Details on Two Changes to the Ninth Edition *AASHTO LRFD Bridge Design Specifications*

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This article focuses on the final two working agenda items that were approved by the American Association of State Highway and Transportation Officials (AASHTO) Committee on Bridges and Structures during their June 2022 meeting for inclusion in the forthcoming 10th edition of the *AASHTO LRFD Bridge Design Specifications*.[1]

Lightweight Concrete Clarifications

The provisions of Section 5 of the AASHTO LRFD specifications[2] are based on design concrete compressive strengths varying from 2.4 to 10.0 ksi for normalweight and lightweight concrete, except where higher strength, not exceeding 15.0 ksi, is allowed for normalweight concrete. To that end, Appendix C5 will be revised to provide clear guidance on the upper limits of compressive strength for normalweight concrete (**Table 1**). Noteworthy changes include that the upper limit of compressive strength that governs Articles 5.10.8.2.5 (welded wire reinforcement) and 5.10.8.2.6 (shear reinforcement) have been revised up to 15 ksi and hoops have been added to Article 5.6.4.6.

In the 9th edition of the AASHTO LRFD specifications, the exceptions for higher-strength normalweight concrete are given in the specific articles. However, the language used to describe the exceptions can be misconstrued and taken to mean that the section is only applicable to normalweight concrete. Additionally, some sections provide extra requirements for lightweight concrete, which are unnecessary.

The revisions will clarify the intent of the specifications and put lightweight concrete on the same plane as normalweight concrete. To that end, Table 5.12.5.3.3-1 (**Table 2**) will be revised, and the lightweight concrete factor λ will be added to the stress limits section. In all, 40 items will be revised within this working agenda item pertaining to lightweight concrete to ensure that the lower tensile strength of lightweight concrete is accounted for only once. Multiple penalties concurrently applied to tensile strength of lightweight concrete and behavioral modes that are governed by the tensile strength have been eliminated. This revision is consistent with the broader philosophy of structural safety and desired levels of target reliability factors in structural design that is inherent to the AASHTO LRFD specifications.

Concrete Anchors

In 2019, the American Concrete Institute (ACI) modified the provisions

Table 1. Excerpt from Appendix C5, "Upper Limits of Normalweight Concrete for Articles Affected by Concrete Compressive Strength," showing revisions in the forthcoming *AASHTO LRFD Bridge Design Specifications*, 10th edition[1]

Article*	Upper limit,† ksi	
	10.0	15.0
5.6.4.6 Spirals, Hoops, and Ties		X
5.8.2.7 Application to the Design of General Zones of Post-Tensioning Anchorages		X
5.9.3 Prestress Losses		X
5.10.8.2.5 Welded Wire Reinforcement		X
5.10.8.2.6 Shear Reinforcement		X
5.11.3.2 Concrete Piles	X	
5.11.4.5 Concrete Piles	X	
5.12.5.3.8 Alternative Shear Design Procedure	X	
5.12.7 Culverts	X	

*Applies to all subarticles within the listed article.
†Article 5.1 establishes the upper limit for the specified design compressive strength of lightweight concrete as 10.0 ksi for all articles in Section 5.

Table 2. Revised Table 5.12.5.3.3-1—Load Factors and Tensile Stress Limits for Construction Load Combinations in the forthcoming *AASHTO LRFD Bridge Design Specifications*, 10th edition[1] (Notes are not shown.)

Load Combination	LOAD FACTORS															STRESS LIMITS				See Note
	Dead Load			Live Load			Wind Load			Other Loads					Earth Loads	Flexural Tension		Principal Tension		
	DC DW	*DIFF*	*U*	*CEQ CLL*	*IE*	*CLE*	*WS*	*WUP*	*WE*	*CR*	*SH*	*TU*	*TG*	*AI WA*	*EH EV ES*	Excluding "Other Loads"	Including "Other Loads"	Excluding "Other Loads"	Including "Other Loads"	
a	1.0	1.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0	γ_{TG}	1.0	1.0	$0.190\lambda\sqrt{f'_c}$	$0.220\lambda\sqrt{f'_c}$	$0.110\lambda\sqrt{f'_c}$	$0.126\lambda\sqrt{f'_c}$	—
b	1.0	0.0	1.0	1.0	1.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0	γ_{TG}	1.0	1.0	$0.190\lambda\sqrt{f'_c}$	$0.220\lambda\sqrt{f'_c}$	$0.110\lambda\sqrt{f'_c}$	$0.126\lambda\sqrt{f'_c}$	—
c	1.0	1.0	0.0	0.0	0.0	0.0	0.7	0.7	0.0	1.0	1.0	1.0	γ_{TG}	1.0	1.0	$0.190\lambda\sqrt{f'_c}$	$0.220\lambda\sqrt{f'_c}$	$0.110\lambda\sqrt{f'_c}$	$0.126\lambda\sqrt{f'_c}$	—
d	1.0	1.0	0.0	1.0	0.0	0.0	0.7	1.0	0.7	1.0	1.0	1.0	γ_{TG}	1.0	1.0	$0.190\lambda\sqrt{f'_c}$	$0.220\lambda\sqrt{f'_c}$	$0.110\lambda\sqrt{f'_c}$	$0.126\lambda\sqrt{f'_c}$	1
e	1.0	0.0	1.0	1.0	1.0	0.0	0.3	0.0	0.3	1.0	1.0	1.0	γ_{TG}	1.0	1.0	$0.190\lambda\sqrt{f'_c}$	$0.220\lambda\sqrt{f'_c}$	$0.110\lambda\sqrt{f'_c}$	$0.126\lambda\sqrt{f'_c}$	2
f	1.0	0.0	0.0	1.0	1.0	1.0	0.3	0.0	0.3	1.0	1.0	1.0	γ_{TG}	1.0	1.0	$0.190\lambda\sqrt{f'_c}$	$0.220\lambda\sqrt{f'_c}$	$0.110\lambda\sqrt{f'_c}$	$0.126\lambda\sqrt{f'_c}$	3

for concrete anchors in Chapter 17, "Anchoring to Concrete," and Chapter 26, "Construction Documents and Inspection," of the *Building Code Requirements for Structural Concrete* (ACI 318-19) *and Commentary* (ACI 318R-19).[3] A 2021 agenda item for the AASHTO LRFD specifications updated Article 5.13 to reflect those changes. This 2022 agenda item will make the next edition of the *AASHTO LRFD Bridge Construction Specifications*[4] consistent with the design provisions that were updated in 2021. This agenda item covers the installation and inspection of cast-in-place and post-installed anchors in concrete that are used to resist tension or shear, or a combination thereof, and designed in accordance with the applicable provisions of Article 5.13 of the AASHTO LRFD specifications, 10th edition (see Editor's Note). The anchor types covered in this specification include:

- headed studs, headed bolts, and hooked bolts,
- post-installed expansion (torque-controlled and displacement controlled) anchors that meet the assessment criteria of ACI CODE-355.2,[5]
- post-installed undercut anchors that meet the assessment criteria of ACI CODE-355.2,
- post-installed adhesive anchors meeting the assessment criteria of ACI CODE-355.4,[6] and
- post-installed screw anchors meeting the assessment criteria of ACI CODE-355.2.

The forthcoming revised construction specifications[4] include in-depth specification and commentary language to cover a broad range of issues. Section 29.2, "Materials and Pre-Qualification," gives important details on materials conformance requirements. Section 29 broadly references the manufacturer's printed installation instructions (MPII) and the use of MPIIs. Importantly, MPIIs are to include all information needed to properly install any post-installed anchors. The types and diameters of drill bits that may be used, cleaning instructions, mixing instructions, gel and cure times, set requirements, and other pertinent installation information are all covered in this section. This section also includes guidance and requirements on the prequalification process, working drawings, and submittal processes for post-installed anchors. Section 29.3 covers the installation and inspection processes. The revised Section 29.3.1 reads as follows:

Substitution of any anchor type for another anchor type shall not be permitted without the approval of the Designer.

When using cast-in-place anchors, all anchors, their attachments, and anchor reinforcement shall be securely positioned in the formwork and oriented in accordance with the contract documents. Concrete shall be consolidated around the anchors and reinforcement in accordance with Article 8.7.4.

For post-installed anchors, drill the hole to the appropriate depth as provided by the contract documents. The hole shall be drilled and cleaned with equipment and using a process in accordance with the MPII. Protect anchors intended for attachment with future work in a manner which will prevent the degradation of the anchor element or any permissible coatings.

For adhesive anchors, ensure that the adhesive has a characteristic bond strength in cracked and uncracked concrete consistent with what is required in the contract documents. Adhesive shall be stored in a manner and at a temperature specified by the manufacturer. Adhesive anchors oriented in a horizontal or upwardly inclined orientation shall be installed by a certified ACI Adhesive Anchor Installer.

(a) The Contractor shall furnish the ACI Registration Number of all Adhesive Anchor Installers working on the project a minimum of 30 days prior to installation.

(b) All Adhesive Anchor Installers working on the project shall provide their ACI Certification Card in the field upon request by the Engineer or Owner.

Adhesives shall be mixed in accordance with the MPII and shall not be disturbed after the manufacturer established gel time. Loads shall not be applied to adhesive anchors until the adhesive has completely cured. Adhesives shall be installed in concrete having a minimum age of 21 days at the time of anchor installation.

Anchors shall be installed with a minimum edge distance of the anchor as established in the contract documents. The hole depth and diameter shall be verified to be consistent with the contract documents and the MPII prior to anchor installation.

If there is a discrepancy between the contract documents and the

MPII, resolve with the Designer and product manufacturer prior to drilling and installation.

Section 29.3.2 articulates that all inspections are to be performed by a certified inspector or a qualified inspector specifically approved for that purpose by the owner, and it provides additional details on important aspects of the inspection process. For example, adhesive anchors in a horizontal or upwardly inclined orientation or intended to hold sustained tension are to be continuously inspected during installation for compliance with the MPII and the contract documents. Other anchors and adhesive anchors are to be periodically inspected during installation for compliance with the MPII and the contract documents. This section also requires demonstration testing and production proof testing of post-installed anchors. Section 29.4 covers measurements, and Section 29.5 focuses on payments.

References

1. Association of State Highway and Transportation Officials (AASHTO). Forthcoming. *AASHTO LRFD Bridge Design Specifications*, 10th ed. Washington, DC: AASHTO.
2. AASHTO. 2020. *AASHTO LRFD Bridge Design Specifications*, 9th ed. Washington, DC: AASHTO.
3. 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.
4. AASHTO. Forthcoming. *AASHTO LRFD Bridge Construction Specifications*, 5th ed. Washington, DC: AASHTO.
5. ACI Committee 355. 2022. *Post-Installed Mechanical Anchors in Concrete—Qualification Requirements and Commentary.* ACI CODE-355.2-22. Farmington Hills, MI: ACI.
6. ACI Committee 355. 2019. *Qualification of Post-Installed Adhesive Anchors in Concrete and Commentary.* ACI CODE-355.4-19. Farmington Hills, MI: ACI.

EDITOR'S NOTE

ASPIRE® *featured a four-part series on concrete anchors and their incorporation into the* AASHTO LRFD Bridge Design Specifications. *The topic of each article, the* ASPIRE *issue in which it appeared, and the corresponding link are as follows:*

Part 1 appeared in the Summer 2020 issue of ASPIRE. *The article discussed results of the National Transportation Safety Board report outlining the failure of epoxy-adhesive anchors on Boston's Big Dig project in 2006 and the PCI program sponsored by the Transportation Research Board to educate bridge engineers on the implementation of the concrete anchorage provisions in the AASHTO LRFD specifications. https://www.aspirebridge.com /magazine/2020Summer/AASHTO -LRFD-AnchorsInConcrete.pdf*

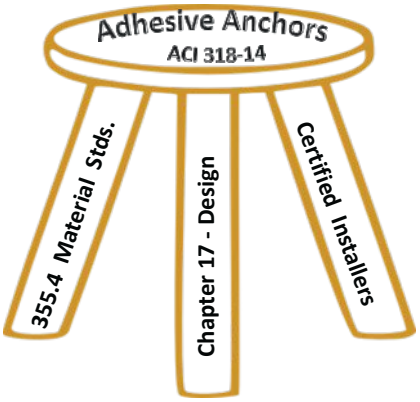
Part 2 appeared in the Fall 2020 issue of ASPIRE. *It discussed the qualification procedures that manufacturers must follow for testing and establishing design values for concrete anchors. (ACI CODE-355.2,* Qualification of Post-Installed Mechanical Anchors in Concrete and Commentary *and ACI CODE-355.4,* Qualification of Post-Installed Adhesive Anchors in Concrete and Commentary*) https://www.aspirebridge.com /magazine/2020Fall/AASHTO-LRFD -AnchorsInConcrete.pdf*

Part 3 appeared in the Winter 2021 issue of ASPIRE. *The procurement of concrete anchors was discussed in this part of the series. Anchor design, materials, installation, installer certification, and inspection requirements to be indicated in contract documents were also covered. https://www.aspirebridge.com /magazine/2021Winter/LRFD -AnchorsInConcrete.pdf*

Part 4 appeared in the Spring 2021 issue of ASPIRE. *This article discussed the certification for anchor installers and inspectors, inspection requirements, and compliance testing of installed anchors. https://www.aspirebridge.com /magazine/2021Spring/AASHTOLRFD -AnchorsInConcrete.pdf*

Access to the PCI five-session webinar training series on concrete anchor design is available at PCI.org/AnchoringToConcreteImp

For each of the five webinars, the following are available to download: the PowerPoint slides used in the presentation, a video of the presentation, the text of the presentation, course resource documents, and a transcript of all the questions asked at the end of each webinar and the answers provided. These materials are available at no charge.



There are three legs to the adhesive anchor quality stool: design procedure, qualification protocol, and installer certification.

Concrete breakout failure of an anchor where the tension load strength has been influenced by the distance from the center of the anchor to the free edge of the member.