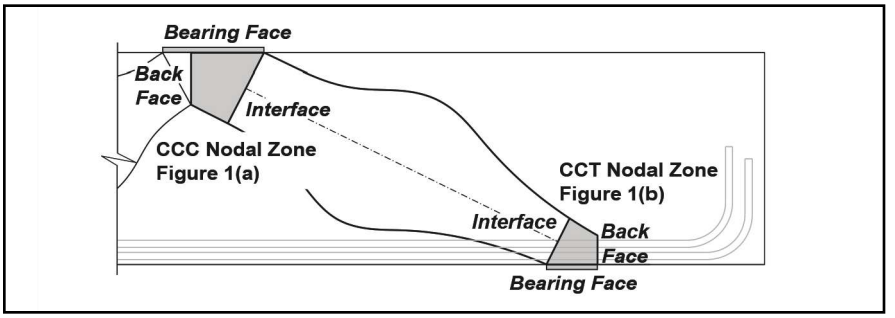
The *AASHTO LRFD Bridge Design Specifications:* Section 5 Reorganization

by R. Kent Montgomery, FIGG, Dr. Shri Bhide, Bentley Systems Inc., and Gregg Freeby, Texas Department of Transportation

The first edition of the American Association of State Highway and Transportation Officials' *AASHTO LRFD Bridge Design Specifications* was published in 1994. Since that time, the AASHTO LRFD specifications have been continuously updated with interim revisions. After nearly 25 years some users were expressing some frustrations about the concrete design section of the specifications, Section 5. Many engineers felt the organization of the section had become confusing and that there were inconsistencies among articles. Therefore, there was a need to reorganize Section 5 of the AASHTO LRFD specifications to provide better organization, clarity, and consistency among articles.



New and enhanced figures explaining strut-and-tie model.

Reorganization Process

A pooled fund project to reorganize Section 5 was initiated by the AASHTO T-10, Concrete Design Technical Committee of the Subcommittee on Bridges and Structures (SCOBS). Oversight throughout the project was provided by the AASHTO T-10 committee and the Federal Highway Administration (FHWA). To obtain a broader perspective, the AASHTO T-10 committee invited industry liaisons, including the Precast/Prestressed Concrete Institute (PCI) and the American Segmental Bridge Institute (ASBI), to participate in the reorganization. Modjeski and Masters, along with Dr. Dennis Mertz, was selected as the contractor for the reorganization process, with Dr. John Kulicki and Dr. Dennis Mertz taking the lead roles in editing and tracking changes.

The project began with a survey of stakeholders early in 2013. The results of this survey were remarkably consistent as to what improvements to Section 5 were needed and provided clear direction to the augmented reorganization committee. Past interim revisions were critically reviewed for accuracy, as well as to make sure no inconsistencies with other articles had been introduced into Section 5. At this point a revised table of contents (TOC) was developed by the reorganization committee. This TOC set the major reorganization of the section. A working draft of the reorganized articles was then developed as the starting point for determining what further changes, clarifications, and updates were needed.

It was determined that the reorganization should be an evolution of Section 5 to make it easier to understand and utilize. It was not to be a revolution of new concepts and procedures, unless especially needed. Major decisions included:

- Keeping the units of kips and inches
- Advancing the concept of beam and disturbed design regions (B-Regions and D-Regions) and promoting the use of the strut-and-tie model (STM) for the analysis of disturbed regions
- Keeping the current bending and axial design articles for B-Regions
- Reducing the number of shear design procedures
- Consolidating prestressed reinforcement details, non-prestressed reinforcement details, and seismic details into three separate articles
- Having topics and procedures appear only once in the section
- Organizing Section 5 such that more common design provisions appear before more unique design provisions

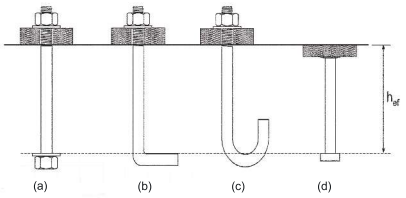
During the project, the reorganization committee determined that two major changes were especially needed. These changes were a significant reformulation of the STM provisions and the addition of an article on anchors. The reformulation of the STM provisions was deemed of such importance that the changes were developed ahead of the reorganization and were included in the 2016 Interim Revisions.

During the course of the reorganization, there were five working meetings of the reorganization committee and seven draft documents. Over 1000 comments on the drafts were addressed and incorporated. In late 2015, the reorganization committee had a completed draft that satisfied the original goals. This draft was made available to AASHTO members for review and comment through the typical SCOBS process. Additionally, a webinar was held to help inform the AASHTO members about the reorganized Section 5. The webinar was taped and is available for those interested in viewing this resource. A final version of Section 5 was balloted at the 2016 annual SCOBS meeting and unanimously passed. The reorganized Section 5 will be included in the Eighth Edition of the *AASHTO LRFD Bridge Design Specifications* available in 2017.

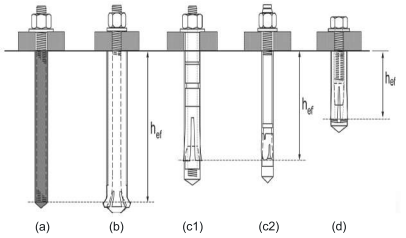
Reorganized Section 5—The Big Picture

Articles 5.1 through 5.5 are largely unchanged except for the introduction of B-Regions and D-Regions in Article 5.1 and articles defining these regions in Article 5.5. Old Article 5.6 received a lot of comments from the survey and contained somewhat miscellaneous information, including provisions for imposed deformations and the STM method. These provisions have been moved to more appropriate articles in Section 5.

Articles 5.6 and 5.7 now cover the sectional (B-Region) design provisions for flexure and axial loads, and shear and torsion, respectively. The shear design section has been condensed. This article now covers general shear and torsion requirements, such as minimum reinforcement and bar spacing, one shear design procedure (modified compression field theory [MCFT]), and shear friction provisions. The outdated prestressed concrete beam shear design



Cast-in-place anchors (a) hex head bolt with washer; (b) L-bolt; (c) J-bolt welded; (d) headed stud. Source: ACI 318-14.



Post-installed anchors (a) adhesive anchor; (b) undercut anchor; (c) Torque-controlled expansion anchors; (c1) sleeve-type and (c2) stud type; and (d) drop-in type displacement controlled expansion anchor. Source: ACI 318-14.

provisions (V_{ci} and V_{cw}) have been eliminated from the specification. The historic segmental shear design provisions from the Segmental Guide Specifications have been retained, but moved to Article 5.12.5, which is a structure-specific article for segmental concrete bridges.

Article 5.8 now contains provisions for the design of D-Regions. The revised STM provisions from the 2016 interim provisions are included in this article and their use is encouraged but not required. However, some engineers may prefer utilizing methods that they have already been using successfully for years. As such, two other methods are allowed and contained in this article. The first is the elasticity-based methods and the second is the historic, and many times semi-empirical, equations that were in the old Article 5.10.9.6, as well as various provisions under the old Article 5.13 for specific members. The older equations became known as the "legacy methods" during the project. The thinking is that these methods will be used less as engineers become more comfortable using the STM.

Article 5.9 still covers design of prestressed elements and now has a better separation of pretensioning and post-tensioning. Note that detailing aspects of prestressing are included, where before they were mixed in with reinforcement detailing in old Article 5.10. The principal stress check for the webs has been added to the stress limitations in this article. The principal stress check has been made applicable to all concrete bridge types, except pretensioned beams with compressive strengths less than 10 ksi where historic evidence has shown web cracking to not be an issue.

Articles 5.10 and 5.11 cover non-prestressed reinforcement and seismic details, respectively. Note that now prestressing details, reinforcing details, and seismic details each have their own article rather than being mixed together throughout various articles as was the case before the reorganization. Article 5.12 contains provisions for specific structure types and components, such as beams and girders, segmental construction, and footings. This article contains much of what used to be contained in old Articles 5.13 and 5.14.

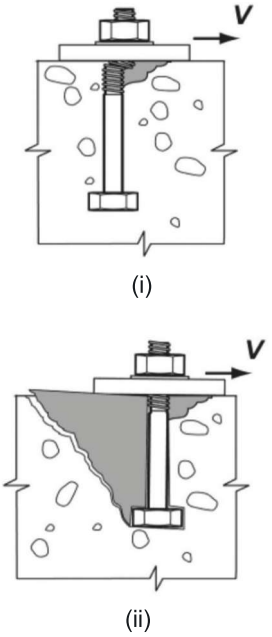
Article 5.13 is new and covers concrete anchors. These are anchor studs and headed bolts, not to be confused with post-tensioning anchorages. This article is linked to Chapter 17—Anchoring to Concrete of the *Building Code Requirements for Structural Concrete (ACI 318-14) and Commentary (ACI 318R-14)*, with some exceptions. Article 5.13 provides guidance on what types of anchors in ACI 318-14 are covered in Section 5. The resistance of cast-in-place anchors can be obtained by the calculation methods of ACI 318-14, or by using the acceptance testing methods specified in ACI 355.2-07, *Qualification of Post-Installed Mechanical Anchors in Concrete & Commentary*. Post-installed anchor resistance is obtained using the acceptance testing methods in ACI 355.4-11, *Qualification of Post-Installed Adhesive Anchors in Concrete and Commentary*. For adhesive anchors, the resistance is further reduced by 50% for sustained tensile loads.

Article 5.14 covers durability. Rather than being prescriptive, it serves as a toolbox of best practices that owners and designers may choose from to achieve greater durability. Finally, Article 5.15 still contains the references.

Throughout the process of reorganizing Section 5, articles were reworded for better clarity. The somewhat ambiguous term "mild reinforcement" was replaced with the preferred "nonprestressed reinforcement" to add clarity to these provisions. Conditional statements were made consistent throughout the section and terminology was condensed and made consistent throughout. Minor corrections were made throughout for any errors that were found.

Summary

The reorganization of Section 5 was a comprehensive effort to improve the concrete design section of the AASHTO LRFD specifications. The augmented reorganization committee included the AASHTO T-10 Committee and representatives from FHWA, as well as liaisons from the concrete industry. This provided a broad range of experience and views to help make the specification as clear, accurate, and user-friendly as possible. The authors of this article hope that users of the reorganized Section 5 concrete specification will find that this goal has been achieved and that this helps make the design of concrete bridges more efficient, both from the standpoint of design efficiency and the engineering effort to produce the design.



Shear failure modes (i) Steel failure preceeded by concrete spall; (ii) Concrete pryout for anchors far from a free edge.

Additional Resources

To aid with the transition, a "cross-walk" is available that lists the old article numbers for all the new article numbers and vice versa. A cross reference document is also available for cross-referencing other AASHTO specifications, such as other sections of the AASHTO LRFD specifications, the *AASHTO LRFD Bridge Construction Specification*, and the *Manual for Bridge Evaluation*. This will aid engineers as they implement designs with the new Section 5, as well as owners and software developers as they update design manuals and software. The aforementioned webinar is also available.

EDITOR'S NOTE

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