Steel Bridge Design Handbook

CHAPTER 18

Load Rating of Steel Bridges

February 2022

Smarter.
Stronger.
Steel.

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Foreword

The Steel Bridge Design Handbook covers a full range of topics and design examples to provide bridge engineers with the information needed to make knowledgeable decisions regarding the selection, design, fabrication, and construction of steel bridges. The Handbook has a long history, dating back to the 1970s in various forms and publications. The more recent editions of the Handbook were developed and maintained by the Federal Highway Administration (FHWA) Office of Bridges and Structures as FHWA Report No. FHWA-IF-12-052 published in November 2012, and FHWA Report No. FHWA-HIF-16-002 published in December 2015. The previous development and maintenance of the Handbook by the FHWA, their consultants, and their technical reviewers is gratefully appreciated and acknowledged.

This current edition of the Handbook is maintained by the National Steel Bridge Alliance (NSBA), a division of the American Institute of Steel Construction (AISC). This Handbook, published in 2021, has been updated and revised to be consistent with the 9th edition of the AASHTO LRFD Bridge Design Specifications which was released in 2020. The updates and revisions to various chapters and design examples have been performed, as noted, by HDR, M.A. Grubb & Associates, Don White, Ph.D., and NSBA. Furthermore, the updates and revisions have been reviewed independently by Francesco Russo, Ph.D., P.E., Brandon Chavel, Ph.D., P.E., and NSBA.

The Handbook consists of 19 chapters and 6 design examples. The chapters and design examples of the Handbook are published separately for ease of use, and available for free download at the NSBA website, www.aisc.org/nsba.

The users of the Steel Bridge Design Handbook are encouraged to submit ideas and suggestions for enhancements that can be implemented in future editions to the NSBA and AISC at solutions@aisc.org.

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Load rating is defined as the determination of the live-load carrying capacity of a bridge using as-built bridge plans and supplemented by information gathered from the latest field inspection. Load ratings are expressed as a rating factor or as a tonnage for a particular vehicle. Emphasis in load rating is on the live-load capacity and dictates the approach of determining rating factors instead of the design approach of satisfying limit states. Existing highway bridges are rated to prioritize a bridge owner's needs, provide safety for the traveling public, and facilitate the passage of goods. Bridges that cannot safely carry statutory loads, based on a load-rating evaluation, should be load posted, rehabilitated or replaced. This chapter informs designers of load ratings and discusses the LRFR methodology used for load rating evaluation.</td></tr>
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Steel Bridge Design Handbook: Load Rating of Steel Bridges

Table of Contents

1.0 BACKGROUND 1
2.0 GENERAL 2
3.0 PURPOSES 3
4.0 ASSUMPTIONS 4
5.0 EVALUATION METHODS 5
6.0 LOAD AND RESISTANCE FACTOR RATING (LRFR) 6
6.1 General 6
6.1.1 General Load-Rating Equation 6
6.1.2 Condition Factors 7
6.1.3 System Factors 7
6.1.4 Load Factors 8
6.1.5 Levels of Evaluation 9
6.2 Design-Load Rating 9
6.2.1 General 9
6.2.2 Live Load 9
6.2.3 Limit States 10
6.2.4 Load Factors 10
6.3 Emergency Vehicle Rating 10
6.3.1 General 10
6.3.2 Live Load 10
6.3.3 Limit States 12
6.3.4 Load Factors and Multiple Presence 12
6.4 Legal-Load Rating 12
6.4.1 General 12
6.4.2 Live Load 12
6.4.2.1 Routine Commercial Vehicle 12

6.4.2.2 Specialized hauling vehicles (SHV's) 13
6.4.2.3 Notional Rating Load (NRL) 13
6.4.3 Limit States 14
6.4.4 Load Factors 14
6.4.4.1 Routine Commercial Vehicles 14
6.4.4.2 Specialized Hauling Vehicles 14
6.5 Permit-Load Rating 14
6.5.1 General 14
6.5.2 Live Load 15
6.5.3 Limit States 15
6.5.4 Load Factors 15
6.5.4.1 Routine/annual Permits 15
6.5.4.2 Special Permits 16
6.5.4.3 Refined Analysis and Permit Load Evaluations 17
7.0 RATING EXAMPLES 18
8.0 REFERENCES 19

List of Figures

Figure 1 Emergency Vehicle Type EV2* 10
Figure 2 Emergency Vehicle Type EV3* 11
Figure 3 NCHRP Project 20-07/Task 410: Comparison of Simple Span Maximum Bending Moments 11

List of Tables

Table 1 Condition Factors 7
Table 2 System Factors 8
Table 3 Evaluation Live-load Factors for Steel Bridges 8
Table 4 Dead Load Factors 9
Table 5 Routine Commercial Vehicle Evaluation Live Load Factors for Strength I 14
Table 6 Specialized Hauling Vehicle Evaluation Live Load Factors for Strength I 14
Table 7 Routine/annual-permit Evaluation Live Load Factors for Strength II for Steel Bridges 16
Table 8 Special Permit Evaluation Live Load Factors for Strength II for Steel Bridges 17
Table 9 Rating Examples in the MBE Appendix A 18

1.0 BACKGROUND

The U.S. 35 “Silver Bridge” between Point Pleasant, West Virginia, and Kanauga, Ohio, collapsed in 1967, killing 46 people and injuring 9 when the bridge fell into the Ohio River and onto the Ohio shore [1].

The Silver Bridge collapse, the first major collapse since the Tacoma Narrows Bridge collapsed in 1940, prompted national concern about bridge safety and led to the establishment of the National Bridge Inspection Standards (NBIS) under the Federal-aid Highway Act of 1968 and the Special Bridge Replacement Program under the Federal-aid Highway Act of 1970.
Load rating is required by NBIS regulations. The regulations state “Rate each bridge as to its safe loading capacity in accordance with the AASHTO manual. Post or restrict the bridge in accordance with the AASHTO manual or in accordance with state law, when the maximum unrestricted legal loads or State routine permit loads exceed that allowed under the operating rating or equivalent rating factor.”

The NBIS regulations apply to structures defined as highway bridges located on public roads. They apply to publicly owned highway bridges longer than twenty feet located on public roads. Railroad/pedestrian structures that do not carry highways are not covered by the NBIS regulations.

2.0 GENERAL

The NBIS regulations define load rating as “The determination of the live load carrying capacity of a bridge using as-built bridge plans and supplemented by information gathered from the latest field inspection.” Load ratings are expressed as a rating factor (RF) or as a tonnage for a particular vehicle. Emphasis in load rating is on the live-load capacity and dictates the approach of determining rating factors instead of the design approach of satisfying limit states.

The rating factor is the multiple of the vehicular live-load effect (for example, moment or shear) that the bridge can carry when the limit-state under investigation is satisfied. The weight of the live-load in tons multiplied by the rating factor is the tonnage that the bridge can safely carry.

Superstructure spans, including the main or primary components of the span and their connections, should be load rated to identify the governing component. The sudden collapse of the I-35W highway bridge in Minneapolis, Minnesota in August of 2007, reiterated the need to load rate connections as well as the members. The National Transportation Safety Board (NTSB) with the aid of the Federal Highway Administration (FHWA) determined that the probable cause of the deck-truss bridge collapse was inadequate load-carrying capacity of gusset plates connecting some truss members together due to a design error [2]. In response, the FHWA developed guidelines for the load rating of such gusset plates [3]. Additionally, the most recent version of the AASHTO Manual for Bridge Evaluation, Third Edition with 2019 Interims (MBE) [4] provides guidelines for the load rating of gusset plates.

3.0 PURPOSES

Existing highway bridges are rated to:

- prioritize an owner's needs,
- provide safety for the traveling public, and
- facilitate the safe passage of goods.

Owners rate bridges upon completion of original construction, when a change in the condition of the bridge suggests that the current rating may have changed, and when unusual loads (overload vehicles) are anticipated.

Bridges that cannot safely carry statutory loads, based on a load-rating evaluation, should be load posted, rehabilitated, or replaced.

Bridge load ratings reported to the NBI weigh heavily in the determination of the Sufficiency Rating (SR). Federal resource allocation determinations utilize the SR to prioritize and distribute funds among the States to replace, rehabilitate, and maintain our nation's highway bridges. States, in addition, use the ratings in prioritizing projects for repair, rehabilitation, or replacement, distributing bridge funds to local governments, determine load-posting needs, and for issuing overload permits.

4.0 ASSUMPTIONS

The load carrying capacity of an existing bridge is based upon its present condition. In general, the bridge will be inspected biennially. The condition of the bridge is captured and the load carrying capacity may be recalculated when the bridge condition or loading has changed. The routine updating to bridge ratings following new findings during field inspections is critical considering capacity often decreases with time due to deterioration, live loads historically increase with time, and dead loads may increase through repairs and rehabilitations.

In order to obtain accurate load ratings, thorough inspections documenting the necessary data required is critical. General descriptions of conditions are not adequate to assess the current load-carrying capacity of the structure. Per MBE Article Commentary C6.1.1, "a load rating of a bridge should not be undertaken without a recent thorough field inspection which:

- Provides the condition data and other critical condition data necessary for evaluation,
- Minimizes the possibility of the evaluator making a gross error in assessing the capacity of a component or connection, and
- Improves bridge safety through early discover of deterioration or signs of distress that could signal impending failure."

Chapters 1 through 5 of the *Manual for Bridge Evaluation* [4] cover the necessary steps and requirements to capture adequate data. Specifically, Article 4.3.8 provide guides on data collection for the purpose of load rating a bridge.

5.0 EVALUATION METHODS

Several philosophies are available to rate bridges through various design methodologies.

Bridge design methodology has evolved over time from allowable stress design (ASD) through load factor design (LFD) to load and resistance factor design (LRFD). The corresponding rating methods are allowable stress rating (ASR), load factor rating (LFR), and load and resistance factor rating (LRFR). While new bridges are currently designed using the LRFD philosophy of the AASHTO LRFD Bridge Design Specifications, 9^{th} Edition (referred to herein as the AASHTO LRFD BDS) [5], bridges may be rated using the ASR, LFR, or LRFR methodology, depending on owner policy and the original design method used to design the bridge.

The Federal Highway Administration (FHWA) considers LRFR as the preferred load-rating methodology for existing bridges. Further, the FHWA adopted a policy that since October 1, 2010, bridges designed in accordance with LRFD be load rated with LRFR [6]. As such, only the preferred load rating methodology, LRFR, will be discussed herein in accordance with the latest edition of the AASHTO Manual for Bridge Evaluation (referred to herein as the MBE) [4]. This methodology has been demonstrated to be most representative of the quantified safety of the bridge in terms of reliability index or probability of failure.

The MBE, however, does address ASR and LFR evaluation which, in some circumstances, may be permitted or required by bridge owners, typically only if the bridge was designed using ASD or LFD methods. AASHTO Technical Committee T-18, Bridge Management, Evaluation and Rehabilitation, commissioned a research project to investigate the validity of the LRFR methodology. The objective of National Cooperative Highway Research Program (NCHRP) Project 20-07 Task 122 [7] was to provide explicit comparisons between the ratings produced by the LRFR and LFR methodologies. This comparison demonstrates the superiority of the LRFR methodology in predicting the reliability or safety of existing bridges.

6.0 LOAD AND RESISTANCE FACTOR RATING (LRFR)

6.1 General

The LRFR methodology consists of three distinct levels of evaluation:

1) design-load rating (first level evaluation),
2) legal-load rating (second level evaluation), and
3) permit-load rating (third level evaluation).

The results of each evaluation serve specific purposes and also inform the need for further evaluations. Each of the above evaluations is performed for a specific live load model with specifically calibrated load factors aimed at maintaining uniform and acceptable levels of reliability in the various evaluations.

6.1.1 General Load-Rating Equation

The general load-rating equation for rating factor, RF, may be rewritten for steel bridges as follows, considering permanent loads other than dead load to be non-existent:

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

For the strength limit states:

$$C = \phi_c \, \phi_s \, \phi \, R_n$$

Where the following lower limit applies:

$$\phi_c \, \phi_s \geq 0.85$$

For the service limit states:

$$C = f_R$$

where:

RF	=	Rating factor
C	=	Capacity
f_R	=	Allowable stress specified in the AASHTO LRFD BDS
R_n	=	Nominal member resistance (as inspected)
DC	=	Dead-load effect due to structural components and attachments
DW	=	Dead-load effect due to wearing surface and utilities
LL	=	Live-load effect
IM	=	Dynamic load allowance

γ_{DC} = LRFD load factor for structural components and attachments
γ_{DW} = LRFD load factor for wearing surfaces and utilities
γ_L = Evaluation live-load factor
ϕ_c = Condition factor
ϕ_s = System factor
ϕ = LRFD resistance factor

6.1.2 Condition Factors

The condition factors, ϕ_c, given in Table 1 (See Tables 6A.4.2.3-1 and C6A.4.2.3-1 of the MBE) are only applied to strength limit-state ratings. The application of condition factors is optional based on the owner's preference.

Table 1 Condition Factors

Structural Condition of Member	NBI Condition Rating	φ_c
Good or Satisfactory	6 or higher	1.00
Fair	5	0.95
Poor	4 or lower	0.85

6.1.3 System Factors

System factors are multipliers related to the level of redundancy of the complete superstructure system. Less redundant structural systems are penalized by requiring their members to provide higher safety levels than those of similar members in bridges with redundant configurations. System factors, ϕ_s, are given in Table 2 See Table 6A.4.2.4-1 of the MBE) for various structure and member types.

Just as for the condition factors, the system factors are only applied to strength limit states. A system factor of 1.0 is used when checking shear at the strength limit state.
Like the condition factors, the application of system factors may be considered optional based on the bridge owner's preference. However, when rating nonredundant superstructures for legal loads using generalized load factors given in MBE Article 6A.4.4.2.3 (see Table 5), the system factors shown in Table 2 can be used to reflect a more consistent evaluation of the level of system safety. Additionally, the system factor for riveted and bolted gusset plates and their connection for both the Strength and Service limit state force effects should be taken as 0.90.

Table 2 System Factors

Superstructure Type	**φ_s**
Welded Members in Two-Girder/Truss/Arch Bridges	0.85
Riveted Members in Two-Girder/Truss/Arch Bridges	0.90
Multiple Eyebar Members in Truss Bridges	0.90
Three-Girder Bridges with Girder Spacing 6 ft	0.85
Four-Girder Bridges with Girder Spacing ≤ 4 ft	0.95
All Other Girder Bridges and Slab Bridges	1.00
Floorbeams with Spacing > 12 ft and Noncontinuous Stringers	0.85
Redundant Stringer Subsystem between Floorbeams	1.00

6.1.4 Load Factors

The load factors for use in the general load rating equation are given in MBE Table 6A.4.2.2-1.

Evaluation live-load factors, γ_L, are specified for each level of evaluation. These factors for steel bridges are summarized in Table 3 (See Table 6A.4.2.2-1 of the MBE).

The MBE allows owners to specify live load factors other than those given in Table 3 if comparable target reliability is achieved with site-specific load factors.

The dead load factors are summarized in Table 4 (See Table 6A.4.2.2-1 of the MBE).

Table 3 Evaluation Live-load Factors for Steel Bridges

Limit State	**Rating Level**			
	Design Live Load		**Legal Load**	**Permit Load**
	Inventory	**Operating**		
Strength I	1.75	1.35	See Table 5 & Table 6	---
Strength II	---	---	---	See Table 7 & Table 8
Service II	1.30	1.00	1.30	1.00 *
Fatigue	0.80 **	---	---	---

* The Service II limit state load combination is optional for permit-load ratings.
** The Fatigue limit state load combination is optional for the inventory rating of the design live load.

Table 4 Dead Load Factors

Limit State	Component of Dead Load	
	DC	DW
Strength I	1.25	1.50
Strength II	1.25	1.50
Service II	1.00	1.00
Fatigue	0.00	0.00

6.1.5 Levels of Evaluation

The various levels of evaluation are structured to be performed in a sequential manner, as needed, starting with the design-load rating. The logical progress of load rating checks provides labor saving in a manual load rating process. In cases where load rating is done by automated methods, bridge owners may find it expedient to define the various load models for analysis in a single run and utilize the results as needed.

6.2 Design-Load Rating

6.2.1 General

The design-load rating level evaluates existing bridges to assess their performance utilizing the LRFD design loading and standards. At this level, the HL-93 live-load model of the AASHTO LRFD BDS is applied. The HL-93 live load model was initially developed as a notional representation of shear and moment produced by a group of vehicles routinely permitted on highways of various states under “grandfather” exclusions to weight laws.

The traditional inventory and operating levels are maintained within the design-load rating procedures. Bridges that pass HL-93 screening at the Inventory level should have adequate capacity for AASHTO legal loads and State legal loads that fall within the exclusion limits described in the AASHTO LRFD BDS.

Bridges that pass HL-93 screening only at the Operating level should have adequate capacity for AASHTO legal loads, but may not rate (The rating factor, RF, is less than 1.0) for State legal loads, specifically those vehicles significantly heavier than the AASHTO trucks.

6.2.2 Live Load

The HL-93 notional live-load model of the AASHTO LRFD BDS discussed in NSBA’s *Steel Bridge Design Handbook: Loads and Combinations* [8], including the dynamic load allowance, is applied in design-load rating to provide a rating evaluation consistent with the loading used for bridge design.

6.2.3 Limit States

Strength I and Service II load combinations should be checked for the design loading. These limit states are as discussed in NSBA's *Steel Bridge Design Handbook: Limit States* [9] for design.

6.2.4 Load Factors

The evaluation live load factors for the design-load rating level are as given in Table 3 above.

6.3 Emergency Vehicle Rating

6.3.1 General

Federal Bridge Formula B sets weight limits on groups of axles that current legal loads are required to obey. The Fixing America's Surface Transportation Act (FAST Act), signed into law in December of 2015, exempted emergency vehicles from meeting the nationwide interstate truck weight limits set by Federal Bridge Formula B and created an opportunity for these vehicles to impose greater load effects in certain bridges than previously established legal loads. Subsequently, the FHWA issued a memorandum titled "Load Rating for the FAST Act's Emergency Vehicles," dated November 3, 2016 [10], to provide guidance on the load rating and posting of bridges for emergency vehicles.

6.3.2 Live Load

The memorandum established two new emergency vehicle configurations known as EV2 and EV3; see Figure 1 and Figure 2, respectively [11]. These two vehicles produce load effects in typical bridges that envelope the effects of the vehicles covered by the FAST Act.

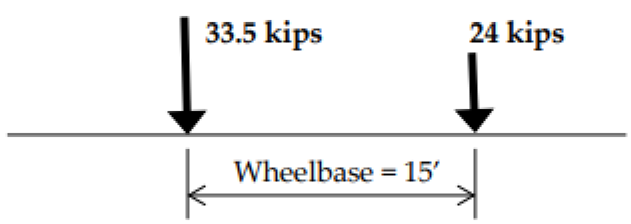

Figure 1 Emergency Vehicle Type EV2*

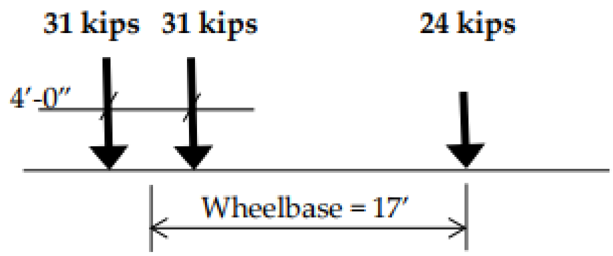

Figure 2 Emergency Vehicle Type EV3*

*Note that a 200plf lane load is also included for continuous spans, as well as simple spans greater than 200’, representing a line of traffic in the same lane as the emergency vehicle.

AASHTO Technical Committee T18, with funding provided through the National Cooperative Highway Research Program (NCHRP) Project 20-07 Task 410 [12] investigated the load effects of the emergency vehicles permitted by the FAST Act with the understanding that the new criteria for these vehicles did not meet the requirements of Federal Bridge Formula-B. The committee compared the maximum force effects produced from the EV2 and EV3 vehicles on 30-ft to 300-ft spans in simple span and two-span bridges to the most critical effects of the three AASHTO legal loads. Figure 3 displays their results, confirming an increased moment effect for the EV3 vehicle over the AASHTO legal loads in simple spans from 30’ to 300’.

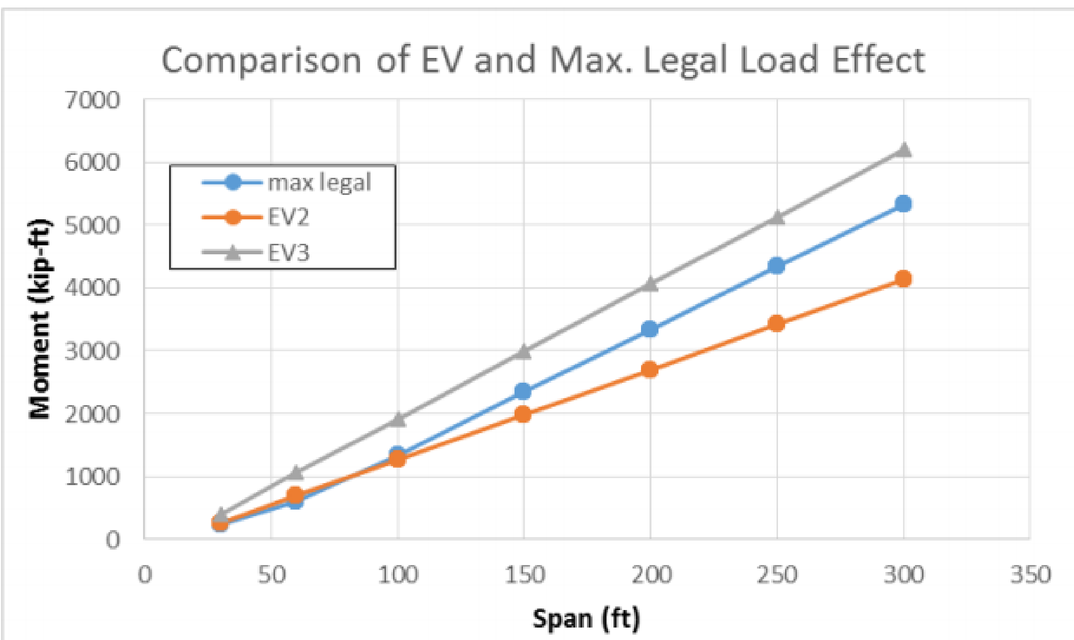

Figure 3 NCHRP Project 20-07/Task 410: Comparison of Simple Span Maximum Bending Moments

6.3.3 Limit States

The emergency vehicle load ratings should be determined at the legal load rating level with exception to the multiple presence and load factors discussed in the following subsection. As such, the Strength I and Service II limit-state load combinations are mandatory. These limit states are as discussed in the NSBA's *Steel Bridge Design Handbook: Limit States* [9].

6.3.4 Load Factors and Multiple Presence

The FHWA memorandum provides specific guidance regarding multiple presence and live load factors that differs from other legal loads. A load factor of 1.3 may be used and, if necessary when combined with other unrestricted legal loads for rating purposes, the emergency vehicle may only be considered in a single lane of one direction of a bridge. For a one-lane bridge, the 1.2 multiple presence factor may be divided out. Refer to the FHWA Questions and Answers document for further guidance [11].

6.4 Legal-Load Rating

6.4.1 General

Legal-load ratings establish the need for posting or bridge strengthening when the controlling rating factor, RF, associated with the legal loads is less than 1.0. This live-load capacity corresponds to a minimum target reliability index, β_T, of 2.5. Bridges with a rating factor, RF, greater than 1.0 for legal loads may be evaluated for overweight permit loads.

6.4.2 Live Load

There are two main categories of legal loads that comply with federal weight laws:

1. Routine commercial vehicles, and
2. Specialized hauling vehicles (SHVs)

The factor used to address dynamic load allowance should be as specified in the AASHTO LRFD BDS except for longitudinal members with spans greater than 40 ft, where the dynamic load allowance may be decreased based upon the observed riding surface condition as provided in the Commentary to Article 6A.4.4.3 of the MBE.

6.4.2.1 Routine Commercial Vehicle

The AASHTO family of legal loads includes three vehicles (Type 3, Type 3S2 and Type 3-3) that represent routine commercial traffic. Each vehicle features fixed axle spacings. These legal loads model three portions of the federal bridge formula which control short, medium, and long span lengths. These AASHTO vehicles model many of the configurations of present truck traffic. They are appropriate for use as rating and posting vehicles as they satisfy the goal of providing uniform reliability over various span lengths. Additionally, they are widely used as truck symbols on load posting signs and provide continuity with past practice.

The traditional family of three AASHTO legal-load vehicles is shown schematically in Figures D6A-1, D6A-2 and D6A-3 of the MBE.

For span lengths up to 200 feet, the MBE requires that only a legal-load vehicle is considered for legal-load rating. For span lengths greater than 200 ft., critical load effects are generated through the application of an AASHTO Type 3-3 vehicle multiplied by 0.75 combined with a lane load of 0.2 kips per linear feet. The superposition of the Type 3-3 vehicle and the lane load results in uniform reliability for span lengths greater than 200 ft (See Figure D6A-4 of the MBE). For negative moments and interior reactions regardless of span length, load effects should also consider the application of two AASHTO Type 3-3 vehicles multiplied by 0.75 combined with a lane load of 0.2 kips per linear feet, where the two vehicles are spaced at 30 feet, between the rear and front axle (See Figure D6A-5 of the MBE).

6.4.2.2 Specialized hauling vehicles (SHV's)

Since the adoption of the AASHTO family of three legal loads, the trucking industry has introduced specialized single unit trucks, with closely-spaced multiple axles and maximum weights of up to 80,000 lbs, that satisfy the federal bridge formula. These trucks, known as Specialized Hauling Vehicles (SHV), are configured to be legal throughout the United States. SHVs commonly have axle groups with lift axles, which should be in the down position when the truck is loaded.

Short multi-axle single-unit trucks with liftable axles are not adequately modeled by the traditional family of three AASHTO legal loads. The adoption of various SHVs into the collection of AASHTO legal loads to represent these new truck configurations provides a standardized way to better capture the loading effects of modern trucks. These new SHVs include the SU4, SU5, SU6 and SU7; shown schematically in Figure D6A-7 of the MBE.

6.4.2.3 Notional Rating Load (NRL)

Notional Rating Load (NRL) was developed to serve as a single load model that will envelop the load effects on simple and continuous span bridges of the most critical single-unit SHV configurations weighing up to 80 kips. It is termed "notional" because it does not represent a particular truck.

Bridges that rate (the rating factor, RF, is greater or equal to 1.0) for the NRL will have adequate load capacity for various legal SHVs up to 80 kips. Bridges that do not rate for the NRL should be investigated to determine posting needs using the specific SHVs discussed previously.

The NRL is shown schematically in Figure D6A-6 of the MBE.

6.4.3 Limit States

The Strength I and Service II limit-state load combinations are mandatory for legal-load ratings. These limit states are as discussed in the NSBA's *Steel Bridge Design Handbook: Loads and Combinations* [8] for design.

6.4.4 Load Factors

The evaluation live-load factors for legal-load rating at the Strength I limit state load combination are a function of the average daily truck traffic (ADTT). The evaluation live-load factor for the Service II limit-state load combination is 1.30 as shown in Table 3.

6.4.4.1 Routine Commercial Vehicles

The evaluation live-load factors for routine commercial vehicles at the Strength I limit-state load combination are given in Table 5 (See Table 6A.4.4.2.3a-1 of the MBE). Linear interpolation is permitted for ADTT values between 1,000 and 5,000.

Table 5 Routine Commercial Vehicle Evaluation Live Load Factors for Strength I

Traffic Volume in One Direction	Load Factor
Unknown	1.45
ADTT ≥ 5,000	1.45
ADTT ≤ 1,000	1.30

6.4.4.2 Specialized Hauling Vehicles

The evaluation live-load factors for SHVs at the Strength I limit-state load combination are given in Table 6. (See Table 6A.4.4.2.3b-1 of the MBE). Linear interpolation is permitted for ADTT values between 1,000 and 5,000.

Table 6 Specialized Hauling Vehicle Evaluation Live Load Factors for Strength I

Traffic Volume in One Direction	Load Factor
Unknown	1.45
ADTT ≥ 5,000	1.45
ADTT ≤ 1,000	1.30

6.5 Permit-Load Rating

6.5.1 General

Permit-load rating reviews the safety and serviceability of bridges in the review of permit applications for the passage of vehicles above the legally established weight limitations. This third level of rating should only be applied to bridges having sufficient capacity for legal loads.

Load factors by permit type and traffic conditions on the bridge are specified for reviewing the safety inherent with the passage of the overweight truck. Guidance is also provided on the serviceability that may be checked when reviewing permit applications.

6.5.2 Live Load

The actual permit vehicle's gross vehicle weight and axle configuration will be the live load used in the permit-load evaluation.

The MBE categorizes permit loads into two classes:

1. Routine/annual permits, and
2. Special (limited crossing) permits.

Routine or annual permits are usually valid for unlimited trips over a period of time, up to one year.

Special permits are usually valid for a single trip, or for a limited number of trips, for a vehicle of specified configuration, axle weights, and gross weight. Special permit vehicles are usually heavier than those vehicles issued annual permits.

For spans up to 200 ft, only the permit vehicle is considered present in the lane. For span lengths between 200 and 300 ft and when checking negative moments in continuous span bridges, an additional lane load is applied to simulate closely following vehicles. The lane load should be taken as 0.2 kips per linear feet in each lane. The lane load may be superimposed on the permit vehicle (for ease of analysis) and is applied to those portions of the span where the loading effects add to the permit load effects.

6.5.3 Limit States

Permits are checked using the Strength II limit-state load combination with the Service II limit-state load combination optional for steel bridges to limit potential permanent deformations. These limit states are as discussed in the NSBA's *Steel Bridge Design Handbook: Loads and Combinations* [8] for design.

6.5.4 Load Factors

6.5.4.1 Routine/annual Permits

Routine permit-load rating uses the multi-lane distribution factors (DFs) of the AASHTO LRFD BDS. This assumes simultaneous side-by-side presence of two equally heavy vehicles in each lane.

The evaluation live-load factors for routine or annual permits are given in Table 7, below (See Table 6A.4.5.4.2a-1 of the MBE).

The live-load factors for routine permits are reduced with increasing permit weight, compared to legal loads, to account for the small likelihood of such simultaneous events during the evaluation period. This reduction accommodates the conservative application of multi-lane DFs.

The live-load factors are derived to account for the possibility of simultaneous presence of heavy trucks on the bridge when the permit vehicle crosses the span. Thus, the load factors are higher for spans with higher average daily truck traffic (ADTT).

In Table 7, load factors are based on the Permit Weight Ratio (PWR), which is equal to the Gross Vehicle Weight (GVW) divided by the Front Axle to Rear Axle Length (AL). Only the axles acting on the superstructure are considered in the calculation of the Permit Weight Ratio.

Table 7 Routine/annual-permit Evaluation Live Load Factors for Strength II for Steel Bridges

Distribution Factor (DF)	ADTT (One Direction)	Load Factor by Permit Weight Ratio (PWR)		
		PWR < 2.0 (kip/ft)	2.0 < PWR < 3.0 (kip/ft)	PWR > 3.0 (kip/ft)
Two or More Lanes	> 5,000	1.40	1.35	1.30
	= 1,000	1.35	1.25	1.20
	< 100	1.30	1.20	1.15
One Lane	All ADTTs	1.40		

Linear interpolation can be used for values of ADTT and weight between the various ADTT and weight limits of the tables.

6.5.4.2 Special Permits

The MBE provides evaluation live-load factors for special permit vehicles for use with the one-lane DF's of the AASHTO LRFD BDS. The permit live-load factor accounts for the probable weight of an adjacent random truck during a special permit crossing when the bridge is open to other traffic.

When performing a special permit-load rating, the single-lane multiple presence factor of 1.20 incorporated into the LRFD one-lane DF should be divided out as it specifically relates to the HL-93 live-load model.

The evaluation live-load factors for special permit-load rating at the Strength II limit-state load combination are given in Table 8 below (See Table 6A.4.5.4.2a-1 of the MBE).

Table 8 Special Permit Evaluation Live Load Factors for Strength II for Steel Bridges

Trip Type	Traffic Condition	Distribution Factor (DF)	ADTT (One Direction)	Load Factor (All Weights)
Single	Escorted with no other vehicles on the bridge	One Lane	N/A	1.10
Single	Mix with traffic (other vehicles may be on the bridge)	One Lane	All ADTTs	1.20
Multiple Trips (Less than 100 crossings)	Mix with traffic (other vehicles may be on the bridge)	One Lane	All ADTTs	1.40

6.5.4.3 Refined Analysis and Permit Load Evaluations

Additional guidelines regarding permit vehicle live load factors are provided in the MBE for multi-girder bridges that utilize refined analysis methods to determine the member force effects.

When routine permit load checks are evaluated using the results of a refined analysis, the load factors given in Table 7 should be increased by adding 0.10 to the load factor shown, and applied on two permit trucks placed in adjacent lanes. In the case of routine permits, the expected number of crossings is unknown so a conservative approach is adopted for the possibility of multiple routine permit loads on the structure at the same time.

When escorted special permits with no other vehicles on the bridge are evaluated using a refined analysis, a live load factor of 1.1 is applied the special permit vehicle, which is similar to the load factor shown in Table 8.

When an escorted special permit is assumed to travel over a bridge at a crawl speed (less than 10 mph), and the Dynamic Load Allowance (Impact) effects are neglected, the rating should consider the load factor provided on Table 8 (Table 6A.4.5.4.2a-1 of the MBE), but increase by a factor of 1.05. This increase in live load factor is intended to satisfy the minimum value of the reliability index, of β_{min} = 1.50.

When special permits mixed with traffic are evaluated using a refined analysis, a live load factor of 1.0 is applied to the special permit truck, while a live load factor of 1.10 should be applied to governing AASHTO legal truck placed in the adjacent lane.

The calibration of these previously discussed load factors for refined analysis for multi-girder bridges accounts for the conservatism and the variability of the AASHTO LRFD load distribution factors compared to those obtained from refined methods of analysis.

7.0 RATING EXAMPLES

Up-to-date rating examples are included in an appendix to the MBE. These examples are continually updated with any interim revisions to the MBE.

The rating examples are summarized in Table 9 below.

Table 9 Rating Examples in the MBE Appendix A

Example Number	Description
A1	Load rating of an interior and exterior girder of a simple-span composite steel stringer bridge.
A5	Load rating of an interior girder of a four-span continuous straight welded plate girder bridge.
A6	Load rating of selected members of a simple-span steel through Pratt truss bridge.
A8	Load rating of a girder and floorbeam of a simple-span two-girder steel bridge.
A11	Single-span through truss illustrating the load rating of gusset plates.

8.0 REFERENCES

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