Approved Changes to the 9th Edition *AASHTO LRFD Bridge Design Specifications:* Use of 0.7-in.-Diameter Strands in Precast, Pretensioned Concrete Girders

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The forthcoming 10th edition of the American Association of State Highway and Transportation Officials' *AASHTO LRFD Bridge Design Specifications*[1] will include revisions to simplify designs, streamline specification language, clarify concepts and design expressions, and make allowances for new materials that have recently been introduced into the marketplace. This article focuses on the changes that involve the use of 0.7-in.-diameter strands in precast, pretensioned concrete girders. The benefits of using 0.7-in.-diameter strands are discussed in depth by Salazar et al.[2] In a nutshell, by using 0.7-in.-diameter strands in a 2-in. grid, we can lower the centroid of the prestressed reinforcement in a typical pretensioned girder and therefore increase the internal lever arm between the compressive and tensile resultants for flexural capacity. The increased internal lever arm can improve structural efficiency in cases where the flexural capacity check controls the superstructure design. A similar benefit exists for service-level stress checks. The concerns that stem from using larger strands carrying higher forces in a 2-in. grid have been addressed by several research groups at the University of Nebraska, the University of Florida, the University of Texas at Austin, and the University of Cincinnati. National Cooperative Highway Research Program (NCHRP) project 12-109 examined the body of knowledge and enhanced it by conducting additional tests and analyses to fill the gaps in our knowledge. NCHRP Research Report 994[3] includes recommendations stemming from that project, and those recommendations are the primary basis for the the changes to the AASHTO LRFD specifications[4] that will be made in the forthcoming 10th edition. The following changes to the specifications and additional specification language will all facilitate the addition of 0.7-in.-diameter strands to the bridge engineer's toolbox.

Table 5.9.4.1-1, which lists various strand sizes and minimum center-to-center spacings, will be modified to accommodate 0.7-in.- and 0.62-in.-diameter Grade 270 strands (**Table 1**). It should be noted that the 10th edition AASHTO LRFD specifications will retain the requirement that the clear distance between strands be not less than 1.33 times the maximum size of aggregate.

Article 5.9.4.3.3 item B will be revised to read as follows:

> *Debonding shall not be terminated for more than six strands in any given section or four strands for girders using 0.7-in.-diameter strand. When a total of ten or fewer strands are debonded, debonding shall not be terminated for more than four strands in any given section.*

In this way, abrupt changes made to the prestressing force and the cracking that may occur at sections where debonding begins and ends are controlled, and the potential adverse effects of debonding are minimized while the beneficial effects of strand debonding to control stresses are leveraged.

To provide additional clarification and guidance for structural detailing, new commentary (C5.9.4.4.2) will be added, as follows:

> *Several Owners have elected to provide No. 3 deformed bars beyond the end region due to past detailing practices and better performance of the girder if impacted by an over-height vehicle. The spacing varies by state, with 6 inches to 18 inches spacings being commonly noted. NCHRP Project 12-109 also noted better performance and ductility of girders with debonded strands if confinement reinforcement is extended to a location 1.5d past the end of the last debonded strands. Note the research showed the predicted girder ultimate capacity was achieved without the confinement steel.*

A new Article 5.9.4.4.3 providing guidance for horizontal transverse tension tie reinforcement will be added and will read as follows:

> *Horizontal transverse reinforcement provided to satisfy Articles 5.9.4.4.1 and 5.9.4.4.2 may also be used to satisfy this Article.*
>
> *Steel bearing plate with embedded shear studs at the girder ends may be used in lieu of the requirements of this article. Articles 5.9.4.4.1 and 5.9.4.4.2 shall still be applicable when a steel bearing plate is used.*
>
> *For all single-web beam sections with a bottom flange, horizontal transverse tension tie reinforcement shall be provided to resist potential longitudinal*

Table 1. Minimum center-to-center spacings for Grade 270 strand in the forthcoming *AASHTO LRFD Bridge Design Specifications,* 10th edition[1]

Strand size, in.	Spacing, in.
0.7 0.62 0.6 0.5625 special 0.5625	2.00
0.5000 0.4375 0.50 special	1.75
0.3750	1.50

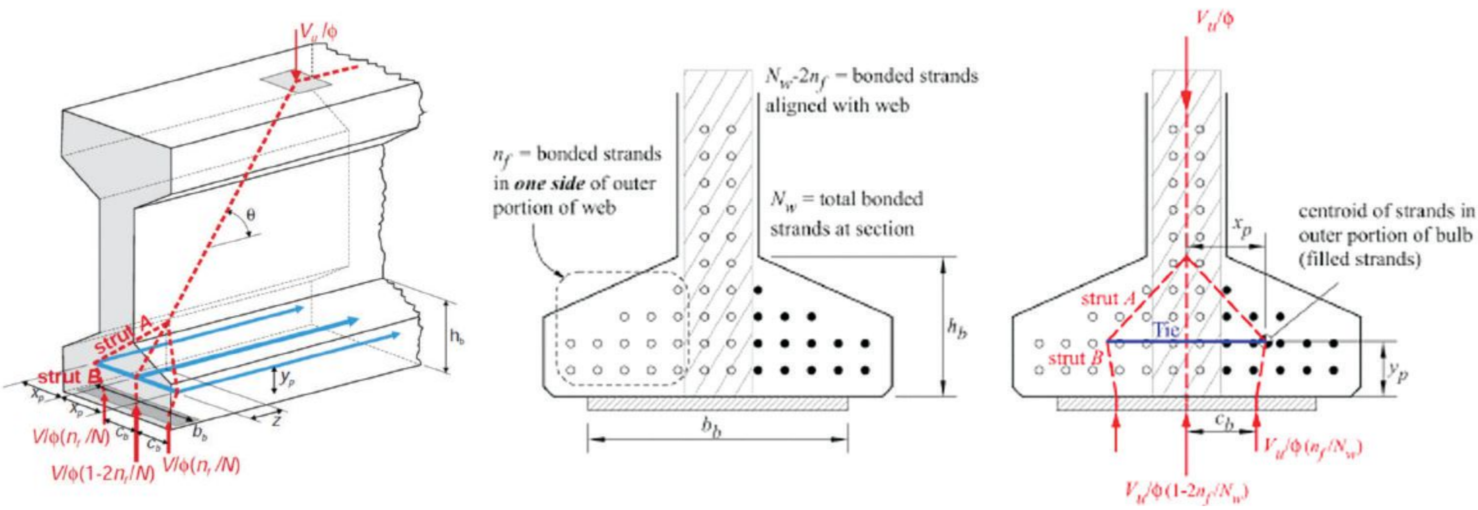

Figure 1. Strut-and-tie model for confinement reinforcement design that was developed by National Cooperative Highway Research Program (NCHRP) project 12-109. Provisions for the confinement reinforcement will be included in the new Article 5.9.4.4.3 in the forthcoming *AASHTO LRFD Bridge Design Specifications,* 10th edition.[1] Source: Fig. 2.10 in NCHRP Research Report 994.[3]

splitting cracks in the bottom flange. The strut-and-tie model and the associated Equation 5.9.4.4.3-1 shall be used to determine the required amount of horizontal transverse tie reinforcement.

The horizontal transverse tie reinforcement shall be uniformly distributed above the bearing from the end of the girder to a point h/4 beyond the bearing.

The horizontal transverse tie reinforcement shall be greater than:

$$A_s f_y = \left(\frac{n_f}{N_w}\right)\left[\frac{x_p}{h_b - y_p} + \frac{x_p - c_b}{y_p}\right]\left(\frac{V_u}{\phi}\right) \qquad (5.9.4.4.3\text{-}1)$$

where:

- A_s = *area of tie reinforcement (in.*^{2}*)*
- b_b = *width of bearing (in.)*
- c_b = *distance from the bearing reaction force on either side of the girder to the girder center line (in.)*
  = $(b_b/2)(1 - n_f)/N_w$
- f_y = *yield strength of tie reinforcement (ksi)*
- h_b = *depth of bottom bulb (in.)*
- N_w = *total number of bonded strands at section*
- n_f = *number of bonded strands in one side of outer portion of web*
- V_u = *maximum factored reaction at bearing (kip)*
- x_p = *horizontal distance from girder centerline to centroid of bonded strands in outer portion of bulb (in.)*
- y_p = *vertical distance from girder soffit to centroid of bonded strands in outer portion of the bulb (in.)*
- ϕ = *0.9 (resistance factor for tension in strut-and-tie models)*

A new commentary section (C5.9.4.4.3) will be added, as follows:

Tension forces, oriented transversely across the bottom bulb of single-web flanged sections, develop requiring tie reinforcement across the bottom flange to control longitudinal cracking at the Strength I limit state. The outcome of exceeding this limit, however, is related to transverse deformation and cracking of the flange and is likely to be a serviceability issue and not catastrophic in nature. Minimum confinement reinforcement satisfying Article 5.9.4.4.2 contributes to the tie capacity, and in many instances will be sufficient to fully resist the horizontal transverse tie force calculated using Article 5.9.4.4.3. The horizontal portion of splitting reinforcement required by Article 5.9.4.4.1, if present, contributes to the tie capacity force calculated using Article 5.9.4.4.3. This approach is consistent with the load transfer mechanism in Figure C5.8.2.2-5.

In some instances, these requirements may result in impractical horizontal transverse tie reinforcement details. An embedded bearing plate would likely be practical mitigation in such cases. Research recommends limiting the resistance of the bearing plate to 50 percent of the expected demand.

As the preceding design guidance shows, the aim of the new specification language is to allow the use of 0.7-in.-diameter strands in a rational manner by addressing the effects of larger tie forces that will be developed in 0.7-in.-diameter strands placed in a 2-in. grid spacing. The detailing requirements that apply to 0.7-in.-diameter strands apply to other strand sizes, albeit with a reduced tie force. With that stated, it is important to recognize that these requirements are substantiated with experimental data and explained by appropriate strut-and-tie models (**Fig. 1**).

References

1. American Association of State Highway and Transportation Officials (AASHTO). Forthcoming. *AASHTO LRFD Bridge Design Specifications*. 10th ed. Washington, DC: AASHTO.
2. Salazar, J., H. Yousefpour, A. Katz, R. Abyaneh, H. Kim, D. Garber, T. Hrynyk, and O. Bayrak. 2017. "Benefits of Using 0.7 in. (18 mm) Diameter Strands in Precast, Pretensioned Girders: A Parametric Investigation." *PCI Journal* 62 (6): 59–75. https://doi.org/10.15554/pcij62.6-04.
3. Shahrooz, B. M., R. A. Miller, K. A. Harries, and R. W. Castrodale. 2022. *Use of 0.7-in. Diameter Strands in Precast Pretensioned Girders*. NCHRP Research Report 994. Washington, DC: The National Academies Press. https://doi.org/10.17226/26677.
4. AASHTO. 2020. *AASHTO LRFD Bridge Design Specifications*. 9th ed. Washington, DC: AASHTO.