Introduction

CRSI routinely receives inquiries concerning various aspects of reinforcing bars, and reinforced concrete design and construction. Most of these questions come from design professionals (engineers and architects) and field personnel (inspectors, code enforcement personnel, and contractors). The following are topic areas where we receive a majority of our inquiries:

- Field bending of reinforcing bars
- Field cutting of reinforcing bars
- Welding of reinforcing bars
- Rust on reinforcing bars
- Cover over reinforcing bars
- Epoxy-coated reinforcing bars
- Properties of old reinforcing bars
- Bar support use & types
- Tying of reinforcing bars
- Availability and application of ASTM A706 reinforcing bars
- CRSI-63 and CRSI-65

Given these general areas of inquiry, CRSI responds to the frequently asked questions (FAQ). Specific questions and responses are provided below.

When and how is it acceptable to bend steel reinforcing bars in the field?

The engineer of record (EOR) for the project should specify and/or approve the acceptability of field bending, straightening, or re-bending of reinforcing bars. Section 26.6.3.1(b) of the ACI 318 Building Code (2014) prohibits all reinforcement partially embedded in concrete from being field bent, unless specifically shown on the design drawings or expressly permitted by the licensed design professional.

(Note: The use of shop-type equipment at the jobsite to fabricate reinforcing bars on a just-in-time basis is not covered herein. This jobsite condition is considered initial fabrication or field fabrication, rather than repair, and is applicable in some locales, such as New York City.)

However, many times reinforcing bars which are partially embedded in concrete must be re-configured to meet jobsite demands, whether due to design changes, accidental misplacement, or dislodging during concrete placement. Sometimes they must be reconfigured due to construction accidents, such as footing dowels run over by a truck or column cages laterally displaced because the wind braces were temporarily removed. An example is shown in Figure 1.

In some instances the damage may be too severe, and replacing the damaged bars is most appropriate. Drilling into the concrete and installing new adhesive grouted bars into the concrete substrate is one common repair. Alternately, if the base of the bar protruding from the concrete is undamaged, it may be possible to couple onto the bar extension with a mechanical splice.

Field repair situations become problematic where reinforcing bars have been fabricated and then field re-bent or straightened. Often the condition of the final bar configuration is not clear and can leave questions about adequacy for the EOR. Fabricators are familiar with the properties of reinforcing bars; they adhere to industry standards for minimum bend diameter, and generally do not rework previously bent bars. The yielding and subsequent cold working of the bars may compromise the performance and function of the steel, even where cracks or other indicators may not be visible.

Section 8.4 of the CRSI Manual of Standard Practice (2009) provides recommendations for the realignment of reinforcing bars partially em-
bedded in concrete: #3 through #6 [#10 through #19] bars can be field bent up to a 45° bend, #7 through #18 [#22 through #57] bars can be field bent up to a 30° bend. All bending should be done to the minimum bend diameter as shown in Table 1, which is based on Sections 25.3.1 and 25.3.2 of ACI 318. Caution is offered here because bending with a pipe sleeved over the bar, or the use of a “hickey” or conventional conduit bender may provide a bend radius less than minimum.

### Table 1 – Minimum Bend Diameters of Reinforcing Bars

<table>
<thead>
<tr>
<th>Bar Sizes</th>
<th>Minimum Bend Diameter</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Standard Hooks</td>
</tr>
<tr>
<td>#3 to #5</td>
<td>6 (d_b)</td>
</tr>
<tr>
<td>#6 to #8</td>
<td>6 (d_b)</td>
</tr>
<tr>
<td>#9 to #11</td>
<td>8 (d_b)</td>
</tr>
<tr>
<td>#14, #18</td>
<td>10 (d_b)</td>
</tr>
</tbody>
</table>

*Based on Sections 25.3.1 and 25.3.2 of ACI 318-14 (2014)

Commentary Section R26.6.3.1(b) in ACI 318R offers recommendations concerning the heating of bars to facilitate bending:

“Tests (Black 1973; Stecich et al. 1984) have shown that A615 Grade 40 and Grade 60 reinforcing bars can be cold bent and straightened up to 90 degrees at or near the minimum diameter specified in [Section] 7.2. If cracking or breakage is encountered, heating to a maximum temperature of 1,500° F may avoid this condition for the remainder of the bars. Bars that fracture during bending or straightening can be spliced outside the bend region.

Heating should be performed in a manner that will avoid damage to the concrete. If the bend area is within approximately 6 in. of the concrete, some protective insulation may need to be applied. Heating of the bar should be controlled by temperature-indicating crayons or other suitable means. The heated bars should not be artificially cooled (with water or forced air) until after cooling to at least 600° F.”

Note that the References in the commentary above are, respectively, “Field Corrections to Partially Embedded Reinforcing Bars” by Black (1973) and “Bending and Straightening of Grade 60 Reinforcing Bars” by Stecich, Hanson and Rice (1984).

Section 3.3.2.8 of the ACI 301 (2010) Specification presents a procedure for field bending or straightening reinforcing bars partially embedded in concrete. Below is a summary:

- #3 through #5 [#10 through #16] bars may be bent cold the first time, providing the bar temperature is above 32° F. Otherwise, preheat the bars.
- Apply heat so the bars and surrounding concrete are not damaged. Heat length of bars equal to at least 5 bar diameters (5 \(d_b\)) from the center of the bend, but do not heat the bars below the surface of the concrete.
- Preheat temperature should be between 1,100° and 1,200° F. Do not heat bars at the surface of concrete higher than 500° F. Measure bar temperature using temperature measurement crayons, contact pyrometer, or other acceptable methods. Do not artificially cool the bars until the temperature is less than 600° F.
- Follow minimum bend diameters per ACI 318 (see Table 1). The beginning of the bend should not be closer to the concrete surface than the minimum bend diameter.
- After bending or straightening epoxy-coated, galvanized, or dual-coated reinforcing bars, repair coating damage, as per the applicable ASTM specification. ASTM A775 (2014) is the specification for epoxy-coated bars, A767 (2009) is applicable for galvanized bars and A1055 (2010) is the specification for dual-coated bars.

There is not a lot of practical experience in the field bending/re-bending of high-strength reinforcing bars (i.e., yield strength over 60,000 psi), or bars other than carbon-steel (ASTM A615) and low-alloy steel (ASTM A706). Therefore, field repair of these types of bars should be approached with caution; trial repairs on representative bars are thus recommended.
How can reinforcing bars be cut in the field?

Reinforcing bars are typically delivered to the jobsite in a fabricated form. Field cutting may be required due to design changes, unexpected field conditions, or the planned use of stock bar lengths for straight segments. Contractors should be familiar with the requirements of the contract documents, and should not field cut reinforcing bars for other purposes (such as to “fit it in”).

Acceptable methods of field cutting reinforcing bars up to a #5 (5/8 inch diameter) [#16] bar include hand shears or bolt cutters; abrasive or special metal-cutting circular saw blades and cutting torches should be used for larger bars. Research shows that when cutting with a torch, the heat-affected zone only extends a fraction of an inch beyond the cut. Care should be taken when using flame-cutting techniques to avoid damaging adjacent bars, in-place concrete, or other materials. When the bars are partially embedded or otherwise restrained, care must be taken to avoid injury in case the bar end moves or “springs out” as it is cut. Concrete formwork frequently is coated with combustible materials (e.g., form oil on wood forms). Measures should be taken to avoid combustion of volatiles remaining in the wood. All of these methods for field cutting bars present risks to the workers and those nearby. Measures to ensure the safety of all personnel must be taken.

Can steel reinforcing bars be welded?

There are instances when the welding of reinforcing bars is necessary; however, good quality control must be observed in order for the welds to develop the required steel strength. Mechanical splices are often preferred unless welds are completed in designated areas by properly trained personnel. Field welding should never be undertaken except upon concurrence of the contractor and engineer, and only with qualified personnel, including a certified welder and weld inspector.

The welding of anchors to embed plates, edge angles, and other anchorages should only be completed using automatic end welds (stud welds) and properly prepared materials.

The American Welding Society publishes AWS D1.4, Structural Welding Code—Reinforcing Steel (2011), which describes the procedure for the welding of steel reinforcing bar. This includes determining the weldability of the steel, joint preparation, any required preheating before welding, and temperature control during and after welding.

ASTM A706 (2014b) reinforcing bars are intended for welding without preheating and therefore should be specified for applications that require an appreciable amount of welding. ASTM A615 (2014a) reinforcing bars can be welded, but may require preheating the bars up to 500° F.

Is it OK if there is rust on the reinforcing bars when the concrete is placed?

The presence of “tight” rust on reinforcing bars does not inhibit bond or development length. When reinforcing bars are produced, they frequently are coated with mill scale which will rust easily, but this type of rust is not detrimental to the bars. As a matter of fact, this “tight” rust can enhance the bond of the reinforcing steel to the hardened concrete. Once the bars are embedded in the concrete, the alkalinity of the cement passivates the steel, while the concrete keeps oxygen and moisture away. These characteristics prevent further corrosion of the reinforcing steel in uncracked concrete.

Rust that is flaky or easily removed, such as by dropping or striking with a hammer, indicates excessive rust may be present and the bars should not be used until they are cleaned and the extent of the rust has been determined. Guidance to determine if a bar has too much rust is given in Section 26.6.1.2(b) of ACI 318. Rust, mill scale, or a combination of both are considered satisfactory providing the bar dimensions (including deformation height) and weight of a hand-wire-brushed test specimen meets the applicable ASTM specification. Note that all ASTM reinforcing bar specifications permit the weight of the bars to be up to 6 percent below the nominal weight per length, per Table 2.

Table 2 – Nominal and Minimum Weight of Reinforcing Bars

<table>
<thead>
<tr>
<th>Bar Size</th>
<th>Nominal Weight (lb/ft)</th>
<th>Minimum Weight* (lb/ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>#3</td>
<td>0.376</td>
<td>0.354</td>
</tr>
<tr>
<td>#4</td>
<td>0.668</td>
<td>0.628</td>
</tr>
<tr>
<td>#5</td>
<td>1.043</td>
<td>0.981</td>
</tr>
<tr>
<td>#6</td>
<td>1.502</td>
<td>1.412</td>
</tr>
<tr>
<td>#7</td>
<td>2.044</td>
<td>1.922</td>
</tr>
<tr>
<td>#8</td>
<td>2.670</td>
<td>2.510</td>
</tr>
<tr>
<td>#9</td>
<td>3.400</td>
<td>3.196</td>
</tr>
<tr>
<td>#10</td>
<td>4.303</td>
<td>4.045</td>
</tr>
<tr>
<td>#11</td>
<td>5.313</td>
<td>4.995</td>
</tr>
<tr>
<td>#14</td>
<td>7.650</td>
<td>7.200</td>
</tr>
<tr>
<td>#18</td>
<td>13.60</td>
<td>12.79</td>
</tr>
</tbody>
</table>

*94% of nominal bar weight

What happens if there is insufficient concrete cover or if the reinforcing bars are completely exposed?

The corrosion resistance of “black” or uncoated reinforcing bars requires that the bars be completely surrounded by concrete. The alkaline nature of concrete
prevents rust from forming. As concrete ages, carbon dioxide from the air reacts with the surface of the structure to “carbonate” the concrete, which reduces the alkalinity, potentially allowing rust to form on the bars in the presence of moisture. In high-quality concrete, this process may take 100 years or more to penetrate to the depth of the reinforcing steel. Even when this process has occurred, the mass of concrete surrounding the steel still provides protection by occluding the movement of water and oxygen from the concrete surface to the reinforcing steel. In structures not exposed to the elements or deleterious chemicals, the concrete and steel should last indefinitely.

When cracks form in exposed members, the movement of moisture and oxygen will be facilitated through the cracks. Again, the depth of concrete cover over the steel determines how quickly these materials will get to the reinforcement, and the rate at which the steel will corrode. Crack width is an important factor for moisture intrusion. Moreover, exposure to chlorides through deicing chemicals can accelerate the corrosion mechanism.

When there is less concrete cover than required by Code, the time to initiate bar corrosion is reduced, and in most cases, the rate at which the corrosion forms is increased.

When the reinforcement is exposed, or when the concrete cover is significantly less than required, additional measures should be taken to protect the steel from corroding. Measures frequently used include surface coatings, additional cladding, or chemical treatment of the concrete surface. In some cases, insurers or building officials may require added protection to meet the required fire resistance criteria of the structure.

As an example, Table 3 is based on Table 722.2.3(3) from the International Building Code (2012), which lists the minimum concrete cover for reinforced concrete beams, based on type of restraint, beam width, and fire-resistance rating.

Section 722 of the IBC contains tables of minimum concrete cover for slabs and beams, both cast-in-place and precast, for different fire-resistance ratings. In addition, IBC Section 722 provides minimum thicknesses of walls and minimum dimensions of concrete columns for various fire ratings.

**What is the purpose and use of epoxy-coated reinforcing bar (“green or purple bar”)?**

Protecting reinforcing bars from corrosion is very important, particularly where the structure is exposed to salt spray or chemical deicing agents (like road salt). While concrete normally protects reinforcement from the elements, chlorides are one of nature’s corrosion catalysts, increasing the rate of steel corrosion. Elevated roadways are particularly susceptible to this “chloride attack.” In coastal areas, all surfaces of an exposed structure are subject to salt spray from the ocean environment or brackish humidity near the shoreline. In northern climates, bridges and elevated roads become icy, requiring frequent application of de-icing agents, often containing chlorides. When the chloride ions find their way into the concrete through pores in the concrete, or more frequently through cracks, the corrosion of reinforcing steel can be accelerated.

By providing an electrical insulating barrier between the reinforcing steel and the elements, epoxy coating increases the durability of the reinforcement and the structure. The trademark green or purple epoxy is one coating material used to protect reinforcing bars from corrosion in severe exposure. The epoxy material used is durable, and when handled with proper care, it can enhance the service life of the structure once the epoxy-coated bar is encased in concrete. If the epoxy coating is chipped during fabrication or handling, and is not repaired, the effectiveness of the coating has been reduced. In addition, an excessive number of holidays (pinpoint holes) in the coating may impact the coating performance. Therefore, care must be taken to repair coating damage before the concrete is placed.

**How do I find out about vintage reinforcing bars in an existing structure?**

From about 1911 through the 1960’s, reinforcing steel bars had to conform to specification ASTM A15 (precursor to the current A615) and were available in three grades: Structural Grade (fy = 33 ksi), Intermediate Grade (fy = 40 ksi), and Hard Grade (fy = 50 ksi). These bars could be round or square in cross-section, plain, deformed, or twisted. CRSI’s Vintage Steel Reinforcement in Concrete Structures (2014b) presents a great deal of information on early reinforcing steel (bars and welded wire reinforcement), systems of reinforcement and design of reinforced concrete. Table 4 lists minimum yield and tensile strength requirements from past and present ASTM reinforcing bar specifications.

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| Table 3 – Minimum Concrete Cover (in.) for Cast-In-Place Beams, as per Required Fire-Rating* |
|---------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Restrained or Unrestrained      | Beam Width (in.)| Fire-Resistance Rating (hr) | 1 | 1-1/2 | 2 | 3 | 4 |
| Restrained                      | 5               | 3/4                | 3/4 | 3/4 | 1 | 1-1/4 |
| Unrestrained                    | 5               | 3/4                | 1   | 1-1/4 | — | — |
|                                | 7               | 3/4                | 3/4 | 3/4 | 1-3/4 | 3 |
|                                | ≥ 10            | 3/4                | 3/4 | 3/4 | 1-3/4 | |

*Based on Table 722.2.3(3) from the International Building Code (2012)
The most effective way to identify the reinforcing bar yield strength is to excavate enough concrete around the bar to remove a sample for testing. Non-destructive techniques, along with documentation about when and how the structure was built, may provide sufficient information to make an educated assessment of current structural capacity. Obviously, the reinforcing steel only comprises one part of the structure, and the compressive strength of the old concrete may be the deciding factor in determining overall structural capacity.

What kinds of bar supports are used in structures?

CRSI Standard RB4.1, “Supports for Reinforcement Used in Concrete” (2014a), describes the various types of (1) wire, (2) composite, and (3) precast concrete bar supports. The type of bar support used on a project is dependent on a number of factors, such as the type of exposure, concrete finish, and surface finish on the bar (uncoated or coated). The different types of supports are described in the following paragraphs:

**Wire** - Wire bar supports are classified in terms of method used to minimize potential visible rust spots on the concrete surface. The four classes are summarized below and various examples of wire bar supports are illustrated in Figure 2 (next page):

- **Class 1** – Maximum Protection. These wire bar supports are intended for moderate to severe exposure and/or situations requiring light grinding/sandblasting of the finished concrete surface. These supports are either dipped in plastic or pre-molded plastic tips are placed on the support legs.

- **Class 1A** – Maximum Protection for Use with Epoxy-Coated Reinforcing Bars. These wire bar supports are intended for moderate to severe exposure, but without any subsequent surface grinding/sandblasting. They are generally used to support epoxy-coated reinforcing bars. These supports are completely coated with epoxy, vinyl, or other plastic compounds.

- **Class 2** – Moderate Protection. These wire bar supports are intended for moderate exposure and/or light grinding/sandblasting of the finished concrete surface. The legs of these supports are either manufactured from stainless-steel wire or cold-drawn carbon steel with stainless-steel leg extensions attached to the bottom of each leg.

There are two variations of Class 2 supports. Sub Type A bar supports have stainless-steel leg exten-
sions ¼ inch long, while Type B bar supports have ¾ inch long stainless-steel leg extensions.

**Class 3 – No Protection.** This type of wire bar support is manufactured from cold-drawn carbon steel wire without any form of corrosion protection.

**Composite (polymer, plastic)** - Composite bar supports are intended for all exposure conditions and/or where grinding/sandblasting is to occur. They are suitable for supporting all types of reinforcement, including epoxy-coated reinforcing bars, and provide maximum corrosion protection, i.e., Class 1. Figure 3 shows some representative types of composite bar supports available on the market.

**Precast Concrete** - Precast concrete bar supports normally are supplied in three styles: plain, plain with wires, and doweled (a hole is provided for a dowel). In some regions of the country these are referred to as “do-bies.” Plain precast concrete bar supports are used to support reinforcing bars off the ground. Precast concrete bar supports with wires are used where it is necessary to maintain position of the supports by tying them to the reinforcing bars. Doweled, precast concrete bar supports are cast with a hole in the center which is large enough to insert a #4 [#13] dowel with a 90° bend at the top. Precast concrete bar supports provide maximum corrosion protection, (i.e., Class 1). Figure 4 presents sketches of various types of precast concrete bar supports.

It is never acceptable to use materials such as clay brick or wood as bar supports. Wood will deteriorate, leaving voids between the concrete surface and the reinforcement. Clay brick will expand and damage surrounding concrete, leaving a void.

**What is the purpose of tying reinforcing bars together, and how close together must ties be?**

Reinforcing bars are tied in place to resist the forces of construction traffic, flowing concrete, and vibration during concrete placement. In vertical walls, ties must be robust enough to support ironworkers as they climb the reinforcing bar cage (known as ladder ties). In column and pier cages, wire ties must be sufficient to hold the cage together in the proper geometry while the cage is lifted into position. In foundation and slab elements, contract bars, standees, and supports should be used and tied together to keep the bars in place until the concrete is set, without the need to reposition them while the concrete is being placed.

The proper tying of reinforcing bars is essential in order to maintain their position during work performed by other trades and during concrete placement. However, it is not necessary to tie reinforcing bars at every intersection. Tying adds nothing to the strength of the finished structure. In most cases, tying every fourth or fifth intersection is sufficient. For additional guidance on tying reinforcing bars, including the different types of ties and where each type is best suited, see CRSI’s book *Placing Reinforcing Bars* (CRSI 2011).
What is the availability and application of ASTM A706 reinforcing bars?

Before addressing the applications and availability of ASTM A706 (2014b) low-alloy reinforcing bars, it is important to know how this type of reinforcing bar differs from ASTM A615 (2014a) carbon-steel bars.

One important difference is the chemistry of A706 bars. A706 bar chemistry is more tightly controlled than A615 bars in order to enhance the weldability of the steel. There is considerable increased control in the A706 specification with maximum limits on five chemical elements, while the A615 specification limits only one element. Table 5 lists the specific chemistry limits for the two bar types.

Another requirement of A706 is that the carbon equivalent (C.E.) is specified as having a maximum limit of 0.55 percent. C.E. is a numerical value calculated from the chemical analysis of seven elements. The formula is:

\[
\text{C.E.} = \frac{\%C + \%\text{Mn} + \%\text{Cu} + \%\text{Ni} + \%\text{Cr} - \%\text{Mo} - \%\text{V}}{6 + 40 + 20 + 10 - 50 - 10}
\]

The steel’s C.E. value is used in the AWS D1.4 (2011) specification to determine the preheat temperature required before welding. According to Table 5.2 of AWS D1.4, little or no preheating is required for #3 to #11 [#10 to #36] bars with a C.E. of under 0.55 percent. For #14 and #18 [#43 and #57] bars with a C.E. of 0.40 to 0.55 percent, a preheat no greater than 200° F may be required. Table 6 lists the minimum preheat temperatures required by AWS D1.4, based on C.E. values.

For A615 bars with an unknown C.E., the AWS D1.4 specification requires a preheat temperature of 500° F.

Another important difference between A706 and A615 bars is A706 has more stringent strength limits than A615. For A706 bars, the yield strength can be no more than 18,000 psi above the minimum specified yield strength, and the tensile strength must be at least 1.25 times the actual yield strength. In addition, there are minimum elongation requirements for A706 bars that are higher than A615 bars, and the bend test requirements for A706 bars require a smaller pin diameter than A615 bars.

In summary, steel reinforcing bars produced to ASTM A706 have tighter controls on chemistry and metallurgical properties than that produced to ASTM A615. With greater chemistry control, these A706 bars are weldable, have more reliable strength limits, and greater elongation and ductility.

Applications – Because if its greater weldability than A615 bars, A706 bars are well suited for those cases when a significant amount of welding is required for the project. Due to its tighter strength limits, A706 bars are also well suited where greater ductility is needed in the reinforcing steel, such as for blast-resistant and seismic-resistant structures. Chapter 18 of ACI 318 should be consulted for seismic information.

Availability – A recent survey conducted by CRSI of mills producing reinforcing bars showed that 34 out of 36 mills that produce A615 bars can also produce or are producing A706 bars. There is a small premium for A706 bars.

Table 5 – Chemical Limits in ASTM A615 and A706 Reinforcing Bars

<table>
<thead>
<tr>
<th>ASTM Spec.</th>
<th>Condition</th>
<th>Element</th>
<th>Carbon (C)</th>
<th>Manganese (Mn)</th>
<th>Phosphorus (P)</th>
<th>Sulfur (S)</th>
<th>Silicon (Si)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A615</td>
<td>1</td>
<td></td>
<td>0.06%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A615</td>
<td>2</td>
<td></td>
<td>0.075%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A706</td>
<td>1</td>
<td></td>
<td>0.30%</td>
<td>1.50%</td>
<td>0.035%</td>
<td>0.045%</td>
<td>0.50%</td>
</tr>
<tr>
<td>A706</td>
<td>2</td>
<td></td>
<td>0.33%</td>
<td>1.56%</td>
<td>0.043%</td>
<td>0.053%</td>
<td>0.55%</td>
</tr>
</tbody>
</table>

Conditions: 1 = Maximum allowable chemical content for each heat. 2 = Maximum allowable chemical content for finished bar.

Table 6 – Minimum Preheat Temperatures *

| C.E. Range (%) | Bar Sizes | #3 to #6 | #7 to #11 | #14, #18 |
|               |           |          |           |          |
| 0.40 max.     |           | —        | —         | 50° F    |
| 0.41 to 0.45  |           | —        | —         | 50° F    |
| 0.46 to 0.55  |           | —        | 50° F     | 200° F   |
| 0.56 to 0.65  | 100° F    | 200° F   | 300° F    |          |
| 0.66 to 0.75  | 300° F    | 400° F   | 400° F    |          |
| Above 0.75    | 300° F    | 500° F   | 500° F    |          |

*Based on Table 5.2 of AWS D1.4 (2005)
How can I get a copy of CRSI-63 and CRSI-65?

Some project specifications contain references to the following CRSI publications:

- **CRSI-63** Recommended Practice for Placing Reinforcing Bars
- **CRSI-65** Recommended Practice for Placing Bar Supports: Specifications and Nomenclature

These are old references and should be updated to the following:

- For recommendations on placing reinforcing bars: *Placing Reinforcing Bars* by CRSI (2011)
- Reinforcement Supports: *CRSI RB4.1, Supports for Reinforcement Used in Concrete* by CRSI (2014a)

**References**

- **American Concrete Institute (ACI-Committee 301)** [2010], *Specifications for Structural Concrete (ACI 301-10)*, American Concrete Institute, Farmington Hills, MI, 77 pp.
- **American Concrete Institute (ACI-Committee)** 318 [2014], *Building Code Requirements for Structural Concrete (ACI 318-14) and Commentary (ACI 318R-08)*, American Concrete Institute, Farmington Hills, MI, 519 pp.
- **Concrete Reinforcing Steel Institute – CRSI** [2011], *Placing Reinforcing Bars* 9th Edition, Concrete Reinforcing Steel Institute, Schaumburg, IL, 288 pp.
- **Concrete Reinforcing Steel Institute – CRSI** [2014a], *Supports for Reinforcement Used in Concrete*, CRSI RB4.1-2014, Concrete Reinforcing Steel Institute, Schaumburg, IL, 15 pp.
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- **Stecich, J.; Hanson, J.M.; and Rice, P.F.** [1984], “Bending and Straightening of Grade 60 Reinforcing Bars,” *Concrete International: Design & Construction*, V. 6, No. 8, August, pp. 14-23.

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