Details on Several Upcoming Changes to the *AASHTO LRFD Bridge Design Specifications*: Deflection Calculations and Stress Limits

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My article in the Fall 2021 issue of *ASPIRE*® summarized 11 working agenda items prepared by the American Association of State Highway and Transportation Officials (AASHTO) Technical Committee for Concrete Design (T-10) that were adopted by the AASHTO Committee on Bridges and Structures (COBS) at its summer 2021 meeting. This article focuses on two of those items and provides technical details for our readership.

Working Agenda Item 133: Deflection and Camber Calculations

According to the newly revised provisions of Article 5.6.3.5.2 in the *AASHTO LRFD Bridge Design Specifications*,[1] deflection and camber calculations are to consider appropriate combinations of dead load, live load, prestressing forces, erection loads, concrete creep and shrinkage, and steel relaxation. Revised provisions for both instantaneous and time-dependent deflections are forthcoming to improve the accuracy of the predicted deflections, as discussed in the following sections.

Instantaneous Deflections

The calculation of the effective moment of inertia will be updated to improve the accuracy of instantaneous deflection calculations. Unless obtained by a more comprehensive analysis, instantaneous deflections for nonprestressed concrete members are to be calculated using the modulus of elasticity for concrete as specified in Article 5.4.2.4, and the effective moment of inertia I_e calculated in accordance with **Table 1**.

Table 1. Effective moment of inertia I_e from the newly adopted AASHTO LRFD Table 5.6.3.5.2a-1

Service moment	Effective moment of inertia I_e, in.^{4}
$M_a \le \frac{2}{3} M_{cr}$	I_g
$M_a > \frac{2}{3} M_{cr}$	$\dfrac{I_{cr}}{1-\left(\dfrac{\frac{2}{3}M_{cr}}{M_a}\right)^2\left(1-\dfrac{I_{cr}}{I_g}\right)}$

Note: The cracking moment is calculated as $M_{cr} = \dfrac{f_r I_g}{y_t}$.

f_r = modulus of rupture of concrete as specified in Article 5.4.2.6 (ksi); I_{cr} = moment of inertia of the cracked section, transformed to concrete (in.^{4}); I_g = moment of inertia of the gross concrete section about the centroidal axis, neglecting the reinforcement (in.^{4}); M_a = maximum moment in a component due to service loads at the stage for which deformation is computed (kip-in.); M_{cr} = cracking moment (kip-in.); y_t = distance from the centroidal axis of the gross section to the extreme fiber in tension (in.).

For prismatic members, the effective moment of inertia is taken as the value obtained from Table 1 at midspan for simple or continuous spans, or at the support for a cantilever. For continuous, nonprismatic members, the effective moment of inertia is the average of the values obtained from Table 1 for the critical positive and negative moment sections.

For prestressed concrete members meeting the tensile stress limits of Article 5.9.2.3.2b, a provision stating that instantaneous deflections for such members may be calculated based on the moment of inertia of the gross concrete section I_g has been added.

Time-Dependent Deflections

An updated multiplier for estimating time-dependent deflections will be incorporated into the provisions to improve the accuracy of deflection predictions. Unless obtained from a more comprehensive analysis, additional time-dependent deflection for nonprestressed concrete members resulting from creep and shrinkage of flexural members is calculated as the product of the immediate deflection caused by sustained load and the multiplier used for calculating additional time-dependent deflection λ_Δ:

$$\lambda_\Delta = \frac{\xi}{1+50\rho'}$$

where

$$\rho' = \frac{A_s'}{bd}$$

A_s' = area of compression reinforcement (in.^{2})

b = width of compression face of member (in.)

Table 2. Time-dependent factor for sustained loads from the newly adopted AASHTO LRFD Table 5.6.3.5.2b-1	
Sustained load duration (months)	**Time-dependent factor ξ**
3	1.0
6	1.2
12	1.4
60 or more	2.0

d = distance from the extreme fiber in compression to centroid of longitudinal tension reinforcement (in.)

ξ = time-dependent factor in accordance with **Table 2**

The quantity ρ′ is calculated at midspan for simple or continuous spans, or at the support for a cantilever.

Additional time-dependent deflection of prestressed concrete members is calculated considering stresses in concrete and reinforcement under sustained load, and the effects of creep and shrinkage of concrete and relaxation of prestressing reinforcement.

Working Agenda Item 200: Compressive and Tensile Stress Limits

This approved working agenda item clarifies language in a number of different locations within the specifications. Broadly, the terminology is being revised to read "effective prestress," and the terms "after losses" and "before losses" have been eliminated because some type of prestress loss is always present in prestressed concrete elements. Prestressed concrete members first experience elastic shortening; over time, relaxation of strands and creep and shrinkage of concrete all influence the effective prestress.

Article 5.9.2.3.1a—Compressive Stresses—is being revised to provide relief in the following specific, temporary stress conditions. The compressive stress limit for pretensioned and post-tensioned concrete components, including segmentally constructed bridges, is limited to $0.65f'_{ci}$, except when lateral bending due to tilt, wind, or transportation-induced centrifugal force is explicitly considered. In these temporary stress conditions, the compressive stress limit at the component extremities is permitted to be increased to $0.70f'_{ci}$. These stress limits also apply to temporary preservice load stages, such as lifting, hauling, and erection, with concrete strength at the time of loading substituted for f'_{ci} in the stress limits.

Temporary tensile stress limits for concrete bridges other than segmentally constructed bridges are clarified in **Table 3**.

Bonded reinforcement sufficient to resist the tensile force in the concrete is to be located as close to the tension face of the member as possible. This reinforcement must be located on the tension side of the neutral axis. When the depth to the neutral axis from the tension face of the member is less than the concrete cover specified in Article 5.10.1, the reinforcement at a depth equal to the clear cover can be assumed to resist the tension force in the concrete for the purpose of determining the appropriate tensile stress limit in Table 3.

At sections located less than the development length from the end of the reinforcement provided to resist the tensile force in the concrete, the area of reinforcing steel A_s used in design is to be reduced in proportion to the lack of full development.

In future articles, additional changes to the AASHTO LRFD specifications will be discussed in an effort to keep our readership informed of the upcoming changes that will be included in the next edition of the specifications, which is to be published in 2023.

Reference

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

Table 3. Revised temporary tensile stress limits in prestressed concrete in AASHTO LRFD Table 5.9.2.3.1b-1		
Other than segmentally constructed bridges	**Location**	**Stress limits, ksi**
	Areas with bonded reinforcement (reinforcing bars or unstressed prestressing strand) sufficient to resist the tensile force in the concrete computed assuming an uncracked section, where reinforcement is proportioned using a stress of $0.5f_y$, not to exceed 30.0 ksi	$0.24\lambda\sqrt{f'_{ci}}$
	All other areas	$0.0948\lambda\sqrt{f'_{ci}} \leq 0.2$
	For handling stresses in prestressed piles	$0.158\lambda\sqrt{f'_{ci}}$

Note: f'_{ci} = specified concrete compressive strength at time of transfer of prestressing force or application of loading (ksi); f_y = specified minimum yield strength of reinforcement (ksi); λ = concrete density modification factor.