Bridge Load Rating Manual

MONTANA
Department of Transportation

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TABLE OF CONTENTS

1. MANUAL OVERVIEW

1.1. OVERVIEW

The Montana Department of Transportation (MDT) is committed to planning, building, operating, and maintaining a safe and resilient transportation system that moves Montana forward. Bridge load ratings are an essential part of this mission. The safety of the traveling public and the long-term management of these assets rely on accurate load ratings performed by qualified professional engineers. The purpose of this manual is to provide standardized procedures and criteria for load rating structures within the State of Montana, as required by the U.S. Code of Federal Regulations 23 CFR §650.313(k)(2) **"**Develop and document procedures for completion of new and updated bridge load ratings." The manual is intended to provide MDT-specific guidance that supplements national policies and specifications found in the most current version of the **AASHTO Manual for Bridge Evaluation** (MBE) and its latest interims. It is important to note that this manual does not replace the judgment of a qualified professional engineer trained in bridge analysis and evaluation; sound engineering judgment and principles remain necessary to ensure accurate evaluations.

Where this load rating manual is silent on procedures and methodology, the load rater shall consult the following, in order of priority:

1. **AASHTO Manual for Bridge Evaluation** (MBE)
2. **AASHTO LRFD Bridge Design Specifications**
3. **AASHTO Standard Specifications for Highway Bridges**, 17th edition (Service Load Design Method Allowable Stress Design and Strength Design Method Load Factor Design)
4. **MDT Bridge Design Manual**

In the event of any conflict between this manual and the **National Bridge Inspection Standards** (NBIS), the NBIS will govern. Load Raters are not relieved of the responsibility to comply with the NBIS even when a conflict exists.

This manual is published by the Montana Department of Transportation (MDT), Bridge Bureau, Bridge Management Section, and its Load Rating staff. This manual is available online at https://www.mdt.mt.gov/business/contracting/bridge/loadrating/guidance.aspx. Because the manual is available electronically, a hard copy print version will not be published or distributed.

1.2. MANUAL ORGANIZATION

This manual is divided into chapters covering the major aspects of load rating. Each chapter is divided into sections that address specific topics.

- **Chapter 2 – Load Rating Information**
  Covers the ***Why*** (federal and state requirements), the ***When*** (new, replacement, rehabilitation/repair, damage, or other changes), and the ***What*** (superstructure, substructure, deck, culverts). Defines the information needed to perform a load rating (e.g., specifications, plans, inspection records) and applicable data standards.

- **Chapter 3 – Load Rating Procedures**
  Covers the ***How*** of load rating – methods, inputs, material types, vehicle configurations, structure types, and calculation approach.

- **Chapter 4 – Load Rating Process**
  Covers the ***Who*** of load rating – qualifications, program workflows (triggers and responses), quality control (QC), quality assurance (QA).

- **Chapter 5 – Load Posting**
  Covers the ***Why***, ***When***, ***How***, and ***Who*** of load posting and closures, including posting vehicles and signs, thresholds, engineering judgment, posting considerations, posting verification, and correspondence with bridge owners.

- **Chapter 6 – Load Rating Documentation**
  Covers the required file content and format to fully document a load rating, including components of the Load Rating Report and the Load Rating Summary Sheet.

1.3. UPDATING THE MANUAL

This manual will be updated periodically to incorporate revisions consistent with practices outlined by FHWA, AASHTO, and MDT. The Load Rating Program Manager will review Montana load rating practices and procedures for compliance with the **Code of Federal Regulations** (Title 23 CFR §650.3), the **AASHTO Manual for Bridge Evaluation** (MBE), and the **FHWA Specifications for the National Bridge Inventory** (SNBI). In addition, the Load Rating Program Manager will review feedback from the MDT load rating community. Users are encouraged to submit any suspected errors, recommendations, or proposed revisions to the MDT Bridge Management Section.

2. LOAD RATING INFORMATION

2.1. LOAD RATING

A load rating is defined in the **AASHTO Manual for Bridge Evaluation (MBE)**, Section 1.5 as "the determination of the live load carrying capacity of an existing bridge." A load rating reflects a bridge's current capacity to carry traffic and other live loadings, considering its present condition and any changes in loading.

The rating factor can be expressed by a general equation, (see AASHTO MBE Articles 6A.4.2 and 6B.4.1):

Equation 2.1-1

$$RF = \frac{C - DL}{LL}$$

Where RF = Rating Factor
C = Capacity
DL = Dead Load
LL = Live Load

Rating methods described in Chapter 3 apply method-specific factors to modify each variable in the equation.

Load ratings provide a basis for determining bridge posting limits and evaluating whether specific legal or overweight vehicles can safely cross a structure. Each member of a bridge has its own load rating. The overall bridge load rating corresponds to the most critical member, often referred to as the governing or controlling rating. Load ratings are reported as a rating factor, which is calculated with the equation shown in Equation 2.1-1. Multiplying the rating factor by the rating vehicle weight (in tons) yields the bridge's load rating in tons. It is important to note that a bridge will have different rating factors or posted weight limits for different rating vehicles.

Bridge load rating and bridge design differ in important ways. As summarized in AASHTO MBE Section 6A.1.3:

> "Bridge design and rating, though similar in overall approach, differ in important aspects. Bridge ratings generally require the Engineer to consider a wider range of variables than is typical in bridge design. Design may adopt a conservative reliability index and impose checks to ensure serviceability and durability without incurring a major cost impact. In rating, the added cost of overly conservative evaluation standards can be prohibitive as load restrictions, rehabilitation, and replacement become increasingly necessary."

Load rating requires a different mindset than design. The emphasis in load rating is on the as-inspected live load capacity, which dictates a rating-factor approach rather than satisfying design limit states. Many older bridges were designed to live load standards and specifications that are significantly different from current practice. Load rating provides a uniform methodology for evaluating the live load capacity of all bridges in the inventory using current load rating standards and live loads, regardless of the original method of design and underlying design assumptions. An engineer may begin load rating using a conservative approach; however, if the bridge is performing well under current operating conditions and does not show signs of distress consistent with initial results, a more refined analysis may be warranted. Coupled with sound engineering judgment, refined analysis can align calculated capacity with true operating conditions and observed performance while maintaining public safety, structural integrity, and reasonable service levels. See Section 3.10 Analytical Refinement Methods for more information.

2.2. WHY A LOAD RATING IS NEEDED

A load rating provides information about a specific bridge's load-carrying capacity, which plays a key role in the Bridge Bureau's mission to maintain a safe, resilient, economical, and reliable transportation system. This information, provided in a standardized report, is used to:

- Identify bridges with limited capacities and determine safe posting limits to ensure:
  - the safety of the traveling public, and
  - the protection of bridge inventory investments
- Assist in prioritization of rehabilitation or replacement projects
- Support review of overweight vehicle permits
- Satisfy federal requirements that all bridges in the National Bridge Inventory (NBI) must be load rated and restricted, if necessary

2.2.1. Federal Requirements

Title 23, Code of Federal Regulations (CFR), Part 650, Subpart C – National Bridge Inspection Standards (NBIS), § 650.307 outlines state DOT responsibilities for bridge inspection and load rating.

The federal law, Fixing America's Surface Transportation (FAST) Act (Pub. L. No. 144-94) introduced mandated legal loads on the Interstate Highway System. Section 1410 defines a series of emergency vehicles that may operate on, and within reasonable access to, the Interstate without a permit. See Section 3.3.2 Vehicular Live Loads for details about the corresponding live load models.

Additional federal guidance is provided in the current FHWA National Bridge Inspection Program Compliance Review Manual. In particular, Metric 4 (Load Rating Engineer), Metric 13 (Load Rating), and Metric 14 (Post or Restrict) address key elements of bridge load rating and load posting.

2.2.2. State Statutes

The following Montana Code Annotated (MCA) statutes relate to load ratings, overweight permits, postings, and traffic control in the State of Montana.

- MCA 7-14-2201 - Maintenance and Control of Bridges
- MCA 60-1-102 - Legislative Policy and Intent
- MCA 61-8-203 - Department of Transportation to Place Traffic Control Devices on Highways it Maintains and Approve Traffic Control Devices on Highways Under its Jurisdiction
- MCA 61-10-101 - Standards of Maximum Dimensions, Weights, etc.
- MCA 61-10-106 - Measuring Distance Between Axles
- MCA 61-10-107 - Maximum Gross Weight
- MCA 61-10-108 - Reduction Under Special Circumstances
- MCA 61-10-109 - Operation Without Special Permits Prohibited
- MCA 61-10-110 - Federal Law
- MCA 61-10-121 - Permits for Excess Size and Weight
- MCA 61-10-128 - When Authorities May Restrict Right to Use Roadway
- MCA 61-10-155 - Rulemaking Authority

2.3. WHEN A LOAD RATING IS NEEDED

MDT completes load ratings for all structures reportable to the National Bridge Inventory (NBI) per the NBIS. MDT also rates minor structures in its inventory that do not qualify for the NBI (see MDT Bridge Inspection Manual, Section 3.3 for definition of minor structures).

NBIS § 650.313 (k)(2) requires state DOTs to develop and document procedures for completion of new and updated load ratings and to complete load ratings no later than 3 months after the initial inspection, or after a change is identified that warrants a re-rating. A load rating is needed for the following situations (see Section 4.3 Load Rating Triggers and Responses for details):

- Newly constructed structures
- Existing structures new to the inventory
- Repaired or rehabilitated structures
- Existing rating updates (load rating maintenance)

2.4. ELEMENTS TO BE LOAD RATED

Load ratings evaluate structural elements in the direct load path from the vehicle to the supporting ground. In general, the focus is on superstructure elements; bearings and foundations are generally not rated. Elements not typically rated may require evaluation or restrictions when significant deterioration or distress is observed. See Sections 2.4.2 Substructures, 2.4.5 Special Circumstances, and 5.2.3.2.2 Condition-Based Postings or Restrictions for further information.

2.4.1. Superstructures

Superstructure elements are the primary focus of routine load ratings. Load rate all primary load-carrying elements and report the controlling load rating for each element.

2.4.1.1. Structures with Girders, Stringers, Beams, and/or Floorbeams

For girder/stringer/floorbeam bridges, rate representative interior and exterior girders/stringers, and representative floorbeams where present.

2.4.1.2. Truss Bridges

Rate truss members and gusset plate connections. Where stringers, floorbeams, or girders are part of the system, rate those members as applicable.

2.4.1.3. Reinforced Concrete Slab Bridges

Reinforced concrete slabs that act as the primary load-carrying members must be rated. For concrete decks on stringers, see Section 2.4.3 Decks.

2.4.1.4. Complex Structures

Complex structures other than truss bridges (arches, cable-stayed, suspension bridges, frames, movable bridges, etc.) may have superstructure components other than girders, stringers, and floorbeams. Rate the relevant superstructure components, including main/secondary cables, hangers, and connections. Per AASHTO MBE Article 6.1.6, complex structures may require "special analysis methods and procedures." Coordinate with MDT before initiating a complex-structure rating.

2.4.2. Substructures

Substructures are not typically load rated except in unusual circumstances such as severe deterioration of timber substructures. Refer to Section 3.8 Substructures for guidance on evaluating substructures.

2.4.3. Decks

Generally, stringer-supported concrete bridge decks do not control bridge load-carrying capacity and are not typically rated; however, heavily spalled or deteriorated concrete decks may need to be evaluated for punching shear. Concrete slabs that serve as primary members must be rated (see Section 2.4.1.3 Reinforced Concrete Slab Bridges). Timber bridge decks (Section 3.6.4 Timber Decks) and corrugated steel decks (Section 3.5.4 Corrugated Steel Deck) must be rated when determining bridge capacity.

2.4.4. Culverts

Culverts must be load rated. See Section 3.7 Buried Structures, AASHTO MBE 6A.10, and MBE 6B.9.

2.4.5. Special Circumstances

For existing structures, elements not normally included in a routine rating may need evaluation when inspections identify significant deterioration or distress. Such cases may require analysis methods or tools different from those used for superstructure, substructure, or deck elements. Coordinate with MDT as needed.

2.5. INFORMATION NEEDED FOR RATING

2.5.1. General

This section describes the types of information needed to perform a load rating.

NBIS § 650.305 defines a load rating as "the analysis to determine the safe vehicular live load carrying capacity of a bridge using bridge plans and supplemented by measurements and other information gathered from an inspection."

The load rater should make a concerted effort to obtain complete and current information necessary to calculate an accurate load rating. When conflicts exist among available sources, document the assumptions made, the data used in the analysis, and the rationale for data precedence in the load rating report. The following sources of information may be used:

- Current field-verified information
    - Measurements
    - Inspection Reports
    - Material Testing
- Shop Drawings
- Existing Plans (design or as-built)
- Traffic data
- Previous load rating calculations and assumptions
- Number of striped lanes
- Surface roughness
- Presence of NSTM members

If needed information is not available in BrM, it can be requested from MDT. In some cases, information may need to be requested from the bridge owner, fabricator, design engineer, etc. Field visits may be needed to gather complete data.

Other key references for load rating include:

- MDT Load Rating Manual and any interim/additional guidance

- Specifications and standards:
  - MDT Standard Drawings
  - MDT Standard Specifications for Road and Bridge Construction (see online library)
  - AASHTO Manual for Bridge Evaluation (MBE)
  - AASHTO LRFD Bridge Design Specifications and AASHTO Standard Specifications
  - FHWA publications
  - Montana Structures Manual

NOTE: As-Built plans are preferred, but in cases where they are unavailable, Design Plans are sufficient (paired with review of inspection info/photos to reasonably determine that plans reflect as-built condition)

3. LOAD RATING

3.1. GENERAL

This chapter introduces the various load rating methods and their application. It covers various AASHTO and MDT methods for load rating, the load rating of routine and complex bridges, and the load rating of specific elements that require special attention.

3.2. LOAD RATING METHODS

Load raters calculate safe live load capacities for various vehicles, such as design loads, state-specific or national legal loads, and overweight permit loads, during load rating. They determine member resistance and both permanent and transient force effects.

For common bridges, such as slab-on-girder, T-beam, and slab bridges, load raters usually compute ratings for shear and bending moment, which are the dominant force effects. These force effects are computed at common locations, such as the tenth points of each span, and at special points of interest, such as where the member resistance changes, e.g., at a cover plate termination for a steel bridge. Other points are rated as needed, for example, at locations of significant deterioration. For other bridge types, e.g., a truss or arch, the rating involves other force effects such as axial force demand and sometimes includes a combination of forces such as axial load and bending forces.

A bridge's final load rating is governed by the weakest point of the weakest load-rated member (the controlling member). For each rated vehicle, the controlling rating and its associated member, location, and governing limit state is recorded on the Load Rating Summary Sheet and entered into BrM. Note that the controlling member, location, and limit state may change between rating vehicles because differences in weight, axle spacing, and length affect members and spans differently.

There are three primary approaches to load rating: analytical calculation, engineering judgment, and load testing. Calculation methods have evolved over time. Load and Resistance Factor Rating, or LRFR (Section 3.2.1 Load and Resistance Factor Rating (LRFR)), is the current standard practice. Previous methods, such as Load Factor Rating (LFR) and Allowable Stress Rating (ASR) (Section 3.2.2 Load Factor Rating (LFR) and Allowable Stress Rating (ASR)), remain in use in certain situations. These methods are summarized below. For background on allowable methodology, see FHWA's 2006 Memorandum on Bridge Load Ratings for the National Bridge Inventory (https://www.fhwa.dot.gov/bridge/nbis/103006.cfm).

3.2.1. Load and Resistance Factor Rating (LRFR)

The provisions for LRFR load ratings are in the **AASHTO Manual for Bridge Evaluation** (AASHTO MBE) Section 6A. To provide uniform reliability and consistency in load rating and posting practices, MDT has adopted LRFR as its primary load rating method. All Montana bridges, regardless of ownership, should be rated using LRFR unless otherwise indicated in Section 3.2.2 Load Factor Rating (LFR) and Allowable Stress Rating (ASR).

From AASHTO MBE Article 6A.4.2.1, the General Rating Equation for LRFR is:

Equation 3.2-1

$$RF = \frac{C - (\gamma_{DC})(DC) - (\gamma_{DW})(DW) \pm (\gamma_p)(P)}{(\gamma_{LL})(LL + IM)}$$

Where:

- RF = The rating factor for the live load carrying capacity. The rating factor multiplied by the rating vehicle weight in tons gives the rating of the structure.
- C = The capacity of the member
- DC = The dead load effect on the member due to self-weight
- DW = The dead load effect on the member due to wearing surfaces and utilities
- P = The dead load effect on the member due to permanent loads other than dead loads
- LL = The live load effect on the member
- IM = The impact factor to be used with the live load effect
- γ (gamma) = Various load factors applied to each component.

3.2.1.1. Limit States and Load Factors

Limit States and Load Factors for LRFR are defined in AASHTO MBE Table 6A.4.2.2.1. This table provides load combinations and load factors for mandatory and optional checks. MDT's practice is to include optional checks initially and then modify as needed based on judgment and posting/permitting decisions. Optional checks not performed in the final rating shall be documented in the load rating report, including the rationale for their omission. To remove an optional check with BrR rating software, the user must update load factor table settings, so the check does not apply.

3.2.1.2. Condition Factors

The use of condition factors in an LRFR analysis accounts for member deterioration per AASHTO MBE Article 6A.4.2.3-1. Engineering judgment may be used for the basis of condition factors (e.g., element level vs. NBI condition ratings) and must be documented in the load rating report. To compute the capacity of a deteriorated member, load raters shall (1) compute the capacity of the deteriorated member (the nominal resistance including deterioration), and (2) apply the condition factors. Condition factors recognize that deteriorated members will continue to degrade and provide forward-looking conservatism, while also addressing uncertainties in calculating deteriorated nominal resistance.

The use of condition factors requires judgment. The condition factor is chosen based on member condition (good or satisfactory, fair, poor), not on the overall condition of the superstructure, substructure, etc. The condition factor should be selected based on the member being evaluated, not the worst condition of all elements and all locations. The condition factor only affects the locations of members at which the deterioration is measured and shall not be assumed to apply to full members, or all members. For example, assume that deterioration of a flange is measured at an abutment under an open expansion joint and the inspector classifies this region as "poor" based on the observed conditions. Although that might trigger the entire superstructure as being classified as "poor" it is possible this finding has no influence on the controlling load rating (e.g., flexure near midspan).

3.2.1.3. System Factors

System factors are listed in AASHTO MBE Table 6A.4.2.4-1. As noted in the AASHTO MBE, simplified system factors should be applied only when checking flexural and axial effects at the strength limit state of typical spans and geometries. This does not apply to timber bridges, where a constant value of φ_s = 1.0 is assigned for flexure and shear.

3.2.2. Load Factor Rating (LFR) and Allowable Stress Rating (ASR)

The provisions for LFR and ASR load ratings can be found in the AASHTO MBE Section 6B. As noted in Section 3.2.1 Load and Resistance Factor Rating (LRFR), LRFR is the preferred methodology used to load rate bridges in Montana, with some exceptions:

- Using LRFR to evaluate older, in-service structures designed by a method other than LRFD can sometimes produce low ratings for bridges that are in good condition and performing well. In such cases, LFR may be used as an acceptable alternative, as long as the methodology is allowable per FHWA.
- MDT's practice is to rate timber components in ASR.

From AASHTO MBE Article 6B.4.1, the General Rating Equation for LFR and ASR is:

Equation 3.2-2

$$RF = \frac{C - A_1 D}{A_2 L(1 + I)}$$

Where:

- RF = The rating factor for the live load carrying capacity. The rating factor multiplied by the rating vehicle in tons gives the rating of the structure.

- C = The capacity of the member
- D = The dead load effect on the member. For composite members, the dead load effect on the noncomposite section and the dead load effect on the composite section need to be evaluated when the allowable stress method is used.
- L = The live load effect on the member
- I = The impact factor to be used with the live load effect
- A1 = Factor for dead loads
- A2 = Factor for live load

The load factors A1 and A2 are:

- For the allowable stress method, A1 = 1.0 and A2 = 1.0
- For the load factor method, A1 = 1.3 and A2 varies depending on the rating level desired. For inventory level, A2 = 2.17 and for operating level, A2 = 1.3. in the general rating equation.

To determine the nominal capacity for the various material types of members, refer to the AASHTO MBE Article 6B.5.2 (Allowable Stress) and 6B.5.3 (Load Factor).

3.2.3. Field Evaluation and Documentation of Engineering Judgment (EJ)

The field evaluation and documented engineering judgment method is typically used to establish load ratings when analytical calculations are not feasible, such as when plans are unavailable or severe deterioration cannot be reliably captured. See Sections 3.9 Bridges with Missing Information and 5.2.3.2.2 Condition-Based Postings or Restrictions.

3.2.4. Non-Destructive Load Testing (LT)

Details about proof and diagnostic load testing are provided in AASHTO MBE Article 8.4. Load rating using these methods is discussed in MBE Article 8.8. Load testing should be considered when conditions exist that make conventional methods of analysis less reliable or when better understanding of behavior and quantification of reserve capacity is needed (i.e., when approximate methods produce an unexpectedly restrictive rating compared with observed performance). Situations that may benefit from load testing include (see AASHTO MBE 8.2 and 8.3 for more detailed discussion):

- Bridges with beneficial behaviors not captured in routine analysis (e.g., unintended composite action or continuity, participation of secondary or nonstructural members, and superstructure-deck load sharing).

- The need to measure or refine live load distributions, stresses for fatigue evaluation, or dynamic effects (impact).

- Unique or irregular configurations where conventional analysis is difficult to apply.

- Cases where a more refined assessment of in-service behavior is needed to improve accuracy beyond conservative analytical assumptions.

With MDT approval, load testing may be performed for on-system structures to establish a current and accurate load rating where structural information is limited and other methods are impractical. Load testing can also refine capacity estimates when posting is not desired.

For off-system structures, load testing is generally outside the scope of MDT's Load Rating Program and should be performed at the bridge owner's expense, in coordination with MDT.

Diagnostic load testing (AASHTO MBE 8.4.1.1) is used in conjunction with an analytical model to improve understanding of bridge behavior (e.g., degree of composite action, live load distribution, end restraint/continuity affects, participation of secondary members, behavior of damaged members). Results are used to calibrate and adjust the analytical model and compute rating factors that incorporate the field test data.

Proof testing (AASHTO MBE 8.4.12; 8.8.3.3) is a series of repeated tests with increasing loads to "prove" a structure's capacity by either reaching a target load or observing limit behaviors (e.g., cracking, nonlinear response). Proof testing may be appropriate for bridges without plans or with unknown reinforcement. Plan tests and select target proof loads per AASTHTO MDT 8.4.1.2 and 8.8.3.3, including any required adjustments per Table 8.8.3.3.1-1.

3.2.5. Routine vs. Complex Structures

3.2.5.1. Routine Structures

Routine structures are those whose components, geometry, and behavior can be defined and analyzed in AASHTOWare Bridge Rating (BrR), which is MDT's standard software for load rating. Examples of routine structures include typical, straight, multi-girder bridges that use approximate analysis methods. Unless otherwise discussed and approved by MDT, all structures that can be defined and analyzed in BrR should be rated in BrR, using the same BrR version currently being used by MDT (see MDT's Load Rating website for the current version).

3.2.5.2. Complex Structures

Complex structures are those that typically require refined analysis methods due to geometry, structural behavior, or load-path characteristics that often extend beyond the capabilities of BrR. Load ratings for complex structures often involve additional analysis and quality control/quality assurance requirements. The use of alternate analysis software for structures that cannot be represented in BrR must be coordinated with and approved by MDT's Load Rating Program Manager. Some complex structures, such as curved steel girder bridges, can be defined and analyzed in BrR. When possible, these structures should be rated in BrR. When results from other analysis programs can be incorporated into the BrR model – for example, refined live load distribution factors – BrR should still be used as the primary rating software rather than performing the full rating in an alternate program.

3.2.6. Approximate vs. Refined Analysis Methods

3.2.6.1. Approximate Methods of Analysis

Approximate methods of analysis represent the default method of analysis for MDT structures. Most routine structures (e.g., straight-line girders and beams) can be effectively analyzed using approximate methods. Approximate methods include the common use of line girder analysis, which relies on live load distribution factors to approximate how forces are shared within a bridge system. Other approximate methods of analysis include the use of lever rule procedures for two-girder bridges, for distributing loaded lanes to truss and arches, and for simplified load rating of floorbeams.

3.2.6.2. Refined Methods of Analysis

A refined analysis is a bridge analysis that is more rigorous than a typical line girder analysis. Examples include finite element analysis or strut-and-tie analysis. While refined analysis is required for certain bridge types, it can also be used to gain additional insight into bridge behavior for routine structures. For bridges that typically do not require a refined analysis, but for which a more accurate representation of behavior and capacity is desired, a refined analysis may be appropriate. Load rating engineers should consult with MDT to discuss the necessity of the refined approach, along with its potential benefits and costs, and obtain MDT's approval before proceeding.

Bridge types that require a refined analysis:

- Curved steel girder bridges
- Steel girder bridges with skews large enough that line girder analysis no longer accurately captures load path
- Bridges with flared beams where the two-thirds approximation is deemed too inaccurate (see Section 3.5.3.1.3 Variable Girder Spacing for additional information on this approximation)
- Bridges where the construction sequence will have a large effect on results
- Segmental concrete box beam bridges
- Cable-stayed bridges
- Suspension bridges

Benefits of using a refined analysis for bridges that do not typically require a refined analysis:

- More accurate distribution of dead and live loads
- Less conservative connection conditions (partially pinned vs fully pinned)

3.3. LOADS

3.3.1. Dead Loads

For Steel Bridges, refer to Section 3.5.1.7 Additional Dead Load for Misc. Attachments for additional dead loads such as detailing weight and stay-in-place (SIP) forms.

3.3.1.1. Material Unit Weight

Except for asphalt wearing surfaces, use wearing surface unit loads shown in Section 3.3.6 of the AASHTO Standard Specifications for Highway Bridges, 17th Edition (AASHTO Standard Specifications), or Section 3.5.1-1 of the AASHTO LRFD Bridge Design Specifications, 10th Edition (AASHTO LRFD). Use a unit weight of 0.144 kcf for asphalt wearing surfaces.

3.3.1.2. Sacrificial Wearing Surface

Use the as-cast deck thickness. Do not deduct any sacrificial wearing surface for dead load.

3.3.1.3. Application of Superimposed Dead Load (SDL)

Apply the weight of wearing surfaces to all beams evenly.

Apply the weight of utilities based on type, size, and location according to the following:

- For utilities attached to a barrier, follow the guidance for applying the weight of barriers to beams.
- For utilities attached to a beam, apply the weight as a uniform line load along the girder.
- For utilities in a bay between beams attached to the deck, options are:
    - Apply weight as equal uniform line loads to adjacent beams.
    - Apply weight equally to all beams.
- For a deck with various utilities attached to the deck, assume a 2 psf weight in rural areas and a 3 psf weight in cities and urban areas across the entire deck.

- Determine weight of utilities according to the following:
  - Assume a 10 plf weight for conduits, plastic piping, and steel piping 3” or less in diameter.
  - Calculate the actual weight of steel piping greater than 3” in diameter assuming the pipe is full of water (62.4 pcf).

Apply the weight of barriers to beam(s) according to the following:

- For adjacent precast prestressed deck beams without a cast-in-place deck, apply barrier and/or sidewalk loads to the exterior beam only.
- For a median barrier on side-by-side bridges with a joint:
  - For a barrier clearly on the deck of one bridge, apply its weight on that bridge.
  - For a barrier that straddles them or for a continuous deck, apply its weight on both bridges.
- For a single bridge with two edge barriers:
  - For barriers that sit on top of the deck (not directly attached to girders), model as appurtenances and distribute weight evenly to all beams.
  - For rails that are attached directly to exterior girders, apply a member load to the exterior beams only.
  - If alternate distribution is used (e.g., 50/50 to exterior and first interior), clearly document distribution rationale in the load rating report.

3.3.2. Vehicular Live Loads

The nominal live loads to be used in the evaluation of bridges are those found in the Manual for Bridge Evaluation, Section 6A.2.3 for LRFR and 6B.6.2 for LFR and ASR and are dependent on evaluation type.

3.3.2.1. Special Notes for EVs:

Reference for EVs can be found in FHWA’s 2016 Memo and FHWA’s March 2017/2018 Q&A.

- **Multiple Presence:** To account for the low probability of the side-by-side presence of two heavy EVs on a bridge, the load rating analysis may consider only one EV in one lane, combined with other unrestricted legal vehicles in the remaining lanes.

This exception allows evaluation of only one EV in combination with other legal loads, which are typically lighter than the EV.

  - Run EV2 and EV3 for single-lane loading using multiple presence factor for a single truck.
  - Run EV2 and EV3 for multi-lane loading with an adjacent unrestricted legal vehicle, Type 3-3, using the multiple presence factor for multiple trucks.

- **Live Load Factor:** A live load factor of 1.3 is used as the default for EV load ratings. Note – this does not apply to buried structures – see AASHTO MBE Article 6A.5.12.10.3
  - Run EV2 and EV3 using live load factor override of 1.3, consistent with FHWA Q&A guidance and independent of ADTT.
  - In March 2019, NCHRP published a research report (NCHRP 20-07 Task 410) recommending alternate live load factors for inclusion in AASHTO MBE, based on ADTT and EV crossings per day. Until BrR incorporates functionality to apply these alternate live load factors, MDT will continue to use 1.3 as the default live load factor for both EVs unless posting is triggered.
  - If posting is triggered, determine the appropriate live load factor value as recommended by NCHRP and adjust the live load factor override in the Vehicle Analysis Template's advanced settings.

3.3.2.1.1. Tire Pressure Guidance

- LRFR – use modified tire contact area (wheel contact width) per LRFD
- ASR/LFR – use standard 10"x20" tire contact width

Per FHWA's Q&A document for the FAST Act Vehicles (published in March 2017, updated in March 2018), AASHTO LRFD Section 3.6.1.2.5 may be used in lieu of better information to calculate the tire contact width. Calculations are based on P/0.8, where the number of tires per axle are taken as two for the front axle and two* for the rear and/or tandem axles.

** For simplicity, the gap between tandem tires is ignored and assumed two wider tires per axle versus four narrower tires with a gap.*

<u>Tire Contact Area/Wheel Contact Width:</u>

EV2

- Front Axle: $\frac{24}{(2)(0.8)} = 15in$
- Rear Axle: $\frac{33.5}{(2)(0.8)} = 20.94in \rightarrow use\ 21in$

EV3

- Front Axle: $\frac{24}{(2)(0.8)} = 15in$
- Rear/Tandem Axle: $\frac{31}{(2)(0.8)} = 19.38in \rightarrow use\ 19in$

Figure 3.3-1 Emergency Vehicle Tire Contact Width Guidance

3.3.2.2. Application of Vehicular Live Load

Assign the number of traffic lanes and place the wheel lines in accordance with the MBE.

For load rating, MDT considers roadway widths less than 20 feet to be one traffic lane in accordance with the AASHTO Standard Specifications and AASHTO LRFD.

When standard transverse vehicle placement per the MBE does not reflect normal operating conditions and current traffic use, truck loads may be placed within striped lanes to reflect actual usage. Guidance on using striped lanes is provided in MBE Articles 6A.2.3.2 (LRFR) and 6B.6.2.2 (LFR). MDT generally treats the use of striped lanes as an analytical refinement; see Section 3.10.2 Live Load Effects and Traffic Considerations.

3.3.2.3. Live Load Distribution

For approximate methods of analysis (e.g., line girder or equivalent strip analysis), live load distribution factors are calculated using empirical formulas per AASHTO LRFD for LRFR or AASHTO Standard Specifications for LFR and ASR. Additional requirements based on bridge type and specific bridge members shall be followed per Section 4.6.2 in AASHTO LRFD or Sections 3.23 to 3.28 in AASHTO Standard Specifications.

For refined methods of analysis, live load distribution factors are not explicitly calculated. Instead, the analysis program determines live load distribution based on the relative stiffnesses between bridge members. This approach typically results in greater distribution of load to other bridge members, as compared to approximate methods.

Additional guidance for live load distribution for corrugated metal decks and timber decks can be found in Section 3.5.4 Corrugated Steel Deck and Section 3.6.4 Timber Decks, respectively.

3.3.2.4. Impact/Dynamic Load Allowance

Static effects of truck loads should be increased 33% to account for dynamic effects for LRFR per AASHTO MBE Section 6A.4.4.3 and the increases calculated per the AASHTO Standard Specifications for LFR and ASR. No increase for dynamic effects needs to be applied to wood components.

Reductions to impact based on riding surface conditions are uncommon and require prior discussion with MDT's Load Rating Program Manager. Any reduction shall be documented with justification and references in the load rating report.

See Section 3.7 Buried Structures for impact loading on buried structures.

3.3.2.5. Vehicle Placement at Sidewalks or Medians

When a bridge has sidewalks or medians, compute vehicle loads by placing truck and lane loads in the roadway only. Do not place truck and lane on sidewalks or medians, regardless of whether a barrier is present between the sidewalk or median and the roadway.

3.3.3. Pedestrian Live Loads

Do not apply pedestrian live loads when load rating bridges. The likelihood of a sidewalk being fully loaded with pedestrians at the same time that the heaviest truck loading crosses the bridge is very low, so MDT does not typically apply pedestrian loads when rating bridges.

3.3.4. Other Non-Vehicular Loads

Various loads that are included in bridge design are not included in bridge load rating. These include wind loads, ice flow, barge impact, etc.

3.4. CONCRETE STRUCTURES

Follow the requirements of the AASHTO MBE and this section when load rating reinforced and prestressed concrete structures. The information needed to evaluate concrete structures includes concrete strength, reinforcing steel yield strength, and the quantity and layout of reinforcement. In addition to the guidance provided in this section, rating methods for concrete structures with missing reinforcement details are outlined in Section 3.9 Bridges with Missing Information.

3.4.1. General Guidance

3.4.1.1. No Plans/Field Measured

Bridges without plans must be field measured. Document deterioration during the field visit and include notes and photos that support determination of presumptive material properties.

3.4.1.2. *Sacrificial Wearing Surface*

Use the as-cast deck thickness for dead load. Deduct 0.5-inch sacrificial deck thickness when determining the structural thickness that contributes to section capacity, unless an overlay exists that was placed during construction.

For mill and overlays, consider the overlay to be non-structural (with no sacrificial wearing surface) unless the milling extended below the top mat of reinforcement. In that case, assume the overlay is structural and apply the sacrificial thickness deduction to the new deck thickness as described above.

3.4.2. Material Properties

The following guidance is provided for determining material properties for structures. For additional information on material testing, see Section 3.4.8.1 Material Testing.

3.4.2.1. *Reinforcing Steel*

Use the grade of reinforcing steel specified on the design drawings, as-built plans, or shop drawings. If reinforcing steel material grade is unknown, use the value specified in AASHTO MBE Table 6A.5.2.2-1 – Yield Strength of Reinforcing Steel based on the year of construction.

3.4.2.2. *Prestressing Steel*

Use stress-relieved strands for bridges constructed during or before 1980 unless as-built plans, shop drawings, or calculations indicate otherwise. Use low relaxation strands only if specified in the as-built plans, shop drawings, or the standard specifications that were applicable during the date of construction. If the type of strand cannot be determined definitively, assume the strands are stress-relieved, thus yielding a slightly conservative load rating due to higher prestressing losses.

If the ultimate tensile strength of the strand (f_{pu}) is not provided in the as-built plans, shop drawings or calculations, use AASHTO MBE Table 6A.5.2.3-1 – Tensile Strength of Prestressing Strand to determine the value based on the year of construction.

Note: Low relaxation and stress-relieved strands share many common attributes, except that the low relaxation strands have more stringent requirements on the relaxation loss (stress-relieved strands have no such requirement), and low relaxation strands have a measured yield strength equal to 90% of the ultimate tensile strength, while stress-relieved strands have an 85% requirement. Otherwise, the materials are fundamentally the same. If the type of strand cannot be determined definitively, it is acceptable to assume the strands are stress-relieved; this will yield slightly conservative load ratings due to higher prestressing losses.

3.4.2.3. Concrete

Unless the compressive strength of concrete is specified on the plans, use Table 3.4-1 which describes common concrete classes used throughout Montana based on year constructed for structures which were built as part of MDT projects or constructed in accordance with the MDT Standard Specifications for Road and Bridge Construction. (Note that in the case where "top 2 hardrock" is specified in the plans, use the material properties for "body hardrock.")

Table 3.4-1 Common Concrete Classes for Structures Constructed per MDT Standard Specifications

Concrete Class	Year of Construction	Compressive Strength, f'_c ksi
A	1934	2.00
	1935, 1940	2.20
	1946, 1958, 1959, 1962, 1966, 1970, 1976, 1981, 1987, 1995	2.40
	2006	3.00
AD	All years	3.00
B	1934, 1935, 1940	1.60
	1946, 1958, 1959, 1962, 1966, 1970, 1981, 1987	1.80
D	1934	2.20
	1935, 1940	2.80
	1946, 1958, 1959	3.00
	1970, 1976, 1981, 1987, 1995	2.40
	2006	3.00
DD	1946, 1958, 1959, 1962, 1966, 1970, 1976, 1981, 1987, 1995, 2006	3.00
BD	1981	4.50
DP prestressing		f'_c = 5.00, f'_{ci} = 4.00

For structures that were not constructed in accordance with MDT Standard Specifications for Road and Bridge Construction, use AASHTO MBE 6A.5.2.1-1 if the concrete class is unknown and concrete properties cannot be determined from as-built plans, shop drawings, or specifications.

3.4.2.4. *Prestressed Concrete*

Prestressed concrete material properties shall be based on the plans, shop drawings, MDT Standard Drawings, or standard construction specifications based on the year constructed. Similar to the previous section, refer to Table 3.4-1 and AASHTO MBE 6A.5.2.1-1 if compressive strength is not known. When using Table 3.4-1 or AASHTO MBE 6A.5.2.1-1 for prestressed concrete, the compressive strengths may be increased by 25 percent in accordance AASHTO MBE Article 6A.5.2.1. If the prestressed concrete initial strength at release is unknown, use 0.8 times the specified final concrete strength.

3.4.3. Special Requirements for Shear in Concrete Structures

Per AASHTO MBE Article 6A.5.8, in-service concrete bridges that show no visible signs of shear distress need not be checked for shear when rating for the design load or legal loads. Shear checks may be required at MDT's discretion, particularly when the condition of the concrete member drops to a 5 or less, or the member otherwise shows signs of distress.

For sections with concentrated loads within the "d" distance at the end of a span, use AASHTO LRFD Section 5.7.3.2 Sections Near Supports to calculate the member shear capacity.

3.4.4. Reinforced Concrete Slab Bridges

Analyze concrete slab bridges as strips, using a representative interior strip and a representative exterior strip.

MDT's preferred methodology is to load rate concrete slabs on a per-foot basis, using the live load distribution factor effective widths from AASHTO LRFD 4.6.2.3 and the requirements of 5.12.2, including the edge beam criteria.

In some situations – such as when evaluating significant reinforcement deterioration or when attempting to improve a rating – it may be appropriate to analyze the full width of the slab. Before modeling the bridge in this manner, consult with MDT's Load Rating Program Manager to determine whether the additional time and resources involved are warranted.

For example calculations, refer to AASTHO MBE Example A7 – Reinforced Concrete Slab Bridge Design and Legal Load Check.

3.4.4.1. *Exterior Strip*

Calculate effective width per AASHTO LRFD Width of Equivalent Strips at Edges of Slabs in Article 4.6.2.1.4.

Assume the weight of barriers and/or sidewalks is distributed over the full slab width.

3.4.4.2. *Interior Strip*

Calculate the effective width per AASHTO LRFD Width of Equivalent Interior Strips in Article 4.6.2.1.3.

Assume the weight of barriers and/or sidewalks is distributed over the full slab width.

3.4.4.3. Section Properties

Define all longitudinal reinforcement within each slab strip width when calculating the structural capacity of the slab. Include any deterioration of the slab or steel reinforcement in the analysis as discussed in Section 3.4.6.2 Reinforcing Steel Deterioration of this manual.

Assume a ½" sacrificial wearing surface when determining the structural capacity of the slab unless an overlay exists that was placed during construction. Include the full slab depth when determining dead loads. For mill and overlay projects, consider the overlay to be non-structural with no sacrificial wearing surface unless the milling extended below the top mat of reinforcement. In that case, assume the overlay is structural and apply the sacrificial thickness deduction to the new deck thickness as described above.

Do not include any non-structural elements (e.g., sidewalks, barriers, etc.) in the structural capacity of the slab without approval by MDT's Load Rating Program Manager.

3.4.5. Reinforced Concrete and Prestressed Concrete Girder Bridges

3.4.5.1. General Guidance

3.4.5.1.1. Shear

Use the AASHTO LRFD General Procedure in Article 5.7.3.4.2 to evaluate shear as a default. Other widely accepted shear capacity computation methods may be used based on engineering judgment. Document any methods used other than the General Procedure in the load rating report.

3.4.5.1.2. Section Properties

The following guidance applies to prestressed concrete structures, excluding segmental box girders.

Transformed section properties (conversion of the beam steel area to an equivalent concrete area) may be used for prestressed concrete beams. Per AASHTO LRFD Table 3.4.1-4 (MBE Table 6A.4.2.2-2) and LRFD Section 3.4.1 commentary, when transformed sections (required when calculating refined estimates of time-dependent losses) and elastic gains are included in the analysis, the live load factor for Service III must be 1.0.

3.4.5.1.3. Deck Beams

Evaluate adjacent precast prestressed deck beams without a cast-in-place deck as being only connected enough to prevent relative vertical displacement unless detailing indicates sufficient connection to act as a unit.

3.4.5.1.4. Analysis Parameters

Use the following assumptions as general guidance unless there is specific information available.

- Transfer time: 24 hours
- Age at deck placement: 90 days
- Final age: 10,000 days
- Shrinkage: Curing method - moist cured, unless otherwise noted in the shop drawings
- For the Service III Inventory check of tension in the precompressed tensile zone, use γ_{LL}=1.0
    - Include elastic gains
    - Use the AASHTO refined method for calculating prestress losses
- Use stress limits as calculated per AASHTO
- Use 60% humidity in percent format in the analysis
- Evaluate the prestressing per the strand pattern. If the strand pattern is unknown, estimate a pattern based on the prestress force (P) and center of gravity of strands (CGS) in the standard grid. Individual strand input better facilitates incorporating deterioration in specific strands as needed.
- Evaluate the slab interface as unroughened unless plans specify otherwise

3.4.5.2. Reinforcing Steel

When rating reinforced concrete and prestressed concrete girders, include all developed and intact longitudinal reinforcement in the member under consideration when calculating the structural capacity of the member. Deck reinforcement for a simple-span composite girder-deck system does not need to be included for load rating but may be used to increase capacity calculation if needed.

3.4.6. Incorporating Deterioration

Include any deterioration that may affect the structural capacity of the members being rated in the load rating analysis. Use the latest inspection data or field visit information to assess the extent of all deterioration, and apply engineering judgment to determine how best to incorporate deterioration into the analysis. Seek approval from MDT's Load Rating Program Manager if a complex analysis (i.e., FEM) is needed to model deterioration and determine a more accurate load rating. Consider applying the condition factor referenced in AASHTO MBE Article 6A.4.2.3 for LRFR when appropriate. Document all assumptions within the load rating report.

3.4.6.1. Concrete Deterioration

Significant deterioration - such as spalling or scaling that results in section loss to the level of reinforcing steel or beyond - shall be accounted for in the load rating. Insignificant deterioration, including fine cracks and small spalls, generally does not need to be considered. Reduce the concrete cross-section only in areas where the reduction is warranted. Examples of deterioration that may reduce load capacity in concrete structures include spalls and delamination at the level of the reinforcing steel, which expose the structural reinforcement and can affect development length, and spalls and delamination at the top of the member which can affect the structure's compressive strength. See Section 3.4.6.2 Reinforcing Steel Deterioration below for guidance on reinforcing steel deterioration.

3.4.6.2. Reinforcing Steel Deterioration

Account for exposed reinforcing steel with measured section loss in the load rating analysis as a percent section loss based on the measured remaining area of steel. Reinforcing steel that is locally corroded but intact at other locations may be included in the strength computations, provided that all relevant development length considerations are included. Similarly, intact reinforcing steel with spalled and cracked cover should be evaluated to determine whether sufficient development length is provided despite the intact reinforcing steel. Specific consideration should be taken for exposed lap splices and shear reinforcement.

3.4.7. Rigid Frames

Reserved for future use.

3.4.8. Techniques to Improve Capacity

3.4.8.1. Material Testing

More accurate material property values may be obtained by material testing with approval from MDT's Load Rating Program Manager. Material testing may be considered on a case-by-case basis when one of the following situations occurs:

- Existing plans are not available to establish material strengths to use during load rating.
- Material strength estimates, based on year built, would produce an overly conservative load rating.
- There is reason to suspect that material strengths are higher than those shown on plans (i.e., based on observed bridge performance)

Prior to performing material testing, analyze the members requiring increased capacity using higher material strengths to determine whether such testing is warranted and likely to improve the bridge's rated capacity.

Provisions for material testing can be found in Section 5 of the AASHTO MBE. Note that once testing is completed, the actual material properties must be incorporated into the load rating analysis regardless of whether they increase or decrease the bridge's rated capacity.

3.4.8.1.1. Reinforcing Steel Yield Strength

Samples of reinforcing steel may be needed for improvements to flexural or shear strength of reinforced concrete elements. Do not sample corroded reinforcing steel. Only obtain samples from reinforcing bars with no more than surface corrosion, and that are not in locations of maximum shear or flexure loading. Obtain a minimum of three samples of bars of the same size and use. Do not obtain samples from areas that are hooked or have bends. Contact testing laboratories in advance to determine the minimum length required for bars to be sampled (i.e., ASTM E8 testing). Obtain yield and ultimate tensile strength results for a minimum of three samples. If field test data is needed for bars of different diameters, determine if each diameter must be sampled and tested with input from MDT's Load Rating Program Manager. Remove samples from regions where removal does not negatively impact the load rating. For example, sample longitudinal steel near regions of low moment and stirrups from regions of low shear. Establish design values for yield and ultimate tensile strength using the same method of AASHTO MBE Article 6A.5.2.1 as for concrete cylinder testing.

3.4.8.1.2. Concrete Strength

Although in-place strength assessment of concrete is possible with techniques such as Schmidt hammer, Windsor probe, etc., these nondestructive tests are for relatively new concrete and provide more of a qualitative assessment of relative concrete characteristics. Therefore, determine concrete compressive strength by performing destructive testing with concrete core samples.

Sample concrete per AASHTO MBE Article 5.3. Take a minimum of three samples cores at low stress areas deemed representative of the structure/member as outlined in AASHTO MBE Article 5.3. For example, a concrete core of a slab bridge can be taken near the ends of the span. Do not include reinforcing steel in the core.

Evaluate the cores using the provisions of AASHTO MBE Article 6A.5.2.1.

Alternatively, consider the guidance from ACI 318-19, Section 26.12.6 Investigation of Strength Tests shown in Figure 3.4-1.

> (e) Concrete in an area represented by core tests shall be considered structurally adequate if (1) and (2) are satisfied:
> (1) The average of three cores is equal to at least 85 percent of f_c'.
> (2) No single core is less than 75 percent of f_c'.

Figure 3.4-1 Guidance from ACI 318-19

3.4.8.2. Including Compression Reinforcement

Compression reinforcement needs to be considered only when capacity calculations need to be refined. A small increase in rating factor may be achieved in structures such as T-beams and concrete slabs by analyzing as doubly reinforced members. In such cases, include the longitudinal reinforcing in both compression and tension in the load rating analysis.

3.4.9. Complex Concrete Structures

Strut-and-tie or other refined models may be used for load rating concrete elements where the traditional assumptions of flexural shear behavior as outlined in AASHTO LRFD 5.5.1 do not apply. These techniques may be appropriate for load rating structures near bearings or other locations of high concentrated loads such as brackets, corbels, and ledge beams.

3.5. STEEL STRUCTURES

3.5.1. General Guidance

3.5.1.1. No Plans/Field Measured

Bridges without plans must be field measured. Document deterioration during the field visit and include notes and photos that support determination of presumptive material properties.

3.5.1.2. Sacrificial Wearing Surface

Use the as-cast deck thickness for dead load. Deduct ½" inch sacrificial deck thickness when determining the structural thickness that contributes to section capacity, unless an overlay exists that was placed during construction.

For mill and overlays, consider the overlay to be non-structural (with no sacrificial wearing surface) unless the milling extended below the top mat of reinforcement. In that case, assume the overlay is structural and apply the sacrificial thickness deduction to the new deck thickness as described above.

3.5.1.3. Girder Analysis Preferences

3.5.1.3.1. Plastic Moments

Compact sections may be designed for moment strength in excess of first yield.

3.5.1.3.2. Appendix A6 Flexural Resistance

The use of Appendix A6 from AASHTO LRFD is permitted for straight bridges when bridges meet the requirements of AASHTO LRFD A6.

3.5.1.3.3. Appendix B6 Moment Redistribution

The use of Appendix B6 from AASHTO LRFD is allowed to provide improved ratings. First, compute the capacity of the section without the moment redistribution provisions of B6. Consult MDT regarding the need for B6 moment redistribution.

3.5.1.4. Rolled Sections

For steel shapes with only flange and web measurements provided, select the steel section that best matches the field measurements. The selected steel section should consider the steel sections available during the specific year of construction.

3.5.1.5. Composite Action

3.5.1.5.1. Shear Connectors

For steel bridges to be considered composite, beams must be constructed with some type of shear connection. Although detailing has evolved over the years, composite behavior can be assumed whenever the steel beams include shear connectors (typically studs in newer bridges and channels in older construction). If plans do not specifically indicate the presence of shear connectors, the beams should be assumed to be noncomposite.

When inputting shear connector information into BrR, the actual spacing and quantity can be entered; however, this level of detail is not required. Beams with shear connectors can simply be set to “composite” in BrR over the applicable beam length.

3.5.1.5.2. Deck Reinforcement

Bridges with shear connectors in the negative moment region can be load rated as composite sections in negative flexure. This includes longitudinal deck reinforcement in the section properties and moment strength calculations. For bridges without shear connectors in the negative moment regions, beams are treated as non-composite for negative flexure.

Similarly, longitudinal deck reinforcement in positive moment regions may also be included in the section analysis. Although the capacity gain will be small, it may be sufficient to eliminate the need for posting or restricting certain permit loads.

3.5.1.6. Field Splices, Pin and Hangers, Hinges

Typical girder field splices or other connections in a steel bridge, such as cross-frame attachments and similar secondary connections, generally do not need to be load rated. Note that this guidance applies to splices that are assumed to have been designed to transfer load in accordance with the standards in place at the time of construction and observed bridge performance indicates that the splices are performing adequately. Splices of unknown quality or questionable workmanship – specifically welded splices that exhibit cracking, distortion, or other signs of concern – should be evaluated on a case-by-case basis to determine whether additional analysis, inspection, or mitigation is required.

In bridges with nonredundant steel tension members, critical connection elements such as pin-and-hanger assemblies or bracket connections shall be load rated.

3.5.1.7. Additional Dead Load for Misc. Attachments

If available, use plans or shop drawings to input a representative allowance for the weight of stiffeners, studs, bracing, etc. This is considered an additional non-composite dead load. Many typical girder bridges have attachments and bracing that weigh 40 to 50 plf collectively. For girders with extensive bracing, lateral bracing, closely spaced cross-frames (less than 20 ft), or heavy members in the cross-frames (heavy angles or WT sections), the usual allowance may be inadequate. For some truss members, the weight of miscellaneous elements like internal diaphragm plates, fasteners used for stitch bolting box corners, and other attachments can be significant. The engineer must determine a reasonable allowance for these features.

Other loads are occasionally present on steel bridges. Some trusses, arches and other long-span structures have inspection walkways whose weight must be considered. Include the weight of any large signs permanently mounted to the structure. Other loads like sound walls, sidewalks, etc. must also be considered and input as composite or non-composite dead loads as appropriate. If stay-in-place forms are present and measurements of the form dimensions and the corresponding estimated weight of concrete in the form valleys are not available, use 10-15 psf to estimate the weight of forms and nonstructural concrete in the form valleys.

3.5.1.8. Stiffeners

Transverse and longitudinal stiffeners should be considered in the load rating since they are typically required to increase girder capacities for load ratings.

3.5.1.9. Haunches

For steel bridges, the haunch height is typically constant and is defined as the fixed distance from the top of the web (bottom of the top flange) to the bottom of the deck. If this dimension is known and has been verified in the field, use the measured haunch height to offset the slab from the top flange. When the haunch height is known, include an estimate of the concrete weight in the haunch. If no haunch dimension is specified, include a weight allowance of 2 inches of concrete above the top flange and assume the slab rests directly on the top flange with no offset when determining section properties.

3.5.1.10. Variable Width Overhangs

For an exterior beam, if the overhang varies, use an average value for the width of the overhang and the thickness of the overhanging slab.

3.5.1.11. Cover Plates

Assume cover plates are effective at the location where they become fully developed. For cover plates (full width, full length, and tapered), the required development length should be manually determined, and that length can be neglected in the analysis of the cover plate on the beam.

3.5.1.12. Fatigue of Steel Members

The fatigue limit state is an optional check and is not required by MDT. A remaining fatigue life analysis is not generally warranted. Situations where such an analysis may be warranted include major bridges undergoing rehabilitation or replacement evaluation, or bridges where fatigue cracks have been observed. Although a remaining fatigue life analysis is not needed at the location of an actual crack (because the presence of cracking indicates the fatigue life at that detail has been exhausted and repair should be considered), similar details that have not yet cracked may warrant analysis to determine the remaining fatigue life. Any fatigue check is at the direction of MDT. When evaluating the fatigue limit state, use the LRFD fatigue truck described in **AASHTO MBE 6A.6.4.1**. Detailed procedures for remaining fatigue life analysis are provided in **AASHTO MBE Section 7**.

3.5.2. Material Properties

See Section 2.5.1 General for a list of resources which may be used to determine material properties.

If the steel grade is unknown and steel properties cannot be determined from as-built plans, shop drawings, or standard specifications, use **AASHTO MBE** Table 6A.6.2.1-1 Minimum Mechanical Properties of Structural Steel by Year of Construction.

Material testing is another option for determining the strength of unknown steel materials. This involves cutting a steel coupon from a low stress location on the member. See Section 3.5.7.1 Material Properties for additional details.

3.5.3. Girder Bridges

3.5.3.1. Straight

3.5.3.1.1. Diaphragms

The load rating of diaphragms and cross-frames is not required in straight-girder bridges. The load rater should consider the presence of diaphragms and cross-frames as brace points. Include their weight as a dead load.

3.5.3.1.2. Top Flange Bracing

Concrete decks, with or without shear studs, are considered to provide continuous bracing for girder top flanges.

For steel bridges with a non-composite timber deck, consider the girder top flange to be braced at midspan if there is no obvious twisting or warping. See Section 3.6.4 Timber Decks for deck rating.

It is standard practice for corrugated steel decking to be tack-welded to the top flanges of the steel girders. For steel bridges with a corrugated steel deck, assume that girders are braced laterally along the top flange for the full length of the girder, unless inspection notes or photos indicate otherwise.

3.5.3.1.3. Variable Girder Spacing

If beams are flared or otherwise nonuniformly spaced, a constant beam spacing may be assumed to compute the live load distribution factor. The assumed spacing shall be taken as two-thirds of the maximum end-to-end spacing and applied over the full length of the beam span.

3.5.3.2. Curved

Unless a curved bridge is permitted to be treated as an equivalent straight beam (AASHTO LRFD 4.6.1.2.4), a system analysis is required. There are various techniques for performing a system analysis, including 2D grid, plate and eccentric beam methods, and full 3D models with discrete modeling of all components. The load rater must choose a model type and modeling technique that will reliably provide accurate ratings. References such as NCHRP Report 725, *Guidelines for Analysis Methods and Construction Engineering of Curved and Skewed Steel Girder Bridges* should be consulted when using 2D grid or plate and eccentric beam models. Ensure that any model using beam elements to model curved and skewed elements has warping stiffness capability or use the results on NCHRP 725 to develop improved grid models.

3.5.3.2.1. Diaphragms

AASHTO MBE Article 6A.6.9.7 states that diaphragms and cross-frames in curved bridges are considered primary members and are to be load rated at the discretion of the owner. Although diaphragms and cross-frames are not routinely evaluated, cases where their capacity may be a limiting factor include bridges with curvature and skew, especially for bracing lines close to the skewed substructures. Diaphragms or cross-frames might also be a limiting factor in approving some heavy permit loads. All diaphragms and cross frames that are determined to be primary load-carrying members due to skew or curvature need to be rated. If unsure of whether the diaphragms or cross-frames need to be rated on a particular bridge, discuss with MDT Load Rating Program Manager, Bridge Management Engineer, or Load Rating Engineer.

3.5.4. Corrugated Steel Deck

When load rating corrugated steel decks, use a 20” x 20” patch for tire distribution.

If decking manufacturer and corrugation size is not provided, use field measurements and engineering judgment to determine a deck size that most closely matches field measurements. Typical steel decking manufacturers include Contech and TrueNorth Steel (used in modular rolled girder bridges).

Analyze the deck in BrR as both continuous and simply supported between beams and use the least conservative deck results for the load rating. MDT considers both methods to be conservative, because the simple-span analysis ignores continuity, while the continuous analysis assumes center-to-center girder spans rather than actual support to flange edges. See Section 6.2.4.3 Decks for corrugated deck reporting details.

3.5.5. Trusses

3.5.5.1. Members to Rate

Load rate these members:

- all main members of the truss (chords, diagonals, verticals, others deemed main by the load rater)
- stringers and floorbeams of the floor system
- pins and eyebar connections of pin-connected trusses
- gusset plates

When rating in LRFR, apply the appropriate system and condition factors to each member separately. Do not globally apply the worst system or condition factors to all members of the bridge.

3.5.5.2. Bracing

Sway bracing, lateral bracing systems, and other elements needed for wind or overall stability do not need to be load rated.

3.5.5.3. Connections

The engineer must determine the significance of connection fixity on the performance and forces in the truss. Though most trusses are load rated as pin-ended, that may not always be an appropriate assumption when large gusset plates and rigid connections are used.

Consider the stiffness and restraint at connections in determining effective length factors for compression member buckling calculations.

Connections between stringers, floorbeams, and the truss members do not require a load rating unless significant deterioration or distress indicates a capacity concern.

3.5.6. Other Steel Structures

3.5.6.1. Through-Girder Bridges

Girder top flanges in through-girder bridges are discretely braced by knee braces and floorbeams. Use the provisions in **AASHTO LRFD Article 6.7.4.2.2** to assess the adequacy of bracing provided by floorbeams and knee braces used to stabilize top flanges in compression.

See Section 3.5.6.3 Two Girder Systems for more information on two-girder bridges.

3.5.6.2. Arches

The analysis and load rating of steel arches is a complex task and should be performed using software that the engineer is comfortable can properly model and provide the critical force effects. Failure modes for the arch include global buckling of the arch as a system as well as conventional "column type" compression or combined compression and bending failure modes between brace points. Estimating the effective unbraced length and various failure modes is critical and no specific guidance can be provided herein since many arch bridges have unique features.

Rating of the arch hangers is required. There is no specific design or rating guidance in **AASHTO** for cable hangers and the engineer shall submit for approval a proposed analysis and load rating approach for these elements.

Load rating of the deck members, such as stringers and floorbeams is also required. They commonly control the load rating and must be included. It is permitted to perform the load rating of the floor system using other programs or using different methods than to load rate the arch members themselves.

Load rating of connections is not required unless the engineer has reason to believe they may control the rating and should then alert MDT accordingly. Similarly, load rating of bracing members, for wind or similar load combinations is not required.

3.5.6.3. Two Girder Systems

Two girder systems should be load rated using a simple beam distribution of live loads to the controlling main girder. Also, load rate all transverse and longitudinal floor system elements such as stringers, floorbeams, truss-type stringer supports, and any other elements in the primary live load path. Consider the two-girder system as braced at floorbeam locations.

Load rate floorbeams and floor trusses. When the top flange of a floorbeam is in contact with a deck capable of providing bracing, the top flange may be considered braced against lateral torsional buckling. When floorbeams or floor trusses are used in a stacked system, the stringers may be considered as brace points of the floorbeam top flange or the floor truss panel points.

3.5.6.4. Multi-Span Continuous Stringers

Bridges such as girder-floorbeam-stringer type, as well as trusses and arches, commonly have a floor system that consists of parallel stringers spanning between floorbeams and with the stringer top flange in continuous contact with the deck. Such stringers can be considered to have a continuously braced top flange. Continuous stringer bottom flanges are discretely braced at floorbeam or floor truss supports. Many bridges have continuous stringers that are only braced at the floorbeam locations. Because of the reverse curvature bending that occurs between the brace points, the traditional moment gradient modifier equations in **AASHTO LRFD** are not appropriate; see Figure 3.5-1. Use the approach detailed in the **AISC Specification for Structural Steel Buildings,** 2022 edition, Commentary to Chapter F, F1 General Provisions, Equation C-F1-5, and associated commentary.

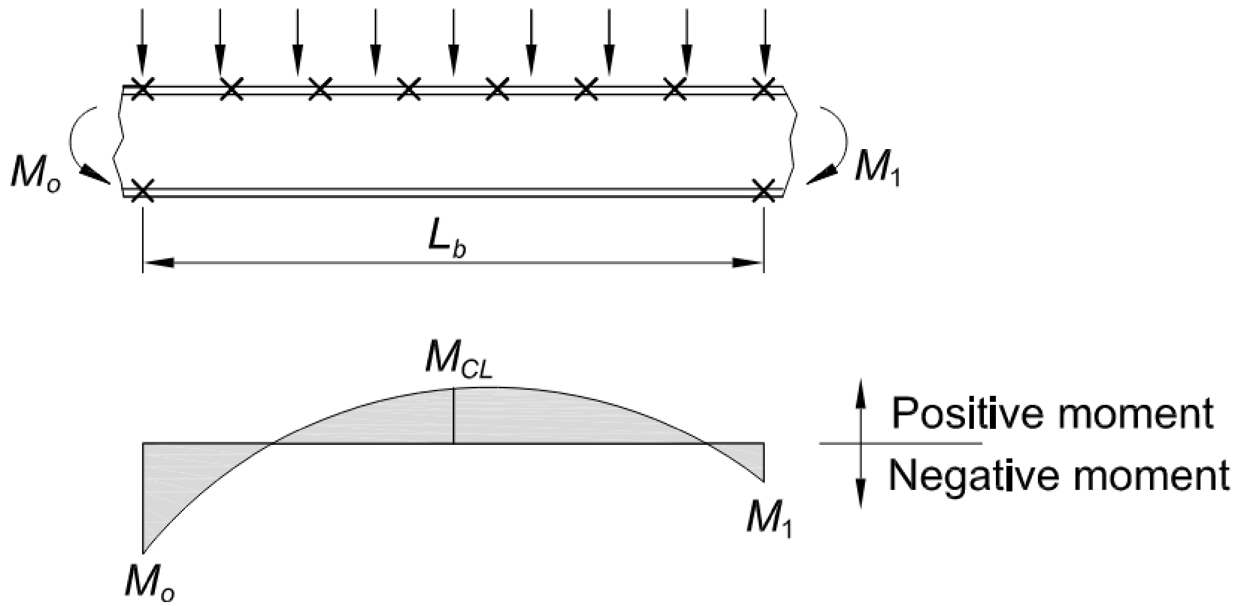


Figure 3.5-1 Reverse Curvature Bending of Members with Continuously Braced Top Flanges

A sample calculation from a previous load rating is presented in Figure 3.5-2 through Figure 3.5-5. These calculations demonstrate an acceptable approach to load rating stringers in a floor system with bracing only present at the floorbeam locations and subjected to moments following the pattern of Figure 3.5-1.

Missouri River Bridge @ Cascade.

This bridge is a 2 girder system that has floor beams and stringers. The controlling members for rating are the stringers. The controlling condition is Lateral Torsional Buckling (LTB) of the stringers based on the unbraced length on the bottom flange.

The Stringers are a W18x50 section that is continuous over the floor beams between bridge substructure units. The continuous stringers have either 6 spans at 24.0 feet or 8 spans at 22.5 feet. The controlling case will have the longer spans at 24 feet.

The original design called for embedding the top flange into the concrete deck 1/2 inch. That provides continuous support for the top flange so LTB based on positive bending is not an issue and the full strength of the stringer section can be used.

The original design ignored LTB due to negative bending and assumed that the full strength of the stringer section could be used. The only bracing points for the bottom flange are the floor beam locations. The bottom flange has an unsupported length equal to the stringer span length. The worst case is 6 spans at 24.0 feet.

An unbraced length, L_b = 24.0 feet puts the W18x50 stringer in the Elastic LTB range as shown in Figure 1 below. That potential for LTB results in a large reduction in available strength.

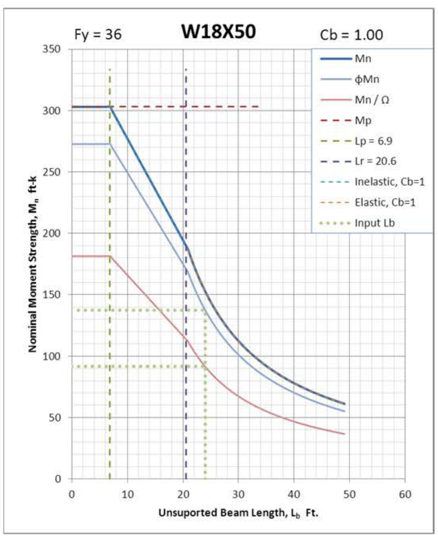


Figure 1 W18x50, C_b = 1.0

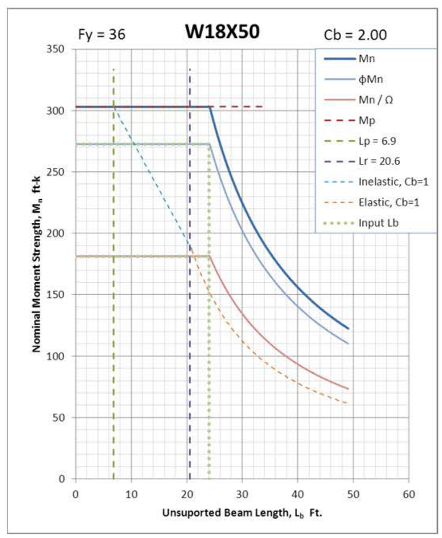


Figure 2 W18x50, C_b = 2.0

1

Figure 3.5-2 Missouri River Bridge guidance - applicable to other similar two-girder system bridges (1 of 4)

Figure 1 is based on a "C_b" factor of 1.0. The C_b factor is a modifier to account for non-uniform moments between support points. Figure 2 uses a C_b factor of 2.0. For a W18x50 with a 24 foot unbraced length, a $C_b \geq 2.0$ allows for utilization of the full section strength.

The original designers didn't consider LTB of the bottom flange. Figure 2 demonstrates that when $C_b \geq 2.0$ the full section strength is available to the designer.

Figures 1 & 2 assume the steel yield strength is 36 ksi. I didn't look up the actual steel used. A higher yield strength will result is a higher C_b for utilization of full section strength and a lower yield strength will result is a lower C_b for utilization of full section strength.

The load rating software checks LTB of the bottom flange and using C_b factors. There are two primary issues with the checks the software performs.

1. The assumptions inherent to the C_b equation used.
2. The use of "envelope" moments in the C_b equation.

The C_b Equation. AASHTO LRFD currently says, "In lieu of an alternate rational analysis, C_b may be calculated as follows:"

$$C_b = 1.75 - 1.05\left(\frac{f_1}{f_2}\right) + 0.3\left(\frac{f_1}{f_2}\right)^2 \leq 2.3 \qquad Eq\ (6.10.8.2.3 - 6)\ page\ 6 - 145$$

Where;
f_1 = smaller compression stress an end of unbraced length for the flange considered calculated from the critical moment envelope value.
f_2 = larger compression stress an end of unbraced length for the flange considered calculated from the critical moment envelope value.

The equation assumes a straight line distribution of stress between the brace points and uses the envelope value. The stress distribution can be significantly different then this assumed straight line. The straight line assumption and moment envelope values work well for short braced lengths within a longer span. This case has bracing only at the ends of the span and the spans are short.

Additionally, the equation assumes no other resistance to LTB between the brace points. In this case, the embedded top flange provides some bracing to the bottom flange. LTB requires both translation and rotation of the section. The embedded top flange partially restrains translation and, to a lesser extent, rotation of the bottom flange. Accounting for this partial restraint will usually result in a higher C_b factor

Use of Envelope Moments. The use of envelope moments is a simple approach that works well for most cases. For the short, continuous spans of these stringers, it ignores significant changes in moment within the span (unbraced length) that would be apparent in individual live load cases. Using envelope moments and the AASHTO equation, the computed C_b for the end spans will be C_b = 1.75 since the

2

Figure 3.5-3 Missouri River Bridge guidance - applicable to other similar two-girder system bridges (2 of 4)

envelope negative moment goes from zero at one end to a maximum at the first support. For the interior spans, $C_b \approx 1.0$ since the envelope will give nearly equal maximum negative moments at each end. The controlling case will be an interior span near the center where $C_b = 1.0$.

Elements of an "Improved" C_b Factor. An improved C_c factor for this case should include these 3 elements.

1. Moment gradients including changes in gradient slope between the brace points.
2. Partial restraint provided by the embedded top flange.
3. Consideration of the effects of individual load cases.

The first 2 consideration can be accounted for directly in the C_b equation. AISC gives an equation for the case of reverse curvature with one flange continuously braced. (AISC Steel Construction Manual, 14th Edition, p 16.1-305, Eq (C-F1-5)) That equation is given below.

$$C_b = 3.0 - \frac{2}{3}\left(\frac{M_1}{M_0}\right) - \frac{8}{3}\left[\frac{M_{CL}}{(M_0 + M_1)^*}\right] \quad Eq\ (C - F1 - 5)$$

$$* \ (M_0 + M_1) = M_0 \quad if \quad M_1 \ is \ positive$$

M_0 = End moment that produced the largest compression stress in the bottom flange.
M_1 = Moment at other end of the unbraced length.
M_{cl} = Moment at the middle of the unbraced length.
(Moments producing bottom flange compression are negative.)

The last condition can be met by a simple analysis of a several span continuous beam with a few loading cases applied to simulate the effects of actual truck point loads.

We did a simple analysis to look at the actual loading effects.

We found that the largest negative moment occurred over the first interior support when there were axel loads in both span 1 and 2. For this loading, the second span was the worst case since it had negative moments over both supports. The AISC equation gave $C_b \approx 4.3$ for this load case. Since 4.3 > 2.0, the full section strength can be utilized.

Other cases were also considered. All of these had lower negative moments but different moment distributions. To handle the cases we looked only at cases where;

$$Actual\ Negative\ Moment > \frac{Maximum\ Negative\ Moment}{Required\ C_b\ for\ using\ full\ section\ Strength}$$

This screening identified load cases where a $C_b > 1.0$ was needed. For each of these load cases, we computed a *Load Case Required C_b* and the *Load Case Actual C_b*. The ratio of these numbers was used to compare individual load cases.

Figure 3.5-4 Missouri River Bridge guidance - applicable to other similar two-girder system bridges (3 of 4)

$$Ratio = \frac{Load\ Case\ Actual\ C_b}{Load\ Case\ Required\ C_b}$$

The load case with the lowest ration is the controlling case. We found that load case to be a span 2 when there is a single axel load in span 1. The moment at the brace point is lower but the lack of an axel load in span 2 give a different moment gradient and a lower C_b factor. For this case we found *Load Case Required* $C_b \approx 1.3$ and the *Load Case Actual* C_b. ≈ 2.2 for a *Ratio* = 1.7.

Conclusion. Based on this work, we concluded that this is a rational method of addressing the C_b factor and LTB strength for this case and that the stringer is not at risk of LTB due to negative bending. Any ratings for the bridge may use "dummy" brace points so that the rating software will use the full section strength in the rating calculations.

The analysis was based on a 36 ksi yield steel. Since the controlling *Ratio* = 1.7, this analysis is valid for a broad range of steel yields.

For the specific case of the Transporter/Erector vehicle, since their analysis only showed a need to add lateral torsional bracing to the stringers, that bracing is not needed.

Prepared by;
Kent Barnes, PE
MDT Bridge Engineer
July 12, 2013

4

Figure 3.5-5 Missouri River Bridge guidance - applicable to other similar two-girder system bridges (4 of 4)

3.5.7. Techniques to Improve Capacity

3.5.7.1. Material Properties

More accurate material property values may be obtained by material testing with approval from MDT's Load Rating Program Manager. Material testing may be considered on a case-by-case basis when one of the following situations occurs:

- Existing plans are not available to establish material strengths to use during load rating.
- Material strength estimates, based on year built, would produce an overly conservative load rating.
- There is reason to suspect that material strengths are higher than those shown on plans (i.e., based on observed bridge performance)

Prior to performing material testing, analyze the members requiring increased capacity using higher material strengths to determine whether such testing is warranted and likely to improve the bridge's rated capacity.

Provisions for material testing can be found in Section 5 of the **AASHTO MBE**. Note that once testing is completed, the actual material properties must be incorporated into the load rating analysis regardless of whether they increase or decrease the bridge's rated capacity.

3.5.7.2. Exterior Girders that Have a Low Load Rating

Some structures have exterior girders that control the analysis with very low capacities. These are often situations in which the exterior members are channels or fascia girders that were never designed or intended to carry live load. This issue is often seen with the lack of curb presence.

The first option to explore in these situations is an alternate rating that removes the exterior girders and assumes they provide no capacity. Sometimes the deck, even with an increased overhang, will rate higher than the exterior girders themselves.

The second option is to restrict the traveled way (if appropriate) using the 'striped lanes' provision in the MBE to move traffic away from weak fascia members. See Section 3.10.2 Live Load Effects and Traffic Considerations.

3.5.7.3. Non-Prismatic Members

The AASHTO LRFD Bridge Design Specifications, 10th edition, added provisions in Appendix D that provide a rational method for calculating the lateral torsional buckling

(LTB) strength of non-prismatic sections. These provisions address members with constant or variable depth webs and with flange transitions within the unbraced length. They also address conservative load ratings produced by earlier LRFD provisions when flange transitions occur within the unbraced length. When LTB governs a steel beam's capacity, calculating the C_b factor instead of assuming a value of 1.0 typically improves the rating.

3.5.7.4. *Stiffened End Panels*

Use the provisions of **AASHTO MBE Article 6A.6.10.1** to evaluate the shear capacity of stiffened end panels. This method, introduced in the 2020 interim release, provides improved shear strength for steel girder end panels with transverse stiffeners.

3.5.7.5. *Finite Element Model Analysis (FEM)*

A refined finite element model (FEM) will typically result in a higher load rating. However, this approach should be reserved for complex structures or those being considered for load posting. Because FEM analysis requires additional labor-hours and specialized expertise, discussion with and approval from MDT's Load Rating Program Manager is required before using it to determine a load rating.

3.5.7.5.1. *Diaphragm Stiffness Reduction*

Include a stiffness reduction factor for eccentrically loaded WT and angle cross-frame members according to **AASHTO LRFD C4.6.3.3.4**. One acceptable approach is to model the members using their rolled shape gross properties and use a Modulus of Elasticity = 0.65E to simulate the stiffness reduction.

3.6. TIMBER

Timber can be challenging to evaluate because of its subjective nature; material properties and defects often require a high degree of engineering judgment. This section provides guidance to support consistency in timber load ratings over time and among different engineers. For additional information, refer to the **National Design Specification for Wood Construction (NDS)**, Section 4.1.5.

3.6.1. General Guidance

MDT's current practice is to rate timber members in ASR. For mixed material structures (i.e., steel girders with a timber deck, or timber girders with a corrugated steel deck), rate the steel members using LRFR or LFR and the timber members using ASR, then report the governing rating. See Section 6.2.4.4 Mixed Methods for mixed method reporting details.

Per Table 13.5.5A of the **AASHTO Standard Specifications**, use a load duration factor C_D = 1.15 for live loads.

3.6.2. Material Properties

With the exception of glulam members, the guidance in this section is based on bridge ownership: State-owned or non-State-owned. Assumptions that differ from these guidelines are permitted, but all deviations must be supported by sound engineering judgment and fully documented and justified.

3.6.2.1. State-Owned Bridges

Most State-owned timber structures were constructed using standard timber details or bridge-specific plans with high quality, old growth, Coastal Douglas Fir. These structures were typically built from the early 1930s to the mid-1950s on primary and secondary routes. Exceptions exist – for example, bridges originally designed and built by other agencies and later taken over by MDT. The following guidance applies to structures that were built using one of MDT's standard timber detail sheets; for exception cases, refer to the guidance for non-State-owned bridges.

3.6.2.1.1. Deck: Nail Laminated Timber

Use a bending capacity of 1.15 ksi (No. 1 & Better Douglas Fir-Larch) for typical nail-laminated decks. The load rater may adjust this assumption based on quality and condition of the deck timber.

3.6.2.1.2. Girders: Sawn Timber

Timber girders in bridges constructed by MDT using one of the standard timber detail sheets were designed with a bending unit stress of F_b = 1.55 ksi (Dense No. 1 Douglas Fir-Larch). Use this value for all girders that are free of deterioration, defects, or repairs unless bending stress is shown on the bridge plans. See Section 3.6.7.1 Assessing Defects and Deterioration for guidance on accounting for deterioration, defects, and repairs.

Timber girders for these bridges were also designed with a shear stress parallel to grain of F_v = 0.120 ksi. These bridges were constructed during a time when most timber beams were cut from old growth Douglas Fir, which is much more dimensionally stable than second growth timber. The Shear Stress Factor C_H – developed later to account for reduced dimensional stability and greater variability in second growth timber – was not part of the original design assumptions for MDT's timber bridges. The tabulated design value for shear stress parallel to grain (F_v) in Table 13.5.1. of the **AASHTO Standard Specifications** assume a worst-case assumption that a check or flaw is the full length of the member (*Timber Bridges – Design, Construction, Maintenance and Inspection, USDA, August 1992, Chapter 5, page 38*). Given the unique material properties of old growth Douglas Fir, the historical design basis, and the fact that very few (if any) shear failures have been documented in these structures, MDT has established the following guidance for modifying F_v for bridges built using MDT standard timber detail drawings:

- Use F_v = 0.085 ksi (tabulated design value for Douglas Fir-Larch Beams and Stringers, from Table 13.5.1A of the **AASHTO Standard Specifications**).
- If there are no documented defects that would correlate to a shear stress factor value lower than 1.5, use C_H = 1.41. This results in a modified F_v that matches the original design shear stress: *(F_v = 0.85) x (C_H = 1.41) = 0.120 ksi.* If there are documented defects, see Section 3.6.7.1.1. State-Owned.

3.6.2.2. Non-State-Owned Bridges

Most non-State-owned bridges were built without MDT oversight and were not constructed using the same standard detail sheets or the same timber materials as State-owned structures. Some county-owned timber structures on Secondary ("S") routes are exceptions, as they were built using MDT's standard timber detail sheets. For these bridges, load ratings should follow the guidance in Section 3.6.2.1 State-Owned Bridges for State-Owned Bridges.

Non-State-owned timber bridges exhibit wide variation in span lengths, materials, quality (grade), element sizes, treatments, and age. While a few may have engineered plans and specifications, this is uncommon. Most of the timber bridges owned by local agencies typically only have measurement sheets available. As a result, numerous assumptions are required, and those assumptions must be supported with sound engineering judgment and documented accordingly. The intent of this guidance is to provide consistency in the rating of local agency-owned timber bridges.

When timber properties are not provided on the original plans and cannot be determined from any other source (i.e., field sketches, measurements, or initial inventory inspection reports), beam stresses should be based on values listed in the *National Design Specification for Wood Construction (NDS)* referenced in the AASHTO Standard Specifications for the applicable wood species.

3.6.2.2.1. Deck: Nail Laminated Timber or Plank

If visual grade and species are not provided, use photos and inspection notes to determine the most appropriate grade for the deck, and document assumptions accordingly. If the species is not obviously something other than Douglas Fir-Larch, assume Douglas Fir-Larch. Use grades "No. 1 & Btr," "No. 1," or "No. 2" for decks unless a higher grade can be verified. A field visit may be necessary when the grade cannot be reasonably determined from available information, especially if the assumed grade results in a load posting.

Increasing the Shear Stress Factor (C_H) for non-State-owned timber decks should always be considered for members loaded perpendicular to their wide face (i.e., plank decks). In these cases, splits or checks are typically oriented parallel to the load direction and therefore do not affect the shear strength parallel to the grain.

3.6.2.2.2. Girders: Sawn Timber

If visual grade and species are not provided, use photos and inspection notes to determine the most appropriate grade for the girders, and document assumptions accordingly. If the species is not obviously something other than Douglas Fir-Larch, assume Douglas Fir-Larch. Use grades "Dense No.1," "No. 1" or "No. 2" for girders unless a higher grade can be verified.

The default C_H value of 1.0 can be overly conservative for timber girders, especially if shear governs the rating. Evaluate girder conditions (checks, shakes, and splits) and adjust C_H upward in accordance with Table 13.5.1A, Footnote 6 of the AASHTO Standard Specifications.

3.6.2.3. Girders: Glulam

If not specified on plans (or if plans are unavailable), use engineering judgment and document all assumed properties accordingly. If the species is not obviously something other than Douglas Fir-Larch, assume Douglas Fir-Larch for both the outer and core laminations. In general, use 20F-V3 (2.0 ksi allowable bending stress) unless a higher grade can be verified.

3.6.3. Dimension and Geometry Guidelines

Use the following guidelines when building models or performing analyses for the load rating of timber structures. These tolerances and procedures are intended to maintain consistency in load rating methodology and assumptions across different bridges over time. Apply engineering judgment in all analyses and document all assumptions, reasoning, and intent, especially when deviating from the dimension and geometry guidelines in this section.

Use the actual measured dimensions to the nearest ¼" for section property calculations, and the nominal measurements for adjustment factors when they are available. If actual measurements are not available, estimate the typical net section or use the dressed size in the AASHTO Standard Specifications.

For bridges with girder spacing that vary only slightly, an average or uniform spacing may be used to simplify the analysis when the differences are not anticipated to significantly impact the rating results. MDT's preferred practice is to model measured spacings, link girders, and document accordingly.

Use measured spacings for any girders whose individual spacing differs significantly from the average spacing. Apply engineering judgment to determine which girders should be analyzed individually based on the analysis type and the bridge geometry. Verify that all girders spacings plus overhangs fall within a reasonable tolerance of the out-to-out deck width. Use actual spacing for sister, helper, or widening girders and for their adjacent girders.

Wearing surface thickness on timber bridges often varies between spans or across the deck width. The depth recorded in BrM (MDT008) is typically an average depth or "best fit" for deck with variable thicknesses and may not reflect the most recent measurements. Always review the multimedia section of BrM for measurement forms or supplemental depth-of-cover sketches that may indicate variable wearing surface thicknesses. Apply engineering judgment when necessary and clearly document all reasoning in the load rating report. Report the wearing surface depth used in analysis on the load rating summary form and notify MDT's Load Rating Program Manager if the value used in analysis differs from the value shown in BrM.

3.6.4. Timber Decks

Most timber decks have gravel, asphalt, running planks, or other material on them that trap moisture against the wood for extended periods. When a cover of overlay is present, use wet condition factors for rating timber decks, regardless of the moisture condition at the time of the inspection or measurement. For bare timber decks located in relatively dry environments, use dry condition factors.

Distribute wheel loads to timber decks in accordance with AASHTO Standard Specification Article 3.25.1.1. For timber decks with longitudinal timber running planks, the deck live load distribution width may be increased to account for load distribution through the running planks, which can improve the rating.

3.6.5. Timber Girders

Use dry condition factors when rating girders, unless a girder is in a wet environment or shows signs of moisture (i.e., algae or mushroom growth, water staining). In such cases, use wet condition factors.

Broken or severely compromised timber girders are sometimes supplemented with a "helper" or "sister" girder, typically placed in contact with the compromised girder. These supplemental girders are usually timber or steel. When rating these components, exclude the compromised girder from the rating model and include the helper or sister girder using its actual dimensions, material properties, and location. In some cases, original girders may still provide partial capacity that needs to be considered in the load rating; such situations should be discussed with MDT's Load Rating Program Manager.

3.6.6. Widened Timber Bridges

Many State-owned bridges have been widened from their original construction. Widening typically involved installing two or three additional girders on each side – one or two next to the original exterior girder and another one or two spaced outward to obtain the required deck width (see Figure 3.6-1). The rating model should reflect the actual spacing between all original and widening girders. Include both the original and widening girders in the load rating model; do not treat widening girders like helper or sister girders as described in Section 3.6.5 Timber Girders.

When State-owned bridges have been widened as described above, the deck is not continuous between the two side-by-side girders (see example in Figure 3.6-1).

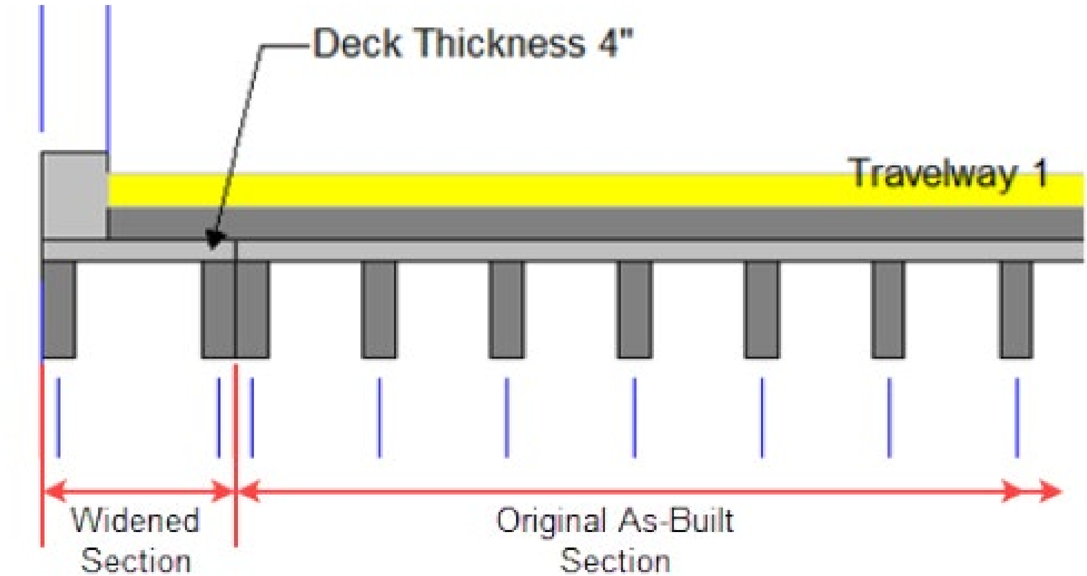


Figure 3.6-1 Girder Layout for Widened Bridges

3.6.7. Timber Bridges with Defects and Deterioration

The condition, extent of deterioration, and defects of structural components (rot, cracks, maintenance repairs, etc.) should be considered in load rating computations. Refer to the MDT Timber Bridge Inspection Guide, along with the following sections, for guidance on evaluating and accounting for deterioration in timber members. Use engineering judgment to appropriately incorporate defects and deterioration and clearly document with rationale in the Defects section of the load rating report. Include a note on the Load Rating Summary Sheet to flag capacity reductions (*i.e., "Span xx Girder xx capacity is reduced to xx%Fb due to xxx. See xxx for further details.")*.

MDT typically accounts for defects and deterioration by reducing the member's bending stress rather than by reducing section dimensions. Section-loss reductions may be used when appropriate, such as in case of fire damage where charred material is removed and remaining sound section is used. Adjusted material properties (i.e., stress reductions) should only be applied to specific member(s) with defects. Do not apply capacity reductions uniformly across all members unless the deterioration is consistent and widespread. Checks, shakes, and splits should be accounted for using the shear factor, C_H.

When a girder is considered failed – meaning it can no longer carry load due to severe deterioration, loss bearing, etc. – remove the girder from the model and rate the bridge (girders and deck) as if the failed girder doesn't exist.

Note: Generally, splits do not affect the bending capacity unless they are determined to be 'severe' (i.e., full-length). Sometimes there is a discrepancy between the terminology used in inspections and the actual condition. If photos are available, reference them to help inform an assumption. If there is not enough detail in the inspection, please contact MDT's Load Rating Program Manager. For example, the inspection calls out "full-length split," but photo (Figure 3.6-2) indicates an intermediate, partial depth checking along the full length of the neutral axis. This would not warrant a reduction in F_b but should be accounted for with C_H.

Figure 3.6-2 Example of Beam Checking

3.6.7.1. Assessing Defects and Deterioration

When rating a bridge with damaged girders, reduce the strength of the damaged girders in the rating model in accordance with the guidelines specific to ownership in Sections 3.6.7.1.1 State-Owned and 3.6.7.1.2 Non-State-Owned. The Assumed Capacity charts below (Figure 3.6-3 and Figure 3.6-4) are intended to provide consistent stress reduction values within each category across the full range of observed severity. Select the category that best reflects the member's available capacity based on the documented condition in the inspection report, site visit notes, or a girder capacity evaluation. Assumptions regarding available capacity should be based on sound engineering judgment and the

MDT Timber Bridge Inspection Guide and should be documented. Any deviations from this guidance require well-justified and fully documented assumptions.

3.6.7.1.1. State-Owned

If there are documented defects (photos or descriptions) that correlate to a shear stress factor C_H less than 1.41 (see Section 3.6.2.1.2 Girders: Sawn Timber for the background to this value) – such as C_H = 1.0 or C_H = 1.33 from Table 13.5.1A, Footnote 6 of the **AASHTO Standard Specifications** – use the C_H factor from the table and apply it to the tabulated value for "Shear Parallel to Grain, F_v" from Table 13.5.1A.

Reductions to bending strength due to defects or deterioration should follow Figure 3.6-3 for State-owned structures, as described in Section 3.6.2.1 State-Owned Bridges.

Assumed Capacity State-Owned Structures

Assumed Capacity: 100% *Condition: No defects* ***Bending Capacity: Use F_b = 1.55 ksi if girder is assumed to have full capacity***
Assumed Capacity: 85% - 99% *Condition: Member may have isolated cracks, isolated low-grade rot, or have robust maintenance repair (hanger or bolt stitching) of a small or minor crack.* ***Bending Capacity: Use F_b = 1.40 ksi***
Assumed Capacity: 75% - 85% *Condition: Member may have multiple areas of low-grade rot, a moderate crack with some type of arresting repair (hanger or bolt stitching), or other minor to moderate defects (knots on tension face, impact damage, small areas of section loss, etc.)* ***Bending Capacity: Use F_b = 1.25 ksi***
Assumed Capacity: 65%-75% *Condition: Member may have areas of low-grade rot, a small to moderate crack with no repair or a repair that is of questionable quality and is clearly not functioning as intended, or other defects that affect the ability of the member to carry load but have not completely diminished the load carrying ability.* ***Bending Capacity: Use F_b = 1.10 ksi***
Assumed Capacity: Less than 65% *Condition: Member has a severe crack, is broken, or rot is extreme. Assumed to contribute no capacity.* ***Bending Capacity: Use F_b = 0.0 ksi (remove from model)***

Figure 3.6-3 Assumed Capacity of State-Owned Structures

3.6.7.1.2. Non-State-Owned

Evaluate girder conditions (checks, shakes, and splits) and assign C_H in accordance with Table 13.5.1A, Footnote 6 of the **AASHTO Standard Specifications**.

Reductions to bending strength due to defects or deterioration should follow Figure 3.6-4 for non-State-owned structures, as described in Section 3.6.2.2 Non-State-Owned Bridges.

Assumed Capacity Non-State Owned Structures

Assumed Capacity: 100% *Condition: No defects* ***Bending Capacity: Use 100% F_b if girder is assumed to have full capacity***
Assumed Capacity: 80% - 99% *Condition: Member may minor cracks, isolated low-grade rot, or have robust maintenance repair (hanger or bolt stitching) of a small or moderate crack.* ***Bending Capacity: Use 90% F_b***
Assumed Capacity: 60% - 80% *Condition: Member has either a moderate crack, moderate but not widespread rot, or a less robust maintenance repair* ***Bending Capacity: Use 70% F_b***
Assumed Capacity: 0% - 60% *Condition: Member has a severe crack, is broken, or rot is extreme. Assumed to contribute no capacity.* ***Bending Capacity: Use 0% F_b (remove from model)***

Figure 3.6-4 Assumed Capacity of Non-State-Owned Structures

3.6.7.1.3. Glulam

Guidance for accounting for deterioration in glulam members is similar to that for sawn timber. See Figure 3.6-3 and Figure 3.6-4 for bending capacities based on level of deterioration and assumed member strength.

For glulam members with checks, the size and location of the checks may influence shear strength. APA Technical Note R475F, July 2021, *Evaluation of Check Size in Glued Laminated Timber Beams* reflects MDT's preferred approach for evaluating such members in load rating.

Note: The APA Technical Note states, "For glulam bending members, the presence of seasoning checks generally affects only the horizontal shear capacity and usually is not significant outside the shear-critical zone. Bending and tensile strengths are virtually unaffected. The shear critical zones, as shown in Figure 2 (of the APA Technical Note), are typically defined as the areas at both ends of a simply supported glulam beam within a distance from each end equal to three times the beam depth and within the middle ½ depth of the beam. For continuous beams, the shear-critical zone also includes a similar area over interior supports."

3.6.7.2. Rating Repaired/Strengthened Timber Girders

3.6.7.2.1. Historic Repair Methods

Historically, various repair methods (of varying construction quality) have been used by county forces or MDT Maintenance to address defective timber girders in Montana. Commonly observed repairs include:

- **Hanger repairs** (the most common) – steel plates installed at the bottom of the girder with vertical steel rods extending up the sides of the girder, through the timber deck to a plate on top, to support the damaged area.
- **Bolt stitching** – multiple long lag bolts driven vertically into the bottom of the girder to intersect cracks or splits, tying the separated sections together and closing the defect gap.
- **Steel side plate** – a steel plate of sufficient length to span the defect, attached to the girder side(s) with multiple lag bolts to "splice" the damaged sections together.

None of the historic repair methods have been standardized or tested. For load rating purposes, assume these repairs only arrest further deterioration and **do not** restore the girder to its original, defect-free capacity. Use a maximum bending capacity of F_b = 1.40 ksi or 90%Fb when rating girders that have undergone these repairs (See Figure 3.6-3 or Figure 3.6-4).

3.6.7.2.2. Fiber Reinforced Polymer (FRP) Repair Method

MDT, in partnership with Montana State University (MSU), has developed, tested, and implemented an in-place repair method for defective timber girders using pultruded FRP sections and strips attached with conventional structural timber connectors. The research project (Use of Fiber-Reinforced Polymer Composites for Bridge Repairs in Montana, Emtiaz Ahmed, Montana State University, College of Engineering, August 2025) evaluated the use of pultruded Glass Fiber Reinforced Polymer (GFRP) channel sections and Carbon Fiber Reinforced Polymer (CFRP) strips installed on defective girders. The standardized repair configurations included:

- Two FRP channels (one on either side of the girder) combined with an FRP strip on the bottom face.
- Three FRP strips (one on each side and one on the bottom face).

The research concluded that both standardized FRP repair methods restored the girder's bending and shear capacities to levels greater than the original undamaged capacity (up to 2x), regardless of the severity of the underlying defect.

For load rating, assume any girder using either of these FRP repair methods to have full capacity in bending and shear (i.e., F_b = 1.55 ksi, C_H = 1.41 for State-owned bridges).

3.6.8. Techniques to Improve Capacity

3.6.8.1. Load Rater Field Visit

If there is uncertainty about timber grade or the extent of a defect, a load rater site visit may be warranted to confirm the appropriate visual grade, verify measurements, and complete a girder capacity assessment. Discuss such situations with MDT's Load Rating Program Manager.

3.6.8.2. Removal of Deteriorated Beam from Analysis

If a damaged or deteriorated girder controls the rating, perform an alternate rating assuming the girder has failed (i.e., remove the girder from the model). Use whichever model ("damaged" girder model or the removed "failed" girder model) produces the **highest** rating factor for the overall bridge rating. Note that using the "failed" girder model will affect the deck rating because the deck span in the failed girder model will be twice the deck span in the damaged girder model. If the failed girder model is used, ensure the final deck rating reflects this doubled deck span.

3.6.8.3. Refined Live Load Distribution Factors for Timber Girders

For State-owned timber bridges, using the approximate live load distribution factors from Table 3.23.1 in the AASHTO Standard Specifications is considered conservative. Because these bridges typically have a wearing surface, the deck system and surfacing are assumed to distribute load laterally beyond what simple distribution assumptions capture. To better reflect actual distribution, MDT commissioned a finite element analysis to more accurately reflect live load distribution to the girders for 19-ft and 25-ft span timber bridges constructed in accordance with MDT standard drawings. The objective was to develop refined live load distribution factors for fill heights ranging from 0 to 24 inches and for various curb and railing geometries. This analysis produced the refined live load distribution factors shown in Figure 3.6-5.

When rating standard State-owned timber bridges that meet the conditions specified in the Figure 3.6-5 footnotes, use the formulas provided in the table to calculate the girder live load distribution factors.

Standard Timber Bridge Refined LLDF

Timber LLDFs		Standard Span Scenario		Girder Width Offset Scenario	12 Inch Offset Scenario	Removed Girder Scenario
		19 ft Span	25 ft Span	19 & 25 ft Span	19 & 25 ft Span	19 & 25 ft Span
	Fill Depth (h_f) (in)	**LLDF Equation**	**LLDF Equation**	**LLDF Equation**	**LLDF Equation**	**LLDF Equation**
Interior Girders	0	$\frac{S}{4.76}$	$\frac{S}{4.76}$	$\frac{S}{5.29}$	$\frac{S}{5.71}$	$\frac{S}{5.91}$
	1-14	$\frac{S}{4.95}$	$\frac{S}{4.95}$	$\frac{S}{5.4}$	$\frac{S}{5.86}$	$\frac{S}{6.03}$
	15-24	$\frac{S}{h_f+3.69}$	$\frac{S}{h_f+3.69}$	$\frac{S}{h_f+4.14}$	$\frac{S}{h_f+4.56}$	$\frac{S}{h_f+4.73}$
Exterior Girders	(6" Offset) 0-15		$\frac{S}{6.07}+0.021*hf$	Shear LLDFs = $0.3+\frac{LLDF_{moment}}{2}$ (Int. & Ext. Girders)		
	(6" Offset) 0-18	$\frac{S}{6.86}+0.024*hf$		Interior Shear at supports = Lever Rule		
	(6" Offset) 16-24		$\frac{S}{4.55}-0.071*hf$			
	(6" Offset) 19-24	$\frac{S}{4.87}-0.054*hf$				
	(12" Offset) 0-24	$\frac{S}{8.34}+0.022*hf$	$\frac{S}{7.6}+0.022*hf$			
	(18" Offset) 0-12	$\frac{S}{10.29}+0.011*hf$	$\frac{S}{9.07}+0.01*hf$			
	(18" Offset) 13-24	$\frac{S}{11}+0.029*hf$	$\frac{S}{9.55}+0.026*hf$			
The use of these LLDF is limited to timber bridges constructed according to the standard drawings r24tt19 and r24tt25 for 19 ft and 25 ft spans with 4" nominal timber deck depths.						
S = Average Stringer Spacing in feet (for exterior girder equations use exterior bay spacing) h_f = Fill Depth in feet						
For bridges with replacement girders placed near failed girders: The girder with the increased tributary area uses the Offset LLDF Equation and all other interior girders use the standard LLDF calculated using the typical spacing and standard equation.						
For bridges where a failed girder is removed from the analysis: On each side of the removed girder use the larger spacing based on the girder next to the removed girder to calculate the LLDF and use that LLDF for two girders (e.g. If G8 is removed, calculate the LLDF for G7 and use for G6 and G7 and calculate the LLDF for G9 and use for G9 and G10). For all other interior girders use the standard LLDF calculated using the typical spacing and standard equation.						

Figure 3.6-5 Standard Timber Bridge Refined LLDF

3.6.9. Timber Abutments and Bents

Timber substructure components with significant deterioration are typically identified through bridge inspection findings. When a timber substructure element appears to be critically compromised and likely to limit the overall bridge capacity, a load rating may be warranted. In some cases, restrictions may be implemented based on engineering judgment. This section provides guidance for load rating timber substructure components.

See Section 3.6.2 Material Properties for guidance on material properties.

If a timber pile has been compromised to the point that it can no longer adequately support loads, remove the pile from the bridge model and evaluate the pile cap spanning between the adjacent intact piles. Pile caps should be analyzed as continuous beams supported at each pile that remains in bearing with the cap.

If a timber cap is deteriorated, assess defects in accordance with Section 3.6.7.1 Assessing Defects and Deterioration.

Only an analysis of the critical member is required for the timber substructure rating.

3.7. BURIED STRUCTURES

Reserved for future use.

3.8. SUBSTRUCTURES

Substructures will seldom govern the load capacity of a bridge. In typical bridge designs, the superstructure components – such as stringers and decks – reach their design capacity well before piles, caps, or other substructure elements experience critical demand. Substructures are also subject to lower live load effects and often have reserve capacity due to conservative design practices, soil confinement, redistribution within pile groups, and overall system redundancy. For these reasons, substructures are generally not load rated unless inspection findings indicate that deterioration, tipping, damage, or other conditions may be limiting the substructure's ability to support the loads that they are subjected to.

When required, substructures should be rated using approved MDT software or calculations in Excel or Mathcad. Mathcad and Excel sheets should be well organized and easily understood to allow verification and future re-rating by MDT staff or MDT's consultants. See Section 6.2.7 Substructure Ratings for load rating report requirements when load rating of substructures is required.

See Section 3.6.9 Timber Abutments and Bents for guidance specific to timber substructure components.

3.9. BRIDGES WITH MISSING INFORMATION

Reasonable effort should be made to locate missing structure information before using the alternative methods below. Relevant sources include, but are not limited to:

- As-let and/or as-built plans
- Rehabilitation or widening plans
- Shop drawings
- Other project documents or drawings
- Field measurements

For structures with partially or completely missing information, follow the guidelines in this section.

Note: AASHTO MBE Article 6.1.4 permits bridges without plans to remain in service without posting if the bridge is inspected by a “qualified inspector” (NBIS 23 CFR 650C §650.309 (a) or (b)) and evaluated by a “qualified engineer” (§650.309 (d)) to establish an approximate load rating based on rational criteria. Use of this MBE provision should be paired with the FH, DL, RE, or FT methods as described in Sections 3.9.1 through 3.9.5.

Bridges with missing information may be evaluated using one or more of the following five methods (adapted in part from NCHRP Synthesis 571 “Load Rating of Bridges and Culverts with Missing or Incomplete As-Built Information.”):

Methods:

- Experience-Based (EB)
- Field Measurements and Historical Data (FH)
- Design Load Rating (DL)
- Rational Evaluation Rating (RE)
- Field Testing (FT) – MDT approval required

NOTE: While these approaches apply broadly, many steel and timber components can typically be rated using field measurements and standard material assumptions outlined in prior sections of this manual. The primary focus of this section is concrete and prestressed concrete structures with missing or incomplete information.

3.9.1. Experience Based (EB)

The Experience Based (EB) method involves the use of engineering judgment informed by material- and system-specific knowledge to develop justified assumptions for unknown components and produce a reasonable rating. Document all assumptions and rationale in the bridge file.

3.9.2. Field Measurements and Historical Data (FH)

Field measurements can be used for any structure to establish bridge geometry and member dimensions. Historical data to estimate material properties or reinforcement details may be used with approval from MDT’s Load Rating Program Manager and when either the structure is state-owned/constructed or there is evidence that a Montana PE designed it.

In some cases, county-owned structures may be evaluated using comparable data from similar structures with known details if they were constructed in the same timeframe and share the same characteristics. Where applicable, use standard plans or plans for similar structures (comparable span length, width, type, and construction era) as indicators of materials and reinforcement layout. Apply reasonable conservatism for unknowns and document assumptions, including which characteristics were matched, any tolerances used (i.e., member sizes and spacing), any deviations from the referenced plan, information referenced, etc.

Standard plans or similar plans may be used to generate the load rating model if the following criteria are met:

Standard Plans

- The original standard plan pre-dates the bridge's year of construction.
- Construction is consistent with the referenced standard plan(s). A site visit may be required if verification cannot be reasonably made from available measurements and inspection records.

Similar Plans

- The subject and reference structures were constructed within a reasonable timeframe of each other.
- Construction is consistent with the referenced similar-structure plan(s). A site visit may be required if verification cannot be reasonably made from available measurements and inspection records.

Similar plans may originate from anywhere in Montana; they need not be from structures in the same district or county.

3.9.3. Design Load Rating (DL)

The Design Load Rating (DL) method uses either the known design load for the bridge or an estimate based on the bridge's age and design loads in use at the time of construction. Reinforcement details can be established by targeting an assumed Inventory Rating result (RF = 1.0) for the design load. The Operating Rating is proportional to the Inventory Rating depending on rating methodology (LFR or LRFR). The load rater may use the Design Load from BrM if it appears to be accurate. If the Design Load is coded "Other" or "Unknown," or the original design loading is otherwise undeterminable through engineering judgment, the load rater may assume design load based on Table 3.9-1.

Note: It is reasonable to assume that prestressed concrete structures were fabricated by a prestressed concrete plant. Therefore, for prestressed concrete structures without shop drawings and/or with unknown strand patterns, it is likely that the design load would have at least met the code in effect at the time. In these cases, model the structure in BrR using all available information and use an iterative process to establish reinforcement that achieves an Inventory Rating of approximately 1.0 for the determined design load.

Table 3.9-1 Design Load, Year of Design & Facility Type Correlation

<table>
<tr><th rowspan="2">Year of Construction</th><th colspan="4">Estimated Design Load based on Facility Type</th></tr>
<tr><th>Interstate</th><th>Primary Routes</th><th>Secondary Routes</th><th>Other Routes (off-system)</th></tr>
<tr><td>Prior to 1960</td><td rowspan="3">HS-20</td><td>H-15</td><td>H-15</td><td rowspan="2">H-15</td></tr>
<tr><td>1960 - 1975</td><td rowspan="2">HS-20</td><td>HS-15</td></tr>
<tr><td>1975 - 2015</td><td>HS-20</td><td>HS-20</td></tr>
<tr><td>After 2015</td><td>HL-93</td><td>HS-20*</td><td>HS-20*</td><td>HS-20*</td></tr>
</table>

**While bridges constructed after 2015 may have been designed for HL-93 live load, consistent use of HL-93 (except for Interstate structures) cannot be assumed with sufficient certainty*

Once a design load is determined or reasonably assumed:

1. Develop a BrR model of the structure using field measurements or other available information (i.e., construction plans, standard drawings, standard beam shapes).
2. Incrementally add reinforcement to the girders until the Design Load Inventory Rating factor (Design Load Rating) is as close as reasonably possible to 1.0. Base reinforcement layouts on patterns from similar bridges with the same standard beam shape and construction timeframe. If a strand pattern is not available, use P and CGS (total strand force P and centroid of the strand pattern CGS) to determine a single equivalent reinforcement centroid consistent with the combined capacity.

   Note: The intent of this method is to replicate the original design outcome. Complete the Design Load Rating using the code that was most likely in effect at the time. For example, do not include AASHTO refined methods, transformed properties, and elastic gains for older structures as they are unlikely to have been part of the original design. Unless available plans indicate otherwise, follow FHWA guidelines for LRFR applicability based on age: assume LDF design if constructed before 2007, assume LRFD design if constructed after 2007.

3. Once the reinforcement (or reinforcement centroid) is established for the design load, create an in-service rating model and include deterioration or damage per the current MDT inspection report.
4. Determine load rating factors for legal loads based on typical load rating methodology. See Appendix C – DL Method – Guidance for Modeling and Reporting.

3.9.4. Rational Evaluation Rating (RE)

Reserved for future use. This section will address deriving load rating values based on the bridge's NBI condition ratings.

3.9.5. Field Testing (FT) (MDT Approval Required)

Field testing (FT) methods including Load Testing (LT) or Nondestructive evaluation (NDE) may be used, with MDT approval, to determine necessary details for load rating or establish capacity of structures with missing information. NDE can help establish cover, bar spacing, and—where feasible—bar size. NDE can also support estimation of concrete properties. A conservative interpretation of NDE results is required due to uncertainties and method limitations. For example, ground penetrating radar can identify the spacing of reinforcing steel, but it is not effective for determining the size of reinforcing bars.

For more in-depth assessments, nondestructive (NDE) and destructive testing may be used in combination with load testing. Refer to Section 3.2.4 Non-Destructive Load Testing (LT) for more information about using load testing to determine a load rating for structures with little or no structural information.

3.10. ANALYTICAL REFINEMENT METHODS

Standard analytical procedures may not fully represent a structure's actual behavior or operational use. When standard (approximate) analysis identifies a need to post, review assumptions for undue conservatism and, where appropriate, consider analytical refinements to better reflect observed performance and operating conditions. Safety must always be prioritized; when the need to post is driven by defects or deterioration, refining the analytical rating may not be appropriate. Apply refinements on a case-by-case basis with sound engineering judgment, and document methodology, assumptions, and justification. Consult MDT's Load Rating Program Manager before initiating advanced refinements (Section 3.10.4 Refined Analysis Methods and later sections). In addition to the commonly used methods described in this section, see the preceding material-specific sections for rating refinement techniques tailored to each material. Refer to Appendix D – Analytical Refinement Methods for guidance on modeling and documenting the following methods.

3.10.1. Alternate Methodology

- Using LRFR to evaluate older, in-service structures designed by a method other than LRFD can sometimes produce low ratings for bridges that are in good condition and performing well. In such cases, LFR may be used as an acceptable alternative, provided the methodology is allowable per FHWA (see reference below).
- Bridges meeting criteria that require LRFD design must be rated in LRFR.
- Reference: FHWA memorandum (October 30, 2006) on permissible rating methods: https://www.fhwa.dot.gov/bridge/nbis/103006.cfm

3.10.2. Live Load Effects and Traffic Considerations

- Reduce live load effects based on ADTT per AASHTO LRFD C3.6.1.1.2 (applicable to LRFR only).

- Use single lane distribution when site conditions support that two rating vehicles are unlikely to be on the bridge simultaneously (i.e., off-system structure, “Single Lane Bridge” signs, running planks indicating single lane use, rural/low traffic area, grassy shoulders, absence of painted lanes, other clear operational evidence of single-lane use).
- Adjust vehicle placement using striped lanes when definitive boundaries exist and it is reasonable to assume that vehicles will remain in those bounds (i.e., timber running planks, grass shoulders, etc.). It’s best practice to consult with the bridge owner that knows the area best and get concurrence that operations match assumptions.
- Use improved plank deck live load distribution when appropriate (i.e., presence of longitudinal timber running planks that help to better distribute load).

3.10.3. Emergency Vehicle Ratings

- When one or more EV triggers posting, ensure the least conservative analysis template is used:
    - LFR: legal operating category with adjacent Type 3-3
    - LRFR: permit category with adjacent Type 3-3
- Adjust the live load factor per NCHRP 20-07/Task 410 (“Load rating for the FAST Act Emergency Vehicles EV2 and EV3”)
- Consider dynamic allowance adjustments where appropriate
- Use single-lane assumptions where warranted (i.e., narrow structure in rural area, unlikely for EV and another vehicle to be on the bridge at the same time)

3.10.4. Refined Analysis Methods

- Derive refined live-load distribution factors using alternative software (input results into BrR to complete analysis)
- Perform 3D finite element analysis (FEM)

3.10.5. Material Property Verification

- Perform material testing to validate or replace conservative defaults used in analysis (i.e., concrete compressive strength, steel yield strength)

3.10.6. Design Review

- Conduct a targeted review of the original design and its assumptions to pinpoint causes of unexpectedly low rating results, and reconcile the load rating model where appropriate

3.10.7. Load Testing

- See Section 3.2.4 Non-Destructive Load Testing (LT)

4. LOAD RATING PROCESS

4.1. GENERAL

NBIS § 650.313 (k)(2) requires state DOTs to develop and document procedures for completion of new and updated load ratings. The following sections outline the load rating process, including qualifications, workflow, and QA/QC.

4.2. QUALIFICATIONS

Per NBIS § 650.309 (Qualifications of personnel) subpart (d), "Load ratings must be performed by, or under the direct supervision of, a registered professional engineer." MDT places a strong emphasis on accurate, high-quality ratings and requires thorough QA/QC by qualified personnel. At a minimum, MDT requires the following qualifications for personnel performing load ratings.

4.2.1. Minimum Qualifications for Load Rater/Originator

The load rater/originator must be a Professional Engineer licensed in the state of Montana, or an individual working under the supervision of a Montana-licensed Professional Engineer. The load rater must have engineering expertise and experience necessary to evaluate the specific bridge being load rated; requirements differ by structure type, and some structures require specialized knowledge. Load raters shall have a working knowledge of the MBE, LRFD, and the Standard Specifications, and should have experience with the software used to perform the rating.

A load rater's work must be finalized by a Professional Engineer, who is the Load Rater of Record.

Note: For internal ratings, the signature on the summary sheet serves as certification that the Load Rater of Record was involved and supervised the work of the originator.

4.2.2. Minimum Qualifications for QC Reviewer

The QC Reviewer must be an independent reviewer with load rating experience and qualifications equal to or greater than those of the load rater.

4.2.3. Minimum Qualifications for QA Reviewer

The QA Reviewer must be an independent Montana-licensed Professional Engineer who is qualified to perform load ratings and has familiarity with the load rating process and MDT manual requirements.

4.3. LOAD RATING TRIGGERS AND RESPONSES

4.3.1. Newly Constructed Structures

An initial load rating is required for all newly constructed structures, including replacement structures. Initial load ratings shall be completed after construction is complete, the bridge has been added to the inventory, and the initial in-service inspection has been performed and finalized. Per NBIS § 650.313 (k)(2)), the load rating must be completed as soon as practical, but no later than 3 months after the initial inspection.

4.3.2. Existing Structures New to the Inventory

An initial load rating is required for all existing structures that are added to the inventory (i.e., a recently identified structure). The load rating shall be completed after the bridge has been added to the inventory and the initial in-service inspection has been performed and finalized. Per NBIS § 650.313 (k)(2)), the load rating must be completed as soon as practical, but no later than 3 months after the initial inspection.

4.3.3. Repaired or Rehabilitated Structures

An updated load rating is required after a bridge is rehabilitated or repaired. Depending on the scope, a rehabilitation or repair project could include changes to permanent loads, capacity of load carrying members, or usable travel way. It's recommended that a preliminary evaluation be completed early in the project development phase to determine the project's impact on the bridge's safe load capacity. An updated load rating shall be completed after construction is complete and a post-rehab inspection has been performed and finalized. Per NBIS § 650.313 (k)(2), the updated load rating must be completed no later than 3 months after the rehab or repair is complete.

4.3.4. Existing Rating Updates (Load Rating Maintenance)

Because a load rating is a measure of allowable live load, it is directly influenced by the structure's capacity and the amount of dead load it supports. Therefore, load ratings shall be maintained over the bridge's life and updated whenever there's a change that affects capacity or dead load. Examples where an update may be warranted include:

- Change in the dead load (e.g., overlays added or removed, deck thickness is modified, added utilities, parapets, or sidewalks, etc.)
- Damage events (e.g., vehicle impact, fire, observed overstress, etc.)
- Deterioration (e.g., concrete spalls/delamination, steel corrosion with section loss, timber rot)
- Change in travel lane limits or operations (e.g., lane configuration, traffic use, or vehicle placement) that affect load paths

Per NBIS § 650.313 (k)(2), an updated load rating must be completed as soon as practical, but no later than 3 months after the change has been identified. Depending on the nature of the change and its anticipated impact on safe load capacity (i.e., new restriction), acceleration of the rating update or implementation of interim measures may be warranted. For critical findings, immediate follow-up action – and all other associated requirements – take precedence over the timeframes in this section. Each situation should be evaluated on a case-by-case basis.

Updated load ratings may also be required due to changes in AASHTO MBE specifications or revisions to state/federal legal load regulations. These systemic changes affect the broader inventory and typically require a coordinated, program-level update effort.

4.3.5. Flagging Load Rating Triggers (MDT034)

MDT034 – the "Request Review of Load Rating" attribute in BrM – is the mechanism used to flag and track initial load rating needs or potential load rating updates for the trigger scenarios outlined in Section 4.3.4 Existing Rating Updates (Load Rating Maintenance). In practice, most requests originate from inspectors who observe changes during field work; however, requests may also be initiated by others (for example, permitting engineers who identify issues during inspection reviews for permitting analysis). Inspector guidance for updating MDT034 is included in MDT's Bridge Inspection Manual.

When MDT034 is updated in BrM, an automatic email notification is sent to the Load Rating Program Manager. A designated reviewer then conducts a cursory assessment to determine the necessary action – whether a load rating update is warranted, whether interim measures are necessary pending analysis, and whether additional information is needed to support the review or load rating update. MDT034 values and comments should be updated to track status from initial observation through final resolution. See Appendix E – Load Rating Updates for guidance on load rating updates and Section 4.3.4 Existing Rating Updates (Load Rating Maintenance) for associated timeframes.

If it is determined that a load rating update is not warranted, the reasoning should be documented in MDT034 comments and supported by a brief memo to file that addresses the observed change(s) and explains the basis for determination.

4.4. BRIDGE OWNER-PROVIDED LOAD RATINGS

On a case-by-case basis, a bridge owner may provide a rating analysis to MDT for consideration. The analysis must comply with all MDT requirements (i.e., qualifications, approved software, applicable guidance, documentation) and is subject to MDT concurrence. Bridge owners shall coordinate with MDT's Load Rating Program Manager prior to taking this approach.

4.5. QUALITY ASSURANCE/QUALITY CONTROL (QA/QC)

4.5.1. General

Section 1.4 of the **MBE** states, “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.” The MBE further states that **QC procedures** are intended to maintain the quality of the bridge load ratings, and are usually performed continuously within the units performing the load ratings, while **QA procedures** are used to verify the adequacy of the quality control procedures to meet or exceed the standards established by the program manager, and are usually performed independently of the bridge load rating teams on a sample of their work.

The requirement for an agency to perform QC/QA procedures is codified in the CFR, which states “Each State transportation department, Federal agency, and Tribal government must include a bridge inspection organization that is responsible for the following…Performing quality control and quality assurance activities;” (NBIS § 650.307 (e)(6)

NBIS § 650.313 (p) outlines what should be included in every QC/QA program:

(1) Assure systematic QC and QA procedures identified in Section 1.4, **AASHTO Manual** (incorporated by reference, *see* § 650.317) are used to maintain a high degree of accuracy and consistency in the inspection program.

(2) Document the extent, interval, and responsible party for the review of inspection teams in the field, inspection reports, NBI data, and computations, including scour appraisal and load ratings. QC and QA reviews are to be performed by personnel other than the individual who completed the original report or calculations.

(3) Perform QC and QA reviews and document the results of the QC and QA process, including the tracking and completion of actions identified in the procedures.

(4) Address the findings of the QC and QA reviews

These requirements are captured in the procedures outlined in the subsections below. Consistent with NBIS and the MBE, MDT employs QC/QA to maintain a high degree of accuracy and consistency in load ratings, ensuring correct load posting and permitting, defensible engineering decisions, and continuous program improvement. MDT is committed to a high-quality Bridge Inspection and Management Program; robust QC/QA processes for bridge load ratings strengthen the program and help achieve its overall goals.

4.5.2. Quality Control Procedures

Quality Control (QC) refers to the operational activities put in place to control the quality of bridge load ratings. QC includes providing clear decisions and directions, constant oversight by experienced personnel, immediate review of completed work for accuracy and completeness, and thorough documentation of all decisions, assumptions, and recommendations. When applied as intended, QC helps ensure that the work is done correctly the first time.

The scope and depth of QC are determined by the complexity and features of the load rating. Common bridge types in good condition generally warrant a lighter review, while complex designs or bridges in poorer condition require more intensive checks.

MDT requires a QC review for every load rating.

4.5.2.1. QC for MDT Performed Ratings

Internal QC reviews are conducted for load ratings completed by MDT personnel. The **Internal Load Rating – MDT QC Review Checklist** (see Appendix G) should be completed at all review levels and kept on file. The Load Rater of Record is responsible for ensuring that the QC Review Checklist is fully completed.

4.5.2.2. QC for Non-MDT Performed Ratings

Non-MDT raters (including consultants and local agencies) must be familiar with MDT load rating procedures and maintain QC processes that ensure accuracy and completeness. QC reviews shall align with the QC plan described in the consultant's Statement of Qualifications (or equivalent submittal) for bridge load rating work. Any changes to the QC plan require MDT approval. At a minimum, the QC process must meet MDT's QC requirements in Appendix G – MDT QC Checklist.

4.5.3. Quality Assurance Procedures

Quality Assurance (QA) provides confidence that load ratings meet established quality requirements and that the QC program is effective. The objective of QA is continuous improvement of the overall delivery process to enhance quality and productivity. MDT conducts QA at two levels: program-level QA of the load rating program as a whole and per-rating QA for individual load ratings.

4.5.3.1. Program-Level QA – Load Rating Program Reviews

Program-level QA evaluates the load rating program as a whole – typically alongside bridge inspection QA – by sampling ratings across regions, structure types, and load raters. It confirms QC effectiveness and compliance with **MBE** Section 1.4 and **NBIS** § 650.313(p), maintains accuracy and consistency, and identifies systemic issues for training and process improvement. Reviews check for file completeness, verifying that:

- A current bridge load rating is on file.
- Required rating information and documentation are included.
- The rating reflects current bridge condition and configuration.
- Resulting rating factors are reasonable for the structure.

- The bridge is load posted at the appropriate level, if required, based on the current rating.
- Data is consistent between the current load rating on file and BrM data entry.

4.5.3.2. Per-Rating QA – Acceptance of Individual Ratings

Before a load rating is accepted as the final rating of record, MDT conducts a per-rating QA acceptance review to ensure completeness, compliance, and implementability. This high-level review applies to external (consultant- or bridge owner-provided) and internal submittals, providing a cursory check for

- Overall completeness
- Compliance with MDT procedures and the MBE
- Reflection of current bridge condition and configuration
- Reasonableness of results
- Consistency among BrR, calculations, and the load rating report

An MDT QA Reviewer, independent of the originator, either accepts the rating as the final record or returns it for revisions with comments.

Quality Assurance reviews of load ratings are conducted alongside QA reviews of bridge inspections. Every bridge that receives a QA review of bridge inspection also receives a QA check of the inspection files to make sure the files are complete. This file review includes checking to make sure a bridge load rating is present in the file, contains the required information, has been updated to account for changes in the condition of the bridge, and yields reasonable rating factors for the bridge in question.

4.5.3.3. QA for External Rating – Consultant Performed, Bridge-Owner Provided

All external rating submittals (i.e., consultant performed, provided by bridge owner) must undergo MDT QA review to check for completeness and compliance with MDT's load rating procedures and requirements before they are accepted as the final load rating of record. Any load ratings that do not pass QA review are sent back for revision.

5. Load Posting Procedures

5.1. OVERVIEW

The Montana Department of Transportation (MDT) is committed to planning, building, operating, and maintaining a safe and resilient transportation system that moves Montana forward. When required, bridge load posting is essential to the safety aspect of this commitment. The authority and responsibility of MDT to post or restrict bridges is outlined in the following regulations.

5.1.1. Federal Regulations

The **National Bridge Inspection Standards** (NBIS), as published in the Code of Federal Regulations (CFR) at 23 CFR §650 Subpart C, require posting or restriction of bridges that are not capable of safely carrying legal loads (23 CFR 650.313(l)(1)).

5.1.2. State Statutes

Montana state laws (Montana Code Annotated, MCA) give MDT the duty, responsibility, and authority to operate and maintain highway facilities. See the following statutes:

- MCA 60-1-102 Legislative Policy and Intent
- MCA 61-10-128 When Authorities May Restrict Right To Use Roadway
- MCA 61-10-155 Rulemaking Authority
- MCA 7-14-2201 Maintenance and Control of General Guidelines

5.1.3. Responsibility for Posting/Closure Determinations

- Posting recommendations are made by load rating engineers based on load rating results and the guidance that follows.
- The Load Rating Program Manager or designee is responsible for making a final determination on all load posting decisions, based on considerations such as the bridge's physical condition, visible distress, structure redundancy, traffic volume, and refined capacity strategies. (See Section 5.3 Posting Considerations.)
- When determining a course of action, the enforceability of weight restriction is taken into account – if there is concern that significant disregard of load posting will occur (or has occurred), the bridge may be closed in the interest of public safety.
- Per MBE 6A.8: "When deciding whether to close or post a bridge, the Owner should consider the character of traffic, the likelihood of overweight vehicles, and the enforceability of weight posting."
- Posting determinations are authorized on the Load Posting form and kept in the electronic bridge file (BrM).

5.1.4. Responsibilities for Posting/Closure Implementation:

- State-owned bridges must be posted or closed by MDT District personnel.
- Non-state-owned bridges must be posted or closed by the owner.
- Bridge owners are responsible for implementing and maintaining an effective, reliable posting or closure (including barricades and signage) that protects public safety.
- Bridge owners, particularly local agencies, may post bridges for less than the calculated capacity at their discretion. This includes posting if not required and posting at a lower level than required. Reasons may include transportation system preservation, adjacent posted bridges, limiting commercial traffic to safeguard infrastructure, no turnaround access. If a bridge owner chooses to post at their own discretion, then coordination and documentation with MDT are necessary to maintain accurate record keeping for databases, mapping, and permitting.
- In some cases, a bridge may be posted for maximum speed, maximum number of vehicles on a bridge, or other non-load related conditions. Decisions to use these types of posting are typically left to the bridge owner.

5.1.5. Definitions

Definitions related to posting are included here. See Appendix A – Glossary for more definitions.

Inventory Rating – describes a live load (in tons) that can safely utilize a structure for an indefinite amount of time.

Operating Rating – describes the maximum permissible live load (in tons) to which a structure may be subjected.

Posting Load – weight limit (in tons) used in signing a bridge for load restriction.

Reasonable Access – Defined by September 30, 1992 Non-Regulatory Supplement to 23 CFR §658 as at least 1-road-mile from access to and from the National Network of highways, which includes the Interstate System, or further if the limits of a State's reasonable access policy for food, fuel, repairs, and rest extend to facilities beyond 1-road-mile. MDT defines reasonable access as 1 mile from any interchange on the Interstate system.

Safe Load Capacity (SLC) – as defined by AASHTO, a live load that can safely utilize a bridge repeatedly over the duration of a specified inspection cycle. When referenced for LRFR, this represents the upper bound for posting loads.

Safe Posting Load (SPL) – a posting load specifically associated with LRFR, based on the statistical probability of higher overloads/failures on posted bridges, calculated from MBE Eq. 6A.8.3-1.

5.2. POSTING REQUIREMENTS

5.2.1. Rating Vehicles to Post

A structure must be posted with weight restrictions when the calculated rating factor for any of the legal loads meets one of the following criteria:

- The operating rating factor is less than 1 based on Allowable Stress (ASR) or Load Factor (LFR) Methods

OR

- The rating factor is less than 1 based on Load and Resistance Factor Method (LRFR)

MDT analyzes the following nine legal load vehicles, any of which may trigger posting.

- Three Standard AASHTO Legal Trucks
  - Type 3, Type 3S2, Type 3-3, or lane loads (LRFR only) – as defined in *MBE Appendix D6A-1 through D6A-5*
- Four Single-Unit Vehicles (SUVs), also known as Specialized Hauling Vehicles (SHVs)
  - SU4, SU5, SU6, SU7 – as defined in *MBE Appendix D6A-7*.
- Two Emergency Vehicles (EVs)
  - EV2, EV3 – as defined in *FHWA's November 3, 2016, memorandum on Load Rating for the FAST Act's Emergency Vehicles*
  - Although MDT includes EVs in the analysis for all bridges, they are only considered for posting on the Interstate system and within reasonable access, which MDT defines as one road mile from an Interstate interchange. Outside of this area, these vehicles require overload permits; therefore, structures not on the Interstate or within reasonable access are not subject to posting for EVs.

5.2.2. Posting Load Thresholds

The minimum permissible posting load is five tons. MBE Sections 6A.8.1 and 6B.7.1 require that bridges not capable of carrying a minimum gross live load weight of three tons must be closed. However, Montana uses five tons as the threshold for keeping a bridge open. The higher limit is intended to more accurately reflect modern-day vehicle weights and reduce the likelihood of inadvertent overloads on limited-capacity structures.

The minimum permissible rating factor is 0.3 for LRFR. MBE Section 6A.8.3 states that vehicles with a rating factor below 0.3 should not be allowed on the bridge. This is typically achieved by the posting value being lower than the empty weight of the vehicle, effectively restricting the vehicle from the bridge.

The maximum permissible posting load is the maximum legal weight of the vehicle as shown in Table 5.2-1 below.

Table 5.2-1 Maximum Legal Weight of Vehicles

Vehicle Type	Maximum Legal Weight
Type 3	25 tons
Type 3S2	36 tons
Type 3-3	40 tons

Vehicle Type	Maximum Legal Weight
SU4	27 tons
SU5	31 tons
SU6	34.75 tons
SU7	38.75 tons

Vehicle Type	Maximum Legal Weight
EV2	28.75 tons
EV3	43 tons

5.2.3. Posting Load Determination

When a posting is triggered, each vehicle's posting load is generally determined in accordance with the applicable sections that follow.

5.2.3.1. Posting Based on Load Rating Results

5.2.3.1.1. ASR/LFR Methods

The posting load(s) for ASR/LFR Methods depend on which vehicle types trigger posting (e.g., Standard AASHTO Vehicles, Specialized Hauling Vehicles, Emergency Vehicles). See Table 5.2-2 below.

Table 5.2-2 Posting Triggers for ASR/LFR Methods

Posting Trigger	**Posting Load (tons)**
Posting is required for more than one standard AASHTO Vehicle (Type 3, Type 3S2, and/or Type 3-3) **Note – when posting is required for Type 3, it will also be required for SHVs*	**Sign Type**: R12-1 or R12-5 Post at the calculated inventory level. Type 3 posting load governs for all single unit vehicles.
Posting is required for Type 3 and SHVs (Type 3, SU4, SU5, SU6 and SU7)	**Sign Type**: R12-6(SHV-only) Post at Type 3 operating level
Posting is required for SHVs only (SU4, SU5, SU6, and/or SU7)	**Sign Type**: R12-6(SHV-only) Post at the lowest value of the following: • Operating rating/weight for lowest restricted SHV • Legal weight of heaviest unrestricted single-unit vehicle If the resulting value is lower than 25T (legal weight of Type 3 Truck), post at: • 25T = minimum posting load for SHV-only postings *See Section 5.2.3.3 SHV Posting Load Considerations for a discussion on posting for SHV vehicles.*
Posting is required for one or more EV (EV2 and/or EV3)	**Sign Type**: R12-7 or R12-7aP Post at calculated gross, single axle, and tandem axle values (see Figure 5.2-1) based on operating rating factor

5.2.3.1.2. LRFR Method

5.2.3.1.2.1. Safe Posting Load (SPL)

The safe posting load for LRFR is calculated using MBE Equation 6A.8.3-1. In cases where the lane load governs, the value of W should be taken as 80 kips.

Equation 5.2-1

$$SPL = \left(\frac{W}{0.7}\right)[RF - 0.3]$$

(MBE 6A.8.3-1)

Where

SPL = Safe Posting Load (in Tons)

W = Weight of Rating Vehicle (in Tons)

RF = Vehicle Rating Factor

5.2.3.1.2.2. Safe Load Capacity (SLC)

The MBE safe posting load equation is a conservative approach that is intended to provide a higher level of safety for load posted bridges. This approach is based on statistical probability of a higher occurrence of overload vehicles and associated failures on posted bridges vs. non-posted bridges. In some cases, this calculation is considered too conservative and overly punitive - particularly for bridges with low rating factors that have previously been unrestricted to traffic and do not exhibit signs of distress or deterioration.

To avoid unnecessary closure of such bridges, an alternate posting load may be used as calculated by the MBE safe load capacity equation 6A.4.4.4-1. In general, the posting load should not exceed this calculated safe load capacity.

Equation 5.2-2

$$SLC = RF\ x\ W$$

(MBE 6A.4.4.4-1)

Where:

SLC = Safe Load Capacity (in Tons)

RF = Vehicle Rating Factor

W = Weight of Rating Vehicle (in Tons)

To use the safe load capacity as the posting load, the following criteria should be met and documented accordingly.

- The bridge is in good to fair condition: Superstructure and Deck condition ratings are 5 or above.
- No serious structural defects are noted on members in the critical load path.

5.2.3.1.2.3. Posting Load

The posting load for LRFR Method depends on which vehicle types are triggering the posting (e.g., Standard AASHTO Vehicles, Specialized Hauling Vehicles, Emergency Vehicles).

Table 5.2-3 Posting Triggers for LRFR Method

Posting Trigger	**Posting Load (tons)**
Posting is required for more than one standard AASHTO Vehicle (Type 3, Type 3S2, and/or Type 3-3) **Note – when posting is required for Type 3, it will also be required for SHVs*	**Sign Type**: R12-1 or R12-5 Post at the calculated SPL. May post at SLC if situation warrants and condition criteria are met. (refer to Section 5.2.3.1.2.2 Safe Load Capacity (SLC)) *Type 3 posting load governs for all single unit vehicles. See Section 5.2.3.3 SHV Posting Load Considerations for a discussion on posting for SHV vehicles.*
Posting is required for Type 3 and SHVs (Type 3, SU4, SU5, SU6 and SU7)	**Sign Type**: R12-6 Post at Type 3 calculated SPL May post at Type 3 SLC if situation warrants and condition criteria are met (refer to Section 5.2.3.1.2.2 Safe Load Capacity (SLC))
Posting is required for SHVs only (SU4, SU5, SU6, and/or SU7)	**Sign Type**: R12-6 Post at the calculated SPL for smallest restricted SHV, ***unless*** this value is lower than the legal weight of the heaviest unrestricted single-unit vehicle. In such cases, post at the lowest value of the following: • SLC for the smallest restricted SHV • Legal weight of heaviest unrestricted single-unit vehicle If the resulting value is lower than 25T (legal weight of Type 3 Truck), post at: • 25T = minimum posting load for SHV-only postings *See Section 5.2.3.3 SHV Posting Load Considerations for a discussion on posting for SHV vehicles.*
Posting is required for one or more EV (EV2 and/or EV3)	**Sign Type**: R12-7 or R12-7aP Post at calculated gross, single axle, and tandem axle values (see Figure 5.2-1) based on LRFR rating factor

5.2.3.2. Posting Based on Engineering Judgment

5.2.3.2.1. Deviations from Standard Posting Load

There may be circumstances where an intermediate posting load is selected between the lower and upper limits of a calculated load rating. Lower limits may be overly conservative for well-performing bridges, while upper limits may be unconservative for bridges in poor condition. For LFR and ASR, the lower and upper limits correspond to inventory and operating levels, respectively. In LRFR, they correspond to the Safe Posting Load (SPL) and the Safe Load Capacity (SLC). Selection of an intermediate posting load may depend on factors such as bridge type, condition ratings, deterioration, redundancy, fatigue-sensitive details, ADTT, traffic type, inspection frequency, previous posting level, enforcement, etc.

There may also be situations where engineering judgment supports posting a structure at a more conservative level than required by the calculated rating due to uncertainties. An example would be concern about continued or accelerating deterioration before the next inspection (e.g., historical trusses).

For posting loads that deviate from the posting loads shown in tables above, rationale must be thoroughly documented on the bridge's Load Posting Form.

5.2.3.2.2. Condition-Based Postings or Restrictions

Condition-based postings are generally used when condition issues or concerns – typically identified during inspection – cannot be reliably accounted for in load rating calculations or require an expedited action. Examples include defects that are difficult to quantify, deformations indicating that a structure is no longer behaving as designed, or deficiencies that introduce uncertainty in the load path or overall bridge response.

When conditions are concerning but closure is not yet warranted, a minimum posting of 5 tons may be implemented to allow local traffic only while the bridge is placed on a more frequent inspection schedule to monitor for further changes. The intent is to maintain limited use of the bridge while allowing the owner time to plan and implement repairs unless continued deterioration is observed and necessitates closure.

Other restrictions may include removing traffic load from an isolated member that is damaged or deteriorated.

Condition-based postings or restrictions must be thoroughly documented and included in the bridge file. These restrictions generally have a finite period of validity and involve coordination to review and monitor during each inspection.

5.2.3.3. SHV Posting Load Considerations

Specialized Hauling Vehicles (SHVs) are purposely configured to maximize payload. When the maximum allowable weight for a specific SHV configuration is restricted, it serves to effectively prohibit that vehicle type in practice. Many SHVs have lift or tag axles, and it's assumed that operators commonly raise these axles when they are not needed to optimize payload and reduce wear. If the legal payload cannot be carried with all axles down, operators are more likely to lift an axle and adjust the load accordingly rather than keep all axles down and reduce load to the posted limit. This changes the vehicle type and footprint.

For example, if an SU4 is restricted and the truck has a lift/tag axle, the operator may lift one axle and operate to the applicable three-axle limits instead of running all four axles down at the posted SU4 limit. When this occurs, the SU4 axle spacings are nearly equivalent to the Type 3 Truck model. When comparing load rating models, the SU4 with has essentially the same footprint as the Type 3 Truck; SU5, SU6, and SU7 configurations are simply longer variants. Accordingly, a Type 3 Truck of a given weight is considered to be nearly equivalent to an SU4 of similar weight, and is conservative relative to longer tSU5, SU6 and SU7 vehicles of similar weight. Therefore, it is reasonable to use the Type 3 Truck rating (or legal weight) to govern the load posting for single-unit vehicles.

5.2.3.4. FAST Act Emergency Vehicle Posting Loads

Posting loads for Emergency Vehicles (EVs) shall be calculated in accordance with Figure 5.2-1 below, which is taken from *FHWA's March 16, 2018, memorandum "Questions and Answers: Load Rating for the FAST Act's Emergency Vehicles."* For LFR and ASR, the operating rating factor should be used.

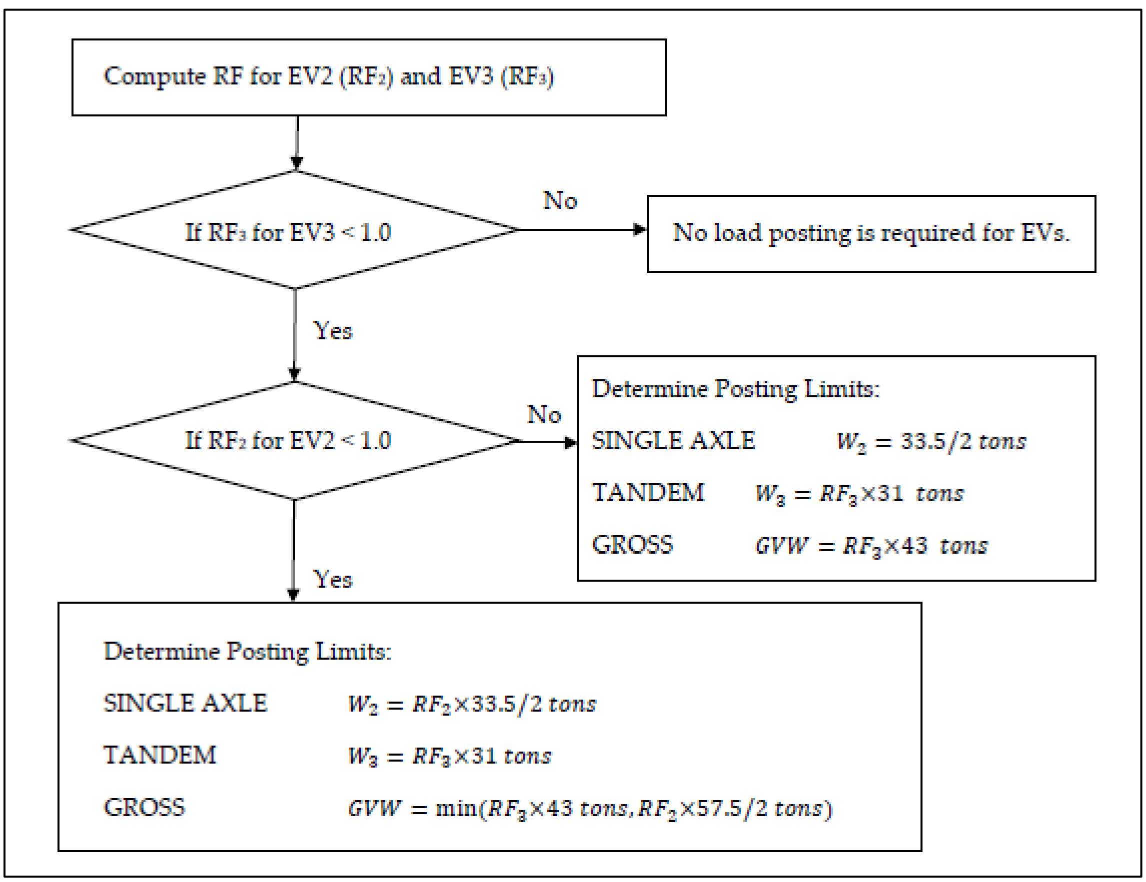


Figure 5.2-1 FAST Act Emergency Vehicle Posting Load Flowchart

5.2.3.5. Railroad Flat Car Posting Loads

Evaluation of railroad car structures is outside the scope of MDT's Load Rating Program because these structures involve a high degree of uncertainty and require assumptions (e.g., varying configurations, unknown materials and history, etc.). For this reason, railroad cars are assigned a 5-ton weight limit unless conditions warrant further review and restriction (e.g., lane restriction, closure).

Alternatively, counties may engage a Montana-licensed Professional Engineer to evaluate the structure and determine a safe posting load. The following details apply:

- The Engineer is expected to gather field data and measurements, perform testing as needed to establish member properties and capacities, research details, materials, and connections, document any necessary assumptions where information is incomplete, and perform load rating calculations to determine a Safe Posting Load. Load rating calculations must meet current MDT criteria, including envelopment of all Montana's legal loads.

- A stamped evaluation needs to be submitted to MDT's Load Rating Program Manager for review and approval. The evaluation needs to include:

    - Safe Posting Load

    - Bridge measurements, drawings, and sketches used in the analysis

    - Results of any testing performed

    - Engineering calculations supporting the Safe Posting Load

    - For load testing specifically (if applicable):

        - Documented procedures and methodology compliant with the **AASHTO Manual for Bridge Evaluation (MBE)**

        - Calculations supporting the Safe Posting Load derived from test data

    - Recommended expiration date for the posting

    - Defined deterioration triggers that would invalidate the Safe Posting Load (MDT will incorporate these triggers into inspection procedures as a guide for monitoring and re-evaluation)

MDT will review the stamped submittal for compliance and either issue concurrence or return comments for resolution. The default 5-ton posting remains in effect until MDT provides notification otherwise.

5.3. POSTING CONSIDERATIONS

Per MBE 6A.8.1, "bridge posting is a policy decision." Determining a posting load can be an iterative process. A bridge is first analyzed using standard methods to establish capacity; if the result is below the legal limit for a posting vehicle, analytical refinements (analysis refinements) may be used to better reflect actual behavior and operating conditions. Load posting can be sensitive, with significant impacts on the traveling public and nearby industries. In appropriate cases, additional investigation and/or rating improvements may be warranted to avoid undue conservatism and unnecessary regional restrictions. When the need to post is driven by defects or deterioration, increasing the analytical rating may not be appropriate; safety and condition-based restrictions are always prioritized.

5.3.1. Analytical Refinement Methods

When justified, analytical refinements can better reflect actual structural behavior and site operations, capturing reserve capacity that standard calculations do not capture. Such refinements may improve posting levels or, in some cases, avoid the need to post. See Section 3.10 Analytical Refinement Methods for analytical refinement methods, criteria, and procedures.

5.3.2. Non-Analytical Improvement Methods

When analytical refinements are not appropriate, operational or physical measures may be used to improve safety. Examples include:

- Structural repairs: strengthening or repair of members or connections
- Dead-load reduction: removal of excess overlay or other non-structural loads where feasible
- Operational controls: lane closures or width restrictions to remove load from deteriorated members
- Monitoring: increased special inspection frequency as a short-term risk measure, with defined triggers for re-evaluation

5.4. POSTING AND CLOSURE PROCEDURES

5.4.1. All Structures

When the decision is made to post, close, or restrict a bridge, it is the responsibility of the bridge owner to erect the necessary signage and barricades in conformance with MUTCD (see Section 5.5.1 Sign Guidance).

Closures are emergency actions to protect the traveling public and should occur as soon as possible, as required by NBIS §650.313(m). Confirmation of closure must be provided to the Load Rating Program Manager within 5 days of notification.

<u>Posting</u> should occur as soon as possible but <u>not later than 30 days</u> after inspection or other notification determines a need, as required by NBIS §650.313(l). In some cases, the bridge owner may expedite repairs and strengthen the bridge within the 30-day period in lieu of posting.

Once posting or closure is enacted, long-term verification will be documented during routine bridge inspections.

When posting or closure is declared a Critical Finding, "immediate follow-up inspection or action" and all other associated requirements take precedence over the procedures in this Section. See the **MDT Bridge Inspection Manual**, Section 5.2 Critical Finding Guidance, for more information.

5.4.2. Structures Owned by MDT

The following procedure should be followed when an MDT-owned structure requires closure or load restriction and signage and/or barricades are not yet installed or are improperly installed (e.g., one sign is missing).

5.4.2.1. Notification

Once a determination has been made that posting or closure is required, the Load Rating Program Manager will notify the District Administrator, the FHWA Division Bridge Engineer, and appropriate MDT personnel, including:

- District Maintenance
- Bridge Bureau Chief
- Bridge Management Personnel
- District/Area Bridge Inspection Manager
- Motor Carrier Services
- MDT Road Condition Reports
- MDT Public Information Officer

A Bridge Maintenance Engineer will work with District Maintenance and others as needed to ensure the proper signing is installed.

5.4.2.2. Action

The District Administrator is responsible for coordinating with District Maintenance personnel to implement posting or closure of the structure. The District is responsible for returning documentation (including photos and implementation date) to the Load Rating Program Manager once posting signs or closure barricades are installed. After the Load

Rating Program Manager verifies that the proper signs and/or barricades are in place, documentation is uploaded to MDT's structure management system (BrM) and the database is updated to reflect the actual posting tonnages or closure (e.g., Items B.PS.01 Load Posting Status, B.PS.02 Posting Status Change Date, B.EP.03 Posting Type, and B.EP.04 Posting Value). Posting signs must be installed within 30 days of the notification, and closure should occur as soon as reasonably possible.

5.4.3. Structures Not Owned by MDT

The following procedure should be followed when a structure not owned by MDT requires closure or load restriction, and signage and/or barricades are not yet installed or are improperly installed (e.g., one sign is missing).

5.4.3.1. Notification

Once a determination has been made that posting or closure is required, the Load Rating Program Manager will notify the bridge owner. For county-owned bridges, notification will be sent to the county commissioners and the county road supervisor or superintendent. For bridges owned by other entities, recipients will be determined on a case-by-case basis. Notifications will include the reason for posting or closure (e.g., new analysis, missing sing, broken pile, severe deterioration, etc.).

5.4.3.2. Action

The bridge owner is responsible for choosing a sign option (if applicable), implementing posting or closure of the structure, and returning documentation (including photos and implementation date) to the Load Rating Program Manager once posting signs and/or barricades have been installed. After the Load Rating Program Manager verifies that the proper signs and/or barricades are in place, documentation is uploaded to MDT's structure management system (BrM), and the database is updated to reflect the actual posting tonnages or closure (e.g., Items B.PS.01 Load Posting Status, B.PS.02 Posting Status Change Date, B.EP.03 Posting Type, and B.EP.04 Posting Value). Posting signs must be installed within 30 days of the notification, and closure should occur as soon as reasonably possible.

5.4.3.3. Notification Follow-Up

5.4.3.3.1. New Postings

MDT will order load posting signs to be sent to the bridge owner and track delivery. If posting confirmation has not been received by 5 days before the 30-day deadline, the Load Rating Program Manager will contact the bridge owner to remind them of the posting deadline. If the owner is non-responsive or uncooperative, escalation procedures will be initiated (see Section 5.4.3.3.3 Escalation Procedures).

5.4.3.3.2. Closures, Restrictions, and Posting Maintenance

If an owner has been notified to close a bridge or revise a posting and a response is not received within five business days, the Load Rating Program Manager will follow up with the bridge owner verbally on day 5. If the owner is non-responsive or uncooperative, escalation procedures will be initiated (see Section 5.4.3.3.3 Escalation Procedures).

5.4.3.3.3. Escalation Procedures

If a bridge owner continues to be non-responsive or uncooperative, the Load Rating Program Manager will issue a second notice copying the Chief Engineer, District Administrator, Maintenance Chief, and Legal Counsel.

If there is still no response from the bridge owner, the issue will be referred to MDT's Director and Chief Engineer for action, which may include, but is not limited to:

a. Coordination with authorities and elected officials

b. State closure of roadway at access points to state route

c. Public warning statements in the area

d. Suspension of federal aid funds

5.4.4. Rescinding or Modifying Restrictions

Once a bridge is posted, closed, or otherwise restricted, the restriction remains in effect until a re-evaluation supports a change. If repairs are completed, the bridge must be re-evaluated – typically through a post-repair inspection and an updated load rating – to verify that the repaired condition has adequate load path and capacity to safely carry traffic. The established restriction must remain in place until post-repair evaluation procedures are complete, and MDT issues a written update on any changes that can be made (e.g., closure rescindment, posting removal, revised posting level).

For local bridge owners pursuing repairs to alleviate a restriction, it is recommended to engage a licensed Professional Engineer (PE) to evaluate bridge condition, design a safe and reliable repair, and provide the necessary construction inspection oversight to verify conformance with the design. Inspection reports and load rating documents are not intended to serve as repair scoping documents; the PE should conduct a thorough site visit to assess conditions, identify potential public safety issues, and determine the feasibility of repair options. Close coordination with the Area Bridge Inspection Manager and Load Rating Program Manager (e.g., advance notice of planned repairs, submittal of finalized repair plans/documents, construction updates) is critical to ensure that MDT is aware of completed work and can schedule post-repair evaluations promptly.

On a case-by-case basis, post-repair restriction updates may be expedited with a stamped recommendation and supporting documentation from the PE involved with the repair. By submitting this recommendation, the PE assumes responsibility for the repaired condition and the proposed change to the restriction, allowing MDT to manage public safety while the post-repair evaluation is completed. The stamped statement should specify the recommended change (e.g., reopen, remove posting, revise posting to specified level) and include supporting documentation such as repair plans, calculations, and field verification that work was completed as designed. This documentation should be submitted to MDT's Load Rating Program Manager for review and concurrence. MDT will still complete its own post-repair evaluation to meet program requirements and update records and will follow up on any discrepancies with the recommendation as needed.

5.5. LOAD POSTING SIGNAGE

5.5.1. Sign Guidance

Load posting signs and installation shall comply with this posting procedure document, the *Manual on Uniform Traffic Control Devices (MUTCD)*, and *MDT Detailed Drawings.* Closure barricades and signs shall conform to *MUTCD Sections 2B.63 and 2B.75 (11th edition)*. The bridge owner is responsible for MUTCD compliance.

MUTCD Section 2B.64 (11th edition) requires advance weight-limit signs, with advisory distance or directional legend, in advance of any load-posted bridge so overweight vehicles have sufficient time and distance to detour or turn around before reaching the structure. Advance sign placement should be determined on a case-by-case basis at locations where motorists can safely detour or reverse course. Additional advance signs may be used as needed based site conditions and network access.

Consideration should be given to practical limitations when selecting a load posting sign. In most cases, it is not useful to post for a vehicle class whose empty weight exceeds the posted limit; however, this approach may be used intentionally to restrict certain vehicle types on a multi-vehicle sign.

5.5.2. Sign Types

MDT's goal for load posting is to balance simplicity with minimizing unnecessary restrictions. Sign selection should limit all necessary vehicles as efficiently as possible while avoiding limits on vehicles that do not require them. The following guidance addresses sign applicability based on posting triggers.

See Figure 5.5-1 for examples of acceptable load posting signs. Appendix H - Load Posting Signage provides sign details. The posting load shown on any given sign should not exceed the maximum legal weight of the most restrictive vehicle type (silhouette), as listed in Table 5.2-1. If a vehicle type appears on a posting sign but does not require posting, use that vehicle type's maximum legal weight as the displayed value.

MDT's load posting signs conform to standard MUTCD regulatory designs. The R12-5a (Historical Use) was developed by MDT to accommodate posting for Specialized Hauling Vehicles (SHVs) prior to the adoption of the MUTCD 11th edition, which introduced the R12-6 sign for SHVs. MDT uses a modified R12-6 (SHV Only) for situations where only SHVs require posting. The R12-5a sign was retired on 1/1/2026 and replaced by R12-6 (SHV Only). R12-

5a signs may still be in place throughout Montana until they are updated with R12-6 (SHV Only).

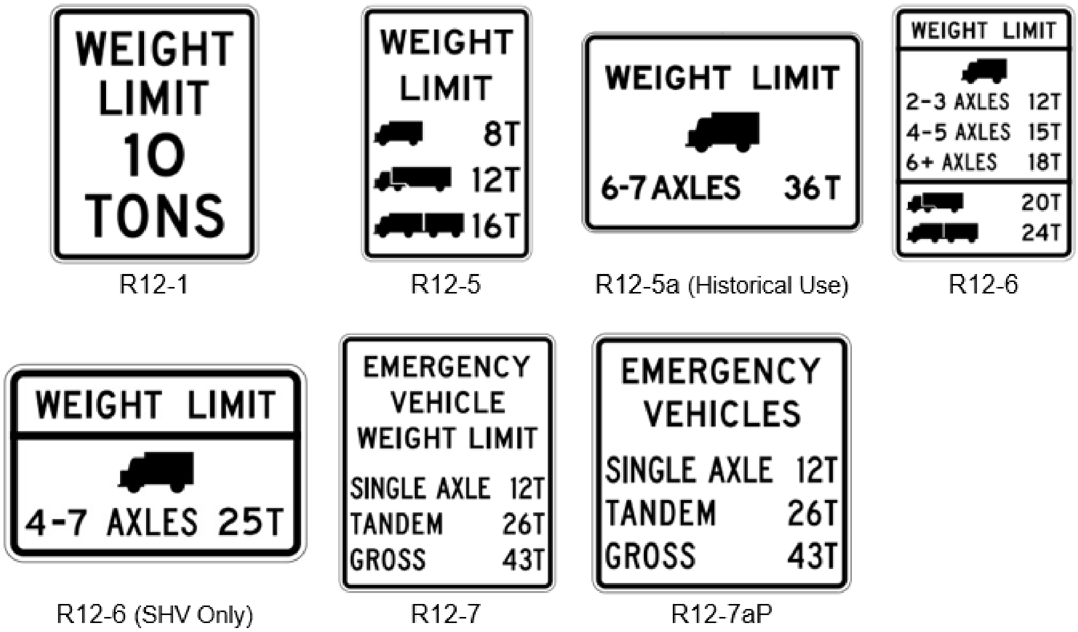


Figure 5.5-1 MDT Load Posting Sign Types

5.5.3. Sign Selection

5.5.3.1. Posting Signs for Standard AASHTO Vehicle Triggers

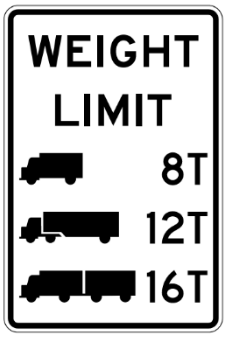
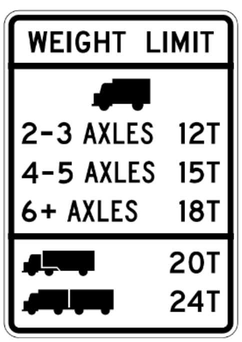
When posting is triggered by standard AASHTO vehicles (Type 3, Type 3S2, Type 3-3), SHV posting is also required. MDT prefers the simplest, most consolidated weight limit sign that achieves the necessary restriction while minimizing undue impact on the trucking industry.

The R12-1 sign provides a single gross weight limit for all vehicles and is the most conservative sign type. It should be used for low-rating bridges where controlling ratings converge toward empty vehicle weights.

Among the three silhouette signs, the R12-5 sign type is generally preferred because it groups all single-unit vehicles together. Although R12-6 provides a breakout option for single-unit vehicles, by the time standard AASHTO vehicles trigger posting, SHV limits are typically at or near empty vehicle weights. Since SHVs are purposely configured to maximize payload, limiting weights for single-unit configurations often ends up restricting these vehicles anyway. As a result, breaking out single-unit vehicles seldom adds benefit and the use of R12-6 is expected to be rare. In most cases, R12-5 should be used.

Recommended usage of each sign is summarized in Table 5.5-1 below.

Table 5.5-1 Recommended Sign Usage for Standard AASHTO Vehicle Postings

MUTCD Sign Designation	Example Posting Sign	Recommended Usage	
R12-1		• Low-rated bridges where rating results converge towards empty vehicle weights	
R12-5		• Most three silhouette postings (common scenarios)	
		• Weight Limit Determination:	
			*Single Unit Vehicle* Posting Load* for Type 3 Truck**
			*Truck & Trailer* Posting Load* for Type 3S2 Truck or 36T if posting is not triggered for Type 3S2
			*Truck & Trailer Combination* Posting Load* for Type 3-3 Truck or 40T if posting is not triggered for Type 3-3
R12-6		• When the difference between single-unit vehicle posting loads is significant and there are benefits to splitting out (unlikely/rare scenarios)	
		• Weight Limit Determination:	
			*Single Unit Vehicle (2-3 Axles)* Posting Load* for Type 3 Truck
			Single Unit Vehicle (4-5 Axles) Posting Load* for SHVs (SU4 & SU5) included in axle grouping***
			Single Unit Vehicle (6-7 Axles) Posting Load* for SHVs (SU6 & SU7) included in axle grouping***
			*Truck & Trailer* Posting Load* for Type 3S2 Truck or 36T if posting is not triggered for Type 3S2
			*Truck & Trailer Combination* Posting Load* for Type 3-3 Truck or 40T if posting is not triggered for Type 3-3

*See Table 5.2-2 and Table 5.2-3 for Posting Load Determinations
**Type 3 governs the posting load for single-unit vehicles. It is valid for SU4 (same footprint) and conservative for SU5-7 (longer variations).
***Axle grouping may be done on a case-by-case basis to balance simplicity and acceptable level of conservatism.

5.5.3.2. Posting Signs for Single-Unit-Only Triggers

Specialized Hauling Vehicles (SHVs) can produce bridge force effects that exceed those from the standard AASHTO vehicles by more than 50 percent. As a result, a bridge may have adequate capacity for the three standard AASHTO vehicles yet still require posting for one or more of the legal 4- to 7-axle SHV configurations. There are also cases where a bridge has sufficient capacity for combination vehicles (Type 3S2 and Type 3-3) but requires posting for single-unit vehicles (Type 3 and SHVs). To avoid penalizing all truck types, the R12-6 (SHV-only) posting sign is used to restrict only single-unit vehicles. To protect bridge infrastructure, SHV-type power units operating as part of combination vehicles (e.g., SHVs pulling trailers) should also comply with single silhouette sign limitations.

Table 5.5-2 Recommended Sign Usage for Single Unit Vehicle Postings

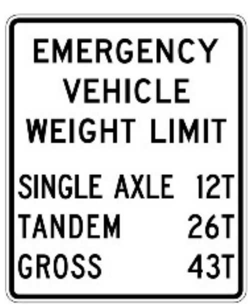
<table>
<tr><th>MDT Sign Designation</th><th>Example Posting Sign</th><th colspan="2">Recommended Usage</th></tr>
<tr><td rowspan="2">R12-6
(SHV Only)</td><td rowspan="2"></td><td colspan="2">• When only single unit vehicles require posting (e.g., Type 3, SU4, SU5, SU6, SU7)</td></tr>
<tr><td></td><td>Weight Limit is determined by the Posting Load*</td></tr>
<tr><td colspan="4">*See Table 5.2-2 and Table 5.2-3 for Posting Load Determinations</td></tr>
</table>

5.5.3.3. Posting Signs for FAST Act Emergency Vehicle Triggers

Emergency Vehicle (EV) restrictions are unique in that they apply to a very specific user group in very specific areas. For this reason, EV postings are handled separately from postings for other legal vehicles (standard AASHTO vehicles and SHVs) and use their own sign type, installed independently.

The EV plaque (R12-7aP) is used as part of a sign assembly mounted below another regulatory Weight Limit sign. Where existing legal vehicles postings are low enough to encompass EV restrictions, a separate EV-specific plaque is not necessary.

Table 5.5-3 Recommended Sign Usage for Emergency Vehicle Postings

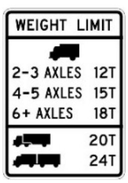
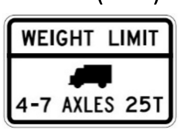
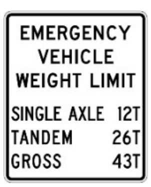


R12-7

R12-7aP

5.5.4. Sign Dimensions

Table 5.5-4 Posting Sign Dimensions

Sign Designation	County/Non-State-Owned Routes ****Minimum Sign Size****		State-Owned Routes		Interstate		Appendix Reference
R12-1 	24” x 30”	2’-0” x 2’-6”	24” x 30”	2’-0” x 2’-6”	36” x 48”	3’-0” x 4’-0“	H-1
R12-5 	24” x 36”	2’-0” x 3’-0”	24” x 36”	2’-0” x 3’-0”	48” x 60”	4’-0“ x 5’-0”	H-2
R12-6 	30” x 42”	2’ 6” x 3’ 6”	36” x 48”	3’-0” x 4’-0”	48” x 60”	4’-0” x 5’-0”	H-3
R12-6 (SHV) 	36” x 24”	3’-0” x 2’-0”	36” x 24”	3’-0” x 2’-0”	TBD - Request Design from Traffic		H-4
R12-7 	30" x 36"	2'-6" x 3'-0"	30" x 36"	2'-6" x 3'-0"	48" x 60"	4'-0" x 5'-0"	H-5
R12-7aP 	30” x 30”	2’-6” x 2’-6”	30” x 30”	2’-6” x 2’-6”	48” x 48”	4'-0" x 4'-0"	H-6

6. LOAD RATING DOCUMENTATION

6.1. OVERVIEW

This chapter defines the documentation that must be generated and retained in BrM (the Bridge File of record) for each bridge load rating.

6.1.1. Purpose and Need

Load rating documentation supports future load ratings, enables sound bridge management decisions, and satisfies federal requirements.

NBIS §650.313(n) requires MDT to prepare and maintain bridge files in accordance with AASHTO MBE Section 2.2.

Under MBE Section 2.2.7, load rating documentation shall include, at a minimum: date, rater name, capacity, posting limits, evaluated loads, methodology, member identification, controlling member, modifying factors, assumptions, updates, and a summary statement of results.

6.1.2. Load Rating Documentation and Filing

Each load rating consists of a Load Rating Report and supporting records (correspondence, analysis files, and database entries). BrM (MDT's Structure Management System) is the electronic Bridge File of record.

Load Rating Report: The Load Rating Report should be in PDF format, primarily in 8.5" x 11" portrait orientation, with all pages rotated to the appropriate viewing orientation. See Section 6.2 Load Rating Report Contents for detailed requirements and contents. The final PDF report shall be uploaded to BrM -Multimedia once load rating data is entered in BrM.

Correspondence: Significant correspondence related to a bridge's load rating (e.g., emails, memos, letters, chats) shall be retained in BrM in PDF format, including communications with bridge owners and FHWA.

Analysis Files: Input and output files from analysis software shall be retained in their native formats for future rating updates. BrR models shall be stored in MDT's record database. Non-BrR analysis files shall be stored in a designated location on MDT's shared drive.

Database Entries: All load rating data shall be entered and retained within BrM load rating events.

6.2. LOAD RATING REPORT CONTENTS

A complete load rating report typically includes the following sections:

- Load Rating Summary Sheet
- Additional Information (if needed)

- Additional Information (if needed)
- Calculations
- Bridge Rating Results
- Vehicle Analysis Template
- Measurements/Plans

Examples are available on MDT's Load Rating website:
https://www.mdt.mt.gov/business/contracting/bridge/loadrating/default.aspx.

6.2.1. Load Rating Summary Sheet

The Summary Sheet is organized into five parts:

- Bridge Information
- Load Rating Information
- Posting Information
- Comments & Assumptions
- Signature Block

Use the appropriate template (per rating method) from MDT's Load Rating Website: https://www.mdt.mt.gov/business/contracting/bridge/loadrating/templates.aspx.

6.2.1.1. Bridge Information

This section is auto-populated by the template and includes identification, location, inspection date, span data, overlay thickness, and related details. Use the latest Summary Sheet from MDT's website to ensure fields are current. If any auto-populated information appears incorrect, verify against BrM, revise the Summary Sheet as needed, and notify MDT so the database can be updated.

6.2.1.2. Load Rating Information

This section covers the rating method and status, the software name and version, and the controlling ratings by vehicle. For each vehicle, enter the controlling rating factor, vehicle load type (for HL-93 and EVs in LRFR), member, location, and limit state. Safe Load Capacity and Safe Posting Loads are auto-calculated for each vehicle; note that these may differ from the bridge's final posting. Refer to the Load Posting Form for authorized posting loads.

6.2.1.3. Posting Required Information

This section indicates whether posting is required for Legal Vehicles and Emergency Vehicles based on the entered rating factors.

6.2.1.4. Comments and Assumptions

This section is intended to flag items that are unique or require special attention. Include brief notes on topics such as:

- Reduced capacity for timber members
- EV live load factors different from the default value of 1.3
- Removal of optional limit state checks
- Reason for alternate superstructures created in BrR (e.g., failed condition check)
- Mixed materials or corrugated decks (see examples for standard wording)
- BrR limitations or workarounds

Attach more detailed documentation as additional pages in the Load Rating Report (see Section 6.2.2 for specific topics to address). Reference the attachments on the Summary Sheet, for example: "Additional assumptions and calculations are detailed within the attached load rating report."

Load rating reports are intended to serve as standalone documents for the structure's condition at the time of rating. Comments about BrM data corrections or monitoring recommendations generally should not be added to the Summary Sheet; they should be communicated separately to MDT (email/phone) for appropriate action.

6.2.1.5. Signature Block

Enter names and dates of the load rater and QC/QA reviewers. Digital signatures are acceptable. For consultant ratings, include the Engineer's Seal of the Load Rater of Record and the date sealed. For internal ratings, include the Load Rater of Record's signature.

6.2.2. Additional Information

Attach pages as needed to document engineering judgment, assumptions, and calculations supporting the rating. Provide clear rationale for decisions. Use the headings below and address each topic:

References: List governing documents with version/interims (e.g., MBE, AASHTO, LRFD, AASHTO Standard Specifications, MDT Load Rating Manual, etc.)

Basis for Load Rating: Identify the sources used in the rating: field measurements (with date), as-built plans, shop drawings, design plans, inspection reports (with dates), etc. Include MDT drawing numbers and construction project numbers if available.

Material Properties: Summarize known or assumed material properties. Explain why assumptions are required and cite the basis for assumed values.

Assumptions Used in Analysis: Describe each assumption, why it is required, and provide justification. Examples include:

- Average beam spacing used in a flared span
- Dimensional assumptions for unusual geometry
- Consideration of sacrificial wearing surface and how it is accounted for

Members Rated: Explain the orientation and naming/numbering convention (e.g., based on plans or measurement sheets). List all rated members using the Member Names from the BrR model, with brief descriptions indicating whether they are representative, deteriorated, original versus widening, etc. Use generic descriptions for members that aren't particularly unique (e.g., Interior Girder). Descriptions should correlate with the Member Alternative Names in the BrR model. Identify any linked members and include a rationale for the grouping. Identify any excluded members and provide reasoning.

Examples:

- G1 – Typical exterior girder. G17 is linked based on the same material properties, conditions, and distribution.
- G2 – Widening girder. G16 is linked based on….
- G3 – Typical interior girder. G5, G6, G7 are linked based on …
- G4 – Interior Girder (reduced capacity)

For multiple spans, clearly note continuous spans. Indicate if one span is modeled to represent others. If spans are modeled separately, list rated members for each span.

Examples:

Span 1

- G1 – Typical exterior girder. G5 is linked based on…
- G2 – Typical interior girder. G2, G3, G4 are linked based on…

Span 2

- G1 – Typical exterior girder. G5 is linked based on…
- G2 – Typical interior girder. G2, G4 are linked based on….
- G3 – Interior Girder (reduced capacity)

Note: Members shall be linked only if they produce similar rating results. Members expected to produce different results—due to differences in spacing, member properties, loads, or condition—shall be defined individually.

Live Load Distribution: State whether the distribution is computed by the software or by manual calculation due to limitations.

Defects: Summarize inspection defects that warrant reduced condition factors or modifications to section properties and briefly summarize how they are accounted for. Address CS3 or CS4 defects; if determined not to affect the rating, state the reasoning.

Analysis Workarounds: Document any alternate ratings, failed-girder checks, software limitations, and workarounds. If applicable, include a JIRA ticket number, a brief description of the issue, how it affects the model/rating, and the workaround performed.

Additional Comments: Include structure-specific considerations, refined analyses, or other unique items that influence the rating outcome.

6.2.3. Calculations

Include any calculations not included in the rating software's analysis (e.g., LLDFs for certain structure types, dead loads, section loss, etc.).

Provide independent calculations to verify results for any unexpectedly low-rated members.

Provide appropriate references to equations, code articles, and sources of information (e.g., plan sheet number).

Organize calculations in a format that is sufficiently detailed to make them easy to follow for checking.

If spreadsheets are used, include sample calculations that demonstrate the sheet's functionality in an easy-to-follow and fully referenced format.

6.2.4. Bridge Rating Results

6.2.4.1. Controlling Bridge Rating

Include a PDF from BrR Bridge Explorer showing the controlling ratings for the entire structure, scaled to fit one page and displayed with "single rating level per row." If workarounds cause the Bridge Explorer results to not accurately reflect controlling values for the structure, omit this summary.

For refined analyses performed in alternative software, display the controlling bridge rating results using PDF printouts where possible. The load rater may adjust the display of controlling ratings for clarity, subject to MDT approval.

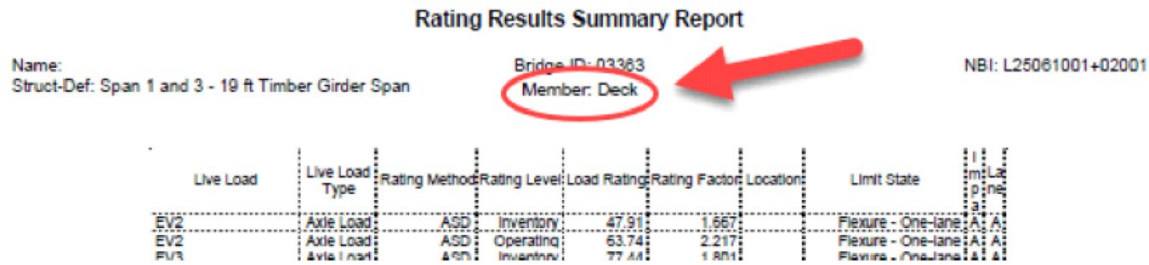
6.2.4.2. Individual Member Ratings

Include a PDF from BrR Bridge Workspace showing the ratings for each individually rated member or component (i.e., not linked), one page for each member, displayed with "single rating level per row." Highlight the member name and controlling bridge rating factors. Note that the controlling rating factors may occur on different members, depending on the vehicle.

For refined analyses performed in alternative software, display individual member rating results using PDF printouts where possible. The load rater may adjust the display of controlling ratings for clarity, subject to MDT approval.

6.2.4.3. Decks

Most member-specific BrR rating summary reports include the member name as a heading; however, decks are an exception. If a deck is rated (e.g., timber, corrugated steel), add "Member: Deck" to the top of the page to clearly identify the member.



Rating Results Summary Report

Name:
Struct-Def: Span 1 and 3 - 19 ft Timber Girder Span

Bridge ID: 03363
Member: Deck

NBI: L25061001+02001

Live Load	Live Load Type	Rating Method	Rating Level	Load Rating	Rating Factor	Location	Limit State	Impact	Lane
EV2	Axle Load	ASD	Inventory	47.91	1.667		Flexure - One-lane	A	A
EV2	Axle Load	ASD	Operating	63.74	2.217		Flexure - One-lane	A	A
EV3	Axle Load	ASD	Inventory	77.44	1.801		Flexure - One-lane	A	A

Figure 6.2-1 Deck Rating Callout on the Rating Results Summary Report

Corrugated Metal Decks – BrR analyzes corrugated metal decks as both simple and continuous spans. MDT has determined that both methods are conservative; report the higher of the two ratings. In some cases, the deck may no longer control the overall rating when the higher value is used.

If the corrugated metal deck controls the rating, omit the overall Bridge Explorer summary and include the following note in the Comments section of the Load Rating Summary Sheet and on the deck rating results summary:

"Per MDT guidance, both deck analysis methods are considered conservative. The least conservative deck results were used in determining the controlling rating factors."

On the deck rating results summary, cross out the less conservative ratings to clearly indicate which results were considered.

6.2.4.4. Mixed Methods

When a structure includes different materials that require different rating methods (e.g., steel members rated in LFR or LRFR and timber members rated in ASR), results may not be directly comparable on a like-for-like basis. Use the guidance below to determine controlling ratings and document results consistently.

General Note

- Design loads are not equivalent and cannot be directly compared (HL-93 vs HS20). Report the design load associated with the controlling method (HS20 for LFR and ASR; HL-93 for LRFR)

ASR/LFR Combinations

- Determine controlling ratings by comparing rating factors for each vehicle
    - If one method controls all vehicles:
        - Use the Summary Sheet for the controlling method (ASR or LFR)
    - If different methods control different vehicles:
        - Use one Summary Sheet with method "ASR/LFR"

        - Use a symbol to indicate which method governs each reported rating factor (e.g., "*" denotes LFR-governed; no symbol denotes ASR-governed)
        - In the Comments section, explain the symbol (e.g., "Ratings marked with '*' symbol are governed by LFR; unmarked ratings are governed by ASR")

- In the Comments section, note the mixed-method evaluation and how controlling values were determined (e.g., "ASR was used for timber deck, LFR was used for steel girders. Controlling values are reported based on comparison of ASR and LFR rating factors").

- Include the overall Bridge Explorer summary from BrR if one analysis template was used (e.g., LFR/ASR in one template based on member alternative method). Omit the overall Bridge Explorer summary if multiple analysis templates were used (e.g., ASR and LFR legal operating templates).

- Include vehicle template(s) used in analysis and all member-level results.

ASR/LRFR Combinations

- Determine controlling ratings by comparing ASR Operating to LRFR rating factors for each legal vehicle. Do not compare design loads (see General Note).

    - If one method controls all vehicles:
        - Use the Summary Sheet for the controlling method (ASR or LRFR).
        - In the Comments section, note the mixed-method evaluation and how controlling values were determined (e.g., "ASR was used for timber deck, LRFR was used for steel girders. Controlling values are reported based on comparison of ASR Operating and LRFR rating factors").
        - Omit the overall Bridge Explorer summary from BrR.
        - Include both vehicle templates and all member-level results.

    - If different methods control different vehicles:
        - Report controlling ratings for each method on separate Summary Sheets.
        - Use a symbol to flag rating factors that govern the overall rating across methods.
        - Add an explanatory note in the Comments section, with a cross-reference note to other method (e.g., "ASR was used for timber deck, LRFR was used for steel girders. This summary sheet reports controlling ASR ratings. See LRFR summary sheet for controlling LRFR ratings. Rating factors marked '**' govern the overall rating based on comparison of ASR Operating and LRFR rating factors.).

- Include the Bridge Explorer summary from BrR for each analysis method.
- Include both vehicle templates and all member-level results.

6.2.5. Vehicle Analysis Template

Include screen captures from the analysis software as follows:

- Vehicle Summary (Analysis Template)
- Vehicle Properties (Advanced Settings)
- Any non-standard library vehicle definitions:
  - For LFR and ASR , use standard definitions for all vehicles. No additional screenshots are required. Add a note on the analysis template to indicate that standard vehicle definitions were used for all vehicles.
  - For LRFR, use a modified contact area for EVs. Include screenshots of agency-defined vehicles (e.g., EVs, Adjacent Type 3-3).

General Notes:

- MDT Vehicle Analysis Templates are available on MDT's Load Rating Website.
- Ensure that the template attached to the load rating report is the actual template used for the rating.
- Include only the analysis template(s) applicable to rating method. For mixed-method ratings (e.g., ASR/LFR or ASR/LRFR), include each applicable template.
- Contact MDT's Load Rating Program Manager for guidance if additional templates are needed (e.g., to address software issues or workarounds).

6.2.6. Measurements/Plans

Include PDF copies of plans, shop drawings, field measurements, and any other documents referenced in the Basis for Load Rating.

Plan and shop drawing attachments are required only for structures without an MDT drawing or Construction Project Number (typically non-state-owned structures).

It is preferred to attach the full plan set for completeness. If necessary to reduce file size, it is acceptable to include only the sheets used in analysis (e.g., general layout with notes, framing plan, cross-sections, beam details, connection details, etc.). If partial plans are attached, add a note in the Basis for Load Rating section stating that only relevant sheets are included and refer to BrM for the full plan set.

6.2.7. Substructure Ratings

Bridges that require a substructure rating should have separate Superstructure and Substructure Load Rating Reports. In the Load Rating Summary heading, clearly label and highlight, “Superstructure Only” or “Substructure Only” to distinguish the scope of each report.

Figure 6.2-2 Load Rating Summary Report Heading

In the Substructure Load Rating Summary, add a note to the Comments section to indicate that superstructure rating results are in a separate “Superstructure Only” Load Rating Report.

FIGURES / TABLES / EQUATIONS

FIGURES

TABLES

EQUATIONS

A. GLOSSARY AND ACRONYMS

This appendix provides definitions of key terms used throughout the MDT Bridge Load Rating Manual. Terms are listed alphabetically. Definitions are based on the MDT manual, supplemented where necessary by AASHTO and FHWA guidance.

GLOSSARY

AASHTO
American Association of State Highway and Transportation Officials

Allowable Stress Rating (ASR)
A load rating method based on allowable stress limits and service-level design assumptions, typically applied to timber and older structures.

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

Capacity (C)
The load-carrying capability of a bridge member used in load rating calculations.

Condition Factor
A modifier used in LRFR to account for deterioration, damage, or uncertainty in member condition.

Controlling (Governing) Rating
The lowest rating among all load-rated members that determines the overall bridge rating.

Dead Load (DL)
Permanent loads acting on a bridge, including self-weight and fixed attachments such as barriers, utilities, and wearing surfaces.

Engineering Judgment (EJ)
A method used to establish load ratings when analytical approaches are not feasible, based on professional evaluation of field conditions and structural behavior.

Finite Element Analysis (FEM)
A refined analytical method that models structural behavior using numerical techniques to evaluate stresses, forces, and load distribution.

Impact Factor (IM) / Dynamic Load Allowance
A factor applied to account for dynamic effects of moving loads on a structure.

Inventory Rating
Describes a live load (in tons) which can safely utilize a structure for an indefinite amount of time.

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

Live Load (LL)
A temporary dynamic load such as vehicular traffic that is applied to a structure; also accompanied by vibration or movement affecting its intensity.

Live Load Distribution Factor (LLDF)
A factor used to distribute live loads among structural members.

Load Factor Rating (LFR)
A load rating method that applies load factors to dead and live loads in accordance with older AASHTO specifications.

Load Rating
The analysis to determine the safe vehicular live load carrying capacity of a bridge using bridge plans and supplemented by measurements and other information gathered from an inspection.

Load and Resistance Factor Rating (LRFR)
The current standard load rating method that incorporates reliability-based factors for loads and resistance.

National Bridge Inspection Standards (NBIS)
Federal regulations governing bridge inspection, evaluation, and load rating requirements.

National Bridge Inventory (NBI)
An aggregation of State transportation department, Federal agency and Tribal government bridge and associated highway data maintained by the Federal Highway Administration (FHWA). The NBIS requires each State transportation department, Federal agency, and Tribal government to prepare and maintain a bridge inventory, which must be submitted to the FHWA in accordance with these specifications on an annual basis or whenever requested.

Operating Rating
The maximum permissible live load to which the structure may be subjected for the load configuration used in the load rating.

Posting Load
The weight limit (in tons) used in signing a bridge for load restriction.

Quality Assurance (QA)
The use of independent sampling and other measures to assure the adequacy of quality control (QC) procedures in order to verify or measure the quality level of an entire program.

Quality Control (QC)
Operational procedures used to ensure the accuracy, completeness, and consistency of load rating calculations and documentation.

Rating Factor (RF)
A dimensionless value representing the ratio of available capacity to applied loads. It is used to determine the load-carrying capability of a bridge.

Reasonable Access
Defined by September 30, 1992, Non-Regulatory Supplement to 23 CFR §658 as at least one-road-mile from access to and from the National Network of highways, which includes the Interstate System, or further if the limits of a State's reasonable access policy for food, fuel, repairs, and rest extend to facilities beyond one-road-mile. MDT defines reasonable access as one (1) mile from any interchange on the Interstate system.

Safe Load Capacity (SLC)
As defined by AASHTO, a live load that can safely utilize a bridge repeatedly over the duration of a specified inspection cycle. When referenced for LRFR, this represents the upper bound for posting loads.

Safe Posting Load (SPL)
A posting load specifically associated with LRFR, based on the statistical probability of higher overloads/failures on posted bridges, calculated from MBE Eq. 6A.8.3-1.

Substructure
Structural components that transfer loads from the superstructure to the foundation, including piers, abutments, and piles.

Superstructure
Primary load-carrying components of a bridge, including girders, beams, truss members and slabs.

System Factor
A modifier used in LRFR to account for structural redundancy and system behavior.

Load Testing (LT)
A method of evaluating bridge capacity through controlled application of loads, including proof and diagnostic testing.

Traffic (Live Load) Effects
Forces generated by vehicular movement across a bridge, including load magnitude, distribution, and dynamic effects.

ACRONYMS

The following abbreviations are used throughout this manual:

- **ADTT** – Average Daily Truck Traffic
- **ASR** – Allowable Stress Rating
- **DL** – Dead Load or Design Load Rating
- **EV** – Emergency Vehicle
- **EJ** – Engineering Judgment
- **FEM** – Finite Element Model
- **FHWA** – Federal Highway Administration
- **LBT** – Lateral Torsional Buckling
- **LFR** – Load Factor Rating
- **LL** – Live Load
- **LRFR** – Load and Resistance Factor Rating
- **LT / FT** – Load Testing / Field Testing
- **MBE** – AASHTO Manual for Bridge Evaluation
- **MCA** – Montana Code Annotated
- **MDT** – Montana Department of Transportation
- **NBIS** – National Bridge Inspection Standards
- **NBI** – National Bridge Inventory
- **QA / QC** – Quality Assurance / Quality Control
- **RF** – Rating Factor

- **SDL** – Superimposed Dead Load
- **SIP** – Stay-in-place

Note: Definitions are consistent with the AASHTO Manual for Bridge Evaluation (MBE), AASHTO LRFD Bridge Design Specifications, AASHTO Standard Specifications for Highway Bridges, MDT guidance, and FHWA guidance documents.

B. BrR NAMING: MODELING CONVENTIONS AND PREFERENCES

General

Program Tolerances *(Configuration > System Defaults > Tolerance)*

Table B-1. BrR Program Tolerances.

Units	Tolerance
ft	0.01
in	0.10
mi	0.01

System Defaults *(Configuration > System Defaults > Superstructure analysis)*

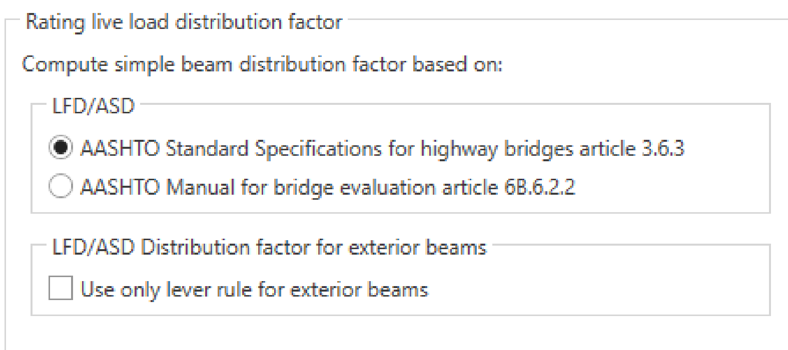


Figure B-1. BrR Live Load Distribution Factor Defaults.

Best practice – purge all unused material properties/factors/definitions.

Bridge Definition

See below for Bridge ID and NBI Structure ID input.

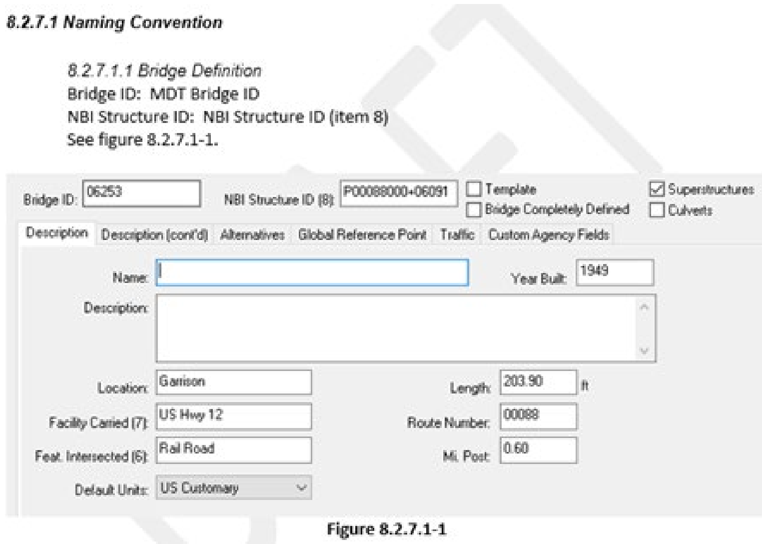


Figure B-2. BrR Bridge Description.

In the Description section, include the following:

- Simple bridge description
- Input by (*Consultant Name)*
- Anything unique about the model or process of rating the structure (workarounds, service III ignored, etc.)
- *Load Rating updates* – add comment to flag and briefly summarize rating update/changes

Input all fields in both 'Description Tabs.'

- Information about existing bridges can be found in BrM.
- Contact MDT's Load Rating Program Manager for new bridges without a complete BrM record.

Naming Convention

Superstructure Definition

- Simple span (single span bridge) – include span length, type of span
- Simple span (multi-span bridge) – include span number(s), span length, type of span
- Continuous spans – include span numbers and type of span
- *Load rating updates* – add inspection date (YYYYMMDD) at beginning

Member Name

- G1, G2, etc. (direction/numbering should be consistent with Load Rating Report – Members Rated section)

Member Alternative Name

- Indicate any representative girders, girders with deterioration or reduced depth, original vs. widening, etc. (should correlate to Load Rating Report – Members Rated section)
- *E.g., Typical Exterior Girder, Typical Interior Girder, Interior Girder-Reduced Capacity, Interior Girder-Reduced Depth, Widening Girder, etc.*

Bridge Alternative

- Always name As-Built
- *Load rating updates – add inspection date (YYYYMMDD) at beginning*

Superstructure

- Single span bridge – name “Single Span”
- Multi-span bridge – name for the span(s) represented

Superstructure Alternative

- Name “Rated XXXX” – *once a rating is finalized in BrM, MDT will update the Superstructure Alternative name to match the rating date*

Example: Single Span

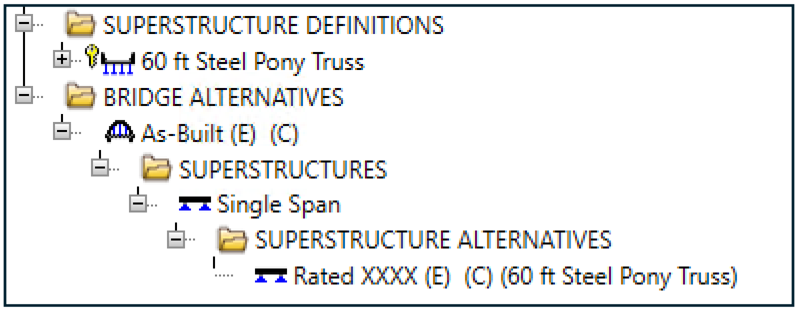


Figure B-3: Naming Conventions for Single Span Superstructures.

Example: Multiple spans with both continuous and simple spans

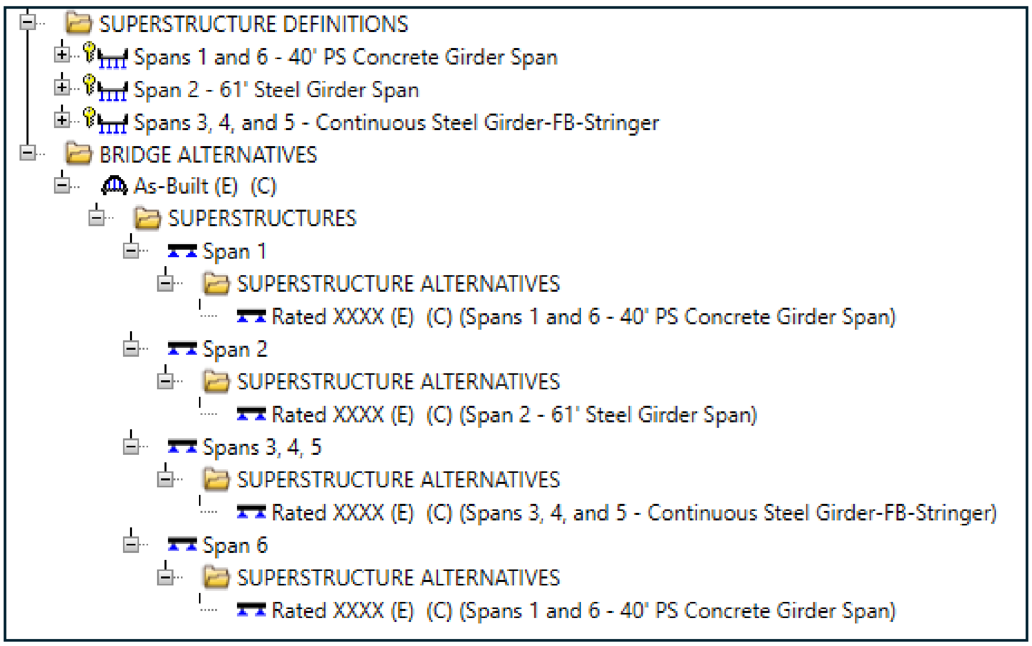


Figure B-4. Naming Conventions for Multiple Spans (Simple and Continuous).

Example: Members, Member Alternatives

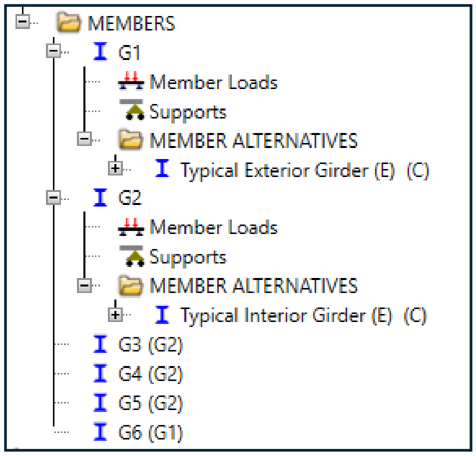


Figure B-5. Naming Conventions for Members and Member Alternatives.

Wearing Surface

Add note to Wearing Surface Description to indicate reference/basis for wearing surface *(i.e. 2005 rehab mill/overlay, per 2022 BrM attribute MDT008, per 2019 measurement form, etc.)*

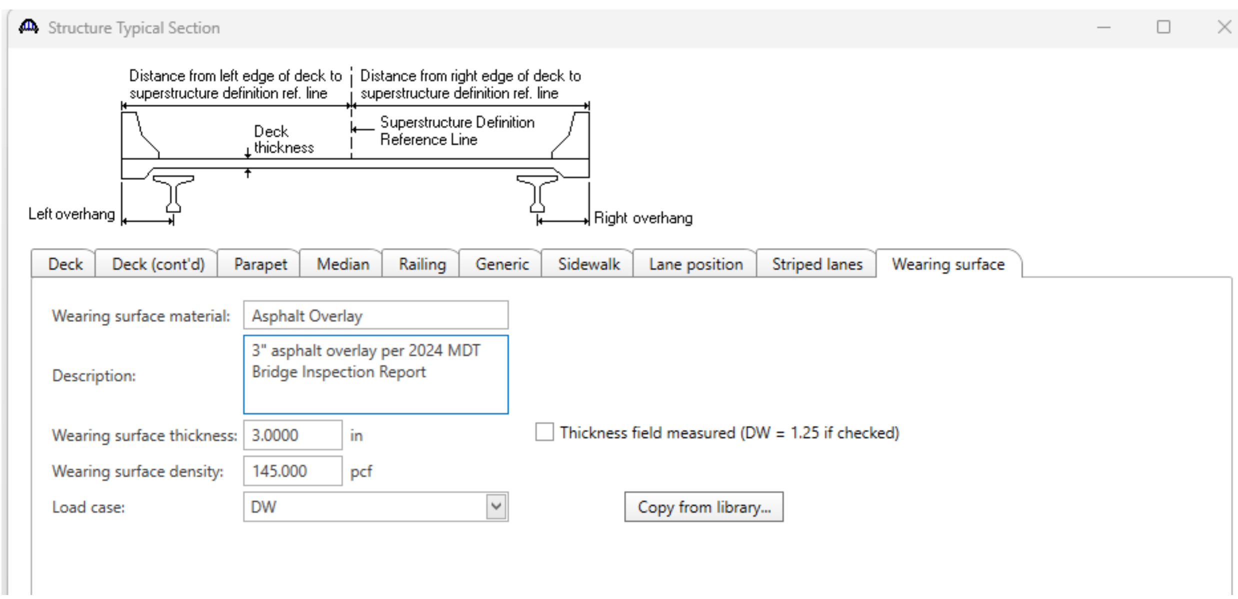
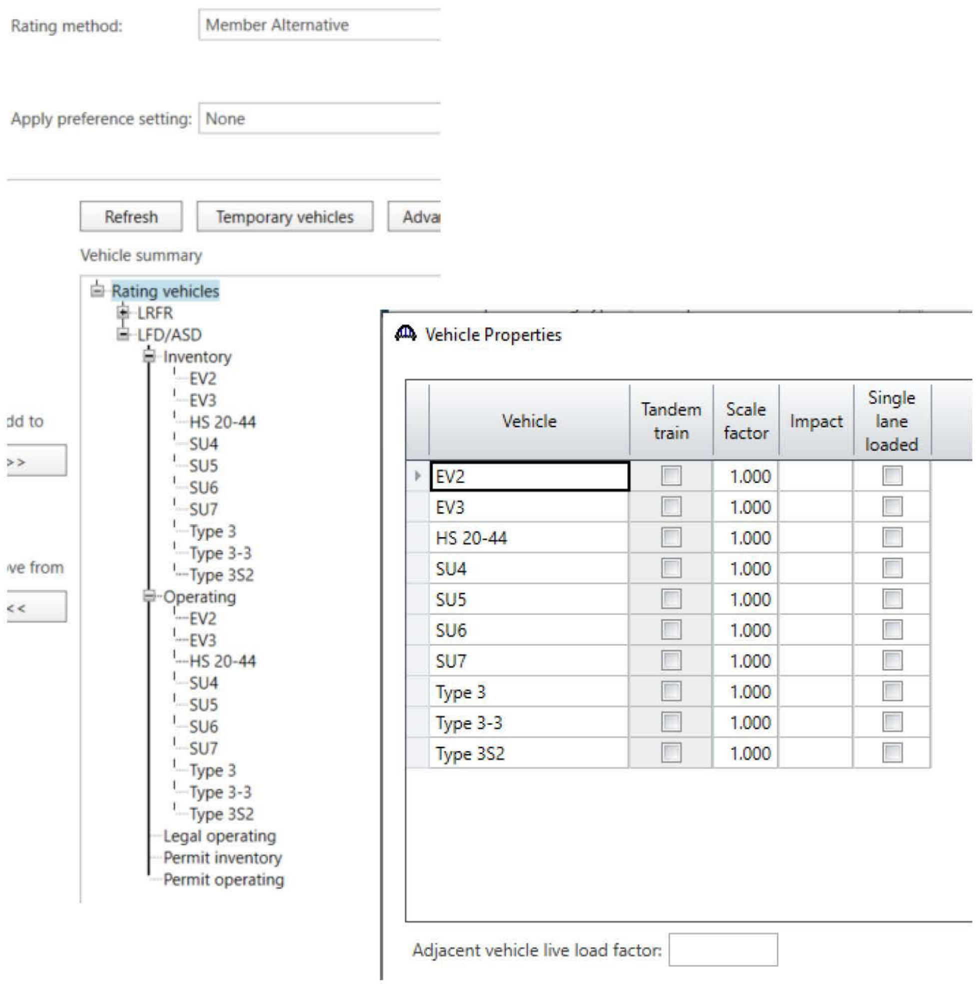


Figure B-6. BrR Overlay description example.

Vehicle Analysis Templates

LFR/ASR: Use this template for mixed material bridges unless LFR is triggering posting for EVs and legal operating template needs to be used.

Vehicle Template for LFR/ASR Analysis

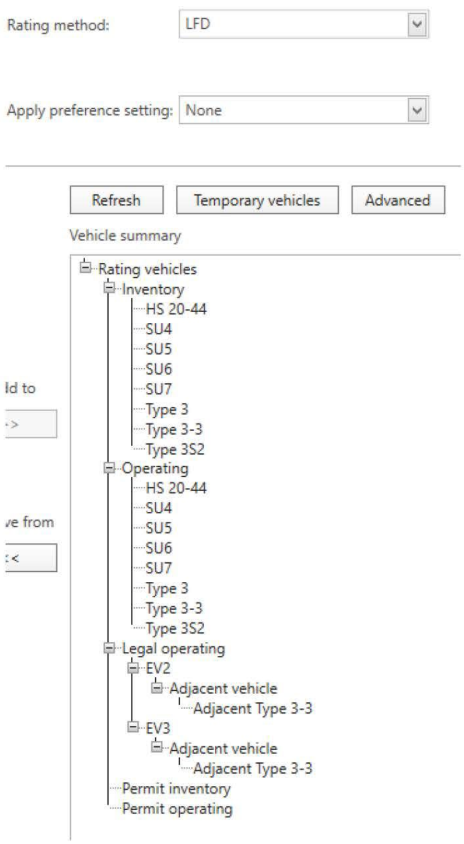


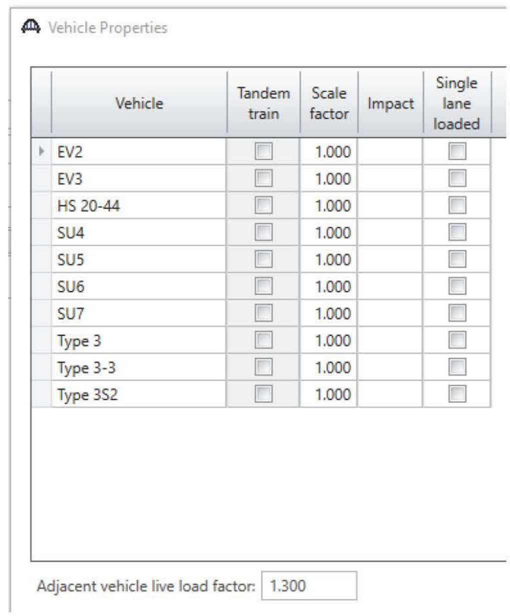
***Standard library definitions used for all vehicles*

Figure B-7. Vehicle Template for LFR/ASR Analysis.

LFR – Legal Operating

Vehicle Template for LFR Analysis





***Adjacent Type 3-3 is an Agency Defined Vehicle*

Standard library definitions used for all other vehicles

Adjacent Type 3-3

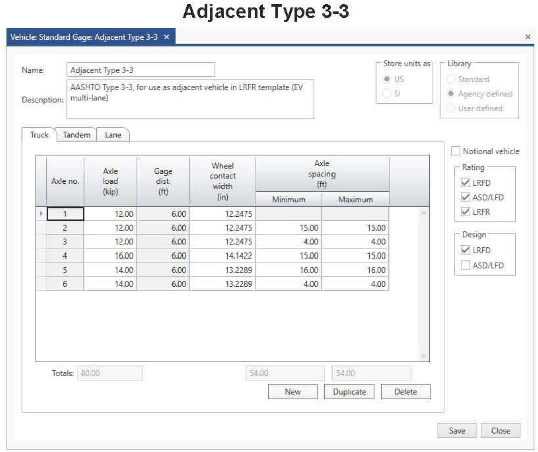
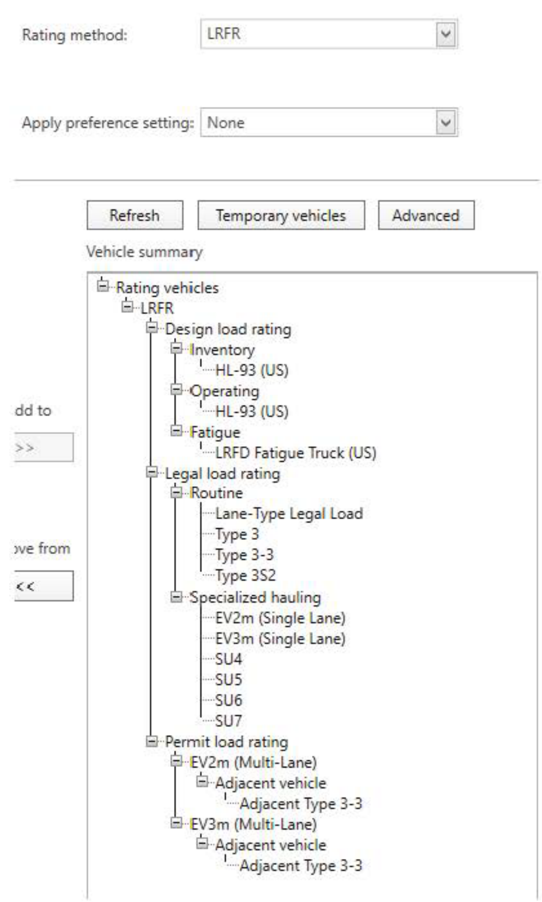


Figure B-8. Vehicle Template for LFR Legal Load Analysis.

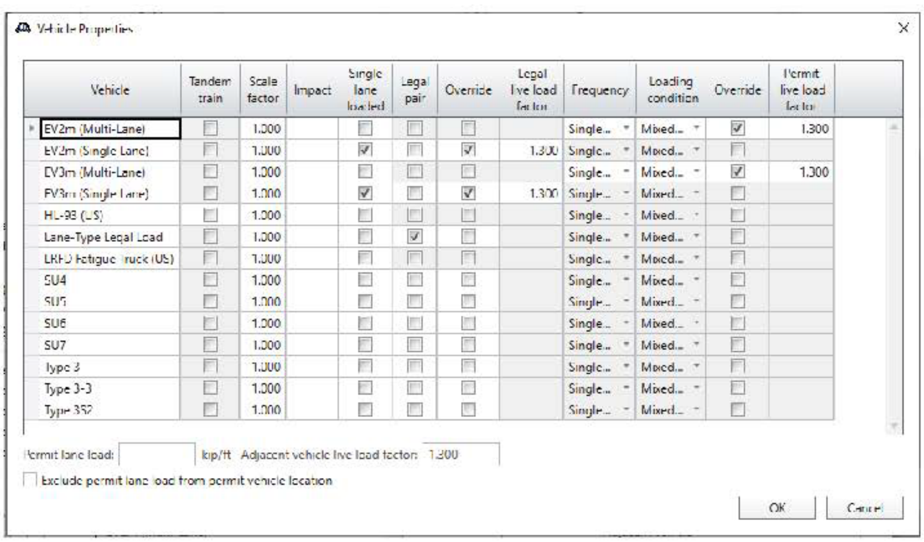
LRFR

Vehicle Template for LRFR Analysis



***EVs and Adjacent Type 3-3 are Agency Defined Vehicles - see next page*

Standard library definitions used for all other vehicles



Vehicle Properties

Vehicle	Tandem train	Scale factor	Impact	Single lane loaded	Legal pair	Override	Legal live load factor	Frequency	Loading condition	Override	Permit live load factor
EV2m (Multi-Lane)	☐	1.000		☐	☐	☐		Single...	Mixed...	☑	1.300
EV2m (Single Lane)	☐	1.000		☑	☐	☑	1.300	Single...	Mixed...	☐	
EV3m (Multi-Lane)	☐	1.000		☐	☐	☐		Single...	Mixed...	☑	1.300
EV3m (Single Lane)	☐	1.000		☑	☐	☑	1.300	Single...	Mixed...	☐	
HL-93 (US)	☐	1.000		☐	☐	☐		Single...	Mixed...	☐	
Lane-Type Legal Load	☐	1.000		☐	☑	☐		Single...	Mixed...	☐	
LRFD Fatigue Truck (US)	☐	1.000		☐	☐	☐		Single...	Mixed...	☐	
SU4	☐	1.000		☐	☐	☐		Single...	Mixed...	☐	
SU5	☐	1.000		☐	☐	☐		Single...	Mixed...	☐	
SU6	☐	1.000		☐	☐	☐		Single...	Mixed...	☐	
SU7	☐	1.000		☐	☐	☐		Single...	Mixed...	☐	
Type 3	☐	1.000		☐	☐	☐		Single...	Mixed...	☐	
Type 3-3	☐	1.000		☐	☐	☐		Single...	Mixed...	☐	
Type 3S2	☐	1.000		☐	☐	☐		Single...	Mixed...	☐	

Permit lane load: kip/ft Adjacent vehicle live load factor: 1.300

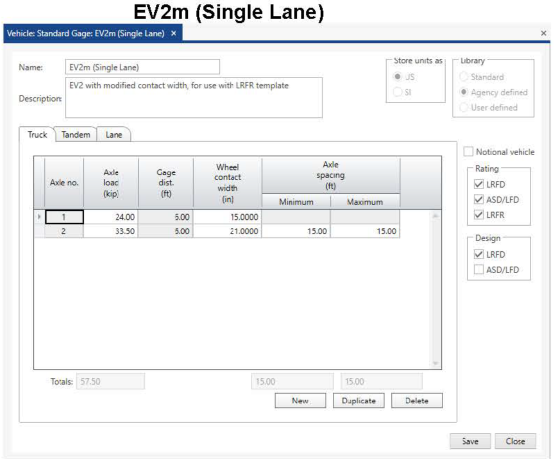
☐ Exclude permit lane load from permit vehicle location

OK Cancel

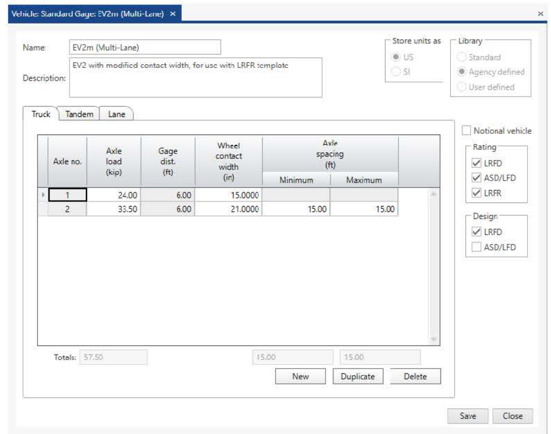
Figure B-9. Vehicle Template for LRFR Analysis.

Agency Defined Vehicles

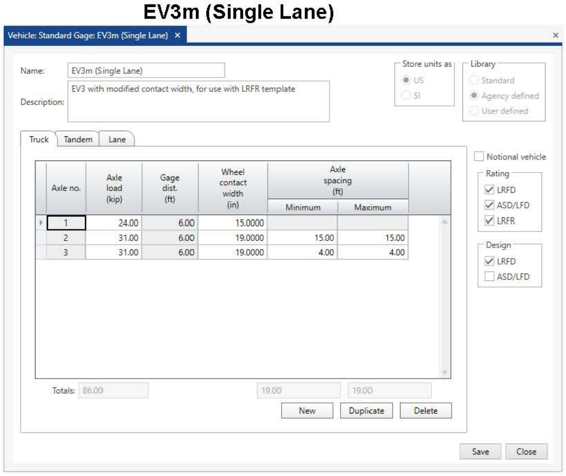
EV2m (Single Lane)



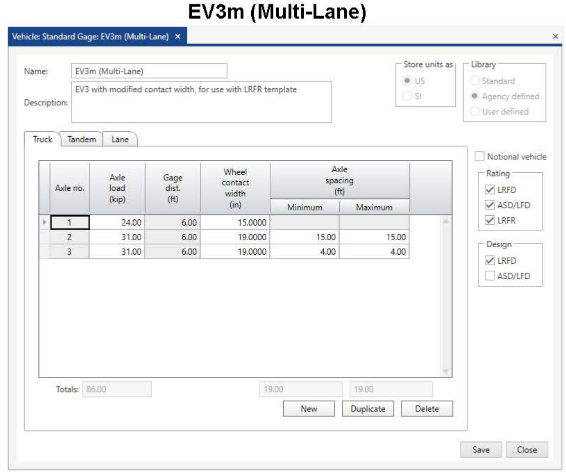
EV2m (Multi-Lane)



EV3m (Single Lane)



EV3m (Multi-Lane)



Adjacent Type 3-3

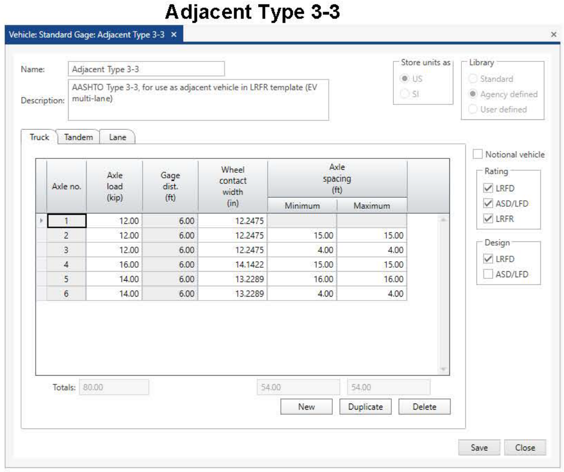


Figure B-10. Agency Defined Vehicles.

C. DESIGN LOAD RATING (DL METHOD) – BrR MODELING / REPORTING GUIDANCE

BrR Model

General Bridge Description

- Include 'DL Rating' in Name
- Description: add standard note to flag that [shop drawings/modify as applicable] were not available at time of rating, briefly summarize approach to model/rate the bridge. Summarize the two superstructure definitions included in BrR model – e.g. XXX superstructure definition was used to determine the design/evaluate design load rating (design 'proof' model), and XXX superstructure definition is used as the rating model (in-service conditions).

Example:

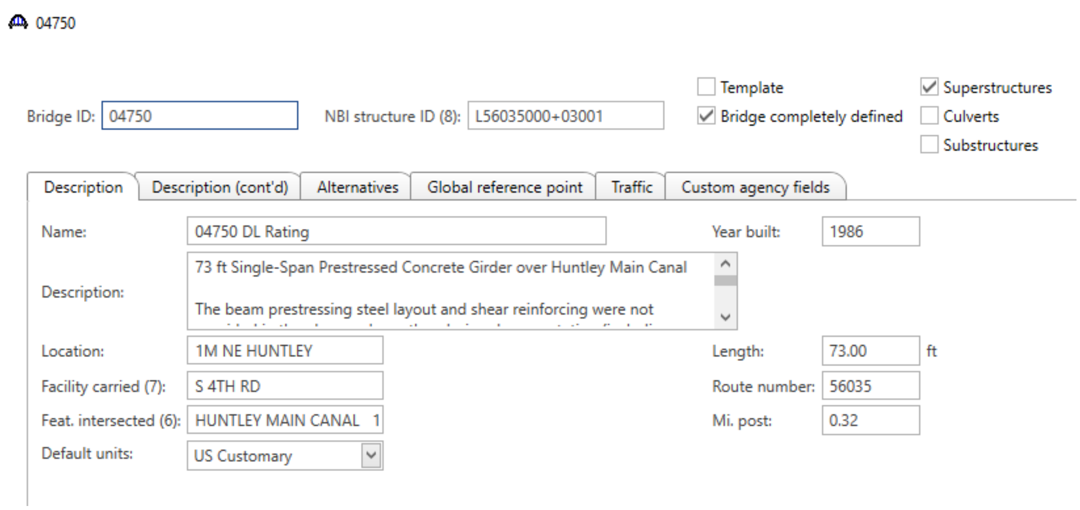


Figure C-1. Example of General Bridge Description.

Description Notes:

The beam prestressing steel layout and shear reinforcing were not provided in the plans, and no other design documentation (including shop drawings) was available. An assumed design was determined based on the year built (1986) and the plans with the following conditions:

Design vehicle: HS20

Design Method: LFR

The sacrificial wearing surface thickness was not deducted from the design beam section properties.

Prestressing steel layout which passes initial stress checks and results in an inventory rating factor of approximately 1.0 for the design vehicle.

Two superstructure models were created in BrR: "Design" superstructure definition was used to validate the assumed prestressed girder design. The "Rating" superstructure definition was used for load rating the in-service condition.

The 11/17/2022 inspection report does not indicate signs of shear or flexural cracking. Per MDT guidance, in accordance with MBE 6A.5.4.2.2a, the optional Service III Limit State check for legal loads was not evaluated for the controlling load rating analysis.

Superstructure Definitions

- Use two separate superstructure definitions for Design and Rating. Add notes to each Superstructure Definition Description

Examples:

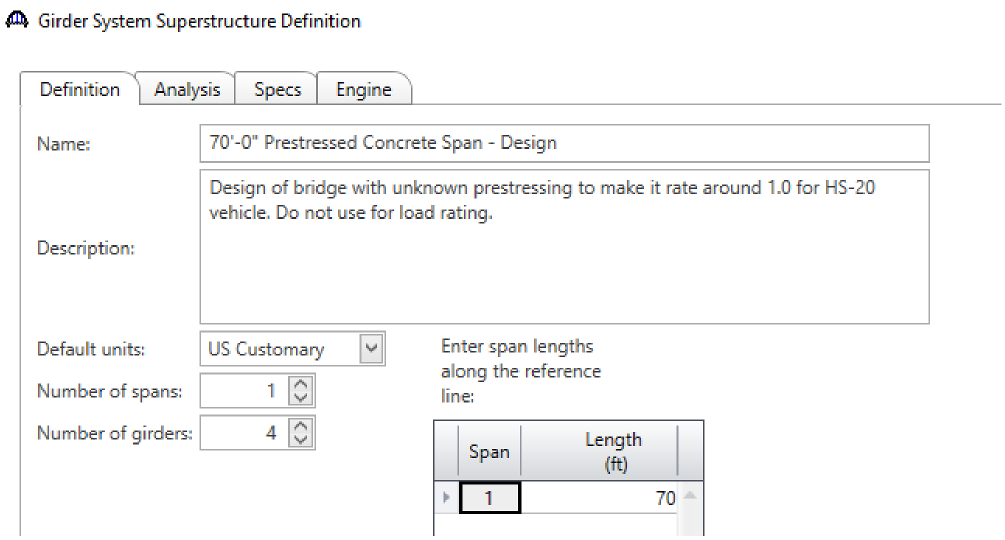


Figure C-2. Example of Design Description for Girder System Superstructure Definition.

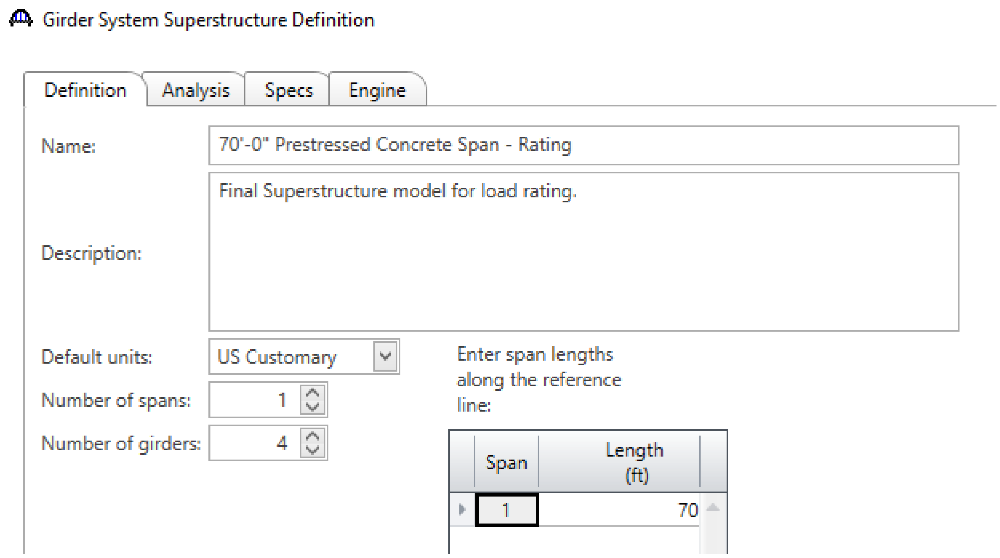


Figure C-3. Example of Rating Description for Girder System Superstructure Definition.

Load Rating Report Format

Keep standard format (regular load rating report). See below for additional details specific to DL ratings:

- Summary Sheet
    - Method – overwrite to add "– DL Rating" *(i.e. LRFR – DL Rating)*
    - Include a standard comment to flag that [*shop drawings/modify as applicable]* were not available at time of rating, briefly summarize approach to model/rate the bridge (e.g., PS strand layout/reinforcement centroid was determined based on an assumed beam design that achieved *{XXX design load}* design load inventory RF = 1.0), refer to Assumptions and Appendix for more details

Example:

Shop drawings showing the prestressed strand pattern in the girders were not available at the time of the load rating. The load rating was derived by assuming a strand pattern which yielded an inventory rating factor of approximately 1.0 for the design vehicle (HS20) using the design method of the time (LFR). See Assumed Design Rationale and the Appendix: Assumed Design Load Rating Process for more details.

Indicate that two superstructure definitions are included in BrR model; one used for design (design 'proof' model), and one to model in-service conditions (rating model)

Example:

Two Superstructure models were created in BrR: a Design superstructure to validate the assumed prestressed girder design, and a Rating superstructure for load rating the in-service condition.

- Basis for Load Rating

  - Add a standard note to indicate that prestressed strand layout is assumed *[or P and CGS]*, reference Assumptions/Appendix
  - Similar Bridges - If a similar bridge is referenced/used to help inform assumptions, add sub-section to Basis for Load Rating (at bottom) with the heading. **Similar bridge info is used to inform assumptions.** Include a note about what's referenced, supporting reasoning for 'similar' determination

Example:

<u>Basis for Load Rating:</u>

1. 04750 Construction plans: Brewer & Associates 37-B-2

2. The prestressed strand layout was assumed, see Assumed Design Rationale and Appendix: Assumed Design Load Rating Process for information.

3. 04750 MDT Structure Inspection Report (11/17/2022)

Similar Bridge used to help inform assumptions:

04761 Construction Plans: Design 3 Engineering Sheet 5 (06/10/1983)

- 04761 was referenced since it has a similar span length, beam section and year of construction.
- This bridge was used to determine the size and spacing of the shear reinforcement in the girders.

Figure C-4. Additional information on Basis for Load Rating.

- Material Properties

  - Include reference for material properties. If unknown/assumed, please include basis for assumption (e.g., Montana Standard Specifications, MBE table and year constructed, nearby/similar bridge)

- Assumptions

  - Break assumptions into 2 different sections/headings: **Design 'Proof' Assumptions** and **In-Service Rating Assumptions** *(or similar)*. Include design assumptions first, then rating assumptions.
  - Design Assumptions – intended to be a high-level summary, refer to more detailed documentation in Appendix at end of report

Example:

Assumed Design Rationale:

A summary of the design load method is shown below. Refer to Appendix: Assumed Design Load Rating Process Report for the detailed design process.

1. The beam prestressing steel layout and shear reinforcing were not provided in the plans and no other design documentation (including shop drawings) was available. An assumed design was determined based on the year built (1986) and the plans with the following conditions:
    - Design vehicle: HS20
    - Design Method: LFR
    - The sacrificial wearing surface thickness was not deducted from the design beam section properties.
    - Shear reinforcing was based on plans for a similar bridge (04761).
    - The prestressing steel layout passes initial stress checks and results in an inventory rating factor of approximately 1.0 for the design vehicle.
2. The assumed design resulted in the following inventory rating factors for the design vehicle:
    - G1 (exterior): RF = 1.021
    - G2 (interior): RF = 1.014

Figure C-5. Example Summary of Assumed Design Rationale.

- Plan Attachments
    - For DL method, include full set of construction plans from BrM
    - Reference plans
        - It's okay to include only applicable sheets –include note about partial plan set in Basis for Load Rating section
        - Add a red box at top of each page with note to identify that they are for similar bridge/reference
- Appendix – add to the end of the standard report (e.g., after plans)
    - Intended for more detailed information about design process/methodology/iterations. Include:
        - Design assumptions
            - Design Vehicle, reference
            - Design Method
            - Summary of methodology/iterations
    - Material Properties
    - Girder Dimensions
    - Include screenshots of strand layout (if applicable) or calculation of PS&G
    - Include screenshot of Member Results
    - Include screenshot of BrR analysis template

BrM Entry

Add comment to Load Rating Event Notes to indicate Design Load Rating (*copy over standard comments from summary sheet*).

D. ANALYTICAL REFINEMENT METHODS – GUIDANCE FOR MODELING AND REPORTING

Alternate LFR Ratings

Would like to retain LRFR rating information (model input, calculations, documentation), but report LFR ratings and set BrR model up with LFR as the default.

Model:

- If an alternate LFR rating is completed, enter LLDFs for both LRFR and LFR methodologies under each member alternative (if manual entry is applicable). Set default rating method to LFD.
- For trusses – if needed, create separate superstructure definitions (LRFR and LFR) and indicate the methodology in the name. Set rating methods accordingly.

Report:

- Address both methodologies in the Live Load Distribution section (i.e. LFR LLDFs calculated internally by BrR, LRFR LLDFS calculated and input manually due to *xx* limitation)
- (If applicable) Include both LFR and LRFR LLDF calculations in the LFR report – make sure they're clearly differentiated
- Report LFR results only (summary sheet, member summaries)

Striped Lanes

Use the striped lanes to adjust vehicle placement in situations where definitive boundaries exist that vehicles are reasonably assumed to operate within (i.e. timber running planks, grassed in shoulders, etc. Generally not intended for low profile running planks – steel, timber graveled in, etc.)

Model:

- Create a separate superstructure definition for striped lanes (add indicator to name) and set as the current bridge alternative
- Add comment documenting justification/assumptions in Superstructure Definition description

Report:

- Add brief note to flag in summary sheet comments, address in further detail in Live Load Distribution Section (bridge-specific reasoning/justification)

LRFD C3.6.1.1.2 (Reduction in Live Load Effects based on ADTT)

Model:

- MDT preference is to account for this by scaling vehicle analysis template accordingly
- Add a comment in the General Bridge description

Report:

- Add a brief note to flag in the summary sheet comments, address in further detail in Live Load Distribution Section (bridge-specific reasoning/justification, how reduction was taken into account)
- Rating results will not show correct tonnage for scaled vehicle template. Cross-out/grey-out and add a comment on each sheet to indicate that the rating factor is correctly computed, but the reported tonnage is not accurate because it's based on a scaled vehicle weight

Number of Lanes

Standard Guidance:

Roadway widths less than 20 ft shall be rated for one lane of traffic (set BrR System Defaults settings accordingly).

Model: n/a

Report: n/a

There may be other cases where judgement is used to determine single lane distribution based on site specific conditions (i.e. off-system, 'single lane bridge' signs, running planks on deck that clearly indicate single lane use, rural/low traffic area, grassy shoulders, lack of painted lanes, other indicators of unlikelihood that two rating vehicles will be adjacent on bridge at same time)

Model:

- Create a separate superstructure definition for single-lane condition (add an indicator to name) and set as the current bridge alternative
- To override the multi-lane condition, manually input single-lane LLDF in the multi-lane row (MDT Preference)

Report:

- Add general comment to summary sheet to flag single-lane only analysis
    - *e.g., Only single-lane distribution is considered for this analysis. Per MDT guidance for off-system, low traffic structures, it is assumed unlikely that two rating vehicles will occupy the structure at the same time. See load rating report for further details.*

- Address in further details in Live Load Distribution Section (include bridge-specific documentation re: justification/reasoning for determination, note how this was accomplished)

  - *e.g., Although usable width is wide enough for two lanes, it is assumed unlikely that two rating vehicles will occupy the structure at the same time due to xxxx (include bridge-specific reasoning – rural location, low ADT, presence of running planks, lack of painted lanes, visible track patterns from inspection photos). This is accomplished by overwriting multi-lane LLDFs in the Superstructure Definition.*

- If LLDFs have to be calculated manually, include calculations for both single and multi-lane (for future reference, if needed)

E. LOAD RATING UPDATES – GUIDANCE FOR MODELING AND REPORTING

BrR Model

General Bridge Description

- Add comment to flag and briefly summarize rating update/changes (same as summary sheet note – see below)

Superstructure Definitions

- Add inspection date at beginning of name in YYYYMMDD format (e.g., 20240418 60ft Steel Pony Truss)

*** Note – this should match inspection date on summary sheet – routine inspection date for condition changes, post-rehab/repair inspection date for repairs*

Bridge Alternative

- Add inspection date at beginning of name in YYYYMMDD format (i.e. 20240418 As-Built)

Load Rating Report

Summary Sheet

- Inspection Date Cell - for repair updates, use the post-repair/rehab inspection date, add inspection type *(e.g., xx/xx/xx post-repair)*
- Add comment to flag and briefly summarize rating update/changes
    - *e.g., Load rating update reflects repairs completed by County in June 2024. Work included placement of a sister girder next to G7, new deck and new bridge rail.*
    - *e.g., Load rating update reflects xxx(defect) on xxx(member) noted in xxxx routine inspection*
    - *e.g., Load rating update reflects change in wearing surface, new measurements, etc.*

Basis for Load Rating

- Include full inspection dates
- For multiple inspections *(typically applicable to repairs)* – reference both inspections, split out and include inspection type (i.e. xx/xx/xx post-repair/rehab, xx/xx/xx routine). Include a note under the post-rehab inspection to indicate that the inspection is limited to evaluation of xxxx *(typically repaired members – see BrM, elements are checked)*; indicate that the routine inspection is referenced for all other member conditions

Members Rated

- Indicate any repaired members or members with deterioration (same for Member Alternative Name in BrR model)

Defects

- *For condition changes* – address flagged issue(s), address how it's accounted for (*e.g.,* specific reductions/inputs in BrR model) or explain reasoning if it's not included in analysis

F. MDT QC/QA RESPONSIBILITIES

Responsibilities for MDT Load Rater/Originator

The basic responsibilities for the person performing the original load rating are:

- Collect all available data and verify completeness and accuracy. See Section 2.5 for information typically required to perform a load rating.
- Compare the inspection report and photos with plans, sketches, and measurements to ensure they correspond to the bridge being analyzed and reflect its current condition.
- Perform the load rating analysis.
- Compile the BrR model and all required documentation (i.e., comments, assumptions, calculations, etc.) See Section 6.2.3.
- Prepare the load rating summary sheet and assemble the draft load rating report for review.

Responsibilities for MDT QC Reviewer

- Review all available data for the bridge and evaluate the load rater's conclusions for overall appropriateness.
- Review BrR (or other software) inputs for accuracy and completeness, and run the analysis to confirm outputs.
- Review all assumptions and calculations, and confirm that documentation is clear and sufficient.
- Perform independent analyses, calculations, or spot checks as needed to validate the accuracy of load rating results.
- Check the summary sheet and load rating report for accuracy, completeness, and consistency.
- Record any discrepancies identified during review and return comments to the load rater for resolution and signature.

Responsibilities for MDT QA Reviewer

- Review the finalized load rating after all comments are addressed and the QC review checklist is complete.
- Perform a cursory review of the load rating report and model for completeness and conformance with the MDT manual. Return any comments back to the load rater for correction.
- Approve the load rating for entry of the load rating event and document upload in BrM.
- Finalize model in BrR once load rating is entered and uploaded to BrM.

G. MDT QC REVIEW CHECKLIST

MDT	***Montana Department of Transportation***		
General Bridge Information	Internal Load Rating – QC Review Checklist		
MDT Bridge ID	Feature Intersected	Facility Carried	Location
NBI Bridge ID	MDT District	County	Bridge Owner
Load Rating Information			
BrR BID	Rating Originated By	Date Originated	Load Rater of Record *(if different than Originator)*

Load Rating QC Review Checklist

Check appropriate boxes if there are no QC comments, or if the item is not applicable. For any item checked "No", attach documentation that lists QC comments and responses or a description of resolution. The Resolved box should only be checked after all QC comments are addressed.

N/A	Yes	No	Resolved	Review Item
☐	☐	☐	☐	1. Overall rating concepts are applied appropriately
☐	☐	☐	☐	2. Assumptions used in rating are valid and clearly documented
☐	☐	☐	☐	3. Overall rating concepts are applied appropriately
☐	☐	☐	☐	4. Overall rating concepts are applied appropriately
☐	☐	☐	☐	5. Assumptions used in rating are valid and clearly documented
☐	☐	☐	☐	6. BrR input is accurate and appropriate (i.e. correct material strengths, beam shapes, member and superstructure definitions).
☐	☐	☐	☐	7. Calculations are verified and match BrR input (i.e. applied dead loads such as deck thickness, railing, diaphragms, member loads, etc., live load distribution factors if not calculated by BrR).
☐	☐	☐	☐	8. Load Rating Summary Sheet is complete and accurate Bridge information (typically auto-populated) is accurate for the current structure, rating factors and additional information agrees with results of program output.
☐	☐	☐	☐	9. Load Rating Report documentation is complete i.e. summary sheet, comments/assumptions, bridge rating results and member summary reports, calculations, vehicle analysis template, measurements or plan sheets (as applicable)
☐	☐	☐	☐	10. Other

Quality Control Engineer

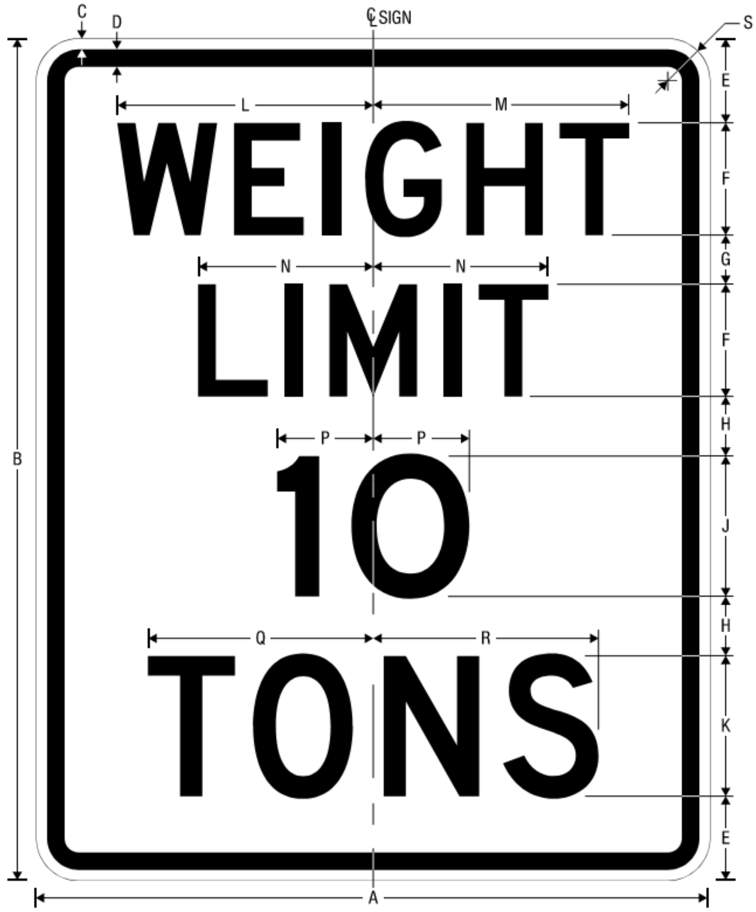
I certify that Quality Control review has been performed and all comments have been resolved with the load rater.

Name/Title		Date	
Signature		The QC Review box on the Load Rating Summary Sheet has been completed	☐

H. LOAD POSTING SIGNAGE

These Load Posting Signs, with the exception of R12-6 (SHV Only), were taken from 2024 Edition of FHWA's "Standard Highway Signs" Releases 1-4, provided for reference only. Sign details should be in accordance with the latest edition of the publication.

R12-1



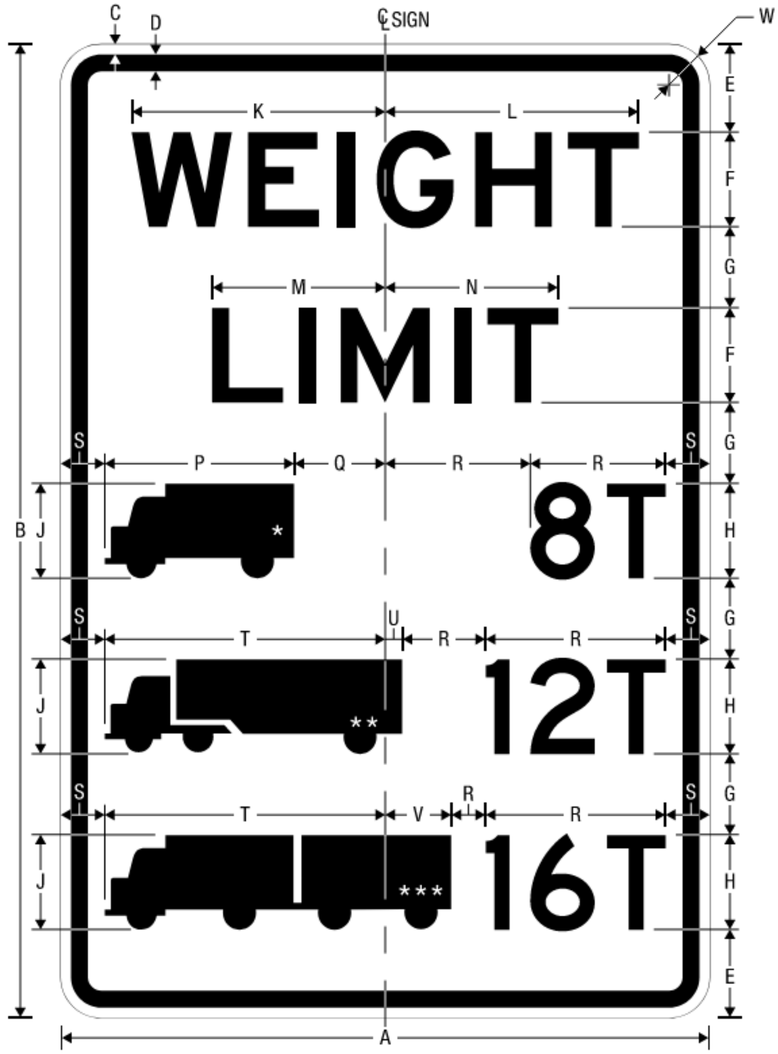
R12-1
WEIGHT LIMIT

A	B	C	D	E	F	G	H	J
24	30	0.375	0.625	3	4 D	1.75	2.125	5 E
36	48	0.625	0.875	4.75	6 D	3	3.75	8 E

K	L	M	N	P	Q	R	S
5 D	9.125	9.125	6.242	VAR	8.031	8.030	1.5
8 D	13.688	13.687	9.363	VAR	12.849	12.849	2.25

COLORS: LEGEND, BORDER — BLACK
BACKGROUND — WHITE (RETROREFLECTIVE)

R12-5



R12-5
WEIGHT LIMIT

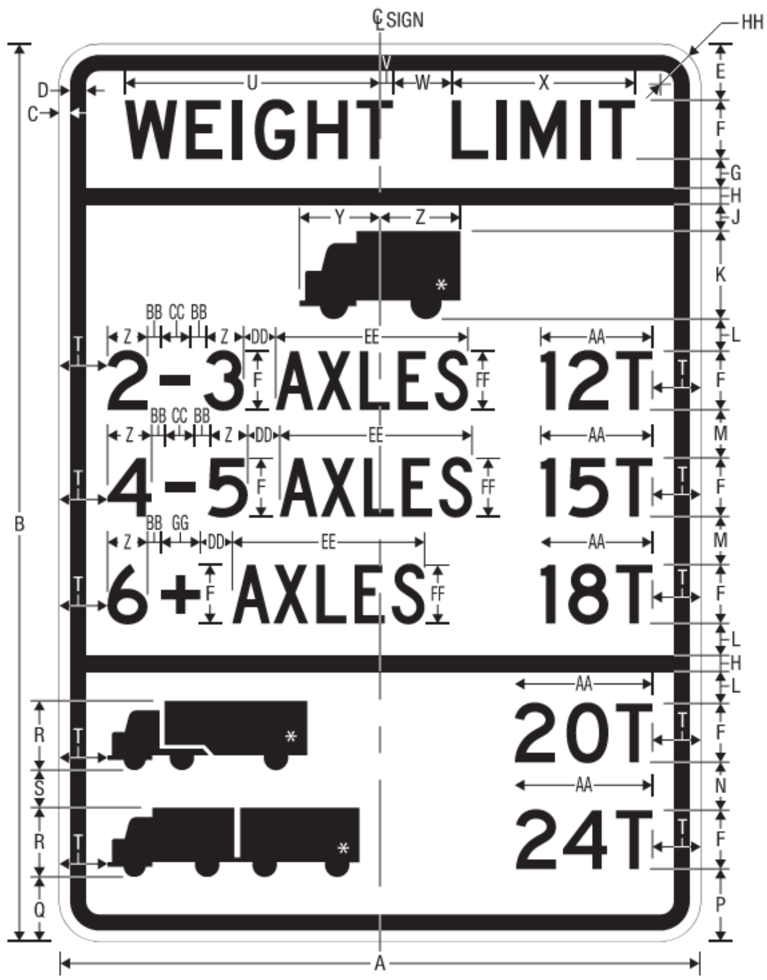
* See page 8-1 for symbol design.
** See page 8-2 for symbol design.
*** See page 8-3 for symbol design.

A	B	C	D	E	F	G	H	J	K	L
24	36	0.375	0.625	3.25	3.5 E	3	3.5 D	3.5	9.383	9.383
36	48	0.625	0.875	5	5 E	3.25	5 D	5	13.405	13.404
48	60	0.75	1.25	6	6 E	4.5	6 D	6	16.086	16.085

M	N	P	Q	R	S	T	U	V	W
6.406	6.406	7	3.375	VAR	1.625	10.375	0.625	2.438	1.5
9.152	9.151	10	5	VAR	3	15	1	4	2.25
10.982	10.981	12	7	VAR	5	19	0	3	3

COLORS: LEGEND, BORDER — BLACK
BACKGROUND — WHITE (RETROREFLECTIVE)

R12-6



R12-6
WEIGHT LIMIT - SPECIALIZED HAULING VEHICLES

* See pages 8-1 - 8-3 for symbol designs.
** Reduce Spacing 20%.

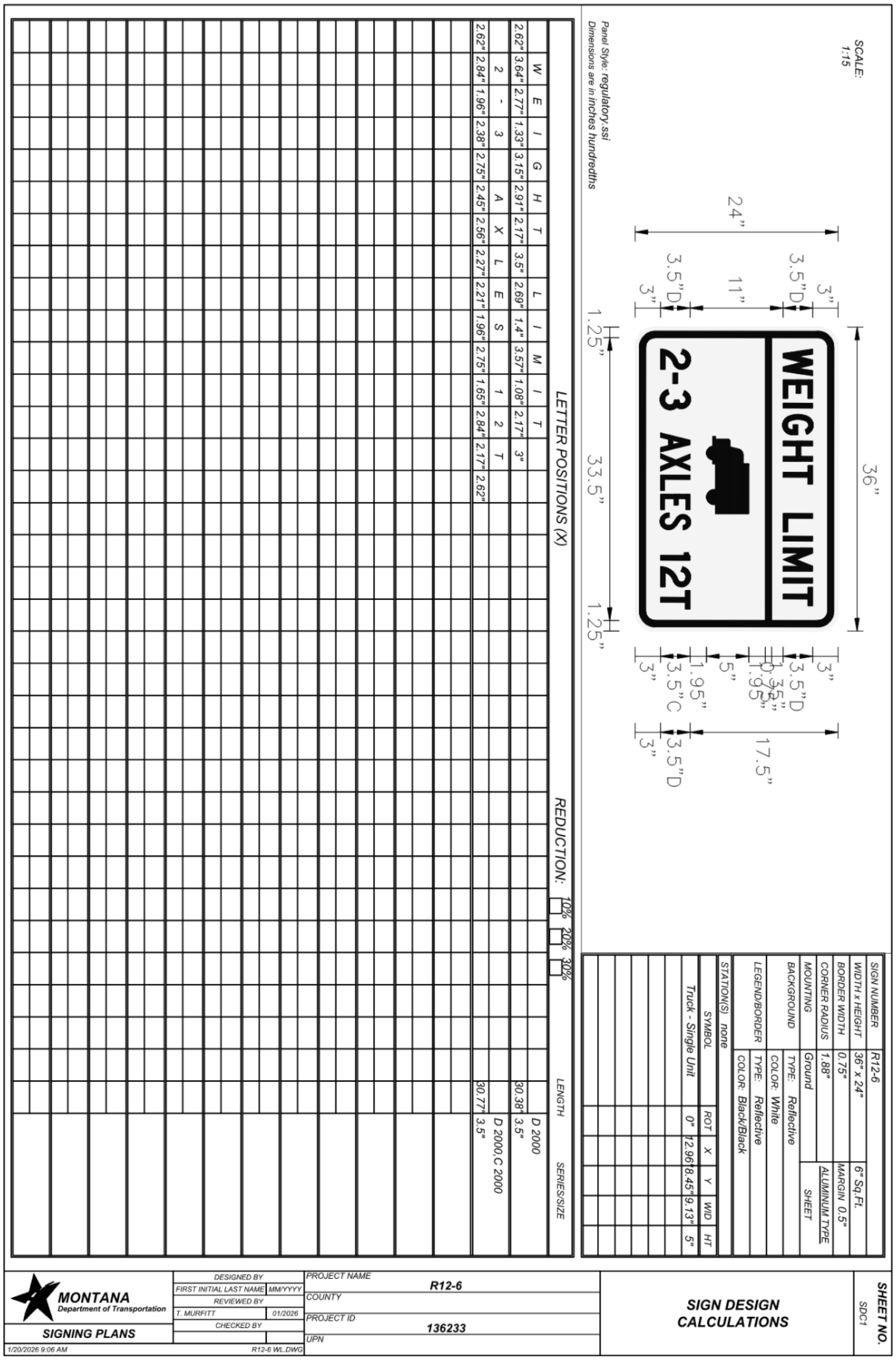
A	B	C	D	E	F	G	H	J	K	L	M	N	P	Q	R
30	42	0.5	0.75	2.625	2.75 D	1.375	0.75	1.25	4.125	1.5	2.25	2.25	3.375	3	3.25
36	48	0.625	0.875	3	3.5 D	1.5	0.875	1.125	5	1.75	2	2.375	3	2.75	4
48	60	0.75	1.25	3.75	4.5 D	1.75	1	1.25	6.25	2	2.625	3	3.75	3.25	5.5

S	T	U	V	W	X	Y	Z	AA	BB	CC	DD	EE	FF	GG	HH
1.75	2.25	11.940	0.607	2.75	8.583	3.769	VAR	VAR	0.625	1.375	1.5	8.996	2.75 C	1.844	1.875
1.875	2.625	14.946	1.024	3	10.924	4.569	VAR	VAR	0.875	1.75	1.75	11.127	3.5 C**	2.347	2.25
2	3.5	19.538	0.993	4.5	14.045	5.711	VAR	VAR	1.125	2.25	2.25	14.721	4.5 C	3.017	3

COLORS: LEGEND, BORDER — BLACK
BACKGROUND — WHITE (RETROREFLECTIVE)

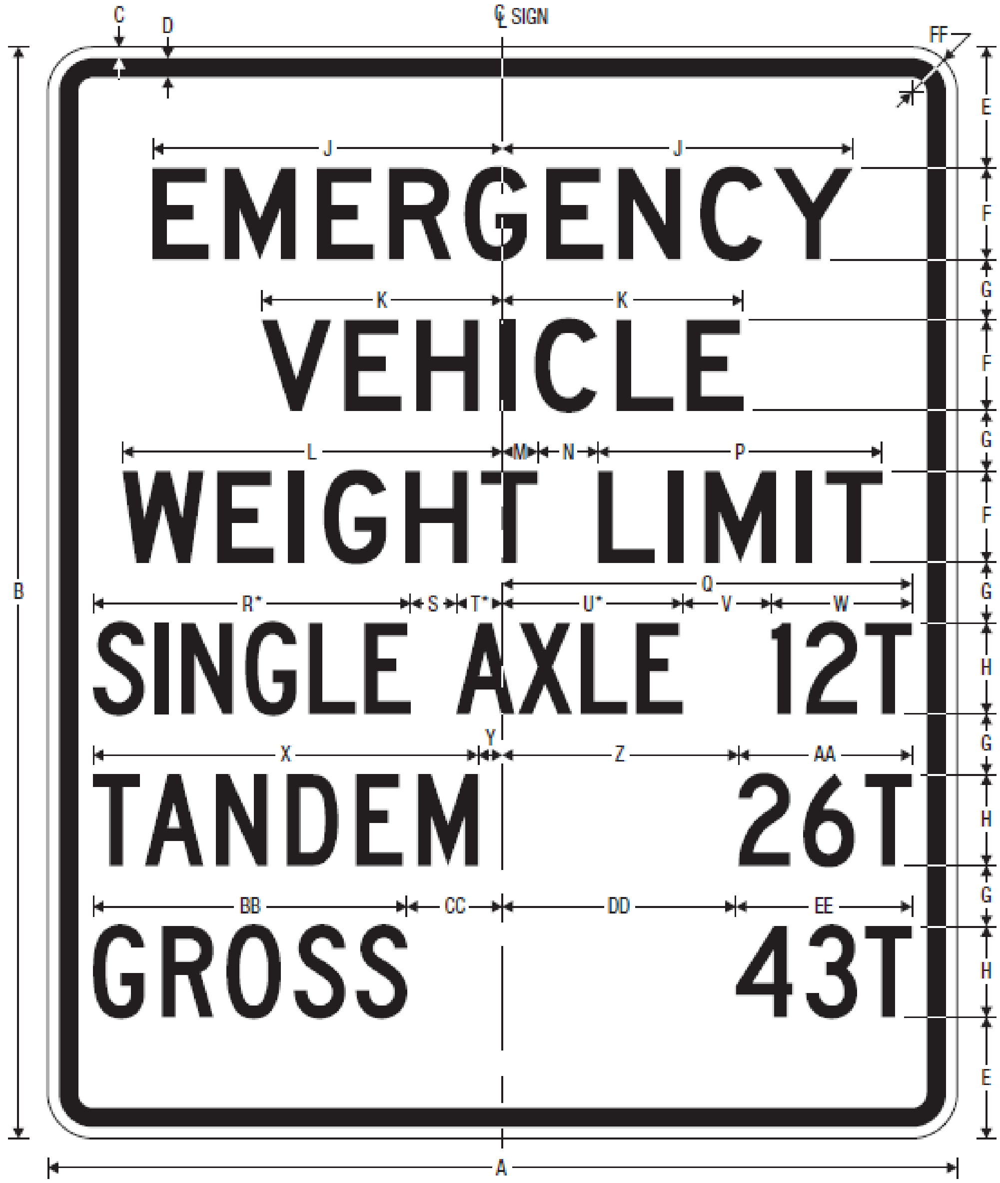
R12-6 (SHV ONLY) ~ 36" X 24"

Per MDT Sign Catalog.



R12-7

R12-7
Issued 3/15/2017



R12-7
EMERGENCY VECHICLE WEIGHT LIMIT

* Reduce character spacing 30%.

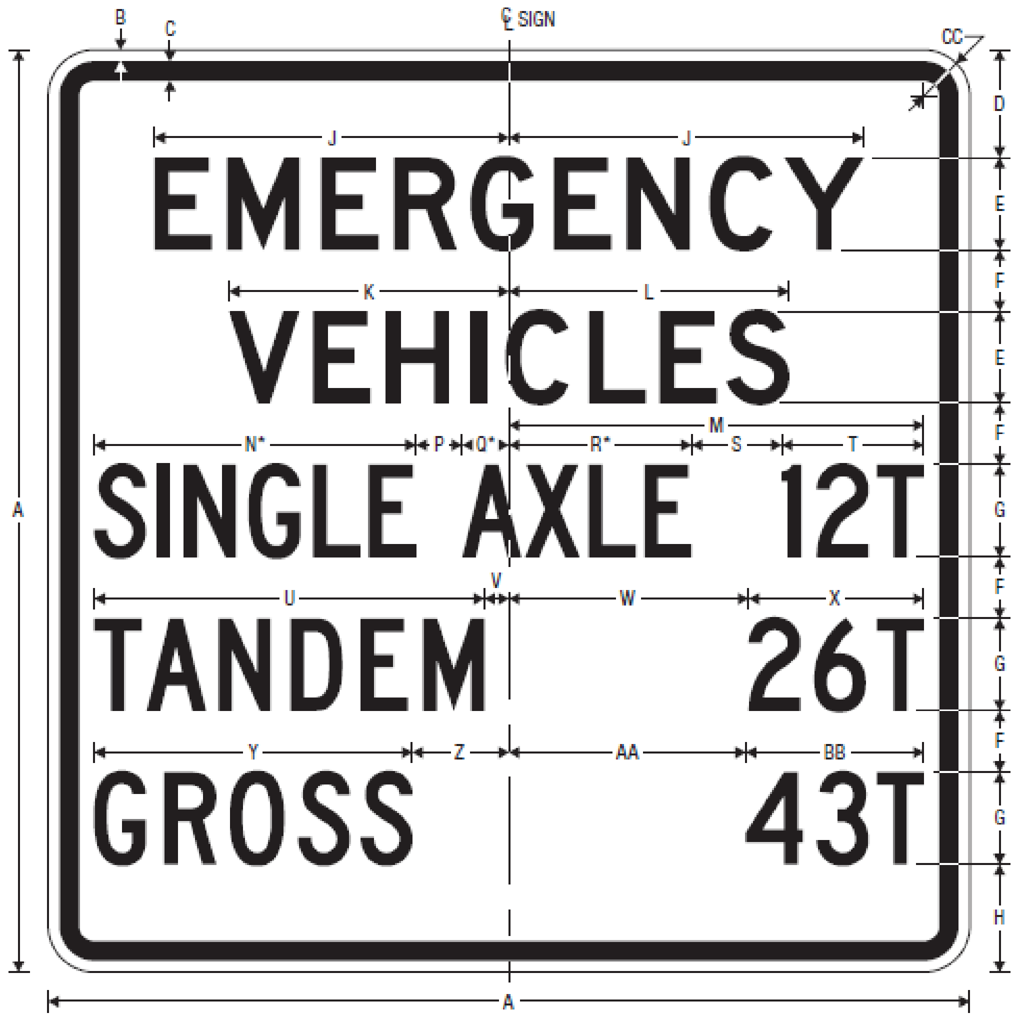
A	B	C	D	E	F	G	H	J	K	L	M	N	P	Q
30	36	0.375	0.625	4	3 D	2	3 C	11.542	7.939	12.525	1.163	2	9.363	13.5
48	60	0.75	1.25	6.875	5 D	3.75	4.5 C	19.237	13.232	20.833	1.979	3.25	15.605	20.833

R	S	T	U	V	W	X	Y	Z	AA	BB	CC	DD	EE	FF
10.477	1.5	1.523	5.944	VAR	VAR	12.695	0.805	VAR	VAR	10.354	3.146	VAR	VAR	1.5
15.715	2.5	2.618	8.583	VAR	VAR	19.043	1.790	VAR	VAR	15.531	5.302	VAR	VAR	3

COLORS: LEGEND, BORDER — BLACK
BACKGROUND — WHITE (RETROREFLECTIVE)

R12-7AP

R12-7aP
Issued 3/15/2017



R12-7aP
EMERGENCY VEHICLE WEIGHT LIMIT (PLAQUE)

* Reduce character spacing 30%.

A	B	C	D	E	F	G	H	J	K	L	M	N	P	Q
30	0.375	0.625	3.5	3 D	2	3 C	3.5	11.542	9.111	9.110	13.5	10.477	1.5	1.523
48	0.75	1.25	5.25	5 D	3.75	4.5 C	5	19.237	15.184	15.184	20.833	15.715	2.5	2.618

R	S	T	U	V	W	X	Y	Z	AA	BB	CC
5.944	VAR	VAR	12.695	0.805	VAR	VAR	10.354	3.146	VAR	VAR	1.5
8.583	VAR	VAR	19.043	1.790	VAR	VAR	15.531	5.302	VAR	VAR	3

COLORS: LEGEND, BORDER – BLACK
BACKGROUND – WHITE (RETROREFLECTIVE)