THE MANUAL FOR BRIDGE EVALUATION

SECOND EDITION

2011

American Association of State Highway and Transportation Officials

FOREWORD

The Manual for Bridge Evaluation (MBE) was first adopted by the AASHTO Highways Subcommittee on Bridges and Structures in 2005. The MBE combines the *Manual for Condition Evaluation of Bridges*, Second Edition (2000) and its 2001 and 2003 Interim Revisions with the *Guide Manual for Condition Evaluation and Load and Resistance Factor Rating (LRFR) of Highway Bridges*, First Edition and its 2005 Interim Revisions. Revisions based on approved agenda items from annual Subcommittee meetings in 2007 and 2008 are also incorporated into the MBE.

The Manual for Bridge Evaluation, First Edition supersedes the *Manual for Condition Evaluation of Bridges*, Second Edition and any revisions made in previous Interim Revisions. With the 2008 publication of the MBE, the Subcommittee confers archive status on the *Manual for Condition Evaluation of Bridges*, the *Guide Manual for Condition Evaluation and Load and Resistance Factor Rating (LRFR) of Highway Bridges*, and all Interim Revisions of both prior bridge evaluation titles.

AASHTO Highways Subcommittee on Bridges and Structures

PREFACE

Long anticipated and painstakingly developed, *The Manual for Bridge Evaluation* (MBE) offers assistance to Bridge Owners at all phases of bridge inspection and evaluation. An abbreviated table of contents follows this preface. Detailed tables of contents precede Sections 1 through 8.

Appendix A includes nine illustrative examples (A1 through A9), previously in the *Guide Manual for Condition Evaluation and Load and Resistance Factor Rating (LRFR) of Highway Bridges*. To assist users who are already familiar with these examples, the example numbers have been maintained. All examples are rated using the LRFR method. In addition, Examples A1, A2, and A4 are now rated using the ASR and LFR methods. To clarify which rating method is being illustrated, Examples A1, A2, and A4 are divided into Parts A through C and their articles are numbered accordingly as follows:

- Part A, LRFR;
- Part B, ASR and LFR; and
- Part C, example summary.

For ease of reference, the table of contents for Appendix A includes a summary table of the bridge types, rated members, rating live loads, limit states for evaluation, and rating methods, with the starting page number for each example and, in the case of Examples A1, A2, and A4, for each rating method. The typical detailed table of contents follows this summary table.

Appendix A includes numerous citations of other AASHTO bridge publications. To save space, the following shorthand has been adopted:

- "AASHTO" refers to *Standard Specifications for Highway Bridges*, 17th Edition, HB-17,
- "LRFD Design" refers to the current edition of the *AASHTO LRFD Bridge Design Specifications*, Fourth Edition, LRFDUS-4-M, and
- "MBE" refers to this publication, *The Manual for Bridge Evaluation*, Second Edition, MBE-2.

MBE includes a CD-ROM with many helpful search features that will be familiar to users of the *AASHTO LRFD Bridge Design Specifications* CD-ROM. Examples include:

- Bookmarks to all articles;
- Links within the text to cited articles, figures, tables, and equations;
- Links for current titles in reference lists to AASHTO's Bookstore; and
- The Acrobat search function.

AASHTO Publications Staff

ABBREVIATED TABLE OF CONTENTS

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SECTION 1:

INTRODUCTION

1.1—PURPOSE

This Manual serves as a standard and provides uniformity in the procedures and policies for determining the physical condition, maintenance needs, and load capacity of the nation's highway bridges.

C1.1

This Manual replaces both the 1994 AASHTO *Manual for Condition Evaluation of Bridges* and the 2003 AASHTO *Guide Manual for Condition Evaluation and Load and Resistance Factor Rating (LRFR) of Highway Bridges*. It serves as a single standard for the evaluation of highway bridges of all types.

1.2—SCOPE

This Manual has been developed to assist Bridge Owners by establishing inspection procedures and evaluation practices that meet the National Bridge Inspection Standards (NBIS). The Manual has been divided into eight Sections, with each Section representing a distinct phase of an overall bridge inspection and evaluation program.

Section 1 contains introductory and background information on the maintenance inspection of bridges as well as definitions of general interest terms. Key components of a comprehensive bridge file are defined in Section 2. The record of each bridge in the file provides the foundation against which changes in physical condition can be measured. Changes in condition are determined by field inspections. A bridge management system is an effective tool in allocating limited resources to bridge related activities. An overview of bridge management systems is included in Section 3. The types and frequency of field inspections are discussed in Section 4, as are specific inspection techniques and requirements. Conditions at a bridge site or the absence of information from original construction may warrant more elaborate material tests, and various testing methods are discussed in Section 5. Section 6 discusses the load rating of bridges and includes the Load and Resistance Factor method, the Load Factor method and the Allowable Stress method. No preference is placed on any rating method. The evaluation of existing bridges for fatigue is discussed in Section 7. Field load testing is a means of supplementing analytical procedures in determining the live-load capacity of a bridge and for improving the confidence in the assumptions used in modeling the bridge. Load test procedures are described in Section 8.

The successful application of this Manual is directly related to the organizational structure established by the Bridge Owner. Such a structure should be both effective and responsive so that the unique characteristics and special problems of individual bridges are considered in developing an appropriate inspection plan and load capacity determination.

C1.2

Much of the 2003 AASHTO *Guide Manual for Condition Evaluation and Load and Resistance Factor Rating (LRFR) of Highway Bridges* has been incorporated and updated in this Manual. Section 6 of this Manual includes the load ratings provisions of both the 2003 AASHTO *Guide Manual for Condition Evaluation and Load and Resistance Factor Rating (LRFR) of Highway Bridges* and the 1994 AASHTO *Manual for Condition Evaluation of Bridges.*

1.3—APPLICABILITY

The provisions of this Manual apply to all highway structures which qualify as bridges in accordance with the AASHTO definition for a bridge (see Article 1.5). These provisions may be applied to smaller structures which do not qualify as bridges.

C1.3

At the discretion of the Bridge Owner, the provisions of this Manual may be applied to highway bridge structures regardless of span or total length of bridge.

Federal regulations entitled the *National Bridge Inspection Standards* (NBIS) have been promulgated which establish minimum requirements for inspection programs and minimum qualifications for bridge inspection personnel. The NBIS apply to all highway bridges on public roads which are more than 20 ft in length.

1.4—QUALITY MEASURES

To maintain the accuracy and consistency of inspections and load ratings, Bridge Owners should implement appropriate quality control and quality assurance measures. Typical quality control procedures include the use of checklists to ensure uniformity and completeness, the review of reports and computations by a person other than the originating individual, and the periodic field review of inspection teams and their work. Quality assurance measures include the overall review of the inspection and rating program to ascertain that the results meet or exceed the standards established by the Owner.

C1.4

Quality control procedures are intended to maintain the quality of the bridge inspections and load ratings, and are usually performed continuously within the bridge inspection or load rating teams or units. The documented quality control plan may include:

- Defined quality control roles and responsibilities;
- Qualifications for Program Managers, bridge inspection personnel, and load rating personnel, including:
  - Education and certifications, or education and registration;
  - Initial training;
  - Years and type of experience; and
  - Periodic refresher training.
- Procedures for review and validation of inspection reports and data;
- Procedures for review and validation of load rating calculations and data; and
- Procedures for identification and resolution of data issues, including errors, omissions, changes, or any combination thereof.

Quality assurance procedures are used to verify the adequacy of the quality control procedures to meet or exceed the standards established by the owning agency. Quality assurance procedures are usually performed independent of the bridge inspection and load rating teams on a sample of their work. The documented quality assurance plan may include:

- Defined quality assurance roles and responsibilities;
- Frequency parameters for review of districts or units and bridges;

- Procedures and sampling parameters for selecting bridges to review, including:
  - Condition rating of elements or change in condition rating,Posting status,
  - Deficiency status,
  - Critical findings and the status of any follow-up action, and
  - Location of bridge.
- Procedures for reviewing current inspection reports, bridge files, and load ratings;
- Quality control procedures to verify the accuracy and completeness of the load ratings;
- Procedures for conducting an independent check of the load rating analysis on a sample of bridges;
- Procedures to validate qualifications of inspector and load rater; and
- Procedures to validate the QC procedures.

Checklists or other standard forms may be used to ensure uniformity and completeness of the established procedures.

Further information and details regarding QC/QA for Bridge Inspection can be found in NCHRP 20-07(252), *Guidelines for Implementing Quality Control and Quality Assurance for Bridge Inspection*.

1.5—DEFINITIONS AND TERMINOLOGY

AASHTO—American Association of State Highway and Transportation Officials, 444 North Capitol Street, NW, Suite 249, Washington, DC 20001.

As-Built Plans—Plans that show the state of the bridge at the end of construction; usually prepared by the Contractor or the resident Engineer.

ASR—Allowable Stress Rating.

Bias—The ratio of mean to nominal value of a random variable.

Bridge—A structure including supports erected over a depression or an obstruction such as water, highway, or railway; having a track or passageway for carrying traffic or other moving loads; and having an opening measured along the center of the roadway of more than 20 ft between undercopings of abutments or spring lines of arches, or extreme ends of openings for multiple boxes. It may also include multiple pipes, where the clear distance between openings is less than half of the smaller contiguous opening.

Bridge Management System (BMS)—A system designed to optimize the use of available resources for the inspection, maintenance, rehabilitation, and replacement of bridges.

Calibration—A process of adjusting the parameters in a new standard to achieve approximately the same reliability as exists in a current standard or specification or to achieve a target reliability index.

Coefficient of Variation—The ratio of the standard deviation to the mean of a random variable.

Collapse—A major change in the geometry of the bridge rendering it unfit for use.

Complex Bridges—Movable, suspension, cable stayed, and other bridges with unusual characteristics

Condition Rating—The result of the assessment of the functional capability and the physical condition of bridge components by considering the extent of deterioration and other defects.

Evaluation—An assessment of the performance of an existing bridge.

Exclusion Vehicle—Grandfather provisions in the federal statutes which allow states to retain higher limits than the federal weight limits if such limits were in effect when the applicable federal statutes were enacted. Exclusion vehicles are vehicles routinely permitted on highways of various states under grandfather exclusions to weight laws.

Failure—A condition where a limit state is reached or exceeded. This may or may not involve collapse or other catastrophic occurrences.

FHWA—Federal Highway Administration, U.S. Department of Transportation.

Inventory Rating—Load ratings based on the Inventory level allow comparisons with the capacity for new structures and, therefore, results in a live load, which can safely utilize an existing structure for an indefinite period of time.

Inventory Level Rating (LRFR)—Generally corresponds to the rating at the design level of reliability for new bridges in the *AASHTO LRFD Bridge Design Specifications*, but reflects the existing bridge and material conditions with regard to deterioration and loss of section.

LFR—Load Factor Rating.

Limit State—A condition beyond which the bridge or component ceases to satisfy the criteria for which it was designed.

Load Effect—The response (axial force, shear force, bending moment, torque) in a member or an element due to the loading.

Load Factor—A load multiplier accounting for the variability of loads, the lack of accuracy in analysis, and the probability of simultaneous occurrence of different loads.

Load Rating—The determination of the live-load carrying capacity of an existing bridge.

LRFD—Load and Resistance Factor Design.

LRFD Exclusion Limits—Weight and length limits of trucks operating under grandfather exclusions to federal weight laws.

LRFR—Load and Resistance Factor Rating.

Margin of Safety—Defined as R-S, where S is the maximum loading and R is the corresponding resistance (R and S are assumed to be independent random variables).

MUTCD—Manual on Uniform Traffic Control Devices.

National Bridge Inventory (NBI)—The aggregation of structure inventory and appraisal data collected to fulfill the requirements of the National Bridge Inspection Standards.

National Bridge Inspection Standards (NBIS)—Federal regulations establishing requirements for inspection procedures, frequency of inspections, a bridge inspection organization, qualifications of personnel, inspection reports, and preparation and maintenance of bridge inventory records. The NBIS apply to all structures defined as highway bridges located on or over all public roads.

NICET—National Institute for Certification in Engineering Technologies.

Nominal Resistance—Resistance of a component or connection to load effects, based on its geometry, permissible stresses, or specified strength of materials.

Operating Rating (ASR, LFR)—Load ratings based on the Operating rating level generally describe the maximum permissible live load to which the structure may be subjected. Allowing unlimited numbers of vehicles to use the bridge at Operating level may shorten the life of the bridge.

Operating Level Rating (LRFR)—Maximum load level to which a structure may be subjected. Generally corresponds to the rating at the Operating level of reliability in past load rating practice.

Owner—Agency having jurisdiction over the bridge.

Posting—Signing a bridge for load restriction.

Quality Assurance—The use of sampling and other measures to assure the adequacy of quality control procedures in order to verify or measure the quality level of the entire bridge inspection and load rating program.

Quality Control—Procedures that are intended to maintain the quality of a bridge inspection and load rating at or above a specified level.

RF—Rating Factor.

Reliability Index—A computed quantity defining the relative safety of a structural element or structure expressed as the number of standard deviations that the mean of the margin of safety falls on the safe side.

Resistance Factor—A resistance multiplier accounting for the variability of material properties, structural dimensions and workmanship, and the uncertainty in the prediction of resistance.

Safe Load Capacity—A live load that can safely utilize a bridge repeatedly over the duration of a specified inspection cycle.

Service Limit State—Limit state relating to stress, deformation, and cracking.

Serviceability—A term that denotes restrictions on stress, deformation, and crack opening under regular service conditions.

Serviceability Limit States— Collective term for service and fatigue limit states.

Specialized Hauling Vehicle (SHV)—Short wheelbase multi-axle trucks used in construction, waste management, bulk cargo and commodities hauling industries.

Strength Limit State—Safety limit state relating to strength and stability.

Structure Inventory and Appraisal Sheet (SI&A)—A summary sheet of bridge data required by NBIS. A copy of the SI&A sheet is contained in Appendix A4.1.

Target Reliability—A desired level of reliability (safety) in a proposed evaluation.

1.6—REFERENCES

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SECTION 2: BRIDGE FILES (RECORDS)

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