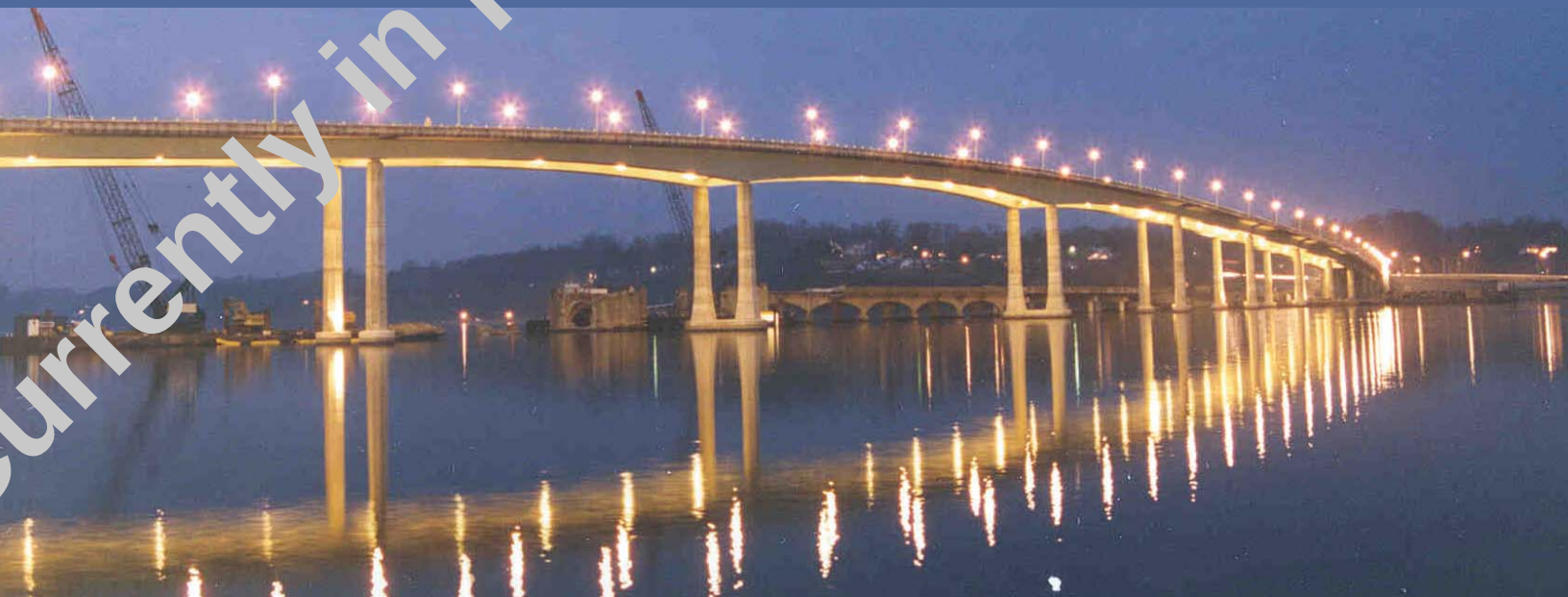
AASHTO LRFD Bridge Design Specifications

SI Units
4th Edition
2007

American Association of State Highway and Transportation Officials



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FOREWORD

The first broadly recognized national standard for the design and construction of bridges in the United States was published in 1931 by the American Association of State Highway Officials (AASHO), the predecessor to AASHTO. With the advent of the automobile and the establishment of highway departments in all of the American states dating back to just before the turn of the century, the design, construction, and maintenance of most U.S. bridges was the responsibility of these departments and, more specifically, the chief bridge engineer within each department. It was natural, therefore, that these engineers, acting collectively as the AASHTO Highway Subcommittee on Bridges and Structures, would become the author and guardian of this first bridge standard.

This first publication was entitled *Standard Specifications for Highway Bridges and Incidental Structures*. It quickly became the *de facto* national standard and, as such, was adopted and used by not only the state highway departments but also other bridge-owning authorities and agencies in the United States and abroad. Rather early on, the last three words of the original title were dropped and it has been reissued in consecutive editions at approximately four-year intervals ever since as *Standard Specifications for Highway Bridges*, with the final 17th edition appearing in 2002.

The body of knowledge related to the design of highway bridges has grown enormously since 1931 and continues to do so. Theory and practice have evolved greatly, reflecting advances through research in understanding the properties of materials, in improved materials, in more rational and accurate analysis of structural behavior, in the advent of computers and rapidly advancing computer technology, in the study of external events representing particular hazards to bridges such as seismic events and stream scour, and in many other areas. The pace of advances in these areas has, if anything, stepped up in recent years. To accommodate this growth in bridge engineering knowledge, the Subcommittee on Bridges and Structures has been granted authority under AASHTO's governing documents to approve and issue Bridge Interims each year, not only with respect to the Standard Specifications but also to incrementally modify and enhance the twenty-odd additional documents on bridges and structures engineering that are under its guidance and sponsorship.

In 1986, the Subcommittee submitted a request to the AASHTO Standing Committee on Research to undertake an assessment of U.S. bridge design specifications, to review foreign design specifications and codes, to consider design philosophies alternative to those underlying the Standard Specifications, and to render recommendations based on these investigations. This work was accomplished under the National Cooperative Highway Research Program (NCHRP), an applied research program directed by the AASHTO Standing Committee on Research and administered on behalf of AASHTO by the Transportation Research Board (TRB). The work was completed in 1987, and, as might be expected with a standard incrementally adjusted over the years, the Standard Specifications were judged to include discernible gaps, inconsistencies, and even some conflicts. Beyond this, the specification did not reflect or incorporate the most recently developing design philosophy, load-and-resistance factor design (LRFD), a philosophy which has been gaining ground in other areas of structural engineering and in other parts of the world such as Canada and Europe.

From its inception until the early 1970s, the sole design philosophy embedded within the Standard Specifications was one known as working stress design (WSD). WSD establishes allowable stresses as a fraction or percentage of a given material's load-carrying capacity, and requires that calculated design stresses not exceed those allowable stresses. Beginning in the early 1970s, WSD began to be adjusted to reflect the variable predictability of certain load types, such as vehicular loads and wind forces, through adjusting design factors, a design philosophy referred to as load factor design (LFD). Both WSD and LFD are reflected in the current edition of the Standard Specifications.

A further philosophical extension results from considering the variability in the properties of structural elements, in similar fashion to load variabilities. While considered to a limited extent in LFD, the design philosophy of load-and-resistance factor design (LRFD) takes variability in the behavior of structural elements into account in an explicit manner. LRFD relies on extensive use of statistical methods, but sets forth the results in a manner readily usable by bridge designers and analysts.

With the advent of these specifications, bridge engineers had a choice of two standards to guide their designs, the long-standing AASHTO *Standard Specifications for Highway Bridges*, and the alternative, newly adopted *AASHTO LRFD Bridge Design Specifications*, and its companions, *AASHTO LRFD Bridge Construction Specifications* and *AASHTO LRFD Movable Highway Bridge Design Specifications*. Subsequently, the Federal Highway Administration (FHWA) and the states have established a goal that LRFD standards be incorporated in all new bridge designs after 2007.

Interim Specifications are usually published in the middle of the calendar year, and a revised edition of this book is generally published every four years. The Interim Specifications have the same status as AASHTO standards, but are tentative revisions approved by at least two-thirds of the Subcommittee. These revisions are voted on by the AASHTO member departments prior to the publication of each new edition of this book and, if approved by at least two-thirds of the

members, they are included in the new edition as standards of the Association. AASHTO members are the 50 State Highway or Transportation Departments, the District of Columbia, and Puerto Rico. Each member has one vote. The U.S. Department of Transportation is a nonvoting member.

Annual Interim Specifications are generally used by the States after their adoption by the Subcommittee. Orders for these annual Interim Specifications may be placed by visiting our web site, bookstore.transportation.org; calling the AASHTO Publication Sales Office toll free (within the U.S. and Canada), 1-800-231-3475; or mailing to P.O. Box 96716, Washington, DC 20906-6716. A free copy of the current publication catalog can be downloaded from our website or requested from the Publications Sales Office.

Attention is also directed to the following publications prepared and published by the Subcommittee on Bridges and Structures:

AASHTO Guide for Commonly Recognized (CoRe) Structural Elements. 1998.

AASHTO Guide Specifications for Horizontally Curved Steel Girder Highway Bridges with Design Examples for I-Girder and Box-Girder Bridges. 2003.

AASHTO Guide Specifications—Thermal Effects in Concrete Bridge Superstructures. 1989.

AASHTO LRFD Bridge Construction. 2004.

AASHTO LRFD Movable Highway Bridge Design. 1998.

Bridge Data Exchange (BDX) Technical Data Guide. 1995.

Bridge Welding Code: AASHTO/AWS-D1.5M/D1.5: 2002, an American National Standard. 2002.

Construction Handbook for Bridge Temporary Works. 1995.

Guide Design Specifications for Bridge Temporary Works. 1995.

Guide for Painting Steel Structures. 1997.

Guide Manual for Condition Evaluation and Load and Resistance Factor Rating (LRFR) of Highway Bridges. 2003.

Guide Specifications and Commentary for Vessel Collision Design of Highway Bridges. 1991.

Guide Specifications for Alternate Load Factor Design Procedures for Steel Beam Bridges Using Braced Compact Sections. 1991.

Guide Specifications for Aluminum Highway Bridges. 1991.

Guide Specifications for Bridge Railings. 1989.

Guide Specifications for Design and Construction of Segmental Concrete Bridges. 1999.

Guide Specifications for Design of Pedestrian Bridges. 1997.

Guide Specifications for Fatigue Evaluation of Existing Steel Bridges. 1990.

Guide Specifications for Highway Bridge Fabrication with HPS070W Steel. 2000.

Guide Specifications for Seismic Isolation Design. 1999.

Guide Specifications for Strength Design of Truss Bridges (Load Factor Design). 1986.

Guide Specifications for Strength Evaluation of Existing Steel and Concrete Bridges. 1989.

Guide Specifications for Structural Design of Sound Barriers. 1989.

Guide Specifications for the Design of Stress-Laminated Wood Decks. 1991.

Guidelines for Bridge Management Systems. 1993.

Manual for Condition Evaluation of Bridges. 2000.

Movable Bridge Inspection, Evaluation and Maintenance Manual. 1998.

Standard Specifications for Movable Highway Bridges. 1988.

Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals. 2001.

Additional bridges and structures publications prepared and published by other AASHTO committees and task forces are as follows:

Guide Specifications for Cathodic Protection of Concrete Bridge Decks. 1994.

Guide Specifications for Polymer Concrete Bridge Deck Overlays. 1995.

Guide Specifications for Shotcrete Repair of Highway Bridges. 1998.

Inspector's Guide for Shotcrete Repair of Bridges. 1999.

Manual for Corrosion Protection of Concrete Components in Bridges. 1992.

Two Parts: Guide Specifications for Concrete Overlay Pavements and Bridge Decks. 1990.

AASHTO Maintenance Manual: The Maintenance and Management of Roadways and Bridges. 1999.

The following bridges and structures titles are the result of the AASHTO/NSBA Steel Bridge Collaboration and are available for free download from the AASHTO web site, bookstore.transportation.org:

Design Drawing Presentation Guidelines. 2003.

Guidelines for Design Constructability. 2003.

Guide Specification for Coating Systems with Inorganic Zinc-Rich Primer. 2003.

Shop Detail Drawing Presentation Guidelines. 2003.

Shop Detail Drawing Review/Approval Guidelines. 2003.

Steel Bridge Fabrication Guide Specification. 2003.

Steel Bridge Fabrication QC/QA Guide Specification. 2003.

The following have served as chairmen of the Subcommittee on Bridges and Structures since its inception in 1921: Messrs. E. F. Kelley, who pioneered the work of the Subcommittee; Albin L. Gemeny; R. B. McMinn; Raymond Archiband; G. S. Paxson; C. M. Johnson; Ward Goodman; Charles Matlock; Joseph S. Jones; Sidney Poleynard; Jack Freidenrich; Henry W. Derthick; Robert C. Cassano; Clellon Loveall; James E. Siebels; David Pope; Tom Lulay; and Malcolm T. Kerley. The Subcommittee expresses its sincere appreciation of the work of these men and of those active members of the past, whose names, because of retirement, are no longer on the roll.

The Subcommittee would also like to thank Mr. John M. Kulicki, Ph.D., and his associates at Modjeski and Masters for their valuable assistance in the preparation of the LRFD Specifications.

Suggestions for the improvement of the LRFD Specifications are welcomed, just as they were for the Standard Specifications before them. They should be sent to the Chairman, Subcommittee on Bridges and Structures, AASHTO, 444 North Capitol Street, N.W., Suite 249, Washington, DC 20001. Inquiries as to intent or application of the Specifications should be sent to the same address.

PREFACE AND
ABBREVIATED TABLE OF CONTENTS

The *AASHTO LRFD Bridge Design Specifications*, 4th Edition contains the following 14 sections and an index:

1. Introduction
2. General Design and Location Features
3. Loads and Load Factors
4. Structural Analysis and Evaluation
5. Concrete Structures
6. Steel Structures
7. Aluminum Structures
8. Wood Structures
9. Decks and Deck Systems
10. Foundations
11. Abutments, Piers, and Walls
12. Buried Structures and Tunnel Liners
13. Railings
14. Joints and Bearings

Index

Detailed Tables of Contents precede each section. References follow each section, listed alphabetically by author.

Figures, tables, and equations are denoted by their home article number and an extension, for example 1.2.3.4.5-1, but when they are referenced in their home article or its commentary, they are identified only by the extension. For example, in Article 1.2.3.4.5, Eq. 1.2.3.4.5-2 would simply be called "Eq. 2." When this equation is referenced anywhere else other than its home article, it is identified by its whole nomenclature; in other words, "Eq. 1.2.3.4.5-2." The same convention applies to figures and tables.

Please note that the AASHTO materials specifications (starting with M or T) cited throughout the LRFD Specifications can be found in *Standard Specifications for Transportation Materials and Methods of Sampling and Testing,* adopted by the AASHTO Highway Subcommittee on Materials. Unless otherwise indicated, these citations refer to the current 25th edition. ASTM material specifications are also cited.

Please note that this year marks the final SI edition of the *AASHTO LRFD Bridge Design Specifications*. In the future, the book will only be published in customary U.S. units. Note also that this time Section 8, "Wood Structures," is in customary U.S. units. AASHTO apologizes for any inconvenience to wood bridge designers working in SI units.

SECTION 1 (SI): INTRODUCTION

TABLE OF CONTENTS

1.1 SCOPE OF THE SPECIFICATIONS 1-1
1.2 DEFINITIONS 1-2
1.3 DESIGN PHILOSOPHY 1-3
1.3.1 General 1-3
1.3.2 Limit States 1-3
1.3.2.1 General 1-3
1.3.2.2 Service Limit State 1-4
1.3.2.3 Fatigue and Fracture Limit State 1-4
1.3.2.4 Strength Limit State 1-4
1.3.2.5 Extreme Event Limit States 1-5
1.3.3 Ductility 1-5
1.3.4 Redundancy 1-6
1.3.5 Operational Importance 1-6
REFERENCES 1-8

SECTION 1 (SI)

INTRODUCTION

1.1 SCOPE OF THE SPECIFICATIONS

The provisions of these Specifications are intended for the design, evaluation, and rehabilitation of both fixed and movable highway bridges. Mechanical, electrical, and special vehicular and pedestrian safety aspects of movable bridges, however, are not covered. Provisions are not included for bridges used solely for railway, rail-transit, or public utilities. For bridges not fully covered herein, the provisions of these Specifications may be applied, as augmented with additional design criteria where required.

These Specifications are not intended to supplant proper training or the exercise of judgment by the Designer, and state only the minimum requirements necessary to provide for public safety. The Owner or the Designer may require the sophistication of design or the quality of materials and construction to be higher than the minimum requirements.

The concepts of safety through redundancy and ductility and of protection against scour and collision are emphasized.

The design provisions of these Specifications employ the Load and Resistance Factor Design (LRFD) methodology. The factors have been developed from the theory of reliability based on current statistical knowledge of loads and structural performance.

Methods of analysis other than those included in previous Specifications and the modeling techniques inherent in them are included, and their use is encouraged.

The commentary is not intended to provide a complete historical background concerning the development of these or previous Specifications, nor is it intended to provide a detailed summary of the studies and research data reviewed in formulating the provisions of the Specifications. However, references to some of the research data are provided for those who wish to study the background material in depth.

The commentary directs attention to other documents that provide suggestions for carrying out the requirements and intent of these Specifications. However, those documents and this commentary are not intended to be a part of these Specifications.

Construction specifications consistent with these design specifications are the *AASHTO LRFD Bridge Construction Specifications*. Unless otherwise specified, the Materials Specifications referenced herein are the AASHTO *Standard Specifications for Transportation Materials and Methods of Sampling and Testing*.

C1.1

Horizontally curved concrete girders are not fully covered and were not part of the calibration data base.

The term "notional" is often used in these Specifications to indicate an idealization of a physical phenomenon, as in "notional load" or "notional resistance." Use of this term strengthens the separation of an engineer's "notion" or perception of the physical world in the context of design from the physical reality itself.

The term "shall" denotes a requirement for compliance with these Specifications.

The term "should" indicates a strong preference for a given criterion.

The term "may" indicates a criterion that is usable, but other local and suitably documented, verified, and approved criterion may also be used in a manner consistent with the LRFD approach to bridge design.