Headed Reinforcement

by Dr. Henry G. Russell, Henry G. Russell Inc.

The traditional method of terminating reinforcing bars in tension is to provide a development length beyond the section where the reinforcing bar is no longer needed. This development length may consist of a straight length or a hooked anchorage. Hooks usually have 90- or 180-degree bends. There are, however, situations where there is insufficient length available to accommodate a straight development length or a hook. There are also locations, such as column-to-bent connections, where reinforcement can become very congested, particularly where hooks are used. These are ideal situations for considering the use of headed reinforcement. The benefits of headed reinforcement include:

- Simplified bar placement by reducing congestion
- Easier concrete placement
- Reduced detailing by using a standard product

Headed Bars Defined

The American Concrete Institute (ACI) defines a headed bar as "a steel reinforcing bar that has steel head(s) on one or both ends with the purpose of anchoring the bar in concrete."[1]

ASTM A970, *Standard Specification for Headed Steel Bars for Concrete Reinforcement*, addresses deformed steel reinforcing bars with a head attached to one or both ends.[2] Various methods are used to form the head. The scope of ASTM A970 includes the following methods for forming the head:

- Welding according to the standards of the American Welding Society.
- Integrally hot forging the head from the reinforcing bar.
- Attaching an internally threaded head to matching threads at the end of the bar. The threads may be straight or tapered. Thread specifications and standards are generally selected by the manufacturer.
- Cold swaging an externally threaded or plain coupling sleeve or headed sleeve onto the reinforcing bar. Radial compression of the swaged sleeve on the reinforcing bar creates a mechanical interlock with the bar deformations.
- Cold extruding an external coupling sleeve onto the reinforcing bar.
- Attaching a coupling sleeve to the end of the reinforcing bar by means of a ferrous filler medium.
- Using a separate threaded nut to secure the head to the reinforcing bar.

The head may be round, elliptical, or rectangular, and it may be forged, machined from bar stock, or cut from steel plate. The purchaser must either specify head dimensions or accept head dimensions supplied by the manufacturer prior to use. Headed deformed reinforcing bar manufacturers may also offer products made from a variety of stainless steel alloys, and some headed deformed bars are offered with epoxy or galvanic coatings.

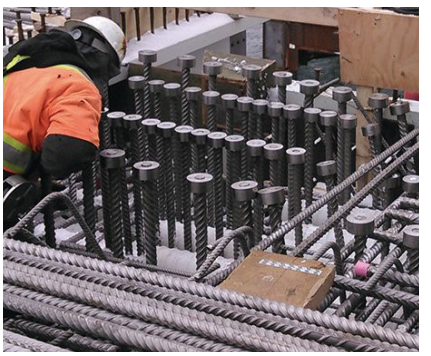
Structural Design

The American Association of State Highway and Transportation Officials' *AASHTO LRFD Bridge Design Specifications* Article 5.10.8.3, Development by Mechanical Anchorages, allows the use of mechanical anchorages if the device is capable of developing the strength of the reinforcement without damage to the concrete.[3] Performance of mechanical anchorages must be verified by laboratory testing, and complete details must be shown in the contract documents.

The AASHTO LRFD specifications also allow the development of reinforcing bars to consist of a combination of mechanical anchorage and the additional development length of reinforcement between the point of maximum bar stress and the mechanical anchorage. In practice, most heads provide a strength greater than that of the reinforcing bar being anchored.

The AASHTO LRFD specifications provide few design details. However, design provisions for headed deformed reinforcing bars are included in Section 25.4.4 of ACI's *Building Code Requirements for Structural Concrete* (ACI 318-19).[4] These requirements allow the use of headed reinforcing bars in tension when the following conditions are satisfied:

- Bars conform with ASTM A970.
- Bar size does not exceed size no. 11.
- Net bearing area of the head is at least four times the area of the bar.
- Normalweight concrete is used.
- Clear cover for the bar is at least twice the bar diameter.



ASTM A970, *Standard Specification for Headed Steel Bars for Concrete Reinforcement*, lists seven methods of forming heads on headed reinforcing bars. Examples of three forming methods are shown here: (top) heads integrally hot forged from the reinforcing bars, (middle) internally threaded heads attached to matching threads at the end of the reinforcing bars, and (bottom) cold swaged headed sleeves on reinforcing bars. Photos: Headed Reinforcement Corp. (top); Dextra America (middle); BarSplice Products Inc. (bottom).

Congestion in a pile-to-pile cap connection was eliminated by using field-installed heads to replace hooked bars. Photo: Headed Reinforcement Corp.

- Center-to-center spacing between bars is at least three times the bar diameter.

The net bearing area is defined as the area of the head projected onto a plane orthogonal to the longitudinal axis of the bar minus the bar cross-sectional area. This area represents the contact surface between the head and the concrete where the bar tensile force is transferred to the concrete through compressive stress.

ASTM A970 requires tensile testing of the full-size reinforcing bar with a head attached to one end. The tensile properties of the headed bar shall conform to one of the following classes:

- Class A: Required to develop the minimum specified tensile strength of the reinforcing bar
- Class B: Required to develop both the minimum specified tensile strength and the minimum specified elongation of the reinforcing bar
- Class HA: Required to develop the minimum specified tensile strength of the reinforcing bar and to satisfy specific requirements for head dimensions

Note that ASTM A970 requires headed bars to develop 100% of the minimum specified tensile strength of the reinforcing bar, whereas the AASHTO LRFD specifications Article 5.10.8.4.2b requires mechanical couplers to develop 125% of the specified yield strength. ACI 318-19 Subsection 20.2.1.6 requires the use of Class HA head dimensions, but Subsection 25.4.5.1 also permits the use of any other type of mechanical anchorage capable of developing the yield strength of the reinforcing bar, provided it is approved by the building official.

Concluding Remarks

Headed reinforcing bars provide a solution to develop reinforcement in tension when the use of straight bars or hooked bars is neither practical nor economical. Further information about their use is available from the Concrete Reinforcing Steel Institute, ACI, ASTM International, and manufacturers' literature.

References

1. American Concrete Institute (ACI). 2018. *ACI Concrete Terminology* (ACI CT-18). Farmington Hills, MI: ACI.
2. ASTM International. 2018. *Standard Specification for Headed Steel Bars for Concrete Reinforcement* (ASTM A970/A970M-18). West Conshohocken, PA: ASTM International.
3. American Association of State Highway and Transportation Officials (AASHTO). 2020. *AASHTO LRFD Bridge Design Specifications*, 9th ed. Washington, DC: AASHTO.
4. ACI Committee 318. 2019. *Building Code Requirements for Structural Concrete* (ACI 318-19) and *Commentary* (ACI 318R-19). Farmington Hills, MI: ACI.

Dr. Henry G. Russell is an engineering consultant and former managing technical editor of ASPIRE®. *He has been involved with applications of concrete for bridges for over 45 years and has published many papers on the applications of high-performance concrete.*