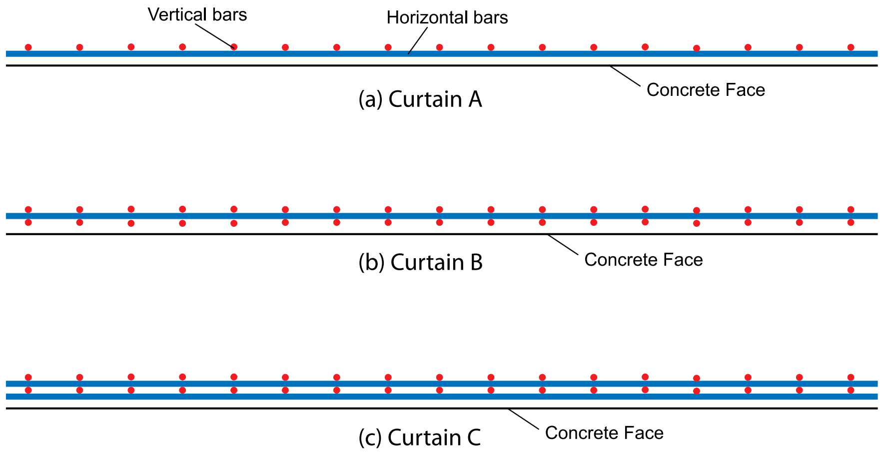
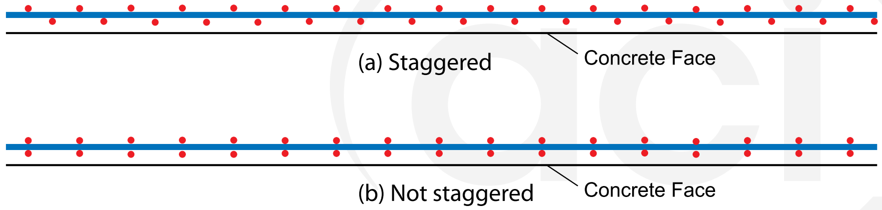


(a) Curtain A

(b) Curtain B

(c) Curtain C

Fig. 1: Multi-layer reinforcing bar curtains: (a) two-layer; (b) three-layer; and (c) four-layer



(a) Staggered

(b) Not staggered

Fig. 2: Bars in parallel layers: (a) staggered; and (b) not staggered

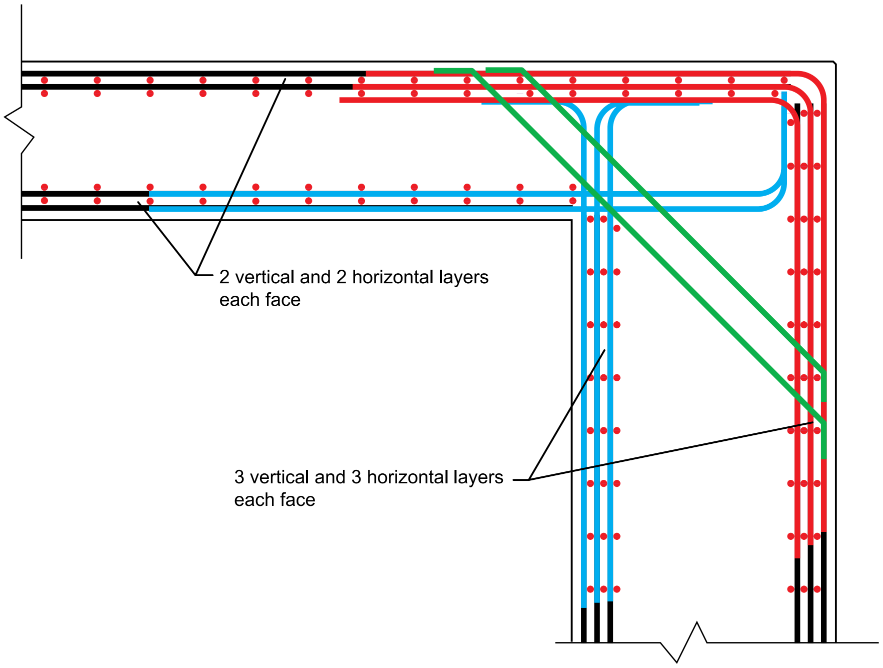


Fig. 3: Wall intersection with four- and six-layer curtains

(shown in black) in all the layers are straight. To provide continuity in the outer layers of reinforcement, corner bars (shown in red) are lap spliced to the horizontal bars. For the inner layers, the horizontal bars are lap spliced to L-shaped bars (shown in blue). Finally, diagonal bars (shown in green) are used in the corner to provide enhanced moment capacity at the joint.

Assuming the preassembled reinforcement curtains shown in Fig. 3 would be erected "from the outside inward," the sequence of placement could be as follows:

1. The outside layers would be erected first, either as stand-alone cages and set in place or erected in place;
2. The corner bars (red) would be placed and lap spliced to the ends of the horizontal bars in the outside layers;
3. The inside layers would be placed next, using methods similar to those used for placement of the outside layers;
4. Next, the L-shaped bars (blue) would be lap spliced to the horizontal bars in the inside layers; and
5. Lastly, the diagonal bars (green) would be placed and tied to the horizontal bars in the outside layers.

Staggered lap splices

Staggering lap splices in members containing layered reinforcing bars can cause problems. A common situation occurs when footing or mat slab reinforcement passes through a construction joint. To have access to the lowest steel layer for lap splicing, the lowest layer must project past the layer immediately above. For large bar sizes, this distance can be significant. If a contractor is unaware of this condition and is excavating just ahead of concrete work for a

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footing (sometimes necessary during winter construction of large mat foundations), the excavation may not be cut back far enough to properly place the bars. In the specific example illustrated in Fig. 4, the excavation would have to extend at least 23 ft (7 m) past the construction joint (CJ). This could cause project delays, as the excavation would require widening prior to bar placement.

Preassembly of wall curtains with staggered horizontal lap splices also requires special attention. This situation is illustrated in Fig. 5, where Fig. 5(a) shows the layers as continuous curtains and Fig. 5(b) shows the layers being lap spliced. As indicated in Fig. 5(b), vertical bars must be left off the curtains at the extended portion of the stagger location during erection. This is required to prevent doubling-up of the vertical bars in the curtain.

Slab top steel over intersecting beams

Layering of slab top steel at beam intersections can create constructibility challenges for the detailer and placer. The sequencing and layering of beam and slab top steel creates serious congestion issues and makes maintaining concrete cover difficult, as illustrated in Fig. 6. The structural designer should consider this situation and perhaps note the layer sequencing on the structural drawings. Moreover, the structural drawings should clearly designate which beam top steel layer is uppermost, and indicate the concrete cover for the various top bar layers.

Although various sequences are possible for placing the reinforcement shown in Fig. 6, one possibility would be:

1. Erect the steel reinforcement for the primary beams (bottom bars, stirrups, top bars) as stand-alone cages and set in place;
2. Place the stirrups (bottom pieces of two-piece stirrups) and the bottom bars for the secondary beams;

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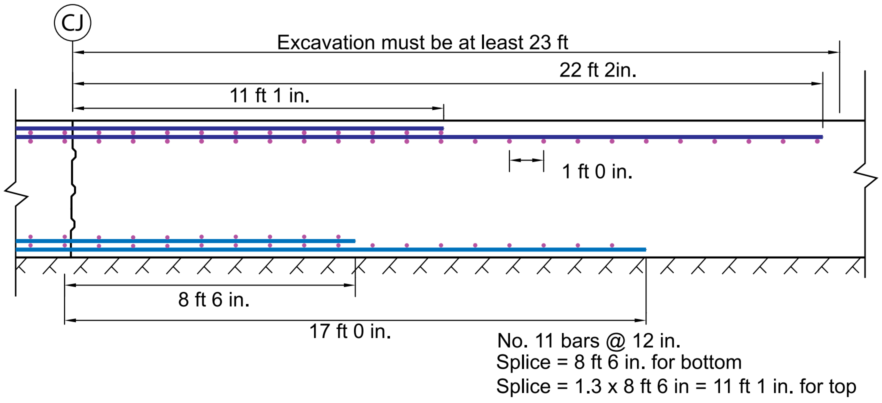
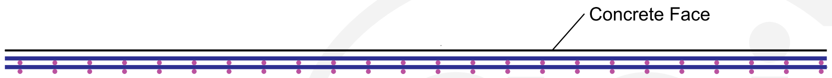
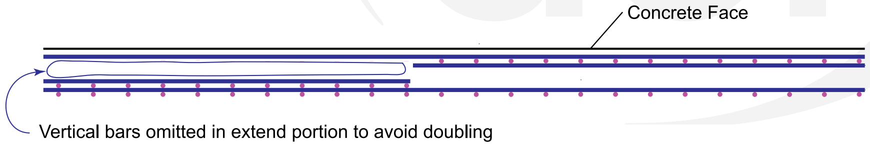


Fig. 4: Staggered lap splices of multiple layers at a construction joint (CJ) (1 in. = 25.4 mm, 1 ft = 305 mm, No. 11 bar = No. 36M)



(a) Continuous curtain without lap splices



(b) Curtain with lap spliced horizontal bars

Fig. 5: Four-layer curtains in wall: (a) continuous; and (b) lap spliced

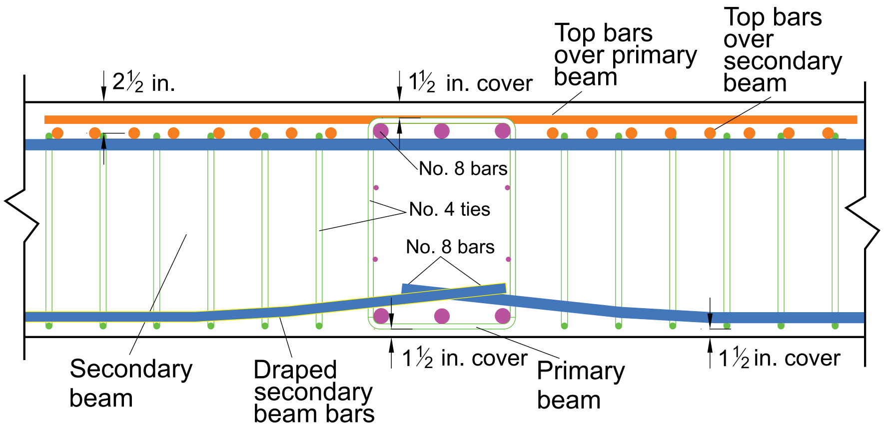


Fig. 6: Layering of beam and slab reinforcing bars can create sequencing issues. Structural drawings should designate layer locations and concrete covers (1 in. = 25.4 mm; No. 8 and No. 4 bars = No. 25M and No. 13M bars)

3. Place the bottom bars for the slab (not depicted in the view shown in Fig. 6 for clarity);
4. Place the top bars and top pieces of the two-piece (cap) stirrups for the secondary beams; and
5. Finally, place the top bars for the slab.

If the beams in Fig. 6 are perimeter beams, note that the structural integrity reinforcement requirements of ACI 318-08, Section 7.13, must also be followed.

DESIGN CONSIDERATIONS

Considering the overall reinforcing bar diameter per Table 1 and planning the bar layering sequence will help avoid many spatial problems associated with multiple-layer curtains. Designers should consider using larger bar sizes, higher strength steel, closer bar spacing, or some combination of these to avoid reinforcing bar curtains with more than two layers of bars.

Thanks to Joint ACI-CRSI Committee 315 member Richard H. Birley for providing the information in this article.

Selected for reader interest by the editors.

TABLE 1:
DIAMETER OF REINFORCING BARS OUTSIDE DEFORMATIONS

Bar size, No. (SI No.)	Approximate diameter outside deformations, in. (mm)
3 (10)	7/16 (11)
4 (13)	9/16 (14)
5 (16)	11/16 (17)
6 (19)	7/8 (22)
7 (22)	1 (25)
8 (25)	1-1/8 (29)
9 (29)	1-1/4 (32)
10 (32)	1-7/16 (37)
11 (36)	1-5/8 (41)
14 (43)	1-7/8 (48)
18 (57)	2-1/2 (64)

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Wide Beam Stirrup Configurations

As beam-slab floor systems become shallower, wide reinforced concrete beams are being used to directly carry applied loads or serve as transfer girders in the framing scheme. Making beams wider than the column width is also a key constructibility concept to avoid interference between longitudinal beam corner bars and column corner bars. In this discussion, a wide reinforced concrete beam has a width b_w that exceeds its effective depth d.

A wide beam will likely have a number of longitudinal tension reinforcing bars distributed across the cross section. Wide beams can also have high shear demands, necessitating the use of stirrups to contribute to the shear capacity. Proper stirrup detailing in these members is imperative to ensure that the distributed longitudinal flexure reinforcement and stirrups are fully effective and behave efficiently.

Wide beam shear behavior has been investigated by Leonhardt and Walther;[1] Anderson and Ramirez;[2] and Lubell, Bentz, and Collins.[3] These studies have shown that locating the stirrups solely around the perimeter of the beam core is not efficient in beams under high shear demand. When viewed as a truss, the internal diagonal compressive struts need to be equilibrated at the internal truss joints. This requires a vertical stirrup leg in close proximity to an internal longitudinal bar used to resist flexure.

Based on previous and current test results, Lubell, Bentz, and Collins summarized some simple design guidelines for transverse spacing of vertical stirrup legs in a wide beam:

- Transverse stirrup leg spacing s_w should be the lesser of d or 24 in. (600 mm); but
- The governing s_w should be halved when the nominal shear strength V_n exceeds $5\sqrt{f_c'}b_wd$ lb ($0.42\sqrt{f_c'}b_wd$ N), where f_c' is the specified concrete strength in psi (MPa).

Figure 1, which is a reproduction of Fig. 10 from Reference 3, illustrates how large transverse stirrup leg spacing can significantly reduce the full shear capacity of a wide beam. When the stirrup legs are concentrated around the perimeter of the wide beam, the shear capacity is reduced, as the shear forces in the beam interior must propagate to the beam exterior to be equilibrated by the vertical stirrup legs.

DESIGN TO FABRICATION

Nesting vertical stirrup legs in a wide beam interior is clearly good detailing practice to ensure this shear

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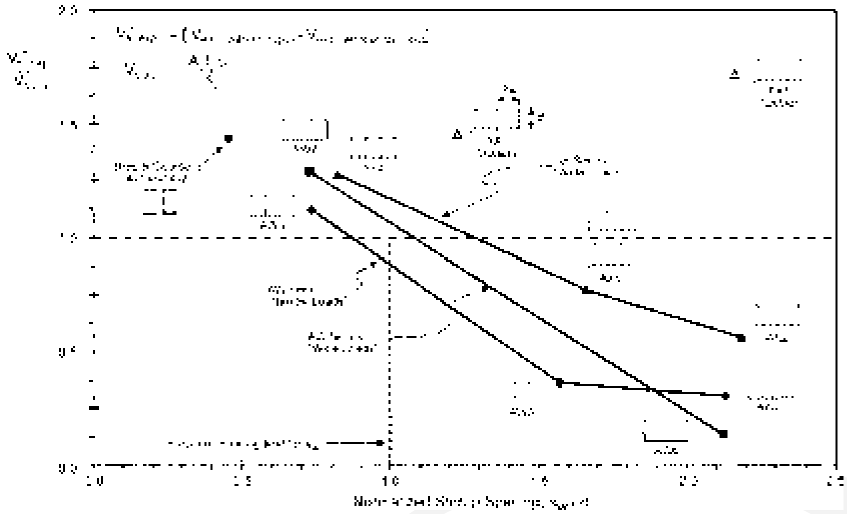

Fig. 1: Influence of transverse stirrup leg spacing on the shear capacity.[3] Beams with perimeter stirrups only (as shown in the lower right portion of the plot) have capacities that are well below the strengths calculated using ACI 318-08, while beams with well-distributed stirrup legs (as shown in the upper left portion of the plot) have shear capacities exceeding values calculated using ACI 318-08

behavior, but detailing of the separate stirrup components can be a fabrication nightmare if done improperly—the stirrup detail must be buildable. When designing stirrups in beams of various widths and depths, the configuration of the stirrups can either simplify or hinder the placement of the reinforcing steel. With the growing trend of using preassembled beam reinforcement, compliance with required concrete cover and ease of placement needs to be addressed at the design level. Figure 2 shows a commonly used stirrup configuration for a wide beam. While it's simple for the designer to specify three closed stirrups with evenly spaced legs in the beam stirrup set, such a configuration presents two problems:

- No stirrup is the full net width of the beam (gross beam width minus concrete cover on each side). This forces the reinforcing bar placer to measure the overall width of the stirrup set and make sure the stirrups are securely assembled to maintain the necessary width. Preassembly of the beam cage and hoisting with a crane may cause the net width to change slightly, increasing the risk of inadequate side concrete cover; and
- If wide beam reinforcement is "stick-built" in place, the closed, one-piece stirrups make it difficult to place all of the reinforcing steel into the beam. Long, large size longitudinal bars are especially difficult to maneuver into the stirrups, so productivity is significantly reduced.

ALTERNATE CONFIGURATIONS

Figures 3 and 4 show two examples of suitable alternate designs that will ease reinforcing bar placement for either preassembly or in-place installation. In both cases, a large, open stirrup is detailed to the full net width within the beam, and a stirrup cap—a top horizontal bar with a 135-degree stirrup hook at one end and a 90-degree stirrup hook at the other—will close the detail. The full-width stirrup will help maintain the correct concrete cover and ease installation after preassembly. Moreover, this full-width, closed stirrup configuration is important if the wide beam is subjected to significant torsional forces; the perimeter stirrup detail confines the beam core, but more importantly, it confines the corner bars. ACI 318-08,[4] Section 11.5.4, gives additional information on torsional reinforcement detailing.

To facilitate the interior stirrup leg placement, two configurations can be contemplated. Both configurations will allow the aforementioned recommended transverse stirrup leg spacing to be maintained. Figure 3 shows a U-stirrup pair with identical dimensions and 135-degree hooks. This configuration simplifies the detail by limiting the stirrup piece types required on the job site. Figure 4 shows a smaller-width hooked U-stirrup nested in a larger-width hooked U-stirrup in the beam interior. With the open-top design of the stirrups, the placer can load all of the longitudinal reinforcing bars from the top and avoid tedious maneuvering of the bars. After the longitudinal bars have been installed, the stirrup cap can be installed to create closed stirrup configurations.

REVIEW OF CODE REQUIREMENTS

For the benefit of the designer, the following is a list of important ACI 318 requirements concerning beam stirrup configurations:

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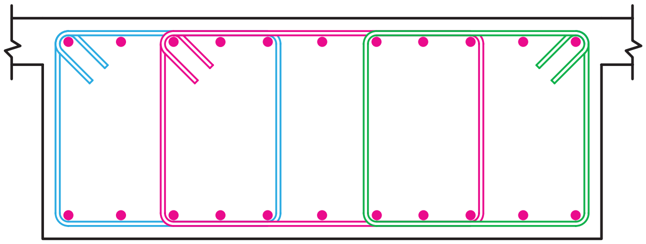

Fig. 2: Beam stirrup configuration with three closed stirrups distributed across the beam width

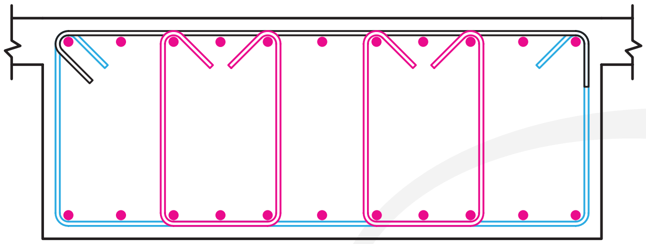

Fig. 3: An alternate configuration consisting of a single U-stirrup (with 135-degree hooks) across the net width of the beam, two identical U-stirrups (each with 135-degree hooks) distributed across the beam interior, and a stirrup cap

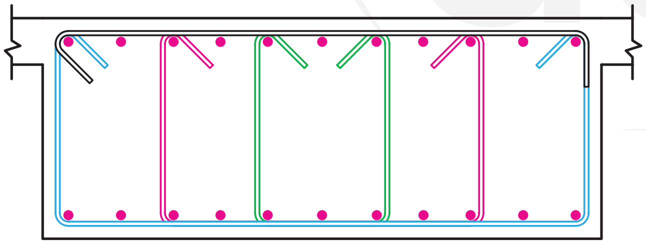

Fig. 4: A second alternate configuration consisting of a single U-stirrup across the net width of the beam, two smaller-width U-stirrups nested in the beam interior, and a stirrup cap

- Transverse reinforcement for perimeter beams and beams with torsion must be closed, one-piece or closed, two-piece stirrups (Sections 7.13.2.3 and 11.5.4.1);
- Transverse reinforcement must be as close to the compression and tension surfaces of the beam as concrete cover requirements and proximity of other reinforcement permits (Section 12.13.1);
- Ends of stirrup caps and U-shaped stirrups must be anchored with a standard hook around a longitudinal bar (Section 12.13.2.1). No. 6, 7, and 8 (No. 19, 22, and 25) stirrups with yield strengths exceeding 40 ksi (280 MPa) must also have a minimum embedment between the midheight of the beam and the outside end of the hook (Section 12.13.2.2 defines the embedment);
- Between anchored ends of a stirrup, each bend in the stirrup must enclose a longitudinal bar (Section 12.13.3);
- Pairs of U-stirrups or ties (in either case, with no end hooks) can be placed to form a closed unit, but they must have minimum laps of 130% of the bar development length, or the bars must meet certain size and strength restrictions and the splices must extend over the full available depth of the member (Section 12.13.5);
- When hoops are required for confinement, every corner and alternate longitudinal bar on the perimeter of the section must have lateral support provided by a corner of a stirrup or tie. Additional restrictions are placed on the tie configuration and spacing (Sections 7.10.5.3 and 21.5.3.3); and
- A seismic hoop can comprise a U-stirrup with seismic hooks closed by a top crosstie (in effect, a stirrup cap with a minimum 3 in. [76 mm] extension on the 135-degree hook). Consecutive crossties must have their 90-degree hooks at opposite sides of the beam. If there is a slab on only one side of the beam, then the 90-degree hooks must be placed on that side (Section 21.5.3.6).

SUMMARY

Wherever possible, the designer should use beam stirrup configurations with a large outer stirrup. The large outer stirrup will allow the side concrete cover to be maintained, and the open, two-piece configuration will allow accurate and efficient installation of the longitudinal reinforcing bars. A separate stirrup cap can be used where needed for torsion or confinement.

Thanks to Joint ACI-CRSI Committee 315 member Greg Birley and Neal Anderson of CRSI for providing the information in this article.

Selected for reader interest by the editors.

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Detailing Corner

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.

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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.

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

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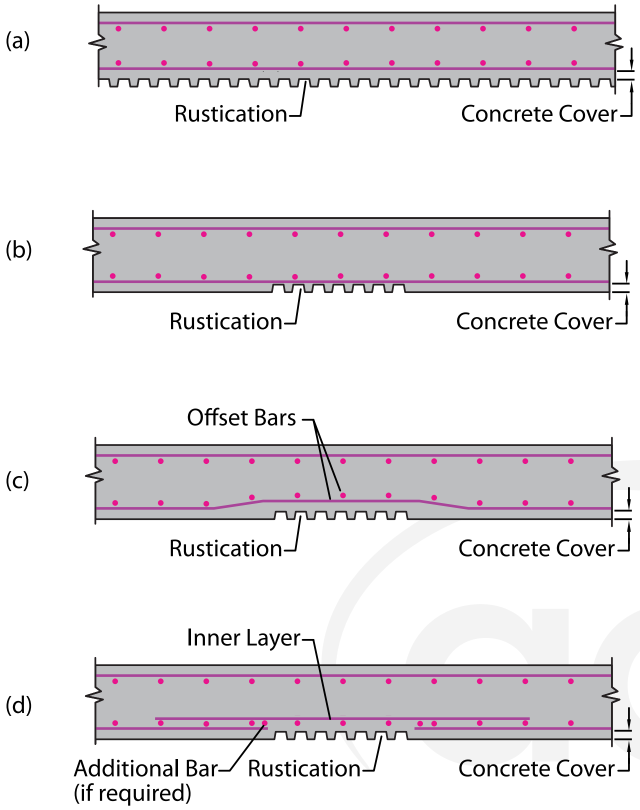


Fig. 1: Horizontal sections through walls with rustication: (a) rustication considered; (b) rustication not considered; (c) rustication considered using offset bars; and (d) rustication considered using inner layer of bars

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

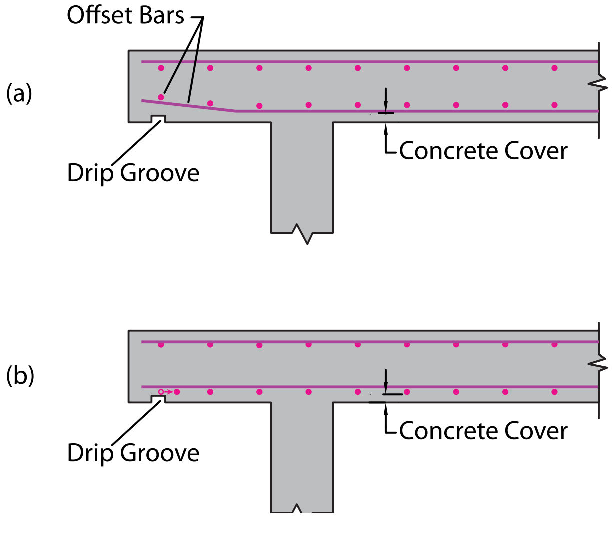


Fig. 2: Slab with drip groove at edge of soffit: (a) offset bars used to maintain cover at drip; and (b) relocated bars used to maintain cover at drip

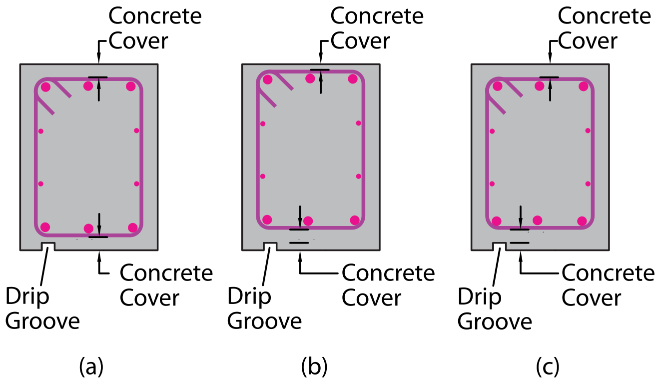


Fig. 3: Beam sections showing drip groove at bottom soffit: (a) inadequate cover at drip; (b) shifting reinforcing cage to maintain adequate cover at drip will cause top cover problems; and (c) to maintain adequate cover at all locations, stirrup sizes may need to be changed. The designer must consider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

Detailing Corner

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.

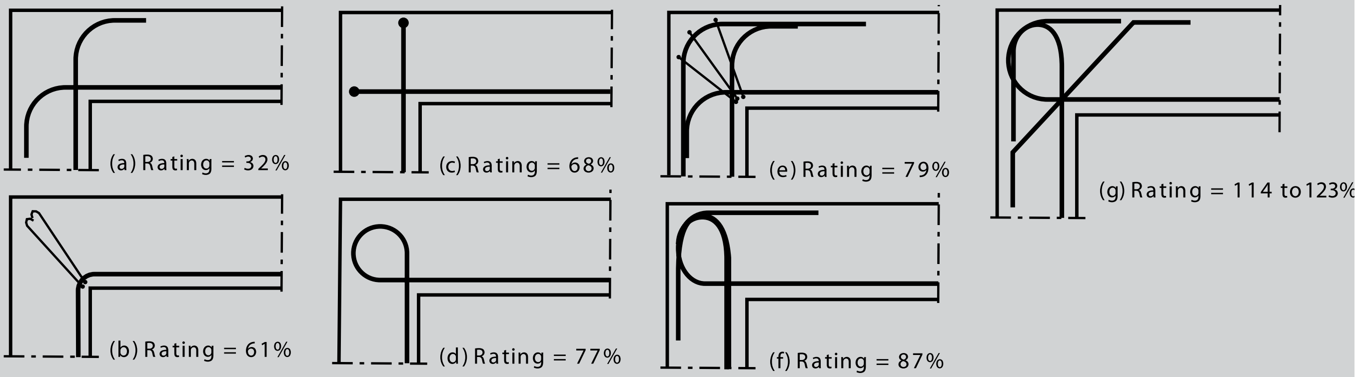


Fig. 10-1.1: Efficiency ratings (quotient of measured capacity and calculated capacity) for different reinforcement details (based on Reference 1)

Detailing Corner

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.

Thanks to Joint ACI-CRSI Committee 315 member Greg Birley and Neal Anderson of CRSI for providing the information in this article.

Selected for reader interest by the editors.

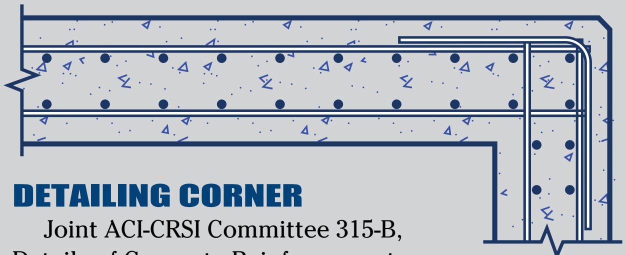
Detailing Corner

Using Standees

As structural engineers, we routinely design reinforced concrete members to resist the required loads, and we generate construction documents showing concrete sections with the reinforcing bars in their final configurations. That is, we graphically depict the reinforcing bars as embedded in the hardened concrete, with no formwork or bar supports indicated.

Although we don't show bar supports on our details, our instructions in the general notes may require the contractor to "Provide adequate bolsters, hi-chairs, or support bars to maintain specified clearances for the entire length of all reinforcing bars." Also, our specification for concrete reinforcing (Division 3 of the project manual) will probably require that bars are supported in compliance with the *ACI Detailing Manual*[1] or the *CRSI Manual of Standard Practice*.[2] Rarely, however, will we place any explicit requirements on how reinforcing bars or bar mats are to be supported, as these concerns are within the domain of the contractor—means and methods.

While polymer, wire, or precast concrete bar supports are commercially available for use in members up to 10 in. (250 mm) thick, reinforcing bar assemblies, known as "standees," are normally required for the support of top mats of reinforcing bars in thick concrete members, such as footings and slabs. Standees are readily available as a standardized product up to 18 in. (457 mm) in height, but various sizes and configurations of standees have also been used in thick mat footings as deep as 12 ft (3.7 m).



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."

STANDEE TYPES

Figure 1 illustrates four common types of standees. Bend Types 25 and 26 are found in Fig. 10, Typical Bar Bends, in the *ACI Detailing Manual*.[1] Bend Type 26 standees are the most commonly used. Shape 27 is a modified Bend Type 26 used by some fabricators, especially near slab edges. Note that all three of these standee types are multiple-plane bent bars (that is, they do not lie flat) and thus are termed "special fabrication" in the industry.

Shape S6 is used in some areas of the country and is a modified version of Bend Type S6 found in Fig. 10 of the *ACI Detailing Manual*.[1] The dimensions "A" and "G" on Shape S6 are specified by the detailer and are usually not the standard hook extension dimensions. This is a single-plane bent bar, which can be bent on a standard tie bender. Legs A and G are then pulled apart in the field, in a direction perpendicular to the original plane of the legs, to create the desired height of the standee similar to Bend Type 25. It's important to note that the detailer must properly dimension the "B" and "D" sides so the standee height is correct once the legs are pulled apart or splayed.

SUPPORT ISSUES

Safety is a primary concern when supporting top reinforcing steel—especially if the member depth is great enough to allow workers to move within the space created between the top and bottom layers. The design of the support system for the top steel must provide for a large margin of safety, and many jurisdictions require that systems with heights exceeding 4 ft (1.2 m) be designed and sealed by an engineer.

In addition to the weights of the top mat, the concrete placing crew, and the placing equipment, impact effects of the concrete itself must be considered in the design of supports. Multiple layers of top bars require close attention to the total load placed on each standee. The lateral stability of the top reinforcing steel mat(s) is also a

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TABLE 1:
SUGGESTED STANDEE WIDTHS* (REFER TO FIG. 2)

Bar size	Finished bend diameter, $D^{\dagger}$	Flat dimension, F	Width, W
No. 3 (No. 10)	1.5 in. (40 mm)	2 in.	4 in. (100 mm)
No. 4 (No. 13)	2 in. (50 mm)	2 in.	5 in. (125 mm)
No. 5 (No. 16)	2.5 in. (65 mm)	2 in.	6 in. (150 mm)
No. 6 (No. 19)	4.5 in. (115 mm)	2 in.	8 in. (200 mm)
No. 7 (No. 22)	5.25 in. (135 mm)	3 in. (75 mm)	10 in. (250 mm)
No. 8 (No. 25)	6 in. (155 mm)	4 in.	12 in. (305 mm)
No. 9 (No. 29)	9.5 in. (240 mm)	4 in.	16 in. (410 mm)
No. 10 (No. 32)	10.75 in. (275 mm)	4 in.	18 in. (460 mm)
No. 11 (No. 36)	12 in. (300 mm)	6 in.	21 in. (530 mm)

*Based approximately on the following formula: $W = 2d_b + D + F$

†Finished bend diameters based on minimum diameters for ties, plus springback

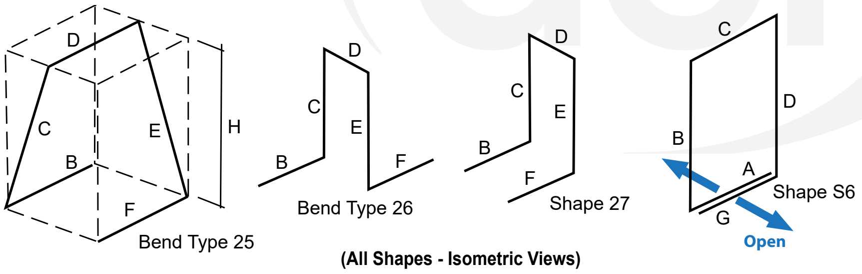
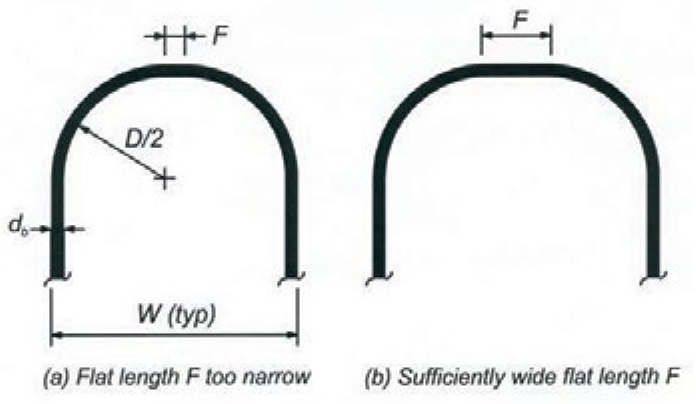


Fig. 1: Common types of standees



(a) Flat length F too narrow (b) Sufficiently wide flat length F

Note: See Table 1 for suggested standee widths, W

Fig. 2: Flat length on a standee

design consideration. Some bar layouts will include a series of temporary horizontal strut bars braced against the concrete formwork (assumed to be well braced itself). These temporary bars are then removed or pushed inboard during concrete placement, thus maintaining concrete cover. Diagonal braces (truss bars) are also tied between the top and bottom reinforcing mats to provide stability to the top mat during placement.

While standees can be used to any depth—provided they are properly braced against lateral and twisting movement—many engineers require some other kind of support when the support height exceeds about 6 ft (1.8 m). Used scaffolding is commonly used, as are special frames or trusses made of welded reinforcing bars or structural steel angles.

MANUFACTURING STANDEES

There are no specified rules for determining the reinforcing bar size to be used in manufacturing a standee. Many detailers select bar sizes based on their past experience. A common industry rule-of-thumb is the standee bar size is about one size smaller than the bars to be supported. This can be modified, of course, depending on the spacing of the supported steel, the number of top layers, and standee height. If an engineering design is performed, a column stability analysis on a standee leg would be appropriate. Regardless of the determination, it's prudent to coordinate with the bar placer to be installing the reinforcement and bar support systems.

The standee width should be sufficient to create a suitable flat length along the top so the supported bar will not have a tendency to roll off (Fig. 2). Table 1 provides a listing of suggested standee widths for reinforcing bar sizes up to No. 11 (No. 36).

The length of each foot at the base of a standee, represented by dimensions "B" or "F" of Bend Types 25 and 26, or Shape 27 in Fig. 1, depends on where

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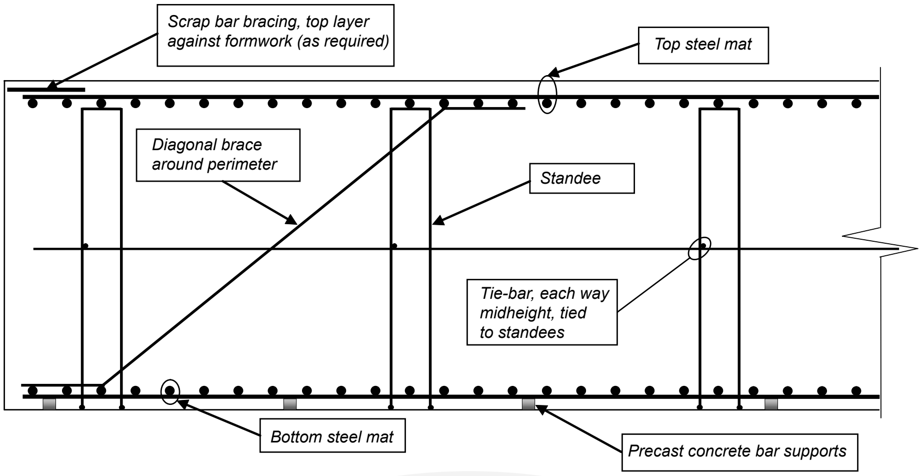

Fig. 3: Top steel mat support for generic raft foundation (elevation view)

the standee will be positioned. If the standee will be supported on a concrete blinding layer or a formed surface, the feet should be about the same length as the width dimension (dimension *D*). Taller standees should have proportionately longer feet to ensure sufficient stability.

If the standee will be supported on a bottom layer of reinforcing bars, each foot should be about 1.5 times the spacing of the supporting bars. This length allows each foot to cross two support bars, thus providing better stability. Because the added weight of the top reinforcing steel will force the use of additional supports for the bottom reinforcing bars, placing heavily loaded standees on the bottom reinforcing steel mat should be avoided.

EXAMPLE PLACEMENT

Figure 3 shows an example of a bar support system for a simple raft footing with two mats comprising orthogonal layers of reinforcing bars. The bottom steel mat is supported on precast concrete blocks (dobies) spaced about 2 to 3 ft (0.6 to 0.9 m) each way. The top layer is supported on standees spaced about 3 to 5 ft (0.9 to 1.5 m) each way, depending on the self-weight of the top reinforcing steel mat. Because the standees are taller than 3 ft (0.9 m), horizontal tie-bars are tied securely at the midheight of the standees in each direction; tie-bars are typically No. 5 (No. 16) bars, but can be larger if required. These bars provide midheight stability for the vertical standee legs. In this example, No. 5 (No. 16) diagonal braces are placed around the foundation perimeter and are spaced to match the standees. Additional lateral support is shown at the top left of Fig. 3; short lengths of horizontal bars are placed so they brace to the formwork.

SUMMARY

While Bend Type 26 is the most stable standee due to the load being vertical on the legs, its height is not adjustable; the same holds true for Shape 27. Because both feet point in the same direction in Shape 27, it tends to tip—the legs may need to be tied down. The tendency to tip can be mitigated by alternating the direction of the legs from one standee to the next, if possible.

Bend Type 25 and Shape S6 share the significant advantage of having an adjustable height, simply by spreading or moving the legs closer together. Tall standees have a tendency to twist under heavy loading, however, so lateral bracing should be used.

Bend Types 25 and 26, and Shape 27 are two-plane bent bars and require special fabrication. Shape S6 is initially a single-plane shape and can be bent on a standard tie bender.

Safety is of paramount importance when designing a bar support system for heavy top mats of reinforcing bars. Standees offer the most economical solution, but care must be taken to consider all forces acting on them. Standee spacing must be carefully determined to support the dead loads, and bracing must be adequate to handle all lateral forces.

References

1. ACI Committee 315, *ACI Detailing Manual*, SP-66(04), American Concrete Institute, Farmington Hills, MI, 2004, 165 pp.

2. *CRSI Manual of Standard Practice*, twenty-eighth edition, Concrete Reinforcing Steel Institute, Schaumburg, IL, 2009, 144 pp.

Thanks to Joint ACI-CRSI Committee 315 member Dick Birley for providing the information in this article.

Detailing Corner

Avoiding Ambiguous Reinforcing Bar Callouts

Construction drawing clarity is one of the most important factors that contribute to a successful construction project. A missing key piece of information, an unclear note, or a misunderstood detail could potentially add weeks to a project and lead to thousands of dollars in extra costs.

One vital class of information is the reinforcing bar callout on the drawings. Callouts typically list the reinforcing bar size along with the number of bars or the bar spacing. ACI 318-08,[1] Section 1.2.1 lists important information that must be included in the design drawings, details, and specifications. Sub-item (e) specifically requires that design drawings or details shall contain: “Size and location of all structural elements, reinforcement, and anchors.” The licensed design professional must ensure that design requirements are clearly expressed in the structural drawings so the contractor will be able to accurately interpret them for the structure being built. Unfortunately, some commonly used callouts for reinforcing bars can be ambiguous.

DETAILING CORNER

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CONCERNS

While a reinforcing bar callout on a structural drawing may seem perfectly clear to the design engineer, it could very well be interpreted in a completely different fashion by another person. The contractor may be confused about the intent of the callout, which will require clarification from the designer and result in lost time in the field.

Example 1—Alternating bar lengths

Calling out the spacing for a series of bars with alternating lengths seems to be a common source of confusion. For example, in Fig. 1(a), the designer has called for a series of top slab bars over a beam for negative moment reinforcement. Does the designer want No. 6 x 16 ft 0 in. at 12 in. and No. 6 x 14 ft 0 in. at 12 in. for a net spacing of 6 in. as shown in Fig. 1(b)? Or, does the designer want a net spacing of 12 in. as shown in Fig. 1(c)? (Note: SI units are also shown on the details and will not be repeated in the text.) Depending on the interpretations of the bar callout, the amount of placed steel could be half or twice the amount intended by the designer.

For this case, if the callout had been **No. 6 x 16 ft 0 in. + No. 6 x 14 ft 0 in. ALT @ 12 in.**, it would be clear that the design called for a net spacing of 12 in. However, if the designer wanted to make the detail absolutely clear, the callout should be as shown in Fig. 2; this figure shows additional information, with the bar spacing between adjacent bars also depicted.

Detailing Corner

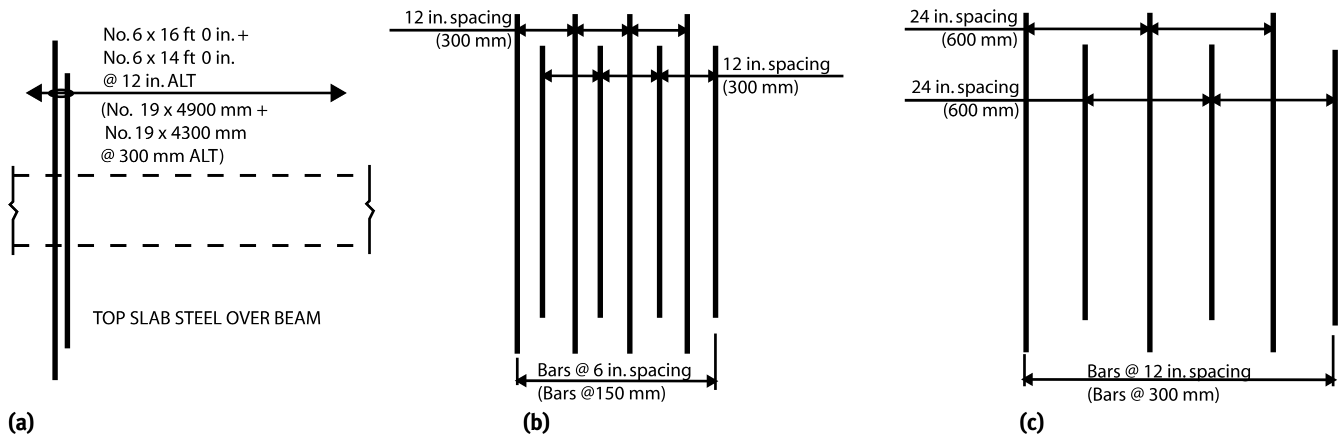


Fig. 1: Callouts for alternate bar lengths: (a) the original detail; (b) one interpretation results in bars at 6 in. spacing; and (c) a second interpretation results in bars at 12 in. spacing

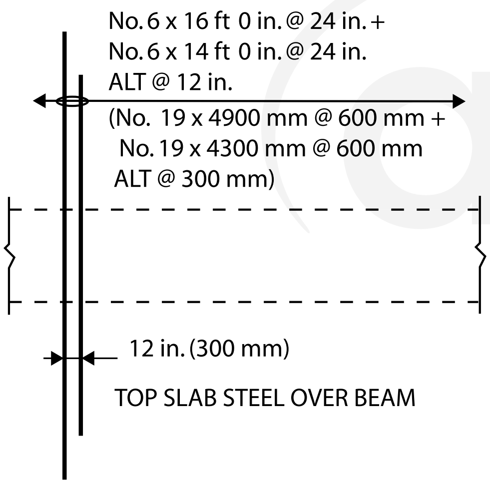


Fig. 2: Suggested callout for alternate bar lengths

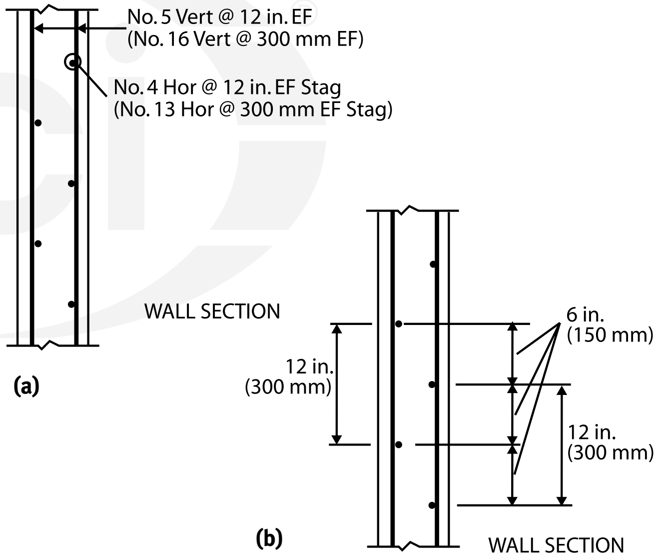


Fig. 3: Callout for horizontal bars in wall: (a) the original detail; and (b) one interpretation results in bars at an aggregate spacing of 6 in.

Example 2—Staggered horizontal bars in a wall

It's common for horizontal bars in a wall to have the same spacing on each face but with the bars on one face offset by half a bar space. How this is called out can be ambiguous. In Fig. 3(a), taken from an actual project, the horizontal bars are called out as **No. 4 Hor @ 12 in. EF Stag** (Hor is horizontal, EF is each face, Stag is staggered). The intent would seem to be that the horizontal bars should be spaced at 12 in. on each face, for an aggregate spacing of 6 in., as shown in Fig. 3(b). In the actual project, the designer intended for the bars to have an aggregate spacing of 12 in., not 6 in. Figure 4 shows what the designer had actually meant for the design.

A less ambiguous callout would have been **No. 4 Hor EF @ 24 in. Stag**. This would clearly indicate the spacing on each face to be 24 in., with an aggregate spacing of 12 in. An even clearer approach would be to augment the detail by showing the bar spacing similar to that shown in Fig. 4.

Example 3—Column ties

Typical callouts for the spacing of column ties can be ambiguous as well. Figure 5(a) is taken from an actual column schedule. The schedule indicated No. 4 ties would be used with the column. The callout at the bottom and top of the column was **8 @ 6 in.**, as shown in Fig. 5(a). It's not clear if this means eight ties and seven spaces (Fig. 5(b)) or nine ties and eight spaces (Fig. 5(c)).

Detailing Corner

For greater clarity, the bottom and top callouts should have been **8 ties @ 6 in.** or **8 spaces @ 6 in.**, depending on the intent of the designer. In this case, simply including the word "ties" or "spaces" would have clarified the intent of the callout completely.

Example 4—Skewed bars

Another situation that occasionally causes some confusion is the manner in which the limit lines of skewed bars are called out, as shown in Fig. 6(a). Normally, a limit line is drawn at a right angle to the indicated bars. As shown in Fig. 6(a), however, the designer may instead draw the limit line parallel to the skew. This detail could be interpreted to mean that the bar spacing of 9 in. should be measured along the extent line, as shown in Fig. 6(b). This interpretation would result in having the No. 5 bars more closely spaced than if the spacing was measured along a horizontal extent line. As a standard industry practice, limit lines should never be drawn parallel to the skew but should always be shown at right angles to the bars, as shown in Fig. 7.

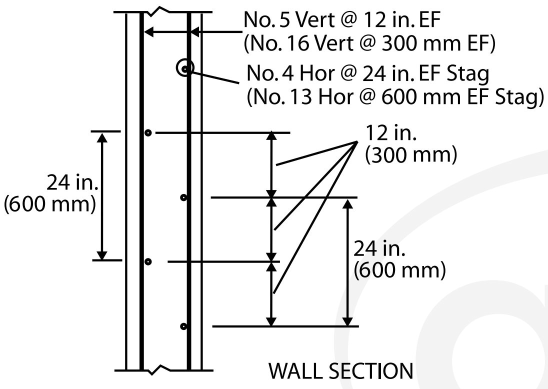
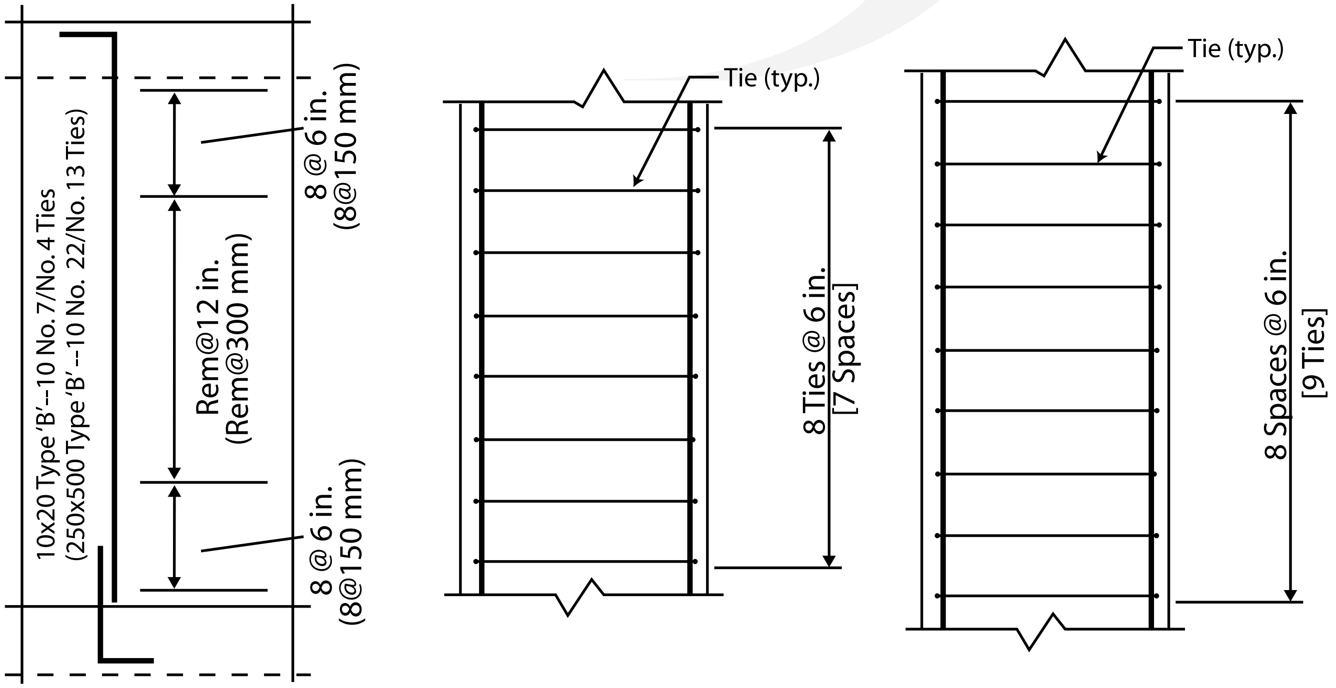


Fig. 4: Suggested callout for horizontal bars in wall

SUMMARY

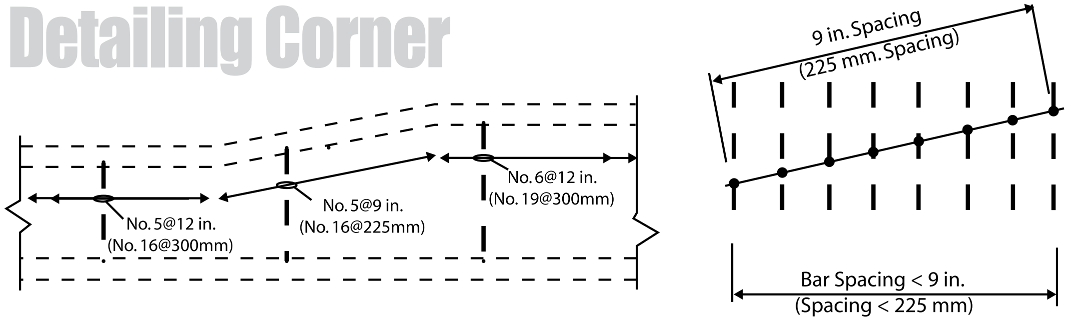
Four examples of ambiguous reinforcing bar callouts were illustrated in this article. All of the examples demonstrate how easily a seemingly simple piece of reinforcing bar callout information could be misinterpreted, with far-reaching results. The designer must always look at the reinforcing bar callouts on the design drawings with a critical eye to determine if they might lead to erroneous interpretations. In most cases, adding a little more text or a simple detail with specific spacing information is all that's needed to help clarify the intent of a bar callout.



(a) (b) (c)

Fig. 5: Callout for column ties at the top and bottom: (a) the original detail; (b) one interpretation results in eight ties; and (c) a second interpretation results in nine ties

Detailing Corner



(a) (b)

Fig. 6: Callouts for skewed bars: (a) original detail; and (b) one interpretation leads to bar spacing < 9 in.

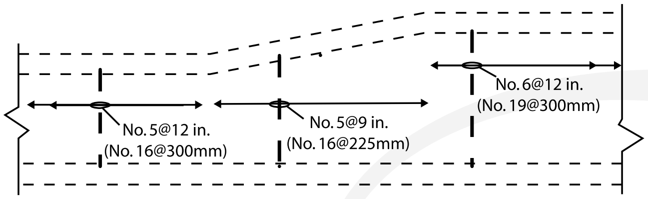


Fig. 7: Suggested callout for skewed bars

Reference

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

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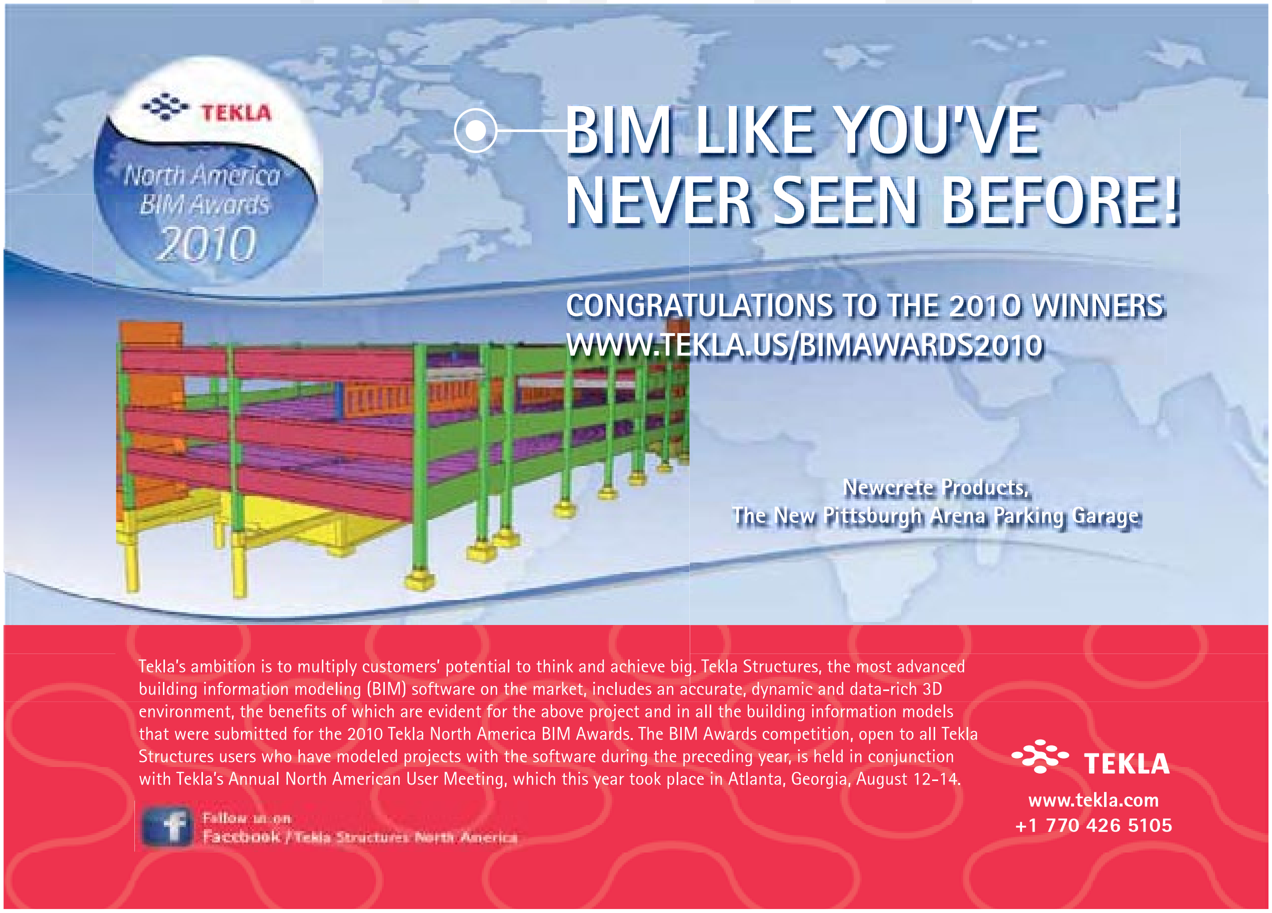

Detailing Corner

Bar Detailing at Wall Openings

It's a necessary fact that any building is going to have openings in walls or structural slabs. Round or rectangular, openings are required for conduit, piping, ductwork, doors, or windows. Their locations are often the responsibility of the architect, and they can change by minor or major amounts throughout the design process (and even during construction). This Detailing Corner focuses on openings in walls, but some of the discussion could be equally applicable for openings in slabs.

In a typical wall with no openings, reinforcing bars will probably consist of layers of bars (curtains) with uniform spacing. The bars will typically be continuous over the full height or width of the wall, but an opening can interrupt the bars. Also, the re-entrant corners created by rectangular openings cause stress risers that will likely lead to diagonal cracking.

So, reinforcing bars are typically added in the perimeter zone of an opening. These added bars are commonly known as **trim bars, opening bars,** or **corner bars**. Trim bars (called trimmer or trimming bars in some regions of North America), are the added bars placed near openings to replace the reinforcement interrupted by the opening. These bars are usually considered structural and are placed so as to provide a reinforced load path around the opening. Opening bars are minimum reinforcement added around windows, doors, and similar-sized openings. Per Section 14.3.7 of ACI 318-08,[1] each layer of reinforcement in the wall requires at least one No. 5 (No. 16) bar around the perimeter of an opening. Opening bars must be developed at the corners, so they extend a development length beyond the opening. Corner bars are opening bars placed on a diagonal at each corner. Although they aren't explicitly required, it's good practice to use them—they provide more efficient restraint of the likely cracks at the re-entrant corners.

DETAILING CORNER

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DESIGN CONSIDERATIONS

On the structural drawings, wall openings are often detailed in a "typical" fashion with a number of generic notes pointing to specific vertical, horizontal, or diagonal bars on the drawing. Figure 1 provides an example of a typical drawing detail. General structural notes for the reinforcement at openings are equally generic. Frequently, the designer's notes specifying trim bars around openings do not clearly express the designer's intent, potentially leaving the detailer or bar placer uncertain about what reinforcement is specifically required.

The most common general note for trim bars requires that one-half the number of cut or interrupted bars be placed on each side of the opening. If an odd number of bars are cut, then the number is rounded up to an even number and one-half of the bars are placed on each side. This practice is generally based on Section 13.4.2 of ACI 318-08, which is specifically required for slabs; however, it is normally followed for walls as well. In the case of nominal-sized openings, this practice usually doesn't create a problem.

Guidance for design and reinforcing bar detailing around openings exists in other ACI documents. ACI 313-97,[2] for example, provides design and construction requirements for concrete silos. In lieu of a detailed analysis of the effects of the stress risers at an opening, the standard requires that trim bars on each side of the opening have a total area of at least one-half the area of the bars interrupted by the opening (in effect, the trim bars must replace the interrupted bars at an opening). For openings located in zones of pressure, the area of the horizontal trim bars must be 20% greater than this minimum. Vertical trim bars on each side of the opening must also be designed as column reinforcement for a narrow strip on each side of the wall. The column width is limited to 4*h*, where *h* is the wall thickness, and the unsupported length of the column is equal to the full height of the opening. The trim bars must be developed at the corners, but they must extend no less than 24 in. (600 mm) or one-half the opening dimension beyond the opening.

Section 14.3.7 and the associated commentary of ACI 350-06[3] require that trim bars replace the interrupted bars at an opening. The trim bars must be developed (or extend at least 24 in. [600 mm]) beyond the corners of an angular opening or the intersection with other trim bars of circular openings. The commentary points out that this is minimum reinforcement—walls with lateral loads should be designed to maintain the strength of the wall and transfer load around the opening.

As both ACI 313-97 and ACI 350-06 emphasize, it's important to develop the bars beyond the opening. But as simple as the design and detailing might appear, there are recurring issues and concerns, as addressed in the following.

TRIM BARS

Issue 1—Full height trim bars

Some designers require vertical trim bars located on each side of the opening to run the full height of the wall, lapped with dowels anchored in the footing and oftentimes embedded in the floor or roof above (Fig. 1). The requirement is applied to all openings, regardless of the opening size or its location relative to the bottom or top of the wall.

For large openings, structural design may dictate full-height wall bars. This practice is usually unnecessary, however, for small openings near the bottom or top of the wall. Trim bars are only required to have full embedment (that is, tension development length) past the edge of the opening. Detailing and placing full-height bars can be a problem because the precise dimensions and location of an opening may not be available at the time the footing concrete is placed. Conversely, if the small opening is moved or the dimensions changed after the footing is cast, the dowels would no longer be properly located. It's recommended that the designer avoid this requirement wherever possible.

Issue 2—Trim bar embedment

There can be a wide variance in how designers call out the embedment or development of trim bars. Figure 2(a) shows the embedment of the trim bars measured from the corner of the opening. This is the preferred method, as it gives the detailer and placer a precise location for the trim bar based on the bar embedment length per the structural drawings. At placement time, the opening location should be marked in the field or formwork should be in place, thus providing a "hard" geometric control point for the placer.

The detail in Fig. 2(b) is also frequently used, whereby the embedment length is referenced to a reinforcing bar. Designers who use this detail may believe that the opening location will not be precisely set and that the bar is a better control point. In this example, the horizontal trim bar embedment is then conditional on the first trim bar location in the perpendicular or vertical direction. The detailer can easily determine the trim bar embedment, assuming that the first perpendicular trim bar will be located at the proper concrete cover distance from the opening. Embedments or other conditions, however, may force the perpendicular trim bar to be placed further away from the opening, resulting in the horizontal trim

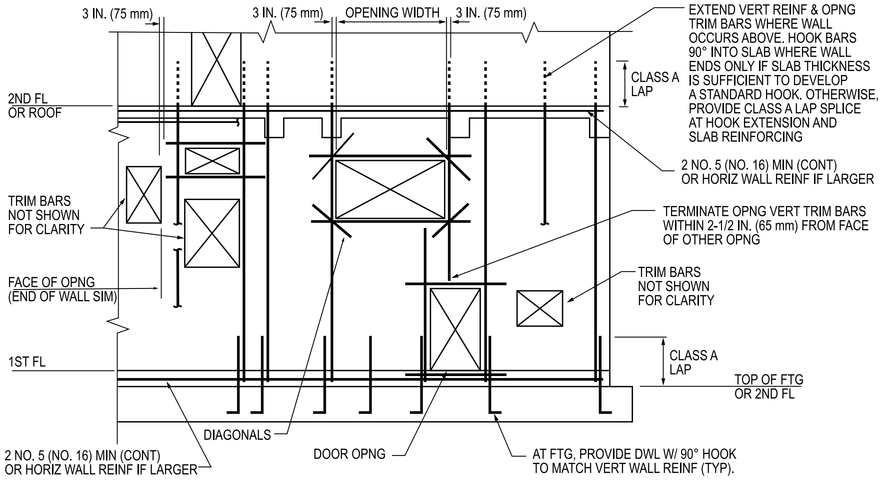

Fig. 1: A typical detail showing reinforcement at wall openings

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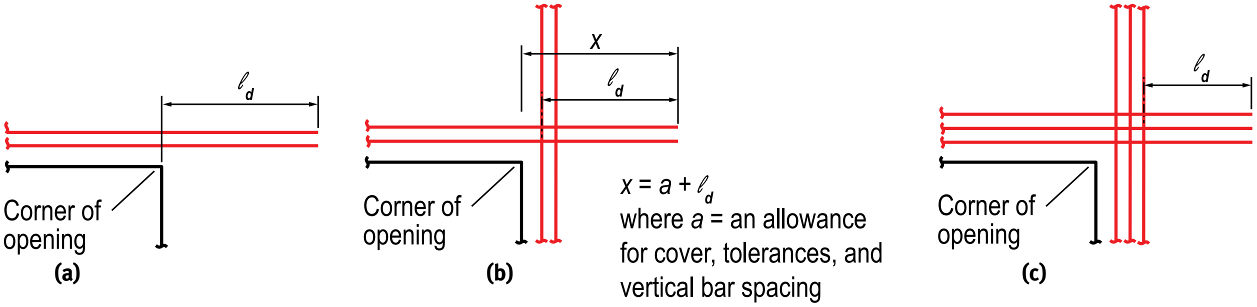

Fig. 2: Designers use different reference points for trim bar extensions: (a) measuring from the opening corner is the most precise; (b) using a trim bar as a reference point can create problems if the trim bar location must shift; and (c) measuring from the outermost trim bar may lead to excessive embedment lengths

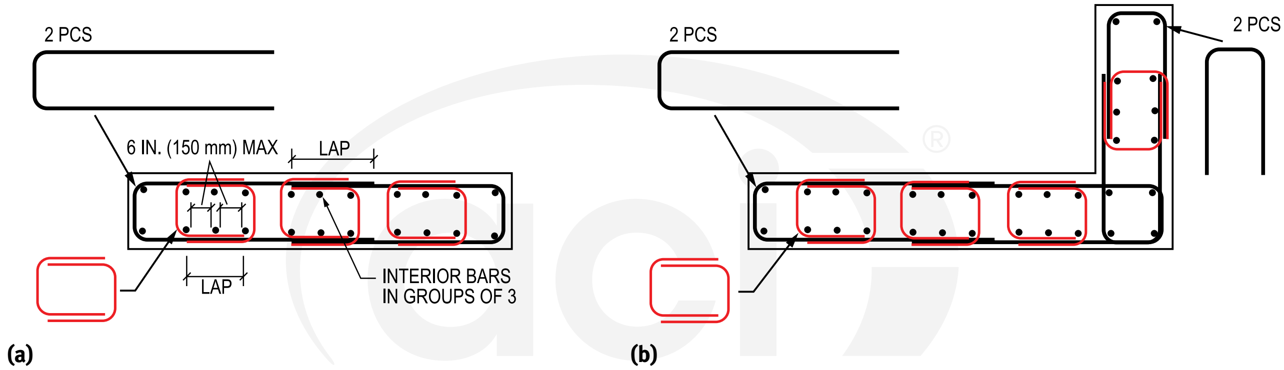

Fig. 3: Examples of column reinforcement details incorporated into a wall: (a) column-like wall; and (b) corner column-like wall (based on Reference 4)

bar embedment length being too short beyond the vertical bar in this case. This can be corrected in the design phase by providing a set horizontal dimension that includes the development length plus a nominal width dimension to account for tolerances, a placement range for the vertical trim bar(s), and concrete cover. From a structural perspective, providing a development length slightly greater than the ACI 318 Code minimum is not harmful and could be helpful; the added cost of the extra length on the bars will be minimal.

The detail in Fig. 2(c) is used occasionally in heavily reinforced walls or opening locations. This detail presents the same potential problems as the detail in Fig. 2(b). Moreover, Fig. 2(c) illustrates that if there are a large number of vertical trim bars adjacent to the opening, the horizontal trim bar length could become excessively long; this excessive length may not be structurally necessary. For these reasons, this detail is not desirable and the designer should strive to use the detail shown in Fig. 2(a).

Issue 3—Opening too wide or high?

When is an opening too wide or too tall to apply the general practice of replacing the interrupted reinforcement? Oftentimes, the general notes do not indicate the maximum dimension beyond which this practice is no longer valid. At some point, the size of an opening could become a structural concern necessitating beam and column design around the opening. Clearly, this is dependent on the opening size, wall thickness, and loading condition at the opening. If the horizontal dimension (span) of the opening is too great, beam-type reinforcement may be required above or below the opening. Likewise, the vertical wall on each side of the opening may necessitate a dedicated reinforced column section with specific longitudinal and tie reinforcement.

Section 4.3.8.4 of ACI 313-97 provides some practical guidance for the engineer, stating that "unless determined otherwise by analysis, walls 8*h* in width or less between openings shall be designed as columns." ACI 315-99[4] illustrates an example of how a column cross section would be incorporated within the confines of the wall thickness (Fig. 3).

The designer should always show the maximum dimensions for which the general practice can be applied. All larger openings should be individually investigated by the designer and the proper reinforcement details should be shown on the structural drawings.

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Issue 4—Spacing of trim bars

What is the spacing of the trim bars? This is usually not indicated in the general notes; in such cases, the detailer will usually not indicate a dimension either. Section 4.3.9 of ACI 313-97[2] requires that horizontal bar clear spacing to be at least 2 in. (50 mm) and center-to-center spacing to be at least five bar diameters. The section also requires that the spacing of horizontal bars in slipformed walls to be large enough to allow bars to be placed and tied during form movement.

Absent any spacing information on the structural or reinforcing bar placing drawings, the bar placer will determine the spacing. The placer will arbitrarily space the bars to a personal preference or experience, usually about 3 in. (75 mm). If for any reason the spacing is critical, the designer should indicate the trim bar spacing on the structural drawings.

Issue 5—Effectiveness of trim bars

How far from the opening can the trim bars be placed before they lose their effectiveness? As was addressed in the section regarding Issue 3, there are times when the maximum opening width is not given in the general notes. By default, the detailer must assume that all of the openings are to be trimmed with one-half of the interrupted bars on each side. If a large amount of bars are cut, however, there will potentially be a large quantity of additional trim bars on each side of the opening (Fig. 4(a)). As they are evenly spaced out from the opening, some of these bars may be too far away from the opening to be considered fully effective.

Section 13.4.2 of ACI 318-08 requires that "an amount of reinforcement equivalent to that interrupted by an opening" be added to the sides of the opening. It doesn't require that the same bar size be used for the trim bars, only that half the area be placed on each side. Using the same bar size is simpler and avoids confusion in the field, but this is not always practical from a potential congestion standpoint.

A solution to this problem would be to use fewer but larger bars (Fig. 4(b)). For example, say 20 No. 5 (No. 16) bars are interrupted by an opening. Rather than placing 10 No. 5 (No. 16) bars on each side (A_s = 3.10 in.^{2} [2000 mm^2]), seven No. 6 (No. 19) bars (A_s = 3.08 in.^{2} [1987 mm^2]) or six No. 7 (No. 22) bars (A_s = 3.60 in.^{2} [2323 mm^2]) can be used. The designer should consider this possibility and account for this option in the general note. Alternatively, specific trim bar details could be indicated on the structural drawings for each affected opening.

DIAGONAL BARS

The minimum opening bars required per ACI 318-08, Section 14.3.7, are illustrated in Fig. 5 for a typical opening.

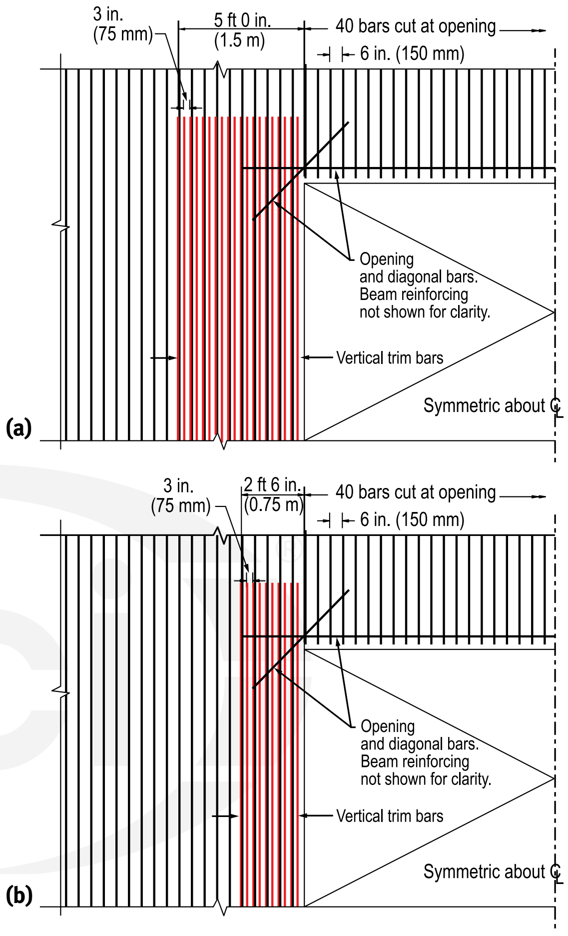

Fig. 4: Trim bars may be located too far from the opening if cut bars are replaced one-for-one: (a) for a large opening, matching the cut bar size can result in a wide band of trim bars; and (b) using larger replacement bars (in this case, using a trim bar with about twice the area of the cut bar) can allow trim bars to be concentrated close to the opening

These bars are intended to restrain cracking, but trim bars will also help keep any cracks tight. Diagonal bars have the primary purpose of arresting cracks at re-entrant corners of wall openings, and they deserve two more comments.

Issue 6—Diagonal bar location in wall thickness

Are diagonal bars effective on multi-layer wall curtains? Due to cover requirements and the thickness of the reinforcing bar curtains, the diagonal bars will likely be placed closer to the center of the wall rather than near the concrete faces. Figure 6 shows a section of a wall with multiple layers of reinforcement and diagonal bars. The diagonal bars are less effective in controlling cracks

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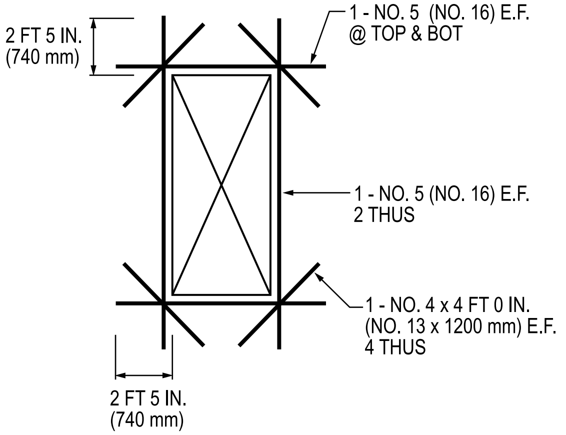

Fig. 5: A typical detail for opening and corner bars used for crack control (based on Reference 5)

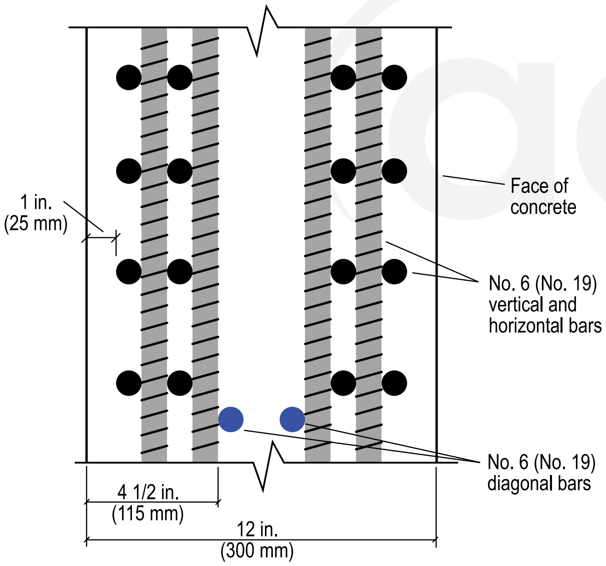

Fig. 6: Likely diagonal bar location in multi-layered wall

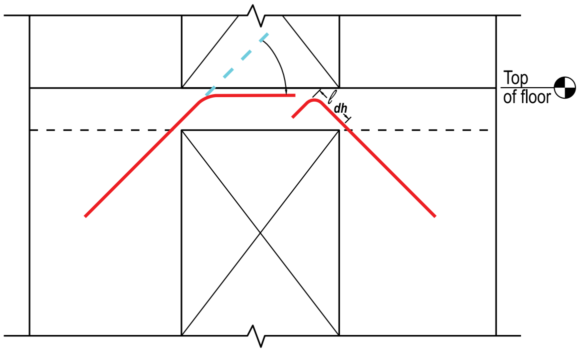

Fig. 7: Development of diagonal bars in close proximity to another opening will require bends or hooks

radiating from the opening corners because the bars are so far from the concrete faces. The vertical and horizontal trim bars should provide the requisite reinforcement near the surface to keep the cracks tight. Because the corner crack will likely propagate through the wall thickness, the diagonal bars will provide supplemental restraint near the midsection of the wall.

Issue 7—Diagonal bar development

For openings close to the top of a wall or near a slab, the normal straight diagonal bar detail may not be possible. In such cases, the diagonal bar detail needs to be modified in one of two ways (Fig. 7). The bars can extend past the opening with a standard hook at the end, or the diagonal bar can be bent to avoid the obstruction.

ADDRESS THE CONDITIONS

Designers should be cautious of generic notes for trim bars around openings. Trim bars should be carefully considered on a project-by-project basis to determine if special conditions exist that may require nonstandard details. These special conditions should be addressed in the general notes or special details should be included in the structural drawings. The designer needs to make his or her intent clear for all aspects of the trim bars around openings.

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Thanks to Greg Birley of Condor Rebar Consultants and a member of Joint ACI-CRSI Committee 315, Details of Concrete Reinforcement, and Neal Anderson and Anthony Felder of CRSI for providing the information in this article.

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Detailing Corner

Closure Strips and Lapped Reinforcement

A closure strip, otherwise known as a pour strip, is typically a temporary gap between two separate concrete slab placements. The closure strip is subsequently infilled with concrete at a later date. Closure strips are common with staged construction where there is a construction sequence involved in casting the slab. Applications of closure strips can be found in bridge deck construction, post-tensioned (P/T) slab construction, and normal two-way slab building construction.

BRIDGE DECKS

Closure strips in a bridge deck are required when an existing deck is replaced under staged construction or bridge widening. More than likely, one-half of the deck would be closed per construction phase, while traffic is maintained on the other half. The closure strip is located near the center of the deck, transversely, and extends the full length of the bridge. It serves to reduce the effect of adjacent traffic live load vibrations during concrete curing. The joint is usually left open for as long as possible to permit transverse shrinkage of the deck concrete to occur.

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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."

Representative requirements from the Nevada and South Carolina bridge manuals indicate that closure strips should have a minimum width of 3 ft (0.9 m) and contain the lap splices for the transverse reinforcing steel.[1,2] The width may be greater, however, to account for the anticipated relative dead load deflection between Stage 1 and 2 concrete placements, across the closure strip. Both bridge manuals indicate two very useful purposes of the closure strip: 1) it delays final connection of the two stages of concrete work until deflection from the deck slab dead weight has occurred; and 2) it provides the deck width necessary to facilitate differences in the final deck grade resulting from theoretical deflection calculations and/or construction tolerances.

P/T SLABS

Closure strips in P/T slabs allow the separate slab sections to have ample time to shorten, and thus minimize any restraint cracking. Shortening has many components in a P/T slab and can be attributed to:

- Elastic shortening due to precompression;
- Creep shortening due to precompression;
- Shrinkage of concrete; and
- Temperature gradients.

The *Post-Tensioning (PT) Manual*[3] provides guidance for the use of closure strips and the length of the slab between closure strips:

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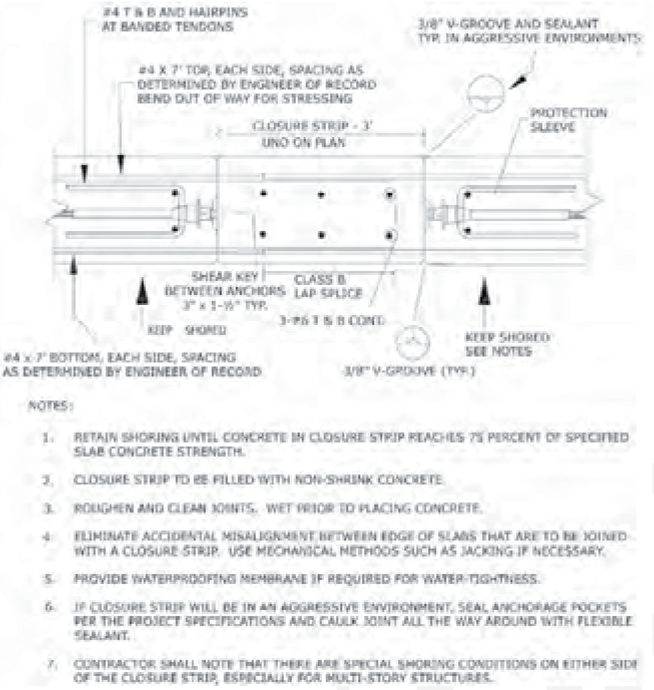

NOTES:

1. RETAIN SHORING UNTIL CONCRETE IN CLOSURE STRIP REACHES 75 PERCENT OF SPECIFIED SLAB CONCRETE STRENGTH.
2. CLOSURE STRIP TO BE FILLED WITH NON-SHRINK CONCRETE.
3. ROUGHEN AND CLEAN JOINTS. WET PRIOR TO PLACING CONCRETE.
4. ELIMINATE ACCIDENTAL MISALIGNMENT BETWEEN EDGE OF SLABS THAT ARE TO BE JOINED WITH A CLOSURE STRIP. USE MECHANICAL METHODS SUCH AS JACKING IF NECESSARY.
5. PROVIDE WATERPROOFING MEMBRANE IF REQUIRED FOR WATER-TIGHTNESS.
6. IF CLOSURE STRIP WILL BE IN AN AGGRESSIVE ENVIRONMENT, SEAL ANCHORAGE POCKETS PER THE PROJECT SPECIFICATIONS AND CAULK JOINT ALL THE WAY AROUND WITH FLEXIBLE SEALANT.
7. CONTRACTOR SHALL NOTE THAT THERE ARE SPECIAL SHORING CONDITIONS ON EITHER SIDE OF THE CLOSURE STRIP, ESPECIALLY FOR MULTI-STORY STRUCTURES.

Fig. 1: Typical closure strip detail[3] (Note: 1 ft = 0.3 m; 1 in. = 25 mm)
(image courtesy of the Post-Tensioning Institute)

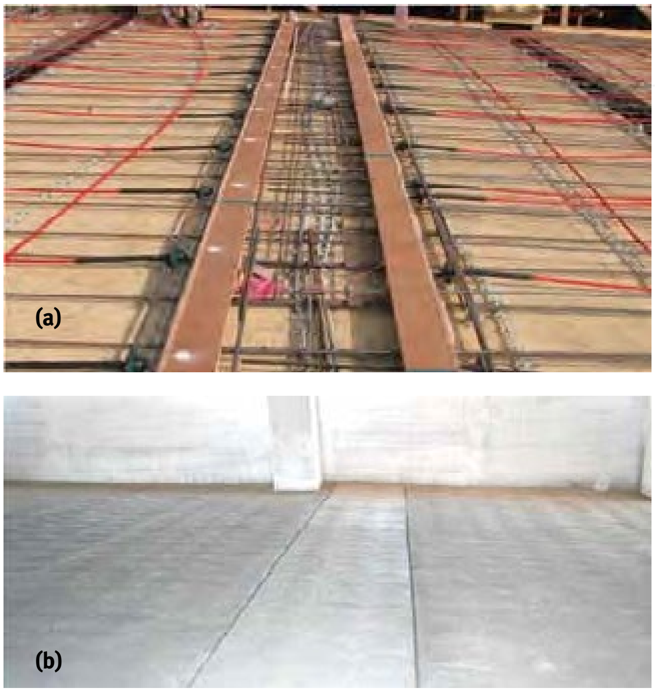

Fig. 2: Examples of closure strips in P/T construction: (a) forms, reinforcing bars, and P/T tendons shown prior to concrete placement; and (b) completed closure strip showing sealant in the construction joints *(photos courtesy of the Post-Tensioning Institute)*

- If the slab length is less than 250 ft (76 m), no closure strip or expansion joint is necessary;
- For slab lengths between 250 and 325 ft (76 and 99 m), provide one centrally located closure strip;
- If the slab length is between 325 and 400 ft (99 and 122 m), consider using two closure strips open for at least 60 days; and
- For slabs greater than 400 ft (122 m), an expansion joint is recommended.

These are guide recommendations, and the plan location of stiff elements and slab geometry can influence the above recommendations.

The closure strip width in P/T construction is generally 3 ft (0.9 m), but it must provide an adequate space to position a stressing jack to conclude stressing operations of the P/T tendons. In addition to the tendons, reinforcing bars will extend from each slab and lap within the closure strip to provide continuity between the slabs. Typically, a closure strip will be placed at the quarter point of the span, where design moments are small. Figure 1 shows a typical closure strip detail from the *PT Manual*. Figure 2 illustrates actual closure strips on P/T slabs during and after construction.

CLOSURE STRIP WIDTH

From a reinforcing bar standpoint, designers may err by dimensioning the width of a closure strip narrower than the lap length required for the reinforcement passing through them. The width of a closure strip should be equal to the length of the lap splice, plus at least 3 in. (75 mm). Figure 3 shows a suggested detail for a closure strip; (a) where only bottom reinforcement is provided; and (b) top and bottom reinforcement exists. Note that when both top and bottom reinforcement is present, the width of the closure strip needs to accommodate the longer lap splice length. The additional 3 in. (75 mm) width is necessary to accommodate cutting and bending tolerances of the reinforcement.

The same concern can also be expressed for slab infills. Figure 4 shows a suggested detail for a slab infill with an additional 3 in. (75 mm) of clear space in both directions to accommodate cutting and fabrication tolerances of the reinforcing bars.

In the case of a closure strip with seismic chord steel passing through, there is the added complication of providing for the lapping of the chord steel. Diaphragm chord steel and collector element steel usually have long lap splice lengths, which would require unacceptably wide closure strips. Consequently, lap splices are normally not an option for chord steel and mechanical splices are used instead. Figure 5 illustrates a suggested detail of a

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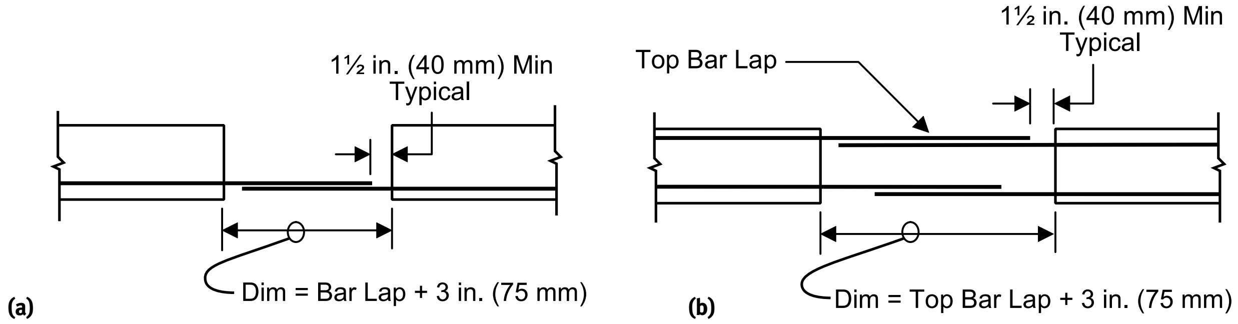

Fig. 3: Typical closure strips for cast-in-place construction: (a) bottom reinforcing steel only; and (b) top and bottom reinforcing steel *(image courtesy of Condor Rebar Consultants, Inc.)*

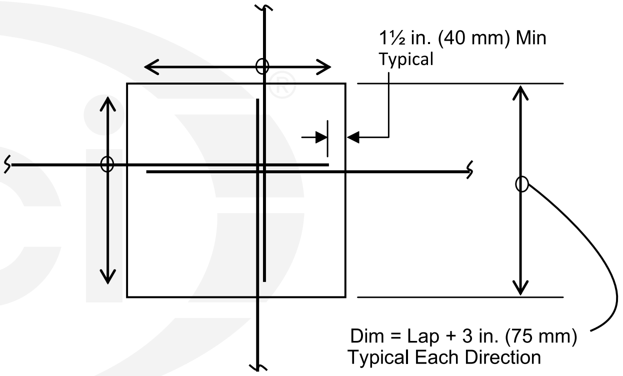

Fig. 4: Simple supported slab infill panel *(image courtesy of Condor Rebar Consultants, Inc.)*

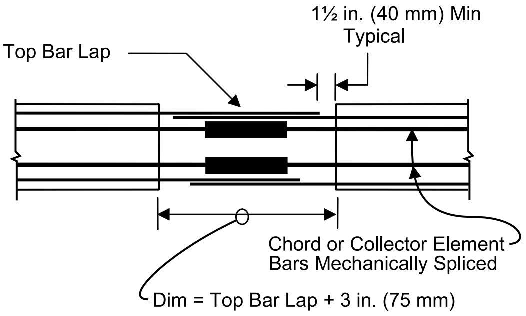

Fig. 5: Top and bottom reinforcing steel with chord or collector element bars *(image courtesy of Condor Rebar Consultants, Inc.)*

closure strip with top and bottom reinforcement and chord steel.

When determining the required lap splice lengths of the reinforcing bars, it's worth noting ACI 318-08, Section 12.2.5, which permits a reduction in tension development based on the amount of reinforcement required versus the amount of reinforcement provided.[4] (Note: lap splice lengths are multiples of tension development lengths; Class A = 1.0 ℓ_d and Class B = 1.3 ℓ_d.) As noted earlier, closure strips are usually placed where moments are small, so the amount of reinforcement in the closure strip could very well be more than is structurally required at that location.

As a simple example, if the amount of reinforcement within the closure strip is twice what is structurally required, ACI 318 would permit a 50% reduction in the lap splice length. Note that there is a limit to how much the lap splice length can be reduced: Section 12.2.1 requires that the tension development length not be less than 12 in. (400 mm).

USE OF MECHANICAL SPLICES/COUPLERS

Sometimes it's not possible to make the closure strip wide enough to accommodate a reinforcing bar splice. In such cases, a grouted mechanical splice sleeve or a threaded coupler should be considered.

Grouted sleeve

The bars to be connected to maintain continuity should be aligned both horizontally and vertically. The grouted coupling sleeve is installed by sliding the sleeve all the way over on one bar. The bar ends are then aligned and the sleeve is slid back over the other bar to be connected. The bar ends will meet in the center of the sleeve with a 1 to 2 in. (25 to 50 mm) gap, which is dependent on the bar size and manufacturer's recommendations. The ends of the grout sleeve are then sealed, and the sleeve is grouted.[5]

The grouted sleeve will have a diameter that is greater than the bars being connected. Thus, it's important to verify that the slab thickness can accommodate the sleeve diameter, top and bottom concrete cover, and an allowance for alignment tolerances.

Threaded coupler

Another option for the closure strip is the use of threaded couplers. Figure 6 shows a sectional detail from the New York State Thruway Authority where threaded couplers are employed on both faces of the longitudinal construction joint to facilitate the lap splice in the closure strip.[6] This detail provides an advantage in that the bars from the previous staged concrete placement are not "hanging" in the closure strip gap, and possibly offering restrictions or interference to the operations in the second stage of construction. When the closure strip (Stage 3) is readied for concrete work, the short lengths of reinforcing bars are inserted into the threaded couplers and lap spliced. Figure 7 shows an example of this splice type.

SOME ADDITIONAL CONSIDERATIONS

Bending bars to be spliced

The practice of bending up reinforcement in staged construction closure strips and then rebending the bars down should be avoided. This is sometimes done on bridge decks because of restricted access or the contractor's perception that they are "in the way anyway." The *Structures Manual* from the New York State Thruway Authority prohibits this practice because it's very difficult to realign the bars properly, and the reinforcing bar coating is likely to become damaged in the bending/rebending operation.[6]

Depending on the bar size and temperature condition, damage to the parent bar could also occur. To avoid any problems, preheating the reinforcing bars during the bending/rebending operation may be warranted, but it might be impractical because of the presence of bar coatings. Thus, this practice is discouraged.

Shear transfer

Once a closure strip is installed, shear transfer across the joint is assumed to occur via shear friction. The reinforcement running through the closure strip is assumed to provide the requisite clamping force for shear friction to occur. The interface surface needs to be clean and rough so the freshly placed closure strip concrete can bond and develop an interface shear strength. If the mating surfaces are not well prepared or the closure strip concrete shrinks excessively, the joint may actually open, thus negating any bond and reducing the shear transfer mechanism; a lower coefficient of friction (μ) may be warranted under such circumstances.

The shear transfer only becomes an issue when highly concentrated loads are anticipated across the joint—for example a bridge deck with concentrated wheel loads or forklift loads on a P/T slab. Partially because of this issue, the Nevada and South Carolina bridge manuals prohibit

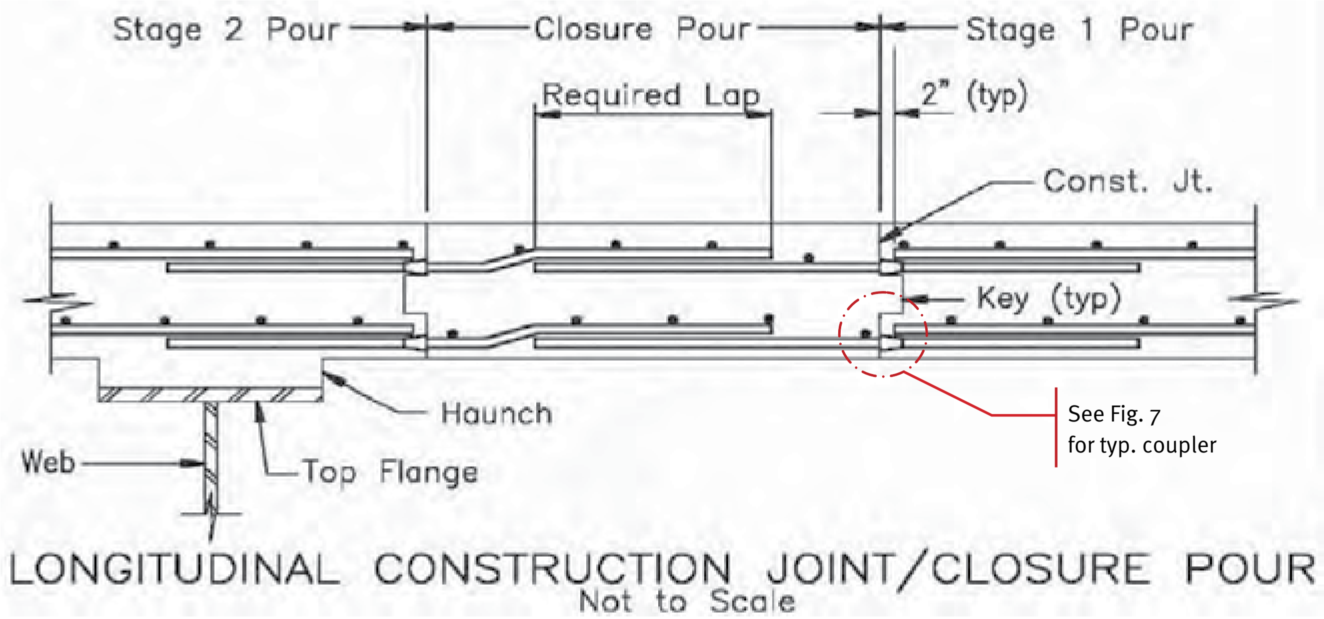

Fig. 6: Closure strip detail[6] (Note: 1 in. = 25 mm) *(image courtesy of Ted Nadratowski, Chief Engineer, New York State Thruway Authority)*

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the longitudinal construction joint in a closure strip to be located beneath a wheel line on the deck.[1,2]

The closure strip detail shown in the *PT Manual* provides good guidance to address the shear transfer mechanism (Fig. 1).[3] Specifically, the detail calls for shear keys, use of nonshrink concrete, and roughening and cleaning the joints. The detail also provides suggestions for waterproofing, should the closure strip be located in an aggressive environment (that is, outdoors or in a parking garage). Figure 6 also shows the addition of shear keys across the longitudinal joint for the staged construction of the bridge deck.

DESIGN CONSIDERATIONS

The designer should carefully consider the dimensions of closure strips and slab infills and their impact on the reinforcing bar details. Chord and collector element reinforcing bars significantly complicate the issue and specific consideration should be given to them.

The aforementioned examples illustrate situations involving slabs, but the same principles would apply to other concrete members such as walls, spandrels, and beams.

Fig. 7: Taper-threaded bar and coupler[5]

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5. ACI Committee 439, "Types of Mechanical Splices for Reinforcing Bars (ACI 439.3R-07)," American Concrete Institute, Farmington Hills, MI, 2007, 20 pp.

6. *Thruway Structures Design Manual*, fourth edition (U.S. Customary Units), New York State Thruway Authority, Albany, NY, March 2010.

Thanks to Dick Birley of Condor Rebar Consultants, Inc., and Neal Anderson of CRSI for providing the information in this article.

Selected for reader interest by the editors.

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Battered Concrete Retaining Walls

Cantilever concrete retaining walls with heights greater than 10 to 12 ft (3 to 3.7 m) will likely have battered or sloped faces. At the wall stem intersection with the footing (toe or heel), the maximum wall thickness is usually selected considering the flexural and shear demands exerted by the retained earth pressures and possible surcharge. The top thickness of the wall is usually on the order of 8 to 12 in. (200 to 300 mm); some state DOTs may have standard minimum top wall thicknesses.

In some instances, a New Jersey-type traffic barrier wall is set atop the retaining wall because of the close proximity of traffic. Impact load application to the top of the wall may be a load case to be considered in design, and thus influence the top wall thickness and reinforcement detailing requirements.

WALL BATTER AND THICKNESS

A concrete retaining wall stem is usually battered to reduce the concrete dead load on the footing. The thickness up the wall can roughly correspond to the flexural demands on the cantilever wall; as the elevation increases and the soil pressure decreases, the thickness of the concrete section can be reduced. Stem thickness up the wall can also be selected based on serviceability to limit the horizontal deflection of the wall due to the retained material or potential forward tilting due to settlement of the toe. Concrete cover requirements or construction conditions can also dictate the stem wall thickness.

A minimum batter of 1:48 (or 1/4 in. per ft) of height is usually recommended for the front face. When the wall deflects or the footing tilts forward after backfilling, the wall will have a resultant vertical appearance.

Some state DOTs have standard retaining wall details that call for batter on the back face of the stem wall; Caltrans has standard details where the design batter is located on the back face. Caltrans also has a requirement that the top of the wall be offset toward the backfill side of the wall when constructed. Thus, after backfilling, the assumption is made that the wall will tilt and/or deflect to a vertical or almost plumb condition. Figure 1 shows the offset values used by Caltrans, from their standard base sheet B3-8, "Retaining Wall Details, No. 1."[1] Caltrans is thus requiring the wall to be formed with batter on the front and back faces, which can be challenging in the field.

DEALING WITH GEOMETRY

Battered walls often present problems for detailers and contractors when the top and bottom of the wall are not parallel, or when the top or bottom of the wall is stepped.

In any consideration of the issues relating to battered walls, there are two universal assumptions. First, the angle of batter is assumed to be constant throughout the entire battered face of the wall. Second, the top of the wall is assumed to have a uniform thickness along its entire length. In cases where the top of the wall is stepped, each step has a different thickness; but that thickness is constant along the length of the step.

This Detailing Corner will deal with walls with only one battered face. The issues are the same for walls with two battered faces but are merely compounded.

DETAILING CORNER

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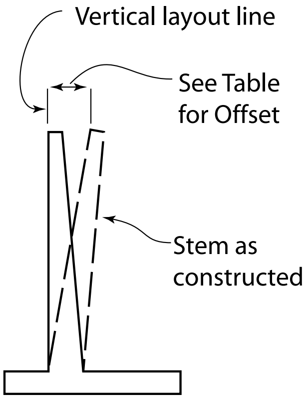

TABLE

H, ft	Offset
4 to 12	H/200
14 to 16	H/160
18 to 20	H/140
22 to 24	H/130
22 to 24	2 1/2 in.

Fig. 1: Wall construction details when the batter is located on the back face (based on Reference 1) (1 ft = 0.3048 m; 1 in. = 25.4 mm)

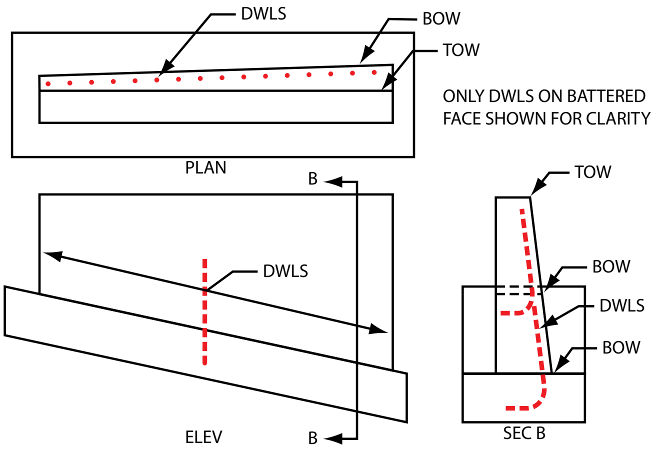

Fig. 4: Schematic of simple battered wall with sloped bottom

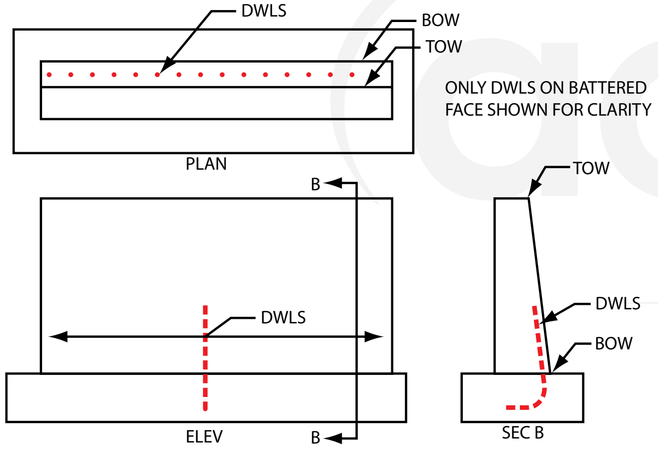

Fig. 2: Schematic of battered wall with parallel top and bottom

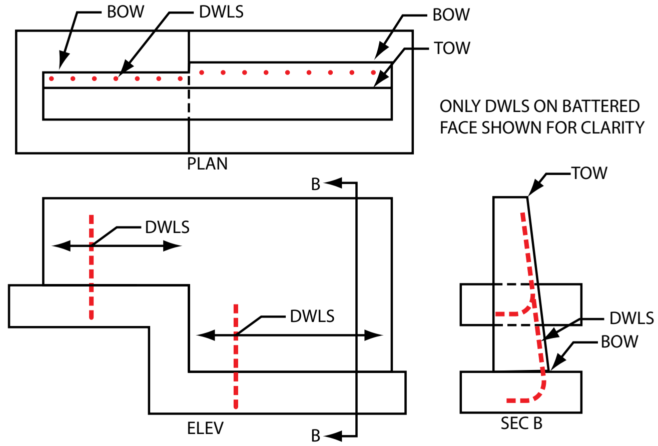

Fig. 3: Schematic of battered wall with stepped bottom

Simple battered wall with parallel top and bottom

Figure 2 illustrates a simple battered wall with a parallel top and bottom. The thickness of both the top and bottom is constant. In the plan view, the top and bottom of the wall are parallel to each other. Correctly locating the footing dowels or other vertical reinforcement to be spliced with the wall vertical reinforcing bars is a simple procedure.

Simple battered wall with stepped bottom

Figure 3 shows a battered wall with a parallel top and bottom but with a stepped bottom. The thickness of the bottom of the wall is constant along the length of each step, but the wall is thicker at the lower elevation step. Note that the rate of batter of the wall (that is, change in height divided by the change in thickness) is constant. In the plan view, the top and bottom of the wall are parallel to each other. Correctly locating the dowels for the wall vertical bars is not quite so simple. The battered face dowels are not in line; rather, they're at different locations in plan at each step location. They're parallel to the battered back face of the wall. Care must be taken when determining the location of the battered face.

Simple battered wall with sloped bottom

Figure 4 represents a battered wall with a sloped bottom. The thickness along the bottom varies throughout the length of the wall, with the wall stem becoming thicker as the footing drops in elevation. As shown in Fig. 4, the dowels are parallel to the battered back face, but each is at a different distance from the vertical front face of the wall.

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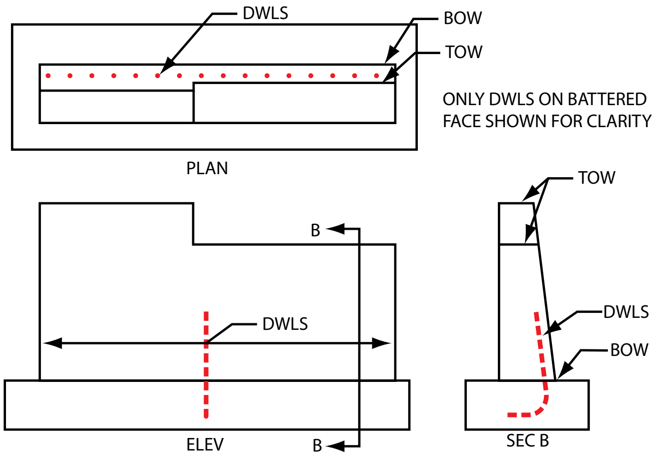

Fig. 5: Schematic of battered wall with stepped top

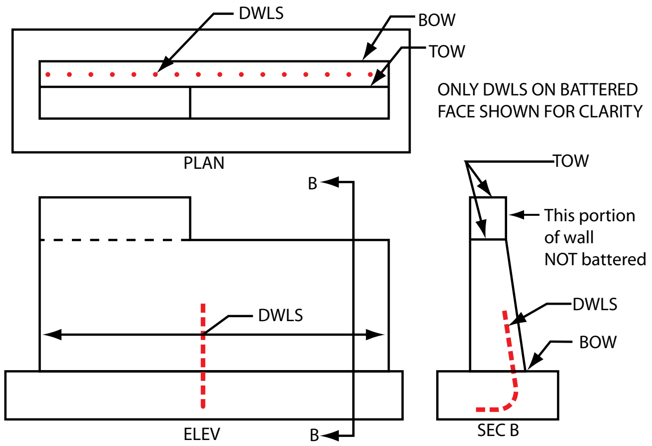

Fig. 6: Schematic of hybrid battered wall with uniform width stepped top

Simple battered wall with stepped top

Figure 5 shows a simple battered wall with a stepped top. The top wall thickness at the higher step is smaller than the top wall thickness at the lower step. In this type of configuration, it's impossible to have the same thickness at both upper and lower steps. If there is some special architectural need to have the two dimensions identical, then a type of hybrid battered wall is required (Fig. 6).

Hybrid battered wall with uniform width stepped top

Figure 6 illustrates a special case of a simple battered wall with a stepped top, with the added requirement that the top of the wall at both steps be uniform in thickness. This may be necessary for architectural reasons, such as the installation of a metal rail or masonry wall above. In this case, the wall can be battered only up to the lowest step at the top of the wall. The entire wall above this step cannot be battered and must maintain the same thickness as the top of the wall at the lowest step. The battered face dowels are in a straight line, parallel to the vertical face.

Simple battered wall with sloped top

Figure 7 represents a simple battered wall with the top of the wall sloped from one end to the other. If the top wall thickness is maintained uniform along its entire length, the batter angle will vary along the length. Moreover, the thickness of the bottom of the wall varies along its length, becoming narrower as the wall becomes shorter. As shown in Fig. 7, the dowels are parallel to the battered back face, not the vertical face of the wall.

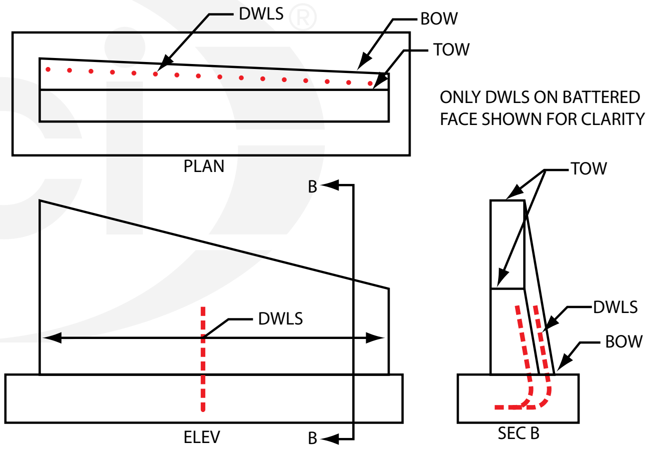

Fig. 7: Schematic of battered wall with sloped top

DOWEL AND VERTICAL REINFORCING BAR DETAILS

Regarding the vertical reinforcement in the stem of the retaining wall, the maximum design moment occurs at the bottom, where the stem intersects the base. Because the design moment decreases rapidly moving up from the base, however, there is an opportunity to adjust the reinforcement details accordingly, based on the height of the wall.

Low walls

When the stem is up to 4 to 5 ft (1.2 to 1.5 m) high, it's most economical to simply extend the dowels from the base to the full height of the stem (Fig. 8(a)). This will require accurate fastening of the dowel bars during concrete placement to ensure correct location.

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Medium walls

As the stem wall height increases past roughly 5 ft (1.5 m), the reinforcement details can be adjusted to take advantage of the decreasing design moment. A handy rule of thumb: assuming only equivalent fluid pressure behind the stem, the design moment is reduced to half its maximum value at one-fifth the stem height. Similarly, the design moment is reduced to one-third its maximum value at three-tenths the stem height. As an example, for a 15 ft (4.6 m) high stem, the design moment is one-half its maximum value at 3 ft (0.9 m) above the base and is one-third its maximum value at 4.5 ft (1.4 m) above the base.

The height of the dowels extending

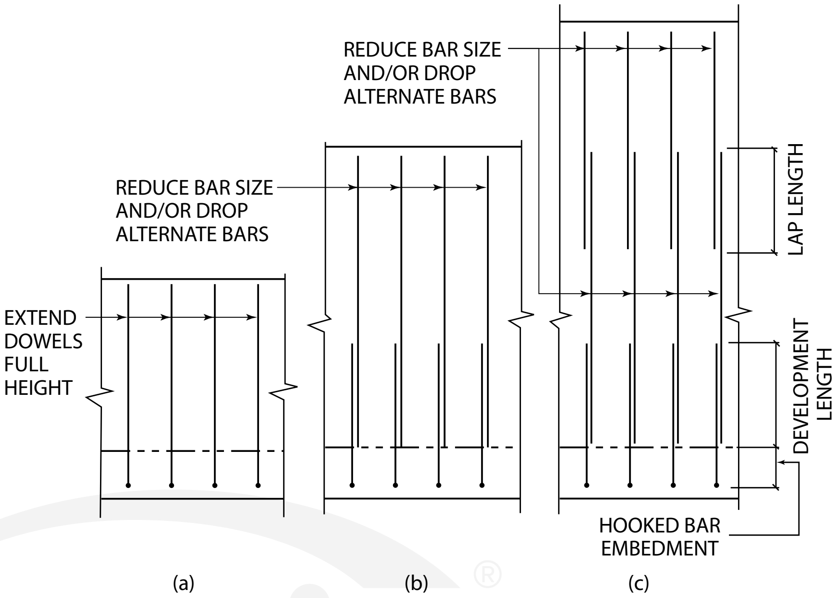

Fig. 8: Dowel and vertical bar details: (a) low walls; (b) medium walls; and (c) high walls (based on Reference 3)

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The following are some of the courses that have recently been added to the program:

- **RAP Bulletin 10—Leveling and Reprofiling of Vertical and Overhead Surfaces;**
- **RAP Bulletin 11—Slabjacking; and**
- **TC-CSC—RILEM Report on Self-Compacting Concrete (Parts 1 & 2).**

In addition, the program includes courses on the following topics:

- **Cracking;**
- **Slabs;**
- **Foundations;**
- **Aggregates;**
- **Reinforcement;**
- **Cementitious materials;**
- **Admixtures;**
- **Repair; and**
- **Shoring.**

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up from the footing can be discontinued at a certain height. Figure 8(b) shows an example detail where the dowels are lap spliced to straight vertical bars and the diameter of these vertical bars can be reduced in size (compared with the diameter of the dowels) or the reinforcing bar size can be kept the same but dropping alternate bars. The dowel bars would essentially be used to resist the maximum moment demand and then extended until they're no longer needed.

When determining the configuration of the stem reinforcing steel, the designer must be careful in choosing the specific reinforcement details. Various key elevations up the stem (at the base, midway up the dowels, at the top of the dowels, etc.) should be checked to verify that the reinforcement provided by both the dowels and the straight vertical bars is adequate in flexure.

As an example, let's assume that the dowels are No. 8 (No. 25) bars at 12 in. (300 mm) on center and that they extend 4 ft (1.2 m) up the stem, which is the tension development length for the dowels in 4000 psi (28 MPa) concrete. Let's also assume the designer has selected No. 6 (No. 19) bars for the straight vertical bars and these bars have a tension development length of 29 in. (737 mm). These bars are placed so their ends rest on the already cast base footing. At 2 ft (600 mm) above the base, the dowel bars and vertical wall reinforcement are partially developed. Calculations would be:

Dowels:	No. 8 @ 12 in. on center = 0.79 in.^{2}/ft Percentage of bar development = 50% Effective reinforcement @ 2 ft = 0.50 (0.79) = 0.395 in.^{2}/ft
Verticals:	No. 6 @ 12 in. on center = 0.44 in.^{2}/ft Percentage of bar development = 24/29 x 100 = 83% Effective reinforcement @ 2 ft = 0.83 (0.44) = 0.365 in.^{2}/ft
Total area:	0.395 + 0.365 = 0.760 in.^{2}/ft

For this example, the designer will need to verify that 0.760 in.^{2}/ft of reinforcement is adequate for the design moment at 2 ft (600 mm) above the base footing.

High walls

When the stem exceeds roughly 20 ft (6.1 m) in height, a further adjustment in the reinforcement details is possible. As shown in Fig. 8(c), the dowel bars extend above the base a distance equal to the tension development length of these bars. The remaining vertical reinforcement is provided by two (or more) runs of straight bars that are lap spliced up the stem. Some important points to remember:

- The moment capacity at the wall base is dependent on the reinforcement provided by the dowels, so these bars must extend up into the stem a distance of at least the tension development length or the required lap splice length, whichever is greater. When the dowel bars are a different size than the straight vertical bars, Section 12.15.3 of ACI 318-08 requires that the lap splice length be the larger of the tension development length of the larger bar and the tension lap splice length of the smaller bar.[2]
- When determining where the vertical reinforcement is cut off in the stem, consideration must be given to Section 12.10.3 of ACI 318-08, which requires that the reinforcement extends beyond the point at which it is no longer needed—a distance equal to the effective depth or 12 bar diameters, whichever is greater.[2]
- If the stem is battered, the effective depth decreases moving up the stem. The varying effective depth must be considered when determining the required amount of flexural reinforcement at a specific stem elevation.

When the reinforcement details become complicated, as illustrated in Fig. 8(c), the engineer should document the design moments, effective depths, required reinforcement, and actual reinforcement at several elevations up the stem. A spreadsheet is a convenient tool for this.

SUMMARY

The placement of the vertical dowel bars and the vertical reinforcing bars is dependent on the retaining wall configuration—sloped, stepped, and/or uniform top wall thickness. When the wall batter is factored into the geometry, the reinforcing bar location is not straightforward and should be detailed appropriately on the drawings.

References

1. "Retaining Wall Details No. 1," Standard Plan B3-8, State of California, Department of Transportation, Sacramento, CA.

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

3. Brooks, H., *Basics of Retaining Wall Design*, eighth edition, HBA Publications, Corona del Mar, CA, 2010, 220 pp.

Thanks to Dick Birley of Condor Rebar Consultants, Inc., and Neal Anderson of CRSI for providing the information in this article.

Selected for reader interest by the editors.

Detailing Corner

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

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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;

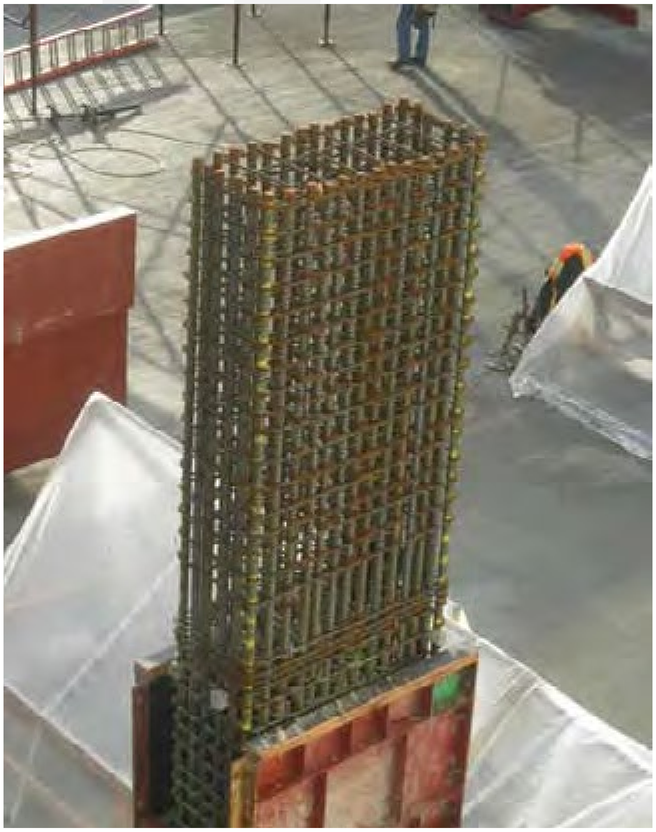

Fig. 2: A column cage with many large vertical bars and crossties can be stable enough to eliminate the need for temporary bracing

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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.

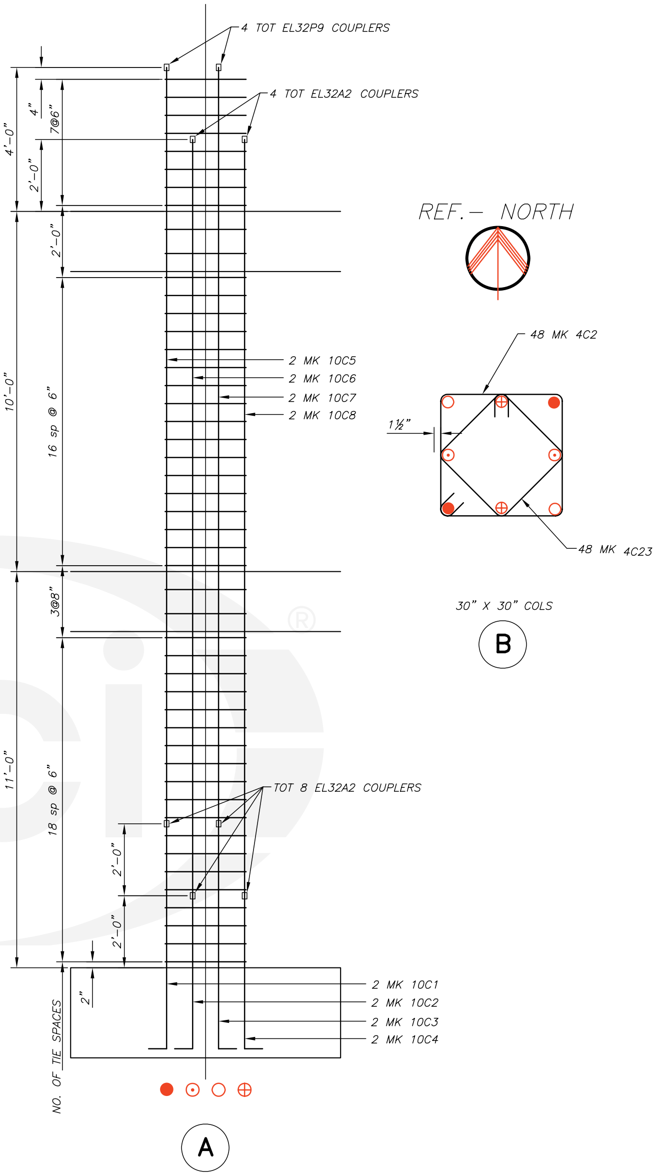

Fig. 3: Typical column details, showing specific bar identification marks and reference north for orientation (colored for emphasis). Column dowel bars are included to show relationship with other bars in the column (1 ft = 0.3048 m; 1 in. = 25.4 mm)

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

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

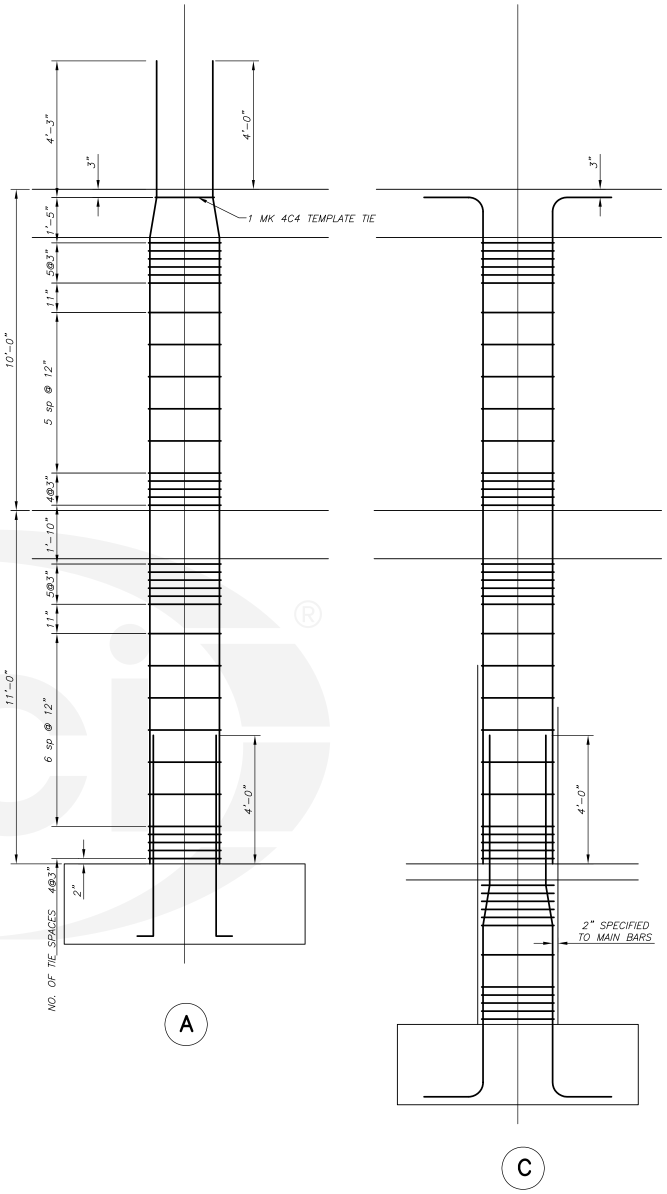

Fig. 5: Typical column details, showing bar offsets and distance from longitudinal bar ends to first and last tie (1 ft = 0.3048 m; 1 in. = 25.4 mm)

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.

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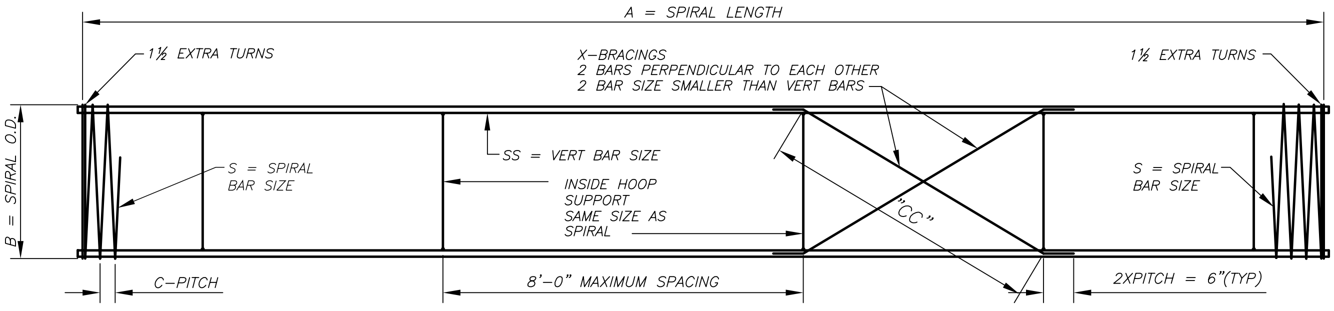

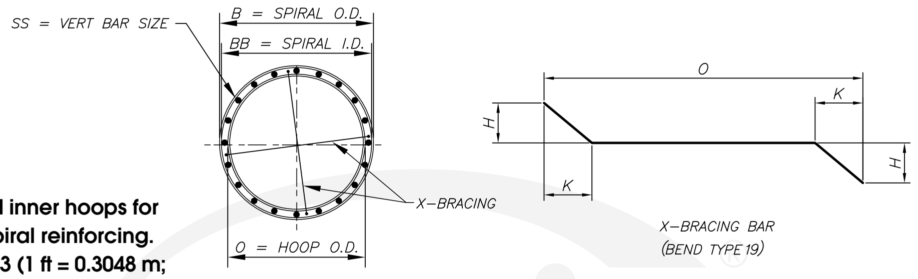

Fig. 6: Cross-bracing and inner hoops for a circular column with spiral reinforcing. Bar type is per Reference 3 (1 ft = 0.3048 m; 1 in. = 25.4 mm)

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.

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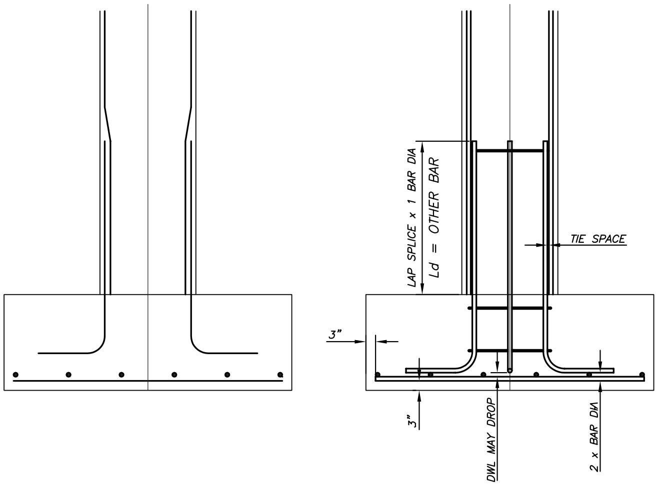
The completed column cage will also have bars added to the pick or lift points to add local strength. Figure 7 shows a well-braced caisson (drilled shaft) cage with X-bracing, inner hoops, and lift point reinforcing, which makes it rigid enough to be picked without deforming.

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



(a) (b)

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:

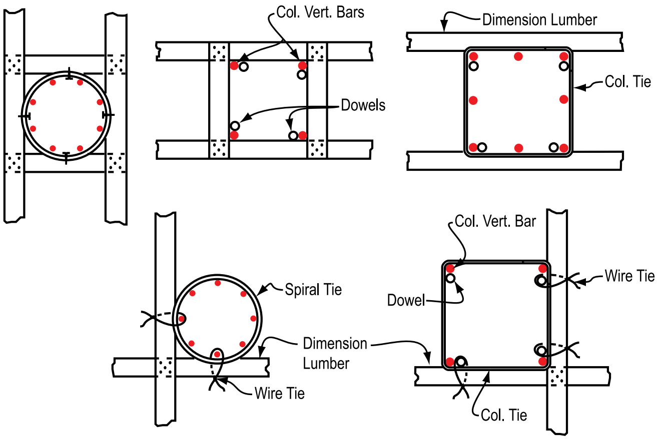


Fig. 9: Examples of templates and ties used for positioning column dowels

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- 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.

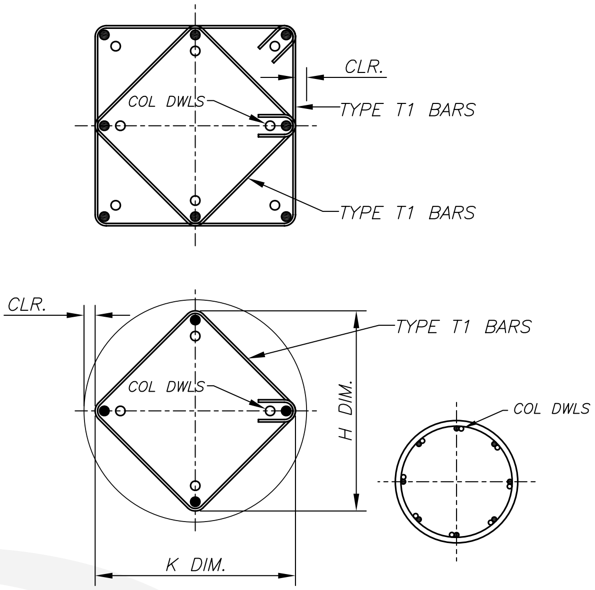


Fig. 10: Typical sections at longitudinal bar splices in columns with rectangular ties. Typical vertical bar splice locations in a circular column with circular ties or spiral are shown for reference. Bar types are per Reference 3

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.

Thanks to Amadeus Magpile of Barlines Rebar Estimating and Detailing, Inc., and Neal Anderson of CRSI for providing the information in this article.

Detailing Corner

RFIs on Circular Ties, Rotating Hooks, Staggered Lap Splices, and Closure Strips

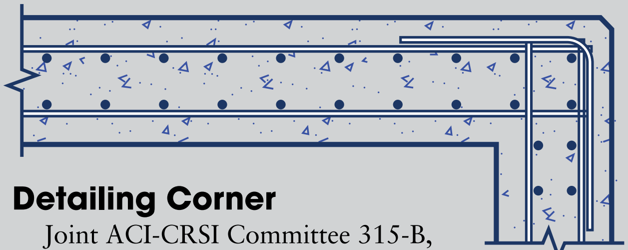
RFIs 11-05, 11-06, 11-07, 11-08, and 11-09

In this month's "Detailing Corner," CRSI staff responds to some outstanding requests for information (RFIs) submitted by reinforcing bar detailers, structural engineers, and construction engineers. We thank those who contacted us and encourage all readers to participate in this forum.

RFI 11-05: Construction details for drilled shafts commonly show the ends of circular ties hooked around a single vertical bar (Fig. 1(a)). Bar placement is slowed because a longitudinal bar must be threaded through the two hooks. We typically resolve this problem by estimating and detailing circular ties with ends partially lapped and hooked around two separate vertical bars (Fig. 1(b)). The longitudinal bar placement is simplified because threading isn't required. Also, because the alternate detail provides a short lap splice in addition to the hooked anchorages, we believe it is superior to the common detail. We were therefore surprised when, on a recent project, the cages assembled using the alternate detail were rejected by the Inspector, the Contractor, and the Engineer—all saying the original detail was better than the alternate we provided. Could you please comment?

Response: The timing of this RFI couldn't be better. Up through ACI 318-08,[1] Section 7.10.5.3 of the Code addressed circular ties with the statement: "Where longitudinal bars are located around the perimeter of a circle, a complete circular tie shall be permitted." A "complete circular tie" was not defined, and explicit requirements for anchorage of discrete circular ties were not provided. However, the commentary to Section 7.10.5 stated:

> Where longitudinal bars are arranged in a circular pattern, only one circular tie per specified spacing is required. This requirement can be satisfied by a



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> continuous circular tie (helix) at larger pitch than required for spirals under [Section] 10.9.3, the maximum pitch being equal to the required tie spacing (see also [Section] 7.10.4.3).

Although this commentary didn't provide guidance for discrete circular ties, ACI 315-99[2] provides a Type T3 tie detail (Fig. 1(c)), showing a circular tie with end extensions. The end extensions are sufficient to provide a lap splice, so this is commonly interpreted as a complete circular tie.

In ACI 318-11,[3] a complete circular tie has been explicitly defined with the addition of a new Section 7.10.5.4:

> **7.10.5.4 –** Where longitudinal bars are located around the perimeter of a circle, a complete circular tie shall be permitted. The ends of the circular tie shall overlap by not less than 6 in. (152 mm) and terminate with standard hooks that engage a longitudinal column bar. Overlaps at ends of adjacent circular ties shall be staggered around the perimeter enclosing the longitudinal bars.

The requirements of the new ACI 318 section on circular ties closely match your alternate detail shown in Fig. 1(b). Therefore, your alternate detail should be acceptable, provided the circular tie lap is at least 6 in. (152 mm) and successive circular ties are arranged around the perimeter so that the lap splices are staggered (that is, not engaging the same two longitudinal bars). It's anticipated that ACI 315 will be updated to supplement the Type 3 tie with a tie similar to the Type 3A tie currently used in Canada,[4] as illustrated in Fig. 1(d).

RFI 11-06: "Detailing Concrete Columns" (*Concrete International*, V. 33, No. 8, Aug. 2011, pp. 47-53) led to a discussion in our office regarding the required lap splice length for circular ties. As illustrated in Fig. 2, our state DOT office uses a Class B splice modified for the top bar effect and coating. We also require that the splices on alternate circular ties be rotated 90 degrees. Do the ACI or AASHTO codes specifically spell out the lap length requirements?

Response: The response to RFI 11-05 addresses the **new** ACI 318 Code provisions for detailing single, circular tie terminations. While the lap-splice detail you present was commonly considered to comply with previous Code requirements for a complete circular tie, it's not ideal from detailing and structural behavior perspectives, as spalling of the column cover (shell) concrete would be expected to expose the splice regions and eliminate the confining effect of the cover on the splice. The new Code provisions provide a much more positive anchorage. Should the concrete cover spall because of load, damage, or corrosion, the tie will remain effective in confining the longitudinal bars and column core.

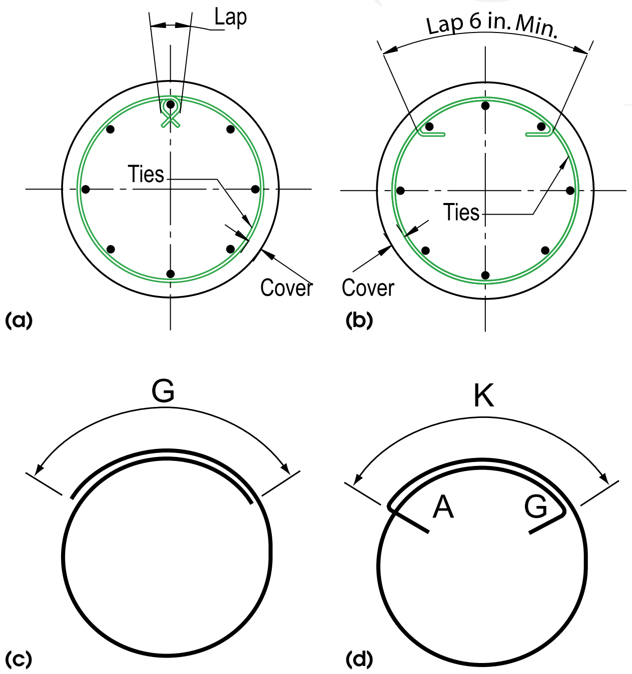

Fig. 1: Construction details for circular ties in drilled shafts: (a) tie hooked around single bar; (b) tie lapped and hooked around separate vertical bars; (c) the Type 3 circular tie detail per Reference 2; and (d) the Type 3A circular tie detail per Reference 4 (1 in. = 25 mm)

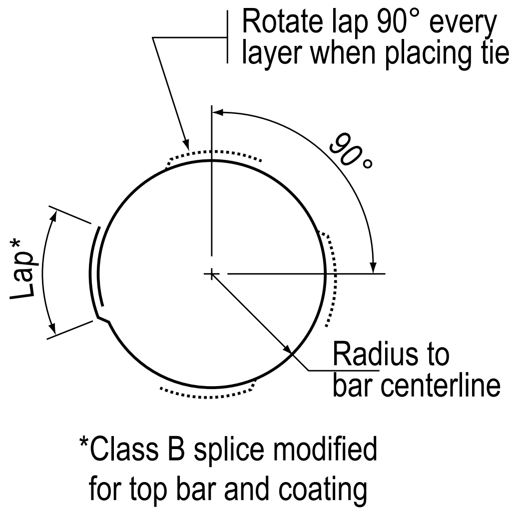

Fig. 2: A standard DOT detail for complete circular ties, adapted from Fig. 6.6.4.1.2.2-1 of Reference 6

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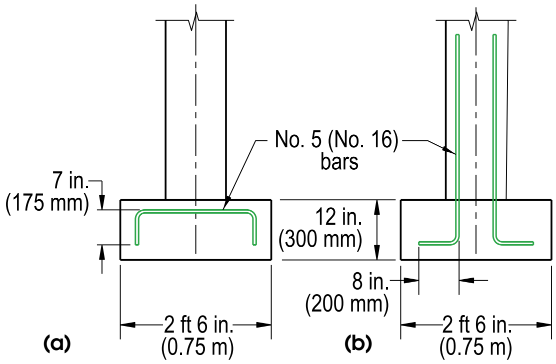

Fig. 3: Because the "A or G" dimension is 10 in. (250 mm) for a No. 5 (No. 16) bar (refer to Fig. 4), the restricted depth provided in this footing will necessitate rotation of the 90-degree hook extensions on: (a) the footing bars; and (b) the column dowels

To our knowledge, the AASHTO LRFD Bridge Design Specifications[5] remain unchanged from your DOT detail (Fig. 2). However, the recent ACI 318 Code hook anchorage modification to the single circular tie pattern provides a better tie detail, which we would recommend adopting given the reasons herein.

RFI 11-07: As a standard practice, we detail 180-degree hooks when a section is too shallow to allow adequate cover or hook extension for 90-degree hooks (Fig. 3). Alternatively, we detail 90-degree hooks with the hooks rotated to reduce the projected length of the hook extensions. Rotating the hooks is easily accomplished on vertical dowels, because the hook extensions are horizontal, and generally rest on and are tied to continuous bars. However, gravity will force the hook extensions for top horizontal bars, such as in slabs or footings, to rotate to the vertical, so each bar extension, if rotated, must be supported with spacers or tied to another "sacrificial" bar. Could you please comment?

Response: Section 12.5 of ACI 318 defines the same development length (ℓ_{dh}) for both 90- and 180-degree standard hooks, so a 180-degree hook can make for a better fit in tight places. As shown in

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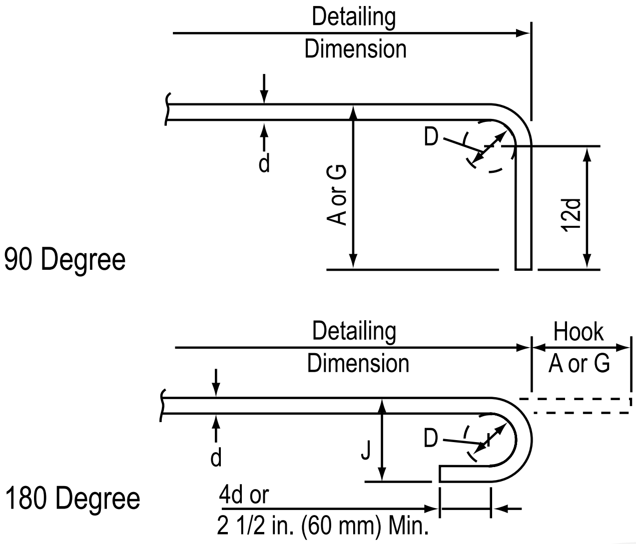

Bar Size No.	90-Degree Hook "A or G"	180-Degree Hook "J" Dimension	Difference In Width
3	6 in.	3 in.	3 in.
4	8 in.	4 in.	4 in.
5	10 in.	5 in.	5 in.
6	1 ft	6 in.	6 in.
7	1 ft 2 in.	7 in.	7 in.
8	1 ft 4 in.	8 in.	8 in.
9	1 ft 7 in.	11 3/4 in.	7 1/4 in.
10	1 ft 10 in.	1 ft 1 1/4 in.	8 3/4 in.
11	2 ft 0 in.	1 ft 2 3/4 in.	9 1/4 in.
14	2 ft 7 in.	1 ft 9 3/4 in.	9 1/4 in.
18	3 ft 5 in.	2 ft 4 1/2 in.	1 ft 0 1/2 in.

Fig. 4: Differences in widths of standard 90- and 180-degree hooks (1 in. = 25 mm)

Fig. 4, the difference in the widths of the two standard hooks (the "A or G" dimension of the 90-degree hook and the "J" dimension of the 180-degree hook) can vary from 3 in. for a No. 3 bar (75 mm for a No. 10 bar) to 12.5 in. for a No. 18 bar (320 mm for a No. 57 bar).

Note that 180-degree hooks must be embedded in a section with adequate depth to provide proper cover over the hook end. This will likely not govern, but it needs to be checked. For example, if 90-degree hooks are replaced with 180-degree hooks (Fig. 3(b)) on column dowels, the dowels must be embedded deep enough into the footing to allow the hook ends to have the required concrete cover over the projecting tail of the hook. For cases like these, Table 1 provides the minimum embedment for 180-degree hooks to provide 2 in. (50 mm) of concrete cover beyond the hook.

Table 1:
Minimum embedment required to provide 2 in. (50 mm) cover over the tail of a 180-degree standard hook

Bar size no.	Minimum embedment, in.
3	6
4	7
5	7
6	8
7	9
8	10
9	13
10	14
11	16
14	20
18	26

(1 in. = 25 mm)

If switching from a 90-degree hook to a 180-degree hook does not provide the required clearance, then rotating 90-degree hooks can be investigated. Besides the constructibility issues raised in the RFI, it's important to note that there are currently no provisions or guidance on how far hooks can be rotated or tilted without affecting their ability to develop the bars or compromising the performance of the reinforced concrete member itself. As an example, consider a slab with all the top bars at a support terminating in hooks. If all the hooks were rotated 90 degrees with the hooks lying in a single plane, would this arrangement cause a weakened, splitting plane in the concrete and lead to reduced performance? Perhaps.

In an effort to answer this question, research is currently underway to study the effect of rotating hooks. The specific goals of the research project are to:

- Evaluate 90- and 180-degree ACI standard hooks to determine the influence of the hook rotation angle on the development of the bar;
- Study the influence of confinement on the development of rotated hooks; and
- Develop design recommendations for limits of rotating hooks.

This research project is being sponsored by the CRSI Education & Research Foundation with testing being conducted at the Missouri University of Science & Technology.

RFI 11-08: Rather than placing lap splices side-by-side (Fig. 5(a)), we detail staggered laps, as shown in Fig. 5(b). An alternate is shown in Fig. 5(c), where there is a gap between the lap splices. Does the configuration shown

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in Fig. 5(c) have any advantages over that shown in Fig. 5(b)?

Response: Although there is no general requirement for the staggering of lap splices, ACI 318[3] acknowledges the benefits of staggering by requiring staggered configurations of bars and splices under various conditions, as listed in Table 2.

Although it is allowed, the reinforcing bar layout configuration shown in Fig. 5(b) is not the most ideal. Because the bar ends of successive terminated bars are aligned, there is a strong tendency for a splitting crack to develop in the concrete, coincident with the bar ends. This is illustrated in Fig. 6(a). Transverse reinforcement in this region may provide confinement and help the situation, but providing a gap between the ends of the staggered lap splices is more desirable. The layout condition shown in Fig. 5(c) is better, as the crack width will be narrower if it develops at the bar ends. A condition similar to Fig. 5(c) is shown in Fig. 6(b).

According to Stöckl,[7] the staggering of lap splices in beams (providing a "negative" gap, as shown in Fig. 6(c)) can reduce the width of flexural cracks at the ends of lap splices, provided that the stagger distance is at least one-half the lap splice length. For a Class A lap splice, with the lap splice length ℓ_{dl} equal to tension development length ℓ_d, the minimum stagger would be $0.5\ell_d$. This is illustrated in Fig. 6(c). For a Class B lap splice, with the lap length of $1.3\ell_d$, the minimum stagger would be $0.65\ell_d$. In either case, a closer stagger where the staggered regions overlap (a negative gap) provides the best structural behavior and will be consistent with the recommendations from Reference 7.

As an aside, one needs to be mindful of the various stagger lengths listed in Table 2. Depending on the condition, these lengths are expressed in terms of either bar diameters, dimensions (in. or mm), or ℓ_d.

RFI 11-09: "Closure Strips and Lapped Reinforcement" (*Concrete International*, V. 33, No. 4, Apr. 2011, pp. 49-53) has the following statement on p. 51:

> When determining the required lap splice lengths of the reinforcing bars, it's worth noting ACI 318-08, Section 12.2.5, which permits a reduction in tension development based on the amount of reinforcement required versus the amount of reinforcement provided. (Note: lap splice lengths are multiples of tension development lengths; Class A = $1.0\ell_d$ and Class B = $1.3\ell_d$.) As noted earlier, closure strips are usually placed where moments are small, so the amount of reinforcement in the closure strip could very well be more than is structurally required at that location.

This paragraph is erroneous. Lap splice lengths must not be reduced by invoking ACI 318-08, Section 12.2.5. Section 12.15.1 of ACI 318-08 explicitly excludes the provisions of Section 12.2.5, so a warning against this common mistake would be more appropriate. Perhaps a discussion of this exclusion should be covered in a future "Detailing Corner" article.

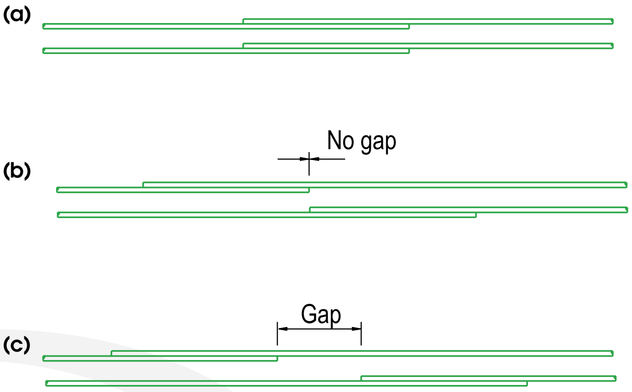

Fig. 5: Lap splice options: (a) aligned; (b) staggered, with no gap; and (c) staggered, with a gap

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Table 2:
Stagger requirements for splices per ACI 318-11

Condition	Stagger distance
Bars within a bundle (Section 7.6.6.4)	40d_b
Mechanical or welded splices that do not meet the 1.25 yield-strength requirement (Section 12.15.5.1)	24 in.
Mechanical or welded splices in tension tie members (Section 12.15.6)	30 in.
Lap splices in columns (Section 12.17.2.2)	ℓ_d
End-bearing splices in columns (Section 12.17.4)	No length specified
Splices of principal tensile reinforcement in shells (Section 19.4.12)	ℓ_d

(1 in. = 25 mm)

Response: You are correct. Section 12.15.1 of ACI 318-08 excludes the modification factor of Section 12.2.5 (Excess Reinforcement) from the calculation of tension lap splice lengths.

Justification for this exclusion is explained in Commentary Section R12.15.1:

> The development length ℓ_d used to obtain lap length should be based on f_y because the splice classifications already reflect any excess reinforcement at the splice location; therefore, the factor from 12.2.5 for excess A_s should not be used.

Accordingly, tension lap splice lengths should be based on the specified yield strength of the reinforcement, f_y, regardless of splice location or demand (stress). Thank you for this correction.

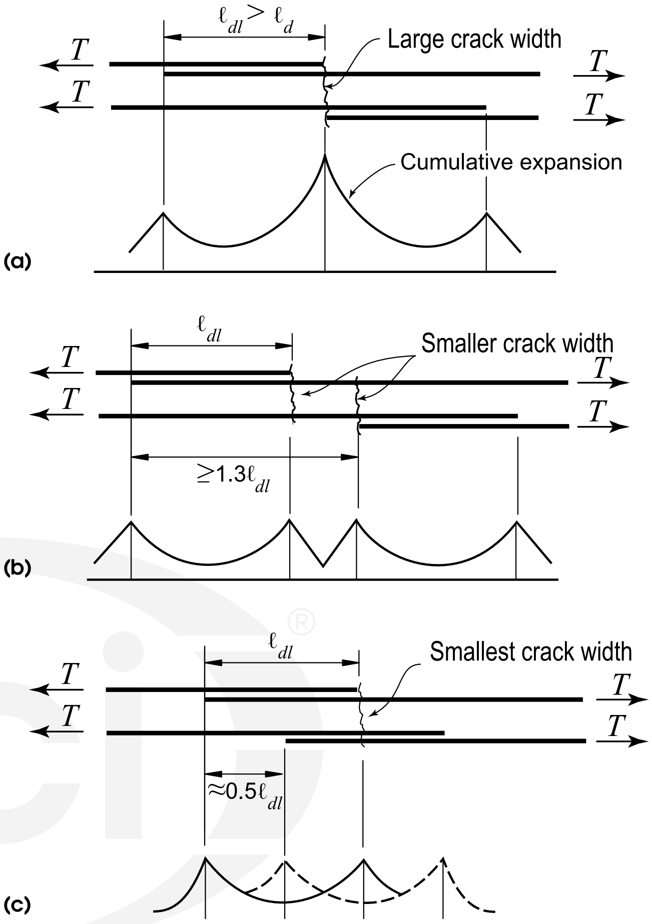

Fig. 6: Crack widths are functions of splice locations: (a) superimposed effects can be adverse, resulting in large crack width even when lap length ℓ_{dl} exceeds tension development length ℓ_d; (b) avoiding superposition reduces crack width; and (c) low superposition results in smallest crack width (based on Reference 7)

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

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5. "AASHTO LRFD Bridge Design Specifications, Customary U.S. Units, fifth edition, with 2010 Interim Revisions," American Association of State Highway and Transportation Officials, Washington, DC, 2010, 1822 pp.

6. "LRFD Design Manual," Iowa Department of Transportation, Ames, IA, 2001, p. 6.6:45 (www.iowadot.gov/bridge/manuallrfd.htm)

7. Stöckl, S., "Übergreifungsstöße von zugbeanspruchten Bewehrungsstäben (Lap Splicing of Reinforcing Bars Subject to Tension)," Beton- und Stahlbetonbau, V. 10, Ernst & Sohn, Berlin, Germany, 1972, pp. 229-234. (in German)

Thanks to Amadeus Magpile of Barlines Rebar Estimating and Detailing, Inc., and Neal Anderson of CRSI for providing the information in this article.

Selected for reader interest by the editors.

Detailing Corner

Dimensions of Sloped Walls and a Clarification to Mechanical Splice Staggering (RFI 11-10)

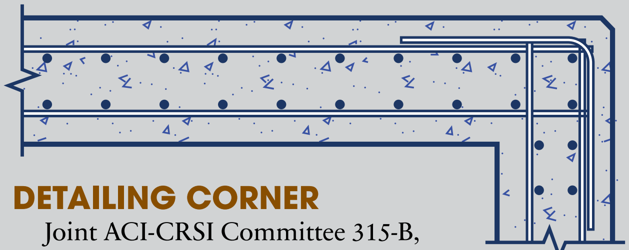
In this month's Detailing Corner, we examine dimensions of sloped walls and how they can affect the reinforcing bar details. In addition, we provide a clarification to the August 2011 *Concrete International* article, "Detailing Concrete Columns," in response to an RFI from members of Joint ACI-ASCE Committee 408, Development and Splicing of Deformed Bars. We thank those who contacted us and encourage all readers to participate in this forum.

Sloped Wall Dimensions

Know your height

Dimensioning wall heights on a slope can be confusing, depending on the height desired for the wall. Figure 1 shows a 10 ft 0 in. (3.05 m) high wall that follows the existing grade with an approximately constant slope. It's customary to dimension the height of a wall along a vertical (plumb) line. This gives a wall a uniform height along its entire length, provided the wall slope is uniform. In Fig. 1, the *A* dimension will be less than the 10 ft dimensioned height along a plumb line, but this dimension nevertheless remains uniform along the wall's entire length.

Figure 2 illustrates a somewhat exaggerated condition where the grade starts at a gradual slope on the left and becomes steeper on the right. In this case, the slope of the wall is not uniform along the entire length. Dimensioning the height of the wall as 10 ft 0 in. (3.05 m) along the vertical gives a wall of uniform height along its entire length, but the dimension of the wall along a line perpendicular to the bottom of the wall is increasingly shorter from the left to the right. From this point of view, this wall is not uniform in height along its entire length. This may or may not be a concern, depending on the wall's intended purpose and/or aesthetic requirements.



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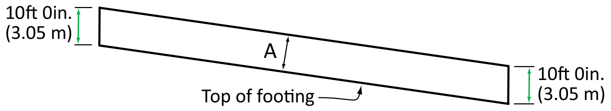

Fig. 1: Wall with a uniform slope

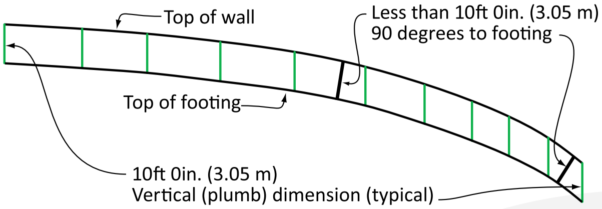

Fig. 2: Wall with a nonuniform slope. Dimension of wall perpendicular to the bottom becomes increasingly smaller as the slope of the grade increases

As to where this may be an issue, consider this wall as one of the sides of a lined, three-sided water channel or a covered water flume. The cross-sectional area of the channel or flume must be constant to provide the necessary drainage capacity, so dimensioning the actual height vertically along a plumb line would be incorrect. The dimension perpendicular to the bottom of the wall is the critical height dimension to maintain the waterway opening, and thus would have to be constant. In such an instance, the vertical plumb dimension would vary, increasing as the slope becomes steeper.

Assuming that the wall can be detailed with a varying vertical (plumb) dimension as shown in Fig. 2, the spacing between "horizontal" wall bars will have to decrease for all of the bars to fit in the wall, moving left to right. Note that the term "horizontal" is used rather loosely here, as it actually refers to the reinforcing bars parallel to the bottom of the wall on the slope. In other words, the bar spacing will narrow so all the bars can fit as the wall gets shorter at the right end, so congestion of the bars may become an issue and minimum bar spacing may need to be verified.

Alternately, as the wall gets shorter at the right end, some of the horizontal runs of bars may be discontinued to maintain a more uniform or consistent spacing of the bars in the wall.

Stairs

The issue illustrated in Fig. 2 arises frequently in dimensioning parapets along stairways with landings. For instance, in Fig. 3, the parapet will usually carry a single dimension; in this case, the 4 ft 0 in. (1.22 m) along the vertical is normally dimensioned on the left only. It's obvious that this dimension holds for the portions of the wall at the upper and lower landings. But at the sloped section at the stairway, what is the intended height of the parapet? More appropriately, what is the architect or the designer (you) expecting?

One possible solution could be as shown in Fig. 3(a). From an architectural point of view, this condition is not visually appealing, and a shorter wall height within the stair run may result in a wall height that doesn't meet the code requirements for railing height—something to watch.

Figure 3(b) presents a more visually appealing solution because the concrete band appears to be a constant dimension. However, it does present a slight issue. The height from the slab and stair to the top of the parapet must be constant, yet the vertical dimension at the stair is greater than at the upper or lower slab levels. Architects typically solve this dilemma by locating the parapet soffit below the slab and stair soffits to compensate for the discrepancy in dimensions. By constructing the wall in this manner, the rail height above the stair and landings can be consistent and the wall will appear to have a constant height.

Design considerations

The designer must be aware that the method of dimensioning has critical ramifications, especially when considering sloped concrete elements exposed to view. The designer must determine which dimension is critical in each particular instance and be sure it is presented clearly and unambiguously.

RFI 11-10: In the August 2011 *Concrete International* Detailing Corner article, "Detailing Concrete Columns," the following statement is made:

"ACI 318-08 requires mechanical splices be staggered, which results in both short and long vertical bars in the column run."

Unfortunately, this maintains the old mythology of staggering being required at all times, which is not necessarily the case. Because staggering is difficult to detail and a costly option to produce, this issue needs clarification.

ACI 318-08[1] requires staggering only when the mechanical splice strength is less than Type 1 (namely, less than 125% of the specified yield strength, f_y, of the reinforcement), or when full mechanical splices are used in tension tie members. In today's domestic (U.S.) market, there are no mechanical splices promoted with design strengths less than Type 1. Thus, the general case is that staggering is not required. In fact, Commentary Section R12.15.5 of ACI 318-08 states, in part: "A full mechanical or welded splice conforming to 12.14.3.2 or 12.14.3.4 can be used without the stagger requirement instead of the lower strength mechanical splice."

Response: You are correct in that the ACI 318-08[1] (and now ACI 318-11[2]) building code requires staggering of

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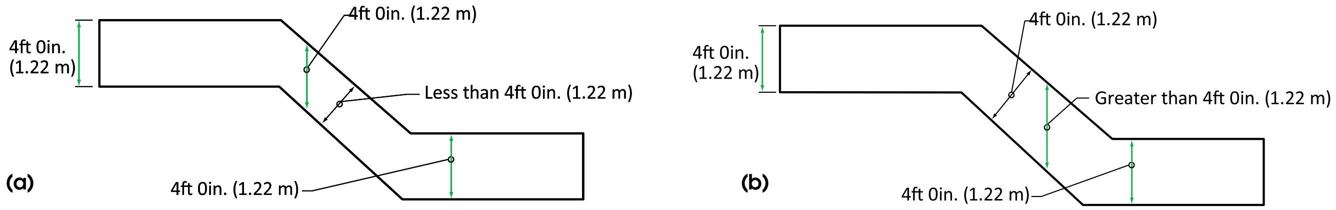

Fig. 3: Concrete parapet wall along a stair and landings: (a) if the vertical height of the parapet remains constant, the proportions are not correct, and the rail height may violate code requirements; and (b) if the vertical height is maintained from the landings to the sloped portion at the stair, the proportions are more balanced

mechanical splices only when they do not meet Type 1 requirements or when used in tension tie members. However, there are several other points to consider regarding the issue of staggering, whether it concerns mechanical splices, lap splices, or hooked reinforcement. Some of these issues are code-related, whereas others are constructibility-focused:

The Commentary to ACI 318-11[2] acknowledges the benefits of staggering, such as the staggering of bar cutoffs in bundles (Section R7.6.6), staggering hooks within a bundle (Section R7.6.6), staggering tie hooks (Section R7.10.5), and staggering the heads of headed bars (Section R12.6). Section R12.15.4 reads, in part: "...when located in regions of high tensile stress in the reinforcement. Such splices need not be staggered, **although such staggering is encouraged where the area of reinforcement provided is less than twice that required by the analysis"** [emphasis added].

In the AASHTO *LRFD Bridge Design Specifications*,[3] there are no stagger requirements when a mechanical splice conforms to the Type 1 ACI equivalent requirements. However, there are some requirements regarding staggering for other cases. Clause 5.11.5.3.2 notes that "mechanical connections or welded splices, used where the area of reinforcement provided is at least twice that required by analysis and where the splices are staggered at least 24.0 in. (600 mm), may be designed to develop not less than either twice the tensile force effect in the bar at the section or half the minimum specified yield strength of the reinforcement." In addition, Clause 5.11.5.4 requires "splices of reinforcement in tension tie members shall be made only with either full-welded splices or full-mechanical connections. Splices in adjacent bars shall be staggered not less than 30.0 in. (750 mm) apart."

The Canadian Standards Association's (CSA) "Design of Concrete Structures," CSA A23.3-04,[4] has similar language to the preceding Item 2 (Clause 12.15.4). Finally, the ACI 343R[5] report "Analysis and Design of Reinforced Concrete Bridge Structures" also has similar language for mechanical splices (Section 13.2.15.a).

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The CSA Canadian Highway Bridge Design Code CAN/CSA-S6-06[6] (Clause 8.15.9.3) requires that all mechanical splices in components subjected to axial tension shall be staggered at least 32 in. (800 mm).

And a sampling of state Department of Transportation (DOT) Bridge Design Specifications reveals that several states, including California, Illinois, New York, Pennsylvania, and Wisconsin, require all splices be staggered a specific distance, whereas some DOTs require splices be staggered "as far as possible".

The ACI Committee 439[7] report, "Types of Mechanical Splices for Reinforcing Bars," has some good information regarding splice staggering. In Section 1.3.1, "Spacing and Cover Requirements," the following is presented:

"Clearance limits for mechanical splices may be a factor in the selection and positioning of the appropriate mechanical splice. The outside diameter of the mechanical splice should be known. Up-to-date dimensional data should be obtained from the splice manufacturer. By knowing the diameter of the mechanical splice, the engineer/specifier can decide whether the mechanical splices need to be staggered on the basis of the clearance required. For constructibility reasons, mechanical splices are usually best located in the same plane or elevation. There is little justification for staggering mechanical splices solely to prevent undesirable failure modes that are associated with lap splices because, unlike lap splices, the ability of mechanical splices to carry and transfer load from bar-to-bar is not affected by concrete cover or the compressive strength of concrete. Nevertheless, it has been the practice of some designers in the past to stagger mechanical splices as if they were lap splices. Pending any future code revisions, however, the minimum stagger length should be checked and specified by the engineer only when required to be consistent with an applicable code section, such as the provisions in Chapter 12 of ACI 318 related to splices that do not meet Type 1 or 2 requirements."

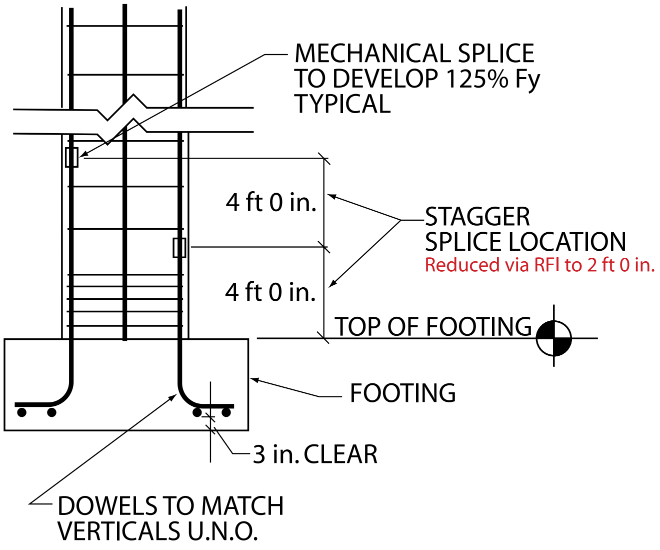

Fig. 4: An example of a project detail showing staggered mechanical splices in a column (1 in. = 25.4 mm; 1 ft = 0.3048 m)

Section 1.3.5 of this document has further discussion regarding field erection. It states:

"In many applications, mechanical splices may be staggered for clearance, access, and code requirements. If staggered mechanical splices are used in columns, for example, free-standing erection and assembly of the reinforcement may be required rather than preassembled cages, thus necessitating use of external bracing or formwork to hold bars while completing splices.

"There is a considerable difference in the time and equipment required to install different mechanical splices. Therefore, the field erection procedure and schedule should be coordinated with the selection and installation procedure of the mechanical splices. If special equipment is required, particular information regarding its size, weight, operation, and availability should be obtained from the supplier or splice manufacturer."

Although staggering of mechanical splices may be construed as legacy thinking in design, there may be good reasons for this. Clearly, from the preceding discussion, the mechanical splices could all be located at the same elevation without compromising strength. With higher percentages of vertical column reinforcement, this may give rise to congestion at the splice elevation, depending on the mechanical splice type used—this may or may not be a consideration. Furthermore, some types of construction rely on having splices at the same elevation; as an example, precast columns oftentimes use a grouted-sleeve mechanical splice to establish continuity.

An informal poll of CRSI detailer/fabricator members showed that mechanical splices are staggered for the majority of cases, as indicated on the designer's structural drawings. A portion of a detail from a project is shown in Fig. 4. (As a side note to the detail shown in Fig. 4, a project RFI asked to lower the elevation of the second splice line. This would allow the ironworkers to stand on the footing and reach the upper coupler, without needing to use a ladder.)

Two benefits of staggering were cited: (1) staggering helps provide adequate room for installation of the mechanical splices, especially if tools are needed to facilitate completion of the splice; and (2) staggering reduces congestion around the splices, which facilitates meeting the spacing requirements of Section 7.6.3 of the ACI 318-11[2] code. This section requires the clear spacing between longitudinal bars be at least 1.5 in. and $1.5d_b$ (d_b is the bar diameter). In the case of bars that are

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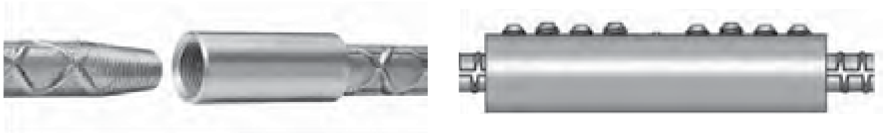

(a) (b)

Fig. 5: Mechanical splices: (a) taper-threaded and (b) shear screw sleeve[7]

mechanically spliced, the clear spacing requirement is traditionally applied to the spacing between neighboring splices, although this section does not specifically address clearance limits for mechanical splices. A closer spacing may prohibit the concrete from fully encapsulating the splicing device, similar to the bars being lap spliced. The inquiry stated that the staggering of mechanical splices is "difficult to detail and a costly option to produce." From Fig. 4 and items addressed previously, it would seem that staggering has a minimal impact on cost and could actually enhance constructibility.

With these points in mind, we'd like to offer the following revision to the statement in the August *CI* article:

"Although ACI 318-08 does not require the staggering of mechanical splices for the general case, other codes may require this in certain instances. Staggering of mechanical splices may actually be preferred from the standpoint of constructibility. If the splices are staggered, this will result in both short and long vertical bars in the column run."

When accommodating mechanical splices in design and construction, it would be helpful to have some idea of the overall dimensions for a typical splice. Although these dimensions vary due to the numerous types of splices available, two general types from various manufacturers were studied—the taper-threaded coupler and the shear screw coupling sleeve (Fig. 5). A conservative length and diameter was determined from these representative mechanical splices, expressed as a multiple of the spliced bar diameter. The rough working dimensions are $3d_b$ to $4d_b$ for length and $1.5d_b$ for diameter of taper-threaded splices, and $13d_b$ to $14d_b$ for length and $3d_b$ for diameter of shear screw couplers; d_b is the spliced bar diameter, as stated previously. These approximate dimensions can be used when checking clear spacing or the layout of staggered splices if required for adequate clear spacing.

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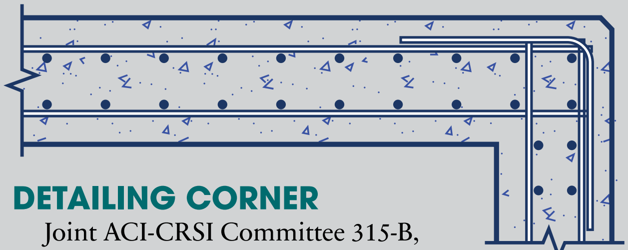
Thanks to Dick Birley of Condor Rebar Consultants Inc. and Neal Anderson of CRSI for providing the information in this article.

Selected for reader interest by the editors.

Detailing Corner

Reinforcing Bar Details for Mat Foundations

Mat foundations are commonly used to support heavy loads from multiple columns. Mats may bear on competent soil, on soil with a low bearing capacity, or be supported on piles or drilled shaft foundations (caissons). Depending on the total load applied to the mat and underlying foundation system, the thickness of mat foundations can vary from 1 ft (0.3 m) to more than 20 ft (7 m). The reinforcing system in the mat can be quite substantial, with heavy reinforcing bar mats in the bottom, top, or both locations within the mat depth. Improper detailing of the reinforcement can result in constructibility issues impacting other trades, the schedule, and costs. This Detailing Corner describes practices that can be used to simplify the design, detailing, and placement of mat reinforcement.



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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."

Setting the Reinforcement

Minimum requirements

The mat depth is normally set by shear strength requirements. The amount of reinforcement A_s for the top and bottom reinforcing layers is set by meeting ACI 318 Code[1] requirements for flexural strength, minimum flexural reinforcement (Sections 10.5.1 through 10.5.4), and shrinkage and temperature reinforcement (Sections 7.12.2.1 through 7.12.2.3). Generally, A_s will be governed by flexural considerations, either through analysis or satisfying the minimum requirements. However, as the thickness of the mat increases, the minimum amount of shrinkage and temperature reinforcement will increase—it could control for very thick mats.

Once this reinforcement quantity is calculated, a suitable bar size and spacing can be selected. Depending on the layout configuration, the reinforcing bars can be placed in two layers (one mat) or four layers (two mats) at both the top and bottom. Per Code Section 7.12.2.2, the bar spacing is limited to five times the slab thickness or 18 in. (450 mm). Code Section 15.10.4 also sets the maximum spacing of mat reinforcement at 18 in.

Bars that are placed in the interior layers should follow the same spacing patterns as the main, outer reinforcement so that all bars in different layers are aligned (Fig. 1). This provides clear passage for concrete placement, which helps to reduce voids. It's considered good practice to select the size of the bars in the interior layers equal to or smaller than the outer layer reinforcing bars. Some designers prefer to specify bars in the interior layers with diameters different than the bars in the outer layer of reinforcement so they can be more easily identified and checked in the field. By a note or a section on the design drawing, the engineer should specify those bars that will be placed in the outer layer and the ones in the inner layer.

It's recommended that a clear spacing of at least 3 in. (75 mm) (more for deeper mats) be provided between the bars to facilitate concrete placement, as shown in Fig. 1. For

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deep foundation mats requiring worker access inside the cage, it's also good practice to provide openings in the top reinforcement. This can be accomplished by bundling the bars and providing additional steel around the resulting opening, as shown in Fig. 2.

As noted in ACI 336.2R,[2] Section 6.14: "It is essential that the engineer prepare thorough drawings documenting all phases of the reinforcement placement.... Specification of placement sequence is very important."

Additional bars

Additional flexural reinforcement may be required at heavily loaded or closely spaced columns or where substructure support conditions change. Any additional top and/or bottom reinforcement can be in the same layer as the outer, main reinforcement or within the interior layers.

Additional bars should be spaced as a multiple or submultiple of the spacing for the main reinforcement. For example, if the mat foundation is 6 ft (2 m) thick and No. 9 (No. 29) bars have been provided at 15 in. (375 mm) on center for the main reinforcement in each direction for both top and bottom reinforcement, any additional bars required in any area can be provided at a spacing of 5, 7.5, 15, or 30 in. (125, 190, 375, or 750 mm).

Other Considerations

Some additional points to consider:

- When the column spacing is not laid out on a regular, symmetric grid, consider locating the bars on an orthogonal grid rather than skewing them with the actual column locations. Additional reinforcement can then be placed wherever it's required.
- It's common practice not to use shear reinforcement in a mat. This ensures that the depth and stiffness is maximized and flexural reinforcement is minimized (ACI 336.2R, Section 6.1.2, Item 2). However, when shear reinforcement is required, it's recommended that the selected vertical bars are larger than the main reinforcement and are placed at larger spacing—easing identification and inspection.
- It's preferable to extend column and wall dowels all the way down to the bottom mat of reinforcement. The dowels should incorporate a 90-degree hook at the bottom end, so the tail of the hook can be used for support and elevation control. This also allows the dowels to be tied to both the top and bottom mats of reinforcement for stability, as the two tie points will properly secure the dowel bars from displacing (Fig. 3).
- If lap splices in the foundation mat reinforcement are to be staggered, they need to be carefully detailed on the design drawings. Otherwise, the staggered splices for different layers of reinforcing bars may become quite confusing to place and subsequently inspect. If it's possible to avoid staggering splices, this should be the preferred placement for ease of constructibility.
- The common mill stock length of straight reinforcing bars is 60 ft (18.3 m). However, a local fabricator may have limitations (such as storage space, crane capacity, and bend table size), requiring stocked straight lengths less than 60 ft. It is thus advisable to verify with the

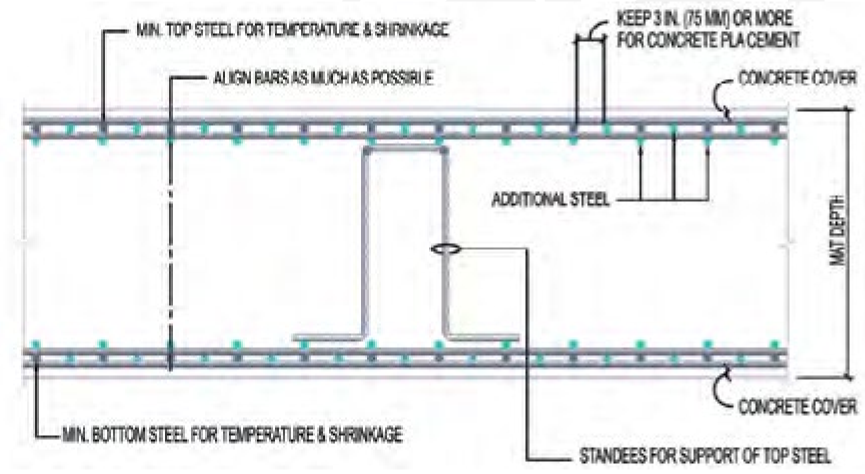

Fig. 1: Typical configuration of reinforcement in a deep mat foundation

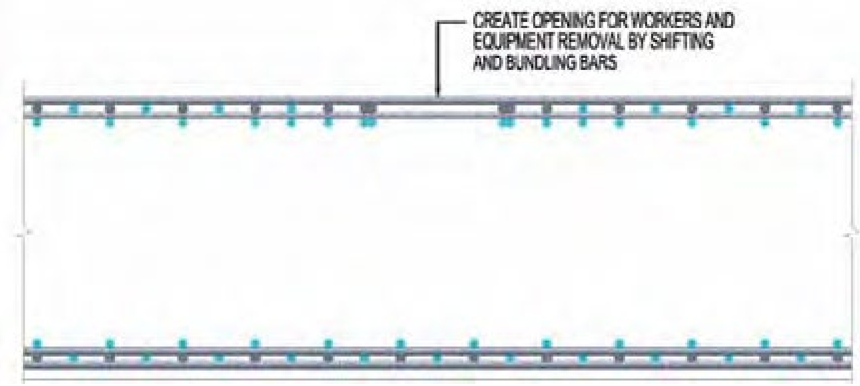

Fig. 2: Openings in the top mat of reinforcement allow access to lower levels

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local fabricator the maximum available stock length. Because a mat foundation requires long runs of straight bars, it's recommended that the maximum straight bar length be used as much as possible. This minimizes the quantity of potential lap splices. If an actual bar length shorter than the typical stock length is needed to complete the reinforcing bar run, this "short bar" should be located at either end of the mat foundation. Alternately, stock length bars could be provided throughout the mat, with the lap lengths increased along the run. Although the lap lengths will be greater than Code minimums, material waste and fabrication costs could be reduced because a long bar will not have to be sheared to a shorter length. It will also aid in constructibility, as a separate bar length bundle will not have to be inventoried at the construction site.

- Standees for supporting the top layers of reinforcement should be sturdy and stable enough to support the weight of the top steel, workers, and equipment. For further guidance of using standees for supporting heavy reinforcement, see the Detailing Corner article "Using Standees."[3] In addition, diagonal bracing bars may be required to ensure stability of the entire reinforcing bar assembly.
- Mat foundations will typically incorporate elevator or sump pits. If the mat depth can accommodate the pit, an additional mat of reinforcing steel can be added to serve as the top steel in the mat section below the pit (Fig. 4). The top reinforcement in the mat foundation (full-depth) will be interrupted, however; so the engineer will have to analyze the opening region to determine if hooks are required on the terminated bars or additional "framing" bars are required adjacent to the opening.

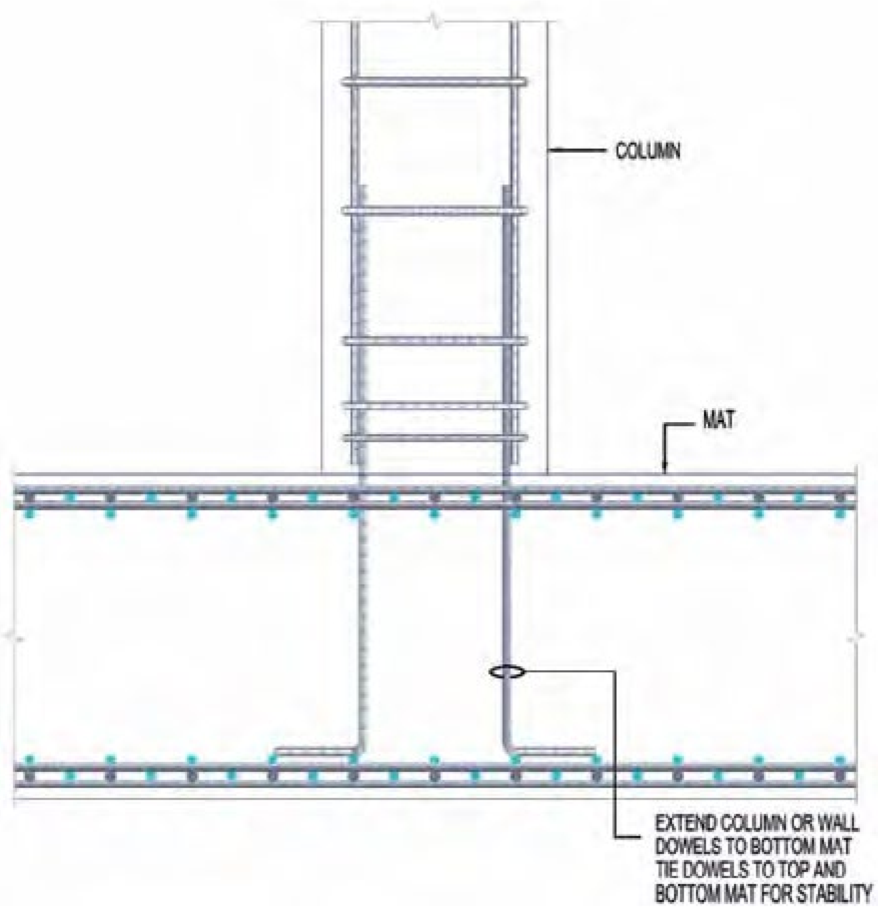

Fig. 3: Column dowels should be hooked and extended to the bottom mat of reinforcement to provide support

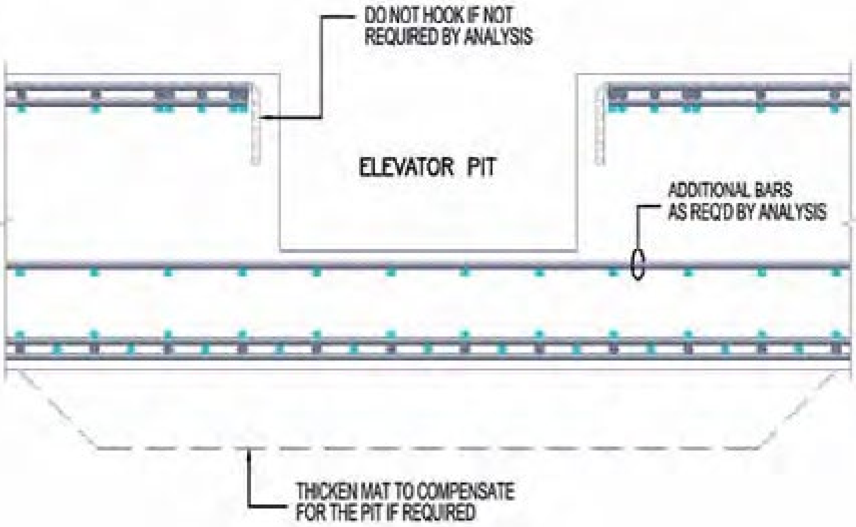

Fig. 4: A schematic of an elevator pit. In a deep mat, a thickened slab may not be required

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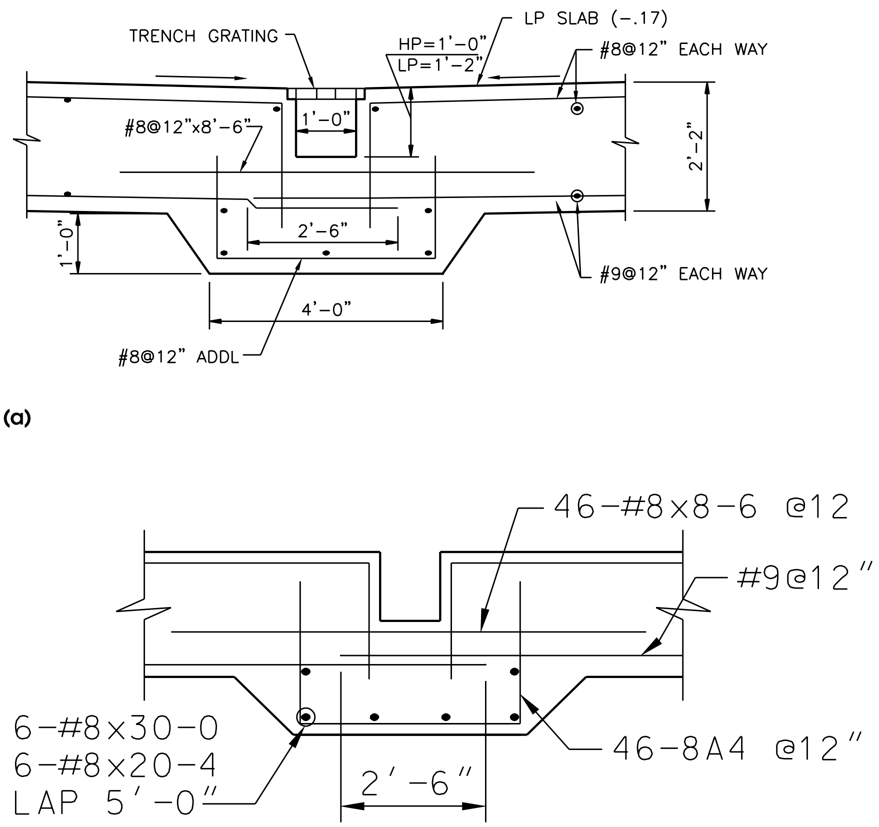

(a)

(b)

Fig. 5: Details for a thickened mat below a trench drain: (a) design detail; and (b) reinforcing bar placing detail

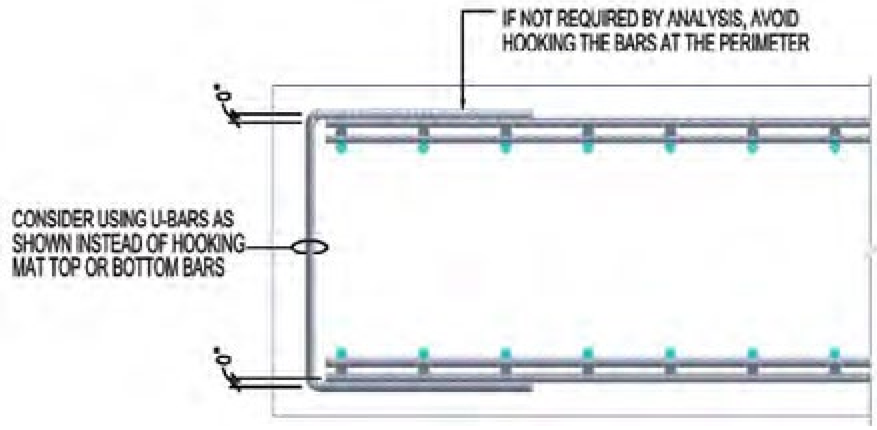

Fig. 6: Designers should consider using U-bars (hairpins) in place of hooked bars for each bar layer at the edge of a mat foundation

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- If the mat depth cannot accommodate the elevator or sump pit, the mat will have to be locally thickened to provide the necessary flexural capacity. A typical reinforcing scheme for this condition is shown in Fig. 5.
- If the horizontal bars must be anchored at the mat edges, it may be necessary to tilt hooks so that hook extensions fit within the geometric depth of the footing (this may require additional horizontal bars in the depth of the footing to hold the hooks at the proper angle). As an alternative, U-bent bars could be lapped with straight bars in the top and bottom layers (a hairpin detail—refer to Fig. 6). Depending on the specific reinforcement layout and spacing, hairpins may be more constructible than individual hooks.
- It's common practice to place sheets of welded wire reinforcement (WWR) between the two layers of reinforcing steel within the top mat. The WWR will allow laborers to walk on the mat before and during concrete placement (when the top bars will be buried in the concrete), preventing them from falling through the mat. The WWR is sacrificial and is not usually considered in the structural design computations. Examples are shown in Fig. 7 on foundations for recently constructed buildings in Chicago.

Summary

Experience has shown that simple measures can have a big impact on the efficiency and cost of constructing mat foundations. Varying bar sizes according to the mat region or the direction of the bars, providing details for openings in the top reinforcement needed for access to the layers below, using a consistent bar spacing, and planning for anchorage at edges of pits and the mat itself can reduce requests for information and/or errors.

References

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2. ACI Committee 336, "Suggested Analysis and Design Procedures for Combined Footings and Mats (ACI 336.2R-88) (Reapproved 2002)," American Concrete Institute, Farmington Hills, MI, 2002, 27 pp.

3. CRSI, "Detailing Corner: Using Standees," *Concrete International*, V. 32, No. 8, Aug. 2010, pp. 52-54.

Thanks to Dick Birley of Condor Rebar Consultants and member of Joint ACI-CRSI Committee 315, Details of Concrete Reinforcement, and Neal Anderson of CRSI for providing the information in this article.

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Fig. 7: WWR placed between the top reinforcing bar layers allows the workers to safely walk on the mat before and during concrete placement: (a) Trump Tower, Chicago, IL; and (b) Roosevelt University, Chicago, IL *(photos courtesy of Jack Gibbons, CRSI)*

Detailing Corner

Connecting Pre-Tied Wall Curtains

Also, RFI 12-01 on circular tie detail hook requirements

In this month's Detailing Corner, we examine the use of noncontact lap splices for pre-tied reinforcing bar wall curtains. We also respond to an inquiry from a reinforcing bar fabricator concerning the new circular tie detailing requirements in ACI 318-11.[1] We thank those who have contacted us and encourage all readers to participate in this forum.

Lap Splices: Contact and Noncontact

Contact lap splices have distinct advantages over noncontact splices:

- Splice lengths are readily measured during installation and inspection;
- Code-imposed maximum bar spacing limits are avoided; and
- Bars can be tied to ensure they are secure against displacement before and during concrete placement.

Contact lap splices are therefore the norm on construction documents. However, there are instances in wall construction when noncontact lap splices must be used.

Code Limits on Noncontact Lap Splices

Section 12.14.2.3 of the ACI Code[1] limits the spacing of reinforcing bars in a noncontact lap splice to the smaller of one-fifth the required lap splice length and 6 in. (150 mm). In this context, bar spacing is measured center-to-center. As explained in Commentary Section R12.14.2.3, the first limit helps to avoid having individual bars so far apart that an unreinforced section is created. The Code provision is designed to force any possible crack that may develop between spliced bars to follow a zigzag line (5-to-1 slope); this is considered a minimum precaution.

The second limit requiring a 6 in. (150 mm) maximum spacing was added because most research available on the lap splicing of deformed bars was conducted with reinforcement within this spacing range.

But what actually happens in a noncontact lap splice to bring about these Code requirements? In the noncontact lap splice, the force in one bar is transferred into the surrounding concrete, which in turn transfers it to the adjacent bar being spliced. This force-transfer mechanism can be illustrated as a planar truss between the bars, where the load transfer occurs through compressive struts in the concrete, as shown in Fig. 1.[2] Placing an upper limit on bar spacing prevents the strut inclination from becoming too steep.

Pre-Tied Wall Curtain

Horizontal bar layers in a pre-tied bar curtain must be spliced with bars in adjacent curtains. To avoid interference

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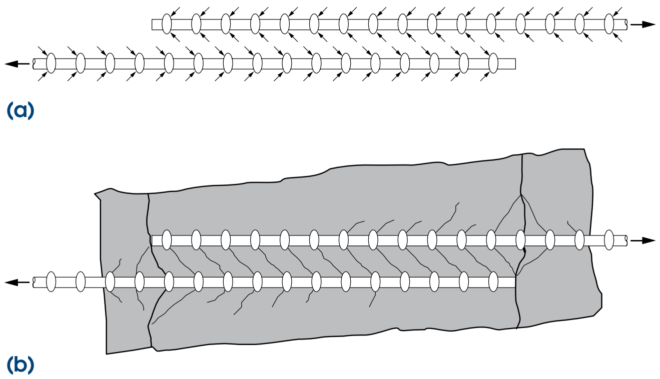

Fig. 1: Load-transfer mechanism in a noncontact lap splice: (a) forces on the bars include diagonal forces from compressive struts that form in the concrete section between the bars; and (b) as the splice capacity is reached, internal cracks form (after Reference 2)

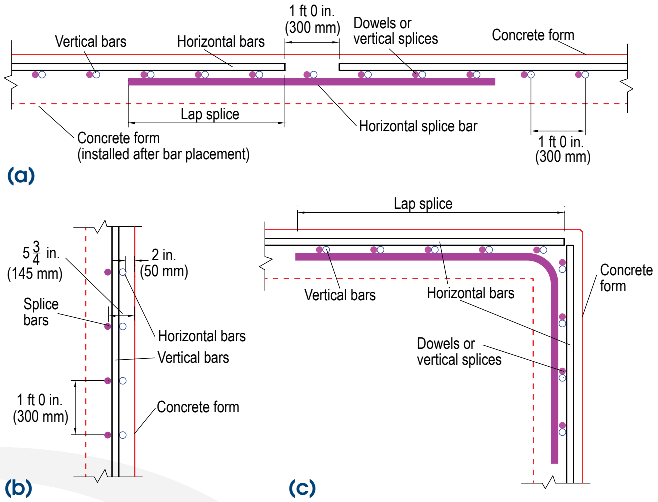

Fig. 2: Possible horizontal bar splice location for a pre-tied wall curtain with a single horizontal bar layer: (a) plan view; (b) elevation view; and (c) corner detail

and binding of adjacent curtains during erection, horizontal splice bars are not tied in their final positions until after adjacent curtains are set in place. Horizontal splice bars can be lifted into place after curtain erection by an ironworker. But it's also common to loosely tie splice bars to the bars in the horizontal bar layer before erection and slide them into position after adjacent curtains are set in place.

Noncontact Solutions

Achieving contact lap splices with the horizontal bars may present challenges for the bar placer, especially if the curtains have multiple layers of reinforcing steel. The following solutions were designed and used for a large nuclear facility in a high seismic zone.

Single horizontal bar layer curtain

In a pre-tied curtain with a single horizontal layer of bars, splice bars would normally be placed so there is a contact lap splice with the horizontal bars. If the curtain is erected against a form and the horizontal bars are located inboard of the vertical bars, the vertical bars are not in the way of placing the horizontal lap splice bars. Achieving contact lap splices will be no problem.

However, if the horizontal bars are outboard of the vertical bars and the splice bars were not loosely tied to the curtains before erection, it will be simpler to place the splice bars inside of the vertical bars rather than trying to place them outside of the vertical bars. The arrangement shown in Fig. 2 would surely meet Code spacing requirements, as any reinforcing bar diameter would be less than either one-fifth the splice length or 6 in. (150 mm). This bar placement configuration is especially beneficial when connecting two curtains at a corner because the splice bar will be a bent bar that must be located in three dimensions.

Double horizontal bar layer curtain

Placing splice bars for walls with two horizontal bar layers in a pre-tied curtain can be slightly more problematic. Splice bars for one of the horizontal bar layers will have to be located between the two vertical bar layers for contact lap splices. If the splice bars are loosely tied to the horizontal curtain bars before erecting the curtains, it could be difficult to slide the bars into the lap splice position. If the splice bars are carried up the wall after curtain erection, placing them between the vertical bar layers would be very difficult, if not impossible.

A simple alternative arrangement for the splice bars is shown in Fig. 3. Here, the horizontal bars in the first layer (near the form surface) have contact lap splices and the horizontal bars in the second or inner layer have noncontact lap splices.

Triple horizontal bar layer curtain

Placing splice bars in walls with three or more horizontal bar layers in a pre-tied curtain presents similar (but obviously greater) challenges than placing splice bars in walls with two horizontal layers. Figure 4 shows two possible arrangements of splice bars in a wall with three horizontal layers, with one arrangement being more desirable than the other.

In Fig. 4(a), Layer 1 bars (near the in-place form surface) are spliced using contact lap splices. The other two layers of

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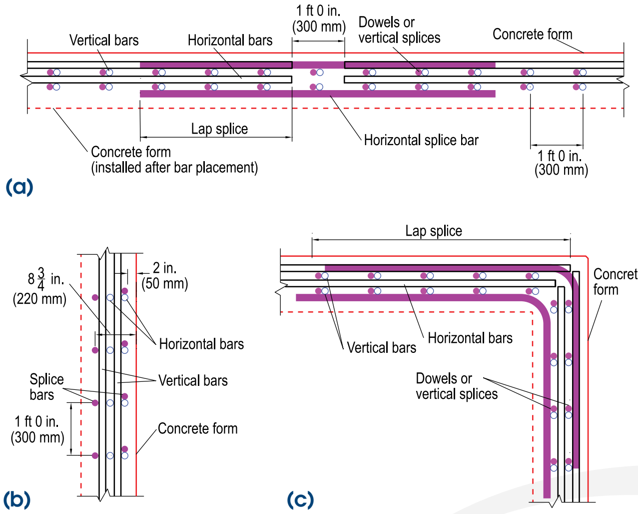

Fig. 3: Possible horizontal bar splice locations for a wall curtain with two horizontal bar layers: (a) plan view; (b) elevation view; and (c) corner detail

horizontal bars, Layer 3 and 5, use noncontact lap splices, with the splice bars located in Layer 7 and placed after the curtains have been set in position. In this configuration, one of the bars in Layer 7 splices with a bar in Layer 5. The other bar in Layer 7 splices with a bar in Layer 3. However, this load path is not entirely direct, and the splice bar in Layer 7 may be shadowed by the normal horizontal bar in Layer 5, thus reducing the effective perimeter of the Layer 3 bar and the effectiveness of the splice. The splice bar location shown in Fig. 4(b) is more desirable because a more direct load path exists for the compressive struts to develop in the splice region and thus maintain the efficiency of the splice transfer mechanism; the splice bar in Layer 1 splices more directly with the bar in Layer 3.

The configuration shown in Fig. 4(b) and 5 result in a maximum center-to-center distance between a splice bar and the associated horizontal bar in the pre-tied curtain equal to the sum of one horizontal and vertical bar diameter. Assuming the vertical and horizontal bars are the same size, the bar diameter would have to be 3 in. (75 mm) or more to cause the bar spacing to exceed the 6 in. (150 mm) limit in the code. No deformed bars are that large. Although splice lengths are generally large enough to avoid violating the spacing limit of one-fifth the lap splice length, that dimension must also be checked.

Note that the corner details shown in Fig. 2, 3, and 5 are for pre-tied walls with low or minimal horizontal moment transfer at the corner. Previously published Detailing Corner articles and RFIs discuss wall corner details for walls that have significant horizontal moments at the corners.[3-5]

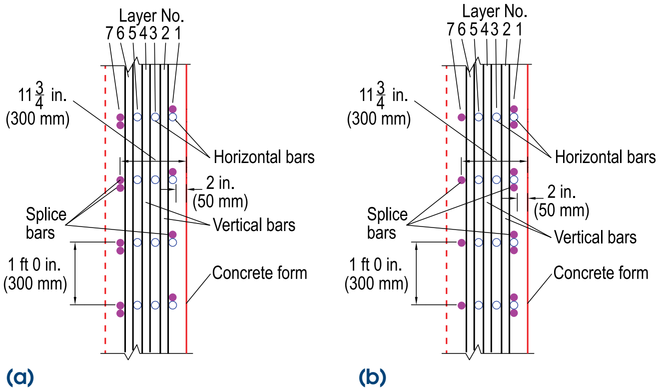

Fig. 4: Elevation views of two possible horizontal bar splice locations for a wall curtain with three horizontal bar layers. In both cases, Layer 1 has contact lap splices and Layers 3 and 5 have noncontact lap splices: (a) splice bars for Layers 3 and 5 are shown installed after the curtains have been placed (Layer 7). Note that the noncontact splice for Layer 3 may be shadowed by the horizontal bar in Layer 5; and (b) splice bars for Layer 3 are shown loosely tied to Layer 1 and slid into final position after curtain placement. The splice bar locations shown in (b) are more desirable because the configuration provides more direct load paths for compressive struts to develop

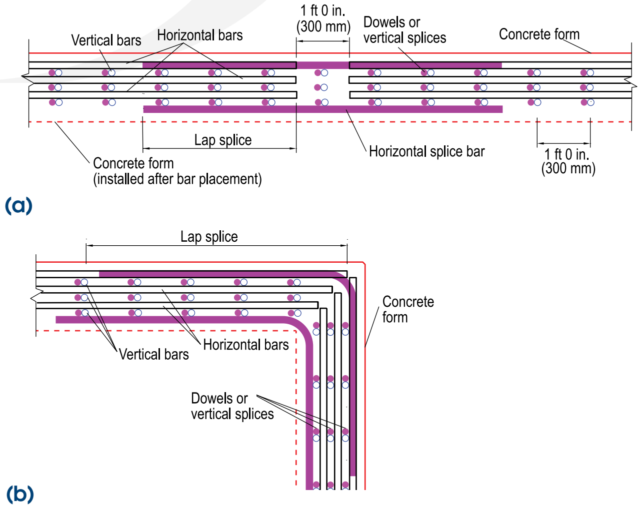

Fig. 5: Possible horizontal bar splice locations for a wall curtain with three horizontal bar layers: (a) plan view; and (b) corner detail

Summary

Noncontact lap splices will facilitate installation of horizontal splice bars between preassembled curtains of reinforcing steel. They may be the only practical means of splicing horizontal bars in walls with multiple-bar layer curtains.

Detailing Corner

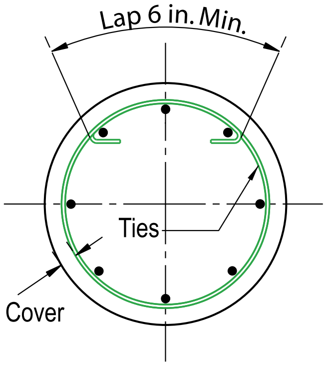

Fig. 6: Circular tie requirements per ACI 318-11, Section 7.10.5.4 (1 in. = 25.4 mm)

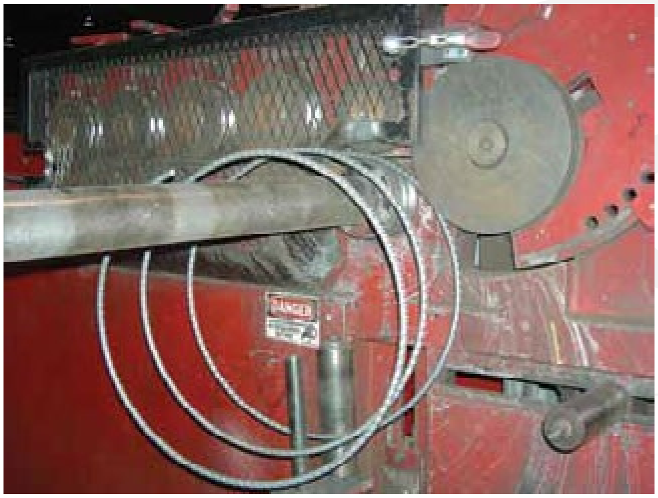

Fig. 7: Fabrication of a continuously wound circular tie or spiral on a "spiral machine"

RFI 12-01: *I have concerns regarding the new circular tie detail hook requirements in ACI 318-11 (they were discussed in RFI 11-05 (Fig. 6)).*[6] *The new detail will necessitate a large number of hook tails projecting inside a column cage. It's likely that a concrete pump hose could get caught on a hook during placement, and pulling the hose free could displace the tie reinforcement or damage the hose. In our region, small diameter, drilled shaft foundations are common. Is the new detail only meant for seismic designs?*

Response: The requirement that circular tie hooks extend into the core of the column is consistent with what has always been required for rectangular ties, and it's valid for nonseismic as well as seismic applications. Previous codes required only "a complete circular tie," but this could be satisfied using a tie with a tension lap or with hooks terminating at a single bar. When the column cover spalls through overload, impact, or corrosion, the loss of cover will render a circular tie with only a tension lap ineffective. Further, as Commentary Section R7.10.5.4 of ACI 318-11 notes, "Vertical splitting and loss of tie restraint are possible where the overlapped ends of adjacent circular ties are anchored at a single longitudinal bar." Hence, Section 7.10.5.4 of ACI 318-11 now requires that circular ties have two end hooks, the ties overlap not less than 6 in. (150 mm), and the hooks engage different longitudinal bars.

The new requirement will certainly increase the risk of snagging a concrete pump hose—especially in small-diameter columns. If interference is an issue, one solution would be to use a continuously wound bar or wire (rather than individual circular ties) for confining reinforcement (Fig. 7). If a reinforcing bar fabricator has a "spiral machine," these can be fabricated very efficiently. As Commentary Section R7.10.5 states:

"Continuously wound bars or wires can be used as ties provided their pitch and area are at least equivalent to the area and spacing of separate ties. Anchorage at the end of a continuously wound bar or wire should be by a standard hook as for separate bars or by one additional turn of the tie pattern. A circular continuously wound bar or wire is considered a spiral if it conforms to 7.10.4, otherwise it is considered a tie."

The maximum 3 in. (75 mm) clear spacing between spirals required in Section 7.10.4.3 is only imposed to distinguish a spiral reinforced compression member from a tied reinforced compression member (refer to ACI 318-11, Sections 10.3.6.1 and 10.3.6.2).

It can be more economical to fabricate and assemble a reinforcing cage using a continuously wound bar rather than discrete ties. The pitch is established by pulling the tie and fastening it to the longitudinal (vertical) bars, resulting in a stable, readily handled cage that can be assembled in the fabrication shop or the field. In some geographical regions, however, the ability to fabricate spirals may be limited. Circular ties continue to be used in those locations, so it's prudent to check local availability of spirals.

With respect to small-diameter, drilled shaft foundations, you raise an interesting conundrum. Although ACI 318-11 does not govern the design of drilled shafts or piers in structures not assigned to Seismic Design Categories (SDC) D, E, and F (Section 1.1.6), the commentary directs the engineer to the report by ACI Committee 336, "Design and Construction of Drilled Piers (ACI 336.3R-93, Reapproved 2006)."[7] This report directs the engineer back to the reinforced concrete design provisions of ACI 318 if a plain concrete section cannot be used. So, if reinforcing bars are used in a drilled pier or shaft foundation, it's likely the bar detailing

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will comply with the requirements in ACI 318, regardless of the SDC.

It may be possible, however, to justify the lap detail allowed in previous Code editions, provided alternate confinement exists. For example, a drilled shaft with permanent steel casing (that is, casing that is left in place) should have adequate confinement and the lap tie detail will not open up. For uncased shafts, a very stiff, competent clay soil may provide adequate confinement to justify the use of a shorter lap on a circular tie. The final decision will come down to engineering judgment and local building code requirements.

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.

2. Wight, J.K., and MacGregor, J.G., *Reinforced Concrete: Mechanics and Design*, fifth edition, Pearson Prentice Hall, 2009, p. 407.

3. CRSI Staff, "Corner Details for Wall Horizontal Bars," *Concrete International*, V. 31, No. 9, Sept. 2009, pp. 43-45.

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5. CRSI Staff, "Concrete Cover at Rustications, Drip Grooves, and Formliners," *Concrete International*, V. 32, No. 6, June 2010, pp. 35-38.

6. 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.

7. ACI Committee 336, "Design and Construction of Drilled Piers (ACI 336.3R-93) (Reapproved 2006)," American Concrete Institute, Farmington Hills, MI, 2011, 30 pp.

Thanks to Greg Birley of Condor Rebar Consultants, Inc. and Neal Anderson of CRSI for providing the information in this article.

Correction: In the February 2012 issue, credit should have been given to Javed B. Malik of Jacobs–Global Building for providing the *Detailing Corner* article on "Reinforcing Bar Details for Mat Foundations." We sincerely regret the error.

Detailing Corner

Steps in Beams

In this month's "Detailing Corner," we examine steps in beams and the modifications necessary for the reinforcement details at a change in floor elevation. In many cases, the engineer may know the location of the step during design. However, there may be instances during construction where the architect or building owner may require a step.

Issue

The top elevation of floor slabs can vary because of raised flooring, other architectural features, or mechanical equipment; and the bottom elevation of a beam can vary because of conflicts with architectural or mechanical systems (Fig. 1). Either condition can introduce a step of any supporting beams or girders, so the depth of affected members will vary along the span.

From a detailing point of view, the ideal location for a beam step is at a column line or at a location where support is provided by another beam or girder. However, as engineers are well aware, this is not always possible. Several situations will be discussed herein, along with suggestions for reinforcement details.

Top Step

Step is 3 in. (75 mm) or less

Small steps at the top of a beam can usually be accommodated in three different ways:

- As shown in Fig. 2, the beam is *originally* designed to have a reduced depth "D1," and it is reinforced appropriately for this depth. The additional concrete after the step-up is considered as dead load and is provided with a nominal amount of reinforcement;
- If beam depth is changed through a change order or request for information (RFI) after design is complete, additional reinforcement may be required. The beam top steel is lowered along the entire beam length, as shown in Fig. 2, so the minimum concrete cover is provided per Section 7.7 of ACI 318.[1] If needed for crack control, additional bars can be provided in the stepped-up portion of the beam. The stirrup height can be increased

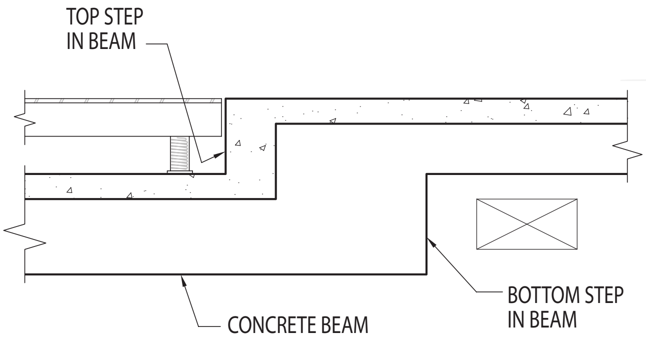

Fig. 1: Floor slab section and beam elevation. Top steps may be required for elevated flooring, and bottom steps may be required for ductwork

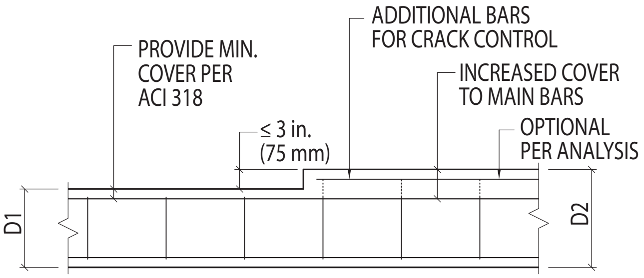

Fig. 2: Reinforcement scheme for a small step at the top of a beam

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in the stepped-up portion, or the top portion can be kept at the same elevation as the main top reinforcement. It's important to note that lowering the top reinforcement will reduce the effective depth of the reinforcing steel in the deeper portion of the beam. This will reduce the negative moment capacity of the beam section and the amount of steel provided will need to be increased appropriately; or

- Alternatively, a change made late in design or early in the construction could be accommodated as shown in Fig. 3. Here, the top reinforcement is offset bent to accommodate the step. If this option is selected, Section 7.8.1.1 of the ACI 318 Code[1] limits the slope in the offset portion to a maximum of 1 on 6. Also, additional stirrups must be provided at bar bends to resist the upward component of the tensile force in the longitudinal bar, which would tend to straighten the top bar(s). It's considered good practice to provide a minimum of two No. 4 stirrups at these bent bar locations, as shown in Fig. 3.

As an alternate to a bent bar, the top reinforcement from the "D1" height of the beam could be lap-spliced with the top reinforcement from the "D2" height of the beam. This condition would create a noncontact lap splice, and the spacing of the bars would be limited to the smaller of one-fifth the required lap splice length and 6 in. (150 mm), conforming to Section 12.14.2.3 of the ACI 318 Code. For a step that is 3 in. (75 mm) or less in height, the offset spacing requirements for the lap should be easily achievable.

Some designers may prefer draping the beam top bars rather than providing bent bars. Although small diameter bars can easily be draped because of their flexibility, larger diameter bars cannot be draped and must be modified by cold bending.

Step exceeds 3 in. (75 mm)

Depending upon the location of the step along the length of the beam, the detail shown in Fig. 4 is usually used with some modifications. If the top step is located close to midspan, where there is little or no tension in the top steel, the top bars of the shallower "D1" beam section can be extended a nominal distance into the deeper "D2" beam section. The top bars of the deeper "D2" beam section can be terminated or hooked at the step location. Structural analysis is required to determine the bar development requirements.

If the step is located near a beam support or where shear and moment values are high, structural design of the reinforcement is required. This condition can be analyzed conventionally or by strut-and-tie modeling techniques. Depending on the step location, it may be convenient to think of the situation as the shallower beam "framing" into the deeper beam for purposes of detailing.

As shown in Fig. 4, the top longitudinal reinforcement in the shallower "D1" beam section is extended into the deeper beam section with a conventional development length (shown) or with a hook detail. Some engineers will extend the top bars into the deeper beam section with a Class B lap splice as a minimum length. Technically, the extension isn't a lap splice because the maximum vertical spacing requirements of ACI 318, Section 12.14.2.3, will normally be exceeded. Even so, an extension equal to a Class B lap length will generally be conservative.

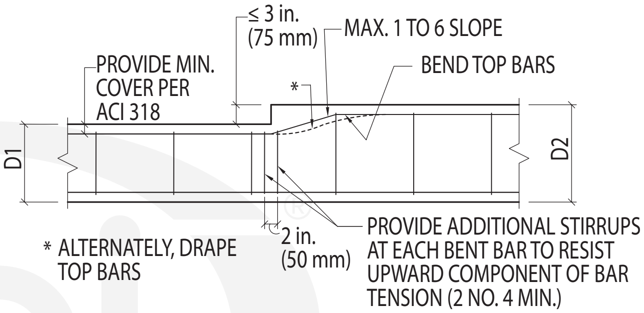

Fig. 3: Alternate reinforcement scheme for a small step at the top of a beam

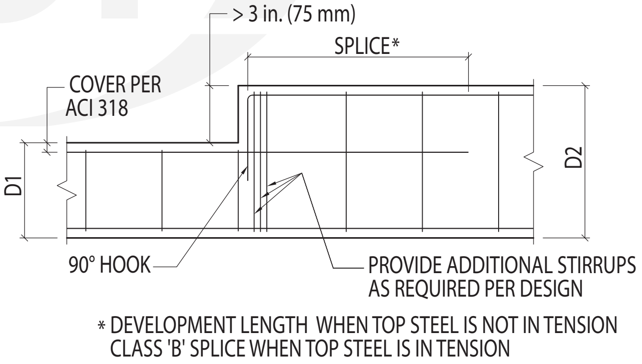

Fig. 4: Example reinforcement scheme for a large step at the top of a beam

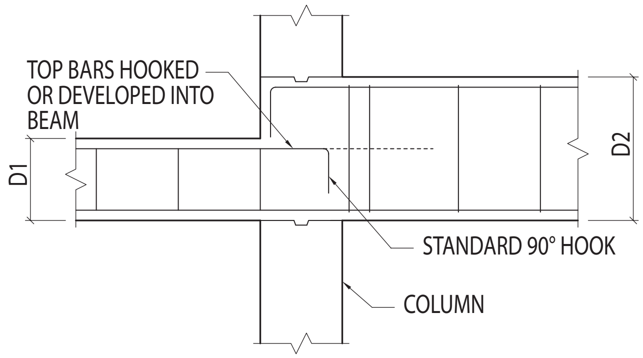

Fig. 5: Step in the beam located at a column

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The top longitudinal reinforcement in the deeper "D2" beam section likely has a high level of force and is developed with a 90-degree hook; this also serves as a framing bar for the step.

With respect to the shear requirements, additional stirrups may be required at the step to essentially "hang" the reaction from the shallower beam into the deeper beam. This is dependent on the shear demand at the step location. It's possible that a group of stirrups may not be necessary if a strut-and-tie model shows a different force flow and resultant reinforcing scheme.[2]

Step is at column or beam location

The ideal location for a beam top step is where the beam frames into another structural member, either a column or a beam. These steps can be detailed similar to other beam steps or as shown in Fig. 5. The top bars in the shallower beam can either be hooked into the column or beam or extended straight into the adjacent beam with a straight embedment length.

Bottom Step

If a bottom step is located close to the column or girder, it is often most economical to eliminate this step and extend the deeper beam into the supporting column. This saves the additional reinforcing steel used in the lap splices and the effort to place it.

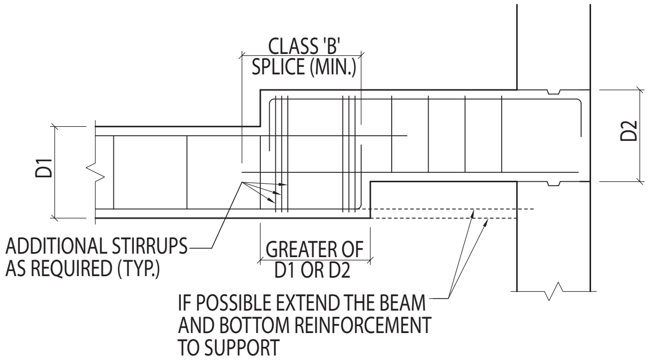
If clearance is required for ductwork, piping, or an electrical chase, a bottom step may be unavoidable. In this case, reinforcing bar details as shown in Fig. 6 can be followed. The length of common beam area should preferably be the greater of the two adjacent beam depths, "D1" and "D2." At a minimum, this ensures that a 45-degree strut can form in the panel region if needed. In addition, as a rule of thumb, it provides enough beam length to fit the reinforcement in this region.

Large Steps

Large beam steps, such that the depth of the step is greater than the beam depth itself, are sometimes required. The step creates a bent that must be carefully analyzed to calculate the moment and shear demands at each critical section. To optimize the beam design, it's good practice to keep the width of the bent equal to or greater than the adjacent beam depths. The width of the bent should also be more than the standard hook development length, ℓ_{db}, of the top beam bar. Reinforcement details shown in Fig. 7 can be used.

Depending on the framing layout and loading conditions, the situation illustrated in Fig. 7 may also be designed as the beam section "D1" being hung from beam section "D2." Alternately, the upper beam section "D2" could be supported by the lower beam section "D1." In the former case, the vertical element would be a tension strut and provided with the appropriate vertical reinforcement for

Fig. 6: Step in the beam bottom located near a column



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tension. In the latter case, the vertical element would behave as a column perhaps built integrally with the lower cantilever beam with depth "D1." The reinforcement would then be detailed according to the function of the vertical member. Moreover, the beam sections would likely be cantilevers with a high percentage of top reinforcement.

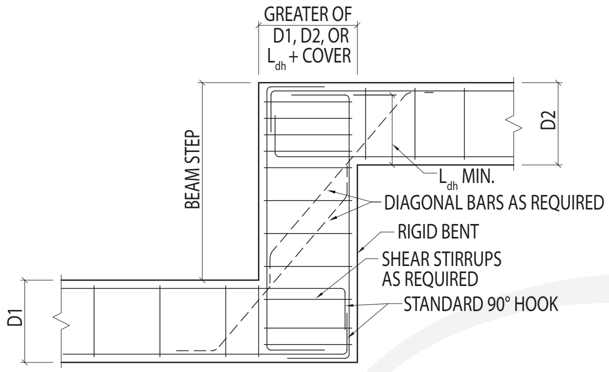


Fig. 7: A large step or elevation change in a beam can create a bent

Summary

Steps in beams require adjustments in the typical reinforcement details. Ideally, the best place to locate a beam step is where the beam frames into a supporting column or girder.

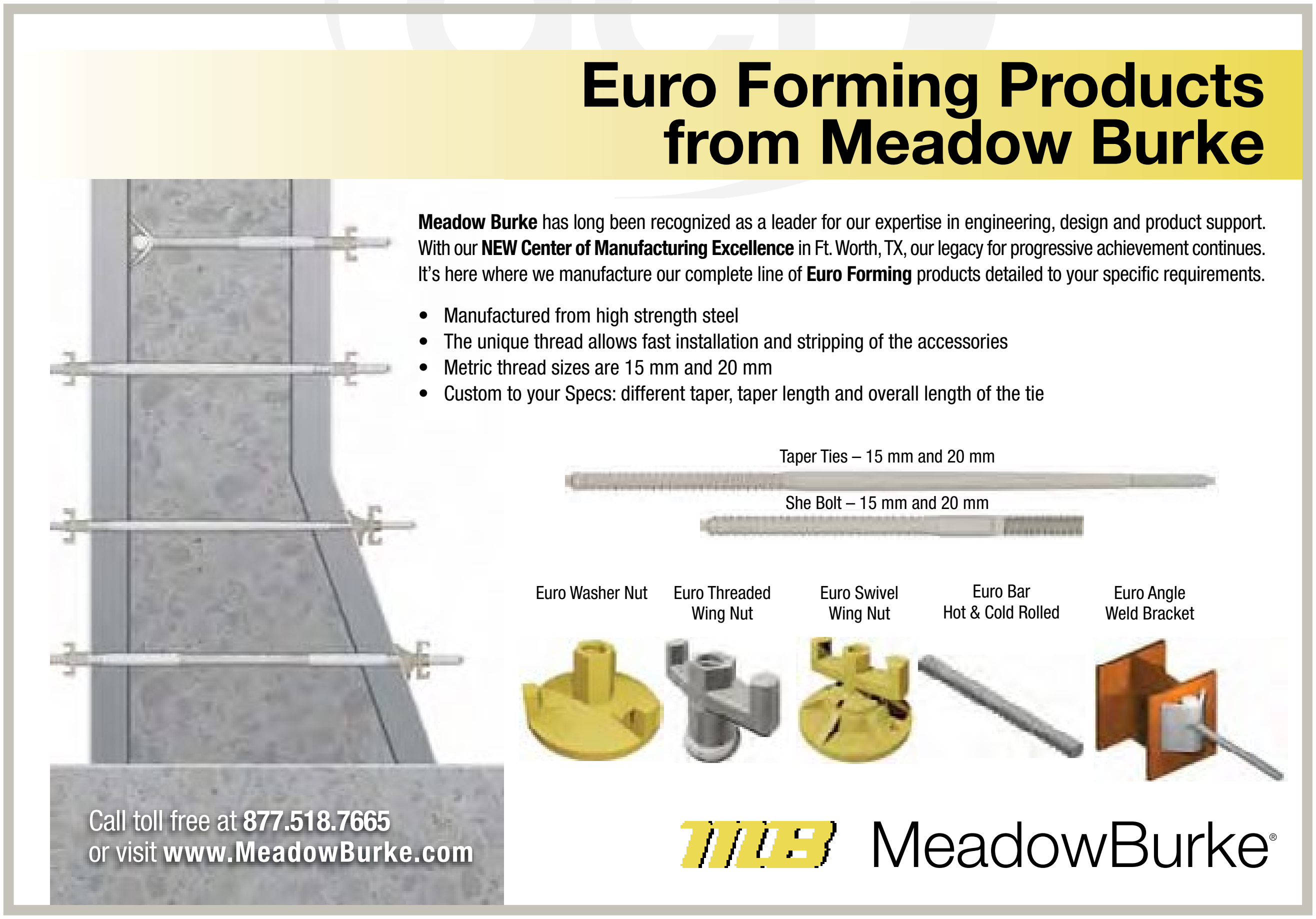
References

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

2. Andermatt, M.F. and Lubell, A.S., "Example 5: Stepped Beam with Multiple Load Combinations," *Further Examples for the Design of Structural Concrete with Strut-and-Tie Models*, SP-273, K.-H. Reineck and L.C. Novak, eds., American Concrete Institute, Farmington Hills, MI, 2011, pp. 5-1 to 5-21.

Thanks to Javed B. Malik of Jacobs-Global Buildings and Neal Anderson of CRSI for providing the information in this article.

Selected for reader interest by the editors.



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Location of Vertical Bars at Wall Intersections and RFI 12-02

In past *Detailing Corner* articles, we have focused on horizontal moment transfer at corner joints and proper reinforcing bar detailing techniques. In this month's *Detailing Corner*, we examine issues associated with vertical bars at intersections of double-curtained walls, showing how some commonly used standard details and tolerance buildup may lead to placement challenges, unnecessary bars, or bar congestion. In addition, we respond to an inquiry concerning conversion of mill marks on reinforcing bars to the in.-lb unit system. We thank those who have contacted us and encourage all readers to participate in this forum.

Issue

As engineers, we design the reinforcement for walls and commonly present section and elevation views as "typical" wall dimensions and reinforcement spacing. The exact details of the wall reinforcement layout are delegated to the reinforcing bar detailer, the bar placer in the field, or even the inspector. Specific layout details that can be obvious to a trained structural engineer because of our design knowledge may not be so obvious to the parties that have to actually detail and build the specific element the engineer designs. Field issues may arise because reinforcing bars are not laid out "exactly" as shown on the design drawings or placing drawings, even though it may be a minor concern from an engineering perspective.

One such potential area where issues arise is at the intersection of two orthogonal walls and the layout of the vertical bars from each wall. Common or "standard" details for wall intersections frequently show less-than-ideal arrangements for the vertical reinforcing bars, particularly in walls with two curtains of reinforcing bars. Details for corner intersections commonly show vertical bars placed directly at the intersection of both bar curtains and details for T-intersections commonly show an inside-curtain vertical bar in the center of the intersecting wall. These locations present varying difficulties, depending on whether the horizontal bars are located inside or outside the vertical bars.

Note that the corner details shown in the following figures are for pretied bar curtains with low or minimal horizontal moment transfer at the corner. Previously published *Detailing Corner* articles and RFIs discuss details for walls that have significant horizontal moments at the corners.$^{1-4}$

Wall corner intersections

The reinforcing bar detail shown in Fig. 1 is typical of details presented in reinforced concrete design books or in

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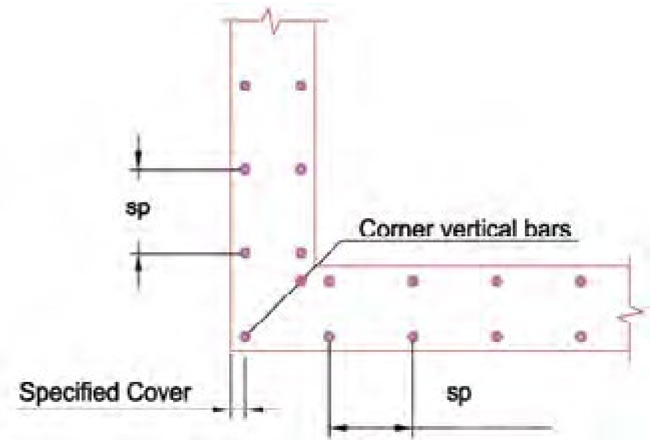

Fig. 1: A commonly used standard detail at a wall corner intersection, showing vertical bars only (sp is the center-to-center distance between bars)

the standard structural details in construction documents. At first glance, the location of the corner vertical bars may seem reasonable. However, once horizontal bars are considered, problems quickly become apparent. Figure 2 shows the same reinforcing bar pattern as in Fig. 1, but with horizontal bars included inside or outside the vertical bars, respectively.

Fabrication and placing tolerances for the horizontal bars can lead to an irregular pattern at the corner formed at the intersection of the two planes of the outside face horizontal bars. According to Section 2.1 of ACI 117-10,[5] the fabrication tolerance for straight bars is ±1 in. (±25 mm) for No. 3 through No. 11 bars. Section 2.2.7 of ACI 117 states that the tolerance on the longitudinal location for ends of bars is also ±1 in. (±25 mm). Even if the horizontal bar ends meet exactly at the corner "on paper," they can be up to 1 in. short of each other yet be within tolerance. In this case, placing a vertical bar at the intersection of the horizontal bars will not be possible. The vertical bar will thus need to be offset a certain distance from the working point.

At a wall corner intersection, the horizontal bars from the two walls will likely be made continuous with "L-shaped" corner bars placed after the curtains are erected. The fabrication tolerance for the bend radius (ACI 117, Section 2.1: ±1 in. [±25 mm]) and angular deviation (ACI 117, Section 2.1: ±2.5 degrees) of the corner bars compound the problem and will make it difficult to locate and tie the outside face corner vertical bar. If the two outside face panels of reinforcing steel were preassembled on the ground, it would be difficult to precisely locate the corner vertical bar once the panels have been erected against the forms and the horizontal corner bars have been placed.

Oftentimes, a corner vertical bar is called out or requested at the theoretical intersection point of the inside corner horizontal bars. Depending on the layout and tolerances, this bar may be hard to locate at the "exact" intersection point of the two horizontal lines. Having a vertical bar at this inside face location is not structurally necessary and it can be moved. The bar may also be in the way of the horizontal corner bars as they are inserted for placement.

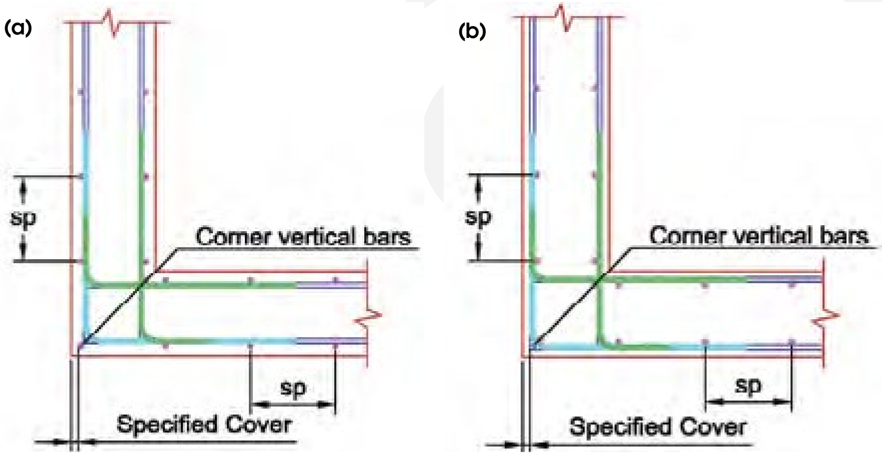

Fig. 2: Standard detail at a wall corner intersection: (a) vertical bars outside the horizontal bars; and (b) vertical bars inside the horizontal bars

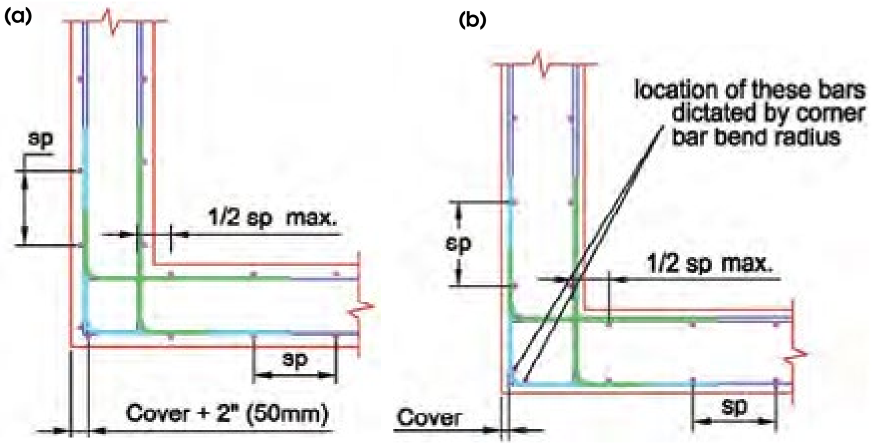

Fig. 3: Preferred detail at a wall corner intersection: (a) vertical bars outside the horizontal bars; and (b) vertical bars inside the horizontal bars

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Additionally, if the horizontal bars are straight but are spliced with separate corner bars, the location of the vertical bar will interfere with placement of the corner bars.

There is one other issue: If the vertical bars in adjacent walls have different sizes, how is the size of the corner vertical bar determined? A note on the drawings may help clarify this issue.

Figure 3(a) and (b) are similar to Fig. 2(a) and (b), but without the problematic corner vertical bars. The single vertical bar at the outside face corner has been replaced with two vertical bars—one on each wall located slightly away from the corner. These vertical bars can be easily placed. The unnecessary inside face vertical bar has been removed and replaced with two bars, spaced no more than one-half a space from the inside corner. If the bar panels are preassembled, the vertical bars can be tied in place and erected with the panels. There is nothing in the way to impede clear installation of the corner bars.

For the wall corner intersection shown herein, the effect of the recommended details shown in Fig. 3(a) and (b) is to locate both corner vertical bars to the outside of the horizontal bar layers, slightly away from the "exact" intersection of the two curtains.

Wall "T" intersections

The detail shown in Fig. 4 may also be found in reinforced concrete design books or in standard details. While the detail may seem reasonable, the inside face vertical bar within the core of the intersecting wall is structurally unnecessary and adds to congestion at the intersection. Figure 5 shows the same reinforcement detail as in Fig. 4, but with horizontal bars included inside or outside the vertical bars, respectively.

Figure 6 shows the preferred detail for the vertical bars at a "T" intersection, without the unnecessary vertical bar within the core of the intersecting wall. If the locations must match for the inside and outside vertical bars, the spacing of the vertical bars near the intersecting wall may be larger than the required minimum spacing. In this case, additional vertical bars can be added to the inside face, spaced a maximum of one-half a space from the plane of the curtain of the intersecting wall and outside the intersecting wall's core.

Design Considerations

Locating reinforcing bars in standard details without serious consideration of constructibility concerns can lead to costly issues in the field. Designers must continually be aware that even seemingly trivial decisions can impact

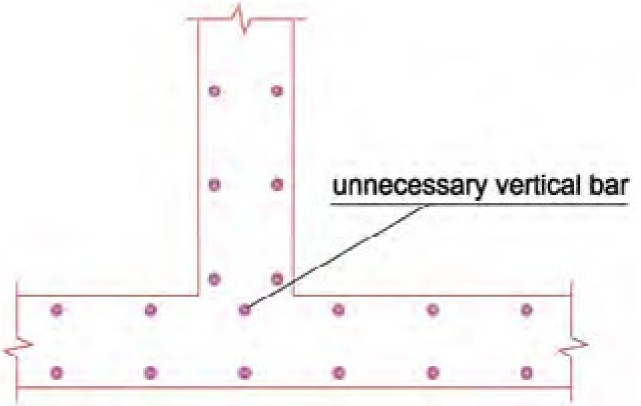

Fig. 4: A commonly used standard detail at a wall "T" intersection, showing vertical bars only

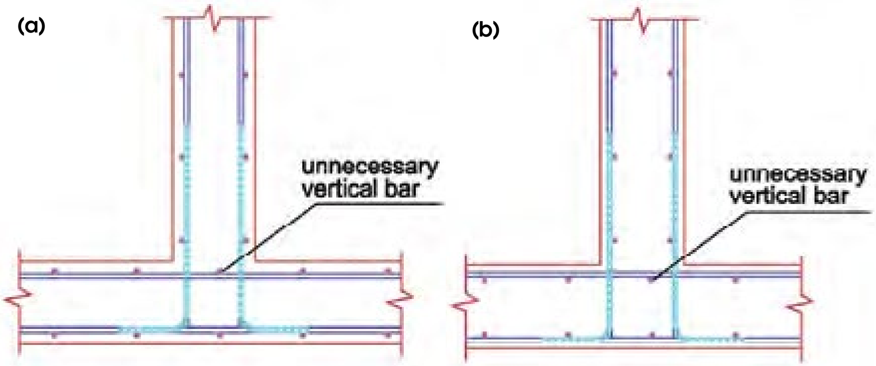

Fig. 5: Standard detail at a wall "T" intersection: (a) vertical bars outside the horizontal bars; and (b) vertical bars inside the horizontal bars

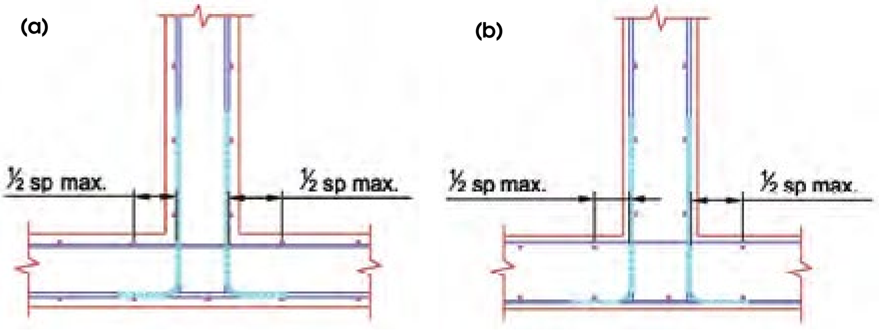

Fig. 6: Preferred detail at a wall "T" intersection: (a) vertical bars outside the horizontal bars; and (b) vertical bars inside the horizontal bars

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constructibility or raise questions during the inspection process—simple and well-thought-out details are the hallmark of a good designer.

Fig. RFI 12-02.1: Examples of finish (or final) rolls used on a reinforcing bar line to roll in the deformations and bar marks. Several of the rolls are kept in inventory at the steel mill *(Photo courtesy of Nucor Steel, Marion, OH)*

Fig. RFI 12-02.2: A four-axis milling machine is used to re-cut and provide better definition to the deformations on a worn roll surface *(Photo courtesy of Nucor Steel, Marion, OH)*

RFI 12-02: I recently noticed in an industry trade magazine that the Concrete Reinforcing Steel Institute (CRSI) is urging all producers of deformed reinforcing steel bars to revert back to an in.-lb bar marking system from the soft-metric bar marking system. I also read that the phase-in target date is January 1, 2014. Why is the phase-in period so prolonged? Why can't this change be implemented by the end of 2012?

Response: Thank you for your inquiry. The CRSI Board of Directors recommended at their November 9, 2011, meeting that CRSI producer members revert back to the in.-lb marking system. This recommendation was the culmination of several recent specification changes and many requests from the construction industry:

- ACI's Technical Activities Committee (TAC) encouraged CRSI mill members to revert back to the in.-lb system. The ACI 318 Building Code[6] and other key ACI documents never converted to the soft-metric designations and continue to reference the in.-lb sizes as their primary designation;
- The Federal Highway Administration (FHWA) no longer mandates the use of the metric system on Federal Aid projects, as noted in a memorandum dated November 25, 2008.[7] Within the last 2 years, the last state DOTs using the soft-metric system have reverted back to the in.-lb system; and
- No action was required in the ASTM standards for reinforcing bars, as the standards recognize both marking systems.

With respect to the time frame for implementation, this issue really concerns the manufacturing process for reinforcing bars. Some reinforcing steel mills in the United States never adopted the soft-metric designations and thus have the in.-lb system already rolled into their bars.

For the mills requiring a changeover, however, a phase-in period is required to avoid a needless waste of existing tooling. When reinforcing bar is produced, the deformations and markings are impressed into the bar during the end of the rolling process using finish rolls. Figure RFI 12-02.1 shows a number of the finish rolls in inventory storage at a CRSI member bar mill. Note that each roll consists of a series of parallel slots or grooves.

These rolls are used multiple times before they must be replaced. For a production sequence of a given reinforcing bar size, one or more of the slots will be used to roll in the deformations and markings. When a slot wears to the point it no longer meets tolerances, the roll is shifted transversely and another slot is used to roll the deformations and markings. Once all of the slots or roll grooves in the roll are worn, the roll is replaced on the production line.

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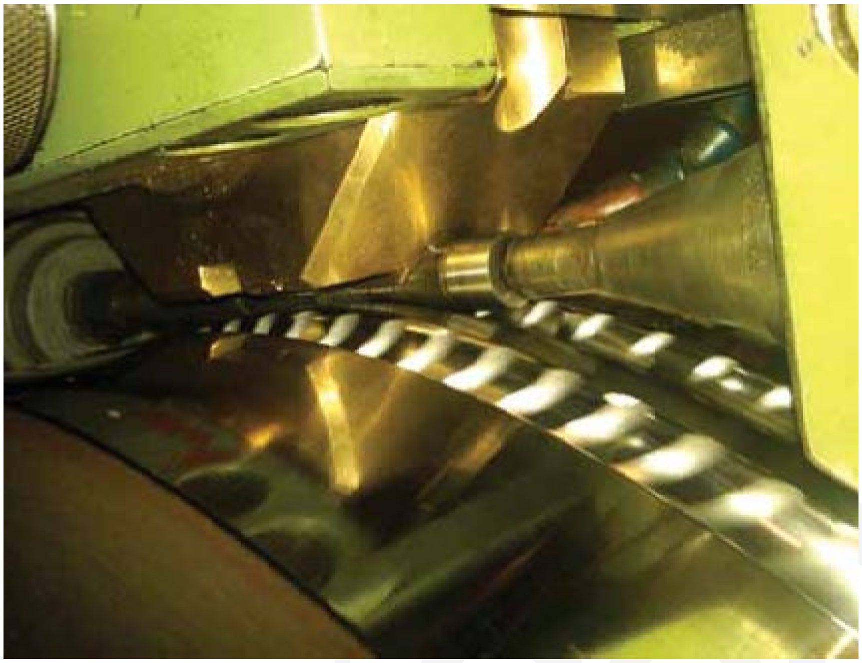

Fig. RFI 12-02.3: The roundness of the slot is also re-established in the milling machine. The roll surface is then cleaned and polished to provide a smooth surface free of burrs and filings, so the roll produces a sharp deformation on the reinforcing bar stock *(Photo courtesy of Nucor Steel, Marion, OH)*

Other minor issues, which are mainly internal to the steel mills, include the following:

- Testing systems for QA/QC will have to be converted over to recognize the in.-lb sizes;
- Internal inventory and tracking systems in the mill will need to be changed to recognize the in.-lb sizes (It's likely that many mills currently have software systems that refer only to soft-metric sizes.); and
- The mill technicians may require re-education to the in.-lb system and measuring the bars (diameter, deformations) in the in.-lb units.

In summary, the changeover to the in.-lb marking system will take time and the implementation period will vary for each mill. The January 2014 implementation date may slide as inventories of soft-metric rolls and bars are depleted, but the industry is committed to reverting to in.-lb bar markings in a reasonable time period.

For economic reasons, worn rolls will be "re-dressed" about 15 to 20 times before they are too worn for further use. During the "re-dress" process, the deformations and markings are re-cut into the roll surface. Figures RFI 12-02.2 and 12-02.3 show this process. Some steel mills have the necessary re-dressing equipment in-house in their shop; other mills may subcontract this service out to a specialty machine shop.

The time necessary for reverting the bar markings to the in.-lb system will depend on the number of rolls the steel mill has in its inventory and the number of times the mill's rolls have been re-dressed in the past. To avoid unnecessary costs, the rolls in inventory will need to be used up. Rolls for more common bar sizes will be replaced sooner than rolls for less common bar sizes. A mill may be capable of rolling bar sizes No. 3 through No. 8, for example, but if the local market demands more No. 4 and No. 6 bars than other sizes, rolls for these bar sizes will likely be replaced sooner than rolls for the other bar sizes. In the interim, the mill's reinforcing bar inventories may carry in.-lb markings for the most-used bar sizes and soft-metric markings for the other sizes. This lag is one of the main reasons a phase-in period is required.

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7. "Information: Update on Metric Use Requirements for FHWA Documents," FHWA Memorandum, Nov. 25, 2008, www.fhwa.dot.gov/programadmin/contracts/1108metr.cfm.

Thanks to Greg Birley of Condor Rebar Consultants, Inc., and Neal Anderson of CRSI for providing the information in this article. Additional thanks to Bryan James of Nucor Steel, Marion, OH, and Thomas Murphy of Cascade Steel, McMinnville, OR, for their assistance on the RFI information.

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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

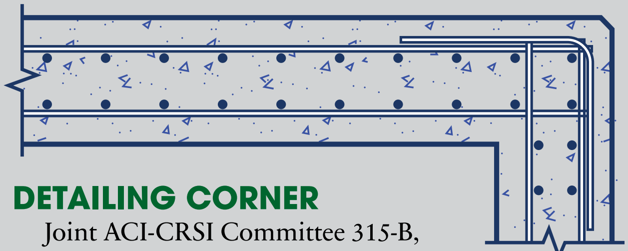
Basic requirements for column tie configurations are listed in Section 7.10.5 of ACI 318. They are summarized here:

- 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.



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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]

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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)

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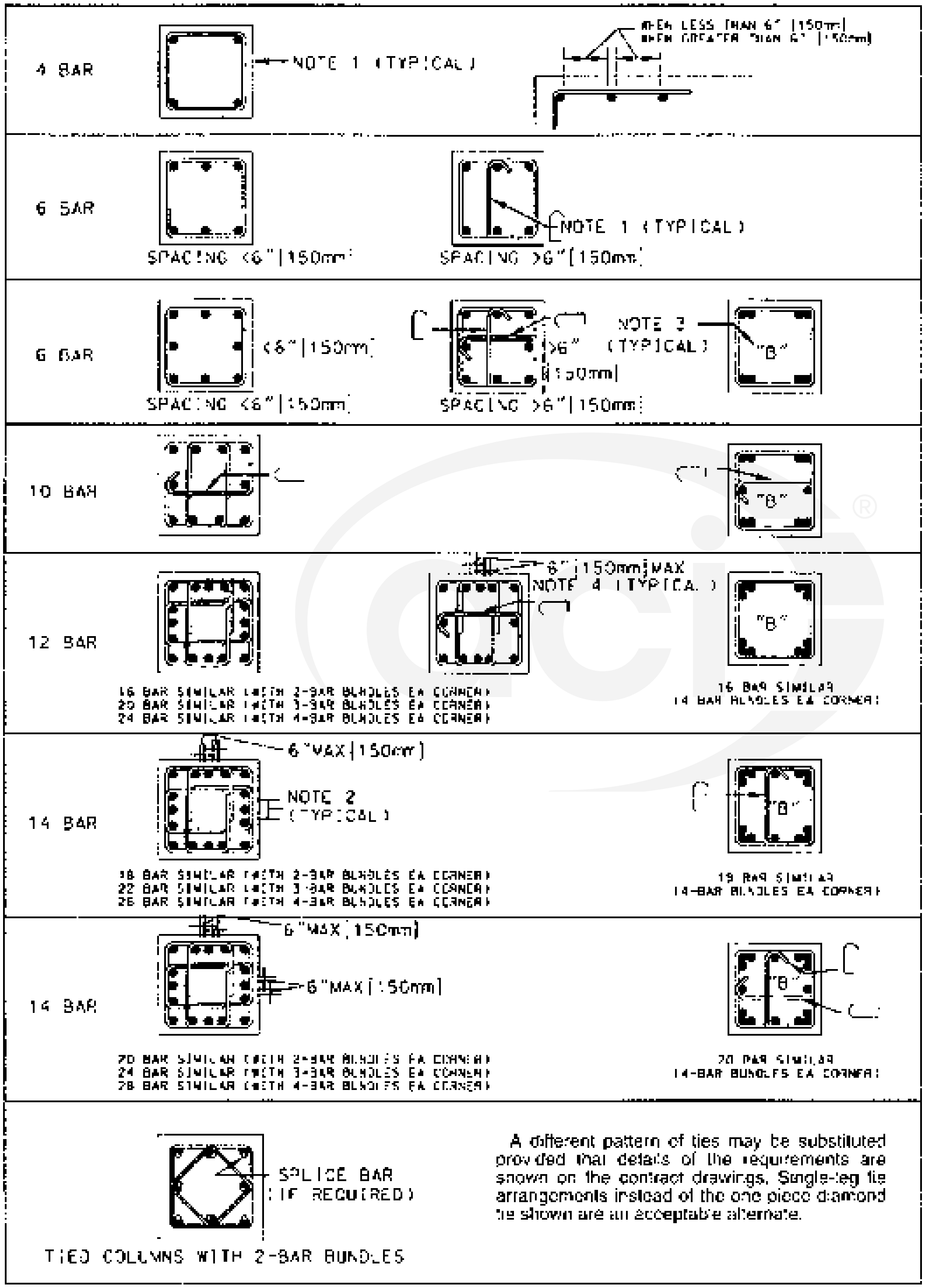

A different pattern of ties may be substituted provided that details of the requirements are shown on the contract drawings. Single-leg tie arrangements instead of the one piece diamond tie shown are an acceptable alternate.

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])

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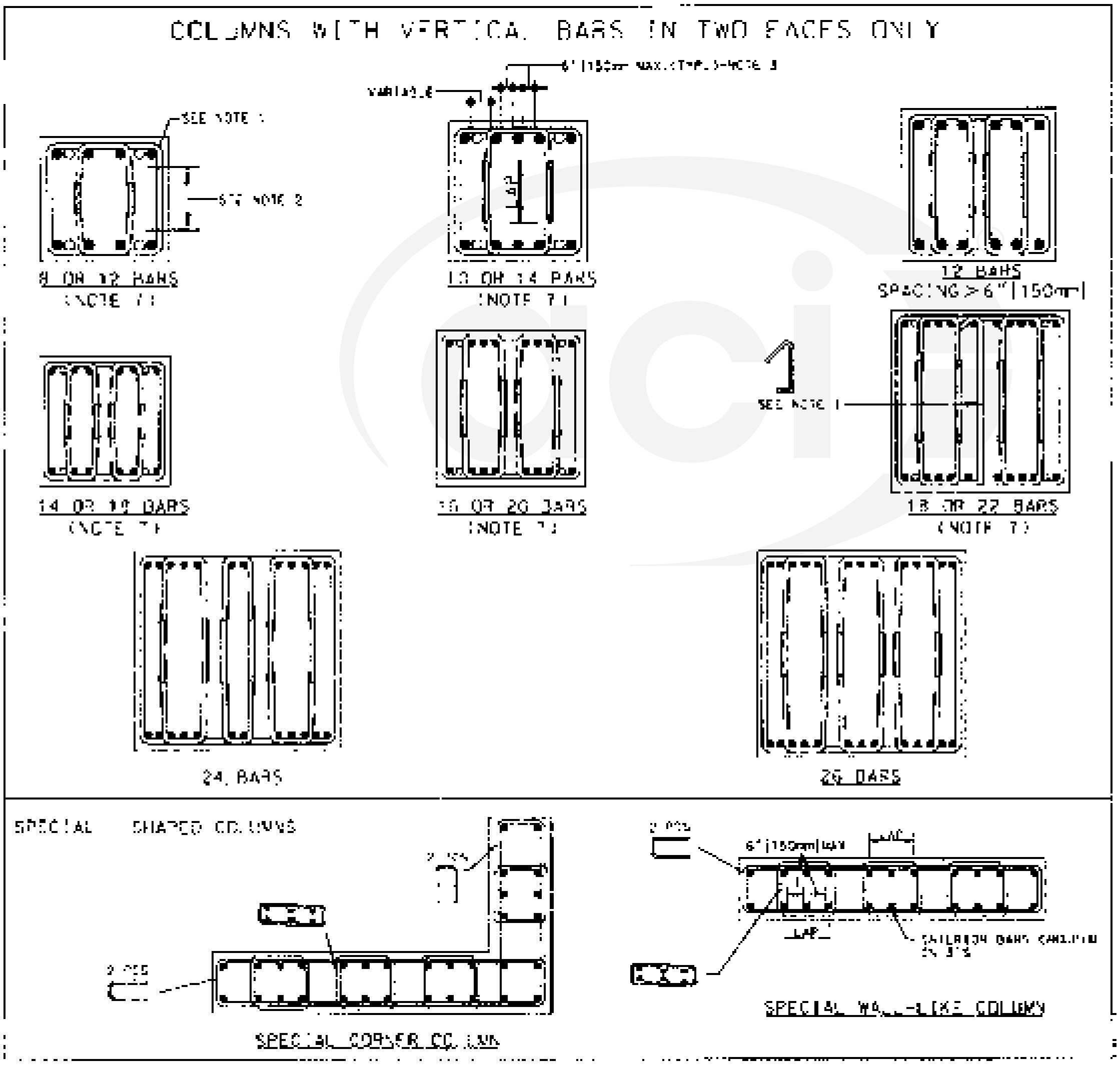
Alternate Configurations

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])

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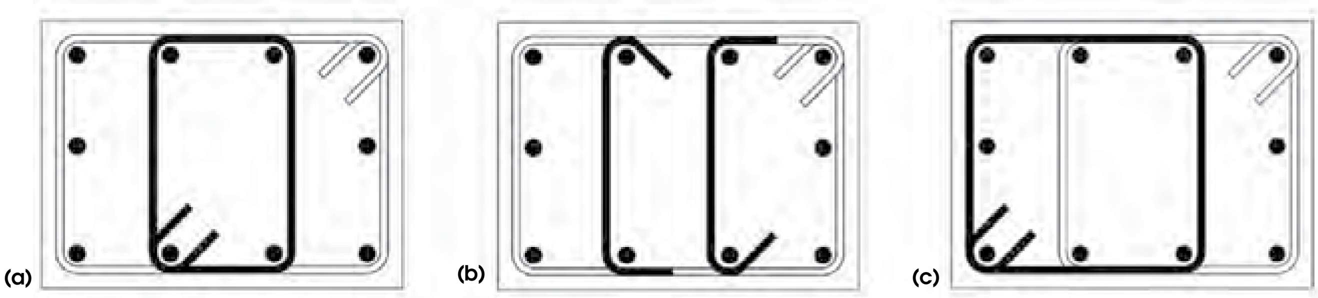

Fig. 3: Column tie sets comprising multiple ties: (a) with outer confinement tie and inner closed tie; (b) with outer confinement tie and candy cane ties; and (c) with paired overlapping ties

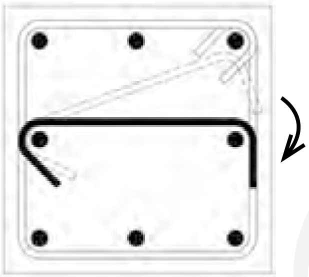

Fig. 4: Installation of a candy cane tie being "snapped" into place

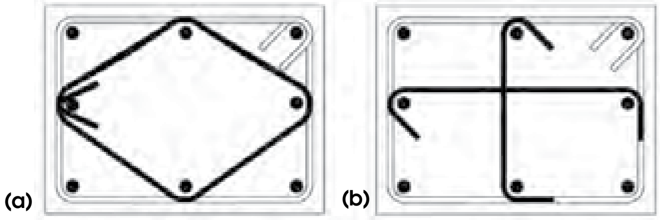

Fig. 5: Column tie configurations using multiple bars: (a) diamond tie (avoid use); and (b) single closed tie with candy cane ties

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.

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

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

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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.

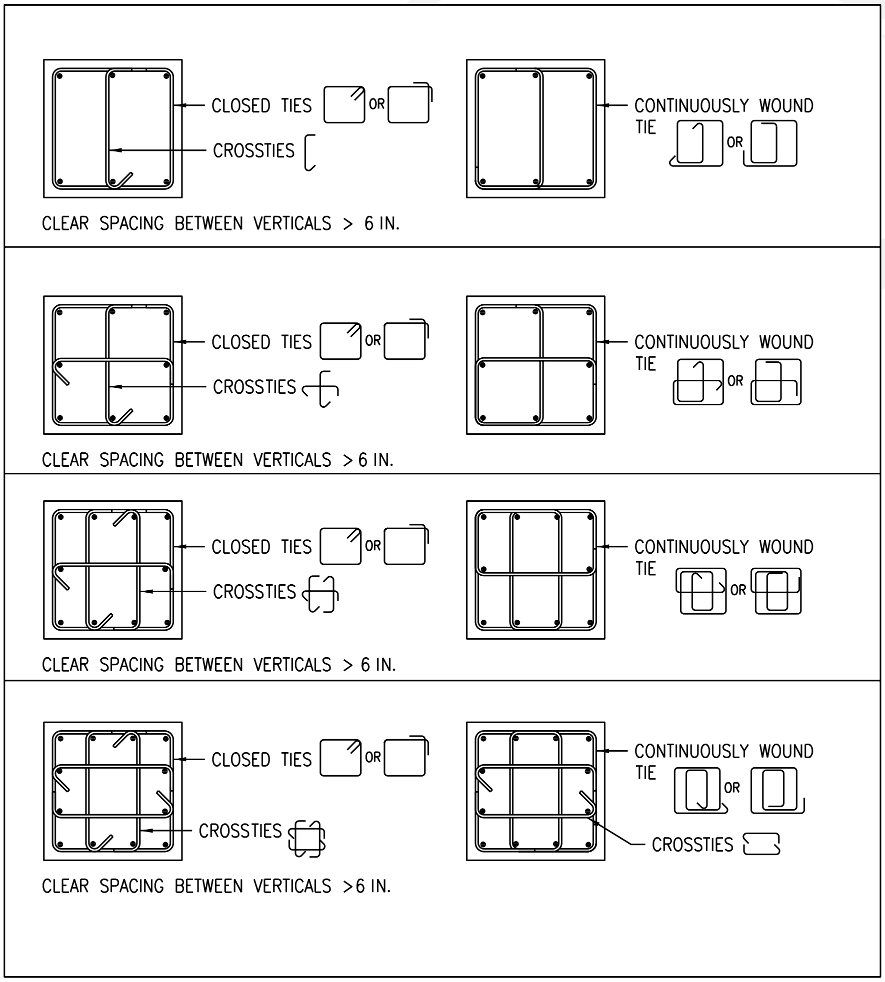

Fig. 7: Traditional column tie sets and continuously wound ties (uni-ties or multi-ties) alternates (Note: Uni-ties are not universally available or used) (Note: 1 in. = 25.4 mm)

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.

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Thanks to Robbie Hall of Gerdau and Neal Anderson of CRSI for providing the information in this article.

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Column and Boundary Element Dowels

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

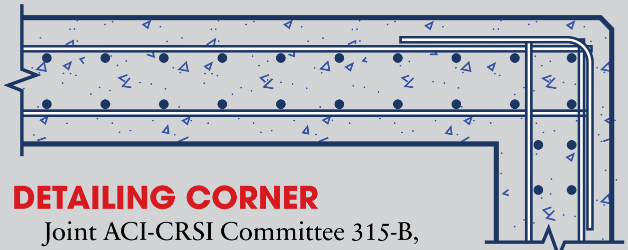
Figure 1 shows a 10-bar column section, including the dowels protruding from the foundation. Each tie set is made up of two closed ties and a crosstie in the center. The figure shows the ideal arrangement of the dowels for ease of installation of a preassembled reinforcement cage.

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



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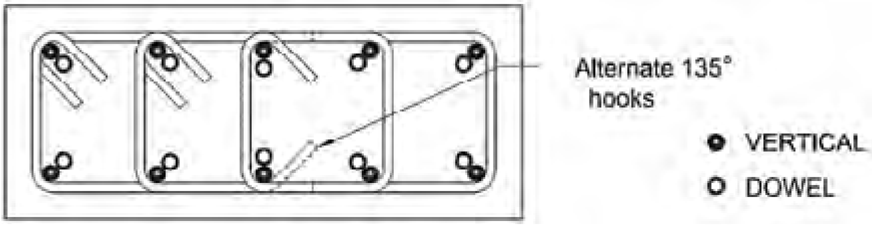

Fig. 1: Ten-bar column with dowels. Ideal arrangement of dowels

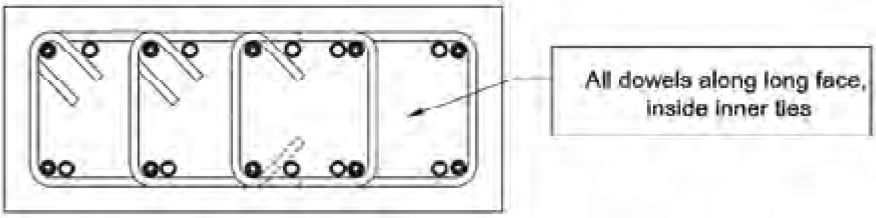

Fig. 2: Ten-bar column with dowels. Dowels along long faces of column

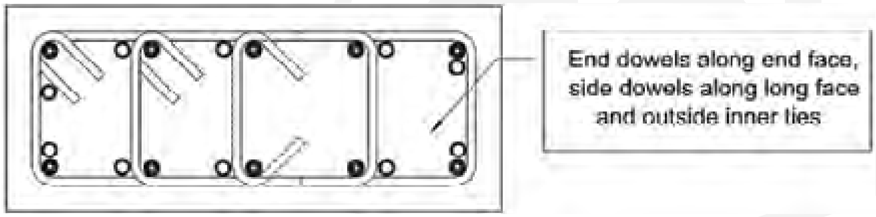

Fig. 3: Ten-bar column with dowels. Least preferable arrangement of dowels

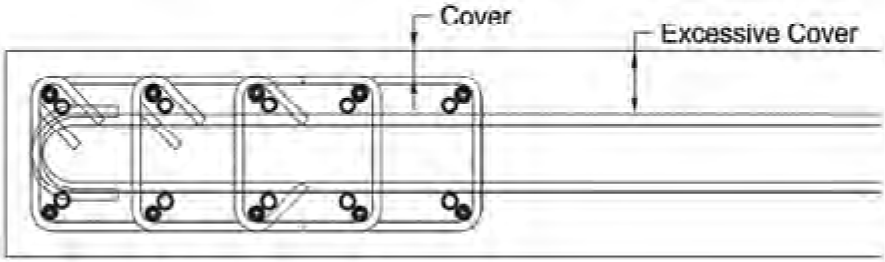

Fig. 4: Ten-bar boundary element. Dowels arranged as in Fig. 1

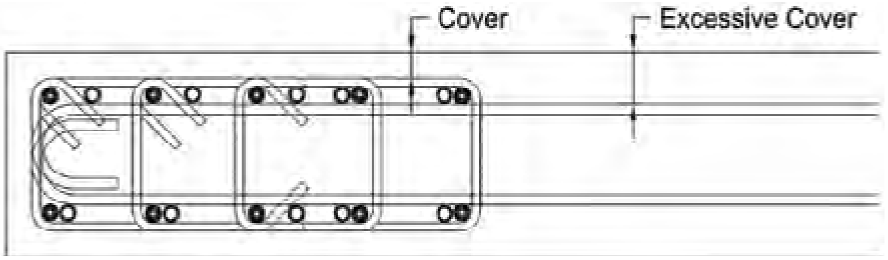

Fig. 5: Ten-bar boundary element. Dowels arranged as in Fig. 2

ends—the ties will allow little flexibility. 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[1] 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

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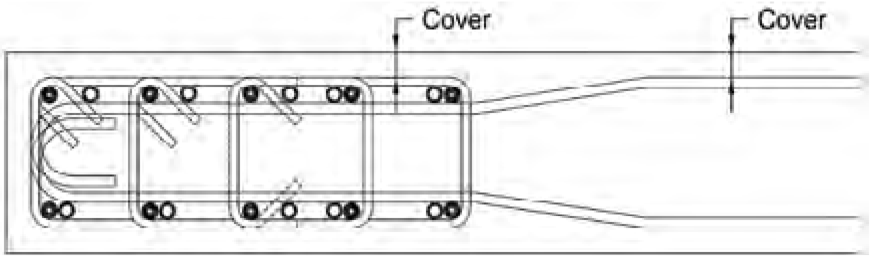

Fig. 6: Ten-bar boundary element. Horizontal wall bars are offset-bent

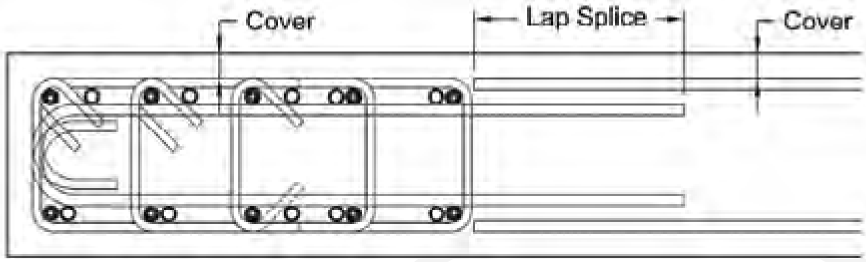

Fig. 7: Ten-bar boundary element with wall horizontal dowels

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.

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

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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

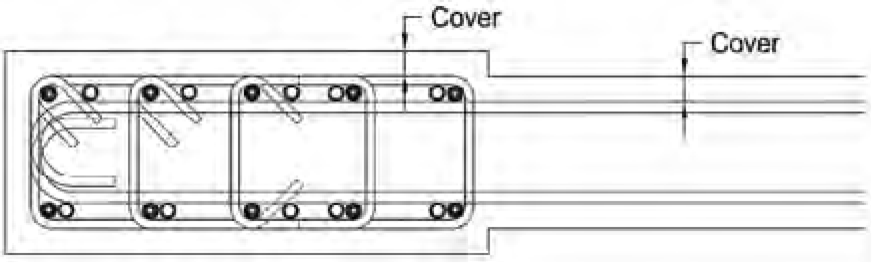

Fig. 8: Ten-bar boundary element with increased boundary thickness

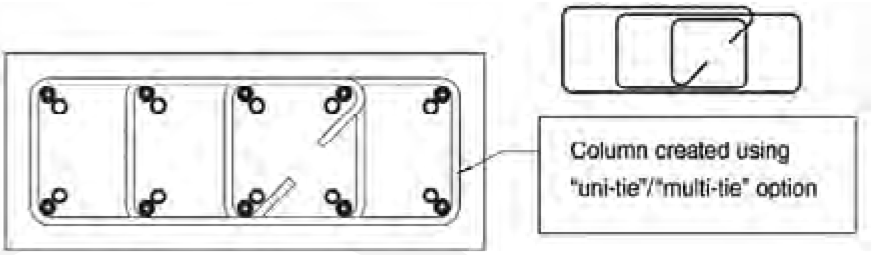

Fig. 9: Ten-bar column with dowels with "uni-ties"/"multi-ties"

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.

Thanks to Dick Birley of Condor Rebar Consultants, Inc., and Neal Anderson of CRSI for providing the information in this article.

Detailing Corner

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."

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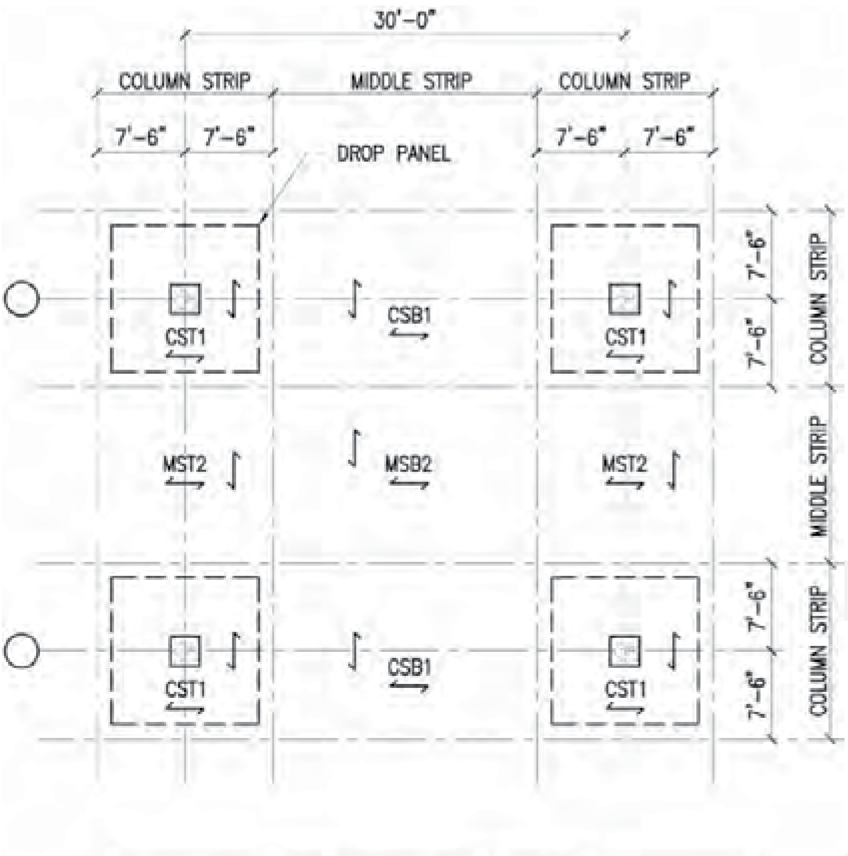

SLAB REINFORCEMENT SCHEDULE

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

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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.

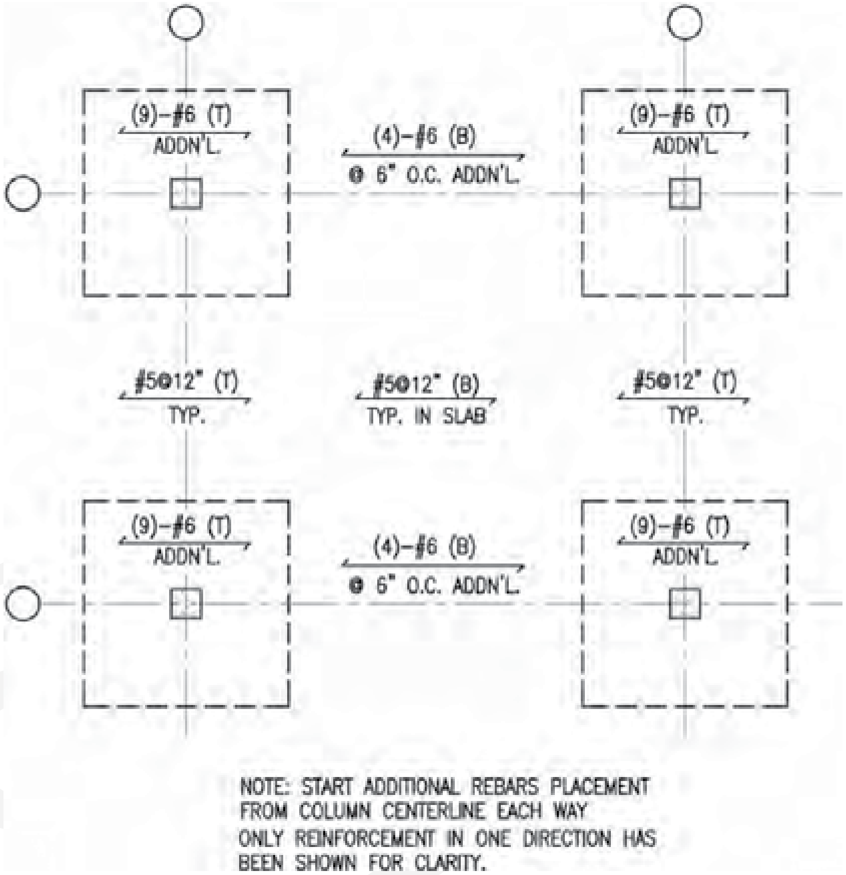

Fig. 2: Alternate method for showing two-way slab reinforcement

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.

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.

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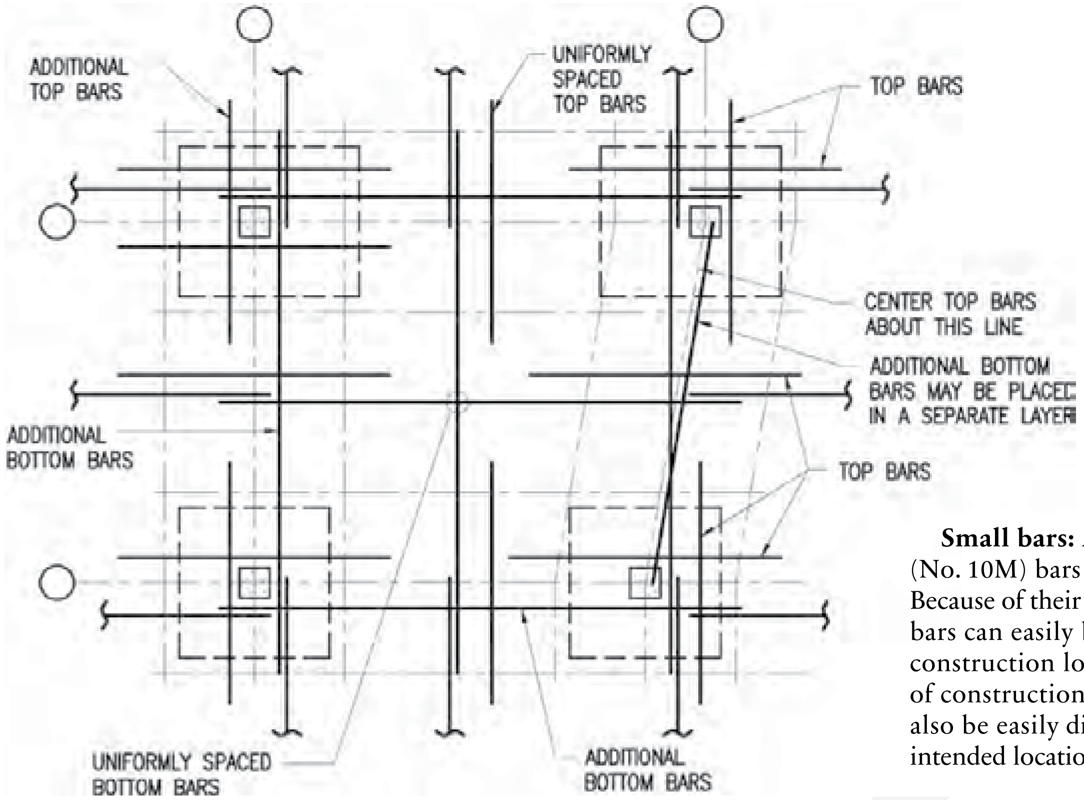

Fig. 3: Reinforcement placement when columns are offset

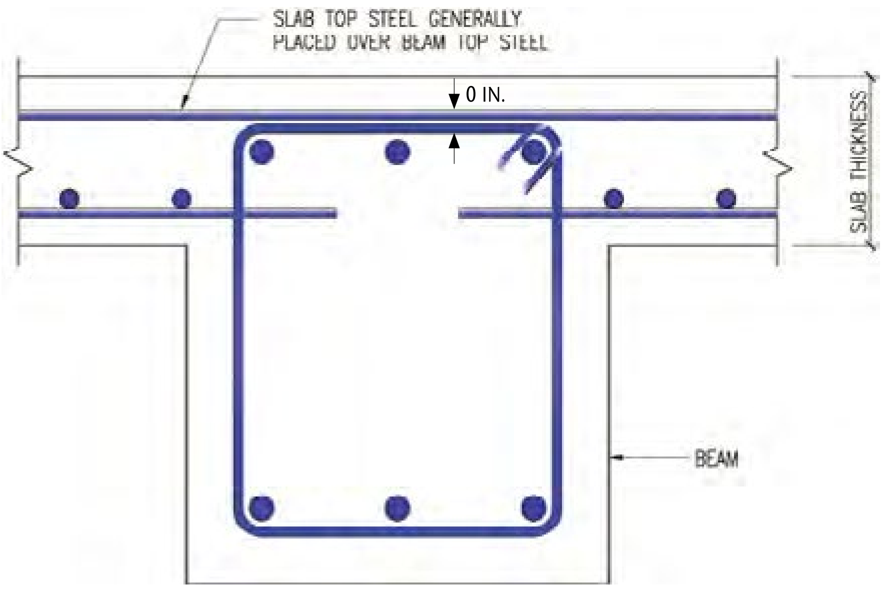

Fig. 4: Placement of slab reinforcement when beams are present

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.

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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.

Detailing Corner

Truss Bars (Bend Type 15)

Since 1946,[1] the reinforcing bar fabrication industry has used a common set of bar bend types to describe and fabricate various reinforcing bar configurations. Each bend type is identified with a number and each segment of the bend type requiring a dimension is represented with a letter. Figure 1 shows examples of the first nine typical bar bend types used today.[2]

Bend Type 15 (Fig. 2), also known as a truss bar or a galloping truss bar, requires a series of bends. Although truss bars are now rarely used in reinforced concrete building construction, a few state departments of transportation (DOTs) continue to use this bar configuration for flexural reinforcement for bridge decks (Fig. 3). In this month's *Detailing Corner*, we discuss the early beginnings and some of the issues concerning truss bars, and we suggest an alternate bar configuration.

Early Beginnings and Designing with Truss Bars

François Hennebique (1842-1921) was a French engineer who patented a reinforced construction system in 1892 in which separate elements such as beams and columns were integrated into a single monolithic element.[3] Hennebique was likely the first person to use stirrups and "bent-up bars" in reinforced concrete construction.

The basic premise of truss bars and bent-up bars was to use one piece of reinforcing steel to provide reinforcement in various locations of the member:

- A horizontal top segment for negative-moment flexural reinforcement near a support;
- An inclined segment for shear reinforcement near a support; and
- A horizontal bottom segment for positive moment flexural reinforcement near the midspan.

Figure 4 shows various layouts of reinforcement, with truss bars in Fig. 4(b) through (d). Usually, straight bars were combined with bent-up bars, as shown in Fig. 4(b) and (c).

The inclined portion of a truss bar was typically bent up at an angle of between 30 and 45 degrees from the horizontal. It was recognized that having a bend that was too sharp would result in high compressive stresses in the concrete within the bend area.

Wherever practical, the top segment was placed to be continuous over the supports of multiple spans. To provide the required amount of shear reinforcement within a given area along the member, designers used multiple small-diameter bars, bent up at various locations, rather

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than using fewer large-diameter bars. Vertical stirrups were also added to the reinforcement layout.

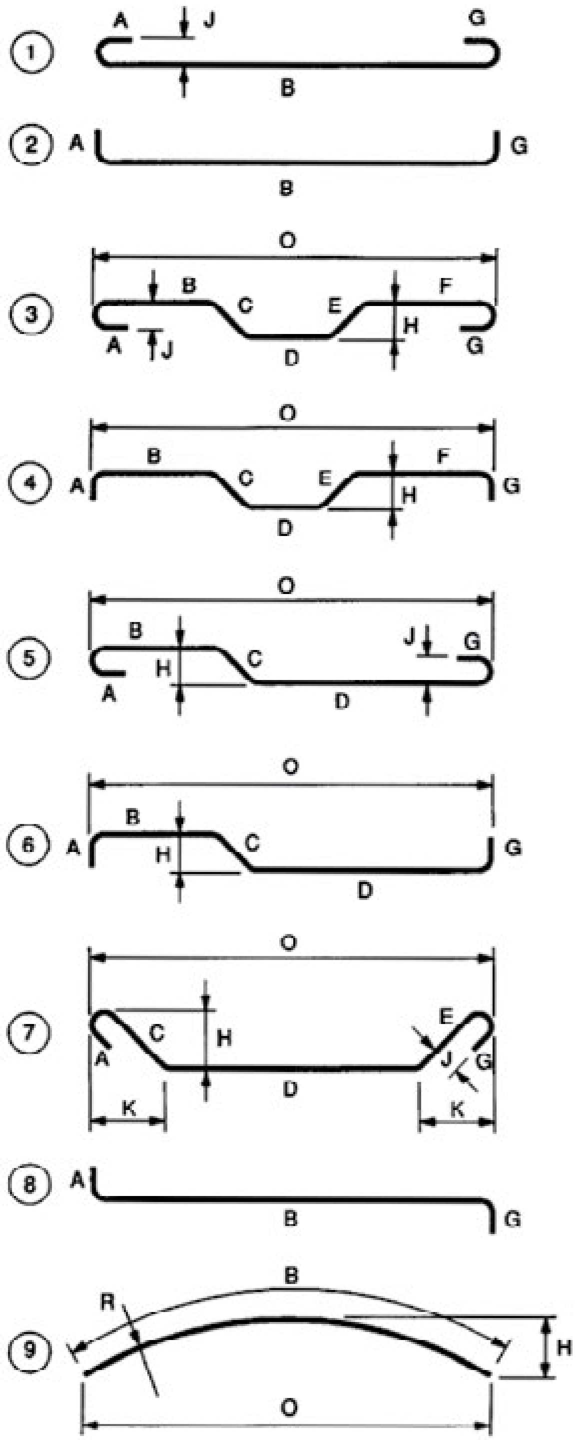

Fig. 1: Examples of bar bend Types 1 to 9 (after Reference 2)

Tests on Truss Bars as Shear Reinforcement

Tests conducted by Regan and Khan[5] indicated the following behavioral issues with truss bars used as shear reinforcement:

- Truss bars are somewhat less effective than vertical stirrups as shear reinforcement;
- If truss bars are used, they should be used in combination with the minimum amount of vertical stirrups as required by code; and
- From strain measurements, 45-degree bends at the top and bottom of the inclined portions provide relatively little anchorage, especially at high shear forces. Therefore, the horizontal portions should be detailed to provide, as a minimum, the full tension development length.

Issues Concerning Truss Bars

Truss bars can be a challenge to fabricate—production can even raise safety concerns. They also create tolerance issues during fabrication and while placing in the field.

During the bending operation in the fabricator's shop, a truss bar becomes more difficult to handle as it is advanced along the bending table and the length of bar extending past the bend point causes the bar to sweep over a progressively wider arc. As a safety precaution, fabrication operations are typically slowed down to reduce the possibility of injuries among shop personnel.

Reinforcing bar fabrication tolerances vary depending on the specific segment in the bend type and the bar size, but the tolerance is generally ±1 in. (±25 mm) for bar sizes No. 3 through No. 11 (No. 10 through No. 32). This is also the tolerance on the overall length of a bent bar. As more bends are incorporated in the bend configuration, variances in the dimensions will accumulate and the ±1 in. (±25 mm) tolerance becomes more difficult to meet. In an effort to stay within fabrication tolerances, some fabrication software programs will determine the running distances from the far left end of a truss bar (origin line) to certain key bend points, as shown along the bottom in Fig. 5. By matching these calculated distances with the distances measured on the fabricated bar, the fabricator is able to make

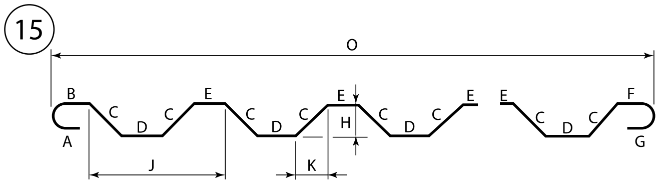

Fig. 2: Continuous truss bar (Bend Type 15) (after Reference 1)

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Fig. 3: Example of truss bars used in a bridge deck. To maintain cover tolerance (normally +0 in. (+0 mm) for bridge decks), top horizontal segments may need to be shifted slightly relative to the bottom horizontal segments

adjustments, when necessary, to stay within the overall length tolerance. Note that the series of distances in Fig. 5 are measured to alternate bend points. In some shops, distances may be measured to every bend point to ensure the overall length tolerance is met.

Truss bars are typically supported on the bottom segments using slab bolsters. To keep the truss bars upright, the top segments are tied to other reinforcement such as transverse top bars. Because the segments of the bar configuration are attached to each other, any adjustment in position for one segment can impact the position of the whole bar and the other segments. This can make it difficult to meet placing tolerances.

It's worth noting that some State DOTs specify a ±1/2 in. (±15 mm) tolerance on the height (the "H" dimension in Fig. 2) of truss bars. This tight tolerance allows the top cover to be maintained (for protection of the bars against corrosion) without having to laterally shift the top segments relative to the bottom segments.

Length Limitations

The overall length of a truss bar is limited by two factors: the stock length of the reinforcing bars stored at the fabricator's shop and transportation length restrictions. Although stock length varies by shop, the maximum stock length for reinforcing bars is generally 60 ft (18.3 m). From the standpoint of transporting truss bars by truck, the overall length is generally limited to a maximum of 45 to 47 ft (13.7 to 14.3 m).

If the required length must exceed these limits, two or more truss bars must be lap-spliced in the field. Unless this arrangement has been covered on the structural drawings,

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the detailer normally will issue a Request for Information (RFI) to the licensed design professional to approve lapping multiple truss bars. The engineer's response must also indicate where the bars are to be lapped: at the bottom "D" segments or at the top "E" segments (Fig. 2). An example RFI would be:

"The truss bars (Bend Type 15) required in the bridge deck cannot be fabricated in one piece as shown on the contract drawings. We intend to supply multiple truss bars (15s) lapped together to achieve the required overall length ("O" dimension). Please verify this is acceptable and if so, provide a sketch indicating how the truss bars need to be lapped. This sketch should depict lap length and lap position (top legs or bottom legs)."

Once the RFI is approved, the specific configuration will be included on the fabricator's placing drawings to make it clear to all concerned how the truss bars are to be lapped.

Alternative to Truss Bars

Apparently, truss bars are still used in bridge decks because of the perceived cost savings in steel material and, more succinctly, the placing costs; placing "half" of the bars is viewed to be a cost savings. However, this notion discounts the fact that tolerances are more difficult to maintain, both in fabrication and in placement, and shop production can be slowed.

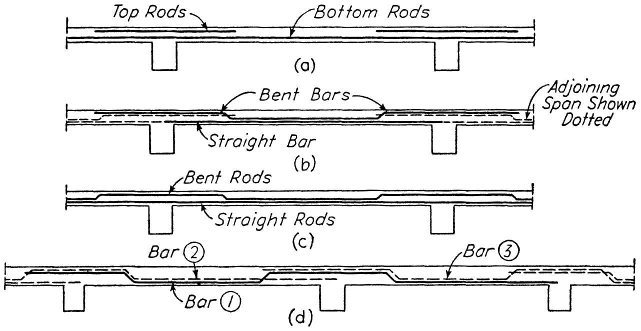

Fig. 4: Different arrangements of reinforcing steel, with and without truss bars (after Reference 4)

Rather than using truss bars, the engineer should consider using separate pieces of reinforcing bars to provide the top and bottom reinforcement. Bars can include standard hooks at the discontinuous end spans if needed for anchorage. If reinforcement is required for shear, it can be provided by vertical stirrups. This simpler, alternate arrangement avoids the fabrication, transportation, and placing issues that have been covered herein.

Summary

Although truss bars have declined in use, a number of State DOTs still include them in their deck slab designs for flexural reinforcement. Using straight or hooked reinforcing bar pieces and vertical stirrups instead of truss bars would help alleviate a number of issues, including maintaining fabrication and placing tolerances. More importantly, avoiding the use of truss bars can result in a safer environment in the fabricator's shop.

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1. Joint ACI-CRSI Committee 315, "Proposed Manual of Standard Practice for Detailing Reinforced Concrete Structures (ACI 315-46)," American Concrete Institute, Farmington Hills, MI, 1946, 55 pp.

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Thanks to Robbie Hall of Gerdau, and Anthony Felder and Neal Anderson of CRSI for providing the information in this article.

Selected for reader interest by the editors.

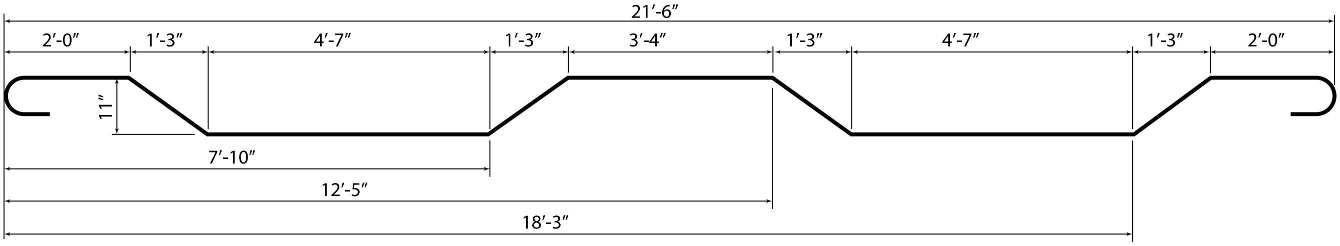


Fig. 5: Truss bar with distances measured from left end to key bend points (Note: 1 ft = 0.3048 m; 1 in. = 25.4 mm)

SECTION 4

APPENDIX

MNL-66(19)—REFERENCE TABLES

Table A-1—Nominal cross section area, weight, and nominal diameter of ASTM standard reinforcing bars

Bar size designation	Nominal cross section area, in.^{2}	Weight, lb/ft	Nominal diameter, in.	Nominal perimeter, in.
No. 3	0.11	0.376	0.375	1.18
No. 4	0.20	0.668	0.500	1.57
No. 5	0.31	1.043	0.625	1.96
No. 6	0.44	1.502	0.750	2.36
No. 7	0.60	2.044	0.875	2.75
No. 8	0.79	2.670	1.000	3.14
No. 9	1.00	3.400	1.128	3.54
No. 10	1.27	4.303	1.270	3.99
No. 11	1.56	5.313	1.410	4.43
No. 14	2.25	7.650	1.693	5.32
No. 18	4.00	13.600	2.257	7.09

Note: The nominal dimensions of a deformed bar are equivalent to those of a plain bar having the same mass per foot as the deformed bars.

Table A-2—Area of bars in a section 1 ft wide

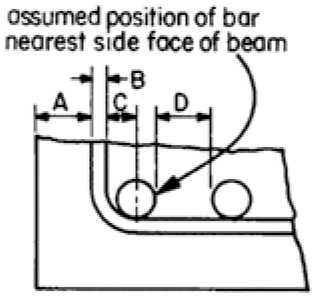
Spacing, in.	Cross section area of bar A_s (or A_s'), in.^{2}											Spacing, in.
	Bar size											
	#3	#4	#5	#6	#7	#8	#9	#10	#11	#14	#18	
4.0	0.33	0.60	0.93	1.32	1.80	2.37	3.00	3.81	4.68	—	—	4.0
4.5	0.29	0.53	0.83	1.17	1.60	2.11	2.67	3.39	4.16	6.00	—	4.5
5.0	0.26	0.48	0.74	1.06	1.44	1.90	2.40	3.05	3.74	5.40	9.60	5.0
5.5	0.24	0.44	0.68	0.96	1.31	1.72	2.18	2.77	3.40	4.91	8.73	5.5
6.0	0.22	0.40	0.62	0.88	1.20	1.58	2.00	2.54	3.12	4.50	8.00	6.0
6.5	0.20	0.37	0.57	0.81	1.11	1.46	1.85	2.34	2.88	4.15	7.38	6.5
7.0	0.19	0.34	0.53	0.75	1.03	1.35	1.71	2.18	2.67	3.86	6.86	7.0
7.5	0.18	0.32	0.50	0.70	0.96	1.26	1.60	2.03	2.50	3.60	6.40	7.5
8.0	0.17	0.30	0.47	0.66	0.90	1.19	1.50	1.91	2.34	3.38	6.00	8.0
8.5	0.16	0.28	0.44	0.62	0.85	1.12	1.41	1.79	2.20	3.18	5.65	8.5
9.0	0.15	0.27	0.41	0.59	0.80	1.05	1.33	1.69	2.08	3.00	5.33	9.0
9.5	0.14	0.25	0.39	0.56	0.76	1.00	1.26	1.60	1.97	2.84	5.05	9.5
10.0	0.13	0.24	0.37	0.53	0.72	0.95	1.20	1.52	1.87	2.70	4.80	10.0
10.5	0.13	0.23	0.35	0.50	0.69	0.90	1.14	1.45	1.78	2.57	4.57	10.5
11.0	0.12	0.22	0.34	0.48	0.65	0.86	1.09	1.39	1.70	2.45	4.36	11.0
11.5	0.11	0.21	0.32	0.46	0.63	0.82	1.04	1.33	1.63	2.35	4.17	11.5
12.0	0.11	0.20	0.31	0.44	0.60	0.79	1.00	1.27	1.56	2.25	4.00	12.0
13.0	0.10	0.18	0.29	0.41	0.55	0.73	0.92	1.17	1.44	2.08	3.69	13.0
14.0	0.09	0.17	0.27	0.38	0.51	0.68	0.86	1.09	1.34	1.93	3.43	14.0
15.0	0.09	0.16	0.25	0.35	0.48	0.63	0.80	1.02	1.25	1.80	3.20	15.0
16.0	0.08	0.15	0.23	0.33	0.45	0.59	0.75	0.95	1.17	1.69	3.00	16.0
17.0	0.08	0.14	0.22	0.31	0.42	0.56	0.71	0.90	1.10	1.59	2.82	17.0
18.0	0.07	0.13	0.21	0.29	0.40	0.53	0.67	0.85	1.04	1.50	2.67	18.0

Example: #9 bar spaced 7-1/2 in. apart provides 1.60 in.^{2}/ft of section width.

Table A-3—Minimum beam web widths required for two or more bars in one layer for cast-in-place nonprestressed concrete

Reference: ACI 318-19 Sections 25.3.2, 25.2.1, 20.5.1.3.1, and AASHTO Standard Specifications for Highway Bridges (17th edition, 2002) Division I, Sections 8.17.3.1, 8.21.1, 8.22.1, 8.23.2.2, and Table 8.23.2.1. For use of this Design Aid, see Flexure Example 1.

Minimum beam width = 2(A + B + C) + $(n - 1)(D + d_b)$ where A + B + C – $1/2d_b \geq$ 2.0 in. cover required for longitudinal bars and these assumptions are made:



for ACI 318

B = 0.375 in. for #3 stirrups
= 0.500 in. for #4 stirrups

D = 1 d_b
≥ 1 in.
≥ 1-1/3 nominal aggregate size

For both ACI and AASHTO

A = 1-1/2 in. concrete cover to stirrup
B = 0.635 in. for #5 stirrups
= 0.750 in. for #6 stirrups

C = stirrup bend radius of 2 stirrup bar diameter for #5 and smaller stirrups
= stirrup bend radius of 3 stirrup bar diameters for #6 stirrups
≥ $1/2d_b$ of longitudinal bars

For AASHTO

B = 0.375 in. for #3 stirrups (minimum stirrup size for #10 and smaller longitudinal bars)
= 0.500 in. for #4 stirrups (minimum stirrup size for #11 and larger longitudinal bars)

D = $1\text{-}1/2d_b$
≥ 1-1/2 in.
≥ 1-1/2 nominal aggregate size

	ACI 318-19 3/4-in. aggregate interior exposure #3 stirrups		ACI 318-19 1-in. aggregate interior exposure #3 stirrups		AASHTO requirements cast-in-place concrete 1-in. aggregate exposed to earth or weather	
Bar size	Minimum web width for 2 bars, in.	Increment for each added bar, in.	Minimum web width for 2 bars, in.	Increment for each added bar, in.	Minimum web width for 2 bars, in.	Increment for each added bar, in.
#4	6 3/4	1 1/2	7 1/8	1 7/8	7.25	2.000
#5	6 7/8	1 5/8	7 1/4	2	7.37	2.125
#6	7	1 3/4	7 3/8	2 1/8	7.50	2.250
#7	7 1/8	1 7/8	7 1/2	2 1/4	7.62	2.375
#8	7 1/4	2	7 5/8	2 3/8	7.75	2.500
#9	7 1/2	2 1/4	7 3/4	2 1/2	8.32	2.820
#10	7 7/8	2 1/2	7 7/8	2 5/8	8.68	3.175
#11	8 1/8	2 7/8	8 1/8	2 7/8	9.52	3.525
#14	8 7/8	3 3/8	8 7/8	3 3/8	10.23	4.232
#18	10 1/2	4 1/2	10 1/2	4 1/2	11.90	5.642

Notes

1. **Stirrups:** For stirrups larger than those used for table above, increase web width by the following amounts (in.):

Source	Main reinforcement size	#4 stirrup	#5 stirrup	#6 stirrup
ACI requirements	#4 through #11	3/4	1 1/2	2 1/4
	#14	1/2	1 1/4	2
	#18	1/4	3/4	1 1/2
AASHTO requirements	#4 through #10	0.75	1.50	2.25
	#11 through #14	—	0.75	1.50
	#18	—	0.49	1.24

2. **ACI cover requirements**: For exterior exposure with use of #6 or larger stirrups, add 1 in. to web width.

3. **AASHTO cover requirements**: For interior exposure, 1/2 in. may be deducted from beam widths.

4. **Bars of different sizes**: For beams with bars of two or more sizes, determine from table the beam web width required for the given number of largest size bars; then add the indicated increments for each smaller bar.

5. **Example**: Find the minimum web width for a beam reinforced with two #8 bars; a beam reinforced with three #8 bars; a beam reinforced with three #9 and two #6 bars.

	2 #8	3 #8	3 #9 + 2 #6
ACI (3/4 in. aggregate)	7 1/4	9 1/4	13 1/4
ACI (1 in. aggregate)	7 5/8	10	14 1/2
AASHTO	7.75	10.25	15.64

Table A-4—Minimum beam web widths for various bar combinations (interior exposure)

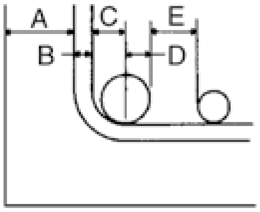
Reference: ACI 318-19 Sections 25.3.2, 25.2.1, and 20.5.1.3.1

Columns at left headed 1-5 and 6-10 bars are for minimum web width b_w of beam having bars of one size only. Remaining columns are for combinations of 1 to 5 bars of each of two sizes.

Calculated values of beam web width b_w rounded upward to nearest half inch.

Where bars of two sizes are used, larger bar(s) assumed to be placed along outside face(s) of beam.

Aggregate size assumed ≤ 3/4 in.



A = clear cover of 1-1/2 in.
B = 3/4 in. diameter of #3 stirrups
C = for #11 and smaller bars: twice diameter of #3 stirrups; for #14 and #18 bars: 1/2 diameter of bar
D = 1/2 diameter of larger bar
E = 1/2 spacing for larger bar plus 1/2 spacing for smaller bar (spacing is d_b for #9 and larger bars, 1 in. for #8 and smaller bars)

		ACI min. b_w, in.			ACI min. b_w, in.						ACI min. b_w, in.						ACI min. b_w, in.				
No. of bars	Bar size	1 to 5 bars	6 to 10 bars	Size of smaller bars	No. of smaller bars 1	2	3	4	5	Size of smaller bars	No. of smaller bars 1	2	3	4	5	Size of smaller bars	No. of smaller bars 1	2	3	4	5
1	#3	5.5	12.5																		
2		7.0	13.5																		
3		8.0	15.0																		
4		9.5	16.5																		
5		11.0	18.0																		
1	#4	5.5	13.0	#3	7.0	8.5	9.5	11.0	12.5												
2		7.0	14.5		8.5	9.5	11.0	12.5	14.0												
3		8.5	16.0		10.0	11.0	12.5	14.0	15.5												
4		10.0	17.5		11.5	12.5	14.0	15.5	17.0												
5		11.5	19.0		13.0	14.0	15.5	17.0	18.5												
1	#5	5.5	13.5	#4	7.0	8.5	10.0	11.5	13.0	#3	7.0	8.5	9.5	11.0	12.5						
2		7.0	15.0		8.5	10.0	11.5	13.0	14.5		8.5	10.0	11.0	12.5	14.0						
3		8.5	17.0		10.0	11.5	13.0	14.5	16.0		10.0	11.5	13.0	14.0	15.5						
4		10.5	18.5		12.0	13.5	15.0	16.5	18.0		11.5	13.0	14.5	16.0	17.0						
5		12.0	20.0		13.5	15.0	16.5	18.0	19.5		13.5	14.5	16.5	17.5	19.0						
1	#6	5.5	14.0	#5	7.0	9.0	10.5	12.0	13.5	#4	7.0	8.5	10.0	11.5	13.0	#3	7.0	8.5	10.0	11.0	12.5
2		7.0	16.0		9.0	10.5	12.0	13.5	15.5		8.5	10.0	11.5	13.0	14.5		8.5	10.0	11.5	12.5	14.0
3		9.0	17.5		10.5	12.0	14.0	15.5	17.0		10.5	12.0	13.5	15.0	16.5		10.5	11.5	13.0	14.5	16.0
4		10.5	19.5		12.5	14.0	15.5	17.0	19.0		12.0	13.5	15.0	16.5	18.0		12.0	13.5	15.0	16.0	17.5
5		12.5	21.0		14.0	15.5	17.5	19.0	20.5		14.0	15.5	17.0	18.5	20.0		14.0	15.0	16.5	18.0	19.5
1	#7	5.5	15.0	#6	7.5	9.0	11.0	12.5	14.5	#5	7.0	9.0	10.5	12.0	13.5	#4	7.0	8.5	10.0	11.5	13.0
2		7.5	16.5		9.0	11.0	12.5	14.5	16.0		9.0	10.5	12.0	14.0	15.5		9.0	10.5	12.0	13.5	15.0
3		9.0	18.5		11.0	12.5	14.5	16.0	18.0		11.0	12.5	14.0	15.5	17.5		10.5	12.0	13.5	15.0	16.5
4		11.0	20.5		13.0	14.5	16.5	18.0	20.0		12.5	14.5	16.0	17.5	19.0		12.5	14.0	15.5	17.0	18.5
5		13.0	22.5		14.5	16.5	18.0	20.0	21.5		14.5	16.0	18.0	19.5	21.0		14.5	16.0	17.5	19.0	20.5
1	#8	5.5	15.5	#7	7.5	9.5	11.0	13.0	15.0	#6	7.5	9.0	11.0	12.5	14.5	#5	7.5	9.0	10.5	12.0	14.0
2		7.5	17.5		9.5	11.0	13.0	15.0	17.0		9.0	11.0	12.5	14.5	16.0		9.0	10.5	12.5	14.0	15.5
3		9.5	19.5		11.5	13.0	15.0	17.0	19.0		11.0	13.0	14.5	16.5	18.0		11.0	12.5	14.5	16.0	17.5
4		11.5	21.5		13.5	15.0	17.0	19.0	21.0		13.0	15.0	16.5	18.5	20.0		13.0	14.5	16.5	18.0	19.5
5		13.5	23.5		15.5	17.0	19.0	21.0	23.0		15.0	17.0	18.5	20.5	22.0		15.0	16.5	18.5	20.0	21.5
1	#9	5.5	17.0	#8	7.5	9.5	11.5	13.5	15.5	#7	7.5	9.5	11.5	13.0	15.0	#6	7.5	9.0	11.0	12.5	14.5
2		8.0	19.0		10.0	12.0	14.0	16.0	18.0		9.5	11.5	13.5	15.5	17.0		9.0	11.5	13.0	15.0	16.5
3		10.0	21.5		12.0	14.0	16.0	18.0	20.0		12.0	14.0	15.5	17.5	19.5		12.0	13.5	15.5	17.0	19.0
4		12.5	23.5		14.5	16.5	18.5	20.5	22.5		14.0	16.0	18.0	20.0	21.5		14.0	16.0	17.5	19.5	21.0
5		14.5	26.0		16.5	18.5	20.5	22.5	24.5		16.5	18.5	20.0	22.0	24.0		16.5	18.0	20.0	21.5	23.5
1	#10	5.5	18.0	#9	8.0	10.0	12.5	14.5	17.0	#8	8.0	10.0	12.0	14.0	16.0	#7	7.5	9.5	11.5	13.5	15.0
2		8.0	20.5		10.5	12.5	15.0	17.0	19.5		10.0	12.0	14.0	16.0	18.0		10.0	12.0	13.5	15.5	17.5
3		10.5	23.5		13.0	15.0	17.5	19.5	22.0		12.5	14.5	16.5	18.5	20.5		12.5	14.5	16.0	18.0	20.0
4		13.0	26.0		15.5	17.5	20.0	22.0	24.5		15.0	17.0	19.0	21.0	23.0		15.0	17.0	18.5	20.5	22.5
5		15.5	28.5		18.0	20.0	22.5	24.5	27.0		17.5	19.5	21.5	23.5	25.5		17.5	19.5	21.5	23.0	25.0
1	#11	5.5	19.5	#10	8.0	10.5	13.0	15.5	18.0	#9	8.0	10.5	12.5	15.0	17.0	#8	8.0	10.0	12.0	14.0	16.0
2		8.5	22.5		11.0	13.5	16.0	18.5	21.0		10.5	13.0	15.0	17.5	19.5		10.5	12.5	14.5	16.5	18.5
3		11.0	25.0		13.5	16.0	19.0	21.5	24.0		13.5	15.5	18.0	20.0	22.5		13.0	15.0	17.0	19.0	21.0
4		14.0	28.0		16.5	19.0	21.5	24.0	26.5		16.0	18.5	20.5	23.0	25.0		16.0	18.0	20.0	22.0	24.0
5		17.0	31.0		19.5	22.0	24.5	27.0	29.5		19.0	21.5	23.5	26.0	28.0		19.0	21.0	23.0	25.0	27.0
1	#14	5.5	22.5	#11	8.5	11.5	14.5	17.0	20.0	#10	8.5	11.0	13.5	16.0	18.5	#9	8.5	10.5	13.0	15.0	17.5
2		9.0	26.0		12.0	14.5	17.5	20.5	23.0		11.5	14.0	16.5	19.0	22.0		11.5	13.5	16.0	18.0	20.5
3		12.5	29.5		15.5	18.0	21.0	23.5	26.5		15.0	17.5	20.0	22.5	25.0		14.5	17.0	19.0	21.5	23.5
4		16.0	33.0		18.5	21.5	24.5	27.0	30.0		18.5	21.0	23.5	26.0	28.5		18.0	20.5	22.5	25.0	27.0
5		19.0	36.0		22.0	25.0	27.5	30.5	33.5		22.0	24.5	27.0	29.5	32.0		21.5	23.5	26.0	28.5	30.5
1	#18	6.5	29.0	#14	10.0	13.5	16.5	20.0	23.5	#11	9.5	12.5	15.0	18.0	21.0	#10	9.5	12.0	14.5	17.0	19.5
2		11.0	33.5		14.0	17.5	21.0	24.5	27.5		13.5	16.5	19.0	22.0	25.0		13.5	16.0	18.5	21.0	23.5
3		15.5	38.0		18.5	22.0	25.5	29.0	32.0		18.0	21.0	23.5	26.5	29.5		18.0	20.5	23.0	25.5	28.0
4		20.0	42.5		23.0	26.5	30.0	33.5	36.5		22.5	25.5	28.5	31.0	34.0		22.5	25.0	27.5	30.0	32.5
5		24.5	47.0		27.5	31.0	34.5	38.0	41.0		27.0	30.0	33.0	35.5	38.5		27.0	29.5	32.0	34.5	37.0

Examples: For 2 #6 bars, minimum b_w = 7.0 in. For 8 #6 bars, minimum b_w =17.5 in. For 2 #7 bars plus 3 #6 bars, minimum b_w = 12.5 in. For 3 #6 bars plus 5 #4 bars, minimum b_w = 16.5 in.

Table A-5—Properties of bundled bars

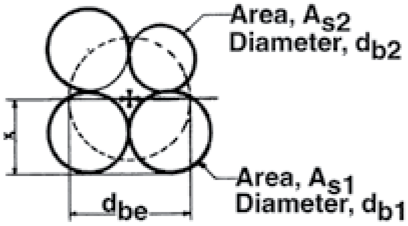
Reference: ACI 318-19 Section 25.6.1.6

Equivalent diameter, $d_{be} = \sqrt{\frac{4}{\pi}A_s}$

Centroidal distance, x

For the bundled bars configuration shown here, the centroidal distance is calculated by the following equation:

$$x = \frac{\frac{5}{2}A_{s1}d_{b1} + A_{s2}(d_{b1} + d_{b2}/2)}{\Sigma A_{si}}$$



Bars				Combination of bars							
Equivalent diameters d_{be}, in.											
#8	1.42	1.74	2.01	#7	#6	1.15	1.37	1.45	1.56	1.63	1.69
9	1.60	1.95	2.26	7	5	1.08	1.25	1.39	1.40	1.52	1.64
10	1.80	2.20	2.54	8	7	1.33	1.59	1.67	1.82	1.88	1.94
11	1.99	2.44	2.82	8	6	1.25	1.46	1.60	1.64	1.77	1.89
				9	8	1.51	1.81	1.88	2.07	2.13	2.20
				9	7	1.43	1.67	1.82	1.89	2.02	2.14
				10	9	1.70	2.04	2.12	2.33	2.40	2.47
				10	8	1.62	1.90	2.06	2.15	2.29	2.42
				11	10	1.90	2.28	2.36	2.61	2.68	2.75
				11	9	1.81	2.13	2.29	2.41	2.55	2.69
Centroidal distance x, from bottom of bundle, in.											
#4	0.25	0.39	0.50	#4	#3	0.23	0.38	0.33	0.43	0.40	0.46
5	0.31	0.49	0.62	5	4	0.29	0.47	0.43	0.55	0.53	0.58
6	0.37	0.59	0.75	5	3	0.28	0.46	0.37	0.49	0.44	0.55
				6	5	0.35	0.57	0.53	0.67	0.66	0.71
7	0.44	0.69	0.87	6	4	0.34	0.55	0.47	0.61	0.57	0.67
8	0.50	0.79	1.00								
9	0.56	0.89	1.13	7	6	0.41	0.67	0.62	0.80	0.78	0.83
				7	5	0.39	0.65	0.56	0.73	0.69	0.79
10	0.63	1.00	1.27	8	7	0.47	0.77	0.72	0.93	0.90	0.95
11	0.70	1.11	1.41	8	6	0.46	0.75	0.66	0.86	0.81	0.92
				9	8	0.54	0.86	0.82	1.05	1.03	1.08
				9	7	0.52	0.85	0.75	0.98	0.94	1.04
				10	9	0.60	0.98	0.92	1.19	1.16	1.22
				10	8	0.58	0.95	0.86	1.11	1.07	1.18
				11	10	0.67	1.08	1.03	1.32	1.31	1.36
				11	9	0.65	1.06	0.96	1.24	1.20	1.31

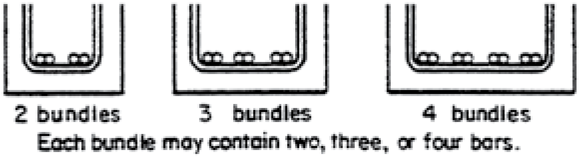
Example: Find the equivalent diameter of a single bar for 4 #9 bars. For 4 #9 bars, read d_{be} = 2.26 in., and the centroidal distance x equals 1.13 in.

Table A-6—Minimum beam web widths b_w for various combinations of bundled bars (interior exposure)

Reference: ACI 318-19 Sections 25.3.2, 25.6.1.1, 25.6.1.2, 25.6.1.3, 25.6.1.6, and 20.5.1.3.1

Calculated values of beam width b_w rounded upward to nearest half-inch.

<u>Assumptions:</u>
Aggregate size: ≤ 3/4 in.
Clear cover of 1-1/2 in.
No. 3 stirrups



Each bundle may contain two, three, or four bars.

	Minimum beam web width b_w, in.*		
Bar size	∞	∴	∷
	Two bundles		
#8	10.0	10.0	10.5
#9	10.5	11.0	11.0
#10	11.0	11.5	12.0
#11	11.5	12.0	12.5
	Three bundles		
#8	13.5	14.0	14.5
#9	14.5	15.0	15.5
#10	15.5	16.0	17.0
#11	16.5	17.5	18.0
	Four bundles		
#8	17.0	17.5	18.5
#9	18.0	19.0	20.0
#10	20.0	21.0	22.0
#11	21.5	22.5	24.0

*For beams conforming to AASHTO specifications, add 1 in. to tabulated beam web width. Fore example, for two bundles of three #10, minimum b_w = 11.5 in.

Table A-7—Basic development length ratios of bars in tension

Reference: ACI 318-19 Sections 25.4.2.2 and 25.4.2.3

Development length ratios:

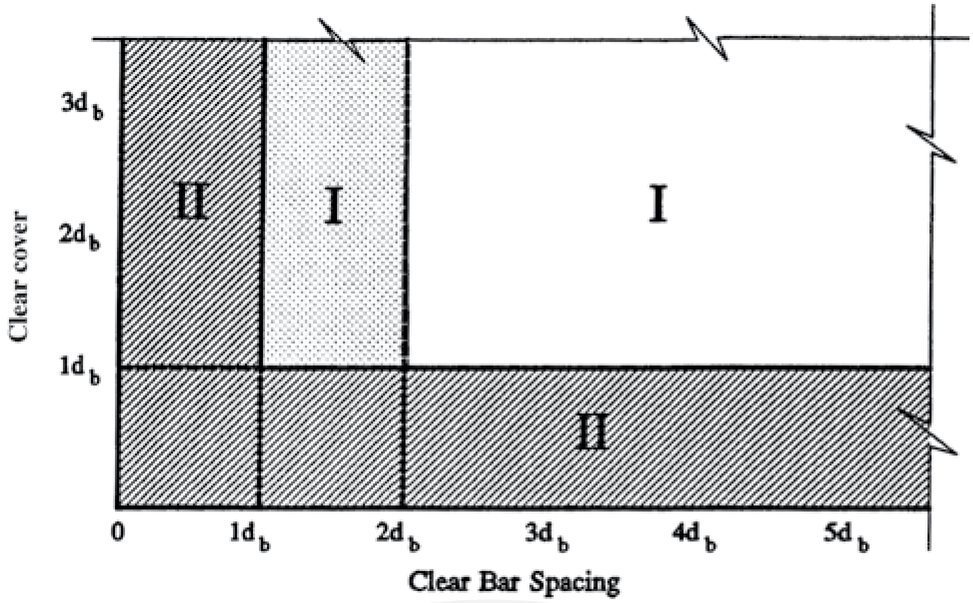
$$\frac{\ell_d}{d_b} = \alpha \frac{\psi_t \psi_e \psi_g}{\lambda} \frac{f_y}{\sqrt{f_c'}}$$

For $\psi_t = 1.0$; $\psi_e = 1.0$, and $\lambda = 1.0$ (see notes below).

			Basic development length ratios of bars in tension																	
Bar size	Category	f_y	60,000 psi						80,000 psi						100,000 psi					
		f_c' α	3000 psi	4000 psi	5000 psi	6000 psi	8000 psi	10,000 psi	3000 psi	4000 psi	5000 psi	6000 psi	8000 psi	10,000 psi	3000 psi	4000 psi	5000 psi	6000 psi	8000 psi	10,000 psi
#3 to #6	I	1/25	44	38	34	31	27	24	67	58	52	48	41	37	95	82	74	67	58	52
	II	3/50	66	57	51	46	40	36	101	87	78	71	62	55	142	123	110	101	87	78
#7 to #18	I	1/20	55	47	42	39	34	30	84	73	65	59	51	46	119	103	92	84	73	65
	II	3/40	82	71	64	58	50	45	126	109	98	89	77	69	178	154	138	126	109	98

Notes:
1. See category chart for Categories I and II.
2. ψ_t = casting position (1.3 for bars placed such that more than 12 in. of fresh concrete is cast below the development length or splice; 1.0 for other bars).
ψ_e = coating factor (1.5 = epoxy-coated reinforcement with cover < $3d_b$ or clear spacing < $6d_b$; 1.2 = all other epoxy-coated reinforcement; and 1.0 = uncoated and zinc-coated [galvanized] reinforcement).
λ = lightweight-aggregate concrete factor (0.75 for lightweight concrete, and 1.0 for normalweight concrete).
3. Minimum development length $\ell_d \geq 12$ in.
4. ψ_g = 1.0, 1.15, and 1.3 for f_y = 60 ksi, 80 ksi, and 100 ksi, respectively

Table A-7—Basic development length ratios of bars in tension (cont.)



CATEGORY CHART

Category I:
- Clear spacing ≥ d_b
- Clear cover ≥ d_b
- Code minimum stirrups or ties throughout ℓ_d

or

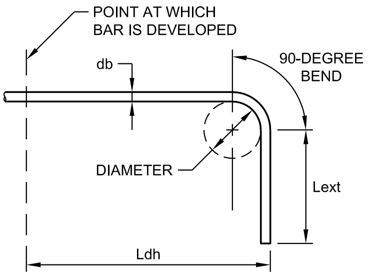
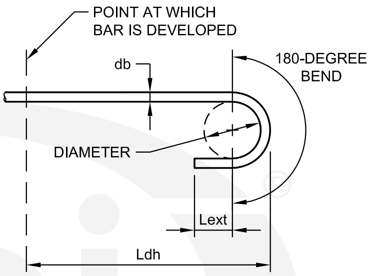
- Clear spacing ≥ $2d_b$
- Clear cover ≥ d_b

Category II: All other cases

Table A-8—Basic development length ℓ_{dh} of standard hooks in tension

Reference: ACI 318-19 Sections 25.3.1, 25.4.3.1, 25.4.3.2, and 25.4.10.1.

STANDARD HOOK GEOMETRY FOR DEVELOPMENT OF DEFORMED BARS IN TENSION

TYPE OF STANDARD HOOK	BAR SIZE	MINIMUM INSIDE BEND DIAMETER, IN.	STRAIGHT EXTENSION [1] Lext, IN.	TYPE OF STANDARD HOOK
90-DEGREE HOOK	#3 THROUGH #8	6db	12db	
	#9 THROUGH #11	8db		
	#14 AND #18	10db		
180-DEGREE HOOK	#3 THROUGH #8	6db	GREATER OF 4db AND 2.5"	
	#9 THROUGH #11	8db		
	#14 AND #18	10db		

[1] A STANDARD HOOK FOR DEFORMED BARS IN TENSION INCLUDES THE SPECIFIC INSIDE BEND DIAMETER AND STRAIGHT EXTENSION LENGTH. IT SHALL BE PERMITTED TO USE A LONGER STRAIGHT EXTENSION AT THE END OF A HOOK. A LONGER EXTENSION SHALL NOT BE CONSIDERED TO INCREASE THE ANCHORAGE CAPACITY OF THE HOOK.

$$\ell_{dh} = \left(\frac{\Psi_e \Psi_r \Psi_o \Psi_c}{55\lambda\sqrt{f_c'}}\right) d_b^{1.5}$$

This table is calculated with ψe = 1.0, ψt = 1.0, and λ = 1.0.

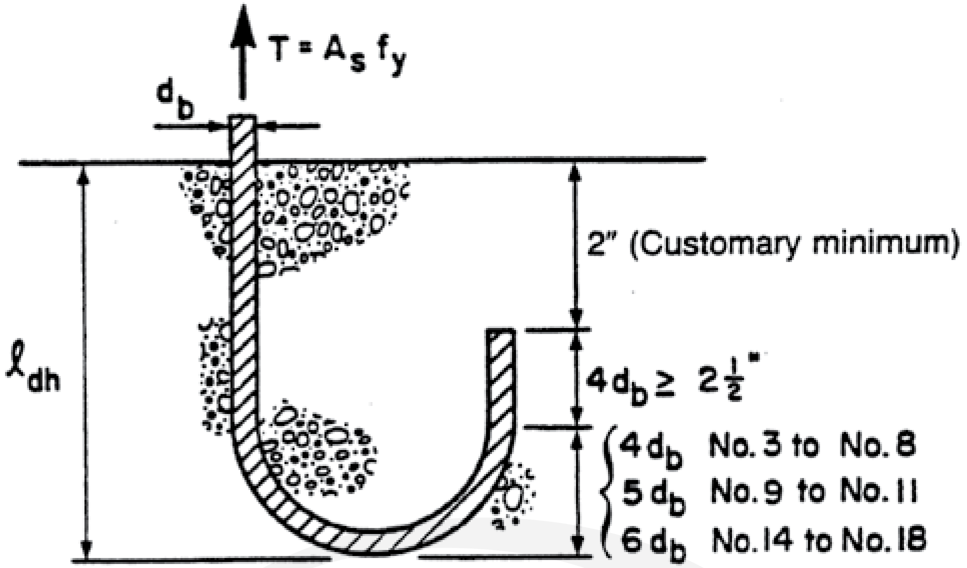
		Basic development length ℓ_{dh}, in., of standard hooks in tension																	
	f_y	60,000 psi						80,000 psi						100,000 psi					
Bar size	f_c' d_b, in.	3000 psi	4000 psi	5000 psi	6000 psi	8000 psi	10,000 psi	3000 psi	4000 psi	5000 psi	6000 psi	8000 psi	10,000 psi	3000 psi	4000 psi	5000 psi	6000 psi	8000 psi	10,000 psi	$8d_b$, in.
#3	3/8	3.7	3.4	3.3	3.2	2.8	2.5	4.9	4.6	4.1	4.3	3.7	3.3	6.1	5.7	5.5	5.4	4.7	4.2	3
#4	1/2	5.6	5.3	5.1	5.0	4.3	3.9	7.5	7.0	6.3	6.6	5.7	5.1	9.4	8.8	8.5	8.3	7.2	6.4	4
#5	5/8	7.9	7.4	7.1	7.0	6.0	5.4	10.5	9.8	8.8	9.3	8.0	7.2	13.1	12.3	11.9	11.6	10.0	9.0	5
#6	3/4	10.3	9.7	9.4	9.1	7.9	7.1	13.8	12.9	11.6	12.2	10.6	9.4	17.2	16.2	15.6	15.2	13.2	11.8	6
#7	7/8	13.0	12.2	11.8	11.5	10.0	8.9	17.4	16.3	14.6	15.4	13.3	11.9	21.7	20.4	19.6	19.2	16.6	14.9	7
#8	1	15.9	14.9	14.4	14.1	12.2	10.9	21.2	19.9	17.8	18.8	16.3	14.5	26.6	24.9	24.0	23.5	20.3	18.2	8
#9	1.128	19.1	17.9	17.3	16.9	14.6	13.1	25.5	23.9	21.4	22.5	19.5	17.4	31.8	29.8	28.8	28.1	24.4	21.8	9
#10	1.27	22.8	21.4	20.6	20.2	17.5	15.6	30.4	28.5	25.5	26.9	23.3	20.8	38.0	35.7	34.3	33.6	29.1	26.0	10
#11	1.41	26.7	25.0	24.1	23.6	20.4	18.3	35.6	33.4	29.8	31.4	27.2	24.4	44.5	41.7	40.2	39.3	34.0	30.4	11
#14	1.693	35.1	32.9	31.7	31.0	26.9	24.0	46.8	43.9	39.3	41.4	35.8	32.0	58.5	54.9	52.9	51.7	44.8	40.1	14
#18	2.257	54.0	50.7	48.8	47.8	41.4	37.0	72.0	67.6	60.4	63.7	55.1	49.3	90.0	84.5	81.4	79.6	68.9	61.7	18

Note 1: To compute development length ℓ_{dh}* for a standard hook in tension, multiply basic development length ℓ_{dh} from table above by applicable modification factors. For ψ_e, ψ_r, ψ_o, ψ_c, and λ values, refer to ACI 318-19 Table 25.4.3.2.

Note 2: Values of basic development length ℓ_{dh} above the heavy line are less than the minimum development length of 6 in. Development length ℓ_{dh} shall not be less than $8d_b$, nor less than 6 in., whichever is greater.

Table A-9—Basic development length ℓ_{dh} of standard hooks in tension

Reference: ACI 318-19 Section 25.3.1



Bar size	#3	#4	#5	#6	#7	#8	#9	#10	#11	#14	#18
ℓ_{dh}, in.	6	7	7	8	9	10	13	14	15	19	25

Example: Find minimum embedment depth ℓ_{dh} that will provide 2 in. cover over the tail of a standard 180-degree end hook in a #8 bar. For #8 bar, read ℓ_{dh} = 10 in.

FIGURE WALL-1_1 AND WALL-1_2: SHEAR WALL SCHEDULE

GENERAL CONSIDERATIONS – NOTE: ALL SECTIONS REFER TO ACI 318-19

1. Each shear wall type is assigned with wall mark in the table and coordinated with wall marks on floor plan drawings
2. Shear walls of same reinforcement and dimensions may use same mark number
3. Shear wall schedule and shear wall typical details are coordinated...

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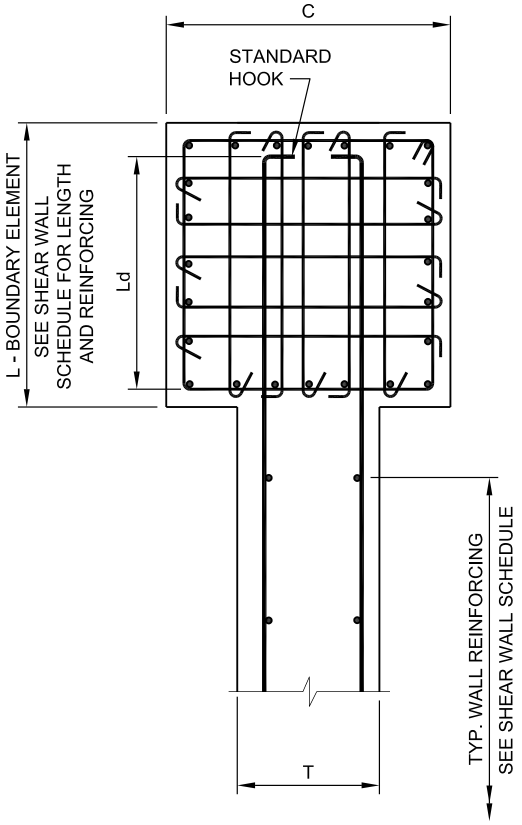
16. Boundary elements satisfy Sections 18.10.6 if special structural wall (SDC D through F)
17. Cover for reinforcement satisfies Section 20.5.1
18. Remove “NOTES TO DESIGN PROFESSIONAL” before placing schedule and details in the Contract Documents



NOTES TO DESIGN PROFESSIONAL:

1. HORIZONTAL REINFORCEMENT EXTENDING INTO BOUNDARY ELEMENT COULD BE STRAIGHT BARS, HOOKED, OR HEADED
2. CROSSTIES IN SPECIAL STRUCTURAL WALL (SDC D-F) BOUNDARY ELEMENT HAVE 135-DEGREE SEISMIC HOOKS AT BOTH ENDS
3. COMPLETE THE ATTACHED CHECKLIST AND MODIFY DETAILS AS REQUIRED BEFORE INCORPORATING THESE DETAILS INTO PROJECT CONSTRUCTION DOCUMENTS

SHEAR WALL SW-1

WORK THESE DETAILS WITH WALL-1.1 SCHEDULE

9 781641 951067