NEW JERSEY DEPARTMENT OF TRANSPORTATION

HIGHWAY BRIDGE LOAD RATING MANUAL

FIRST EDITION

March 2012

Prepared By:

Structural Evaluation & Bridge Management

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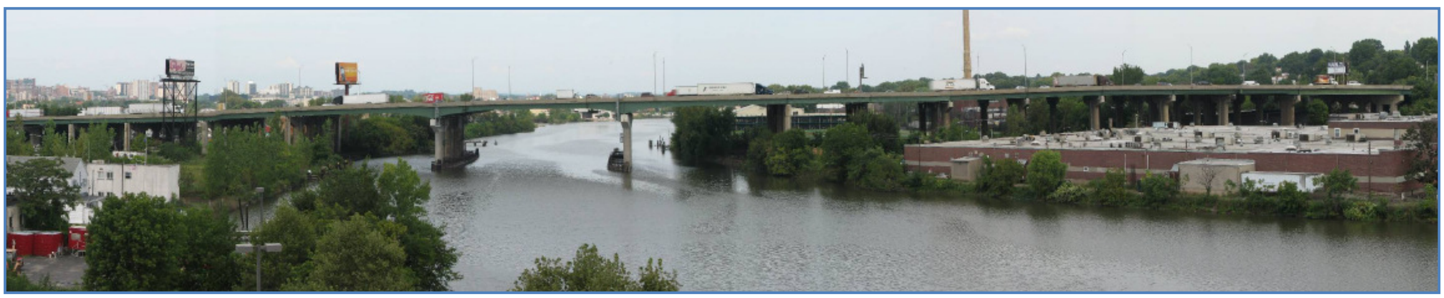

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This Manual provides guidance for the Bridge Load Rating of highway carrying bridges in New Jersey. This is the initial issue of NJDOT Load Rating Manual. The intent of the Manual is to assist bridge engineers to evaluate the load carrying capacity of different structural members of a bridge.

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1 GENERAL

The NJDOT Highway Bridge Load Rating Manual is created using the American Association of State Highway Officials (AASHTO) *Manual for Bridge Evaluation* (MBE), Second Edition, 2011. It provides guidance to Load Rating Engineers (LREs) for performing, analyzing, and submitting load rating calculations using the Load and Resistance Factor (LRFR) as well as Load Factor (LFR)/Allowable Stress (ASR) methodology.

The purpose of this document is to provide consistent guidelines for load rating inputs and deliverables. It serves as a supplement to the AASHTO MBE and deals primarily with New Jersey Department of Transportation (NJDOT) specific load rating requirements, submissions, interpretations, and policy decisions. Although the intention of this manual is to provide bridge load rating policy for work done by or for the NJDOT, it does not preclude justifiable exceptions, subject to the approval of the NJDOT.

This Manual is a living document in that changes will be issued as warranted because of changes in policy, loadings, or evaluation criteria.

The load rating will be an evaluation of the load carrying capacity of the primary superstructure components and other elements as needed. The load rating will be determined by a licensed Professional Engineer through computer analyses, hand calculations, engineering judgment or load testing of the bridge components.

Load ratings are typically determined by analytical methods based on information taken from bridge plans supplemented by information gathered from field inspections and/or field measurements.

The capacity of each bridge to carry loads may be required for the following cases:

- To determine which structures have substandard load capacities that may require load posting or other remedial action.
- To effectively use the available resources that assist in deciding on rehabilitation or replacement of an existing bridge.
- To assist in the analysis and processing of overweight vehicle permits.
- **To satisfy FHWA requirements for submitting load ratings. The NBIS (Title 23, Code of Federal Regulations, Section 650.313 (c)), requires that load ratings be in accordance with the AASHTO Manual. The results are used in conjunction with other bridge inventory and inspection information to determine the Federal Bridge Sufficiency Rating.**

All bridges must have a current Load Rating Summary Sheet in the Evaluation Survey Report and load rating calculations in the bridge database.

All bridges rated less than 3 tons for any New Jersey legal truck at Operating level shall be closed and barricaded to all traffic.

All Railroad carrying bridges should be rated if approved by the Bridge Owner. For load rating information regarding Railroad bridges, refer to Section 43 of NJDOT Bridge and Structures Design Manual.

This Manual is not applicable for permit load ratings. Currently NJDOT processes permit load ratings using the automated internet-based application Superload. The axle configuration and loading of overweight trucks are defined in the system, along with the proposed route. The system will analyze the information and either issue a permit or deny the request.

2 REFERENCES

The sources listed below were used in the development of this Manual. Persons involved with the load rating of bridges must be knowledgeable in the *latest editions* of all sources below:

- AASHTO. *Manual for Bridge Evaluation.* Second Edition, 2011 (MBE).
- AASHTO. *Standard Specifications for Highway Bridges, 17th Edition, 2002.*
- AASHTO. *LRFD Bridge Design Specifications, 5th Edition* with 2010 Edition, including Interims.
- FHWA. *Bridge Load Ratings for the National Bridge Inventory.* Memorandum HIBT-30. October 30, 2006
- FHWA. *Bridge Inspector's Reference Manual.* NH 103-001, Vols. 1 and 2. October 2002; Revised 2006.
- FHWA. *Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges.* Report No. FHWA-PD-96-001. December 1995 with Errata, March 2004.
- FHWA. *Manual on Uniform Traffic Control Devices, 2009 Edition*.
- NCHRP. *Synthesis 354: Inspection and Management of Bridges with Fracture-Critical Details.* 2005.
- NJDOT. *Design Manual for Bridges and Structures*. 5th Edition, 2009.
- NJDOT. *Recording and Coding Guide*. 2003, Revised 2009.
- NJDOT. *PONTIS Manual*. 2003, Revised 2008.
- Bentley Systems, Inc., *LARS Bridge User Manual*. June 2010.
- Bentley Systems, Inc., *LARS Bridge Specifications Analysis Manual*. August 2010.

The MBE supersedes the AASHTO *Manual for Condition Evaluation of Bridge* and interims with the AASHTO *Guide Manual for Condition Evaluation and Load and Resistance Factor Rating (LRFR) of Highway Bridges.* Revisions based on approved agenda items from annual AASHTO Highways Subcommittee on Bridges and Structures meetings in 2007 and 2008 including interims are also incorporated into the MBE. The MBE was adopted by the AASHTO Highways Subcommittee on Bridges and Structures in 2005. With the initial 2008 publication of the MBE, the Subcommittee conferred archive status on the *Manual for Condition Evaluation of Bridges,* the *Guide Manual for Condition Evaluation and Load and Resistance Factor Rating (LRFR) of Highway Bridges* and all Interim Revisions of both prior bridge evaluation titles.

The FHWA updated the NBIS regulations in December 2009 to define the AASHTO Manual in 23 CFR 650.317 as the MBE, effective January 25, 2010. The AASHTO Manual is included in the NBIS through incorporation by reference (IBR), a technique used by Federal Agencies to include and make enforceable materials published elsewhere without republishing those materials in full text in the agencies' regulations. Using IBR, the FHWA incorporates documents such as AASHTO design standards into 23 CFR part 625 and FHWA's Manual on Uniform Traffic Control Devices into 23 CFR part 655.

The National Bridge Inspection Standards (NBIS) takes precedence over any material contained in the reference manuals i.e. AASHTO Manual.

3 ROLES AND RESPONSIBILITIES

3.1 Bridge Owners

Bridge Owners in New Jersey include the NJDOT, cities, municipalities, counties, agencies and private owners of bridges being used by the public.

Bridge Owners are responsible for:

- Establishing load rating and load posting standard procedures that meet or exceed the National Bridge Inspection Standards as given in Title 23 CFR Part 650 Subpart C, Bridges, Structures, and Hydraulics, for all bridges under their authority. Bridge owners can have their own bridge load rating requirements.
- Ensuring that bridges under their authority have a current and complete bridge load rating.
- Maintaining an updated Load Rating Summary Sheet (LRSS) in the Evaluation Survey Report (see Appendix A for a sample LRSS).
- Submitting the original Load Rating Summary Sheet and the deliverables to NJDOT.
- Load posting the bridge if posting is required.
- Placing load rating data for new bridges into the Bridge Inventory and submitting data to NJDOT along with the inventory (first cycle) Evaluation Survey Report.
- Maintaining complete bridge records in their local office.
- Completing Quality Control (QC) of the load ratings done for bridges under their authority.
- Closing bridges under their authority and maintaining the bridge closure barricades if the bridge is closed for critical findings or due to a current load rating of less than 3 tons, Operating level, in accordance with NBIS.

Bridge Owners and their Consultants are responsible for determining when a bridge must be re-rated.

For critical bridges where load posting is required, the Bridge Owner must be <u>notified immediately</u> and obtain further directions to submit updated rating results.

3.2 New Jersey Department of Transportation (NJDOT)

NJDOT is responsible for ensuring Bridge Owners are in compliance with NBIS.

NJDOT will set the policy for bridge load posting in compliance with NBIS.

NJDOT will be the repository of bridge data including bridge plans, pictures and other records. This repository does not constitute the Bridge Owner's official bridge file.

NJDOT is responsible for completing Quality Assurance (QA) on the data provided for the National Bridge Inventory by the Bridge Owners for compliance with Federal regulations.

NJDOT will be responsible for load ratings and load postings of orphan bridges and New Jersey Transit (NJT) owned highway bridges.

3.3 Load Rating Engineer and Load Rating Reviewer

The Load Rating Engineer (LRE) and Load Rating Reviewer (LRR) may be an employee of the Bridge Owner's organization or a civil engineer from a Consultant firm. The LRE shall comply with all AASHTO, FHWA, and NJDOT documents/policies regarding load ratings, and use sound engineering judgment when completing load ratings. LRE and LRR qualifications are described below:

1. The LRE and LRR are expected to have a working knowledge of LRFD Specifications.

2. The LRR must be a Registered Professional Engineer in New Jersey (NJPE)

The LRR is responsible for the data that is submitted to NJDOT for the National Bridge Inventory.

The LRR signs, dates and seals the Load Rating Summary Sheet with the Registered New Jersey Professional Engineer's Seal. The LRR is also responsible for ensuring that an engineer of equal or greater qualifications than the LRE completes QC on the load rating calculations and the LRSS prior to submittal to the Bridge Owner and NJDOT.

3.4 Consultants Performing Rating for Bridge Owners

Consultants are responsible for being familiar with NJDOT Bridge Inspection Program policies and procedures. Consultants performing load ratings for Bridge Owners are responsible for Quality Control (QC) on their work for accuracy and completeness.

The above mentioned qualifications required for the LRE and LRR also apply to the Consultants.

4 BRIDGE INFORMATION NEEDED FOR LOAD RATING

Bridge Owners must keep the Bridge records needed for load rating and structural analysis, including bridge history records, testing reports, and repair or rehabilitation plans.

NJDOT has developed a Structural Document Management System (SDMS), which is an archive of bridge inspection and related data that has been compiled from information available from a variety of sources for both State and Non-State bridges. NJDOT also archives the as-built and design plans, measurements, shop drawings, Evaluation Survey Reports and inspection photos.

The LRE shall contact the Bridge Owner regarding the availability of data for load rating. The LRE must review all available information to determine the impact, if any, on the load carrying capacity of the structure

Bridge Owners must keep all load rating files (input and output). Load rating files must be submitted to Bridge Owners in accordance with Section 5.4.5 of this Manual.

5 LOAD RATING

5.1 General

Bridges must be rated for both the as-built and as-inspected conditions. As-inspected ratings will be revised over time as the condition of the structure deteriorates. As-built ratings will only be revised following major work and/or rehabilitation.

All new and replacement bridges opened to public traffic must be load rated.

Existing bridges, which are physically altered, during a widening or deck replacement project, where the original deck width or thickness is changed, must be re-rated.

Existing bridges, which are supporting increased dead load, due to a thicker layer of gravel, or having received an overlay on the existing deck, shall be assessed by the Bridge Owner to determine if they will be re-rated. Load rating shall not include the future wearing surface as a dead load because it is not part of the as-built condition.

Existing bridges, which exhibit additional section loss in controlling members, non-controlling members, or critical connections, or damage affecting the section properties as compared to the previous inspection, shall be assessed for possible re-rating. When re-rating a structure due to section losses, all members must be re-rated including non-controlling members for as-inspected conditions. In LARS input files, the LRE only needs to modify those members that exhibit new or additional section losses. Members that do not exhibit any additional section losses do not need to be modified, but should be included in the analyses and final ratings.

Existing bridges, which undergo a drop in condition rating of Item 59 (Superstructure) as follows, may need to be re-rated:

- Condition rating drops from Code 5, Fair Condition to Code 4, Poor Condition
- Condition rating drops from Code 4, Poor Condition to Code 3, Serious Condition

Load ratings shall not be performed for Deck or Substructure elements, except for members mentioned in Section 5.3 or on an as-needed basis.

A prior approval from NJDOT is required before performing any kind of Load Rating of bridge components or other elements.

For Load and Resistant Factor Rating (LRFR), a re-rating would be necessary if there are significant changes in truck traffic volume used for selecting the live load factor.

Re-rating will be necessary if there are any significant changes in the rating specifications, including this Manual.

All existing bridges must be reviewed and assessed by the Load Rating Reviewer (LRR) for possible re-rating.

For further detail on specific bridge elements that require rating, see Section 5.3 of this Manual.

5.2 LARS Load Rating Software

NJDOT has adopted the LARS Bridge software developed by Bentley, Inc., latest version, for load ratings of the bridges in New Jersey. NJDOT recommends that other Bridge Owners and their Consultants use LARS Bridge rating software to maintain the uniformity of the New Jersey Bridge Inventory database.

In order to rate a superstructure systems in LARS, it is necessary to follow a logical progression of rating analysis for a Girder-Floorbeam or Girder-Floorbeam-Stringer systems.

5.3 General Guidance on Load Rating Methodology and Software

In order to maximize efficiency, provide consistency, and facilitate future revisions of load ratings by different parties, NJDOT has adopted the LARS Bridge Suite (latest version) as the acceptable load rating software. If a bridge is capable of being defined within the parameters of the LARS bridge software, it must be rated using LARS.

Bridges that cannot be modeled in LARS shall be analyzed using STAAD, BOX 5, SAP, DESCUS, or other NJDOT-approved software in accordance with the requirements of this Manual.

Table 5.3.1 provides guidance for using the appropriate rating methodology accepted by NJDOT for the load rating of bridges. The Load Rating Engineer and Reviewer of record for any bridge are responsible for using sound engineering judgment in the selection of the appropriate load rating methodology. The list of figures presented in Appendix C serves as a supplement to this table.

TABLE 5.3.1: LOAD RATING METHODOLOGY GUIDANCE

Structure Member Type	Software	LARS Mem. ID	Fig. No.
Steel			
Steel, Multi Beam/Girders, Simple/Continuous Spans	LARS	**G**nn	A3.1.1
Steel, Girder Floorbeam System	LARS*	**G**nn, **B**nn	A3.1.2
Steel, Thru-Girder Floorbeam System	LARS*	**G**nn, **B**nn	A3.1.3
Steel, Floorbeam and Stringer System	LARS*	**B**nn, **S**nn	A3.1.4
Steel, Girder Floorbeam and Stringer system	LARS*	**G**nn, **B**nn, **S**nn	A3.1.5
Steel, Rectangular/Trapezoidal Box Girder	Appropriate tools	**-**	A3.1.6
** LARS analysis will require ratings to be done in a proper sequence. For detail see Appendix A.*			
Prestressed Concrete			
Prestressed Concrete, Voided/Solid Slab, Simple/Continuous Spans	LARS	**G**nn	A3.2.1
Prestressed Concrete, I-Beam, Simple/Continuous Spans	LARS	**G**nn	A3.2.2
Combined Prestressed and Post-tensioned Concrete, I-Beam, Simple/Continuous Spans	LARS	**G**nn	A3.2.2
Prestressed Concrete, Adjacent Box Beam, Simple/Continuous Spans	LARS	**G**nn	A3.2.3
Prestressed Concrete, Spread Box Beam & Standard Sections	LARS	**G**nn	A3.2.4
Prestressed Concrete, Rectangular/Multiple Cell Box	Appropriate	**-**	A3.2.5

Structure Member Type	Software	LARS Mem. ID	Fig. No.
Girders	tools		
Reinforced Concrete			
Reinforced Concrete, Slab, Simple/Continuous Spans	LARS	**G**nn	A3.3.1
Reinforced Concrete I-Beam/T-Beam/Rectangular Beam/Standard Section, Simple/Continuous Spans	LARS	**G**nn	A3.3.2
Timber			
Glue-Laminated Timber Slab, Simple Spans (LRFR Only)	LARS	**G**nn	A3.4.1
Timber Beams, Glue-Laminated Timber Beams, Simple Spans	LARS	**G**nn	A3.4.2
Stress Laminated Timber Slab	Appropriate tools	**-**	A3.4.3
Truss			
Steel, Simple Through Truss-Floorbeam System	LARS	**T**nn, **B**nn,	A3.5.1
Steel, Simple Deck Truss-Floorbeam System	LARS	**T**nn, **B**nn	A3.5.2
Steel, Simple Through Truss-Floorbeam Stringer System	LARS*	**T**nn, **B**nn, **S**nn	A3.5.3
Steel, Simple Deck Truss-Floorbeam Stringer System	LARS*	**T**nn, **B**nn, **S**nn	A3.5.4
Steel, Complex Truss	LARS Complex Truss	**-**	
** LARS Truss analysis will require ratings to be done in a proper sequence. For detail see Appendix A.*			
Other			
Culverts, Concrete, Single/Twin Cell, Frames without Slab with Legs Fixed to Footings	BOX5, BXLRFD, or Equivalent	-	
Three Barrel Concrete Culvert	STAAD, or Equivalent	-	
Culverts, Corrugated Metal Pipe	Ohio DOT Spreadsheet	-	
Precast Three-sided Concrete Culvert	STAAD, or Equivalent	-	
Rigid Frame, Steel or Concrete	STAAD, or Equivalent	-	
Arch, Steel or Concrete or Masonry	STAAD, or Equivalent	-	

Structure Member Type	Software	LARS Mem. ID	Fig. No.
Gusset Plates, Steel, Bolted/Riveted or Welded	NJDOT Spreadsheet, or Equivalent	-	
Curved Girders, Steel Box or I-Girders	DESCUS I, DESCUS II	-	
Pin & Hanger, Steel	-	-	
Complex			
Cable-Stayed, Steel	Appropriate tools	-	
Suspension, Steel	Appropriate tools	-	
Segmental Box, Post-tensioned Concrete	Appropriate tools	-	
Movable, Single/Double Bascule, Vertical Lift, or Swing	Appropriate tools	-	

Load ratings shall include analysis of the following items:

- All elements defined as "primary members", i.e. main load carrying members of the superstructure, including girders, floorbeams, stringers, box beams, truss members, slabs, rigid frames, etc.
- Stringer-floorbeam connections, girder-floorbeam connections and truss member connections.
- Gusset plates, including splice plates (see Technical Advisory T5140.29 in the paragraph below)
- Connection elements for non-redundant steel truss bridges
- Other connections of non-redundant systems (e.g. floorbeam connections, pin and hanger assemblies)
- Non-redundant steel pier caps
- Timber pile bents
- Other substructure elements on as-needed basis, as directed by NJDOT.

FHWA Technical Advisory T5140.29, dated January 15, 2008, recommends that during future recalculations of load capacity on existing non-load path redundant steel bridges, the capacity of gusset plates be checked to reflect changes in condition or dead load, to make permit or posting decisions, or to account for structural modifications or other alterations that resulted in significant changes in stress levels. 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 the gusset plates were adequately considered. 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 Technical Advisory T5140.29.

Refined analysis for distribution of loading will only be accepted with the expressed written consent of NJDOT and should not be undertaken without the prior approval of NJDOT.

The LRFR provisions of MBE Articles 6A.5 (concrete), 6A.6 (steel) and 6A.7 (wood) apply to components of straight or horizontally-curved I-girder bridges and straight or horizontally-curved single or multiple closed-box or tub girder bridges. A 2D grid analysis using the DESCUS computer program would be an acceptable approach in most cases for curved girder ratings. A 3D FEM analysis may be considered for curved girders with tight radius, severe skews, or irregular framing.

Refined methods of analysis are justified where needed to avoid load posting.

Some of the more complex structures (segmental bridges, cable-stayed, etc.) were designed using sophisticated analysis methods. Therefore, a sophisticated level of analysis will be required to rate these structures.

5.4 Load Rating Records

Load rating documentation will be initialed by the Load Rating Engineer (LRE) and Load Rating Reviewer (LRR) with the firm name, date, and the NJPE license number of the LRR.

A complete record of the load rating analyses and results must be maintained as part of the Evaluation Survey Report for each bridge. This includes the electronic file(s) used to perform the analysis.

Accurate and complete data will simplify future efforts to re-rate a structure due to modification or condition deterioration.

5.4.1 Load Rating Deliverables

Load rating deliverables at a minimum shall include the following:

- Load Rating Summary Sheet (LRSS) with original sign and seal by the LRR and retained in the Bridge Owner's Evaluation Survey Report.
- Member Identification Sheet (MIS) with spans and members correctly identified and retained in the Bridge Owner's Evaluation Survey Report.
- The bridge Evaluation Survey Report stating the condition that generated the need for re-rating in the "Conclusions and Recommendations" and "Field Notes" sections.
- Dead load assumptions, calculations and supporting documentation used in the load rating including live load distribution factors and dead load values.
- Relevant as-built drawings, sketches, etc.
- Bridge load rating analysis input file(s) for all members (see Section 5.4.5 of this Manual for naming conventions of LARS input files).
- Output documentation of controlling member(s).
- Load testing results (if performed).
- For LRFR, LRFD distribution factors, Average Daily Truck Traffic, Conditions Factors, Surface Roughness, System Factors, Resistance Factors, and other related inputs must be documented and submitted as a part of LRSS.

5.4.2 Load Rating Summary Sheet (LRSS)

The LRSS shall include the load rating results for the design truck, NJ legal trucks, and any trucks for which the structure was rated. Refer to Appendix E Section E.2 for live loading configurations.

The LRSS shall include all comments, assumptions, and notes involving the load rating.

The Load Rating Reviewer must affix his or her seal and sign the original Load Rating Summary Sheet, and submit the originally signed document to the Bridge Owner and NJDOT.

For all bridges, a Load Rating Summary Sheet must be included in the bridge Evaluation Survey Report. The format of the LRSS and some additional guidance is shown in Appendix A.

5.4.2.1 Load Rating Engineer or Reviewer Inputs

The LRSS shall include the Load Rating Engineer's and Reviewer's name, the firm name, and the New Jersey P.E. license number of the LRR as shown on the license or the New Jersey Board for Professional Engineers registration listings.

5.4.2.2 Additional Comments

The Additional Comments section of the LRSS shall include the following:

- Assumptions, recommendations, posting requirements, and future considerations
- Reason for rating the bridge, and reasons for not rating particular members (if applicable)
- Load path of the superstructure
- The location of critical gusset plates connections within the structure
- The rating methodology applied (if non-standard software was used for computations)

  Examples of comments would include these types of statements:

- "The bridge is currently posted at XX tons."
- "The bridge is currently posted at XX, XX and XX tons for trucks Type 3, NJDOT 3S2 and 3-3, respectively."
- "The calculated bridge load rating is greater than the legal limits for NJ legal trucks; load posting is not required."
- "The calculated bridge load rating is lower than the current posting of XX tons. Load posting must be adjusted accordingly. See Priority 1 Repair letter".
- "The bridge is currently not posted. The calculated load rating is shown above, and the bridge needs to be load posted accordingly. See Priority 1 Repair letter".

5.4.2.3 Load Rating Results

The LRSS shall include LRFR results whenever applicable. The LRSS shall also include *either* ASR *or* LFR results, depending on the structure type and/or the material type. The LRSS should contain data for the controlling member(s) only. Rating data for non-controlling members shall be included as LARS software output *only* in the Evaluation Survey Report in which rating calculations were performed.

5.4.3 Member Identification Sheet (MIS)

NJDOT requires that all primary members be rated. Therefore, there will be bridges that require two or more LARS input (*.BMD*) files to avoid duplicate LARS Member ID's within a single bridge. This establishes a need for a unique member identifier to be used throughout the rating process for referencing and locating specific member.

Unique Member Identifier (UMI) is a unique number across multiple files and is defined as an 8 character code as shown below:

SS-LL###

Where,

SS represents the span number. Begin at 01 for South (or West) span, and increment by one for each adjacent span.

LL is the two-letter code for type of member. See Table 5.4.3.1 for list of codes.

is three digit numbers to represents the member number. Begin at 001 for South (or West) member in Span 1. Upon reaching the next span, start member number at 001 again.

For example,

"01-EG001" is the first exterior girder in span 1

TABLE 5.4.3.1: MEMBER TYPES

Longitudinal Members:		Transverse Members:	
Girder…	**Code**	**Floorbeam…**	**Code**
Exterior Girder	EG	End Beam	EB
Interior Girder	IG	Interior Beam	IB
Thru-Girder, Top	TG	End Cantilever Beam	XB
Thru-Girder, Bottom	BG	Interior Cantilever Beam	YB
Slab *	SG		
GFS System, Truss…	**Code**		
Exterior Stringer	ES		
Interior Stringer	IS		
Through Truss	TT		
Deck Truss	DT		
** Slabs can be modeled as girders with a 1 foot width*			

A sketch will be necessary to clearly show each primary member and its corresponding unique identifier. The sketch will typically consist of a simple framing plan entitled the Member Identification Sheet (MIS), and shall be included in the Evaluation Survey Report for all cycles.

The MIS sketch is not required to be drawn to scale or detailed, but it must be clear. If there is enough space, include the unique member identifier adjacent to the member on the sketch. If the sketch becomes too crowded, you may instead create a table that clearly relates each unique member identifier to the member on the sketch.

Sample sketches are shown in Appendix A, along with two sample MIS pages and some general guidelines for proper member identification.

MIS shall be created for the first time a structure is rated. If MIS is not created for an existing structure, it shall be created in the cycle in which next ratings are performed. MIS should not require revisions, unless the structure undergoes major rehabilitation and/or widening. Once created, MIS shall be part of each Evaluation Survey Report. The LRE for future ratings shall review the existing MIS for completeness and accuracy.

5.4.4 LARS Member ID

LARS Member ID is a key field used in the LARS software. LARS Member ID for each member must be a three digit code as per LARS Bridge User Manual, such as G01, with "G" being a specific letter based on the member type as Girder and "01" being a unique two-digit number up to 99.

5.4.5 LARS Files

LARS files must adhere to the following limitations:

- Structure – single structure processed at a time (i.e. all modeled members in a single LARS input file, up to 50 as mentioned below)
- Flexural Members – 50 members per structure
- Flexural Spans – 20 spans per continuous member
- Flexural Ranges – 500 ranges per member
- Flexural Sections – 99 sections per member
- Flexural Checkpoints – total of 428 per member including default of 2 checkpoints per span plus an additional checkpoint for the end span
- Truss Span – 9 spans per continuous truss
- Truss Panels – 90 panels per truss
- Truss Members – 500 members per truss
- Truss Panel Point Loads – 100 per truss

If a bridge cannot be rated due to LARS limitations, please contact the NJDOT Project Manager for further guidance.

Bridges with members of differing materials (steel, prestressed concrete, reinforced concrete and timber) can be modeled in a single LARS file, unless the number of members exceeds the LARS system limitations outlined above. In such cases, additional LARS file(s) can be created.

It is required that LARS files be named according to the following convention:

"***SSSSSSS_YYYYMMDDcyXX_ NNofNN.bmd"***

Where,

SSSSSSS represents structure number (7 characters)
YYYYMMDD is the date on which rating is completed (8 digits)
cyXX is the cycle number in which rating is performed (4 characters)

NNofNN represents a simple sequenced number out of the total number of files associated with one structure. (2 digits, 2 characters, 2 digits)

.bmd is the file extension for LARS input file.

Examples: "1227154_20081212cy12_01of01.bmd"
"3001960_19981212cy08 _01of02.bmd"
"3001960_19981212cy08 _02of02.bmd"

Similar naming convention can be used if using any other rating software other than LARS.

5.4.6 LARS Material Codes

TABLE 5.4.6.1 - RATING MATERIAL TYPE CODE

***ZZZ* Code** (3 characters)	**Composite Action?**	**Description**
SS_	N	The member is structural steel without a composite slab. The member may be a plate girder, standard section or combination of the two. Non-standard sections can be included under this category, which does not compute deck slab self-weight. Concrete encased steel beams are included in this category when non-composite action is considered.
CSC	Y	The member is composed of structural steel and a composite concrete slab. The slab can be composite over different ranges along the member. Non-standard sections can be included under this category which computes deck slab self-weight. Concrete encased steel beams can be included in this category if composite action is considered.
HS_	N	The member is hybrid structural steel consisting of web and flange elements having different yield strengths. These members have no composite slab.
HSC	Y	The member is composed of hybrid structural steel and a composite concrete slab. The slab can be composite over different ranges along the member.
PSC	N	The member is prestressed concrete including both prestressed and non-prestressed steel
CPC	Y	The member is composed of a prestressed concrete section and composite concrete slab. The slab can be composite over different ranges along the member.
RC_	N	The member is reinforced concrete (concrete section and reinforcing steel).
TMB	N	The member is timber.

5.5 Load Rating Methods

Load Rating Engineers and Reviewers shall be familiar with the latest FHWA Memorandum for Bridge Load Ratings for the National Bridge Inventory.

All existing bridges shall be load rated for all primary members for Allowable Stress Rating or Load Factor Rating (ASR/LFR), and Load and Resistance Factor Rating (LRFR) analyses in accordance with the requirements of this Manual, the MBE, the latest AASHTO Allowable Stress Design (ASD), Load Factor Design (LFD), and Load and Resistance Factor Design (LRFD) Specifications.

For bridges designed with HL-93 as a design vehicle (using LRFD Specifications) report the LRFR results as the Final Ratings in the SI&A data. For bridges not designed with HL-93, report the LFR results as the Final Ratings in the SI&A data.

For load posting purposes, use the higher rating values of the different methodologies by a comparison of the State legal loads. For cases where the controlling methodology varies amongst the State legal loads, report the values obtained by the design methodology used for the bridge.

Note that ASR is not permitted for bridges on the National Highway System (NHS); all NHS bridges must be load rated using LFR and LRFR. ASR is only permitted for non-NHS bridges where required by State (including timber, masonry, truss spans under 500' in length, and wrought iron).

5.5.1 Load and Resistance Factor Rating (LRFR)

Load and Resistance Factor Rating compares factored load effects to the resistance of a member of a given material in accordance with the MBE LRFR. Bridges designed by LRFD Specifications using HL-93 shall be computed and reported to the NBI as a Rating Factor (RF) based on LRFR results.

The general rating equation in LRFR (MBE Eq. 6A.4.2.1-1) is given as:

$$RF = \frac{\phi_c \ \phi_s \ \phi \ R_n - (\gamma_{DC})(DC) - (\gamma_{DW})(DW) \pm (\gamma_p)(P)}{(\gamma_L)(LL + IM)}$$

In the LRFR Rating Factor equation above:

RF = Rating Factor
R_n = Nominal member resistance (as inspected)
ϕ_c = Condition Factor
ϕ_s = System Factor
ϕ = LRFD Resistance Factor

DC = Dead load effect due to structural components and attachments
DW = Dead load effect due to wearing surface and utilities
P = Permanent loads other than dead loads (secondary pre-stressing effects, etc.)
LL = Live load effect of the rating vehicle
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_{p} = LRFD load factor for permanent loads other than dead loads
γ_{L} = Evaluation live load factor for the rating vehicle

For NJDOT, the LRFR analyses shall be performed using HL-93 as a design vehicle, Type 3, NJDOT Type 3S2, and Type 3-3 as legal loads, and HS20 as a rating vehicle. The γ-values for HS20 shall be the same as those used for HL-93. NJDOT does not currently rate for Specialized Hauling Vehicles as they are not in common use in New Jersey.

For other Bridge Owners, the LRFR analyses can be performed as per Owner's requirement.

5.5.2 Load Factor Rating (LFR)

Load Factor Rating compares factored load effects and stresses to the strength of a member of a given material, which typically is less than a material's strength limit. The policy of NJDOT is to use LFR for steel and concrete elements using HS20 and legal loads, including H15 if required by the Bridge Owner.

5.5.3 Allowable Stress Rating (ASR)

Allowable Stress Rating compares unfactored load effects and stresses to an allowable stress for a given material in accordance with the MBE. The policy of NJDOT is to compute ASR on timber, wrought iron, and masonry elements, and also for truss members with spans less than 500 feet in length. Also, NJDOT requires using ASR for HS20 and legal loads, including H15 if required by the Bridge Owner.

5.6 Load Rating Levels

Load rating levels are defined in the MBE and are briefly summarized in this section.

5.6.1 LFR and ASR Levels

The following load rating levels are applicable for LFR and ASR methodologies.

5.6.1.1 Inventory Level

The AASHTO MBE states that "Inventory rating level generally corresponds to the customary design level of stresses but reflects the existing bridge and material conditions with regard to deterioration and loss of section. Load ratings based on the Inventory level allow comparisons with the capacity for new structures and, therefore, results in a live load which can safely utilize an existing structure for an indefinite period of time."

Inventory level corresponds to the design level capacity with consideration of member condition and loss of section. Load effects are compared to the calculated Inventory level capacity.

5.6.1.2 Operating Level

The AASHTO MBE states that "Operating rating level generally describes the maximum permissible live load to which the structure may be subjected. Allowing unlimited numbers of vehicles to use the bridge at Operating rating may shorten the life of the bridge."

Operating level corresponds to the maximum permissible level of load capacity with consideration of a member condition and loss of section. Load effects are compared to the calculated Operating level capacity.

5.6.1.3 Posting Level

Posting level corresponds to a load capacity selected by the governing agency for load posting bridge structures. NJDOT's policy is that a bridge will need posting if the <u>load effects exceed the maximum permissible level of load capacity, i.e. Operating level</u>.

5.6.2 LRFR Levels

The following load rating levels are applicable for LRFR methodology.

5.6.2.1 Design Load Rating

Design load rating applies HL-93 and LRFD design standards to the bridge in its present as-inspected condition to measure the performance of an existing bridge against current standards. The LRFD design level of reliability (Inventory Load Factor) is comparable to a traditional Inventory rating. The second lower level of reliability (Operating Load Factor) is comparable to a traditional Operating rating. The results are suitable for NBI and BMS reporting.

5.6.2.2 Legal Load Rating

Legal load rating provides a single safe load capacity for each State legal load. The rating results are used to determine if a structure requires load posting and/or strengthening measures.

5.6.2.3 Permit Load Rating

Permit load ratings verify the safety and serviceability of bridges handling vehicles that exceed the State legal loads. NJDOT is not calculating Permit load ratings at this time.

5.6.2.4 Load Posting

A structure shall be load posted when a State legal load rating factor is calculated as less than 1.

5.7 Load Rating Vehicles

Standard vehicles used in the load rating analyses are shown in the Table 5.7.1. See Appendix E for information on New Jersey legal axle weight limits.

TABLE 5.7.1: VEHICLE LEGAL WEIGHTS

Vehicle Type	AASHTO Weight	New Jersey Legal Weight
H15	15 Tons	15 Tons
H15 Lane Load	*See Notes 1 & 2*	
HS20	36 Tons	36 Tons
HS20 Lane Load	*See Notes 1 & 2*	
Type 3	25 Tons	25 Tons
Type 3S2	36 Tons	**40 Tons**
Type 3-3	40 Tons	40 Tons
HL-93	*Notional Load (NL)*	

Note:

1. For simple spans, see AASHTO Standard Specifications, Figures 3.7.6B – “Lane Loading” for ASR/LFR analyses.
2. For continuous spans, see AASHTO Standard Specifications, Article 3.11.3 – “Lane Loads on Continuous Spans” for ASR/LFR analyses.
3. NJDOT does not currently rate for Specialized Hauling Vehicles as they are not in common use in New Jersey.

All State-owned bridges must be load rated for the AASHTO design trucks. Compute applicable Inventory and Operating level ratings for HS20 (truck and lane loads), HL-93 and New Jersey legal loads (Type 3, NJDOT Type 3S2 and Type 3-3 trucks). Bridges owned by other Agencies must be load rated for vehicles mandated by that Bridge Owner.

Wheel loads for analysis shall be equal to half of the axle load for a given truck.

5.8 Analysis Considerations

5.8.1 Load and Distribution Factors (D.F.)

Parameters such as load factors and distribution factors shall be determined by the LRE or LRR using the current editions of the MBE, AASHTO Standard Specifications for Highway Bridges, and LRFD Bridge Design Specifications.

5.8.1.1 ASR/LFR Distribution Factor for Moment and Shear in Wheel Loads

Based on different structure configurations, two tables – Table B.1.1 and Table B.1.2 are developed and included in Appendix B, Section B.1 of this Manual.

5.8.1.2 ASR/LFR Distribution Factor for Moment and Shear for Floorbeams in Wheel Loads

To calculate D.F. for moment and shear for the floorbeams which are directly supporting the deck/floor system of the bridge, use Table 3.23.3.1 of the AASHTO Standard Specifications (current edition). If the deck/floor system is not directly supported by the floorbeams (in this case it is supported by the stringers), then there is no need to calculate the D.F. for Floorbeams.

5.8.1.3 LRFR Distribution Factors

See Appendix B, Section B.2 of this Manual for calculating LRFR Distribution.

5.8.2 Loads

5.8.2.1 Dead Load

The dead load effects on the structure shall be computed in accordance with the conditions existing at the time of analysis. Dead loads should be based on dimensions shown on the plans and verified with field measurements.

The self-weight of the member being rated is automatically computed by LARS.

Two types of dead loads shall be computed for load rating:

- Dead load DL1, which consists of diaphragms, bracings, stiffeners, utilities, encasements (if any), SIP forms, etc.

- Dead load DL2, which consists of superimposed loads, which includes sidewalks, parapets, railings, median barriers, superimposed utilities, overlays, etc.

DL1 shall be included as part of the stage 1 dead load in addition to what LARS computes automatically. It can be entered into LARS using the ***Description→ Dead Load*** command and selecting the ***Continuous Constant (Stage 1)*** option, as shown below, for the Load Type.

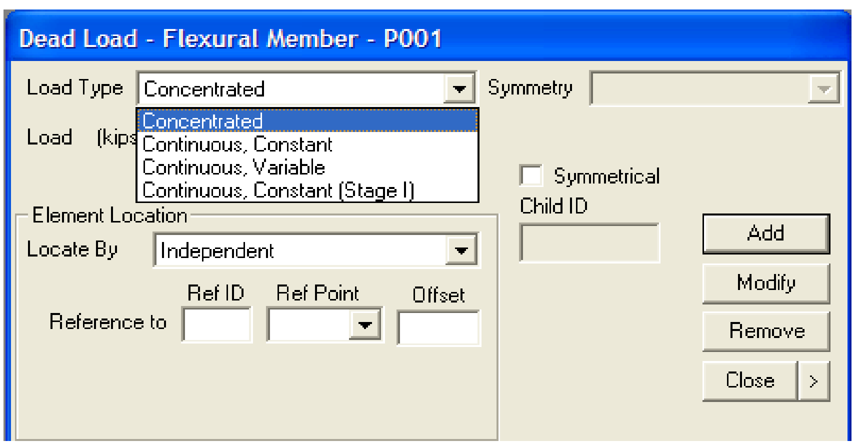


FIGURE 5.8.2.1.1: LARS STAGE 1 DEAD LOAD INPUT SCREEN

Any loads entered in this manner will be added to the automatically calculated dead load for stage 1 analysis. This applies for LRFR, LFR and ASR rating.

For non-uniform height or thickness of parapets or pylons, DL2 shall be calculated by taking the average of the thickness and height and distributing accordingly as per the type of structure.

For supplementary dead load components on truss bridges, an increase in dead load shall be included based on the engineering judgment of the LRE, but shall not be less than 5% of the dead load of the primary members. In LARS, this increase is not accounted for automatically.

For composite structures, superimposed load DL2 shall be calculated in accordance with conditions existing at the time of analysis and distributed to each girder in linear feet.

Minimum unit weights of materials used in computing dead loads DL1 shall be in accordance with current AASHTO Standard Specification in the absence of more precise information.

TABLE 5.8.2.1.1: MATERIAL UNIT WEIGHTS

Material *	lb/ft^3
Steel or cast steel	490
Cast iron	450
Aluminum alloys	175
Timber (treated or untreated)	50
Concrete, plain or reinforced	150
Lightweight concrete	120
Compacted sand, earth, gravel or ballast	120
Loose sand, earth and gravel	100
Macadam or gravel, rolled	140
Cinder filling	60
Pavement, other than wood block	150
Railway rails, guiderails and fastenings (per linear foot of track)	200
Stone masonry	170
Asphalt plank 1 in. thick	9 (psf)
Asphalt overlay	150
Polymer concrete overlay	150

**For additional loads, see Appendix E Section E.1 of this manual*

For non-composite structures, superimposed load DL2 shall be calculated in accordance with conditions existing at the time of analysis and applied to specific girders, which are handling the superimposed load. An example for the load distribution for a median barrier (DL2) in between two girders is shown in the sketch below:

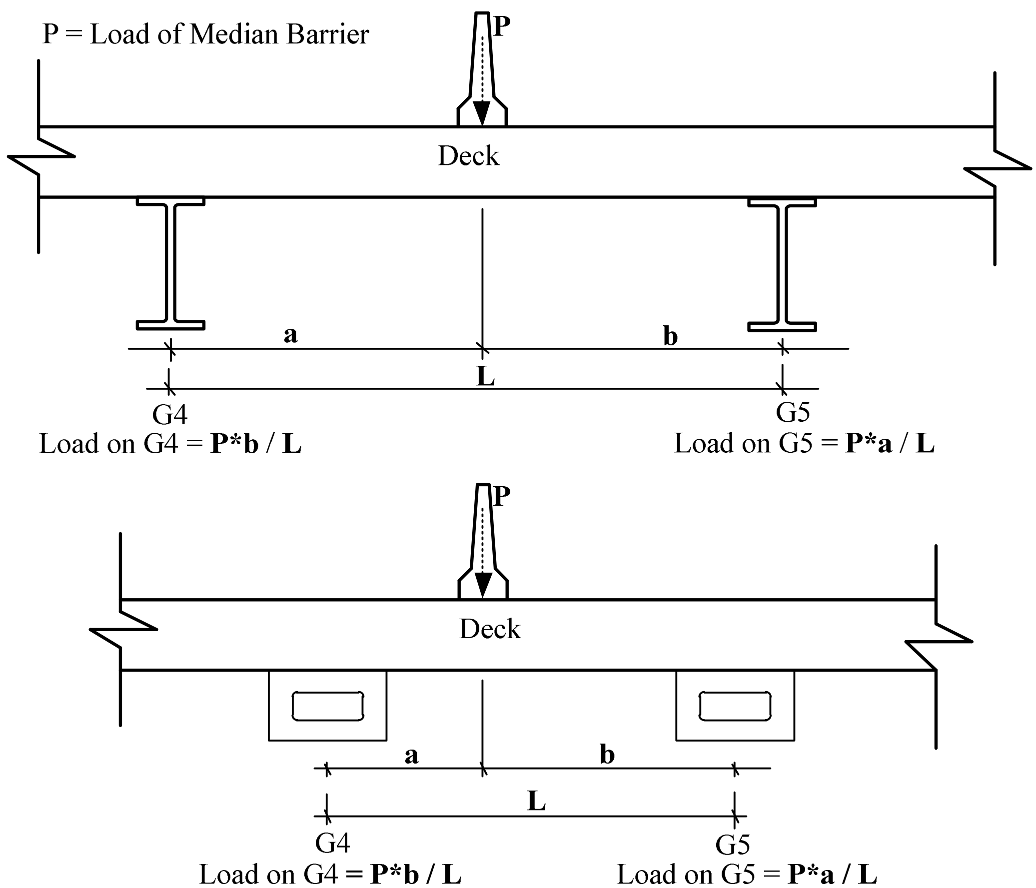


FIGURE 5.8.2.1.2: SAMPLE LOAD DISTRIBUTION FOR MEDIAN BARRIER

5.8.2.2 Live Load

LFR/ASR live load models to be used in the rating of bridges are selected based upon the purpose and intended use of the rating results. LRFR live load models outlined below shall be evaluated for the Strength and Service limit states in accordance with table below:

TABLE 5.8.2.2.1: APPLICABLE LIMIT STATES

Bridge Type	LRFR Limit State	Design	State Legal Loads
		HL 93	Type 3, NJDOT Type 3S2, Type 3-3
Steel	Strength I	●	●
	Service II	●	●
Reinforced Concrete	Strength I	●	●
Prestressed	Strength I	●	●
	Service III	●	●
Timber	Strength I	●	●

Each bridge shall be load rated for the following live load models:

1. **Design load rating** is a first-level rating performed for all bridges (including bridges designed using the Standard Specifications) using HL-93 loading at the Inventory (design) and Operating levels.

2. **Legal load rating for routine commercial traffic**: Rate for the NJ state legal loads: Type 3, NJDOT Type 3S2, and Type 3-3.

5.8.2.3 Lane Load

The Bridge Owner must use the standard AASHTO HS20 lane load for all span lengths where it may result in load effects which are greater than those produced by the AASHTO standard HS20 truck loading.

HS20 live load truck models in LARS include the effects of lane loading for the rating analysis.

5.8.2.4 Sidewalk Load

Primary load carrying members shall not be rated if the LRR determines that the member does not take any truck loading, due to the presence of wide sidewalks, as per the NJDOT Design Manual for Bridges and Structures, Section 43. This situation shall be clearly documented in the LRSS "Rating Comments" section, if applicable.

5.8.2.5 Live Load Effects

Live load moments in longitudinal stringers and girders may be calculated using the MBE Tables C6B-1 and C6B-2 for live load moments produced by the HS20/H15 load. Live load moments in the intermediate and end floorbeams of trusses and thru-girders may be calculated by using the MBE Tables D6B-1, D6B-2, E6B-1, and E6B-2. The tables, along with the moment formulas on the same sheets, provide a convenient means of computing the live load moments based on the HS20/H15 load.

Live loads in truss members can be calculated by using the formulas for maximum shear and moments given in the MBE Appendices F6B through J6B. Using these formulas will give the maximum live load stresses for the HS20/H15 truck.

5.8.2.6 Distribution of Loads

The fraction of live load transferred to a single member should be selected in accordance with the current AASHTO Standard and LRFD Specifications. These values represent a possible combination of diverse circumstances. The option exists to substitute field-measured values, analytically-calculated values, or those determined from advanced structural analysis methods based on the properties of the existing structure. Loadings shall be placed in positions causing the maximum response in the components being evaluated.

5.8.2.7 Roadway Width / Numbers of Lanes

The number of traffic lanes to be loaded and the transverse placement of the wheel line shall be in conformance with the current edition of the MBE Section 6B.6.2.2 and the following:

- Roadway widths from 18 to 20 feet shall have two traffic lanes, each equal to one half the roadway width.
- Roadway widths less than 18 feet shall carry one traffic lane only.

5.8.2.8 Dynamic Load Allowance (IM)

Dynamic Load Allowance shall be added to the live load used for rating in accordance with the current AASHTO Standard Specifications, Table 3.8.2.1 and LRFD Specifications, Table 3.6.2.1.1.

Dynamic Load Allowance may be reduced if the truck crossing the structure has a travelling speed of 10 mph or less. Additionally IM can be reduced based on the conditions of deck wearing surface and deck joints. See Appendix E, Section E.3.3 of this Manual for more details.

5.8.2.9 Deflection

Live load deflection limitations should not be considered in load rating except in special cases.

5.8.2.10 Longitudinal Loads

The rating of the bridge members to include the effects of longitudinal loads in combination with dead and live load effects should be done at the Operating level. Where longitudinal stability is considered inadequate, the structure may be posted for restricted speed. In addition, longitudinal loads should be used in the evaluation of the adequacy of the substructure elements.

5.8.2.11 Wind

Lateral loads due to wind normally shall not be considered in load rating. However, the effects of wind on special structures such as movable bridges, suspension bridges, and other high-level structures should be evaluated.

5.8.3 Material Strength

Stress levels for Operating and Inventory ratings shall be determined by the LRE using the latest applicable AASHTO MBE, AASHTO Standard Specifications and AASHTO LRFD Bridge Design Specifications.

For steel structures with an unknown date of construction, yield strength shall be based on best available information or coupon testing.

Coupon testing is one method used to determine the unknown yield strength of a steel member. For more information, refer to the latest AASHTO Manual for Bridge Evaluation, Section 5.3 for Material Sampling, Section 5.4 for Laboratory Test, and Section 5.6 for Testing Report. For this approach, prior NJDOT approval is required.

In the absence of other data, it should be assumed that the structure was built prior to 1905.

The NJDOT modifications to MBE Table 6A.6.2.1 are as follows:

TABLE 5.8.3.1: NJDOT MODIFICATIONS TO MBE

Year of Construction	Minimum Yield Strength, ksi	Minimum Tensile Strength, ksi
Prior to 1905	26.5	53
1905 to 1936	30	60
1936 to 1963	33	66
After 1963	36	66

The allowable stresses listed in MBE Table 6B.5.2.1-2 and 6B.5.2.1-1 (for Operating and Inventory ratings, respectively) are not absolute, but rather are intended to provide general guidance. These allowable stresses may be modified if other values can be justified by test results, more detailed information of the materials, more refined structural analysis, consideration of traffic types and volumes, frequency of interim inspection or other related factors.

For concrete in Bending, MBE 6B.5.2.4.1 Page 100, the allowable stresses for compression due to bending should be 0.40 f'_c for Inventory and 0.55 f'_c for Operating ratings provided that the field investigation indicates that the concrete is sound and that contract plans and controls specified and furnished compressive strengths of 2,400 psi or more.

For prestressed concrete, MBE 6B.5.2.5 Page 102, the allowable stresses in the pre-compressed tensile zone of prestressed concrete members is specified in the AASHTO Standard Specifications for Highway Bridges, Article 9.15.2.2. For calculating Inventory ratings by the working stress or load factor (serviceability) methods, an allowable tension stress of $3\sqrt{f'_c}$ shall be utilized for members with bonded reinforcement.

Truss members may be modeled in LARS by inputting the section properties calculated manually. If trusses have eye bars that are loose, cracked or gapped, they shall not be considered effective when calculating a load rating. Eye bars with forged seams should be noted on the LRSS comment section, but the member may be considered effective when calculating a load rating.

5.8.4 Deck Load Rating

NJDOT policy is not to perform deck load ratings.

5.8.5 Span Lengths

The span length considered for load rating analysis is the distance between the centerlines of bearing. For more information, refer to latest AASHTO Standard Specifications and AASHTO LRFD Bridge Design Specifications.

For slab bridges, see AASHTO Standard Specification, Article 3.24.1.1 and Article 8.8.

5.8.6 Plate Girder Stiffeners

Stiffeners should be included in the load rating analysis to determine the shear capacity.

5.9 Special Considerations

5.9.1 Steel

5.9.1.1 Fracture Critical (FC) Structures

Steel fracture critical structures with fatigue-prone connection details (pins, gusset plates, etc.), require connections be rated if the connection shows any sign of deterioration, or if the dead load supported by the structure has increased over that originally imposed on the bridge. The LRE should evaluate the fatigue of the detail with due consideration of the ADTT.

5.9.1.2 Steel Thru-Girders

Compression flanges of thru-girders shall be assumed to be braced if knee bracing is present.

It is assumed that floorbeams are attached to vertical transverse stiffeners that are attached to the compression flange.

5.9.2 Timber

Evaluation of the load capacity of the existing timber members requires knowledge of the material species, grade of the timber and current condition after the effects of any deterioration.

For the design values and adjustment factors (such as Wet Service Factor, $\mathbf{C_M}$, Load Duration Factor, $\mathbf{C_D}$, etc.), follow the AASHTO Specifications for Wood (Timber) structures.

If the bridge plans are not available, the data collection, inspection and field measurement will be required.

Critical connections of timber bridges shall be evaluated only if the connections are shown to have deterioration or signs of distress.

If substructure elements are shown to have deterioration or signs of distress, it may be evaluated for load rating. Design stress values shall be based on species and grade as given in AASHTO (2002).

5.10 Bridges without Plans

5.10.1 General

Load ratings should be determined by calculations based on plans and current conditions found in the bridge's Evaluation Survey Report. Steel and timber bridges without plans must be field measured to provide the Load Rating Engineer with the dimensional data necessary to complete the load rating.

5.10.2 Load Rating Based on Load Testing

The load rating of an individual structure can be obtained through load testing. The Bridge Owner shall make this decision on a case-by-case basis after consultation with the LRR. It is not advisable to perform load tests on concrete bridges with no plans.

5.10.3 Load Rating Based on Engineering Judgment

The load rating for a structure can be estimated with engineering judgment based on available data, condition of the structure and the NJDOT memorandum dated September 8, 2008, entitled Load Capacity Ratings by Engineering Judgment. The Bridge Owner shall make this decision on a case-by-case basis after consultation with the LRR.

5.10.4 Steel Bridges with Concrete Decks

Steel bridges with concrete decks that have no plans shall be rated as though there is no composite action between the steel girders and the deck.

6 BRIDGE LOAD POSTING

6.1 General

The Bridge Owners must have a current load rating in the bridge database at the Owner's office.

Bridges capable of carrying New Jersey legal loads do not require posting.

Federal Register states –

> ***"Rate each bridge as to its safe load carrying capacity in accordance with the AASHTO Manual (incorporated by reference, see § 650.317). 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."***

If the Operating level load rating is less than New Jersey legal weights for the Type 3 (25 tons), NJ Modified Type 3S2 (40 tons), and Type 3-3 (40 tons), the bridge shall be load posted as determined by the Load Rating Reviewer (LRR).

Any bridge, which has SI&A Item 70 coded less than 5, must be load posted.

All bridges requiring posting shall be posted at the Operating level or below for ASR/LFR, or the safe posting load for LRFR. All bridges rated less than 3 tons shall be closed and barricaded to all traffic.

Bridge Owners and their Consultants are responsible for reviewing Evaluation Survey Reports and assessing the structures for the need to revise the load rating.

Bridge Owners shall be notified immediately by the Load Rating Reviewer if a structure's load rating indicates load posting is required, or if an existing posting needs to be revised, or if the bridge should be closed due to ratings.

6.2 Load Posting Signs

NJDOT requires that signs be installed and that the Bridge Owner provide written notification to the Program Manager immediately after the load rating date that documents the load restriction is required.

The weight limit sign shall be used to indicate restrictions pertaining to total vehicle weight including cargo.

Weight limit signs should be installed in accordance with the Manual of Uniform Traffic Control Devices. NJDOT also recommends that advance notice signs be installed at the intersections closest to the load posted bridge.

Bridge Owners can load post a bridge for other reasons besides load rating.

7 QUALITY CONTROL

Quality Control (QC) is a system of routine technical activities, to measure and control the quality of the bridge load rating data as it is being developed. The QC system is designed to include general methods such as accuracy checks on data acquisition and calculations, and the use of approved procedures for measurement, calculation, recording information and reporting.

In cases where computer programs are used, the Load Rating Engineer (LRE) and Load Rating Reviewer (LRR) shall perform independent checks to validate the accuracy of the load ratings results generated by the program. The final load rating results shall be verified by the LRE.

Both LRE and LRR shall complete Quality Control review on the load ratings work produced.

LRE and LRR shall make sure that the technical load rating activity has followed procedures as set by NJDOT, provide routine and consistent checks for data integrity, correctness and completeness, identify and address errors and/or omissions, and record the QC activities.

QC must be done on deliverables prior to submittal to the Bridge Owner in accordance with approved NJDOT Standards.

8 QUALITY ASSURANCE

Quality Assurance (QA) procedures are required to verify the accuracy and adequacy of the Quality Control procedures to meet or exceed the standards established by the agency or the Consultant.

Guidance on quality measures for load rating may be found in Manual of Bridge Evaluation, Article 1.4.

Ratings for each structure will be complete only after review by the concerned Project Manager and acceptance by Load Rating Review Team at NJDOT.

APPENDIX A – ADDITIONAL GUIDANCE FOR LRSS AND MIS

A.1 Load Rating Summary Sheet Instructions

The Load Rating Summary Sheet (LRSS) shall be submitted as part of the Evaluation Survey Report. This sheet must be completed in its entirety. If rating calculations have been performed in the current cycle, the LRSS should be signed and sealed by a Registered Professional Engineer. If rating calculations were performed in a previous cycle(s), then the LRSS include the latest load rating data.

A.1.1 Additional Remarks for Section Loss

Section loss for load rating considerations will vary based on the structure and the material(s) types.

Steel beams (rolled sections, built-up members, etc) can exhibit section loss through corrosion, delamination, and/or collision damage.

Primary reinforcement in concrete members (rebar, pre-tensioning strands, etc.) can also demonstrate section loss from corrosion or collision damage.

Timber members may experience section loss through rot and decay, marine borers, insect damage, etc.

NJDOT requires that the remaining section be measured and documented in the Evaluation Survey Report. Regardless of the material, it is important that the extent of section loss be accurately recorded and modeled to ensure proper rating calculations.

A.1.2 Additional Remarks on Superstructure Systems

The LRE must accurately determine the load path of each structure prior to rating.

The load path should be clearly identified in the Rating Comments section of the LRSS.

A.1.3 Load Rating Summary Sheet Sample

A sample form NJ-BI-101 for LRSS is shown below:

Structure No.: ####-### Route: ## Cycle No.: ##
Name: I ## over XX Road and XX River or Railroad Insp. Date: MM/DD/YYYY

LOAD RATING SUMMARY SHEET (LRSS) (Revise as required)
(Form NJ-BI-101 Created 1/25/2011)

Project Information:

Group: ________ Agreement No.: ______________ Contract ID: _____________ Agree/Mod No.: ______

Rating Information:

Method: LRFR: Yes / No LFR: Yes / No ASR: Yes / No Other (Specify): ___________

Rating Date: ___________ Computer Software Used: _________________ Version: ___________

Load Testing: Yes / No Cycle when Rating Performed: _____________ Design Load: ___________

Structure Information: (Indicate N/A where appropriate)

Plans Available? Yes / No Contract Designation: ______________________________________

Overlay? Yes / No Considered in Rating? Yes / No Type/Thickness: ___________________

Section Losses? Yes / No Considered in Rating? Yes / No Item 59 Cond.: ___________________

For LRFR Use Only: (Indicate critical value if it varies amongst different members)

Dynamic Load Allowance: __________ Condition Factor: ___________ System Factor: __________

ADTT (one direction): __________ Resistance Factor: ___________ FCM: Yes / No

Load Rating Engineer (LRE):

Name: __________________________ Firm: ________________________________ Initial: _________

Load Rating Reviewer (LRR) certification as per the NBIS Title 23 CFR Section 650.309(c):

Name: ____ N.J. P.E. No.: ________________________

Firm: ____

I certify that this rating is an accurate representation of the subject structure, considering all deterioration and/or changes to loading conditions, to the extent determinable by research and visual inspection and testing performed. I am charged with the overall responsibility for bridge capacity evaluation for the above mentioned structure.

Sign and Seal if Rating Performed in this Cycle

Sign, seal, and date, if rated this cycle.
Sign Date

##-#

Structure No.:	####-###	Route:	##	Cycle No.:	##
Name:	I ## over XX Road and XX River or Railroad			Insp. Date:	MM/DD/YYYY

LOAD RATING SUMMARY SHEET (LRSS) (*cont.*)

Rating Comments:

List any assumptions. List any comments on posting requirements. Indicate the specific reason(s) for rating the bridge. Indicate the load path of the structure. Indicate all superstructure members that have not been considered in this rating. If non-standard rating software is used, indicate methodology used for rating calculations. List any considerations that may simplify future ratings. Add lines as necessary.

The Load Factor/Working Stress and LRFR ratings, computed in accordance with the FHWA directive dated November 1993, AASHTO Manual for Bridge Evaluation, 2011, as modified by the NJDOT Highway Bridge Load Rating Manual and Section 43 of the NJDOT Design Manual, Bridges and Structures, are as follows:

		Allowable Stresses (Psi)			
Material add/delete as necessary	**Compressive Strength f'c**	**Tensile Strength**	**Yield**	**Inventory**	**Operating**
Concrete		---	---		
Concrete (Beam)		---	---		
Structural Steel	---	---			
Reinforcing Steel	---	---			
Prestressing Steel	---			---	---

			Rating (Tons) / Rating Factor							
			ASR -or- LFR				LRFR			
Member	**Truck Type (Tons)**		As-Built		As-Insp.		As-Built		As-Insp.	
			Inv.	Op.	Inv.	Op.	Inv.	Op.[1]	Inv.	Op.[1]
Interior Stringer[2] 02-IG003 Cond. Rating = # Include the location(s) and remaining section (in inches) of any section loss, if applicable.	H15	(15T)								
	HS-20	(36T)								
	3	(25T)					---		---	
	3S2	(40T)					---		---	
	3-3	(40T)					---		---	
	HL-93	(NL)	---	---	---	---				
Interior Stringer[2] 03-IG002 Cond. Rating = # Include the location(s) and remaining section (in inches) of any section loss, if applicable.	H15	(15T)								
	HS-20	(36T)								
	3	(25T)					---		---	
	3S2	(40T)					---		---	
	3-3	(40T)					---		---	
	HL-93	(NL)	---	---	---	---				

[1] Operating level rating of design load or legal load rating
[2] Controlling Member
NL – Notional Load

##-#

A.2 Member Identification Sheet (MIS) Sample and Guidelines

The MIS is discussed thoroughly in Section 5.4.3. Refer to the examples provided below for clarification on member identification.

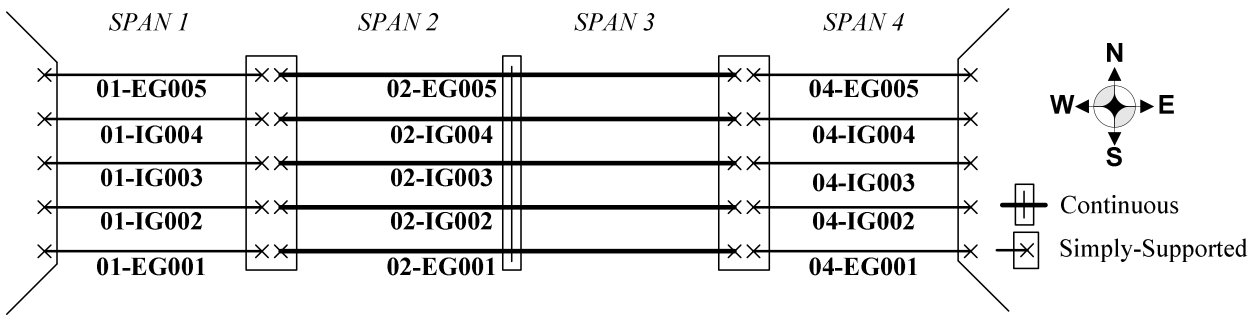


FIGURE A.2.1: MIS EXAMPLE 1

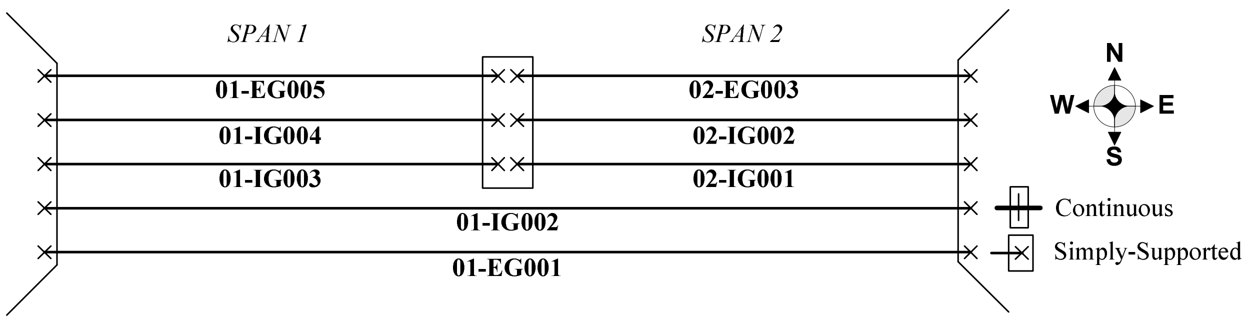


FIGURE A.2.2: MIS EXAMPLE 2

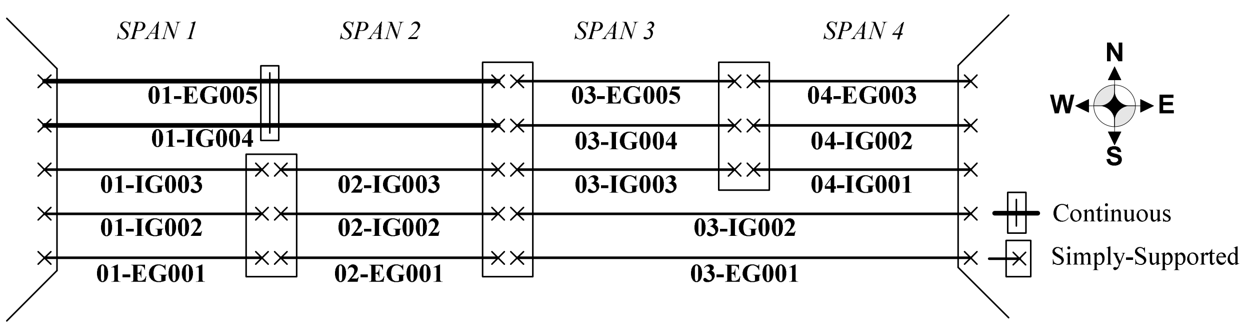


FIGURE A.2.3: MIS EXAMPLE 3

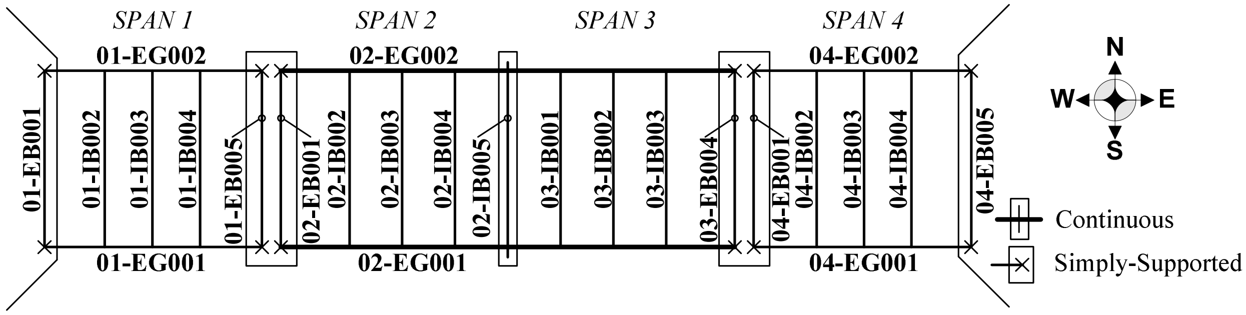


FIGURE A.2.4: MIS EXAMPLE 4

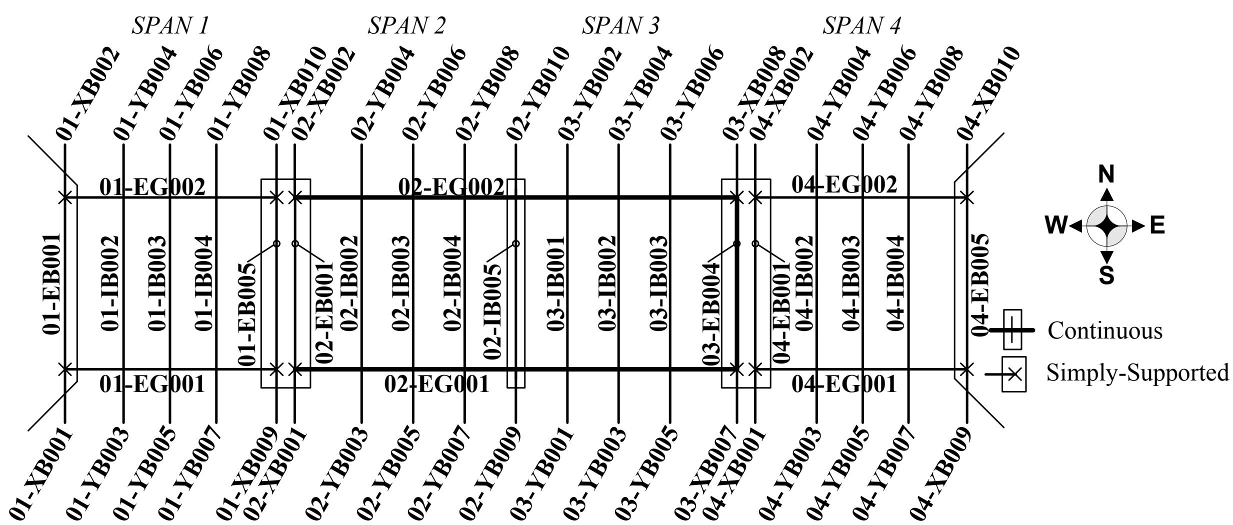


FIGURE A.2.5: MIS EXAMPLE 5

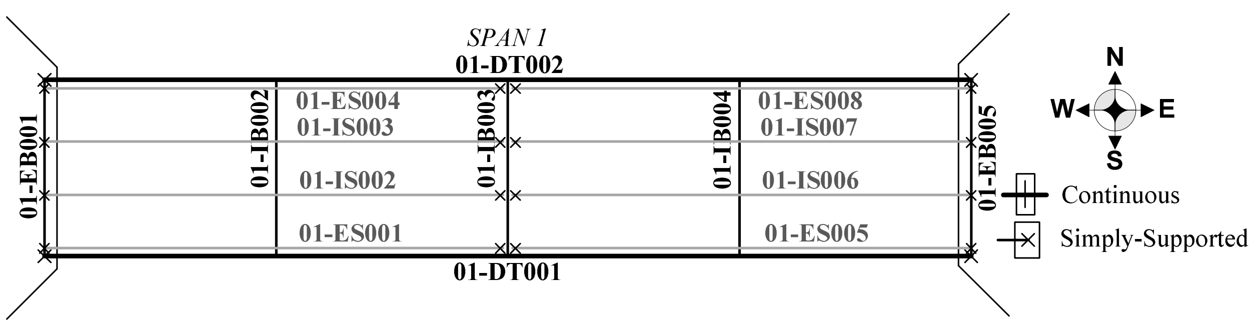


FIGURE A.2.6: MIS EXAMPLE 6

The following are some general guidelines to use the sketches above while identifying the members:

1. Single members that extend over multiple spans (continuous members) should contain the span number in which the member begins (meaning the south-most or west-most span in which the member is a part of). Refer to Figure A.2.1 MIS Example 1.

2. Floorbeam(s) located directly over a pier should be associated with the span to the south or west side. This would typically classify the member as an Interior Floorbeam, since it would be acting on a Continuous Girder. Simply-supported Girders will have an End Floorbeam associated with each span. Refer to Figure A.2.4 MIS Example 4.

3. The span number will increment over all supports (simple or continuous). Refer to Figure A.2.1 MIS Example 1.

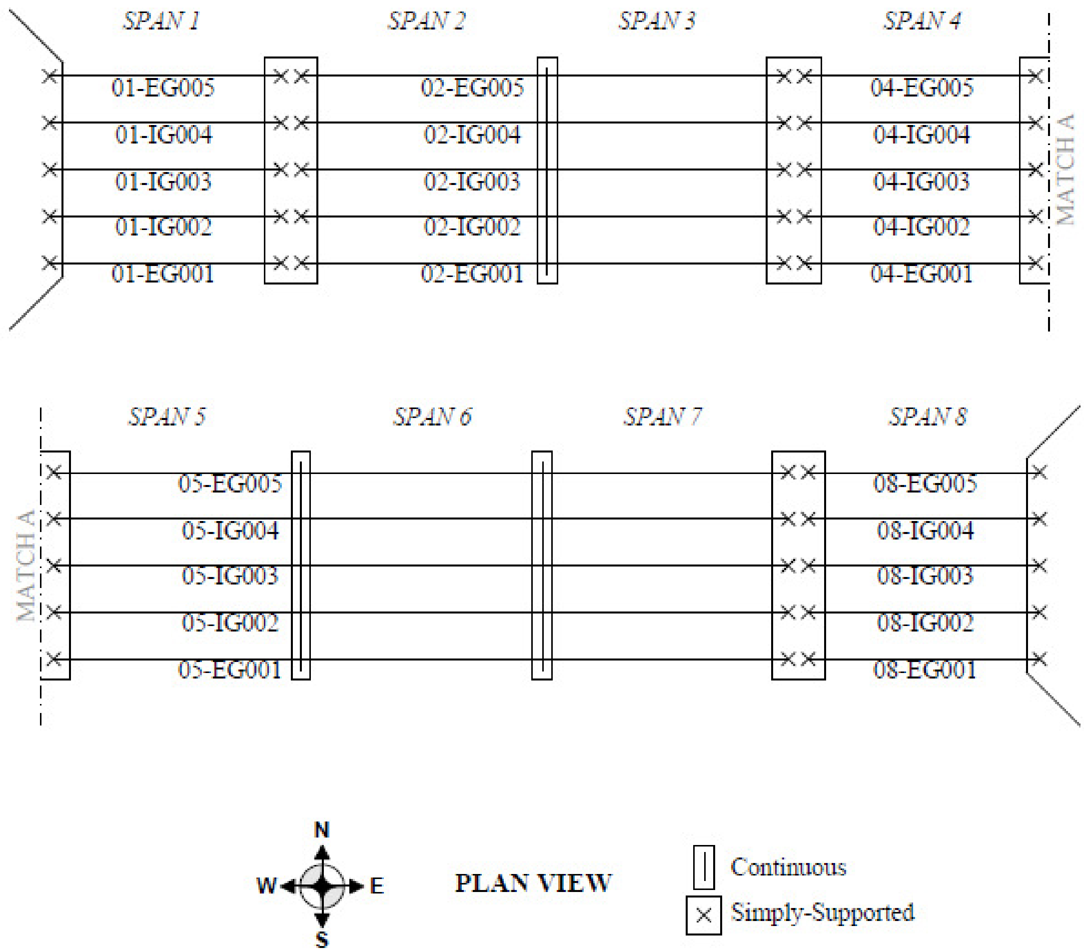
4. If there are multiple groups of simply-supported stringers within a single span, begin numbering at the southwest corner, increment transversely across the structure, then move to the next grouping of stringers. Refer to Figure A.2.6 MIS Example 6.

5. Load Rating Engineer and Reviewer shall accurately model the load path of the structure and classify members as exterior, interior, end, etc., based on the role the member plays in carrying the load.

The sample form NJ-BI-102 for MIS is shown below for different examples:

Structure No.:	####-###	Route:	##	Cycle No.:	##
Name:	I-## over XX Road and XX River or Railroad			Insp. Date:	MM/DD/YYYY

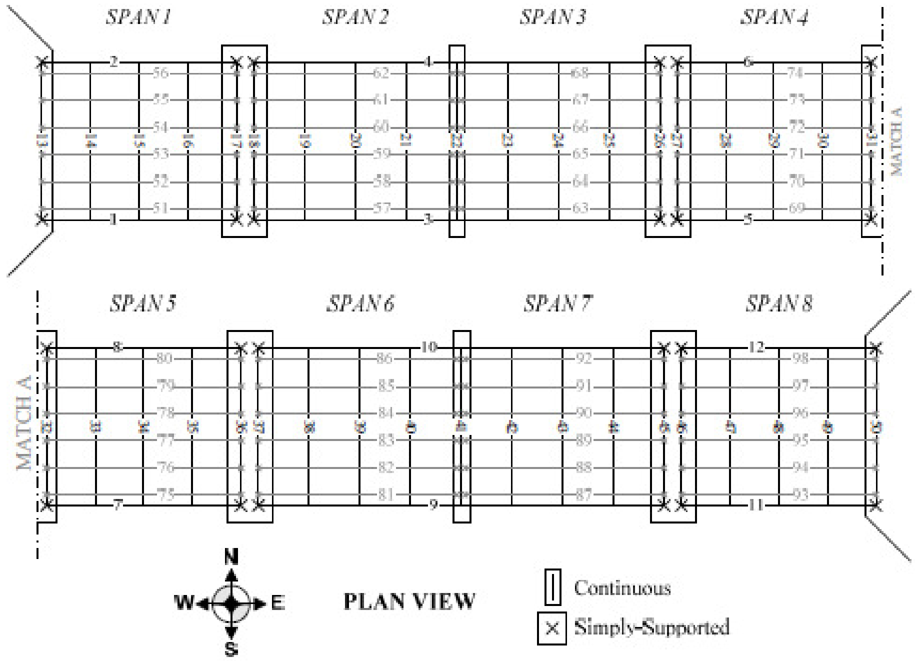
LARS Member Description Sketch:



##-#

Structure No.:	####-###	Route:	##	Cycle No.:	##
Name:	I-## over XX Road and XX River or Railroad			Insp. Date:	MM/DD/YYYY

LARS Member Description Sketch:



Sketch ID	LARS Member Description	Sketch ID	LARS Member Description	Sketch ID	LARS Member Description	Sketch ID	LARS Member Description
1	01-EG001	26	03-EB004	51	01-ES001	76	05-IS002
2	01-EG002	27	04-EB001	52	01-IS002	77	05-IS003
3	02-EG001	28	04-IB002	53	01-IS003	78	05-IS004
4	02-EG002	29	04-IB003	54	01-IS004	79	05-IS005
5	04-EG001	30	04-IB004	55	01-IS005	80	05-ES006
6	04-EG002	31	04-EB005	56	01-ES006	81	06-ES001
7	05-EG001	32	05-EB001	57	02-ES001	82	06-IS002
8	05-EG002	33	05-IB002	58	02-IS002	83	06-IS003
9	06-EG001	34	05-IB003	59	02-IS003	84	06-IS004
10	06-EG002	35	05-IB004	60	02-IS004	85	06-IS005
11	08-EG001	36	05-EB005	61	02-IS005	86	06-ES006
12	08-EG002	37	06-EB001	62	02-ES006	87	07-ES001
13	01-EB001	38	06-IB002	63	03-ES001	88	07-IS002
14	01-IB002	39	06-IB003	64	03-IS002	89	07-IS003
15	01-IB003	40	06-IB004	65	03-IS003	90	07-IS004
16	01-IB004	41	06-IB005	66	03-IS004	91	07-IS005
17	01-EB005	42	07-IB001	67	03-IS005	92	07-ES006
18	02-EB001	43	07-IB002	68	03-ES006	93	08-ES001
19	02-IB002	44	07-IB003	69	04-ES001	94	08-IS002
20	02-IB003	45	07-EB004	70	04-IS002	95	08-IS003
21	02-IB004	46	08-EB001	71	04-IS003	96	08-IS004
22	02-IB005	47	08-EB002	72	04-IS004	97	08-IS005
23	03-IB001	48	08-IB003	73	04-IS005	98	08-ES006
24	03-IB002	49	08-IB004	74	04-ES006		
25	03-IB003	50	08-IB005	75	05-ES001		

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APPENDIX B – DISTRIBUTION FACTORS

B.1 ASR/LFR Distribution Factors

To calculate ASR/LFR distribution factors, use Tables B.1.1 and B.1.2 for moment and shear.

Refer to AASHTO Standard Specifications, Article 3.23, if distribution factor cannot be calculated using these tables.

TABLE B.1.1 – ASR/LFR DISTRIBUTION FACTORS FOR MOMENT IN WHEEL LOADS

Type	Figure	Member	Exterior Members	Interior Members
Steel Multi-Beam or Multi-Girder	13.1.1	Beam, Girder	Determined by applying to beams the reaction of wheel loads obtained by assuming the flooring to act as a simple span of length S between beams. Additionally, in the case of a span with concrete floor supported by 4 or more steel stringers, D.F. shall not be less than: $S/5.5$ for $S < 6$ ft $S/(4+0.25S)$ for $6' < S < 14'$ For $S > 14'$, use Footnote F of AASHTO 2002 Std. Spec. Table 3.23.1 and Manual Appendix D Sec. 14.1	AASHTO 2002 Standard Specification Table 3.23.1.
Steel Girder and Floor beam System	13.1.2 13.1.5	Stringer, Girder	Determined by applying to beams the reaction of wheel loads obtained by assuming the flooring to act as a simple span of length S between beams. Additionally, in the case of a span with concrete floor supported by 4 or more steel stringers, D.F. shall not be less than: $S/5.5$ for $S < 6$ ft $S/(4+0.25S)$ for $6' < S < 14'$ For $S > 14'$, use Footnote F of AASHTO 2002 Std. Spec. Table 3.23.1 and Manual Appendix D Sec. 14.1	AASHTO 2002 Standard Specification Table 3.23.1
PS Concrete Voided Slab, PS Concrete Adjacent Box Beam	13.2.1 13.2.3	Voided Slab, Box Beam	DF = 1 or S/D (whichever is less) S = width of the precast member $D = (5.75 - 0.5 \times \text{Number of lanes}) + 0.7 \times \text{Number of lanes}\ (1 - 0.2C)^2$ $C = 0.8 \times W/L$ for $W/L < 1$; $C = 0.8$ for $W/L > 1$ W = Overall width in ft of the bridge measured perpendicular to the longitudinal beams L = Span length measured parallel to longitudinal beams in feet The above equation is not valid if skew angle exceeds 45^o.	
PS Concrete I-Beam (Narrow/Wide Top Flange)	13.2.2	I-Beam	Footnote F of AASHTO 2002 Standard Specification Table 3.23.1 and Appendix D Section D.1	AASHTO 2002 Standard Specification Table 3.23.1

TABLE B.1.1 – ASR/LFR DISTRIBUTION FACTORS FOR MOMENT IN WHEEL LOADS (Contd.)

Type	Figure	Member	Exterior Members	Interior Members
PS Concrete Spread Box Beam	13.2.4	Box Beam	Determined by applying to beams the reaction of wheel loads obtained by assuming the flooring to act as a simple span of length S between beams, but shall not be less than $2N_L/N_B$	$DF = 2\,N_L / N_B + (K \times S) / L$ N_L = Number of lanes N_B = Number of beams, ($4 \le N_B \le 10$) S = Beam spacing in feet, ($6.57 \le S \le 11.00$) L = Span Length in feet $K = 0.07W - N_L\,(0.10\,N_L - 0.26) - 0.20\,N_B - 0.12$ W = Numeric value of roadway width between curbs expressed in feet, ($32 \le W \le 66$)
Reinforced Concrete Slab	13.3.1	Slab Section	DF = 1/E, where E = Width of slab in ft over which a wheel load is distributed E = (4 + 0.06S), where S = Effective Span Length in ft as defined in AASHTO 2002 Standard Specification Article 3.24.1	
Reinforced Concrete Beam	13.3.1	Beam (Rect., T, Double-T)	Footnote F of AASHTO 2002 Standard Specification Table 3.23.1 and Appendix D Section D.1	AASHTO 2002 Standard Specification Table 3.23.1
Glued-Laminated Timber Slab	13.4.1	Slab	Two or more traffic lanes: $DF = W_p/(3.75+L/28)$ or $W_p/5.00$ (whichever is greater) One traffic lane: $DF = W_p/(4.25+L/28)$ or $W_p/5.50$ (whichever is greater) W_p = panel width in feet, ($3.5 \le W_p \le 4.5$) and L = span length	
Glued-Laminated Timber Beam	13.4.2	Beam	Footnote F of AASHTO 2002 Standard Specification Table 3.23.1 and Appendix D Section D.1	AASHTO 2002 Standard Specification Table 3.23.1

TABLE B.1.2 – ASR/LFR DISTRIBUTION FACTORS FOR SHEAR IN WHEEL LOADS

Type	Figure	Member	Exterior Members	Interior Members
Steel Multi-Beam or Multi-Girder	13.1.1	Beam, Girder	AASHTO 2002 Std. Spec. Article 3.23.1.2 Manual Appendix D Section D.1	AASHTO 2002 Std. Spec. Article 3.23.1.2 Manual Appendix D Section D.2
Steel Girder and Floor beam System	13.1.2 13.1.5	Stringer, Girder	AASHTO 2002 Std. Spec. Article 3.23.1.2 Manual Appendix D Section D.1	AASHTO 2002 Std. Spec. Article 3.23.1.2 Manual Appendix D Section D.2
Prestressed Concrete Voided Slab	13.2.1	Voided Slab*	1.0	
Prestressed Concrete I-Beam (Narrow or Wide Top Flange)	13.2.2	I-Beam	AASHTO 2002 Std. Spec. Article 3.23.1.2 Manual Appendix D Section D.1	AASHTO 2002 Std. Spec. Article 3.23.1.2 Manual Appendix D Section D.2
Prestressed Concrete Adjacent Box Beam	13.2.3	Adjacent Box Beam*	1.0	
PS Concrete Spread Box Beam	13.2.4	Spread Box Beam	AASHTO 2002 Std. Spec. Article 3.23.1.2 Manual Appendix D Section D.1	AASHTO 2002 Std. Spec. Article 3.23.1.2 Manual Appendix D Section D.2
Reinforced Concrete Slab	13.3.1	Slab Section*	1.0	
Reinforced Concrete Beam (T or Double-T, Rectangular)	13.3.1	Rect. Beam, I-Beam*	AASHTO 2002 Std. Spec. Article 3.23.1.2 Manual Appendix D Section D.1	AASHTO 2002 Std. Spec. Article 3.23.1.2 Manual Appendix D Section D.2
Glued-Laminated Timber Slab	13.4.1	Gluelam Slab*	$W_p /4 \geq 1$ W_p = width of the panel , ft and $3.5 \leq W_p \leq 4.5$	
Glued-Laminated Timber Beam	13.4.2	Gluelam Beam	AASHTO 2002 Std. Spec. Article 3.23.1.2 Manual Appendix D Section D.1	AASHTO 2002 Std. Spec. Article 3.23.1.2 Manual Appendix D Section D.2

** Conservatively taken as 1.0*

B.2 LRFD Distribution Factors

This information is a supplement and not a substitute to the detailed provisions of the AASHTO LRFD and is intended for load rating bridge using approximate methods of analysis. LRFD live load distribution tables and related requirements are developed by reformatting and/or simplifying to the extent possible provisions of Article 4.6.2.2 Beam-Slab Bridges, of the AASHTO LRFD Bridge Design Specifications (5th Edition, 2010). It is applicable to straight girder bridges. Also, it can be used for horizontally curved concrete bridges, in addition to horizontally curved steel girder bridges that comply with Article 4.6.1.2.4, whose provisions may be used as a starting point for some analysis methods for curved girders. To calculate LRFD distribution factors, use Tables B.2.1 thru B.2.10 as needed.

Live load multiple presence factors (m) in Article 3.6.1.1.2 are already incorporated in the approximate live load distribution factors/equations, and therefore should not be applied again. An exception to this is the lever rule method, whereby multiple presence factors should be applied; these factors are 1.20 for 1 lane, 1.00 of two lanes, 0.85 for three lanes, and 0.65 for more than three lanes loaded. For example if a distribution factor is determined by the lever rule for a single lane, it should be multiplied by 1.20. However for the fatigue limit state with a single lane loaded, the live load distribution determined by one-lane factors/equations should be divided by 1.2.

Conditions for using approximate methods of analysis are:

- Width of deck is constant
- Number of beams is more than four (4), unless otherwise specified
- Parallel beams with approximately same stiffness
- Roadway part of overhang is less than 3ft, unless otherwise specified
- Curvature, in plan, is less than limit specified in 4.6.1.2.4
- Cross-section is consistent with the types shown Table 4.6.2.2.1-1

The lever rule is a statical moment method for determining wheel load distribution on a particular deck support (such as a beam or beam web) by (i) assuming the deck to be hinged at all interior supports, (ii) summing moments of wheel loads about an adjacent support, and (iii) calculating a force reaction on the selected support.

If beam spacing exceeds the range of applicability as specified in the tables, live load distribution should be based on the lever rule unless specified otherwise.

For moderate deviations from the required conditions of constant deck width or parallel beams, the distribution factor may either (i) be varied at selected locations along the span or (ii) a single distribution factor may be used in conjunction with a suitable value for beam spacing.

Bridges that do not satisfy the requirements for using approximate methods of analysis should be analyzed by refined methods of analysis (specified in Article 4.6.3).

Load distribution requirements are presented in a series of tables, based on LRFD Articles 4.6.2.2 and 4.6.2.3. While most of the tables are reformatted versions of LRFD tables, some tables are created from the LRFD requirements.

TABLE B.2.1 – LIST OF REFORMATTED TABLES FROM AASHTO LRFD BRIDGE DESIGN SPECIFICATIONS

NJDOT Table	AASHTO LRFD Table	Title of Table
B.2.2	none	Notation (Parameters) in LRFD Live Load Distribution for Beam-Slab Bridges (Created based on Article 4.6.2.2.1
B.2.3	none	Notes for Live Load Distribution Tables (Created based on Article 4.6.2.2.1)
B.2.4	C4.6.2.2.1-1	Length *L* for Use in Live Load Distribution Factor Equations (Reformatted)
B.2.5	4.6.2.2.1-1	Common Deck Superstructures Covered in Articles 4.6.2.2.2 and 4.6.2.2.3 (Reformatted)
B.2.6	4.6.2.2.2b-1	Distribution of Live Loads per Lane for Moment in Interior Beams (Reformatted and Combined with Table 4.6.2.2.2a-1 for Wood Decks, Table 4.6.2.2.1-2 for Simplified Constant Values, and Table 4.6.2.2.2c-1 for Corrugated Steel Plank Decks)
B.2.7	4.6.2.2.2d-1	Distribution of Live Loads per Lane for Moment in Exterior Longitudinal Beams (Reformatted)
B.2.8	4.6.2.2.2e-1	Reduction of Load Distribution Factors for Moment in Longitudinal Beams on Skewed Supports (Reformatted)
B.2.9	4.6.2.2.2f-1	Distribution of Live Load per Lane for Transverse Beams for Moment and Shear (Reformatted)
B.2.10	4.6.2.2.3a-1	Distribution of Live Load per Lane for Shear in Interior Beams (Reformatted)
B.2.11	4.6.2.2.3b-1	Distribution of Live Load per Lane for Shear in Exterior Beams (Reformatted)
B.2.12	4.6.2.2.3c-1	Correction Factors for Load Distribution Factors for Support Shear of the Obtuse Corner (Reformatted)
B.2.13	4.6.2.3-1	Typical Schematic Cross-Sections for Slab-Type Bridges (Reformatted)
B.2.14	4.6.2.3-2	Equivalent Strip Widths Per Lane for Shear and Moment for Slab-Type Bridges (Created based on Article 4.6.2.3)

TABLE B.2.2—NOTATION (PARAMETERS) IN LRFD LIVE LOAD DISTRIBUTION FOR BEAM-SLAB BRIDGES (CREATED BASED ON ARTICLE 4.6.2.2.1)

Parameter	Unit	Definition
A	in^2	area of stringer, beam or girder
b	in	width of beam
C		stiffness parameter
D	ft	width of distribution per lane
d	in	depth of beam or stringer
d_e	ft	horizontal distance from the centerline of the exterior web of exterior beam at deck level to the interior edge of curb or traffic barrier
e		correction factor
g		distribution factor
I_p	in^4	polar moment of inertia
J	in^4	St. Venant's torsional inertia
K		constant for different types of construction
K_g	in^4	longitudinal stiffness parameter
L	ft	span of beam
N_b		number of beams, stringers or girders
N_c		number of cells in a concrete box girder
N_L		number of design lanes as specified in Article 3.6.1.1.1
S	ft	spacing of beams or webs
t_g	in	depth of steel grid or corrugated steel plank including integral concrete overlay or structural concrete component, less a provision for grinding, grooving, or wear
t_o	in	depth of structural overlay
t_s	in	depth of concrete slab
W	ft	edge-to-edge width of bridge
W_e	ft	half the web spacing, plus the total overhang
θ	degrees	skew angle
μ		Poisson's ratio
E_B	ksi	modulus of elasticity of beam material
E_D	ksi	modulus of elasticity of deck material
I	in^4	moment of inertia of beam
e_g	in	distance between the centers of gravity of the basic beam and deck
n		ratio of modulus of elasticity of beam to that of deck

TABLE B.2.3—NOTES FOR LIVE LOAD DISTRIBUTION TABLES (CREATED BASED ON ARTICLE 4.6.2.2.1)

Note Number	NJDOT Table	AAHTO LRFD Table	Definition
1	B.2.5	4.6.2.2.1-1	Transverse post-tensioning (P/T) in cross-sections (g), (i), and (j), is intended to make the bridge units act together. A minimum 0.25ksi prestress is recommended.
2	B.2.6 B.2.8 B.2.12	4.6.2.2.2b-1 4.6.2.2.2e-1 4.6.2.2.3c-1	For beams with variable moment of inertia, the longitudinal stiffness parameter K_g may be based on average properties. Parameters A and I in the equation for longitudinal stiffness parameter K_g shall be taken as those of the non-composite beam.
3	B.2.6 B.2.7 B.2.10 B.2.11	4.6.2.2.2b-1 4.6.2.2.2d-1 4.6.2.2.3a-1 4.6.2.2.3b-1	For cast-in-place concrete multi-cell box (cross-section d), the distribution factors shall be applied to a notional shape consisting of a web, overhangs of an exterior web, and the associated half flanges between a web under consideration and the next adjacent web or webs. For cast-in-place concrete multi-cell box (d), whole-width design per Article 4.6.2.2.1 may be applied, whereby the distribution factor for interior beam is multiplied by the numbers of beams (or webs).
4	B.2.7 B.2.11	4.6.2.2.2d-1 4.6.2.2.3b-1	Horizontal distance, d_e, measured from centerline of exterior web of exterior beam at deck level to interior edge of curb or traffic barrier, should be taken as positive if exterior web is inboard of interior face of traffic railing and negative if outboard of the curb or traffic barrier. For beam-slab bridge cross-sections with diaphragms or cross-frames, especially cross-section types a, e, and k, the distribution factor shall not be taken to be less than that obtained by assuming that the cross-section deflects and rotates as a rigid unit. This can be done by utilizing the same procedure as for load distribution on piles, as outlined in Article C4.6.2.2.2d. Apply multiple presence factors.
5	B.2.6	4.6.2.2.2b-1	For multiple steel box girders with a concrete deck (cross-sections b and c) in bridges satisfying Article 6.11.2.3, the distribution factor for moment in interior girder may be used to determine live load flexural moment. If girder spacing varies along the bridge length, the distribution factor may either be varied at selected locations along the span or a single factor may be used along with a suitable value for number of design lanes, N_L. In either case, N_L shall be determined based on Article 3.6.1.1.1, using the width, w, taken at the section being considered.
6	B.2.6 B.2.10	4.6.2.2.2b-1 4.6.2.2.3a-1	For concrete box beams used in multi-beam decks, if the values of I or J do not comply with the limitations in Table 4.6.2.2.3a-1, the distribution factor for shear may be taken as that for moment.

TABLE B.2.3—NOTES FOR LIVE LOAD DISTRIBUTION TABLES (CREATED BASED ON ARTICLE 4.6.2.2.1) (Contd.)

7	B.2.6 B.2.10	4.6.2.2.2b-1 4.6.2.2.3a-1	St. Venant's torsional inertia J may be determined as follows, in lieu of more refined information: For thin-walled open beam: $J = \frac{1}{3}\sum bt^3$ For stocky open sections (such as prestressed I-beams, T-beams, and other types) and solid sections: $J = \frac{A^4}{40.0 I_p}$ For closed thin-walled shapes: $J = \frac{4A_o^2}{\sum \frac{s}{t}}$ where: b = width of plate element (in) t = thickness of plate-like element (in) A = area of cross-section (in^2) I_p = polar moment of inertia (in^4) A_o = area enclosed by centerlines of elements (in^2) s = length of a side element (in)

TABLE B.2.4— LENGTH *L* FOR USE IN LIVE LOAD DISTRIBUTION FACTOR EQUATIONS (REFORMATTED)

Force Effect	Definition of Length *L* (in feet)
Positive Moment	Length of the span for which force effect is being calculated
Negative Moment – Other than near interior supports of continuous spans	
Shear	
Negative Moment – Near interior supports of continuous spans from point of contra-flexure to point of contra-flexure under a uniform load on all spans	Average length of the two adjacent spans
Interior Reaction of Continuous Span	
Exterior Reaction	Length of the exterior span

TABLE B.2.5 [AASHTO LRFD TABLE 4.6.2.2.1-1]—COMMON DECK SUPERSTRUCTURES COVERED IN ARTICLES 4.6.2.2.2 AND 4.6.2.2.3 (REFORMATTED)

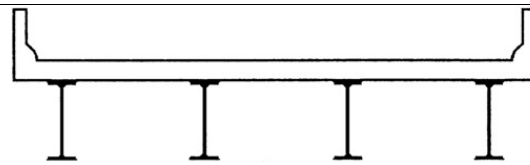
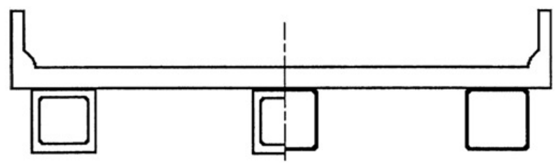
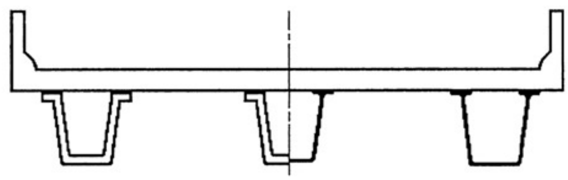
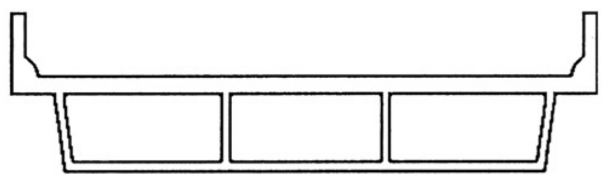
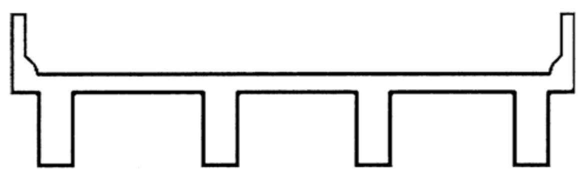
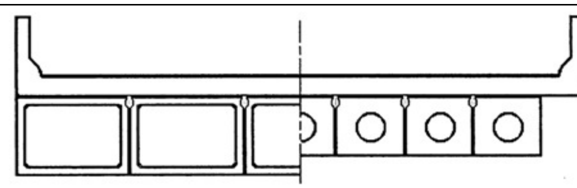
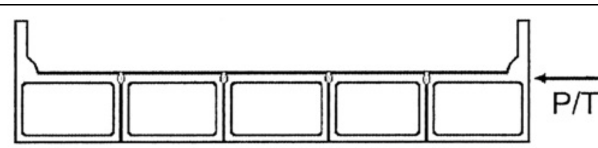
	Superstructure Type **Deck Type and Supporting Components**	**Typical Cross-Section**
(a)	Deck: Cast-in-place concrete slab, precast concrete slab, steel grid, glued/spiked panels, stressed wood. Components: Steel Beams	
(b)	Deck: Cast-in-place concrete slab Components: Closed Steel or Precast Concrete Boxes	
(c)	Deck: Cast-in-place concrete slab, precast concrete deck slab Components: Open Steel or Precast Concrete Boxes	
(d)	Deck: Monolithic concrete Components: Cast-in-Place Concrete Multi-cell Box	
(e)	Deck: Monolithic concrete Components: Cast-in-Place Concrete Tee Beam	
(f)	Deck: Cast-in-place concrete overlay Components: Precast Solid, Voided or Cellular Concrete Boxes with Shear Keys	
(g)	Deck: Integral concrete Components: Precast Solid, Voided, or Cellular Concrete Box with Shear Keys and with or without Transverse Post-Tensioning	

TABLE B.2.5 [AASHTO LRFD TABLE 4.6.2.2.1-1]—COMMON DECK SUPERSTRUCTURES COVERED IN ARTICLES 4.6.2.2.2 AND 4.6.2.2.3 (REFORMATTED) (Contd.)

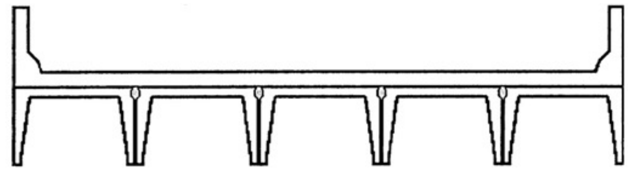
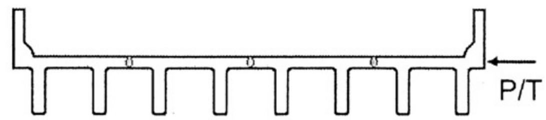
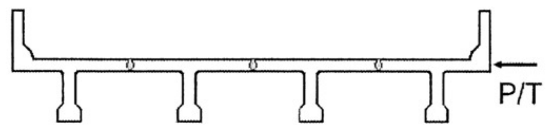
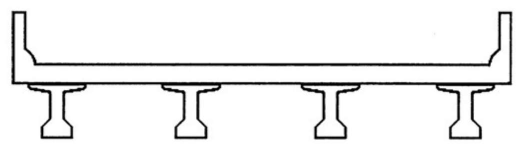
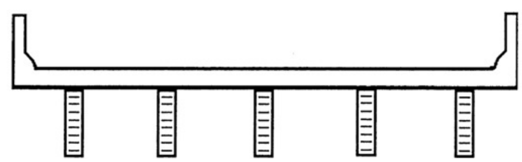
	Superstructure Type Deck Type and Supporting Components	Typical Cross-Section
(h)	Deck: Cast-in-place concrete overlay Components: Precast Concrete Channel Sections with Shear Keys	
(i)	Deck: Integral concrete Components: Precast Concrete Double Tee Section with Shear Keys and with or without Transverse Post-Tensioning	
(j)	Deck: Integral concrete Components: Precast Concrete Tee Section with Shear Keys and with or without Transverse Post-Tensioning	
(k)	Deck: Cast-in-place concrete, precast concrete Components: Precast Concrete I or Bulb-Tee Sections	
(l)	Deck: Cast-in-place concrete or plank, glued/spiked panels or stressed wood Components: Wood Beams	

TABLE B.2.6 [AASHTO LRFD TABLE 4.6.2.2.2b-1]—DISTRIBUTION OF LIVE LOADS PER LANE FOR MOMENT IN *INTERIOR* BEAMS (REFORMATTED AND COMBINED WITH TABLE 4.6.2.2.2a-1 FOR WOOD DECKS, TABLE 4.6.2.2.1-2 FOR SIMPLIFIED CONSTANT VALUES, AND TABLE 4.6.2.2.2c-1 FOR CORRUGATED STEEL PLANK DECKS)

Superstructure Type (Cross-section)	**Live Load Distribution Factors**		**Applicability Range**
	One Design lane loaded	**Two or More Design Lanes Loaded**	
Wood Plank Deck on Wood or Steel Beams; (*a, l*)	$S/6.7$	$S/7.5$	$S \le 5.0$
Stressed Laminated Deck on Wood or Steel Beams; (*a, l*)	$S/9.2$	$S/9.0$	$S \le 6.0$
Spike Laminated Deck on Wood or Steel Beams; (*a, l*)	$S/8.3$	$S/8.5$	$S \le 6.0$
Glued Laminated Panels on Glued Laminated Stringers; (*a, l*)	$S/10.0$	$S/10.0$	$S \le 6.0$
Glued Laminated Panels on Steel Stringers; (*a, l*)	$S/8.8$	$S/9.0$	$S \le 6.0$
Concrete Deck on Wood Beams; (*l*)	$S/12.0$	$S/10.0$	$S \le 6.0$
Concrete Deck, Filled Grid, Partially Filled Grid, or Unfilled Grid Deck Composite with Reinforced Concrete Slab on Steel or Concrete Beams; Concrete T-Beams, T- and Double T-Sections; (*a, e, k* and also *i, j* if sufficiently connected to act as a unit)	$0.06+\left(\frac{S}{14}\right)^{0.4}\left(\frac{S}{L}\right)^{0.3}K_1$	$0.075+\left(\frac{S}{9.5}\right)^{0.6}\left(\frac{S}{L}\right)^{0.2}K_1$	$3.5 \le S \le 16.0$ $4.5 \le t_s \le 12.0$ $20 \le L \le 240$ $N_b \ge 4$ $10{,}000 \le K_g \le 7{,}000{,}000$
	Where $K_1 = \left(\frac{K_g}{12.0Lt_S^3}\right)^{0.1}$ and $K_g = n(I + A(e_g)^2)$ $n = E_B/E_D$ Simplified values from Table 4.6.2.2.1-2 (Owner's approval required): P_k = 1.02 for (a), 1.05 for (e), 1.09 for (k).		
	Use lesser values with $N_b = 3$ or the lever rule		$N_b = 3$
Cast-in-Place Concrete Multi-cell Box; (*d*)	$\left(1.75+\frac{S}{3.6}\right)\left(\frac{1}{L}\right)^{0.35}\left(\frac{1}{N_c}\right)^{0.4}$	$\left(\frac{13}{N_c}\right)^{0.3}\left(\frac{S}{5.8}\right)\left(\frac{1}{L}\right)^{0.25}$	$7.0 \le S \le 13.0$ $60 \le L \le 240$ $N_c \ge 3$ If $N_c > 8$, then use $N_c = 8$
Concrete Deck on Concrete Spread Box Beams; (*b, c*)	$\left(\frac{S}{3.0}\right)^{0.35}\left(\frac{Sd}{12.0L^2}\right)^{0.25}$	$\left(\frac{S}{6.3}\right)^{0.6}\left(\frac{Sd}{12.0L^2}\right)^{0.125}$	$6.0 \le S \le 18.0$ $20 \le L \le 140$ $18 \le d \le 65$ $N_b \ge 3$
	Use Lever Rule		$S > 18.0$

TABLE B.2.6 [AASHTO LRFD TABLE 4.6.2.2.2b-1]—DISTRIBUTION OF LIVE LOADS PER LANE FOR MOMENT IN *INTERIOR* BEAMS (REFORMATTED AND COMBINED WITH TABLE 4.6.2.2.2a-1 FOR WOOD DECKS, TABLE 4.6.2.2.1-2 FOR SIMPLIFIED CONSTANT VALUES, AND TABLE 4.6.2.2.2c-1 FOR CORRUGATED STEEL PLANK DECKS) (Contd.)

<table>
<tr><th rowspan="2">Superstructure Type (Cross-section)</th><th colspan="2">Live Load Distribution Factors</th><th rowspan="2">Applicability Range</th></tr>
<tr><th>One Design lane loaded</th><th>Two or More Design Lanes Loaded</th></tr>
<tr><td rowspan="2">Concrete Beams used in Multi-beam Decks; (f; g if sufficiently connected to act as a unit)</td><td>$k\left(\frac{b}{33.3L}\right)^{0.5}\left(\frac{I}{J}\right)^{0.25}$</td><td>$k\left(\frac{b}{305}\right)^{0.6}\left(\frac{b}{12.0L}\right)^{0.2}\left(\frac{I}{J}\right)^{0.06}$</td><td rowspan="2">$35 \le b \le 60$
$20 \le L \le 120$
$5 < N_b < 20$</td></tr>
<tr><td colspan="2">where: $k = 2.5(N_b)^{-0.2} \ge 1.5$
Simplified value from Table 4.6.2.2.1-2 (Owner’s approval required):
$(I/J) = 0.54(d/b) + 0.16$</td></tr>
<tr><td>Concrete Beams used in Multi-beam Decks; (h; g, i, j if connected only enough to prevent relative vertical displacement at the interface)</td><td colspan="2">Regardless of Number of Loaded Lanes: S/D
where:
$C = K\,(W / L) \le K$
$D = 11.5 - N_L + 1.4N_L(1 - 0.2C)^2$ when $C \le 5$
$D = 11.5 - N_L$ when $C > 5$
$K = [(1 + \mu)(I/J)]^{0.5}$
For preliminary design, the following values of K may be used:
<u>Beam Type</u> — <u>K</u>
Non-voided rectangular beams — 0.7
Rectangular beams with circular voids — 0.8
Box section beams — 1.0
Channel beams — 2.2
T-beam — 2.0
Double T-beam — 2.0

Simplified value from Table 4.6.2.2.1-2 (Owner’s approval required):
$(I/J) = 0.54(d/b) + 0.16$</td><td>Skew $\le 45°$
$N_L \le 6$</td></tr>
<tr><td>Open Steel Grid Deck on Steel Beams; (a)</td><td>If $t_g < 4.0$, then $S/7.5$
If $t_g \ge 4.0$, then $S/10.0$</td><td>If $t_g < 4.0$, then $S/8.0$
If $t_g \ge 4.0$, then $S/10.0$</td><td>$S \le 6.0$ (for 1 lane); $S \le 10.5$ (for ≥ 2 lanes)</td></tr>
<tr><td>Concrete Deck on Multiple Steel Box Girders; (b, c)</td><td colspan="2">Regardless of Number of Loaded Lanes:
$0.05 + 0.85(N_L/N_b) + 0.425/N_L$</td><td>$0.5 \le (N_L/N_b) \le 1.5$</td></tr>
<tr><td>Corrugated Steel Plank Deck on Beams; (a, k)</td><td>$S/9.2$</td><td>$S/9.0$</td><td>$S \le 5.5$
$t_g \ge 2.0$</td></tr>
<tr><td colspan="4">Notes: Refer to Notes 2, 3, 5, 6 and 7 in Table B.2.3.</td></tr>
</table>

TABLE B.2.7 [AASHTO LRFD TABLE 4.6.2.2.2d-1]—DISTRIBUTION OF LIVE LOADS PER LANE FOR MOMENT IN *EXTERIOR LONGITUDINAL* BEAMS (REFORMATTED)

Superstructure Type (Cross-section)	Live Load Distribution Factors: One Design lane loaded	Live Load Distribution Factors: Two or More Design Lanes Loaded	Applicability Range
Wood Deck on Wood or Steel Beams; *(a, l)*	Lever Rule	Lever Rule	N/A
Concrete Deck on Wood Beams; *(l)*	Lever Rule	Lever Rule	N/A
Concrete Deck, Filled Grid, Partially Filled Grid, or Unfilled Grid Deck Composite with Reinforced Concrete Slab on Steel or Concrete Beams; Concrete T-Beams, T- and Double T-Sections; (*a*, *e*, *k* and also *i*, *j* if sufficiently connected to act as a unit)	Lever Rule	$g = e\ g_{interior}$ $e = 0.77 + (d_e/9.1)$	$-1.0 \leq d_e \leq 5.5$
		Use lesser of the values obtained from the equation above with $N_b = 3$ or the lever rule	$N_b = 3$
Cast-in-Place Concrete Multi-cell Box; *(d)*	$g = W_e/14$	$g = W_e/14$	$W_e \leq S$
	or provisions for a whole-width design per Article 4.6.2.2.1		
Concrete Deck on Concrete Spread Box Beams; *(b, c)*	Lever Rule	$g = e\ g_{interior}$ $e = 0.97 + (d_e/28.5) \geq 1.0$	$0 \leq d_e \leq 4.5$ $6 < S \leq 18.0$
		Lever Rule	$S > 18.0$
Concrete Box Beams used in Multi-beam Decks; *(f, g)*	$g = e\ g_{interior}$ $e = 1.125 + (d_e/30) \geq 1.0$	$g = e\ g_{interior}$ $e = 1.04 + (d_e/25) \geq 1.0$	$d_e \leq 2.0$
Concrete Beams Other than Box Beams Used in Multi-beam Decks; (*h*, *i*, *j* if connected only enough to prevent relative vertical displacement at the interface)	Lever Rule	Lever Rule	N/A
Open Steel Grid Deck on Steel Beams; *(a)*	Lever Rule	Lever Rule	N/A
Concrete Deck on Multiple Steel Box Girders; *(b, c)*	Regardless of Number of Loaded Lanes: $0.05 + 0.85(N_L/N_b) + 0.425/N_L$		$0.5 \leq (N_L/N_b) \leq 1.5$
Notes: Refer to Notes 3 and 4 in Table B.2.3.			

TABLE B.2.8 [AASHTO LRFD TABLE 4.6.2.2.2e-1]—REDUCTION OF LOAD DISTRIBUTION FACTORS FOR MOMENT IN *LONGITUDINAL* BEAMS ON *SKEWED* SUPPORTS (REFORMATTED)

<table>
<tr><th>Superstructure Type (Cross-section)</th><th>Live Load Distribution Factors
For Any Number of Design Lanes Loaded</th><th>Applicability Range</th></tr>
<tr><td>Concrete Deck, Filled Grid, Partially Filled Grid, or Unfilled Grid Deck Composite with Reinforced Concrete Slab on Steel or Concrete Beams; Concrete T-Beams, T- and Double T-Sections; (a, e, k and also i, j if sufficiently connected to act as a Unit)</td><td>$1 - c_1(\tan\theta)^{1.5}$
where $c_1 = 0.25\left(\frac{K_g}{12.0Lt_s^3}\right)^{0.25}\left(\frac{S}{L}\right)^{0.5}$

If $\theta < 30^o$ then $c_1 = 0.0$

If $\theta > 60^o$ use $\theta = 60^o$

Simplified values from Table 4.6.2.2.1-2 shown below may be used for equation parameter K_2, if approved by the bridge owner:

K_2 = 1.03 for section (a), 1.07 for section (e), 1.15 section for (k)
Where, $K_2 = \left(\frac{K_g}{12.0Lt_s^3}\right)^{0.25}$</td><td>$30^o \leq \theta \leq 60^o$
$3.5 \leq S \leq 16.0$
$20 \leq L \leq 240$
$N_b \geq 4$</td></tr>
<tr><td>Concrete Deck on Concrete Spread Box Beams, Cast-in-Place Multi-cell Box Concrete Box Beams and Double T-Sections used in Multi-beam Decks; (b, c, d, f, g)</td><td>$1.05 - 0.25\tan\theta \leq 1.0$

If $\theta > 60^o$ use $\theta = 60^o$</td><td>$0^o \leq \theta \leq 60^o$</td></tr>
<tr><td colspan="3">Note: This table is applicable to bridges with skewed line supports, whereby the difference between skew angles of two adjacent lines of supports does not exceed 10 degrees. For bridge cases not covered in this table, accepted reduction factors are not currently available.

Refer to Note 2 in Table B.2.3.</td></tr>
</table>

TABLE B.2.9 [AASHTO LRFD TABLE 4.6.2.2.2f-1]—DISTRIBUTION OF LIVE LOAD PER LANE FOR TRANSVERSE BEAMS FOR MOMENT AND SHEAR (REFORMATTED)

Deck Type	**Fraction of Wheel Load to Each Floorbeam**	**Applicability Range**
Plank	$S/4$	N/A
Laminated Wood Deck	$S/5$	$S \leq 5.0$
Concrete	$S/6$	$S \leq 6.0$
Steel Grid and Unfilled Grid Deck Composite with Reinforced Concrete Slab	$S/4.5$	$t_g \leq 4.0$ $S \leq 5.0$
Steel Grid and Unfilled Grid Deck Composite with Reinforced Concrete Slab	$S/6$	$t_g > 4.0$ $S \leq 6.0$
Steel Bridge Corrugated Plank	$S/5.5$	$t_g \geq 2.0$
Note: This table is applicable to transverse floorbeams that support a deck. The given distribution factors shall be used in conjunction with the 32.0-kip design axle load alone. For floorbeam spacing outside the ranges of applicability, all of the design live loads shall be considered, and the lever rule may be used.		

TABLE B.2.10 [AASHTO LRFD TABLE 4.6.2.2.3a-1]—DISTRIBUTION OF LIVE LOAD PER LANE FOR SHEAR IN *INTERIOR* BEAMS (REFORMATTED)

Superstructure Type (Cross-section)	Live Load Distribution Factors		Applicability Range
	One Design lane loaded	Two or More Design Lanes Loaded	
Wood Plank Deck on Wood or Steel Beams; (*a, l*)	$S/6.7$	$S/7.5$	$S \leq 5.0$
Stressed Laminated Deck on Wood or Steel Beams; (*a, l*)	$S/9.2$	$S/9.0$	$S \leq 6.0$
Spike Laminated Deck on Wood or Steel Beams; (*a, l*)	$S/8.3$	$S/8.5$	$S \leq 6.0$
Glued Laminated Panels on Glued Laminated Stringers; (*a, l*)	$S/10.0$	$S/10.0$	$S \leq 6.0$
Glued Laminated Panels on Steel Stringers; (*a, l*)	$S/8.8$	$S/9.0$	$S \leq 6.0$
Concrete Deck on Wood Beams; (*l*)	Lever Rule	Lever Rule	N/A
Concrete Deck, Filled Grid, Partially Filled Grid, or Unfilled Grid Deck Composite with Reinforced Concrete Slab on Steel or Concrete Beams; Concrete T-Beams, T- and Double T-Sections; (*a, e, k* and also *i, j* if sufficiently connected to act as a unit)	$0.36+\frac{S}{25.0}$	$0.2+\frac{S}{12}-\left(\frac{S}{35}\right)^{2.0}$	$3.5 \leq S \leq 16.0$ $4.5 \leq t_s \leq 12.0$ $20 \leq L \leq 240$ $N_b \geq 4$
	Lever Rule	Lever Rule	$N_b = 3$
Cast-in-Place Concrete Multi-cell Box; (*d*)	$\left(\frac{S}{9.5}\right)^{0.6}\left(\frac{d}{12.0L}\right)^{0.1}$	$\left(\frac{S}{7.3}\right)^{0.9}\left(\frac{d}{12.0L}\right)^{0.1}$	$7.0 \leq S \leq 13.0$ $60 \leq L \leq 240$ $N_c \geq 3$; If $N_c > 8$, then use $N_c = 8$
Concrete Deck on Concrete Spread Box Beams; (*b, c*)	$\left(\frac{S}{10.0}\right)^{0.6}\left(\frac{d}{12.0L}\right)^{0.1}$	$\left(\frac{S}{7.4}\right)^{0.8}\left(\frac{d}{12.0L}\right)^{0.1}$	$6.0 \leq S \leq 18.0$ $20 \leq L \leq 140$ $18 \leq d \leq 65$ $N_b \geq 3$
	Lever Rule	Lever Rule	$S > 18.0$
Concrete Box Beams Used in Multi-beam Decks; (*f, g*)	$\left(\frac{b}{130L}\right)^{0.15}\left(\frac{I}{J}\right)^{0.05}$	$\left(\frac{b}{156}\right)^{0.4}\left(\frac{b}{12.0L}\right)^{0.1}\left(\frac{I}{J}\right)^{0.05}B$ where, $B = b/48 \geq 1.0$	$35 \leq b \leq 60$ $20 \leq L \leq 120$ $5 \leq N_b \leq 20$ $25{,}000 \leq J \leq 610{,}000$ $40{,}000 \leq I \leq 610{,}000$

TABLE B.2.10 [AASHTO LRFD TABLE 4.6.2.2.3a-1]—DISTRIBUTION OF LIVE LOAD PER LANE FOR SHEAR IN *INTERIOR* BEAMS (REFORMATTED) (Contd.)

Superstructure Type (Cross-section)	Live Load Distribution Factors		Applicability Range
	One Design lane loaded	Two or More Design Lanes Loaded	
Concrete Beams Other Than Box Beams Used in Multi-beam Decks; (*h; i, j* if connected only enough to prevent relative vertical displacement at the interface)	Lever Rule	Lever Rule	N/A
Open Steel Grid Deck on Steel Beams; *(a)*	Lever Rule	Lever Rule	N/A
Concrete Deck on Multiple Steel Box Beams; *(b, c)*	Regardless of Number of Loaded Lanes: $0.05 + 0.85(N_L/N_b) + 0.425/N_L$		$0.5 \leq (N_L/N_b) \leq 1.5$
Notes: Refer to Notes 3, 6 and 7 in Table B.2.3.			

TABLE B.2.11 [AASHTO LRFD 4.6.2.2.3b-1] – DISTRIBUTION OF LIVE LOAD PER LANE FOR SHEAR IN *EXTERIOR* BEAMS (REFORMATTED)

Superstructure Type (Cross-section)	Live Load Distribution Factors		Applicability Range
	One Design Lane Loaded	**Two or More Design Lanes Loaded**	
Wood Plank Deck on Wood or Steel Beams; *(a, l)*	Lever Rule	Lever Rule	N/A
Concrete Deck on Wood Beams; *(l)*	Lever Rule	Lever Rule	N/A
Concrete Deck, Filled Grid, Partially Filled Grid, or Unfilled Grid Deck Composite with Reinforced Concrete Slab on Steel or Concrete Beams; Concrete T-Beams, T- and Double T-Beams; (*a, e, k* and also *i, j* if sufficiently connected to act as a unit)	Lever Rule	$g = e\ g_{interior}$ $e = 0.6 + (d_e/10)$	$-1.0 \leq d_e \leq 5.5$
		Lever Rule	$N_b = 3$
Cast-in-Place Concrete Multi-cell Box; *(d)*	Lever Rule	$g = e\ g_{interior}$ $e = 0.64 + (d_e/12.5)$	$-2.0 \leq d_e \leq 5.0$
	or provisions for whole-width design specified in Article 4.6.2.2.1		
Concrete Deck on Concrete Spread Box Beams; *(b, c)*	Lever Rule	$g = e\ g_{interior}$ $e = 0.8 + (d_e/10)$	$0 \leq d_e \leq 4.5$
		Lever Rule	$S > 18.0$
Concrete Box Beams Used in Multi-beam Decks; *(f, g)*	$g = e\ g_{interior}$ $e = 1.25 + (d_e/20) \geq 1.0$	$g = e\ g_{interior}\ (48/b)$ $e = 1 + \left(\frac{d_e + \frac{b}{12} - 2.0}{40}\right)^{0.5}$ $(48/b) < 1.0$ $e \geq 1.0$	$d_e \leq 2.0$ $35 \leq b \leq 60$
Concrete Beams Other Than Box Beams Used in Multi-beam Decks; (*h; i, j* if connected only enough to prevent relative vertical displacement at the interface)	Lever Rule	Lever Rule	N/A
Open Steel Grid Deck on Steel Beams; *(a)*	Lever Rule	Lever Rule	N/A
Concrete Deck on Multiple Steel Box Beams; *(b, c)*	Regardless of Number of Loaded Lanes: $0.05 + 0.85(N_L/N_b) + 0.425/N_L$		$0.5 \leq (N_L/N_b) \leq 1.5$
Notes: Refer to Notes 3 and 4 in Table B.2.3.			

TABLE B.2.12 [AASHTO LRFD TABLE 4.6.2.2.3c-1]–CORRECTION FACTORS FOR LOAD DISTRIBUTION FACTORS FOR SUPPORT SHEAR OF THE OBTUSE CORNER (REFORMATTED)

<table>
<tr><th>Superstructure Type
(Cross-section)</th><th>Correction Factor</th><th>Applicability Range</th></tr>
<tr><td>Concrete Deck, Filled Grid, Partially Filled Grid, or Unfilled Grid Deck Composite with Reinforced Concrete Slab on Steel or Concrete Beams; Concrete T-Beams, T- and Double T-Section; (a, e, k and also i, j if sufficiently connected to act as a unit)</td><td>$1.0 + 0.20\left(\frac{12.0Lt_s^3}{K_g}\right)^{0.3} \tan\theta$

Simplified values from Table 4.6.2.2.1-2 shown below may be used for equation parameter K_3, if approved by the bridge owner:
K_3 = 0.97 for section (a), 0.93 for section (e), 0.85 section for (k)

Where, $K_3 = \left(\frac{12.0Lt_s^3}{K_g}\right)^{0.3}$</td><td>$0^o \le \theta \le 60^o$
$3.5 \le S \le 16.0$
$20 \le L \le 240$
$N_b \ge 4$</td></tr>
<tr><td>Cast-in-Place Concrete Multi-cell Box; (d)</td><td>$1.0 + \left(0.25 + \frac{12.0L}{70d}\right)\tan\theta$</td><td>$0^o \le \theta \le 60^o$
$6.0 \le S \le 13.0$
$20 \le L \le 240$
$35 \le d \le 110$
$N_b \ge 3$</td></tr>
<tr><td>Concrete Deck on Spread Concrete Box Beams; (b, c)</td><td>$1.0 + \frac{\sqrt{\frac{Ld}{12.0}}}{6S}\tan\theta$</td><td>$0^o \le \theta \le 60^o$
$6.0 \le S \le 11.5$
$20 \le L \le 140$
$18 \le d \le 65$
$N_b \ge 3$</td></tr>
<tr><td>Concrete Box Beams Used in Multi-beam Decks; (f, g)</td><td>$1.0 + \frac{12.0L}{90d}\sqrt{\tan\theta}$</td><td>$0^o \le \theta \le 60^o$
$20 \le L \le 120$
$17 \le d \le 60$
$35 \le b \le 60$
$5 \le N_b \le 20$</td></tr>
<tr><td colspan="3">Note: For skewed bridges, shear in the exterior beam at the obtuse corner of the bridge shall be adjusted when the line of support is skewed. This shall be done by applying a correction factor from this table to a lane fraction specified in Table 4.6.2.2.3a-1 for interior beams and in Table 4.6.2.2.3b-1 for exterior beams. When determining the end shear in multi-beam bridges, the skew correction at the obtuse corner shall be applied to all the beams. For bridge cases not covered in this table, verifiable correction factors are not available. Equal treatment of all beams in a multi-beam bridge is conservative regarding positive reaction and shear. However for the case of large skew and short exterior spans of continuous beams, this is not necessarily conservative regarding uplift. A supplementary investigation of uplift should be considered using the correction factor from this table, which is, the terms other than 1.0, taken as negative for the exterior beam at the acute corner.

Refer to Note 2 in Table B.2.3.</td></tr>
</table>

TABLE B.2.13 (4.6.2.3-1) – TYPICAL SCHEMATIC CROSS-SECTIONS FOR SLAB-TYPE BRIDGES (REFORMATTED)

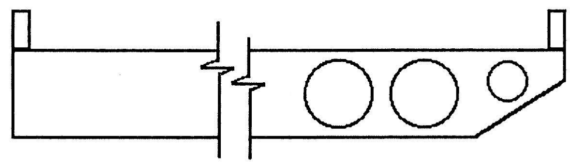
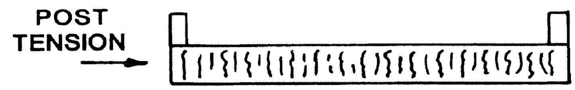
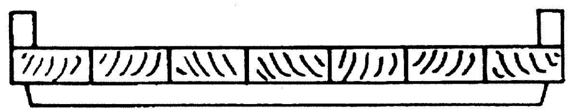
	Superstructure Type Deck Type and Supporting Components	Typical Cross-Section
(a1)	Deck: Monolithic Components: Cast-in-Place Concrete Slab or Voided Slab	
(b1)	Deck: Integral Wood Components: Stressed Wood Deck	
(c1)	Deck: Integral Wood Components: Glued/Spiked Wood Panels with Spreader Beam	

TABLE B.2.14 (4.6.2.3-2) – EQUIVALENT STRIP WIDTHS PER LANE FOR SHEAR AND MOMENT FOR SLAB-TYPE BRIDGES (CREATED BASED ON ARTICLE 4.6.2.3)

<table>
<tr><th rowspan="2">Superstructure Type (Cross-section)</th><th colspan="2">Equivalent Width of Longitudinal Strips</th><th rowspan="2">Applicability Range</th></tr>
<tr><th>One Design Lane (Two Wheel Lines) Loaded</th><th>Two or More Design Lanes Loaded</th></tr>
<tr><td rowspan="2">Monolithic, Cast-in-Place Concrete Slab or Voided Slab; Integral, Stressed Wood Deck; Integral, Glued/Spiked Wood Panels with Spreader Beam; (a1, b1, and c1)</td><td>$E = 10.0 + 5.0\sqrt{L_1 W_1}$</td><td>$E = 84.0 + 1.44\sqrt{L_1 W_1}$

$E \leq \frac{12.0W}{N_L}$</td><td rowspan="2">N/A</td></tr>
<tr><td colspan="2">where:
E = equivalent width, (in)

L_1 = modified span length taken equal to the lesser of the actual span or 60.0, (ft)

W_1 = modified edge-to-edge width of bridge taken to be equal to the lesser of the actual width or 60.0 for multilane loading, or 30.0 for single-lane loading, (ft)

W = physical edge-to-edge width of bridge, (ft)

N_L = number of design lanes as specified in Article 3.6.1.1.1

For skewed bridges, the longitudinal force effects may be reduced by the factor:
$r = 1.05 - 0.25\tan\theta \leq 1.00$

where:
θ = skew angle (degrees)

Note: The strip width has been divided by 1.20 to account for the multiple presence effect.</td></tr>
</table>

APPENDIX C – CROSS-SECTION SKETCHES

C.1 Steel Structure Type Sketches

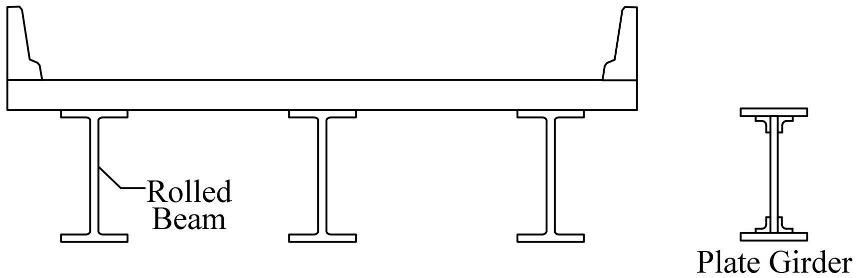


FIGURE C.1.1: STEEL MULTI-GIRDER

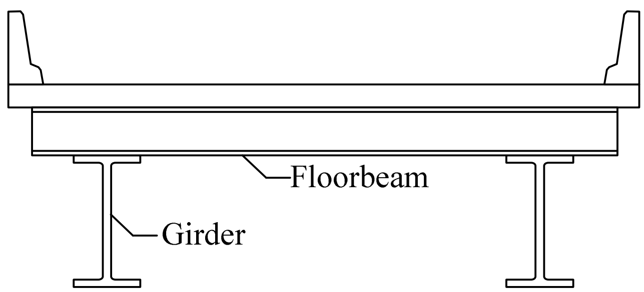


FIGURE C.1.2: STEEL GIRDER-FLOORBEAM SYSTEM

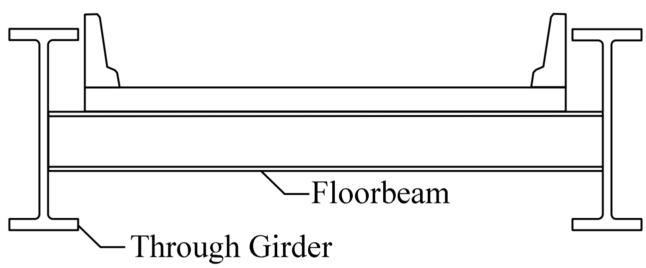


FIGURE C.1.3: STEEL THRU-GIRDER-FLOORBEAM SYSTEM

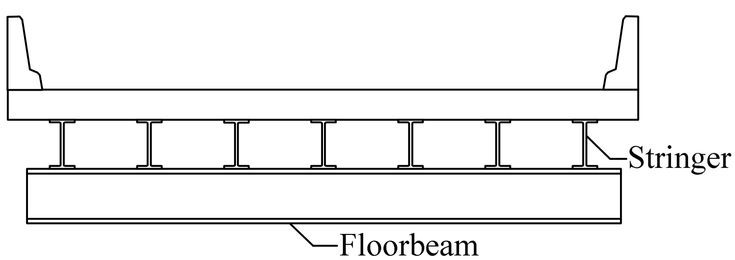


FIGURE C.1.4: STEEL FLOORBEAM-STRINGER SYSTEM

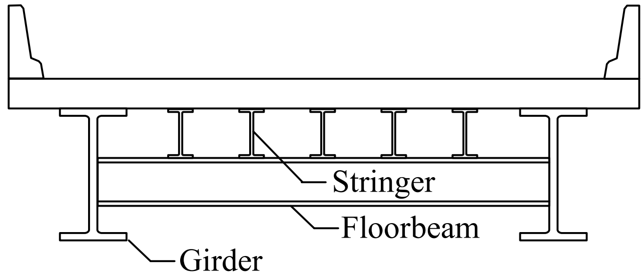


FIGURE C.1.5: STEEL GIRDER-FLOORBEAM-STRINGER SYSTEM

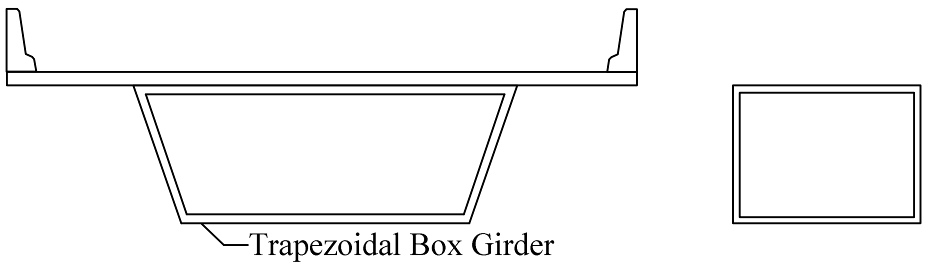


FIGURE C.1.6: STEEL TRAPEZOIDAL OR RECTANGULAR BOX GIRDER

C.2 Prestressed Concrete Structure Type Sketches

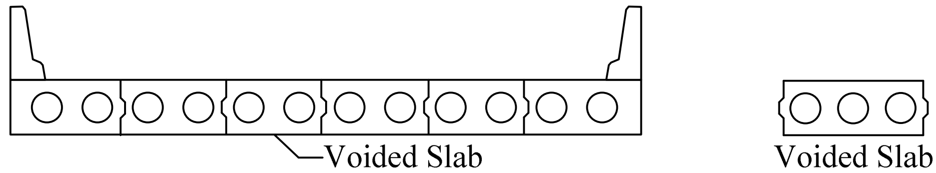


FIGURE C.2.1: PS CONCRETE VOIDED SLAB

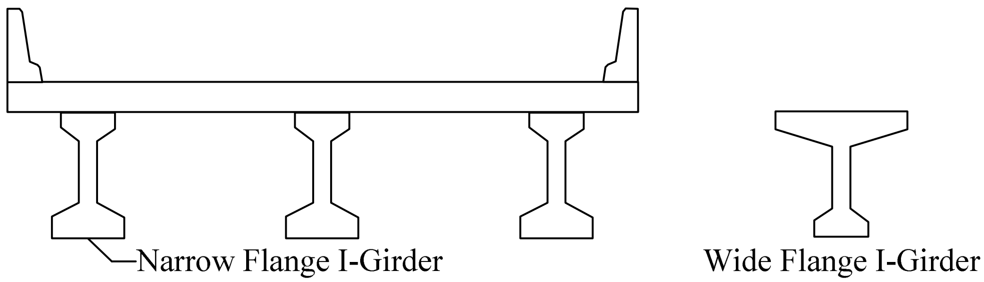


FIGURE C.2.2: PS CONCRETE I-GIRDER (NARROW OR WIDE TOP FLANGE)

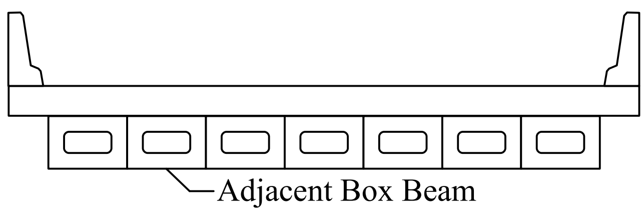


FIGURE C.2.3: PS CONCRETE ADJACENT BOX BEAM

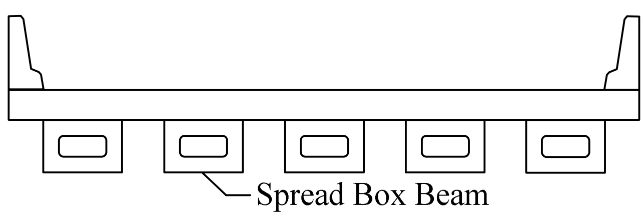


FIGURE C.2.4: PS CONCRETE SPREAD BOX BEAM

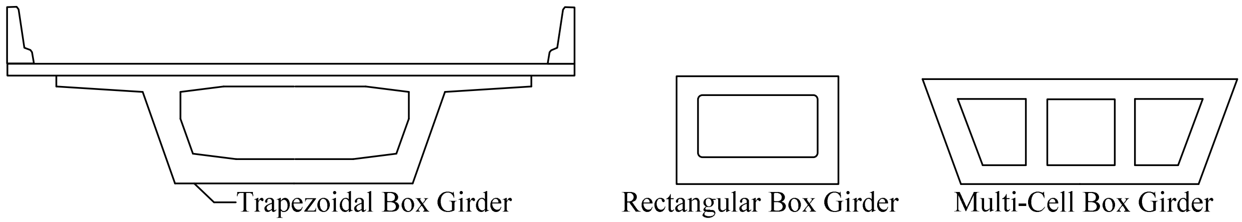


FIGURE C.2.5: PS CONCRETE TRAPEZOIDAL/RECTANGULAR/MULTI-CELL BOX GIRDER

C.3 Reinforced Concrete Structure Type Sketches

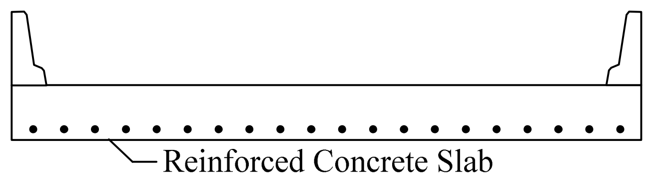


FIGURE C.3.1: REINFORCED CONCRETE SLAB

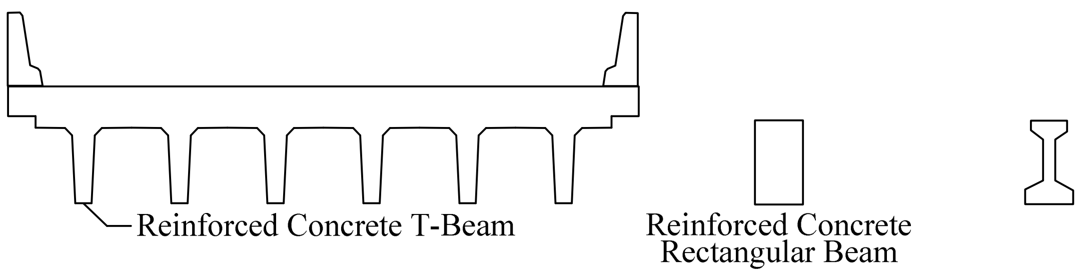


FIGURE C.3.2: REINFORCED CONCRETE T-, DOUBLE T-, RECTANGULAR, OR I-BEAM)

C.4 Timber Structure Type Sketches

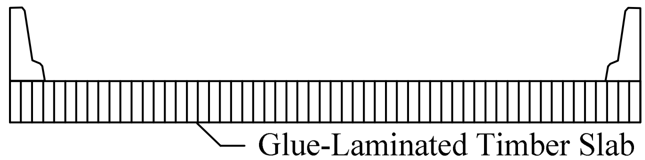


FIGURE C.4.1: GLUE-LAMINATED TIMBER SLAB

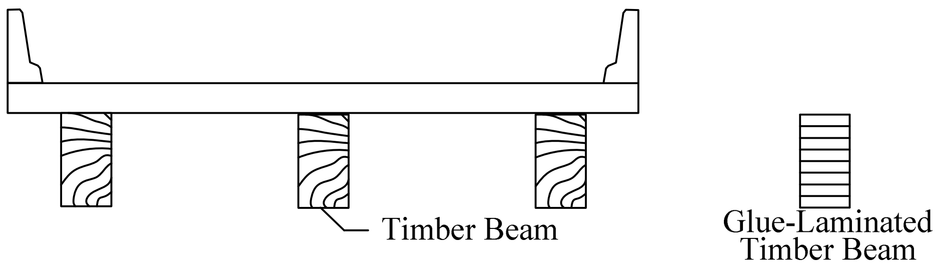


FIGURE C.4.2: TIMBER OR GLUE-LAMINATED BEAM

FIGURE C.4.3: STRESS-LAMINATED TIMBER SLAB

C.5 Truss Structure Type Sketches

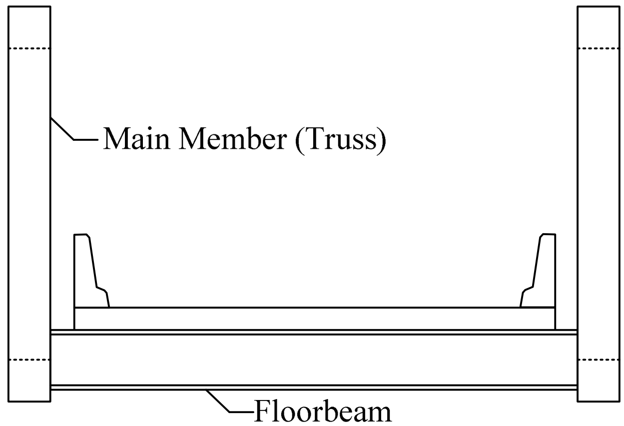


FIGURE C.5.1: TRUSS-FLOORBEAM SYSTEM (THROUGH)

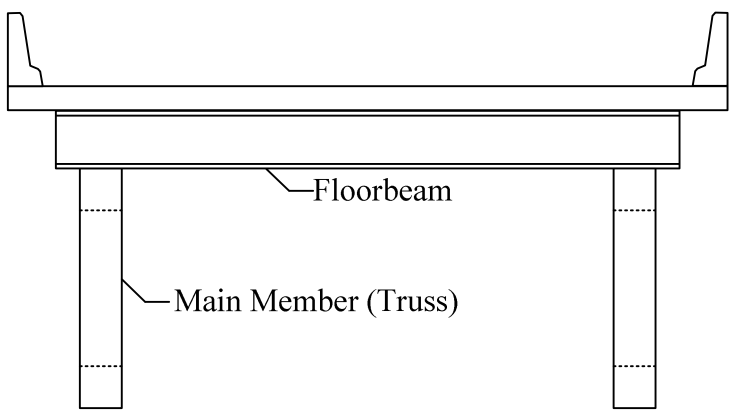


FIGURE C.5.2: TRUSS-FLOORBEAM SYSTEM (DECK)

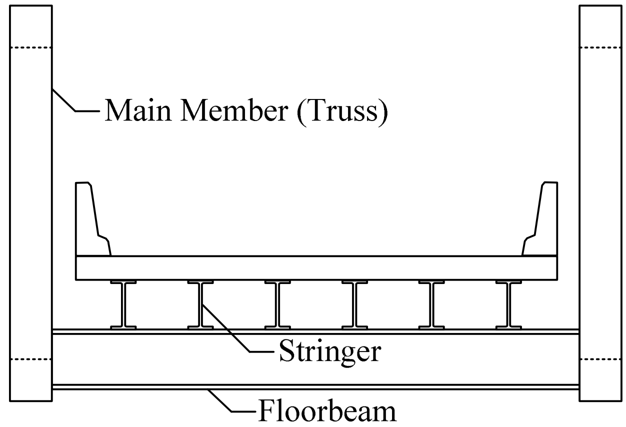


FIGURE C.5.3: TRUSS-FLOORBEAM-STRINGER SYSTEM (THROUGH)

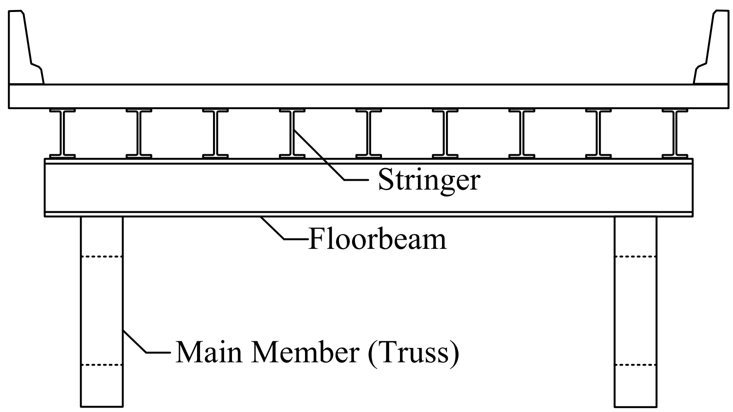


FIGURE C.5.4: TRUSS-FLOORBEAM-STRINGER SYSTEM (DECK)

APPENDIX D – SPECIAL CONSIDERATIONS

D.1 Multiple Presence Factor

The influence of multiple vehicle presence on a span is an important variable in the calibration of live load factor for design and evaluation. An event with simultaneous truck presence in multiple lanes usually corresponds to the maximum bridge loading event.

The controlling load case for LRFD calibration was the two lanes loaded condition with two HL-93 loads side-by-side. It was shown that this loading condition could occur with a two month return period. The multiple presence factor for two-lane loaded condition was set as 1.0. Multiple presence reduction factors for more than two lanes are specified in the Table D.1.1 below.

TABLE D.1.1: MULTIPLE PRESENCE FACTOR

# of Loaded Lanes	LFD Factor, 'm'	LRFD Factor, 'm'
1	1.00	1.20
2	1.00	1.00
3	0.90	0.85
> 3	0.75	0.65

For LRFD, one-lane loaded includes a "1.2 multiple presence factor" built into the distribution factor to account for differences in expected maximum load effects and provides a built-in conservative bias for spans where the maximum loading is controlled by a single truck.

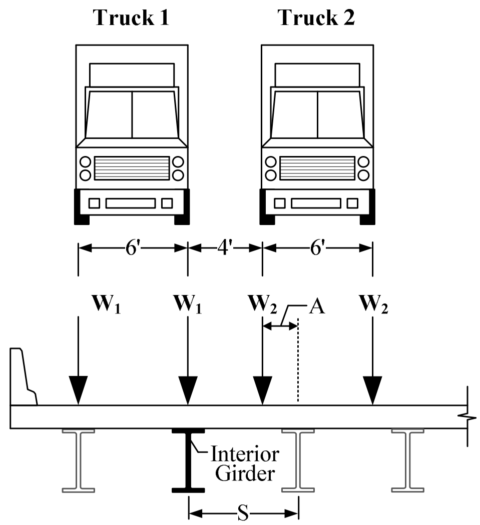
Multiply Distribution Factor by Multiple Presence Factor, '**m**', for:

1. Lever Rule
2. Special Analysis
3. Refined Analysis

Multiple presence factor is already included in LRFR distribution formulas.

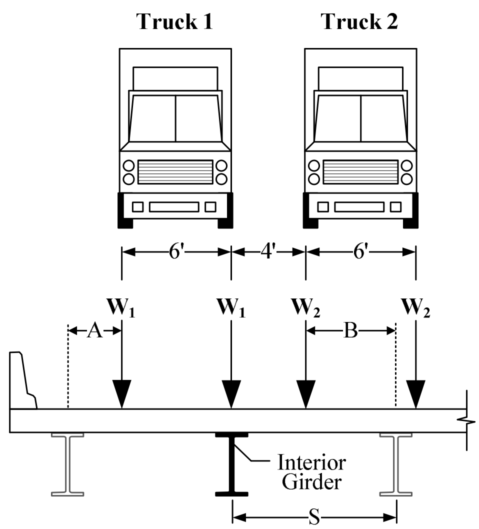
D.2 Shear Distribution Factors for Interior Longitudinal Members using Lever Rule

Live Load Distribution Factor for Shear for Interior Girders
(longitudinal members receiving load directly from deck)



Case I: 4 < S < 6 (Two wheel load between centerline of adjacent girders)

$$DF = 1 + \frac{A}{S}$$



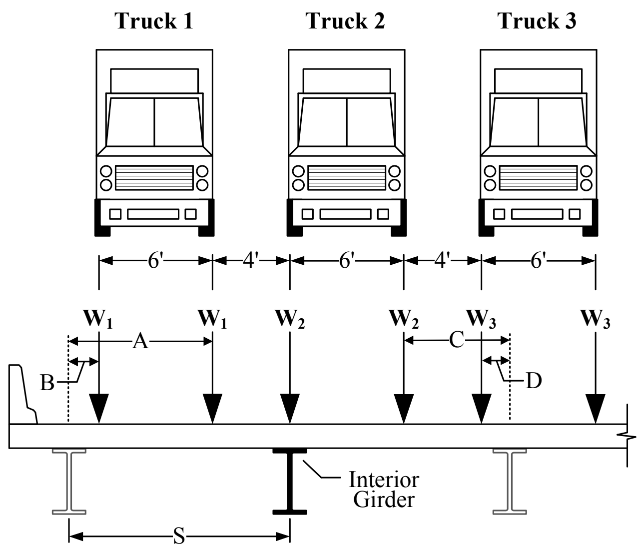
Case II: 6 < S < 10 (Three wheel loads between centerline of adjacent girders)

$$DF = 1 + \frac{A}{S} + \frac{B}{S}$$

*** <u>Notes and Assumptions</u>:**
1. **A wheel gage of 6 feet**
2. **A vehicle spacing of 4 feet (may be adjusted as necessary to reflect actual lane widths)**
3. **All equations provided are for wheel loads**
4. **Equations do not include factor for multiple presence.**

FIGURE D.2.1: SHEAR DISTRIBUTION FACTORS FOR INTERIOR LONGITUDINAL MEMBERS

Live Load Distribution Factor for Shear for Interior Girders
(longitudinal members receiving load directly from deck) - continued



Case III: S > 10 (Five wheel load between centerline of adjacent girders)

$$DF = 1 + \frac{A}{S} + \frac{B}{S} + \frac{C}{S} + \frac{D}{S}$$

*** <u>Notes and Assumptions</u>:**

1. **A wheel gage of 6 feet**
2. **A vehicle spacing of 4 feet (may be adjusted as necessary to reflect actual lane widths)**
3. **All equations provided are for wheel loads**
4. **Equations do not include factor for multiple presence.**

FIGURE D.2.1: SHEAR DISTRIBUTION FACTORS FOR INTERIOR LONGITUDINAL MEMBERS (Contd.)

D.3 Special Analysis for Exterior Girders

D.3.1 The LRFD Distribution Factor for Exterior Longitudinal Member

Live load distribution factor for exterior beams shall be selected as the largest value obtained from the three approximate analysis methods specified below:

1. Lever Rule Method using static analysis for one lane loaded:
   One lane loading is analyzed using the traditional lever rule to determine the fraction of LL carried by the exterior girder. The center of the first wheel load shall be placed two feet from the edge of the exterior curb or parapet.

2. Distribution Formulas for two plus lanes loaded:
   For two or more loaded lanes, a distribution formula modifier of the one lane is provided for exterior girders. It is a function of the deck overhang dimension.

3. Special Analysis for entire section which deflects and rotates as a rigid cross-section:
   In a beam-slab bridge with diaphragms or cross-frames, the distribution factor for the exterior beams shall not be taken less than that which would be obtained by assuming that the superstructure deflects and rotates as a" rigid cross-section." This Special Analysis provision was added to the LRFD specifications because the original study that developed the distribution factor equation did not consider intermediate diaphragms. Multiple Presence Factors are manually included when Lever Rule and Special Analysis are used.

D.3.2 Lever Rule Method for Exterior Members

Live load distribution for exterior longitudinal member with single lane loaded shall be checked using the lever rule. Lever Rule is the statically summation of moments about one point to calculate the reaction at a second point. That reaction as a fraction of the live load is the distribution factor predicted by the lever rule method.

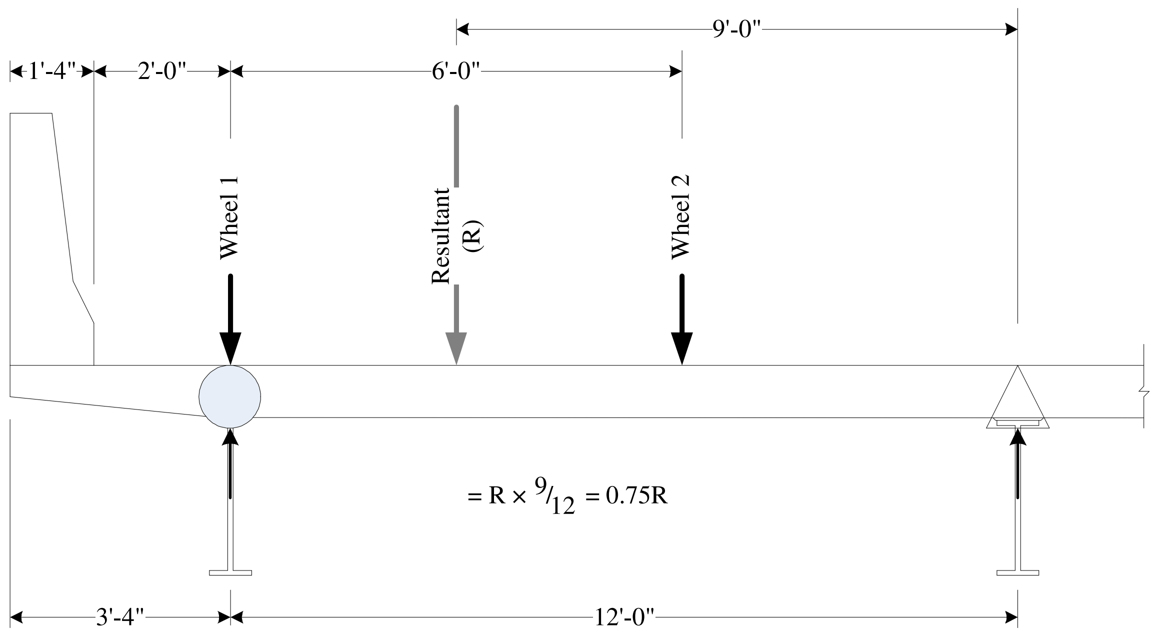
The lever rule method conservatively predicts live load reaction on exterior beam lines. The lever rule only depends on geometry and not on the stiffness of the members since the assumed structural model is determinate.

A 1.2 multiple presence factor shall be applied when the lever rule is used. Whereas, the multiple presence factor is already built into the distribution formula for two or more lanes loaded.

One lane loading is analyzed using the traditional lever rule to determine the fraction of live load carried by the exterior girder. The center of the first wheel load shall be placed two feet from the edge of the exterior curb or parapet. The bridge should be load rated for the way it is being used at the time of evaluation.

HL-93 has a center to center wheel spacing of 6 feet. The point load representing the wheels is assumed to come within 2feet of the edge of the design lane for the design or rating of all members other than the deck overhang. The two wheel loads separated by 6 feet are represented in Figure D.3.2.1 with their resultant load, R. The roadway portion of overhang is assumed to be 2'-0" in the lever rule example below.

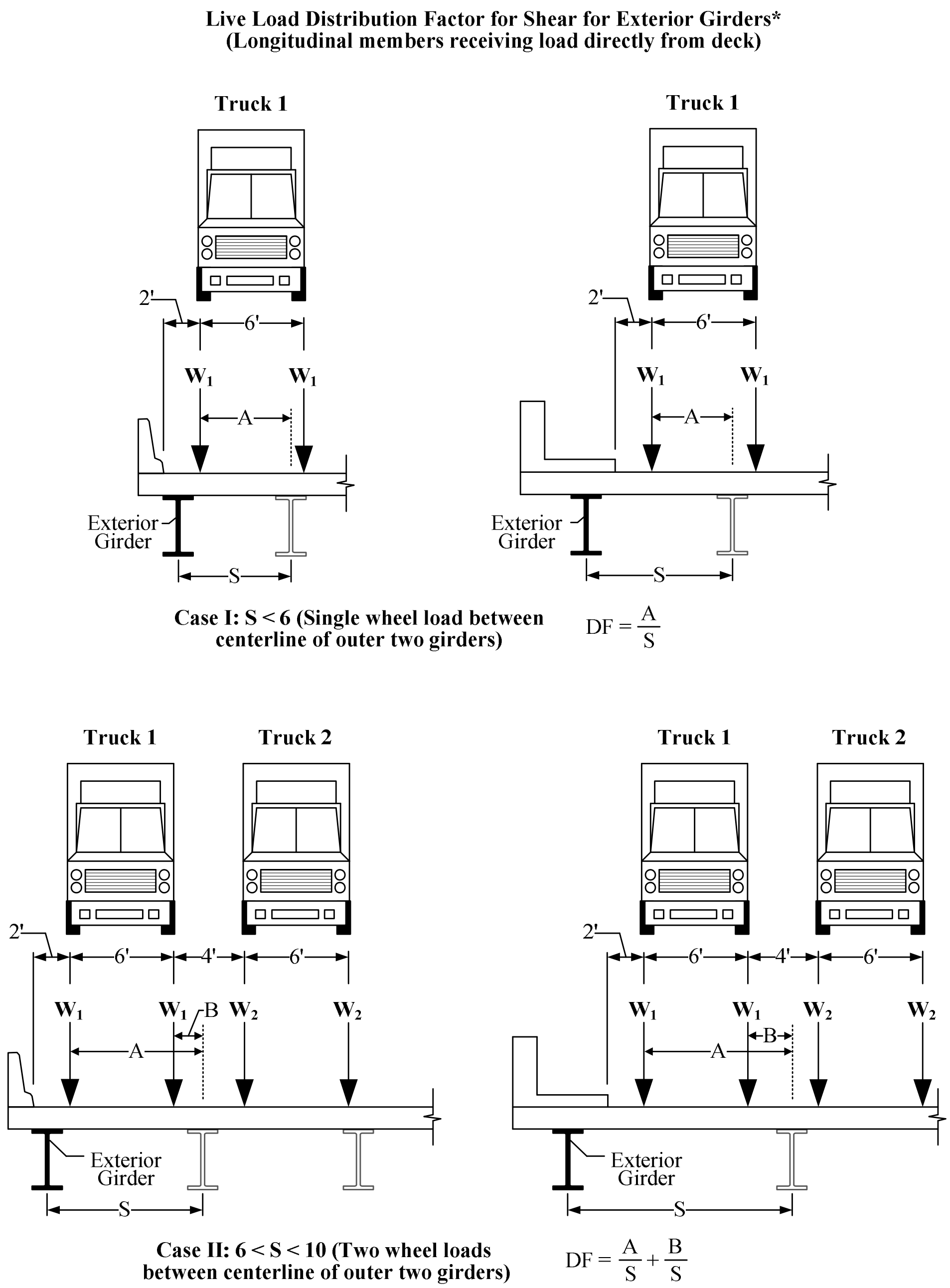
Single lane loaded condition should be checked by the Lever Rule as illustrated in Figure D.3.2.1. That reaction as a fraction of the live load is the distribution factor for the exterior girder by the lever rule method. The multiple presence factor of 1.2 for one lane needs to be included in the distribution analysis when using the Lever Rule method.



DF = 0.75 x 1.2 = 0.9 (per lane)

FIGURE D.3.2.1: EXTERIOR GIRDER EXAMPLE FOR LEVER RULE

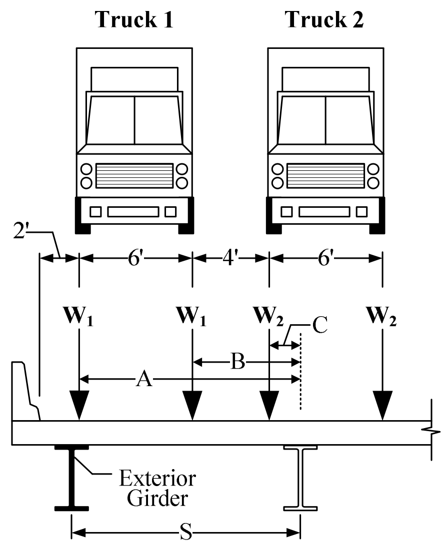
D.3.3 Shear Distribution Factors for Exterior Longitudinal Members using Lever Rule



* Notes and Assumptions:
1. First load placed at 2' spacing from parapet or sidewalk for exterior beam D.F.
2. A wheel gage of 6 feet
3. A vehicle spacing of 4 feet (may be adjusted as necessary to reflect actual lane widths)
4. All equations provided are for wheel loads
5. Equations do not include factor for multiple presence.

FIGURE D.3.3.1: SHEAR DISTRIBUTION FACTORS FOR EXTERIOR LONGITUDINAL MEMBERS

Live Load Distribution Factor for Shear for Exterior Girders *
(longitudinal members receiving load directly from deck) - continued

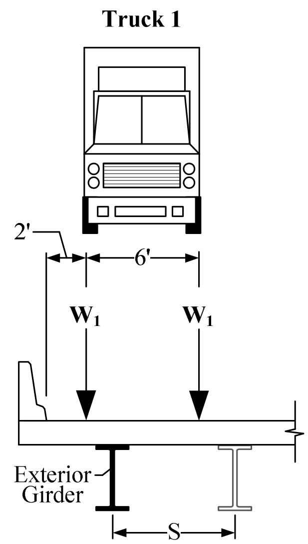


Case III: S > 10 (Three wheel load between centerline of outer two girders)

$$DF = \frac{A}{S} + \frac{B}{S} + \frac{C}{S}$$

* **Notes and Assumptions:**
1. **First load placed at 2' spacing from parapet or sidewalk for exterior beam D.F.**
2. **A wheel gage of 6 feet**
3. **A vehicle spacing of 4 feet (may be adjusted as necessary to reflect actual lane widths)**
4. **All equations provided are for wheel loads**
5. **Equations do not include factor for multiple presence.**

FIGURE D.3.3.1: SHEAR DISTRIBUTION FACTORS FOR EXTERIOR LONGITUDINAL MEMBERS (Contd.)



Case I: Wide overhang with first wheel beyond exterior girder DF = 1

* Notes and Assumptions:
1. First load placed at 2' spacing from parapet or sidewalk for exterior beam D.F.
2. A wheel gage of 6 feet
3. A vehicle spacing of 4 feet (may be adjusted as necessary to reflect actual lane widths)
4. All equations provided are for wheel loads
5. Equations do not include factor for multiple presence.

FIGURE D.3.3.2: SHEAR DISTRIBUTION FACTORS FOR EXTERIOR LONGITUDINAL MEMBERS ON BRIDGES WITH WIDE OVERHANG

D.4 Rigid Cross Section Requirement for Beam-Slab Bridges

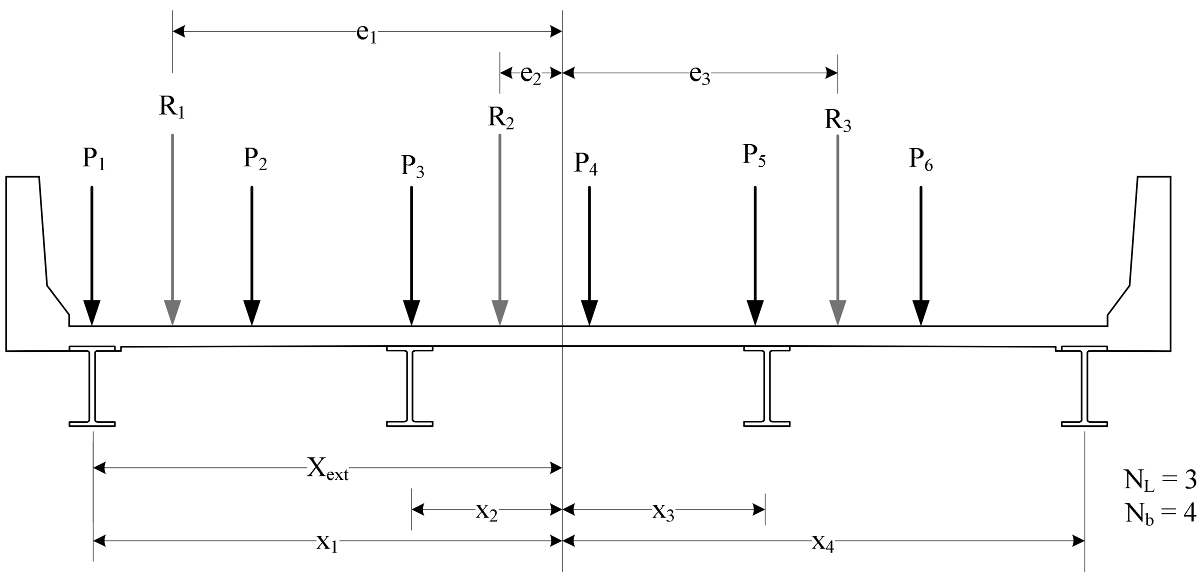
The following equation is applicable for a Rigid Cross Section of a Beam-Slab bridge with cross frames or diaphragms:

$$R = \frac{N_L}{N_b} + \frac{X_{ext}\sum^{N_L} e}{\sum^{N_b} X^2}$$

AASHTO LRFD Equation C4.6.2.2.2d-1

R = Reaction on exterior beam in terms of lanes
N_L= Number of loaded lanes under consideration
e = Eccentricity of design truck/design lane load from c.g. of pattern of girders (ft)
x = Horizontal distance from c.g. of pattern of girders to each girder (ft)
E_{est} = Horizontal distance from c.g. of pattern of girders to exterior girder (ft)
N_b = Number of beams or girders

$$R = \frac{N_L}{N_b} + \frac{X_{ext}\sum^{N_L} e}{\sum^{N_b} X^2}$$



AASHTO LRFD Article 4.6.2.2.2d

FIGURE D.4.1: ANALYSIS DEFINITION SKETCH

Moment and Shear Distribution Factors must be greater than or equal to R. This equation assumes that cross-section deflects and rotates as a rigid cross section. An additional requirement is presented in AASHTO LRFD Articles 4.6.2.2.2d and 4.6.2.2.3b for Beam-Slab Bridges with rigid cross section.

APPENDIX E – LRFR AND LFR

E.1 Weights for Load Rating

TABLE E.1.1: LOAD RATING DEAD LOADS

i.	**Bridge Railing:**		
a.	Single Rail, Steel & Pipe	22	lb/lf
b.	Single Rail, Aluminum	6	lb/lf
c.	Two Rail, Aluminum	12	lb/lf
d.	Three Rail, Aluminum	20	lb/lf
e.	2’-8” high NJ Type Median Barrier	410	lb/lf
f.	2’-8” high Split NJ Type Median Barrier (each half)	305	lb/lf
g.	2’-10” high NJ Type Parapet	567	lb/lf
h.	4’-6” high chain link fence	6	lb/lf
i.	6’-0” high chain link fence	10	lb/lf
ii.	**Stay-in-Place Forms**	12	lb/sf
iii.	**Pipe & Conduits:**		
a.	6” diameter Water Main w/out water	29	lb/lf
b.	6” diameter Water Main w/ water	38	lb/lf
c.	8” diameter Water Main w/out water	40	lb/lf
d.	8” diameter Water Main w/ water	57	lb/lf
e.	10” diameter Water Main w/out water	51	lb/lf
f.	10” diameter Water Main w/ water	79	lb/lf
g.	12” diameter Water Main w/out water	62	lb/lf
h.	12” diameter Water Main w/ water	103	lb/lf
i.	18” diameter Water Main w/out water	94	lb/lf
j.	18” diameter Water Main w/ water	192	lb/lf
k.	20” diameter Water Main w/out water	105	lb/lf
l.	20” diameter Water Main w/ water	227	lb/lf
m.	24” diameter Water Main w/out water	126	lb/lf
n.	24” diameter Water Main w/ water	306	lb/lf
o.	30” diameter Water Main w/out water	235	lb/lf
p.	30” diameter Water Main w/ water	511	lb/lf
q.	36” diameter Water Main w/out water	374	lb/lf
r.	36” diameter Water Main w/ water	786	lb/lf
s.	4” diameter Gas Main	19	lb/lf
t.	6” diameter Gas Main	29	lb/lf
u.	8” diameter Gas Main	40	lb/lf
v.	10” diameter Gas Main	57	lb/lf
w.	12” diameter Gas Main	71	lb/lf
x.	16” diameter Gas Main	90	lb/lf
y.	4” diameter Telephone Conduit	3	lb/lf
z.	4” diameter Electric Conduit	3	lb/lf
aa.	4” diameter CATV Conduit	3	lb/lf

E.2 Live Load Vehicles Sketches

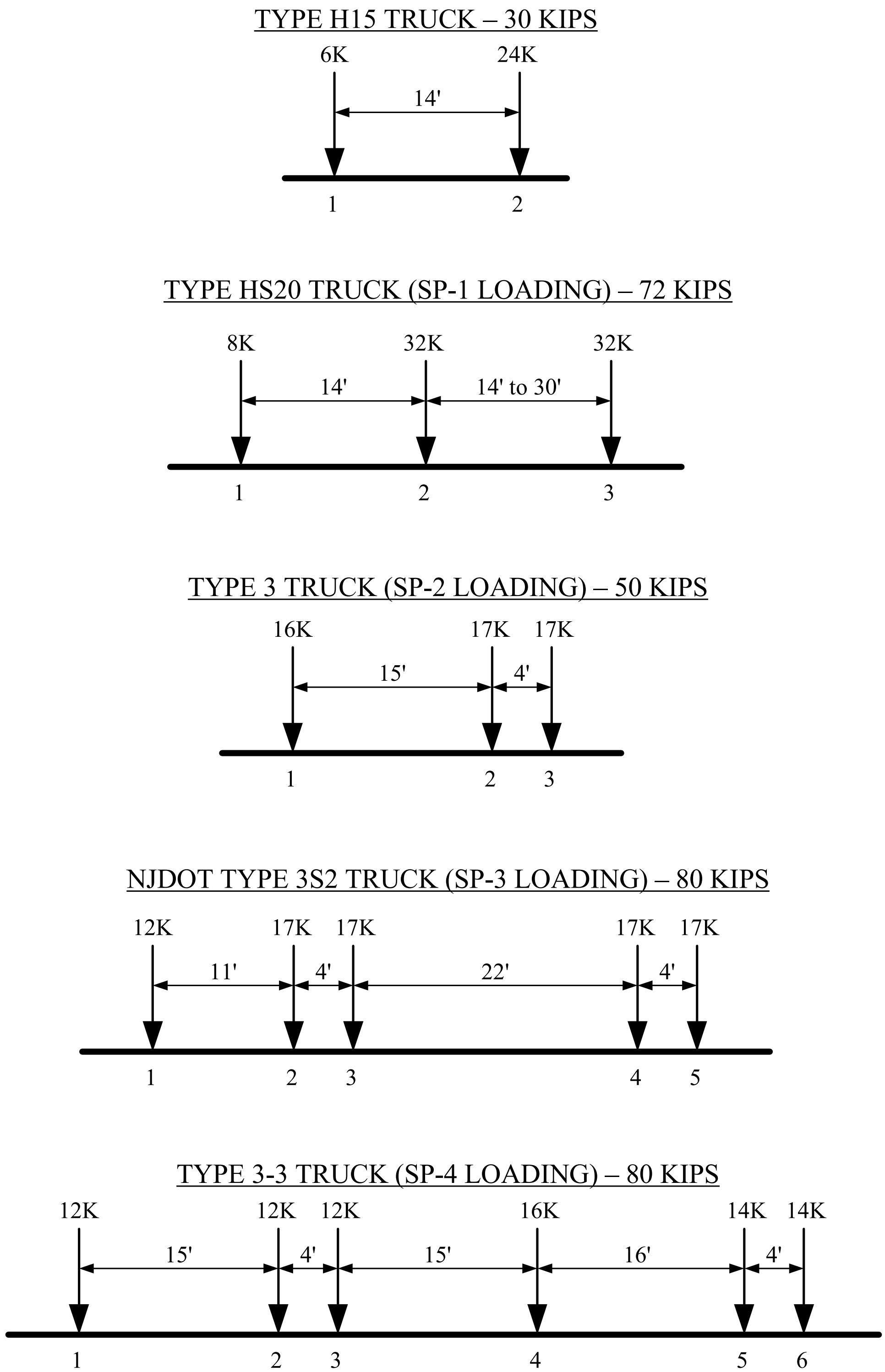


FIGURE E.2.1: NJ LEGAL LOAD CONFIGURATIONS

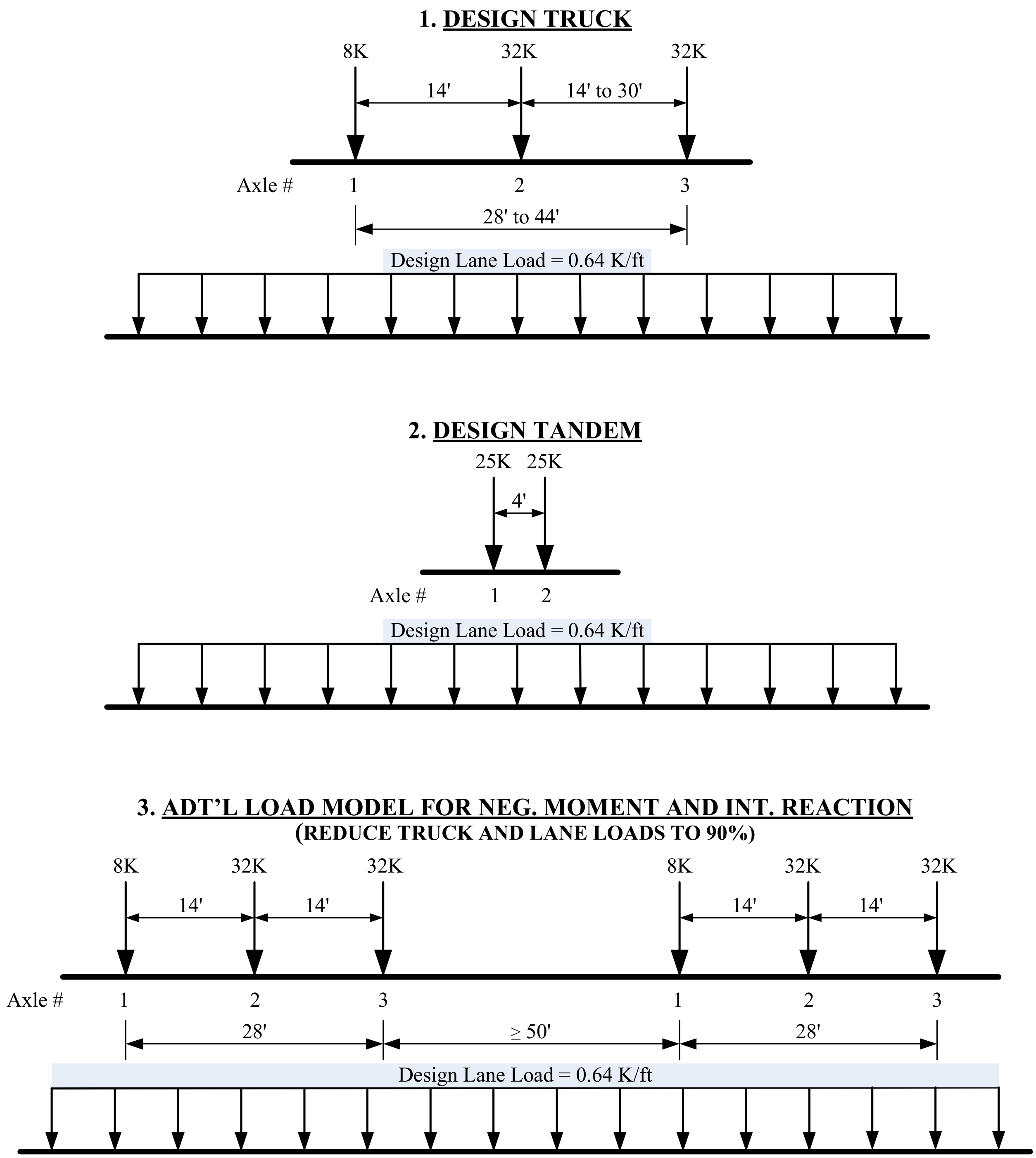


FIGURE E.2.2: LRFD DESIGN LIVE LOAD – HL-93

Note:

Pick the largest extreme force effect of the three scenarios in Figure E.2.2 above. For additional details, refer to AASHTO LRFD.

E.3 LRFR Live Load Supplement

E.3.1 Design Load Rating for HL-93 Loading

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 condition.

HL-93 rating 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.

The evaluation live-load factors for the Strength I limit state shall be taken as given in MBE Table 6A.4.3.2.2-1.

TABLE E.3.1.1 [MBE 6A.4.3.2.2-1]: LOAD FACTORS FOR DESIGN LOAD: γ_L

Evaluation Level	Load Factor
Inventory	1.75
Operating	1.35

The dynamic load allowance specified in the LRFD Specifications for new bridge design (LRFD Article 3.6.2) shall apply.

The results of the HL-93 rating are to be reported to the FHWA as a Rating Factor for Structural Inventory and Appraisal (SI&A) Items 64 and 66 using the HL-93 loadings.

E.3.2 Legal Load Rating for Routine Commercial Traffic

In LRFR, assuming HL-93 as the design load, load ratings determine a single safe load capacity of a bridge for legal loads. **The previously existing distinction of Operating and Inventory level ratings is no longer maintained when performing load ratings for legal loads.**

The live load to be used in the LRFR rating for routine commercial traffic shall be any of the State legal loads shown in Section 5.7 and Appendix E.2 of this Manual.

The live-load factors for legal loads for the Strength I limit state shall be taken as given in Table E.3.2.1.

TABLE E.3.2.1 [MBE 6A.4.4.2.3a-1]: LIVE LOAD FACTORS, γ_L FOR NJ LEGAL LOADS

Traffic Volume (One direction)	LRFR Load Factor For Type 3, NJDOT Type 3S2, Type 3-3, Lane Loads
Unknown	1.80
ADTT ≥ 5,000	1.80
ADTT = 1,000	1.65
ADTT ≤ 100	1.40

Note: Linear interpolation is permitted for other ADTT values

It is unnecessary to place more than one vehicle in a lane for spans less than 200 feet because the LRFR live load factors provided have been modeled for this possibility (no lane load to be used).

E.3.3 Reduced Dynamic Load Allowance for Rating (Legal Loads) – MBE C6A.4.4.3.1

For design load rating, regardless of the riding surface condition or the span length, always use 33% for the dynamic load allowance (IM) for all limit states except fatigue and fracture limit states.

For legal load rating of longitudinal members having spans greater than 40 feet with less severe approach and deck surface conditions, the Dynamic Load Allowance (IM) may be decreased from the LRFD design value of 33%, as given below in Table E.3.3.1, for the Strength and Service limit states.

Dynamic load allowance shall be applied to the state legal vehicles and not the lane loads. Regardless of riding surface condition, always use 33% for longitudinal members with spans 40 feet or less and for all transverse members.

Selection of IM shall be in accordance with the requirements of Section 5.8.2.8. Document what value of IM was used for the load rating in the Load Rating Summary Sheet.

If the permit vehicle proceeds at a crawl speed under escorted conditions, at less than 10 miles per hour, then the impact can be assumed to be 0%.

TABLE E.3.3.1: DYNAMIC LOAD ALLOWANCES

Wearing Surface Condition	Deck Joint Differential Settlement	IM
Good or Above	No differential settlement observed	10%
Satisfactory	Minor differential settlement < ½”	20%
Fair & Below	Major differential settlement ≥ ½”	33%

Note: In the Table E.3.3.1, the controlling condition (worst of either wearing surface or deck joint differential settlement) should be considered when selecting IM.

E.3.4 Strength Limit States Resistance Factor, ϕ

For Strength Limit States, member capacity is given as:

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

Where:
ϕ_c = Condition Factor
ϕ_s = System Factor
ϕ= LRFD Resistance Factor

Where, the following lower limit shall apply:
$\phi_c \phi_s \geq 0.85$

Resistance factor has the same value for new design and for load rating.

Resistance factors, ϕ, shall be taken as specified in the LRFD Specifications for new construction.

A reduction factor based on member condition, Condition Factor ϕ_c, is applied to the resistance of degraded members.

An increased reliability index is maintained for deteriorated and non-redundant bridges by using condition and system factors in the load rating equation.

E.3.5 Strength Limit States Condition Factor, ϕ_c

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.

Current NJDOT policy is to set this factor equal to the values presented in Table E.3.5.1.

TABLE E.3.5.1 [MBE 6A.4.2.3-1]: CONDITION FACTOR, ϕ_c

Superstructure Condition Rating (SI&A Item 59)	Structural Condition of Member	ϕ_c
6 or higher	Good or Satisfactory	1.00
5	Fair	0.95
4 or lower	Poor	0.85

The Condition Factor, ϕ_c, does not account for section loss, but is used in addition to section loss. If section properties are obtained accurately, by actual field measurement of losses rather than by an estimated percentage of losses, the values specified for ϕ_c in Table E.3.5.1 may be increased by 0.05 ($\phi_c \leq 1.0$).

For instance, a concrete member may receive a low condition rating due to heavy cracking, spalling or other types of deterioration to the concrete member. 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 shall 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.

E.3.6 Strength Limit States System Factor, ϕ_S

System Factors are multipliers applied to the nominal resistance to reflect the level of redundancy of the complete superstructure system. Bridges that are less redundant will have their factor 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.

Current NJDOT policy is to use the System Factors provided in Table E.3.6.1 when load rating for Flexural and Axial Effects for steel members and non-segmental concrete members.

**TABLE E.3.6.1 [MBE 6A.4.2.4-1]: SYSTEM FACTOR, ϕ_s
FOR FLEXURAL AND AXIAL EFFECTS**

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
All Other Girder Bridges and Slab Bridges	1.00
Floorbeams with Spacing >12ft. and Non-Continuous Stringers	0.85
Redundant Stringer Subsystems Between Floorbeams	1.00
Three Girder Bridges *	0.90
Four Girder Bridges *	0.95

** These are NJDOT additions to the table that may be adjusted as per the LRE's judgment.*

The System factor is set equal to 1.0 when checking shear.

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

The System Factor is used with all live load models.

E.3.7 Service Limit States Resistance Factors

For all non-strength limit states, φ =1.0, ϕ_c = 1.0, ϕ_s = 1.0

E.3.8 Service Limit and Fatigue Limit States for Load Rating

E.3.8.1 General Overview

Service and fatigue limit states to be evaluated during a load rating analysis shall be as given below in Table E.3.8.1.1:

TABLE E.3.8.1.1 [MBE E.4.2.2-1]: LIMIT STATES AND LOAD FACTORS

Bridge Type	Limit State	Dead Load	Dead Load	Design Load		Legal Load
				Inventory	Operating	
		DC	DW	LL	LL	LL
Steel	Service II	1.00	1.00	1.30	1.00	1.30
	Fatigue	0.00	0.00	0.75	NA	NA
Prestressed Concrete	Service III	1.00	1.00	0.80	NA	1.00

E.3.8.2 Concrete Bridges

For 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 and legal load ratings of prestressed concrete bridges.

An allowable tension stress in the pre-compressed tensile zone of $3\sqrt{f'_c}$ in prestressed concrete members with bonded reinforcement shall be utilized when performing the design load check at the Inventory level and legal load ratings.

E.3.8.3 Steel Bridges

Steel structures shall satisfy the overload permanent deflection check under the Service II load combination for design and legal load ratings using load factors as given in Section E.3.8.1.

Maximum steel stress is limited to 95% and 80% of the yield stress for composite and non-composite compact girders respectively.

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.

If directed by NJDOT, bridge details that fail the infinite-life check can be subject to the finite-life fatigue evaluation using evaluation procedures given in the MBE Section 7.

E.4 AASHTO MBE and NJDOT Modified Tables

E.4.1 AASHTO MBE Tables

1. Live Load Moments on Longitudinal Stringers or Girders for Routing Commercial Traffic.*
   a. Refer to MBE Table No. C6B-1

2. Live Load Moments on Longitudinal Stringers or Girders for Specialized Hauling Vehicles.*
   a. Refer to MBE Table No. C6B-2

3. Live Load Reactions **R** in kips per Wheel Line, No Impact, for Routing Commercial Traffic, on Transverse Floorbeams and Caps (Intermediate Transverse Floorbeams) (Simple Span Only)
   a. Refer to MBE Table No. D6B-1

4. Live Load Reactions **R** in kips per Wheel Line, No Impact, for Specialized Hauling Vehicles, on Transverse Floorbeams and Caps (Intermediate Transverse Floorbeams) (Simple Span Only)
   a. Refer to MBE Table No. D6B-2

5. Live Load Reactions **R** in kips per Wheel Line, No Impact, for Routing Commercial Traffic, on Transverse Floorbeams and Caps (End Transverse Floorbeams) (Simple Span Only)
   a. Refer to MBE Table No. E6B-1

6. Live Load Reactions **R** in kips per Wheel Line, No Impact, for Specialized Hauling Vehicles, on Transverse Floorbeams and Caps (End Transverse Floorbeams) (Simple Span Only)
   a. Refer to MBE Table No. E6B-2

* *For 3S2 Type loading refer to Table E.4.2.1 of this Manual.*

E.4.2 NJDOT Modified MBE Table C6B

Table E.4.2.1 provides the live load moments on longitudinal members from MBE Table C6B-1 that have been revised for the NJDOT Type 3S2 legal truck:

TABLE E.4.2.1: LIVE LOAD MOMENTS FOR LONGITUDINAL STRINGERS OR GIRDERS WITH NJDOT TYPE 3S2 TRUCK

Live Load Moments per Wheel Line			Live Load Moments per Wheel Line		
Span C/C (feet)	**without Impact (ft-kips)**	**with Impact* (ft-kips)**	**Span C/C (feet)**	**without Impact (ft-kips)**	**with Impact* (ft-kips)**
5	10.6	13.8	32	134.3	174.7
6	12.8	16.6	34	145.9	189.7
7	15.2	19.7	36	157.3	204.5
8	19.1	24.9	38	168.8	219.5
9	23.1	30.1	40	180.4	234.5
10	27.2	35.4	42	191.6	249.3
11	31.3	40.7	44	203.3	263.5
12	35.4	46.0	46	214.8	277.6
13	39.6	51.4	48	226.2	291.6
14	43.7	56.8	50	244.1	313.8
15	47.9	62.3	52	263.8	338.2
16	52.1	67.7	54	283.3	362.5
17	56.3	73.1	56	303.0	386.7
18	60.4	78.6	58	322.8	411.0
19	64.6	84.0	60	342.2	434.9
20	68.9	89.5	70	441.2	554.3
21	73.1	95.0	80	540.3	672.1
22	77.3	100.5	90	639.6	788.3
23	82.8	107.6	100	739.1	903.3
24	88.5	115.0	120	938.2	1129.7
25	94.2	122.5	140	1137.6	1352.3
26	100.0	129.9	160	1337.2	1571.8
27	105.7	137.4	180	1536.7	1788.6
28	111.4	144.9	200	1736.5	2003.6
29	117.2	152.4	250	2236.0	2534.2
30	122.9	159.8	300	2736.2	3057.9

** Note that this column is based on the impact factor of the AASHTO Standard Specifications for ASD/LFD.*

E.5 LFD Redistribution Requirements

For LFD analysis, re-distribution of negative moment, in steel compact continuous spans, can be considered as per AASHTO Standard Specifications, Article 10.48.1.3.

E.6 Prestressed Concrete Bridges Built before 1970

As per MBE 2011, Article 6.A.3.2, Commentary C6A.3.2, a minimum prestress of 0.25 ksi (LRFD Design Article C4.6.2.2.1) is required to act as a unit.

To calculate the distribution factors for prestressed concrete adjacent box beam and slab bridges built before 1970, which do not meet the above criteria, use *S/D* method of live load distribution provided in the AASHTO LRFD Bridge Design Specifications, Table 4.6.2.2.2B-1, page 4-36.

APPENDIX F – LARS

F.1 LARS Bridge General Instructions

Follow instructions as indicated on the form. For detail see NJDOT Structural Evaluation website at http://www.state.nj.us/transportation/eng/structeval/downloads.shtm

APPENDIX G – FORMS

G.1 FORMS

Forms used in completing load ratings are listed below. Participants and contributors to the New Jersey Bridge Inspection Program are advised to go to the NJDOT Structural Evaluation website at http://www.state.nj.us/transportation/eng/structeval/ for the current list of applicable forms and the most recent versions of each form. Memorandums and other guidance that may have been issued after the issuance of the current revision of this Chapter can also be found on the same website. Bridge Owners and Load Rating Engineers are urged to check this site to ensure they have all the most current information and forms for load rating.

TABLE G.1.1: NJDOT STRUCUTRAL EVALUATION FORMS

Name	Form Number	Revision Date
Load Rating Summary Sheet	NJ-BI-101	Created on 1/25/2011
Member Identification Sheet	NJ-BI-102	Created on 8/1/2011

APPENDIX H – HISTORY

H.1 MANUAL REVISION HISTORY

TABLE H.1.1: MANUAL REVISION HISTORY

Rev	Date	Description
1	March 2012	First Edition – NJDOT Highway Bridge Load Rating Manual