Frequently Asked Questions (FAQ) About Headed Reinforcing Bars

Introduction

Headed deformed reinforcing bars are in increasing demand for use in reinforced concrete projects for a variety of reasons. Headed deformed bars reduce reinforcing bar congestion where terminating bars with 90 or 180 degree hooks are needed. Such regions where termination is difficult include, but are not limited to, beam-column joints, beam ends, and corbels. Figure 1 illustrates some common uses of headed reinforcing bars where considerable congestion would exist if hooked bars were used. Headed bar use has also been on the rise as acceptance of strut-and-tie analysis modeling techniques, permitted in the ACI 318 Building Code [ACI 2011], receive greater acceptance by the design profession.

CRSI routinely receives inquiries concerning various aspects of reinforcing bars, reinforced concrete design, and reinforced concrete construction. Most of these inquiries originate from design professionals (engineers and architects) and field personnel (inspectors, code enforcement personnel, and contractors). This Technical Note presents a collection of questions frequently asked regarding headed reinforcing bars. It should be noted that typical headed bar questions vary by region, manufacturer, and project type.
This document has been prepared to address questions related to headed bars when used in conjunction with the 2012 *International Building Code* [IBC 2013], *Building Code Requirements for Structural Concrete* (ACI 318-11) [ACI 2011], and *Standard Specifications for Headed Steel Bars for Concrete Reinforcement* (ASTM A970/A970M-09) [ASTM 2009c]. Projects designed and built to other standards such as *Code Requirements for Nuclear Safety-Related Concrete Structures and Commentary* (ACI 349-06) [ACI 2006] or Department of Transportation requirements are not addressed in this document. For specifics regarding these types of projects contact the manufacturers.

Specific frequently asked questions (FAQ) and responses are provided below.

**General Information**

**What is a headed bar?**

A headed bar is either an oversized coupler, plate, or head attached to one or both ends of a deformed reinforcing bar. Heads may be attached through mechanical means or integrally forged from the bar material itself. The most common applications for headed deformed bars is to provide anchorage to terminate a reinforcing bar, replace standard hooks, or shear reinforcement, although they can be used as confinement reinforcement as well. The capacity of a headed bar is achieved by either a combination of concrete bearing from the head and bond development length in front of the head, or simply by concrete bearing alone.

**What is common industry practice for the use of headed bars?**

Due to their versatility, headed deformed bars are used in a variety of ways throughout the industry, but primarily they are used as an alternative to hooked bar reinforcement anchorages. Besides being added during the construction phase for constructability purposes, headed deformed bars are becoming a more specified product during the design phase as well. This practice has been greatly influenced by the current development of the ACI building code and ASTM A970 specification.

**How does the headed deformed bar development length compare to a standard hook development length?**

A headed deformed bar performs the same as a standard hook and is an equal acceptable substitute. When calculating the development length for a hooked bar and headed deformed bar using the ACI building code, without reduction factors, a headed deformed bar has a 20% reduction in development length when compared to a standard hooked bar.

**What are some advantages of utilizing a headed bar over a standard hook?**

Some of the advantages that headed bars have over a reinforcing bar with a standard hook are:

- Shorter basic tension development length
- Ease of placement and installation in highly congested areas
- Easier to insert or “fish” the longitudinal bar in a cage during construction. Longitudinal bars with a hook protruding at one or both ends can make insertion of the hooked bar into a reinforcing bar cage difficult, especially if there are bars transverse to the hooked bar
- Since headed bars don’t protrude as much as hooks there is less impact on cover constraints

**Are the heads available in stainless steel, or as galvanized or epoxy-coated to match the parent reinforcing bar?**

Many headed deformed bar manufacturers offer products made from a variety of stainless steel alloys. Headed deformed bars are also offered in epoxy and galvanic coatings. These coatings typically conform to the same coating standards as the reinforcing bar coatings (ASTM A775, A934, and A767). Details on the products and coating processes may vary between head manufacturers. For specifying engineers, it is recommended to contact the manufacturer prior to finalizing the drawings and specifications, to verify the commercial availability of these products.

**Product Standards**

**What Standards govern headed reinforcing bars?**

There is presently only one standard specification that addresses headed reinforcing bars in concrete, and it is maintained by ASTM. This document is:

- ASTM A970 – *Standard Specifications for Headed Steel Bars for Concrete Reinforcement* [ASTM 2009c]

**What requirements are contained in ASTM A970?**

ASTM A970 provides the minimum requirements for headed bars. This is a standard specification prepared by the ASTM International, formerly known as the American Society for Testing and Materials (ASTM) governing the production and performance requirements of headed bars. Specification A970 governs the methods of head attachment to the reinforcing bar, the materials used to produce the head, the mechanical tests required to verify the quality of the head attachment, the testing frequency, the head finish type, and markings required on the head. ASTM A970 separates these distinctions
into three classes of headed deformed bars, Class A, B and HA.

**When should a Class HA head be specified or used?**

Both the IBC and ACI 318 require headed bars to meet the Class HA head requirements of Annex A1 of ASTM A970. Annex A1 contains specific language pertaining to headed bar geometry, method of attachment, performance requirements, obstructions in front of the head, interruptions in deformation patterns of the reinforcement, and labeling or identification requirements. The provisions of a Class HA head were formulated based on the products that were used in the physical tests that formulated the provisions of the ACI building code. These requirements are shown in Figure 2.

**What are the specific Annex A1 requirements for Class HA headed bars?**

- The purchaser must specify the dimensions of the head, including the head thickness and diameter, or height and width.
- Class HA heads must have a net bearing area of at least 4 times the area of the bar ($A_{brg} \geq 4A_b$). The net bearing area equals the area of the head minus area of the bar ($A_{brg} = A_{head} - A_b$). The bearing area is to be a single, nominally flat surface perpendicular to the longitudinal axis of the bar.
- Class HA heads must not have obstructions or interruptions in the deformation pattern in front of the head greater than $2d_b$ (2 nominal bar diameters) along the axis of the bar. The obstructions must not have a diameter greater than $1.5d_b$ (1.5 nominal bar diameters), as shown in Figure 2.
- Class HA heads must develop the minimum specified tensile strength of the bar.
- Class HA heads must be marked with a letter “H” to indicate it was produced in conformance with Annex A1 of ASTM A970.

**Do all headed bar products currently available on the market meet A970 Class HA requirements?**

No, not all headed bars in the market today meet the Class HA requirements of ASTM A970. Check with the manufacturer for a statement of conformance.

**Governing Design Codes and Standards**

**What current forms of head attachment are covered in ASTM A970?**

ASTM A970-09, as referenced by ACI 318-11 contains three forms of head attachment as shown in Figure 3.
• **Welded Heads** – The head is welded to the reinforcing bar either through stick welding or friction welding. For this head attachment method, A970 limits its use to ASTM A706 reinforcement.

• **Threaded Heads** – The head is attached by using taper or straight threads internal to the head, or by a separate internally threaded nut and counter nut securing the head to the reinforcing bar end. For threaded heads, A970 permits either ASTM A615 or A706 reinforcing bars to be used. Figure 4 shows an example of reinforcing bars that have been threaded and are awaiting attachment of the head assembly.

![Figure 4 – Reinforcing bars threaded at a fabrication shop and ready for head attachment at the jobsite.](image)

• **Forged Heads** – The head is produced by integrally hot-forging the head from the bar itself. For this head attachment method, A970 permits either ASTM A706 or A615 reinforcing bars to be used.

**What are the requirements of ACI 318 Building Code for headed reinforcing bars?**

Section 3.5.9 of ACI 318 governs the production specification of headed bars, and refers to ASTM A970, Annex A1. In the Commentary to Section 3.5.9, the limitation to Class HA head dimensions is attributed to a lack of experimental test data for headed deformed bars not meeting the Class HA dimensional requirements. The Commentary notes that heads not conforming to Class HA limits on bar deformation obstructions and bearing face features could cause unintended splitting forces in the concrete. Such behavior was not characteristic of the heads used in the tests forming the basis for the ACI 318 Chapter 12 provisions.

Section 12.6 of ACI 318 governs the tension development length and use of headed deformed bars and requires headed deformed bars to develop the specified yield strength, $f_y$, of the reinforcing bar. The Code states the use of headed deformed bars shall not be considered effective in developing reinforcing bars in compression.

**Does the International Building Code (IBC) have any modifications to the ACI 318 requirements?**

Chapter 19 of the IBC references the ACI 318 building code for reinforced concrete design. The IBC does not contain any amendments to the ACI 318 Code regarding headed deformed bar requirements, so the requirements of the two Codes are identical. ASTM A970 is a referenced standard specification to both the IBC and ACI building codes.

**How is the development length of a headed bar computed?**

The development length for a headed bar can be calculated using the following equation in Section 12.6.2 of ACI 318:

$$\ell_{dt} = \left( \frac{0.016 \psi_e f_y}{f'_c} \right) d_b \geq 8d_b \text{ and } 6 \text{ in.}$$

(Equation 1)

$$\ell_{dt} = \left( \frac{0.19 \psi_e f_y}{f'_c} \right) d_b \geq 8d_b \text{ and } 150 \text{ mm}$$

(Equation 1M)

where:

- $\ell_{dt}$ = development length in tension of headed deformed bar, measured from the critical section to the bearing (inside) face of the head, in. (mm)
- $f_y$ = specified yield strength of the reinforcing bar, psi (MPa)
- $f'_c$ = specified compressive strength of concrete, psi (MPa)
- $d_b$ = nominal diameter of the bar, in. (mm)
- $\psi_e$ = factor used to modify development length based on reinforcement coating,
  - $= 1.2$ for epoxy-coated bars
  - $= 1.0$ for uncoated or zinc-coated bars
- $\leq 6,000$ psi (40 MPa)

The development length of a headed deformed bar, $\ell_{dt}$, is illustrated in Figure 5, which shows the length is measured from the critical section to the bearing face of the head.
**Table 1 — Tension Development Length for Headed Bars**

<table>
<thead>
<tr>
<th>Concrete Strength, psi, (MPa)</th>
<th>3,000 (21)</th>
<th>4,000 (28)</th>
<th>5,000 (35)</th>
<th>6,000 (42)</th>
</tr>
</thead>
<tbody>
<tr>
<td>#4 (#13)</td>
<td>9</td>
<td>8</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>#5 (#16)</td>
<td>11</td>
<td>10</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>#6 (#19)</td>
<td>13</td>
<td>12</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>#7 (#22)</td>
<td>16</td>
<td>14</td>
<td>12</td>
<td>11</td>
</tr>
<tr>
<td>#8 (#25)</td>
<td>18</td>
<td>15</td>
<td>14</td>
<td>13</td>
</tr>
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<td>#9 (#29)</td>
<td>20</td>
<td>17</td>
<td>16</td>
<td>14</td>
</tr>
<tr>
<td>#10 (#32)</td>
<td>23</td>
<td>20</td>
<td>18</td>
<td>16</td>
</tr>
<tr>
<td>#11 (#36)</td>
<td>25</td>
<td>22</td>
<td>19</td>
<td>18</td>
</tr>
</tbody>
</table>

**Notes:**
1. Tabulated values based on a minimum reinforcing bar yield strength $f_y = 60,000$ psi (420 MPa).
2. For epoxy-coated reinforcement, increase the above values by 20 percent (i.e. multiply by 1.2).
3. 1 in. = 25.4 mm

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**Figure 5** — Development length in tension of a headed deformed bar, defined from the bearing face to the critical section. [adapted from ASTM A970].

**What are the conditions that must be met to utilize Equation 1 (1M) above?**

To utilize the equation above, as shown in ACI 318 12.6.2, there are several conditions that must be met as listed below.

(a) Specified yield strength of the reinforcing bar ($f_y$), shall not exceed 60,000 psi (420 MPa)

(b) Bar size shall not exceed #11 (#36)

(c) Concrete shall be normalweight

(d) Net bearing area of the head $A_{brg}$ shall not be less than $4A_b$

(e) Clear concrete cover for bar shall not be less than $2d_b$

(f) Clear spacing between bars shall not be less than $4d_b$
Table 1 provides the tension development lengths for headed reinforcing bars according to Equation 1 and conditions (a) through (f) listed above. Table 1 lists bar sizes from #4 to #11 (#13 to #36), for concrete strengths of 3,000 to 6,000 psi (21 to 42 MPa).

**Detailing and Placement of Headed Bars**

**How is the concrete cover measured for a headed bar?**

The minimum clear concrete cover required in Section 12.6.1 of ACI 318, per condition (e) above is \(2d_b\). When measuring cover under Section 12.6.1, the measurement is taken from the edge of concrete to the bar, not to the head. However, the head is considered part of the bar in Section 7.7 of ACI 318 to satisfy where the concrete cover requirements for protection of reinforcement are prescribed.

**How is bar spacing measured for headed bars?**

The minimum clear bar spacing required per condition (f) above is \(4d_b\). To satisfy this spacing requirement, the spacing is measured from the inner edge of each bar, not to the reinforcing bar centerline or the head. For this measurement the head is not considered part of the bar.

**Are headed reinforcing bars permitted to be staggered?**

Staggering of closely spaced heads to reduce congestion is permitted, as noted in Section R12.6 in ACI 318R.

**Can transverse reinforcement be added or wrapped around the reinforcing bar head region to improve the performance and behavior?**

While transverse reinforcement has not been shown to have a significant impact on reducing development lengths when used in conjunction with headed deformed bars, it does help limit splitting cracks in the vicinity of the head. For that reason transverse reinforcement is recommended.

**Beam-column joints get fairly congested with reinforcing bars. Are there any special detailing requirements for headed reinforcing bars in these regions?**

Where longitudinal, headed deformed bars from a beam or a slab terminate within a supporting member, such as the column shown in Figure 6, the bars should extend through the joint to the far face of the supporting member’s confined core. This allows for the proper cover and avoids interfering with the vertical column reinforcement, even though the anchorage length will likely exceed \(\ell_{dt}\). As noted in the ACI 318 commentary, extending the bar to the far side of the column helps anchor the compressive forces (as identified in a strut-and-tie model) that are likely to form in such a connection. This also improves the performance of the joint.

Section 4.5.3 of ACI 352R [ACI 352R-02], *Recommendations for Design of Beam-Column Connections in Monolithic Reinforced Concrete Structures*, also presents more specific recommendations for beam-column connections with headed bars. These include the following:

- Bar heads should be located in the confined core within 2 in. (50 mm) from the back of the confined core.
- For headed bars adjacent to a free face of the joint having a side cover normal to the longitudinal axis of the bar less than \(3d_b\), each head should be transversely restrained by a stirrup or hoop leg that is anchored in the joint.
- If the side cover is greater than \(3d_b\), the restraining force should be determined using the ACI 349 design approach; however, minimum transverse reinforcement as required in Section 4.2 of ACI 352R should always be provided.

**The ACI requirements are fairly restrictive on the use of headed reinforcing bars. What if the design does not meet these conditions of use, per the ACI 318 Code?**

The alternatives for designs outside Section 12.6.1 of ACI 318 are either qualification tests or the use of other design methods.

![Figure 6 – Detailing of a headed bar connection at a beam-column joint. The headed bar is extended to the far side of the column core, even though the anchorage length may exceed \(\ell_{dt}\). [ACI 2011].](image-url)
Section 12.6.4 of ACI 318 states:

“Any mechanical attachment or device capable of developing $f_y$ of deformed bars is allowed, provided that test results showing the adequacy of such attachment or device are approved by the building official. Development of reinforcement shall be permitted to consist of a combination of mechanical anchorage plus additional embedment length of deformed bars between the critical section and the mechanical attachment or device.”

Other methods of design that are less limiting, but more time consuming include utilizing strut-and-tie modeling, Appendix A of ACI 318 or as anchorage to concrete, Appendix D of ACI 318.

**Qualification of Headed Bars**

**Are there any qualifications necessary to ensure a headed reinforcing bar meets the minimum requirements of the building code?**

The IBC or International Building Code [IBC 2012] requires verification that headed reinforcing bars meet the minimum standards of the Code. This is contained in Section 104.11 of IBC, which provides guidance to the building official for accepting these products. Specifically, IBC states:

104.11 Alternative materials, design and methods of construction and equipment.

The provisions of this code [IBC] are not intended to prevent the installation of any material or to prohibit any design or method of construction not specifically prescribed by this code, provided that any such alternative has been approved. An alternative material, design or method of construction shall be approved where the building official finds that the proposed design is satisfactory and complies with the intent of the provisions of this code, and that the material, method or work offered is, for the purpose intended, at least the equivalent of that prescribed in this code in quality, strength, effectiveness, fire resistance, durability, and safety.

Generally, an evaluation service (ES) develops acceptance or evaluation criteria for products and systems that (1) are alternates to those specified in the code, or (2) fall under code provisions not sufficiently clear for the issuance of an evaluation report. Evaluation criteria are written for products where an existing standard or protocols for product evaluation does not exist or the reference standards do not specify design guidelines for these products. An ES is usually accredited by the American National Standards Institute (ANSI) per the ISO/IEC Guide 65, General Requirements for Bodies Operating Product Certification Systems [ISO 1996]. Accreditation by ANSI ensures the evaluation criteria was developed through a consensus process and the criteria document was subject to public comment procedures.

In addition to developing the criteria, the ES is responsible for performing technical evaluations of building products, components, methods of construction, and materials. The process commonly concludes with the issuance of an evaluation report. This report directly addresses the issue of code compliance, and is extremely relevant to regulatory agencies and building-product manufacturers. Agencies use evaluation reports to help assess code compliance, enforce building regulations, and assist with product approval. In a similar fashion, manufacturers use reports as evidence their products meet minimum code requirements and warrant regulatory approval.

**What evaluation service organizations evaluate headed bar systems to the IBC? Do they have the same or different evaluation criteria?**

Currently there are two ES organizations that evaluate headed bars to the IBC. One is the IAPMO Evaluation Service (IAPMO-ES), a nonprofit, limited liability company, which is a separate, stand-alone subsidiary of the International Association of Plumbing and Mechanical Officials (IAMPO). The other is the ICC Evaluation Service (ICC-ES), a nonprofit, limited liability company, which is a separate, stand-alone subsidiary of the International Code Council (ICC). Each one of these evaluation services has its own acceptance or evaluation criteria for headed, deformed reinforcing bars. These are as follows:

- IAPMO-ES: Evaluation Criteria For Headed And Mechanically Anchored Deformed Reinforcement Bars In Tension (EC 006) [IAPMO-ES 2010]
- ICC-ES: Acceptance Criteria for Headed Deformed Bars (AC 347) [ICC-ES 2010]

Evaluation of headed reinforcing bars in tension meeting one of the above criteria and proof of conformance will qualify the product for use, per the IBC. An evaluation report is usually issued for the product, as proof of its conformance.

**Are there any documents containing information on the different headed bar types commercially available today?**

CRSI has a publication, Reinforcing Bars: Anchorages and Splices [CRSI 2008], which contains information on some of the headed reinforcing bar types and systems available in the U. S. construction market.
Contributors: The principal authors on this publication are the CRSI Anchorages and Splices Committee (Task Group Lead: Michael Ugalde), Anthony L. Felder, P.E., and Neal S. Anderson, P.E., S.E.

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Historical: None. New Technical Note.

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