Bridge and Structures Office
Washington State
Department of Transportation

Design Memorandum

TO: All Design Section Staff
FROM: Bijan Khaleghi
DATE: February 15, 2019
SUBJECT: Compressive Stress Limits for Temporary Stresses

This design memorandum provides revisions to the compressive stress limits for temporary stresses in precast prestressed girder. BDM Section 5.2.1 shall be revised as described given below. Revisions to Chapter 15, Section 15.5.3A are not required because it references Table 5.2.1-1. The PGSuper, PGSplice and PGStable software programs will be updated to implement these changes.

Revisions to Chapter 5: Concrete Structures

5.2.1C ~~Allowable Stresses~~ Stress Limits in Prestressed Concrete Members

~~Allowable concrete stresses~~ Concrete stress limits for the service and fatigue limit states are shown in Table 5.2.1-1. For prestressed concrete girders, the ~~allowable concrete stresses~~ concrete stress limits shall be satisfied at all pre-service stages of girder construction and in service in accordance with Section 5.6.2.C. The tensile stress in the precompressed tensile zone for the final service load condition (Service III) is limited to zero. This prevents cracking of the concrete during the service life of the structure and provides additional stress and strength capacity for overloads.

For ~~allowable tensile stresses~~ tensile stress limits that require bonded reinforcement sufficient to resist the tensile force in the concrete, the tensile force shall be computed using the procedure illustrated in AASHTO LRFD C5.9.2.3.1b assuming an uncracked section. The bonded reinforcement is proportioned using a stress of $0.5f_y$, not to exceed 30 ksi. Individual reinforcing bars are only considered if they are fully developed and are located within the tensile stress region of the member.

The variable λ is the concrete density modification factor calculated in accordance with AASHTO LRFD Section 5.4.2.8.

Table 5.2.1-1 Allowable Stresses in Prestressed Concrete Members

Condition	Stress	Location	Allowable Stress (ksi)
Temporary Stress at Transfer and Lifting from Casting Bed	Tensile	In areas without bonded reinforcement sufficient to resist the tensile force in the concrete	$0.0948\lambda\sqrt{f'_{ci}} \leq 0.2$
		In areas with bonded reinforcement sufficient to resist the tensile force in the concrete	$0.24\lambda\sqrt{f'_{ci}}$
	Compressive	All locations	$0.65f'_{ci}$
		At section extremities (i.e. flange tips) when lateral bending from girder tilt due to assumed sweep and lift point offset is considered	$0.70f'_{ci}$
Temporary Stress at Shipping and Erection	Tensile	In areas without bonded reinforcement sufficient to resist the tensile force in the concrete	$0.0948\lambda\sqrt{f'_c}$
		In areas with bonded reinforcement sufficient to resist the tensile force in the concrete	$0.19\lambda\sqrt{f'_c}$
		In areas with bonded reinforcement sufficient to resist the tensile force in the concrete when shipping at 6% superelevation, without impact (see Section 5.6.2.C.2.d)	$0.24\lambda\sqrt{f'_c}$
	Compressive	All locations	$0.65f'_c$
		At section extremities (i.e. flange tips) when lateral bending from girder tilt due to assumed sweep, bunk point offset, and roadway crown slope and superelevation is considered	$0.70f'_c$
Final Stresses at Service Load	Tensile	~~Precompressed tensile zone~~All locations	0.0
	Compressive	All locations due to ~~E~~effective prestress and permanent loads	$0.45f'_c$
		All locations due to ~~E~~effective prestress, permanent loads and transient (live) loads	$0.60f'_c$
Final Stresses at Fatigue Load	Compressive	All locations due to Fatigue I Load Combination plus one-half effective prestress and permanent loads in accordance with AASHTO LRFD Section 5.5.3.1	$0.40f'_c$

Figure 5.2.1-1 illustrates the application of compressive stress limits and during lifting and shipping.

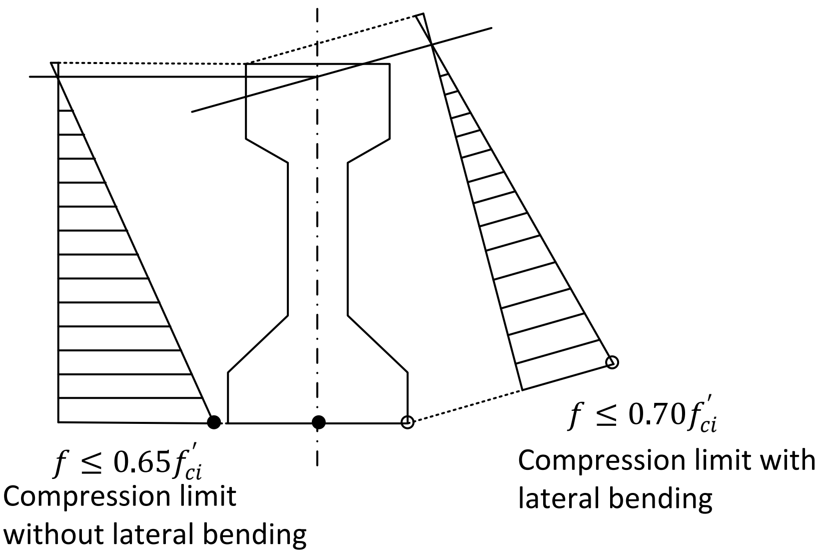
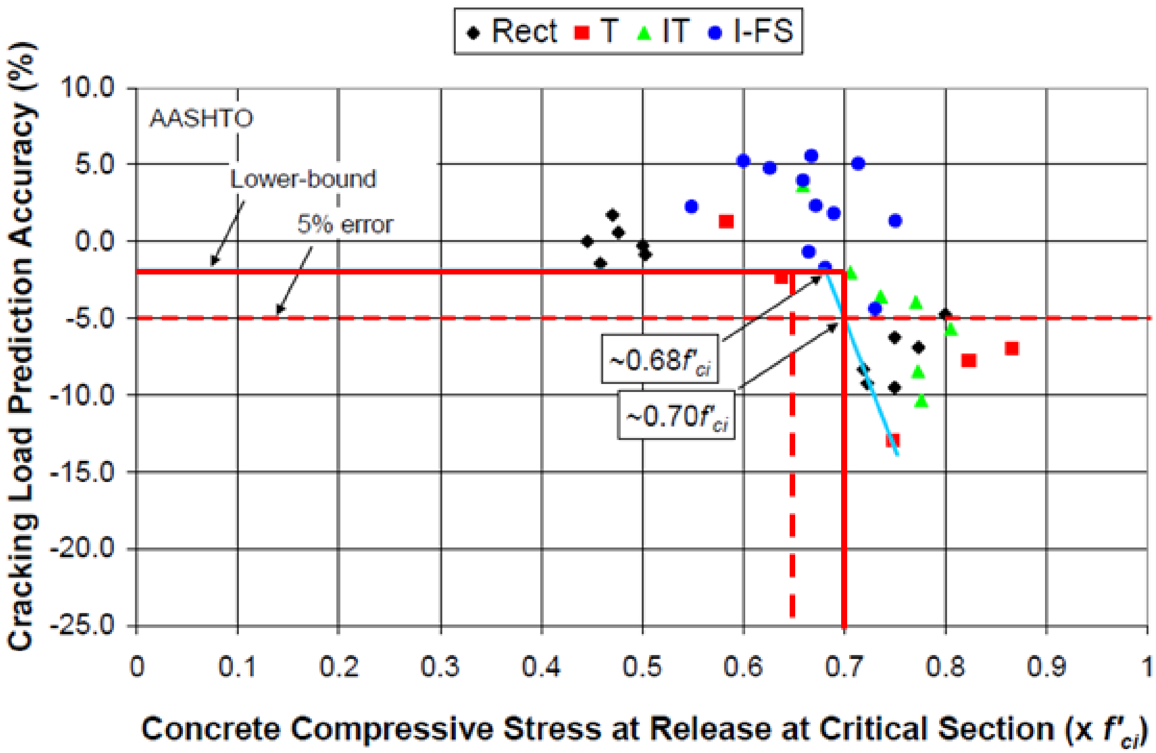


Figure 5.2.1-1 – Application of compressive stress limits for lifting and shipping.

Background:

The intent of these revisions is to provide relief from high concrete strength requirements due to compressive stresses at the extremities of the cross-section when lateral bending is present and explicitly considered.

The basis for the current concrete compressive stress limit is research by Birrcher and Bayrak[1]. It is important to note that the limit on concrete compressive stress is based on performance of the member in service, not the potential crushing of concrete during lifting and shipping. High compressive stress can cause micro-cracking in early-age concrete, potentially increasing the camber in an unpredictable fashion and reducing the modulus of rupture, leading to premature flexural cracking in service. The referenced research advised that the prediction of camber was generally not affected by an increase in allowable compressive stress. With respect to the reduction in modulus of rupture, Fig. 1 (reproduced from Figure 5-20, Reference 1) shows a comparison of the predicted flexural cracking load versus the level of allowable compressive stress for a variety of section shapes tested in the lab. On the vertical axis, an accuracy of zero indicates that the predicted cracking load matched the measured cracking load. Negative accuracy values indicate that the specimens cracked before reaching the predicted cracking load. The red vertical dashed line indicates a compressive stress limit of $0.65f'_{ci}$, which comfortably fits the data, but an argument can be made that the solid red vertical line at $0.70f'_{ci}$ is also justifiable.



According to descriptions of relevant research provided in Birrcher, et. al. [2], the $0.65f'_{ci}$ recommendation was based on tests of specimens that were either uniformly loaded in compression or did not have lateral bending concerns as noted above. Therefore, the experimentation represents a "global" stress condition in the specimens. Bending about the minor axis does not result in a net change in these "global" stresses, but introduces peak stresses at the extremities of the member.

The peak stresses at the extremities of a member typically occur during handling, shipping and erection. These peak stresses are temporary, occurring a limited number of times during pre-service conditions and occur for very short durations.

References

1. Birrcher, David, and Bayrak, Oguzhan, "Effects of Increasing the Allowable Compressive Stress at Release of Prestressed Concrete Girders", Research Report 0-5197-11, Center for Transportation Research, The University of Texas at Austin, January 2007, 226 pp.
2. Castro, Alfredo, Kreger, M., Bayrak, O. Breen, J. and Wood, S., "Allowable Design Release Stresses in Pretensioned Concrete Beams", Research Report 0-4086-2, Center for Transportation Research, The University of Texas at Austin, August 2004, 140pp.

If you have any questions regarding this policy memorandum, please contact Richard.Brice@wsdot.wa.gov or (360) 705-7174, Anthony.Mizumori@wsdot.wa.gov or (360) 705-7228, Bijan.Khaleghi@wsdot.wa.gov at 705-7181.

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