Changes to CRSI Standard Bar Bend Diameters for Stirrups and Ties

by Dr. Krista Brown

Many readers may still be unaware of changes made in the Concrete Reinforcing Steel Institute's (CRSI's) latest edition of the *Manual of Standard Practice*[1] regarding minimum inside bar bend diameters for no. 3, 4, and 5 steel reinforcing bars that are used for stirrups and ties. This change was recently brought to the attention of the *ASPIRE*® team by a precaster.

What Is the Change?

In 2018, CRSI published the 29th edition of its *Manual of Standard Practice*,[1] including changes to Table 7-2 (**Fig. 1**) which lists the minimum inside bar bend diameters as 2, 2½, and 3¼ in. for no. 3, 4, and 5 stirrups and ties, respectively. In general, these values equate to a minimum bend diameter of five bar diameters ($5d_b$) for all grades, instead of four bar diameters ($4d_b$) as given in earlier CRSI manuals and other current specifications and standards such as the American Concrete Institute's *Building Code Requirements for Structural Concrete* (ACI 318-19) *and Commentary* (ACI 318R-19)[2] and the American Association of State Highway and Transportation Officials' *AASHTO LRFD Bridge Design Specifications*.[3] **Table 1** compares the minimum inside bar bend diameters for different specifications and standards.

ASTM A615/A615M-20, *Standard Specification for Deformed and Plain Carbon Steel Bars for Concrete Reinforcement*,[4] specifies pin diameters for bend tests; it does not specify minimum inside bend diameters for reinforcing bar detailing and fabrication, which are typically given in design specifications and codes. The pin diameters are fully defined in ASTM A615, which is used to determine compliance with material property requirements of reinforcing bars. The specified pin diameters for bend tests of no. 3, 4, and 5 reinforcing bars are a function of steel reinforcement grades, with a pin diameter of $3.5d_b$ required for Grades 40 and 60 and a pin diameter of $5d_b$ required for Grades 80 and 100. For larger bars, the pin diameter for bend tests is not a function of grade. Only one pin diameter is specified in ASTM A615 for no. 3, 4, and 5 reinforcing bars; no distinction is made for stirrups and ties.

Why Was the Change Made?

According to CRSI vice president of engineering, Amy Trygestad, the CRSI committee responsible for the change discussed the topic during the CRSI Fall 2017 meeting. At that time, it seemed that ACI Committee 318 was looking to adopt a $5d_b$ minimum bend diameter for no. 3, 4, and 5 stirrups and ties when adopting Grade 80 and Grade 100 reinforcement. Furthermore, the CRSI committee discussed that ASTM A615 was changing pin diameters for bend tests to $5d_b$ for steel reinforcement grades higher than 75. After consideration, the committee decided against requiring different minimum bend diameters for different grades and agreed that the 29th edition of the *Manual of Standard Practice* should be revised to reflect the change in ASTM and the anticipated change in ACI 318-19, while maintaining uniformity and simplicity of fabrication for stirrups and ties across all grades for no. 3, 4, and 5 reinforcing bars.

Table 1. Comparison of minimum inside diameters of bends for 90-degree bend of stirrups and ties

Reinforcing bar size	CRSI[1] Table 7-2	ACI 318-19[2] Table 25.3.2	AASHTO[3] Table 5.10.2.3-1	ASTM A615/A615M-20[4] Table 3 pin diameter
No. 3	2 in. ($5.3d_b$)	$4.0d_b$	$4.0d_b$	$3.5d_b$ for Grades 40 and 60 $5.0d_b$ for Grades 80 and 100
No. 4	2½ in. ($5.0d_b$)	$4.0d_b$	$4.0d_b$	
No. 5	3¼ in. ($5.2d_b$)	$4.0d_b$	$4.0d_b$	

Note: d_b = reinforcing bar diameter. AASHTO and ACI 318-19 require $6.0d_b$ for general-use bars. This table does not apply to galvanized or epoxy-coated reinforcing bars.
Table: Dr. Krista Brown.

Table 7-2 Standard Stirrup/Tie Hooks

90° Stirrup/Tie Hooks

Stirrup & Tie Hooks	90°	
Bar Size	D, (in.)	A or G, (ft-in)
#3	2"	4 1/2"
#4	2 1/2"	4 3/4"
#5	3 1/4"	6"
#6	4 1/2"	1' – 0"
#7	5 1/4"	1' – 2"
#8	6"	1' – 4"

Notes:
D = Finished bend diameter
All grades and coatings (except galvanized)

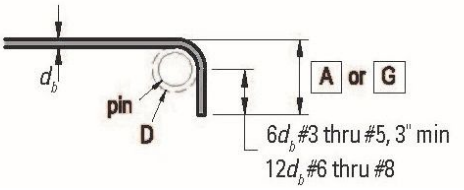

Figure 1. Minimum bar bend diameters from Table 7-2 in the Concrete Reinforcing Steel Institute's *Manual of Standard Practice*, 29th edition.[1] Minimum bend diameters for 135- and 180-degree bends are the same. Figure: Concrete Reinforcing Steel Institute.

Implications of the Change

Prestressed concrete producers have strand patterns that are somewhat "set in stone." Stress heads, bulkheads, and templates on production lines are governed by the minimum allowable distance between strands and minimum concrete cover to outside strands and stirrups. This is especially the case for bridge beams, where typically there are standard cross sections and reinforcement details that are fabricated by multiple producers. **Figure 2** compares the reinforcement details of the traditional 2½-in. ($4d_b$) bend diameter of a no. 5 tie with that of the newer 3¼-in. ($5.2d_b$) bend diameter required by CRSI. This shows that holding the corner strand in the same position would result in less cover. Typically, reduction of cover is not an option, so using fewer strands or shifting them slightly might be an alternative. Neither option is efficient. Cases with ½-in.-diameter strand and/or no. 4 bars have similar outcomes.

Figure 3 illustrates the case of a voided slab beam for which a state department of transportation (DOT) required a 2-ft 8-in. out-to-out stirrup

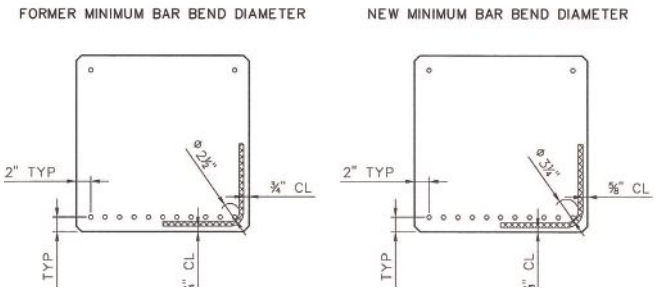

Figure 2. Comparison of no. 5 stirrup bar bends with 0.6-in.-diameter strand in the corners. The section on the left shows a typical cross section with $4d_b$ as the minimum diameter bend for a no. 5 bar with ¾ in. cover. The section on the right reflects the 3¼ in. bar bend diameter listed in Concrete Reinforcing Steel Institute's *Manual of Standard Practice*, 29th edition,[1] for the same situation. When the strand position is the same, the cover is reduced by ⅛ in. to accommodate the larger bend diameter. Figure: J.R. Parimuha.

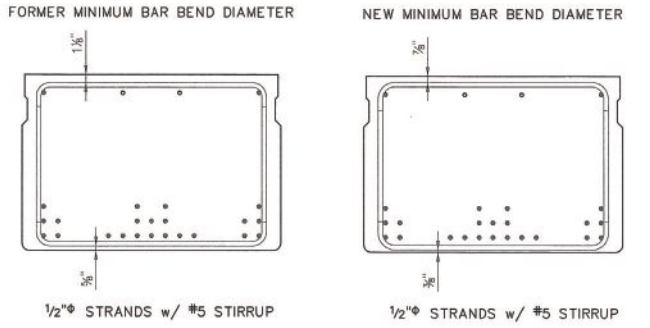

Figure 3. Effect of the larger no. 5 stirrup bar bend diameter for a voided slab cross section (voids not shown) when strand locations are the same. Due to the presence of top strands, the effect is compounded, and cover is reduced at both top and bottom. Figure: J.R. Parimuha. When the strand position is the same, the cover is reduced by ¼ in. to accommodate the larger bend diameter. Figure: J.R. Parimuha.

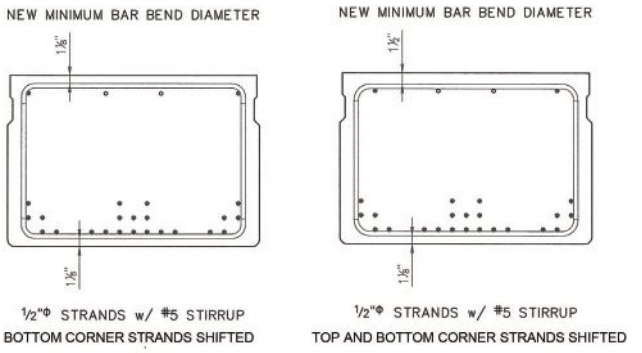

Figure 4. To meet a state department of transportation's required 2-ft 8-in. out-to-out stirrup dimension and accommodate the larger minimum bar bend diameter, a prestressed concrete producer relocated the corner strands at the top and bottom of the section inward to retain concrete cover. The alternative would have been a ¼ in. loss of cover, as shown in Fig. 3. This is not an option when all strand positions in a row are occupied. Figure: J.R. Parimuha.

dimension. In this case, the issue is compounded by the presence of top strands. With the larger bend diameter for the stirrup, the concrete cover would be decreased. **Figure 4** shows how a producer shifted the top and bottom corner strands inward to meet cover requirements while keeping the same number of strands in each row as originally designed. Because many bridge beams are optimized by placing the maximum number of strands in the bottom row, this shift is not always a viable option. If strands must be removed from the bottom row to achieve cover, placing an equivalent number of strands in higher rows reduces the moment capacity and could easily upset the delicate balance of top and bottom stresses. Shifting the entire bottom row up and/or the top row down would have similar consequences.

Exceptions to the Rules

CRSI acknowledges that there are times when specifiers and/or contractors may need special fabrication requirements, such as small bend diameters or tighter fabrication tolerances. Such requirements are commonly needed for precast concrete elements because they are often much thinner than cast-in-place concrete elements. The CRSI *Manual of Standard Practice* states in Section 7.3.2, Item 3d, that bending shapes for precast concrete units are classified as "Special Bending." CRSI does not prohibit the bending of Grade 60 stirrups and ties to the $4d_b$ bend diameter; however, the tighter bend diameter is not standard fabrication practice, is considered a special-order item, and must be clearly noted in the construction documents. To ensure that the bending operations do not damage the reinforcing bars during fabrication and that they are compliant with the AASHTO LRFD specifications, ACI 318, and the applicable ASTM specification, CRSI recommends the following for each bar size: first, the inside bend diameters specified and fabricated are equal to or larger than the applicable minimum inside bend diameter that is defined in the AASHTO LRFD specifications; second, the diameters of the bending pins used for reinforcing bar fabrication must be equal to or larger than the pin diameters described and required in the applicable ASTM specification.

—Amy Trygestad, Concrete Reinforcing Steel Institute

Who Does the Change Affect?

Use of the revised CRSI minimum finished bend diameters for no. 3, 4, and 5 stirrups and ties will affect DOTs and other agencies that reference the current edition of the CRSI *Manual of Standard Practice*. Specifications that reference the AASHTO LRFD specifications or ACI 318 are not affected, provided the ASTM A615 requirements are met. However, it should be noted that, for no. 3, 4, and 5 bars other than ties and stirrups, the AASHTO LRFD specifications and ACI 318 require a minimum bend diameter of $6.0d_b$.

What Is the Status?

The CRSI fabrication committee has formed a task group to issue a position statement for clarification on the bar bend changes, as well as how those changes relate to ACI 318-19 and ASTM A615/A615M-20. According to CRSI, members of ACI Committee 318 Subcommittee B, Anchorage and Reinforcement, recognize that the ACI 318-19 bar bend values do not comply with ASTM bend test requirements for Grades 80 and 100 and may need to be revised accordingly.

References

1. Concrete Reinforcing Steel Institute (CRSI). 2018. *Manual of Standard Practice*, 29th ed. Schaumburg, IL: CRSI.
2. American Concrete Institute (ACI) Committee 318. 2019. *Building Code Requirements for Structural Concrete* (ACI 318-19) *and Commentary* (ACI 318R-19). Farmington Hills, MI: ACI.
3. American Association of State Highway and Transportation Officials (AASHTO). 2020. *AASHTO LRFD Bridge Design Specifications*, 9th ed. Washington, DC: AASHTO.
4. ASTM International. 2020. *Standard Specification for Deformed and Plain Carbon Steel Bars for Concrete Reinforcement*. ASTM A615/A615M-20. West Conshohocken, PA: ASTM International. https://doi.org/10.1520/A0615_A0615M-20.

EDITOR'S NOTE

Contributions to the content of this article from CRSI vice president of engineering, Amy Trygestad, and others at CRSI are greatly appreciated.