CONNECTICUT DEPARTMENT OF TRANSPORTATION

BRIDGE LOAD RATING MANUAL

Prepared by the Load Rating Section

Please direct all question and inquiries to DOT.BridgeRating@ct.gov

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DEFINITIONS

As-Built Plans (As Constructed) – Plans that show the state of the structure at the end of construction.

Bent – A substructure unit with two or more columns or pile extensions with a cap or cross bracing that supports the spans of a multi-span superstructure at an intermediate location between its abutments.

Box Culvert – A mildly reinforced concrete culvert, with or without a bottom slab.

Bridge Management System – A system designed to optimize the use of available resources for inspection, maintenance, rehabilitation, and replacement of bridges.

Complex Bridges – These structures are movable, suspension, cable stayed or have other unusual characteristics.

Condition Rating – A judgement of a bridge component condition in comparison to its original as-built condition, used to provide an overall characterization of the general condition of the component being rated.

Crossbeam – A transverse beam supporting longitudinal girders at a bent, also known as a Bent Cap.

Cross-frame – A transverse truss framework connecting adjacent longitudinal flexural components or inside a tub section or closed-box used to transfer and distribute vertical and lateral loads and to provide stability to the compression flanges.

Diaphragm – A vertically oriented solid transverse member connecting adjacent longitudinal flexural components or inside a closed-box or tub section to transfer and distribute vertical and lateral loads and to provide stability to the compression flanges.

Emergency Vehicle – Vehicle used under emergency conditions to transport personnel and equipment to support the suppression of fires and mitigation of other hazardous situations.

Inventory Level Rating – Represents the maximum load allowed to stress the structure on a continuing basis, but reflects the existing structure and material conditions with regard to deterioration and loss of section.

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

Load Effect – The response (axial force, shear force, bending moment, torque) in a member or an element due to the loading.

Load Factor – A load multiplier accounting for the variability of loads, the lack of accuracy in analysis, and the probability of simultaneous occurrence of different loads.

Load Rating – The determination of the available live load capacity of an existing structure.

Load Rating Package – The load rating report and load references folder submittal.

Load Rating Reference Folder – A zip archive folder which contains files generated to complete the load rating.

Load Rating Report – A PDF file which documents the load rating results, methodology, calculations, program input, and back-up documentation.

Load Rating Section – The Load Rating specialist group that is part of the Bridge Design Unit in the Office of Engineering - Division of Bridges.

Low Rating – A rating factor less than 1.0 for any of the required loading conditions.

Metal Pipe Arch – Closed shape steel or aluminum structure that has individual radii measurements between the crown, the floor, and the corner.

Metal Pipe Culvert – Circular steel or aluminum culvert.

National Bridge Inspection Standards – Federal regulations establishing requirements for inspection procedures, frequency of inspections, qualifications of personnel, inspection reports, and preparation and maintenance of bridge inventory records. The NBIS apply to all structures defined as highway bridges located on all public roads.

National Bridge Inventory – The aggregation of structure inventory and appraisal data collected to fulfill the requirements of the National Bridge Inspection Standards.

Nominal Resistance – Resistance of a component or connection to load effects, based on its geometry, permissible stresses, or specified strength of materials, also referred to as Unfactored Resistance.

Operating Level Rating – The maximum permissible live load that can be placed on a structure.

Pier – A substructure unit with one column or shaft supported by a footing or pile cap that supports the spans of a multi-span superstructure at an intermediate location between abutments.

Posting – Signing a bridge for load restriction.

Primary Member – Any member that receives traffic loads either directly or from the deck and distributes them to main supporting elements, substructure units, or foundation soil or rock.

Rating Factor – The ratio of the available load capacity to the load produced by the live load that was considered.

Redundancy – The quality of a bridge that enables it to perform its design function in a damaged state.

Redundant Member – A member whose failure does not cause failure of the bridge.

Reliability Index – A computed quantity defining the relative safety of a structural element or structure expressed as the number of standard deviations that the mean of the margin of safety falls on the safe side.

Resistance Factor – A resistance multiplier accounting for the variability of material properties, structural dimensions and workmanship, and the uncertainty in the prediction of resistance.

Service Limit State – Limit state relating to stress, deformation, and cracking.

Specialized Hauling Vehicles – Short but heavy vehicles that may or may not meet the provisions of Federal Bridge Formula B but induce load effects greater than Routine Commercial Traffic, especially on short spans.

Strength Limit State – Safety limit state relating to strength and stability.

ABBREVIATIONS

AASHTO – American Association of State and Highway Transportation Officials

ACI – American Concrete Institute

ADTT – Average Daily Truck Traffic

AISC – American Institute of Steel Construction

ASD – Allowable Stress Design

ASR – Allowable Stress Rating

ASTM – American Society for Testing and Materials

BDS – AASHTO LRFD Bridge Design Specifications

BIM – CTDOT Bridge Inspection Manual

BIR – Bridge Inspection Report

BLRM – CTDOT Bridge Load Rating Manual

BWS – AASHTOWare Bridge Workspace Report

CTDOT – Connecticut Department of Transportation

DC – Dead Load of Structural Components and Nonstructural Attachments

DW – Dead Load of Wearing Surface and Utilities

EV – Emergency Vehicle

FDP – Final Design Plans

FEA – Finite Element Analysis

FEM – Finite Element Model

FHWA – Federal Highway Administration

IM – Dynamic Load Allowance

LFD – Load Factor Design

LFR – Load Factor Rating

LLDF – Live Load Distribution Factor

LRE – Load Rating Engineer

LRFD – Load and Resistance Factor Design

LRFR – Load and Resistance Factor Rating

LRS – CTDOT Load Rating Section

MBE – AASHTO Manual for Bridge Evaluation

MPF – Multiple Presence Factor

NBI – National Bridge Inventory

PDF – Portable Document Format [File type]

PCI – Precast/Prestressed Concrete Institute

QA – Quality Assurance

QC – Quality Control

SIP – Stay-In-Place [Formwork]

SMS – Structural Management Software/InspectTech

CHAPTER 1 GENERAL

1.1 Purpose

The primary mission of the CTDOT is to provide a safe and efficient intermodal transportation network that improves the quality of life and promotes economic vitality for the State and Region. Maintaining and improving upon the State's bridge inventory is necessary to accomplish this goal. A critical step in determining if a bridge inventory is in a good state of repair is the evaluation and analysis of each structure's capacity to safely carry live loads in its current condition. A load rating must provide this information in an accurate, organized, and standardized report. The information contained in this report is used for several purposes:

- To determine which structures may require remedial action.
- To determine safe posting limits for structures with substandard load capacities.
- To assist in the most effective use of available resources for rehabilitation or replacement.
- To assist in permit vehicle reviews.
- To satisfy FHWA requirements that every NBI structure in the State has an associated load rating in accordance with the most recent MBE.

This document shall provide a methodology that will result in consistent and reproducible load rating inputs and deliverables. It was developed in accordance with the most current editions of the *AASHTO Manual for Bridge Evaluation* and the *AASHTO LRFD Bridge Design Specification*, including interims or errata. The BLRM conforms to the criteria set forth in these AASHTO manuals and provides guidance in areas that are not specifically called out by AASHTO or that require Owner decisions.

1.2 Scope and Format

The requirements set forth in this Manual apply to all Department and consultant personnel involved in load rating and bridge posting. While this Manual is intended to provide bridge load rating policy for work done by or for CTDOT, it does not preclude justifiable exemptions, subject to the approval by the LRS. The principal areas of emphasis are on methodology, requirements for load rating report submittals, approved software, and the quality assurance and checking process.

This Manual shall serve as a supplement to the most recent MBE. It is not intended to be a stand-alone document for load rating for the state of Connecticut. Rather, this Manual should be consulted wherever the AASHTO manuals leave room for interpretation and where policy decisions are required.

In instances where information contained herein conflict with the most recent MBE, the guidance in this Manual shall be followed.

This Manual is a living document. The official copy of this Manual can be found on the CTDOT Bridge Load Rating Website. Changes will be issued as necessary to incorporate changes in policy, loadings, or evaluation.

Changes to this manual are documented in the *Summary of Changes*, which can be found on the CTDOT Bridge Load Rating Website.

1.3 Methodology

LRFR shall be the only method of rating accepted for submittal. Exceptions must be approved by the LRS prior to beginning the rating. Exceptions will only be granted for evaluation of material or geometry that is not currently included in the most recent *BDS* or *MBE*.

1.3.1 **Judgment Ratings**

Judgment Ratings, made by the State Load Rating Engineer, will be considered if the structure is:

- Concrete and if the following conditions are satisfied:

  - All avenues for locating plans for the structure have been exhausted. This includes design plans, shop drawings, working drawings, and as-built plans stored with the Department, design engineer, precasters or contractors;
  - Reinforcement steel cannot be discerned through inspection methods,
- In service, buried, and exhibits negligible vehicular loading as defined in Article 10.3.2.1 or Article 10.3.2.2.

1.4 Requirements to Perform a Load Rating Analysis

Each occurrence described in this Section shall require a load rating completed in accordance with this Manual.

1.4.1 **Structures in Projects**

If the load carrying capacity of the structure will be affected by a Project, then a new load rating shall be performed. A new Load Rating shall also be performed when new structural components are added.

1.4.2 **Existing Structures**

A new Load Rating shall be performed for structures which exhibit a change in condition or loads from the existing load rating on file

1.4.2.1 Change in Condition

a) The capacity of structural components, required for evaluation, can change due to deterioration, distress, impact, or construction damage.

b) The load on a structure can change due to the addition of new or relocated dead loads or altering the distribution of live load.

1.4.2.2 Live Load Analysis

The main purpose of performing a live load analysis is to provide load ratings for specific vehicles.

1.5 Components for Evaluation

a) All components required for evaluation, listed in this Section, shall be evaluated or represented in each load rating performed for a structure; despite if only a limited number of components experience a change in conditions. Components which were previously rated to the current BLRM standards and the LRE concurs with the existing load rating, need not be re-evaluated. In such cases, supporting documentation and rating files shall be provided in the load rating package.

b) Members within a bridge which exhibit identical force effects and capacities may be enveloped for the purpose of reducing the number of components required for evaluation. All unique components must be evaluated regardless of comparative measures between members.

1.5.1 **Decks**

- Steel decks
- Corrugated metal bridge planking (Deck pans, not SIP forms)
- Timber decks
- Concrete decks with longitudinal post tensioning
- Decks of girder-floorbeam systems
- Reinforced concrete decks shall be evaluated if the condition rating in the BIR is appraised as poor or worse and thought to reduce the available live load capacity. Prior to performing an evaluation the

LRE shall request concurrence from the LRS. The LRE shall provide a justification for the request.

1.5.2 **Superstructure**

- Girders, beams, and stringers
- Floorbeams
- Trusses
- Spandrel arches
- Adjacent deck or slab units
- Slab spans
- Rigid frames and arches
- Steel cantilever sidewalk supports located on the outside of through plate girders and trusses
- Critical connections as defined in Section 6.8
- Diaphragms and cross-frames of curved structures and structures with a support skewed greater than 30 degrees, as defined in Article 6.7.1

1.5.3 **Substructure**

- Pier caps (Steel and timber)
- Columns (Steel and timber)
- Bents (Steel and timber)
- Concrete Substructure
    - Special geometry or configuration (e.g., long cantilever cap) shall be rated at the discretion of the LRS.
    - Shall be evaluated if the condition rating of the member in the BIR is appraised as poor or worse and thought to reduce the available live load capacity. Prior to performing an evaluation the LRE shall request concurrence from the LRS. The LRE shall provide a justification for the request.

1.5.4 **Culverts**

Buried structures shall be rated in accordance with this Manual if the structure length, BRI-19 item 49, is 6 feet or greater.

1.6 System of Units

The structure should be modeled and analyzed in the system of units used for design. However, all input into the Bridge Load Rating Form shall be in US customary units regardless of the system of units used for modeling or analysis.

1.7 Bridge Component Labeling

The structure shall be logged and follow the same naming convention as documented in the most recent BIR. All working files and report documents submitted shall reference and label the structure's components as such. For new structures and bridge components the bridge shall be logged as specified in the *CTDOT Bridge Inspection Manual*, *Chapter 06, General, Bridge Component Labeling Systems For Inspection Reporting*. Diaphragms and cross-frames shall be labeled as shown in Figure 1.4.2.2-1.

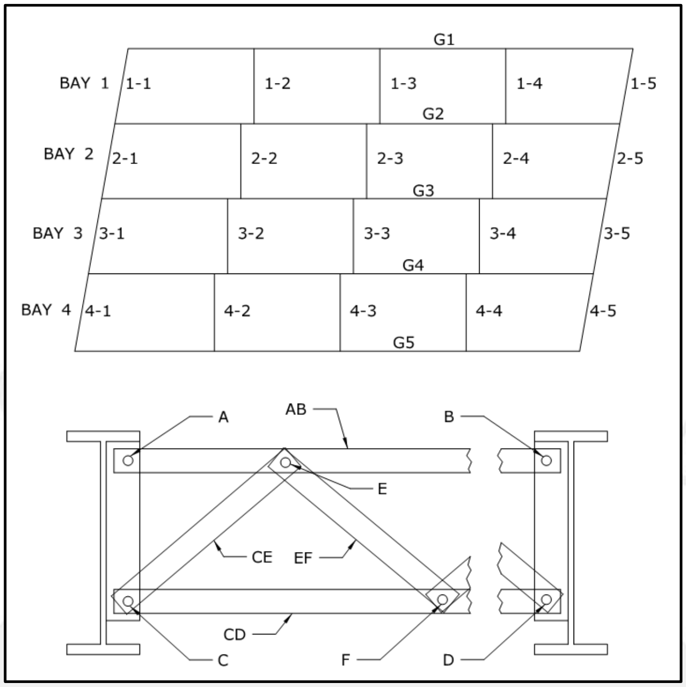


Figure 1.4.2.2-1

1.8 Responsibilities of the Load Rating Section

1.8.1 Perform Load Ratings

Perform load ratings and complete load rating packages in accordance with AASHTO and the BLRM.

1.8.2 Perform Load Rating Reviews

Conduct quality checks of Department and consultant load rating packages in accordance with AASHTO and the BLRM.

1.8.3 Documentation

- Enter the structure’s inventory and operating rating factors to SMS.
- Upload completed load rating packages to the Bridge folder on ProjectWise.
- Maintain the Department’s BrR database.
- Maintain a database of searchable load rating results.

1.8.4 Posting Meetings

Initiate Posting Meetings for structures with low rating results.

1.8.5 Load Rating Manual

Maintain and update this Manual as necessary according to Department procedures.

1.8.6 Load Rating Practices and Policies

Establish and interpret the Department's standard load rating practices and policies, including interpretation of the AASHTO's literature.

CHAPTER 2 LOADS FOR EVALUATION

2.1 Permanent Loads

2.1.1 **General**

All dead and permanent loads shall be determined through calculation or reputable references. Assumed weights shall not be used. Dead load weight calculations shall be submitted in accordance with Article 12.2.6.

2.1.1.1 Unit Weight of Materials

The minimum unit weights of materials used in computing dead loads should be in accordance with *BDS Table 3.5.1-1* in the absence of more precise information, except that:

a) Pervious structure backfill, in-situ soils, and other soil fill shall be evaluated with a unit weight of 0.125 kcf.

b) Bituminous wearing surfaces shall be evaluated with a unit weight of 0.155 kcf. Aggregate sourced for Connecticut's pavement mixtures, trap rock, have a higher specific gravity than the typical granite aggregate.

c) The unit weight of reinforced concrete shall be taken as 0.005 kcf greater than the unit weight of plain concrete shown in *BDS Table 3.5.1-1*.

2.1.1.2 Wearing Surfaces

a) The wearing surface thickness of existing structures shall be calculated from the average curb reveal of each span as annotated in the most recent BIR, when available.

b) When the wearing surface thickness cannot be determined from BIRs, the thickness in the plans shall be used in analysis. If no plans are available, assume values given in Table 2.1-1. This does not relieve the LRE from analyzing the structure with a thicker wearing surface if BIR photos indicate that the thickness is greater than this section assumes.

c) Wearing surfaces are considered to be field measured when measurements are taken along transverse and longitudinal intervals of the bridge deck. These measurements may be taken from surveys, core samples, or any other suitable mean. Measured curb reveals are not to be considered as field measured wearing surfaces.

Unknown Wearing Surface Thickness	
Structure and Route Type	**Bituminous Wearing Surface Thickness**
Buried Structures – State & Interstate Routes	10 inches
Buried Structures – Local Roads	6 inches
All Other Structures & Routes	6 inches

Table 2.1-1

2.1.1.3 Utilities

a) All utility weight calculations, in lieu of performing more precise calculations, shall include an additional 10% to account for miscellaneous hardware, e.g., bolts, welds, hangers, etc.

b) All utility weight calculations shall be submitted in accordance with Chapter 12 requirements.

2.1.2 **Earth Pressures: EV, EH, & ES**

Earth pressures shall be considered for all buried structures in accordance with Section 10.1.

2.1.3 **Creep and Shrinkage: CR & SH**

For less complex structures creep and shrinkage effects shall not be considered. For more complex structures, the creep and shrinkage effects shall be accounted for at the discretion of the LRS when determining dead load effects.

2.2 Load Factors

2.2.1 **Wearing Surface**

The load factor at the strength limit state for the wearing surface shall be reduced to 1.25 if the wearing surface is considered field measured, as defined in Article 2.1.1.2c.

2.2.2 **Stress Reversal**

For components which undergo opposing force effects, minimum and maximum load factors shall be applied as appropriate to produce the greatest factored force effect within each component. The force effects for each individual load may be combined for each load type, and applied the minimum or maximum load factor for each load type to produce the critical load combination. Minimum load factors for permanent loads shall be selected from *BDS Table 3.4.1-2*.

2.3 Transient Loads

2.3.1 **Longitudinal Braking Forces**

The effects of longitudinal braking forces need not be considered unless requested by LRS.

2.3.2 **Application of Vehicular Live Load**

See Chapter 4 of this Manual for required vehicular live load cases.

2.3.2.1 Striped Lanes

The alternate load rating method of limiting the placement of vehicular loads within the striped lanes, as described in *MBE Article 6A.2.3.2*, shall not be initially assumed. Striped lanes shall only be assumed at the direction of the LRS.

2.3.2.2 Mountable Curbs

Curbs with a reveal less than 6 inches shall be considered mountable and vehicular traffic shall be placed transversely without restriction from the curb.

2.3.2.3 Dynamic Load Allowance: IM

The IM used in analysis shall be taken as specified in the *MBE Section 6 Part A* for all vehicle axles excluding buried structures. For buried structures see Article 10.4.3. The IM shall not be reduced based on riding surface conditions, as described in *MBE Article C6A.4.4.3*. Use of an IM other than that specified herein must be pre-approved by the LRS.

2.3.3 **Live Load Surcharge: LS**

Live load surcharge shall be considered for all vertical earth retaining walls transverse to traffic, e.g., abutments and culvert walls, in accordance with *MBE Article 6A.5.12.10.3*.

2.3.4 **Pedestrian Live Loads: PL**

Members required for analysis which support pedestrian live load and exhibit insignificant to zero vehicular force effects shall only be rated for pedestrian live load. Pedestrian live load shall be rated at the operating load rating level. Pedestrian live load shall not be considered in combination with vehicular live load.

2.3.5 **Wind Loads: WL & WS**

Wind loads need not be considered unless specifically requested by the LRS.

2.3.6 **Temperature Effects**

Temperature effects need not be considered for non-segmental bridge components.

2.3.7 **Centrifugal Forces: CE**

The effect of centrifugal forces may be considered at the discretion of the LRE or LRS.

CHAPTER 3 STRUCTURAL ANALYSIS

3.1 General

- The LRE shall determine the analysis method if not specifically requested by the Department, or specified within this manual for a particular structure type.
- Alternative types of structural analysis methods, not listed within this Manual, shall be preapproved by the LRS prior to beginning the analysis.
- See Chapter 13 for selecting structure analysis software.

3.2 Approximate Methods of Structural Analysis

3.2.1 **Line Girder**

The line girder method analyzes a member or strip width as a straight beam or using one dimensional element in a one dimensional space.

3.2.2 **Plane Frame**

The plane frame method analyzes a cross-section of a frame with one dimensional elements in a two dimensional space. Approximate methods of distributing dead and live loads to the plane frame are used.

3.3 Refined Methods of Analysis

3.3.1 **Finite Element Analysis**

a) FEA evaluates a model in a virtual environment with assigned variables to simulate the stiffness of a structure to realistically determine force effects and deformations of the structure.

b) FEM will more accurately distribute loads and may improve a structure’s rating factor. When a line girder system rating does not achieve the desired rating factor, the LRS will determine the need for a FEA.

c) Horizontally curved girder bridges and bridges with a skew greater than 30 degrees shall be evaluated using one of the methods in Article 3.3.1.1. Curved girders meeting the requirements of *BDS Articles 4.6.1.2.4b* or *4.6.1.2.4c*, as applicable, may be analyzed using the line girder method.

3.3.1.1 Types of FEM for Beam Slab Bridges

The LRE shall determine from the list below an analysis method which is appropriate to capture the desired behavior for each structure and obtain the required force effects.

- 2D Analysis
  - Grid Analysis Model
  - Plate and Eccentric Beam Analysis Model
- 3D Analysis Model

Additional guidance for selecting an analysis method can be determined from *AASHTO's Guidelines for Steel Girder Bridge Analysis*, and *NCHRP Report 725*.

CHAPTER 4 LOAD RATING PROCEDURES

4.1 General Load Rating Equation

Structures shall be load rated using the general load rating equation and procedures outlined in this Chapter and *MBE Section 6A.4*. Modifications to the procedures contained in this Chapter for buried structures can be found in Chapter 10.

4.1.1 **Limit States**

Limit states shall be in accordance with *MBE Article 6A.4.2.2, Table 6A.4.2.2-1* except that all optional checks shall be performed in the analysis.

The provisions of Article 2.2.1c, reduction of the wearing surface load factor, shall only be considered for the strength limit state.

4.1.1.1 Definitions of LRFR Limit States

- **Strength I Limit State**
  Checks the strength and stability of a structure for the design and legal load cases.
- **Strength II Limit State**
  Checks the strength and stability of a structure for the permit load cases.
- **Service I Limit State**
  Checks the $0.9F_y$ stress limit in reinforcing steel. This limit state addresses permanent deformation of reinforcing steel in reinforced concrete and prestressed concrete members for permit loads.
- **Service II Limit State**
  Checks for permanent deformation of steel members.
- **Service III Limit State**
  Checks for cracking of prestressed components using an un-cracked section analysis.
- **Fatigue Limit State**
  Checks the fatigue life of fatigue-prone details using the LRFD Fatigue Truck, in accordance with Section 6.2 and *MBE Article 6A.6.4.1*.

4.1.2 **Condition Factor: φ_c**

a) The condition factor shall be used in all load ratings and determined from *MBE Tables 6A.4.2.3-1* and *C6A.4.2.3-1* as they relate to the recent inspection condition for existing structures.

b) The condition factor shall be used in addition to the reduced section when determining member resistances and structural behavior.

c) The condition factor shall be increased by 0.05 so long as the section properties are obtained by actual field measurements of losses, as allowed by *MBE Article C6A.4.2.3*, the condition factor shall not exceed 1.00.

d) The condition factor of a member is based on the specific condition of that member and should not necessarily be based on the overall condition rating of the member's type. This provision means that the poor condition of one member, which would cause a poor condition rating of a member type as documented in the BIR, will not reduce the carrying capacity of a similar member that may be in better condition. Guidance for determining the condition rating of a member can be found in *BIM Chapter 10*.

e) When load rating a structure as part of a replacement or rehabilitation project, the condition factor of all new and rehabilitated members should be 1.00, granted the rehabilitation restores the condition of the structure and arrests active deterioration. Additional guidance for selecting a condition factor for a rehabilitated member can be found in item 'f' below.

f) Condition factors may be modified as prescribed in this Manual if all of the following items are considered.
   1) The advancement of deterioration between inspections.
   2) The uncertainty of the extent of the deterioration.
   3) The uncertainty of the effects the corrosion has on the capacity of the member.

   The LRE shall document how the modified condition factor was determined. Acceptance of the modified condition factor will be at the discretion of the LRS.

4.1.3 System Factor: φ_s

The system factors specified in *MBE Article 6A.4.2.4* and supplemented by *MBE Table 6A.4.2.4-1* shall be used at the strength limit states. The systems factors specified in *MBE Article 6A.4.2.4* shall be modified by Articles 4.1.3.1 through 4.1.3.4. Non-redundant systems not covered by this Manual or the *MBE* shall be determined based on consideration of redundancy, i.e., load path, structural, and internal, and understanding of the failure mechanism.

4.1.3.1 Rolled Shapes

Sections made of a single rolled shape, an internally non-redundant cross-section, shall be treated as welded construction when selecting the system factor, from *MBE Table 6A.4.2.4-1*.

4.1.3.2 Internally Redundant Members

Internally redundant steel members shall be treated as riveted construction when selecting the system factor, from *MBE Table 6A.4.2.4-1*.

4.1.3.3 Substructure

System factors for steel substructure components shall be taken as those for a two-girder system, from *MBE Table 6A.4.2.4-1*. This provision extends the MBE applicability of system factors to substructure components, which are commonly a non-redundant sub-system.

4.1.3.4 Diaphragms and Cross-frames

System factors for diaphragms and cross-frames in straight girder bridges may be taken equal to 1.20 for structures where all bracing members within the span exhibit no signs of distress.

4.1.4 Average Daily Truck Traffic

a) The ADTT used in rating to determine items such as load factors or fatigue remaining life shall be the one directional ADTT based on the ADT provided in the Most Current Traffic Log Data information. This information is contained on the Department's Traffic Monitoring Volume Information Traffic Count Data website. The percent truck shall be based on NBI item 109 on the BRI-19.

b) When ADT cannot be obtained from the Department's Traffic Monitoring Volume Information, such as structures on local roads, the ADT may be determined from NBI item 29 on the BRI-19.

c) The one directional ADTT should be taken as 55 percent of bidirectional ADTT as suggested in *BDS Article C3.6.1.4.2* in lieu of more precise site specific information.

d) The number of lanes available to the trucks shall be based on striped lanes for determining the ADTT in a single lane in *BDS Table 3.6.1.4.2-1*.

4.1.5 **Traffic Growth Rate**

Estimated annual traffic growth rates vary between urban and rural areas. Urban and rural classifications for each structure can be found on the BRI-19, NBI item 26. The following parameters for the estimated annual traffic growth rates should be taken as:

- Urban: 0.75%
- Rural: 1.50%

4.2 Design Load Rating

Axle configurations for these vehicles can be found in the Rating Aids.

4.2.1 **Design Inventory and Operating Ratings**

Design Inventory and Operating Ratings are required by FHWA and shall be performed. These rating factors are used for comparative purposes in order to compare structures across the nation on an equal scale. These rating factors are recorded on the BRI-19. HL-93 Design Inventory and Design Operating levels shall be rated in accordance with *MBE Article 6A.4.3*. HL-93 loading shall be in accordance with *BDS Article 3.6.1.3*. The Design load rating shall not be used to screen the need to perform Legal and Permit load ratings.

4.3 Legal Load Rating

Axle configurations for these vehicles can be found in the Rating Aids.

4.3.1 **Purpose**

The legal load rating results are a major factor in the determination of which structures receive remedial action, rehabilitation or replacement, and safe posting limits. Each vehicle is required to be analyzed regardless of the design ratings. Notional load configurations that are intended to substitute the requirement to rate each of the vehicles listed herein are not permitted.

4.3.2 **Routine Commercial Traffic**

Loading shall be in accordance with *MBE Article 6A.4.4.2.1a* and modified by the following:

a) For calculating negative moments and reactions at interior supports, a lane load of 0.200 klf combined with two CT-L3S2 vehicles, whose axle weights are factored by 0.75, headed in the same direction, separated by 30 ft, shall be evaluated instead of two AASHTO Type 3-3 vehicles.

b) For span lengths greater than 200 ft, one CT-L3S2 vehicle axle loading factored by 0.75 combined with a lane load of 0.200 klf shall be evaluated instead of one AASHTO Type 3-3.

c) If the ADTT is less than 500, the lane load shall not be excluded and the 0.75 factor shall not be changed to 1.0 for spans greater than 200 ft or continuous spans. This provision eliminates the last sentences of *MBE Article 6A.4.4.2.1a*.

4.3.2.1 AASHTO Routine Commercial Legal Loads

The following vehicles shall be rated.

- Type 3
- Type 3-3
- Type 3S2

4.3.2.2 CT Routine Commercial Legal Loads

The following vehicles shall be rated.

- CT-H20
- CT-HS20
- CT-L3S2

4.3.3 **Specialized Hauling Vehicles**

4.3.3.1 AASHTO Single Unit Specialized Hauling Vehicles

The following vehicles shall be rated.

- SU4
- SU5
- SU6
- SU7

The NRL vehicle is not required for rating, and shall not be used to substitute ratings for the SU4, SU5, SU6 and SU7.

4.3.3.2 CT Legal Specialized Hauling Vehicle

The following vehicle shall be rated.

- CT-L73.0

4.3.4 **Live Load Factors**

The Generalized Live Load Factors specified in *MBE Table 6A.4.4.2.2-1* shall be used with linear interpolation for ADTT between 1,000 and 5,000. The ADTT shall be taken as specified in Article 4.1.4. The live load factors shall not be increased or decreased due to conditions or situations not accounted for in the *MBE* without prior approval from the LRS. Site specific live load factors detailed in *MBE Article C6A.4.4.2.3a* shall not be used.

4.3.5 **Rating Tons**

The legal rating in tons shall be determined as the gross vehicle weight multiplied by the rating factor. The safe posting load specified in *MBE Article 6A.8.3* shall not be used to compute rating tons.

As per *MBE Article C6A.4.4.2.1a* use an 80kip vehicle equivalency for tonnage when a lane load is included in the legal live load model.

$$Rating\ Tons = GVW * RF$$

Equation 4.3.5-1

Where:

$Rating\ Tons$ = Gross rating tons (ton)
GVW = Gross vehicle weight (ton)
RF = Rating factor for vehicle

4.4 Permit Load Rating

Axle configurations for these vehicles can be found in the Rating Aids.

4.4.1 **Purpose**

Permit load rating results assist in the oversize/overweight permitting process and are sometimes used to determine which structures receive remedial action, rehabilitation or replacement. Permit loading shall be in accordance with *MBE Article 6A.4.5*, except that these vehicles shall be analyzed regardless of the design and legal rating factor results.

4.4.2 **Permit Types**

4.4.2.1 Routine (Annual) Permits

The following vehicles shall be rated.

- CT-P76.5
- CT-P120(6)
- CT-P140(7)a
- CT-P140(7)b
- CT-P160(8)a
- CT-P160(8)b

4.4.2.2 Special (Limited Crossing)

4.4.2.2.1 Single-Trip, Mixed with Traffic

The following vehicles shall be rated.

- CT-P180(9)
- CT-P200(10)

4.4.2.2.2 Single-Trip, Escorted

The following vehicle shall be rated.

- CT-P380

4.4.3 **Multiple Presence**

a) MPF are not applicable for permit analyses per *MBE Article 6A.4.1*. When the *BDS* approximate LLDF equations are used, the MPF shall be divided out of the LLDFs for permit vehicles.

b) When permits are analyzed using a refined analysis the provisions of *MBE Article 6A.4.5.4.2c* shall apply.

c) For routine permit analyses, when the lever rule or other similar methods of statically applying wheel loads to a structure is used for line girder analyses outside of the *BDS* approximate LLDFs, the number of lanes loaded shall be limited to two lanes.

4.4.4 **Rating Tons**

The permit rating in tons shall be determined as the gross vehicle weight multiplied by the rating factor.

$$Rating\ Tons = GVW * RF$$

Equation 4.4.4-1

Where:

$Rating\ Tons$ = Gross rating tons (ton)
GVW = Gross vehicle weight (ton)
RF = Rating factor for vehicle

4.4.5 Spans Greater than 200 Feet, Continuous Spans and Interior Reactions

A 0.200 kip per linear foot lane load shall be applied to permit vehicles for spans greater than 200 feet, checking negative moments in continuous spans or checking reactions at interior supports. This provision removes the upper 300 ft threshold from *MBE Article 6A.4.5.4.1*. The lane load may be omitted from escorted permits if low ratings are produced.

4.5 Emergency Vehicle Rating

Axle configurations for these vehicles can be found in the Rating Aids.

4.5.1 General

Notional single and tandem rear axle EVs, Type EV2 and Type EV3 respectively, operated by Fire Departments, defined in FHWA Memorandum titled *Load Rating for the FAST Act's Emergency Vehicle*, dated November 3, 2016 are used for establishing safe load limits for EVs.

The following vehicles shall be rated.

- Type EV2
- Type EV3

Ratings shall be produced and reported to the Department for the Type EV2 and Type EV3 load combinations for all structures.

Additional EVs representative of local jurisdictions may be requested by the Department.

4.5.2 Application of Live Load

EVs are evaluated using the legal load rating procedure with the following modifications:

a) **Live Load Factor, γ_{LL}:** taken as 1.30 in *MBE Equation 6A.4.2.1-1* for all strength limit states and vehicular traffic densities. Structures load rated with Chapter 10 or *MBE Equation 6A.5.12.4-1* are unaffected by this provision.

b) **Multiple Presence:** one EV on a bridge combined with the other legal vehicles. For simplified live load distribution, e.g., line girder analysis, the EV may be assumed to occupy up to every lane in combination with multiple presence factors. For refined analyses, the EV shall occupy one lane, with another legal vehicle required for analysis in all other available design lanes to produce the maximum force effects.

c) **Spans Greater than 200 ft:** apply a 0.200 klf lane load in lanes with an EV or adjacent legal vehicles to produce the maximum force effect under consideration.

d) **Checking Negative Moments in Continuous Spans, and Checking Interior Reactions:** apply a 0.200 klf lane load in lanes with an EV or adjacent legal vehicles to produce the maximum force effect under consideration.

e) **Striped Lanes:** striped lanes, as described in *MBE Article 6A.2.3.2*, shall not be considered for the rating of EVs.

4.5.3 **Rating Tons**

Single Axle, Tandem and Gross Vehicle Tonnage shall be determined for EVs.

a) Single axle and tandem axle tonnage shall be determined for single rear axle and tandem rear axle EVs respectively using Equation 4.5.3-1.

$$Rating\ Tons_{Axle} = RF * W$$

Equation 4.5.3-1

Where:

$Rating\ Tons_{Axle}$ = Axle rating tons (ton)

RF = Rating factor for EV vehicle

W = Weight of single axle or combined weight of tandem axles (ton)

b) Gross Vehicle tonnages shall be determined for EVs using Equation 4.5.3-2.

$$Rating\ Tons_{Gross} = RF * GVW$$

Equation 4.5.3-2

Where:

$Rating\ Tons_{Gross}$ = Gross rating tons (ton)

RF = Rating factor for EV vehicle

GVW = Gross vehicle weight (ton)

CHAPTER 5 CONCRETE STRUCTURES

5.1 Materials

5.1.1 **Concrete**

5.1.1.1 Strength

a) *MBE Table 6A.5.2.1-1*, Minimum Compressive Strength of Concrete by Year of Construction, shall be used only when the concrete compressive strength cannot be discerned from available records.

b) When only a class of concrete without a material strength is available in the structures records, *MBE Table 6A.5.2.1-1* shall be used to determine concrete strength. Correlating concrete classes, e.g., Class "A" Concrete, to a concrete strength shall not be used without documentation of the specification.

c) For prestressed concrete components, the compressive strengths given in *MBE Table 6A.5.2.1-1* shall be increased by 25%.

d) If the initial concrete compressive strength at time of prestressing release is not present on any available bridge records, 80% concrete compressive strength may be used.

5.1.1.2 Unit Weight

The unit weight of concrete to calculate material properties shall be taken as specified in *BDS Table 3.5.1-1*.

The practice of increasing the unit weight of concrete by 0.005 kcf to account for reinforcing steel as previously mentioned in Article 2.1.1.1and *BDS Article C3.5.1* shall be used for calculating dead loads.

5.1.1.3 Modulus of Elasticity

The modulus of elasticity shall be computed based on *BDS Article 5.4.2.4*.

5.1.1.4 Material Sampling

The mechanical properties of the concrete shall not be determined by material sampling without prior approval from the LRS. If core tests are approved, the nominal value for compressive strength shall be taken as the mean test value minus 1.65 standard deviation to provide a 95 percent confidence limit. Average test values shall not be used for evaluation.

5.1.2 **Reinforcing Steel**

MBE Table 6A.5.2.2-1, Yield Strength of Reinforcing Steel, shall be used only when the reinforcing steel yield strength cannot be discerned from available records.

5.1.3 **Prestressing Steel**

For determining the properties of unknown prestressing steel, Articles 5.1.3.1 and 5.1.3.2 should be worked concurrently, and practiced with sound engineering judgment.

5.1.3.1 Strand Type

If available records do not specify a strand type, e.g., Stress-Relieved or Low-Relaxation, Equation 5.1.3-1 should be performed and provided. If Equation 5.1.3-1 results in Low-Relaxation but is likely to be Stress-Relieved based on year of construction when compared with historic Connecticut bridge construction practices, and the ultimate strength of the strands is unknown, the LRE shall consider re-evaluating Equation 5.1.3-1 with an increased ultimate tensile strength of the strand.

$$\text{Strand Type} = \begin{cases} \text{Stress-Relieved,} & 0.70 * f_{pu} \geq f_{pj} \\ \text{Low-Relaxation,} & 0.70 * f_{pu} < f_{pj} \leq 0.75 * F_u \end{cases}$$

Equation 5.1.3-1

Where:

$f_{pu}=$ Tensile strength of strand (ksi)

$f_{pj}=$ Jacking stress of strand (ksi)

5.1.3.2 Strand Strength

Prestressing steel ultimate strength and yield strength listed in *MBE Tables 6A.5.2.3-1* and *6A.5.4.2.2b-1* respectively, shall be used only when the strength of the prestressing strand cannot be discerned from available records. The strength of the strand used in the analysis may also be increased as discussed in Article 5.1.3.1.

5.2 Assumptions for Load Rating

5.2.1 **Deterioration**

a) Rebar with section loss shall have a reduced area as depicted in the BIR.

b) Exposed prestressing strands shall be considered effective if only surface rust is noted in the BIR. Any exposed prestressing strand with deterioration leading to section loss, separation, or wires being fractured shall be discounted in the load rating analysis.

5.3 Evaluation for Shear

Rating for shear shall be performed for all rating levels and vehicles required for analysis as defined in Chapter 4 of this Manual.

5.3.1 **Shear Resistance**

Shear resistance of non-prestressed members, meeting the requirements in *BDS Article 5.7.3.4.1*, may be determined by the Simplified Procedure. However, if the shear load rating results are low for any required loading condition, the General Procedure described in *BDS Article 5.7.3.4.2* shall be used.

5.3.2 **Longitudinal Reinforcing**

When using the General Procedure for shear, the longitudinal reinforcing requirement shall be evaluated in accordance with *BDS Article 5.7.3.5*.

5.4 Concrete Bridges with Unknown Reinforcement

See Article 1.3.1 on assignment of Judgment Ratings.

5.5 Prestressed Concrete Structures

5.5.1 **Prestress losses**

For composite members, prestress losses shall be calculated using the AASHTO Approximate Method in accordance with *BDS Article 5.9.3.3*. The values listed below shall be used if actual values cannot be discerned from available records:

- **Service life:** 75 years (27,400 days)
- **Transfer time:** 24 hours
- **Age at time of deck placement:** 28 days old

- **Humidity:** 80%

If low ratings result from the AASHTO Approximate Method or for non-composite members, the prestress losses shall be calculated using the AASHTO Refined Method in accordance with *BDS Article 5.9.3.4*.

PCI or lump sum methods are not permitted.

5.5.2 **NEXT Beams**

5.5.2.1 Live Load Distribution Factors

The LLDFs for NEXT beam types D and F should follow the guidance provided on PCI Northeast's website.

5.6 Continuity Diaphragms

Concrete structures which meet the requirements of *BDS Article 5.12.3.3* to make simple span precast members act as continuous shall be analyzed for rating as such. If the age of a member when continuity was established is not clearly specified, but the structure was clearly designed to be made continuous, that member shall still be analyzed as continuous for transient, short-term, loads.

CHAPTER 6 STEEL STRUCTURES

6.1 Materials

6.1.1 **Mechanical Properties**

a) *MBE Table 6A.6.2.1-1*, The Minimum Mechanical Properties of Structural Steel by Year of Construction, shall be used only when the minimum yield and tensile strengths cannot be discerned from available records. Even when these strengths are not specified in the structure's records, the AASHTO or ASTM designation is often cited. The LRE should review the designation specification and use the corresponding minimum strengths when possible. In other instances, the steel fabricator may be known and the manufacturer's data on the material properties should be used prior to consulting *MBE Table 6A.6.2.1-1*.

b) For structures constructed with *Connecticut Standard Specifications for Roads, Bridges and Incidental Construction* and with unknown steel, Table 6.1-1 should be used to determine the mechanical properties before *MBE Table 6A.6.2.1-1* is considered.

c) For pins and wrought iron with unknown material properties a similar process should be followed as previously stated in Article 6.1.1a using *MBE Articles 6A.6.2.2* and *6A.6.2.3*, respectively.

Historic Connecticut Standard Specifications - Structural Steel					
Form	**Year**	**Item**	**Material Designation**	**F_y (ksi)**	**F_u (ksi)**
802	**1929**	No Structural Steel Specified	-	-	-
803	**1932**	All Structural, Rivet, and Eyebar Steel	ASTM A7-29	30	55-65
		Wrought Iron	ASTM A41-30	-	-
804	**1935**	All Structural, Rivet, and Eyebar Steel	ASTM A7-33	33	60-72
		Wrought Iron	ASTM A41-30	-	-
805	**1940**	Structural and Eyebar Steel	ASTM A7-39	33	60-72
		Rivet Steel	ASTM A141-39	28	52-62
		Structural Silicon Steel	ASTM A94-39	45	80-95
		Structural Nickel Steel	ASTM A8-39	50	85-100
806	**-**	-	-	-	-
807	**1947**	Structural (Carbon) and Eyebar Steel	ASTM A7	33	60-72
		Rivet Steel	ASTM A141	28	52-62
		Structural Silicon Steel	ASTM A94	45	80-95
		Structural Nickel Steel	ASTM A8	50	85-100
		High Strength Rivet Steel	ASTM A195	38	68-82
		Wrought Iron Plates	ASTM A42	27	48
		Wrought Iron Bars and Shapes	ASTM A207	Varies	Varies
		Welded Wrought Iron Pipes	ASTM A72	25	42
808	**1955**	Structural (Carbon) and Eyebar Steel	ASTM A7	33	60-72
		Rivet Steel	ASTM A141	28	52-62
		Structural Steel for Welding	ASTM A373	32	58-75
		Structural Silicon Steel	ASTM A94	45	80-95
		Structural Nickel Steel	ASTM A8	50	85-100
		High Strength Rivet Steel	ASTM A195	38	68-82
		Wrought Iron	ASTM A207	-	-
809	**1963**	Structural, Eyebar and Rivet Steel	ASTM A7	33	60-75
		Rivet Steel	ASTM A141	28	52-62
		Structural Steel for Welding	ASTM A36, A373, A411, A242	Varies	Varies
		High Strength Low Allow Structural Steel	ASTM A440 or A441	Varies	Varies
		Structural Silicon Steel	ASTM A94	45	80-95
		Structural Nickel Steel	ASTM A8	50	85-100
		High Strength Rivet Steel	ASTM A195	38	68-82
		High Tensile Strength Bolts	ASTM A325	-	Varies
810	**1969**	Structural Steel for Riveted, Bolted or Welded Construction	ASTM A36	36	58-80
		Rivet Steel	ASTM A502, Grade 1	-	60
		Eyebar Steel	ASTM A36	36	58-80
		High Strength Rivet Steel	ASTM A502, Grade 2	-	80
		High Strength Low Alloy Welded Structural Steel	ASTM A441, A588, A572	Varies	Varies
		High Strength Low Allow Bolted or Riveted Structural Steel	ASTM A440, A588, A572	Varies	Varies
		High Strength Bolts	ASTM A325	-	Varies
811	**1974**	Structural Steel for Riveted, Bolted or Welded Construction	ASTM A36	36	58-80
		Rivet Steel	ASTM A502, Grade 1	-	60
		Eyebar Steel	ASTM A36	36	58-80
		High Strength Rivet Steel	ASTM A502, Grade 2	-	80
		High Strength Low Alloy Welded Structural Steel	ASTM A441, A588, A572	Varies	Varies
		High Strength Low Alloy Bolted or Riveted Structural Steel	ASTM A440, A588, A572	Varies	Varies
		High Strength Bolts	A325	-	Varies

Table 6.1-1

6.1.2 **Material Sampling**

The mechanical properties of the structural steel shall not be determined by material sampling without prior approval from the LRS. If coupon tests are approved, the nominal value for yield and tensile strengths shall be taken as the mean test value minus 1.65 standard deviation to provide a 95 percent confidence limit.

6.2 Fatigue

6.2.1 **Fatigue Prone Details**

Fatigue-prone details, Category C details and lower, shall be analyzed for infinite fatigue life. If members do not satisfy the infinite fatigue life check, they shall be evaluated for remaining fatigue life using procedures given in *MBE Section 7*. Fatigue details categories A, B, and B' rarely, if ever, govern and need not be routinely evaluated.

6.2.2 **Remaining Life**

The remaining fatigue life should be initially evaluated at the Evaluation 1 level, as defined in *MBE Article 7.2.5.1*. If the computed estimated remaining life has expired, the provisions of *MBE Article 7.2.7.2 – Recalculate Fatigue Serviceability Index* shall be investigated and documented within the report. The methods described in *MBE Article 7.2.7.2.2 – Through More Accurate Data* should not be incorporated without prior approval from the LRS.

6.2.3 **Traffic Growth Rate**

See Article 4.1.5.

6.2.4 **Partial Length Cover Plate**

6.2.4.1 Peened welds

Partial length cover plate end transition details with peened welds shall be considered Fatigue Category C. Transverse stiffener details on the tension flange and web with peened welds shall be considered Fatigue Category B and will therefore no longer require fatigue evaluation. This recommendation is from the Applied Ultrasonic report, *Fatigue Strength Enhancement by Means of Weld Design Change and the Application of Ultrasonic Impact Treatment*.

6.2.4.2 Fatigue Analysis Location

The fatigue analysis of partial length cover plate end welds shall be evaluated at the actual location of the weld, not at the end of the theoretical length of the cover plate.

6.3 Effects of Deterioration on Load Rating

In addition to sound engineering judgment, the guidelines of *MBE Article C6A.6.5* shall be considered for localized and uniform corrosion. The LRE shall provide documentation as to how the deterioration is considered in analysis and how the BIR data is interpreted.

6.3.1 **Beam Ends**

The CTDOT Bridge Load Rating Website provides an approved Excel spreadsheet program, CT-BeamEnd, for analyzing and load rating beam ends with section loss.

6.3.1.1 Stiffened Webs

Bearing stiffeners not meeting the slenderness proportions defined in the *BDS* may be considered to be effective provided that the slender element reductions are applied to the stiffener.

The bearing resistance of a fitted end bearing stiffener need not be evaluated.

6.3.1.1.1 Partial Height Stiffeners and Connection Plates

Web crippling for partial height stiffeners and connection plates, based on the guidance provided in *AISC Engineering Journal, Volume 52, No. 4* article titled *Crippling of Webs with Partial-Depth Stiffeners under Patch Loading*, may be taken as:

- If:
  - the stiffener is in contact with the loaded flange;
  - and the stiffener height is greater than three quarters the height of the web $d_s \geq 0.75d,$
  - then:

    Web crippling can be ignored.

- otherwise if:
  - the stiffener is in contact with the loaded flange;
  - and the stiffener height is greater than half the height of the web: $d_s \geq 0.5d;$
  - and the number of stiffener pairs shall satisfy: $N_p \geq 1;$
  - and the thickness of the stiffener is approximately equal to the thickness of the web: $t_p \approx t_w;$
  - and the slenderness ratio of the stiffener shall satisfy:

    $$\frac{b_t}{t_p} \leq 0.56\sqrt{\frac{E}{F_{ys}}}$$

  - then:

    The web crippling resistance shall be taken as:

    $$\varphi_w P_n = K + 2F_{ys}t_p b_t(R)\left(\frac{2\,d_s}{d}\right)^X$$

    Equation 6.3.1-1

    where:

    $$K = 0.80t_w{}^2\left\{1+3(N/d)\left(t_w/t_f\right)^{1.5}\right\}\left(EF_{yw}t_f/t_w\right)^{0.5}$$

    $$R = 2e_1\left\{\left(t_f/t_w\right)^{0.5}\left(t_f/t_p\right)^{0.5}/1.55-1\right\}+1$$

    $$X = 0.50(d/d_s)$$

- otherwise:

  The section shall be analyzed as unstiffened or by other rationale means.

Where:

N	=	Width of path load (in)
e_1	=	Eccentricity of load with respect to the plan of stiffeners (in)
P_n	=	Partially stiffened web crippling resistance (ksi)
N_p	=	Number of stiffener or connection plate pairs
t_p	=	Stiffener thickness (in)
t_w	=	Web thickness (in)
t_f	=	Flange thickness (in)
b_t	=	Stiffener width (in)
E	=	Modulus of elasticity of steel (ksi)
F_{yw}	=	Web yield strength (ksi)
F_{ys}	=	Stiffener yield strength (ksi)
d_s	=	Depth of stiffener (in)
d	=	Depth of web (in)
φ_w	=	Resistance factor for web crippling specified in *BDS*

6.3.1.2 Unstiffened Webs

For section loss to the unstiffened webs of flexural members near the supports – The effects of web local yielding and web local crippling shall be evaluated at the strength limit state according to the provisions of *BDS Appendix D6.5*.

For section loss at the critical section of the web just above the bottom flange, the distance, k, from the bottom of the bottom flange to the top of the bottom flange-web fillet shall be taken as the thickness of the bottom flange. This assumes that the fillet is corroded completely.

6.3.1.2.1 Effective Section

The length of beam beyond the back face of the bearing may be relied upon for support up to a distance, 2.5k, but not greater than the distance from the back face of the bearing to the end of the beam.

This provision effectively removes the BDS provision that the concentrated load shall be greater than the depth of the member from the end of the beam to use *BDS Eq. D6.5.2-2*. Note that the intention of removing the aforementioned BDS provisions is to accept a greater level of risk.

6.3.1.2.2 Section Loss Assumptions

The web thickness used in analysis shall be the average thickness at the base of the web within the limits shown in Figure 6.3.1.2-1.

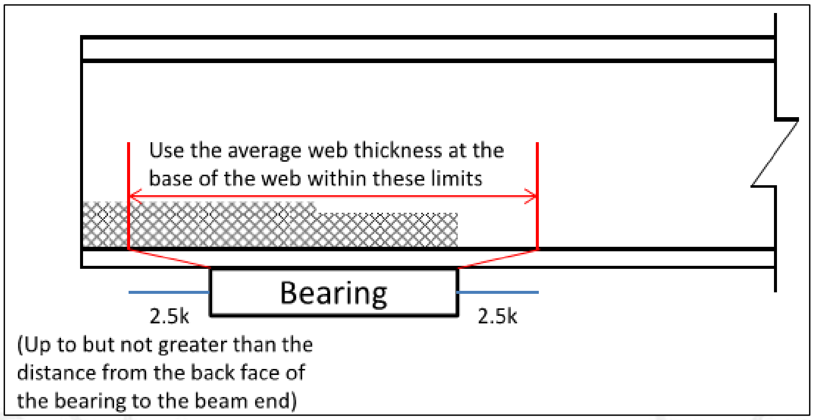


Figure 6.3.1.2-1

6.3.2 **Gusset Plates**

When analyzing section loss to gusset plates, the methods described in *MBE Article CA6.5* shall be used as a guideline. Since the criticality of the section loss varies depending on its location and the failure mode analyzed, do not simply determine an average thickness for the entire gusset plate to use in analysis.

6.4 Combined Axial Compression and Flexure

For steel compression members with eccentric connections, the Secant Formula Method described in *MBE Appendix I6A* shall be used for analysis provided that its specified requirements are satisfied. Otherwise, *MBE Appendix H6A* shall be used for analysis.

6.5 I-Sections in Flexure

6.5.1 **General**

6.5.1.1 Flange Lateral Bending

The inclusion of flange lateral bending stresses is optional for straight girder bridges with skews less than or equal to 30 degrees. All straight girder bridges with skews greater than 30 degrees and bridges with horizontal curvature shall include flange lateral bending stresses in analysis.

6.5.1.2 Plastic Analysis

Compact composite sections in positive flexure shall be analyzed at the plastic moment capacity.

6.5.1.3 *BDS* Appendix A6

The provisions of *BDS Appendix A6* shall apply for flexural resistance of straight composite I-sections in negative flexure and straight non-composite I-sections with compact or non-compact webs so long as the requirements set forth in *BDS Article A6.1* are satisfied.

6.5.1.4 *BDS* Appendix B6

The provisions of *BDS Appendix B6* shall apply for moment redistribution from interior-pier I-sections in straight continuous-span bridges at the service and strength limit states so long as the requirements of *BDS Article B6.2* are satisfied.

6.5.2 **Non-composite and Unknown Mechanical Shear Connector Details**

6.5.2.1 Top Flange Lateral Bracing

The compression flanges of sections where the deck is not connected to the steel section by shear connectors in positive flexure shall be assumed to be adequately braced by the concrete deck, and the compression flange bracing requirements need not be checked where the top flange of the girder is fully in contact with the deck and no sign of cracking, rust, or separation along the steel-concrete interface is indicated in the most recent BIR.

6.5.2.2 Composite Action

Flanges with signs of cracking, rusting, separation along the steel-concrete interface, or any other sign that the steel-concrete bond has broken shall not be evaluated as composite with the deck and the provisions contained within this section shall not apply.

The following guidance is from NCHRP Research Results Digest, November 1998 – Number 234, Manual for Bridge Rating Through Load Testing.

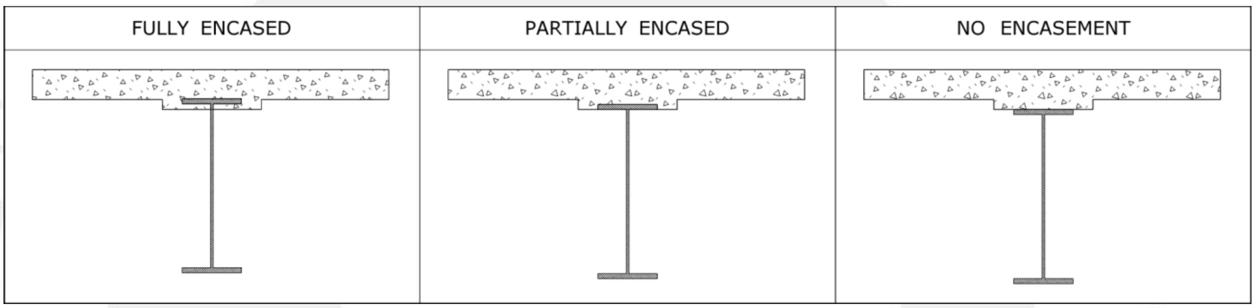


Figure 6.5.2.2-1

6.5.2.2.1 Service & Fatigue Limit States

- **Fully Encased Top Flanges** shall be evaluated as composite with the deck.
- **Partially Encased Top Flanges** shall be evaluated as composite with the deck.
- **Top Flange Not Encased** shall be evaluated as composite with the deck if the requirements of Article 6.5.2.2.3 are satisfied.

6.5.2.2.2 Strength Limit State

- For steel I-sections in flexure with non-composite concrete decks and unknown composite action, the I-section shall initially be evaluated as non-composite.
- Rating factors shall not be reported assuming composite action at the strength limit states unless directed by LRS. Bond integrity may need to be verified through field investigation, and may need to be continually monitored throughout the remainder of the bridge's service life. These determinations will be made by the Posting Committee.

6.5.2.2.3 Steel-Concrete Bond Strength

The beam has the potential to act compositely when Equation 6.5.2-1 is satisfied.

$$f_u \leq F_b$$

Equation 6.5.2-1

$$F_b = \begin{cases} 70\ psi, & \text{No Encasement} \\ 100\ psi, & \text{Otherwise} \end{cases}$$

Equation 6.5.2-2

$$f_u = \left(\frac{t_s * b_s}{n * b_f}\right) * \left[\frac{V_{PU} * \left(y_{LT} - \frac{t_s}{2}\right)}{3 * I_{LT}} + \frac{RF * V_{LU} * \left(y_{ST} - \frac{t_s}{2}\right)}{I_{ST}}\right]$$

Equation 6.5.2-3

Where:

F_b = Allowable interface shear stress across the width of the top flange as determined from Equation 6.5.2-2 (psi)

b_f = Width of top flange (in)

f_u = Horizontal shear stress across the width of the top flange, as determined from Equation 6.5.2-3 (psi)

V_{PU} = Factored vertical shear force acting on the long-term section caused by permanent loads for the limit state under consideration (lb)

V_{LU} = Factored vertical shear force acting on the short-term section caused by the vehicle under consideration for the limit state under consideration (lb)

RF = Controlling rating factor for the vehicle and limit state under consideration assuming composite action, regardless of failure mode. The ability of the section to retain composite action is dependent on the rating factor. Therefore, this assumption that the section retains composite action must be evaluated after the rating has been computed assuming composite action.

b_s = Effective width of the concrete slab per AASHTO (in)

t_s = Thickness of the concrete slab (in)

y_{LT} = Distance from the top of the slab to the neutral axis of the long-term composite section (in)

y_{ST} = Distance from the top of the slab to the neutral axis of the short-term composite section (in)

I_{LT} = Moment of inertia of the long-term composite section (in^4)

I_{ST} = Moment of inertia of the short-term composite section (in^4)

n = Modular ratio

6.6 Partial Length Cover Plates

Partial length cover plates shall be evaluated over the theoretical length of the cover plate. For fatigue provision pertaining to partial length cover plates see Article 6.2.4.

6.6.1 Terminal Development Length

a) The theoretical end of the cover plate shall be determined by subtracting the terminal development length from both sides of the cover plate ends. The terminal distance beyond the theoretical end of the cover plate shall not be included to determine girder section properties.

b) If a continuous fillet weld is present across the end and along both edges of the cover plate or flange to connect the cover plate to the flange, the terminal development length measured from the actual end of the cover plate shall be 1.5 times the width of the cover plate at its theoretical end.

c) If no weld across the end of the cover plate, as shown in Figure 6.5.2.2-1, is provided the terminal development length shall be equal to the length of the taper if all of the following conditions are met:

- The terminal development length is twice the width of the cover plate, measured from the actual end of the cover plate.
- The tapered width of the cover plate is no greater than 1/3 the width at the theoretical end, but no less than 3 in. (75 mm).
- There is a continuous fillet weld along both edges of the plate in the tapered terminal development length to connect it to the flange.

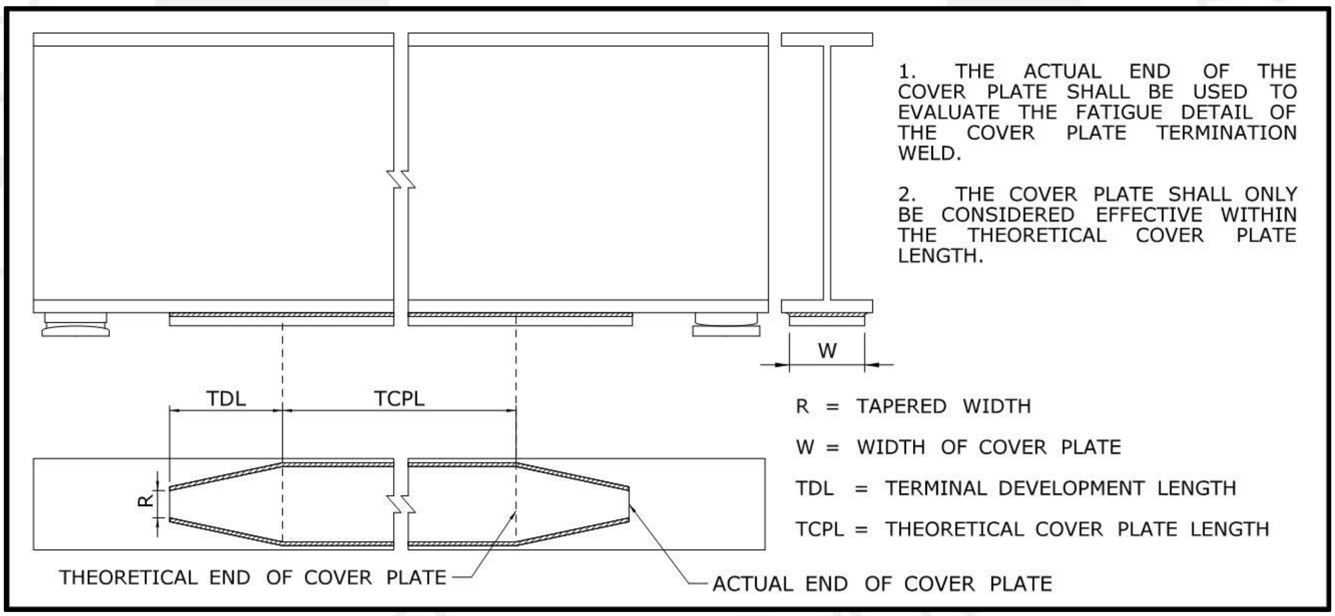


Figure 6.5.2.2-1

6.7 Diaphragms and Cross-Frames

6.7.1 Requirements for Rating

Diaphragms and cross frame members in horizontally curved bridges or bridges with a support skewed greater than 30 degrees shall be load rated.

Lateral bracing members shall not be analyzed unless specifically requested by the LRS.

6.7.2 **Self-Weight**

When calculating the weight of diaphragms or cross-frames, in lieu of performing more precise calculations, at minimum, an additional 10% shall be added to the total diaphragm or cross-frame weight to account for miscellaneous hardware (e.g., bolts, welds, etc.). Note that the transverse stiffeners and connection plate weights are not accounted for in the additional 10% applied for miscellaneous hardware, while the gusset plates which connect multiple members to a transverse stiffener or connection plate are included.

6.8 Evaluation of Critical Connections

It is common practice to assume that connections and splices are of equal or greater capacity than the members they adjoin. With the introduction of more accurate evaluation procedures to identify and use increased member load capacities, it becomes increasingly important to also closely scrutinize the capacity of connections and splices to ensure that they do not govern the load rating, as discussed in *MBE Article C6A.6.12.1*.

6.8.1 **Connections Required for Evaluation**

Connections which meet either of the following shall be evaluated:

- External connections of non-redundant systems shall be evaluated.
- External connections of redundant systems shall be evaluated if there is section loss, signs of distress, change to its original designed conditions, specified for evaluation in Section 6.8.2, or requested by the Department.

6.8.2 **Requirements for Specific Connections**

6.8.2.1 Hinges

a) Pin and hanger assemblies and other hinge assemblies shall be rated regardless of the redundancy of the system.

b) Pins shall be evaluated in all structures as specified in *MBE Article 6A.6.12.4*. The capacity of a pin in combined bending and shear computed based on *BDS Article 6.7.6.2.1* shall be expressed in terms of the normal force acting on the pin.

6.8.2.2 Field Splices

Field splices shall be rated if they are located on non-redundant members, there is section loss, evidence that a slip critical connection has slipped and is now acting as a bearing-type connection, or if requested by LRS.

6.8.2.3 Gusset Plates

Gusset plates shall be analyzed for all trusses regardless of redundancy. The analysis shall be performed in accordance with *MBE Article 6A.6.12.6*.

6.8.2.3.1 Slip Resistance

The surface condition factor, K_s, specified in *MBE Table 6A.6.12.6.3-2*, shall be taken as 0.33, in the absence of more detailed information.

6.8.2.3.2 Layered Plates

For gusset plate connections built-up from multiple layers of individual plates, the individual shear resistances for each plate shall be calculated individually and added together to determine the total nominal resistance. This assumption neglects any composite behavior between the plate layers. This guidance is from *NCHRP Web-Only Document, February 2013 – Number 197, Guidelines for the Load and Resistance Factor Design and Rating of*

Riveted and Bolted Gusset-Plate Connections for Steel Bridges.

6.8.2.3.3 Compressive Resistance

a) Gusset plates shall be initially load rated with consideration of the Traditional Whitmore Section as specified in *MBE Article 6A.6.12.6.7*, and Partial Shear Plane as specified in *MBE Article 6A.12.6.5*.

b) In the event low rating factors are computed at the legal and permit load rating levels, the LRE may consider the provisions of *MBE Article 6A.6.12.6.11* for the as-inspected rating. The LRE is responsible to document the results of the Traditional Whitmore and Partial Shear Plane checks and also document the rationale in selecting alternate methods.

c) For load ratings preformed for proposed conditions: major rehabilitation or new superstructures, the provisions of *MBE Article 6A.6.12.6.11* shall not be considered without prior approval from the LRS.

6.9 End Condition Assumptions

The following assumptions may be made to simplify the analysis:

6.9.1 **Floor Systems**

a) Floorbeams and stringers may be evaluated assuming pinned supports unless the connection is detailed to provide full moment restraint.

b) The span of a spanning member, e.g., stringers or floorbeams, which frame into a supporting member, e.g., truss, girder or floorbeam, using single or double angle connections may be taken as the centerline to centerline distance of supporting members, or more liberally, the outside face of the spanning member. See Figure 6.8.2.3-1 for an example for span lengths for a floorbeam framed into a truss.

c) The span of stringers or floorbeams which bear upon supporting members should be taken at the center of the contact surfaces.

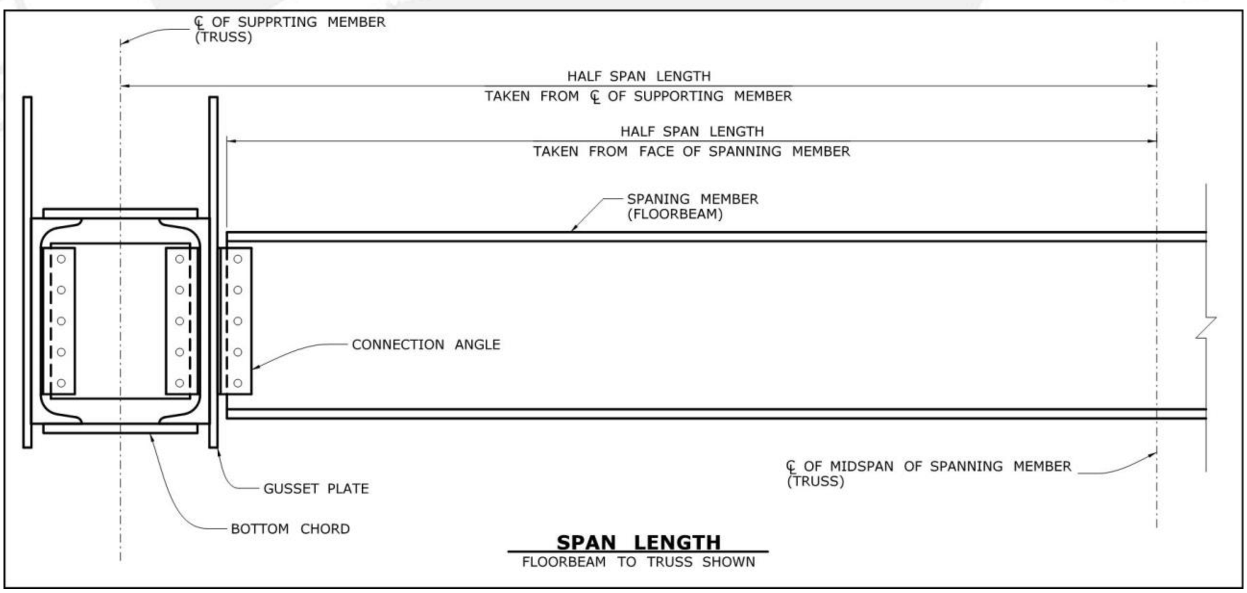


Figure 6.8.2.3-1

6.9.2 **Truss Members**

6.9.2.1 Structural Analysis

Where loads, other than self-weight of the members and wind loads there on, are transmitted to the truss at the panel points, the truss may be analyzed as a pin-connected assembly.

6.9.2.2 Effective Length Factor: K

Effective length factors for truss members shall be determined from *BDS Article 4.6.2.5*. The use of elastic supports, to determine an effective length factors, may be used at the discretion of the LRE.

6.9.2.2.1 Half-Through Trusses

The top chord shall be considered as a column with elastic lateral supports at the panel points.

6.9.2.2.2 Torsional & Warping Restraint: K_z

For the purposes of determining the effective length factor for torsional buckling the following assumptions may be made:

- For bolted or welded end connections at both ends: $K_z = 0.5$
- For pinned end connections at both ends: $K_z = 1.0$

6.9.3 **Encased I-Sections**

Concrete encased I-sections shall be analyzed assuming pinned support conditions, in the absence of more detailed information. The condition and detailing of members past the face of support cannot typically be inspected due to concrete encasement, and therefore the ability of the member to develop moment restraint is uncertain.

6.9.4 **Steel Piles**

Steel piles shall be assumed to be fixed at some depth below the ground, as discussed in *BDS Article 6.15.3.3*.

CHAPTER 7 TIMBER STRUCTURES

7.1 Materials

If the species or grade of wood cannot be determined by field confirmation or grade marks, refer to Table 7.1-1 for material assumptions for timber components.

Timber Component	Assume
Sawn Lumber	No. 1 Southern Pine
Structural Glued Laminated Timber (Beams)	Combination 24F-1.7E
Structural Glued Laminated Timber (Deck)	Combination 20F-1.5E

Table 7.1-1

7.2 Resistance Factors

7.2.1 Lateral Support

If it cannot be determined that the deck is continuously attached to the beam, the unsupported length, L_u, shall be assumed as the distance between brace points.

7.2.2 Wet Service Factor: C_M

Wet-use conditions should be assumed.

7.2.3 Flat-Use Factor: C_{fu}

The flat-use factor shall not be applied to decking.

7.2.4 Deck Factor: C_d

For decking that meets the Deck Type specified in *BDS Table 8.4.4.8-1* or a plank size specified in *BDS Table 8.4.4.8-2*, the deck factor shall be adjusted accordingly.

7.3 Deflection Control

Evaluation of deflection shall not be considered unless requested by BS&E or LRS.

7.4 Evaluation of Critical Connections

External connections of non-redundant members are considered critical and shall be evaluated at the strength limit state. If details of such connections do not exist and cannot be verified by field measurements, the load rating report must state that “Critical connections exist but are not evaluated in this load rating report because details of the connection(s) cannot be verified by plans or other means.”

CHAPTER 8 LOW RATINGS, POSTING & RESTRICTION

8.1 Interpretation of Ratings

a) If the LRE determines that there is an immediate threat to public safety, the LRE shall immediately notify the Department.

b) In cases where low ratings, rating factors less than 1.0, are produced, the LRE shall review the rating to ensure that overly conservative assumptions and methods have not led to overly conservative rating results prior to submission to the Department.

c) The LRE shall notify the LRS of low legal or permit ratings, excluding Service III, upon submission of the load rating package.

8.1.1 Refinement of Analysis

Unless otherwise directed within this Manual, the LRE shall contact the LRS prior to performing refinement to the analysis to improve low ratings. Refinement of the analysis may include:

- Structural Analysis Methods
- Capacity Methods
- Material Testing

8.2 Design Rating

The design load ratings are not typically used for determining posting and restriction; therefore, no special procedures are specified.

8.3 Legal Rating

Low legal ratings will trigger a posting recommendation from the LRS to the Posting Committee. Upon submission of the load rating package to the LRS, the LRE should notify the LRS that low ratings were generated.

8.3.1 LRS Responsibilities

- Ensure the load rating is not overly conservative, following the load rating review, feedback will be provided to the LRE for inclusion in the load rating analysis and the load rating report. This could be in-house staff or consultants.
- If required, initiate a Posting Meeting with the Posting Committee, as organized in *BIM Chapter 8*, with the recommended posting tonnage for the structure.
- If a Posting Meeting was held, provide all feedback and comments to the LRE that performed the analysis for inclusion in the load rating analysis. This feedback might require additional analysis.
- To keep an accurate report of the Posting Committee's findings, the Posting Meeting Minutes are to be placed in the Bridge asset folder on ProjectWise.

8.4 Permit Rating

The LRS shall be responsible to inform the Manager of Bridge Operations of the low permit ratings.

CHAPTER 9 SPECIAL TOPICS

9.1 Evaluation of Unreinforced Masonry Arches

Masonry structures shall be load rated using the Allowable Stress method and in accordance with the provisions of *MBE Article 6A.9.1*.

9.2 Evaluation of Pedestrian Bridges

Pedestrian bridges, intended to carry primarily pedestrians, bicyclists, equestrian riders, and light maintenance vehicles, shall be evaluated in accordance with the AASHTO *LRFD Guide Specifications for the Design of Pedestrian Bridges*.

CHAPTER 10 RATING OF BURIED STRUCTURES

10.1 General Buried Structure Rating Procedures

10.1.1 **Loads for Evaluation**

10.1.1.1 Loads

Loads identified in Chapter 2 and *MBE Section 6A.5.12.10* shall apply with incorporation of the provisions specified in Sections 10.3 and 10.4.

10.1.1.2 Load Factors

a) Load factors for permanent loads shall be taken from *MBE Table 6A.5.12.5-1* for reinforced box culverts and *BDS Table 3.4.1-2* for all other buried structures.

b) Load factors for live loads shall be taken as specified in *MBE Article 6A.5.12.10.3*.

10.1.2 **Rating Equation**

MBE Equation 6A.5.12.4-1 shall apply as a general rating equation for buried structures which do not meet the provisions of Section 10.3.2.

10.2 Structural Analysis

The load rating analysis may be initially performed using simplified plane frame methods.

10.2.1 **Installation Method**

If the installation method of a buried structure cannot be determined by plans or other means, assume embankment installation, which tends to produce more conservative results than trench installation.

10.2.2 **Depth of Fill**

The structure shall be analyzed at the critical depth of fill for each vehicle. The critical depth of fill may vary by vehicle due to spacing and loading of interacting axle combinations. The maximum or minimum fill depth may not be the critical depth. It should be noted that 2 feet of fill, in some cases, is the most conservative case, based on *BDS Article 12.11.2.1*.

10.3 Permanent Loads

The provisions of Article 2.1 and *MBE Article 6A.5.12.10* shall apply with incorporation of the provisions herein.

10.3.1 **Earth Pressure**

When considering earth pressures for buried structures the following assumptions shall be applied:

- The soil pressure shall be based on the at-rest pressure coefficient.
- The coefficient of lateral earth pressure, k_o, shall be based on normally consolidated soil.
- The effective friction angle of soil, ϕ'_f, shall equal 30 degrees.

10.3.2 **Permanent Load Only Analysis**

Live load analysis may be omitted if the distribution of wheel loads through the depth of fill is negligible, as defined in Articles 10.3.2.1 or 10.3.2.2.

If live loads are neglected, a capacity to demand ratio equation shall be substituted for the rating factor equation. The capacity to demand ratio shall be determined using Equation 10.3.2-1.

$$\frac{Capacity}{Demand} = \frac{C}{\pm\gamma_{DC} * DC \pm \gamma_{DW} * DW \pm \gamma_{EV} * EV \pm \gamma_{EH} * EH \pm \gamma_{ES} * ES}$$

Equation 10.3.2-1

Variable definitions are in accordance with *MBE Article 6A.5.12.4*

For reporting in the CTDOT Bridge Load Rating Form, the RF fields shall be populated using the following values:

- Design Inventory Live Load: $\begin{cases} 99.9, & \frac{Capcity}{Demand} \geq 1.00 \\ 0, & \frac{Capacity}{Demand} < 1.00 \end{cases}$
- Design Operating Live Load: $\begin{cases} 999, & \frac{Capcity}{Demand} \geq 1.00 \\ 0, & \frac{Capacity}{Demand} < 1.00 \end{cases}$
- All remaining Live Loads shall be left blank

The Methodology section of the load rating report shall provide the explanation for neglecting live loads and report the load combination that produced the controlling capacity to demand ratio for the structure.

10.3.2.1 Depth of Fill

The effects of live load shall be neglected for single-span culverts, where the depth of fill exceeds 8 ft, and for multiple span culverts, where the depth of fill exceeds 10 ft.

10.3.2.2 Distribution Slabs

The effects of live load shall be neglected for buried structures with rigid concrete pavement and depth of fill exceeds 5ft, including the rigid concrete pavement and wearing surface, based on data presented in the *Kansas Department of Transportation Report, dated July 2013 – Number KU-12-3, Improved Load Distribution for Load Rating of Low-Fill Box Structures.*

10.4 Live Load

10.4.1 **Live Load Distribution**

Distribution of wheel loads through fill for buried structures shall be taken as specified in the *BDS*.

10.4.1.1 Distribution Slabs

Buried structures with rigid concrete pavement, may be analyzed using a modified vertical crown pressure, as determined by Equation 10.4.1-1, (Han, Acharya, Parsons, & Khatri, 2013).

$$P_L' = P_L * K_R$$

Equation 10.4.1-1

Where:

P_L' = Modified vertical crown pressure (ft)
P_L = Original vertical crown pressure (ft)
K_R = Rigid concrete reduction factor as determined by Equation 10.4.1-2.

$$K_R = 0.23 * \ln(H) + 0.2$$

Equation 10.4.1-2

Where:
H = Depth of fill including the rigid concrete and wearing surface (ft)

10.4.2 **Tire Contact Area**

The tire contact area for distribution purposes of all design, legal, and permit tires shall be 20 in. wide by 10 in. long, in the absence of more precise information.

10.4.3 **Dynamic Load Allowance: IM**

The dynamic load allowance shall be taken as specified in the *BDS* for buried structures.

10.5 Reinforced Concrete Box Culverts

Section 10.1 and rating procedures specified in *MBE Article 6A.5.12* shall apply as modified by this Section. The provisions of this Section and *MBE Article 6A.5.12* shall be extended to include buried reinforced concrete three-sided frames and arches.

10.5.1 **Structural Analysis**

10.5.1.1 Analysis Method

The two-dimensional frame analysis, described in *MBE Article C6A.5.12.3*, shall be used for modeling, which is a simplified method designed to provide a quick, conservative, and repeatable load rating.

10.5.1.2 Boundary Conditions

Three sided frames on spread footings shall be analyzed with pinned supports at the bottom of the walls.

10.5.2 **Limit States**

Reinforced concrete box culvert shall be rated for the limits states and failure mechanisms as specified in *MBE Section 6A.5.12* as modified by Article 10.5.3.

10.5.3 **Shear**

Shear for top slabs with less than 2 ft of fill, designed for moment, shall not be assumed to be adequate. This specification effectively deletes the last sentence of the paragraph of *MBE Article C6A.5.12.2*.

10.5.4 **Earth Pressure**

The earth loads shall be modified for soil-structure interaction in accordance with *BDS Article 12.11.2.2.1*.

10.5.4.1 Soil-Structure Interaction Factor for Embankment Installation: F_e

The soil-structure interaction factor shall be determined based on uncompacted fill along the sides of the box section, in lieu of more precise information.

10.5.4.2 Load Coefficient for Trench Installation: C_d

The load coefficient for trench installation shall be determined by *BDS Figure 12.11.2.2.1-3*. In the absence of more detailed information, the K_μ and K_μ' values, used in the load coefficient equation, shall equal 0.165, which corresponds to the maximum values for sand and gravel.

10.6 Metal Culverts

10.6.1 **Structural Analysis**

For metal culverts, without perforations, the analysis shall be performed using a simplified method and consider ring compression theory for all applied loads.

10.6.1.1 Metal Pipes

For circular or semicircular metal culverts, the loads shall be modeled as a uniformly radial pressure around the pipe creating a compressive thrust in the pipe walls using the ring compression theory, as discussed in the *ConnDOT Drainage Manual Section 4.2.*

10.6.1.2 Metal Pipe Arches

Metal pipe arch analysis utilizes the ring compression theory as described in Article 10.6.1.1, but evaluates the thrust at the crown, thrust at the floor, and the thrust at the corner haunch.

10.6.2 **Limit States**

Metal culverts shall be rated for failure mechanisms at the strength limit state listed in *BDS Section 12.5*.

10.6.3 **Thrust**

The provisions of *BDS Article 12.7.2.2* shall apply for considering thrust in metal culverts. The dead and live load force effects due to thrust, determined from *BDS Equation 12.7.2.2-1*, shall be replaced with Equation 10.6.3-1 and Equation 10.6.3-2.

$$T_{UD} = \frac{D_o}{2}\left[\gamma_{EV} K_{\gamma E} K_2 (VAF) P_{sp} + \gamma_{DW} P_{DW} + \gamma_{DC} P_{DC}\right]$$

Equation 10.6.3-1

$$T_{UL} = \frac{D_o}{2}\left[\gamma_{LL} C_L F_1 F_2 P_L\right]$$

Equation 10.6.3-2

Where:

T_{UD} = Factored thrust due to dead loads (kip/in)
T_{UL} = Factored thrust due to live loads (kip/in)
C_L = *BDS Equation 12.12.3.5-5*
F_1 = *BDS Equation 12.7.2.2-3* or *12.7.2.2-5* as applicable
F_2 = *BDS Equation 12.12.3.5-8*
VAF = 1.0
D_o = Culvert span (ft)
$K_{\gamma E}$ = 1.5

All remaining terms shall be taken as specified in *BDS Article 12.12.3.5*.

For determining the hoop stiffness factor, S_H, the soil shall be assumed to be 85% compacted silty sands, in absence of more precise information.

10.6.4 **Earth Pressure**

Earth load on buried metal pipes shall be based on the soil prism load considering the condition of the water table below the top of the pipe as discussed in *BDS Article 12.12.3.7*.

10.6.4.1 Installation Factor: $K_{\gamma E}$

The installation factor shall be taken as 1.5, which is consistent with the value providing traditional safety, in the absence of more detailed information.

10.6.5 **Host Pipe and Grout Loads**

For pipe liner applications, the following assumptions shall be considered during analysis.

a) The host pipe failed; therefore, the load rating analysis shall consider only the capacity of the pipe liner.

b) The depth of fill shall be taken as the depth of fill over the top of the pipe liner, which includes the host pipe and grout.

CHAPTER 11 REPORTING LRFR RATINGS

11.1 General

The contents of this Chapter are to document the State Bridge Load Rating Engineer's coding procedures.

Load rating data is submitted annually to FHWA as part of the NBI submittal. The Department must comply with National Bridge Inspection Standards Regulation, which is evaluated with the Metrics for the Oversight of the National Bridge Inspection Program – specifically Metric #13: Inspection procedures - Load Rating. This Chapter is to insure proper coding of NBI Items 31, 63, 64, 65, and 66.

11.2 Item 31: Design Load

This item specifies the live load used to originally design the structure.

This item is coded as:

Code	Description
0	Other/Unknown
4	H20
5	HS20
7	Pedestrian
8	Railroad
A	HL93

11.3 Item 63: Method to Determine Operating Rating

This item specifies the method used to determine the Design Operating rating.

This item is coded as:

Code	Description
0	Field evaluation and documented engineering judgment
1	Load Factor
2	Allowable Stress
5	No rating analysis performed [A]
8	Load and Resistance Factor Rating (LRFR) reported by rating factor (RF)

A. This shall be used on structures in which a load rating was not performed (e.g., change in conditions, increased permanent loading, or a new structure with an unverified load rating).

11.4 Item 64: Operating Rating

This item is coded as the Design Operating rating in units based Item 63 and using the following table:

Item 63	Item 64 Unit
0	Tonnage [A]
1	Tonnage [A]
5	Unitless [B]
8	Rating Factor

A. If the tonnage is greater than 1000 or the structure is buried and meets the provisions of Section 10.3.2, then code as 999.

B. Code as 777 until a load rating is performed.

11.5 Item 65: Method to Determine Inventory Rating

This item specifies the method used to determine the Design Inventory rating.

This item is code as:

Code	Description
0	Field evaluation and documented engineering judgment
1	Load Factor
2	Allowable Stress
5	No rating analysis performed [A]
8	Load and Resistance Factor Rating (LRFR) reported by rating factor (RF)

A. This shall be used on structures in which a load rating was not performed (e.g., change in condition, increased permanent loading, or a new structure with an unverified load rating).

11.6 Item 66: Inventory Rating

This item is coded as the Design Inventory rating in units based Item 65 and using the following table:

Item 65	Item 66 Unit
0	Tonnage [A]
1	Tonnage [A]
5	Unitless [B]
8	Rating Factor

A. If the tonnage is greater than 100 or the structure is buried and meets the provisions of Section 10.3.2, then code as 99.9.

B. Code as 77.7 until a rating is performed.

11.7 Connecticut Specific Coding

11.7.1 Evaluation Code

Evaluation Code shall be coded as the following:

Code	Title	Description
E	Evaluated	For buried structures which met the provisions of Section 10.3.2 and the capacity to demand ratio is greater than or equal to a 1.0.
F	Load & Resistance Factor Rating	For load ratings performed using LRFR
J	Judgement Rating	For structures which meet the provisions of Article 1.3.1
L	Load Factor Rating	For load rating performed using LFR
R	Evaluation Required	For structures which require a load rating to be performed
T	Timber Rating	For timber structures load rating using ASR

11.7.2 Year of Evaluation

This shall be coded as the year the load rating was performed or the year that the structure was built when the load rating was performed during the design phase.

CHAPTER 12 LOAD RATING PACKAGE

12.1 General

A load rating package shall be prepared and submitted to the LRS in accordance with this Chapter and conform to the following requirements.

a) The load rating package shall contain standalone content for the entire structure and shall only contain load rating content for a single structure per package.

b) All structural components required for evaluation under a single unique structure number shall be included in each load rating package.

c) The load rating package shall reflect either the as-inspected condition or the FDP proposed condition of the structure. Load rating packages containing analysis for partial conditions or multi-conditions shall not be submitted to the LRS.

d) Load rating packages shall contain all analysis content without references to other load rating reports and packages, as each shall be a standalone package.

12.1.1 **Submission Procedures**

12.1.1.1 General

a) For load ratings performed as part of a design project, upload the final load rating package to ProjectWise following the procedures of the Digital Project Development Manual.

b) For load ratings performed outside of design projects, upload the final load rating package to ProjectWise or as requested by the LRS.

12.1.1.2 Transmittal

Send an email to: DOT.BridgeRating@ct.gov, notifying the LRS that the load rating is uploaded and ready for review. The subject line of the e-mail notifying the LRS that a load rating package is ready for review shall include the following information:

- Structure Identification Number, NBI item 8
- Project Number
- Review Submission Number

Example:

Subject:	00001_0123-0123_LR Submission-1

- Maintain all leading zeros for the structure number and project number.
- Review submission numbers shall be numbered sequentially and based off submissions to the LRS. Review submissions between intermediate parties shall be excluded from the review submission number.

For structures with low ratings, refer to Article 8.1c for additional provisions prior to submission.

12.1.2 **Load Rating Package Contents**

The load rating package shall include the following two files:

- Load Rating Report (refer to Section 12.2)
- Load Rating References Folder (refer to Section 12.3)

12.2 Load Rating Report

This Section describes the contents and format of the load rating report.

12.2.1 **Report PDF Requirements**

a) The load rating report shall be in a PDF digital format. Scanning previously printed computer generated documents results in increased file sizes and poor quality report sheets, therefore, shall be avoided. Digital PDF mark-ups shall be utilized in lieu of printing a document and performing marks-up by hand.

b) The load rating report shall be Digitally Certified by a Professional Engineer registered in the State of Connecticut as defined in the Digital Project Development Manual.

c) The LRE shall make every effort to contain the load rating documents in one PDF file for ease of future use and reference. It is understood that some of the more complex structures will require multiple PDF files; in this case each volume shall be bound in one PDF package.

12.2.2 **Report Contents**

The load rating report shall contain the following sections in order as follows:

Report Section	BLRM Section
Bridge Load Rating Form	Section 12.2.3
Rating Factors Less than 1.0	Section 12.2.4
Methodology	Section 12.2.5
Calculations	Section 12.2.6
Schematics	Section 12.2.7
Program Input Data	Section 12.2.8
Appendix	Section 12.2.9

Each of the above sections shall be digitally bookmarked within the report PDF. Additional digital bookmarks may be created at the discretion of the LRE.

12.2.3 **Bridge Load Rating Form**

The Bridge Load Rating Form can be found on the CTDOT Bridge Load Rating Website. The fillable fields in the Bridge Load Rating Form are exported into a central load rating database by the LRS. To maintain consistency within the load rating database, some drop- down fields are non-editable and restrict custom inputs while other drop down fields are editable and allow the LRE to enter custom input data. Non-editable fields shall not be overridden without prior approval from the LRS. The Bridge Load Rating Form contains tooltips for each field. Hover the mouse cursor over the field for clarification. The description of each field is also defined within this Section.

12.2.3.1 General Information

Enter the Structure Inventory & Appraisal information and Age & Service information. The descriptions of each field can be found in Table 12.2-1. For Structure Inventory & Appraisal information, reference the most recent BIR’s BRI-19. The information in these fields shall be entered as coded in the BRI-19.

Field Name	Description
Structure No.	Enter the Structure Identification Number NBI item 8. Maintain all leading zeros.
Town	Enter the City or Town NBI item 4 description.
Route	Enter the Route Number NBI item 5D. Maintain all leading zeros.
Mile Point	Enter the Mile Point NBI item 11.
Feature Carried	Enter the Feature Carried by Structure NBI item 7.
Feature Crossed	Enter the Feature Crossed by Structure NBI item 6A.
Year Built	Enter Year Built NBI item 27.
Year Rebuilt	Enter Year Rebuilt NBI item 106.
Project No.	The Project Number is used for new and rehabilitated structure load ratings that are submitted for FDP. Maintain all leading zeros.
Construction No.	The Construction Number is used if a separate construction project number is used than the design project number for load rating submitted with working drawings. Maintain all leading zeros.
Billable Project No.	The Billable Project Number is the core number used for charging man hours to rate and review the load rating.
Superstructure Type	Enter or select from the drop downs the appropriate item.
Substructure Type	Enter or select from the drop downs the appropriate item.
Deck Type	Enter or select from the drop downs the appropriate item.
Composite	Enter or select from the drop down the appropriate item.
Design Code	Select from the drop down the design code of the original construction.
Design Load	Select from the drop down the design load of the original structure. Note that the H20-S16-44 is the equivalent to the HS20.
Rating Code	Select from the drop down the Analysis Code used for the rating.
Rating Load	Select from the drop down the Design Vehicle used in the rating.
Analysis Method	Enter or select from the drop down the appropriate item.
Trunk Routes	Enter N/A. This field is a place holder for future use.
Basis of Rating	Select the reason for the load rating.
Rated By/ Date	Enter the name of the engineer who performed the rating and date last revised.
Reviewed By/ Date	Enter the name of the engineer who reviewed the rating and date last reviewed.
Reviewed By (Department Personnel Only)	Leave this field blank.

Table 12.2-1

12.2.3.2 Rating Summary Sheets

Enter the governing rating information for each vehicle. If multiple locations have the same rating, only one location shall be entered.

Column Heading	**Description**
Live Load	Select the live load combination from the drop down list for each row which reflects the controlling live load configuration corresponding to the controlling rating factor.
RF	Enter the governing rating factor for each live load. The Bridge Load Rating Form will truncate the rating factors to the hundredths place.
Tons	Enter the rating tons in the Design and Legal Service III Rating table and Additional Ratings table. This column will automatically compute for all other tables based on the rating factor entered in the RF field.
Span	Enter the span number of the controlling rating factor. For culverts enter the cell number. The information for this field shall meet the labeling requirements specified in Article 1.7.
Controlling Member	Enter the name of the controlling member. The information for this field shall meet the logging requirements specified in Article 1.7.
Member Length (ft)	Enter the span length, from centerline to centerline of support, or length between connections for axial members, of the controlling member.
Control Loc (x.xL)	Enter the controlling location along the member in terms of a multiplier of L, where L is the length of the member (e.g., 0.5L is at mid-span). For axial failure mechanisms or other similar global failure of the member, leave this cell blank.
Limit State	Select the controlling limit state from the drop down list.
Controlling Mechanism	Select the controlling failure mechanism from the drop down. If the controlling mechanism is not contained in this list, enter the controlling mechanism.
Expiration Year	Enter the four digit year of estimated fatigue exhaustion of the controlling fatigue detail.
Fatigue Category	Select the fatigue category of the controlling fatigue detail.
Environmental Conditions	Select the environmental conditions used to determine the controlling rating factor for the Service III limit state.

Table 12.2-2

12.2.3.2.1 Vehicle Summary Tables:

AASHTO Vehicular Loading, CT Legal Vehicular Loading, CT Permit Vehicular Loading, and Emergency Vehicular Rating Tables.

These tables shall only include ratings for the following Limit States:

- Strength I
- Strength II
- Service I
- Service II

The governing ratings for the Fatigue and Service III Limit States shall be entered in the AASHTO Fatigue Rating Table, and the Design and Legal Service III Rating tables.

12.2.3.2.2 AASHTO Fatigue Loading Table

This table shall only include the governing rating for the Inventory Rating Level at the Fatigue Limit State.

The Expiration Year field is the four digit year of the estimated finite fatigue life exhaustion year.

Example:

A structure was built in 2010 and the fatigue detail has an estimated fatigue finite life of 30 years, therefore, 2040 is inputted in the Exp. Year field.

12.2.3.2.3 Design and Legal Service III Load Case Table

This table shall include the governing Service III rating for Inventory in the first row, and the governing Service III rating out of all of the AASHTO and CT Legal loads in the second row of the table.

12.2.3.2.4 Additional Ratings Table

If the LRE is directed by the Department to provide ratings for a vehicle not listed in the summary tables, provide these ratings in this form. These tables shall also be used to enter the governing pedestrian rating.

12.2.3.3 References

- Include all references, e.g., AASHTO, AISC, ASTM, etc., including version and most recent interims used in the load rating analysis.

  Example:

  AASHTO The Manual for Bridge Evaluation 2nd ed. 2010, with up to 2016 interim revisions.

- Most recent BIR plus any other BIRs used for analysis, with the following information; inspection date, inspection type, and inspector.

  Example:

  10/21/2016 – Routine Inspection – Team 2

- All design plan, shop drawings and working drawings, as-built plans, project numbers, even if the construction for that project has no effect on the rating. The project information shall have at least the following information; Project number, brief description and Construction Complete Year.

  Example:

  0301-0001 – Original Design Plans – 1958
  0301-0020 – Reconstruction of the deck, parapet, and bridge rail – 1996

12.2.3.4 Calculation Tools

Include all software used to develop the load rating. Include the version of the software and any maintenance patches if applicable.

12.2.4 **Rating Factors Less than 1.0**

Include a tabularized output including all rating factors that do not achieve a rating greater than 1.0, and separate the ratings into the following tables:

- AASHTO Legal & CT Legal Vehicles
- CT Permit Vehicles
- Emergency Vehicles

Each of these tables shall include and be formatted as such:

- These tables shall only include all Strength, Service I, and Service II ratings.
- Service III and Fatigue limit states shall be excluded from these tables.
- These tables shall contain the following headings:

Failure Mechanism	Limit State	Span	Member	Location on Member (x.xL)	Member Length (ft)	Rating Factor	Rating Tons*	Vehicle

*Sorted low to high

12.2.5 **Methodology**

The Methodology shall include the following sections:

Methodology Section	**BLRM Article**
Analysis Method	Article 12.2.5.1
Comments	Article 12.2.5.2
Assumptions	Article 12.2.5.3
Rated Members	Article 12.2.5.4

The Methodology section shall not include sections which serve only to provide an executive summary or a general description of the structure.

12.2.5.1 Analysis Method

State the structural analysis type performed in this load rating.

For ratings performed using refined analysis methods, as described in Section 3.3, or when substructure rating were performed, the following subheadings shall be included within this section:

- **Reason**
  Briefly explain why the chosen analysis method is appropriate.
- **Choice of Elements**
  Briefly state the elements types used to model the behavior of the structure.
- **Utilization of Links**
  Briefly state how and where link constraints are applied to the model.
- **Support Degrees of Freedom**
  Briefly state the locations where support conditions are applied and the degrees of freedom of the constrictions of the support.
- **Artificial Elements**
  Briefly state where and why 'dummy' elements were utilized.
- **Construction Stage Activities**
  Briefly summarize the sequence of construction activities used in performing the analysis.

- **Placement of Lanes**
  Briefly state the longitudinal and transverse placement of lanes applied to the model. Include which elements lanes are applied to, e.g., deck plates. Provide a reference to elsewhere in the report which further describes the placement of lanes if cannot be stated briefly; schematics may be provided at the discretion of the LRE.

When BrR is used to perform a refined analysis, only the 'Reason' subheading is required, which shall include the BrR version number and analysis type.

12.2.5.2 Comments

a) Include clear and concise statements that are specific to the structure being load rated. Each comment should be accompanied by rationale if applicable. A comment is generally warranted to reflect atypical considerations for a specific structure type, when additional refinement was performed, when simplified conservative methods were used compared to typical methods, or when overly conservative simplifications were applied.

b) Provide concise statements to describe undocumented changes made to the structure. Provide a brief timeline of convoluted rehabilitations and reconstructions.

c) Include all workarounds performed to address program related issues.
   - Reference ID (i.e. BrR Jira ticket IDs)
   - A brief statement of the problem and how the model was affected
   - The workaround procedure performed

12.2.5.3 Assumptions

- Include all assumptions that were required to complete the load rating. Minor assumptions with little effect on the rating may be omitted from this Section if those assumptions are documented elsewhere in the report, such as the Calculations section.
- Assumptions shall contain all of the following information.
  - What is the assumption
  - Why is the assumption required
  - What is the rationale and justification that shows the assumption is reasonable

12.2.5.4 Rated Members

List and define all rated members which were evaluated for each member. Summarize any grouped members for analysis as discussed in Article 1.5.

12.2.6 **Calculations**

a) Any calculations not included in the rating program's analysis should be shown on a calculation sheet that has been well prepared, contains appropriate references to equations and relevant code articles, and can be easily followed for checking purposes. This may include loads, LLDFs, section losses, beam end calculations, etc.

b) When excel sheets are utilized, sample calculations working through the entire excel workbook's functionality in an easily followed and fully referenced format shall be submitted as a proof of the spreadsheet's equations accuracy. An easily followed format shall include hand-calculations or Mathcad files without programming other than simple Boolean programming functions.

c) Sample proof calculations should be submitted for each type of equation the excel sheet uses. When excel functions, macros or any other excel programing is used, sample calculations should cover all possibilities to prove the function is working as intended.

12.2.7 **Schematics**

If the program capabilities exist, the following schematics shall be provided:

- **Structure Framing Plan**
- **Structure Cross-Section**
  For multi-span structures, if the structure cross-section views are identical, the schematics may be consolidated into typical views.
- **Member Elevation**
  For identical members, if the member properties and characteristics are identical, the schematics may be consolidated into typical views.
- **Member Cross-Section**
  For identical member cross-sections, if the properties and characteristics of the cross-sections are identical, the schematics may be consolidated into typical views.

12.2.8 **Program Input Data**

a) Program input should not contain any program output.

b) For large FEM program inputs: elements, nodes, loads, links and etc. should not be included within the report. For this case, include the program input report in the Load Rating References Folder.

12.2.9 **Appendix**

- **Manuals & Publications**
  Include copies of pages from a reputable manual (MSC, PCI, etc.) to show beam shapes and member properties. These copies do not need to be included if the shapes and properties used in analysis are derived through a prebuilt library inherent to the program used in analysis.
- **Data Sheets**
  Include copies of pages that support any assumptions.
- **Reference Calculations**
  Include copies of calculations referenced.
- **Inspection Reports**
  Include copies of BIR sheets used for the analysis. When available, provide the field note sheets from the 'Files' portion of SMS, as opposed to extracting Report sheets.
- **Plans**
  Include copies of all plan sheets used in analysis.

All sheets included should be rotated to the appropriate viewing orientation.

12.3 Load Rating Reference Folder

The Reference folder shall contain all computer files, also called Raw Files, used to generate the load rating. The load rating references folder shall be ZIP archived for submission; the ZIP archive shall not be encrypted.

Raw files include but are not limited to the following:

- Program Input files
- Program Output files
- Excel files
- Mathcad files
- CAD files (e.g., drawings used to calculate curved deck overhangs, girder lengths, etc.)
- Complete set of structure plans, if not available on ProjectWise
- All other files used to perform the load rating analysis

12.4 Naming of Submission Files

Load Rating Report:

00000_YYYY-MM-DD_Code.PDF

Load Rating References Folder:

00000_YYYY-MM-DD_Code References.ZIP

Where:

00000	=	Structure Identification Number, NBI item 8 (maintain leading zeros)
YYYY	=	Four Digit Year of submission
MM	=	Two Digit Month of submission
DD	=	Two Digit Day of submission
Code	=	Determined from Table 12.4-1

Code	Description
LR	Existing Load Rating Report
LR-FDP	Final Design Load Rating Report

Table 12.4-1

An example is shown in Figure 12.2.5.4-1.

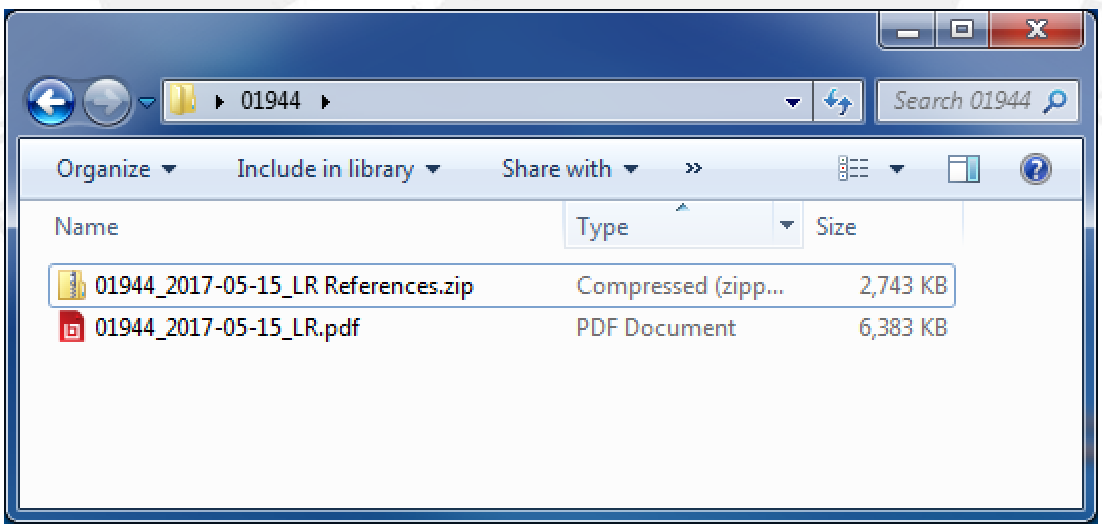


Figure 12.2.5.4-1

12.4.1 Raw Files

Raw files shall be named with a clear description of the contents of the file. An example is shown in Figure 12.2.5.4-1.

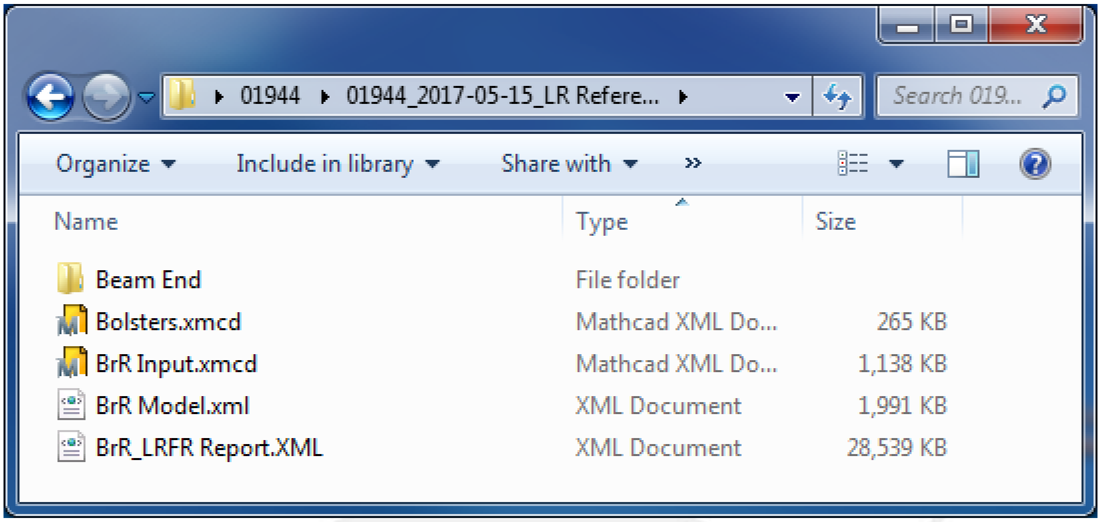


Figure 12.2.5.4-1

CHAPTER 13 ANALYSIS SOFTWARE

13.1 General

BrR is the Department's software of choice for load rating. All other software must be approved by the LRS prior to the start of the load rating.

BrR shall be used for all CTDOT load ratings with the following exceptions:

- Timber superstructures and decks
- Arches (steel, concrete, masonry)
- Rigid Frames (other than 3 and 4 sided box culverts)
- If given prior approval from the LRS.

Approval may be granted for structures that would otherwise require significant hand calculations or manipulation of the program in order to produce a valid load rating or where the BrR analysis engine would require excessive run times.

It is the Department's preference that a load rating for each structure be performed in only one bridge analysis software. If the LRE has reason to use multiple analysis software, the LRE must secure approval from the Department prior to the start of the load rating. This provision does not apply to the use of software needed to provide inputs, or to perform post-processing procedures, such as the use of Mathcad to calculate utility loads to be inputted in bridge analysis software.

The LRE is responsible for the accuracy of all analysis software; therefore, calculations and results produced by analysis software shall be scrutinized.

13.2 AASHTOWare Bridge Rating

13.2.1 **Modeling**

Structures modeled in BrR shall be in accordance with the provisions of this Manual and the CTDOT BrR User Guide, available on the CTDOT Bridge Load Rating Website.

13.2.2 **Program Input**

The Program Input Data for the structure shall be generated using a CTDOT BWS template, available on the CTDOT Bridge Load Rating Website, and inserted as a PDF in the Program Input section of the report.

a) In the event that a CTDOT BWS template does not fit the structure type or a template is not available, the LRE shall create their own BWS template following the configuration of available CTDOT BWS templates.

b) Each structure number shall be contained in a single input file. Therefore, the load rating package shall contain only one XML input file containing all the information for the structure unless software limitations limit the ability to contain the entire structure in a single file.

13.2.3 **Program Output**

This Section outlines the required raw files to be included within the References folder required for the load rating package.

13.2.3.1 Rating Results: LRFR Report

The References folder shall include the LRFR Report in an xml file format for superstructures definitions which support the LRFR Report Type. Superstructure definitions which do not support the LRFR Report Type shall follow Article 13.2.3.2. The LRFR Report shall be generated with only the contents shown in Figure 13.2.3.1-1. The LRFR Report xml is copied from the location shown in Figure 13.2.3.1-2.

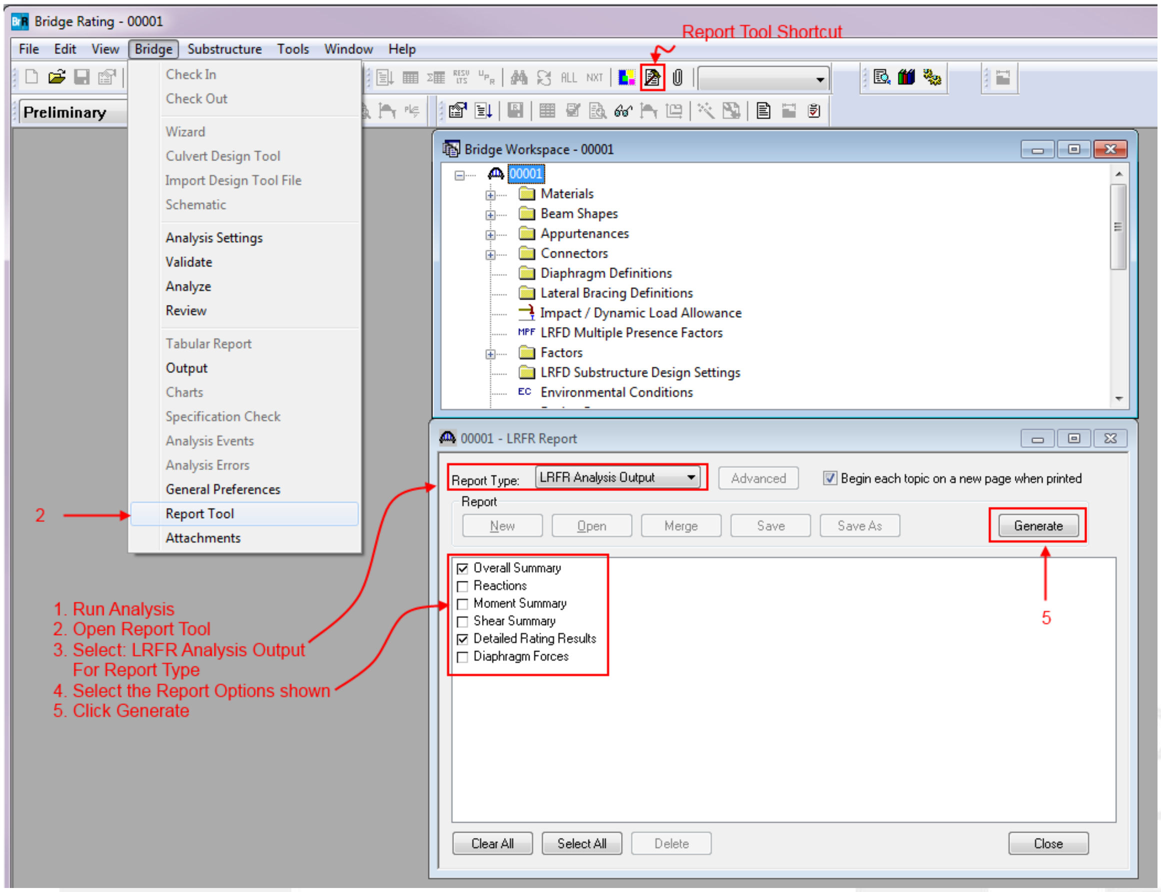


Figure 13.2.3.1-1

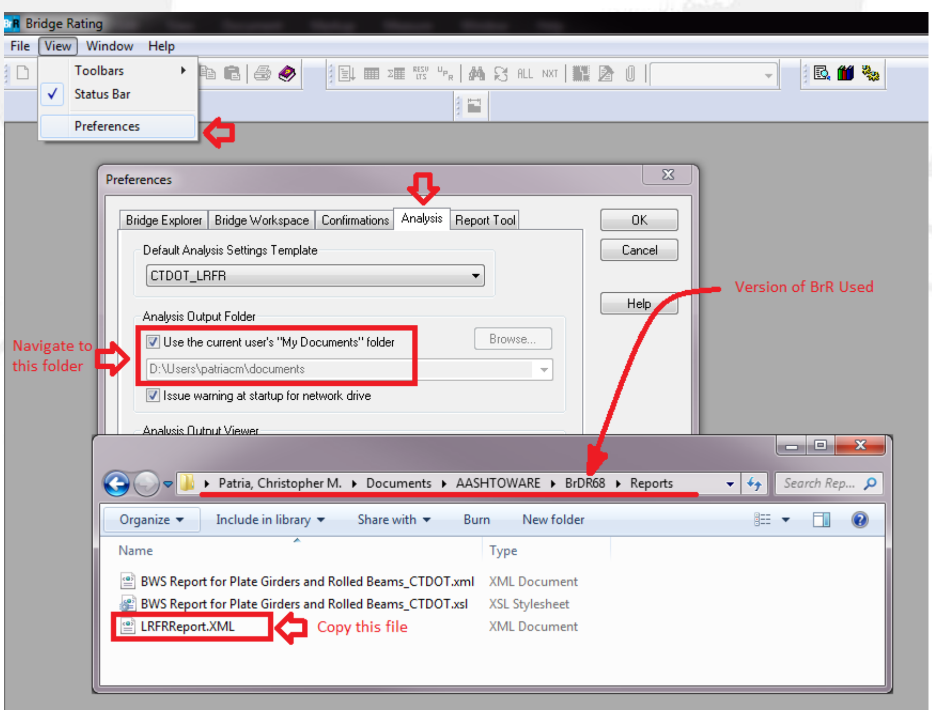


Figure 13.2.3.1-2

13.2.3.2 Analysis Output

The References folder shall include the analysis files for superstructure definitions which do not support the LRFR Report Type. Copy the analysis folder from the location shown in Figure 13.2.3.2-1.

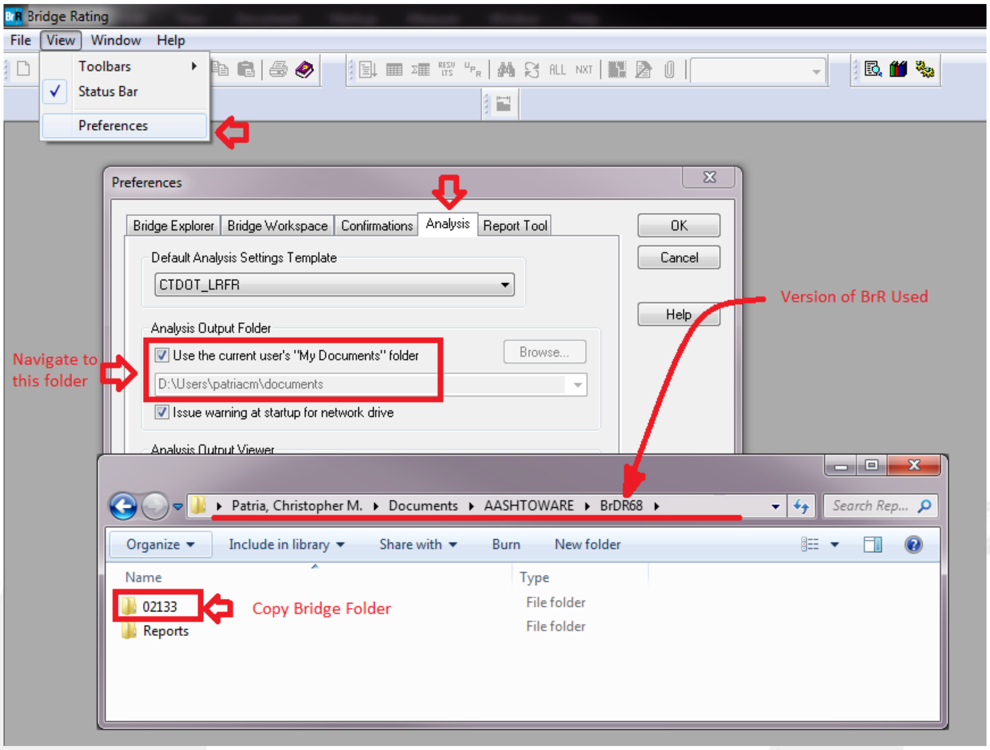


Figure 13.2.3.2-1

13.2.4 **Bugs, Issues, and Unexpected Behavior**

The LRE is responsible for reviewing all applicable Jira tickets to ensure the reported issues do not affect the BrR model. If a Jira ticket affects the BrR model and a workaround for this issue is available or possible, refer to Article 12.2.5.2 for reporting. Contact the LRS for read-only access to Jira website at DOT.BridgeRating@ct.gov.

13.3 Bentley Software Packages

13.4 CANDE

The CANDE Software package is freely available at http://www.candeforculverts.com/

13.4.1 **Analysis Level**

A Level 3 analysis is required in order to accurately place the wheel loads of CTDOT's required load conditions. The following are requirements for a level 3 analysis:

- Wheel loads may only be placed at nodes. Therefore, the spacing of nodes at the surface must be such that the axle spacing can be accurately represented in the model.
- A minimum of four load steps are required for analysis. This is necessary in order to separate the results and apply the correct load factors to each load step's effects. The minimum required load steps are as follows:
  1) The culvert/buried structure material
  2) The soil at the sides of the buried structure
  3) The soil at the top of the buried structure
  4) Live loads applied as boundaries.

13.4.2 **Application of Live Load**

- Applying the wheel load incrementally leads to fewer convergence issues. Four wheel load increments are suggested.
- CANDE will distribute the transient loading across the direction of the span through the soil material. The load distribution perpendicular to the span must be accounted for manually before entering the load into CANDE.

13.4.3 **Applicability**

CANDE may be used for the following structure types:

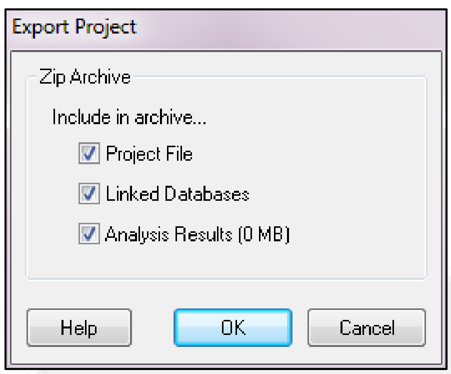
- Pipe culverts
- Lined pipes
- Arch structures

13.5 Staad.Pro

13.6 Larsa 4D

13.6.1 **Program Output**

Create a Zip Archive of the Project File, Linked Databases, and Analysis Results. The archive can be created by LARSA4D: Click File – Export – Zip Archive and check data to include in the archive as shown in Figure 13.2.3.2-1.



13.6.2 **Section Composer Tool**

Generate and include the Section Composer Report within the Program Input section of the load rating report. The report can be generated by the Section Composer Tool: Click File – Report.

13.6.3 **CTDOT Vehicle Libraries**

A vehicle database can be downloaded from the CTDOT Bridge Load Rating Website to be used in the analysis. Please check the website at the start of every analysis that the latest files are downloaded from the website.

13.7 Midas Civil

13.7.1 **Program Output**

Program output shall only be included within the References folder if requested by the Department.

13.7.2 **Wizards**

When the wizard is utilized to create a structure, the wizard must be saved as a *.wzd file and placed in the References folder.

13.8 CTDOT Developed Software

CTDOT developed software can be downloaded from the CTDOT Bridge Load Rating Website. Routinely monitor the webpage for updates to the programs.

13.8.1 **CT-LoadFactor**

CT-LoadFactor is a spreadsheet program that computes live load factors for CTDOT's rating vehicles at the LRFR strength limit state.

Permit live load factors are dependent on the axles on a structure. The program will march each truck pattern across the structure length, compute the permit weight ratio for each set of axles acting on the structure, and then return the maximum live load factor based on the controlling permit weight ratio.

13.8.2 **CT-Fill**

CT-Fill is a spreadsheet program that computes the distribution of wheel loads through earth fills in accordance with *BDS Article 3.6.1.2.6b*.

13.8.3 **CT-MPipe**

CT-MPipe is a Mathcad worksheet that computes rating factors for corrugated metal structures. This worksheet requires the live load pressures computed using the CT-Fill program. Further documentation of the program is contained within a separate instruction manual included in the CT-MPipe Package.

13.8.3.1 Applicability

The program may be used for the following metal structure types:

- Round pipes
- Pipe arches
- Arches

13.8.3.2 Limitations

- Structural plate box structures are not supported.
- Analysis of perforations is not supported. The program does not account for stress concentrations adjacent to perforations or section loss.

13.8.4 **CT-BeamEnd**

CT-BeamEnd is a spreadsheet program that will produce rating factors for steel webs subjected to a concentrated load with deterioration and generic reactional failure mechanisms. The spreadsheet has the ability to import BrR loads to streamline the analysis. Further documentation of the program is contained within a separate instruction manual included in the CT-BeamEnd Package.

CHAPTER 14 QUALITY CONTROL/QUALITY ASSURANCE PROCEDURE

14.1 General

Proper QC and QA are critical to producing load ratings that are accurate and consistent with this manual. Consultants performing load rating for the Department are responsible for development of their own systematic QA/QC plan that shall be submitted to the Department upon request. This plan shall address the complexity level of the load rating being performed and the level of review required.

14.2 Quality Control Review

The person responsible for QC is an independent reviewer of the load rating package. The person performing the load rating shall not be the QC reviewer. However, the LRE reviewing their work is the single most important step in the QC plan.

14.3 Quality Assurance Review

The person responsible for QA is an independent reviewer of the QC, ensuring that the load rating package is consistent with the requirements of this manual. The CTDOT QA Checklist, available on the CTDOT Bridge Load Rating Website, shall be used when performing a QA review. This document shall be submitted to the Department with the load rating package.

CHAPTER 15 REFERENCES

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Salkar, R., Salkar, A., & Davids, W. (2015). Crippling of Webs with Partial-Depth Stiffeners under Patch Loading. *Engineering Journal, 52*(4), 221-231.

White, D. W. (2012). *Guidelines for Analysis Methods and Construction Engineering of Curved and Skewed Steel Girder Bridges.* NCHRP.

APPENDIX A. CODING DEFINITIONS AND FORMS

I. FORM NAMES

Bridge forms 18 and 19 are used to store inventory and appraisal attributes of each bridge. BRI-18 and BRI-19 forms contain required information to successful complete a load rating. These two forms can be found within the BIR or on SMS.

BRI-18 – Highway Bridge Coding Items Form
BRI-19 – Structure Inventory & Appraisal form

II. BRI-19 CODING DEFINITIONS

Coding Definitions values for each Asset can be found on the BRI-19

i. IDENTIFICATION

NBI Item 8 – Structure Number (5 or 6 digits CT)
NBI Item 4 – Place Code (5 digits)
Cities, towns, townships, villages, and other census-designated places shall be identified using the Federal Information Processing Standards (FIPS) codes given in the current version of the Census of Population and Housing - Geographic Identification Code Scheme. If there is no FIPS place code, then code all zeros.
NBI Item 5D – Route Number (5 digits)
The route number presently assigned to the roadway.
NBI Item 6A – Feature Intersected
This item contains a description of the features intersected by the structure and a critical facility indicator.
NBI Item 7 – Facility Carried by Structure (18 digits)
NBI Item 11 – Mile Point (5 digits)
The mile point that references the inventory route of the structure in the log direction using the “Highway Log of Connecticut State Numbered Roads", most recent edition. If the roadway passing under the sign is a town road, code this item "000.00".

ii. CLASSIFICATION

NBI Item 26 – Functional Class
Functional classification of the inventory route. This item contains the urban and rural classification of the structure.

iii. AGE AND SERVICE

NBI Item 27 – Year Built (4 digits)
The year of construction of the structure. Coded as 4 digits of the year in which construction of the structure was completed. If the year built is unknown, the value is a best estimate. See also Item 106 - Year Reconstructed.
NBI Item 106 – Year Reconstructed.
The year of most recent reconstruction of the structure. Coded as 4 digits of the latest year in which reconstruction of the structure was completed. For a bridge to be defined as reconstructed, the type of work performed, whether or not it meets current minimum standards, must have been eligible for funding under any of the Federal-aid funding categories. The eligibility criteria would apply to the work performed regardless of whether all State or local funds or Federal-aid funds were used.
NBI Item 109 – Percent Truck
A 2-digit percentage that shows the percentage of Item 29 - Average Daily Traffic that is truck

traffic. Does not include vans, pickup trucks and other light delivery trucks in this percentage. If this information is not available, an estimate which represents the average percentage for the category of road carried by the bridge is used. May be left blank if Item 29 - Average Daily Traffic is not greater than 100.

iv. LOAD RATING

See Chapter 11 Reporting LRFR Ratings for further information of these items.

NBI Item 31 – Design Load
NBI Item 63 – Method Used to Determine Operating Rating
NBI Item 64 – Operating Rating
NBI Item 65 – Method Used to Determine Inventory Rating
NBI Item 66 – Inventory Rating
NBI Item 106 – Year Reconstructed
NBI Item 109 – Average Daily Truck Traffic
NBI Item 104 – Highway System of the Inventory Route (1-NHS and 2-Non-NHS)
Evaluation Code – Rating Code Used to Determine Rating
Year of Evaluation – Year Rating was performed (4 Digits)