The *AASHTO LRFD Bridge Design Specifications:* A Retrospective

by Dr. Henry G. Russell

The first edition of the American Association of State Highway and Transportation Officials' *AASHTO LRFD Bridge Design Specifications* was published in 1994 after 8 years of study and development. The eighth edition will be published in 2017 and will include the first reorganization of Section 5: Concrete Structures. This article reviews some of the changes introduced in the specifications from the first to the eighth editions and is based largely on the articles written by Dr. Dennis Mertz for *ASPIRE*.™

Methodology

The specifications were based on a new probabilistically based design methodology termed *load and resistance factor design* (LRFD). Although similar to the AASHTO *Standard Specifications*, which the LRFD specifications replaced in 2008, the load and resistance factors of the LRFD specifications were determined using the theory of structural reliability. The goal was to provide bridges with a target reliability index of 3.5, which corresponds to a probability of failure of 2 in 10,000.

The LRFD specifications introduced the concept of limit states for service, fatigue, strength, and extreme event design along with a new live load model. Section 5: Concrete Structures introduced a unified approach to concrete bridge design by combining the design provisions for nonprestressed and prestressed concrete members. The concept of having a parallel commentary was also adopted to provide background or additional explanation of the articles without becoming a textbook.

Shear Provisions

The first edition of the AASHTO LRFD specifications introduced the sectional design model for shear design based on the modified compression field theory (MCFT). The method involved the determination of β, a factor indicating the ability of diagonally cracked concrete to transmit tension and shear, and θ, the angle of inclination of diagonal compressive stresses. Graphs and tables were provided for their determination. Engineers and bridge owners did not readily accept the complications and iterative nature of the MCFT as presented.

This lack of acceptance led to a research project to find a simpler way to estimate shear resistance and to the introduction of a simplified method in the 2007 Interim Revisions. The simpler method was similar to that used in the AASHTO *Standard Specifications* and the American Concrete Institute approach for buildings. This method will not be included in the eighth edition.

In the 2008 Interim Revisions, the MCFT was simplified by including equations for the calculation of β and θ. This made the MCFT easier to use for both design and analysis. The tables associated with the previous method were retained in an appendix.

High-strength Concrete

The first edition of the LRFD specifications limited the concrete compressive strength to be used in design to a maximum value of 10.0 ksi unless tests are made to establish relationships with concrete strength. Subsequently, four National Cooperative Highway Research Program (NCHRP) projects addressing prestress

Dr. Dennis R. Mertz

Dr. Dennis R. Mertz, PE, professor of civil and environmental engineering and director of the Center for Innovative Bridge Engineering at the University of Delaware, died on August 12, 2016.

Mertz contributed articles about the *AASHTO LRFD Bridge Design Specifications* to every issue of *ASPIRE* from its inaugural issue in 2007 through Summer 2016. He had a tremendous knowledge of these specifications, having been a co-principal investigator for the development and writing of the first edition. Subsequently, he continued to work with the AASHTO Subcommittee on Bridges and Structures and its technical committees to advance the implementation of new technology through the development of new specification articles. This included at least 16 years with Technical Committee T-10—Concrete Design. Mertz was always there to clarify language and intent and redirect committees when their proposed changes became too complex because of their desire to be precise. He had the ability to take a complex subject and make it sound simple in both the written and spoken word. His technical presentations were always well received.

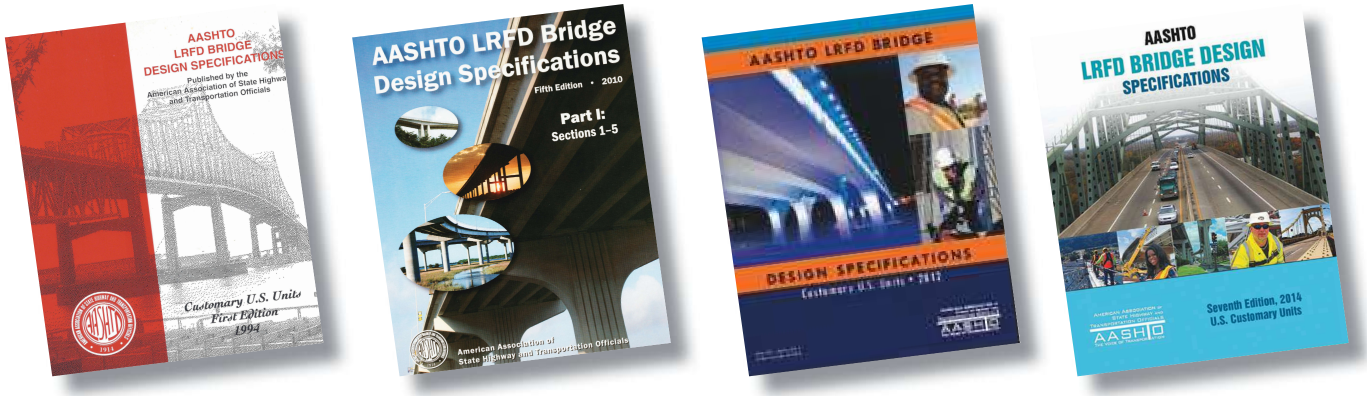
Mertz devoted himself to bridge engineering for both steel and concrete bridges, so much so that he spent his 2003 sabbatical at the Florida Department of Transportation helping to coalesce its design and load rating procedures. He loved conceptualizing complex, interdependent variables. His involvement in the activities of the National Academies included participation in many National Cooperative Highway Research Program projects and membership in several Transportation Research Board committees.

Mertz was the founding editor of the American Society of Civil Engineers' *Journal of Bridge Engineering*. He received many awards for his contributions to the bridge industry. Earlier this year, he was the recipient of the International Bridge Conference John A. Roebling Medal, which recognizes an individual for lifetime achievement in bridge engineering.

When asked why Mertz should be selected to write for *ASPIRE*, John Dick—the magazine's first executive editor—responded, "There is no better person to write on behalf of concrete bridges than someone known for his work on steel bridges." Mertz's contributions to *ASPIRE* have ranged from articles about shear and torsion to explaining load ratings. He kept us updated with explanations about the changes in each interim and new edition of the LRFD specifications. He was actively involved in preparing the recently approved reorganization of Section 5.

These brief articles in *ASPIRE* provide us with a legacy record of what has changed over the years and why. They will be available to bridge engineers for years to come when nobody can remember why an article on the specifications was written in the first place.

Thank you, Dennis, for your many important contributions and for a job well done.



Several editions of the AASHTO LRFD Bridge Design Specifications.

losses, shear design, development lengths, and design for flexure and axial load were initiated to investigate the use of higher-strength concretes. Over a period of several years, the results of the research were implemented in the specifications to permit concrete compressive strengths up to 15.0 ksi for many design provisions.

High-strength Reinforcement

The first edition of the LRFD specifications limited the yield stress to be used in design for nonprestressed reinforcement to a maximum value of 75.0 ksi. The 2013 Interim Revisions extended the minimum yield strength for use in design to 100.0 ksi for most nonseismic bridge applications without significant changes to the LRFD design philosophy and methodology.

Lightweight Concrete

The 2016 Interim Revisions included a comprehensive revision of the articles related to lightweight concrete based on Federal Highway Administration and NCHRP research projects. The definition of lightweight concrete was extended up to an equilibrium density of 0.135 kip/ft^3, which is considered the lower limit for normalweight concrete. The terms *sand-lightweight concrete* and *all-lightweight concrete* were removed. Instead, a concrete density modification factor λ was introduced to modify various traditional resistance equations, stress limits, and development lengths based on the concrete unit weight. The shear strength reduction factor for lightweight concrete was set equal to the factor for normal-weight concrete.

Strut-and-tie Modeling

The first edition of the AASHTO LRFD specifications introduced a limited amount of procedures for strut-and-tie modeling. The 2016 Interim Revisions provided a complete rewrite of this material. The rewrite was based on an examination of previous tests; additional large-scale, deep beam tests; and a comparison of current AASHTO provisions with those used in Europe for many years.