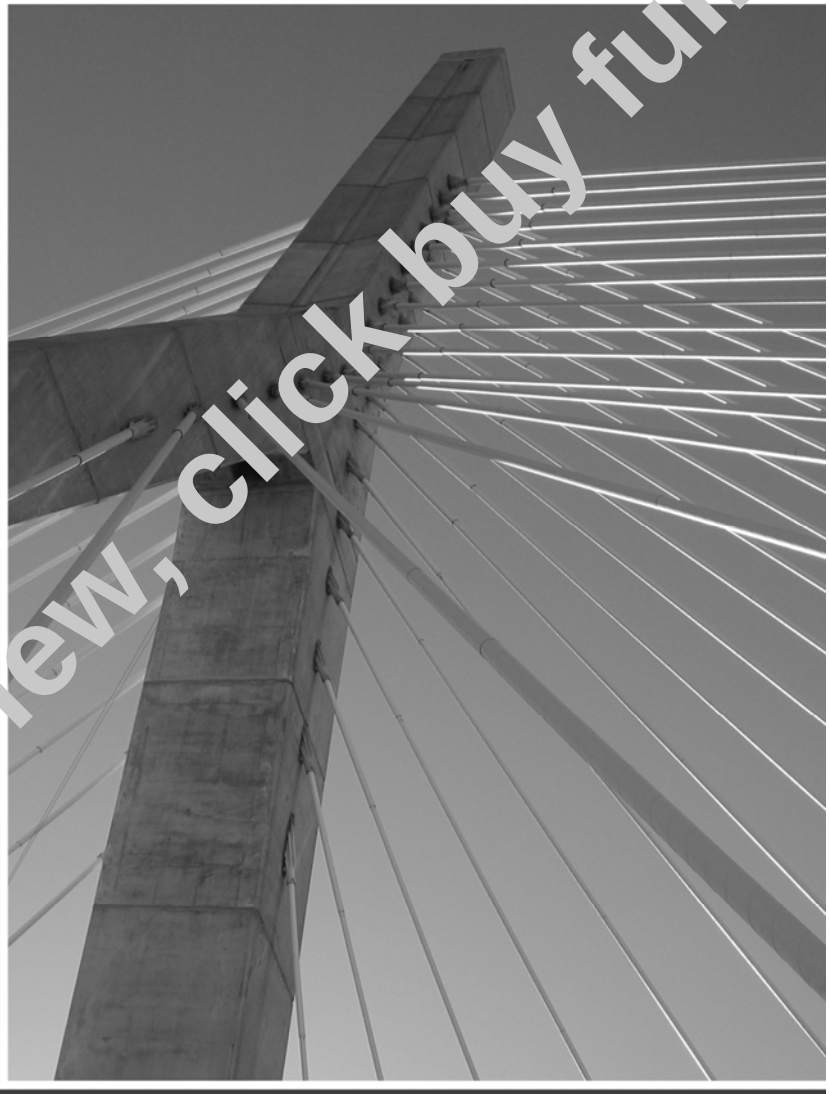
THE MANUAL FOR BRIDGE EVALUATION



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Cover photos: **Top Left:** Photo of a demonstration of Olson Instruments Bridge Deck Scanner system on a bridge taken by Larry Olson, Olson Engineering, Inc. **Second Left:** Photo of a through truss bridge taken by Thomas Drda, FHWA. **Third Left:** Photo courtesy of Idaho Department of Transportation. **Bottom Left:** Photo of an inspection of a deck truss bridge using an under bridge inspection truck. Taken by John Thiel, FHWA. **Right:** Leonard P. Zakim Bunker Hill Bridge in Boston, MA. Courtesy of Shay Burrows, FHWA.

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FOREWORD

The Manual for Bridge Evaluation (MBE) was first adopted by the AASHTO Highways Subcommittee on Bridges and Structures in 2005. The MBE combined the *Manual for Condition Evaluation of Bridges* with the *Guide Manual for Condition Evaluation and Load and Resistance Factor Rating (LRFR) of Highway Bridges* to provide owners with a single document for evaluating and load rating bridges.

The Manual for Bridge Evaluation, Third Edition incorporates the Interim Revisions issued to the Second Edition, as well as many other improvements. In order to better address the evolving requirements and technology related to bridge management systems, Section 3: Bridge Management Systems has been completely revised and updated.

AASHTO Highways Subcommittee on Bridges and Structures

PREFACE

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*, and two more (A10 and A11) that were added in the Interim Revisions for the Second Edition of this title. All examples are rated using the LRFR method. In addition, Examples A1 and A2 are also rated using the ASR and LFR methods, A4 is also rated using the ASR method, and A11 is also rated using the LFR method. To clarify which rating method is being illustrated, examples using multiple methods are generally 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, A4, and A11, 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 Standard Specifications" refers to the current edition of the AASHTO *Standard Specifications for Highway Bridges*, 17th Edition, HB-17,
- "LRFD Design" refers to the current edition of the *AASHTO LRFD Bridge Design Specifications*, Eighth Edition, LRFD-8, and
- "MBE" refers to this publication, *The Manual for Bridge Evaluation*, Third Edition, MBE-3.

AASHTO Publications Staff

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SECTION 1:

INTRODUCTION

1.1—PURPOSE

The purpose of *The Manual for Bridge Evaluation* (MBE) is to serve as a resource for use in developing specific policy and procedures for the inspection and evaluation of existing in-service highway bridges. The MBE also includes the nationally recognized guidance for the load rating of highway bridges.

The National Bridge Inspection Standards (NBIS), as found in the Code of Federal Regulations (23 CFR 650 Subpart C), define the regulations for the inspection and evaluation of the nation's bridges.

The MBE is incorporated by reference in the CFR (23 CFR 650 Subpart C) to be used along with other reference documents such as the American Association of State Highway and Transportation Officials (AASHTO) *Manual for Bridge Element Inspection*, the Federal Highway Administration's (FHWA) *Bridge Inspector's Reference Manual* (BIRM), and the latest National Bridge Inventory (NBI) coding guidance document for the inspection and evaluation of the nation's bridges.

The NBIS have evolved and been improved over the years since their creation in the early 1970s.

The MBE has also evolved and been revised and improved to reflect best practices as determined by research, state departments of transportation (DOTs), and others. In the future as improved practices and research are developed, the MBE will reflect those improvements.

Throughout this Manual there are subsections labeled in part "Provisions to Support the NBIS Requirements." These subsections were developed to provide specific guidance and best practices that are considered to be required under the regulations.

1.2—SCOPE

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—Purpose, scope, applicability, inspection and evaluation quality measures, and definition of general interest terms.
- Section 2—Provisions for proper documentation to be included in a bridge file. The bridge file associated with each bridge provides the foundation against which changes in physical condition can be compared.

- Section 3—Overview of bridge management systems and their key elements.
- Section 4—Types and frequency of field inspections, as well as specific inspection techniques and procedures.
- Section 5—Various inspection and evaluation testing methods. Conditions at a bridge site or the absence of information from original construction may warrant more elaborate material tests to determine properties for evaluation.
- Section 6—Nationally recognized specification for the load rating of bridges. Includes the Load and Resistance Factor method, the Load Factor method, and the Allowable Stress method.
- Section 7—Provisions for the evaluation of existing bridges for fatigue.
- Section 8—Field-performed load test procedures. 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.

The successful application of this Manual is directly related to the DOT organizational structure. 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.

1.3—APPLICABILITY

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

The NBIS establish minimum requirements for inspection programs and minimum qualifications for bridge inspection personnel. The NBIS apply to all highway bridges that are more than 20 ft in length and located on public roads.

Where conflicts or inconsistencies exist between this Manual and the federal requirements specified in the NBIS, the FHWA coding guidance, or BIRM, the federal requirements shall govern.

1.4—QUALITY

To maintain the accuracy and consistency of inspections and load ratings, bridge inspection programs need to have appropriate quality control (QC) and quality assurance (QA) measures in place. QC procedures are intended to maintain the quality of the bridge inspections, bridge data, scour evaluations, and load ratings, and are usually performed continuously

within the bridge inspection teams or units performing these functions. QC procedures can vary depending on the structural and scour conditions of a bridge with increased level of review commensurate with increased deterioration of bridge conditions. QA procedures are used to verify the adequacy of the quality control procedures to meet or exceed the standards established by the program manager. QA procedures are usually performed independently of the bridge inspection and load rating teams on a sample of their work.

1.4.1—Provisions to Support the NBIS Requirements

A quality control and quality assurance (QC/QA) program is to include periodic field review of inspection teams, periodic bridge inspection refresher training for program managers and team leaders, QC/QA measures for inventory data, and independent review of inspection reports and computations. The program manager is responsible for developing a QC/QA program that generally conforms to the provisions of Article 1.4. Specific details are to be determined by the program manager.

1.4.2—QC/QA Procedures

Typical quality procedures may 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. The documented quality control plan may include:

- Defined QC roles and responsibilities;
- Qualifications for the program manager, bridge inspection personnel, and load rating personnel, including:
  - Education,
  - Certification or registration,
  - Training, and
  - Years and type of experience;
- Procedures for review and validation of inspection reports and data;
- Procedures for documenting important bridge inspection information;
- Procedures for review validation of load rating and scour calculations and data; and
- Procedures for identification and resolution of data issues including errors, omissions, compatibility between items, changes, or any combination thereof.

QA measures include the overall review of the inspection and rating program to ascertain that the

results meet or exceed the standards established by the program manager. The documented QA plan may include:

- Defined quality assurance roles and responsibilities;
- Frequency parameters for review of districts or units and bridges; and
- Procedures and sampling parameters for selecting bridges to conduct independent review and check of results, including:
  - Condition rating of elements or change in condition rating,
  - Load rating and scour evaluations,
  - Posting status,
  - Deficiency status,
  - Critical findings and the status of any follow-up action, and
  - Location of bridge.

QA measures provide a validation that QC practices are resulting in accurate and thorough inspections, complete bridge files, accurate and complete load ratings and scour evaluations, and qualified inspectors and load raters. Results from QA reviews are used by the program manager to maintain the quality of the program and make improvements where needed.

1.5—DEFINITIONS AND TERMINOLOGY

AASHTO—American Association of State Highway and Transportation Officials.

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.

Scour Critical Bridge—A bridge whose foundation (or foundations) has been determined to be unstable for the predicted scour conditions.

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 the 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.

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

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				Permit	Strength II Service II		
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