MaineDOT

Load Rating Guide

April 2015

TABLE OF CONTENTS

SECTION 1 INTRODUCTION AND GENERAL OVERVIEW

1.1 INTRODUCTION

Live load rating is the determination of the live load carrying capacity of a bridge whether it be a new design or an existing bridge. Load ratings are determined by analytical methods based on information taken from bridge construction plans, construction shop drawing, field inspections and testing. Knowing the carrying capacity of each bridge in the Department's inventory is critical for several reasons;

1.1.1 To protect the public.
1.1.2 To determine which structures have substandard load capacities that may require posting or other remedial action.
1.1.3 To assist in planning the most effective use of available resources for rehabilitation or replacement.
1.1.4 To assist in the overload vehicle permitting process.
1.1.5 To meet the Federal Highway Administration (FHWA) requirement that bridge load ratings be submitted annually. The load ratings are used in conjunction with other bridge inventory and inspection information to determine the Federal Bridge Sufficiency Rating. The Sufficiency Rating is a tool used by FHWA for budget allocation planning and federal funding eligibility.

1.2 PURPOSE OF THIS DOCUMENT

This document was developed in accordance with the American Association of State Highway Officials (AASHTO) *Manual for Bridge Evaluation*, 2nd Edition, 2011 with Interim Revisions, hereinafter referred to as the MBE, and the MaineDOT Bridge Design Guide, 2003 with Updates. These documents provide guidance to load rating engineers for performing and submitting load rating calculations and used for posting bridges for load restrictions using the Load and Resistance Factor Rating (LRFR) methodology. The procedures stated in this document are to provide guidelines that will result in consistent and reproducible load ratings. This document is a supplement to the AASHTO MBE and contains MaineDOT specific load rating requirements, interpretations, and policy decisions.

The LRFR load rating provisions in the MBE include several evaluation factors and checks that may be considered optional based on an agency's load-rating practice. In this regard, this document provides the Department's best-practices recommendations for implementing the LRFR methodology. There are a number of cases where 'provisions' are stated as mandatory in this document, although they are optional in the MBE. The document will highlight when these cases exist/occur and provide a brief explanation why these requirements are recommended.

SECTION 2   GENERAL LOAD RATING REQUIREMENTS

2.1   NEW OR RECONSTRUCTED BRIDGES

2.1.1 New and reconstructed bridges shall be load rated using HL-93 live loadings. HL-93 shall be used in reporting purposes for the inventory.

2.1.2 If HL-93 Inventory Rating Factor is less than 1.0, Maine's legal loads are to be evaluated. These vehicles are found in Section 3.3 of this document.

2.1.3 FHWA policy requires that all LRFD designs after October 1, 2010 shall be load rated by LRFR, and Load and Resistance Factor Design (LRFD) designs prior to October 1, 2010 may be load rated using LRFR or LFR and reported to the NBI. Further, FHWA strongly encourages the load rating of all existing bridges using LRFR as stated in a memo dated October 30, 2006.

2.1.4 LRFR load rating calculations shall be performed as part of the design process and reflect the bridge "As-Built" or "As-Rehabilitated" condition.

2.1.5 Do not include the future wearing surface in the load rating calculation because it is not part of the "As-Built" condition.

2.1.6 An "As Designed" load rating report shall be submitted as part of the PS&E package. If changes affecting load capacity occur during construction, an "As Built" condition load rating report shall be submitted.

2.1.7 The live load distribution factor and other basic assumptions used in the design and initial load rating shall be clearly noted in the load rating report for use in future load rating.

2.1.8 Buried reinforced concrete structures (precast or cast-in-place) shall be load rated for the following situations:

1. All structures with clear spans between 10 feet and 15 feet with 4 feet or less of fill over the top of the structure.
2. All structures with clear spans between 15 feet and 20 feet with 8 feet or less of fill over the top of the structure.
3. All structures with clear spans 20 feet or greater.

2.1.9 Legal Load Configuration #6 shall be checked for all buried structures (i.e. cast in place or precast concrete three sided frames, arches, or box culverts) for spans 10' or greater when the depth of fill over the top of the structure is less than 8 feet and rating factor based on HL-93 is 1.10 or less.

2.2 EXISTING BRIDGES

2.2.1 The Assistant Bridge Maintenance Engineer shall review the bridge file after each inspection to see if a re-rating is required and provide documentation of that recommendation to the Posting Committee. A re-rating would usually be necessary if any of the following have occurred since the last load rating was completed:

1. Dead loads have changed due to re-surfacing or other non-structural alterations such as installation of utilities.
2. Section properties have changed due to deterioration, rehabilitation, re-decking or other alterations.
3. Damage due to vessel or vehicular hits.
4. Cracking in primary members.
5. Losses at critical connections.
6. Significant changes in traffic including loading and volume that might affect the live load factor in rating calculations.
7. Specific changes that affect the capacity or change the use of the structure.

2.2.2 All existing bridges that have not been load rated previously shall be load rated as soon as practical using LRFR in accordance with the requirements of this document and the MBE.

2.3 QUALIFICATIONS AND RESPONSIBILITIES

2.3.1 All load rating calculations and reports shall be sealed by a Professional Engineer licensed in the State of Maine. The Load Rating Engineer shall have experience in the type of bridge being load rated.

2.3.2 All load rating calculations shall be performed or supervised and checked by the Load Rating Engineer who seals the calculations and report.

2.3.3 It is expected that engineers performing load ratings and using LRFR will have a working knowledge of the AASHTO LRFD Specifications.

2.3.4 Quality control of all load ratings is performed by requiring all load rating calculations be checked by a State of Maine licensed Professional Engineer, other than the Load Rating Engineer.

2.3.4 Load Rating Engineer shall use engineering judgment when rating a bridge. Calculations alone should not be blindly followed and taken as gospel.

2.3.6 Load Rating Engineer shall call the Department if the rating shows the bridge warrants immediate action

2.4 ELEMENTS TO BE LOAD RATED

2.4.1 Load ratings will include analysis of the following items:

1. All elements defined as "primary members" as well as stringer-floorbeam, and girder-floorbeam connections.
2. Capacity of gusset plates and connection elements for non-redundant steel truss bridges.
3. Other connections of non-redundant systems.
4. Timber and metal bent elements, as condition warrants.
5. Concrete pier caps and bent caps if condition (deterioration) warrants, at MaineDOT's discretion.
6. Members with section loss

2.4.2 Interior and exterior girders shall be load rated with both values placed in the Breakdown of Bridge Ratings form.

2.4.3 Substructure elements are not routinely analyzed as part of a load rating, except as noted above. Substructure elements may be qualitatively assessed to prove that they do not govern the load rating.

2.4.4 Gusset Plate Connections of non-redundant load path steel bridges

2.4.4.1 During future recalculations of load capacity the gusset plates shall be checked to reflect changes in condition, changes in dead load, structural modifications and other alternations that would result in significant changes in stress levels.

2.4.4.2 Previous load ratings should also be reviewed for bridges which have been subjected to significant changes in stress levels, either temporary or permanent, to ensure that the capacities of gusset plates were appropriately computed and utilized.

2.4.4.3 Gusset plates and connection elements of existing non-load path redundant steel bridges that have not undergone a load capacity evaluation in the past shall be checked for compliance with;

2.4.5 Members with section loss in high stress areas shall be load rated. Similar members without section loss shall also be rated. Both scenarios shall be documented in the Breakdown of Bridge Rating form.

2.5 LOAD RATING COMPLEXITY

2.5.1 Routine Load Ratings consist of computations made from design plans, as-built drawings, field measurements, and inspection reports based on common analytical methods, such as LRFD distribution analysis. The Load Rating Engineer should review the original design plans as the first source of information for material strengths and allowable stresses. If the material strengths are not explicitly stated on the design plans, MaineDOT construction and material specifications applicable at the time of the bridge construction shall be reviewed. The MBE also provides guidance and data on older bridge types and materials that allows the evaluation of existing bridges without having to resort to their original design specifications.

2.5.2 Higher Complexity Load Ratings consist of routine computations adjusted for actual material properties as determined from field sampling and tests of the materials. Higher complexity load ratings may also require the use of refined methods of analysis such as 2-D grillage or 3-D finite element models. Refined methods of analysis are justified where needed to avoid load posting or to ease restrictions on the flow of permitted overweight trucks. Some of the newer more complex structures (segmental bridges, curved-girders, integral bridges, cable stayed, etc.) were designed using sophisticated analysis methods. Therefore, a sophisticated level of analysis will be required to rate these structures. Before refined analyses methods can be used, it must be approved by the Bridge Posting Committee.

2.5.3 <u>Field Load Tests:</u> The actual performance of most bridges is more favorable than conventional theory dictates. If directed by MaineDOT, the safe load capacity for a structure can be determined from nondestructive field load tests, which may be desirable to establish a higher safe load carrying capacity than that calculated by analysis. Refer to the MBE Section 8 for information on conducting field load tests and using the results to establish a new or updated load rating. Before field load testing can be used it must be approved by the Bridge Posting Committee.

2.6 ANALYSIS TOOLS

2.6.1 Any proven analysis tools can be used for Load Rating determination. Analysis tools applicable to the MaineDOT bridge inventory can maximize efficiency, provide consistency, and also facilitate future revisions of Load Ratings.

2.6.2 Advanced structural modeling shall be used if traditional methods give a legal load rating factor less than 1.0.

2.6.3 Curbs and barriers shall be modeled as structural members when determining rating capacity.

2.7 BRIDGES WITH UNKNOWN PARAMETERS

There are bridges for which common analytical methods are not adequate to determine a load rating. For bridges where details, such as reinforcing details for a concrete bridge are not available from plans or field measurements, knowledge of the live load used in the original design, the current condition of the structure and live load history may be used to provide a basis for assigning a safe load capacity. Per Manual for Bridge Evaluation, a concrete bridge with unknown details need not be posted for restricted loading if it has been carrying normal traffic and shows no distress. Nondestructive proof load tests can be helpful in establishing the safe load capacity for such structures. Section 8 of the MBE provides guidance on the use of proof load tests, the interpretation of load test results, and the types of bridges that are suitable candidates for proof load tests. Proposed proof load tests, if needed, shall be reviewed and approved by MaineDOT prior to use. In these circumstances, the engineers shall document their recommendations that a bridge does not have to be load tested or load rated in the MaineDOT load rating summary form.

2.8 REPORTING LRFR TO THE NBI

For all new load ratings based on the LRFR methodology, the load rating data shall be reported to the NBI as a Rating Factor, for NBI Items 63, 64, 65 and 66, using the HL-93 loading.

2.9 TIMBER BRIDGES

Load rating of timber bridge components shall be performed in accordance with MBE Section 6A.7.

2.10 CURVED STEEL GIRDERS

Diaphragm and cross-frames of curved steel girder bridges shall be considered primary members and load rated.

2.11 BURIED STRUCTURES

For single span culverts, the effects of live load may be neglected where the depth of fill is more than 8.0 ft and exceeds the span length; for multiple span culverts, the effects may be neglected where the depth of fill exceeds the distance between inside faces of end walls. For documentation purposes, the inventory and operating rating shall be considered 2.0 and 3.0, respectively.

2.12 RAILROAD BRIDGES

Load ratings of railroad bridges shall be performed in accordance with American Railway Engineering and Maintenance-of-Way Association (AREMA) Manual for Railway Engineering. The bridge's load rating capacity shall be expressed in Cooper's E configurations and the speed in which it was rated.

SECTION 3 LOAD AND RESISTANCE FACTOR RATING GUIDELINES

3.1 DATA COLLECTION FOR LRFR LOAD RATING

3.1.1 Review of Existing Bridge Plans and Documents

As-built plans are contract design plans which have been modified to reflect changes made during construction. As-built plans are used to determine dead loads, bridge geometry, section, and material properties. Shop drawings are also useful sources of information about the bridge. Plans may not exist for some bridges. In these cases complete field measurements will be required. Certain structures or components of structures are built from standard drawings. These standard drawings may have been changed and revised over time. The specific standard drawings used for construction are generally identified in the roadway plans for the project under which the bridge was built. Other appropriate bridge history records, testing reports, repair or rehabilitation plans should be reviewed to determine their impact on the load carrying capacity of the structure.

3.1.2 Bridge Inspection for Load Rating

Bridges being investigated for load capacity must be inspected for condition as per the latest edition of the MBE and the FHWA *Bridge Inspector's Reference Manual*. Bridge inspections are conducted to determine the physical and functional condition of the bridge; to form the basis for the evaluation and load rating of the bridge, as well as analysis of overload permit applications. The Load Rating Engineer must verify the accuracy of existing plans or sketches in lieu of plans with field measurements. It is especially important to measure and document items that may affect the load capacity, such as dead loads and section deterioration and damage. Only sound material should be considered in determining the nominal resistance of the deteriorated section. Where present, utilities, attachments, depth of fill, and thickness of wearing surface should be field verified at the time of inspection.

3.1.3 Assessment of Truck Traffic Conditions at Bridge Site

LRFR live load factors appropriate for use with legal loads and permit loads are defined based upon the Average Daily Truck Traffic (ADTT) available or estimated for the bridge site. FHWA requires an ADTT to be recorded on the Structural Inventory and Appraisal (SI&A) form for all bridges. In cases where site traffic conditions are unavailable from the bridge file, the MaineDOT Traffic section should be contacted for current ADTT information for the route carried by the bridge or routes with a similar functional classification. ADTT may also be estimated from Average Daily Traffic (ADT) data for the site.

3.1.4 Material Properties

Material properties used in the load rating should be taken from existing plans. In the absence of bridge plans, coupon tests or cores shall be collected to determine actual material properties. If material sampling is not practical or preliminary evaluation is required, the guidance in the MBE for estimating material properties shall be followed.

3.2 DYNAMIC LOAD ALLOWANCE (IM)

3.2.1 Design Loads: MBE 6A.4.3.3 applies for all bridges.

3.2.2 Legal Loads: MaineDOT policy is to use the LRFD dynamic load allowance of 33% in all cases regardless of surface roughness. No reductions shall be made for wearing surface condition.

3.2.3 Permit Loads: IM may be reduced depending upon the approach/bridge surface roughness. The IM shall not exceed 33% for permit loads above 150,000 lbs. When speed is limited to 5 MPH or less, IM = 0%

3.2.4 Spans 40’ or less not including buried structures: IM = 33% regardless of riding surface conditions.

3.2.5 Document what value of IM was used for the load rating in the Load Rating Summary Form.

3.3 LIVE LOADS

3.3.1 Overview of LRFR Load Rating Process for MaineDOT Bridges

Live loads to be used in the rating of bridges are selected based upon the purpose and intended use of the rating results.

3.3.1.1 Design load rating is a first-level rating performed for all bridges using the HL-93 loading at the Inventory (Design) and Operating levels. HL-93 ratings are used for National Bridge Inventory (NBI) reporting.

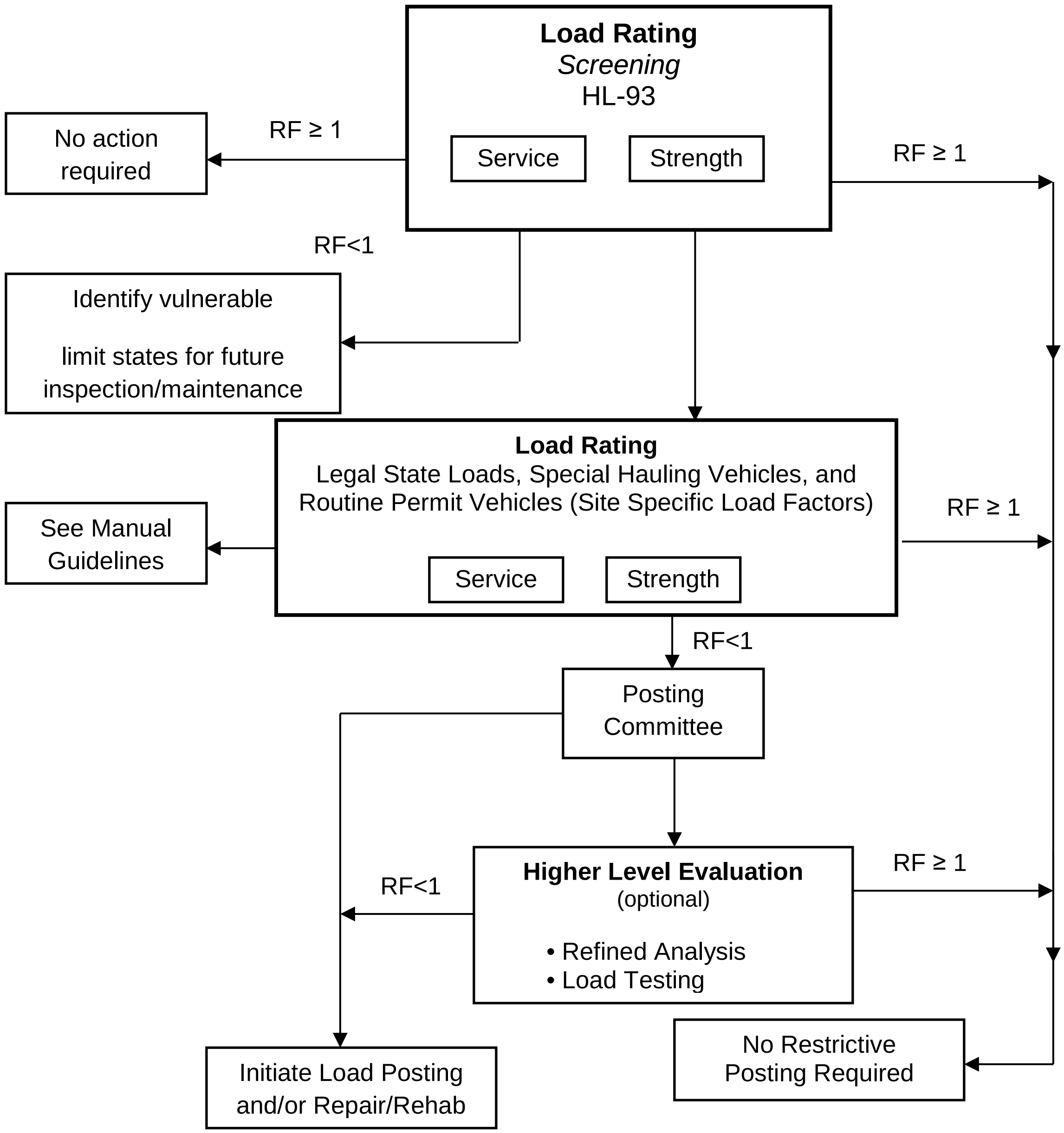
3.3.1.2 HL-93 loading shall be used to screen whether an evaluation of legal loadings is required. If the Inventory Rating Factor is 1.0 or greater for the HL-93 load, then legal level rating is not required.

3.3.1.3 Legal level rating consists of Maine Legal Load Configurations 1 thru 8.

3.3.1.4 Routine Permit Vehicles shall be rated when HL-93 Inventory rating factor is less than 1.0 and Maine Legal Load Configuration’s 1 thru 8 rating factors are 1.0 or greater.

3.3.1.5 Special Hauling Vehicles need not be rated because the moment combined with the load factor is enveloped by the that caused by the 4-axle Forest Products Truck, Legal Load Configuration 6.

3.3.1.6 Addition design lanes shall be included in the design when parking is designated on the bridge.



The flowchart demonstrates the decision making process involved in the LRFR approach. Source: *AASHTO Guide Manual for Condition Evaluation and Load and Resistance Factor Rating (LRFR) of Highway Bridges*.

3.3.2 Design Load Rating

The design-load rating (or HL-93 rating) assesses the performance of existing bridges utilizing the LRFD HL-93 design loading and design standards with dimensions and properties for the bridge in its present as-inspected condition. It is a measure of the performance of existing bridges to new bridge design standards contained in the LRFD Specifications. The design-load rating produces Inventory and Operating level rating factors for the HL-93 loading.

3.3.2.1 The results of the HL-93 rating are to be reported to the NBI as a Rating Factor.

3.3.3 Legal Load Rating

3.3.3.1 In LRFR, load rating for legal loads determines a single safe load capacity of a bridge. The distinction of Operating and Inventory level ratings is no longer maintained when load rating for legal loads.

3.3.3.2 Maine legal vehicle configurations should be used rather than AASHTO legal vehicles.

3.3.3.3 For negative moments and interior reactions, use a lane configuration of 0.20 klf plus two Maine legal vehicles multiplied by 0.75 separated by 30 feet heading in the same direction, or a single Maine legal load configuration, whichever is greater.

3.3.3.4 For spans greater than 200 feet use a single Maine legal load configuration multiplied by 0.75 plus a lane load of 0.20 klf.

3.3.3.5 One direction ADTT < 500: The lane load component may be excluded and the 0.75 factor changed to 1.0.

3.3.3.6 Maine Legal Load Configurations 1 thru 5, 7 and 8 are significantly heavier than the AASHTO legal loads and should be rated using load factors specified for Routine Commercial Traffic in the MBE. The live load factors for Routine Commercial Traffic need not be increased in accordance with Section 6A.4.4.2.3a of the MBE.

3.3.3.7 The vehicles referred to as specialized hauling vehicles (SHV) are legal single-unit short-wheelbase multiple-axle trucks commonly used in the construction, waste management, bulk cargo and commodities hauling industries. Maine legal vehicle Configuration 6, four-axle, tri-axle unit, meets the definition but exceeds the weight limits of the AASHTO SHV units. The live load factors for Configuration 6 need not be increased in accordance with Section 6A.4.4.2.3b of the MBE.

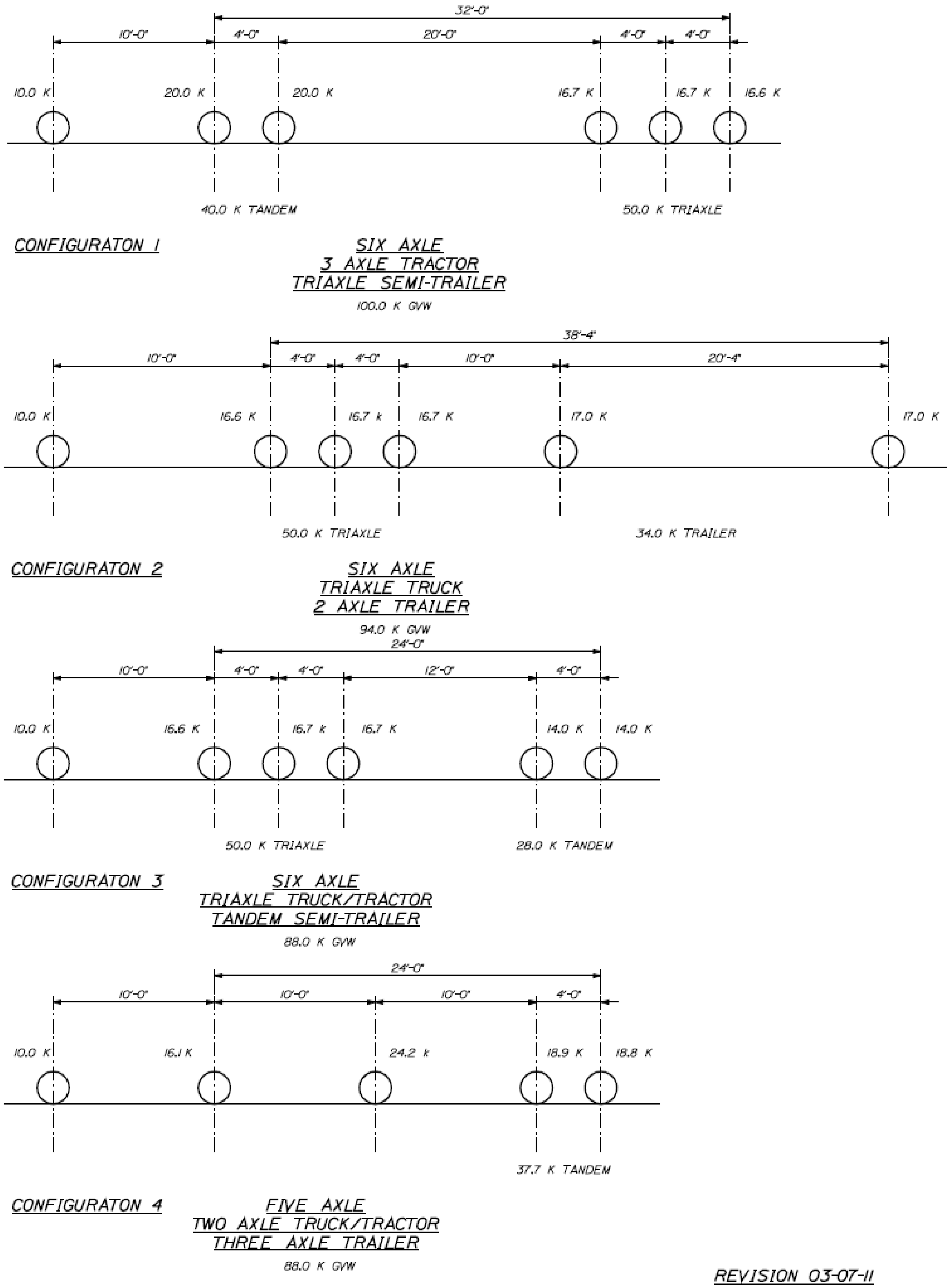


Figure 1. Maine DOT Legal Loads

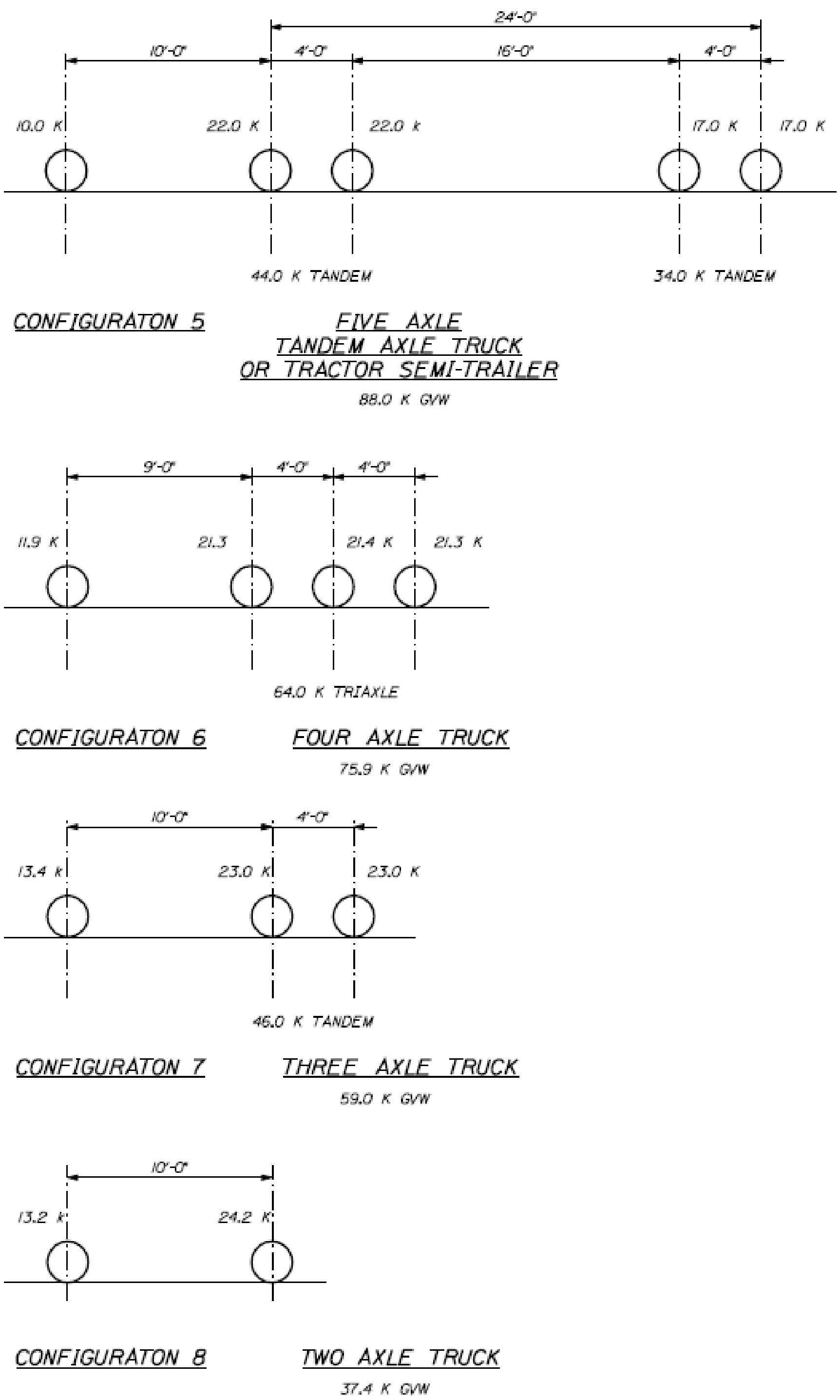


Figure 2. Maine DOT Legal Loads

3.4 DEAD LOADS

3.4.1 Wearing surface thicknesses are highly variable. Multiple measurements at curbs and roadway centerline should be used to determine an average wearing surface thickness. Load factor for DW at the strength limit state may be taken as 1.25 where cores have been taken or other advanced techniques were used to verify thickness (i.e. ground penetrating radar).

3.5 RESISTANCE FACTORS AND RESISTANCE MODIFIERS

3.5.1 Condition Factor: φc

3.5.1.1 The condition factor provides a reduction to account for the increased uncertainty in the resistance of deteriorated members and the likely increased future deterioration of these members during the period between inspection cycles. The Condition Factor φc does not account for section loss, but is used in addition to section loss.

3.5.1.2 If section properties are obtained accurately, by using a calibrated D-meter or calipers rather than by an estimated percentage of losses, the values specified for φc in Table 6A.4.2.3-1 shall be increased by 0.05 ($\varphi c \leq 1.0$). For instance, a concrete member may receive a low condition rating due to heavy cracking and spalling or due to the deterioration of the concrete matrix. Such deterioration of concrete components may not necessarily reduce their calculated flexural resistance. But it is appropriate to apply the reduced condition factor in the LRFR load rating analysis. If there are also losses in the reinforcing steel of this member, they should be measured and accounted for in the load rating. It is appropriate to also apply the reduced condition factor in the LRFR load rating analysis, even when the as-inspected section properties are used in the load rating as this reduction by itself does not fully account for the impaired resistance of the concrete component.

3.5.1.3 The condition factor accounts for member deterioration due to natural causes. Damage caused by accidents is specifically not considered here.

3.5.1.4 A condition factor, ϕ_c, of 1.0 shall be used unless there is rust staining or the reinforcing steel can be seen and there is section loss present in reinforced concrete. This condition factor is used because the reinforcing steel in tension and the upper portion of concrete in compression are the main contributors in moment capacity. The moment capacity is not compromised unless there is section loss of the reinforcing steel.

3.5.2 System Factor: φs

3.5.2.1 The system factor is a multiplier applied to the nominal resistance to reflect the level of redundancy of the complete superstructure system. Bridges that are less redundant will have their member capacities reduced, and accordingly, will have lower ratings. The aim of the system factor is to provide reserve capacity for safety of the traveling public.

3.5.2.2 The system factors provided in Table MBE 6A.4.2.4-1 shall be used when load rating for Flexural and Axial Effects for steel members and non-segmental concrete members.

3.5.2.3 Subsystems that have redundant members should not be penalized if the overall system is non-redundant (i.e. multi stringer deck framing members on a two-girder or truss bridge).

3.5.2.4 The system factor is used with all live load models.

3.6 STRENGTH LIMIT STATES FOR LOAD RATING

3.6.1 Concrete

3.6.1.1 Shear capacity of all reinforced and prestressed concrete bridge members shall be evaluated.

3.6.1.2 The main reinforcing steel in concrete T-beams that is bent up at a diagonal near the end of the beams shall be included when calculating the shear capacity. The main reinforcing steel shall be considered in direct tension and the angle of stirrup, α, is equal to 45 degrees.

3.6.1.3 Concrete slabs shall be analyzed using Slab Rate computer software within the limits of the product.

3.6.1.4 Modified compression field theory shall be used to calculate concrete shear strength if traditional methods result in rating factors less than 1.0.

3.6.1.5 The implication of MBE 6A.5.8 is that a posting decision does not have to be dictated by the legal load rating results for shear for concrete bridges that show no visible signs of shear distress.

3.6.2 Steel

3.6.2.1 When rating steel stringers and girders without shear connectors with cast-in-place concrete decks with a direct bond with the beams, the horizontal shear shall be checked to determine whether the bridge system will act compositely when under load. If the calculated horizontal shear is less than or equal to a threshold τ, then the beam and deck act compositely. If the calculated horizontal shear is greater than τ, the posting load shall be determined as what vehicle weight will cause the bond to break.

3.6.2.2 When the top flange is at least partially embedded in concrete slab the threshold τ = 100 psi, else τ = 70 psi.

3.6.2.3 If there is an observed break in the bond between the top flange and deck, the capacity of the beam shall be determined as though it is partially braced non-composite.

3.6.2.4 The top flange of the beam shall assumed to be braced when determining the positive moment capacity when rating steel floor beams with cast-in-place concrete decks with a direct bond with the beams. If there is an observed break in the bond between the top flange and deck, then the beams shall be considered partially braced non-composite.

3.6.2.4 Longitudinal reinforcing steel in the deck shall be included in determining the negative moment capacity of the section over a pier.

3.6.2.5 Local section loss shall be ignored when evaluating lateral torsional buckling.

3.7 SERVICE AND FATIGUE LIMIT STATES FOR LOAD RATING

3.7.1 General

Strength is the primary basis for evaluation. The focus of serviceability checks in evaluation is to identify and control live load effects that could potentially damage the bridge structure, and impair its serviceability and service life. The MBE recommends applicable service limit states for LRFR evaluation and permits. The serviceability checks will only be evaluated on individual basis where the bridge's use, structure type, or specific details may cause concern.

3.7.2 Concrete Bridges

3.7.2.1 For non-segmental prestressed concrete bridges, LRFR provides a limit state check for cracking of concrete (SERVICE III) by limiting concrete tensile stresses under service loads. SERVICE III check shall be performed during design load, legal load, and permit load ratings of prestressed concrete bridges. No tension stresses are allowed in the precompressed tensile zone when performing the design load check at the Inventory level.

3.7.3 Steel Bridges

3.6.3.1 In situations where fatigue-prone details are present (category C or lower), a Fatigue Limit State Rating Factor for infinite fatigue life shall be computed. Bridge details that fail the infinite-life check shall be subject to the more complex finite-life fatigue evaluation using evaluation procedures given in the MBE (Section 7).

3.7.3.2 Truck Traffic Volume counts used for fatigue life calculations shall be the 20 year projected volume counts.

3.7.3.3 In the Service II load combination, check of the flange lateral bending stress (*fl*) shall not be considered for straight girder bridges.

3.8 FACTORS NOT TO CONSIDER IN LOAD RATINGS

3.8.1 <u>Longitudinal Forces:</u> The evaluation of bridge components to include the effects of longitudinal braking forces, specified in LRFD design article 3.6.4 in combination with DL & LL effects should be done only where concerns are raised about the longitudinal stability of the structure.

3.8.2 <u>The “fl” term:</u> The flange lateral bending stress determined as specified in LRFD Article 6.10.1.6 need not be considered for straight steel girder bridges with skews less than 20 degrees.

SECTION 4 LOAD RATING DELIVERABLES

4.1 LOAD RATING REPORT

Load rating calculations and documentation shall be incorporated into a comprehensive report to facilitate updating of the information and calculations in the future.
The report shall follow the following format:

1. Title Sheet
2. Summary of Bridge Rating
3. Breakdown of Bridge Rating
4. Assumptions
5. List of References used in the Load Rating Analysis.
6. Description of Bridge
7. Load Rating Computations.
8. Sketches of section losses incorporated into the load rating analysis.
9. Photos
10. Bridge Plans

All structures do not need a detailed inspection prior to the load rating being performed. State inspection reports shall be reviewed to determine if deficiencies are noted which may affect the rating. A site inspection may be required to verify the information shown in the inspection report or to gather more information needed to perform the load rating analysis. When refined methods of analysis or load testing are used, the load rating report shall include all assumptions and procedures to determine live load effects in all rated members. For more complex structures where computer models are used in the analysis, a copy of the computer models with documentation shall be made and submitted to MaineDOT. For new, replaced, and rehabilitated bridges designed using LRFD, the LRFR ratings shall be computed at the time of design and shall be verified/updated with the as-built condition after construction.

The procedures are considered more cost-effective in the long term considering the ease in updating the ratings when re-rating is necessary in the future. The automated processes with an established load library will provide the complete level of information to base future permit decisions. The requirements are geared to maximizing efficiency and providing consistency in load ratings.

Once the load rating is complete, an electronic copy shall be placed into TEDOCs. An example of the mandatory first four pages of the Load Rating Report can be found in Appendix A. Every load rating shall begin with these pages in that order.

4.2 QUALITY CONTROL AND QUALITY ASSURANCE REVIEW OF LOAD RATINGS

Quality control procedures are intended to maintain the quality of the bridge load ratings and are usually performed continuously within the load rating teams/units. When Consultants perform load ratings, the consultant shall have quality control procedures in place to assure the accuracy and completeness of the load ratings. All load rating calculations shall be checked by a professional engineer other than the Load Rating Engineer.

Quality assurance procedures are used to verify the adequacy of the quality control procedures to meet or exceed the standards established by the agency or the consultant performing the load ratings.

REFERENCES

AASHTO. 2011. *The Manual for Bridge Evaluation and Interims*, Second Edition, American Association of State Highway and Transportation Officials, Washington, DC.

AASHTO. 2012. *AASHTO LRFD Bridge Design Specifications and Interims*, Sixth Edition, American Association of State Highway and Transportation Officials, Washington, DC.

AREMA. 2012. *Manual for Railway Engineering*, American Railway Engineering and Maintenance of Way Association, Washington, DC.

NCHRP. 1998. *Bridge Rating Through Nondestructive Load Testing.* NCHRP Report 234. Transportation Research Board, National research Council, Washington, DC.

Simpson, Josh. 2015. *Parametric Study Comparing Design Loads, Legal Loads, Special Hauling Vehicles, and Routine Permit Vehicles*. Report prepared by Maine Department of Transportation.

APPENDIX A. – LOAD RATING REPORT EXAMPLE FORMAT

Bridge Load Rating

Prepared for

Maine Department of Transportation

CITY/TOWN

BRIDGE NAME

Bridge No. XXXX

ROUTE CARRIED

OVER

CROSSING

Date of Inspection: LATEST INSPECTION DATE

Date of Rating: DATE RATING SUBMITTED

Prepared By:

Checked By:

ENGINEER & COMPANY

Bridge No:		Bridge Name:	
Town/City:	[INSERT LOCATION]	Owner:	
Route Carried:	[INSERT LOCATION]	Year Built	
Crosses:		Year(s) Rebuilt/Rehab:	

SUMMARY OF BRIDGE RATING

VEHICLE TYPE		RF	RT (TONS)	POSTING LOAD (TONS)
HL-93	INVENTORY	1.00	36.00	
	OPERATING	1.00	36.00	
HL-93 modified	INVENTORY	***0.00***	0.00	
	OPERATING	***0.00***	0.00	
CONFIGURATION 1		***1.00***	50.00	50.00
CONFIGURATION 2		1.00	47.00	47.00
CONFIGURATION 3		1.00	44.00	44.00
CONFIGURATION 4		1.00	44.00	44.00
CONFIGURATION 5		1.00	44.00	44.00
CONFIGURATION 6		1.00	37.95	37.95
CONFIGURATION 7		1.00	29.50	29.50
CONFIGURATION 8		***1.00***	18.70	18.70

Group 1 Posting Analysis (Configuration 1)
Governing Posting: 50.00
Governing Load Model: CONFIGURATION 1

Group 2 Posting Analysis (Configurations 2 - 5)
Governing Posting: 44.00
Governing Load Model: CONFIGURATION 2

Group 3 Posting Analysis (Configurations 6 - 8)
Governing Posting: 18.70
Governing Load Model: CONFIGURATION 8

LRFR Evaluation Factors:

Live Load Distribution Factor: ______
Impact Factor: ______
Governing Condition Factor, ϕ_c: ______
System Factor, ϕ_s: ______
ADTT (one-way): ______

Please check all the boxes that apply:

- ☐ Bridge load rating is governed by substructure rating
- ☐ Connections control the load rating
- ☐ Exterior girder controls load rating
- ☐ As-built load rating
- ☐ As-inspected load rating
- ☐ One Lane Loaded
- ☐ Advanced Analysis Used
- ☐ Actual Measurements Taken
- ☐ Finite Fatigue Life ______ years

BREAKDOWN OF BRIDGE RATING

Town/City: [INSERT LOCATION]　　Route Carried: [INSERT LOCATION]

Bridge No: 0　　Crosses: 0

LOAD RATING POINTS OF INTEREST

Bridge Component	HL-93		HL-93 Modified		MaineDOT Truck Configurations							
	Inv 72.0 kip	Oper 72.0 kip	Inv 90.0 kip	Oper 90.0 kip	1 100.0 kip	2 94.0 kip	3 88.0 kip	4 88.0 kip	5 88.0 kip	6 75.9 kip	7 59.0 kip	8 37.4 kip
[COMPONENT] [LIMIT STATE] [ANALYZED CONDITION]	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
[COMPONENT] [LIMIT STATE] [ANALYZED CONDITION]												
[COMPONENT] [LIMIT STATE] [ANALYZED CONDITION]												
[COMPONENT] [LIMIT STATE] [ANALYZED CONDITION]												
[COMPONENT] [LIMIT STATE] [ANALYZED CONDITION]												
[COMPONENT] [LIMIT STATE] [ANALYZED CONDITION]												
[COMPONENT] [LIMIT STATE] [ANALYZED CONDITION]												
[COMPONENT] [LIMIT STATE] [ANALYZED CONDITION]												
[COMPONENT] [LIMIT STATE] [ANALYZED CONDITION]												
[COMPONENT] [LIMIT STATE] [ANALYZED CONDITION]												
[COMPONENT] [LIMIT STATE] [ANALYZED CONDITION]												
[COMPONENT] [LIMIT STATE] [ANALYZED CONDITION]												
[COMPONENT] [LIMIT STATE] [ANALYZED CONDITION]												
[COMPONENT] [LIMIT STATE] [ANALYZED CONDITION]												
CONTROLLING RATING FACTORS	1.00	1.00			1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

DESCRIPTION OF BRIDGE

Bridge Number:	BRIDGE NO.
Owner:	OWNER
Maintained By:	MAINTAINER
Location:	TOWN/CITY
Route Carried:	STREET
Feature Intersected:	FEATURE INTERSECTED
Latest NBI Inspection Date:	DATE
Field Verification Date (if applicable):	DATE
Date of Construction:	YEAR
Bridge Type:	P/T CONC. BOX ETC.
Material Properties:	CONC., STEEL, REBAR, ETC.
Original Design Loading:	TYPE
Date(s) of Rebuild/Rehab :	YEAR
Description of Rebuild/Rehab :	TYPE
Posting:	TYPE
Superstructure:	X
Substructure:	X
Bearings:	X
Bridge Spans:	TOTAL LENGTH & INDVIDUAL SPAN LAYOUT
Bridge Skew:	X °X'X"
Bridge Width:	X'-XX" out-to-out
Roadway Width:	X'-XX" curb-to-curb
Roadway Surface:	X
Curbs:	X
Sidewalk/Walkway/Median:	X
Utilities:	X
Bridge Railing:	X
Approach Railing:	X
Wearing Surface Condition:	X
Bridge Railing Condition:	X
Deck Condition:	X
Beam Condition:	X
Bearing Condition:	X
Abutment Condition:	X
Pier Condition:	X

Railroad Bridge Load Rating

Prepared for

Maine Department of Transportation

CITY/TOWN

BRIDGE NAME

Bridge No. XXXX

BRANCH CARRIED

OVER

CROSSING

Date of Inspection: LATEST INSPECTION DATE

Date of Rating: DATE RATING SUBMITTED

Prepared By:

Checked By:

ENGINEER & COMPANY

Bridge No: ____________ Bridge Name: ____________
Town/City: [INSERT LOCATION] Owner: ____________
Branch Carried: [INSERT LOCATION] Year Built ____________
Crosses: ____________ Year(s) Rebuilt/Rehab: ____________

SUMMARY OF BRIDGE RATING

VEHICLE TYPE		25 mph RF	25 mph E Rating	10 mph RF	10 mph E Rating
Cooper E80	Normal	1.00	80.00	1.00	80.00
	Maximum	1.50	120.00	1.50	120.00
Alternate	Normal	1.00	80.00	1.00	80.00
	Maximum	1.50	120.00	1.50	120.00
Service Vehicle 1	Normal	***1.00***		1.00	
	Maximum	1.50		1.50	
Service Vehicle 2	Normal	1.00		1.00	
	Maximum	1.50		1.50	
Service Vehicle 3	Normal	1.00		1.00	
	Maximum	1.50		1.50	
Service Vehicle 4	Normal	1.00		1.00	
	Maximum	1.50		1.50	

Factors:

Class of Line ____________
Rating Type ____________
Service Vehicle 1 ____________
Service Vehicle 2 ____________
Service Vehicle 3 ____________
Service Vehicle 4 ____________

Please check all the boxes that apply:

- ☐ Bridge load rating is governed by substructure rating
- ☐ Connections control the load rating
- ☐ Exterior girder controls load rating
- ☐ As-built load rating
- ☐ As-inspected load rating
- ☐ Advanced Analysis Used
- ☐ Actual Measurements Taken
- ☐ Finite Fatigue Life ____ years

BREAKDOWN OF BRIDGE RATING

Town/City: [INSERT LOCATION]
Bridge No: 0

Branch Carried: [INSERT LOCATION]
Crosses: 0

LOAD RATING POINTS OF INTEREST

Bridge Component	Cooper E80		Alterante Loading		Sevice Vehicle 1		Sevice Vehicle 2		Sevice Vehicle 3		Sevice Vehicle 4	
	25 mph	10 mph	25 mph	10 mph	25 mph	10 mph	25 mph	10 mph	25 mph	10 mph	25 mph	10 mph
[COMPONENT] Normal [ANALYZED CONDITION]	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
[COMPONENT] Maximum [ANALYZED CONDITION]	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
[COMPONENT] Normal [ANALYZED CONDITION]												
[COMPONENT] Maximum [ANALYZED CONDITION]												
[COMPONENT] Normal [ANALYZED CONDITION]												
[COMPONENT] Maximum [ANALYZED CONDITION]												
[COMPONENT] Normal [ANALYZED CONDITION]												
[COMPONENT] Maximum [ANALYZED CONDITION]												
[COMPONENT] Normal [ANALYZED CONDITION]												
[COMPONENT] Maximum [ANALYZED CONDITION]												
[COMPONENT] Normal [ANALYZED CONDITION]												
[COMPONENT] Maximum [ANALYZED CONDITION]												
CONTROLLING RATING FACTORS - Normal	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
CONTROLLING RATING FACTORS - Maximum	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50

DESCRIPTION OF BRIDGE

Bridge Number:	BRIDGE NO.
Owner:	OWNER
Maintained By:	MAINTAINER
Location:	TOWN/CITY
Branch Carried:	STREET
Feature Intersected:	FEATURE INTERSECTED
Latest Inspection Date:	DATE
Field Verification Date (if applicable):	DATE
Date of Construction:	YEAR
Bridge Type:	P/T CONC. BOX ETC.
Material Properties:	CONC., STEEL, REBAR, ETC.
Original Design Loading:	TYPE
Date(s) of Rebuild/Rehab :	YEAR
Description of Rebuild/Rehab :	TYPE
Superstructure:	X
Substructure:	X
Bearings:	X
Bridge Spans:	TOTAL LENGTH & INDVIDUAL SPAN LAYOUT
Bridge Skew:	X °X'X"
Bridge Width:	X'-XX" out-to-out
Curbs:	X
Sidewalk/Walkway/Median:	X
Utilities:	X
Deck Condition:	X
Beam Condition:	X
Bearing Condition:	X
Abutment Condition:	X
Pier Condition:	X

APPENDIX B. – SUPER LOAD PERMIT PROCESS

The Secretary of State, acting under guidelines and advice of the Commissioner of Transportation, may issue permits to move non-divisible vehicles and/or loads which exceed the legal length, width, height, or weight limits established in Title 29-A, Chapter 157, over roads, highways and bridges maintained by the Maine Department of Transportation.

An Overlimit Permit is required to transport a non-divisible over dimensional and/or overweight vehicle and/or load upon public highways, using certain routes, from a single origin to a single destination. An Extreme or Super Load Permit, as described in Title 29-A Chapter 157, is an Overlimit Permit which can be:

1. Oversize
2. Overweight
3. Oversize & Overweight

Bridge Maintenance, coordinating with the Overlimit Permit Unit of the Bureau of Motor Vehicles, reviews the impact the heavy cargo of Super Loads on the State's bridges.

Engineering Process: Bridge Maintenance promptly responds to the requests from carriers via the Bureau of Motor Vehicles. This is accomplished through computer software, technical research, experience, and engineering judgment. Axle loads & their respective configurations are examined with regard to all encountered bridges the super load vehicle may ride. Dimensional over height issues are reviewed. The MaineDOT's Traffic Division concurrently may receive requests and analyzes geometric issues such as turning radius, widths and as well as escort requirements along the proposed route. Approvals and necessary restrictions are coordinated and submitted to the Bureau of Motor Vehicles.

Bridge Analysis Process: Carriers submit proposed axle weights and spacing as well as the proposed route. The Department uses the axle information as input into its Structural Analysis Software (SAS) program. The SAS output is a curve on an X-Y axis coordinate system where X represents bridge span (not bridge length) and the Y axis depicts the stress ratio. The SAS Program is further described in Appendix B.

A reference vehicle type is set in the input. For most cases the reference vehicle is a HS-20 Truck. The output displays this as a 3 axle vehicle with 8 kips, 32 kips & 32 kips axle loads, and axles located at 0, 14 feet & 28 feet. The proposed vehicle is also displayed in this output with up to 15 axles.

Several horizontal dashed lines are displayed in the Stress Ratio vs Span Length output. These represent limitations computed by the reference vehicle. The limit line we are most concerned about is the one set at 1.30 (Stress Ratio). Curves (representing proposed carriers) below the 1.3 Stress Ratio are carriers ok to travel. However, if the curve breaks through that 1.30 limit line, the program is run again after removing the "impact factor" (input toggle adjustment). No Impact represents a vehicle being required to slow down to steady 5 mph before traveling over bridges. Once again, the curve should be below the limiting stress ratio.

Occasionally the 1.36 Stress Ratio is used as the upper limit. This is in cases where the Department is substantially confident the axle weights have been weighed accurately.

Engineering judgment combined with the computer analysis is exercised by:

1. Investigating span lengths on route.
2. Awareness of bridges in unsatisfactory condition along the route.
3. Reviewing "Operating Rating" of bridges on route.
4. Understanding the nature of the type of bridges encountered (i.e. Concrete T-Beam, Buried Structure, Fracture-Critical Steel Structures, etc.).
5. Viewing as-built plans.

Additional restrictions besides slowing the vehicle down to 5 mph can be placed in writing on the Super Load Permit. These normally may include:

1. Move carefully down the centerline of the bridge structure.
2. The carrier shall be the only vehicle on the bridge while crossing.
3. Speed is to be steady at legal limit (moderate mitigation).
4. Rejecting the application and requiring additional axles to be added to the proposed vehicle.
5. Placing Department personnel to observe the move.
6. Reviewing plans to place wheel loads as practical as possible over the stringers/beams using paint marks on the deck pavement.

<u>Extreme Load Analysis:</u> Infrequently, the Department receives extremely heavy load proposals (600,000 – 900,000 + lbs.). Bridge Maintenance likely would require engineered RoRo or temporary Ramps to be utilized. These are temporary bridges that will extend over state bridges. Bridge lengths are limited to approximately 50 feet +/- maximum. Therefore, the proposed route becomes even more important. At this juncture, the Department requires stamped engineered submittals involving RoRo Ramps, tire footprint with associated pressures, and other pertinent information.

<u>Overheight Review:</u> Upon the submittal of the permit application, the carrier's vehicle height is reviewed by the Overlimit Permit Unit of the Department of Motor Vehicles. In addition, Bridge Maintenance of the MaineDOT performs a backup check and makes recommendations regarding pilot-pole-cars. Recommendations are based on the <u>Limiting Structures on State and State Aid Highways</u> reference which is maintained by the Bridge Maintenance Division of MaineDOT. The latest edition is 2007.

The reference book lists bridge clearance heights at the centerline of roadway, the left shoulder and the right shoulder per bridge. An amount of 2" is subtracted from the actual bridge height at each of these measurements in order to account for pavement overlays and a small amount of safety factor.

Response & Coordination: Super Load Permit response is accomplished in a prompt manner as this work is important to the State of Maine commerce. It is coordinated with the MaineDOT Traffic Division and the BMV Overlimit Permit Unit. The final approval addresses bridge crossings, overheight & other geometric issues, escorts matters and times, and dates for the move.

Other Permit Types: Bridge Maintenance of the MaineDOT does not regularly review other type of permits.

For informational purposes note the following:

Chapter 157: THE ADMINISTRATION OF OVER DIMENSION AND OVERWEIGHT PERMITS, within Title 29-A specifies other permit types utilized by the trucking industry. This includes Long Term Permits, also termed Blanket Permits, and Instant Overlimit Permits. The dimensions and weights are such that the carriers can be reviewed by the Overlimit Permit Unit using thresholds established in Chapter 157. Some of these permits allow truck weight limits up to 177,000 lbs without review by MDOT.

All bridge and road postings must be observed regardless of permit type.

The Secretary of State issuance of a permit listing the Maine Turnpike as a route does not relieve the permitee of the obligation to also obtain a Turnpike-issued permit. Travel on the Maine Turnpike is governed by Rules and Regulations adopted by the Maine Turnpike Authority.

APPENDIX C. – STRUCTURAL ANALYSIS SOFTWARE

Attached is a typical output sheet for the Department's SAS program. The top portion displays the reference vehicle and the test vehicle axle loads and distances. The bottom depicts a graph representation of the test vehicle in an X-Y coordinate system of span length versus stress ratio.

Background

In the early 1980's, Walter Verrill (ret. MaineDOT) wrote the original SAS program based on the Department's perspective on truck loading on bridges. Memos from this era demonstrated the assumptions & concerns for which the program is based. Chip Getchell (MaineDOT) & others rewrote and adjusted the software when it was converted from its Mainframe existence to the PC age. It was at this time the graphics output was created and updated AASHTO Specifications were implemented in the software.

The program calculates moment ratios as a surrogate for actual stress ratios. It is developed for simple spans that are noncomposite. The program can consider various superstructure type, but the default steel beam with concrete deck is generally used. The deck or substructure are not factors in the SAS program.

General Assumptions

The ratio of actual stress to design stress is known as the "Bridge Stress Ratio". A bridge stress ratio of 1.36 is used as the limiting value for older H-15 design type bridges. The Department also uses this for HS-20 design bridges.

It has been suggested the Federal Bridge Formula desired to apply this 1.36 or 36% overload apply to H-15 designs and 1.05 or 5% overload apply to HS-20 designs. The general idea was to not worry so much about the older H-15 bridges as they were essentially being replaced at a reasonable pace. The Department chose to place both designs, as well as HS-25, into the same category of allowing a 36% overstress beyond design. These are all approximations. The actual yield point was likely closer to 1.81 Stress Ratio.

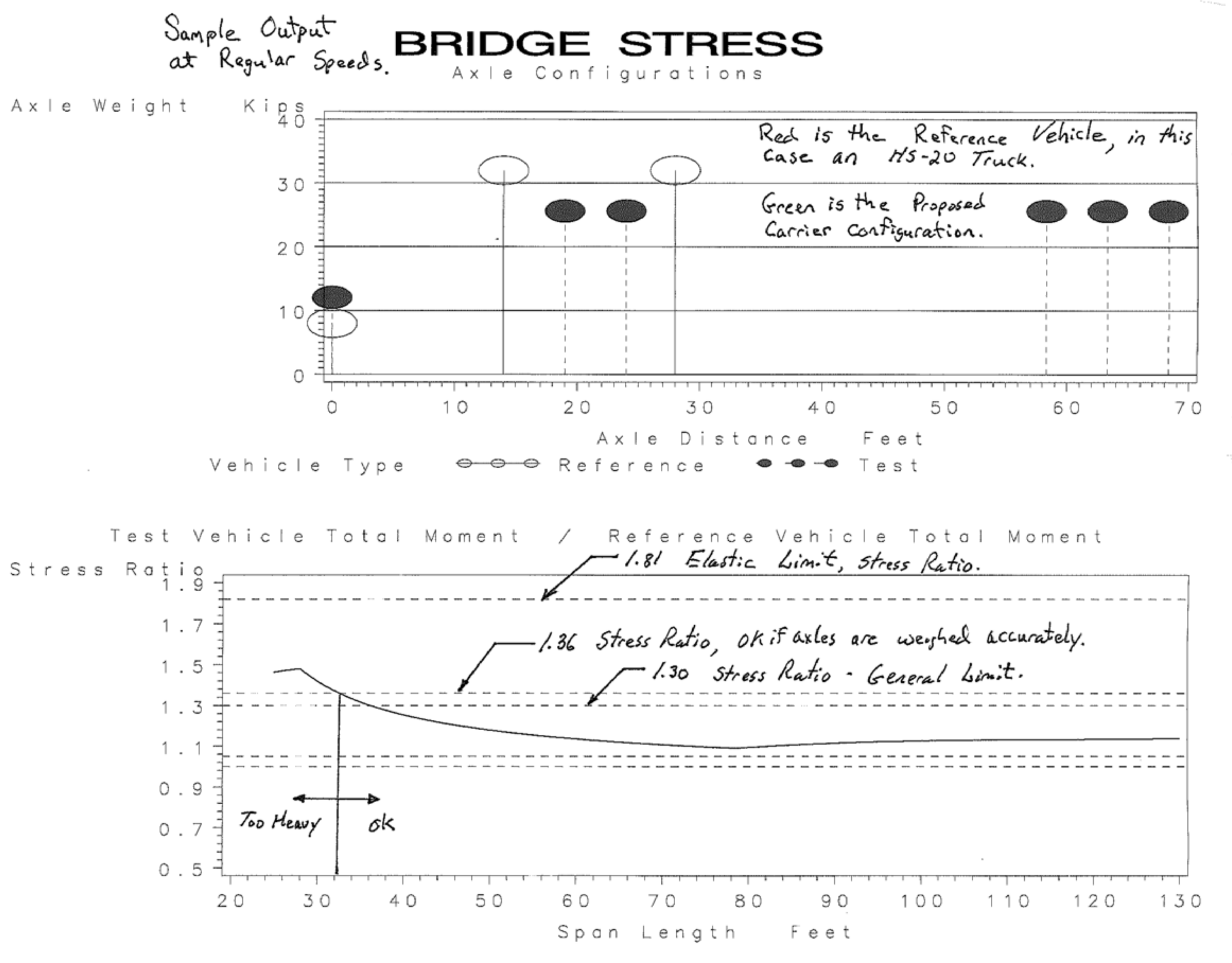
If you look at the origin of these specific values:

0.75/0.55 = **1.36**
Whereas 0.75 F(yield) = suggested upper limit.
0.55 is the old Allowable Stress Design safety factor.

Elastic Limit = 1/0.55 = **1.81**
Whereas 0.55 is the old Allowable Stress Design safety factor.

Various load configurations are analyzed with every axle placed at midspan for span lengths of 25 to 145 feet. Lane loading was also used. The SAS program is written such that one or the other ruled (i.e. written according to LFD specifications).

One of the "toggles" of the SAS program is to remove the truck impact (the equivalent of slowing to 5 mph before crossing the bridge). This is not a straight 30% reduction, but follows the AASHTO reduction formula (15 +/- years ago).



Sample Output at Regular Speeds.
BRIDGE STRESS
Axle Configurations
Axle Weight Kips
40
30
20
10
0
Red is the Reference Vehicle, in this case an HS-20 Truck.
Green is the Proposed Carrier Configuration.
0
10
20
30
40
50
60
70
Axle Distance Feet
Vehicle Type
Reference
Test
Test Vehicle Total Moment / Reference Vehicle Total Moment
Stress Ratio
1.9
1.7
1.5
1.3
1.1
0.9
0.7
0.5
1.81 Elastic Limit, Stress Ratio.
1.36 Stress Ratio, OK if axles are weighed accurately.
1.30 Stress Ratio - General Limit.
Too Heavy
OK
20
30
40
50
60
70
80
90
100
110
120
130
Span Length Feet