Details on Two Upcoming Changes to the *AASHTO LRFD Bridge Design Specifications:* Creep and Shrinkage Estimates and Regions Requiring Minimum Transverse Reinforcement

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At its summer 2021 meeting, the American Association of State Highway and Transportation Officials (AASHTO) Committee on Bridges and Structures approved 11 agenda items to the *AASHTO LRFD Bridge Design Specifications*.[1] In previous articles published in the Fall 2021 and Winter and Spring 2022 issues of *ASPIRE*®, I discussed some of these 11 agenda items and provided details on upcoming changes to the specifications that were approved in 2021. In this article, I provide insights and details on two additional agenda items that were approved in 2021 and will be published in the 10th edition of the *AASHTO LRFD Bridge Design Specifications*. These items have been topics of ongoing technical debate and research within the structural and bridge engineering communities.

Creep and Shrinkage Estimates for Segmentally Constructed Concrete Bridges

In its simplest form, creep can be defined as the volume changes that concrete experiences under sustained loads. Shrinkage, which is made up of autogenous and drying shrinkage components, also causes volume changes, but the volume changes are not load related. Autogenous shrinkage is caused by the chemical reaction that takes place in early-age concrete, and drying shrinkage is basically the volume reduction that results from loss of moisture in hardened concrete. These volume changes are influenced by the type and volume fraction of the constituent materials used in the fresh concrete mixture, loading age, volume-to-exposed surface area ratio of the structural component, exposure time, and ambient conditions—to list just some of the key factors. Bridge construction type, locally available materials and associated concrete mixture proportions, specified strength of concrete at transfer of prestress and/or at the time of post-tensioning, and the final compressive strength of concrete are additional design- and construction-related factors that directly or indirectly affect the volume changes that bridge components experience.

For many bridge owners, concrete bridges provide a versatile solution, partly thanks to the flexibility in design and analysis decision-making that they allow both the owners and designers. With this backdrop, researchers have contributed over the years to the development of different approaches to estimating creep and shrinkage effects. These approaches vary in their complexity, accuracy, and application. But regardless of the calculation type and reference design code or specification, prestress losses stemming from creep- and shrinkage-induced volume changes cannot be determined to high levels of accuracy. In the author's opinion, even the most sophisticated efforts can result in ±25% to 30% variability compared with experimental and field measurements.

The agenda item is intended to clarify the techniques that are most appropriate for estimating creep and shrinkage for segmentally constructed bridges. With the upcoming changes to the AASHTO LRFD specifications, the third and fourth paragraphs of Article 5.4.2.3.1 will be revised to reference acceptable codes and provisions,[2-5] as follows:

> *Except for segmentally constructed bridges, or where mix-specific data are not available, estimates of shrinkage and creep may be made using the provisions of any of the following:*
>
> - *Articles 5.4.2.3.2 and 5.4.2.3.3,*
> - *The* fib Model Code for Concrete Structures 2010 *(*fib *2010),*
> - CEB-FIP Model Code for Concrete Structures 1990 *(CEB 1990), or*
> - *ACI 209.2R-08,* Guide for Modeling and Calculating Shrinkage and Creep in Hardened Concrete*, First Printing May 2008.*
>
> *For segmentally constructed bridges, estimates of shrinkage and creep may be made using the provisions of the* fib Model Code for Concrete Structures 2010 *(*fib *2010), or the* CEB-FIP Model Code 1990 *(CEB 1990). In addition, a more precise estimate shall be made, including the effect of the following:*
>
> - *specific materials when known,*
> - *structural dimensions,*
> - *site conditions,*
> - *construction sequence, and*
> - *concrete age at various stages of erection.*

In addition, the corresponding commentary will be revised to include the following:

> *Comparisons of creep coefficients show that AASHTO Article 5.4.2.3.2 and ACI 209 estimate lower creep coefficients than the* fib Model Code for Concrete Structures 2010 *(*fib *2010) and the* CEB-FIP Model Code 1990 *(CEB 1990) in*

segmentally constructed bridges. The use of the fib Model Code for Concrete Structures 2010 *(*fib *2010) is recommended by the American Segmental Bridge Institute for creep and shrinkage calculations of segmentally constructed bridges.*

Where mix-specific data are available, more precise models can be utilized for creep and shrinkage estimates for segmental bridges, including the B4 model from American Society of Civil Engineers (ASCE), 9th International Conference on Creep, Shrinkage, and Durability Mechanics*: Pages 429-436 "The B4 model for multi-decade creep and shrinkage prediction" by R. Wendner, M. H. Hubler, and Z. P. Bažant.*

The changes made to the AASHTO LRFD specifications for creep and shrinkage calculations for segmentally constructed bridges reflect current, as well as past, design practices. These changes were motivated by the concerns raised by some design professionals, that, despite the ongoing conventions employed by knowledgeable designers in the industry, it is possible for some designers to make decisions that could be inconsistent with the industry standards and conventions while seemingly being in conformance with the applicable design rules.

Regions Where Minimum Transverse Reinforcement Is Required

The size effect on shear behavior, especially for beam shear, has been a topic of discussion and research for many decades. Whereas modern design specifications have provisions that explicitly consider the size effect and the associated reduction in concrete contribution to shear strength, early attempts were aimed at providing a minimum quantity of transverse reinforcement and mitigating the size effect. The shear design provisions of the AASHTO LRFD specifications, which are based on the modified compression field theory given in Article 5.7.3, explicitly consider the size effect. In regions where a minimum quantity of transverse reinforcement is used, in compliance with the Section 5 design provisions, the concrete contribution to shear strength is calculated differently than in regions where the minimum transverse reinforcement is not provided. It is with this understanding that the specifications provide guidance on regions where a minimum quantity of transverse reinforcement shall be provided.

Except for slabs, footings, and culverts, Article 5.7.2.3 of the current AASHTO LRFD specifications requires that transverse reinforcement be provided when

$$V_u > 0.5\phi(V_c + V_p)$$

where

V_u = factored shear force
ϕ = resistance factor for shear
V_c = nominal shear resistance of the concrete
V_p = component of prestressing force in the direction of the shear force

However, it is not clear whether this requirement applies to conventional retaining walls. This working agenda item is intended to remove that ambiguity. It is important to note that Article 5.2 defines a slab as "a component having a width of at least four times its effective depth."

Retaining walls typically meet the definition for a "slab" and therefore are exempt from the minimum transverse reinforcement requirements of Article 5.7.2.3. Accordingly, Article 5.7.2.3 is revised to read as follows:

Except for footings, culverts, slabs, and other members that meet the Article 5.2 definition of a slab, transverse reinforcement shall be provided where:

- $V_u > 0.5\phi(V_c + V_p)$

  or

- *Where consideration of torsion is required by Eq. 5.7.2.1-3.*

The commentary in Article C5.7.2.3 is also revised as follows:

Transverse reinforcement is required in all regions where there is a significant chance of diagonal cracking. Slabs are defined as members that have widths at least four times their effective depth, and therefore members such as cantilever semi-gravity (conventional) retaining walls can be considered exempt from these requirements.

Publication of 10th Edition Delayed

The effects of COVID-19 on our community have been felt by many and in a variety of ways. In this context, AASHTO made the decision to continue the technical work on working agenda items to improve the AASHTO LRFD specifications and delay the publication of the new edition until 2024. The positive side of this delay is that it gives the AASHTO Technical Committee T-10 Concrete Design, along with other technical committees, an additional year to continue their work and improve concrete bridge design specifications. I will continue to provide updates on approved changes to the AASHTO LRFD specifications in future *ASPIRE* articles.

References

1. American Association of State Highway and Transportation Officials (AASHTO). 2020. *AASHTO LRFD Bridge Design Specifications*, 9th ed. Washington, DC: AASHTO.

2. American Concrete Institute (ACI) Committee 209. 2008. *Guide for Modeling and Calculating Shrinkage and Creep in Hardened Concrete*. ACI 209.2R. Farmington Hills, MI: ACI.

3. *fib* (International Federation for Structural Concrete). 2013. *fib Model Code for Concrete Structures 2010*. Berlin, Germany: Ernst & Sohn.

4. Comité Euro-International du Beton (CEB) and International Federation for Prestressing (FIP). 1993. *CEB-FIP Model Code 1990*. CEB Bulletin 213/214. Lausanne, Switzerland: CEB.

5. Wendner, R., M. H. Hubler, and Z. P. Bažant. 2013. "The B4 Model for Multi-decade Creep and Shrinkage Prediction." In *Ninth International Conference on Creep, Shrinkage, and Durability Mechanics (CONCREEP-9), September 22-25, 2013, Cambridge, Massachusetts*. Reston, VA: American Society of Civil Engineers. https://doi.org/10.1061/9780784413111.051.