October 18, 2016

To: Members ACI/CRSI Committee 315 - Details of Concrete Reinforcement

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From: Anthony L. Felder
Secretary

Subject: Meeting Notice and Agenda
October 23, 2016
Philadelphia Marriott Downtown
Philadelphia, PA

Our next meeting will be held on Sunday, October 23, 2016 from 2:00 p.m. to 5:00 p.m. in Independence Ballroom 1 of the Philadelphia Marriott Downtown in Philadelphia, PA.

A proposed agenda is attached.

Copy to: Harry A. Gleich, TAC Contact
Matthew R. Senecal, ACI Engineering Manager
AGENDA
ACI/CRSI COMMITTEE 315 - DETAILS OF CONCRETE REINFORCEMENT

Philadelphia Marriott Downtown, Philadelphia, PA
October 23, 2016  2:00 – 5:00 p.m.  Independence Ballroom 1

1. 2:00 p.m. - Call Meeting to Order

2. Self-Introductions

3. Approval of Minutes of Last Meeting, April 17, 2016, Distributed June 1, 2016

4. Review Committee Membership. See First Exhibit, Current Roster.

5. Review Purpose of “Designer’s Guide to Reinforcing Bar Detailing”

6. Status Reports
   a.  ACI 131 BIM / CRSI BIM - David Grundler / Dennis Fontenot
   b.  CRSI Detailing - Robbie Hall
   c.  CRSI Standards (Placing, Fabrication, Supports) - Robbie Hall

7. Review Table of Contents

8. Documents for Review (Exhibits Attached)
   a.  Chapter 1 – Introduction and Scope
   b.  Chapter 2 – Notation and Definitions
   c.  Chapter 3 – General Considerations
   d.  Chapter 4 – Structural Drawings
   e.  Chapter 5 – Designing for Constructability
   f.  Chapter 6 – Review of Placing Drawings

9. Review of Task Group

10. Discuss Steps Going Forward

11. New Business

12. Motion to Adjourn
ACI/CRSI COMMITTEE 315 ROSTER
October 2016

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CHAPTER 1 – INTRODUCTION AND SCOPE  (Mandated by TCM)
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CHAPTER 1—INTRODUCTION AND SCOPE

1.1—General

“ACI Designer’s Guide to Reinforcing Bar Detailing” is not intended to instruct the LDP how to detail rebar. Its purpose is to show LDPs the information a reinforcing bar detailer needs to properly detail rebar and how to present that information on their structural drawings so that his design intent is effectively and accurately conveyed.

It is hoped that information in this guide on structural members of reinforced concrete structures will advance standardization through the detailing, fabrication, and installation of concrete reinforcement. The information presented herein complies with the requirements of the following ACI committees:

- ACI 318 – Building Code Requirements for Structural Concrete
- ACI 301 – Specifications for Structural Concrete
- ACI 117 – Tolerances
- ACI 131 – Building Information Modeling for Concrete Structures
- ACI 132 – Responsibilities in Concrete Construction

This guide is intended to facilitate clear communication between LDP’s, reinforcing bar detailers, fabricators, and placers by encouraging standard presentation of details and information.

1.2—Scope

This guide provides both general and specific information and illustrative details that are required by reinforcing steel detailers in steel reinforced concrete members such as slabs, beams, and columns. It stresses the importance of this information to ensure that the detailer effectively and accurately captures the intent of the LDP and presents it in a manner that is clear and unambiguous to the rebar fabricator and placer.
CHAPTER 2—NOTATION AND DEFINITIONS

1.1—Notation

2.0—Definitions

ACI provides a comprehensive list of definitions and terminology through an online resource:

“CT-13: ACI Concrete Terminology - An ACI Standard”

It can be downloaded without charge from the ACI website at:

CHAPTER 3—GENERAL CONSIDERATIONS

3.1 —Building Information Modeling (BIM)

3.1.1 Introduction to Building Information Modeling

Building information modeling (BIM) is a 3D process used to generate and manage digital models of buildings and other constructed infrastructure. This process is used by those who plan, design, construct and manage facilities. The process involves creating and maintaining intelligent models that represent physical characteristics of a facility, and also contain parametric data about the elements within the model. Numerous software packages exist that fall within the definition of BIM, and each of these have distinct advantages to different parts of the life cycle of a facility, from the design to construction through operation.

Although the focus of most BIM discussions centers on the 3D model, the information contained within is of equal importance. The following is from NBIMS 2007:

“(A) Building Information Model, or BIM, utilizes cutting edge digital technology to establish a computable representation of all of the physical and functional characteristics of a facility and its related project/lift-cycle information, and is intended to be a repository of information…”

In general, what makes BIM more than a simple 3D model is the information. BIM should be thought of not only as a full size virtual mock-up of a structure, but also as a database of included information.

BIM is applied to the details of concrete reinforcement in both the design and construction phases of a facility. 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 by the use of either data within the concrete elements or physical representations of the reinforcement. This definition of concrete and reinforcement information is often to a ‘design intent’ level of modeling. In the construction phase, the concrete geometry is often defined to a construction level of detail, and the reinforcement is defined to a level from which it can be fabricated and installed.

3.1.2 Level of Development

The content and reliability of a Building Information Model is defined by an industry standard referred to as the Level of Development (LOD). The AIA and BIMForum have developed the LOD Specification to standardize these definitions. From BIMForum [Provide Reference]:

“The Level of Development (LOD) Specification is a reference that enables practitioners in the AEC Industry to specify and articulate with a high level of clarity the content and reliability of Building Information Models (BIMs) at various stages in the design and construction process. The LOD Specification utilizes the basic LOD definitions developed by the AIA for the AIA G202-2013 Building Information Modeling Protocol Form[1] and is organized by CSI Uniformat 2010[2]. It defines and illustrates characteristics of model elements of different building systems at different Levels of Development. This clear articulation allows model authors to define what their models can be relied on for, and allows downstream users to clearly understand the usability and the limitations of models they are receiving. The intent of this Specification is to help explain the LOD framework and standardize its use so that it becomes more useful as a communication tool. It does not prescribe what Levels of Development are to be
reached at what point in a project but leaves the specification of the model progression to the user of this document.”

3.1.3 Benefits of BIM

The benefits of using BIM are numerous and vary from project to project and depending on where in the design/construction process it is utilized. Potential benefits include:

- Design and Detailing
  - Better visualization, especially when dealing with complex structures.
  - Improved coordination between trades through the sharing of information, which is one of the tenets of BIM.
  - Ability to easily provide multiple ‘what-if’ scenarios.
  - Improved communications and efficiency and reduced errors through:
    - Addressing items earlier in the process, thereby reducing the number of RFI’s and issues in the field.
    - Clearer communication of structural geometry and design intent from the engineer to the reinforcement detailer than that which is possible using traditional 2D documents.
    - Reinforcing details presented in 3D at a construction level of development.
    - Better communication of reinforcement fabrication and placement information to downstream entities.

- Construction
  - Enhanced project visualization made possible my having full building models and related information at your fingertips.
o More accurate material take-offs, leading to less waste and reduced overall project costs.

o Improved project coordination, clash detection and resolution achieved by combining 3D models from various sub-contractors into a single consolidated model.

o 4D Schedule simulation animations produced by combining the 3D model with a construction schedule.

• Operation

o Better ‘as-built’ documentation than conventional 2D drawings, leading to easier remodels, rebuilds and additions.

o Improved management of a building’s lifecycle achieved by using the 3D model as a central database of all of the building’s systems and components.

o Enhanced tracking of building maintenance needs.

3.1.4 IFC Files and BIM File Transfers

Numerous BIM software packages exist that are capable of defining concrete geometry and data, detailing reinforcement, or both. Most BIM software is compatible with an open file format specification know as Industry Foundation Classes (IFC) data models. This is an object-based file format that allows ease of interoperability between software platforms. IFC files are able to be exported from and imported into most BIM software platforms, allowing model content created in different software to be viewed and used in other software.

3.1.5 State of the Technology

BIM has been around since the late 1990s, but one characteristic making it different from past technologies is its openness to continuous change and evolution. The State of BIM adoption and use
varies with companies, industry segments and regions, but it has been expanding. The introduction of tablet computers, laser scanning, drones, 3D printers, and more all have had a role in shaping where BIM is today and where it is going. One large focus for the evolution of BIM is improving the ability of different users applying different tools to utilize the information in the database. Most BIM software products are compatible with opening IFC format databases, but each still interprets the data differently leading to differences and errors when applying this method at this time. The improvement focus is not only intended for designer to designer transfer, there has also been much effort in developing ways to transfer the data for downstream fabrication uses allowing structural steel, pipe and duct, and even rebar fabricators the ability to seamlessly utilize the information from the BIM directly on the fabrication line of these elements.

3.2 —Tolerances

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 can have an effect on cover, strength, constructability, and serviceability but are required to make concrete construction physically possible and economically practical. If more restrictive tolerances are required than those shown in ACI 117, they need to be clearly indicated in the construction documents.

In areas of potential congestion, the LDP must consider combinations of tolerances, namely reinforcing bar fabrication, reinforcing bar placement and formwork. Certain combinations of tolerances can result in conflicts that are not simple to remedy in the field. For instance, the “+” tolerance for a bent bar may cause the bar to encroach into the concrete cover and exceed the “-”
tolerance for that cover. The design/construction team must 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:

- **Face Cover** – measured from the face or surface of a bar to the concrete surface
- **End Cover** – measured from the end of a bar (straight or hooked) to the concrete surface

![Fig. 3.2.2—Face cover and end cover for reinforcement](image)

Face cover values defined by ACI 301 and ACI 318 vary based on exposure conditions and the concrete element the bar is in. End cover values are simplified in industry practice based on code definition, rather than an actual code definition. Generally, end cover provided in practice is 2 in. unless required to be to be 3 in. (3 in. when cast against earth, 2 in. everywhere else).

Where concrete cover is prescribed for a class of structural members, it is measured to the outer edge of stirrups, ties, or spirals if transverse reinforcement encloses main bars; to the outermost layer of bars if more than one layer is used without stirrups or ties; to the metal end fitting or duct on post-
tensioned prestressing steel; to the outer edge of mechanical splices; or to the outermost part of the head on headed bars.

The condition “concrete surfaces exposed to earth or weather” refers to direct exposure to moisture changes and not just to temperature 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 needs to comply with the project drawings, but there are times where the spacing will need to differ due to field conditions, accumulating tolerances and/or coordination of concrete reinforcement and 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 number of reinforcing bars used.

Designers are cautioned that selecting element sizes that exactly meet their design requirements may not allow for reinforcement placement tolerance. This sometimes happens when lap spliced bars take up extra space and cannot accommodate the placement tolerance. Where reinforcement quantities and available space are in conflict with spacing requirements, the contractor and designer might consider bundling a portion of the reinforcement. Bundling of bars requires approval of the designer.

3.2.4 Placing of reinforcement
3.2.4.1 General information

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 LDP’s and reinforcing bar detailers may overlook the impact of placement tolerances on constructability, it’s worthwhile to use a couple of examples to take a brief look at what can occur.

3.2.4.2 Tolerance cloud

The tolerances for reinforcement location are found in ACI 117. Cover tolerances vary from 1/4 in. for member sizes of 4 in. or less to 1 in. when member size is over 2 ft. The maximum reduction in cover is limited to 1/3 of the specified cover. In slabs and walls, the spacing tolerance is 3 in. for reinforcement other than stirrups and ties. As an example, consider the simple 14 x 14 in. concrete column shown in Fig. 3.2.4.2a.

![Diagram of the column](image-url)

*Fig. 1: The column the designer expects*

*Fig. 3.2.4.2a—Column the designer defined*
The column is reinforced with 4 #8 bars enclosed within #4 ties. The normal concrete cover to the ties of this column would be 1-1/2 in. The cover tolerance is ±1/2 in. If the reinforcement was placed to the minimum tolerance in two directions, the column could appear as in Fig. 3.2.4.2b.

**Fig. 3.2.4.2b—Column that could be placed within the specified tolerances**

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 quite a different image than the precise image one might have had in mind at the outset.

**Fig. 3: The column with “Placement Tolerance Clouds”**
For a second example, consider the case of a simple 14-in.-thick wall reinforced with #8 vertical bars at 12 in. on center each face and #4 horizontal bars at 12 in. on center each face (Fig. 3.2.4.2d).

The outside face cover is 1-1/2 in. and inside face cover is 3/4 in. The cover tolerance for the bars on the outside face is ±1/2 in. 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. Thus the outside face cover could be as little as 1 in. and the inside face cover as little as 1/2 in. (Fig. 3.2.4.2e).
If we also consider that any one of the vertical and horizontal bars may be located as far as 3 in. either way from its designated location, the tolerance cloud would appear as in Fig 3.2.4.2f.

**Fig. 3.2.4.2e—Wall that could be placed within the specified tolerances**

**Fig. 3.2.4.2f—Wall with “placement tolerance clouds”**

### 3.2.4.3 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 reinforcing bar detailer. 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 tolerance clouds may lead to design options that make these tolerances no longer a factor.

3.2.5 Reinforcing bar fabrication

3.2.5.1 General information

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 both ACI 117 and in the CRSI Manual of Standard Practice for both straight and bent bars. Where more restrictive tolerances are required than those shown in the referenced figures, they shall be clearly indicated in the contract documents.

3.2.5.2 Restrictive tolerances

Tolerances more restrictive than those reported by CRSI 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, inspection devices, etc. Special bending is generally more time consuming than normal bending, may be subject to additional costs, and may create delays in material deliveries to the jobsite.

3.2.5.3 Fabrication tolerance clouds
LDP’s need to be aware of the tolerance cloud that exists for fabricated reinforcing bar. As a simple example, let’s consider the fabrication tolerances for a simple reinforcing bar with 90-degree bends (Fig. 3.2.5.3a). For the purposes of our example, let’s assume that the bar is a #8 bar and that Side A is anchored in the (idealized) plane ABG. For this bar size, the standard hook is 16 in. long, and the linear and angular tolerances are ±1 in. and ±2.5 degrees, respectively.

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

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. 3.2.5.3c. (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. 3.2.5.3d) and the in-plane angular deviation of ±2.5 degrees to Side G (Fig. 3.2.5.3e). 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. 3.2.5.3f.
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.
3.2.5.4 Design considerations

Clearly, the fabricated bar arriving on the construction site can be quite different from the bar the LDP or reinforcing bar detailer might have envisioned. Keeping this in mind during design could significantly reduce constructability problems. For instance, if our example bar were 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.

![Figure 3.2.5.4a](image)

Fig. 3.2.5.4a—Reducing tolerance problems by replacing single bar with lapped bars (lap splice shown offset for clarity only)

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 such cases, one must deal with an accumulation of tolerances.
ACI 318 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. The 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. 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 may 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, the diameter of one bar and the 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 may be $8d_b$ or $10d_b$.

![Incorrect 1d bend diameter illustration in drawing](image1.png)

Incorrect 1d bend diameter illustration in drawing

![Correct 6d_b bend diameter when placed](image2.png)

Correct $6d_b$ bend diameter when placed

Fig. 3.2.5.4b—Comparison of minimum bend diameter position effect for a #7 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, the reasonable constraints of time, technology, and economy make this impractical. That’s why 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 the previous section of a 14 x 14 in. column, the tolerance is +1/2 in. or –3/8 in. 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. or as small as 13-5/8 x 13-5/8 in.

While it is highly unlikely that these small variations would create any constructability or design concerns with everything else being perfect, a very different picture arises when we consider them in conjunction with the other possible tolerances.

![Fig. 1: "Forming Tolerance Cloud" for the column](image1.png)

![Fig. 2: Combining the maximum acceptable tie dimensions with the minimum acceptable column dimensions effectively limits placing tolerances to ±1/16 in. (±2 mm)](image2.png)
With 1-1/2 in. cover, the design width for the column ties is 11 in., and the tolerance is ±1/2 in. 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. on all four sides. Recalling that the placement tolerances allow the cover to decrease to 1 in. minimum, the cage must be placed within ±1/16 in. 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 wall that we discussed in previous sections, 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. and 13-5/8 in. thick as shown in Fig. 3.2.6.2c.

![Forming tolerance cloud for the wall](image-url)

**Fig. 3.2.6.2a—Forming . . . . Fig. 3.2.6.2b—Combining . . . .

**Fig. 3.2.6.2c—Forming tolerance cloud for the wall**
Reinforcing placement tolerances allow the 1-1/2 in. design cover on the outside face to be between 1 and 2 in. and the 3/4 in. design cover on the inside face to be between 1/2 and 1-1/4 in. The minimum wall thickness combined with the maximum cover on the outside face reinforcing is shown in Fig. 3.2.6.2d.

![Diagram of wall with reinforcing bars]

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 tolerances. However, effective depth is usually not checked in the field.

In this situation, the original effective depth of 12 in. for the vertical No. 8 bars on the outside face has decreased to only 11-1/8 in. Assuming 4000-psi 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 to 41.6 kip·ft/ft—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 places a tolerance on effective depth d of ±3/8 in. for d ≤ 8 in. and ±1/2 in. for d > 8 in. 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.

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 a big deal, other than the tolerance issues previously discussed. However, when considering the fact that in most cases there is adjacent reinforcing for a beam, column or wall, this double-hooked bar needs to fit within, the situation becomes much more complicated as shown in Fig. 3.2.7b.

The designer needs to consider that a bar with hooks at each end creates a situation where the bar is extremely restricted and must be exactly right, otherwise the ironworker may not be able to place it.
The reality is even if the reinforcing bar detailer details this double hooked bars as shown in the design drawings with the correct concrete cover, it will almost never fit during field installation. Since there is no flexibility with this bar, if it doesn’t fit it will most likely need to be replaced, causing delays on the jobsite. There are two ways to address this situation.

The first and most preferred way would be to allow the use of a lap splice. This allows the ironworker the flexibility to place the bars in their intended position within the beam while avoiding conflicts with the adjacent steel.

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

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

[Should hooks be on outside here? see next figure discussion]

The second way to address this situation if a lap splice is not permissible, is for the designer to understand and accommodate the end of the bar being held inside the adjacent steel, increasing the end cover measured from the edge of the concrete to the end of the bar.

![Fig. 3.2.7d—Single bar with hook at both ends placed within beam cages](image)

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

This situation needs to be addressed by the reinforcing bar detailer and shown in one of these ways on the placing drawings. Notating this practice on the design drawings will provide clear direction
to the detailer and the ironworker and avoid confusion during the detailing process and during 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 and the right illustration shows the end of a confined bar with adjacent steel that must be accounted for in the design, detailing and installation processes.

Fig. 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 must be accounted for in the design, detailing and installation processes.
3.2.8 Accumulating (combined) tolerances

The effects of tolerances on cover, strength, constructability, and serviceability of the structure should be considered by the LDP. 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 constructability problems. Any combination of tolerances, as discussed in this section, working against each other has the potential to create a constructability 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 of the structure and consider options that mitigate or eliminate the possible constructability problem.

3.3—General Cautions

3.3.1—Revisions of drawings

3.3.2—Dimensioning

3.3.3—Field cutting of bars

3.3.4—Field bending of bars

3.3.5—Mechanical connectors

3.3.6—Mixing grades of steel on a project
CHAPTER 4 — STRUCTURAL DRAWINGS

4.1—Scope

This chapter describes information that is typically found on structural drawings. In US engineering practice each design office usually develops an “office standard” sheet order and naming convention. This guide, as an example, presents the project sheet order found in the United States National CAD Standard – V6, as outlined in 4.3.

4.2—General

Structural drawings are those prepared for the owner or purchaser of engineering services and along with the project specifications form a part of the contract documents. Structural drawings must 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 is the largest portion of the sheet 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 CAD filename and path to the file, default settings, pen assignments, printer/plotter commands, date and time of plot, overlay drafting control data, and reference files.

The title block area is located at the right side of the sheet. It usually includes the designer's name, address, and logo; basic information about the project including location of the worksite, owner, and project name; an information block regarding issue type (addendum, design development, bidding, bulletin, etc.) of this sheet; 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.

4.3—Order of sheets

The order of drawings shown in the United States National CAD Standard – V6 is as
listed in Table 4.3.

Table 4.3—NCS drawing sheet numbering
<table>
<thead>
<tr>
<th>Sheet number</th>
<th>Sheet title</th>
<th>Information included</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>General notes</td>
<td>Symbols legend, general notes</td>
</tr>
<tr>
<td>1</td>
<td>Plans</td>
<td>Horizontal views of the project</td>
</tr>
<tr>
<td>2</td>
<td>Elevations</td>
<td>Vertical views</td>
</tr>
<tr>
<td>3</td>
<td>Sections</td>
<td>Sectional views, wall sections</td>
</tr>
<tr>
<td>4</td>
<td>Large-scale views</td>
<td>Plans, elevations, stair sections, or sections that are not details</td>
</tr>
<tr>
<td>5</td>
<td>Details</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Schedules and diagrams</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>User defined</td>
<td>For types that do not fall in other categories, including typical detail sheets</td>
</tr>
<tr>
<td>8</td>
<td>User defined</td>
<td>For types that do not fall in other categories</td>
</tr>
<tr>
<td>9</td>
<td>3D Representations</td>
<td>Isometrics, perspectives, photographs</td>
</tr>
</tbody>
</table>

If more than one sheet is required within the listed order, then decimal sheet numbers are used, e.g., 5.0, 5.1, 5.2, 5.3.

**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. The 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/or the authority having jurisdiction requires specific information to be included on the construction documents and the general notes sheet(s) present this information. ACI 318 also requires that all applicable information from Chapter 26 related to construction be included in the construction documents.

**4.4.2 Design loads**
Section 1603.1 of the 2012 IBC states: “The design loads and other information pertinent to the structural design required by Sections 1603.1.1 through 1603.1.9 shall be indicated on the construction documents.” The titles of these 9 referenced sections are listed below:

1603.1.1 Floor live load
1603.1.2 Roof live load
1603.1.3 Roof snow load data
1603.1.4 Wind design data
1603.1.5 Earthquake design data
1603.1.6 Geotechnical information
1603.1.7 Flood design data
1603.1.8 Special loads
1603.1.9 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 is usually presented as a list of the different criteria used to develop the design earthquake loads. It is desirable 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. It can be presented as a note if the soil and water table on site is relatively consistent or in a table format if 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 the live loads. Examples of such loads are architectural features, partition live loads, ceiling and hanging loads, and super-imposed dead loads. A diagram may 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, the concrete density should be provided on the drawings so that the self-weight of the structure can be accurately determined by the formwork engineer.

4.4.3 Specifications

The first concrete general note is commonly a reference to require construction to 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 shall comply with ACI 117.

ACI 301 contains the following three checklists: mandatory, optional requirements, and submittals. The LDP is often also the specifier on a project and must 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

ACI 301 Mandatory Requirements Checklist items related to concrete can be specified in the general concrete notes and indicate that the construction documents include:
Exposure class and specified compressive strength \( f'_c \) for different elements

Handling, placing and constructing requirements

Designations and requirements for architectural concrete, lightweight concrete, mass concrete, post-tensioned concrete, shrinkage-compensating concrete, industrial floor slabs, tilt-up construction and pre-cast concrete

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

The 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:

- Air entrainment in percentage (%), along with the respective tolerance
- Slump in inches (in), along with the respective tolerance
- When high-range-water-reducing admixtures are allowed or required
- Additional testing and inspection services

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

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:

- Type and grade of reinforcing bars
- Bar development and splice lengths and locations
Types of reinforcement supports and locations used within the structure

Specify the cover for headed shear stud reinforcement and headed reinforcing bars

The construction documents must 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 may include the following:

- Weldability of bars
- Concrete cover to reinforcement
- Specialty item type and grade
- Coatings such as epoxy or galvanized and where applicable
- Permitting field cutting of reinforcement and the cutting methods

Reinforcing bars require concrete cover to protect the steel from corrosion. ACI 301 shows concrete cover requirements for specific members in Table 3.3.2.3. The concrete cover requirements for a project are typically shown in a table or list showing the type of member, the concrete exposure, the type of reinforcement and the concrete cover requirements for each. If there are locations on a specific project that are questionable, the LDP should indicate which concrete cover requirement controls at each location (i.e. 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 reinforcing requirements

Reinforcing bars, spirals, wires and bar mats in conformance with ASTM International specifications are accepted for construction in the United States and are required by ACI 318. Type and grade of reinforcing are typically shown in a note. When there are more than one type
and/or grade of reinforcing used on a project, it may be easier to show this information in a table indicating what type and grade is used in what parts of the structure (Table 4.4.5.1).

Table 4.4.5.2—Example table of reinforcing bar locations and grades

Insert table of locations and grades.

(indicate it’s an example)

(indicate the ASTM types and grades, locations)

4.4.5.2 Development and splices

ACI 318 requires that the development length/embedment of reinforcement and location and length 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. When engineering judgment indicates that lap splice location and length are less critical, a table can be used (refer to Table 4.4.5.2). Structural 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 on the project can be found on the drawings. (MENTION THE CONCRETE STRENGTH APPLICABLE; CURTIS WILL GIVE US THE BEST TABLE; AND STEEL GRADE)

Table 4.4.5.2a—Example reinforcing bar lap schedule
If mechanical splices are permitted or required on a project, a note is needed 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 (refer to Table 4.4.5.2b).

### Table 4.4.5.2b—Example table of mechanical splices

<table>
<thead>
<tr>
<th>BASE SIZE</th>
<th>TOP BAR</th>
<th>OTHER BAR</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>#3</td>
<td>24&quot;</td>
<td>19&quot;</td>
<td>1. Values for Uncoated Reinforcement and Normal Weight Concrete with Clear Spacing &gt; d_p Clear Cover &gt; d_p &amp; Minimum Stirrups or Ties Throughout L_d with Clear Spacing &gt; 2d_p &amp; Clear Cover &gt; d_p.</td>
</tr>
<tr>
<td>#4</td>
<td>32&quot;</td>
<td>25&quot;</td>
<td>2. Develop all Reinforcing in Structural Slabs with Minimum Development Length L_d.</td>
</tr>
<tr>
<td>#5</td>
<td>40&quot;</td>
<td>31&quot;</td>
<td>3. Top Bar = Horizontal Bar with More Than 12&quot; Fresh Concrete Below (Excluding Wall Horizontal Reinforcing) or as Noted on Documents as &quot;Top Bar&quot;.</td>
</tr>
<tr>
<td>#6</td>
<td>48&quot;</td>
<td>37&quot;</td>
<td></td>
</tr>
<tr>
<td>#7</td>
<td>70&quot;</td>
<td>54&quot;</td>
<td></td>
</tr>
<tr>
<td>#8</td>
<td>80&quot;</td>
<td>62&quot;</td>
<td></td>
</tr>
<tr>
<td>#9</td>
<td>91&quot;</td>
<td>70&quot;</td>
<td></td>
</tr>
</tbody>
</table>
If headed bars are permitted or required on a project, a note is needed on the general notes sheet or project specifications to permit them as well as the required bearing area, cover and embedment lengths. The LDP should also include a typical detail or specific details on where headed bars are required or permitted (refer to Table 4.4.5.2c). Use an illustration on how we want to see it.

### Table 4.4.5.2b—Example table of headed bars

<table>
<thead>
<tr>
<th>NOM. PROPERTIES</th>
<th>A615 Gr60 (lbs)</th>
<th>A615 Gr75 (lbs)</th>
<th>A706 (lbs)</th>
<th>HEAD DIMENSION (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bar No.</td>
<td>Dia. (in)</td>
<td>Area (inch^2)</td>
<td>YIELD STRENTH</td>
<td>TENSILE STRENGTH</td>
</tr>
<tr>
<td>#4</td>
<td>0.500</td>
<td>0.20</td>
<td>12,000</td>
<td>18,000</td>
</tr>
<tr>
<td>#5</td>
<td>0.625</td>
<td>0.31</td>
<td>18,600</td>
<td>27,900</td>
</tr>
<tr>
<td>#6</td>
<td>0.750</td>
<td>0.44</td>
<td>26,400</td>
<td>39,600</td>
</tr>
<tr>
<td>#7</td>
<td>0.875</td>
<td>0.60</td>
<td>36,000</td>
<td>54,000</td>
</tr>
<tr>
<td>#8</td>
<td>1.00</td>
<td>0.79</td>
<td>47,400</td>
<td>71,100</td>
</tr>
<tr>
<td>#9</td>
<td>1.128</td>
<td>1.00</td>
<td>60,000</td>
<td>90,000</td>
</tr>
<tr>
<td>#10</td>
<td>1.270</td>
<td>1.27</td>
<td>76,200</td>
<td>114,300</td>
</tr>
<tr>
<td>#11</td>
<td>1.410</td>
<td>1.56</td>
<td>93,600</td>
<td>140,400</td>
</tr>
<tr>
<td>#14</td>
<td>1.693</td>
<td>2.25</td>
<td>135,000</td>
<td>202,500</td>
</tr>
</tbody>
</table>

Table of locations and table of headed bars.

### 4.4.5.3 Supports for reinforcing bars

Before and during concrete casting, reinforcing bars should be supported and held firmly in place at the proper distance from the forms. The LDP specifies acceptable materials and corrosion protection for reinforcing bar supports, side form spacers, and supports or spacers for other embedded structural items or specific areas. Specifications for reinforcing bar supports and spacers usually are consistent with established industry practice.

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

There are three common material types of bar supports: wire bar supports, precast concrete block bar supports, and composite (plastic) bar supports. A common sub-type of wire bar supports is plastic-tipped wire bar supports which are often used when aesthetics are a concern. CRSI RB4 describes the various types of wire, composite and precast bar supports. Examples of bar supports are shown in Fig. 4.4.5.3a.

As mentioned above, certain 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 may be objectionable. Another example of aesthetic issues is that Class 3 wire bar supports may leave rust stains on the exposed concrete surfaces. The LDP and contractor should work together to help prevent these issues from occurring because repair for aesthetic issues 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 may also be supported with individual chairs or blocks placed under the beam stirrups.
Typical Wire Beam Bolster

Bar supports are furnished for bottom bars in grade beams or slabs-on-ground (Fig. 4.4.5.3b) only if required by the LDP in the construction documents. For a structural element, it is recommended that the LDP 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.
Fig. 4.4.5.3b—Bar supports for slab-on-ground reinforcement

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

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

4.4.5.4 Weldability of bars

The weldability of steel is established by its chemical composition. 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/A 706M are pre-approved for welding without preheating. Welding of rail-and axle-steel bars is not recommended.

4.4.5.5 Hooks and bends

It is standard practice in the industry 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. It is important to note the difference between “minimum” bend diameter and “finished” bend...
diameter. “Finished” bend diameters includes 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 bent in more than one plane involve greater difficulty and are subject to added costs.

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

<table>
<thead>
<tr>
<th>Are hooks dimensioned on plan?</th>
<th>Yes</th>
<th>Use plan dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Does a standard 90 degree hook fit?</td>
<td>Yes</td>
<td>Use a standard 90 degree hook</td>
</tr>
<tr>
<td>No</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Does a standard 90 degree hook rotated 45 degrees fit?</td>
<td>Yes</td>
<td>Use a standard 90 degree hook rotated 45 degrees</td>
</tr>
<tr>
<td>No</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Does a standard 180 degree hook fit?</td>
<td>Yes</td>
<td>Use a standard 180 degree hook</td>
</tr>
<tr>
<td>No</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Does a standard 180 degree hook rotated 45 degrees fit?</td>
<td>Yes</td>
<td>Use a standard 180 degree hook rotated 45 degrees</td>
</tr>
<tr>
<td>No</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RFI</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

To avoid RFI’s, the design might consider … For this reason, it is prudent for the LDP to check hooks throughout the project during the constructability check suggested in chapter 8,
especially if rotating the hooks causes issues with design. A standard hook only defines
dimensions of the bend shape. This is not an indicator of development strength. See Fig.

CJP passive. (TASK GROUP REVISE)

4.4.5.6 Welded wire reinforcement

Welded wire reinforcement consists of a series of cold-drawn steel wires arranged at right
angles to each other and electrically welded at all intersections. Welded wire reinforcement has
many uses in reinforced concrete construction. It can be used in slabs-on-ground, joist and
waffle slab construction, walls, pavements, box culverts and canal linings.

The general notes or the specifications will specify the welded wire reinforcement
required. Welded wire reinforcement can be in the form of flat sheets normally 8 ft. 0 in. by 20
ft. 0 in. or rolls which are usually 5 ft. 0 in. by 150 ft. 0 in. The wire may be plain or deformed.

Welded wire reinforcement in conformance with ASTM International specification A1064
is accepted for construction in the United States and is required by ACI 318. Table 4.4.5.6 gives
common styles of welded wire reinforcement in the U.S.

Table 4.4.5.6—Common stock styles of welded wire reinforcement
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 may include information pertinent to detailing. For example:

- Procedure for resolution of discrepancies
- Storage of material on site
- (NEEDS DEVELOPMENT)

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).
Section 1603.1 in the 2012 IBC states: “Construction documents shall show the size, section, and relative locations of 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, concrete member width and thicknesses (either directly or by a designation keyed to a schedule), and 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 sheet or a 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 or indirectly provided through use of schedule marks, such as beam numbers.
Plan drawings are usually drawn to 1/16 or 1/8 inch scale. For small floor plans larger scales may 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 needs to be conveyed in a small area of the plan. If the designer needs to break up the plan into several parts for a floor, they should take into account portions of the structure, assumed placement sequences, or some other easily readable way of breaking the plan into smaller pieces.

Because plans only provide information in the horizontal direction, section cuts and elevations are needed 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.

4.5.1 Plan graphics and member geometry

The assumed viewpoint for a plan drawing is above the slab on each floor level of a structure. Therefore, slab edges are usually shown as solid lines on the plan drawings (Fig.4.5.1a). Beam and girder locations are typically shown as hidden on the plan drawings because they are typically below the 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 of 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 grade and solid when not covered by structural members or slab on grade concrete. Soil is not considered a structural member for this purpose. Slabs, beams, girders, columns, walls, and foundations are sometimes given schedule marks on the plan drawings (Fig. 4.5.1b) to indicate the type of member, size of concrete member, and reinforcement required.

4.5.2 Reinforcement on plan views
Reinforcement that is not typical, 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, one shows the top reinforcement,
and another that shows additional steel such as that required around openings and should be properly labeled. Additional beam and girder reinforcement is not typically shown on the 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 plan drawings, the scale is often based on the complexity of the structure and the elevation can be split into several drawings as required to show enough detail.

Photo 6: Perry Project 15030.00 – Pricing Drawings – 2/S1.0

Fig. 4.6a—Building elevation with detail call-outs
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 of 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.

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

4.7 Section sheets

A section sheet is used for most projects. Sometimes, a single sheet combines sections, details (3.4.6), and schedules (3.4.7). Most sections are drawn at 3/4 inch scale but larger scales may be used, if more detail is needed 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 call out (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.
Fig. 4.7—Example plan sheet section cut call out and section sheet section cut detail

4.8 Large scale view sheets

Large scale views are used if a dramatically increased scale of a section or detail is needed 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 stair case, complex elevator core, or heavily reinforced link beam. These sheets are rarely titled "large scale views" but are 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. See Fig. XXXXXXX

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 (4.7), details, and schedules (4.10). Many details are drawn at 1/2 inch to 1 inch 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. <a couple of figures will be helpful to show this>

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 drawn exactly. 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 just as an example of what needs to be done and the contractor has some freedom to choose the best means and methods for building the detailed item as shown.

For example, trim reinforcement around a slab or wall opening is often standard for a certain range of opening sizes, and this arrangement is shown in a typical detail. This allows the
contractor 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.

Bundling bar details for splice and special development lengths that affect many different types of members, such as heavily reinforced slabs, beams, columns, and walls is best shown in a typical detail on the respective member schedule sheet because the information is member specific and should be shown in the typical details sheets. See Fig. XXXXXXX – what’s the offset at laps?

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 and sometimes on the slab schedule sheet to indicate bar size, spacing of shear reinforcement, and shape of bent bar. Headed shear studs may also be a viable option and a detail should be drawn if chosen. See Fig. XXXXXXX

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 information in the schedule is usually provided (Fig. 4.10).
Fig. 4.10—Diagram provided to explain schedule information

Member schedules usually contain the following:

- Member mark which should have a standard naming convention and be identified on plans and elevations
- Member dimensions
- Member reinforcement
  - Remarks or notes describing atypical reinforcement patterns, elevation, concrete strength etc.

4.10.1 Slab Schedules

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

For one-way slabs, the LDP can use the termination rules to use material more efficiently.

Please see Figure X.XX for example details.
Two-way slabs supported by edge walls or by edge-beams require reinforcement in the top and the 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. Please see Figure X.XX for example details.

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. When using shearheads, the two column strip bottom bars or wires should be shown in a typical detail. Please see Figure X.XX for example details.

Two-way shear reinforcement in slabs could be headed shear studs, typical stirrups, or structural steel members. Headed shear studs are used most often and 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. The plan drawings should be marked at each column to indicate which particular 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 should be shown using the methods described above for showing headed shear studs. Structural steel members are rarely used and if used their locations should be identified and special details provided. See Fig. XXXXXXX.
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 term 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).

<table>
<thead>
<tr>
<th>MARK</th>
<th>SIZE</th>
<th>REINFORCING</th>
<th>STIRRUPS</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>TOP BARS</td>
<td>BOTT. BARS</td>
<td>MID BARS</td>
</tr>
<tr>
<td>GB1</td>
<td>30 x 42</td>
<td>(8) #10</td>
<td>(6) #7</td>
<td>(2) #5 E.F.</td>
</tr>
<tr>
<td>GB2</td>
<td>46 x 36</td>
<td>(10) #8</td>
<td>(6) #8</td>
<td>(1) #5 E.F.</td>
</tr>
<tr>
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<td>(6) #9</td>
<td>(6) #9</td>
<td>(1) #5 E.F.</td>
</tr>
<tr>
<td>GB4</td>
<td>24 x 36</td>
<td>(4) #9</td>
<td>(4) #9</td>
<td>(1) #5 E.F.</td>
</tr>
<tr>
<td>GB5</td>
<td>24 x 30</td>
<td>(3) #6</td>
<td>(4) #8</td>
<td>(1) #5 E.F.</td>
</tr>
<tr>
<td>GB6</td>
<td>30 x 36</td>
<td>(4) #8</td>
<td>(7) #8</td>
<td>(1) #5 E.F.</td>
</tr>
<tr>
<td>GB7</td>
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<td>(5) #5</td>
<td>(4) #5</td>
<td>(1) #5 E.F.</td>
</tr>
<tr>
<td>GB8</td>
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<td>(4) #6</td>
<td>(1) #5 E.F.</td>
</tr>
<tr>
<td>GB9</td>
<td>24 x 16</td>
<td>(4) #6</td>
<td>(4) #6</td>
<td>(1) #5 E.F.</td>
</tr>
</tbody>
</table>

Photo 10: https://sites.google.com/site/ae390final/gradebeamschedule.JPG

Fig. 4.10.2—Example grade beam schedule

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 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 may need 6-#4 stirrups at 2”o.c. and then 6-#4 stirrups at 6”o.c. at each beam end and the remainder along the length of the beam at 12” 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 LDP should provide a detail of stirrups showing the shape of the stirrup.

4.10.3 Column schedules

Column schedules usually contain the column mark, a vertical reinforcement, and the size and spacing of shear reinforcement. See Fig. XXXXXXX 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, the spacing of the shear reinforcement at the tops and bottoms of columns varies and is shown in a typical diagram on the column schedule sheet. If applicable, the following diagrams also should be included with the column schedule: basic transition 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 the 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 reinforcement should be clearly shown, such as VEF, HIF, HOF, caps, etc. See Fig. XXXXXXX See Chapter 3 for other abbreviations. [Johnston
comment: ACI style is to define acronyms where they first appear in the text. If there is a need to provide acronyms or abbreviations commonly used in concrete reinforcing steel drawings, we should consider adding a table of abbreviations in Chapter 3, perhaps in a Section “3.3 Abbreviations”.

4.11 Foundation sheets and schedules

Foundations are sometimes treated separately from the remainder of the structural systems because of their unique characteristics and in general, the fact that foundation systems are used for many various superstructure types. Foundation drawings may be issued separately from the superstructure drawings or may be the only reinforced concrete drawings on a project. Foundation sheets are commonly used for shallow foundations (Fig. 4.11a) such as strip footings, isolated footings, combined footings, mat foundations and grade beams or for deep foundation systems that may include pile caps, piles, drilled piers and caissons.
Foundation drawings can be individualized or used with schedules and foundation marks used to represent the foundation type are usually identified by the first letter of the foundation member represented. For example, P1 is usually related to a pile cap over piles, while F1 is often used to describe a shallow footing and GB1 is often used to mark grade beams. In any case, it is recommended that an Abbreviation and Notation Legend be included in the drawing sheet for clarity and ease of identification. Grade beam schedules are similar to elevated beam schedules and guidelines regarding beam schedules are shown in 3.4.7.2. Pile cap schedules should include the 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 must extend into the top of the pier. See Fig. XXXXXXX

Each different 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. See Fig. XXXXXXX

Shear reinforcement in a foundation is not frequently used, but when it is, it is typically detailed 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 should be considered.

**4.12 User defined sheets**

User defined sheets are used to show information that is not presented on other sheets,

**List of examples needed.**

**4.13 3D Representations**
3D representations or isometric sketches are not commonly used but can be very helpful to show an especially complicated connection or joint or to coordinate among different disciplines to prevent clashes between different systems. (Sample needed.)
CHAPTER 5—DESIGNING FOR CONSTRUCTIBILITY

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

5.1.1—Clear Cover

5.1.2—Bar development

5.1.3—Bar Splices

5.1.4—Clearance between bars

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 wall horizontals.

The LDP should clearly indicate the nature of the stagger. Is the stagger one lap length, a double lap length, or a specified dimension between the laps? A detail such as shown in Fig. 5.2.1 is the best way to show the intent.

Figure 5.2.1

Lap locations should be clearly indicated, as well areas where laps are not allowed. Staggering of couplers should be equally defined and indicated.

5.2.2—Embedment into support

Tables of embedment requirements are usually sufficient (see Table 5.2.2). Care should be taken to clearly indicate special embedment locations and appropriate instructions given to ensure they are correctly placed.

Figure 5.2.2

5.2.3—Bar dimensioning

The most common bar dimensioning issue involves hooks. When the LDP dimensions hooked bars, he should be sure to indicate at least in the General Notes whether the dimension does or does not include the hook.

(Insert Fig.)
Rebar 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 be no lap. The LDP should clearly indicate if a lap is intended and if so, dimension the lap. (Insert Fig.)

Where standard hooks are too long to fit with the concrete member, the hook should be clearly dimensioned on the drawing.

5.2.4—Skewed bars

In trapezoidal shaped slabs, the LDP should clearly indicate if the main bars are perpendicular to the parallel sides or parallel to the sloped sides. He should 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. (Figures may be beneficial).

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

5.2.5—Termination of vertical bars

The LDP should always indicate how vertical bars are to be terminated. If the bars are to be hooked there are several things to be considered. If the hook is not a standard hook the length should be indicated. Is the hook located in either of the top layers or beneath both layers? Is the member into which the hook is to be embedded sufficiently deep to accommodate the curvature of the bend? If the direction of the hook is critical this should be clearly indicated. Member intersections may 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, for 3 @ 6”; 5 @ 9”; rem @ 12”, 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 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 try if possible to provide a continuous top bar in each stirrup hook. Consider a greater quantity of smaller bars rather than fewer larger bars.
In very narrow beams consider 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 non-prestressed steel reinforcement of shallow and deep structural foundations as defined by ACI 318 Chapter 13. See Section 5.6 for supplemental requirements for deep foundations in structures assigned to Seismic Design Categories D, E, and F as prescribed by ACI 318 Section 18.13.

5.3.1 Types

Foundation systems can be categorized as either shallow foundations or deep foundations. Shallow foundations include types such as strip footings; isolated, spread, or pad footings; mat foundations, and grade beams. Deep foundation types include piles, drilled piers, and caissons as described in ACI 336.3R and ACI 336.3R. Pile caps are 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 torsion loadings imposed on the foundations. The bar arrangements described in this section are general and common arrangements. The LDP should specify needed bar arrangements for the appropriate conditions.

Shallow foundations such as strip, isolated, and mat foundations often have a bar arrangement similar to that of a slab having a top and/or bottom mat of reinforcement with bars in each direction. In some instances, the bars may 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 around the perimeter of the beam, top and bottom longitudinal steel, and in some cases side longitudinal steel. The second arrangement is still similar to a beam, however may only have top and bottom reinforcement. Ties in the second arrangement may only be required for constructability as a method to hang the top reinforcement. See Fig. 5.3.2a and 5.3.2b for examples.
Deep foundations are often circular and thus have a bar arrangement similar to that of a circular column with a tie around the perimeter and longitudinal steel spaced around the perimeter inside the tie. Smaller drilled piers may only have longitudinal steel that is centered in the drilled pier; in these cases, reinforcement may be added for constructability to keep the reinforcement centered in the shaft. Though reinforcing 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 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. See Fig. 5.3.2a and 5.3.2b for examples.

5.3.3 Layering

Layering in foundations primarily only applies to non-grade beam shallow foundations as grade beams are typically reinforced similar to beams and deep foundations are typically reinforced similar to columns as noted in 5.3.3. For strip footings, the layering is most commonly found with longitudinal reinforcement running flush to the top and bottom covers and any transvers reinforcement inset from the longitudinal reinforcement. Isolated pad footing layering most often depends on the geometry of the pad footing. For square pad footings, layering can go either way, and for rectangular pad footings reinforcement along the larger dimension should be pushed to the bottom and top cover and the reinforcement along the shorter dimension should be inset. For mat foundations not supported by deep foundations, the layering will be similar to that of a rectangular pad footing with the reinforcement running along the larger dimension placed at cover and the transvers reinforcement inset. Each case discussed above are typical layering conditions for foundations; however, each is also dependent on the design of the foundation. One should always refer to the contract documents for specific requirements. Contract documents should specifically note the layering arrangement when it is critical to the design. See Fig. 5.3.3a and 5.3.3b for examples.

All reinforcement layering should be properly supported to keep the reinforcement at the correct location in the element. For bottom reinforcement cast against the earth, concrete or masonry blocks also known as “dobies” are most commonly used. Bar supports with feet can dig into the soil causing a loss of cover and should be avoided when on earth. For bottom layers on voids, wire bolsters and chairs can also be used. The support of top mats of reinforcement can be supported by bolsters, chairs, or standees depending on the supporting height. Cover for
drilled piers can be obtained with alignment bars, alignment wheels, or in the case of centered reinforcement without ties by using crossing reinforcement.

5.3.4 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.

5.4—Walls

5.4.1—Introduction

In ACI 318, Chapter 2, Section 2.3, a wall is defined 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 above grade 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 must absorb and resist all reactions from the these systems.

5.4.2—Scope

This section shall apply to steel reinforcement of nonprestressed ordinary structural walls, including: cast-in-place, precast in-plant and precast on-site, including tilt-up construction, as defined in ACI 318 Chapter 11. This section shall also apply to retaining walls and walls that are part of underground or above ground tanks designed for the purpose of containing liquids or granular materials. For steel reinforcement in special structural walls see Section 5.6 of this Manual.

5.4.3—General

Steel reinforcement shall be provided in walls to resist all in-plane and out-of-plane forces acting on ordinary structural walls, as shown in Figure 5.2.1. 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.
Design of cantilever retaining walls shall be designed in accordance with ACI 318-14, Sections 22.2 through 22.4, with minimum horizontal reinforcement in accordance with ACI 318-14, Section 11.6.

Figure 5.2.1: In-plane and out-of-plane forces.
(Source: ACI 318-14. Chapter 11)

5.4.4—Considerations

Reinforcement limits for vertical and horizontal bars are indicated in Section 11.6 (Sub-Sections 11.6.1 and 11.6.2) of ACI 318, for relative values of Vu (factored shear force). General bar detailing should conform to ACI 318 Section 11.7. Concrete cover for reinforcement shall conform to Table 20.6.1.3.1 of ACI 318, Chapter 20. Development lengths and splice lengths of reinforcement shall be in accordance with ACI 318, Sections 25.4 and 25.5, respectively. Distribution and spacing of transverse and longitudinal reinforcement shall conform to ACI 318, Sub-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 shall be laterally supported by transverse ties. In all walls, reinforcement is required around wall openings and shall comply with ACI 314 Section 11.7.5.

5.2.5—Best Practices

It is generally recommended, for constructability purposes, that steel reinforcement on both faces of a wall be placed with equal spacing or that spacing of reinforcing bars of one face be a multiple of the other or that spacing of bars at each face be multiple of a common value, for example: 2", 3" or 4", etc. Transverse or
horizontal reinforcing bars should be placed closest to wall face and conform to cover limits mentioned in Table 20.6.1.3.1 of ACI 318, Chapter 20. Reinforcement is required in both directions and also diagonally at the corners, around wall openings. This reinforcement shall consist of at least 2 No. 5 bars, anchored to develop $f_y$ in tension, and as a rule of thumb, should be at least equal in area to the bars interrupted by the openings.

5.4.5.1—Footing to wall connections

In cantilever retaining walls, vertical reinforcement should extend through the height of the wall foundation and be anchored on top of the foundation slab bottom reinforcement. The slab height dimension should be such as to permit the vertical reinforcement bar standard hooks to be correctly anchored a distance $ldh$.

5.4.5.2—Corners and intersections

Horizontal wall reinforcement must be anchored in vertical wall corners and intersections, preferably with standard 90 degree hooks. To achieve proper anchorage, the bar must 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 mid intersections.

When additional diagonally placed horizontal reinforcement is needed, to resist shear forces and to help avoid cracking and opening at the corner or intersection, it should also be extended to the opposite face of each intersecting wall and terminate with a bar bend at least equal to the bar Development Length ($ld$).

A typical detail of the correct bar arrangement at wall corners and mid length intersections will clarify the information for the detailer, for correct bar dimensioning and placing of reinforcing bars and will help avoid errors that may compromise the structural integrity of the walls.

5.4.5.3—Steps and sectional transitions

Steps and sectional transitions at base of walls should be correctly detailed, showing the transitional reinforcement bars. Steel reinforcement across wall steps or sectional transitions shall comply with ACI 318-14 Chapter 25. Special attention should be given to bar anchorage, development lengths, and to providing continuous and correctly anchored reinforcement across any section change.

5.4.5.4—Multiple curtains and layers
5.4.5.5—Construction Joints, Contraction Joints, Expansion Joints and Waterstops

**Construction Joints:** Can be vertical or horizontal joints that are left in place between two successive pours 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 must be cleaned and roughened previous to the next concrete pour. Keys are more usually formed in the wall base to give the stem more sliding resistance. *Wall reinforcement is placed continuously across the joint.*

**Contraction Joints:** Vertical joints formed or cut into the wall that allow the concrete to shrink without noticeable cracking. Contraction joints can usually be about 5-6 mm. (1/4”) wide and about 12 to 20 mm. (1/2” to 3/4”) deep, and are provided at various intervals, depending on wall height, thickness and amount of reinforcement, but usually not exceeding 9 to 10 m. (around 30 ft.). *Wall reinforcement is placed continuously across the joint.*

**Expansion Joints:** Vertical expansion joints are placed into the wall to permit expansion due to temperature changes. These joints should be filled with flexible joint fillers to impede passage of water or other liquids. Horizontal greased steel dowels are usually placed across the joint to tie adjacent sections together. Expansion joints are located at various intervals, depending on wall dimensions, but should not be separated more than 25 to 30 m. (75 to 90 ft.) apart. *Wall reinforcement is discontinuous across the joint (not placed across the joint but rather terminated at each joint face).*

**Waterstops:** These are continuous molded sections, traditionally made of rubber, neoprene or PVC, that are placed along the joint, embedded equally in each adjacent section, with the purpose of making the joint watertight. There are various sections that can be used for the different types of joints named above. *Steel reinforcement should be detailed with consideration to the required waterstop to be used in the joint.*

**References**

5.5—Columns

This section applies to non-prestressed and steel reinforcement of structural columns as defined by ACI 318 Chapter 10 and portions of deep foundations described by ACI 318 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 Section 10.7.3 requiring a minimum of (3) vertical bars with a triangular tie, (4) vertical bars with in rectangular and circular ties, and (6) 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 non-circular columns.

5.5.2—Ties

Tie reinforcement is prescribed by ACI 318 Section 10.7.6 and Section 25.7.2. As noted in ACI 318 Section 25.7.2 ties should have a minimum clear spacing of four-thirds the nominal maximum coarse aggregate size and a maximum of the lesser of sixteen longitudinal bar diameters, forty-eight tie bar diameters, and the smallest dimension of the column. Spirals should be spaced continuously with the clear spacing being at least the greater of one inch and four-thirds the nominal maximum coarse aggregate size and a maximum of three inches. The smallest tie size should be #3 for longitudinal bars #10 and smaller and #4 for ties enclosing #11 bars and larger. Alternatively, typical tie reinforcement can be replaced by welded wire reinforcement of an equivalent area except for spiral ties and special seismic systems. For rectangular ties, the tie arrangement must provide lateral support for every corner and alternate longitudinal bar with a hook of a tie no more than 135 degrees. Tie reinforcement must provide lateral support for every longitudinally bar enclosed by a rectangular tie when the clear spacing between laterally supported longitudinal bars exceed six inches on each side. Circular tie reinforcement...
must lap by a minimum of six inches, terminate with standard hooks at each end that enclose a longitudinal bar, and laps must be staggered around the perimeter.

Per ACI 318 Section 10.7.6, at member ends or transitions the bottom tie must 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 must be located within three inches 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 and the top should conform to ACI 318 Table 10.7.6.3.2 shown below.

Anchor bolt confinement must also be provided by tie reinforcement per ACI 318 Section 10.7.6.1.6 requiring that anchor bolts must be enclosed by transvers reinforcement that also surrounds at least four longitudinal bars with in the column. The transvers should be distributed within the top five inches of the top of the column and consist of at least two #4 bars or three #3 bars.

5.5.3—Detail at Steps and Transitions

At steps and transitions, the longitudinal reinforcement often is detailed with an offset bend, covered in ACI 318 Section 10.7.4. The slope of this transition should not exceed one to six. If there is a column offset greater than three inches this transition is not allowed and must be made with separate dowels adjacent to the offset column faces. Where longitudinal bars are offset, horizontal support should be provided throughout by either ties, spirals, or parts of the floor construction. If transverse reinforcement is provided, they should be placed no more than six inches from the points of the bend per ACI 318 Section 10.7.6.4. See below for detail examples at column steps and transitions.

5.5.4—Laps

Offset bend locations should be specifically noted by the LDP?
Column lap lengths should be specifically noted by the LDP. Guidance should be given through schedules, notes, or other methods to accurately prescribed lap requirements per column. Generally, compression laps can be allowed in gravity columns. These splices lengths can be factored by .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 .75 when spiral reinforcement is provided in accordance to ACI 318 Section 25.7.3. Special attention should be given to areas of laps due to congestion.

ACI 318 Table 25.7.3.6 dictates spiral reinforcement laps where the most common lap length is forty-eight bar diameters. See below for ACI 318 Table 25.7.3.6. Spiral reinforcement shall be anchored by 1 1/2 extra turns of the spiral bar per ACI 318 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 Chapter 15. Termination of vertical column reinforcement into foundations is prescribed by ACI Section 16.3.

5.6—Beams

This section applies to steel reinforcement of non-prestressed beams, as defined in ACI 318 Section 9.1.1. General reinforcement bar detailing should conform to ACI 318 Sections 9.6 and 9.7. Bundled bars should be in accordance with ACI 318 Section 25.6. Development lengths and splices of deformed reinforcement should be in accordance with ACI 318 Sections 25.4 and 25.4, respectively. Reinforcement detailing for beams that are part of a seismic force resisting system is covered in Chapter XX of this Manual.
Code requirements often refer to minimum or maximum values. Being equal to or greater than a minimum value is acceptable; being equal to or less than a maximum value is acceptable. A good design should avoid issues that may arise due to the indiscriminate use of minimum code values without considering other factors. For example, it is important to avoid or reduce constructability issues due to interference between or overcrowding of steel reinforcement and loss of concrete cover or spacing problems between reinforcing bars due to incremental tolerance buildup. The LDP should also present clear information in design drawing details and schedules, which will aid the detailer in correctly understanding the essence and intent of the design, thus saving time in additional consultations and revisions. These considerations will help the process of producing good detailing drawings for construction.

5.6.1—Layering of beam bars at intersections

ACI 318 Sections 15.2 and 15.4 provide requirements for steel reinforcement at beam-column joints. Longitudinal beam reinforcement in beam to beam and beam to girder connections should be detailed in such a way that the beam’s top and bottom steel bar layers will be contained between the girder’s top and bottom longitudinal reinforcing bars. Consideration should be given to intersecting beam depth dimensions and concrete cover for each of intersecting members. Special attention should be given to ACI 318 Sections 9.7 and 25.4.

5.6.2—Layering of slab bars at beam intersections

ACI 318 Section 7.7 provides reinforcement detailing requirements for slabs. Slab longitudinal top layer reinforcement is placed on top of beam top layer reinforcement and properly secured directly to beam bars. Slab longitudinal bottom layer reinforcement runs continuously through the beam web in intermediate connections and at end supports is anchored in the beam web width. In one-way joist systems, consideration for structural integrity should be given in compliance with ACI 318 Section 9.8.

5.6.3—Depth of beams at intersections

Generally, principal beams or girders will be dimensioned for greater loads than secondary intersecting beams, thus will normally be larger in both width and depth. In any case, dimensioning different depths for members in
beam to beam and beam to girder connections will facilitate passage of longitudinal reinforcing rebar layers through the intersection without affecting specified concrete cover. As discussed in Section 6.6.1, special attention should be given to ACI 318 Sections 9.7 and 25.4.

*Figures*

### 5.6.4—Tie arrangements

ACI 318 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 and can consist typically of deformed bars, deformed wires, or welded wire reinforcement 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 for enclosing bars No. 10 or smaller and No. 4 for enclosing bars No. 11 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 stirrups may reduce constructability. The long bars should 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 being required. This significantly reduces the labor cost of installation. Once the bars are installed the stirrups may be capped as necessary.

If closed stirrups are the only option shown on the design documents, the detailer should issue an RFI requesting a change of stirrup configuration to open/capped style. This process may delay the detailer days or even weeks depending on the turn-around time for RFI’s. This is usually an unnecessary interruption since 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.

*Figures*
5.6.5—Arrangement of longitudinal bars

ACI 318 Chapters 9 and 25 provide requirements for longitudinal reinforcement bars in beams. Clear spacing in a horizontal layer should be at least the greatest of 1 in., $d_b$, 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. Standard hooks for the development of deformed bars in tension should conform to ACI 318 Table 25.3.1. Reinforcement limits should be in accordance with ACI 318 9.6. Attention should be given to ACI 318 9.7.2.3, for detailing skin reinforcement in beams with depth $h$ exceeding 36 in. Design of longitudinal reinforcement should comply with ACI 318 9.7.3. Requirements for structural integrity are contained in ACI 318 9.7.7.

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

Figures

5.6.5—Beam steps

ACI 318-14 Chapters 9 and 25 provides requirements for steel reinforcement across beam steps or along beam section changes. Special attention should be given to bar anchorage, development lengths, and providing continuous and correctly anchored reinforcement across any section change.

Figures

5.6.6—Special details

Requirements of special details for steel reinforcement in beams are subject to the LDP’s judgement where non-typical conditions, either geometrical or for other reasons, cannot be fully and correctly represented by only typical details such as Elevations and Sections. 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.

Figures
5.6.7—Beam schedules

Beams with similar geometry and steel reinforcement distribution can be represented with typical details and a beam schedule containing the specific information for bar diameters and dimensions, development and cut-off lengths, etc. Clarity in identifying the different beams and their corresponding reinforcement is important for the detailer to be able to correctly specify and detail the steel reinforcement in the placing drawings.

Figures

Section 5.7—Slabs

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

5.7.1 Bottom Bars

The construction documents should include the minimum cover from the bottom, sides and or top of concrete in sections or details along with the suggested bar support types to be used.

ACI 318 Section 25.5 provides reinforcement design requirements for splices. The drawings should include the minimum splice lengths and embedment lengths into beams, columns, pilasters or other supporting elements. These lap lengths should be shown in details, sections, plan or schedules.

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.

Figures

5.7.2 Top bars

The construction documents should include the minimum cover from the top and sides of concrete in sections or details along with the suggested bar support types to be used. Support bar details with bar size and spacing should be included on the drawings.

ACI 318 Section 25.5 provides reinforcement design requirements for splices. The drawings should include the minimum splice lengths and embedment lengths into beams, columns, pilasters or other supporting elements. These lap lengths should be shown in details, sections, plan or schedules.
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 ends, the LDP should verify the hook dimension can be placed within the specified slab thickness.

Figures

5.7.3 One-Way slabs

ACI 318 Section 7 provides reinforcement design requirements for one-way slabs.

Transverse bottom layer reinforcement runs continuously across the span and is anchored in the beam web a minimum of 6 inches. If using the 50% method, every other bar in the intermediate connection will be held back from the beam face 0.125 of the clear span distance.

Transverse top layer reinforcement is placed on top of beam top layer reinforcement and properly secured directly to beam bars and shall 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.

Longitudinal temperature bars run continuously with the specified lap and shall run through the beam web in intermediate connections and at end supports is anchored in the beam web a minimum of 6 inches.

Specific details for projections of top bars and bars at openings and varying span widths should be included in the contract documents. The support lines should be clearly marked to insure that the intent of the design drawings are met. The 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 insure accurate placing of the reinforcement and required dowels. 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.
ACI 318 Section 7 provides reinforcement design requirements for two-way slabs.

Slab bottom layer reinforcement is placed in both directions and runs continuously across the span and is anchored in the beam web a minimum of 6 inches.

Slab top layer reinforcement is placed in both directions on top of beam top layer reinforcement and properly secured directly to beam bars and shall end 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 and bars 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 insure accurate placing of the reinforcement and required dowels. 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.
5.7.5 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.

Figures

5.7.6 Steps and Depressions

Details for slab steps and depressions should include separate details for different step dimensions. This should include directions for draping the main reinforcing, hooking and lapping or furnishing a bent bar. Special attention should be given to bar anchorage, development lengths, and providing continuous and correctly anchored...
reinforcement across any section change. Dimensions to steps and depressions should be clearly shown on the structural drawings and be located from column lines or from edge of concrete.

**Figures**

### 5.7.7 Stud Rails, etc.

Stud rails should conform to ACI 421.1. They are an effective way of increasing punching shear capacity and minimizing congestion around the slab-column connections. The LDP should furnish specific details, dimensions and information on the number of rails required at each column with the diameter of studs, number of studs per rail, overall height, distance to the first stud and between studs and the clear cover from top and bottom of slab.

*NOTE: We will discuss whether or not to include Stud Rails in this document at the meeting in Philadelphia.*
CHAPTER 6—PLACING DRAWINGS

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 the Detailing section of the “CRSI Manual of Standard Practice”. Additionally, for a better understanding of the fundamentals and best practices in the preparation of reinforced concrete placing drawings, refer to the “CRSI Reinforcing Bar Detailing Handbook”.

6.1—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.

6.2—Overview

Placing drawings are the fabricator’s interpretation of the LDP’s design intent as covered 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 and engineer’s seal. The LDP must furnish a clear statement of the design requirements in the project specifications and structural drawings and may not refer to an applicable building code or other codes for information necessary to prepare the placing drawings. Such information must 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 must be supplied by the contractor. Commonly this information is only becomes available just prior to construction, making it impractical to complete placing drawings within submittal date deadlines required of shop drawings for reinforcement fabrication. It is more important that placing drawings be prepared based on construction ready data and that all parties work together in order to complete
submittal, review and approval processes in a timely manner as to not impact construction
schedules. After approval by the LDP, including necessary revisions, the drawings may be used
for fabrication and placing of reinforcing steel.

6.3—Procedure

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

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
LDP for their review and approval. Refer to sections 6.4 and 6.5 for detailed
explanations of placing drawing review and approval processes.

3) Once placing drawings have been approved, bar fabrication releases are prepared from
the bar lists on the placing drawings, based upon a delivery sequence agreed upon
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.

6.4—Reviewing placing drawings

In some areas of North America, review of placing drawings by the contractor and LDP is
not required and is rarely done. LDP’s in these areas take the view that since their inspection of
installed reinforcing steel is made using their contract design drawings, placing drawings serve
no purpose in the inspection process and therefore require no review. Errors are picked up and
corrected at inspection time. The downside to this approach is that correcting errors in the field
can cause delays and increase costs.
For this reason, most areas of North America encourage review of placing drawings by the contractor and LDP.

6.4.1 Benefits of review

Review is deemed to have a number of worthwhile benefits such as:

a) Tends to include the LDP as part of the team effort
b) Verifies conformance with general design intent
c) Verifies that the most recent revised contract drawings have been used
d) Catches and corrects small errors or omissions that would otherwise delay the project if left to be discovered during inspection in the field
e) Provides an opportunity for the LDP to make small changes or corrections to the design “on the fly”
f) Provides assurance that the detailer understands the design concepts and is proceeding correctly
g) Allows 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 two weeks. The detailer and construction team factor this review time into their schedules. It is therefore important for the LDP to work within this constraint to help keep the project on schedule.

6.4.2 Review process

Ideally the process for submission and review of placing drawings should be outlined in the contract documents. The process varies from project to project but 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
6.4.3 Checklists for review of placing drawings

Each LDP will have their own check list but generally will include at least the following items:

a) Verify latest issue of contract drawings

b) Verify latest issue of addenda and supplementary documents such as requests for information (RFI’s), design change notices (DCN’s), and field change notices (FCN’s)

c) Verify grades, coatings, and sizes of reinforcing steel

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

6.5—Levels of Approval

There are many variations of approval levels. Each LDP usually develops one that suits their requirements. Although the terms may 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. The LDP must review them again before he can approve them. Resubmittal is required.

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 completely new detailing is required and submitted.

It must be noted that by approving reinforcing steel placing drawings for fabrication and installation, the LDP does not incur any responsibility for delays and costs associated with errors or omissions on those drawings. These delays and costs remain the responsibility of the contractor, fabricator, and the placer.